VOLUME 1

Application for Permit No. 63-32573

M3 EAGLE, LLC EXHIBITS 1-20

Original

IDWR Hearing
April 15,16, 22-24, May 4-5, 2009

Givens Pursley LLP
601 W. Bannock Street
Boise, Idaho 83702
(208) 388-1200

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	M3 EAGLE'S TECHNICAL REPORTS AND SUPPORTING DOCUMENTATION (submitted 11/26/08)
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2	M3 Eagle Regional Hydrogeologic Characterization Year One Progress Report
3	Map of Protestants Wells 10-14-2008
4	M3 Eagle SVR #6 Composite - FINAL
5	M3 Eagle SVR #7 Composite by Hydro Logic, Inc. 4-14-2008 - FINAL
6	M3 Eagle SVR #9 Test Well Composite Diagram by Hydro Logic, Inc 07-07-2008 smaller
7	M3 Eagle Test Well #1 Composite by Hydro Logic, Inc. 4-23-2008
8	M3 Eagle Test Well #2 Composite - FINAL
9	M3 Eagle Test Well #3 Composite Diagram by Hydro Logic, Inc. 9-27-2007
10	M3 Eagle Test Well #4 Composite Diagram by Hydro Logic, Inc 4-16-2008
11	Magnetometer Report for M3 Eagle May 20, 2007
12	RE-Analysis of 16 Aquifer Tests in the Greater Eagle-Star Area of North Ada County, Idaho
13	Seismic Reflection Profiling in the Big Gulch Area - Report by John Bradford at CGISS (BSU) - September 2006
14	Star Supply Well #3 Composite - FINAL smaller
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18	Water Level Measurement Survey Update to M3 Eagle Hydrogeologic Characterization
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	19B (Wood May 20, 2007 Qualitative Interpretation of Magnetic Anomalies and Progress Report on Geologic Mapping in the Foothills North of Eagle, Ada and Gem Counties, Idaho)

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Exhibit numbers reserved for documents not yet identified in each category are noted as [RESERVED].

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	19C (Wood/USGS 2004 Geological Field Trips in Southern Idaho, Eastern Oregon, and Northern Nevada)
	19D (Wood/Clemens 2002 Geologic and Tectonic History of the Western Snake River Plain, Idaho and Oregon)
	19E (Wood/Squires 1/8/2001 Stratigraphic Study of the Boise (Idaho) Aquifer System Using Borehole Geophysical Logs with Emphasis on Facies Identification of Sand Aquifers)
	19F (Wood August, 1997 Structure Contour Map of Top of the Mudstone Facies, Western Snake River Plain, Idaho)
	19G (Wood January, 1994 Seismic Expression and Geological Significance of a Lacustrine Delta in Neogene Deposits of the Western Snake River Plain, Idaho)
	19H (Wood/Anderson December, 1981 Geothermal Investigations in Idaho, Part II Geological, Hydrological, Geochemical and Geophysical Investigations of the Nampa-Caldwell and Adjacent Areas, Southern Idaho)
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	33G (Hutchings & Petrich Dec 2002 Ground Water Recharge and Flow in the Regional Treasure Valley Aquifer System Geochemistry and Isotope Study)
	33H (Hutchings & Petrich Dec 2002 Influence of Canal Seepage on Aquifer Recharge Near the New York Canal)
	33I (Urban Water Budget for the Treasure Valley Aquifer System for the Years 1996 and 2000)

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	33J (Dittus, Allred, Squires Oct. 1999 Hydrogeology, Geochemistry, and Well Construction of the Treasure Valley Hydrologic Project Monitoring Well #1, Ada County, Idaho)
	33K (Treasure Valley Hydrologic Project #2 Monitoring Well Nov. 1999)
	33L (Scanlan July 2001 Final Report on the Quarry View Park Well Project)
	33M (Municipal Park Monitoring Well (TVHP#4) July 2002)
	33N (Beukelman 1997 Treasure Valley Hydrologic Project Geological and Geophysical Framework of the Treasure Valley Reports on the Ontario, Parma, Notus and Boise Cross Sections)
	33O (Squires & Wood Jan 2001 Stratigraphic Studies of the Boise (ID) Aquifer System Using Borehole Geophysical Logs with Emphasis on Facies Identification of Sand Aquifers)
	33P (Wood Aug 1997 Structure Contour Map of the Base of Quaternary Basalt, Murphy and west part of Mountain Home Map Sheets, Idaho)
	33Q (Wood Aug 1997 Structure Contour Map of Top of the Mudstone Facies, Western Snake River Plain, Idaho)
	33R (Geologic Cross-Section Across the Treasure Valley from 15 Miles Northwest of Star to the Snake River)
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	33T (Othberg & Stanford 1992 Geologic map of the Boise Valley and Adjoining Area, Western Snake River Plain, Idaho)
	33U (Liberty & Wood Apr 2001Treasure Valley Seismic Reflection Project - UPRR 2000 Profile)
	33V (Treasure Valley's Water Future, Summary of the Treasure Valley Water Summit, Jan 14-15, 2000 (May 2002))
34	Map and composite diagram of Eagle Pines Water Association well
35	Draft spreadsheet containing information currently known about Protestants' wells (HLI 2008)
36	November 6, 2008 Memorandum from Dale Ralston, PhD and Professor Emeritus to Josephine Beeman
37	Compact disc of ground water level monitoring data and aquifer test data obtained by Hydro Logic, Inc. in the North Ada County Area
38	M3 Eagle Potable Water Facility Planning Progress Update Meeting #3 Presentation Slides, November 25, 2008, prepared by Stanley Consultants, Inc.
39	Map of Preliminary Sewer Plan, prepared by Stanley Consultants, Inc.
40	Demographic Forecast: Economic & Fiscal Impact Analysis, October 2008, prepared by Dr. John Church
41	Development of a Numerical Ground Water Flow Model for the M3 Eagle Development Area Near Eagle Idaho, Douglas, Stacey L., Master's Thesis (December 2007).

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	M3 EAGLE'S SUPPLEMENTAL REPORTS BY HLI (submitted in 2009)
43	Ground Water Geochemistry of Wells in the North Ada County Area of Idaho (Jan. 20, 2009)
44	A Nine-Day Constant-Rate-Discharge Aquifer Test of the SVR #7 Test Well In Big Gulch, North Ada County, Idaho (Jan. 20, 2009)
45	Technical Memorandum re Response to IDWR's March 2, 2009 Staff Memorandum On M3 Eagle Hydrogeologic Studies (with exhibits), prepared by Hydro Logic Inc., dated April 1, 2009 (submitted April 3, 2009)
	DOCUMENTS SUBMITTED BY NACGUA
46	Memorandum from Dale R. Ralston to Jo Beeman regarding Initial Hydrogeologic Analysis, dated November 6, 2008
47	Hydrogeologic Analysis of the M3 Eagle Site, Expert Report Prepared for the North Ada County Groundwater Users Association, by Ralston Hydrologic Services, Inc., dated January 2009
48	Hydrogeologic Analysis of the M3 Eagle Site: Supplement #1 Comments from Review of Geochemistry Report, Expert Report Prepared for the North Ada County Groundwater Users Association, by Ralston Hydrologic Services, Inc., dated January 2009
49	Letter from Dr. Dale Ralston to NACFA c/o David Head re comments relative to IDWR's March 2, 2009 Staff Memorandum, dated March 31, 2009 (submitted April 3, 2009)
	IDWR STAFF MEMORANDUM
50	IDWR Staff Memorandum re Application for Water Right 63-32573, dated March 2, 2009
	OTHER DOCUMENTS OFFERED BY M3
51	Technical Memorandum from Ed Squires, Hydro Logic, Inc., to Dennis Owsley, IDWR, re Written Analysis of Dale Ralston's Technical Report Per Hearing Officer's February 10th, 2009 Order, dated March 2, 2009
52	Refined Analysis of 2008 Water Level Data from TW #1 and TW #4 Using BETCO to better correct for Barometric Effects, M3 Eagle Master Planned Community, dated April 8, 2009
53	M3 Eagle Master Potable Water & Wastewater Study, by Stanley Consultants (04/28/06)
54	M3 Eagle Financial Statement, dated March 30, 2009
55	Letter from J. Fereday to D. Tuthill re M3 Eagle Planned Community, dated March 23, 2007.
56	Letter from J. Fereday to D. Tuthill re M3 Eagle Amended Water Right Application, dated September 24, 2007.
57	Eagle Foothills Comprehensive Plan
58	Pre-Annexation and Development Agreement by and between City of Eagle and M3 Eagle LLC, dated/recorded December 27, 2007.
59	M3 Eagle Average Monthly Residential Housing Additions cmopared to Monthly Residential Dwelling Unit Permits Issued in Ada and Canyon Counties 2000-2008, prepared by Dr. John Church

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61	Graphs: The Idaho Economy has Recovered from Severe Recessions in the Past, prepared by Dr. John Church
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64	Letter from E. Squires to Nichole Baird Spencer (City of Eagle) re Comments on Letters Submitted by NACFA and Phillip Fry Concerning the M3 Eagle Proposed Planned Community Development North of Eagle, Idaho, dated October 16, 2006.
65	M3 Eagle slide presentation (April 2009)
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102	Affidavit of Dale R. Ralston in Support of NACGUA's Reply to M3 Eagle's Response to NACGUA's Motion for Stay, and Limited Discovery for Purposes of Settlement, dated November 24, 2008
103	Dale Ralston List of References Reviewed, dated Feb. 2, 2009
104	Alan Smith Response to Discovery Request of Applicant M3 Eagle LLC, dated October 27, 2008.
105	Letter from K. Pennisi to Gary Spackman re NACFA's assignment of protest to NACGUA, dated August 26, 2008.
106	David Head notes re water quantity calculations (David Head Deposition Ex. 86)
107	NACGUA bullet list re M3 Eagle water right application (Morgan Masner Deposition Ex. 107)
108	E-mail and attachments from K. Pennisi to "NACFA Supporters" (Conrad Deposition Ex. 24)
109	Letter from David Head to "NACFA Water Group a/k/a . . . . NACGWUA," dated August 12, 2008
110	Letter from David Head to Karl J. Dreher re Request for Comprehensive Groundwater Resource Evaluation and Consideration for New Water Rights Moratorium, dated January 25, 2006
111	Letter from Karl J. Dreher to David Head re Request for Comprehensive Groundwater Resource Evaluation and Consideration for New Water Rights Moratorium, dated May 2, 2006
112	Letter from David Head to David Tuthill re Status of Comprehensive Water Resource Evaluation in North Ada County / Follow-Up on May 12, 2006 Correspondence with Director Dreher, dated January 16, 2007
113	NACFA/NACGUA letter from David Head and John Thornton to M3 Water Protestants re Status on Protest with M3 Municipal water right application, dated September 28, 2008

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131	Memorandum from Sean Vincent to Gary Spackman re Review of Addendum to City of Eagle, Idaho 7-Day Aquifer Test Report, dated February 27, 2006 [*sic - should be 2007*]
132	City of Eagle, Idaho 7-Day Aquifer Test Report prepared by Holladay Engineering Company, dated June 2006
133	Addendum to City of Eagle, Idaho 7-Day Aquifer Test Report prepared by Holladay Engineering Company and SPF Water Engineering, dated February 22, 2007
	SUNCOR WATER RIGHT APPLICATION DOCUMENTS
140	Letter from Terry Scanlan (SPF Water Engineering LLC) to Steve Lester (IDWR) re Application for Permit No. 63-32061 - SunCor Idaho, LLC, dated March 3, 2005
141	Lynn Well Water Level Measurement Table and Graph prepared by SPF Water Engineering LLC, dated 10/19/2006 (Application for Permit No. 63-32061, Ex. 38)
142	Maps regarding Avimor and Spring Valley Ranch Resource Area prepared by SPF Water Engineering LLC, all dated January 20, 2006 (Application for Permit No. 63-32061, Exs. 32-34, 36)
143	Letter from Terry Scanlan (SPF Water Engineering LLC) to Bob Taunton (SunCor) re SunCor Water Level Monitoring Program Status, dated October 16, 2006, with enclosed Stipulation to Withdraw Protest between SunCor and NACFA (Application for Permit No. 63-32061, Ex. 42)
144	Aquifer Evaluation in the Big Gulch and Little Gulch Areas of Spring Valley Ranch prepared by SPF Water Engineering LLC, dated October 2004 (Application for Permit No. 63-32061, Ex. 27)

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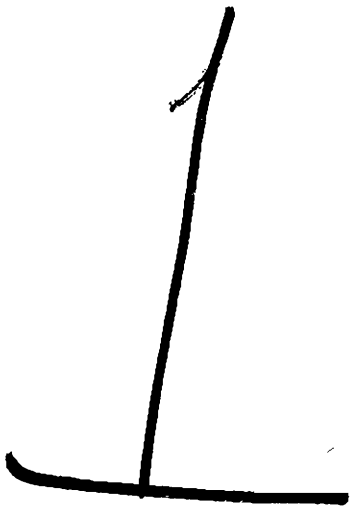

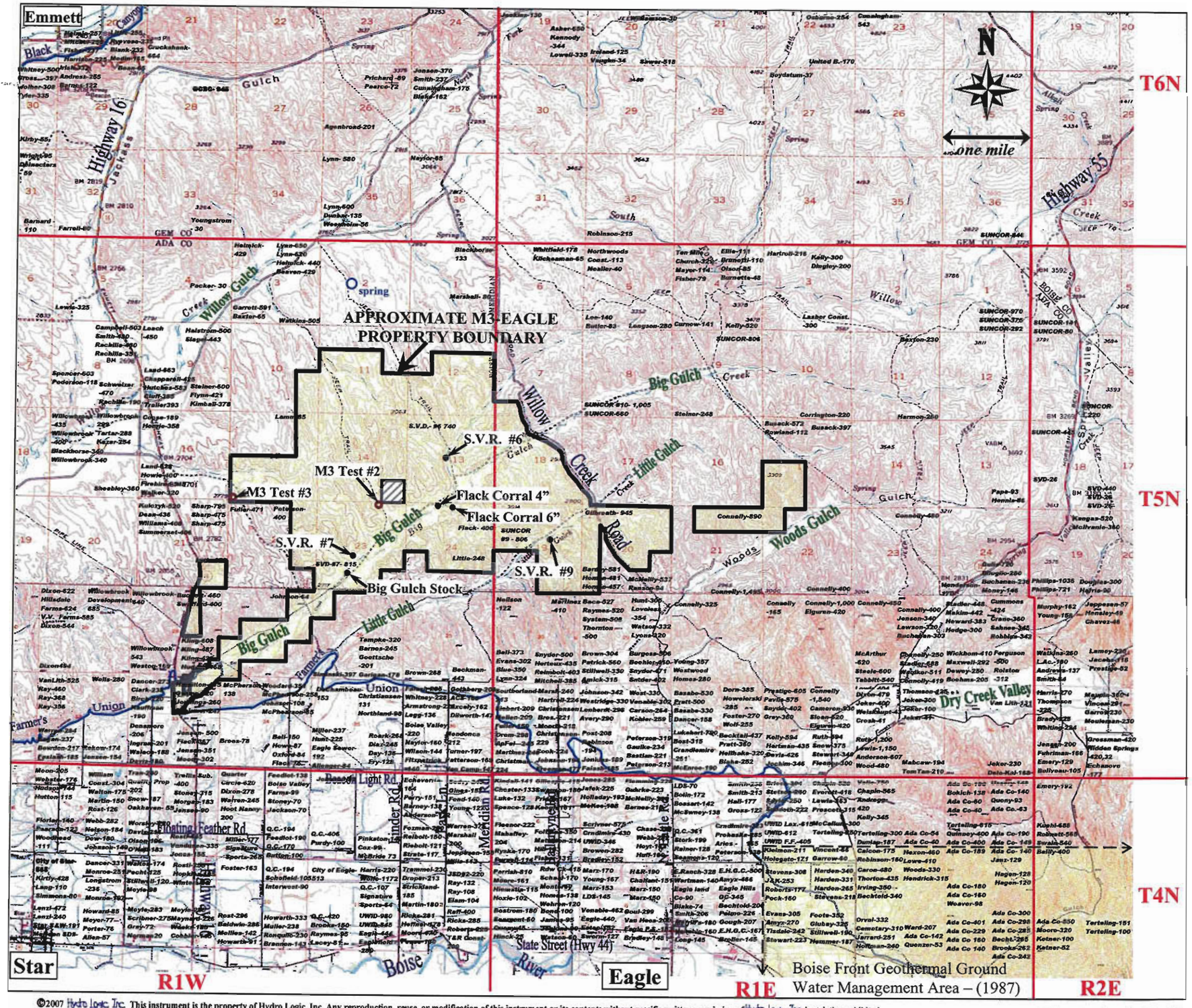

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Regional Well Location and Depth Map showing recorded wells in proximity to the proposed M3-Eagle planned community development boundary. The area within the dark grey borders, owned by M3 Companies, Inc., is a proposed 6,005 acre, 8,169 unit planned community.

Owing to space constraints, no more than five wells are shown for any given ¼ section. If five wells are shown, these are the five deepest wells located within that ¼. If less than five wells are shown, all recorded wells within the ¼ are listed. For a listing of the total numbers of recorded wells in the area, refer to Hydro Logic, Inc.'s "Well Density Map" and/or "Well Data Tabulation."

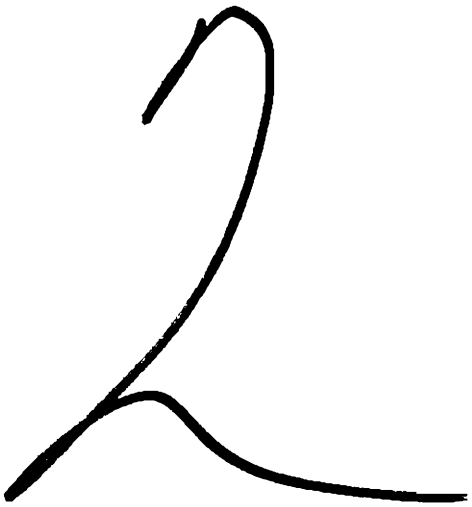
Water well locations were plotted from available driller's logs within the IDWR's electronic web-site data-base, hard copy and microfiche files of the Western Regional Office, and the files of Hydro Logic, Inc. The total number of wells within the study area of this map is 2,386.

Township and range boundaries are denoted in red and the approximate boundary of the development in gray with yellow shading.

M3 EAGLE LLC
EXHIBIT
1

Hydro Logic, Inc.
Boise, ID

Drillers Logs Location Map For M3 Eagle 09-13-2007



M3 EAGLE REGIONAL HYDROGEOLOGIC CHARACTERIZATION
NORTH ADA, CANYON AND GEM COUNTIES, IDAHO
YEAR-ONE PROGRESS REPORT

May 4, 2007

prepared
for

m3companies
M3 Eagle

by

Hydro Logic, Inc.

[1] E. Squires
[2] M. Utting
[3] L. Pearson

M3 EAGLE LLC
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ACKNOWLEDGEMENTS

Financial support and strong encouragement to provide significant and useful hydrogeologic information for the north Ada County area was provided by M3 Eagle, LLC. The M3 Companies understands and appreciates the significance of long term planning for water needs and has encouraged us to continue to expand the hydrological studies and models to provide confirmation of adequate and long term supplies for its project.

The authors would like to recognize the thorough and timely peer reviews of this report by Dr. S.H. Wood of Boise State University, Dr. Jim Osiensky of the University of Idaho, and Jeff Fereday of Givens-Pursley LLP. We appreciate all of their good comments and edits; all of which were taken into consideration and incorporated where applicable.

We are indebted to Spence Wood for a generous commitment to sharing his previous geologic mapping and long-term knowledge of the north Ada County Foothills geology with us on several field trips. The research of Dr. Wood and his colleague, the late Willis Burnham, has been invaluable to us and provides the real basis for all hydrogeologic investigations in this area.

For access to wells and sharing of other hydrogeologic and geophysical data, we are indebted to Greg Wyatt and Roger Dittus of United Water Idaho, Robert DeShazo of Eagle Water Company, the City of Star Idaho, Nancy Merrill of the City of Eagle, Brad Watson of the City of Meridian, Chris Duncan of Holladay Engineering, Co., Lynne Sedlacek of Eagle Sewer District, Bob Taunton of SunCor, Mike Moyle, and Brad Little.

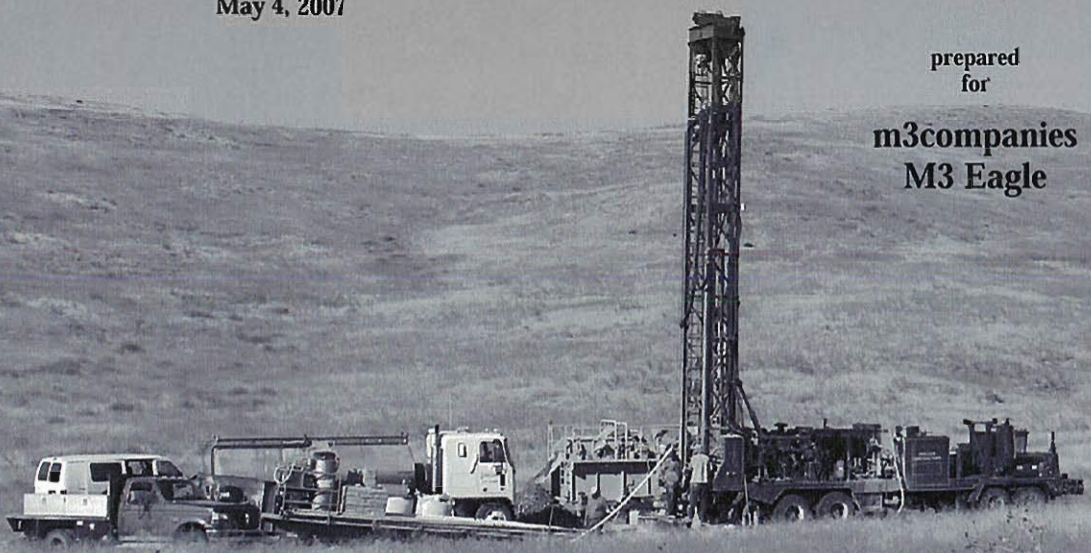
A special recognition goes to the citizens of Eagle, Star, and north Ada County for their wholesale willingness to allow us access to measure domestic wells in the area. Of over 200 wells measured, we were refused access to only a single well. Not only are the residents willing to help and contribute to this study but they have indicated a strong desire to better understand the water resource in the area in the face of rapid growth.

George Post, Chance Chandler, and crew, of Treasure Valley Drilling deserve much credit for their excellent work with the exploratory drilling and construction of the difficult and very technical M3 Eagle multi-level tube wells. David and Daniel McLeran of McLeran Well Drilling were likewise instrumental in rehabilitating several of the older wells in the area for testing and in developing the test wells drilled and completed by SunCor / Spring Valley Ranch. Steve Cook and Scott Astle of Layne of Idaho deserve our thanks for facilitating several aquifer tests that will be described in future reports.

Last, but not least, we are thankful for the insights and guidance offered by Sean Vincent of the Idaho Department of Water Resources during our previous meetings and field trip to the north Ada County foothills.

M3 EAGLE REGIONAL HYDROGEOLOGIC CHARACTERIZATION
NORTH ADA, CANYON AND GEM COUNTIES, IDAHO
YEAR-ONE PROGRESS REPORT

May 4, 2007



prepared
for

m3companies
M3 Eagle

by

Hydro Logic, Inc.

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M3 EAGLE REGIONAL HYDROGEOLOGIC CHARACTERIZATION
NORTH ADA, CANYON AND GEM COUNTIES, IDAHO
YEAR ONE PROGRESS REPORT – MAY 4, 2007

Overview

Hydrogeologic studies commissioned by M3 Eagle in the North Ada County area have delineated a highly productive regional sand aquifer with good water quality that underlies the area near Eagle and Star and the proposed M3 Eagle planned community. This aquifer, herein named the Pierce Gulch Sand Aquifer, underlies the north Ada County Foothills where it extends continuously from the Eagle-Star area to the Payette River Valley. Because the Payette Valley near Letha is almost 300 feet lower than the Boise Valley near Eagle, ground water flows out of the Boise River Basin and into the Payette River Basin through the sands of this aquifer. This conclusion is supported in this report by corresponding water level measurements in wells, by several exploratory test well drilling projects, by borehole geophysical surveys, and by other hydrogeologic analyses. Because the Pierce Gulch Sand Aquifer underlies this area, it appears highly likely that the M3 Eagle planned community will be able to develop its entire water needs from beneath its site without transporting water from the Valley areas of either basin. Extensive water-level monitoring in the area shows water levels in wells to be stable under current levels of use. The ground water proposed to be withdrawn by M3 Eagle for its development will be from subsurface flow that has already departed the Boise Basin, on its way to the Payette Basin, so that impacts to existing area water users in the lowlands near Eagle are predicted to be small. M3 Eagle has already implemented a significant ground water monitoring program to document aquifer conditions prior to development and to be able to assess any future impact to the aquifer from its proposed withdrawals over time. M3 Eagle is committed to continue its monitoring of aquifer pressures throughout the proposed development and beyond build out. Hydro Logic, Inc. has been commissioned by M3 Eagle to provide additional water studies to include future aquifer tests, numerical modeling, and ground water geochemistry modeling.

Introduction

Scope of Work. Hydro Logic, Inc. (HLI) was hired by M3 Eagle in March of 2006 to conduct a regional scale hydrogeologic characterization study to determine the ground water development potential for a proposed 8,160-unit planned community in the foothills area north of Eagle, Idaho. M3 Eagle's regional water study is divided into the following five sections: 1) characterization of the hydrogeologic framework, 2) aquifer testing and characterization, 3) development of a long-term water level monitoring network, 4) geochemical modeling, and 5) numerical modeling. Progress and findings for all five sections of the investigation are discussed below. This interim progress report concludes with a Summary of Preliminary Conclusions developed to date (April 1, 2007).

The ground water study was commenced to evaluate where and how the M3 Eagle project could obtain adequate water supplies for its proposed development. As such, it is a regional scale study intended to provide a broadened understanding of the aquifer system for the entire Eagle community and a larger regional area. All analyses conducted to date by HLI indicate a high likelihood that adequate ground water supplies are present beneath the M3 Eagle site to support the planned community without importing water from outside the area and without causing unreasonable impacts to existing water rights. A final comprehensive report for the study is being developed as supporting documentation for M3 Eagle's municipal water right application to the Idaho Department of Water Resources (IDWR), filed November 21, 2006. The preliminary findings of this study are set forth in this report in keeping with M3 Eagle's intentions to ensure that the public is well informed of its on-going studies and interim conclusions. We particularly want to inform the City of Eagle's Planning and Zoning Commission, the City of Eagle's Mayor and Council, the City of Star, United Water Idaho, Inc., Eagle Water Company, the IDWR, NACFA, and other water users in the Eagle area of Hydro Logic, Inc.'s findings to date. On behalf of M3 Eagle, HLI will be continually updating these findings and providing the results to all interested parties through ongoing presentations and reports such as this one.

Study Goals. An extensive hydrogeologic characterization program has been conducted by a number of entities on behalf of M3 Eagle as part of its plan to develop 6005 acres in the foothills north of Eagle, Idaho (see Figure 1). This program, commenced in March, 2006, has used the services of Hydro Logic, Inc., the University of Idaho, and Boise State University to develop an in-depth understanding of the groundwater flow system over an area extending from south of the Boise River near Eagle to north of the Payette River near Emmett. In addition, HLI has reviewed all available hydrogeologic studies completed to date and all available well information, from the region.

The purposes of M3 Eagle's water studies are to:

1) Develop an understanding of the three-dimensional hydrogeologic framework beneath the area
2) Assess the groundwater development potential for the planned community
3) Describe and quantify the occurrence and flow of groundwater throughout the study area
4) Provide data and scientifically-based conclusions to accompany M3 Eagle's water right request to IDWR for a supply that will average about 7.5 million gallons per day (mgd), equivalent to an average annual diversion rate of about 3,600 gallons per minute (gpm), at the end of the planned 20-to-30-year period of development[1].
5) Assess the impacts to existing wells from the proposed M3 Eagle water development.
6) Assess the total ground water development potential within the study area.

[1] This diversion rate is based on preliminary engineering assessments that are based on preliminary housing densities that are under discussion with the City of Eagle. This rate may be changed for future analyses.

This Report. This first-year Progress Report presents an overview and the major findings to date of the HLI ground water studies. A comprehensive report is anticipated to be completed in time to be presented in support of IDWR's review of M3 Eagle's water right application. HLI's comprehensive report will contain the supporting data files and findings based upon additional well tests, hydrological data collected from additional well studies and completion of a ModFlow numerical model. In the mean time, and as the water study progress, additional reports will be issued to document and present refinements of the findings presented here.

Hydrogeologic Framework

Pierce Gulch Sand Aquifer. This study has determined that a significant regional sand aquifer underlies the M3 Eagle site. All hydrogeologic evidence obtained to date indicate a high likelihood that all of the water needed for the planned development is available from beneath the M3 Eagle properties utilizing 6-to-10 on-site production supply wells. The Pierce Gulch Sand Aquifer consists of a 150-to-275-foot thick sequence of stratified sand layers with inter-bedded thin and locally discontinuous layers of silt and clay. The base of the dipping aquifer is typically 480-to-700 feet deep beneath land surface of the M3 Eagle site. The aquifer sand thickens and descends deeper beneath the land surface to the south and southwest in the Eagle-Star-Meridian area and is believed to do the same to the northwest toward Payette River. The Pierce Gulch Sand Aquifer is a very productive aquifer as evidenced by the many large bore production supply wells which are completed into it including the City of Star's wells, the City of Eagle's wells, and the public water utility wells of United Water Idaho and Eagle Water Company, all located throughout the area (see Figure 5).

Geophysical Log "Signature". Natural gamma-ray, single-point resistance, and electrical resistivity borehole geophysical logs of exploratory test wells and of water wells in the greater Eagle-Star-M3 area show a clear and identifiable "geophysical signature" of the basal sand section of the Pierce Gulch Sand Aquifer and the underlying sediments of the Terteling Springs Formation (Figure 2). This signature is characteristic of the thick sand sequence originally deposited as river and lake sediments in an ancient lake system (referred to as "Lake Idaho," by geologists) that formerly occupied what is now the Boise-Snake-Payette River Basins. This sand sequence is the same 250-ft thick medium-to-coarse grained sand unit that caps the foothills to the east of Eagle, named the Pierce Gulch Sand Member of the Idaho Group of formations (Wood and Clemens, 2002; Wood, 2004). The entire sedimentary sequence has dropped downward several hundred feet by structural faulting and now lies buried beneath the Boise River Valley and much of the western Snake River Plain where it is more difficult to identify and map. The geophysical signature recognized in this study (see Figure 2) provides a new means to map the areal extent of the aquifer over a vast area. We now know that the Pierce Gulch Sand Aquifer is the same aquifer that supplies the Eagle-Star-Meridian area and extends northwest beneath the M3 Eagle site to the Payette River Valley at least as far west as the City of Payette.

Extent of the Aquifer. The Pierce Gulch Sand Aquifer is bounded on its northeast side by the geologic fault system shown in Figure 3, originally named the West Boise-Eagle fault by Wood and Anderson (1981). The base of the aquifer is underlain (and bounded) by the thick clays and

mudstones of the Terteling Springs Formation. The base of the aquifer shown in Figure 3 is inclined about 100 ft per mile downward to the southwest. This structural dip explains why the municipal wells in Star are deeper than they are in Eagle. In the Boise River Valley near Eagle and Star, the Pierce Gulch Sand Aquifer is overlain by clays, some other minor sand aquifers, and a shallow surficial flood-plain-gravel aquifer (the present day floodplain of the Boise River). Beneath most of the M3 Eagle site, the aquifer is overlain by clay layers with no shallow surficial aquifer present. Figure 4 shows a simplified conceptual diagram of the regional aquifer. The figure is a cross-sectional schematic of the aquifer beneath the Boise River Valley extending to the Payette River Basin. The West Boise-Eagle Fault and the projection of the contact between the bottom of the aquifer and the underlying clay are also depicted on this "block" diagram.

Willow Creek Aquifer. A foothills aquifer, informally named the "Willow Creek Aquifer" (SPF, 2004) is a thick sand sequence that overlies granite and volcanic bedrock in the area northeast of the West Boise-Eagle fault system. Hydro Logic, Inc.'s concept of this aquifer is shown in Figure 5. It is an older geologic unit and stratigraphically deeper (older in time) than the Pierce Gulch Sand Aquifer. It is probably correlative to the sand facies of the Terteling Springs Formation described by Wood and Clemens (2002). The Willow Creek Aquifer consists of highly permeable sands and gravels (SPF, 2004) that appear to us to be bounded by (or grade laterally into) the clays underlying the Pierce Gulch Aquifer to the southwest and bedrock lying to the northwest of a major regional fault system, shown in Figure 3. The upper part of the Willow Creek Aquifer is exposed along the upturned section near the West Boise-Eagle fault system and in the foothills northeast of the fault. The approximate areal extent of this aquifer is shown by the shaded-turquoise region of Figure 6.

Hydraulic Interconnection Between Aquifers. In the Big Gulch area, the Willow Creek Aquifer has water levels that are more than 150 feet lower than water levels in nearby wells of the Pierce Gulch Sand Aquifer, as shown by the triangular water level symbols in Figure 5. The measured offset in water levels in the two aquifers is shown to occur over horizontal distances as short as one-quarter mile, suggesting a hydraulic disconnection between the two aquifers. The geochemistry of the ground waters in the two aquifers is also very different (see the section below on Geochemical Modeling). The differences in water levels and water chemistry, in concert with low-permeability clay strata between the two aquifers demonstrate that the Willow Creek Aquifer is distinct and separate from the Pierce Gulch Sand Aquifer. The differences in water chemistry also show that ground water in the Pierce Gulch Sand Aquifer does not flow in significant quantities to the Willow Creek Aquifer. The limited and bounded areal extent of the Willow Creek Aquifer, its high pumping lifts and associated energy costs, and the small amount of available recharge serves to limit its potential as a source for significant groundwater supply. The SPF (2004) report estimated that the total recharge to this aquifer is 3,300 acre feet annually (equivalent to about 3 million gallons per day or 2,000 gallons per minute). SPF estimated that a fourth of this recharge is from direct infiltration of precipitation and the remainder from up-basin runoff or ground water underflow source (a highly speculative conclusion in our opinion). In contrast, the Pierce Gulch Aquifer is areally extensive, benefits from a strong source of recharge from the southeast from surface water irrigation diversions and the upper Boise River and has the additional advantage of reasonably high water levels with relatively low pumping lifts.

Sub-Surface Cross-Section. Figure 5 presents one of thirteen cross-sections of the subsurface geology developed as part of the characterization program using existing well data. (The other cross-sections will be included in a future report). The line of section for this cross-section for this sketch, which shows HLI's interpretation of the regional aquifer beneath the M3 site, is shown on Figure 1. The cross section depicts the Pierce Gulch Sand Aquifer dipping to the southwest and rising to the northeast where it projects to ground surface between Spring Valley Ranch test wells #6 and #7 in Big Gulch. The dashed green line in Figures 3 and 4 represents the approximate position of the base of the Pierce Gulch Sand Aquifer where it crops out at land surface.

Pierce Gulch Sand Aquifer Characterization

Conceptual Model. Using the derived aquifer transmissivity values and the measured water levels in wells to derive a ground water gradient, our analyses indicate that 20 to 30 mgd (million gallons per day (equivalent to approximately 22 thousand to 34 thousand ac ft/yr. (acre feet per year)) of ground water currently flows in a northwesterly direction through the Pierce Gulch Sand Aquifer beneath a five-mile wide strip of the M3 site between State Highway 16 and the inferred edge of the pierce Gulch Sand Aquifer (shown as a dashed green line on Figure 6). This quantity represents three to four times the projected demand at build out. The five mile swath approximates the expected width of the capture zone (cone of depression from pumping) for M3-Eagle's proposed on-site production wells. This ground water flows from south of Eagle and areas south of the Boise River toward the Payette River Valley where it ultimately discharges. Most of this groundwater originates as recharge in the east and south Boise regions augmented by leakage from canals south and east of Meridian and recharge from the Boise River in the Boise area. There is likely some localized shallow aquifer recharge from area canals such as the Farmers Union Ditch and from flood irrigation although these sources are believed to recharge only the uppermost floodplain terrace gravel in the lowland Eagle area and ultimately discharge quickly to the Boise River. This localized recharge is not believed to be significant to ground water flow beneath the M3 Eagle site. Contrary to popular notion, the deeper (Pierce Gulch) aquifer is not recharged by the Boise River in the Eagle-Star area. In fact, the opposite is true. Owing to the upward ground water gradient in the area (increasing potential with depth) the Boise River actually gains water from the aquifers underlying it. It is this upward ground water flow from below that makes the River a "gaining stream" in the Eagle reach and also is the source of Eagle's many flowing artesian wells, as discussed in Petrich and Urban (2004).

Ground Water Flow Direction. Figure 6 indicates the general ground water flow directions and water level contours for the Pierce Gulch Sand Aquifer, the Willow Creek Aquifer and the undifferentiated localized aquifer(s) within granitic and volcanic rocks and local sedimentary aquifers of the foothills to the northeast of the M3 site. These contours were generated from data derived from two sources. The first and primary source is a series of 167 water levels measured by HLI and the University of Idaho in the M3-Eagle-Star vicinity during the summer of 2006. The second source of water level data is from IDWR's on-line data base, for wells located further away from the project area. The IDWR data consists of levels measured by IDWR and levels reported on Well Driller's Reports. Our level of confidence in the interpretation of ground

water flow in the area where HLI collected water level data (the Eagle-Star-M3 area) is much higher than in the regions to the west (the Caldwell-Meridian and northward area). Lower confidence is noted by the dashed contour lines in the regions of less reliable (driller) data.

The combined water level data are contoured to show the potentiometric surface with arrows indicating the inferred ground water directions, based on ground water flow at right angles to the contours (ground water flow from higher pressure levels to lower pressure levels). The water level contour map illustrates that although the Willow Creek Aquifer is adjacent to the Pierce Gulch Aquifer, only small quantities of ground water flow from the Pierce Gulch Sand Aquifer to the Willow Gulch Aquifer. In our conceptual model, low-permeability clay and mudstone strata underlying the Pierce Gulch Sand Aquifer significantly restricts ground water flow to the Willow Creek Aquifer; the steep hydraulic gradient (close to 1.0) between the aquifers in the Big Gulch area notwithstanding. The contours shown for the Willow Creek Aquifer, and the undifferentiated upland zone in the northeast, are only approximate because of the limited number of water level data points available for contouring.

Interbasin Transfer of Ground Water Under Natural Gradients and Recharge. Prior to the HLI study, the prevailing conceptual models indicated that recharge to the ground water system beneath the Eagle area originated primarily in the foothills to the north and east of Eagle (Petrich and Urban, 2004; and SPF, 2004). In HLI's view of ground water flow (conceptualized on Figure 7), the previous conceptual models are incorrect. In other words, regional ground water *does not* flow from the uplands in the northeast to the valley in the southwest. Instead, ground water flows from southeast to northwest beneath the City of Eagle and the M3 Eagle site through the Pierce Gulch Sand Aquifer because the northwest ground water flow gradient is toward the Payette Valley. The gradient is driven by the higher pressures ("head" or water levels in wells) in the aquifer to the south beneath the Boise Valley and the lower aquifer pressures in the aquifer to the northwest beneath the Payette Valley. The water levels in the aquifer beneath the Payette Valley are lower because the land surface of the Payette Valley near Letha is about three hundred feet lower than the Boise Valley near Eagle (see Figures 7). The existence of significant ground water flow from the Boise Basin to the Payette Basin was discounted by Newton (1991) and again by Petrich and Urban (2004) although Urban acknowledges (personal communication, 2007) that he believed such an exchange could happen, "there just was not sufficient data at that time to substantiate it".

Vertical Gradients and Confining Conditions. Although Figure 6 shows the general horizontal components of ground water flow in the region, vertical flow gradients are not yet fully understood and are not illustrated in this report. A significant observation, however, is that there is an upward vertical gradient within all three of the test well piezometer nests drilled beneath the M3 Eagle project site, as part of the HLI characterization study. Even though these vertical gradients are relatively small (typically less than a foot difference over a vertical difference of 100 to 200 feet), the upward gradient indicates that ground water beneath the M3 Eagle site is under similar confining conditions to those in the Eagle-Star Valley areas. These measured vertical gradients that exist in the foothills region also serve to refute the prevailing notion of the foothills as a recharge area for the City of Eagle's water supply. Because the M3 Eagle project site ground surface is at higher elevations than the Valley, water levels in upland wells of the

Pierce Gulch Aquifer do not rise to the surface and flow as they do throughout the lowland areas of the Cities of Eagle, Star and Meridian. Figure 7 shows this relationship with aquifer water levels ("potentiometric surface") above the Boise and Payette Rivers but below ground surface beneath the M3 Eagle site and adjacent uplands.

Aquifer Transmissivity. HLI analyzed the data from fifteen well pumping tests of other workers in the study area (including three on the M3 Eagle site). The locations for the analyzed wells (including selected observation wells) are shown in Figure 8. These analyses indicate that individual well yields from the Pierce Gulch Sand Aquifer are high – in excess of 1,000 gpm and at some locations as high as 2,000 gpm. The calculated transmissivities (a property that helps to quantify how much water can flow through an aquifer) for the entire aquifer thickness are estimated by us to be on the order of 100,000 gallons per day per foot (gpd/ft) and in some areas values of 200,000 gpd/ft and higher were derived. Figure 8 shows eighteen calculated transmissivity values in map view by location for the various tests. Several of the tests included multiple observation wells which allowed evaluations of transmissivity at more than one location per test. The range of calculated transmissivity values compare reasonably well with those of Baker (1991) for the Eagle area. HLI's analyses for the fifteen pumping tests will be released by M3 Eagle as a separate, stand-alone report in the near future.

Large values of aquifer transmissivity indicate that the draw down (cone of depression) of a pumping well will translate into relatively smaller water level/pressure declines around and at distance from the pumping well and that the decline will be spread over a larger area. In other words, large transmissivity generally results in smaller impacts (well interference effects) to other wells in the area. Because of the relatively undeveloped foothills area surrounding the proposed M3 Eagle development, and also because a one mile wide strip of BLM desert land separates the M3 Eagle site from the City of Eagle, interference effects to existing domestic wells are lessened simply due to the distances to nearby wells. The largest potential for interference effects to existing wells is on the west side of the M3 Eagle lands near State Highway 16. Although the actual extent of any future impacts cannot be truly known until actual pumping wells are in place, M3 Eagle has constructed a multi-level monitoring well at this location. This piezometer nest and several other local domestic wells are being measured, and will continue to be measured to determine the extent of any well interference impacts that do occur. It is anticipated that M3 Eagle will drill, construct, and test a large bore supply well within the next sis month period.

Aquifer Storativity. Figure 8 indicates computed short-term and estimated long-term storativity coefficients calculated for the greater project area. Storativity is an aquifer property that indicates how much water is released from the aquifer to a well when it is pumped. The results of the short-term pumping tests (a few days or less) all indicate storativities on the order of 0.001 or less, demonstrating "confined to semi-confined conditions." Confined conditions generally cause the effects of pumping to be spread out relatively rapidly from the pumping well and over a large area, as water is drawn toward the pumping well. Confined conditions can also mean that the effects of pumping would be somewhat-to-completely attenuated in overlying aquifers. A confining layer, typically lower-permeability clay and/or mudstone, allows only minor leakage across the stratigraphic layering such that the effects of pumping take longer to reach the

overlying shallow ground water zones. In other words, a clay layer between two aquifers slows down and reduces the draw down effects in one aquifer when the other aquifer is pumped.

Two longer-term aquifer tests have been conducted in the Eagle area (CH2M-Hill, 1991, Holladay Engineering Company, 2006). HLI's re-analysis of these tests, generated aquifer storativity values of 0.01 and higher, indicating "semi-confined" to "unconfined conditions" under longer-term pumping. The larger storativities with longer-term pumping indicate that the confining clay layers are likely discontinuous over a broad region allowing the draw down pressure gradients from the pumping well to propagate upwards into shallow less confined-to-unconfined aquifers and/or surface water sources with the result that the water level in the pumping well ceases to draw down under continued pumping. In other words, the cone of depression ceases to expand so that interference effects to surrounding wells are arrested.

High-quality long-term pump testing has not yet been conducted beneath the M3 Eagle site. However, hydrogeologic data from two of the M3 Eagle exploratory test wells indicate the northeast edge of the aquifer is defined by an unconfined water table or a water level that is only slightly above the overlying (confining) clay. These conditions suggest that long-term pumping could lead to unconfined conditions near some of the proposed M3 Eagle pumping wells in the Pierce Gulch Sand Aquifer. Pumping under unconfined conditions generally results in smaller interference effects to other wells in the area, especially to those at more distal locations (several miles), compared to pumping under confined conditions.

Predicted Impacts of M3 Eagle's Ground Water Development at Full Build-Out. We have used the results of the pumping tests to estimate the effects of yet-to-be-constructed production wells on the M3 Eagle site. The drawdown effects of each pumping well are additive. The impact at any given site or well location will be the sum of the impacts caused by all pumping wells. Figures 9 and 10 show the collective predicted drawdown (cone of depression) that could be caused by six hypothetical production wells completed in the Pierce Gulch Sand Aquifer on the M3 Eagle site. These proposed supply wells are labeled PS1 through PS6 in the figures. Based on the understanding that the Pierce Gulch Sand Aquifer is bounded along its northeast edge (as shown by the green line in Figures 9 and 10), the proposed well locations lie within the southwest portion of the M3 Eagle site, oriented at right angles to ground water flow. These locations and orientations were chosen to allow for an optimal yield while minimizing impacts to off-site wells. The actual well locations, total quantity of water pumped from individual wells, and the actual number of wells constructed will be determined as the water supply for the project is developed and as additional wells are drilled and tested. M3 Eagle's existing monitoring network will also be utilized to understand the impacts of newly completed wells to the aquifer system. The predicted drawdown interferences were generated using an analytical model that calculated drawdowns at one-mile centers within a 42 square mile area surrounding the M3 Eagle project. The predicted drawdowns within each one square mile area were then contoured to show lines of equal predicted drawdown-inference throughout the region shown in Figures 9 and 10. The model used the method of Theis (1935) and image well theory to replicate the effects of the pumping wells and the northeastern edge of the aquifer that acts as a no-flow boundary. A total of 12 wells were used in the simulation (six pumping wells and six "image"

wells). The image wells (not shown in the figures) were used to simulate the effects of the aquifer boundary.

The analysis used a range of transmissivity and storativity coefficients calculated from the fifteen pumping-test results for the Pierce Gulch Sand Aquifer. The best-case analysis was based on an aquifer transmissivity of 200,000 gpd/ft while the worst case used a transmissivity of 100,000 gpd/ft. This worst-case is based on lower values calculated from short-term pumping tests conducted in the regional aquifer while the best case is based on the upper-end values calculated from the long-term tests. The actual results are likely to lie somewhere between the two end-point predictions.

Two values of storativity were used in the analysis. A best-case value of 0.01 was used to represent semi-confined-to-unconfined conditions that have been observed during long-term testing and are likely to occur over a season of pumping. As a worst case, a value of 0.005 was used in the analysis. This value is slightly larger than those calculated from short-term test data but smaller than those calculated from the longer tests that better represent our best understanding of how the aquifer will behave during extended pumping. Since the Pierce Gulch Sand Aquifer is leaky and likely to become locally unconfined over time, we believe that the actual effective storativity will fall within the range of values reflected in the best- and worst-case analyses.

Figure 9 shows the predicted drawdowns at full M3 Eagle build out for the best (least drawdown) case scenario. This analysis indicates collective drawdowns of 6 to 8 feet are likely one mile from the project boundaries. Figure 10 shows the worst-case predictions with interference drawdowns on the order of 10 to 16 feet one mile from the project. Additional aquifer testing planned for summer of 2007 will help to refine these predictions. The actual real-world inference drawdowns will be measured and reported as the project develops. As new wells are put into service and the water demand increases over time, the in-place monitoring program (discussed below) will allow for actual measurement of interference drawdowns. Any potential impacts to the small number of domestic wells adjacent to the M3 Eagle site would be able to be predicted and identified through this monitoring program because M3 Eagle has commenced a monitoring program that includes wells in all areas of potential impact.

It should be noted that the predictions shown in Figures 9 and 10 are for wells completed into the Pierce Gulch Sand Aquifer and do not directly address impacts to shallow wells (most often domestic wells) that may be completed into overlying aquifer zones that are separated from the main body of the Pierce Gulch Sand Aquifer by low-permeability sediments (clay layers). Interference draw downs in wells completed within an overlying aquifer unit would be expected to be reduced in magnitude and delayed from those predicted in Figures 9 and 10. If the overlying aquifer is separated from the regional aquifer by a clay layer that is low in permeability, the interference effects of deeper pumping wells could remain small, or even be immeasurable over time, in wells completed into the shallower aquifer units. Conversely, if the layers separating the regional and shallow aquifer are leaky and permeable, interference in shallow wells could possibly approach the same levels as those predicted for wells completed in the Pierce Gulch Sand Aquifer after an extended period of pumping. With an eye toward

potential impacts to shallow domestic wells, M3 Eagle has constructed monitoring wells that monitor all saturated aquifer units at a given location to be able to asses the effects of deep well pumping to shallower sub-aquifer units. M3 Eagle's monitoring plan utilizes continuous measurements from digital data loggers with periodic calibration checks (hand measurements) rather than relying on a few "spot" measurements of a well through time. Therefore, on-going monitoring is in place to better assess impacts (if any) to shallow wells; even if such effects are delayed.

Domestic Wells. A records survey of over 1,600 domestic (single family household) wells in the greater project area from Eagle to Emmett shows that the preponderance of domestic wells are located up-gradient (toward Eagle and Star) from the M3 site (see Figure 11). That is to say, ground water flow in the aquifer encounters these wells first before flowing to the M3 site. Water levels would likely be lowered to some degree in some of these wells under long-term pumping, as discussed above. Wells close to the M3 site would be expected to be impacted to a larger extent than wells at a distance from the pumping centers. While it is conceivable that a few nearby wells may require mitigation to honor their pre-existing water rights, we believe that the existing water level monitoring network is adequate to predict such interference effects before anyone would experience an actual water shortage and M3 Eagle's proactive pre-development water level monitoring of local area domestic wells will be instrumental in assessing such interference effects. M3 Eagle is absolutely committed to mitigating unreasonable and damaging interference effects that would be a result of its water development whether this would require lowering of a pump in a nearby well and/or even deepening of the well in an extreme case.

Long Term Aquifer Monitoring

M3 Eagle Aquifer Monitoring. M3 Eagle commenced long-term monitoring of groundwater pressures (water levels in wells) in the Big Gulch and Little Gulch areas in March 2006. To date, three, multi-level, long-term designated monitoring wells have been installed and instrumented by M3 Eagle at a cost of over $100,000 per well. Water levels at various depths of the Pierce Gulch Sand Aquifer are currently being monitored in these wells. Figure 12 shows the details of well construction for one of the M3 Eagle monitoring wells. In addition HLI is monitoring levels in five other Pierce Gulch Sand Aquifer wells in the area. As of February 2007, a total of 17 separate wells are being monitored with electronic data loggers by HLI for M3 Eagle. These data loggers have helped in the assessment of seasonal water level trends, changes in water levels caused by pumping and even changes resulting from changes in weather patterns and daily earth tides. These wells will provide good documentation of predevelopment aquifer water levels. They will also be used in longer-term aquifer testing in conjunction with one or more high-capacity test wells that will be installed at some future date. Local residents and well owners, along with IDWR, will be advised of the tests and invited to participate.

Other Monitoring. The United States Geological Survey (USGS), IDWR, United Water of Idaho (UWID), and others also are monitoring ground water levels in wells of the Eagle area. It is estimated that approximately 70 wells are currently being monitored in the uplands and lowlands

in and around the City of Eagle. In general, water levels in wells appear to be stable with no apparent declines over the last ten years. (Bendixsen, 2007).

This ongoing monitoring, along with additional pumping tests associated with new well installations, studies by faculty and students at the Boise State University, and numerical modeling by the University of Idaho, will allow for refinements in the understanding, and better management of the ground water system in the entire Eagle-Star-M3 area. As this understanding is improved, supplemental reports will be released by M3 Eagle to regulatory agencies and the public.

Ground Water Geochemistry Modeling

Drinking Water Quality. All ground water samples collected and analyzed from the Pierce Gulch Sand Aquifer indicate that water quality is excellent and will meet all state and federal drinking water standards. To date, HLI has collected and had analyzed eleven ground water samples from test wells M3-TW#1 and M3-TW#3 and the Kling Irrigation well. The results all indicate that ground water from the Pierce Gulch Aquifer beneath the M3 site meets the drinking water standards of the United States Environmental Protection Agency (USEPA) Safe Drinking Water Act and will require no treatment to meet the administrative rules of the Idaho Department of Environmental Quality (IDEQ) for Public Drinking Water Systems.

Geochemical Flow Paths. Comparison of ground water chemistry analyses for water samples from both the Pierce Gulch Sand Aquifer and the Willow Creek Aquifer, supports the conclusion that the ground water in the Willow Creek Aquifer cannot have evolved from the ground water in the Regional Aquifer. The ground water in the Willow Creek Aquifer has a much lower concentration of dissolved solids than the ground water from the Pierce Gulch Sand Aquifer. The dissolved solids in ground water tend to increase along a flow path, because of "residence time" that a given ground water is in contact with the aquifer host rocks. This is why the concentration of total dissolved solids is greater in the Pierce Gulch Sand Aquifer compared to the Willow Creek Aquifer. Figure 6 demonstrates that the flow path in the Pierce Gulch Sand Aquifer is much longer than the flow path in the Willow Creek Aquifer (longer residence time = ground water in contact with the aquifer rocks longer = more dissolution of minerals into the ground water). The water level contour map shows ground water flows through the Pierce Gulch Sand Aquifer from south of Eagle (and off the map) to the M3 Eagle site where the samples were collected, a distance of many miles. The highly bounded Willow Creek Aquifer has no such long-distance flow path. Instead, its ground water recharge is believed by us to originate mostly from the infiltration of local precipitation and from upland streams infiltrating the top of the unit; a theory shared in part by previous researchers (SPF, 2004). The flow paths, and thus the residence times, are much shorter for the Willow Creek Aquifer. These geochemical observations support our understanding of the ground water flow paths demonstrated by the water level contour map (Figure 6) and discussed throughout this report. Our preliminary geochemical analyses also support our contention that the Boise River near Eagle does not locally recharge the Pierce Gulch Sand Aquifer.

Natural Separation of Aquifer Waters. In addition to the measured total dissolved solids concentration, nitrate concentrations in the samples from the Pierce Gulch Sand Aquifer are elevated compared to those from the Willow Creek Aquifer. Nitrate is a conservative "tracer" in that it does not react or become significantly adsorbed onto the aquifer matrix along a flow path. The lack of nitrate in the Willow Creek Aquifer also appears to support our contention that groundwater does not flow *from* the Pierce Gulch Sand Aquifer *to* the Willow Creek Aquifer in any significant quantity, even through a steep water level gradient (much lower water levels in the wells completed in the Willow Creek Aquifer compared to the Pierce Gulch Aquifer) exists between the two aquifers. These ground water quality parameters support the conclusion that the two aquifer flow systems are, for all practical considerations, separate and that their source waters (recharge) are different. Ground water in the Pierce Gulch Sand Aquifer enters the M3 Eagle area primarily through underflow of ground water from southeast of Eagle while recharge to the Willow Creek Aquifer is primarily through limited infiltration of precipitation and runoff from the uplands to the northeast via intermittent streams and seasonal snowmelt.

Geochemical Modeling. As soon as the final geochemical analyses are available, the ground waters from selected well locations will be modeled using "the Geochemists Work Bench" software to obtain further insights into the regional ground water flow paths. The results and interpretations from this work will be included in HLI's future comprehensive project report.

Computer Modeling

HLI has been working with the University of Idaho's Department of Geological Sciences (U of I) to provide data for their use in developing a computerized numerical ground water flow model for the M3 Eagle development and surrounding communities. M3 Eagle commissioned the U of I to develop a detailed numerical model independent of HLI's ongoing modeling efforts and has additionally funded a Master's Thesis at U of I's Department of Geological Sciences in response to a request by local-area residents to have an independent unbiased model constructed. All the data collected to date by the HLI team has been shared with the U of I modelers and regular review meetings are conducted. The U of I modelers have reviewed HLI's conceptual understanding of ground water flow presented in this Hydrogeologic Characterization Progress Report and are using it in the development of their computer model. They are basing their model on "Modflow 2000," the current *de facto* standard for regional computer flow models, developed by the United States Geological Survey and used extensively throughout the United States for regional modeling and aquifer management.

It is anticipated that the U of I model will be available for predictive use in 2008, although preliminary testing of hypotheses may be possible sooner. To be able to test our aquifer theories on an ongoing basis, HLI is simultaneously developing simplified models using a variety of software packages that will be able to be compared to the U of I model when it is completed in the future. It is anticipated in the mean time, however, that the HLI model simulations will be adequate and available to support M3 Eagle's water right application pending before IDWR. The predictions made by the models will include estimates of general water level and flow changes that would be caused by the pumping of new wells drawing from the Pierce Gulch Sand

Aquifer. After the U of I model is completed in 2008, additional time-series data will likely be needed to verify model calibration. This verification would increase the certainty of model predictions, which at this time can only be based on the available data from the site and the greater Eagle-Star area. Additional planned aquifer testing and water level collection, followed by adjustment of the Modflow model to better replicate known hydrologic events, will improve confidence that the model can accurately predict long-term response to pumping. HLI and M3 Eagle intend for the model to be a predictive tool to assist in aquifer characterization. It is our conviction that the actual and real results from the aquifer testing and high quality monitoring of water levels in wells will provide the best information on the sustainability of the aquifer.

Preliminary Conclusions

Based on the work conducted to date, we present the following preliminary conclusions:

1) A single, regionally extensive aquifer underlies Eagle, Star and portions of the M3 project site.
    a. The aquifer, designated the "Pierce Gulch Sand Aquifer" (after a significant geologic unit of the same name) underlies the M3 Eagle site. The aquifer has been delineated by a series of exploration test wells, surface geologic mapping, geophysical surveys, analyses of pumping tests, collection of water level data, ground water geochemical analyses, and computer modeling.
    b. The aquifer is comprised of granitic sands, with inter-bedded thin and locally discontinuous clay layers, that range from 150 to 275 feet in total thickness in the project area.
    c. The aquifer dips at low angles to the southwest so that it lies at a deeper level beneath land surface at Star than beneath Eagle.
    d. The aquifer sands are approximately 275 feet thick under the M3 Eagle site but appear to thicken down dip to the southwest. The aquifer as a whole may be effectively "thicker" in terms of aquifer transmissivity in parts of the Eagle and Star area where overlying saturated zones are hydraulically interconnected.

2) Ground water in the Pierce Gulch Sand Aquifer flows beneath the Boise River, beneath the City of Eagle, and beneath the M3 Eagle lands from south of the Boise River, northwestward to the Payette River Basin.
    a. The major source of ground water in the aquifer in the vicinity of Eagle is ground water underflow from areas south and east of the Boise River at Eagle.
    b. This ground water originates as direct infiltration from the Boise River in the east-central Boise area and through leakage from irrigation canals south and east of Eagle.

3) The Boise River near Eagle and Star does not recharge the Pierce Gulch Sand Aquifer.
    a. The Boise River receives discharge *from* the Pierce Gulch Sand Aquifer and a shallow surficial aquifer via the upward vertical ground water gradients that prevail within the Eagle area.

b. The upward ground water gradient (increasing potential with depth) is most easily recognized in the preponderance of flowing artesian wells in the Eagle and Star areas and by the fact that the Boise River is a "gaining stream" in the Eagle reach.
c. Recharge that occurs through infiltrated precipitation, applied surface water irrigation, and from canal leakage in the Eagle area mostly enters the shallow surficial aquifer which lies above the Pierce Gulch Aquifer and is believed to drain to the Boise River without significant effect to the underlying deeper aquifers.

4) Water levels in wells completed within the Pierce Gulch Sand Aquifer appear stable at the current level of ground water withdrawal in the Eagle area.
   a. The monitoring of 70 wells by state and federal agencies, local water utilities, and others, show generally stable or rising water levels in wells (Bendixsen, 2007).
   b. Water level monitoring by UWID, of a designated monitoring well completed into the Pierce Gulch Sand Aquifer at the intersection of State and Linder in Eagle, shows water levels to be constant for the last ten year period (Roger Dittus, personal communication, 2007).Perceived and/or alleged declines in above-ground artesian pressures of some local area wells are likely true in some cases but are considered to be most likely the result of poorly constructed (unsealed) air-rotary-drilled wells and corrosion of thin-wall steel casing used for most wells in the area historically. A "water level change map" of measured water levels in comparison to water levels reported on driller's reports is planned for HLI's comprehensive report.
   c. A water level change map developed by HLI supports these conclusions where the only apparent pressure declines are where a well field of unsealed domestic wells allows artesian pressure to escape through unsealed annular spaces of air-rotary and cable-tool drilled wells.

5) Ground water in the Pierce Gulch Sand Aquifer under the M3 Eagle site is of excellent quality for all purposes.
   a. Tested waters meet all drinking water standards of the USEPA Safe Drinking Water Act.
   b. No treatment will be required to use this water in a Public Drinking Water System under current Idaho Department of Environmental Quality's administrative rules.

6) The Pierce Gulch Sand Aquifer is moderately to highly productive.
   a. Yields from properly designed and constructed wells are projected to be on the order of 1,000 gpm to 2,000 gpm (1.5 to 3 mgd) or more.
   b. Calculated Transmissivity values from 15 pumping tests show a range from 30,000 gpd/ft to over 300,000 gpd/ft.

7) Sufficient quantities of ground water appear to be present beneath M3 to supply its development.

a. At the current level of understanding of the aquifer it appears possible, if not likely, that the full M3Eagle water demand can be obtained from 6-to-10 on-site water supply wells.
b. At "full build-out" of the M3 project (20 to 30 years), a total average daily water demand of about 7½ mgd will be needed to supply the project or about 25 % to 30% of the 20 to 30 mgd daily flow underlying the property.
c. Based on the work completed to date, it is deemed unlikely that water would have to be transported from wells in the lowlands of the Valley near Eagle and Star to supply the proposed development.
d. Calculated northwest groundwater flow beneath a five-mile wide section of the Pierce Gulch Aquifer beneath the M3 area is on the order of 20 to 30 mgd.

8) Impacts to existing water users from the M3 Eagle development are expected to be few and small-to-moderate in magnitude.
   a. The majority of ground water proposed to be withdrawn by M3 Eagle, will be water that would have already departed the Boise Basin and become tributary to the Payette River Valley.
   b. Most existing wells in the area are up-gradient in the flow system from the M3 Eagle site such that ground water flows to the Eagle area wells before it flows to the M3 site. After flowing beneath the M3 site, groundwater continues toward the Payette River Valley.
   c. A best-case analysis using upper-end aquifer parameter values derived from numerous tests conducted in the Pierce Gulch Sand Aquifer indicate that reductions in water levels in wells one mile from the project boundaries caused by a six hypothetical supply wells, each pumping at 1,000 gpm well for 90 days, could be on the order of 6 to 8 feet.
   d. A worst-case analysis using lower-end aquifer parameter values indicates these reductions could be on the order of 8 to10 feet, one mile from the site.
   e. The actual impacts will likely lie between these two analyses. Additional aquifer testing, scheduled for late summer 2007, and on-going monitoring are planned to refine these estimates of impacts to adjacent wells.

9) M3's monitoring program is adequate to document the impacts of its water withdrawals.
   a. M3 Eagle has commenced long-term monitoring of aquifer water levels with the installation of three monitoring well nests and 17 electronic data loggers.
   b. These loggers are currently collecting data from a total of eight wells, each monitoring one to five depth zones in the Pierce Gulch Aquifer, to measure and document the changes to the aquifer caused by M3 Eagle's ground water development.
   c. As each new supply well is added, additional monitoring and testing will be employed to assess the impacts to other groundwater users in the area as well as the ability of the Pierce Gulch Sand Aquifer to supply the needed water from wells completed on the M3 Eagle property.

10) Additional drilling and long-term pumping tests of one or more high-capacity supply wells are planned to better refine the properties of the Pierce Gulch Aquifer beneath the M3 Eagle property.
    a. These studies will better predict long-term yield and impacts to existing wells.
    b. Local well owners and IDWR will be advised of, and invited to participate in these tests.

11) The on-going monitoring, testing, and numerical ground water modeling and calibration will be used to refine the current understanding of groundwater flow and potential yield of the regional flow system that underlies the M3 site and the greater Eagle-Star areas.

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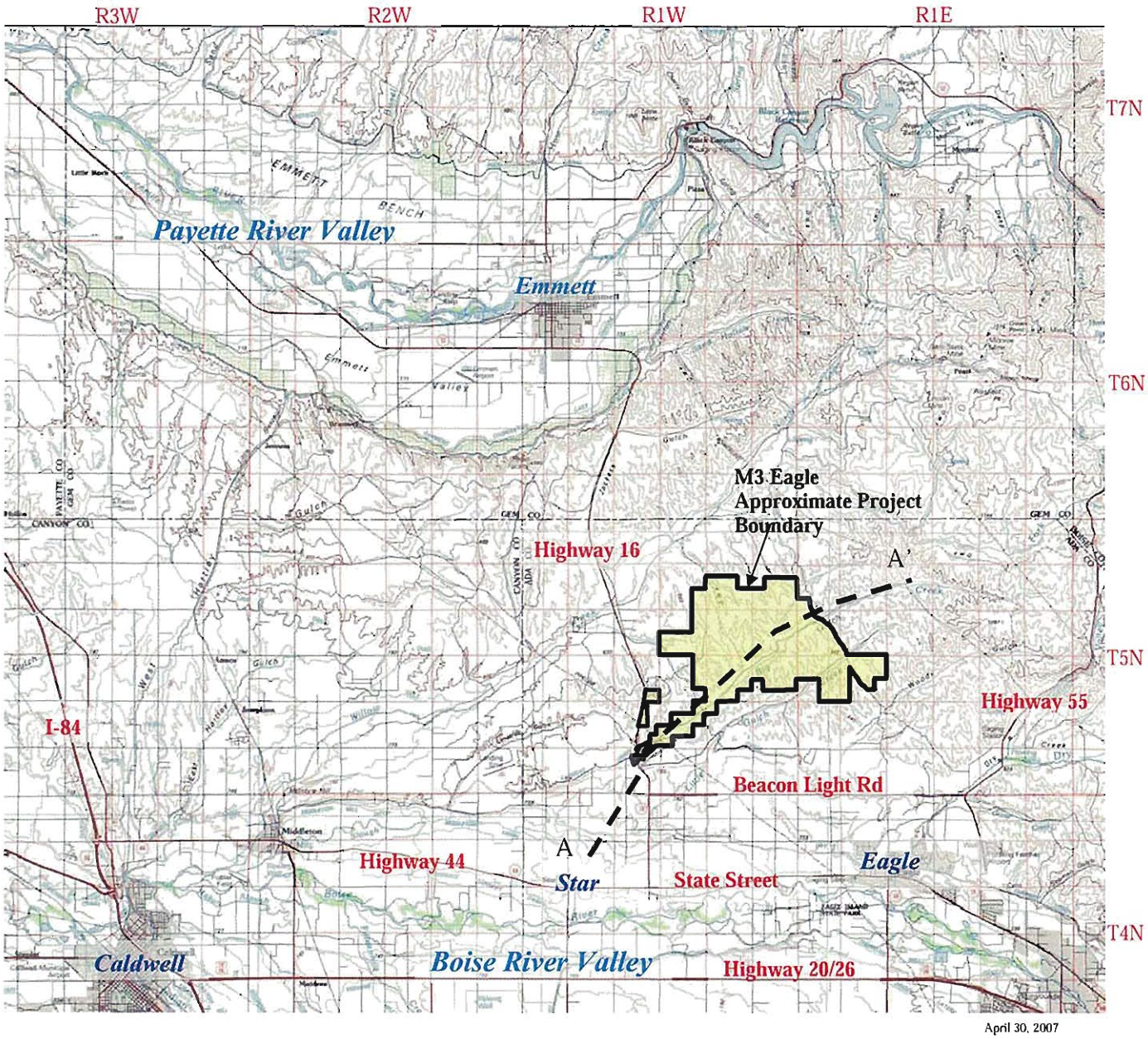
FIGURES



This regional map shows the location of the M3 Project and its relationship to Eagle, Star, the Boise River Valley, Payette River Valley and surrounding area.

N = 1 Mile A A' Geologic Cross-Section Location for Figure 5

Figure 1. M3 Eagle Project-Area Location Map

Figure 1.

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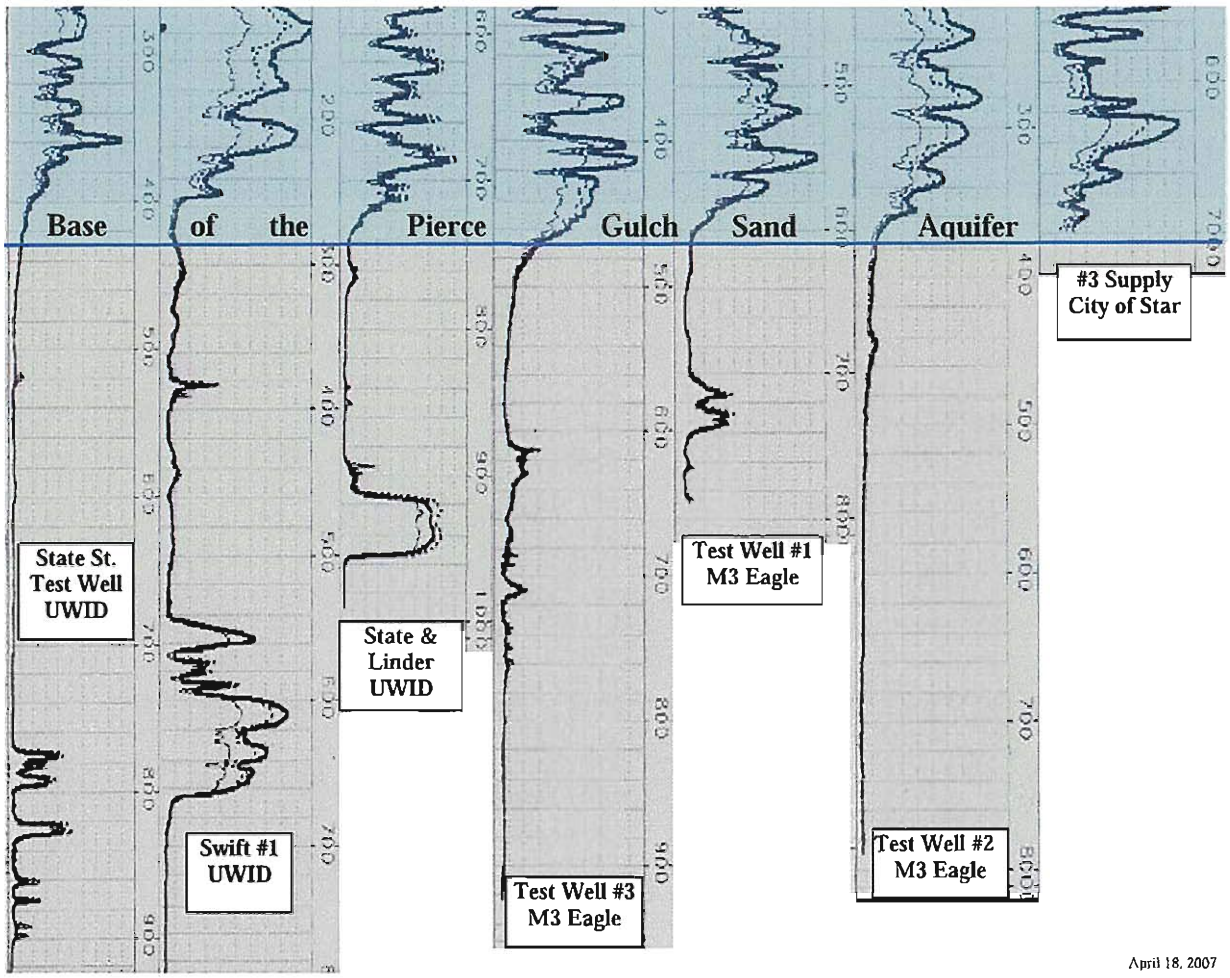
Boise, Idaho

Figure 2. Geophysical Resistivity Logs From Seven Wells in the Eagle Area



Normal resistivity traces at three electrode spacings show a consistent "geophysical signature" at 7 wells completed to different depths over a 50 square miles confirming the presence and base of the Pierce Gulch Sand Aquifer (regional aquifer) over the greater Eagle-Star-Meridian-M3 area. The borehole geophysical logs from these seven wells have been plotted side by side for clarity of correlation. In actual fact, the Pierce Gulch Aquifer is tilted so that it descends deeper below ground to the south and west as shown on Figures 3, 4 and 5. The geophysics also show a less extensive thin sand aquifer at depth beneath the Pierce Gulch Sand Aquifer. Wells completed into the lower sand unit have shown severe hydraulic boundary effects and poor-quality ground water for drinking water purposes.

Figure 2.

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Boise, Idaho

Bottom elevation based on geophysical logging conducted by Hydro Logic, Inc.

GPS locations and ground surface elevations based on TOPO®

Data contoured using Surfer® then hand contoured to remove edge contouring irregularities introduced by gridding algorithms in Surfer®

Contour of Pierce Gulch Aquifer bottom (South of Fault and Geologic Contact) (feet asl)

2000

West Boise-Eagle Fault (inferred location)

Geologic Contact between Pierce Gulch Sand Aquifer and underlying mudstone facies of the Terteling Springs Formation (approximate location)

Pierce Gulch Sand Aquifer Well With Geophysical Log

Well in Willow Creek Aquifer

North

Scale: 1 Mile =

April 30, 2007

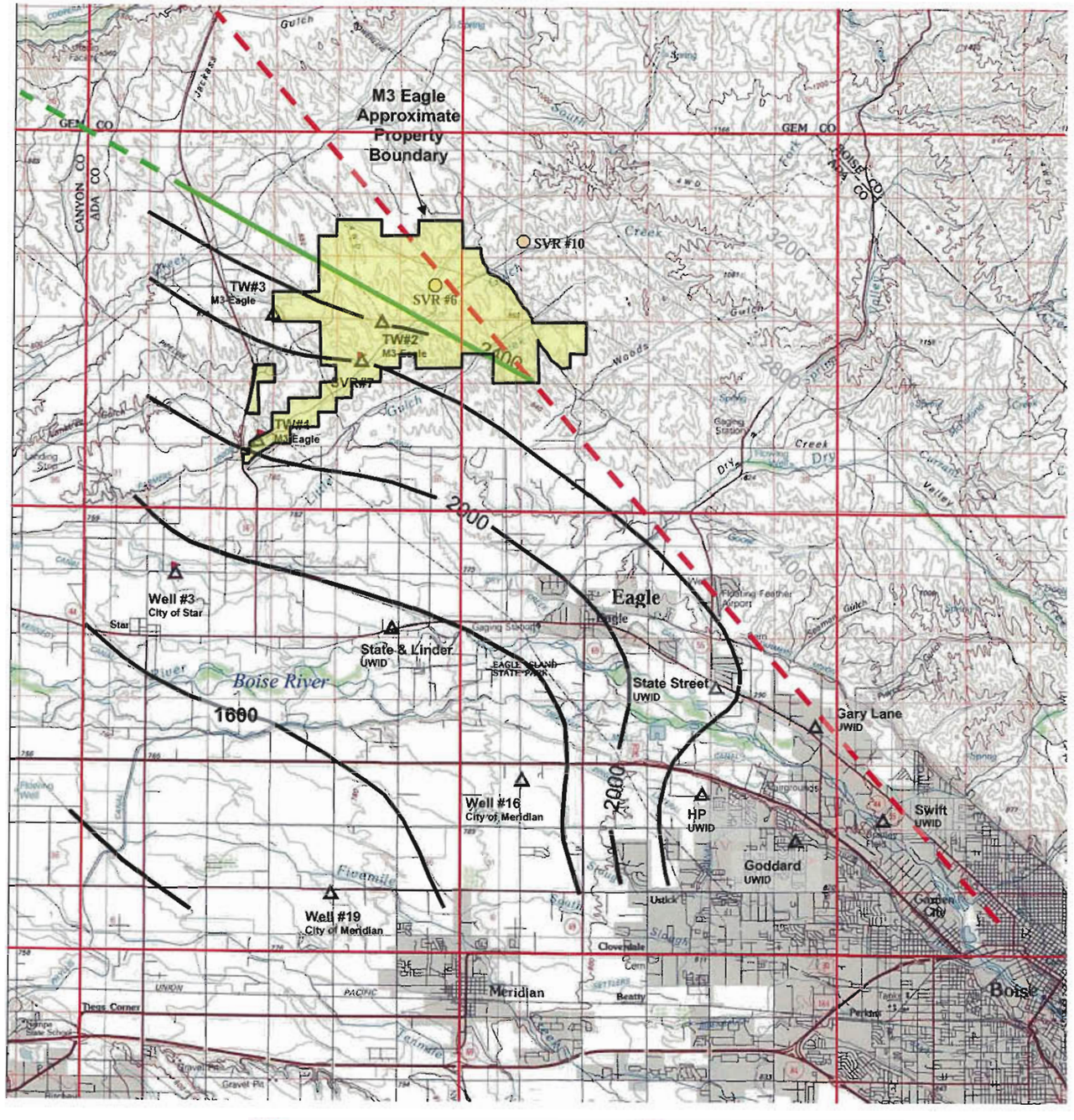


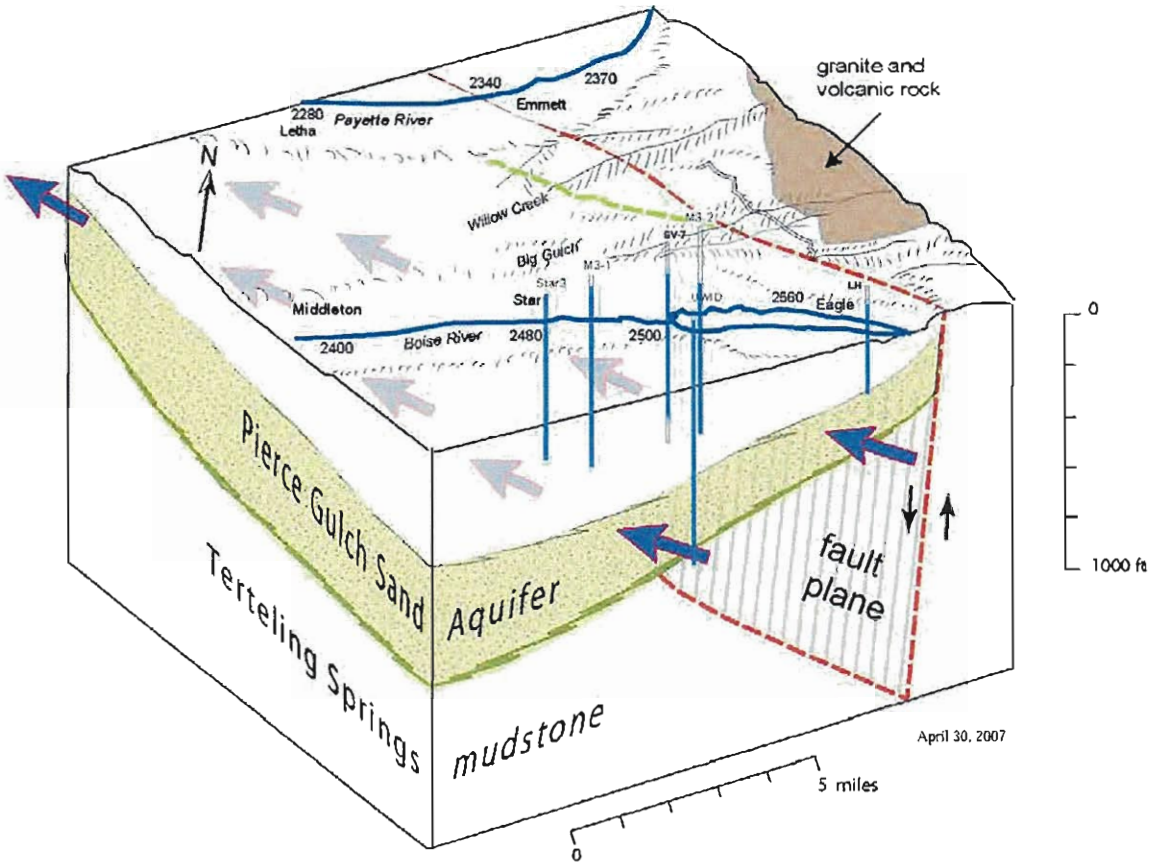
Figure 3. Contours on the Bottom of the Pierce Gulch Sand Aquifer In the Greater M3 Eagle Project Area

Structural contours of the base of the Pierce Gulch Sand Aquifer (regional aquifer) beneath the Eagle area north of the Boise River. The contours are based upon the analysis of drill-cuttings and borehole geophysical logs from thirteen test wells (see Figure 2). The contoured surface represents the base of the regional cold water aquifer. In other words, the occurrence of significant quantities of drinking- water-quality ground water is not likely beneath the contoured depths southwest of the red-dashed fault line.

Figure 3.

Hydro Logic, Inc.
Boise, Idaho

Figure 4. Conceptual Block Diagram of the Pierce Gulch Sand Aquifer.



Three-dimensional "block diagram" showing sub-surface geologic features between the Boise River Basin (near Eagle) and the Payette River Basin. The cross-sectional "cut-away" views depict the regional aquifer (Pierce Gulch Sand Aquifer) dipping away from the mountain front in a continuous layer between the Boise and Payette basins. The blue arrows indicate the NW direction of ground water flow through the aquifer from Eagle to the lower elevation Payette Valley. These arrows show that the Boise River does not recharge the ground water in the Eagle area owing to an upward ground water gradient (flowing artesian wells). The upward gradient results in the river being a "gaining" stream in this reach. The Pierce Gulch regional aquifer is actually recharged by the Boise River miles upstream from the Eagle area. The green dashed line across the land surface denotes the general locations where the dipping sand aquifer crops out at land surface. The red dashed line (plane) shows the West Boise-Eagle fault system that effectively truncates the sand aquifer on the northeast. Vertical blue lines show drilled depth and approximate location of several deep test wells into the aquifer.

Figure 4.

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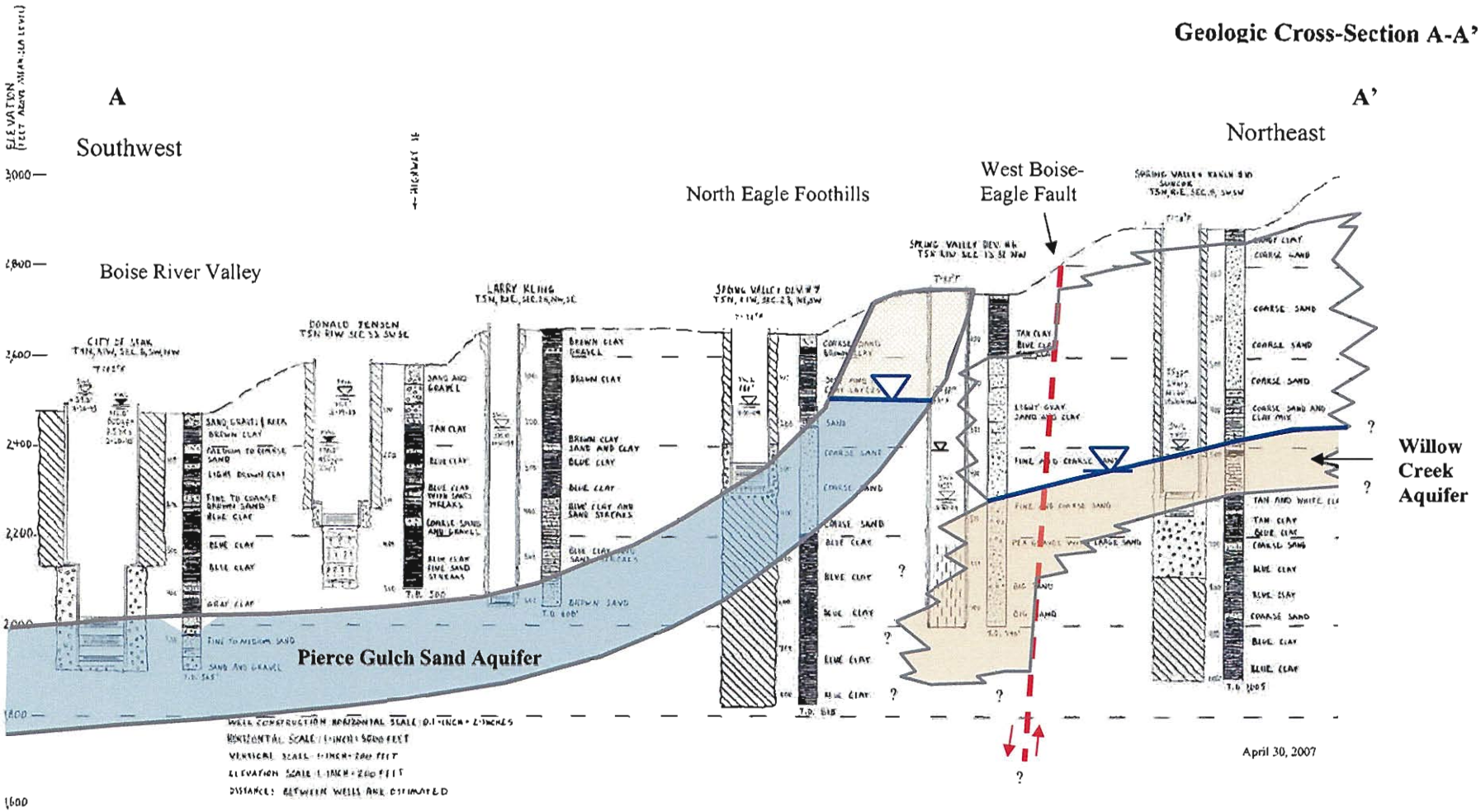
Boise, Idaho

Figure 5. Geologic Cross-Section through the M3 Eagle Site



Southwest to northeast cross-section showing Pierce Gulch Sand Aquifer tapped by Valley and Upland wells. Note: Pierce Gulch Sand Aquifer continues to northwest, west and south off figure. Spring Valley #6 taps Willow Creek Aquifer separated by contact of clay underlying the Pierce Gulch Aquifer. Clay *below* the Pierce Gulch Aquifer in Spring Valley #7 is believed to be equivalent to clay *above* the Willow Creek Aquifer in Spring Valley #6. The coarser-grained upper portion of the Willow Creek Aquifer is unsaturated at Spring Valley Ranch #10 because of relative uplift by West Boise-Eagle fault. The fault dips to the southwest at about 70 degrees but because of 10:1 vertical exaggeration (to allow well logs to be readable) true dip angle is not shown. The tops of the Willow Creek Aquifer and the Pierce Gulch Sand Aquifer in the northwest are defined by the water table. Unsaturated sands lie above the water table at these locations. The exact lateral extent of the Willow Creek Aquifer is not precisely known but is believed to be defined by a facies change to clay to the southwest and by granitic bedrock to the northeast. An accurate delineation of its boundaries was beyond the scope of this study and not considered to be critical to the assessment of the Pierce Gulch Aquifer. See Figure 1 for cross-section location.

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Boise, Idaho

Figure 6. Preliminary Regional Ground Water Level Contours and Flow Directions

Water Level Data Sources:

M3 Project Area: Measurements Summer of 2006by HLI and U of I

Other Areas:
Wells from IDWR Data Base. Locations / Elevations From Google Earth®, MapQuest® and TOPO®

Data "smoothed" by averaging of water levels in wells within 2,500-feet distances. Dashed contours where sparce or approximate data appear to yield contours that may or may not be representative.

Approximate Well Locations Used to Calculate Ground Water Flow Direction

Approximate Ground Water Flow Directions:

Pierce Gulch Sand Aquifer

"Willow Creek Aquifer"

Water Level Contour Elevation in Feet MSL

2400

(Dashed Where Inferred)

West Boise-Eagle Geologic Fault System

(Dashed Where Inferred)

Contact between bottom of Pierce Gulch Aquifer and underlying mudstone facies of the Terteling Springs Formation (inferred location, dashed where speculative)

Scale: = 1 Mile

North

April 30, 2007

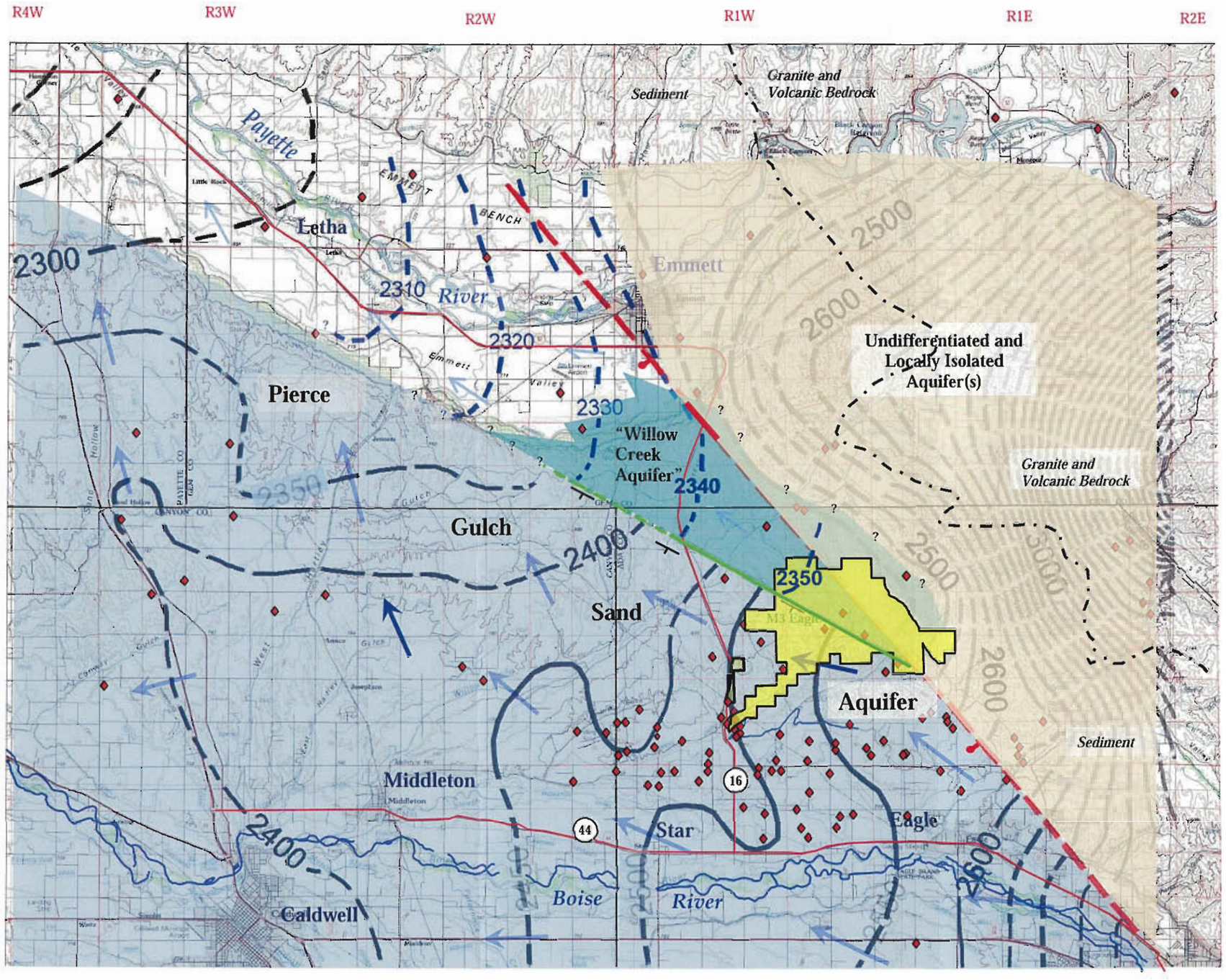

Figure 6.

Dashed grey 50-foot contours to the right side of the map depict the steep gradient and negligible ground water movement through the mudstone facies of the Terteling Springs Formation mudstone and the volcanic tuffs of the Boise Volcanic Assemblage. The black-colored, 50-foot water level contours inside blue shading indicate the northwesterly movement of ground water from the Boise Basin to the Payette Basin north of the Cities of Star, Eagle, and Middleton through the Pierce Gulch Sand Aquifer. The blue-colored and dashed 10-foot water-level contours inside the turquoise area illustrate the relatively flat ground water gradient within the recharge-limited informally named "Willow Creek Aquifer" isolated between low-permeability sediments of the uplands lying to the east of the M3 site and by stratigraphic layering (a day-lighting clay stratum) on the southwest (green solid and dashed line). The boundaries of this aquifer have not been defined as indicated by the "?" symbol.

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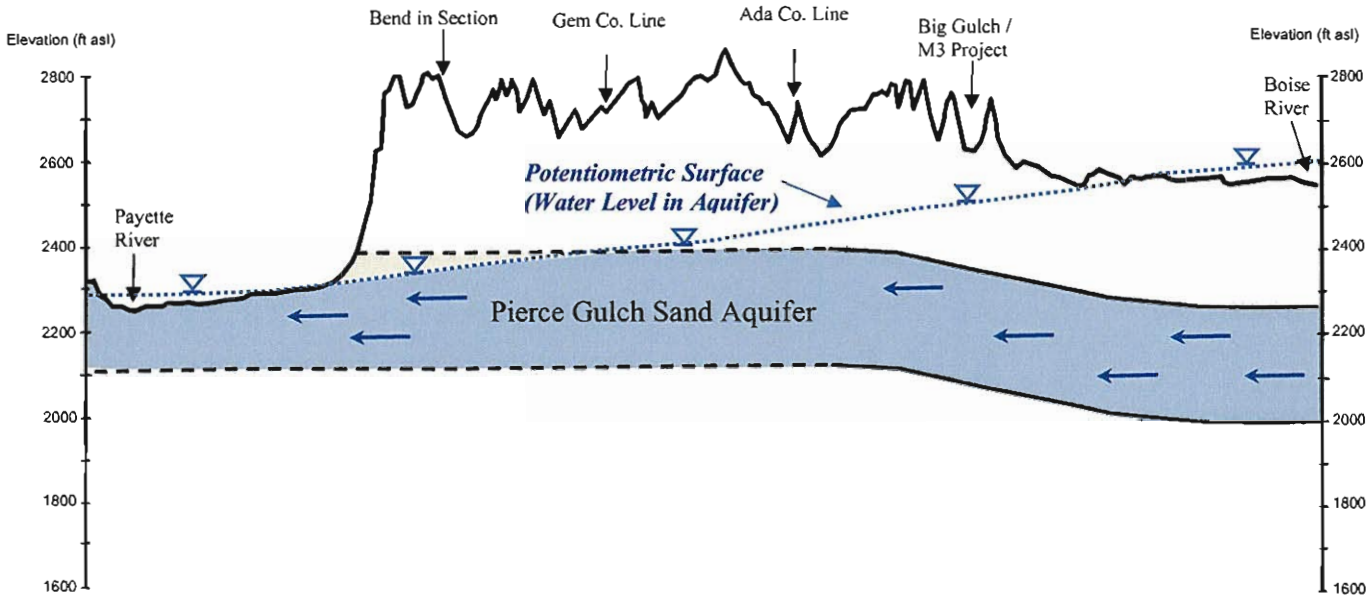
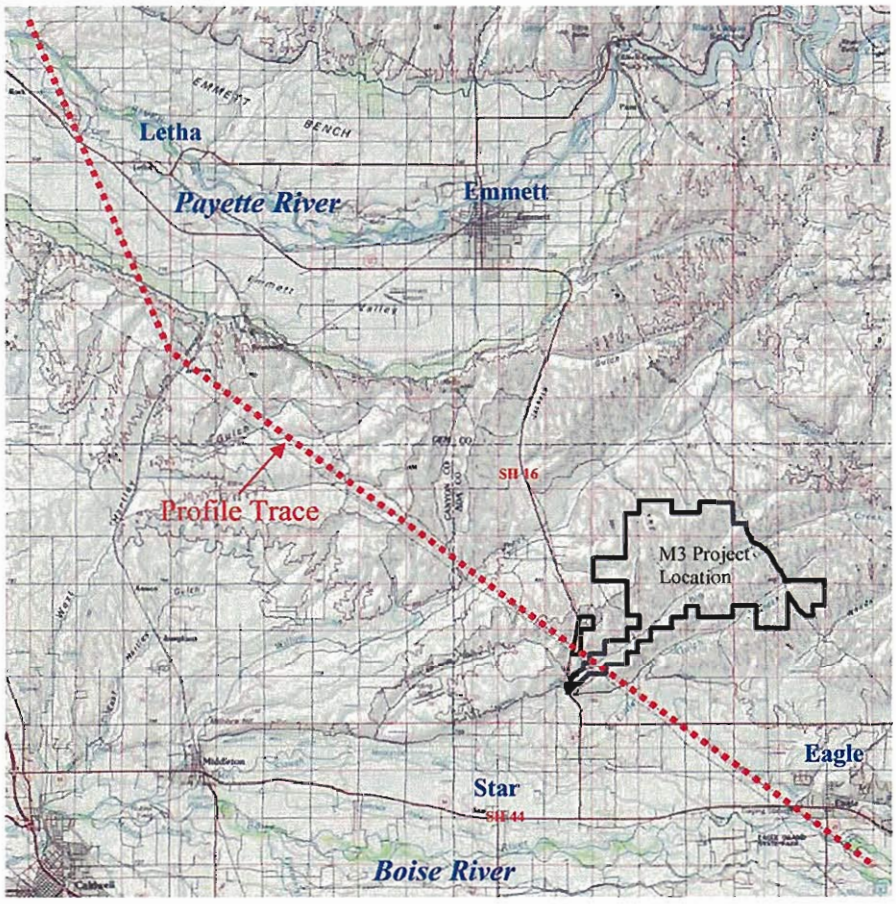
Figure 7. Conceptual Profile of Pierce Gulch Sand Aquifer Between Boise and Payette Rivers





April 30, 2007

Conceptual profile of the Pierce gulch Sand Aquifer through the M3 Eagle project area from Eagle in the Boise River Valley to north of Letha in the Payette River Valley. This profile (generally along strike of the aquifer) demonstrates that ground water flow is elevation driven with water levels in wells (shown as the "potentiometric surface") near Eagle in the Boise River Valley around 300 feet higher than those in wells completed in the Payette River Valley near Letha. The profile trace bends to better show the current understanding of groundwater flow path as shown in Figure 6.

N

= 5 Miles (Map and Section)

Figure 7.

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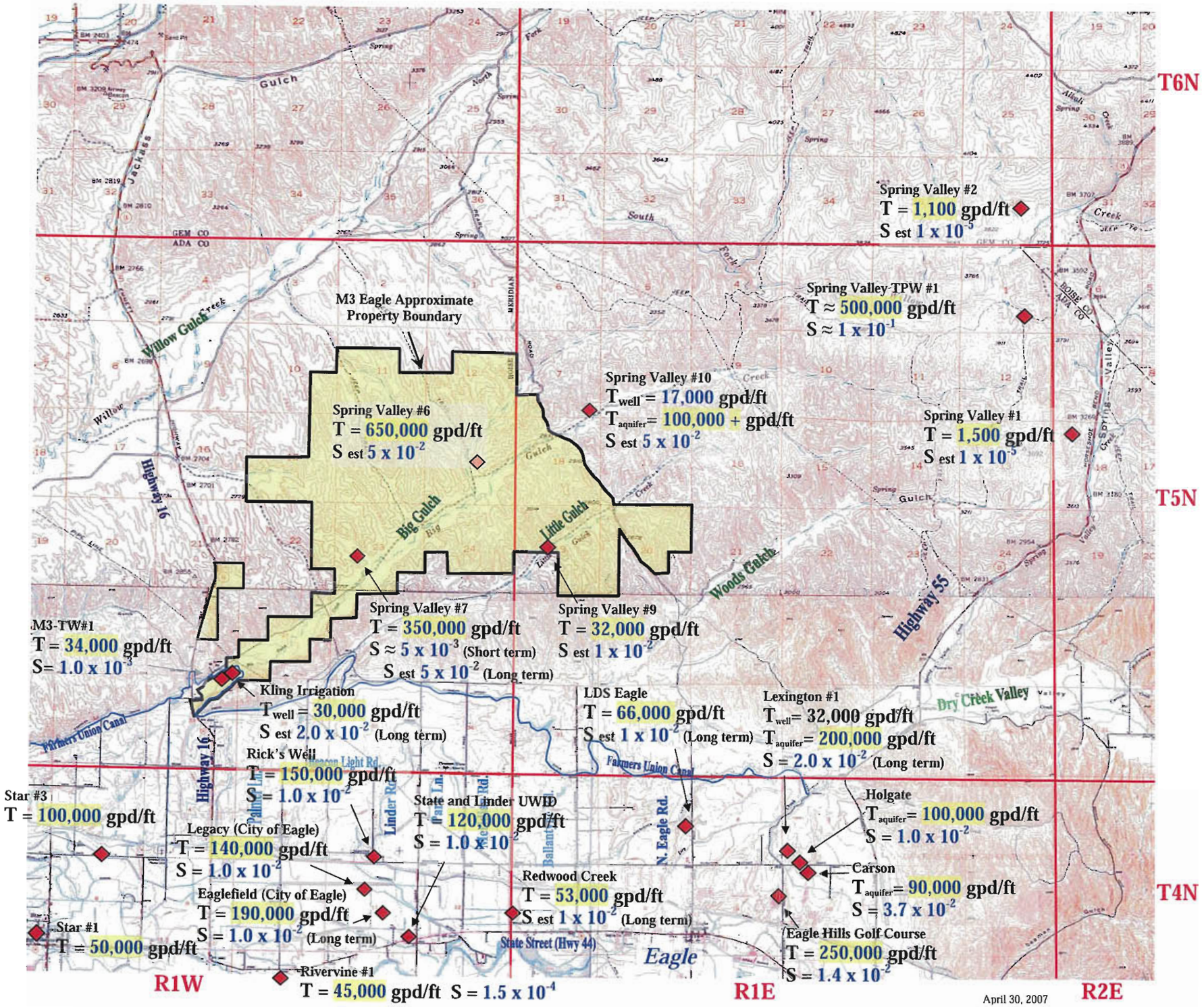

Figure 8. Calculated Values of Transmissivity and Storativity for Selected Wells in the Greater M3 Eagle Project Area

Location map for aquifer transmissivity values calculated from pump tests in the vicinity of the proposed M3 Eagle Development. The tests were conducted by various entities but all tests were reanalyzed by HLI and presented here. Where poor quality tests or poor well construction appeared to give misleading data, "whole-aquifer" values for the entire aquifer thickness were estimated and presented here. These whole aquifer values are presented to support an understanding of total flow of water through the aquifer and would only represent the value that would be indicated by a well that fully screened the entire thickness of the aquifer. See text of report for details.

Wells were surveyed using a GPS system. Base map is (1:62,500 scale) USGS 15 minute map

◆ Wells Analyzed for Aquifer Parameters of Transmissivity and (where possible) Storativity.

one mile

N

Figure 8.

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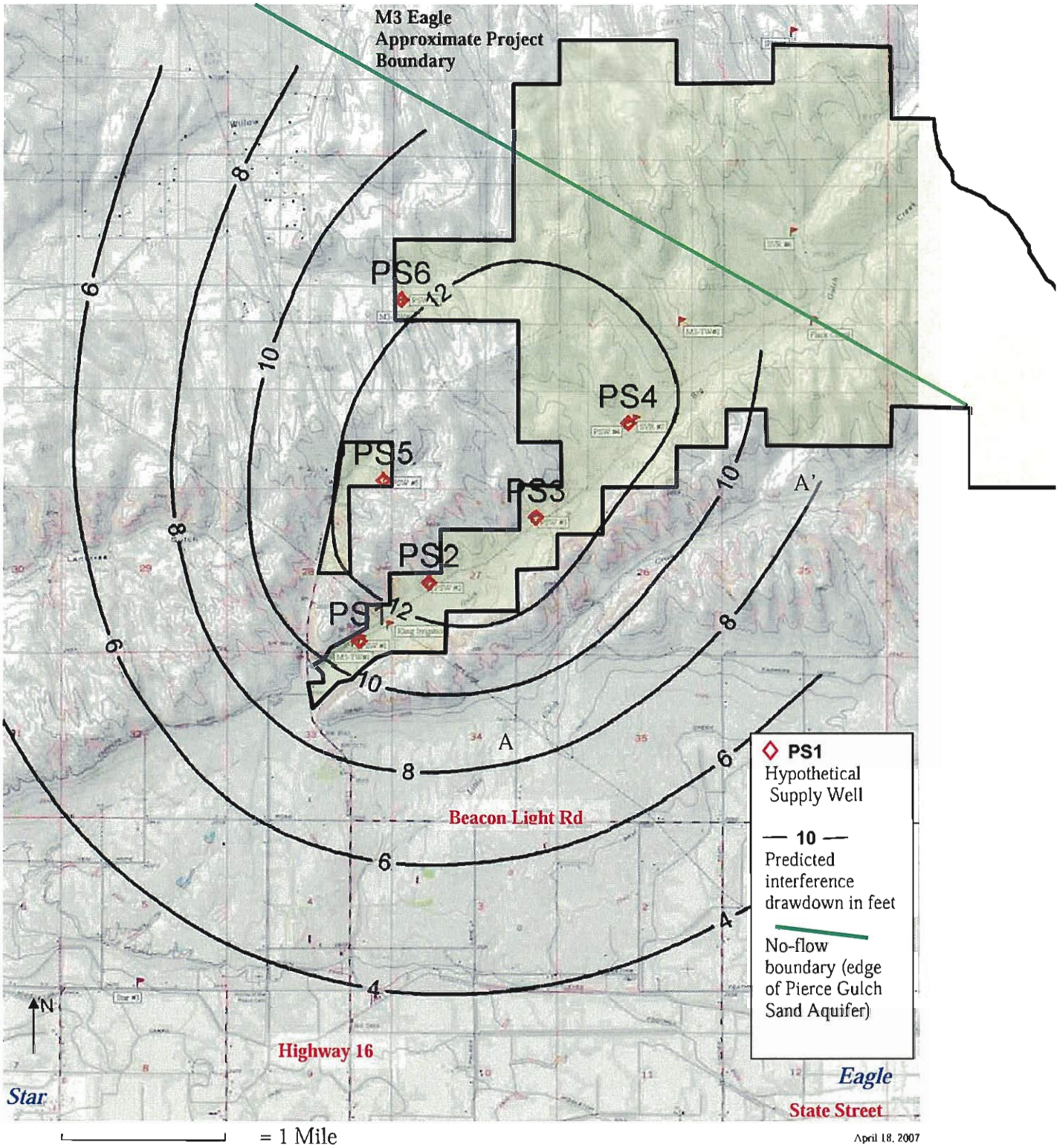
Boise, Idaho

Figure 9. Best-Case Predicted Interference from Six Hypothetical Wells



Map showing predicted interference drawdowns at full project build out from 6 hypothetical supply wells pumping at 1,000 gpm for 90 days within the Pierce Gulch Sand Aquifer with a possible high-end transmissivity of 200,000 gpd/ft, a storativity of 0.01 and a "no-flow" (edge of aquifer) boundary along the northeast. Drawdowns in domestic and other wells in overlying aquifers will likely be less to unmeasurable. See text for details.

Figure 9.

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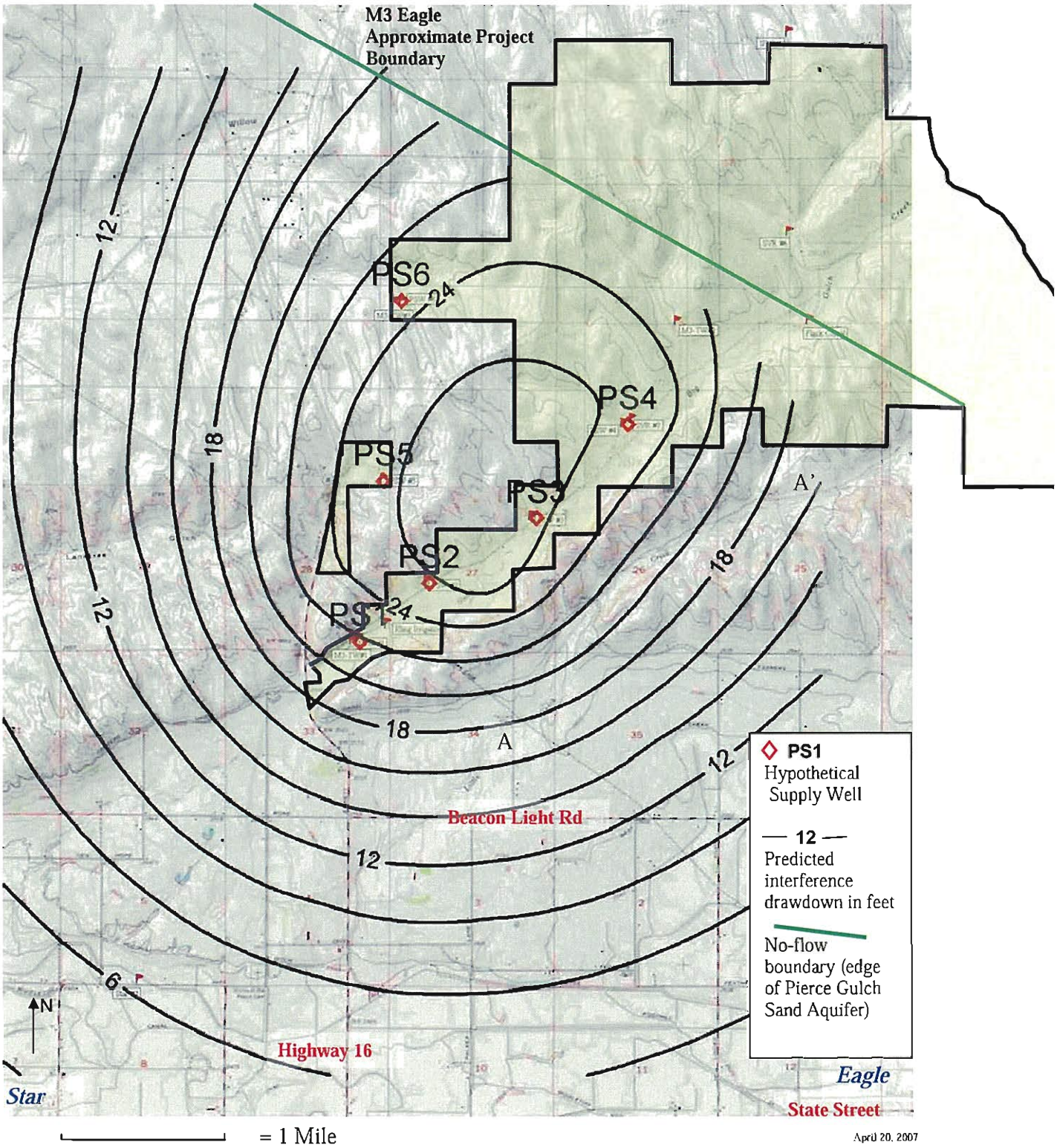
Boise, Idaho

Figure 10. Worst-Case Predicted Interference from Six Hypothetical Wells



Map showing predicted interference drawdowns at full project build out from 6 hypothetical supply wells pumping at 1,000 gpm for 90 days within the Pierce Gulch Sand Aquifer with a possible low-end transmissivity of 100,000 gpd/ft, a storativity of 0.005 and a "no-flow" (edge of aquifer) boundary along the northeast. Drawdowns in domestic and other wells in overlying aquifers will likely be less to unmeasurable. See text for details.

Figure 10.

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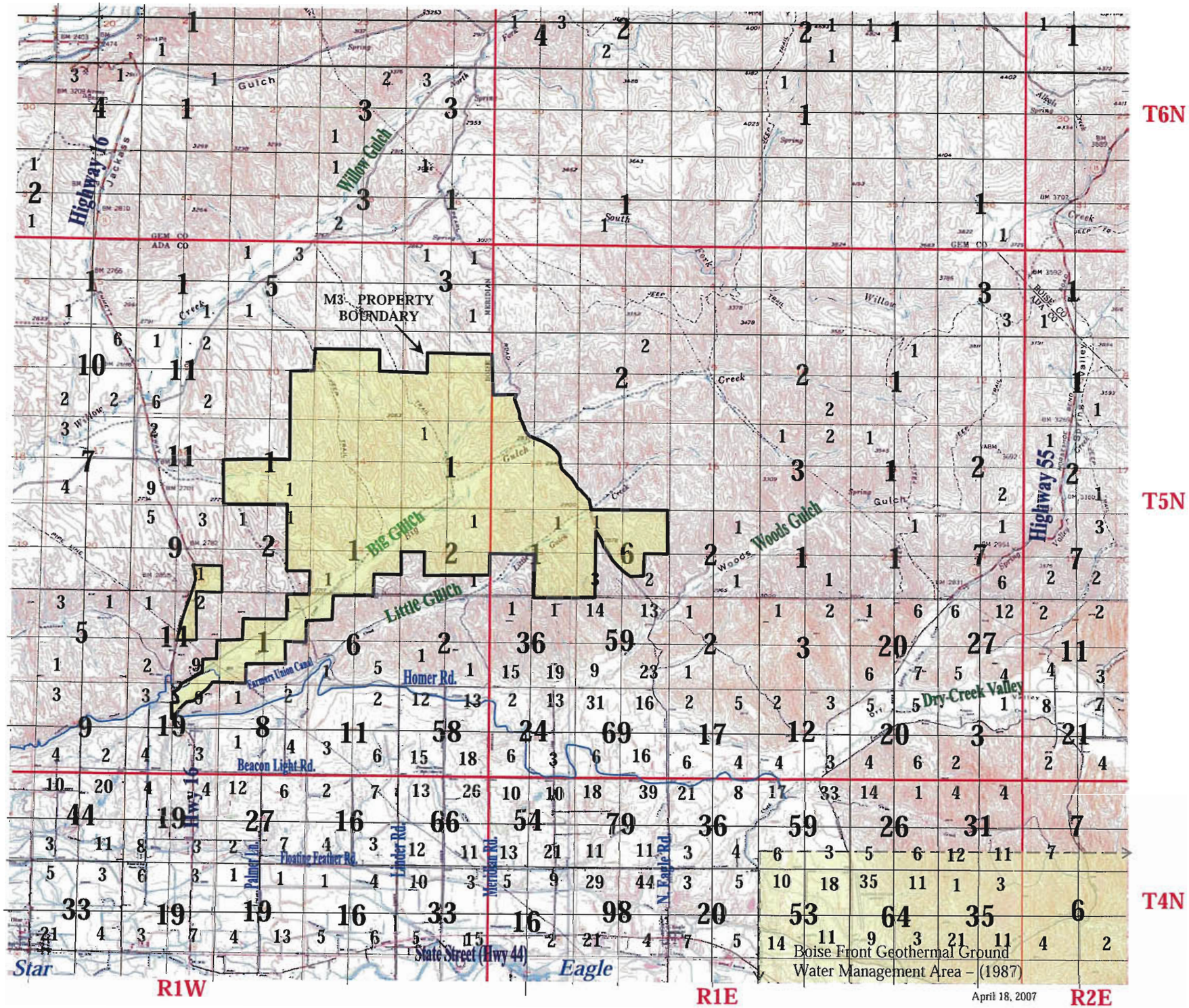


Figure 11. Number of Wells by Section and Quarter Section in the M3 Project Area

The total number of wells in each Section is shown by the larger numerals at the center of each Section. The number of wells within each Quarter-Section is indicated by the smaller numerals on the grid. Data were derived from the Idaho Department of Water Resources Driller's Report file from the Western Regional Office and IDWR on-line database as of July 2006. Some wells may be missing and others may be mislocated.

Township and range boundaries are denoted in red, and the approximate boundary of the proposed development is gray with yellow shading.

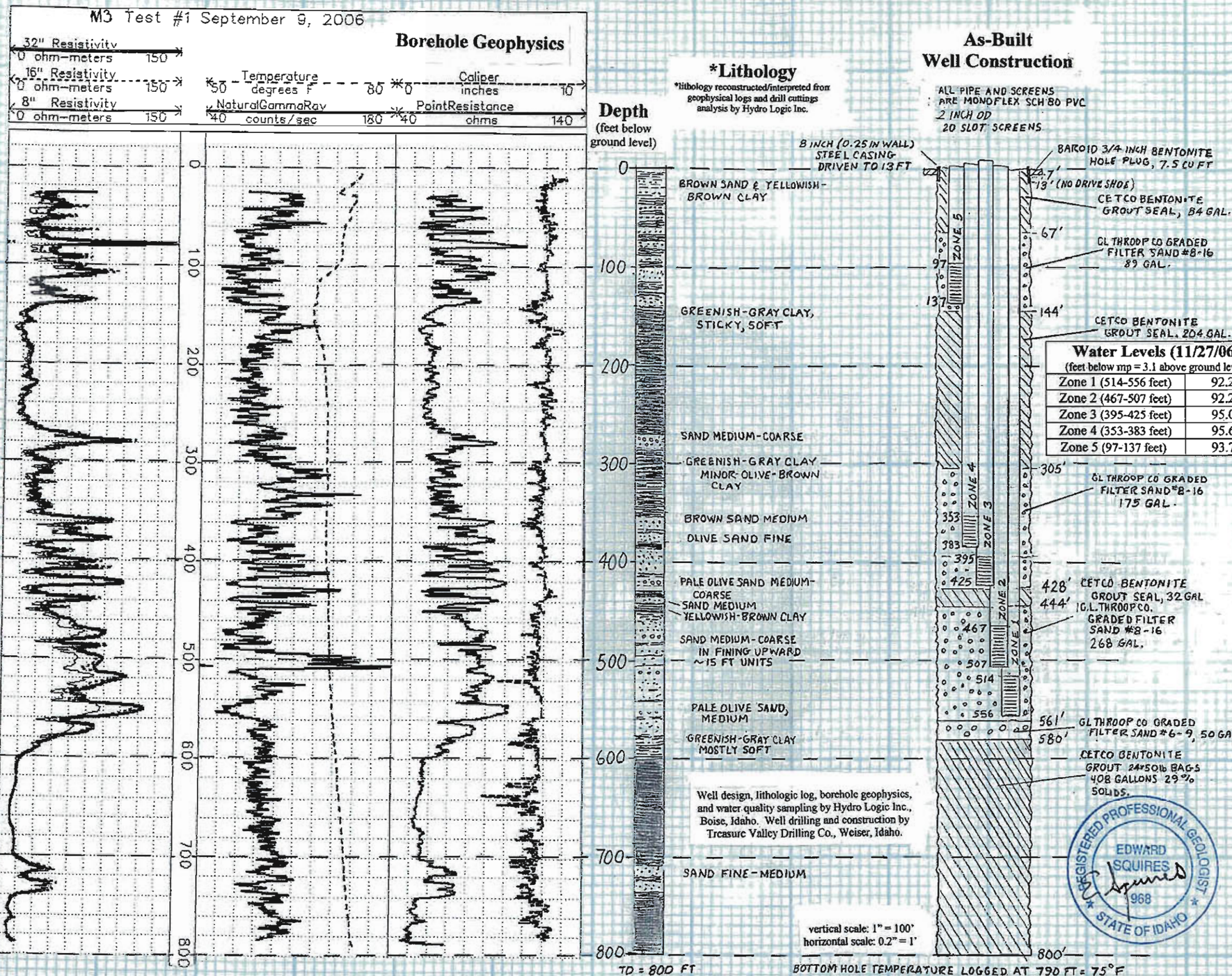
USGS 15 -minute (1:62,500 scale) quadrangle base map.

Figure 11.

Hydro Logic Inc.
Boise, Idaho

M3 Eagle - Test Well #1

T. 5 N., R. 1 W., Section 28, SE ¼, SE ¼
September, 2006
(N43° 44' 12.2", W116° 27' 26.9")



Water Levels (11/27/06)

(feet below mp = 3.1 above ground level)

Zone 1 (514-556 feet)	92.23
Zone 2 (467-507 feet)	92.23
Zone 3 (395-425 feet)	95.05
Zone 4 (353-383 feet)	95.63
Zone 5 (97-137 feet)	93.75

Water Chemistry

Analyte (mg/L unless noted)	Zone 1 516-556 feet	Zone 2 467-507 feet
Alkalinity	133.0	125.0
Ammonia as N	0.37	0.06
Arsenic	<0.003	<0.003
Calcium as CaCO3	84.4	85.5
Chloride	3.42	3.22
Conductivity (uS/cm)	302	297.0
Corrosivity	-0.40	-0.44
Fluoride	0.69	0.60
Hardness	111.0	109.0
Iron (dissolved/filtered)	0.23	<0.01
Magnesium	6.50	5.73
Manganese (dissolved)	0.10	0.02
Nitrate as N	<0.10	<0.10
Nitrite as N	<0.01	<0.01
pH (SU)	7.47	7.48
Potassium	2.26	2.21
Silica	31.8	30.7
Sodium	22.1	21.7
Sulfate	17.2	20.7
Sulfide	<0.05	<0.05
Total Dissolved Solids	173 .0	188.0
Total Kjeldahl Nitrogen	0.39	0.13
Total Organic Carbon	<1.0	<1.0
Field Temperature (°F)	67.1	66.0
Field Conductivity (uS)	305	295
Dissolved Oxygen	+1.7	+2.6
Field pH (S.U.)	7.19	7.19

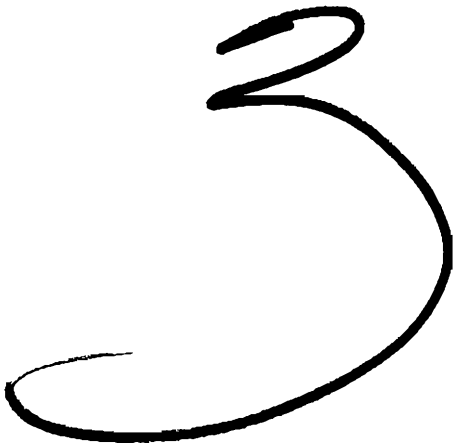
Analyses by Alchem Laboratories, Boise, Idaho.
Zones 1 to 3 sampled 10/09/06. Zones 4 & 5 sampled 10/9/06.
Field measured parameters by Hydro Logic, Inc.

Analyte (mg/L unless noted)	Zone 3 395-425 feet	Zone 4 352-382 feet	Zone 5 98-138 feet
Alkalinity	119.0	114.0	119.0
Ammonia as N	0.04	<0.01	<0.01
Arsenic	<0.003	0.0049	0.0081
Calcium as CaCO3	77.7	81.3	85.9
Chloride	3.57	3.54	4.36
Conductivity (uS/cm)	282.0	285.0	281.0
Corrosivity	-0.50	-0.61	-1.16
Fluoride	0.60	0.50	0.24
Hardness	102.0	105.0	111.0
Iron (dissolved/filtered)	0.01	<0.01	<0.01
Magnesium	5.83	5.85	6.22
Manganese (dissolved)	<0.01	<0.01	<0.01
Nitrate as N	0.30	0.33	2.30
Nitrite as N	<0.01	<0.01	<0.01
pH (SU)	7.84	7.40	6.91
Potassium	2.07	2.10	2.74
Silica	29.5	28.7	38.0
Sodium	21.1	17.9	13.6
Sulfate	21.4	22.3	12.0
Sulfide	<0.05	<0.05	<0.05
Total Dissolved Solids	185.0	203.0	208.0
Total Kjeldahl N	<0.10	<0.10	<0.10
Total Organic Carbon	<1.0	<1.0	<1.0
Field Temperature (°F)	64.7	63.8	57.4
Field Conductivity (uS)	274	268	265
Dissolved Oxygen	+4.9	+2.63	+9.51
Field pH (S.U.)	7.27	7.07	6.72

Figure 12. M3 Eagle Test Well #1

Aquifer Test of the M3 Eagle Kling Irrigation Well

November 2006



M3 Eagle

Map of Protestants Wells

October 14, 2008

Protestant's Well Completion Aquifer

- Pierce Gulch Sand Aquifer
- Un-named alluvial aquifer
- Boise River Gravel Aquifer
- Terteling Springs Mudstone
- Unknown aquifer (no Well Driller's Report)
- Unknown aquifer (no data at HLI)

5 — Contour (ft) of Model-Generated Drawdown from Pumping 3 Wells at 1,500 gpm each for 50 Years (Worst Case)

PROPOSED SUPPLY WELLS

APPROXIMATE M3-EAGLE PROPERTY BOUNDARY

R1W R1E R2E

T5N T4N

Highway 16 · Willow Creek Rd · Big Gulch · Little Gulch · Woods Gulch · Farmers Union Ditch · Eagle Road · Park Lane · Linder Rd · Ballantyne Rd · Highway 55 · Highway 44 · Star · Eagle · Dry Creek Valley

N

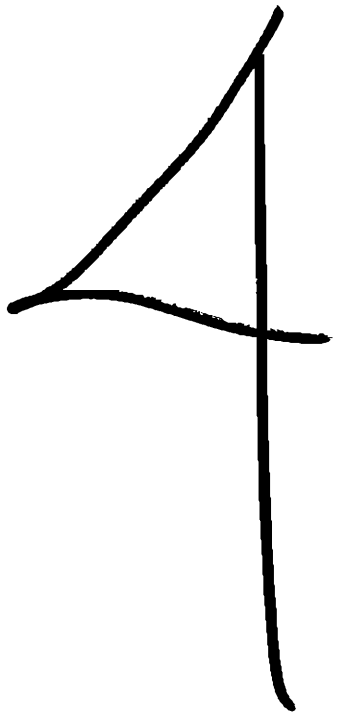
one mile

Hydro Logic, Inc.
Boise, Idaho

U.S. Geological Survey
7.5-min. series quads
scale 1:48,000

Map created with TOPO! ©2008 National Geographic

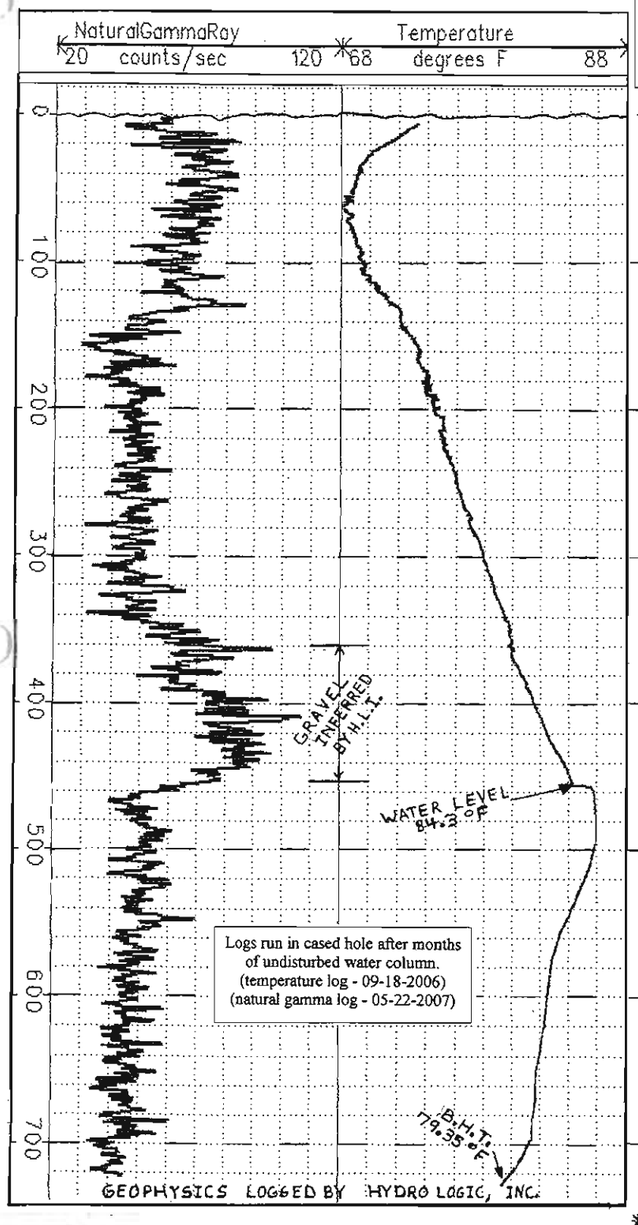
M3 EAGLE LLC
EXHIBIT
3



M3 Eagle - S.V.R. Well #6

T5N R1W Section 13, SE¼, SE¼, NW¼
Latitude 43° 46' 19.8" Longitude 116° 24' 16.3"
Completed February 2004

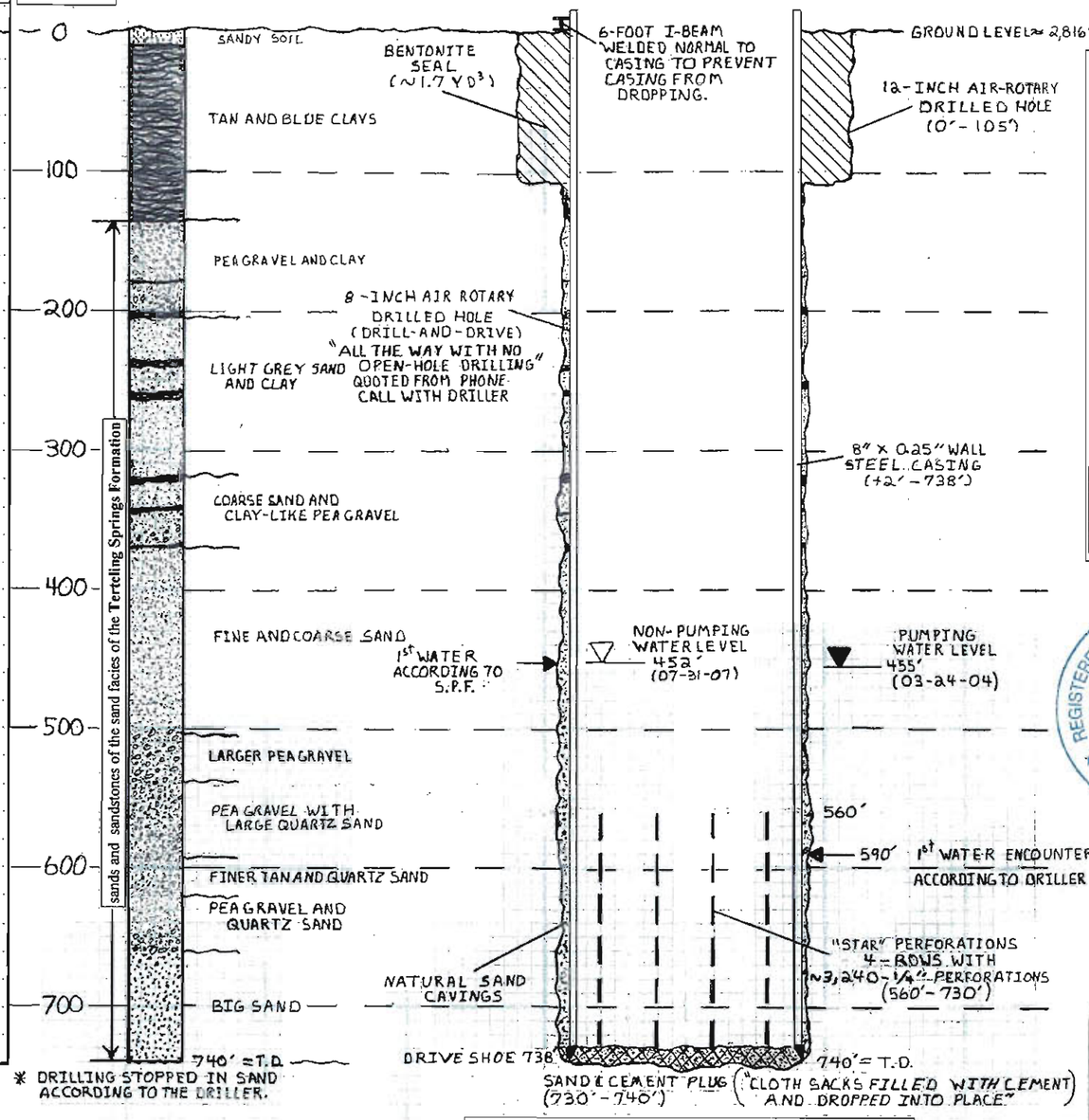
Geophysical Logs



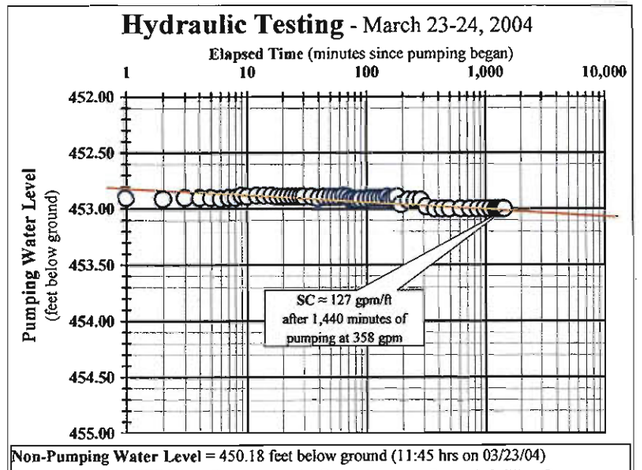
Depth
(feet below ground level)

Driller's Lithology
(from IDWR well log)

As-Built Well Construction
(horizontal scale 0.1"=0.5")
(vertical scale 1"=100')



Hydraulic Testing - March 23-24, 2004



Non-Pumping Water Level = 450.18 feet below ground (11:45 hrs on 03/23/04)
Test conducted by SPF Water Engineering, LLC and Adamson Pump & Drilling Co.
According to the driller, the well was not developed prior to pumping and is believed (HLI) to have been developing during the short-term test, imparting some uncertainty into the results.

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Ground Water Chemistry

Lab Analyses	SPF Water Engineering Results (in mg/L unless noted) SCREENED (560 -730 feet bgl)
Alkalinity	58.8
Ammonia as N	0.13
Arsenic	0.067
Calcium as $CaCO_3$	9.71
Chloride	5
Conductivity (uS)	
Corrosivity	
Fluoride	0.95
Hardness	<5.0
Iron (total)	0.09
Magnesium	0.69
Manganese	<0.05
Nitrate as N	1.09
Nitrite as N	0.02
pH	
Potassium	1.5
Sodium	27.8
Sulfate	13
Sulfide	<0.05
Total Dissolved Solids	98
Field Analyses	
Field Conductivity (µS)	189.9
Field pH (S.U.)	7.67
Field Temperature (°F)	81.1

Water samples and field parameters collected on March 16, 2004 by SPF Water Engineering. Analyses by Analytical Laboratories, Boise, ID.

M3 EAGLE LLC EXHIBIT 4

Well design, pump test design, and water quality sampling by SPF Water Engineering, LLC, Boise, ID
Air-rotary drilling, well construction, and pump testing by Adamson Pump & Drilling Co., Nampa, ID

Data compiled and plotted by Hydro Logic, Inc. from available data of others with the exception of the geophysical logs and a video inspection run in the completed well. HLI was not involved with the drilling project.

drafted August 15, 2007
by Loren Pearson,
Hydro Logic, Inc.

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M3 Eagle - S.V.R Well #7

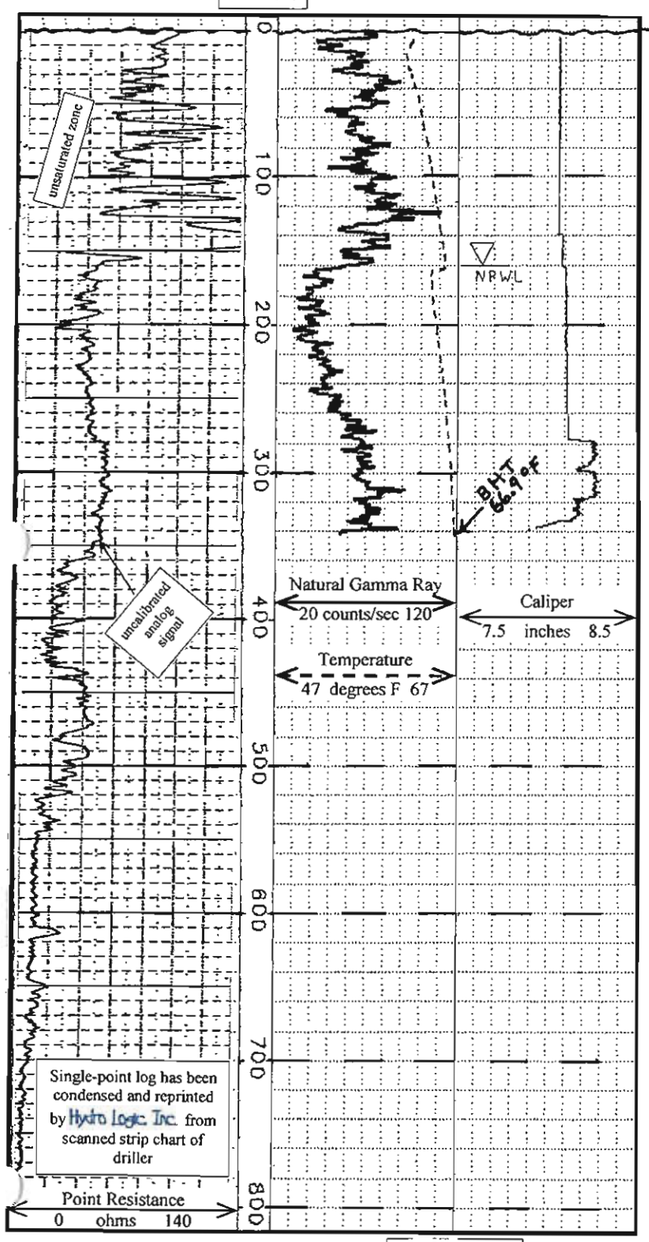
T5N R1W Section 23, NE¼, SW¼
Latitude 43° 35' 16.8" Longitude 116° 40' 18.0"
Completed April 2004

Geophysical Log
(March 2004)
by Stevens and Sons Drilling
in a mud-filled borehole.

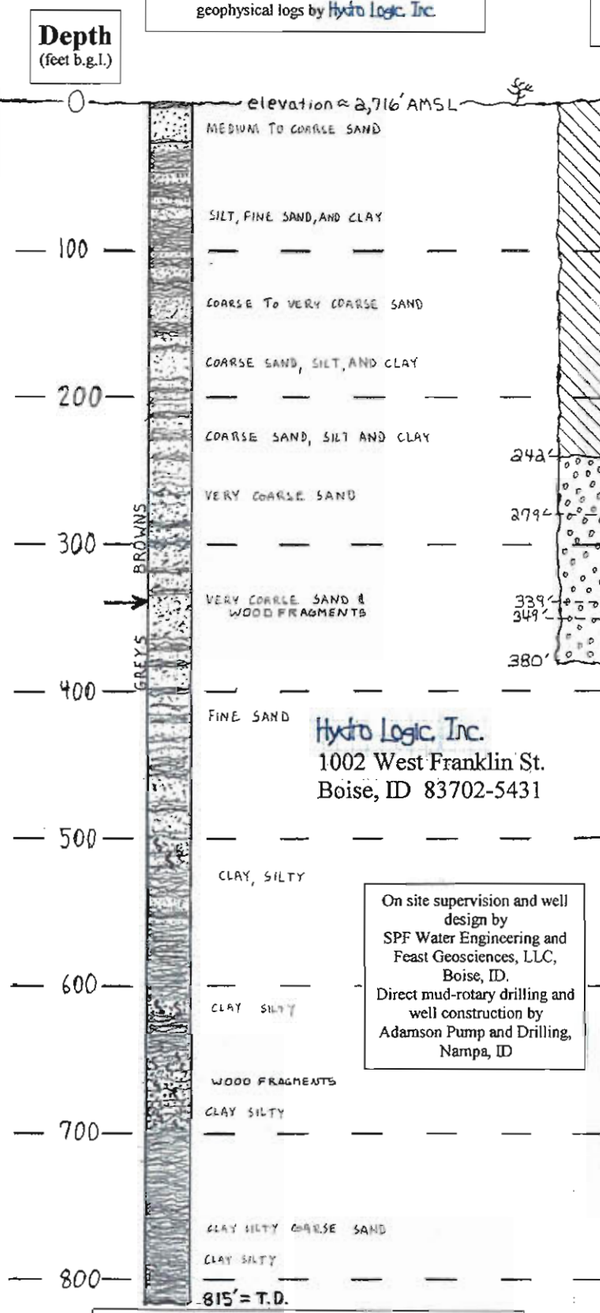
Geophysical Logs
(April 27, 2007)
by Hydro Logic, Inc.
in a steel cased well.

Lithology
Feast Geosciences lithologic log was developed from drilled cuttings. Lithology has been reinterpreted and readjusted to better fit with geophysical logs by Hydro Logic, Inc.

As-Built Well Construction
(from IDWR Driller's Report and Hydro Logic, Inc. downhole camera survey conducted on August 28, 2007)
(horizontal scale 0.1"=0.5")
(vertical scale 1"=100')



Drafted 02-15-08
by Loren Pearson,
Hydro Logic, Inc.



Hydro Logic, Inc.
1002 West Franklin St.
Boise, ID 83702-5431

On site supervision and well design by SPF Water Engineering and Feast Geosciences, LLC, Boise, ID.
Direct mud-rotary drilling and well construction by Adamson Pump and Drilling, Nampa, ID

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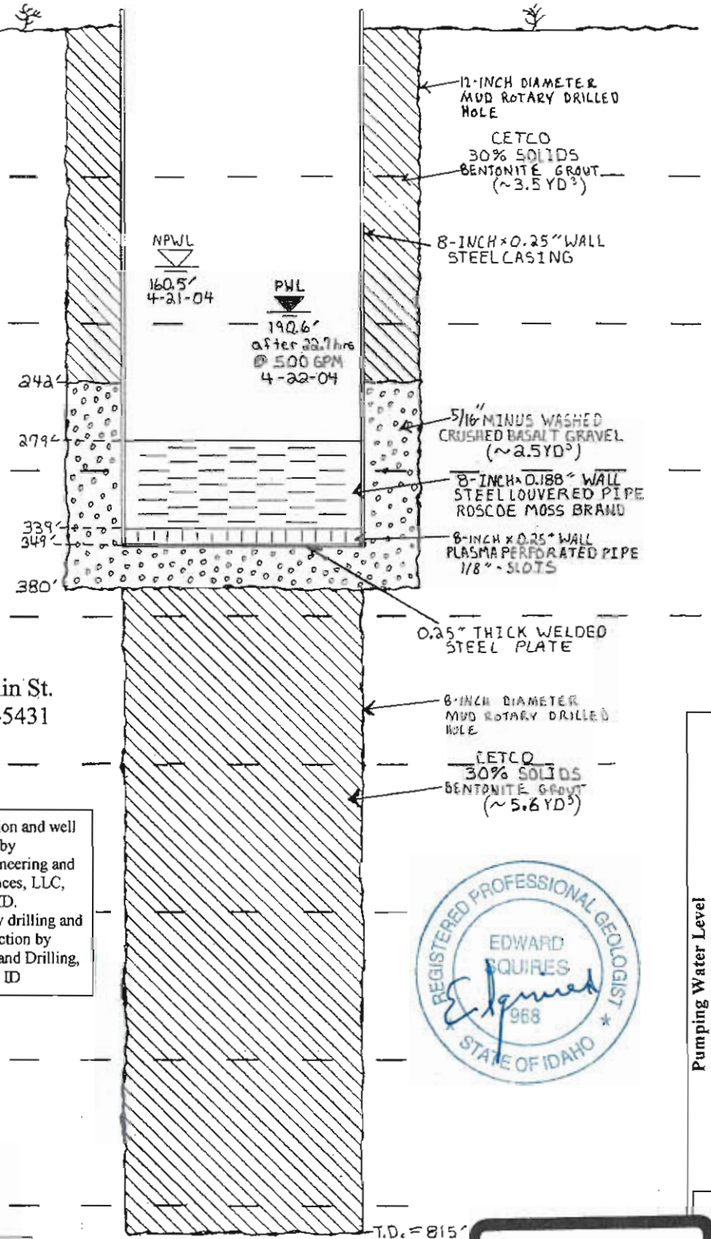

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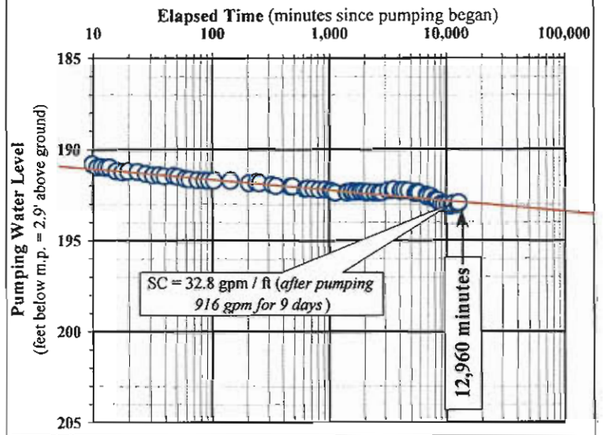
M3 EAGLE LLC EXHIBIT 5

Ground Water Chemistry

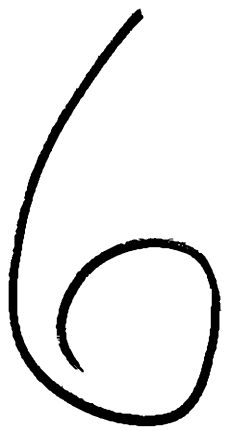
Lab Analyses	SPF Water Engineering Results (in mg/L unless noted) SCREENED (279 - 349 feet bgl)	Hydro Logic, Inc. Results (in mg/L unless noted) SCREENED (279 - 349 feet bgl)
Alkalinity		120.0
Ammonia as N	<0.04	0.02
Arsenic	<0.005	0.0037
Calcium as $CaCO_3$	29.1	77.8
Chloride	5	4.42
Conductivity (µS)		305.0
Corrosivity		-0.35
Fluoride	0.44	0.43
Hardness	110	115.0
Iron (dissolved)		0.11
Iron (total)	0.11	0.11
Magnesium	8.19	8.91
Manganese	<0.05	0.02
Nitrate as N	0.31	0.34
Nitrite as N	<0.01	<0.01
Odor		<1
pH		7.63
Potassium	2.0	2.60
Silica		38.9
Sodium	22.9	23.2
Sulfate	24	23.5
Sulfide	<0.05	<0.05
Total Dissolved Solids	212	235.0
Total Kjeldahl Nitrogen		<0.10
Total Organic Carbon		3.36
Field Analyses		
Field Conductivity (µS)	300	382
Field Dissolved Oxygen		+1.37
Field Odor (describe)		minor H_2S
Field O.R.P. (mV)		+55
Field pH (S.U.)	7.00	7.40
Field Temperature (°F)	68.1	67.0
Field Visible Gas (yes or no)		yes

HLI samples collected on March 14, 2008 by Hydro Logic, Inc.
Analyses by Alchem Laboratories, Boise, ID
SPF samples collected on April 21, 2004 by Feast Geosciences.
Analyses by Analytical Laboratories, Boise, ID

Hydraulic Testing - (March 10-19, 2008)



Non-Pumping Water Level = 165.00 feet below m.p. (16:00 hrs on 03/10/2008)
Testing conducted by Hydro Logic, Inc. and McLeran Well Drilling, LLC.
(no barometric or antecedent trend corrections applied to this plot.)



M3 Eagle - S.V.R. Well #9

T.5.N R.1E. Section 19, SW¼, NE¼
Latitude N43° 45' 33.3" Longitude W116° 22' 52.1"
Completed June 2004

Geophysical Log

(June 2004)
by Stevens and Sons Drilling
in a mud-filled borehole.

Single-point log has been condensed and reprinted by Hydro Logic, Inc. from scanned pen and ink strip chart of driller.

0 single-point resistance 100

unsaturated zone

water table

Pierce Gulch Sand Aquifer

CLAY LINE ?

SAND LINE ?

uncalibrated, poor quality, analog signal

Terteling Springs Formation

BHT* 93°F @ 810 FT

Lithology

Feast Geosciences lithologic log was developed from drilled cuttings. Lithology has been reinterpreted and readjusted below 120 feet to better fit with HLI's interpretation of the geology and the geophysical log.

As-Built Well Construction

(horizontal scale 0.1"=1.0")
(vertical scale 1"=100')

Depth (feet b.g.l.)	
0	ELEV. = 2,753' AMSL = GROUND LEVEL
	INTERBEDDED COARSE-GRAINED BROWN SANDS & TAN-TO-LIGHT GREY TACKY CLAYS
100	BROWN FINE-TO-COARSE GRAINED SAND WITH CLAY LENSES
200	REDDISH-BROWN ARKOSIC MEDIUM-COARSE SAND (BROWNS)
	LIGHT BROWN FINE-TO-COARSE GRAINED SANDS, CLAY LENSES, & ABUNDANT WOOD FRAGMENTS IN LOWER PORTION
300	LIGHT BROWNISH-GREY FINE-TO-COARSE GRAINED SANDS WITH MINOR CLAY BEDS & ABUNDANT WOOD FRAGMENTS IN UPPER PORTION (GREYS)
400	MEDIUM-GREY SILTY TACKY CLAY WITH SOME FINE GRAINED SAND
500	STICKY MEDIUM-GRAY CLAY
600	HARD STICKY MEDIUM-GRAY CLAY (HARD SHALE NOTED BY DRILLER ON IDWR DRILLERS REPORT: 530-531 FEET, 780-781 FEET)
700	
800	810' = T.D.

8"×0.250" WALL STEEL CASING

BENTONITE GROUT (~1.5 YD³) (From undocumented source. Presumed to be from Teague pits in Adrian, Oregon.

3/10/08 NPWL 195.3' 207'

#8-#12 GRADED COLORADO SILICA FILTER SAND (~1.5 YD³)

6"×0.250" WALL STEEL PIPE (-245FT-253FT)

BENTONITE GROUT (~6.2 YD³) (From undocumented source. Presumed to be from Teague pits in Adrian, Oregon.

8-INCH DIRECT MUD-ROTARY DRILLED HOLE

Depth (feet b.g.l.)	
0	GROUND LEVEL
	BENTONITE CHIP (~14 FT³) (From undocumented source. Presumed to be from Teague pits in Adrian, Oregon.
100	12-INCH DIRECT MUD-ROTARY DRILLED HOLE
200	PWL 6/23/04 AT 43 GPM FOR 3 HOURS
	6"-INCH STAINLESS STEEL 0.030" SLOT WIRE-WRAP SCREENS (235 FT-245 FT, 253 FT-263 FT)
300	
400	
500	
600	
700	
800	810' = T.D.

Data presented was compiled and plotted by Hydro Logic, Inc. from available data of others. HLI was not involved with the drilling project.

Drafted June '08 by Loren Pearson, Hydro Logic, Inc.

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* SPF report of 10-13-2004 states:
"The driller measured the bottom-hole temperature (at 810 feet below ground surface) by running a bit to the bottom of the borehole, then pulling up and measuring the temperature of a chunk of clay attached to the bit. He recorded a temperature of 93°F in the clay. The actual temperature of the clay is probably higher (but cooled as the bit was retracted to ground surface)."

On site supervision and well design by:
SPF Water Engineering and Feast Geosciences, LLC, Boise, ID.
Direct mud-rotary drilling and well construction by:
Stevens and Son Drilling Co., Nampa, ID

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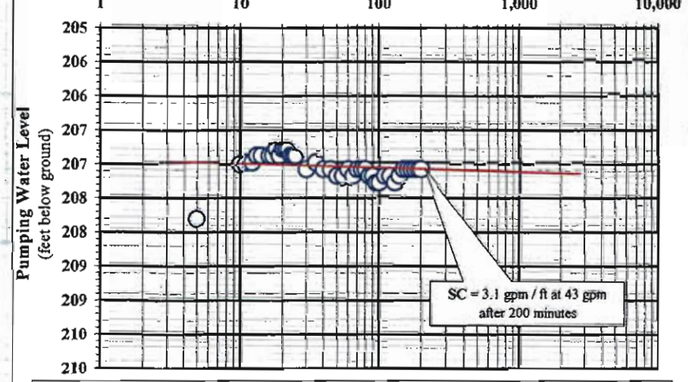
Ground Water Chemistry

Lab Analyses (note: all samples with 0.45µm filter prior to analysis except sulfide)	SPF Water Engineering Results (in mg/L unless noted) SCREENED (235 - 263 feet bgl)
Ammonia as N	0.10
Antimony	<0.005
Arsenic	<0.005
Barium	0.10
Beryllium	<0.0005
Bicarbonate	107
Cadmium	<0.0005
Calcium as $CaCO_3$	24.9
Chloride	10
Chromium	<0.002
Conductivity (µS)	336
Fluoride	0.45
Hardness	102
Iron (dissolved)	0.60
Magnesium	10.4
Manganese	0.12
Mercury	<0.0002
Nickel	<0.02
Nitrate as N	<0.2
Nitrite as N	<0.01
pH (S.U.)	2.5
Potassium	2.0
Selenium	<0.005
Sodium	26.9
Sulfate	44
Sulfide (*unfiltered*)	<0.05
Thallium	<0.002
Total Dissolved Solids	216
Field Analyses	
Field Temperature (°F)	68

SPF samples collected on June 23, 2004 by Feast Geosciences.
Analyses by Analytical Laboratories, Boise, ID

Hydraulic Testing - (June 23, 2004)



Non-Pumping Water Level = 193.3 feet below ground (09:10 hrs on 06/23/04)
Test conducted by Feast Geosciences and Stevens and Son Drilling Co.
Well was developed by pumping and surging according to SPF report.
Plotted by Hydro Logic, Inc.

M3 EAGLE LLC
EXHIBIT
6

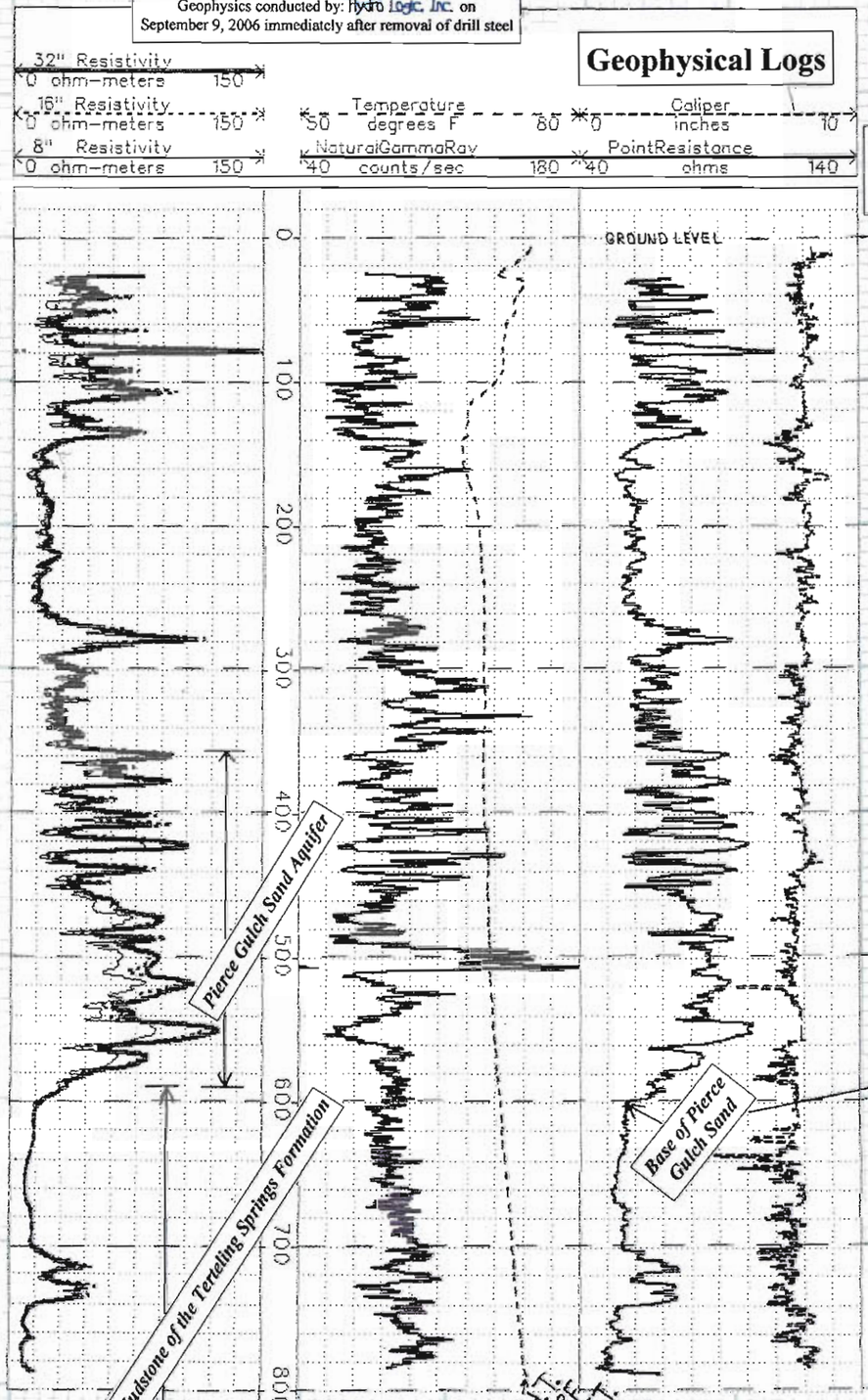
M3 Eagle - Test Well #1

T. 5 N., R. 1 W., Section 15, SE¼, SE¼
Latitude 43° 44' 12.37" Longitude 116° 27' 26.86"
Well completed September 2006

M3 EAGLE LLC EXHIBIT 7

Geophysics conducted by: Hydro Logic, Inc. on September 9, 2006 immediatly after removal of drill steel

Geophysical Logs



drafted April 23, 2008 by Loren Pearson

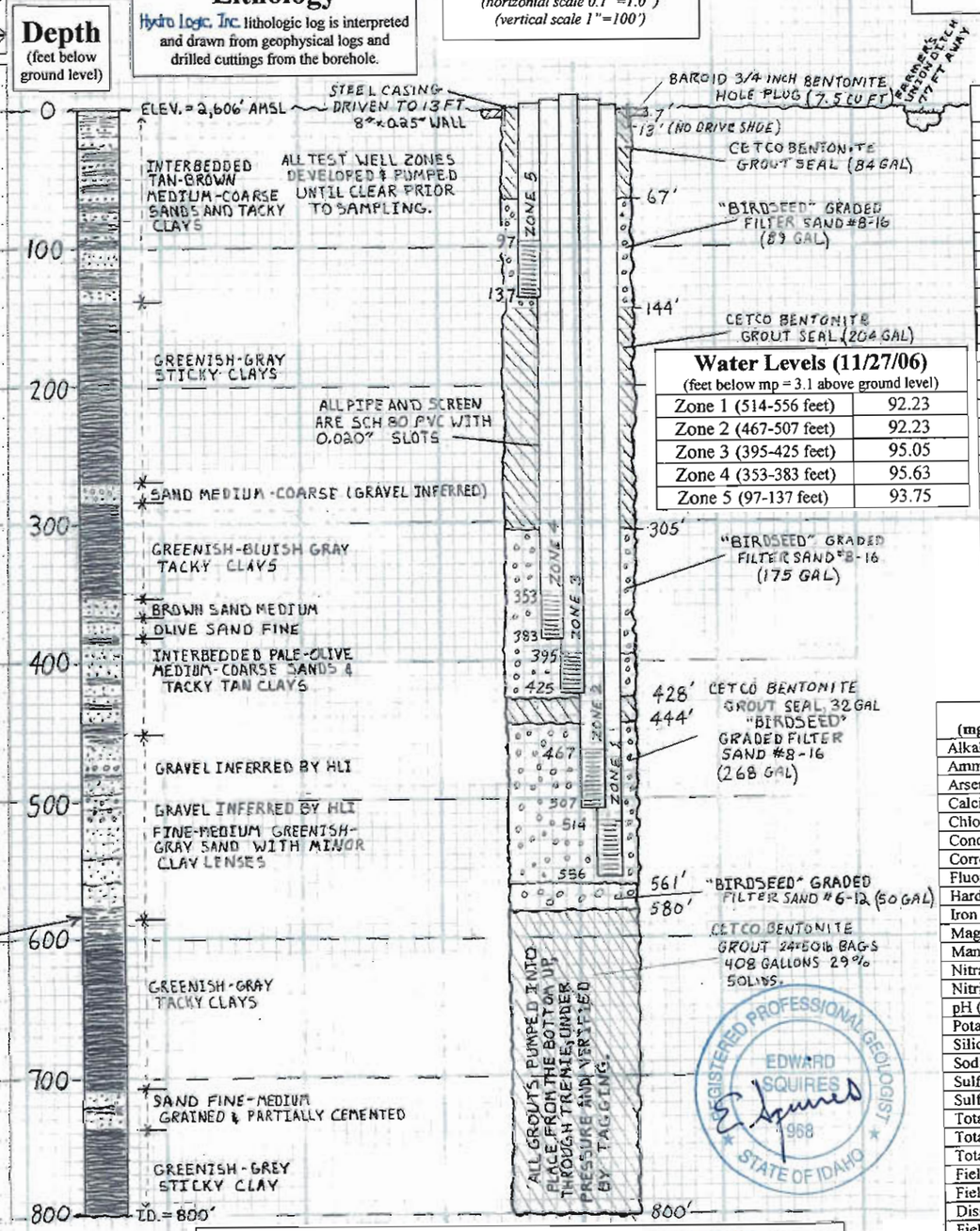
Depth
(feet below ground level)

Lithology

Hydro Logic, Inc. lithologic log is interpreted and drawn from geophysical logs and drilled cuttings from the borehole.

As-Built Well Construction

(horizontal scale 0.1"=1.0")
(vertical scale 1"=100')



Water Levels (11/27/06)
(feet below mp = 3.1 above ground level)

Zone 1 (514-556 feet)	92.23
Zone 2 (467-507 feet)	92.23
Zone 3 (395-425 feet)	95.05
Zone 4 (353-383 feet)	95.63
Zone 5 (97-137 feet)	93.75

Water Chemistry

Analyte (mg/L unless noted)	Zone 1 514-556 feet	Zone 2 467-507 feet
Alkalinity	133.0	125.0
Ammonia as N	0.37	0.06
Arsenic	<0.003	<0.003
Calcium as CaCO3	84.4	85.5
Chloride	3.42	3.22
Conductivity (µS/cm)	302	297.0
Corrosivity	-0.40	-0.44
Fluoride	0.69	0.60
Hardness	111.0	109.0
Iron (dissolved/filtered)	0.23	<0.01
Magnesium	6.50	5.73
Manganese (dissolved)	0.10	0.02
Nitrate as N	<0.10	<0.10
Nitrite as N	<0.01	<0.01
pH (SU)	7.47	7.48
Potassium	2.26	2.21
Silica	31.8	30.7
Sodium	22.1	21.7
Sulfate	17.2	20.7
Sulfide	<0.05	<0.05
Total Dissolved Solids	173 .0	188.0
Total Kjeldahl Nitrogen	0.39	0.13
Total Organic Carbon	<1.0	<1.0
Field Temperature (°F)	67.1	66.0
Field Conductivity (µS)	305	295
Dissolved Oxygen	+1.7	+2.6
Field pH (S.U.)	7.19	7.19

Analyses by Alchem Laboratories, Boise, Idaho.
Zones 1 to 3 sampled 10/09/06. Zones 4 & 5 sampled 10/9/06.
Field measured parameters by Hydro Logic, Inc.

Analyte (mg/L unless noted)	Zone 3 395-425 feet	Zone 4 352-382 feet	Zone 5 98-138 feet
Alkalinity	119.0	114.0	119.0
Ammonia as N	0.04	<0.01	<0.01
Arsenic	<0.003	0.0049	0.0081
Calcium as CaCO3	77.7	81.3	85.9
Chloride	3.57	3.54	4.36
Conductivity (µS/cm)	282.0	285.0	281.0
Corrosivity	-0.50	-0.61	-1.16
Fluoride	0.60	0.50	0.24
Hardness	102.0	105.0	111.0
Iron (dissolved/filtered)	0.01	<0.01	<0.01
Magnesium	5.83	5.85	6.22
Manganese (dissolved)	<0.01	<0.01	<0.01
Nitrate as N	0.30	0.33	2.30
Nitrite as N	<0.01	<0.01	<0.01
pH (SU)	7.84	7.40	6.91
Potassium	2.07	2.10	2.74
Silica	29.5	28.7	38.0
Sodium	21.1	17.9	13.6
Sulfate	21.4	22.3	12.0
Sulfide	<0.05	<0.05	<0.05
Total Dissolved Solids	185.0	203.0	208.0
Total Kjeldahl N	<0.10	<0.10	<0.10
Total Organic Carbon	<1.0	<1.0	<1.0
Field Temperature (°F)	64.7	63.8	57.4
Field Conductivity (µS)	274	268	265
Dissolved Oxygen	+4.9	+2.63	+9.51
Field pH (S.U.)	7.27	7.07	6.72

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On site supervision, well design and water quality sampling by Hydro Logic, Inc., Boise, ID.
Direct mud-rotary drilling and well construction by
Treasure Valley Drilling and Pump, Inc., Weiser, ID
Wells developed by McLeran Well Drilling, LLC, New Plymouth, ID.

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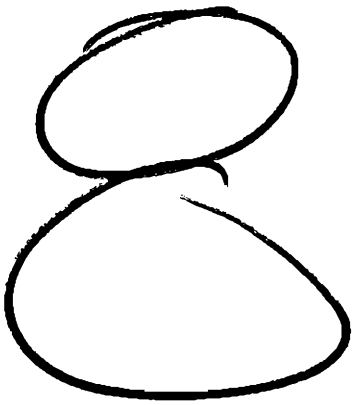

M3 Eagle - Test Well #2

T. 5 N., R. 1 W., Section 23, NE¼, NW¼, NE¼
Latitude 43° 45' 50.63" Longitude 116° 25' 6.58"
Well completed October 2006

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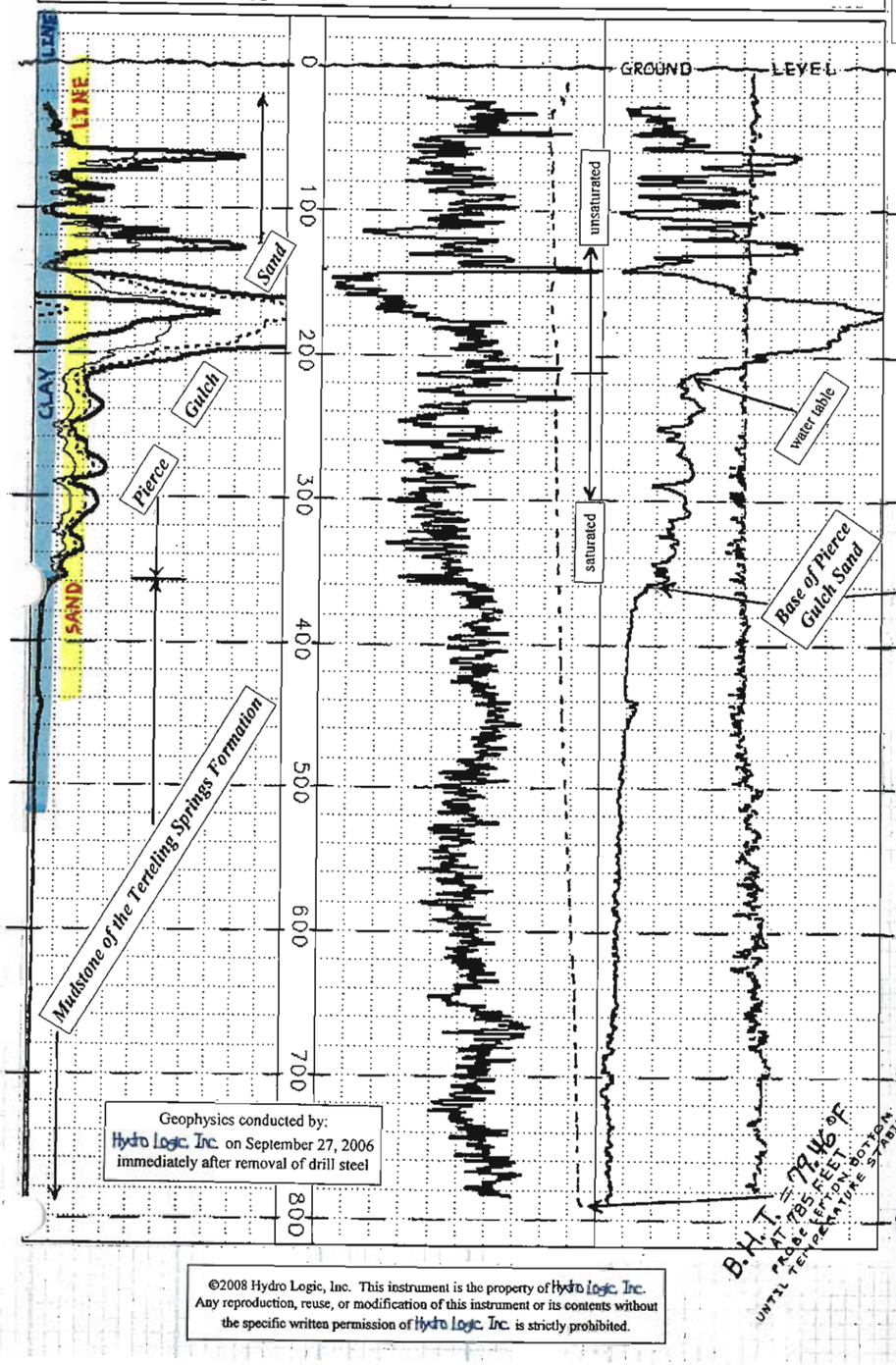
STATE OF IDAHO

Geophysical Logs

8" Resistivity: 0 ohm-meters 500
16" Resistivity: 0 ohm-meters 500
32" Resistivity: 0 ohm-meters 500
Natural Gamma Ray: 40 counts/sec 140
Temperature: 30 degrees F 80
Point Resistance: 40 ohms 200
Caliper: 0 inches 15

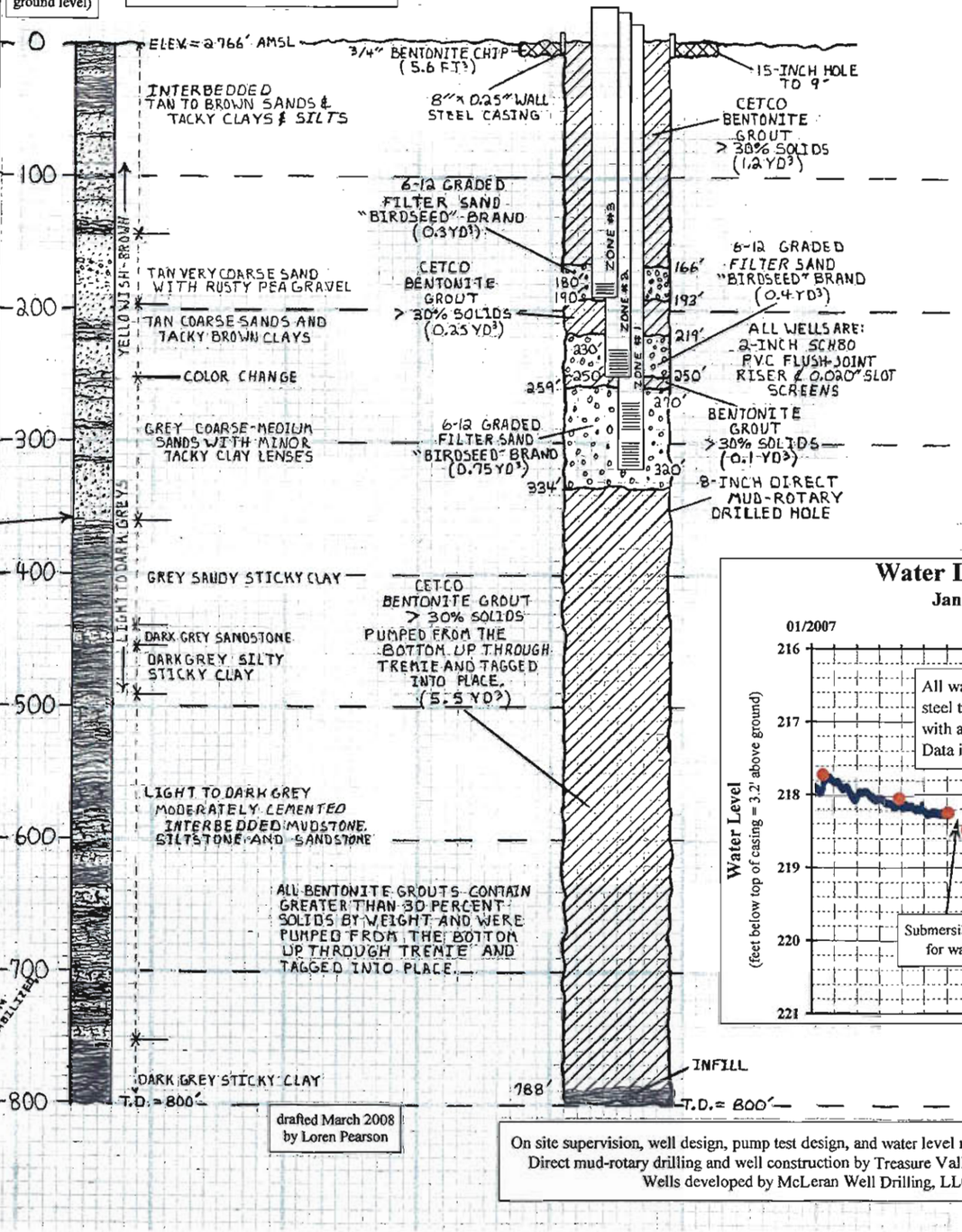


Geophysics conducted by:
Hydro Logic, Inc. on September 27, 2006
immediately after removal of drill steel

Depth
(feet below ground level)

Lithology
Hydro Logic, Inc. lithologic log is interpreted and drawn from geophysical logs and drilled cuttings from the borehole.

As-Built Well Construction
(horizontal scale 0.1"=1.0")
(vertical scale 1"=100')



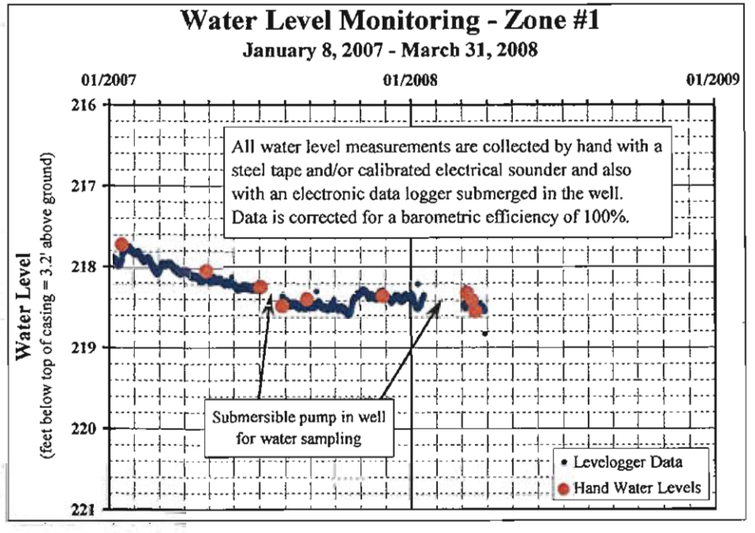
drafted March 2008
by Loren Pearson

Water Levels
(feet below measure point = 3.0 feet above ground)

Date / Time (24-hr clock)	ZONE #1 (320 - 270 feet bgl)	ZONE #2 (250 - 230 feet bgl)	ZONE #3 (190 - 180 feet bgl)
10/10/06 13:05	216.87	-	unsaturated zone (installed to confirm water table depth)
11/07/06 12:00	217.23	217.36	
1/18/07 14:27	217.19	217.37	
4/30/07 15:25	216.97	215.76	
6/01/07 12:00	216.17	216.75	
7/24/07 12:30	-	217.11	
7/31/07 13:00	217.58	217.91	
8/30/07 12:20	217.60	217.93	
9/19/07 16:30	215.93	216.26	

Water levels recorded by Hydro Logic, Inc.

Water Level Monitoring - Zone #1
January 8, 2007 - March 31, 2008



On site supervision, well design, pump test design, and water level monitoring by Hydro Logic, Inc., Boise, ID.
Direct mud-rotary drilling and well construction by Treasure Valley Drilling and Pump, Inc., Weiser, ID
Wells developed by McLeran Well Drilling, LLC, New Plymouth, ID.

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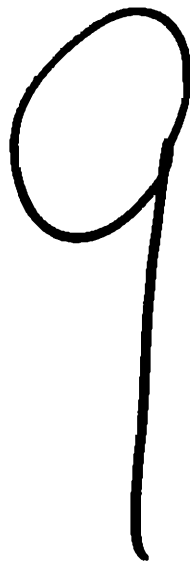
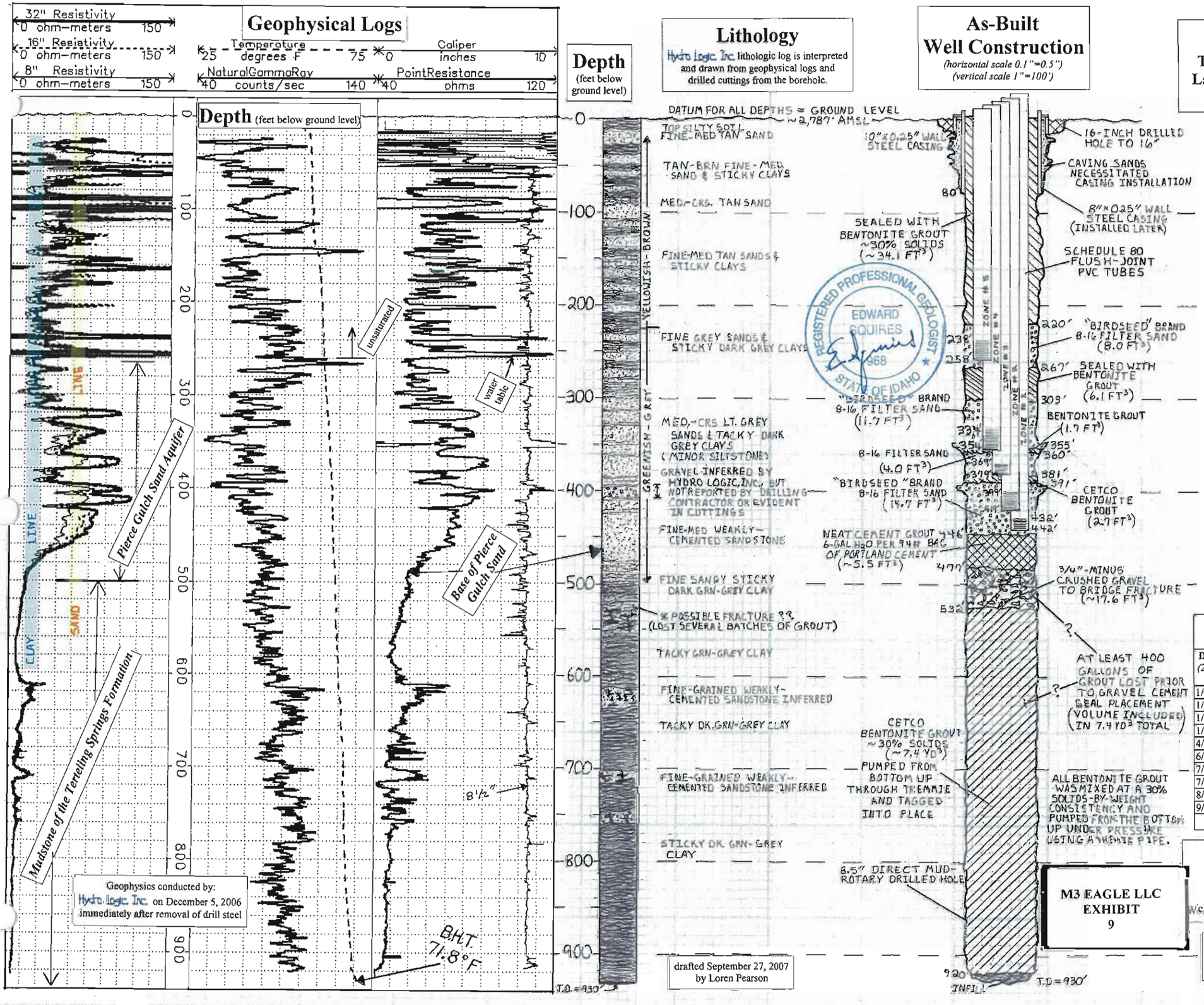


M3 Eagle - Test Well #3

T. 5 N., R. 1 W., Section 15, SW¼, SW¼, SW¼
Latitude 43° 45' 56.44" Longitude 116° 27' 8.35"
Well completed December, 2006



drafted September 27, 2007 by Loren Pearson

Ground Water Chemistry

Analysis (in mg/L unless noted)	ZONE #1 (442 - 432 feet bgl)	ZONE #2 (419 - 399 feet bgl)	ZONE #3 (379 - 369 feet bgl)
Alkalinity	136.0	123.0	117.0
Ammonia as N	0.28	0.14	0.05
Arsenic	0.008	0.005	0.009
Calcium as $CaCO_3$	69.8	74.8	86.5
Chloride	5.39	5.31	7.02
Conductivity (µS)	316.0	305.0	321.0
Corrosivity	-0.14	-0.46	-0.30
Fluoride	0.51	0.52	0.52
Hardness	98.4	106.0	118.0
Iron *(dissolved)*	0.16	0.09	0.03
Magnesium	6.94	7.48	7.47
Manganese *(dissolved)*	0.07	0.09	0.05
Nitrate as N	0.13	0.13	0.12
Nitrite as N	<0.01	<0.01	<0.01
Orthophosphate	0.477	0.270	0.276
pH - Lab *(S.U.)*	7.90	7.59	7.72
Potassium	2.90	2.54	2.53
Silica	43.5	41.2	35.8
Sodium	30.4	24.3	26.2
Sulfate	22.7	23.9	32.3
Sulfide	< 0.05	< 0.05	< 0.05
Total Dissolved Solids	253	235.0	238.0
Total Kjeldahl Nitrogen	0.35	0.23	0.18
Total Organic Carbon	1.34	< 1.0	< 1.0
Field Conductivity (µS)	*310*	*307*	*321*
Field Dissolved Oxygen	*6.64*	*4.89*	*4.87*
Field O.R.P. (mV)	*+106*	*+6*	*+110*
Field pH (S.U.)	*7.62*	*7.22*	*7.46*
Field Temperature (°F)	*64.2*	*63.2*	*62.2*

Analyses by Alchem Laboratories, Boise, ID
Samples collected on January 30, 2007 by Hydro Logic, Inc.

Water Levels

(feet below measure point = 3.5 feet above ground)

Date / Time (24-hr clock)	ZONE #1 (442 - 432 feet bgl)	ZONE #2 (419 - 399 feet bgl)	ZONE #3 (379 - 369 feet bgl)	ZONE #4 (354 - 334 feet bgl)	ZONE #5 (258 - 238 feet bgl)
1/05/07 13:05	261.42	261.48	261.68	261.79	unsaturated zone (installed to prove water table depth)
1/08/07 17:34	262.28	262.34	262.43	262.62	
1/18/07 10:07	263.30	263.34	263.42	263.60	
1/29/07 09:26	262.22	262.30	262.35	262.54	
4/30/07 11:39	262.62	262.63	262.71	262.90	
6/01/07 09:45	261.85	261.84	261.90	262.09	
7/03/07 09:54	262.34	263.74	263.81	263.99	
7/31/07 10:58	263.85	263.82	263.92	264.07	
8/30/07 10:01	263.93	263.95	263.96	264.18	
9/20/07 16:06	262.15	262.10	262.17	262.35	

Water levels recorded by Hydro Logic, Inc.

On site supervision, well design, pump test design, and water quality sampling by Hydro Logic, Inc., Boise, ID.
Direct mud-rotary drilling and well construction by Treasure Valley Drilling and Pump, Inc., Weiser, ID
Well development by McLeran Well Drilling, LLC, New Plymouth, ID.

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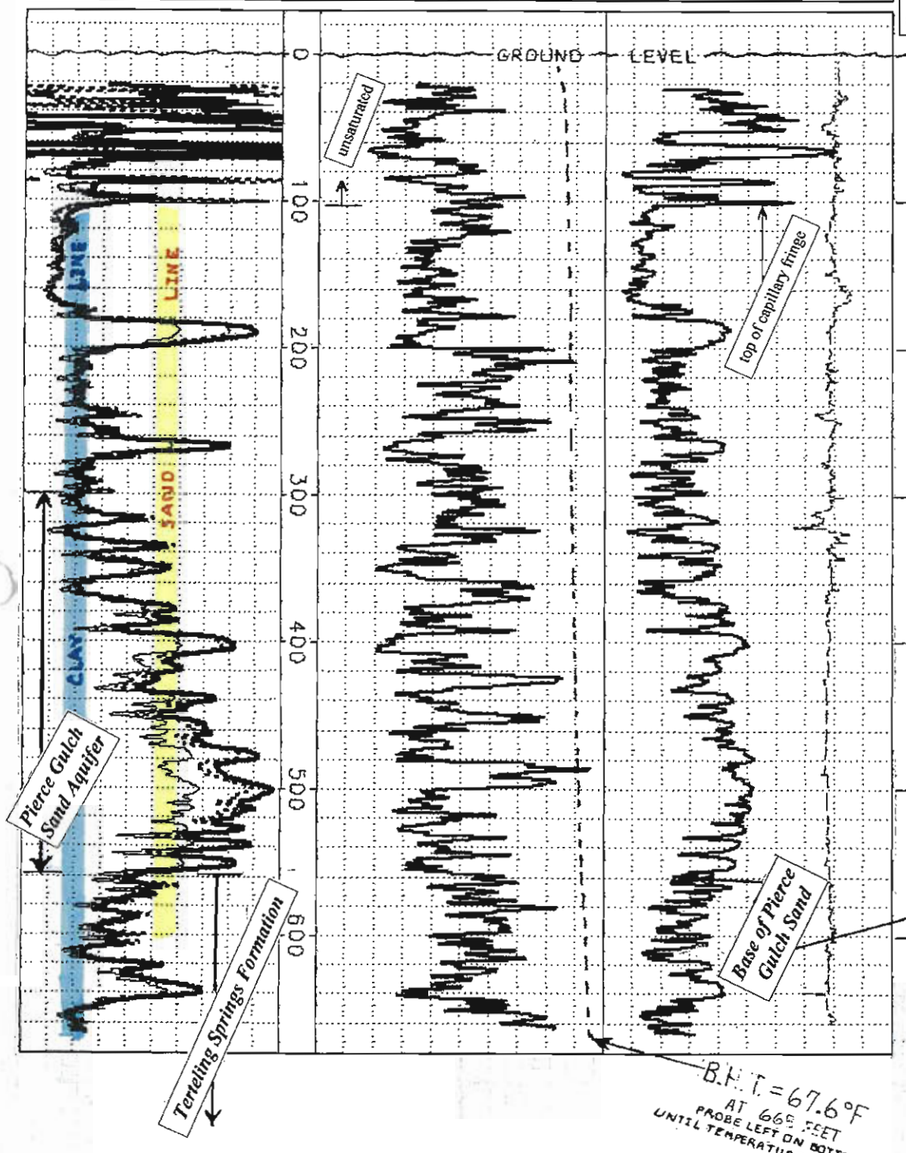
M3 Eagle - Test Well #4

T. 5 N., R. 1 W., Section 27, NW¼, SE¼, NE¼
Latitude 43° 44' 48.7" Longitude 116° 26' 14.6"
Well completed February 2008

Geophysical Logs

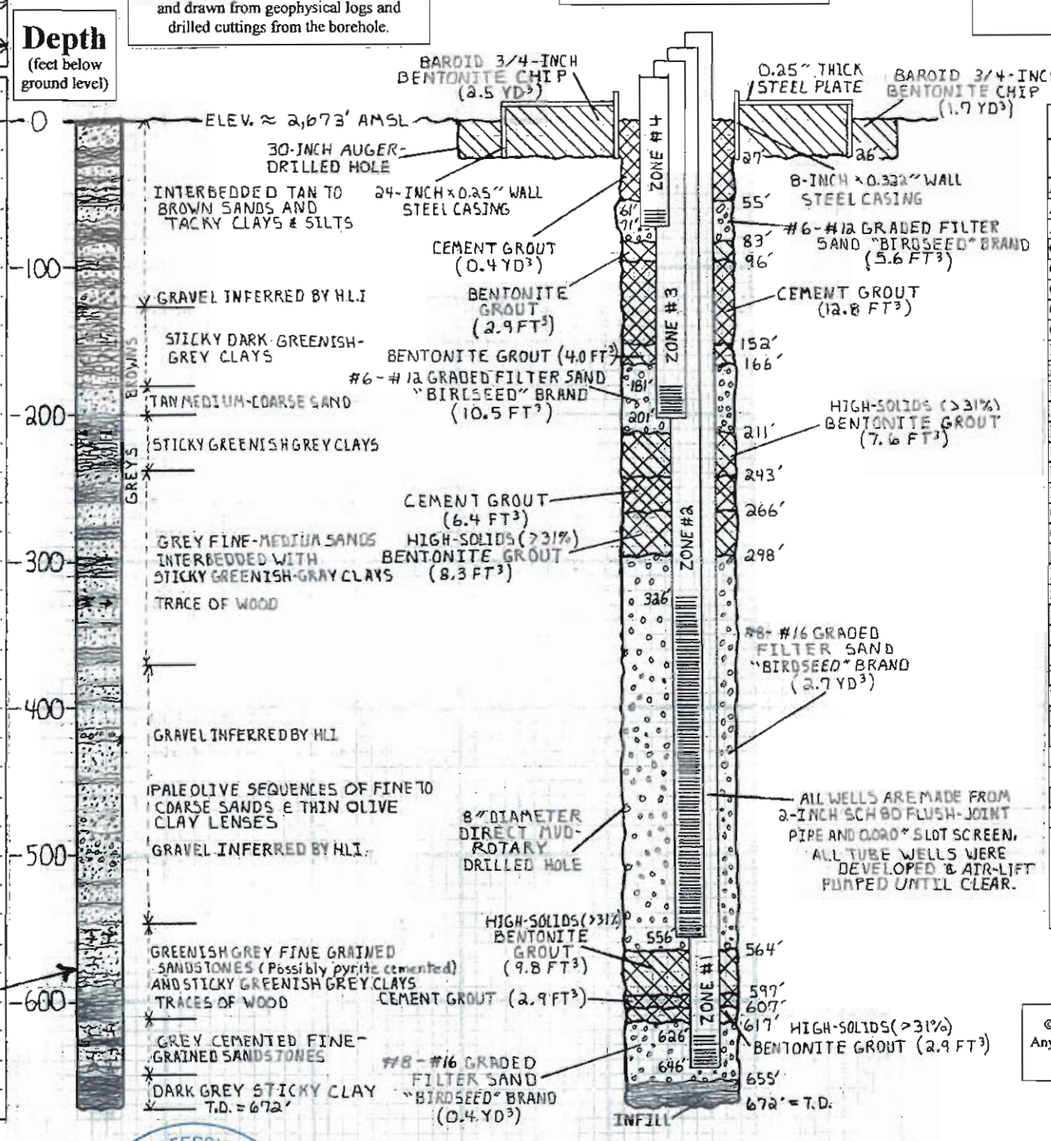
Geophysics conducted by: Hydro Logic, Inc. on September 27, 2006 immediately after removal of drill steel



Lithology

Hydro Logic, Inc. lithologic log is interpreted and drawn from geophysical logs and drilled cuttings from the borehole.

Depth (feet below ground level)



As-Built Well Construction

(horizontal scale 0.1"=1.0")
(vertical scale 1"=100')

Ground Water Chemistry

Analysis *(in mg/L unless noted)*	ZONE #1 *(646 - 626 ft bgl)*	ZONE #2 *(556 - 326 ft bgl)*
Alkalinity	128.0	122.0
Ammonia as N	0.11	<0.01
Arsenic	0.0029	0.0066
Calcium as $CaCO_3$	83.9	81.0
Chloride	4.13	4.57
Color (apparent)	<1	<1
Conductivity *(µS)*	307.0	300.0
Corrosivity	-0.45	-0.46
Fluoride	0.48	0.43
Hardness	118.0	109.0
Iron *(total)*	0.31	0.02
Iron *(dissolved)*	0.27	0.01
Magnesium	8.33	6.81
Manganese *(dissolved)*	0.07	0.01
Nitrate as N	<0.10	0.39
Nitrite as N	<0.01	<0.01
Odor	<1	<1
Orthophosphate	0.104	0.133
pH - Lab *(S.U.)*	7.45	7.52
Potassium	2.52	2.28
Silica	37.2	32.5
Sodium	24.0	25.8
Sulfate	21.2	23.0
Sulfide	<0.05	<0.05
Total Dissolved Solids	225.0	223.0
Total Kjeldahl Nitrogen	0.11	<0.10
Total Organic Carbon	<1.0	1.00
Field Conductivity (µS)	*316 to 333*	*303 to 334*
Field Dissolved Oxygen	*0.09*	*2.26*
Field O.R.P. (mV)	*-122 to -105*	*+99 to +116*
Field pH (S.U.)	*7.48 to 7.64*	*7.53 to 7.70*
Field Temperature (°F)	*68.9*	*64.6*

Water samples and field parameters collected on April 3, 2008 by Hydro Logic, Inc.
Each field parameter (except DO) was acquired with two separate calibrated meters to validate measurements.
Analyses by Alchem Laboratories, Inc., Boise, ID

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NOTES: ALL GROUTS PUMPED FROM THE BOTTOM UP THROUGH TREMIE AND TAGGED INTO PLACE.
ALL BENTONITE GROUTS CONTAIN GREATER THAN 31% SOLIDS BY WEIGHT.
ALL CEMENT GROUTS WERE MADE WITH 6 GALLONS OF WATER MIXED WITH 94 POUNDS OF PORTLAND CEMENT.

Water Levels

(feet below measure point = 3.5 feet above ground)

Date / Time *(24-hr clock)*	ZONE #1 *(646 - 626 ft bgl)*	ZONE #2 *(556 - 326 ft bgl)*	ZONE #3 *(201 - 181 ft bgl)*	ZONE #4 *(61 - 71 ft bgl)*
3/07/08 18:31	130.25	130.72	134.76	unsaturated zone (installed to confirm vadose zone)
3/14/08 17:12	130.25	130.73	134.20	
3/20/08 12:27	130.32	130.79	134.49	
3/22/08 18:12	130.43	130.92	134.74	
3/31/08 14:51	130.11	130.60	134.56	

Water levels recorded by Hydro Logic, Inc.

On site supervision, well design, pump test design, and water quality sampling by Hydro Logic, Inc., Boise, ID.
Direct mud-rotary drilling and well construction by Treasure Valley Drilling and Pump, Inc., Weiser, ID
Well development by McLeran Well Drilling, LLC, Fruitland, ID

REGISTERED PROFESSIONAL GEOLOGIST
EDWARD SQUIRES
968
STATE OF IDAHO

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drafted March 2008 by Loren Pearson

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Qualitative Interpretation of Magnetic Anomalies and Progress Report on Geologic Mapping in the Foothills North of Eagle, Ada and Gem Counties, Idaho

Report prepared for HydroLogic, Inc. (May 20, 2007)

by

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MAGNETOMETER SURVEY

Summary: The survey clearly identifies a down-to-SW fault along Willow Creek Road (Fig.1), and width of the anomaly suggests the sediment section over volcanics is at least 3,000 feet deep (a surprisingly deep estimate, which if important, needs verification by more detailed survey and interpretation). The fault aligns with the NW extension of the previously identified West Boise – Eagle fault. Another major down-to-SW fault is identified near the mouth of Big Gulch, and crude estimate of thickness of sediment section over faulted volcanics is 2,300 to 4,600. Better definition of faulting on the M3 properties could be obtained by a long magnetometer line (14 km), along ridgetop roads between Willow Creek and Big Gulch, with close supervision of data quality.

Measurements: Data was acquired under the supervision of Dr. Paul Donaldson, mostly by graduate student Carlyle Miller.

The first data set was acquired in about June, 2006 as lines along Little Gulch and Big Gulch. The data set is generally of good quality with a noise level of ± 5 nanoTeslas (nT).

A second set of data was acquired later in the summer of 2006 along Willow Creek and Chaparral Road ("north line"), along the Farmers Union Canal ("south line"), an extension of the Big Gulch Line to the southwest, and a short line near Highway 16 between Big Gulch and Willow Creek (Figs. 2 and 3). This data set is quite noisy with a level of ± 15 nT, and many unexplained excursions exceeding 80 nT. It is likely that the magnetometer malfunctioned intermittently. The instrument was subsequently sent to Geometrics for repair by Lee Liberty, and a number of problems were repaired. However, the majority of measurements cluster along a trend, so that the larger anomalies were measured. Nevertheless, it is recommended that anomalies detected by the second data set be verified by running an additional line between Willow Creek and Big Gulch, along the ridge top roads through the northern M3 properties and as far SW and NE, as is possible on other lands. The fluctuation in altitude along such a line, greater than 20 m along such should be noted, but it is not likely to significantly affect the measurement of anomalies arising from buried volcanics over 300 m deep (see for example Figs. 5 and 6), which shows that elevation (depth) difference from 300 to 400 m causes a diminishment of 80 to 60 nT, or 20 nT. These anomalies also have an associated long wavelength, greater than 600 m, and should be easily distinguished from elevation effects. However,

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for shallow anomalies, shallower than 300 m depth, the effect is greater, and elevation effect over a few hundred meters distance could be mistaken for a shallow anomaly if not noted or corrected.

The instrument used is a Geometrics G-858 cesium magnetometer with two sensors spaced one meter apart, on a vertical staff, the lower sensor about 1 meter off of the ground. This instrument measures the total magnetic field of the earth on each sensor to a precision of 1 nanoTesla (nT. The field values ranged from 53,600 to 53,900 nT. The survey was made by walking and continuously recording. Locations were obtained by simultaneous recording from a GPS unit with an accuracy of ± 8 m. No base stations measurements were made, but tie lines on the Big Gulch and Little Gulch lines gave agreement measurements, indicating no drift or large secular variation in the first set of data. It is possible that gradual diurnal variation of up to 60 nT may occur over a period of 12 hours. I was not provided with detailed field notes showing times of measurement – so one cannot evaluate that source of error – when splicing data together taken at very different times of day.

Source of magnetic anomalies: Magnetic anomalies arise from faulted rock sequences or topographic variation in rocks having a substantial magnetic susceptibility (k), i.e. greater than 0.0001 SI units. (note: SI values are 4π times cgs units, and both are dimensionless). Anomalies may also arise from spatial variation in k of rocks. Basaltic volcanic rocks range from 0.001 to 0.05, dependent largely upon the percent and grain size of the mineral magnetite. For example, a rock with 7 per cent magnetite will have a volume susceptibility of 0.038 SI units (Breiner, 1999). In addition to the magnetism induced in rocks by the prevailing magnetic field, basaltic rocks in particular may have a frozen remnant magnetism set by crystallization of magnetite when the lava cooled. Polarity of the frozen magnetism may be of different or opposite polarity from the induced magnetism, on account of reversed polarity of the earth's magnetic field at the time of crystallization. Remnant effects are difficult to predict without detailed sampling and modeling. For this qualitative interpretation, it is assumed that anomalous magnetism is entirely caused by induced magnetism of the present earth's field.

Qualitative interpretation of anomalies of this survey is based on an assumption that most of the magnetic features are faulted volcanic rocks beneath the Idaho Group sediments. Mapping the in the Pearl area by Clemens (1993) indicates that above the granitic rocks is about 100 m thick section of basalt, locally overlain by as much as 120 m of rhyolite, which is in turn overlain by another 25 m of basalt. Overlying this volcanic section are the Idaho Group sediments which are at least 200 m thick over most of the area. The faulted basalt and rhyolite would produce magnetic anomalies. The deeper granite may produce broad anomalies of longer wavelength and lower amplitude than the volcanics. Very low k of sediments indicate they to not contribute to the field. A reasonable model is 100 to 200 meter thick slab of volcanic rock, overlain by sediments and faulted by normal faults.

Models of faulted volcanic rocks at depth:

Analytical models of the total-field magnetic anomalies for a 2-dimensional faulted slab are published int Telford et. al. (1990). The model is for a cross section of a plate of

thickness, t, extending infinitely in the 3rd dimension. The formula on p. 100, Eqn 3.59b was calculated to visualize the effect of depth, thickness and susceptibility, for offset volcanic rocks. Figures 5 and 6 show a simplified version, of just the upthrown block, assuming an offset of 100 m, of a 100 meter thick section of volcanic rocks of susceptibility of 0.003 SI.

$$F(x) = +2\,k\,t\,F_e\,\{1/(d^2+x^2)\}\{d\sin 2I\sin\beta - x(\cos^2 I\sin^2\beta - \sin^2 I)\}.$$

In terms for EXCEL:

F(x) =+ 2*(*k*)*(*t*)**Fe***((1/((*d*^2)+A5^2))*(*d**(SIN(2*RADIANS(*I*)))* (SIN(RADIANS(*strike*))) - A5*(((COS(RADIANS(*I*)))^2)*((SIN(RADIANS(*strike*)))^2) - ((SIN(RADIANS(*I*)))^2)))).

Where
k = magnetic susceptibility, SI units
t = thickness of slab of magnetic rock, in meters.

F(x) = total field measured by the magnetometer.
F_e =Approximate total field of the earth in the area, which induces the anomalous field in susceptible rocks. i.e., the background value, estimated to ± 1000 nT (used a value of 54,000 nT) for model calculations,

d = depth to top of slab
x = horizontal distance from fault edge (parameter A5 in EXCEL code above) (assumed vertical fault plane)
I = inclination of the earth's magnetic field, which for this area is 60 degrees.
β = strike angle between magnetic north, and the strike of the fault. For a fault with strike of N45W, and down to SW, use 45 degrees. For a fault N45W and down to NE use 225 degrees. Telford et. al. (1990) are not clear on their conventions, and to make their formula reproduce their Fig. 3.22b on page 103, I had to change the sign of the equation above from – to a +.

In all formulas for 2D bodies of uniform cross section, the amplitude varies as $2\,k\,t\,F_e$, so that for any given fault depth and offset, at a given orientation to the earth's magnetic north, the anomaly varies linearly with the thickness of the magnetic slab (t) and the susceptibility (k).

Figures 5 and 6 show results of calculation for NW-SE trending faults with vertical planes. The model is appropriate, since faults in the area generally trend NW-SE. The anomaly shape is the same, and changes sign, if faulting sense is opposite (i.e., up to southwest, or up to northeast)

Figure 5 shows that a down-to-SW fault, with 100 m of displacement on the volcanic section will have a positive bulge in the field of 100 to120 nT, if top of upthrown block is 200-m deep, the width of anomaly will be about 600 m. If top of the block is 600-m deep, the anomaly will diminish to 20 to 40 nT, and width will be about 1200 m.

Figure 6, is the anomaly of a down-to-NE fault, and is just the negative value of Figure 4. This calculation for a 700-m deep anomaly show a width of about 1700 m, and an anomaly of 20 to 40 nT for the 100 m thick volcanic section, offset 100 m.

To re-iterate again, the strength of the modeled anomaly is linearly related to the magnetic susceptibility and thickness of the section of volcanic rocks, and diminishes with depth as 1/d.

Specialized and costly software exists for more exact modeling of anomalies (QUICKMAG-PRO $2850 from Rockware), however it was not immediately available for this study. However, I just became aware of a freeware GEOMODEL, also from Rockware, that allows 2.5 D modeling, and that will be done subsequent to this report.

Simple estimates of depth to anomalous features: Because distance breadth of the anomaly increases with increasing depth of the anomalous feature, the width is an indicator of depth to rock feature or susceptibility giving rise to the change in the earth's field. A rule of thumb is that depth is about ½ the width of the anomaly. For example, if an anomaly is 1200 m wide, the depth is about 600 m. Such depth estimates are crude and may be off by 50 per cent (Breiner, 1999).

Another simple measure is to measure the map distance, x_z, of the straight portion of the slope of one of the limbs of an anomalous bulge or depression in field values. "Straight portion" is the distance between the inflection point (i.e.curvature changes from concave upward to convex upward, for positive anomalies). In this estimate, the depth, z, is simply calculated from:

$$z = C\ x_z$$

where C varies from 0.5 to 1.5 (Breiner, 1999).

Discussion of observed anomalies along survey lines. All survey lines trend approximately SW-NE, so that they will yield profiles perpendicular to strike of SW-NW trending faults, believed to be the dominant structures in the area (Fig. 1). Their location will be discussed in terms of UTM km easting coordinate for easy reference on profiles and map. Because the lines are oriented mostly SW-NE, the easting km coordinate separation is multiplied by 1.4 to determine the width of anomaly along the SW-NE oriented survey line. Anomalies are labeled by circled letters on Figure 1, and the following sections discuss the profile lines in terms of those lettered anomalies.

North Line (Chaparral Road – Willow Creek Valley), 9 km long

A: A +20 nT positive anomaly, with a (600-m x 1.4) = 840-m width can be discerned from the rather noisy data at the NE end of the line, centered at 546.15 east (Fig. 2). Anomaly is not well defined, and large excursions of 100 nT in the data are probably

instrument malfunction – indicating the data should be re-run if this anomaly is of interest.

B: Field values rise to the SW to point 544.0, 30 to 40 nT, and then fall off sharply to the SE to point **C**. Interpretation of point B is uncertain. Elevation drop of 33 ft between point is not enough to explain rise in values.

C: Most profound anomaly along this 9-km line is a negative anomaly centered at UTM km 543.0, of -60 to -80 nT, and a width of (1.2 km x 1.4) = 1700 m. The negative value indicates a down-to-SE fault, with more than 100 m displacement, and at an estimated depth to volcanic section on the upthrown block of (½ x 1700 m) = 850 m (2,800 ft).

D: Values rise irregularly from edge of the point **C** anomaly to the end of the line, 60 nT, over a distance of 2.5 km. Data is so noisy (±20 nT) that shape of any individual anomalies, if they exist, cannot be discerned.

Big Gulch Line and the SW extension, 12-km long.

E: A positive +50 nT anomaly, centered at 550.5 east, has a width of (1.4 x 3 km) = 4.2 km (Fig. 2). The same anomaly is larger on the Little Gulch line (Fig. 3), and the tie line (Fig.4), where its magnitude is + 100 to + 180 nT, and breadth is 3 to 4 km. The positive value and width suggest a down-to-SW faulted volcanic section, perhaps 1.5 to 2 km (4,800 to 6,000 ft) deep. Magnitude of the anomaly suggests large displacement (>200 m). The depth estimate seems large, and it is possible that the diminishing NE limb may be a thinning of the volcanic section, and the anomaly width due to faulting is less.

F: A well defined low of -20 nT, with a width of (1.4 x 2 km) = 2800 m. Possibly a down to NE fault at depth, but associated with anomaly at E, may indicate complicated geometry of faulted volcanics.

G. Slight rise and decline with amplitude of about 20 nT, and width of less than (1 km x 1.4) = 1.4 km may indicate a down to SW fault of small displacement (< 100 m).

H: A + 80 nT anomaly centered at 544.5 east with a width of at least (1.4 x 2 km) = 2.8 km, suggests a large down to SW fault, with top of upthrown block about 1.4 km (4,600 ft) deep; however, the SW definition is very noisy due to malfunction of the magnetometer when that SE extension data of this line was obtained (i.e., data SW of 545.0 east). The "south line" point **M**, indicates a 2,300 to 3,300 ft sediment section over the volcanics here, but in both cases the data is very noisy, and needs to be re-run for more precise estimates.

Little Gulch line

I: The largest and best defined anomaly of the survey is this +100 nT, (1.4x 2km) 2.8 km wide positive anomaly, centered at 550.8 east (Fig 3). The positive value suggests a large-displacement (>200 m), down-to-SW fault, with top of faulted volcanics on the upthrown block of about 1.4-km (4,600-ft depth. As discussed above under point E, depth estimate seems much larger than expected, and none of the lines fully defines the full NE limb of the anomaly. NE extension of line could allow better modeling, and also tie to the known volcanic section in upper Little Gulch area drilled by Conolley's wells about 1000 ft deep, 4 km west of here, and the exposed volcanic contact about 4 km to the NE (Fig. 1).

J: A negative anomaly of about -20 nT and a width of (1.2 x 1.2 km) = 1.4 km is centered at 547.3 east, suggesting a small displacement fault at a depth of 700 m (2,300 feet).

K: The rise from anomaly J, at end of line, may be the NE limb of the larger positive anomaly detected by the SW end of the "south line". That SW continuation is shown on this profile, and defines a + 80 nT anomaly centered at about 544.8 east.

South Line (Farmers' Union Canal)

L: Values rise at the east end of the line at 551.7, and are likely the west limb of the anomaly I on the Little Gulch line (Fig 3).

M: Values rise continuously to the west along this line, and then jump up sharply at 547.2 (Fig. 3). The sharp jump may be a splice of data taken at different times, and a result of diurnal variation and of no geologic significance. The peaking of values at 545.5 suggest a large displacement, down-to-SW fault, shown by a positive anomaly of at least + 100 nT, and a width of (2 to 3 km x 0.7) = 1.4 to 2 km. Because this is an EW line, the width of the anomaly, measured perpendicular to a NW-SE strike fault, is reduced by multiplying by 0.7. This same feature is also defined on the Big Gulch line at point **H** (Fig.2) confirming its NW-SE trend, and together suggest a volcanic-section feature at least ½ x 1.4 to 2 km (2,300 to 3,300 ft) deep beneath the sedimentary section.

Willow Creek Road Line ("perpendicular tie line")

N: Data on this line is displayed on both the northing coordinate and the easting coordinate, to better define this large (+200 nT) anomaly centered at 550.4 east (Fig. 4). This is the same feature detected on the Little Gulch line at point **I** (Fig. 3), and probably also at lesser magnitude as point **E** on the Big Gulch line (Fig. 2), and defines a large down-to-SE fault with NW-SE strike.

GEOLOGIC MAPPING PROGRESS & DISCUSSION OF FAULTS

Mapped geologic features are compiled on Fig. 1. Thorough geologic mapping is shown in the northeast corner of the area from Clemens (1990). Mappable faults shown in Fig. 1 are from a number of unpublished mapping projects by S.H.Wood.

Oolitic sands: Occurrence of oolitic sands has been mapped as a part of this project, because they are one of the few cemented rock outcrops in the sedimentary section. Oolitic sands are carbonate coated grains of lake shore deposits, and their origin and significance is discussed in Swirydczuk et al (1980), Wood and Clemens (2002), Wood (2004), Wood and Squires (2007). Significant to this study is the observation that these carbonate-cemented sands occur over a stratigraphic interval, limited to a few hundred feet, in the upper part of the Terteling Springs Formation, on the north side of the western Snake River Plain. Therefore these outcrops are considered a rough geologic marker bed, and the elevation of their occurrence a rough indicator of the tectonic tilting or faulting across the area. Elevations of oolite outcrops are posted on the map (Fig. 1). In the SE Pearl area, their elevation is 3,100 to 3,200 feet. Along Willow Creek, near Lynn's Ranch they occur at 2,900 to 3,000 feet, and along the Old Freezeout Hill Road they occur at 2,700 to 2,750. From these elevations, it is concluded that the vertical-fault offset combined with tectonic tilt of the sedimentary section is about (3,200 - 2,700), 500 ft, from the Pearl area (NE corner of map) to Old Freezeout Hill Road.

Oolitic sands and the Terteling Springs Formation: The oolite deposits are also an identifying feature of sand facies of the Terteling Springs Formation, a facies that lies within several miles of the contact with the Idaho batholith, and grades basinward to the SW to the mudstone faceies (Wood and Clemens, 2004). Therefore, the thick sand section observed along the Old Freezeout Hill Road is Terteling Springs Formation, and is not the overlying Pierce Gulch Sand.

Pierce Gulch Sand: Apparently the Pierce Gulch Sand, with a significant thickness in the western part of the M3 properties, is in a downfaulted section exposed along the bluffs of the Payette River Valley, west of the Old Freezeout Hill Road. I believe the strata in the bluffs in Section 28, T2W, R6N is the Pierce Gulch Sand, because a characteristic white volcanic ash bed (locally 2-ft thick) occurs at elevation 2,610 ft within the dominantly coarse sand deposits. A similar volcanic ash bed occurs in the bluffs of sand sediment along the north side of the Payette River near Birding Island, 18 miles to the northwest. However mapping of the section exposed along the Payette River is in the very preliminary stages, and these correlations are tentative.

Faults: Exposures of strata in the M3 area are scarce; however faint stratification lines are apparent on Google-earth imagery and BLM aerial photography. The faults indicated by the magnetometer survey do not have obvious surface expression, except for one small fault exposed in the roadcut along Willow Creek Road in the hill just north of Big Gulch (Fig.1). That fault is associated with the major down-to-SW fault along Willow Creek Road detected by the magnetometer survey (points **E, I, L,** and **N**), and also known in the southwestern part of the map area from drillers logs and geophysical logs (Fig. 1). Width of the magnetic anomaly suggests a thick sediment section over the volcanics here; however these depth estimates of 4,800 ft are crude. If one uses the formula $z = Cx_z$, and

x_z = (1.4 x 1.5 km) = 2000 m, and a constant for C of 0.5, the depth of sediment over volcanics computes to 1000 m (3,300 ft). The fault is a NW extension of the West Boise – Eagle fault system identified by Squires (1992).

It is puzzling that the down-to-SW fault exposed in the Highway 16 roadcut at Freezeout Hill (Fig. 1) does not have a strong expression on the magnetometer survey (as noted above, that data on the "north line" is very poor in quality on account of instrument malfunction, and another traverse is needed to understand this puzzle). Because the exposed fault shows strata that cannot be matched up in the 60 ft vertical exposure, the offset on this down-to-SW fault must exceed 60 ft. However I believe that the sands at this exposure are entirely the Terteling Springs Formation sand facies. The fault projects SE to the oolite bed exposures on the north side of Willow Creek, near Lynn's Ranch, but the oolite beds are not faulted; therefore, if it is a significant fault, it must project to the SW or to the NE of these beds.

The magnetometer survey of Big Gulch and the "south line" shows a major down-to-SE fault at the western M3 property, labeled points **H, K**, and **M** (Fig. 1). Thickness of sediment over the volcanic section is crudely estimated at 2,300 ft based on width of magnetic anomaly. This fault could be better defined by a survey along the ridgetop roads between Big Gulch and Willow Creek, west of Highway 16 (not M3 property).

The fault indicated by point **C** on the "north line" has an unexpected down-to-NE magnetic signature (negative anomaly) (Figs 1 and 2). Data is very noisy along this line, and the data between points **C** and **D**, while suggestive of complicated faulting, need to be repeated before a more confident interpretation can be made.

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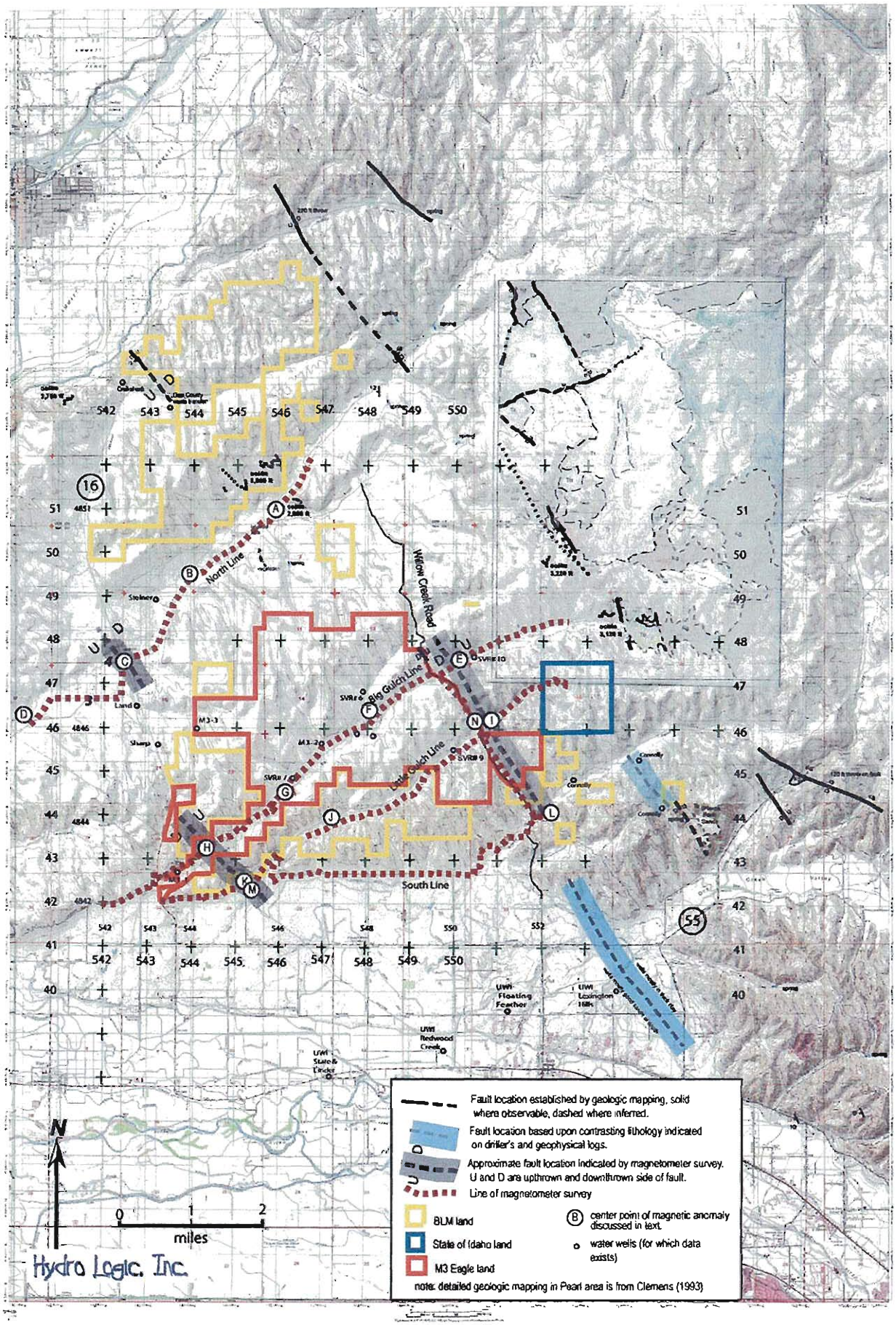

Figure 1. Map showing M3 property, geologic mapping in progress, and location of magnetometer lines. Center point of magnetic anomalies are circled - refer to text for discussion.

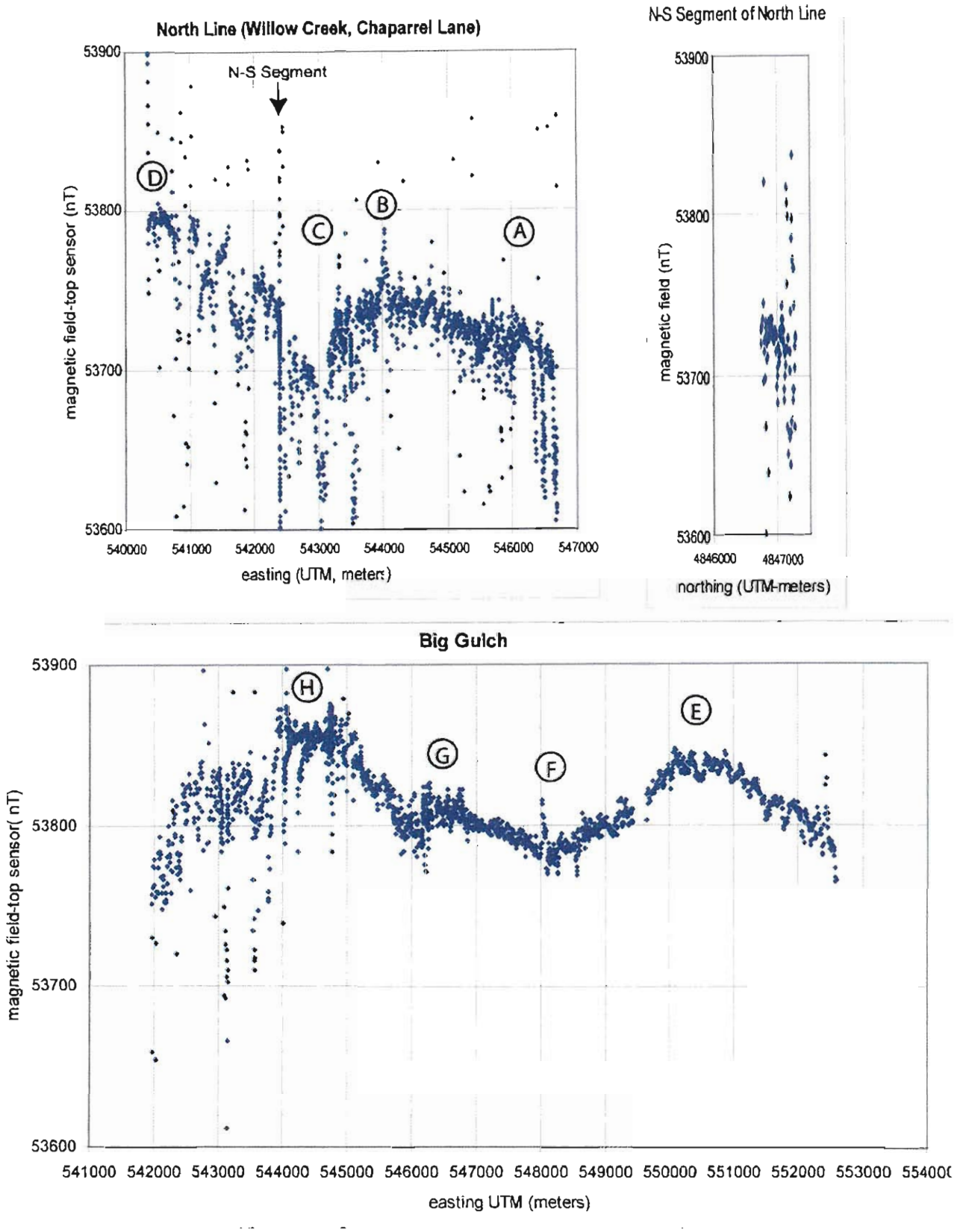

Figure 2. Magnetometer lines along Willow Creek - Chaparral Lane and Big Gulch

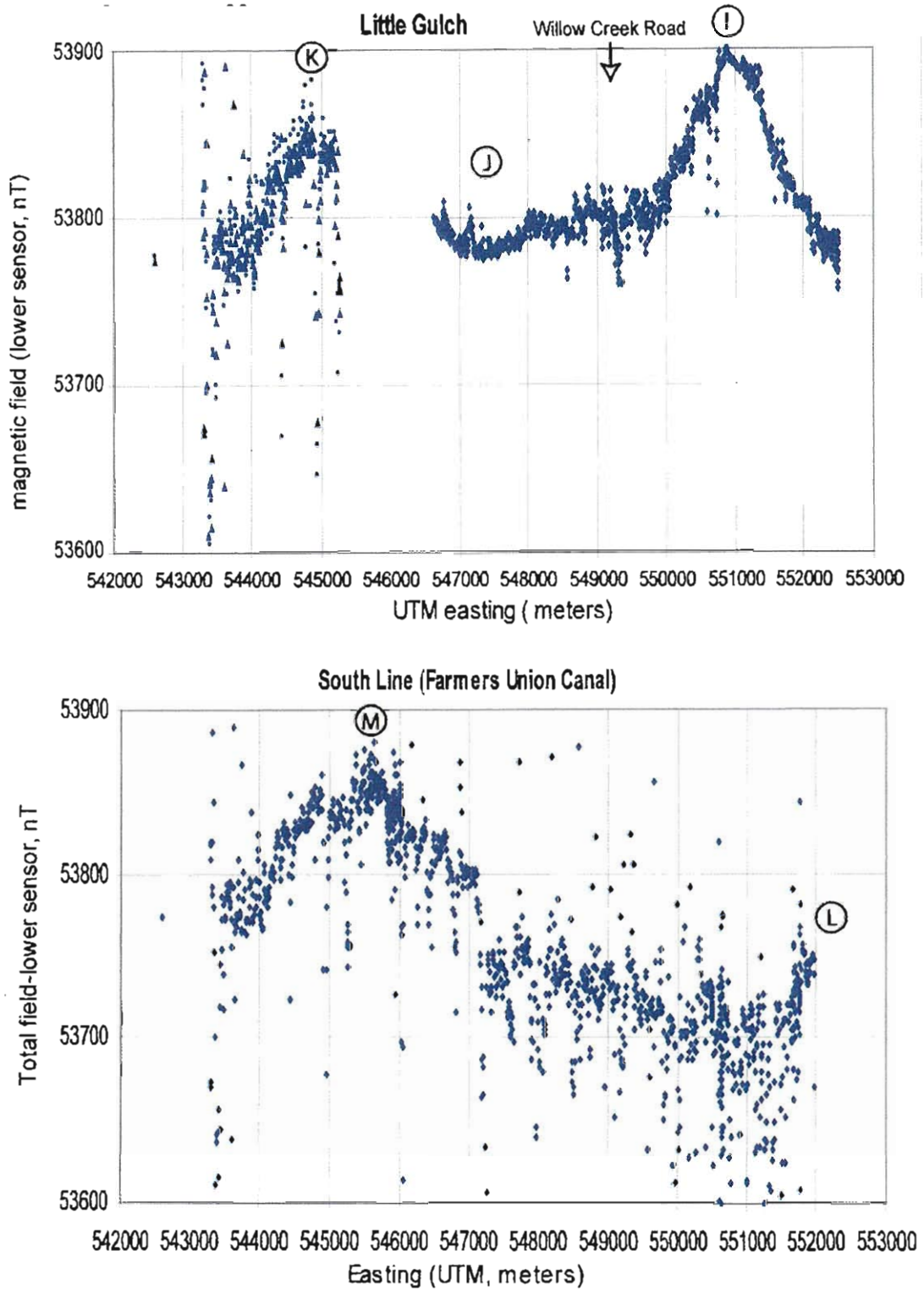

Figure 3. Magnetometer lines along Big Gulch and the Farmers' Union Canal.

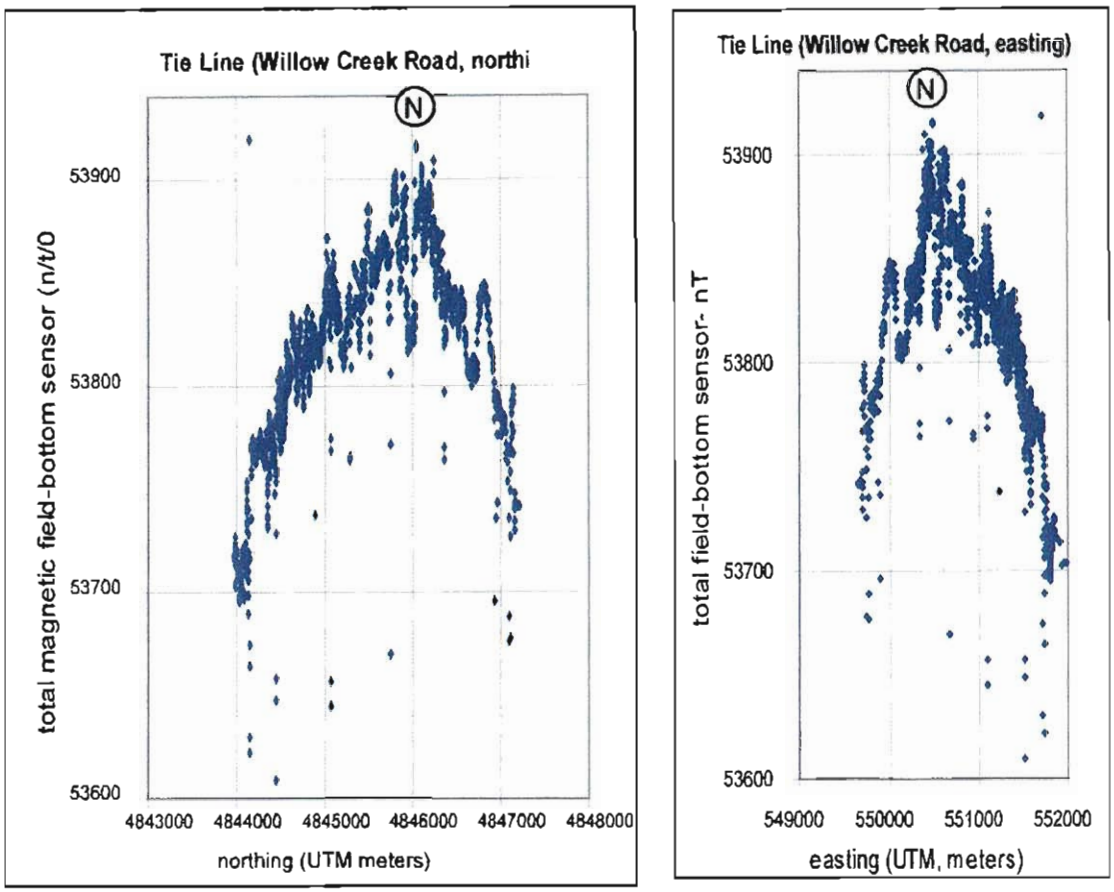

Figure 4. Magnetometer line along Willow Creek Road.

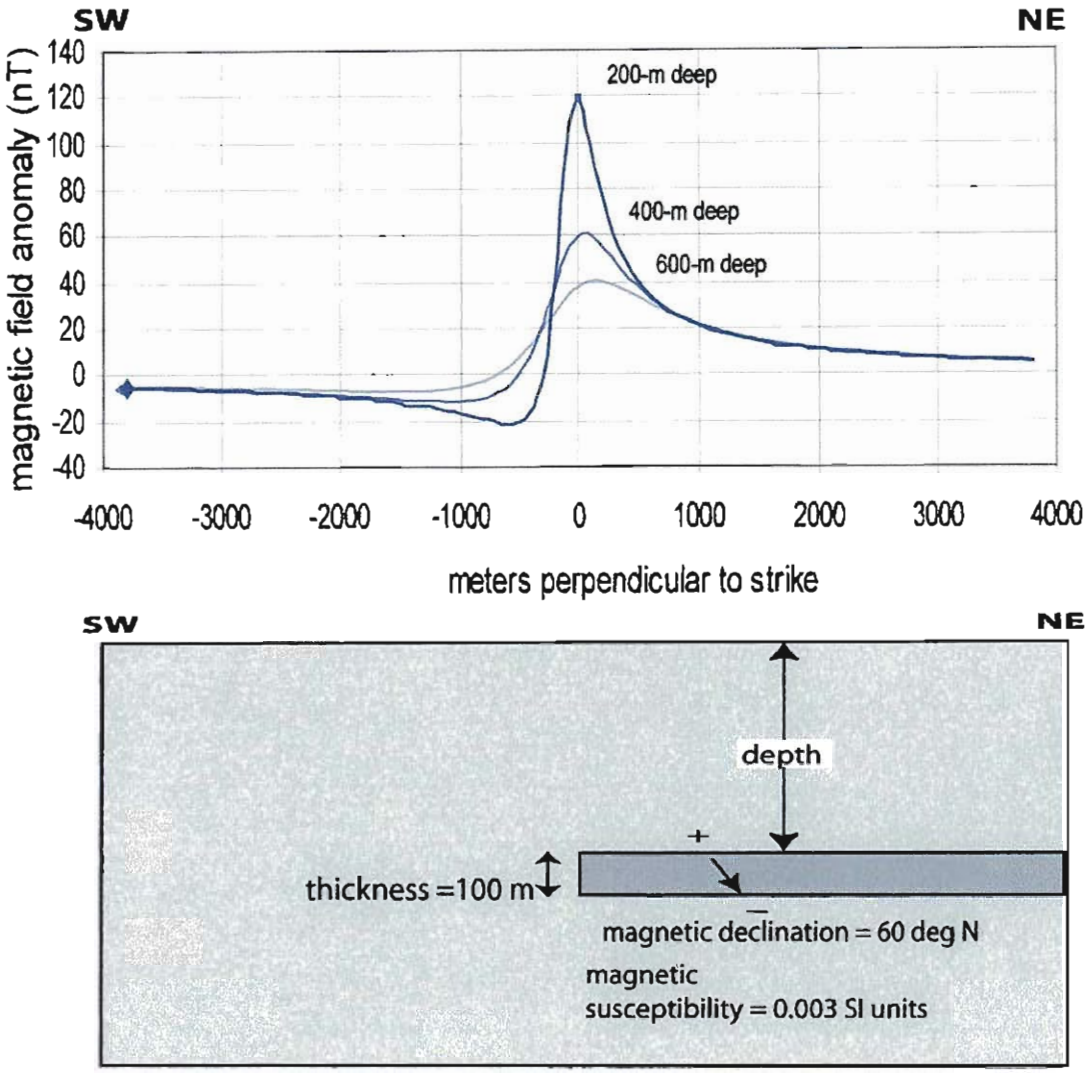

Figure 5. Model calculation of a down-to-SW faulted volcanic slab, fault with a NW-SE strike - simplified to show only the upthrown block.

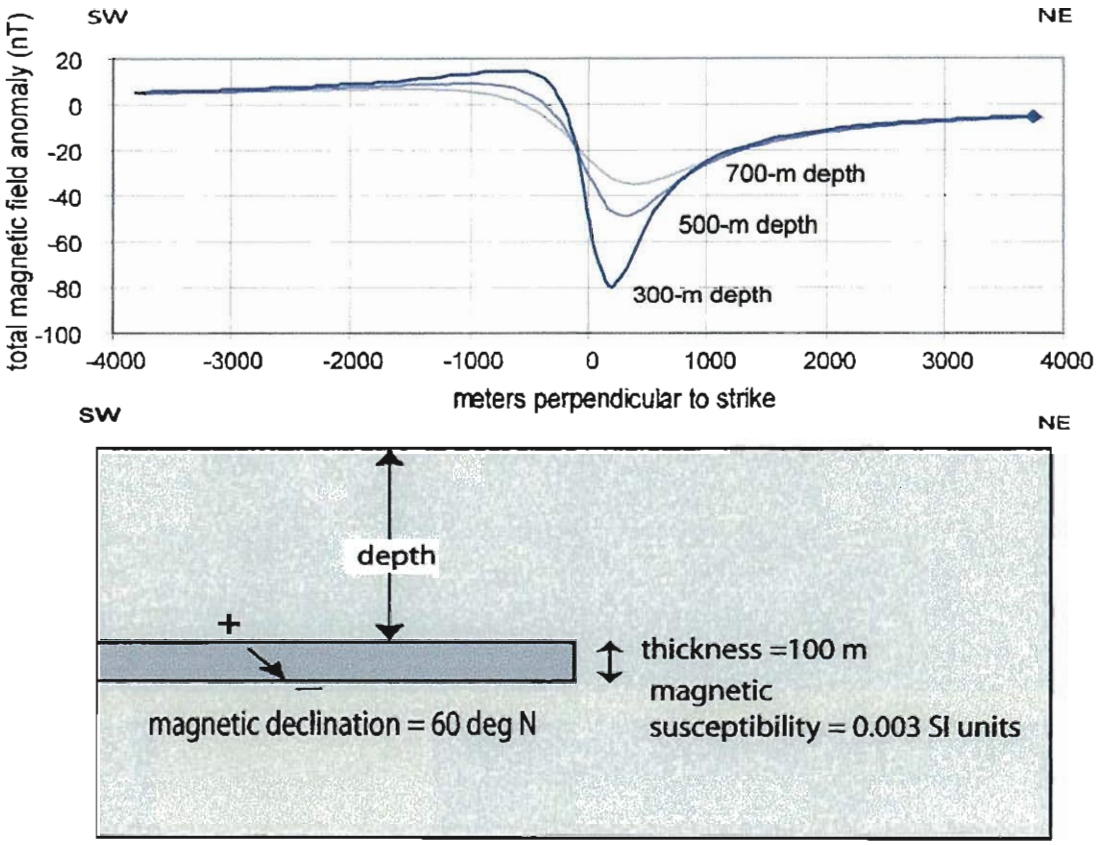

Figure 6. Model calculation of a down-to-NE faulted volcanic slab, fault with a NW-SE strike - simplified to show only the upthrown block.

12

RE-ANALYSIS OF 16 AQUIFER TESTS IN THE GREATER EAGLE-STAR AREA OF NORTH ADA COUNTY, IDAHO

prepared for

m3companies

July 4, 2008

KLING AQUIFER TEST

M3 EAGLE LLC
EXHIBIT
12

M3 EAGLE
EAGLE IDAHO

by

Hydro Logic, Inc.
Boise, Idaho

Reanalysis of 16 Aquifer Tests In the Greater Eagle-Star Area of North Ada County, Idaho

Prepared for:
M3 Eagle, LLC

July 4, 2008

Prepared by:

Hydro Logic, Inc.
Boise, Idaho

Mark Utting
Ed Squires

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Overview

Hydro Logic, Inc (HLI) has conducted a series of analyses and reanalyses of 16 well and aquifer tests carried out over the past 17 years in the greater Eagle-Star and foothills areas of northwest Ada and southwest Gem Counties of Idaho. The work was authorized and funded by M3 Eagle, LLC, to develop a rigorous, rational, and scientifically based understanding of a ground-water supply for its planned community and to support its application for a municipal water right. This report, which is aimed at developing values for the aquifer hydraulic parameters of transmissivity ("T") and storativity ("S") for the aquifers beneath the greater Eagle-Star-M3 area, is one part of a larger regional hydrogeologic characterization by HLI that includes: exploration drilling, geochemical modeling of groundwater flow, geophysical studies, aquifer testing, water level monitoring, and the development of a new numerical model of the ground water flow system (in addition to, and independent of the model developed as part of a University of Idaho Master's Thesis).

A report released by Hydro Logic, Inc in the spring of 2007 (HLI, 2007), demonstrates that a regional water-supply aquifer, named therein the Pierce Gulch Sand Aquifer, underlies the Boise River Valley in the greater Eagle-Star and Meridian area, and the foothills lying to the north of these cities. The HLI study further shows that the Pierce Gulch Sand Aquifer connects to aquifers in the Payette Valley west of Emmett, allowing significant quantities of ground water to move from the Boise River basin to the Payette River basin. This is a new conceptual model for this area that updates the conceptual model that was included as part of the Treasure Valley Hydrologic Project (Petrich and Urban, 2004). The aquifer sands are typically on the order of 275 feet thick, but in some areas have a thickness of over 500 feet, as delineated by geophysical logging of the subsurface and through exposure in outcrops to the east. The aquifer dips to the southwest at about 100 feet per mile and is tapped by supply wells that are more than 550 feet deep toward the west in the vicinity of Star and less than 200 feet toward the east in the vicinity of Lexington Hills. The 2007 HLI report indicated that the quantities of ground water currently flowing through the Pierce Gulch Sand Aquifer under the City of Eagle are on the order of many tens of millions of gallons per day but did not refine this estimate, in part because the properties of the aquifer were then only partially understood.

The purpose of this Aquifer Test Report is to provide information needed to better quantify the amount of groundwater flowing through the aquifer. To do so, we used the state-of-the-art computer program Aqtesolv® to analyze 16 pumping tests, combined with the new conceptual model of the aquifer as indicated by test-well drilling, borehole geophysics, geochemical studies, water level monitoring and analysis, and geological mapping and characterization. The result is a new understanding of the spatial distribution of the transmissivity and storativity of the Pierce Gulch Sand Aquifer throughout the Eagle-Star-M3 vicinity. This new understanding is now being incorporated into a three-dimensional, numerical, ground-water flow-model, currently under development, that will better quantify the amounts of ground water flowing

through the entire aquifer system beneath this area and to predict the effects of the development of ground water for the proposed M3 Eagle project as it is developed over the next 30 years.

This Overview summarizes this study's contributions, significant findings and recommendations. The main body of the report should be consulted for supporting details. Well details and results from the test analyses are included in Table i-1 (page ix). The tested wells and associated observation wells are shown in Figure i-1[1] (page xiii).

Contributions of this Study

Using data from fifteen well and aquifer tests conducted over the past 17 years, along with one aquifer test conducted by HLI under the authorization of M3 Eagle in 2006 (Kling Well), this study makes five new contributions to the understanding of the ground-water resources of the greater North Ada County area, as summarized below:

The first contribution of this report to compile most of the significant pumping test data conducted over the region into one document. This report presents the physical details, the test data, a summary of the previous analyses and HLI's reanalysis, presented by area and by aquifer. An included CD contains the drawdown data in digital format from the 16 tests analyzed in this report.

The second contribution is to apply the new understanding that the Pierce Gulch Sand Aquifer is *the* regional aquifer system beneath the greater Star-Eagle-M3 area to the pumping test analyses. Geologic, hydraulic, geochemical, and geophysical data show that all the major supply and irrigation wells in the Eagle, Star, upland foothills area, and even the City of Meridian tap the same, regional-supply aquifer.

The third contribution is to use multiple methods to analyze each test. In addition, each analysis included sub-analyses to indicate the applicability of the method to the data. We used derivatives[2] to show the time period (if any) where the data match a theoretical type-curve appropriate to the method. Where the data did not match the type curve, the selected methods were deemed unlikely to generate valid or defensible analytical results. In many cases, the derivative analyses indicated that previous analytical methods used were invalid. This report points this out and in reaching its conclusions, relies on what is scientifically supportable.

The fourth contribution is to recognize the full thickness of the Pierce Gulch Sand Aquifer. Many previous analyses assumed that the aquifer was only as thick as the screened section of the pumping well, an assumption that often caused the *under*-estimation of transmissivity of the full thickness of the aquifer.

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[1] The figure and table presented at the end of this *Overview* are identical to those presented in the last chapter of the report, *Section Six: Summary of Regional Aquifer Characteristics*. They are repeated in this *Overview* for the convenience of the reader.

[2] A derivative analysis considers the slope of the line fit through the drawdown data. By comparing the actual derivatives (slopes) and the ideal derivatives that should occur, the validity of the method is appraised.

The fifth contribution is to apply the better understanding of the physical nature of the Pierce Gulch Sand Aquifer to the interpretation of the test results. The aquifer dips toward the southwest, causing it to be unconfined along its eastern borders beneath the foothills and in the Lexington Hills area, and confined beneath the western and southern parts of the study area. Variations in thickness and permeability cause the transmissivity and storativity of the aquifer to vary significantly over the project area. A structural geologic fault and other edge-of-aquifer boundaries along the eastern edge of the Pierce Gulch Sand Aquifer appear to act as no-flow boundaries such that little if any significant quantities of ground water appear to cross this boundary. The newly appreciated understanding that ground water flows to aquifers beneath the Payette River Valley helps to explain previously unexplained attributes of the ground-water flow system beneath the Boise River Valley.

This study builds upon the previous scientific work conducted by others who developed the initial concepts and interpretations of the hydrogeology of the area. As we analyzed the data and developed new understandings, previous interpretations had to be modified and updated. Some concepts have stood the test of reanalysis based on the additional knowledge acquired over time; others have had to be revised or even discarded. This changing and revision of concepts and models is the way of scientific advancement. As the authors of this study, we have striven to provide a meaningful and lasting contribution to the understanding of the ground-water resources of the greater Eagle-Star-M3 area.

Significant Findings for the Pierce Gulch Sand Aquifer

The analyses of the pumping tests conducted in the Pierce Gulch Sand Aquifer indicate a highly-productive and extensive, regional-scale aquifer capable of supplying large ground-water withdrawals from beneath both the lowlands of the Boise River Valley and beneath the western portion of the north Ada County foothills. The specific results of the analyses are presented below:

Transmissivity

Our analyses indicate that the Pierce Gulch Sand Aquifer is highly transmissive, with transmissivities typically ranging from around 40,000 gpd/ft (gallons per day per foot[3]) to over 500,000 gpd/ft. Some localized portions of the Pierce Gulch Sand Aquifer appear to have transmissivities on the order of 800,000 gpd/ft. The overall average (mean) of the valid transmissivities calculated in this study for the Pierce Gulch Sand Aquifer, to two significant figures, is 210,000 gpd/ft. This relatively large value confirms the role of the Pierce Gulch Sand Aquifer in transmitting large volumes of water as *the* major, regional ground water supply aquifer in the study area.

Many of the recalculated transmissivity values are significantly higher than those reported by previous workers. The mean of the values calculated by these workers listed in Table i-1 is 140,000 gpd/ft, or about one-third lower than the recalculated mean. We

[3] In this report, transmissivities are presented in units of gallons per day per foot. Transmissivities in units of ft^2/day are also included in the summary tables at the end of this Overview and at the end of Section Six.

attribute the lower, previously-reported values to the fact that the earlier workers did not recognize the full thickness of the Pierce Gulch Sand Aquifer and in some situations, used analytical methods that derivative analyses indicate are invalid.

Storativity

Calculated storativities in the Pierce Gulch Sand Aquifer ranged from 0.02 to $2x10^{-4}$ (unitless). The results of a 30-day test that included observation wells, conducted during spring of 1991 on the eastern side of Eagle in the Lexington Hills area, indicated that the aquifer is unconfined. When pumped sufficiently long, (as it was during the test) the aquifer demonstrates "delayed yield effects" (drainage of some of the pore spaces within the aquifer). During this 1991 test, the water level dropped below the top of the aquifer at some locations resulting in specific yields ("unconfined aquifer storativity") on the order of 0.02 ($2x10^{-2}$). A shorter-term test (a day or less) conducted in this area would not have indicated delayed-yield behavior of the aquifer. Rather, analysis of a shorter-term test would have indicated storativities on the order of 10^{-3} to 10^{-4}, suggestive of a confined aquifer. The Lexington Hills test demonstrated that conducing a pumping test for more than a day or two may lead to a more-complete understanding of aquifer behavior.

Storativity values from other Pierce Gulch Sand Aquifer tests, (in western, central and northern parts of the study area) indicate that the aquifer is confined. Pumping did not draw the water levels down below the top of the aquifer. In these tests the storativity ranged from about 10^{-3} to 10^{-4} with a representative value on the order of about $5x10^{-4}$.

A Conceptual Model of a Single Aquifer vs Multiple Aquifers

In the HLI analyses we considered whether the Pierce Gulch Sand Aquifer behaves as one aquifer or as a system of discrete aquifers separated by continuous, leaky aquitards. Although it is certain that the Pierce Gulch Sand Aquifer *is* overlain by shallower, distinct aquifers at some locations in the study area, we believe the contiguous "sand sheet" we have identified as the Pierce Gulch Sand Aquifer behaves as, and is best conceptualized as, one continuous heterogeneous aquifer. Certainly, and as with all natural depositional processes, the Pierce Gulch Sand Aquifer exhibits lateral and vertical variations in hydraulic conductivity and thickness. However, the observations and lines of evidence supporting a single aquifer concept are compelling. These include:

a) Tests where deeper observation wells responded before shallower wells even though the shallower part of the aquifer was pumped (Kling test).
b) Wells completed at similar depths as the pumped well and on strike with each other responded differently in both timing and magnitude (Eaglefield test).
c) Pumping of deeper zones indicated a direct connection to the water table through delayed yield (unconfined) response (Lexington Hills test).
d) Borehole geophysical analyses indicated that the lower-permeability regions within the aquifer are not continuous layers of clay defining separate sub-aquifers.
e) None of the pumping tests generated data that fit well with the conceptual model or methods for analyzing multiple, layered, sub-aquifers separated by leaky aquitards.

Significant Findings for Other Aquifers

The Willow Creek Aquifer, the Sandy Hill Aquifer, and the unnamed mixed-sediment/bedrock aquifer beneath Spring Valley, have severe limitations for use as ground-water supply-aquifers. Results of the analyses and our interpretations are summarized below:

Transmissivity

Transmissivity values for the Sandy Hill Aquifer were on the order of 300,000 gpd/ft. Values from short-term tests in the Willow Creek Aquifer were even higher, possibly 1,000,000 gpd/ft or more. Transmissivities for the Spring Valley mixed sediment/bedrock aquifer were less than 2,500 gpd/ft. None of the wells used for these tests were properly completed or developed to allow for more meaningful calculations of transmissivity. All of these results are only approximations.

Storativity

None of the tests conducted in these other aquifers allow for accurate quantification of storativity. Based on the geologic information available for their wells, we believe that these aquifers are unconfined and therefore likely to have storativities on the order of 0.01 to 0.3 or more.

Viability for Sustained, Large-Volume Supply

The analyses of the tests conducted in the Willow Creek and Sandy Hill Aquifers along with geologic interpretation of the physical extents of the aquifers, indicate that these ground-water systems are highly bounded, receive only small amounts of natural recharge, and are hydraulically isolated from the Pierce Gulch Sand Aquifer. These two aquifers have limitations on their viability for large, sustainable supplies. Development of large quantities of ground water from the Willow Creek Aquifer is feasible but would likely require high pumping rates (and associated high energy costs) to reverse the direction of the natural ground-water flow-gradients to cause ground water to flow *from* the Payette River Valley aquifers to the Willow Creek Aquifer. Development of sustainable, large quantities of water from the Sandy Hill Aquifer is likely to require artificial recharge because natural recharge is insufficient to sustain long-term pumping. The combined mixed sediment/bedrock aquifer beneath Spring Valley is not capable of supplying significant quantities of water to a well or well field. Only small-scale domestic supplies are possible.

Recommendations

After review and analysis of the available pumping tests of the Pierce Gulch Sand Aquifer, HLI makes the following main recommendations. In summary these are:

Aquifer Tests

We recommend two comprehensive, long-term tests of the Pierce Gulch Sand Aquifer: one in the valley and one in the foothills. We do not believe that these tests are necessary at this time (July 2008) to demonstrate that additional water is available from the Pierce Gulch Sand Aquifer. The large withdrawals that have been occurring over the past years

along with the relative stability of water levels in the Eagle-Star-M3 area already have demonstrated that an overdraft situation has not occurred. Rather, these tests would help to better define aquifer properties, help to quantify the hydraulic interconnectedness across the aquifer, and asses the potential for mutual interference[4] between the numerous supply wells in the area to better manage the ground-water resource in the future. We believe that *all* water right applications should be obliged to provide the data needed to understand and manage the resource. Properly designed and conducted pumping tests are part of the process that provides these data. We believe that all applicants for withdrawal of significant quantities of ground water be required to provide the rigorous and defensible aquifer-test data that would be generated following the recommendations below. *All* ground-water users in the region, present and future, would benefit were these recommendations to be followed and become standard procedure.

The pumping (discharge) rates for the tests should be high, preferably from 2 to 6 cubic feet per second (approximately 900 to 2,700 gpm). Barometric efficiencies for all the wells monitored during each test should be calculated and barometric data should be collected before, during and after (recovery phase) each test in order to correct the data for the effects of changes in atmospheric pressure. Water levels in wells should be measured before each test to allow the analysis to compensate for antecedent water level trends. After the data are collected, the appropriate methods for the analyses should be employed based on the configuration of the test and the quality of the generated data. Data should be pre-processed to account for barometric effects and antecedent water level trends. Water levels and barometric pressure should be measured using electronic data loggers recording data on a short-time interval, complemented by frequent hand measurements using calibrated well sounders. Only with regular and frequent measurement of water levels can the effects of drawdown caused by the pumping well be separated from barometric effects, antecedent trends and interference from other pumping wells.

Valley Aquifer Test

A test of the Pierce Gulch Sand Aquifer should be conducted in the lowland area near Eagle. The tested well should be pumped at a significantly high rate for about a week. This test should be conducted with the cooperation of *all* the major ground-water pumpers in the area and should be coordinated with the Idaho Department of Water Resources. It should be conducted when the canals and ditches are not flowing and when irrigation pumping is at a minimum (preferably zero). These conditions would best be met during late winter or early spring. Ideally, no well capable of more than a few hundred gpm should pump during the test. Wells to be monitored during the test should be selected based on their positions relative to the pumping well and on the availability of high-quality data on geology and well construction. Because all municipal wells cannot

[4] Interference is a hydrogeologic term. It is defined as the amount of drawdown (change in water level) in a well caused by pumping from another well. *All* ground water withdrawals from a well result in some interference. Theoretically, a well cannot produce water without causing some interference. Small amounts of interference generally go unnoticed.

be shut off during the test, arrangements will need to be made to minimize variations in pumping rates and to carefully monitor any essential pumping.

Foothills Test

A second aquifer test is recommended for the Pierce Gulch Sand Aquifer beneath the upland, foothills area on M3 Eagle's property. The test should be conducted generally as described above for the Valley Aquifer test. Such a test has recently been conducted as part of the M3 aquifer characterization program, in spite of the fact that no properly designed and constructed, high-capacity supply well producing from the Pierce Gulch Sand Aquifer currently exists within the upland, foothills area.

HLI recently conducted a long-term aquifer test using an existing, but newly developed eight-inch test well (SVR #7 – see Figure i-1), during April 2008. Preliminary analysis indicates that the test was sufficient to characterize this part of the Pierce Gulch Sand Aquifer. In spite of its small diameter, the well was pumped for 9 days at a sustained 916 gpm (2.05 cfs), with a total of 23 observation wells (located from 845 feet to over 4 miles from SVR #7) monitored in addition to the pumped well. Pre- and post-pumping water levels were measured along with atmospheric pressure. This test was conducted before irrigation pumping had begun and before filling of the nearby irrigation canals. There was no known significant ground water pumping from wells in this area during the test. The timing and the execution of the test meet all of the recommendations for a regional aquifer test made above, with the exception of rate. However, preliminary analysis indicates that a drawdown of about one foot was recorded at an observation well almost one mile from the pumping well and lesser drawdowns (a few tenths of a foot) were recorded in more distant observations wells, indicating that the rate of 916 gpm was sufficient to stress the aquifer over a distance of at least two miles. After we finalize the data analysis (in progress), a report will be issued.

Monitoring wells

A network of dedicated, long-term, properly-designed-and-constructed monitoring wells should be established in the Eagle-Star-M3 area. The wells should be strategically placed to measure water levels at selected points within the Pierce Gulch Sand Aquifer and overlying water bearing zones. All wells should be equipped with electronic data logging equipment backed up by hand measurements to track water level changes over time and as ground-water pumping increases within the community. Continuous monitoring would also be expected to provide insight into interference effects between wells and the magnitude of the annual water-level fluctuations within the aquifer. The monitoring well network should be funded by local development, legislative appropriations, and municipal water providers, and operated by a single entity (preferably the IDWR) with data made available to the public domain.

M3 Eagle, United Water Idaho and others have installed monitoring wells that could be incorporated into the monitoring well network. Exploratory test wells drilled by United Water Idaho (State and Linder and TVHP#1) and SunCor (SVR#6, SVR#7 and SVR#9) have been converted into monitoring wells. M3-Eagle has drilled four multi-level

piezometer nests specifically as long-term designated monitoring wells (M3-TW#1 through #4). M3-Eagle is currently monitoring water levels in 24 wells in the upland (foothills) area, although the number of wells to be measured over the long term will likely be less.

Table i-1 - Summary of Aquifer and Well Test Parameters

Well Test / Well	Fig. No.	Well Elev.	Water Level DTW -=agl	Water Level Elev.	Q	Max. DD	Screen top/bottom Depth	Screen top/bottom Elev	Entire Aquifer** top/bottom Depth	Entire Aquifer** top/bottom Elev	Thickness "b"	Dist. "r" to Well	Analysis	Analytical Results**** T (raw data)	T (corrected data)	S	Hydraulic Conductivity		Mat'l type based on Hydraulic Conductivity*	Comments
Map of Well Locations	1	ft amsl	ft	ft amsl	gpm	ft	ft	ft	ft	ft	ft	ft		gpd/ft	gpd/ft	ft^2/day		ft/day	cm/sec		
Valley Wells																				
Eagle 7-Day Test - Pierce Gulch Sand Aquifer																				
Eaglefield Well #2 (pumping)	3	2514	-8.61	2523	1580	20.91	345	2169	181	2333	498	-	Cooper-Jacob	200,000	800,000	110,000	-	2.2E+02	7.8E-02	coarse sand	Match only valid: 20 to 80 minutes. Correction Includes PP (Butler) adjustment.
	4						425	2089	679	1835			Semi-Log Theis***	850,000	1,000,000	130,000	-	2.6E+02	9.2E-02	coarse sand	Match 20-80 min. Hantush PP correction. Correction for well-loss increases T by 18%
	5												Theis Butler PP corr.	200,000	760,000	100,000	-	2.0E+02	7.1E-02	coarse sand	Butler PP corrections yield similar results to Hantush supporting their validity
	6												Theis Recovery	200,000	800,000	107,000	-	2.1E+02	7.6E-02	coarse sand	No well loss to effect plot. Correction Includes PP (Butler) adjustment
Legacy #1	7	2513	-16.25	2529		2.73	282	2231	175	2338	500	1605	Theis/Hantush	no match	100,000	13,000	1.0E-02	2.6E+01	9.2E-03	clean sand	Trend correction needed for match before 500 min. No match after 500 min.
(observation)	8						352	2161	675	1838			Hantush-Jacob	no match	100,000	13,000	1.0E-02	2.6E+01	9.2E-03	clean sand	Leakage factor r/B = 4.6x10-4
UWID State and Linder #1A	9	2519	-12.83	2532		5.67	280	2239	210	2310	525	2405	Theis (early-time)	500,000	500,000	67,000	2.3E-03	1.3E+02	4.5E-02	clean sand	Theis gives average of near (pumping) and far (obs well) values.
(observation)	11						370	2149	735	1785			Butler (at obs well)	84,000	84,000	11,000	3.7E-03	2.1E+01	7.4E-03	clean sand	Butler method only gives approx. results as model does not strictly apply
UWID State and Linder #1B	10	2519	-12.53	2532		5.49	400	2119	210	2310	525	2405	Theis (early-time)	400,000	400,000	50,000	1.3E-03	9.5E+01	3.4E-02	clean sand	Theis gives average of near (pumping) and far (obs well) values.
(observation)	12						490	2029	735	1785			Butler (at obs well)	84,000	84,000	11,000	1.3E-03	2.1E+01	7.4E-03	clean sand	Butler method only gives approx. results as model does not strictly apply
Ricks Irrigation Well	13	2526	7.23	2519		1.09	234	2292	260	2266	416	3340	Theis/Hantush	no match	no match	-	-	-	-	-	Derivative analysis indicates no data match to type curve.
(observation)							395	2131	676	1850											
													Holladay means	187,000	187,000	25,000	5.0E-03				Mean based on 8 separate analyses
													SPF means	110,000	110,000	15,000	5.0E-03				Mean based on 24 separate analyses. SPF did not specify a mean.
Test summary ranges: PGSA near Eaglefield: Mean T = 460,000gpd/ft with a range of 200,000 to 800,000 gpd/ft, from UWID State and Linder: T = 80,000 to 400,000 gpd/ft, from Legacy T = 100,000? gpd/ft, S = 2x10 $^{-3}$																				***Analytical models only approximate assumptions required; therefore results only approximate. Pumping projections for individual wells will need PP corrections.***
Lexington Hills 30-Day Test - Pierce Gulch Sand Aquifer																				
Lexington Hills Well #1 (pumping)	17	2645	71.00	2574	732	81.00	215	2430	75	2570	326	-	Cooper-Jacob	15,000	50,000	6,700	-	2.1E+01	7.3E-03	clean sand	Early-time data. Includes PP (Butler) corrections. Delayed yield indicated
	18						385	2260	401	2244			Moench	80,000	80,000	10,700	-	3.3E+01	1.2E-02	clean sand	Good match to delayed-yield curve.
													CH2M average	170,000	170,000	22,700	-	7.0E+01	2.5E-02	clean sand	CH2 average T too high. Delayed yield portion analyzed. Early time better
Holgate Well (observation)	19	2645	65.58	2579		3.85	?	?	89	2556	306	900	Theis (early time)	120,000	120,000	16,000	5.0E-04	5.2E+01	1.8E-02	clean sand	Only data for t<80 min match. Delayed yield indicated
	20						171	2474	395	2250			Moench	96,000	96,000	13,000	1.2E-02	4.2E+01	1.5E-02	clean sand	Good match to delayed-yield curve.
													CH2M averages	100,000	100,000	13,000	1.3E-02	4.2E+01	1.5E-02	clean sand	Good agreement with Moench.
Carson Well (observation)	21	2630	62.48	2568		2.47	?	?	75	2555	305	1300	Theis (early time)	Analysis Likely Invalic	-	-	-	-	-	-	Well may be too shallow to properly indicate aquifer parameters
	22						90	2540	380	2250			Moench	77,000	77,000	10,000	3.5E-02	3.3E+01	1.2E-02	clean sand	Good match to delayed-yield curve.
													CH2M averages	110,000	110,000	15,000	2.6E-02	4.9E+01	1.7E-02	clean sand	Average includes early time data does not considering delayed yield
Eagle Hills Golf Course Well	23	2610	55.59	2554		1.05	?	?	78	2532	302	2500	Theis (early time)	420,000	420,000	56,000	5.0E-03	1.9E+02	6.6E-02	coarse sand	Largest value in area. Poor derivative match. Results may be invalid
(observation)	24						175	2435	385	2230			Moench	400,000	400,000	53,000	8.0E-03	1.8E+02	6.2E-02	coarse sand	Good match to delayed-yield curve.
													CH2M averages	280,000	280,000	37,000	1.2E-02	1.2E+02	4.3E-02	clean sand	Analyses do not take into account delayed yield
Floating Feather Irrigation Well	25	2670	86.80	2583		2.00	?	?	75	2595	315	5100	Semi-Log Theis	Analysis Likely Invalic	-	-	-	-	-	-	Poor data resolution. No derivative match. No analysis possible
(observation)							270	2400	390	2280			CH2M averages		-	-	-	-	-	-	Not presented in report.
Test summary: PGSA average near Lexington Hills #1 T = 160,000 gpd/ft, S = 3x10 $^{-3}$ (short-term pumping) and Sy = 0.02 (long-term pumping).																				***Analytical results indicate delayed-yield (unconfined) aquifer with high-rate, long-term pumping.***
Rivervine 6-Hour Test - Shallow Aquifer Overlying the Pierce Gulch Sand Aquifer																				
Rivervine (pumping)	28	2500	-1.75	2502	350	22.73	72	2428	4	2496	116	-	Cooper-Jacob	43,000	43,000	5,700	-	4.9E+01	1.7E-02	clean sand	Log suggests unconfined aquifer. Only upper portion of aquifer tested
	29						118	2382	120	2380			Theis/Hantush	48,000	48,000	6,400	-	5.5E+01	2.0E-02	clean sand	Recharge boundary indicated: river? canal? pond? delayed yield?
6-In Observation	30	2500	-2.25	2502		4.85	65	2435	4	2496	116	283	Cooper-Jacob	37,000	37,000	4,900	2.2E-04	4.2E+01	1.5E-02	clean sand	Obs well data better than pumping well data. No PP correction needed.
	31						75	2425	120	2380			Theis	36,000	36,000	4,800	2.5E-04	4.1E+01	1.5E-02	clean sand	Sensitivity analysis indicates PP correction not needed.
Redwood Creek 8-hour Test - Pierce Gulch Sand Aquifer																				
Redwood Creek Well (pumping)	33	2545	-4.70	2550	2100	96.00	298	2247	295	2250	350	-	Cooper-Jacob	50,000	140,000	18,700	-	5.3E+01	1.9E-02	clean sand	Includes PP (Butler) corrections
	34						401	2144	411	1900			Theis/Hantush	140,000	150,000	20,100	-	5.7E+01	2.0E-02	coarse sand	Includes PP (Hantush) correction. Well loss correction increased T by 7%.
													Scanlan	55,000	55,000	7,400	-	2.1E+01	7.5E-03	clean sand	No PP correction leads to under-estimate for T
Ricks Well (Observation)	35	2545	-12.00	2557		4.40	?	?	260	2285	385	2500	Theis/Hantush	140,000	140,000	19,000	1.8E-04	4.9E+01	1.7E-02	coarse sand	Obs well analyses agrees with Theis/corrected C-J analysis for pumped well.
(not same well as "Ricks Irrigation")							284	2261	404	1900			Scanlan	154,000	154,000	21,000	2.0E-04	5.5E+01	1.9E-02	coarse sand	Reasonable agreement.
Test summary: PGSA average near Floating Feather T = 170,000 gpd/ft, S = 4x10 $^{-4}$.																				

Table i-1
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Boise, Idaho

Table i-1 - Summary of Aquifer and Well Test Parameters (continued)

Well Test / Well	Fig. No.	Well Elev.	Water Level DTW -neg	Water Level Elev.	Q	Max. DD	Screen top/bottom Depth	Screen top/bottom Elev	Entire Aquifer** top/bottom Depth	Entire Aquifer** top/bottom Elev	Thickness "b"	Dist. "r" Well	Analysis	Analytical Results**** T			Hydraulic Conductivity		Mat'l type based on permeability*	Comments
		ft amsl	ft	ft amsl	gpm	ft	ft	ft	ft	ft	ft	ft		gpd/ft	ft²/day	S	ft/day	cm/sec		
Floating Feather 51-hour Test - Pierce Gulch Sand Aquifer																				
Floating Feather (pumping)	47	2599	44.20	2555	1500	30.16	183	2416	113	2486	386	-	Semi-Log Theis	140,000	160,000	21,000	-	5.4E+01	1.9E-02	clean sand	Mean T = 160,000 gpd/ft from est. likley max. well loss of 0 to 10 ft
	48						330	2269	499	2100			Theis Recovery	160,000	320,000	43,000	-	1.1E+02	3.9E-02	clean sand	"Corrected" likley to be incorrect because well in middle of aquifer
													Seanlan averages	150,000	150,000	20,000		5.2E+01	1.8E-02	clean sand	Agreement with new analyses
Crandlemire Irrigation (observation)	49	2599	45.30	2554		11.60	176	2423	111	2488	388	65	Semi-Log Theis	170,000	170,000	23,000	3.7E-04	5.9E+01	2.1E-02	clean sand	Obs well data likely better than pumping well data. No PP correction needed.
	50						316	2283	499	2100			Theis Recovery	170,000	170,000	23,000	-	5.9E+01	2.1E-02	clean sand	Likely good T value. No PP correction needed
													Seanlan averages	150,000	150,000	20,000	1.0E-04	5.2E+01	1.8E-02	clean sand	Reasonable agreement.
Valley Single Well Tests - Pierce Gulch Sand Aquifer																				
Star #1 8-Hour Test	38	2512	-40.60	2553	800	29.39	452	2060	350	2126	310	-	Cooper-Jacob	50,000	120,000	16,000	-	5.2E+01	1.8E-02	clean sand	Includes PP (Butler) correction.
	39						550	1962	660	1816			Theis/Hantush	100,000	120,000	16,000	-	5.2E+01	1.8E-02	clean sand	Includes correction for estimated max. likely well loss.
Star #3 24-Hour Test	41	2476	-31.19	2507	3008	176.02	544	1932	390	2086	310	-	Cooper-Jacob	100,000	180,000	24,100	-	7.8E+01	2.7E-02	clean sand	PP (Butler) correction indicates 90% larger T.
	42						643	1833	700	1776			Theis/Hantush	100,000	140,000	18,700	-	6.0E+01	2.1E-02	clean sand	Includes correction for estimated max. likely well loss
LDS Eagle 4-Hour Test	44	2610	28.6	2581	95	17.52	397	2213	90	2520	380	-	Cooper-Jacob	60,000	90,000	12,000	-	3.2E+01	1.1E-02	clean sand	Development obscures true response. Includes PP (Butler) correction.
	45						465	2145	470	2140			Theis/Hantush	70,000	70,000	9,400	-	2.5E+01	8.7E-03	clean sand	Poor match. Sensitivity analysis indicates PP affects result by 80%
													BSU averages	37,000	37,000	4,900	-	1.3E+01	4.6E-03	clean sand	No PP corrections or recognition of well development effects
Upland Wells - Pierce Gulch Sand, Willow Creek, Sandy Hill and Eastern-Upland Aquifers																				
Pierce Gulch Aquifer Wells																				
SVR #7 22-Hour Test- Pierce Gulch Sand Aquifer																				
SVR #7 (pumping)	66	2710	160.54	2549	500	31.04	280	2430	180	2530	260	-	Theis Step	150,000	150,000	20,000	-	7.7E+01	2.7E-02	clean sand	Decline in PWL during test. Well developing. Analysis invalid
	67						350	2360	440	2270			Theis Recovery	150,000	150,000	20,000	-	7.7E+01	2.7E-02	coarse sand	Recovery better match than pumping. Max DD at 60 min, then decline
													SPF averages	370,000	370,000	49,000		1.9E+02	6.7E-02	coarse sand	
Big Gulch Stock Well	68	2698	150.00	2548		0.54	?	?	170	2528	230	845	Theis/Hantush	180,000	180,000	24,000	1.0E-02	1.0E+02	3.7E-02	coarse sand	No log for obs well. Better match than pumping data
	69						180	2518	400	2298			Theis Recovery	180,000	290,000	39,000	-	1.7E+02	6.0E-02	coarse sand	General agreement with pumping well recovery.
													SPF averages	270,000	270,000	36,000	-	1.6E+02	5.5E-02	coarse sand	
SVR Well #9 3.3-Hour Test																				
	72	2753	197.33	2556	43	14.00	235	2518	197	2556	73	-	Cooper-Jacob	120,000	120,000	16,000	-	2.2E+02	7.7E-02	coarse sand	Log suggests unconfined aquifer
	73						263	2490	270	2483			Theis/Hantush	120,000	120,000	16,000	-	2.2E+02	7.7E-02	coarse sand	Test too short. Development makes results questionable
													SPF averages	13,0007	13,0007	-	-	-	-	-	No analysis presented in SPF, only range of results.
Kling Irrigation Well 50-Hour Test- Pierce Gulch Sand Aquifer																				
Kling Irrigation (pumping)	83	2614	95.42	2519	900	94.39	198	2416	341	2273	240	-	Theis/Hantush	29,000	37,000	4,900	-	2.0E+01	7.2E-03	clean sand	Includes correction for est. well loss and PP (Hantush).
	84						408	2206	581	2033			Cooper-Jacob	20,000	36,000	4,800	-	2.0E+01	7.1E-03	clean sand	Includes PP (Butler) corrections. Partially plugged screen.
	85												Theis Recovery	27,000	45,000	6,000	-	2.5E+01	8.8E-03	silty sand	Includes PP (Butler) corrections.
M3-TW #1 (composite: Zones 1-4)	86	2606	90.23	2516		8.95	353	2253	350	2253	240	1050	Theis (mean of 4 zones)	140,000	140,000	18,700	1.1E-03	7.8E+01	2.8E-02	clean sand	Composite (mean of 4 zones) averages anomalies in separate obs wells
	87						556	2050	590	2013			Theis 4-well plot	110,000	110,000	15,000	1.0E-03	6.3E+01	2.2E-02	clean sand	Best fit of 4 plots for 4 zones. General agreement with mean plot
M3-TW #1 Individual Zones 1-4	88,90,92,94												Mean of Theis Drawdown	120,000	120,000	16,000	1.4E-03	6.7E+01	2.4E-02	clean sand	In range of composite and single mean plot analyses
	89,91,93,95												Mean of Theis Recovery	35,000	35,000	4,700	-	2.0E+01	6.9E-03	clean sand	Recovery is consistent with pumped well analysis

Test summary: PGSA average near Kling Irrigation well: T = 39,000 gpd/ft, S =0.0009. Higher average T of 110,000 to 140,000 gpd/ft in larger region of aquifer as indicated by obs wells at M3-TW #1.

Table i-1
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Table i-1 - Summary of Aquifer and Well Test Parameters (continued)

Well Test Well	Fig. No.	Well Elev.	Water Level DTW - wgl	Water Level Elev.	Q	Max. DD	Screen top/bottom Depth	Screen top/bottom Elev	Entire Aquifer** top/bottom Depth	Entire Aquifer** top/bottom Elev	Thickness "b"	Dist. "r" Well	Analysis	Analytical Results**** T		S_{ss}	Hydraulic Conductivity		Mat'l type based on permeability*	Comments
		ft amsl	ft	ft amsl	gpm	ft	ft	ft	ft	ft	ft	ft		gpd/ft	ft²/day		ft/day	cm/sec		
Willow Creek Aquifer Wells																				
SVR Well #6 24-Hour Test	60	2816	450.18	2366	358	2.82	560	2256	450	2366	290	-	Semi-Log Theis	1,000,000+	1,000,000+	100,000+	-	>300	>E-01	coarse sand	Development during pumping: Indicated T likely too high.
	61						720	2096	740	2076			Theis Recovery	650,000	1,000,000	134,000	-	4.6E+02	1.6E-01	coarse sand	Better match than pumping analysis. Includes PP (Butler) correction.
													SPF averages	1,300,000	1,300,000	170,000	-	5.9E+02	2.1E-01	coarse sand	SPF best estimate for aquifer is 1,000,000+ gpd/ft
SVR Well #10 24-Hour Test	63	2870	482.08	2388	55	59.90	630	2240	480	2390	190	-	Cooper-Jacob	300,000+	300,000+	7,000	-	4E+01+	1.E-02+	clean sand	Meter problems. Screen flaw. Flat DD. Analysis not accurate.
	64						640	2230	670	2200			Theis Recovery	-	-	-	-	-	-	-	No meaningful analysis possible Poor test
													SPF averages	-	-	-	-	-	-	-	
Eastern Upland Mixed Sediment/Bedrock Wells																				
SVR Well #1 7.5-Hour Test	54	3390	16.80	3373	51	102.00	125	3265	125	3265	275	-	Cooper-Jacob	1,500	1,500	200	-	7.3E-01	2.6E-04	Bedrock/sediment	Low yield aquifer.
	55						400	2990	400	2990			Theis Recovery	2,300	2,300	310	-	1.1E+00	4.0E-04	Bedrock/sediment	
													Scanlan averages	1,700	1,700	230		8.4E-01	3.0E-04	Bedrock/sediment	
SVR Well #2 2.5-Hour Test	57	3630	32.10	3598	50	159.90	300	3330	300	3330	460	-	Cooper-Jacob	720	720	96	-	2.1E-01	7.4E-05	Bedrock/sediment	Low yield aquifer.
	58						760	2870	760	2870			Theis Recovery	270	270	40	-	8.7E-02	3.1E-05	Bedrock/sediment	
													Scanlan averages	350	350	47		1.0E-01	3.6E-05	Bedrock/sediment	
Eastern Upland Sandy Hill Aquifer 71-Hour Test																				
TPW #1 (pumping)	75	3600	177.84	3422	2050	16.81	238	3362	178	3422	114	-	Cooper-Jacob	200,000	300,000	40,000	-	3.5E+02	1.2E-01	coarse sand	Includes PP (Butler) corrections Highly bounded aquifer.
	76						290	3310	292	3308			Moench	300,000	300,000	40,000	-	3.5E+02	1.2E-01	coarse sand	Reasonable match
	77												Theis Recovery	300,000	300,000	40,000	-	3.5E+02	1.2E-01	coarse sand	Incomplete recovery suggests highly bounded aquifer.
SVR #3 (observation)	78	3600	175.38	3425		159.90	175	3425	175	3425	105	150	Moench	-	-	-	-	-	-	-	No fit. Invalid analysis.
	79						240	3360	280	3320			Theis Recovery	1,000,000?	1,000,000?	134,000	-	1.3E+03	4.5E-01	coarse sand	Likely invalid analysis. Straight-line plot poor. Highly bounded system.

*Hydraulic conductivity (permeability) range from Freeze and Cherry (1979) - silty sand: k $5x10^{-4}$ to $5x10^{-3}$, clean sand. $5x10^{-3}$ to $5x10^{-2}$, coarse sand $5x10^{-2}$ to $5x10^{-1}$, gravel $5x10^{-1}$ to $5x10^{0}$+

Ver: 7/8/2008

** Top of aquifer estimated from Well Driller's Reports may be inaccurate. Aquifer bottom depths estimated from geophysical contours are considered more accurate.

*** All Theis (1935) analyses of drawdown data include Hantush (1961a and b) corrections for Partial Penetration, even if not stated in this table. See text for further explanation.

**** If T for raw data = T for corrected data, then no correction applied.

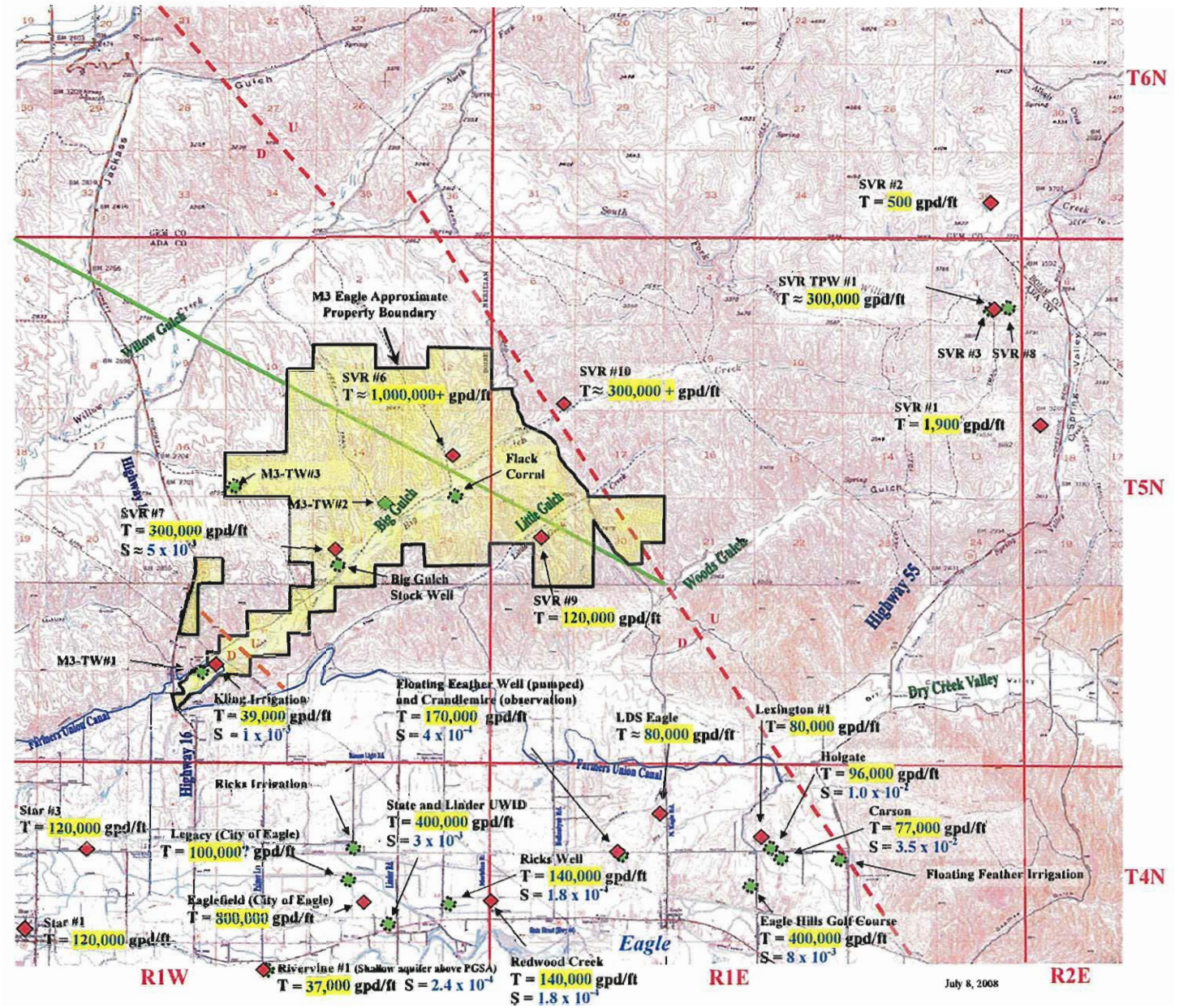

Figure i-1. Calculated Values of Transmissivity and Storativity based on Analyses for Selected Wells in the Greater M3 Eagle Project Area

Location map for aquifer transmissivity values calculated from pump tests in the vicinity of the proposed M3 Eagle Development. The tests were conducted by various workers but all tests were reanalyzed by HLI with results presented here. See text of report for details.

Wells were surveyed using a GPS system. Base map is (1:62,500 scale) USGS 15 minute map

Figure i-1.

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SECTION ONE: OVERVIEW AND INTRODUCTION

Introduction

This report presents the results of an analysis and re-analysis by Hydro Logic, Inc. (HLI) of 16 supply-well and test-well pumping-tests conducted over the past 17 years, in an area that includes the proposed M3 Eagle development, the cities of Eagle and Star, and surrounding region (Figure 1 on page 10). The primary purpose of this report is to develop the best understanding to date of the properties of the regional Pierce Gulch Sand Aquifer that currently supplies water to the municipalities of Eagle and Star and more than 3,000 domestic water wells in the area. Development of ground water from the Pierce Gulch Sand Aquifer, is also proposed for the M3 Eagle development in the foothills north of Eagle. A secondary purpose is to assess the properties of other, small and isolated aquifers found beneath the foothills to the northeast of Eagle (and to the east of the M3 Eagle property). This regional analysis is being developed by Hydro Logic, Inc. (HLI), as part of a program to better understand the source and sustainable supply of ground water in the area and to support a municipal water rights application for the M3 Eagle, LLC and its proposed planned community. This study is intended to provide data and information useful to the Idaho Department of Water Resources' (IDWR) future administration of water resources in the area, as the department is pressed to protect existing water rights and provide for development of ground water supplies to support the anticipated population growth.

This report reviews 16 aquifer tests conducted by various workers in the lowland valley areas near Eagle and Star and in the foothill uplands northeast of Eagle, including an aquifer test conducted by HLI using the existing Kling Irrigation well located on the southwest corner of the M3 Eagle property. Because the previous tests were conducted by different workers using a variety of analytical techniques, the results are of varying quality. The analysis of the Kling Irrigation well test and the reanalyses of previous tests used a unified approach and incorporates recently developed understanding of the aquifer itself.

Acknowledgements

The analysis and preparation of this report benefited from the reviews conducted by Dr. Jim Osiensky of the University of Idaho. His insight into the various methods used in our analyses and the discussions that followed, improved this report. Dr. Spence Wood, professor emeritus at Boise State University, improved our understanding of the Pierce Gulch Sand on many enjoyable field trips. Input from Sean Vincent of the IDWR was also appreciated. His experience in the analysis of pumping test data especially relating to his practical experience in dewatering analyses aided these analyses.

Several organizations supplied data and information that proved to be of great assistance in analyzing the various pumping tests conducted over the past 17 years. We would specifically like to acknowledge Chris Duncan of Holladay Engineering, Inc., Roger Dittus of United Water Idaho, Terry Scanlan and Christian Petrich of SPF Water

Engineering, Inc., and Chuck Feast of Feast Geosciences. Their input laid the foundations for this work. We would also like to thank Glenn Duffield, the developer of Aqtesolv®, and Dr. Jim Butler of the Kansas Geological Survey, for the time they took to personally address issues of partial penetration and the analysis of pumping well data, through email and telephone conversations.

Scope of Work

The scope of work for this project which was developed by Hydro Logic, Inc., and authorized by M3 Eagle, LLC, included the following:

Select wells of special interest. Wells that could provide data to help delineate the characteristics of the regional water supply system were selected based on position within the project area, the availability of geologic, hydrogeologic and hydraulic information (especially pumping test data), and quality of well construction. Our intent was to select wells from each part of the project area that would provide hydrogeologic information on regional water supply. Available well data in Appendix A included: Well Driller's Reports, information on geologist's logs of materials penetrated by each well, well construction details, ground-water chemistry and other pertinent information presented in the original pumping test reports or consultant's analyses. HLI has generated composite diagrams for many of the wells completed in the Pierce Gulch Sand Aquifer and reanalyzed in this report. The composite diagrams are included in Appendix A.

Obtain, enter, process and present pumping test data in a uniform manner and in one document. Some of the wells had pumping-test data presented as changes in water level from some reference point while others had data presented as changes in level from pretest or "static" conditions. Some data were available in electronic format while others required entry from printed data tables. All data in our analyses were converted to drawdown from pretest conditions after careful selection of a representative pretest water level. Our digital pumping test data files are included on a compact disk (CD) in a pocket at the back of the report.

Review available hydrogeologic reports, well construction records and lithologic logs to assess aquifer and well characteristics. Well driller's reports, geologist's logs and geophysical logs were reviewed, and aquifer depths, type (unconfined, semi-confined or confined) and materials were interpreted and tabulated along with the details of well construction. Of particular interest was the relationship between pumping well and observation wells in multi-well pumping tests.

Conduct a constant-rate pumping test using the Kling Irrigation well. The pumping well (Kling) and 6 other wells were used to collect pumping and drawdown data. Some of the monitoring wells allowed for the collection of data from one, two, four or five zones within the regional Pierce Gulch Sand Aquifer.[5] Water-level and atmospheric-pressure

[5] The name Pierce Gulch Sand Aquifer has been adopted during the course of the project to identify the regional aquifer that underlies Meridian, Eagle, Star and the M3 Eagle project. See Hydrogeologic Overview below or Hydro Logic, Inc. (2007) for more details.

(barometric) data were collected before, during and after 3,000 minutes of pumping to allow for analysis of non-pumping-related water level changes and isolate drawdowns caused by the pumping well. The testing of the Kling Irrigation well (located on the southwest end of the M3 property) allowed for a controlled analysis of an area where only limited data on the regional aquifer existed previously. This well is currently the only large-diameter, relatively high-capacity well located on the 6,005-acre M3 property.

Analyze pumping test data using uniform, thorough, and up-to-date techniques and methods. The latest (2008) version of Aqtesolv® *(4.50.002) Professional* (HydroSOLVE, Inc., 2008) pump test analysis software was used to analyze the pumping test data. The preferred analytical method was selected for each set of well data based on aquifer geometry, well construction, duration of the test, relationship between the pumping and observation well(s) and other pertinent factors. In many previous cases, only simplified methods were used to analyze the data with no review of the results to assess whether such methods were appropriate or not. In some cases, the data were presented without analysis or supported interpretations. In the HLI analyses, we selected (as appropriate) one or more of the following methods to account for: confined and unconfined aquifer conditions, variable pumping rates, well-bore storage, and partial well-penetration of the entire aquifer thickness, and aquifer-aquitard leakage.

- "Cooper-Jacob straight-line" (Cooper and Jacob, 1946),
- "Theis log-log" (Theis 1935),
- "Theis semi-log" (Theis 1935),
- "Partial-penetration" for log-log analyses (Hantush, 1961a and b),
- "Partial-penetration" for semi-log analyses (Butler, 1957)
- "Theis straight-line recovery" (Theis, 1935) ,
- "Well-bore storage correction" (Papadopoulos and Cooper, 1967),
- "Leakage through a confining layer" (Neuman and Witherspoon, 1969),
- "Delayed yield" Neuman (1974) and Moench (1997)
- "Non-uniform aquifer log-log method" (Butler, 1988)

In addition, we conducted "derivative analyses" to verify the validity of the method selected for the data used for the analysis. We also conducted a "critical time analyses" when certain types of methods ("straight-line") were used. Each method is discussed in Section Two of this report (page 11). A detailed presentation of each method as outlined in Aqtesolv®, including diagrams, equations and the assumptions used in the analyses are included in Appendix B.

Predict impacts to aquifer pressures ("heads") and water levels in well caused by proposed ground water withdrawals using results of pumping test analyses. The aquifer parameters[6] of transmissivity and long-term storativity calculated in our analyses, along with pumping rates listed in various sources, were used to predict the drawdown in

[6] Some workers (Freeze and Cherry, 1979; Batu, 1998; and others) refer to transmissivity and storativity as aquifer "parameters" or "characteristics." However, because transmissivity and storativity were formerly termed the "coefficient of transmissibility" and "storage coefficient," some workers (Osiensky, 2007 and others) prefer the term "aquifer coefficients." We have used both terms interchangeably in this report.

aquifer water levels produced by several selected regional supply wells in the project area. In cases where the pumped well was a small-diameter test well, a low-yield supply well, or not in a representative portion of the Pierce Gulch Sand Aquifer (or not in the Pierce Gulch Sand Aquifer at all), such predictive "distance-drawdown" analyses were not performed.

Present the results in an easily understood and uniform format. Regional maps and tables of results were prepared to show and compare coefficients of aquifer transmissivity and storativity at various places. Well drawdown effects are presented as figures of distance versus drawdown. This information will also be used in regional assessments of groundwater flow, in subsequent reports and numerical modeling efforts.

Review, critique and independently reinterpret the previous well tests conducted by others. An overview of the previous tests including discussion of methods, assumptions, conclusions and predictions was prepared. Conclusions about the previous tests along with selected recommendations for future work to better understand the groundwater flow system are included in this review and critique.

Project Area

The project area includes the property owned by M3 Eagle, north of Eagle, Idaho and the surrounding area. The study-area boundaries are approximately as follows:

- western - the Ada/Canyon county line,
- southern - the Boise River,
- eastern - State Highway 55 and
- northern - vicinity of the Ada/Gem county line.

Specifically, wells in all or part of the following townships were reviewed: T4N/R1W, T4N/R1E, T5N/R1W, T5N/R1E, T5N/R2E, and T6N/R1E. The project area and selected wells are shown in Figure 1.

Hydrogeologic Overview

A brief overview of the hydrogeologic framework of the greater M3-Eagle-Star area is presented to help the reader better understand the hydrogeologic conditions present within the area of investigation. (More detailed discussion and analyses have been presented in a first year project summary report - HLI, 2007.) The significant hydrostratigraphic units in the study area are briefly described. The regional aquifer is then discussed in more detail in a following sub-section.

Overview of Significant Hydrostratigraphic Units

Terteling Springs Aquitard: Analyses of Well Driller's Reports, geologists' lithologic logs and borehole geophysical logs of wells drilled in the area, show a thick sequence of

clay and claystone (mudstone facies) of the Terteling Springs Member of the Idaho Group of Formations at depths of 400 to 600+ feet below ground surface in the Boise River Valley near Eagle and Star. The Terteling Springs mudstones were deposited in large lake (called Lake Idaho by geologists) that filled what is now the Boise River basin, 4 million years ago. The Terteling Springs mudstones comprise an aquitard that defines the bottom of the potable water system in the study area; no significant cold-water aquifers that supply high-quality, potable water lie beneath this unit. Low-temperature geothermal water aquifers, however, lie below the Terteling Springs Member, but are restricted to heat-value uses and are not generally suitable for potable water supply.

Pierce Gulch Sand Aquifer: A layer of lake-margin sediments about 275-feet thick (and locally more) directly overlie the mudstone facies of the Terteling Springs Member. These deposits, named the Pierce Gulch Sand after their type locality exposure in Pierce Gulch (Wood and Anderson, 1981), consist of sands (along with minor interbedded, discontinuous, and thin layers of clay and silt) that were spread out over the top of the Terteling Springs mudstones. The Pierce Gulch Sand was initially deposited in large deltas and beach deposits where rivers flowed into prehistoric Lake Idaho. The draining of the lake through what is now Hells Canyon allowed the sands and clays to be spread out over most of the basin to the west of the project area following the slope of the original lake bottom. This spreading of sediments along the sloping bottom left a continuous layer of sand with some interbedded clay and silt gently dipping to the southwest beneath the project area, at a slope of about 100 feet per mile. The slope (dip) of the deposits becomes slightly steeper beneath the M3 project site where the sand units that lie 250 to 500 feet beneath the valley floor in the Eagle-Star area rise and subcrop just below the surficial soils on the M3 site. The Pierce Gulch Sand is exposed in out crop several hundred feet above the valley floor in the foothills areas north of Boise. Limited exposures are also present north of Eagle.

Where saturated (as it is beneath the Boise Valley and much of the foothills containing the M3 project site), the Pierce Gulch Sand forms a regional aquifer named the Pierce Gulch Sand Aquifer (PGSA) by Ed Squires (HLI, 2007). Borehole-geophysical logs from more than a dozen deep wells in the area have been shown to exhibit a distinct and recognizable character that is traceable across the region. The basal sand of the Pierce Gulch Sand Aquifer, as shown by the geophysical logging[7], lies beneath the foothills of the greater M3-project area and beneath the Boise Valley in Eagle, Star and Meridian; the Pierce Gulch Sand Aquifer appears to be present beneath a very extensive area.

Unnamed Fluvial Sand Aquifer: Other, as yet unnamed, sands overlie the Pierce Gulch Sand Aquifer. These sand units consist of alluvium deposited by the ancestral Boise River in the flood plain of the valley formerly occupied by the lake. At many locations, these sand units are saturated from applied irrigation and canal leakage and form a separate and significant aquifer in the Valley area. These unnamed sand units also contain lower-permeability discontinuous silt and clay deposits where the ancestral river meandered back and forth depositing over-bank flood deposits along with more-

[7] All geophysical logs discussed in this section of the report (and for all tested wells discussed in this report that have been geophysically logged) are included in Appendix A.

permeable sands and occasional gravels. Typically, the unnamed aquifer is separated from the underlying Pierce Gulch Sand Aquifer by a sequence consisting mostly of clay and silt. In the eastern portion of the study area (near Lexington Hills in northeast Eagle) where the Pierce Gulch Sand Aquifer is relatively shallow, the clay layer is thin or absent, possibly allowing a hydraulic connection with the underlying Pierce Gulch Sand Aquifer.

Boise River Gravels: A relatively thin (35± ft) layer of floodplain gravels of the present-day Boise River forms the upper-most hydrogeologic unit in much of the lowland project area. This permeable gravel hydraulically connects directly to the Boise River and is typically underlain by clay and sand strata. These gravels are not present in the foothills; their northern extent in the project area is generally coincident with the Farmers Union Ditch (Figure 1, page 10). The upland areas of the Boise front prevented the floodplain from broadening to these areas. None of the well tests presented in this report are for wells completed in the Boise River gravels. Osiensky (1995), however, reported on the hydraulic properties of this aquifer in the Eagle Island area.

Eastern Upland Mixed Sediment/Bedrock Aquifers: Mixed bedrock and sediment underlies much of the higher elevation areas to the northeast of Eagle. The bedrock consisting of granitic rocks of the Idaho Batholith and overlying volcanic flows and tuffs, lies generally to the north of a major northwest-southeast striking geologic fault system shown by the dashed-red lines[8] in Figure 1. The main structural fault in this area (known as the West Boise-Eagle fault – Wood and Anderson, 1981; and Squires, 1992), appears to run approximately from State Street in west Boise toward Emmett and probably beyond. The fault has lowered geologic materials southwest of the fault by several hundred feet, relative to materials northeast of the fault. Groundwater in the mixed sediment/bedrock zones only flows at low rates and volumes. A portion of this water bearing unit was informally called the "Spring Valley Aquifer" by Scanlan (2003).

Eastern Upland Bounded Sand and Gravel Aquifers: Two bounded, high-permeability aquifers consisting of sand facies of the Terteling Springs Member overlie portions of the bedrock in the northern and northeastern portion of the study area. The sand and occasional gravels were deposited as deltas at the margins of Lake Idaho while the finer-grained clays and silts that define the bottom of the Valley cold ground water system were being deposited further to the west. These aquifers were informally called the "Sandy Hill Aquifer" and the "Willow Creek Aquifer" by SPF Water Engineering (2004a and b). The Willow Creek Aquifer appears to be time-correlative to the upper-most clay underlying the Pierce Gulch Sand Aquifer to the west beneath the M3 Eagle property. While the finer-grained sediments (clays) were being deposited offshore in the deeper waters of Lake Idaho, the coarser-grained sediments (sands and gravels) were being deposited in deltas and beaches along the near-shore margins of the lake.

[8] The position of the fault differs from that shown in HLI, 2007. Additional unpublished magnetometer studies and surficial geologic mapping conducted by Wood (2007) and funded by M3 have redefined the position of the southern branch of the fault. The position of the northern branch has not been revised suggesting an en échelon fault system of one or more parallel, offset faults.

Details of the Pierce Gulch Sand Aquifer

The Pierce Gulch Sand Aquifer varies in thickness. The thickest sequence identified during our study (through borehole geophysics) was 525 feet at the UWID State and Linder test well. In the middle portion of the study area near the UWID Floating Feather Well, the Pierce Gulch Sand Aquifer is about 386 feet thick. It is still relatively thick along the eastern portions of the study area where borehole geophysical logging of the Lexington Hills well #1 indicated a 326-foot sequence that consists mostly of sand. Because the Pierce Gulch Sand Aquifer is shallower in the east (the result of the 100 feet per mile dip of the unit) it is possible that part of the upper portion of the 326-foot sand sequence identified through geophysics, includes unnamed fluvial sands.

Beneath the M3 Eagle property, the Pierce Gulch Sand Aquifer is somewhat thinner, in part because portions of the Pierce Gulch Sand are unsaturated. At test well M3-TW#1 (located in the southwest portion of the M3 Eagle property), the Pierce Gulch Sand is fully saturated and is 275 feet thick. Beneath the eastern portion of the M3 Eagle property, the upper portions of the sand are dry and the top of the aquifer is defined by the water table. For example, at SVR #9 near the edge of the aquifer, the saturated thickness of the Pierce Gulch Sand Aquifer is only 73 feet. The 197 feet between the water table and ground surface consists mostly of unsaturated ("dry") sand.

The Pierce Gulch Sand Aquifer behaves as a single aquifer, with varying permeability at different depths and lateral positions within the aquifer. Because of these variations, pumping from one depth interval within the Pierce Gulch Sand Aquifer does not immediately affect all depths of the aquifer. Short-term tests (less than a day) generally affect mostly the zones comparable to the depth of the pumped well. The relatively-flat lying and discontinuous clay layers that are present above and below the zone screened by a given well, initially direct the hydraulic effects to the same general depth interval that is being pumped. Eventually the hydraulic effects of pumping are transmitted throughout the aquifer because the clay layers are discontinuous and/or varying in permeability over a lateral extent. In other words, pumping a deeper zone ultimately affects the shallower portions of the aquifer. Similarly, pumping a shallower zone ultimately affects deeper zones.

The Pierce Gulch Sand Aquifer does not behave as a series of individual aquifers separated by extensive, continuous clay layers. Data from pumping tests analyzed as part of this report do not support a model of a multi-layered, aquifer-aquitard system; during tests with multiple observation wells completed at different depths, pumping from wells completed in one depth interval of the aquifer system caused wells completed at different depths to respond within minutes after the initiation of pumping. For example, the observation wells completed at the bottom of the aquifer, responded first during the test of the Kling Irrigation well (screened at the top of the aquifer 1,050 ft away); wells completed within the top of the aquifer at the same location responded many minutes later. The earlier bottom-of-the-aquifer response indicates that the deeper water-bearing strata do not comprise a separate aquifer, separated by a continuous aquitard, from a separate overlying aquifer containing the pumped well. To the contrary, the response at

both the top and bottom of the water bearing strata within minutes of each other indicate a single aquifer. (Please see Section Five, for more details).

Previous workers (Holladay Engineering and SPF Water Engineering, 2007) divided the Valley flow system based on depth alone into the "deep aquifer zone" (greater that 200 ft bgl), the "intermediate aquifer zone" (100 to 200 ft bgl), and the "shallow aquifer zone" (less than 100 ft bgl). These divisions were based solely on depth and not on hydrostratigraphy. We believe the ground water flow system in the Valley is more accurately defined (from deep to shallow) as: the Pierce Gulch Sand Aquifer, overlain by unnamed clay and silt layers, overlain by an unnamed fluvial sand aquifer, overlain by the Boise River gravels. Because of the dipping nature of the Pierce Gulch Sand, the top of the Pierce Gulch Sand Aquifer and the depths of the overlying units do not match the arbitrary depth intervals previously used.

Beneath the foothill uplands to the north of Eagle and Star, the ground water flow system is generally defined as the Pierce Gulch Sand Aquifer overlain by unsaturated units of sand and clay. At some locations directly adjacent to the lowland valley (such as beneath the southwest corner of the M3 Eagle property) the unnamed sand overlying the Pierce Gulch Sand Aquifer (and separated by a sequence of clay) is saturated and forms a local unnamed aquifer. Beneath most of the foothill upland where the unnamed sand is present, however, it is unsaturated and therefore does not comprise an aquifer. The Boise River gravels are not present beneath the upland foothills.

Report Organization

This report is organized into six main sections. Section One is this Overview and Introduction of the report. Section Two reviews the Methods of Analysis used in the various tests. Section Three: Analyses of Valley Well Tests Conducted by Others, presents our reanalyses of pumping tests conducted on wells completed in the Boise River Valley in the greater Eagle and Star vicinity. Section Four, Analyses of Foothills Well Tests Conducted by Others, presents our reanalyses of pumping tests conducted on wells completed in the foothill uplands north and northeast of Eagle. In these two sections (Three and Four), each well test is discussed and reanalyzed in its own subsection of the report. Each subsection starts with an overview of the test. This overview describes the test, includes a review of the general methods of analysis used by the original workers and presents a critique of issues encountered during the test and/or analysis. Following this overview, the data are reanalyzed by HLI. Because we anticipate that this report will be used as a reference document in the future, we have repeated details on the physical testing (rates, timing, etc) in the HLI reanalysis sections. Although it may appear to be redundant, we believe including these details will assist future readers by keeping this information in the same part of the report as the HLI reanalysis. The HLI reanalysis includes details on the methods used, why the specific method was chosen and our results for quantification of transmissivity and storativity. Conclusions are made about the overall results of the tests, the representativeness of the analysis, issues encountered during the test and our critique of the test. In cases where the well test was conducted using a major regional supply well, the derived aquifer coefficients are used in

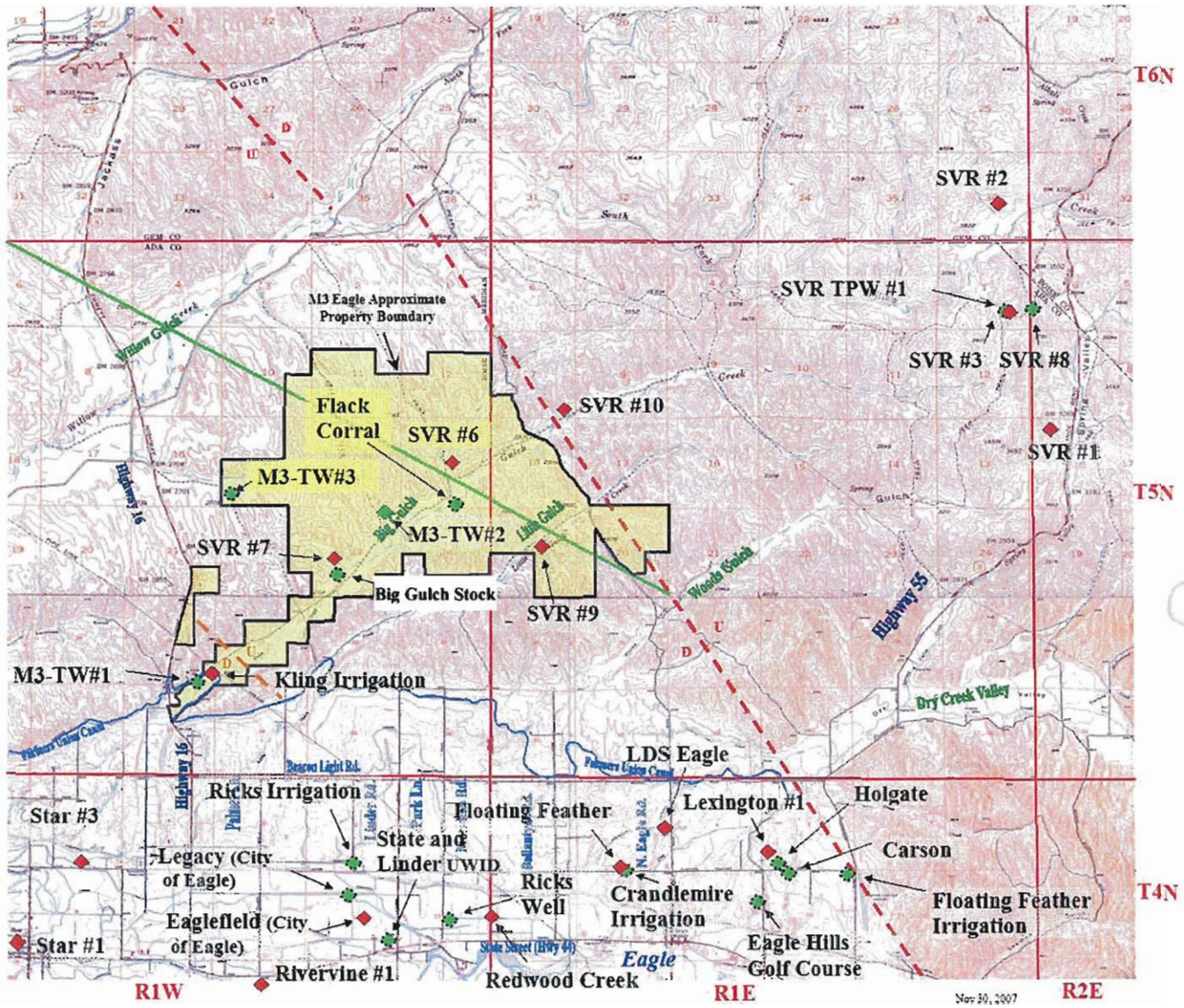
a prediction of the potential impacts caused by longer-term pumping. Following the two review sections, Section Five: Analysis of the Kling Irrigation Well and Aquifer Test conducted by HLI, presents the setup, analysis and conclusions from the January 2007 pumping test conducted at the Kling Irrigation well by HLI under the authorization of M3-Eagle. In Section Six: Summary of Regional Aquifer Characteristics, we present an overview of the characteristics of the Pierce Gulch Sand Aquifer system based on the results presented in the previous three sections. This section also discusses recommendations for additional testing and better methods for future testing to improve the current understanding.

This report has 100 supporting figures and tables in the main body of the report; they are located at the end of each report subsection pertaining to an individual pumping test. A single figure showing all the well locations is presented at the end of this section of the report. Additional, more-detailed well location maps showing the distances between the pumping well and each analyzed observation well are included after the text for each pumping test. Appendix A contains supporting data on the wells used in the analyses while Appendix B gives supporting information on the analytical methods. Figures depicting the pre-processing of the data used in the analysis of the Kling Irrigation well are included in Appendix C and Appendix D. The digital data used in the pumping test analyses are included on a compact disk (CD) attached at the end of the report.

Copyright, Warranty and Limit of Use/Liability Disclosure

This report was prepared for the exclusive use and distribution by M3 Eagle LLC, following hydrogeologic practices generally accepted and in use in this geographic area at this general time. The information and analyses presented in this report are copyrighted by Hydro Logic, Inc., for exclusive use by M3 Eagle, LLC, and may not be used for any other purpose without specific written permission from Hydro Logic, Inc. There is no other warranty, express or implied.

Figure 1. Locations for Wells Analyzed as Part of This Report



Pumping Well Location

Observation Well Location

Approximate Northern Boundary of the Pierce Gulch Sand Aquifer

Approximate position of the West-Boise-Eagle Fault
D on down-dropped side
U on up-thrown side

Fault located by magnetometer survey
D on down-dropped side
U on up-thrown side

N

One Mile

SECTION TWO: METHODS OF ANALYSIS

Introduction

HLI analyzed the data from sixteen pumping tests. To accomplish each analysis we: 1) obtained, collated and processed raw data collected by others; 2) selected the appropriate analytical method (at least two for each well); 3) calculated values for hydraulic parameters (transmissivity and storativity) of the aquifer tapped by each well and 4) predicted long-term changes in water levels from pumping at selected locations within the aquifer, using these calculated values.

Initially, reports and data on past pumping tests conducted by others were obtained and reviewed. In many cases, information on selected wells was available from our files. Data important for the analysis included detailed information on both subsurface geologic conditions and well construction. Ideally, we would have a detailed description of the subsurface materials logged by a field geologist based on samples collected during well drilling. We would also have geophysical logs of the test boring that included resistivity (at various electrode spacings) and a natural gamma ray count. An accurate description of the well construction details would also be included showing well screen design, sealing, casing diameters and depths and water levels all based on an as-built diagram prepared by a hydrogeologist, geologist or engineer. Wells with all three sources of information allowed for the best interpretation of subsurface conditions. Table 3 (page 247) lists the selected wells. Details on well construction and subsurface information available to HLI, are included in Appendix A. In many cases, wells monitored during a test but not pumped ("observation wells') did not have complete geologic or construction information. These wells were still used in the analysis, but the incompleteness reduced our confidence of the analytical results and is noted in the analyses, where appropriate.

Pumping test data were entered into MS-Excel-spreadsheet format in preparation for analysis. During this synthesis, we selected the most representative pre-pumping water level for use in each analysis. In some cases, these differed from the water levels used in previous analyses because of our inclusion of pretest changes caused by recovery from pumping before the test and/or changes in atmospheric conditions, known as the "barometric effect" where the water level in a well completed in a confined aquifer goes up when atmospheric pressure goes down or goes down when atmospheric pressure goes up. In other words, the water level in the well varies inversely proportional to changes in barometric pressure, as a function of the rigidity and isolation of the aquifer. The pretest water levels used in our analysis are included in Table 3 as "DTW," or depth to water. (In Table 3, a negative number indicates a pretest water level above ground level).

The data were then plotted and analyzed using Aqtesolv® *4.50.002 Professional* software (HydroSOLVE, Inc., 2008). Analyses were conducted for each pumping well and when available, for observation well(s) monitored during the test. In the cases of the two

longer-term tests ("Eagle 7-Day Test" and the "Lexington Hills 30-Day Test") four observation wells were reanalyzed for each test.

Not all wells monitored during the original tests were reanalyzed; we culled observation wells that we deemed of little value. In many cases, such as when the observation well and pumping well were completed in a aquifers, or when the observation well was too far away from the pumping well, no meaningful changes in water level were observed during the test. In some cases, a very small change might have been observed had not another well in the area started pumping and/or had not the barometric effect been larger than the change in water level caused by pumping well. In such cases, the data from these wells were deemed neither representative nor useful and therefore, not reanalyzed.

Water level data were graphed and reviewed in several formats. In cases where meaningful data were available for both pumping and post-pumping ("recovery") periods, both drawdown and recovery plots were created and reviewed. Attention was paid to the effects of changes in well development; in the cases of some of the newly-constructed wells[9], aquifer material and residual drilling fluids ("mud") were removed during the test, causing near-well aquifer permeability to increase over the term of the test. This increase in permeability introduces a potential error in the analysis. In two of the tests included in this report, the water levels that would otherwise have declined during constant-rate pumping actually rose, making analysis of the pumping portion of the test less meaningful. In these cases, recovery data were used when available to generate a more realistic analysis of the aquifer.

In cases where pumping rates were relatively small compared to the volume of standing water in a well casing, early-time, well-bore storage effects were considered. In cases where a well was completed in only a portion of the whole-aquifer thickness, the effects of partial penetration were considered.

Analytical Methods

We used a variety of methods after reviewing "straight-line" (semi-log time versus arithmetic drawdown) and "curved-line" (log-time versus log drawdown) plots of the data along with geologic and well-construction data. Each method and the conditional

[9] It appears that in many of the tested wells, very little to no significant well development occurred prior to testing. In Idaho, the "standard of care" practiced by many well drillers and consultants is just to pump the well for a couple hours as the main development tool. A more thorough and stable development of the well occurs when the well is jetted and / or surged with material removed (including residual drilling mud) until the pumped water is clear and sand free. A well that has undergone only limited pumping prior to testing often produces sand and silt during testing, causing test results to be of limited value. An underdeveloped well may also be partially plugged with drilling mud that was not fully removed during development, causing additional drawdowns and erroneous test results, especially if otherwise permeable zones cannot contribute to water production during pumping. The worst case is a well that develops during the test to such an extent that the water level in the well actually rises (instead of falling) during constant-rate pumping, making analysis less meaningful and the money spent on testing less cost-effective.

assumptions for each method are described in Appendix B. The various methods used in this report are summarized below:

Well-Bore Storage (HydroSOLVE, Inc., 2007): A log-log, radial flow plot of every well test was examined before any data analysis was conducted. A slope of 1 during early-time pumping indicated the effects of well-bore storage and the appropriate method of aquifer analysis was then selected (see below).

Derivative (HydroSOLVE, Inc., 2007): A derivative (slope) of the drawdown curve was generated for each pumping test plot using the Bourdet (1989) method. The characteristic type curve was also generated for each method of analysis. The type curve indicates which portion of the test data (if any), is valid for the selected method of analysis. For example: Cooper-Jacob (1946) analyses are only valid where the derivative is a flat line (constant slope), a Theis (1935) analysis requires a derivative curve that rises with a decreasing slope that approaches a constant value, and a Hantush-Jacob (1955) leakage analysis begins with a curve that rises at fist and then drops down toward zero. Application of the test method on data not matching the characteristic derivative shape can lead to erroneous results. In each set of test data, a differentiation interval of 0.3 log cycles was typically used to help "smooth" the derivative curves. The occasionally a higher value of 0.4 was used when the value of 0.3 generated too much scatter in the derivative plot. Each pumping test plot includes a derivative analysis to help indicate the relative validity of the method.

Cooper-Jacob (1946): straight-line (semi-log) plots for drawdown versus log of time. When the Cooper-Jacob straight-line method was used, a check on the "u assumption" was made. The "u assumption" indicates the critical time (t_c) after which the method is considered valid and the data plot as a straight line on a semi-logarithmic graph (logarithmic time versus arithmetic drawdown) and the derivative is constant. When "u" is sufficiently small, the non-linear terms of the Cooper-Jacob approximation of the Theis equation become insignificant resulting in a logarithmic curve that becomes a straight line on a semi-log plot. We have used a "u" equal to or less than 0.05 as our criteria for validity. Our experience along with that of many workers (including Driscoll, 1986), has shown that a smaller value such as 0.02 or 0.01 is not generally necessary for the data to plot in a straight line. In many cases, previous analyses quantified aquifer parameters when the "u assumption" was not valid, leading to questionable results. Partial penetration corrections are not applied by Aqtesolv® in the Cooper-Jacob method of analysis. Because the cone of depression caused by the pumping well must move outward for a sufficiently long time for the Cooper-Jacob method to approximate the Theis method, Butler (1990) indicates the results of the Cooper-Jacob analysis generally indicate the average properties of the aquifer over relatively large area.

Theis (1935): Type-curve-matching (log-log) plots for drawdown and recovery. When unconfined aquifers were analyzed, the correction developed by Jacob (1944) was used to correct the data to make the analysis applicable, especially where the drawdown at the well was significant relative to the aquifer thickness. In some cases, a semi-log Theis plot was used to better match the data where drawdowns were relatively large and early-time

data were questionable. Because Aqtesolv® can generate a type curve for any system of axes, the semi-log plot allowed for better curve matching where large drawdowns caused the drawdown curve to appear relatively flat on a log-log plot. Because the Theis and other curve matching methods require matching the data generated when the drawdown levels begin to change most rapidly (the cone of depression is just passing the observation well), Butler (1990) indicates the results of the Theis analysis generally indicate the average properties of the aquifer over a relatively small area defined by the radius of the distance between the pumped and observation well.

Theis (1935): straight-line (semi-log) plots for recovery data where backflow from the pump column into the well did not mask actual water level recovery. This method helps to remove the effects of well loss and small pumping variations that affect the analysis of pumping data. It also indicates whether hydraulic boundaries and /or recharge affected recovery. Partial penetration corrections are not applied by Aqtesolv® in this method of analysis.

Papadopoulos – Cooper (1967): Type-curve-matching (log-log) plots for wells where well bore storage is significant. This method accommodates the lag effect (less drawdown than predicted using the Theis method) that is caused by water standing in a well casing.

Hantush (1961a and b): Type-curve-matching (log-log) plots for confined-aquifer wells not fully penetrating the aquifer. This correction was applied to other log-log analytical methods to correct for the effects of apparent increased drawdown caused by a well screened in only a portion of the aquifer and not the full thickness. This partial screening causes vertical flow gradients within the aquifer, near the pumped well. Wells significantly far from the pumping well did not need this correction because vertical gradients become negligible (in a homogeneous and isotropic aquifer) when the observation well is sufficiently far from the pumped well.

Neuman (1974): Type-curve-matching (log-log) plots for unconfined-aquifer wells not fully penetrating the aquifer. This method accounts for the flattening of the drawdown curve that occurs when an unconfined aquifer is pumped and vertical (downward) drainage within the aquifer causes the water levels to apparently stabilize for a short period (several hours to several days), before continuing to decline. This drawdown sequence of decline-stabilize-decline is known as "delayed yield." The method indicates both storativity (initial response similar to a confined aquifer) and specific yield (unconfined aquifer behavior).

Moench (1997): Type-curve-matching (log-log) plots for unconfined-and semi-confined-aquifer wells not fully penetrating the aquifer and having well-bore storage effects. This method is similar to the Neuman method but allows incorporation of additional factors that affect the analysis of the drawdown data such as the time lag of gravity drainage or delayed yield.

Neuman-Witherspoon (1969): Type-curve-matching (log-log) plots for a "leaky," confined-aquifer system (aquifer/leaky-aquitard/aquifer) for wells fully screening (penetrating) the pumped aquifer. This method allows for flow through a leaky aquitard to be incorporated into the analysis. The Neuman-Witherspoon method allows for interpretation of confined aquifer test data that flatten out after a time and remain (apparently) stabilized (no increase in drawdown with time). The method requires an understanding of the geometry of the unpumped aquifer and aquitard.

J. Butler (1988): Type-curve-matching (log-log) plots for a non-uniform confined-aquifer system (a zone of one value of transmissivity and storativity surrounded by another zone of differing values) for wells fully penetrating the pumped aquifer. This method allows for interpretation of confined aquifer test data affected by variations in aquifer homogeneity. It assumes the inner zone is a cylinder with the pumped well at the center. The method is sensitive to radius of the cylinder of aquifer, which is rarely known, and therefore must be estimated. In addition, because heterogeneity in an aquifer rarely (if ever) can be represented by a cylindrical region of different properties, the method can only serve as an approximation.

S. Butler (1957): An approximate correction for drawdown and recovery data from pumping wells only partially penetrating the aquifer. We only applied this method to the "straight-line semi-logarithmic" methods, where Aqtesolv® does not apply any partial penetration corrections. In the Butler method presented in Walton (1962), raw drawdown and residual (recovery) drawdown data are "corrected" before the semi-log plots are generated. The data are corrected by multiplying the measured drawdown by a correction coefficient that is generated through a "look up" table based on ratios of vertical to horizontal permeability of the aquifer, ratio of the well diameter to aquifer thickness, and percentage of the aquifer thickness screened by the pumping well. The method is considered only to be an approximation because it was developed for steady-state conditions but applied in our analyses, to a transient test. Walton indicates that the method gives "fair results" and that should be considered "approximate." The method tends to "over-correct" the data such that the analysis using the corrected data generates transmissivity values that are larger than the actual value for the aquifer. This method is based on the assumption that the pumped well is completed in either the top or the bottom of the aquifer. When the well is completed near the middle of the aquifer (vertically), the over-correction errors are largest. The method has value, however, in that it helps to define the upper end of the range for actual aquifer transmissivity whereby the uncorrected analysis helps to define the lower end.

Issues Affecting the Selected Method of Analysis for Pumping Wells

Selecting the appropriate method of analysis for pumping wells is often problematic. Some workers consider the use of log-log methods of analysis (Theis, Neuman, Moench, Butler, etc.) invalid for the pumping well because the selection of an effective well radius affects the analytical results. In addition, well loss (drawdown in the well caused by frictional head loss through the well screen and near-screen materials) affects the calculations for transmissivity. Semi-log methods (Cooper-Jacob, Theis recovery, etc.) on

the other hand, do not need input of effective well radius or well loss as these methods rely solely on the slope of the straight-line plot; these methods are independent of effective well radius and well loss for calculations of transmissivity. In cases where the pumping well is open to all or most of the aquifer thickness, the semi-log Cooper-Jacob method is generally more accurate than the Theis log-log methods for the pumping well. Because few of the tested wells discussed in this report screened most or all of the aquifer, partial penetration had to be addressed.

Partial Penetration

When the pumping well only is open to only a relatively small portion of the entire aquifer thickness, the effects of "partial penetration" can result in errors (Freeze and Cherry, 1979). Because of this potential for error, the issue of partial penetration for pumping well analyses was an "issue of concern" during our review of existing pumping test analyses and our reanalysis of the pumping test data. Hantush (1961a and b) developed a method for correcting for the effects of partial penetration that applies to the log-log methods of analyses such as that of Theis (1935). When we applied the Theis method with Hantush corrections for partial penetration to data from pumping wells that screened less than 20 percent of the whole-aquifer thickness as indicated by borehole geophysics, we found that the calculated transmissivity was up to 200 percent greater than the results generated using the Theis method alone – a considerable difference. The Hantush corrections, however, only apply to the log-log methods such (as Theis) and not the semi-log methods (such as Cooper-Jacob). As discussed below, problems inherent in the Theis method do not allow it to be preferred over the Cooper-Jacob method, resulting in a quandary: When the pumped well only partially penetrates the aquifer which method – Theis or Cooper-Jacob better indicates the true properties of the entire aquifer thickness?

Previous workers made no corrections for partial penetration; instead they assumed that the aquifer was close in thickness to the length of the well screen assembly. In the case of the Pierce Gulch Sand Aquifer system which at some locations is over 500 feet thick, the assumption that the well screen length is approximately the same as aquifer thickness does not lead to an accurate understanding of the water transmitting ability of the *entire* thickness of the aquifer. It may, however, indicate the relative properties of the portion of the aquifer tested and therefore the performance of the tested well[10]. The Pierce Gulch Sand Aquifer contains relatively thin, discontinuous layers of clay, silt and silty sands within the overall sand section that defines the aquifer. These discontinuous clay and silt layers result in an aquifer system that has a bulk anisotropy that directs the initial effects of pumping primarily in a lateral direction with slower effects directed vertically. Through discussion with the developer of Aqtesolv® (Glen Duffield, personal communications, January 2008), we believe that shorter-term data (a day or so) generally indicate the properties of the aquifer in the vicinity and depth interval of the pumped well. Thus, for example, the 80-foot long screened section of the Eaglefield pumping well (discussed in the following section) likely indicates the properties of the aquifer at the

[10] Indeed, most tests analyzed in this report are better described as "well tests" as opposed to "aquifer tests."

depth interval of the pumped well but not the entire 500 foot thickness of the Pierce Gulch Sand Aquifer system. Flow within the entire aquifer cannot be accurately quantified assuming the transmissivity indicated for the approximately 100 foot tested thickness represents the entire 500 foot thickness of the aquifer.

The discontinuous layering of clay and variations in permeability with depth within the Pierce Gulch Sand Aquifer system are also problematic for application of the Hantush corrections to the Theis method. The effects of the layering can only be approximate as the ratio between the relative vertical and horizontal hydraulic conductivity of the aquifer must be estimated as input to the method. This ratio is never measured directly in a pumping test. In lieu of direct measurement we have assumed that the thin discontinuous low-permeability layers result in an overall preference for flow in the horizontal direction, in other words we have estimated that the ratio of the bulk vertical to bulk horizontal permeability of the aquifer is about 0.1 on average. The log-log methods assume a uniform permeability throughout the vertical section of the aquifer. Butler and Healey (1998) show that a semi-log analysis of a pumped well may indicate an average transmissivity of the entire section, but Duffield (personal communication on partial penetration, January 2008) states that this method only works when the well has been pumped for a sufficiently long time and the storativity of the aquifer is relatively small, conditions not met in most of the tests analyzed as part of this report. During short-term testing, the test results are more likely to represent the transmissivity of the aquifer in the aquifer near the pumped well at similar elevation zones. Because partial penetration effects decrease with distance from the pumped well, most workers indicate that observation well data are preferred for analyzing the average properties of the aquifer.

In order to better understand the overall properties of the entire aquifer thickness, we applied the corrections of Butler (1957) in our semi-log, straight-line analyses of pumped well data. Since these corrections are only approximate, as discussed above, the results of the analyses using the Butler corrections are only approximations of the upper-end values for aquifer transmissivity for the entire aquifer thickness.

Effective Well Radius

To better quantify the potential errors inherent in the Theis method, we conducted sensitivity analyses on the effective well radius, which cannot be known exactly. When a well is developed, the permeability of the aquifer materials just outside the well screen and filter pack is increased. This increase causes the well to behave as if it had a larger radius than the actual drilled bore hole. The actual size of this effective well radius is typically a few inches larger than the actual radius of the borehole, but is not directly measurable. Our analyses indicated that doubling the effective well radius from the actual bore-hole radius to twice that value, resulted in differences in analytical results of around five percent. (i.e., using actual well-bore radius resulted in transmissivity calculations that were five percent larger than those using an effective radius twice that of well bore diameter.) Since the true effective radius is very likely to be much less than twice that of the actual well bore radius, we deemed this an acceptable potential error that is within the range of other errors caused by variations in pumping rate and water level measurements,

inherent in a pumping test often conducted under the direction of a well driller. We therefore used an effective well radius equal to the well borehole radius and acknowledge a potential error of up to 5 percent.

Well Loss

Sensitivity to well loss effects was examined on a test-by-test basis. Well loss is the increased drawdown in the pumped well, unrelated to aquifer properties, caused by frictional and turbulent-flow head loss of water flowing through the well screen, filter pack and/or the under-developed aquifer directly adjacent to the pumped well. Well loss can be quantified through a properly designed and conducted step-rate pumping test. None of the pumping tests we reviewed and reanalyzed as part of this study included quantification of well loss. Some of the tests did, however, have data that allowed us to estimate well loss or at least the maximum likely well loss; water-level drawdowns from the first 10 to 60 seconds of the initiation of pumping and/or the first 10 to 60 seconds of recovery after pumping stopped were used to estimate maximum likely well loss in order to define the upper end of the range of possible transmissivity. Not all the drawdown or recovery observed during the first 10 to 60 seconds is well loss; these initial drawdowns (and initial recoveries) are the sum of well loss *and* aquifer loss. However, well loss cannot exceed the observed initial drawdowns (and initial recoveries). Since well loss remains constant for a given pumping rate, these initial values define the maximum possible well loss that could occur during a constant rate pumping test.

Our estimating method for possible well loss to calculate the upper end of the range of possible transmissivity was as follows: We assumed (for the sake of the analysis) that well loss was equal to about half of the drawdown measured during the first 30 seconds of pumping and/or it was equal to the difference between the drawdown at the end of pumping and the residual drawdown 10 to 60 seconds after pumping stopped. We then subtracted this amount from the measured drawdown data to generate drawdown data representing a pumping well with no well loss. We then calculated transmissivity with these "corrected" data and compared the results to calculations based on the measured data. The differences between these two analyses were typically on the order to 10 to 20 percent. (i.e., using no corrections for well loss resulted in transmissivity calculations that were 10 to 20 percent smaller than those using an estimated well loss equal to half the initial drawdown). Even when we conducted a sensitivity analysis based on the assumption that well loss was equal to *all* the drawdown measured one minute into the test (an impossibility), the error was less than 25 percent. Based on these analyses, we believe the maximum error introduced by using the Theis (and related) methods without correcting for well loss is less than 25 percent, and often less than 10 percent. None-the-less, all of our log-log plots for pumping well analyses include plots and calculated results for both the raw (uncorrected data) and data using the estimated, maximum-likely well loss.

HLI Analyses Considering Partial Penetration, Effective Well Radius, and Well Loss

When the pumped well penetrated a significant portion of the aquifer, the semi-log Cooper-Jacob method was superior to the log-log Theis method and its derivatives, for reasons described above. However, where partial penetration effects are significant and the test is of relatively short duration (or usable data only allowed for analysis during the early portions of the test), our choice became one of: a) using the Cooper-Jacob method without corrections (with potential errors as high as 200 percent as indicated by the differences between the Theis method with and without Hantush corrections for partial penetration) or b) correcting the data with the Butler approximations (resulting in unknown errors associated with using a correction derived for steady state conditions but applied to a transient analysis) or c) using the Theis method or its log-log derivatives (with potential errors caused by misestimation of well loss and/or effective well radius. We generally chose to conduct a series of analyses using all three of these methods, and then bracket the results. For example, we would conduct one Theis analysis with raw data and one with data corrected using an upper-end estimate of likely well loss (both analyses with Hantush corrections for partial penetration). The larger transmissivity value derived from the analyses would define a likely upper end for transmissivity while the uncorrected data would give a lower end. In a similar way, Cooper-Jacob pumped-well drawdowns and Theis post-pumping recovery analyses would include raw data and data adjusted using Butler corrections for partial penetration. The Butler-corrected data would define upper end transmissivity values. All the results would be presented and reviewed with the actual transmissivity likely lying within the range of the corrected-data and raw-data analyses. As seen on the test analyses presented in this report, whenever we conducted an analysis using corrected data, we also present the raw data and its associated analysis for comparison.

Issues Affecting the Method of Analysis for Observation Wells

Observation well data had different issues. The Cooper-Jacob method requires that pumping occurs for a sufficiently long period such that the "u assumption" is met and the data plot as a straight line on a semi-log graph. The length of time ("critical time" - t_c) required to meet the "u assumption" becomes larger as the distance between the observation well and the pumping well increases. In many of the data sets we analyzed as part of this project, the observation wells were sufficiently far from the pumping well such that the calculated critical time was too large before the "u assumption" was met to allow the Cooper-Jacob method to generate accurate results. In these cases, we used log-log methods to analyze the data. When the log-log plot of the middle-to-late-time data was too flat and/or the initial data showing the most rapid change in water levels were corrupted, we used a semi-log Theis plot to allow for a better match of the type curve to the data. This method has no "u-assumption" requirement (in contrast to the Cooper-Jacob method) and typically allows a more accurate placement of the type curve than when using the standard log-log Theis when the initial data cannot be used. Aqtesolv® incorporates the partial penetration corrections developed by Hantush when using the Theis and most other log-log methods. Incorporation of these corrections eliminates potential errors that might occur where partial penetration effects are significant.

Issues Affecting Pumping and Observation Wells: No-Flow Boundaries

In cases where a no-flow hydraulic boundary that could potentially affect aquifer response to pumping was known or presumed to be present in an area, the analytical methods that used curve matching were augmented through the use of image well techniques. Image wells are imaginary wells that pump at the same rate and timing as the well undergoing the analysis. In the case of a no-flow boundary, the well is incorporated into the analysis by placing it on the opposite side of the boundary, at a distance equal to the distance between the pumped well and the boundary. An image well in this position produces the same hydraulic effects on a well in an infinite aquifer (as is assumed in the Theis and other methods of analysis) comparable to the effects caused by a no-flow (or "edge-of-aquifer") boundary (Ferris et al, 1962).

Image well techniques were used in the analysis of the valley tests at Eaglefield #2, Lexington Hills #1, Floating Feather, and Redwood Creek, and the upland test of the Kling Irrigation well. In the Valley well tests, a major northwest-trending geologic structural fault (the West-Boise-Eagle fault) forms the northeastern edge of the aquifer. In the case of the Kling Irrigation well, the northwest trending outcropping of the aquifer that underlies the M3 project area is believed to form the northeastern edge of the aquifer. (Both boundaries are shown in Figure 1, page 10). The edge of the aquifer acts as a no-flow, hydraulic boundary. This no-flow boundary appears to have no significant effect during short-term pumping but was included in these analyses for completeness. Through the principal of superposition, the type curves used in the data matching for the log-log analyses were generated by Aqtesolv® to model the type curve that would result from pumping a well in the bounded system.

In all cases, we reviewed the computer-generated match and then manually adjusted the curve match to best fit the data, when needed. Computer-generated matches often were less accurate when small variations in pumping rates, measurement errors and/or interference[11] from sources other than the pumping well caused minor variations in the data. The computer match would consider these variations to be as significant as data falling on the theoretical curve. Through manual matching, we were able to apply "best professional judgment" in deciding which data were representative and which data were likely to be less representative.

One Aquifer Versus Several Aquifers Separated by Aquitards

Another issue of concern with the interpretation of the pumping test data and the selection of the preferred methods of analyses was the interpretation of the aquifer system as one aquifer with zones of varying properties versus several aquifers separated by aquitards. Review of the high-quality data (geological data collected and interpreted by a professional geologist and the borehole geophysical data interpreted by a professional

[11] Interference is a hydrogeologic term. It is defined as the amount of drawdown (change in water level) in a well caused by pumping from another well. *All* ground water withdrawals from a well result in some interference. Theoretically, a well cannot produce water without causing some interference. Small amounts of interference generally go unnoticed.

geophysicist) indicates a single water bearing and transmitting unit, consisting predominantly of sand but with relatively thin discontinuous clay layers. Even when high quality data indicate that the aquifer is over 500 feet thick (as it is at the UWID State and Linder well), thin layers of discontinuous clay and silty sand are present. These alternating layers of sand and silty sand are geologically consistent with the interpretation of a redeposited delta where the main region of deposition shifted spatially over time. The thickest region of sand deposition likely occurred near where the main channel of the river entered the lake while areas further away would be thinner.

These discontinuous lower-permeability layers do not appear to act as aquitards that separate a series of layered aquifers. For example, in one case pumping from the top of the Pierce Gulch Sand Aquifer caused a response at the bottom of the aquifer before a response was noted at the top of the aquifer in vertical set of wells located the same distance from the pumping well (the Kling Well test discussed in Section Five). In another case, a well closer to the pumping well than one further away (with both wells completed at similar depths, and with both wells along geologic strike and therefore, less likely to be affected by the 100 foot per mile dip of the aquifer) had a smaller response than the more distal well (the Eaglefield #2 test discussed in Section Three). In both of these examples, the entire, deeper, water-bearing unit acted as a single aquifer but one with properties that vary spatially. These responses do not support a multiple aquifer system with pumping from one aquifer causing a delayed and reduced response in other aquifers at different depths, after the drawdown response is transmitted through separating aquitards.

In the eastern portion of the study area, we have identified all of the water bearing zones between a depth of 75 ft bgl and 401 ft bgl as the Pierce Gulch Sand Aquifer, based on geophysical logging of the Lexington Hills Well #1 (included in Appendix A). It is not clear whether all of the sand between a depth of 75 ft bgl and 401 ft bgl actually is Pierce Gulch Sand. An upper portion of the sand could, in theory, be unnamed fluvial sands in direct hydraulic continuity with the underlying Pierce Gulch Sand Aquifer. If so, the clay and silt that separates the Pierce Gulch Sand Aquifer from the overlying unnamed fluvial sand aquifer beneath other parts of the Eagle-Star area further to the west, is very thin or missing all together. As such, some of the shallow observations wells monitored during the 30-Day test (page 57) may be completed in the unnamed fluvial sand aquifer. However, it makes little if any difference hydraulically. Because the pumping well and several observation wells exhibited what appears to be a "delayed-yield" response and the observation wells indicated unconfined storage coefficients, we believe that all of the water-bearing zones tapped by the wells completed between 75 and 401 ft bgl in the eastern portion of the study area (near Lexington Hills) are completed in a single-aquifer, the Pierce Gulch Sand Aquifer. This single-aquifer does, however, have different properties at different locations with transmissivities varying by factors of four to five as is discussed in Section Three.

In summary, we believe the data better support the interpretation that the Pierce Gulch Sand Aquifer is a single aquifer with properties that vary throughout the aquifer, both vertically and horizontally. We believe that the data are less supportive of the

interpretation of a system of several aquifers separated by aquitards. In some areas detailed geophysical logging indicates that the aquifer is over 500 feet thick. In the uplands north of Eagle and Star (the M3 Eagle project area), the Pierce Gulch Sand Aquifer is about 275 feet thick where fully saturated. In some areas, the upper regions of the Pierce Gulch Sand and overlying unnamed sand units are unsaturated resulting in a thinner, unconfined aquifer with the top of the aquifer defined by a water table. Not all portions of this 275-foot thickness have the same properties, however. As in the Pierce Gulch Sand Aquifer beneath the valley, discontinuous layers of clay and silty sand are also present. Similarly to the Pierce Gulch Sand Aquifer beneath Eagle and Star, these discontinuous layers do not appear to result in a series of distinct aquifers separated by aquitards.

In the eastern part of the study area, the Pierce Gulch Sand Aquifer system appears to connect hydraulically to overlying unnamed fluvial sands and likely to the shallow Boise River gravel aquifer. These connections are suggested by: a) unconfined storage coefficients calculated from the pumping test data and b) positive responses to the onset of canal flows (and the subsequent leakage from the canals to underlying aquifers). Both of these factors suggest an unconfined, watertable aquifer in hydraulic connection to the surface. These interpretations are further discussed in Section Three of this report (page 25).

Procedure for Analyzing Pumping and Observation Well Data

Two to four types of analysis were initially performed for each well, in order to compare results and develop a range of values, especially where data appeared to have flaws that could influence a part of the test analysis. We selected the methods most likely, in our professional opinion, to best model the aquifer based on: 1) the observed data, 2) comparison of the calculated derivatives and the theoretically "perfect" derivative curve for the method, 3) our three-dimensional understanding of the hydrogeologic framework of the aquifer system, and 4) our best understanding of well construction. The results of the set of analyses for each well were bracketed as a range with the most likely (in our professional opinion) indicated in Table 3 (page 247). The method of analysis for each test and its likeliness to best represent aquifer conditions are also noted in Table 3.

The results of the analyses presented in Table 3 show transmissivity and storativity values calculated for each well test for the pumping and observation wells, where appropriate. Results and averages are typically presented to two significant figures. A summary of the results generated by the original workers, are also included for comparison. Typically, the short-term tests (less than a few days) give a short-term storativity. The inter-bedded nature of the aquifer (layers of fine-to-medium-grained sand, silt and minor clay) cause the Pierce Gulch Sand Aquifer to behave initially as a confined-aquifer such that the effects during early-time pumping (the first few days or less) are transmitted horizontally through the aquifer relatively quickly. However, because these layers are often discontinuous and/or vary in permeability, they eventually allow the movement of water between deeper and shallower zones in response to pumping. Over time (several weeks or more of pumping), depressurizing effects caused

by pumping are transmitted vertically to all portions of the aquifer (and even zones that might be considered a separate overlying aquifer, based on Well Driller's Reports alone) causing water levels in shallower wells to drop. Such "across the bed" permeability demonstrates that the Pierce Gulch Sand Aquifer behaves as a single aquifer. This type of behavior was demonstrated during the two long-term (one week and one month) tests. The extensive nature of the Pierce Gulch Sand Aquifer is also demonstrated by the relatively stable water levels in the Eagle-Star area over the past ten years of steadily-increasing, ground-water pumping.

In each analysis, we calculated the hydraulic conductivity ("permeability to water") by dividing the transmissivity by the thickness of the aquifer as indicated by geophysical logs or well driller's reports. We then compared these calculated hydraulic conductivities with the range of values presented in Freeze and Cherry (1979). Our calculated hydraulic conductivities were within the middle portion of the range appropriate for the aquifer materials reported on well logs and Well Driller's Reports, thereby supporting the validity of the analysis. The following ranges (in cm/sec) were used in our comparison: silty sand: $5x10^{-4}$ to $5x10^{-3}$; clean sand: $5x10^{-3}$ to $5x10^{-2}$; coarse sand $5x10^{-2}$ to $5x10^{-1}$; and gravel: $5x10^{-1}$ to $5x10^{0}$+. These values represent the center of the ranges presented in Freeze and Cherry.

Predicted Interference Drawdown Effects from Long-Term Pumping

After the aquifer coefficients were calculated, the amount of interference-drawdowns in water level caused by pumping, were calculated using the method of Theis (1935) for selected representative wells. In these analyses, we assumed that: 1) the aquifer was uniform, 2) the aquifer is bounded on the northeast by the West-Boise-Eagle fault (or edge of the aquifer in the case of the M3 site), 3) pumping would occur continuously for three months without interruption, and 4) well and aquifer water levels would stabilize at levels equal to or higher than those predicted at the end of 90 days of pumping. Each of these assumptions is discussed below.

We assumed that the aquifer is uniform in its hydraulic properties (homogeneous). The results of the pumping test analyses discussed later in this report show that the hydraulic properties of the aquifer vary at different locations (as is typical in natural, geologic systems). In order to accommodate this variation, we typically conducted a set of two analyses for each prediction, using a range of values likely to represent the conditions throughout the area affected by the pumping well. By bracketing the likely range of values for transmissivity and storativity, we believe the actual effects from pumping will fall within the range of the two analyses.

We assumed that the aquifer is bounded by a "no-flow," edge-of-aquifer boundary along the northeast. To simulate this no-flow boundary we have used image well technique; an image well was placed on the opposite side of the no-flow boundary, at a distance from the boundary equal to the distance of the pumping well from the boundary. In the simulations, the image well was pumped at the same rate and timing as that of the pumping well. By using an image well, we consider our analysis to be "conservative"

(likely to over-estimate drawdown effects); an analysis without an image well would predict smaller interference drawdowns.

We have used a 90-day pumping period in our analysis. We have assumed that during a typical hot summer, the well would be pumped continuously at its full capacity for 90 days without interruption. Based on our experience with wells in the Boise Valley, few wells pump continuously at their full rate, even during the entire summer, making it likely that actual pumping would be less than that used in the analysis. We consider the assumption of continuous pumping at a constant rate for 90 days at a constant rate to be conservative.

We have assumed that water levels would stabilize within the 90 days used in our analysis. This is contrary to a major assumption of the Theis analysis in which there is *no* capture of recharge and therefore *no* stabilization of pumping water levels; in the Theis analysis, pumping causes the drawdown "cone of depression" (the portions of the aquifer in which pumping causes the water levels in the aquifer to decline) to expand ever outward, such that drawdown levels continue to decline *forever* in order to supply water to the pumping well. Our experience in the Boise Valley has shown that drawdown levels typically stabilize in less than 90 days of pumping. The stabilization occurs because the drawdown cone of depression expands outward far enough to intersect and capture ground water flowing through the aquifer equivalent to the amount being pumped from the well. At this point, the drawdown levels in the pumped well and aquifer stabilize. Since capture and stabilization typically occurs in less than 90 days, our assumption of 90 days of continuous pumping needed to allow levels to stabilize is also conservative.

SECTION THREE: VALLEY WELL TESTS

This section of the report analyses seven Boise River Valley well tests. Each of these wells tests represents a different sector of the regional Pierce Gulch Sand Aquifer. Generally, the aquifer and wells are deeper toward the western parts of the study area. As discussed in Section One in the sub-section on *Hydrogeologic Overview*, the Pierce Gulch Sand Aquifer dips to the southwest at about 100 feet per mile and is therefore deeper toward Star in the west and shallower toward the Eagle area in the east. This dip in the strata explains why wells in Star completed between depths of 450 and 570 feet, tap the same aquifer as those in the Lexington Hills (Eagle) area completed at depths between 215 and 385 feet. The shallower, eastern end of the Pierce Gulch Sand Aquifer is unconfined, as indicated by long-term, high-discharge-rate pumping tests.

Eaglefield Seven-Day Test

Overview and Previous Analyses

The City of Eagle Eaglefield Well #2 was drilled by Riverside, Inc. using the, reverse-circulation mud-rotary method during March through May of 2006. The well was drilled to a total depth of 444 ft bgl, and completed with stainless steel well screen open to the aquifer between depths of 345 and 425 ft bgl. The pretest water level was 16.25 ft above ground level which translates to an elevation of about 2,523 ft above mean sea level (amsl).

Holladay Engineering (2006) directed a pumping test that occurred June 2-9, 2006 with pre- and post-pumping water level measured the weeks before and after pumping. A total of eight wells were monitored and reported by Holladay. These wells included the pumping well (Eaglefield #2) and seven observation wells. The four observation wells that responded during the test include Legacy well #1, United Water Idaho State and Linder wells #1A and #1B, and Ricks Irrigation well. Collectively, the analyses of the data from these five wells comprise the "Eaglefield test." Three other monitored wells did not appear to respond to pumping during the test. These wells included the Strata #1A and #1B wells, and the Quarter Circle D. J. Ranch well #4. The non-responding wells are not discussed in this report.

The average pumping rate over the 7-day pumping period was 1,580 gpm. Drawdown in the pumped well (Eaglefield Well #2) was 20.91 ft, for an end-of-test specific capacity[12] of 75.6 gpm/ft. Observation wells showing response to pumping indicated maximum

[12] Specific Capacity is the rate of withdrawal (often in gpm) divided by the amount of drawdown (often in feet). Specific capacity is not a constant for a given well; rather it varies as a function of pumping rate, length of the pumping period, previous pumping history, and deterioration of the well over time. Nonetheless it gives a *general* indication of the potential productivity of a well.

drawdowns of 5.67 to 1.09 feet, generally decreasing with the distance from the pumped well. Pumping at Eaglefield #2 during the test well did not appear to affect any of the measured wells completed at depths shallower than 100 feet.

The analyses of the data were first presented by Holladay (2006) and later by SPF Water Engineering (SPF, 2007). Holladay collected the data using electronic data loggers. Hand-measured water-level data were collected but not presented in the reports. The collected electronic data were presented as linear graphs and tables. Holladay also collected atmospheric pressure data to convert non-vented pressure transducer data into water level data. They were also collected to allow for barometric efficiency corrections to adjust the collected data for atmospheric effects.

Pretest data were not, however, used to generate barometric efficiency corrections to remove the effects of water level fluctuations caused solely by changes in atmospheric pressure. The pretest data also were not used to assess antecedent water-level trends unrelated to test pumping that may have affected water levels during the test. All monitored wells were affected by antecedent trends. The Eaglefield #2 well was pumped four times just before the test and was not allowed to fully recovery, thereby affecting the test data. In addition, daily fluctuations in water levels of up to two feet were observed in all the data collected from the Eaglefield well, including the week before and after the test started. All of these fluctuations occurred at the same general daily time-frame: peaks occurred during early evening and troughs occurred during early morning. The Legacy well was also allowed to discharge (under artesian pressure) just before the test affecting the test data. Because of these discharge events, the data were compromised such that the analytical results should be considered less accurate than they should have been.

Holladay analyzed the pumping well (Eaglefield) and three of the of the wells (the Legacy well, and UWID State and Linder wells #1A and #1B) using computer software for pumping test analyses developed by Waterloo Hydrogeologic. In their analyses, Holladay assumed a uniform aquifer thickness of 100 feet, however, the actual aquifer is as much as 500 feet thick, as measured in several observation wells in the area. Partial penetration corrections were not applied as would benefit the analysis for a pumping well that is open to less than 20 percent of the full thickness of the aquifer. Log-time vs. log-drawdown plots of the data were analyzed using automated software (AquiferTest 4.0) following the Theis (1935) method. In many cases, the automated software did not generate good matches between the plotted data and the type curves (used to quantify the aquifer parameters of transmissivity and storativity). The discrepancies between the observed data and the type curves were not discussed in the report. Semi-log, Cooper-Jacob plots were presented, but without analysis. Holladay presented a table of transmissivities and storativities for the four analyzed wells, along with average values, which we included in our Table 3 (page 247).

The data from the Eaglefield Seven-Day test were subsequently reanalyzed through a joint effort by Holladay Engineering and SPF Water Engineers (2007). The reanalysis (termed the SPF report for convenience, below) was directed by IDWR to augment the original analysis presented at a water right hearing. The SPF report generally followed

the same procedures and methods of the initial report, but provided additional detail on the analyses. In addition to the straight-line Cooper-Jacob and log-log Theis analyses of drawdown data, semi-log plots and analyses of water-level-recovery data were also presented. The report stated that alternative methods of analysis "were considered" to explore for the possible effects of leakage (such as described in Hantush, 1955, 1960 and 1964) but were dismissed because of the complexity of the aquifer system and the fact that ignoring leakage would be more "conservative."

The SPF report also stated that analyses and corrections for barometric effects and antecedent water-level trends were considered but dismissed because "confounding factors such as well interference in some wells and inconsistent water-level responses to possible barometric effects minimized the value of these corrections." Partial penetration effects and possible corrections were not discussed. As Holladay had done, The SPF report also assumed a 100-ft thick aquifer.

The Holladay and SPF reports indicated a range of aquifer hydraulic coefficients. Transmissivity coefficients ranged from 1.3 to 1.5 $x10^5$ gallons per day per foot (gpd/ft) in the Holladay report and from $7.5x10^4$ to $2.8x10^5$ gpd/ft in the SPF report. Storativity ranged from $7.8x10^{-4}$ to $1.6x10^{-2}$ in Holladay and from $5.5x10^{-4}$ to $1.5x10^{-2}$ in SPF. In several cases (more so in SPF), two or three values of transmissivity were reported for one well based on analyses of different portions of the plotted drawdown curve. No discussion was presented to indicate what the different transmissivity values represented or which values were most representative of actual aquifer conditions.

One issue that concerns us with the test was the diurnal variations in water level observed in the pumping well drawdown data. The SPF report noted these diurnal fluctuations in the pumping well data but suggested they may have resulted from a partially blocked transducer vent tube. They also indicated that the fluctuations in water level were not observed in any of the other wells monitored during the test, and that the fluctuations occurred during the week before the test started.

We believe the water level fluctuations observed in the pumped well were unlikely to be caused by a partially blocked transducer vent tube. The daily variations in water level in the Eaglefield well were on the order of 2 feet while the recorded barometric fluctuations recorded during the test were less than 0.3 feet. A totally blocked transducer tube would have resulted in fluctuations equal to the changes in atmospheric pressure, a partially blocked tube would have caused fluctuations even smaller. Since the recorded barometric changes were less than 0.3 feet (of water), the fluctuations in water level in the Eaglefield well should have been 0.3 feet or less and not the 2 feet reported during the test. Our explanation for the variations is discussed in the following section.

HLI Analysis of Pumping Test

A seven-day pumping test was conducted by Holladay Engineering (2006) using the City of Eagle, Eaglefield well #2 as the pumping well along with eight reported observation wells. Pumping occurred June 2-9, 2006 with pre- and post-pumping water levels

measured the weeks before and after pumping. The well was pumped at an average rate of 1,580 gpm with a maximum drawdown of 20.91 feet for an end-of-test specific capacity of 75.6 gpm/ft. Observation wells showing response to pumping indicated maximum drawdowns of 5.67 to 1.09 feet, generally decreasing with the distance from the pumped well. Pumping at Eaglefield #2 during the test did not appear to affect any of the measured wells completed at depths shallower than 100 feet. Since these wells are not completed in the Pierce Gulch Sand Aquifer, this lack of response is expected.

The data presented as part of the Holladay report were reanalyzed after careful review of geologic and well construction information available from the report and other sources. We also reviewed information on the elevation contours of the bottom of the Pierce Gulch Sand Aquifer in the overall study area as presented in HLI (2007). The geologic and elevation data indicate that the four observation wells selected by HLI for reanalysis and the Eaglefield #2 pumping well all are completed in the Pierce Gulch Sand Aquifer. The data for the pumping well and the four observation wells are included in Table 3. Well locations are shown in Figure 1 (page 10). The table shows that the pumping well is completed in a portion of the Pierce Gulch Sand Aquifer between 260 ft and 395 ft bgl.

Geophysical and lithologic logging of one of the observations wells (UWID State and Linder) indicates an aquifer thickness of over 500 feet. Similar geophysical logging at Star Well #1 and other locations in the greater Eagle-Star vicinity have helped to define the spatial configuration of the base of the aquifer (HLI, 2007). Within the area that includes the pumped and observation wells monitored during the Eaglefield test, the base of the Pierce Gulch Sand Aquifer lies at depths of 675 to 735 feet. This geophysical information and geologic materials data on Well Driller's Reports for wells in the area indicate the top of the aquifer lies at depths of 175 feet (Legacy Well) and 260 feet (Ricks Well). Thus, the aquifer thickness ranges from about 416 to 525 feet. For our analysis, we have assumed a representative thickness of 500 feet.

This thickness of 500 feet is considerably greater than the thickness of 100 feet assumed in the Holladay and SPF analyses, although SPF did indicate that the UWID wells "penetrate a more extensive and consistent sand sequence" than the Eaglefield and Legacy wells (neither of which penetrated the bottom of the aquifer).

All of the Well Driller's Reports and geophysical logs for wells in the area indicate stratified sediments (layers of sand, silt and clay) throughout the aquifer. Because of this layering, we have assumed that the overall behavior of the aquifer is anisotropic with bulk vertical hydraulic conductivities less than bulk horizontal conductivities. Because of this layering, we have assumed an effective vertical-to-horizontal anisotropy of 0.1 in all our analyses for wells measured as part of this test. Sensitivity analyses comparing the effects of using anisotropies ranging from 1 to 0.001 in the analyses show that transmissivity values vary by a few percent to a few tens of percent, depending on the degree of partial penetration and distance from the pumping well. We believe that an anisotropy value of 0.1 best represents effective bulk aquifer conditions where clay layers interbedded with sand layers are thin, discontinuous and varying in permeability. Anisotropy is indirectly included in Cooper-Jacob analyses only when partial penetration

corrections following the method of Butler (1957) are employed. It was, however, directly included in all the type-curve matching methods discussed below.

We did not correct the data to remove the effects of atmospheric pressure changes. Data were not presented in either the Holladay or SPF reports to accurately quantify barometric efficiency, a parameter needed to remove barometric effects. A period of non-pumping coupled with numerous and simultaneous measurements of both water levels and atmospheric pressure are needed to calculate barometric efficiency. (This topic is addressed in greater detail in Section Five of this report, starting on page 195.) The drawdown data for the pumping well and four observation wells are plotted in Figures 3 through 11. Well locations are included in Figure 2, page 42.

Eaglefield Well #2 (Pumping Well)

The Eaglefield well served as the pumping well during this test. It is screened from 345 to 425 feet below ground surface. It was pumped at 1,580 gpm for a period of 7 days. The maximum drawdown experienced by this well during the test was 20.91 feet for an end-of-test specific capacity of 75.6 gpm/ft. These details along with other pertinent data are included in Table 3. This well is located in Figure 2 (page 42) as a red diamond with a solid boundary.

The pumping well (Eaglefield #2) analyses are shown in Figure 3 (Cooper-Jacob semi-log plot of drawdown on page 43) and Figure 4 (Theis semi-log plot of drawdown on page 44). The pumping rate for this well varied during the first 10 minutes of the test as shown by the rise, fall and subsequent rise of drawdown levels in both figures. Middle-time data (200 to 1,200 minutes) show a sharp rise and then decline in drawdown while late-time data (after 1,200 minutes) show a substantial increase in drawdown (about 5 feet) above the projection of the type curves along with a cyclic rise and fall. A rise and fall in the level during middle and late time suggests that a pumping well in the vicinity was pumping either at varying rates or going through daily on and off cycles, causing the water level variations. The effect of this unknown pumping well reduces the value of the data collected after the beginning of the test. The variations in initial pumping make the data obtained during the first 10 minutes of little value.

The derivative plots for both the Cooper-Jacob and Theis analyses only match the type derivative curve over the period from about 20 to 80 minutes. The irregularity of pumping before this time and the effects of possible aquifer heterogeneity, faults and/or the effects of an unknown pumping well make the data collected over the 20 to 80 minute period the only useful data for quantitative analysis of transmissivity. Thus, we have only used the data collected from this period in our transmissivity analysis.

The semi-log Cooper-Jacob method using uncorrected data applied to the middle-time data (20 to 80 minutes) shown in Figure 3 indicates a transmissivity (T) of 200,000 gallons per day per foot (gpd/ft.) An analysis using Butler (1957) approximate-corrections for partial penetration results in a transmissivity of 800,000 gpd/ft or about 4 times greater than the analysis using uncorrected data. These values define the likely

range for transmissivity of the Pierce Gulch Sand Aquifer near the Eaglefield well. Since a pumping well can only indicate transmissivity and not storativity, no storativity values were calculated.

A semi-log Theis analysis (including corrections for partial penetration effects following the method of Hantush (1961a and b); and the potential effects of the fault boundary depicted in Figure 1, using image well theory) is shown in Figure 4. Initially, a log-log plot was generated, but the type curve for times after 10 minutes of pumping was too flat for an accurate match. The semi-log plot for the 20 to 80 minute time period, however, generated a relatively steep curve allowing us to better match the data than we could using the flatter curve of the log-log plot. The semi-log curve that includes partial penetration effects indicates a transmissivity of 850,000 gpd/ft (Figure 4). Performing the analysis without corrections for partial penetration indicates a transmissivity of about 200,000 gpd/ft (curve not shown), indicating the relative importance of applying the Hantush corrections in the analysis.

The Theis method has an inherent potential for error when used to analyze pumping well data because well loss[13] causes a portion of the drawdown in the pumped well. To address this issue we reanalyzed the data subtracting an estimated, upper-end (and relatively large) well loss to compare the results for the analysis without well loss. Both data plots are shown on Figure 4. Because no stepped-discharge-rate-test and associated data were included in the report, we have assumed that the upper-end value for well loss (which goes to zero after pumping stops) was equal to the recovery that occurred during the first 30 seconds after pumping stopped defines; a value of 5 ft. A second approach to define the upper end of well loss was to assume that most of the drawdown observed during the very beginning of pumping was caused by well loss. The projection of the raw-data drawdown at t = 1 minute in Figure 4 shows that a well loss of 5 ft would represent more than 80 percent of the observed drawdown at this time. Since this estimated maximum well loss is likely larger than the well loss that actually occurred, it defines the upper end value for actual well loss. When incorporated into the Theis analysis, this upper-end well loss defines the upper end of the range for actual transmissivity of the aquifer.

In our comparative analysis, we subtracted 5 feet from all the drawdown measurements for the pumping well to simulate the effect of removing well loss effects. The analysis using this assumed well loss indicates a transmissivity of 1,000,000 gpd/ft, a result that is about 18 percent greater than the 850,000 gpd/ft calculated without considering well loss. Since the 5 feet of well loss is likely too large, we believe that actual value of transmissivity is closer to 850,000 gpd/ft than 1,000,000 gpd/ft. We also believe that closeness of the results of these two analyses demonstrates that a Theis analysis that does

[13] Well loss is the drawdown in a pumping well caused by frictional head loss as water flows at relatively high velocities through the constrictions of a well screen, filter pack, and low-permeability materials just outside the well bore not removed through the well development process. It is considered to be a constant for a non-varying pumping rate such as that maintained during a pumping test. In other words, as long as the pumping rate remains constant and the well does not experience additional development during the test, well loss will remain at a constant value throughout the test, no matter how long it is.

not remove the effects of well loss, even when extreme, still indicates a reasonable approximation of transmissivity. It also indicates that a Theis analysis that includes corrections for the effects of partial penetration (when significant, as they are in the Eaglefield well) better represents true full-aquifer-thickness transmissivity than does the Cooper-Jacob method without partial penetration corrections.

With partial-penetration corrections, both the Theis and Cooper-Jacob methods indicate similar results. A comparison of partial penetration correction methods was made to help verify the validity of the Butler method (which, strictly speaking, applies to steady-state analyses and not transient analyses). When we conducted a Theis analysis using data adjusted for partial penetration using the Butler method and conducted an Aqtesolv® analysis without the Hantush corrections (analysis as if the well fully penetrated the aquifer) a transmissivity of 760,000 gpd/ft was indicated (Figure 5 – page 45).

Figure 6 (page 46) shows a plot of residual drawdowns for the Eaglefield well after pumping ceased. The recovery plot shows a straight-line between t/t' = 100 and 2,000, (the equivalent of 6 to 180 minutes after pumping stopped). After 180 minutes of recovery the effects of the unknown pumping well caused residual drawdown to vary in a cyclic manner similar to that observed during pumping. The straight-line plot using the raw data (without corrections for partial penetration) indicates a transmissivity of about 200,000 gpd/ft. With the Butler (1957) corrections applied, a transmissivity of 800,000 gpd/ft is indicated, a value that is similar to the drawdown analyses using the Theis method and the Cooper-Jacob method using partial penetration corrections.

The transmissivities calculated from all analyses of the data from the Eaglefield well ranged from 200,000 gpd/ft to about 1,000,000 gpd/ft. The lower-end values were derived from analyses that were based on the assumption that the screened interval was approximately equal to the thickness of the aquifer. In other words: an approximately 100-foot thick Pierce Gulch Sand Aquifer near the Eaglefield well had a transmissivity of about 200,000 gpd/ft. The developer of Aqtesolv® (G. Duffield, personal communication, January 2008) indicated that a Cooper-Jacob analysis without corrections for partial penetration, using short-term data from a pumping well in a stratified aquifer (layers of higher and lower permeability), is likely to indicate the transmissivity of just the zone pumped. We believe that the uncorrected result is representative of the portion of the aquifer screened by the well and that this transmissivity is appropriate for analyses evaluating short-term drawdown in the pumping well.

The Pierce Gulch Sand Aquifer, however, is considerably thicker than 100 feet. Therefore, analyses designed to evaluate "big-picture" water supply and pumping impacts to other water users in the area would likely be compromised, were this transmissivity value to be used to represent the entire thickness of the Pierce Gulch Sand Aquifer. We believe analyses using the appropriate corrections for partial penetration (Hantush for the Theis analyses and Butler for the semi-log analyses) better represent the entire aquifer thickness of 500 feet. These corrected analyses indicate a transmissivity of about 800,000 gpd/ft.

Legacy Well #1 (Observation Well)

Legacy Well #1 is located approximately1,605 feet to the northwest of the pumping (Eaglefield) well. It is screened from 282 to 352 feet below ground surface. The maximum drawdown experienced by this well during the test was 2.73 feet. These details are included in Table 3. Its location is shown in Figure 2 as a green diamond with a dashed boundary.

Figure 7 (page 47) show HLI's Theis (1935) analysis for the Legacy well # 1, the nearest observation well during the test. The analyses indicate a transmissivity of 100,000 gpd/ft, with a storativity of $1x10^{-2}$. This analysis was generated based on pretest trend-corrected data using the following method: we evaluated the changes in water level that occurred during the two hours before the test and calculated a linear trend corresponding to a decline in water level of 0.12 ft/day. Applying this correction generated the drawdown points shown by larger black diamonds in Figure 7. (No realistic curve match could be made to the uncorrected data - shown by small blue circles- as the apparent initial drawdown change was too rapid. A value of about 4,000 gpd/ft – typical of a sand aquifer only 10 feet thick was possible matching the raw data from 400 to 500 minutes, a value that is incompatible with the known geology of the area).

The Theis analysis also included corrections for the effects of partial penetration (which are minimal at this distance from the pumping well) and the potential hydraulic effects of the fault (no-flow boundary) shown in Figure 1 (which are also minimal at this distance). Barometric corrections could not be applied as the rising, antecedent water level trend masked possible barometric effects. Our attempt to use barometric and water level data collected at one-minute intervals from the period May 25 through 31, 2006 (not shown) indicated a *negative* correlation (water level rose with an increase in barometric pressure) which would occur in a confined artesian aquifer were changes in atmospheric pressure the only causes of the changes in water levels in the well. The water level rise during a period when atmospheric pressure increased indicated that barometric effects were overshadowed and obscured by the antecedent trend.

The derivative analysis indicates the Theis-curve match is relatively good up to about 500 minutes. After this time, the data plot below the type curve, suggesting that the cone of depression expanded outward from the pumping well to intersect a positive (recharge) boundary. This boundary could be a portion of the aquifer containing materials with higher permeability and/or higher storativity, although other sources of water (such as leakage) are possible.

The daily variations at the magnitude observed in the Eaglefield well (about 2 feet) were not directly observed in the Legacy well. Small water level variations in the Legacy well of less than 0.1 foot were observed, however. The different timing and smaller magnitude of these variations suggests a different source than that which affected the Eaglefield well. These effects are discussed further (along with similar effects seen in the other analyzed observation-well data) on page 35.

A semi-log Hantush-Jacob analysis using the antecedent-trend-corrected data is shown in Figure 8 (page 48). The transmissivity and storativity values for this match are the same as for the Theis analysis. A relatively small leakage factor (r/B) of 4.6×10^{-4} ft $^{-1}$ was calculated. Normally, a leaky system would result in a drawdown curve that totally flattened out after extended pumping. Only a slight flattening was observed in the data, suggesting only small amounts leakage. Since leakage was not observed at other wells analyzed as part of this test, leakage would have to be localized to aquifer in the vicinity of the Legacy well. We therefore believe that variations in aquifer transmissivity are a better explanation for the drawdown curve for the Legacy well than is significant leakage.

The two Legacy analyses indicate a storativity of 1×10^{-2}, an unrealistically large value for such a deep well/aquifer system. We believe that the indicated storativity value is likely incorrect. Storativity calculations are based on the assumption that the aquifer is homogeneous (uniform transmissivity). In cases where the transmissivity varies at different locations within an aquifer (the aquifer is heterogeneous), it is likely that the calculated storativity will be incorrect. In addition, the trend correction applied to the data was only based on the two hours before the test started and can only be an approximation. Because the Legacy well was allowed to discharge under artesian pressure shortly before the test started, it was still recovering. An observation well undergoing recovery will indicate an incorrect storativity because the timing of the apparent initial indication of drawdown (a critical factor in the storativity analysis) will not be the true timing that would have occurred were the well fully recovered. Therefore, we do not believe that the aquifer behaves as an unconfined aquifer at this location, as would be suggested by a storativity of 10^{-2}.

Because of the need to adjust the raw data, the recovery of the well at the time of test startup, and the apparently large short-term storativity, we believe our analyses for the Legacy well data must be considered approximations.

United Water Idaho State and Linder Test Well (Observation Wells)

The United Water Idaho, Inc. (UWID) State and Linder well located near the intersection of State and Linder Streets has two small diameter wells ("piezometers") completed at different depths within the same borehole. Well #1A is completed at depths of 280-370 ft bgl and well #1B is completed a depths of 400-490ft bgl. Since the wells were designed and built to sample water quality and not necessarily to monitor water levels in different aquifers, a seal was not installed between the two completion intervals in the common bore hole. Both wells, however, are completed in the Pierce Gulch Sand Aquifer, as is the Eaglefield pumping well.

Figures 9 and 10 (pages 49 and 50) show Theis analyses for the two wells. The analyses indicate a transmissivity of 500,000 gpd/ft (well #1A) and 400,000 gpd/ft (well #1B) for an average of 450,000 gpd/ft. Both plots show a good match for early time data (before 80 to 90 minutes, as indicated by the derivative analysis). After this time the drawdown plots for both wells rise significantly above the type curve (more drawdown than

predicted), likely indicating the effects of a lower transmissivity zone affecting drawdown. We have ruled out the West-Boise-Eagle fault acting as a no-flow boundary as the cause of this increased drawdown because performing the type-curve analysis both with and without the no-flow-boundary effects of the fault are, for all practical purposes, identical, indicating the fault lies too far from the monitored wells to cause measurable interference. None-the-less, the effects of this boundary are included in the type curve shown in Figures 9 and 10.

We have also considered the possibility of a more localized, unknown fault or faults acting as one or more no-flow boundaries within the Pierce Gulch Sand Aquifer. Using Aqtesolv®, we experimented by placing a fault and multiple faults at various locations (based in part on projection of a fault indicated by a magnetometer survey on the M3 property as shown on Figure 1, page 10) relative to the pumping well to see if we could generate a response similar to those observed in the two UWID wells. We were unable to generate a reasonable match, perhaps in part to the effects of the unknown pumping well. If such a fault or fault system exists, we were unable to model it with Aqtesolv®.

Butler (1988) analyses were conducted to help assess the possible effects of non-uniformity of the aquifer. This method of analysis incorporates two zones of transmissivity: one around the pumping well and one further away. The high value of transmissivity indicated for the area near the pumping well (900,000 gpd/ft) and the lower value indicated by the Legacy well (100,000 gpd/ft) suggest that two such zones may be present within the aquifer. The Butler analyses for State and Linder well #1A (Figure 11 page 51) and well #1B (Figure 12 page 52) support the assumptions of varying transmissivity. Our Butler analyses indicate a near-pumping-well transmissivity of about 1,300,000 to 1,600,000 gpd/ft with a lower, away-from-pumping well value of 84,000 gpd/ft. The radius of the contact between the zones is unknown and has to be estimated. Since the two zones are unlikely to be cylindrical (as assumed in the method), these values can only be general guidelines to actual aquifer conditions. The average of these four Butler-derived values is about 790,000 gpd/ft, or approximately the same as the value indicated by the Theis analysis for the pumped well. Since the Theis method is based on the assumption of a homogeneous aquifer, the correlation between the value indicated by the Theis method and the average of the values indicated by the Butler method, suggests that both methods may roughly indicate average aquifer properties.

The derivative analysis for these two wells indicates the Butler method fits the data up through about 1,000 minutes. Deviations from the type curve after this time are probably caused by inconsistencies between the assumptions of the Butler method and actual aquifer conditions/properties.

Storativities indicated by the Theis and Butler analyses for the State and Linder wells range from 1.3×10^{-3} to 3.7×10^{-3}. The mean of these values to one significant figure is 2×10^{-3}, a value that we believe to be representative for the Pierce Gulch Sand Aquifer in the vicinity of the Eaglefield/State and Linder/Legacy wells.

The large differences between the indicated transmissivities of the aquifer zone near the pumped well and the aquifer zone near the UWID well, and the differences in the results of the Theis and Butler analysis, suggest that neither the Butler nor Theis model accurately fit the aquifer system in the vicinity of the Eaglefield and State and Linder wells; the Theis model assumes a uniform aquifer while the Butler model assumes a two-zone system with a sharp demarcation between the zones and the centering of the pumping well in a cylindrical, inner zone. In reality, there are likely non-cylindrical variations in transmissivity throughout the aquifer. For this reason, we believe the results are only approximate and are therefore presenting transmissivity and storativity rounded to one significant figure, based on both the Theis and Butler analyses.

Ricks Irrigation Well (Observation Well)

Figure 13 (page 53) shows a Theis analysis for "Ricks Irrigation well" which lies 3,340 feet north-northwest from the Eaglefield well. The small drawdown at the Ricks Irrigation well caused by pumping the Eaglefield well coupled with the relatively large drawdown and cyclic interference caused by an unknown pumping well made an accurate curve match impossible. The derivative analysis indicates that any results indicated by the rough, apparent fit of the type curve to the data, are invalid. No meaningful calculations of transmissivity and storativity are possible with these data. A Cooper-Jacob analyses was performed but is not presented here because the distance of the Ricks Irrigation well from the Eaglefield well meant the "u assumption" was not met for the analysis until long after the unknown well interfered with water levels at the Ricks Irrigation well.

Even though no quantitative analysis for aquifer properties is possible with the Ricks well data, they are valuable in that they show the interference from an unknown pumping well. Figure 13 shows that the effects of an unknown pumping well appear to be much larger than the drawdown effects caused solely by pumping at the Eaglefield well, suggesting that the unknown well lies closer to the Ricks well than any of the other wells discussed in this section of the report. This interference is discussed further, in the next section of the report.

Rhythmic Variations in Water Levels

All of the wells analyzed by HLI indicated a rhythmic variation in water levels during the test. We believe that the cause or causes of this variation could be: a) interference by a nearby pumping well, b) variations in barometric pressure, and/or c) a malfunction of the data-logger. Based on our analysis below, we believe that the rhythmic variation in water levels on the order of 0.1 ft observed in the observation wells was caused by variations in barometric pressure. The cause of the larger variations observed in the pumping well is not clear and could be interference from an unknown well and/or malfunction of the data logger, possibly related to incorrect temperature compensation.

All of the wells analyzed by HLI indicate a rhythmic variation in water level. Such variation could, in theory, have been caused by a nearby, high-capacity well pumping

during the test. A review of the IDWR files for Well Driller's Reports indicates at least six irrigation wells capable of pumping at around 1,000 gpm or more are recorded for the nine sections adjacent to, and including, the test well. It is not known if any of these irrigation wells were being pumped during the Eaglefield test. In addition, two municipal suppliers may have been pumping during the test: United Water Idaho (Redwood Creek and Floating Feather Wells) and the Eagle Water Company (numerous wells). Of these, the Redwood Creek well lies closest to the monitored wells. The Redwood Creek well is located about 1-½ miles to the east of the Eaglefield well.

In order to better evaluate the possible causes of the water-level variations, we assessed the data with the Eaglefield drawdown-effects (inference) removed. We then compared the water-level variations that remained with changes in atmospheric pressure (to assess the potential for barometric effects) and with timing (to see if the changes correlated to time of day and therefore to a possible pumping schedule of a nearby well or with some other factor such as temperature). The following procedure was used: drawdown data from the last four days of the test were plotted. We then generated a logarithmic curve to best-fit the data plot. This logarithmic curve represents the approximate drawdown caused by pumping at the Eaglefield well. The differences between the logarithmic curve and the actual drawdowns were then plotted along with atmospheric pressure recorded at 10 minute intervals. Lastly, the variations observed in the Eaglefield well were scaled to 20-percent of actual, to allow all plots to fit on the same graph. The results - variations in water levels *not* caused by pumping at the Eaglefield well, are graphed on Figure 14 (page 54).

The figure shows that water level variations in the observation wells track changes in atmospheric pressure, with no discernable time lag. Based on this close tracking, we believe that the water-level variations in the observation wells are the direct result of barometric effects. In fact, the magnitude of the variations in these wells gives a general indication of barometric efficiency. The magnitude of the variations in water levels in the Legacy and State and Linder wells is about 50-percent of the variation observed in atmospheric pressure, indicating a barometric efficiency of about 50 percent. The Ricks Irrigation well demonstrates a similar, but smaller (about 30-percent) barometric efficiency. The variations observed in the Eaglefield well do not correlate at all with changes in atmospheric pressure. The changes are opposite in direction and about ten-times greater than the changes in atmospheric pressure. The variations must therefore be related to another cause.

Figure 14 shows that the variations in water levels in the Eaglefield well correlate to the time of day. The highest levels occur around 6 AM with the lowest levels occurring around 3 PM to 7 PM. (We note a similar timing in the pretest data included in the SPF (2007) report) The timing suggests interference from a well pumping only during the day and/or to daytime heat causing an error in the readings collected by the electronic data logger. We do not know which of these is the actual cause of the variation.

If the cause were a nearby pumping well, we would expect a similar variation to be observed in other wells, but such a variation was not seen. The lack of a response in the

other wells would suggest that any unknown pumping well would have to be located very close to the Eaglefield well and far from the other wells. No such well is known in the near-vicinity of the Eaglefield well. The variation could, in theory, have been caused by some other factor related to time of day, such as temperature. However, the submersion of the data logger transducer in the well would dampen daily temperature changes which would have occurred. In addition, most data loggers correct for temperature variations. For the daily two-foot variations to have been the result of incorrect temperature compensation, the data logger would have to have been severely compromised.

Figure 14 does, however, appear to indicate the presence of an unknown pumping well near Ricks Irrigation well. The sharp increase in drawdown that began during the evening of June 7, suggests local well interference that was not observed in the other wells. The beginning of this interference five days into the test indicates the increase in drawdown was too late into the test to have been caused by the Eaglefield well.

Test Results Summary

In summary, our analyses of the Eaglefield, Legacy and UWID State and Linder wells indicate that the transmissivity of the Pierce Gulch Sand Aquifer varies widely in the tested area. Our analyses indicate that a zone of higher transmissivity appears to be present near the pumping well (Eaglefield) and the UWID State and Linder wells. Near Eaglefield Well #2, the full-thickness aquifer transmissivity may be around 800,000 gpd/ft with values of around 200,000 gpd/ft representative of the middle portion of the aquifer tapped by the Eaglefield well. Full-aquifer-thickness transmissivities of about 100,000 to 400,000 gpd/ft are representative of the aquifer near the UWID State and Linder well site. The Legacy well appears to be completed in a lower-transmissivity portion of the Pierce Gulch Sand Aquifer; a transmissivity of 100,000 gpd/ft was calculated for this portion of the aquifer. The transmissivity near the Ricks well may also be high, possibly approaching the values calculated for the Eaglefield and UWID State and Linder wells. However, the curve matches are so poor that we cannot accurately quantify a value for transmissivity in this area, beyond stating it appears to be high.

The transmissivities calculated for the various wells ranged from about 84,000 gpd/ft to 1,000,000 gpd/ft. Based on this range of calculated transmissivities, we calculated a mean transmissivity for the whole aquifer thickness in the greater Eaglefield vicinity of 460,000 gpd/ft. Some parts of the aquifer (such as near the Eaglefield well) have much higher transmissivities and other parts (such as near the Legacy well) have much lower values.

The transmissivity calculated for the Eaglefield #2 well without any corrections for partial penetration (using the Cooper-Jacob drawdown method for pumping and the Theis straight-line method for recovery) indicated a value around 200,000 gpd/ft. This transmissivity value is comparable to those calculated by previous workers who also did not account for partial penetration. Because of stratification within the aquifer (thin, discontinuous clay layers within the overall sand sequence), short-term pumping (a day or so) causes most of the hydraulic impact to be directed laterally through transmissive

zones at depths similar to that of the screened interval of the pumping well. This concentration of flow within the same depth zone (which only represents about 20 percent of the full thickness of the aquifer) causes gradients to steepen near the well, and water levels within the well to be lower than they would be had the well been screened over the entire aquifer thickness, as is assumed in the methods of Cooper-Jacob and Theis (without Hantush corrections). Thus, the calculated transmissivities using these methods are less than would be calculated using either: 1) a well that fully screened the aquifer or 2) using partial penetration corrections (as we have used) on the well that only screens less than one fifth of the aquifer. The transmissivity indicated by the Cooper-Jacob or Theis (with out Hantush corrections) is most likely representative of just this small vertical portion of the aquifer. When the remaining 420 vertical feet of aquifer (not screened by the pumped well) are taken into account, the average transmissivity value or 460,000 gpd/ft more realistically represents the entire aquifer thickness, than does the 200,000 gpd/ft results of the analyses that did not take into account the effects of the full aquifer thickness.

Storativities calculated from the test data indicate that the westerly portion of the Pierce Gulch Sand Aquifer is confined with a mean calculated value of $2x10^{-3}$.

Based on the transmissivities calculated for each well and the thickness of the aquifer as indicated in the available Drillers' Reports and/or Hydrogeologist's reports, representative aquifer hydraulic conductivities were calculated and are included on Table 3. These values are typical of clean to coarse sands, the types of aquifer materials generally indicated on the available records for the wells.

Well Interference and the Effects of Seasonal Pumping

The mean transmissivity and two end-points to the range of calculated transmissivities were used in a simulation to predict inference effects in the aquifer at distances to almost 4 miles from the Eaglefield #2 well. In this simulation, the Theis method was used to generate drawdown curve as a function of distance from pumping the Eaglefield well #2 at a continuous rate of 1,300 gpm which is the rate that appears likely under the current (April 2008) IDWR water rights decision. The Theis method was selected as it is generally conservative (tending to over estimate drawdown) as it does not consider leakage from overlying zones or the capture of recharge. The calculated mean transmissivity of 460,000 gpd/ft was bracketed by 900,000 gpd/ft (upper end of the range) and 100,000 gpd/ft (lower end of the range) in our analysis along with a storativity of $2x10^{-3}$. An image well was used to simulate the hydraulic effects of the no-flow boundary represented by the West-Boise-Eagle fault.

Our results are presented in Figure 15 (page 55) which shows that at the end of a 90-day summer pumping season, interference drawdowns in the range of 2 to 7 feet are predicted for wells completed in the aquifer, one mile away from the Eaglefield well #2 and may be on the order of 1 to 3 feet up to four miles away. As discussed in the methods section above, this analysis is conservative and likely over-estimates interference; the drawdown cone of depression from the pumping well would probably expand sufficiently to capture

recharge equal to the pumping rate before 90 days, such that the pumping water level in the well would cease to draw down. The Theis analysis assumes no recharge (water pumped by a well comes only from aquifer storage) such that a pumping-well water-level always continue to draw down. In reality (and observed many times, in our experience) the rate of drawdown in a well pumped for 90 days in a hydrogeologic setting like that of the Eaglefield well, typically declines or stops before 90 days.

We consider the predicted interferences to be only an approximation because the Pierce Gulch Sand Aquifer system is not uniform. The actual drawdown that would occur with summer-long pumping will vary from our predictions, depending on the actual properties of the aquifer between the Eaglefield well and a given point of interest. We used a transmissivity of 460,000 gpd/ft in the prediction while calculated transmissivities ranged (to one significant figure) from 100,000 to 900,000 gpd/ft for the five wells discussed above. The non-uniformity of the aquifer was demonstrated by the amounts of maximum drawdowns measured during the test. The Legacy well, which is 1,605 ft from the pumping well, had a maximum drawdown of 2.73 ft while the UWID State and Linder wells which are 2,405 feet from the pumping well had a maximum drawdown of 5.67 ft. Both wells are completed at similar depths and are on-strike with the pumping well (Eaglefield #2) and therefore likely to be completed in the same depth interval of the Pierce Gulch Sand Aquifer. In a uniform system the closer well would have had the larger drawdown. None the less, the prediction gives general guidelines for the amount of interference that would be expected by a large supply well in the Eaglefield area, on other wells completed in the Pierce Gulch Sand Aquifer, in this part of the greater-Eagle vicinity.

Conclusions from the Eaglefield Test

Based on the overview and analysis presented above, we draw the following conclusions:

1. The Eaglefield, UWID State and Linder, Legacy and Ricks Irrigation wells are all completed in the Pierce Gulch Sand Aquifer. This aquifer averages about 500 feet thick but ranges from 416 to 525 feet thick. The top of the aquifer lies at depths of 181 to 260 feet below land surface. These wells are all hydraulically connected to each other.

2. The calculated transmissivities of the Pierce Gulch Sand Aquifer ranged from 100,000 to 900,000 gpd/ft in the vicinity of Eaglefield well #2 with an average (mean) representative value of 460,000 gpd/ft.

3. Storativity values calculated from valid test analyses ranged from 1.3×10^{-3} to 3.7×10^{-3} with a mean value of 2×10^{-3}. Based on these values, the aquifer is considered to be confined in the area containing the pumping and observation wells.

4. The Pierce Gulch Sand Aquifer is highly productive in this area. Well yields greater than 2,000 gpm are possible from properly designed and completed wells.

5. A single production well pumping at 1,300 gpm from this portion of the Pierce Gulch Sand Aquifer is likely to cause drawdowns of about 2 to 7 feet at wells completed over the same depth intervals in the same aquifer, at a distance of one mile, after 90 days of continuous pumping. Drawdowns in wells four miles away are estimated be on the order of 1 to 3 feet, but would likely be less based on the conservative nature of our analysis.

6. The original report by Holladay did not include analysis beyond a general estimate of transmissivity and storativity. Because the Holladay analyses did not incorporate the effects of partial penetration, we believe they under-estimated actual full-aquifer-thickness transmissivities. The newer HLI analyses incorporate the effects of partial penetration and can therefore better represent full-aquifer-thickness conditions, especially with regard to quantifying the total amounts of ground water flow within the full thickness of the aquifer.

7. In a similar manner, SPF also did not include partial penetration effects in their re-analysis of the Holladay pumping-test data. SPF presented a wider range of values for transmissivity and storativity than did Holladay but did not clarify which values they believed to best represent actual aquifer conditions. SPF noted that the aquifer is heterogeneous (non-uniform) and that both positive and negative boundary effects consistent with variations in aquifer characteristics were observable in the plotted drawdown data.

8. In their work, Holladay and SPF did not include derivative analyses to quantify which portions of the data sets would indicate whether the selected method of analysis were likely valid and therefore which portions of the data set were suitable for analysis. Derivative analyses conducted as part of the HLI reanalysis indicated that only the data collected from 20 to 80 minutes into the test were suitable for quantitative analysis of aquifer parameters of transmissivity and storativity using data from the pumping well.

9. Rhythmic variations in water levels were observed in all the wells we analyzed for this test. Small variations on the order of 0.1 ft measured in the observation wells were caused by changes in atmospheric pressure. These variations showed no discernible time lag to, and were about 30 to 50 percent as large as, changes in atmospheric pressure. Water levels varied daily in the pumping well at a much larger magnitude (0.5 ft and more) before, during and after the test with the highest levels occurring around 6 AM and the lowest between 3 and 7 PM. These water-level variations did not correlate with changes in atmospheric pressure. The timing and magnitudes suggests that the variations could have been caused by interference from a nearby pumping well or by an error in the data logger. Similar variations were not observed in the other wells we analyzed as part of this test, indicating that a pumping well causing the variations would have to have been very close to the pumping well. However, no such wells are known in the vicinity of the Eaglefield well. The timing could also suggest that the cause of the

variations could be related to erroneous temperature compensation of the water level data by a malfunctioning data logger. It is not clear, which, if either, of these possible explanations, is valid.

10. Future testing at the Eaglefield Well #2 would better be accomplished with coordination of all major ground water pumpers within 3 miles or more of the pumped well. It would be best to conduct the test during winter when water demand would be relatively low. Ideally, all significant groundwater pumping from the target aquifer (Pierce Gulch Sand Aquifer) would be curtailed before, during and after the pumping test to allow for collection and use of antecedent trend data to correct changes in water levels that are not caused by the pumping well. The test should be preceded by barometric and water level measurements during a non-pumping period to develop barometric corrections for the observation well data. Coordination with all interested parties and significant water users is strongly recommended. The ability to coordinate and conduct such a test grows more difficult with time as more and more wells go into production.

Figure 2. Well Locations for Eaglefield Seven-Day Test

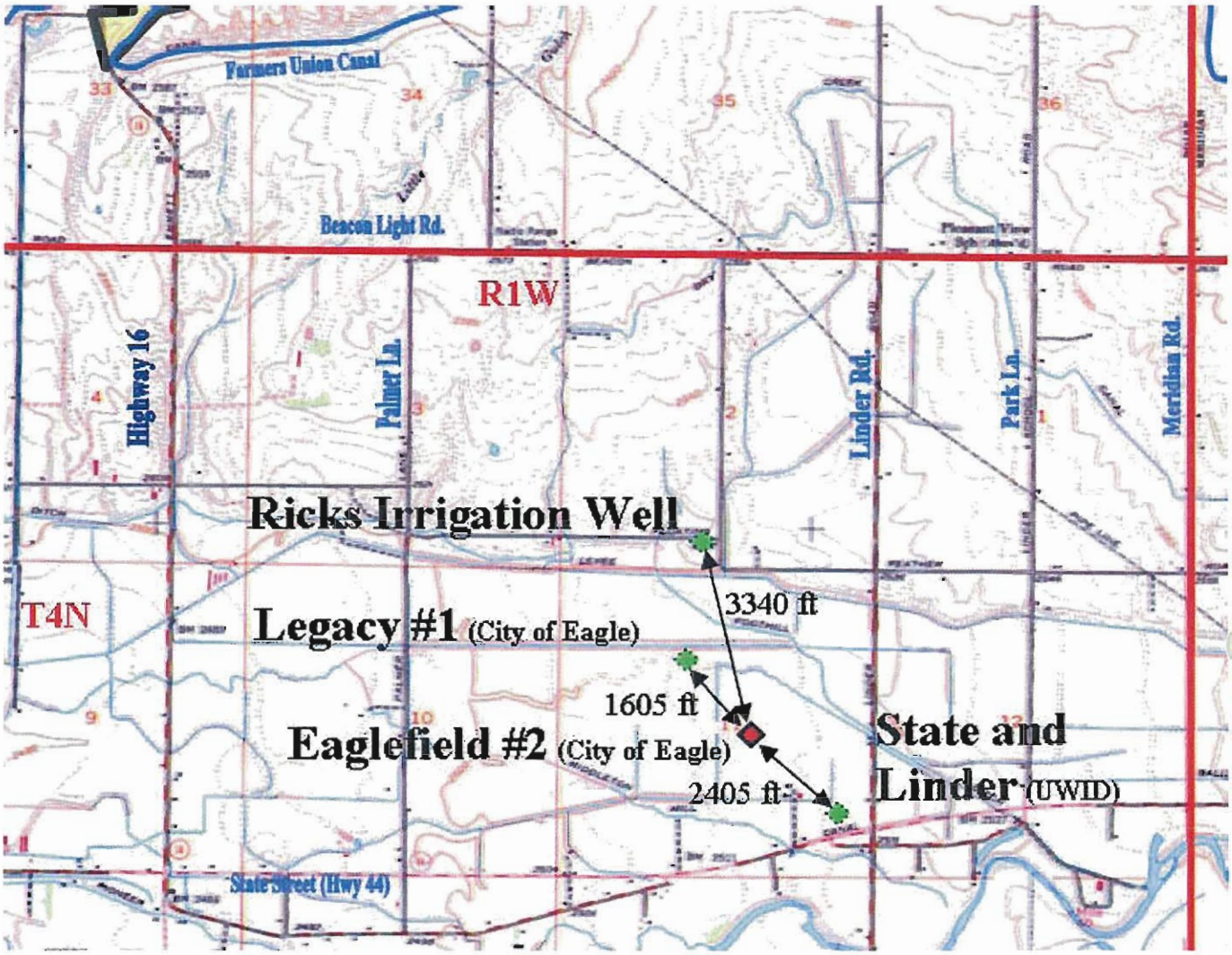
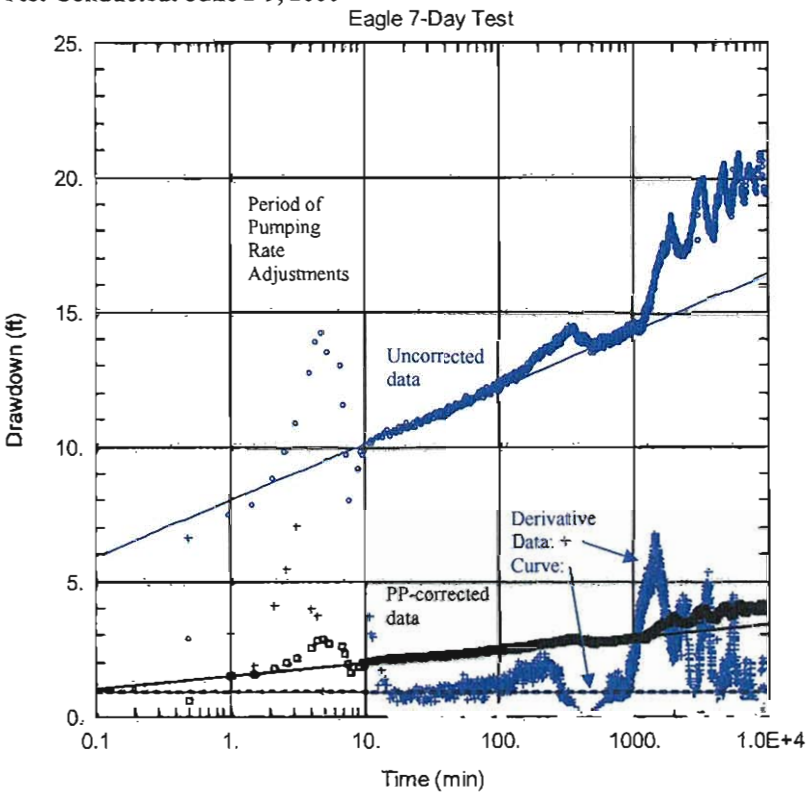


Figure 3. Cooper-Jacob Analysis for Eaglefield Well #2 Seven-Day Test
Test Conducted: June 2-9, 2006



Eaglefield Well # 2
Screen = 345-425 ft
T=200,000 gpd/ft
(no PP corrections)
T=800,000 gpd/ft
(with PP corrections)
S = Not Calculable
Kv/Kh=0.1
b = 500 ft
t_c < 1 min
r = 1 ft
Q = 1,580 gpm

Derivative analysis indicates only data from 20 to 80 min are valid for this method.

Note: local cyclic variations in drawdown and increased drawdown caused by unknown well during late time.

Partial penetration correction suggests calculated T for whole-aquifer thickness may be 4 times greater than calculated value without PP.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

$u = 1.87r^2S/Tt$
t = time in days
r = effective radius of pumping well (ft)

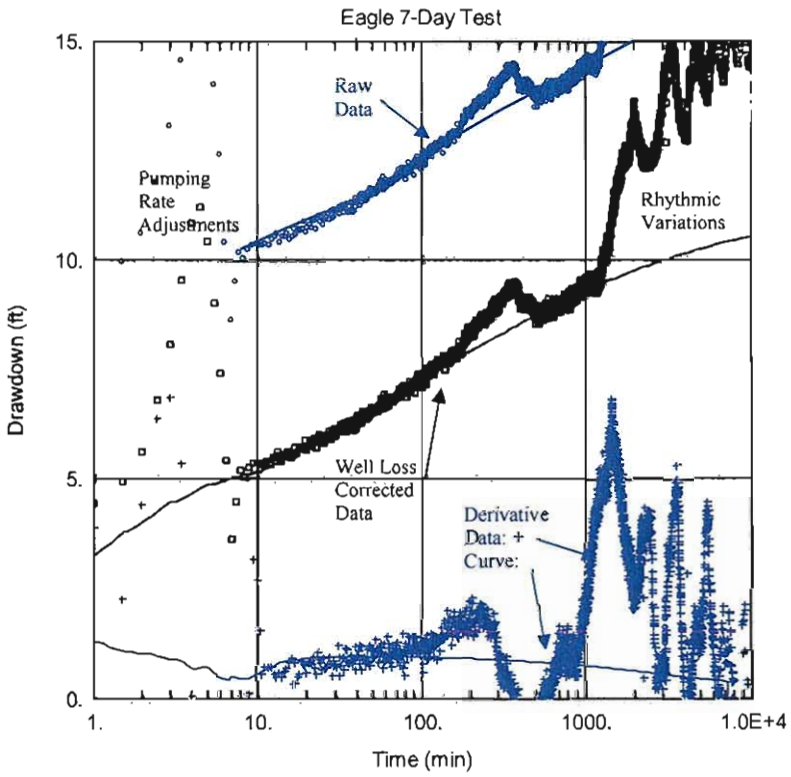
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

$s_{pp} = 0.2\ s_{observed}$ where:

s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Based on the analytical method of Cooper and Jacob (1946).
Partial penetration corrections from Butler (1957).

Figure 4. Semi-Log Theis Analysis with Hantush Corrections for Partial Penetration for Eaglefield Well #2 Seven-Day Test
Test Conducted: June 2-9, 2006



Eaglefield Well # 2
Screen = 345-425 ft
T = 850,000 gpd/ft (no well loss correction)
T ≈ 1,000,000 gpd/ft (w/ well loss correction)
S Not Calculable
Kv/Kh=0.1
Fault (no-flow) at 5 mi.
b = 500 ft
Well Loss $_{(est)}$ **= 5 ft**
r = 1 ft
Q = 1580 gpm

Derivative analysis indicates only data from 20 to 80 min are valid for this method.

No match before 10 minutes because of pumping rate variations. Approximate match 10 to 80 minutes. No match after 80 minutes because of non-uniform aquifer and/or rhythmic variations.

Estimated maximum well loss of 5 ft used in analysis based on first half-minute of recovery (see text for details).

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

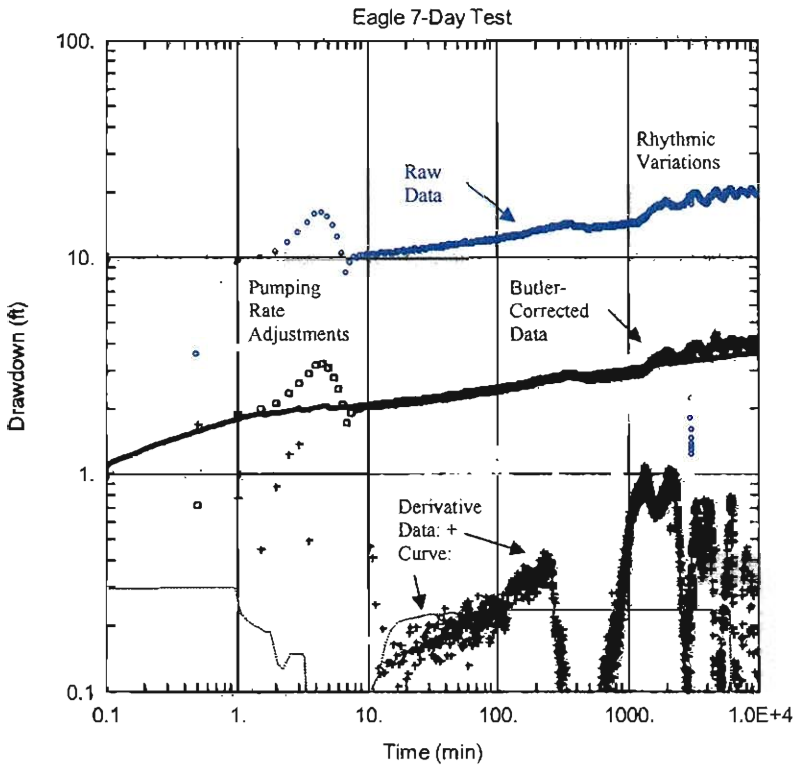
$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown. Variations from "smooth," semi-log curve the result of Aqtesolv® generating type curve based on variations in reported pumping rate. Poor match during early time suggests flawed data.

Based on the analytical method of Theis (1935) with partial penetration corrections of Hantush (1961a and b).

Figure 5. Theis Analysis with Butler Corrections for Partial Penetration for Eaglefield Well #2 Seven-Day Test
Test Conducted: June 2-9, 2006



Eaglefield Well # 2
Screen = 345-425 ft
T = 200,000 gpd/ft (no well loss correction)
T = 760,000 gpd/ft (w/ well loss correction)
S Not Calculable
Kv/Kh=0.1
Fault (no-flow) at 5 mi.
b = 500 ft
r = 1 ft
Q = 1580 gpm

Derivative analysis indicates only data from 20 to 80 min are valid for this method.

No match before 10 minutes because of pumping rate variations. Approximate match 10 to 80 minutes. No match after 80 minutes because of non-uniform aquifer and pumping effects.

Butler corrections to raw data before analysis with well input as fully penetrating.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

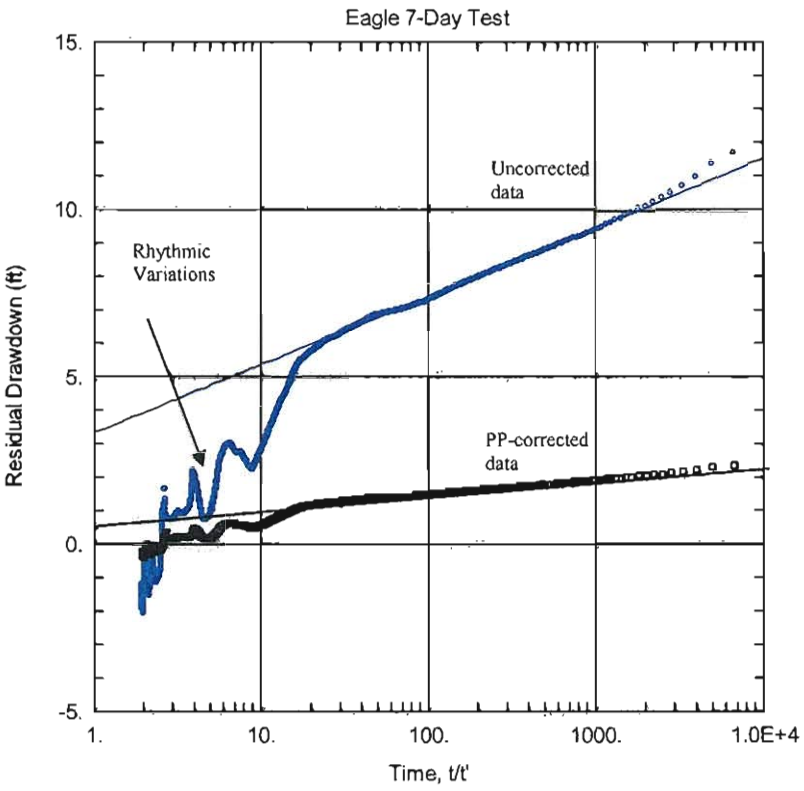
$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area
$s_{pp} = 0.2\ s_{observed}$ where:

s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Solid Line represents "type curve" where T and S best match observed drawdown. Variations from "smooth," semi-log curve the result of Aqtesolv® generating type curve based on variations in reported pumping rate. Poor match during early time suggests flawed data. Based on the analytical method of Theis (1935) with partial penetration corrections of Butler (1957).

Figure 6. Recovery Analysis for Eaglefield Well #2 Seven-Day Test
Test Conducted: June 2-9, 2006



Eaglefield Well # 2
Screen = 345-425 ft
T= 200,000 gpd/ft
(no PP corrections)
T=800,000 gpd/ft
(with PP corrections)
S/S' =0.02
Kv/Kh=0.1
b = 500 ft
r = 1 ft
Q = 1,580 gpm

Poor match during late time (t/t' < 20; equivalent to t > 530 min after pump shutdown). S/S' is incorrect because water level trend not caused by pumping test could not be incorporated into analysis. Note local rhythmic variations during late time.

Partial penetration correction suggests calculated T for whole-aquifer thickness about 4 times greater than calculated value without PP correction.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

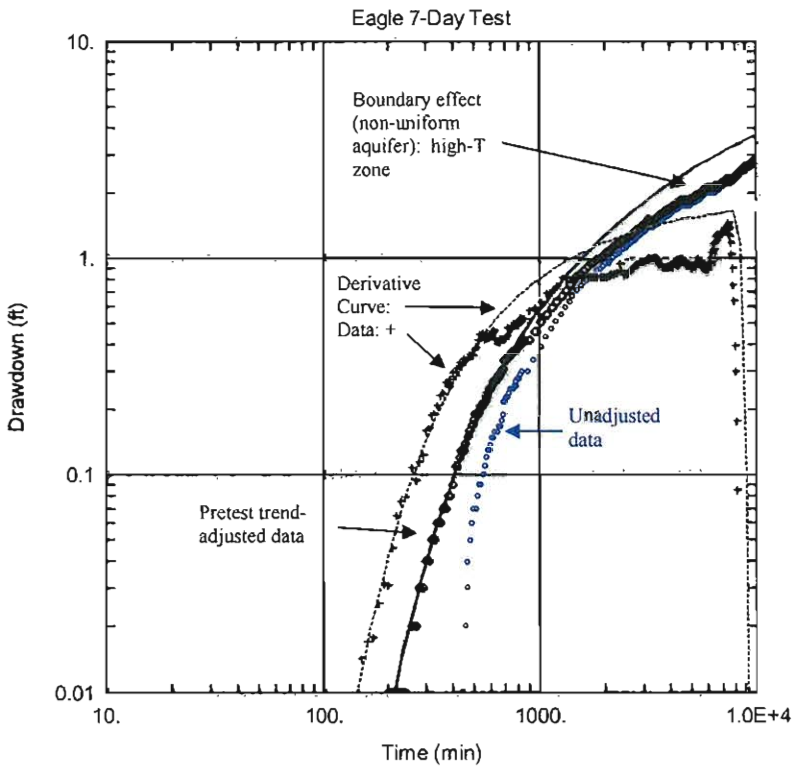
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
r = effective radius of pumping well (ft)

$s_{pp} = 0.2\ s_{observed}$ where:

s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Based on the analytical method of Theis (1935). Partial penetration corrections from Butler (1957).

Figure 7. Theis Analysis for Legacy Well #1 Seven-Day Test
Test Conducted: June 2-9, 2006



Legacy Well #1
Screen = 282-352 ft
T=100,000 gpd/ft
S = $1x10^{-2}$ (likely invalid)
Kv/Kh=0.1
b = 500 ft
Fault (no-flow) at 5 mi.
r = 1,605 ft
Q = 1,580 gpm
(at Eaglefield Well #2)

Derivative analysis indicates only data from before 500 min are valid for this method.

Good match to trend-adjusted data for middle time (t< 500 min), but likely affected by earlier artesian discharge of well just before test. No match possible to unadjusted data.

Positive boundary (higher T zone?) indicated by late-time data. S likely to be incorrect as data were affected by pretest artesian discharge. Late-time drawdown fluctuations caused by barometric effects.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

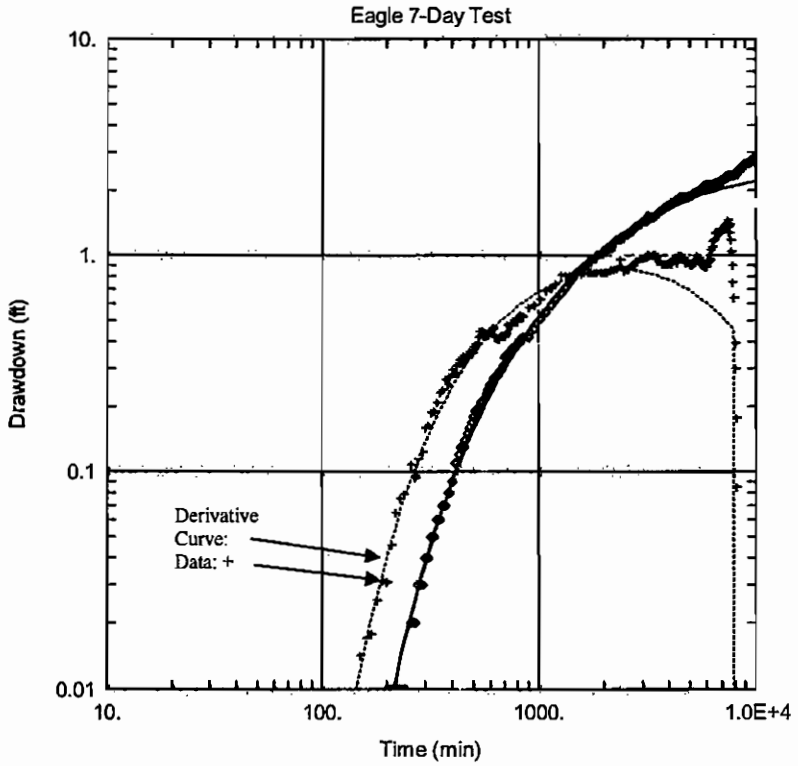
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 8. Hantush-Jacob Analysis for Legacy Well #1 Seven-Day Test
Test Conducted: June 2-9, 2006



Legacy Well #1
Screen = 282-352 ft
T=100,000 gpd/ft
S = $1x10^{-2}$ (likely invalid)
r/B = $4.6x10^{-4}$ ft^{-1}
Kv/Kh=0.1
b = 500 ft
Fault (no-flow) at 5 mi.
r = 1,605 ft
Q = 1,580 gpm
(at Eaglefield Well #2)

Derivative analysis indicates only data from before 2,800 min are valid for this method.

Good match to trend-adjusted data for middle time (t< 2,800 min), but likely affected by earlier artesian discharge of well before test.

Leakage may explain drawdown behavior after 500 minutes.

T = 114.6 Q W(u, r/B)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u,r/B) = "Hantush well function" (defined below)

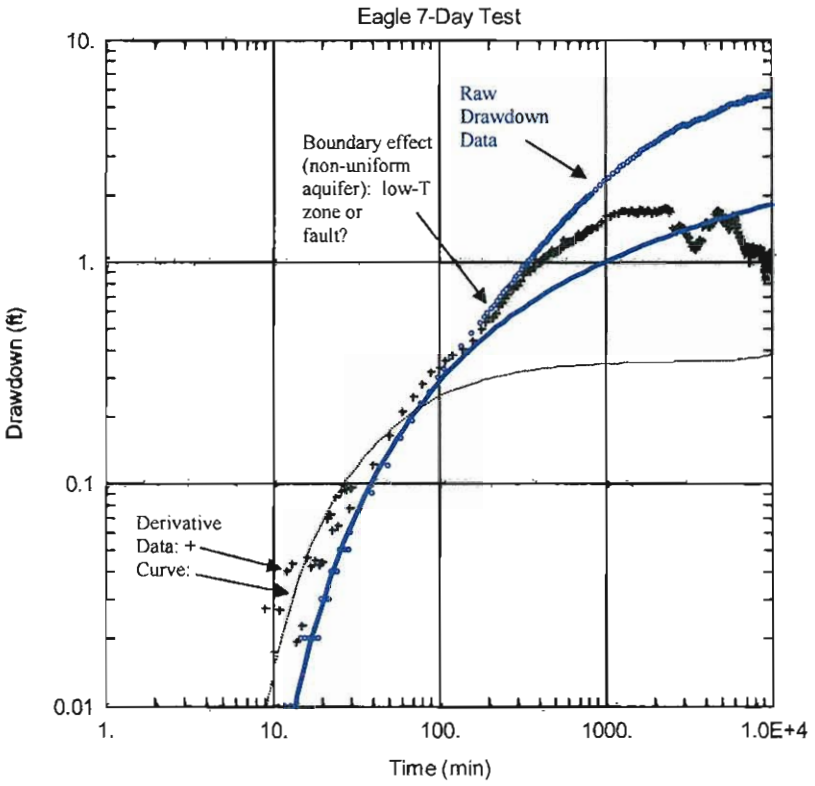
W(u, r/B) = $1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days
B = sqrt (Tb'/K') (leakage factor) (ft^{-1})

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b' = aquitard thickness (ft), estimated from geophysical logs and well logs in the area
K' = vertical hydraulic conductivity of aquitard
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T, S, and r/B best match observed drawdown

Based on the analytical method of Hantush and Jacob (1955).

Figure 9. Theis Analysis for UWID State and Linder Well #1A Seven-Day Test
Test Conducted: June 2-9, 2006



UWID State and Linder Well #1A
Screen = 280-370 ft
T=500,000 gpd/ft
S = 2.3×10^{-3}
Kv/Kh=0.1
Fault (no-flow) at 5 mi.
b = 500 ft
r = 2,405 ft
Q = 1,580 gpm
(at Eaglefield Well #2)

Derivative analysis indicates only data from before 80 min are valid for this method.

Good match early time-data. Very high T indicated. Middle-time data indicate effects of lower transmissivity zone in aquifer. Late time-data (t>2,000 min) show small variations in drawdown caused barometric effects.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

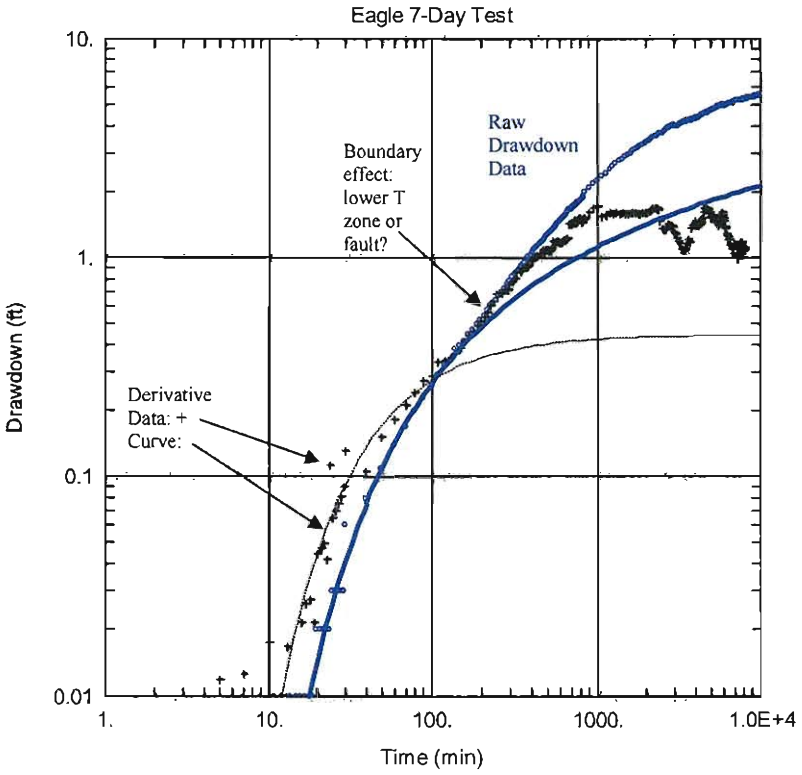
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 10. Theis Analysis for UWID State and Linder Well #1B Seven-Day Test
Test Conducted: June 2-9, 2006



UWID State and Linder Well #1B
Screen = 400-490 ft
T=400,000 gpd/ft
S = 1.3×10^{-3}
Kv/Kh=0.1
b = 500 ft
Fault (no-flow) at 5 mi.
r = 2,405 ft
Q = 1,580 gpm
(at Eaglefield Well #2)

Derivative analysis indicates only data from before 90 min are valid for this method

Good match early time-data. Very high T indicated. Middle-time data indicate effects of lower transmissivity zone in aquifer. Late time-data (t>2,000 min) show small variations in drawdown caused by caused barometric effects.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

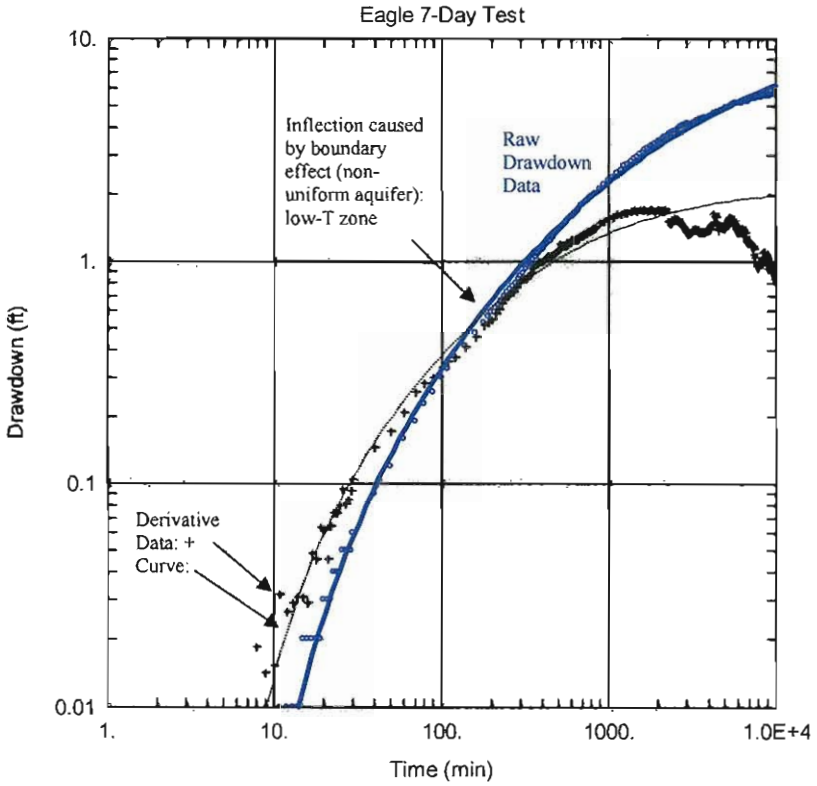
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 11. Butler Analysis for UWID State and Linder Well #1A Seven-Day Test
Test Conducted: June 2-9, 2006



UWID State and Linder Well #1A
Screen = 280-370 ft
T_p= 1,600,000 gpd/ft
$S_p = 2.6x10^{-3}$
T_o = 84,000 gpd/ft
$S_o = 3.7x10^{-3}$
R_p = 1,500 ft
Fault (no-flow) at 5 mi.
Kv/Kh = 0.1
b = 500 ft
r = 2,405 ft
Q = 1,580 gpm
(at Eaglefield Well #2)

Derivative analysis indicates only data from before about 2,000 min are valid for this method.

Good match early and middle time. Radius (R_p) of High-T zone arbitrarily picked for best curve match. Radius differs from that used in analysis of 1A. **Results only approximate because of match selecting five variables.**

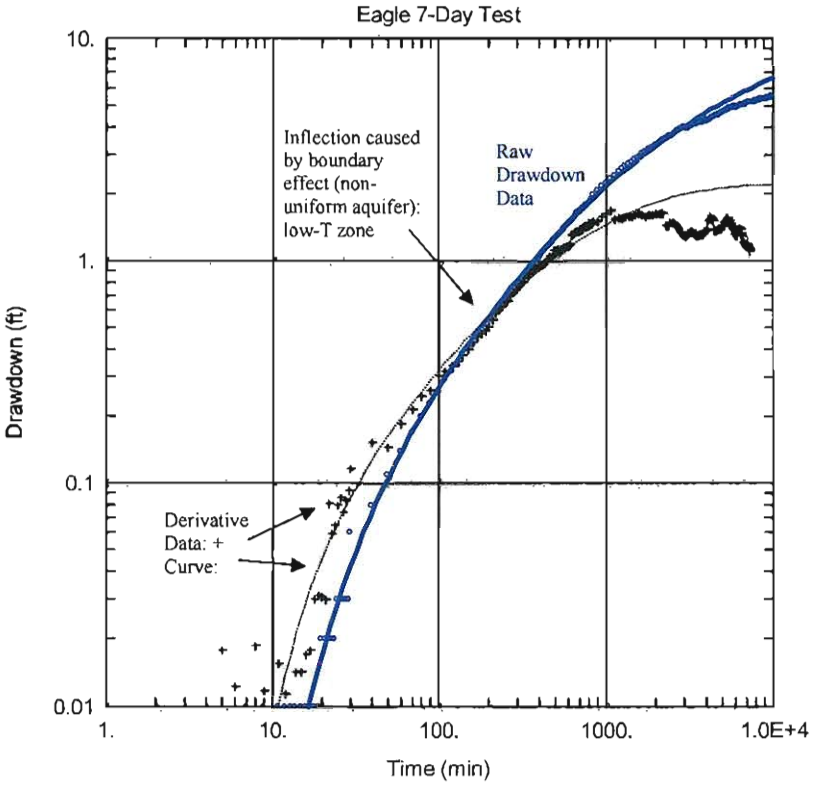
Where:

T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days
Rp = radius of aquifer zone that surrounds pumping well, in feet (ft)
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T_p, S_p, T_o, S_o and R_p best match observed drawdown. Note: "p" indicates zone of pumping well, "o" indicates zone of observation well.

Based on the analytical method of Butler (1988) for non-uniform aquifers but with no partial penetration corrections. Modified from Theis (1935).

Figure 12. Butler Analysis for UWID State and Linder Well #1B Seven-Day Test
Test Conducted: June 2-9, 2006



UWID State and Linder Well #1B
Screen = 400-490 ft
T_p= 1,300,000 gpd/ft
$S_p = 2.4x10^{-3}$
T_o = 84,000 gpd/ft
$S_o = 1.3x10^{-3}$
R_p = 2,200 ft
Fault (no-flow) at 5 mi.
Kv/Kh=0.1
b = 500 ft
r = 2,405 ft
Q = 1,580 gpm
(at Eaglefield Well #2)

Derivative analysis indicates only data from before about 2,000 min are valid for this method.

Good match early and middle time. Radius (R_p) of High-T zone arbitrarily picked for best curve match. Radius differs from that used in analysis of 1A. **Results only approximate because of match selecting five variables.**

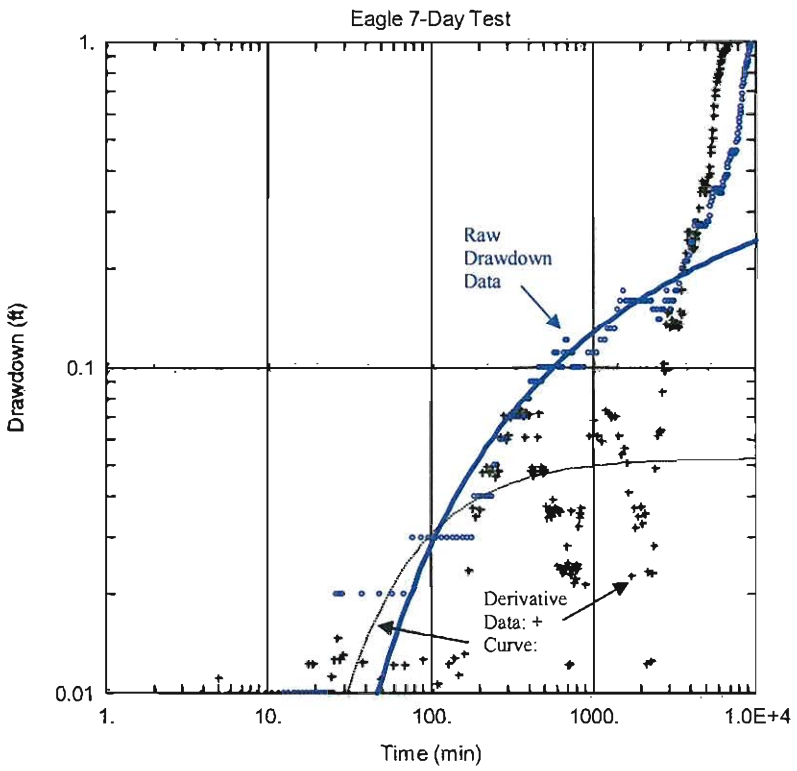
Where:

T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days
Rp = radius of aquifer zone that surrounds pumping well, in feet (ft)
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T_p, S_p, T_o, S_o and R_p best match observed drawdown. Note: "p" indicates zone of pumping well, "o" indicates zone of observation well.

Based on the analytical method of Butler (1988) for non-uniform aquifers but with no partial penetration corrections. Modified from Theis (1935).

Figure 13. Theis Analysis for Rick's Irrigation Well Seven-Day Test
Test Conducted: June 2-9, 2006



Ricks Irrigation Well
Screen = 234-395 ft
T = Invalid
S = Invalid
Fault (no-flow) at 5 mi.
Kv/Kh = 0.1
b = 500 ft
r = 3,340 ft
Q = 1,580 gpm
(at Eaglefield Well #2)

Derivative analysis indicates that method is invalid. Apparent curve match before 2,000 minutes is not real. No real data match to type curve is possible. Increase in drawdown after 3,000 min probably the result of an unknown pumping well.

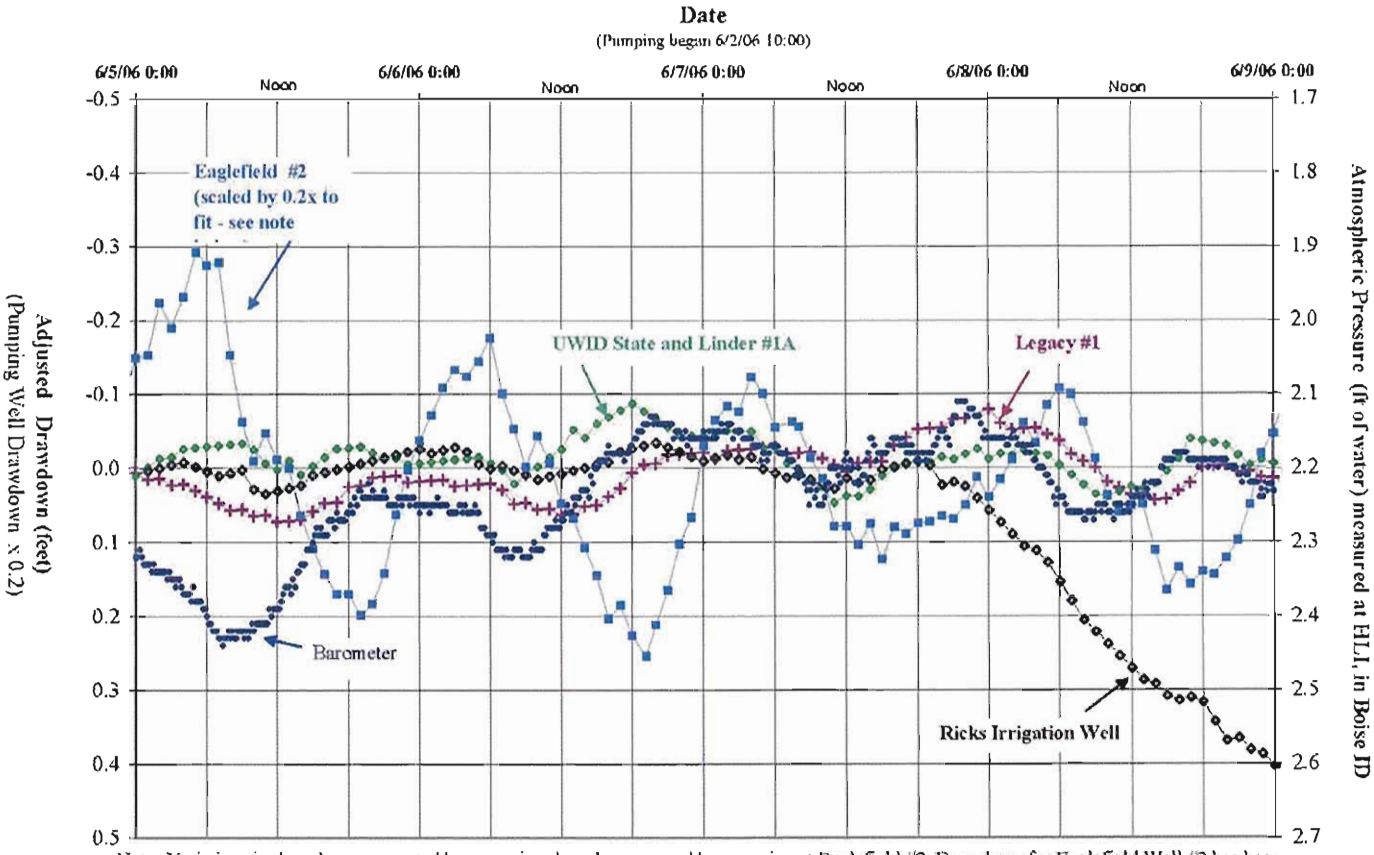
Where:

T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days
Rp = radius of aquifer zone that surrounds pumping well, in feet (ft)
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown.

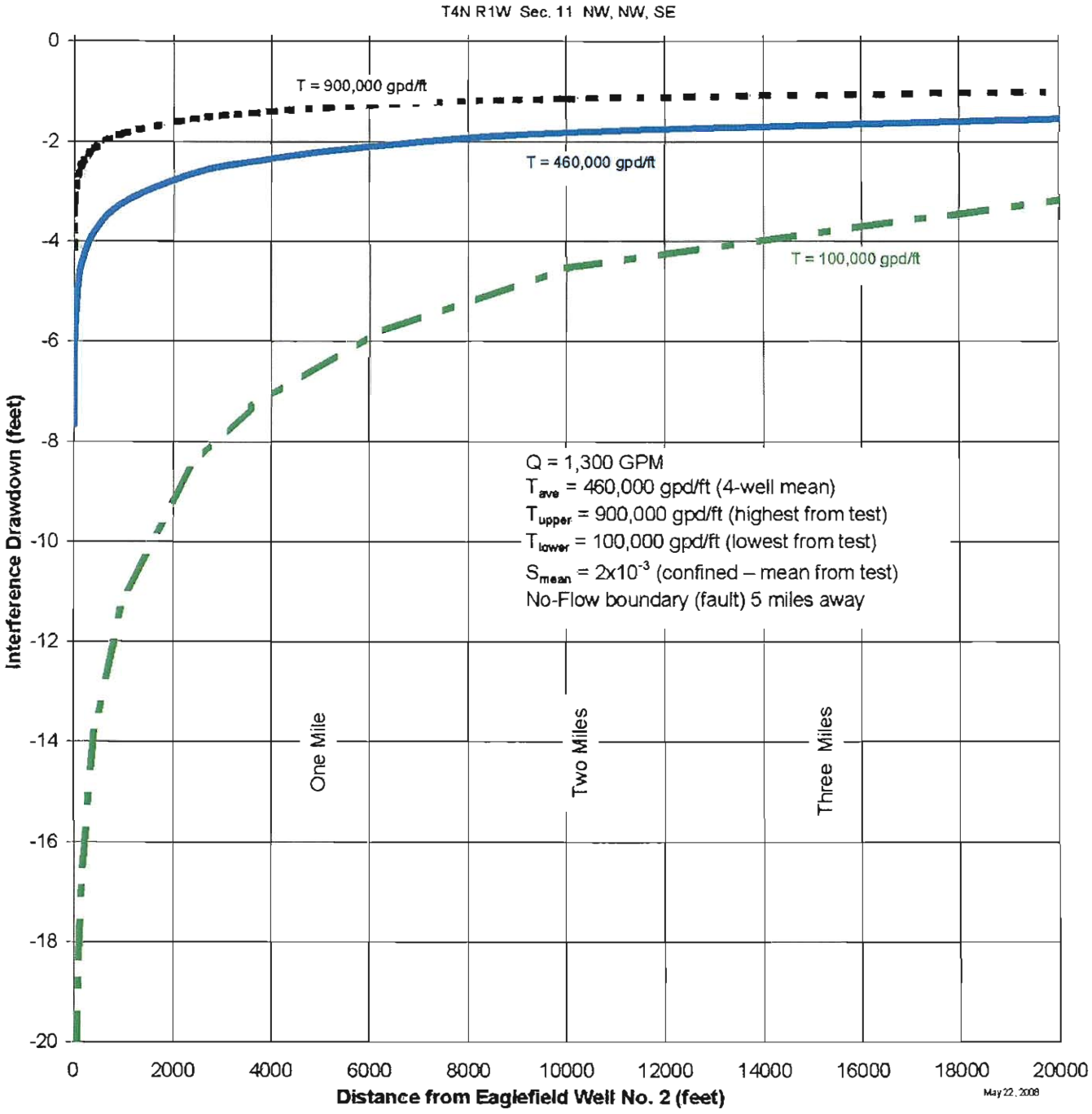
Based on the analytical method of Theis (1935).

Figure 14. Adjusted Drawdowns Showing Water Level Variations Caused by Barometric Effects in Observation Wells and Either Unknown Pumping Well or Possible Temperature Effects in the Pumping Well



Note: Variations in drawdown generated by removing drawdown caused by pumping at Eaglefield #2. Drawdown for Eaglefield Well #2 has been scaled by 0.2 times the actual variations to allow for a better fit on the graph with the three observation wells. Actual variations are 5x greater than shown on graph. The figure shows that the variations in the observation well levels are primarily caused by barometric effects while the variations observed in the pumped well are related to time of day with peak levels generally occurring near 6 AM and troughs occurring near 7 to 8 PM. Increase in drawdown in Ricks Irrigation well from 6/8/06 on may be caused by interference from pumping well other than Eaglefield #2.

Figure 15. Predicted Interference at End of Summer from Pumping Eaglefield #2



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Lexington Hills Thirty-Day Test

Overview and Previous Analyses

Lexington Hills Well #1 was drilled by Pete Cope Drilling using the, reverse-circulation rotary-drilling method during February and March of 1991. The well was drilled to a total depth of 405 ft bgl, and completed with stainless steel well screen open to the aquifer between depths of 215 and 265 ft bgl and 375 and 385 ft bgl. The pretest water level was 71.00 ft bgl which translates to an elevation of about 2,574 ft amsl. Riverside Electric Motor and Pump Specialists installed the temporary production pump and CH2M-Hill (1991) directed a pumping test that began on March 26, 1991. The average pumping rate over the 30-day pumping period was reported at 732 gpm. Drawdown in Lexington Hills Well #1 generally stabilized after about 14 days of pumping at 81 ft, for an end-of-test specific capacity of 9.0 gpm/ft.

The 30-day pumping test was carried out over the period March 26-April 25, 1991 with pretest water levels measured about a week before the test started and post-test levels (including recovery) measured for about 12 days after pumping ceased. Observation wells showing response to pumping and analyzable data indicated maximum drawdowns of 1.1 to 3.8 feet, decreasing with the distance from the pumped well. Wells completed to the east of a major geologic structural fault, called the West Boise-Eagle fault, (and thereby separated from the Pierce Gulch Sand Aquifer) did not indicate detectible response during the test.

Data collected during the test were presented by CH2M-Hill as tables and as linear, semi-log and log-log graphs of drawdown and recovery. Atmospheric pressure data were not collected to generate barometric efficiency corrections that would have allowed for removal of the effects of water level fluctuations caused solely by changes in atmospheric pressure and not by the pumping well. The pretest water levels were analyzed to develop a linear water level trend (measured in ft/day) but irrigation-canal leakage that occurred during the test did not allow this linear trend correction to be realistically applied during the later parts of the test, as noted in the report. Although not supported by any presented analysis, CH2M-Hill indicated that the non-corrected drawdown data gave results that were "not materially different" during the early and middle parts of the test but did "deviate dramatically" late into the test. CH2M-Hill did not apply water-level-trend corrections to any of the data analyzed for aquifer coefficients.

Data from the pumping well and six observation wells were originally analyzed using visual curve matching on log-log plots and straight line analysis on semi-log plots of drawdown and recovery. The analytical methods used by CH2M-Hill were: Theis non-equilibrium (Theis, 1935), Cooper-Jacob straight-line (Cooper-Jacob, 1946), Chow straight-line (Chow, 1952) and delayed-yield (Prickett, 1965). Straight-line analyses included approximate best-fit lines drawn on plotted graphs. The curve-matching methods plotted the collected data but did not include the type curve that best matched

the data. Calculations and assumptions were included, however. The data were not corrected for partial penetration, perhaps in part because the thickness of the aquifer (the Pierce Gulch Sand Aquifer) was not known at the time of the test, and only the pumping well was analyzed for well-bore storage effects. A summary table indicated the analytical methods in which type curves could not be fit to the data. The report presented a table of transmissivities and storativities for the production well and four analyzed observation wells, along with average values, which are included in our Table 3 (page 247).

HLI Analysis of the Pumping Test

A 30-day pumping test was conducted by CH2M-Hill (1991) using the Floating Feather Hills, Inc., Lexington Hills Well #1 as the pumping well along with eight measured observation wells. Pumping occurred over the period March 26-April 25, 1991 with pretest water levels measured about one week before the test started and post-test levels (including recovery) measured for about 12 days after pumping ceased. Lexington Hills Well #1 was pumped at an average rate of 732 gpm with drawdown generally stabilizing at around 81 feet during the last 14 days of pumping for an end-of-test specific capacity of 9.0 gpm/ft. Observation wells showing analyzable responses to pumping indicated maximum drawdowns of 3.8 to 1.1 feet, decreasing with the distance from the pumped well. Wells completed to the east of a major geologic structural fault, the West Boise-Eagle Fault, did not indicate detectible response during the test.

The data presented as part of the CH2M-Hill report were reanalyzed by HLI after careful review of hydraulic, geologic and well construction information available from their report and other from sources. Our summary of the data about the pumping well and the four analyzed observation wells is included in Table 3 with well locations shown in Figure 16 (page 68). The geologic data in the CH2M-Hill report were limited to the production well. Additional Well Driller's Reports were obtained from the IDWR on-line data base to supplement our analysis. Our database search indicated only one additional Well Driller's Report was available for the actual observation wells used in the test. Other Well Driller's Reports were available, however, from the same 40-acre quarter-quarter sections as the observation wells without available reports. We used these nearby logs to supplement our understanding of the hydrogeology of the area and helped us to interpret test results. These are included in Appendix A.

As shown in Table 3, the Lexington Hills #1 pumping well was completed in the Pierce Gulch Sand Aquifer between depths of 215 ft (top) and 385 ft (bottom), equivalent to an elevation of about 2,430 and 2,260 ft amsl, respectively. The contours of the Pierce Gulch Sand Aquifer presented in HLI (2007) show that the bottom of the aquifer lies at an elevation of about 2,280 ft while reviews of the geologic information for the test area shows that the top of the aquifer lies at depths of about 75 ft near the pumped well, or at an elevation of about 2,570 ft amsl. The four observation wells analyzed as part of our review are completed at higher elevations (shallower depths) than the pumping well in thick, stratified sand and clay zones with well depths of 90 to 175 feet. These zones likely represent an upper portion of the regional Pierce Gulch Sand Aquifer (or at least, overlying sands in hydraulic connection to the Pierce Gulch Sand Aquifer). Well

Driller's Reports for these observation wells (or wells near these observation wells) show that the upper portion of the aquifer is much coarser grained; deeper water-bearing zones consist of fine-grained sand while the shallower water bearing zones consist of fine-, medium- and coarse-grained sand and even some sandy gravel. Based on these observations, the shallower portions of the Pierce Gulch Sand Aquifer in the vicinity of the Lexington Hills well appear to be more permeable than the deeper portions.

The fact that the four observation wells responded during pumping supports the conclusion that all five wells are hydraulically connected. However, only the Floating Feather Irrigation well appears to be completed in the same depth zone as the pumping well and even this conclusion is tentative, as it is based solely on the comment in the CH2M-Hill report that the depth is "approximately 270 feet" (no Driller's Report is available). Because the water levels in this well were only measured with an air line (an inexact method with resolution to ±1 foot, at best), we consider the data from this well to be of questionable quality.

As noted in the Hydrogeologic Overview section of this report, the West-Boise-Eagle Fault lies approximately one-half mile to the northeast of the Lexington Hills Well #1 (Figures 1 and 16). Review of Well Driller's Reports and the hydraulic data included in the CH2M-Hill report indicate this fault acts as a no-flow barrier and edge to the Pierce Gulch Sand Aquifer. We incorporated the effects of this no-flow boundary into all the log-log, type-curve analyses (Theis, Moench and Butler) discussed below. Aqtesolv® generated type curves that reflected the effects of this boundary by simulating this boundary using image well theory.

The drawdowns for the pumping and four selected observation wells are shown in Figures 17-25.

Lexington Hills Well #1

Lexington Hills Well #1 served as the pumping well during this test. It is screened from 215 to 265 feet below ground surface and 375 to 385 feet below ground surface. It was pumped at 732 gpm for a period of 30 days. The maximum drawdown experienced by this well during the test was 81 feet, which occurred at the end of about two weeks of pumping for an end-of-test specific capacity of 9.0 gpm/ft. The pumping water level remained generally stabilized at this level, until pumping ceased two weeks later. Details on the well and test are included in Table 3. This well is located in Figure 16 (page 68) as a red diamond with a solid boundary.

The drawdown measured in the pumping well (Lexington Hills Well #1) is shown in Figure 17 (Cooper-Jacob early-time semi-log plot of drawdown on page 69) and Figure 18 (Moench log-log plot of drawdown on page 70). The pumping rate for this well averaged 732 gpm over the entire test but varied from below 600 to 829 gpm with an average rate of 749 gpm over the first hour. After about 30 minutes of pumping, the drawdown curve flattens and remains so until about 2,000 to about 2,500 minutes where it begins to rise again. This increase in drawdown, followed by decrease in drawdown,

followed by increase in drawdown, appears to be "delayed yield" which occurs in thick, unconfined aquifers where pumping causes the upper portions of the aquifer to partially dewater by gravity drainage, but only after the aquifer has been pumped for a while.

This downward flow of pore water ("gravity drainage" / "delayed yield") under pumping conditions takes a finite period of time to begin. At first, the pumping well causes water to move laterally toward the well much like as in a confined aquifer. After a short time (a few minutes to a few hours), however, the drawdown "cone of depression" slows its outward (radial) movement as pore water drains from upper portions of the aquifer near the pumping well. If unrecognized, this capture of drainage appears as a flattened drawdown curve that could easily be misinterpreted as a misleadingly high transmissivity (in a Cooper-Jacob analysis), a positive recharge boundary (such as a lake or a river), or the cone of depression capturing water from a portion of the aquifer with a much higher transmissivity. Over time, the gravity drainage diminishes and the cone of depression continues to expand. The water level in the pumping well begins to fall again and the drawdown plot begins to rise and steepen, in part replicating the initial drawdown curve that was generated during the initial stages of pumping. Typically, the curves generated by the early and late data have the best likelihood of indicating the true aquifer transmissivity while the middle portion will indicate misleadingly high values that are not representative of actual aquifer properties. The transition between the two curves allows for calculation of various properties associated with vertical drainage (Neuman, 1974 and Moench, 1997). The early-time data can be used to analyze the storativity "S" and the late-time data can be used to analyze the specific yield "S_y" (effectively the "longer-term, unconfined aquifer storage coefficient"). Of course, these storage coefficients can only be assessed using observation well data as a pumping well cannot indicate accurate storativity or specific yield.

A Cooper-Jacob (1946) plot of the raw (uncorrected) drawdown data (Figure 17- page 69) indicates a transmissivity of 15,000 gpd/ft. With the approximate partial penetration corrections of Butler (1957) applied to the drawdown data, a transmissivity of 50,000 gpd/ft is indicated (plot on lower portion of the graph in Figure 17). Because the Lexington Hills Well #1 is only open to 60 feet of the 326-ft thick aquifer, we believe the partial-penetration-corrected value of 50,000 gpd/ft is likely to be the more representative of the true whole-aquifer transmissivity at the Lexington Hills Well #1 location, than is the lower value using the uncorrected data. The Cooper-Jacob analysis without partial penetration corrections likely represents the transmissivity only of the zone screened by the well (60 ft) and not the entire aquifer thickness (326 ft). The response of wells in shallower and deeper zones (discussed below) indicates that the entire aquifer thickness is affected during pumping and that a whole-aquifer transmissivity analysis should incorporate the entire aquifer. Therefore, we believe the higher value generated with the Butler corrections to be more representative.

Our analysis using the Moench method (Figure 18 page 70) indicates a transmissivity of 80,000 gpd/ft. As explained in the methodology section (page 18) we have taken into account a maximum likely well loss in order to better assess the range of likely transmissivity using the partial penetration corrections possible using the type curve

methods. In our log-log Moench analysis we estimated maximum likely well loss and then subtracted it from the raw data. To do so, we estimated maximum well loss as being equivalent to the water level recovery that occurred in the pumping well 30 seconds after pumping stopped. This value (35 ft) represents about one-half of the drawdown observed just before pumping stopped and about 80 percent of the drawdown 30 seconds after pumping started. Our sensitivity analysis using estimated-maximum well-loss versus no well loss indicated a 12-percent higher transmissivity when the estimated-maximum well loss was incorporated into the analysis. This low sensitivity to well loss suggests that any error in the difference between actual and estimated well loss would only introduce an error in our calculated value for transmissivity on the order of a few percent. This relatively small potential error inherent in using the Moench method for the pumping well (which incorporates the effects of partial penetration but uses estimated maximum well loss) makes this method more accurate than using the Cooper-Jacob method which is not affected by well loss but cannot directly account for the effects of partial penetration of the pumping well or delayed yield.

In our analysis we have also assumed that most of the significant production of ground water came from the upper 50-ft section of the well screen (215 to 265 ft below ground surface) and that only a small, less-significant portion of the water originated from the 10-ft section of the screen located between 375 and 385 ft below ground surface. This assumption was based on the finer-grained nature of the aquifer as noted on Well Driller's Reports. Aqtesolv® (and probably all other commercially available analytical software packages) can only assume that the well is open over *one* of the intervals or the *entire* interval (top of the top screen section to bottom of the bottom screen section). Since there is a 110 ft blank section between the two screen-intervals, we chose to use the upper section that represents over 83 percent of the open area. In addition, based on our experience with the driller who constructed the well, we believe it highly unlikely that the lower-most screen section was properly developed and able to contribute significant ground water to the well. We believe the error introduced by assuming a 170-ft open screened interval is much greater than the error introduced by assuming that all the production originated from the single, upper, screened section.

The Moench analysis indicated a transmissivity of 80,000 gpd/ft. This value is on the low end of values calculated for other portions of the Pierce Gulch Sand Aquifer in the greater Eagle-Star-M3 vicinity. These relatively low values are likely the result of the finer-grained nature of the lower portions of the aquifer in the region of the Lexington Hills Well #1.

The average value reported in the CH2M-Hill report was 170,000 gpd/ft but this value represents analyses of the flattened, delayed-yield portion of the drawdown curves. Analysis using this portion of the curve indicates a so-called "apparent transmissivity" which is incorrect.

The pumping well can only indicate transmissivity and not storativity (S). No S values are presented for our Moench analysis of the pumping well data.

Holgate Well

The Holgate well is the observation well nearest to the pumping well. The depths of the top and bottom of the well screen (if present) are unknown; no Well Driller's Report is available from IDWR and no well construction information was included in the CH2M-Hill report. The well is reportedly 171 feet deep and therefore likely open to the aquifer at this depth. The maximum drawdown experienced by this well during the test was 3.85 feet which occurred at the end of the 30-day test; the water level in this well did not stabilize. These details are included in Table 3. Its location is shown in Figure 16 as a green diamond with a dashed boundary, labeled "Holgate."

Figures 19 (early-time Theis – page 71) and 20 (Moench – page 72) show our analyses for the Holgate Well, completed 900 feet away from, but at a slightly shallower depth (171 ft) than, the pumping well (upper screen: 215 to 265 ft). The Theis plot in Figure 19 shows a type curve match for the first 80 minutes into the test, before delayed yield caused the drawdown plot to flatten. The Moench analysis in Figure 20 incorporates the effects of delayed yield with both the early-time and late-time data. The Theis curve indicates a transmissivity of 120,000 gpd/ft and a storativity of $5x10^{-4}$. The Moench analysis indicates a transmissivity of 96,000 gpd/ft and a storativity of $3x10^{-4}$ and a longer-term specific yield of $1.2x10^{-2}$.

We believe the Moench method yields a better analysis for aquifer coefficients than the Theis method because it generally matches both early-time and late-time data. The calculated values for the storage coefficients demonstrate the transition from initial behavior that mimics a confined-type aquifer system (storativity of $3.0x10^{-4}$) to unconfined conditions over longer-term pumping (specific yield of $1.2x10^{-2}$).
The recovery data shown in Figures 19 and 20 show a water-level recovery that appeared to be faster than that plotted by the type curve. CH2M-Hill indicated that nearby irrigation canal flow began during the end of the test. Leakage from the canal flowing downward into the aquifer could explain the apparent "early" recovery (and the imperfect fit of the data to the type curve during the last 20,000 minutes, or two weeks of pumping).

Carson Well

The Carson well is located approximately 1,300 feet from the pumping well. The depth of the well screen (if any) is unknown; no Well Driller's Report is available from IDWR and no well construction information was included in the CH2M-Hill report. The well is reportedly 90 feet deep and therefore it is likely open to the aquifer at this depth. The maximum drawdown experienced by this well during the test was 2.47 feet which occurred at the end of the 30-day test; the water level in this well did not stabilize. These details are included in Table 3. Its location is shown in Figure 16 as a green diamond with a dashed boundary, labeled "Carson."

Figures 21 (page 73) shows our Theis (1935) analysis for the Carson well. The log-log plots in this figure show an initial Theis drawdown curve followed by a flattening of the curve to almost a straight line on the log-log plots. The first part of the curve (initial time

data) indicates a transmissivity of about 600,000 gpd/ft and a storativity of $2.5x10^{-2}$. These values are much greater than other values indicted from analyses of data from deeper wells, suggesting that the Theis analysis of the Carson well may be in error. The derivative analysis indicates that the Theis analysis is likely to be invalid. The results of this analysis are shown in Table 3 (page 247) as "likely invalid" and therefore not included in our calculations for mean aquifer transmissivity and storativity.

The plot does show a delayed-yield curve, but one that is more subdued that those observed in the pumping and Holgate wells. A Moench analysis is presented in Figure 22 (page 74). This analysis indicates a transmissivity of 77,000 gpd/ft and a storativity of $5x10^{-3}$ and a specific yield of $3.5x10^{-2}$. These values indicate the transition from confined aquifer-type behavior during the initiation of pumping to unconfined behavior during longer-term pumping, as seen in the other Moench analyses. The derivative analysis supports the Moench analysis of the data from this well.

Eagle Hills Golf Course Well

The Eagle Hills Golf Course well is located approximately 2,500 feet from the pumping well. The depths of the well screens are unknown; no Well Driller's Report is available from IDWR and no well construction information was included in the CH2M-Hill report. CH2M-Hill indicated the well is 175 feet deep and therefore likely to be open to the aquifer at this depth. The maximum drawdown experienced by this well during the test was 1.05 feet which occurred at the end of the 30-day test; the water level in this well did not stabilize. These details are included in Table 3. Its location is shown in Figure 16 as a green diamond with a dashed boundary.

Figures 23 and 24 (pages 75 and 76, respectively) show the HLI analysis for the Eagle Hills Golf Course well. Completed at a depth of 175 ft, this well is shallower than the 215 to 275 ft upper screen depth of the pumping well. The early-time Theis plot (Figure 23) indicates a transmissivity of 420,000 gpd /ft with a storativity of $5x10^{-3}$. The Moench analysis (Figure 24) indicates a similarly large transmissivity of 400,000 gpd/ft and a storativity of $3x10^{-3}$ and a specific yield of $8x10^{-3}$. The closeness of these values is unusual for a "delayed-yield" aquifer but consistent with the drawdown data plotted in the two figures which does not show a large flattened zone for middle-time data which typically would represent the delayed-yield portion of the curve. The small amount of delayed yield may have been caused by greater drawdown near the pumping well compared to the drawdown at the observation well. Pumping at the Lexington Hills well appears to have caused the aquifer water level to drop below the top of the aquifer, thereby allowing dewatering, as indicated by the water and aquifer depths included in Table 3. Near the observation well, however, drawdown was much smaller, possibly allowing the water level to drop only a small amount below the top of the aquifer, if at all. With only a small water level drop, significant delayed yield (dewatering of the aquifer) did not occur. With less dewatering occurring near the observation well, the curve did not flatten as much and only a small difference between storativity and specific yield was indicated.

The derivative type curve match was fair for the Moench analysis supporting its general validity. The derivative type curve match for the initial-time portion of the Theis analysis was also fair. After about 500 minutes the match is poor indicating the Theis method is not valid for the data collected after 500 minutes.

Floating Feather Irrigation Well

The Floating Feather Irrigation well is located approximately 5,100 feet from the pumping well. The depths of the well screens are unknown; no Well Driller's Report is available from IDWR and no well construction information was included in the CH2M-Hill report. The well is 270 feet deep and therefore likely to be open to the aquifer at this depth. The maximum drawdown experienced by this well during the test was about 2 feet which occurred at the end of the 30-day test; the water level in this well did not stabilize. These details are included in Table 3. Its location is shown in Figure 16 as a green diamond with a dashed boundary, labeled Floating Feather Irrigation.

The 270-foot deep Floating Feather irrigation well was the only well monitored during the test that is completed at a depth that overlaps the completion depth of the pumped well (215 to 275 ft and 375 to 385 ft). In other words, it is the only well that appears to be completed in at least part of the same depth interval within the Pierce Gulch Sand Aquifer pumped by the Lexington Hills #1 well. Unfortunately, the use of an air line to measure water levels with its resolution of ±½ foot (at best) and the distance of this well from the pumping well (5,100 feet) generated data that had very poor resolution. Figure 25 (page 77) shows our attempt to analyze the data using the Theis method. Poor data resolution made any meaningful type-curve match to the data, difficult. The poor match of the derivatives to the type curve also indicates that the Theis analysis (with these data) is invalid. No results are therefore, indicated on Figure 25 or included in Table 3.

Test Results Summary

In summary, the analyses of the four wells indicate transmissivity values that appear to range from moderate values of about 80,000 to 100,000 gpd/ft (the Lexington Hills #1, Carson, and Holgate wells) to 200,000 to 400,000 gpd/ft (Eagle Hills Golf Course well). The range in transmissivities is likely the result of variations in aquifer permeability caused by varying amounts of clay within the aquifer. The lithologic logs for the area show that the shallow portions of the aquifer are coarser with fine-to-coarse-grained sand and minor gravel. The logs indicate that sand in the deeper zones is fine-grained; no coarser-grained materials are reported in the logs which we examined, although these Well Driller's Reports are of generally poor and uneven quality. We believe, however, that the permeability of the upper portions of the Pierce Gulch Sand Aquifer is generally larger than the transmissivity in the lower portions of the aquifer in the Lexington Hills area.

We calculate an average transmissivity of the 310 ft thick Pierce Gulch Sand Aquifer of 160,000 gpd/ft. This value is based on a mean of the Moench analyses for the four wells with high-resolution data. The results of the Floating Feather irrigation well analysis were

not included in the average. The mean of storativities from the Carson, Holgate and Eagle Hills Golf Course wells was $3x10^{-3}$. The mean for specific yield from these wells was $2x10^{-2}$, indicating an unconfined aquifer.

The stratigraphic layering of aquifer materials causes short-term pumping of deeper wells (such as the Lexington Hills well) to affect other deeper wells initially in a manner similar to a confined system. However, over time, the reduction of water levels caused by pumping causes the upper portion of the aquifer to drain and partially dewater. This behavior was demonstrated by the change in storativities calculated from early-time data ($S = 5x10^{-4}$ to $5x10^{-3}$) to the larger values calculated from the late-time data ($Sy = 2x10^{-2}$ to $3.5x10^{-2}$). This behavior is typical of an aquifer partially dewatering and demonstrating delayed yield (unconfined) behavior.

Well Interference and the Effects of Seasonal Pumping

The mean transmissivity of 160,000 gpd/ft, an upper-end transmissivity of 400,000 gpd/ft, and a low-end transmissivity of 80,000 gpd/ft were used in a simulation to predict interference effects in the aquifer at distances up to 2 miles from the pumped well. A storativity of $2x10^{-2}$ was used with each of these transmissivities. In this simulation the Theis method was used to generate drawdown curves as a function of distance from pumping at the location of the Lexington Hills Well #1 at 1,000 gpm for 90 days which is a rate that appears feasible with an efficient well design at this location. An image well was used in the analysis to simulate the effects of the no-flow boundary (West-Boise-Eagle Fault). This image well was located 2,500 feet from the pumping well and on the opposite side (northeast) of the fault. In the simulation the image well was pumped at the same rate and timing as the pumped well. The use of the image well allows for the simulation on an semi-infinite aquifer bounded on one side by a no-flow zone (the fault). The results of the analysis are for wells lying on a line extending from the northeast to the southwest through the pumping well. Wells at other locations (not on this line) will have slightly smaller interference drawdowns.

The upper-end, and lower-end, transmissivities were used to bracket the possible interferences caused by pumping the Lexington Hills #1 well. Our analysis, presented in Figure 26 (page 78), predicts interferences of 1½ to 5½ ft at distances of one half mile and 1 to 3 ft at distances of one mile. Actual drawdowns will likely vary because of variations in aquifer transmissivity. Since calculated transmissivities varied from 80,000 to 400,000 gpd/ft, interferences will also vary accordingly. By using an average (mean) value from our analyses, we believe that the predictions in Figure 25 serve as a reasonable mid-point estimate.

As discussed in the methods section above, we consider this analysis to be conservative and likely to over-estimate interference as the drawdown cone of depression from the pumping well is likely to expand sufficiently to capture flow with the aquifer and therefore slow its rate of outward movement. The capture of aquifer flow would allow water level declines to slow and even stop their rate of decline. The Theis analysis assumes no recharge, that water pumped by a well only comes from aquifer storage and

that a well pumping water level never stabilizes. In reality (and observed many times, in our experience) the drawdown in a well pumped continuously for 90 days in a hydrogeologic setting like that of the Lexington Hills well, typically stabilizes before 90 days. Leaky canals, such as the Farmers Union Ditch[14], Ballantine Ditch and shallow ground water in the flood plain terrace gravels, are likely to provide local sources of recharge that would help to stabilize the water levels in the pumping well (in addition to the capture of water flowing through the aquifer originating from more distal recharge sources).

Our drawdown interference calculations are greater than those predicted in the CH2M-Hill report. They predicted drawdowns of about two feet at a distance of a mile using a transmissivity of 160,000 gpd/ft and a storativity of $2x10^{-2}$, after 180 days of pumping. They did not use an image well to simulate the no-flow boundary/edge of the aquifer. The lack of a no-flow boundary in their simulation likely caused the smaller predicted interference drawdown.

Conclusions

Based on the overview and analysis presented above, we make the following conclusions:

1. The Lexington Hills, Holgate, Eagle Hills Golf Course and Floating Feather Hills irrigation wells are hydraulically connected and completed in the regional Pierce Gulch Sand Aquifer, that on average, is about 310 feet thick at this location.

2. The high degree of hydraulic interconnection, both horizontally and vertically, over horizontal distances of more than a mile within the Pierce Gulch Sand Aquifer near the Lexington Hills vicinity, allows pumping at any one location to cause small-scale water-level interference at any other location in this area.

3. The calculated transmissivity of the aquifer ranged from 80,000 to 400,000 gpd/ft (to one significant figure). This range is explained by local variations in hydraulic conductivity caused by differences in aquifer-material grain sizes.

4. The deeper parts of the aquifer appear to consist of fine-grained sands while the upper portions have fine- to-coarse-grained sand and occasional sandy gravel lenses. Discontinuous clay layers varying in thickness, hydraulic conductivity and lateral extent are common throughout the aquifer.

5. We calculate a mean transmissivity of 160,000 gpd/ft for the entire aquifer thickness. Deeper, fine-sand-and-clay zones such as those tapped by the Lexington Hills well have lower transmissivities when considered separately from

[14] The "Farmers Union Ditch" has been miss-labeled the "Farmers Union Canal" on many publications included USGS maps, topographic maps, the CH2M-Hill report and other published reports. In the text of our report we will refer to the Farmers Union Ditch by the name preferred by its owners, the Farmers Union Ditch Co. Our maps and figures will retain the name by which it is commonly called, the Farmers Union Canal.

the entire aquifer section. The Lexington Hills well indicated a transmissivity of 80,000 gpd/ft.

6. Transmissivities in parts of the aquifer can be very large. The analysis of the Eagle Hills Golf Course well indicated a transmissivity of 400,000 gpd/ft.

7. The average long-term storativity ("specific yield") of the Pierce Gulch Sand Aquifer was calculated to be $2x10^{-2}$. Based on this value, the aquifer is considered unconfined in the general vicinity of the Lexington Hills.

8. Partial dewatering of the aquifer caused a "delayed yield" condition during the initial two days of pumping; the pumping water level appeared to stabilize while water moved downward under gravity. After two more days of pumping, this effect became less significant and the water level continued to decline.

9. The aquifer is highly productive with well yields of greater than 2,000 gpm possible from properly designed and completed wells.

10. Interference drawdown from production of 1,000 gpm at the Lexington Hills well is predicted to cause drawdowns of about 1 ½ to 5 ½ feet at wells completed at the same depth in the same aquifer, at a distance of one half mile, after 90 days of continuous pumping. Interference drawdown at a distance of one mile, after 90 days of continuous pumping is predicted to be on the order of one to three feet.

11. Some of the earlier analyses by CH2M-Hill indicated aquifer transmissivities that were too large and some that were too small. In cases where delayed yield was misinterpreted or unrecognized, their calculated transmissivities were greater than actual. In cases where the effects of partial penetration were significant (and not incorporated in their analysis), their calculated transmissivities were too small. In addition, many of the observation wells used in the test do not have Driller's Reports or other information on well construction that could be obtained after-the-fact (such as video inspection or geophysical surveys) making conclusions potentially less valid, if our understanding of well construction details is incorrect..

12. A more comprehensive and more valuable aquifer test could be conducted by selecting observation wells based on having complete data on well construction and subsurface geology, and by timing the test to reduce competing water use in the aquifer that could cause complicating water level interference effects and the resulting obfuscation of data. Even so, the CH2M-Hill test appears to be the best aquifer-wide test available to date for the area. Such testing becomes more difficult over time with more and more pumping wells going into production in the area and all the coordination requirements associated with an aquifer-wide, long-term, pumping test.

Figure 16. Well Locations for Lexington #1 Thirty-Day Test

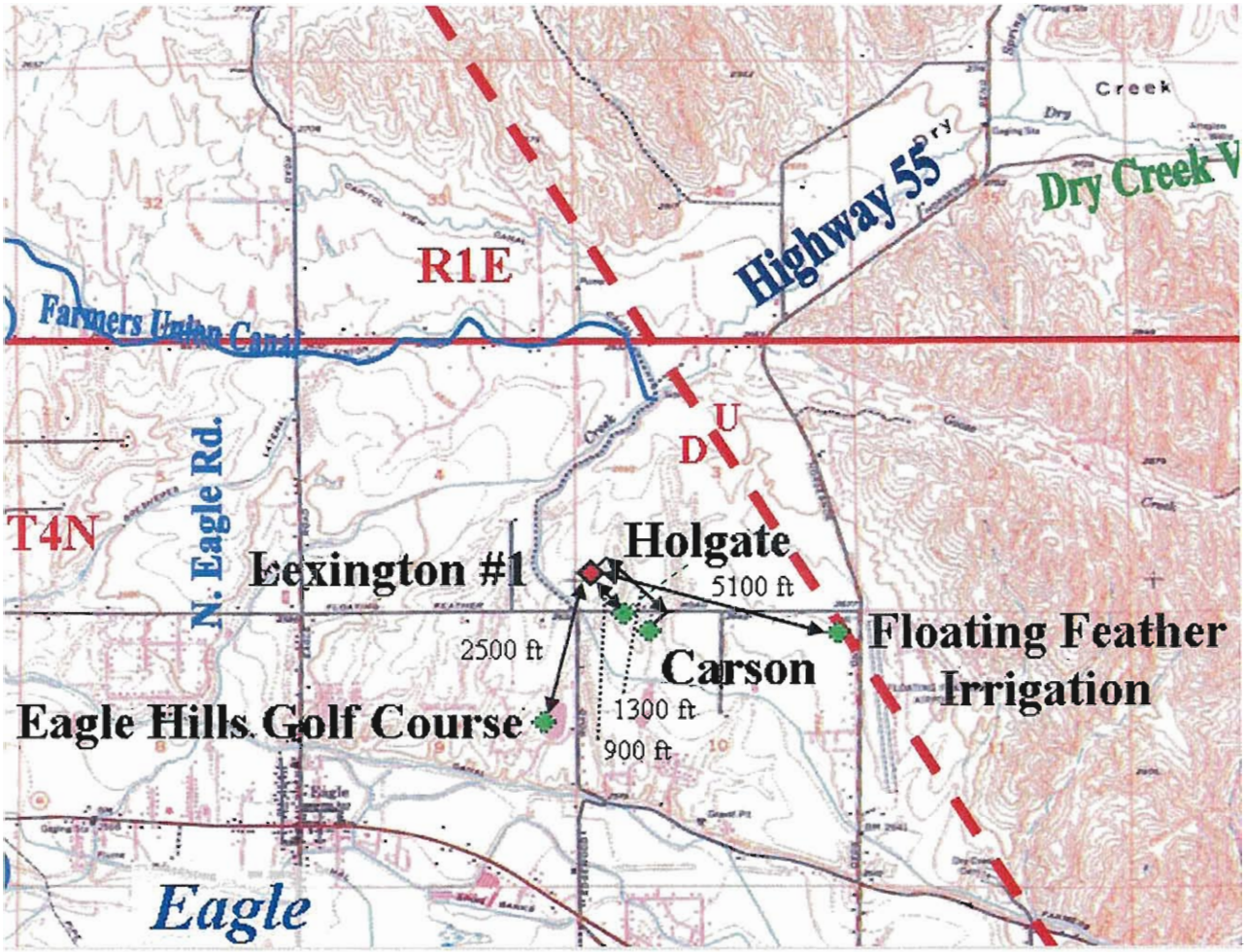
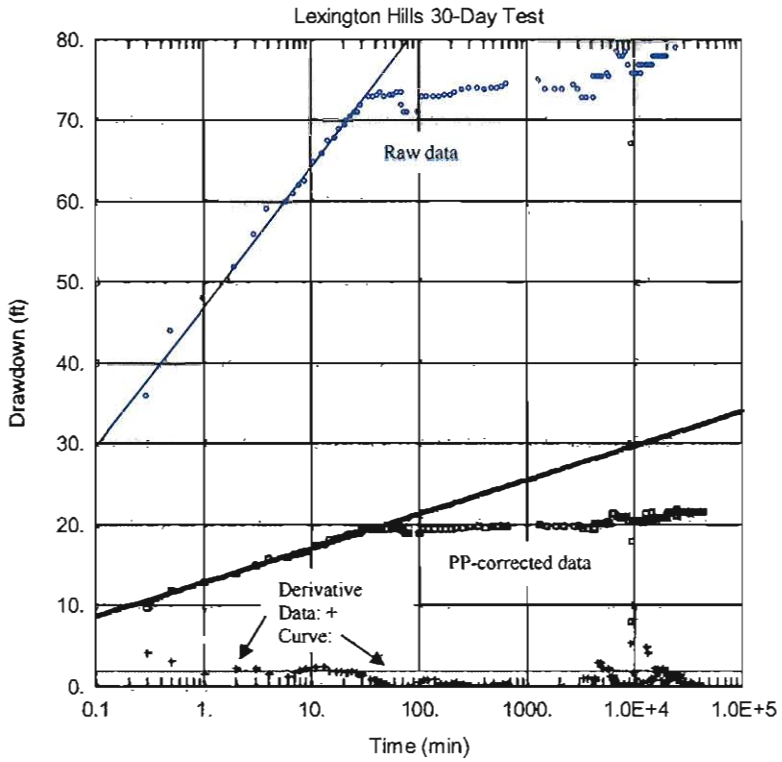


Figure 17. Cooper-Jacob Analysis for Lexington Hills Well #1 Thirty-Day Test
Test Conducted: Mar 26-April 25, 1991



Lexington Hills Well #1
Screen = 215-265 ft
T=15,000 gpd/ft
(no PP corrections)
T=50,000 gpd/ft
(with PP corrections)
S= Not calculable
Kv/Kh=0.1
b = 310 ft
t_c < 1 min
r = 1 ft
Q = 732 gpm

Early-time data used to match because of delayed yield. Derivative analysis indicates method valid through first 30 minutes, only.

Partial penetration correction (Butler) makes calculated T for whole-aquifer thickness about 3 times greater than calculated value without PP correction.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

$u = 1.87r^2S/Tt$
t = time in days
r = effective radius of pumping well (ft)

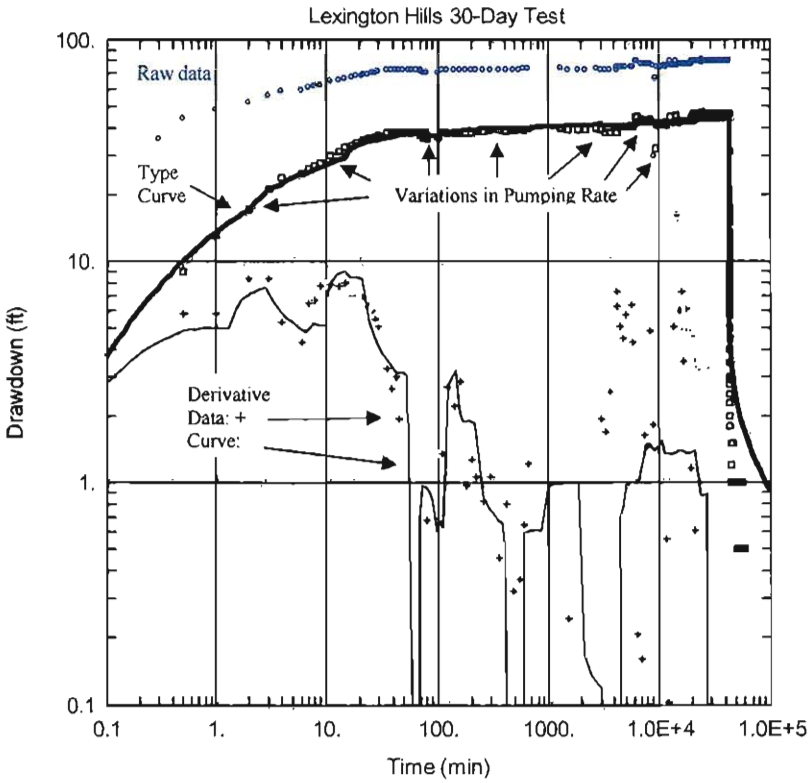
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

$s_{pp} = 0.376\ s_{observed}$ where:

s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Based on the analytical method of Cooper and Jacob (1946).
Partial penetration corrections from Butler (1957).

Figure 18. Moench Analysis for Lexington Hills Well #1 Thirty-Day Test
Test Conducted: Mar 26-April 25, 1991



Lexington Hills Well #1
Screen = 215-265 ft
T= 80,000 gpd/ft
S= Not calculable
S_y = Not calculable
Kv/Kh=0.1
Fault (no-flow) at 0.5 mi.
b = 310 ft
s_w = 0.2
$\alpha = 10^{-30}$ min^{-1}
Max Well Loss $_{(est)}$ = 35 ft
Q = 732 gpm (average)

Fair match for derivatives support method. Variations may have been caused by pumping-rate variations.

"Delayed Yield" (Moench) analysis used to accommodate downward (gravity) flow from upper portion of aquifer. Analysis with no-flow boundary (fault) 1/2 mile from pumping well trending N45W. Not sensitive to empirical drainage timing factor: α.

Good data match for drawdown. Poor match at end of recovery probably caused by canal leakage that causes recovery to appear earlier than calculated.

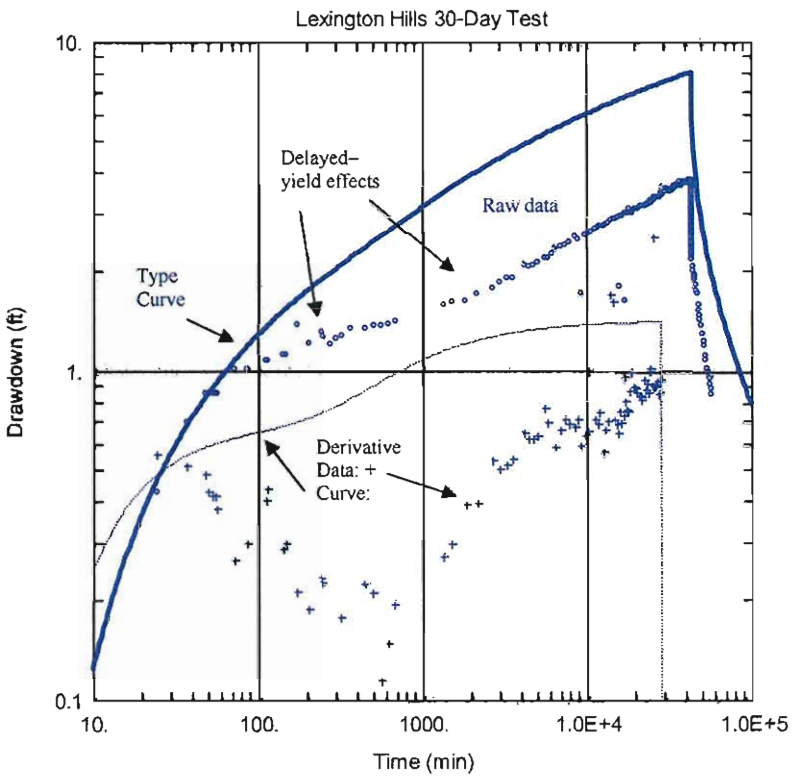
Where:

T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
S = Storativity (unitless)
S_y = Specific Yield (unitless)
s_w = Wellbore skin factor (unitless)
t = time in days
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
α = "empirical fitting parameter for non-instantaneous drainage" (min^{-1}) from curve adjustments

Solid Line represents "type curve" where T, S, Sy, Kv/Kh, s_w and α best match observed drawdown. Variations from "smooth," semi-log curve the result of Aqtesolv® generating type curve based on variations in reported pumping rate. Poor match during early time suggests flawed data.

Based on the analytical method of Moench (1997).

Figure 19. Theis (Early-Time) Analysis for Holgate Well Thirty-Day Test
Test Conducted: Mar 26-April 25, 1991



Holgate Well
Depth = 171 ft
T=120,000 gpd/ft
S=5.0x10^{-4}
Kv/Kh=0.1
Fault (no-flow) at 1/2 mi.
b=310 ft
r = 900 ft
Q = 732 gpm
(at Lexington Hills well #1)

Analysis with no-flow boundary (fault) 0.5 mile from pumping well trending N45W.

Fair early time match before delayed-yield effects at t>80 min. Poor fit of derivative curve indicates method not ideal, even for initial data.

Partial penetration effects minimal at this distance from pumping well.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

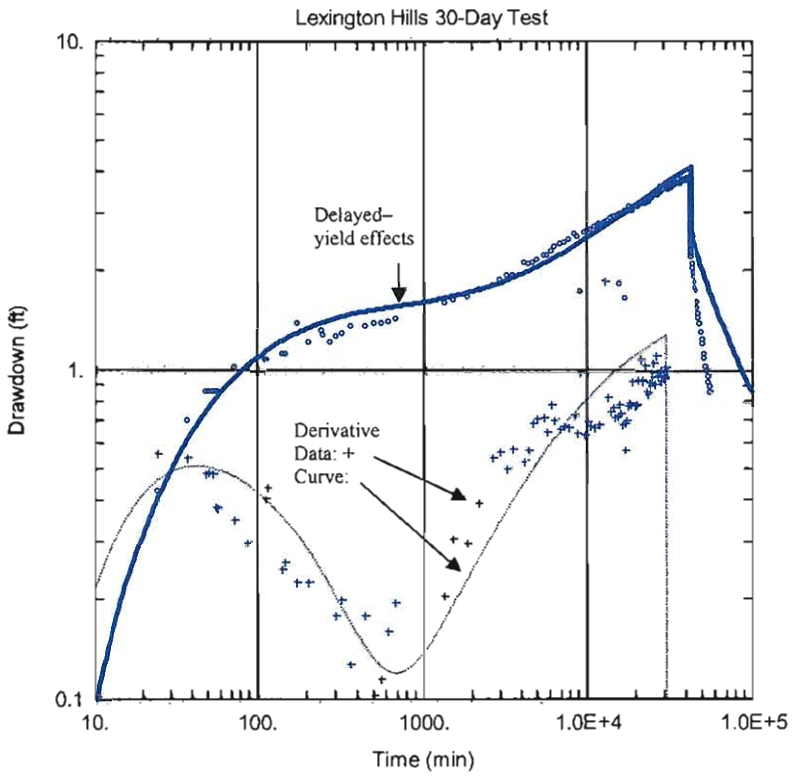
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 20. Moench Analysis for Holgate Well Thirty-Day Test
Test Conducted: Mar 26-April 25, 1991



Holgate Well
Depth = 171 ft.
T=96,000 gpd/ft
$S=3.0x10^{-4}$
$S_y= 1.2x10^{-2}$
Kv/Kh=0.1
Fault (no-flow) at 1/2 mi.
b =310 ft
r = 900 ft
$\alpha= 0.0002\ min^{-1}$
Q = 732 gpm
(at Lexington Hills well #1)

Good match for derivatives support method.

"Delayed Yield" (Moench) analysis used to accommodate downward (gravity) flow from upper portion of aquifer. Analysis with no-flow boundary (fault) 1/2 mile from pumping well trending N45W.

Good data match for drawdown. Less-good match at end of recovery probably caused by canal leakage that causes recovery to appear earlier than calculated.

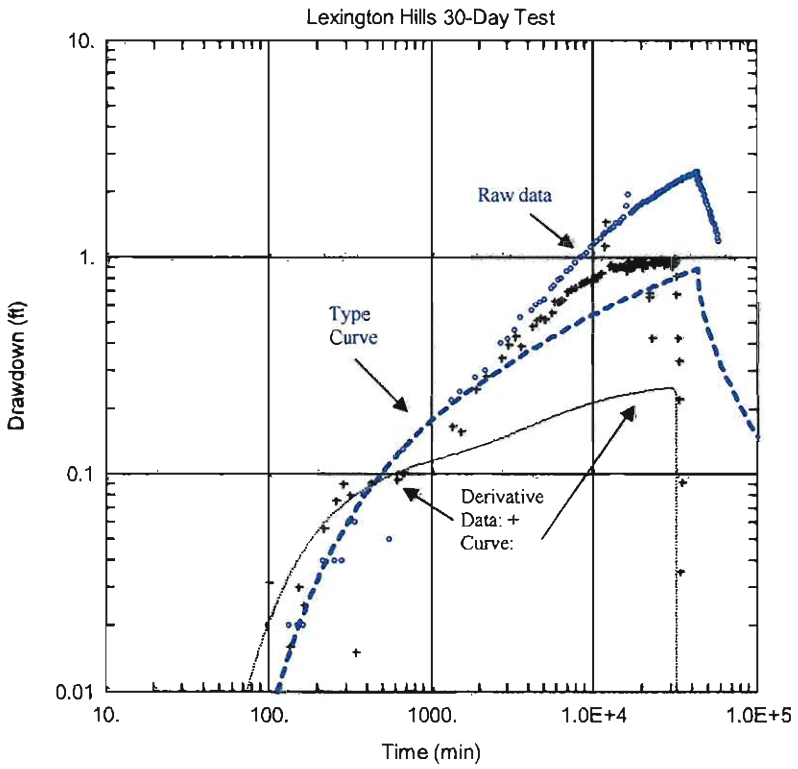
Where:

T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
S = Storativity (unitless)
S_y = Specific Yield (unitless)
s_w = Wellbore skin factor (unitless)
t = time in days
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
α = "empirical fitting parameter for non-instantaneous drainage" (min^{-1}) from curve adjustments

Solid Line represents "type curve" where T, S, Sy, Kv/Kh, and α best match observed drawdown

Based on the analytical method of Moench (1997).

Figure 21. Theis Analysis for Carson Well Thirty-Day Test
Test Conducted: Mar 26-April 25, 1991



Carson Well
Depth = 90 ft.
T = "600,000" gpd/ft
S = "2.5x10^{-2}"
Kv/Kh=0.1
b = 310 ft
r = 1,300 ft
Q = 732 gpm
(at Lexington Hills well #1)

Apparent early time match before t=1,000 min. may be valid. However, shallow nature of well may indicate a lower permeability zone between pumped zone and observation well. Poor fit of derivative curve after t=700 min indicates **method likely invalid**.

Analysis with no-flow boundary (fault) 0.5 mile from pumping well trending N45W.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

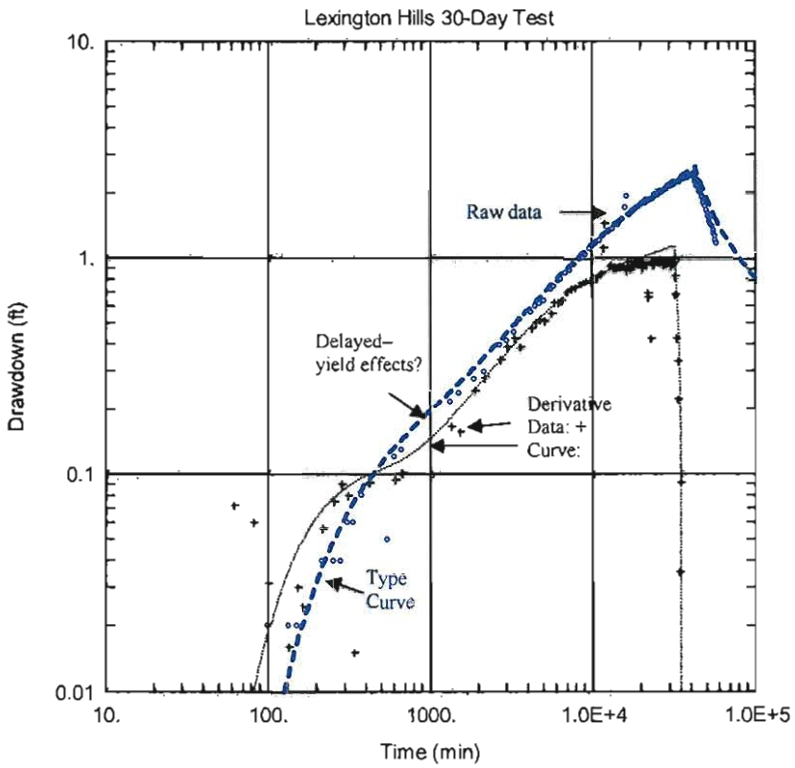
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 22. Moench Analysis for Carson Well Thirty-Day Test
Test Conducted: Mar 26-April 25, 1991



Carson Well
Depth = 90 ft.
T = 77,000 gpd/ft
S = 5.0×10^{-3}
$S_y = 3.5 \times 10^{-2}$
Kv/Kh=0.1
b = 310 ft
r = 1,300 ft
$\alpha = 0.0015\ min^{-1}$
Q = 732 gpm
(at Lexington Hills well #1)

Good match for derivatives support method.

"Delayed Yield" (Moench) analysis used to accommodate downward (gravity) flow from upper portion of aquifer. Analysis with no-flow boundary (fault) 1/2 mile from pumping well trending N45W.

Good data match for drawdown. Less-good match at end of recovery probably caused by canal leakage that causes recovery to appear earlier than calculated.

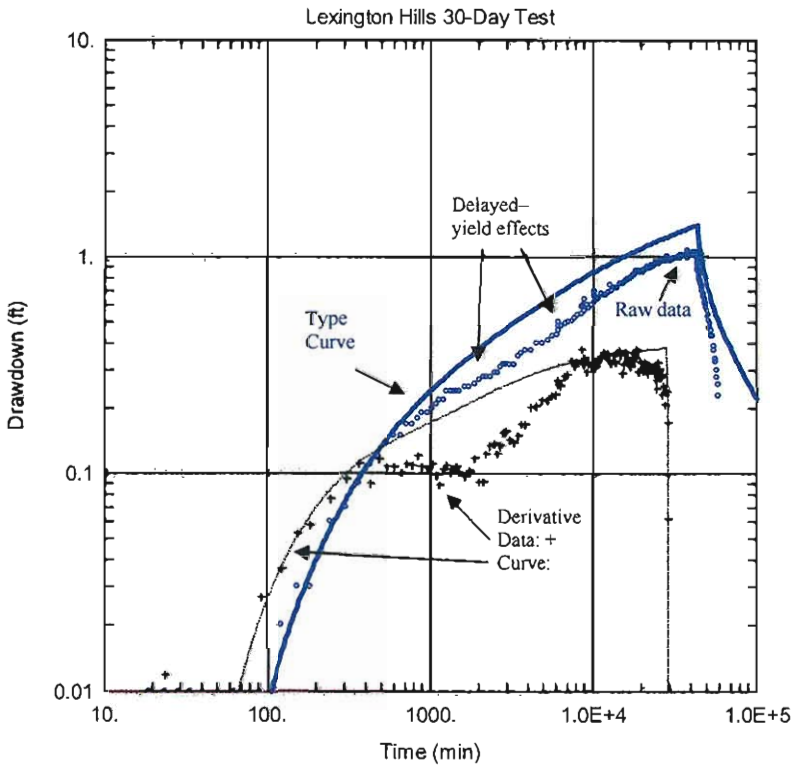
Where:

T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
S = Storativity (unitless)
S_y = Specific Yield (unitless)
s_w = Wellbore skin factor (unitless)
t = time in days
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
α = "empirical fitting parameter for non-instantaneous drainage" (min^{-1}) from curve adjustments

Solid Line represents "type curve" where T, S, Sy, Kv/Kh, and α best match observed drawdown

Based on the analytical method of Moench (1997).

Figure 23. Theis Analysis for Eagle Hills Golf Course Well Thirty-Day Test
Test Conducted: Mar 26-April 25, 1991



Eagle Hills
Golf Course Well
Depth = 175 ft
T= "420,000" gpd/ft
S= "5x10^{-3}"
Kv/Kh=0.1
Fault (no-flow) at 1/2 mi.
b = 310 ft
r = 2,500 ft
Q = 732 gpm
(at Lexington Hills well #1)

Apparent early time match before t=500 min. may be valid. Poor fit of derivative curve after t=500 min indicates **method likely invalid.**

Analysis with no-flow boundary (fault) 0.5 mile from pumping well trending N45W.

Partial penetration effects minimal at this distance from pumping well.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

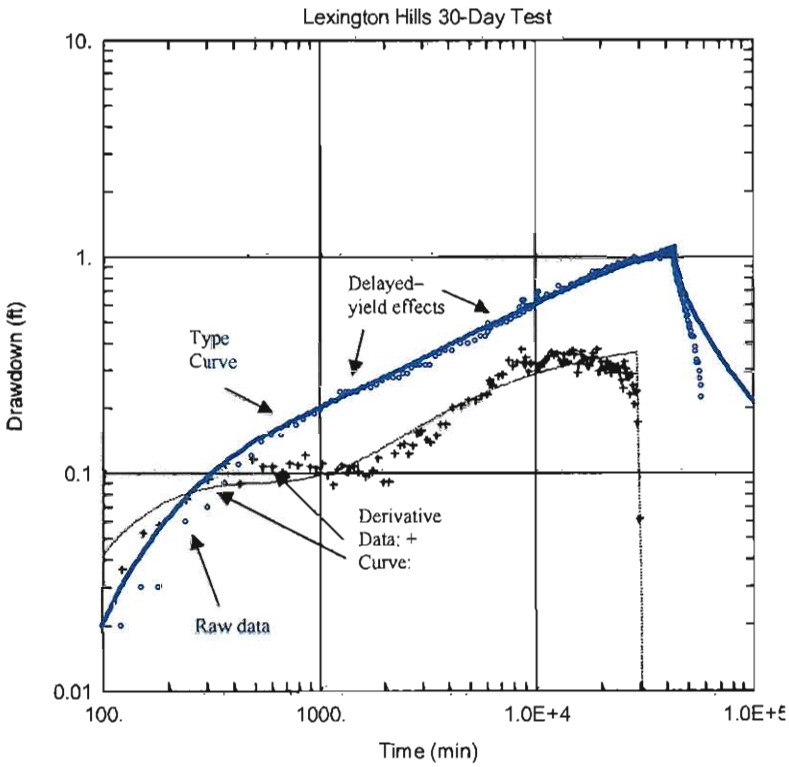
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 24. Moench Analysis for Eagle Hills Golf Course Well Thirty-Day Test
Test Conducted: Mar 26-April 25, 1991



Eagle Hills
Golf Course Well
Depth = 175 ft
T= 400,000 gpd/ft
S= $3x10^{-3}$
S_y= $8x10^{-3}$
Kv/Kh=0.1
b = 310 ft
r = 2,500 ft
α= 0.0007 min^{-1}
Q = 732 gpm
(at Lexington Hills well #1)

"Fair" match for derivatives support method.

"Delayed Yield" (Moench) analysis used to accommodate downward (gravity) flow from upper portion of aquifer. Analysis with no-flow boundary (fault) 1/2 mile from pumping well trending N45W.

Good data match for drawdown, however, only fair match into recovery probably caused by canal leakage that causes recovery to appear earlier than calculated.

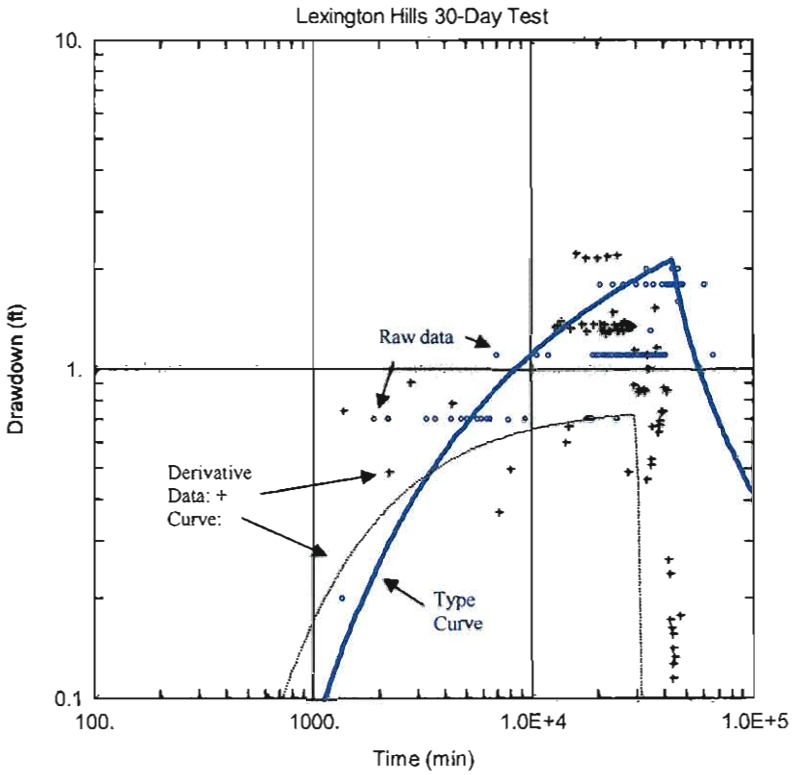
Where:

T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
S = Storativity (unitless)
S_y = Specific Yield (unitless)
s_w = Wellbore skin factor (unitless)
t = time in days
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
α = "empirical fitting parameter for non-instantaneous drainage" (min^{-1}) from curve adjustments

Solid Line represents "type curve" where T, S, Sy, Kv/Kh, and α best match observed drawdown

Based on the analytical method of Moench (1997).

Figure 25. Theis Analysis for Floating Feather Irrigation Well Thirty-Day Test
Test Conducted: Mar 26-April 25, 1991



Floating Feather Irrigation Well
Depth = 270 ft
T = Invalid No Match
S = Invalid
Kv/Kh=0.1
b = 310 ft
r = 5,100 ft
Q = 732 gpm
(at Lexington Hills well #1)

No fit to derivative curve indicates **results invalid.**

Resolution of air-line-collected data too coarse for analysis.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

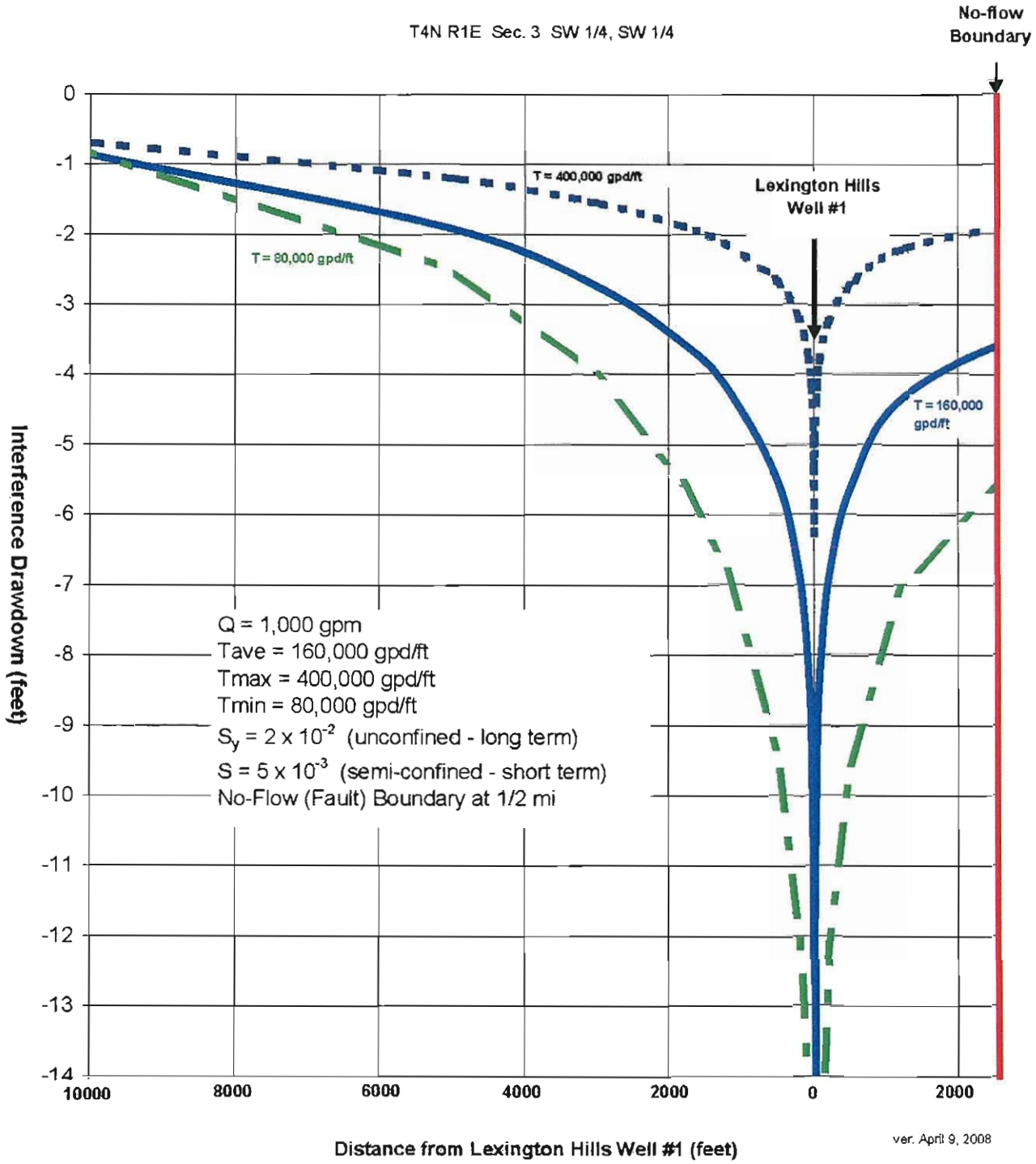
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 26. HLI's Predicted Interference at End of Summer Pumping from Lexington Hills #1



Rivervine Subdivision Well Six-Hour Test

Overview and Previous Analyses

The Rivervine Subdivision well was drilled by Treasure Valley Drilling and Pump co., Inc. using the, direct mud-rotary method during May of 2004. The well was drilled to a total depth of 190 ft bgl, backfilled and sealed to 120 ft bgl, and completed with stainless steel well screen open to the aquifer between depths of 72 and 118 ft bgl. The pretest water level was 1.75 ft above ground level which translates to an elevation of about 2,502 ft amsl. Treasure Valley Drilling conducted a pumping test on May 19th, 2004, for a period of 6 hours at an average rate of about 350 gpm, under the direction of Hydro Logic, Inc. At the end of the test, the reported drawdown was 22.73 ft, for an end-of-test specific capacity of 15.4 gpm/ft.

The Rivervine well is completed in a shallow undefined-aquifer that overlies the Pierce Gulch Sand Aquifer. This well is located in Figure 27 (page 83) as a labeled red diamond with a solid boundary. The well is completed between elevations of 2,428 ft amsl and 2,380 ft amsl. Well Driller's Reports for other wells in the area show that permeable sands and gravels lie at zones up to 72 feet below the bottom of the well. Analyses for the Eaglefield 7-Day well test (discussed above) indicate the top of the Pierce Gulch Sand Aquifer lies at depths of about 200 feet in the area one mile to the northeast of the Rivervine well site. Based on a dip of 100 feet per mile from the northeast to the southwest (HLI, 2007), we estimate that the top of the Pierce Gulch Sand Aquifer lies about 300 feet bgl in the vicinity of the Rivervine well, or at an elevation of about 2,200 ft amsl. Lower-permeability (but probably discontinuous and leaky) layers of clay and fine-grained sand separate the shallow undefined-aquifer tapped by the Rivervine well and the underlying Pierce Gulch Sand Aquifer. Non-pumping water levels in the shallow undefined-aquifer tapped by the Rivervine well are above ground, reflecting the upward ground-water flow-gradients shown by deeper wells in the area.

During the six-hour pumping test, HLI measured water levels in both the pumped well and an older domestic well 283 feet away from the Rivervine well. This well is located in Figure 27 as a green diamond with a dashed boundary. The maximum drawdown observed in the observation well was 4.85 ft at the end of the test. According to the Well Driller's Report, this domestic well is screened between 65 and 75 ft bgl, shallower than the Rivervine well. Water level drawdowns in both the pumped and observation wells leveled out during the last three hours of the test suggesting a source of recharge water either from nearby surface water sources such as the Boise River, subdivision ponds, Middleton Mill Canal or the Pioneer Canal; or from the delayed yield (gravity drainage) of water moving downward toward the well.

The purpose of the pumping test was to size the production pump for the newly completed well and to provide information to the Idaho Department of Environmental Quality (HLI, 2004). The test was *not* conducted to assess aquifer properties and so no

reports were issued discussing transmissivity or storativity. Pumping test data sheets including water levels measured during the test were prepared, however, and these data were available for analysis of aquifer parameters through the kind permission of Reed DeMordaunt. The Rivervine test is meaningful because it shows the properties of one of the shallow undefined-aquifers that overlie the Pierce Gulch Sand Aquifer.

HLI Analysis of the Pumping Test

A six-hour, 350 gpm pumping test was conducted on the Rivervine Well by Hydro Logic, Inc. on May 19th, 2004. At the end of the 6 hour test, the pumped well indicated 22.73 ft of drawdown for an end-of-test specific capacity of 15.4 gpm/ft. An older domestic well, 283 feet away, indicated a drawdown of 4.85 ft at the end of the test. A Cooper-Jacob straight-line plot (Figure 28 - page 84) and a Theis log-log plot (Figure 29 – page 85) show drawdown in the pumped Rivervine well. The Cooper-Jacob plot shows that lowering water levels followed a predicted straight-line trend up until about 3 hours into the test. After this time, the rate of drawdown began to decrease (drawdown was less than predicted by the straight line), following a more "flattened" line through the end of the test. (This flattening is not as noticeable on the Theis plot because of the scale of the logarithmic plot of drawdown displacement.) The straight-line plot indicated a transmissivity of 43,000 gpd/ft while the Theis curve generated a transmissivity of 48,000. Be believe that the Cooper-Jacob plot is probably more accurate than the Theis curve because the Theis curve was relatively flat, making an exact curve match more difficult than a best-fit straight line. In addition, the Theis analysis could have been affected by well loss which was not quantified with a step-rate test and could not be estimated because no recovery data were obtained or reported.

The derivative curve match for the two analyses supports their validity up through about 70 minutes. After which, deviations of the data from the type curves suggest a positive recharge boundary or leakage. The "u assumption" was met for the Cooper-Jacob analysis, also supporting its validity.

The observation well data were analyzed using the Cooper-Jacob method (Figure 30 – page 86) and the Theis method (Figure 31 – page 87). Both methods indicated similar values of transmissivity (36,000 gpd/ft for the Cooper-Jacob analysis and 37,000 gpd/ft, for the Theis analysis) and similar values for storativity (2.2×10^{-4} and 2.5×10^{-4}, respectively).

The derivative curve match for the two analyses supports their validity up through about 60 minutes. As with the pumped well, deviations of the data from the type curves suggest a positive recharge boundary or leakage. The "u assumption" was met for the Cooper-Jacob analysis after 25 minutes into the test, supporting its validity.

We believe the transmissivity results from these observation-well analyses may be more accurate than those for the pumped well because well loss and local permeability effects near the pumped well have only small to no effect on the observation well. In addition, partial penetration effects are minimal in the observation-well data; a sensitivity analysis

indicated little difference between the Theis analysis with partial penetration corrections based on Hantush (1961a and b,) and those without.

Because the wells are completed in the shallow undefined-aquifer overlying the Pierce Gulch Sand Aquifer, this transmissivity value only represents a portion of the shallow aquifer and not the Pierce Gulch Sand Aquifer itself. It does, however, show the hydraulic properties of the shallow undefined-aquifer, the possible interconnection to shallow ground water and surface water, and provide information that will help to quantify ground water flow beneath the Boise River Valley. The calculated transmissivity value is relatively large for such a limited thickness of sand. The flattening of the drawdown curve after 60 minutes of pumping may demonstrate leakage (and a hydraulic connection to the underlying Pierce Gulch Sand Aquifer) or the overlying shallow, unconfined, Boise River gravel aquifer. In other words, the lower-permeability sediments between the shallow undefined aquifer tapped by the Rivervine well and the deeper Pierce Gulch Sand Aquifer and/or the overlying Boise River gravel aquifer, may allow a hydraulic connection between the aquifers. Such behavior was noted in the Lexington Hills well test (discussed above) whereby shallower wells completed at 90 feet responded to pumping from a well completed at depths greater than 215 feet. Such behavior strongly suggests that the discontinuous interbedded clays are leaky, allowing hydraulic connection between the aquifers through or around these clay interbeds.

The calculated storativity of about $2x10^{-4}$ represents short-term pumping conditions when the system behaves in the manner of a confined aquifer. Based on the lithologic log for the well, we believe that pumping at high rates for periods of several weeks or more could cause the aquifer to behave as either 1) an unconfined aquifer or 2) a leaky confined aquifer. The flattening of the drawdown curve after three hours of pumping indicates the drawdown cone of depression intersected a source of water, but the source is not clear. This flattening could have been the beginning of the delayed yield phenomenon where the aquifer is beginning to partially dewater. If so, longer pumping would have caused the rate of drawdown to increase again with a resulting rise in the drawdown curve. The flattening could also have been the result of leakage from another aquifer flowing through an overlying or underlying aquitard. If so the drawdown curve would have remained flat. A third possibility is that the flattening indicated the intersection of the cone of depression with a surface recharge source such as a river, canal or pond. If so, the drawdown curve would have become less steep and possibly flat, as the recharge allowed the pumping water levels to stabilize. A longer pumping test of two to seven days or more would be necessary to properly assess the flattening of the curve to evaluate which of these sources was the more likely. Based on the behavior of this well and on the behavior of other wells evaluated as part of this report, we believe that an unconfined storativity of 10^{-2} to 10^{-1} (or larger) would be likely under high-rate, long-term pumping at this location.

This 6-hour test was insufficiently long to generate the data needed to better assess the properties of the shallow undefined-aquifer and how pumping this aquifer would affect water levels in the underlying Pierce Gulch Sand Aquifer (or the overlying Boise River gravel aquifer). The test did, however, yield good-quality data on short-term aquifer

behavior of the shallow undefined-aquifer. A longer-term test and monitoring in the Pierce Gulch Sand Aquifer would be necessary to better assess the ground water flow system in the vicinity of the Rivervine well.

Well Interference and the Effects of Seasonal Pumping

Because the Rivervine well has a relatively low yield and is completed in a shallow undefined-aquifer that overlies the Pierce Gulch Sand Aquifer, no seasonal pumping effect analysis was conducted.

Conclusions

Based on the overview and analysis presented above, we make the following conclusions:

1. The Rivervine well is completed in a shallow undefined-aquifer that consists of permeable, coarse-grained sand. This undefined aquifer overlies the regional Pierce Gulch Sand Aquifer.

2. Analyses of pumped-well and observation-well data indicate the transmissivity of this shallow undefined-aquifer is about 40,000 gpd/ft.

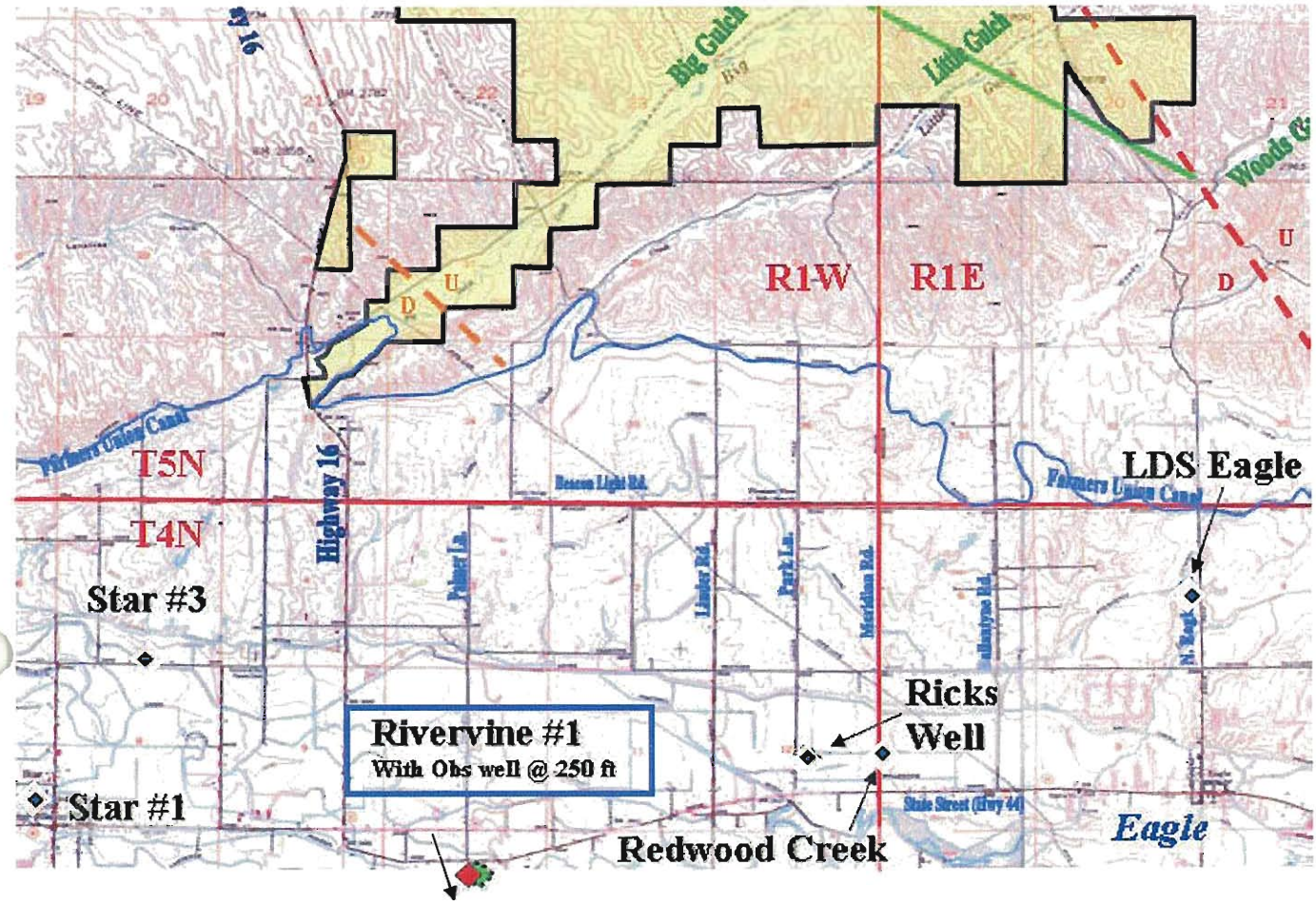
3. Short-term storativity was calculated at 2.2 to 2.5×10^{-4}. This value indicates short-term, confined-aquifer behavior.

4. The drawdown curve flattened during the last three hours of testing suggesting leakage from other aquifers, recharge from surface water or delayed yield of the aquifer. The data are insufficient to determine which of these possibilities occurred.

5. A longer term-test of two days to a week would be needed to better characterize whether the aquifer is leaky-confined or unconfined and to better quantify aquifer storativity. Were a long-term test to indicate that the aquifer is unconfined (i.e., recharge from a surface source was indicated or delayed yield occurred), specific yield (effectively long-term storativity) is predicted to be on the order of 10^{-2} to 10^{-1} or more

6. The Rivervine well test indicates the properties of a shallow undefined-aquifer overlying the Pierce Gulch Sand Aquifer. The calculated value does not represent the transmissivity of the regional aquifer at this location. The test results are helpful, however, in providing information on a shallow aquifer that is part of the overall regional ground water system that includes the Pierce Gulch Sand Aquifer. Such information will aid in the quantification of the overall ground water resources of the greater Eagle-Star vicinity and beyond.

Figure 27. Well Locations for Rivervine Six-Hour Test



Pumping Well Location

Observation Well Location

Approximate Northern Boundary of the Pierce Gulch Sand Aquifer

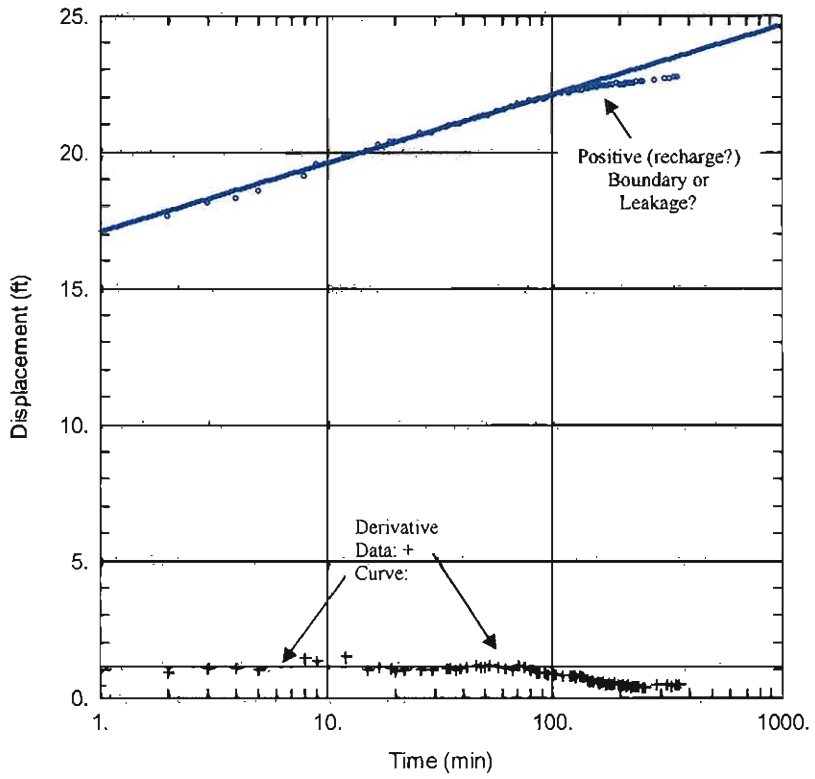
Approximate position of the West-Boise-Eagle Fault
D on down-dropped side
U on up-thrown side

Fault located by magnetometer survey
D on down-dropped side
U on up-thrown side

One Mile

N

Figure 28. Cooper-Jacob Analysis for the Rivervine Well 6-Hour Test
Test Conducted: May 19, 2004



Rivervine Well
Screen = 72-118 ft
T=43,000 gpd/ft
S = Not Calculable
Kv/Kh=0.1
b = 116 ft
t_c < 1 min
r = 1 ft
Q = 350 gpm

No correction for partial penetration.

Derivative curve match indicates method is applicable up to 70 minutes into test. Positive boundary (or leakage) after 70 minutes is indicated.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

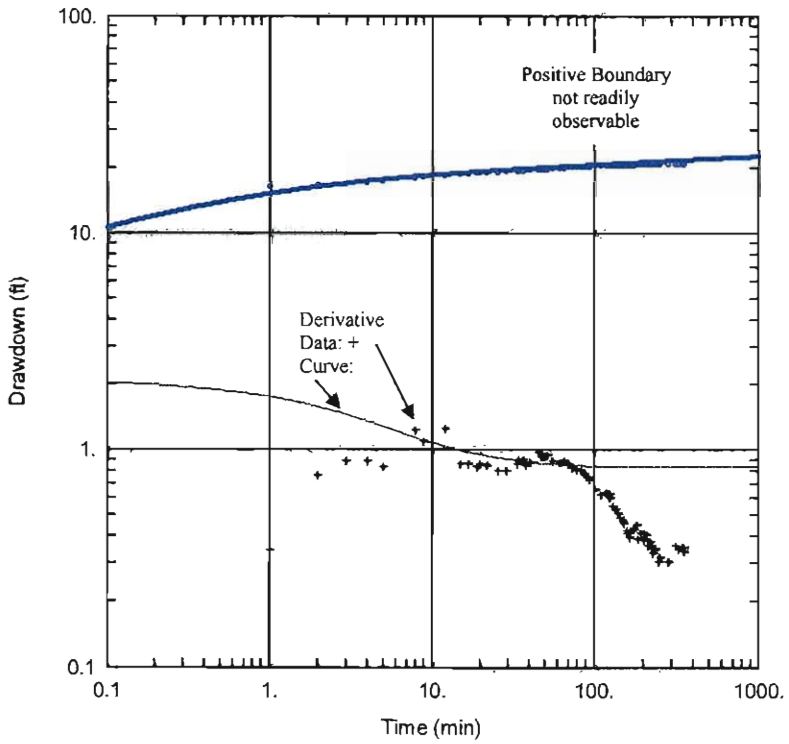
t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid (less than 1 minute and therefore not shown on graph).

$u = 1.87r^2S/Tt$
t = time in days
r = effective radius of pumping well (ft)

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs from the pumping well and other wells in the area

Based on the analytical method of Cooper and Jacob (1946).

Figure 29. Theis Analysis for the Rivervine Well 6-Hour Test
Test Conducted: May 19, 2004



Rivervine Well
Screen = 72-118 ft
T=48,000 gpd/ft
S = Not Calculable
Kv/Kh=0.1
b = 116 ft
r = 1 ft
Q = 350 gpm

No correction for well loss (no data available). Partial penetration correction applied.

Fair derivative curve match indicates method is applicable up to 70 minutes into test. Positive boundary (or leakage) after 70 minutes is indicated. Variations and poor fit to derivative curve before 5 minutes likely the result of pumping rate adjustments.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

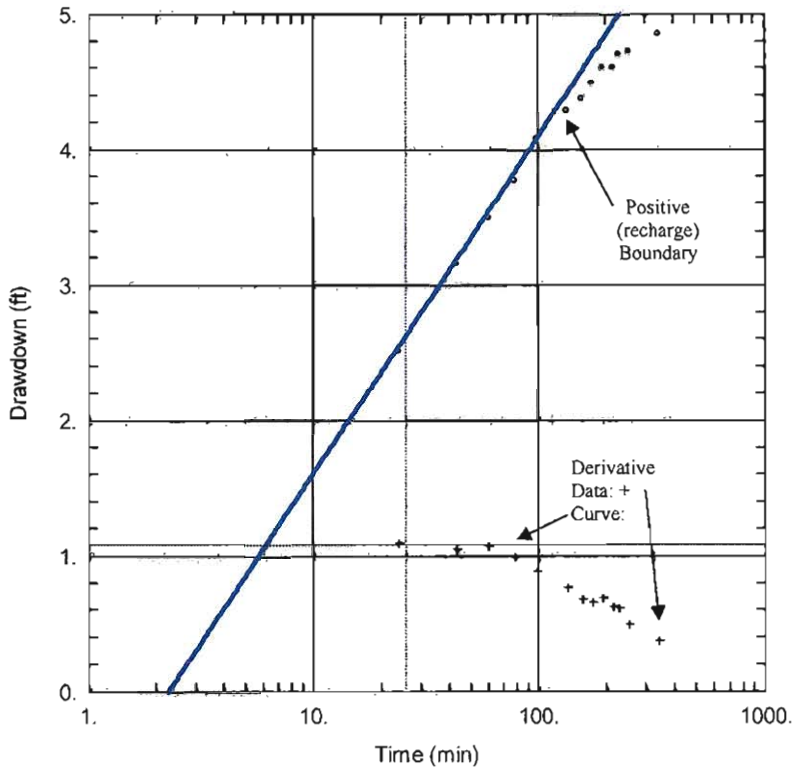
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs from the pumping well and other wells in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935) with partial penetration corrections of Hantush (1961a and b).

Figure 30. Cooper-Jacob Analysis for the Rivervine Observation Well 6-Hour Test
Test Conducted: May 19, 2004



6-In Observation Well
Screen = 65-75 ft
T=37,000 gpd/ft
S = 2.2×10^{-4}
Kv/Kh=0.1
b = 116 ft
r = 283 ft
t_c = 25 min
Q = 350 gpm
(At Rivervine Well)

No correction for partial penetration. However, sensitivity analysis using Theis/Hantush shows PP correction not significant.

Critical time t_c and "u assumption" met. Fair derivative curve match indicates method is applicable up to 60 minutes into test. Positive boundary (or leakage) after 60 minutes is indicated.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

$S = (0.3\ Tt_0)/r^2$, where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t_0 = intercept of the straight line at zero drawdown, in days (where solid line intercepts time axis)

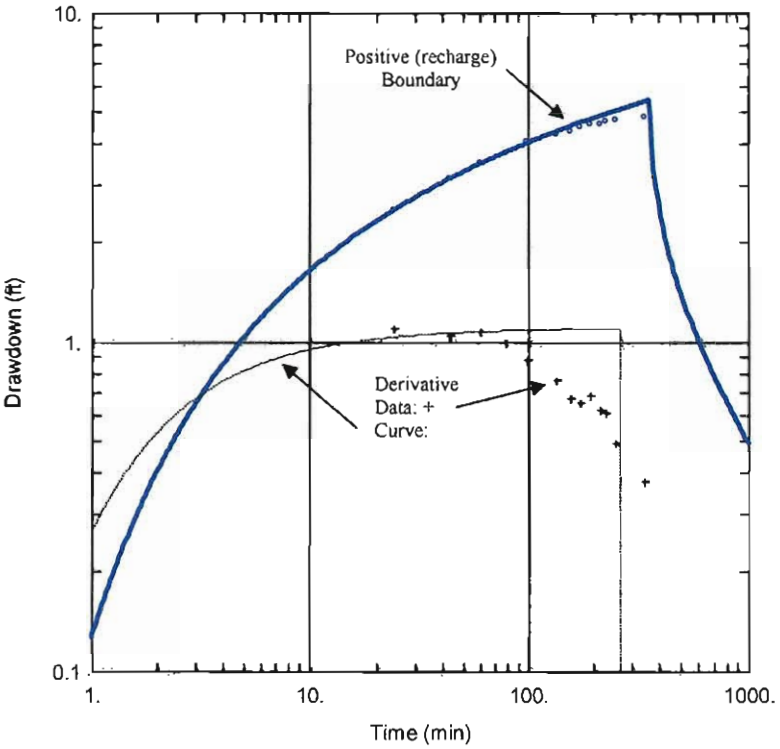
t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

$u = 1.87r^2S/Tt$ (dashed vertical line above where u = 0.05)
t = time in days

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs from the pumping well and other wells in the area

Based on the analytical method of Cooper and Jacob (1946).

Figure 31. Theis Analysis for the Rivervine Observation Well During 6-Hour Test
Test Conducted: May 19, 2004



6-In Observation Well
Screen = 65-75 ft
T = 36,000 gpd/ft
S = 2.5 x10^{-4}
Kv/Kh=0.1
b = 116 ft
r = 283 ft
Q = 350 gpm
(At Rivervine Well)

Includes Hantush (1961a and b) correction for partial penetration. However, sensitivity analysis using Hantush shows PP correction not significant.

Fair derivative curve match indicates method is applicable up to 60 minutes into test. Positive boundary (or leakage) after 60 minutes is indicated.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

W(u) = 1.87r^{2}S/Tt Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs from the pumping well and other wells in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935) with partial penetration corrections of Hantush (1961a and b).

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Redwood Creek Subdivision Well Eight-Hour Test

Overview and Previous Analyses

The Redwood Creek subdivision well was drilled by Pete Cope Drilling using the reverse-circulation, mud-rotary method during March and April of 1994. The well was drilled to a total depth of 415 ft bgl and completed with stainless steel well screen open to the aquifer between depths of 298 and 401 ft bgl. The pretest water level was 4.70 ft above ground level which translates to an elevation of about 2,550 ft amsl. A pumping test was conducted on April 7, 2004, for a period of 8 hours at an average rate of about 2,100 gpm. Although the pumping test was discussed in Scanlan Engineering (1994), the pumping contractor was not named. At the end of the test, the reported drawdown was 96.0 ft, for an end-of-test specific capacity of 21.9 gpm/ft. This well is located in Figure 32 (page 94) as a red diamond with a solid boundary.

The Redwood Creek well is completed in the middle portion of the Pierce Gulch Sand Aquifer between elevations of 2,144 ft amsl to 2,247 ft amsl. Driller's Reports indicate that layers of sands and clays overlie the aquifer zone tapped by the Redwood Creek well. An irrigation well known locally as the Ricks well (*not* the same well monitored as part of the Eaglefield well test discussed above) served as an observation well during the test. According to Scanlan Engineering (1994) it lies approximately 2,500 feet from the pumped well, is 284 feet deep (shallower than the Redwood Creek well), and indicated 4.4 ft of drawdown at the end of the test. The exact well location and screen depths were not noted in the Scanlan Engineering report nor was a map provided showing its location. Our estimate of approximate well location based on the written description in Scanlan is shown in Figure 32 as a green diamond with a dashed boundary. Data from the pumping test, along with plots of water levels, were included, in the Scanlan report.

Scanlan Engineering calculated a transmissivity of 54,000 gpd/ft from pumping well data and 154,000 gpd/ft from the Ricks observation-well data. He attributed the difference in values to an "indirect hydraulic connection between the two wells." He calculated a storativity of $2x10^{-4}$. Scanlan had no quantitative analyses or curves presented along with the plotted data to support his analytical results. Scanlan's results are included in Table 3 (page 247).

HLI Analysis of the Pumping Test

HLI analyzed the data generated from a pumping test of the Redwood Creek well using the Ricks well as an observation well. The Redwood Creek well is completed between 298 and 401 ft bgl, and experienced 96 ft of drawdown after being pumped for 8 hours at 2,100 gpm, for an end-of-test specific capacity of 21.9 gpm/ft. The Ricks well lies an estimated 2,500 ft away, is completed to a depth of 284 ft bgl and experienced 4.4 ft of drawdown at the end of the test. A Cooper-Jacob straight-line plot (Figure 33 page 95) and a Theis log-log plot (Figure 34 page 96) show drawdown data from the pumped (Redwood Creek) well. The Cooper-Jacob plot shows that water levels followed the

straight-line trend after about 8 minutes of pumping. The apparent delay in the straight-line plot appears to have been the result of variations in pumping rate that occurred during the first six minutes of pumping. Our radial flow analysis indicated that well-bore storage did not measurably affect the data (as is reasonable, given the high discharge rate). The straight-line Cooper-Jacob plot with the raw data indicates a transmissivity of 54,000 gpd/ft while our analysis using the data corrected with the Butler (1957) approximations for the effects of partial penetration, indicates a transmissivity of 140,000 gpd/ft. The Theis analysis (with partial penetration corrections of Hantush, 1961a and b), generated a transmissivity of 120,000 gpd/ft from the raw data and 150,000 gpd/ft for the data corrected for maximum likely well loss. The Cooper-Jacob analyses with partial penetration corrections, and the Theis analysis with Hantush corrections for partial penetration and estimated maximum likely well loss, both indicated similar results. We believe that the analyses with partial penetration corrections are more likely to better represent true aquifer transmissivity, than are the analyses without these corrections.

Our Theis analysis that included corrections for estimated maximum well loss resulted in a calculated transmissivity about 20 percent greater than the analysis using the raw (uncorrected) data. The upper plot in Figure 34 (page 96) shows the raw data while the lower plot shows the corrected data. The correction was based on an estimated maximum well loss because sufficient data were not included in the Scanlan report to calculate well loss. We conducted our analysis using an estimated maximum well loss of 25 ft, to calculate the potential upper end-value for transmissivity that would result were actual well loss incorporated into the analysis. The assumed well loss of 25 ft represents about 50 percent of the drawdown observed at two minutes into the test, a well loss that we believe to be greater than that which actually occurred. The transmissivity calculated using drawdown data minus 25 ft (our estimate of maximum likely well loss) was about 10 percent higher than that calculated using the raw data. Since a well loss of 50 percent is probably at the high end of likely actual well losses for a well pumping at 2,100 gpm with 65 feet of screen opening (0.040-in slot size), we believe that the analysis using this estimated maximum well loss probably defines the upper end of possible transmissivity. The actual transmissivity in the region of the pumping well is likely to be smaller. We believe transmissivity is likely to be in the range of the 140,000 gpd/ft (indicated by the Cooper-Jacob analysis using approximate corrections for partial penetration) to 150,000 gpd (indicated by the Theis analysis using a approximate corrections for maximum likely well loss).

The observation well data were analyzed using the semi-log Theis method (Figure 35 – page 97). We used the semi-log Theis method instead of the Cooper-Jacob method as it allows for the use of an almost straight line independent of the "u assumption." (A Cooper-Jacob straight-line analysis could not be used with confidence because the "u assumption" was not met until 330 minutes into the 500-minute test.) The Theis method indicated a transmissivity of 140,000 gpd/ft and a storativity of 1.8×10^{-4}. The transmissivity results from our observation-well analysis is almost identical to the values calculated for the pumping well (Redwood Creek). Because the Ricks well is sufficiently far from the pumped well (2,500 ft) partial penetration effects are insignificant, as was indicated in a sensitivity analysis (not shown) which demonstrated no significant

difference in results with or without the Hantush (1961a and b) corrections for partial penetration. The analyses for the Ricks well, however, are based on only five data points (all that were provided in the Scanlan Engineering report). The small number of data points reduces the certainty of the analyses.

The derivative analyses support the use of the Cooper-Jacob analysis of the pumping well data. The derivatives for the Theis analysis do not match as well but still suggest that the method is applicable for the pumping well. The mismatch is likely the result of adjustments made at the flow-valve which altered the amount of drawdown and thereby made the derivatives vary. Thus, we believe the Theis analysis gives a reasonable approximation. There are too few data points for the observation well data for a derivative analysis to be of use to indicate the degree of validity of the method but the close agreement with the pumping well analysis is conformational.

Based on the pumping well and observation well analyses, we believe a transmissivity of 140,000 gpd/ft best represents the average in the vicinity of the Redwood Creek and Ricks well. This value is in the range of other transmissivity values calculated for other aquifer tests in the greater Eagle area, as listed in Table 3 (page 247).

The storativity of $2x10^{-4}$ indicates a confined aquifer. Based on the behavior of other wells completed at similar depths in the areas to the west of the Redwood Creek well, we believe that aquifer will remain confined over long-term pumping (periods of one or more weeks), even at relatively high pumping rates (3,000 gpm).

Well Interference and the Effects of Seasonal Pumping

The representative transmissivity (plus a higher and lower value to bracket the analysis) and the representative storativity values were used in a simulation to predict inference effects in the aquifer at distances to almost 4 miles from the Redwood Creek well. In this simulation, the Theis method was used to generate drawdown curves as a function of distance from the Redwood Creek well pumping at 1,000 gpm which is an estimate of what the well appears to pump on average during the summer pumping season. (A selection of August 2002, daily average pumping data from this well was reviewed and pumping varied from about 700 to 1,250 gpm during this period. We believe that the Redwood Creek well could be pumped on a continuous basis at 1,000 gpm and have selected this rate for our analysis.) The Theis method was selected as it is generally conservative (tending to over estimate drawdown) as it does not consider leakage from overlying zones or the capture of recharge. The representative transmissivity of 140,000 gpd/ft was used in our analysis along with values twice as large and half as small (280,000 gpd and 70,000 gpd/ft, respectively). We used a storativity of $2x10^{-4}$ (a value representative of the test conditions) in the analysis. An image well was used to simulate the hydraulic effects of the no-flow boundary represented by the West-Boise-Eagle fault, which lies about 20,000 feet to the northeast of the Redwood Creek well.

Our results, presented in Figure 36 (page 98), show that at the end of a 90-day summer pumping season, interference drawdowns of about 7 to 9 feet are predicted for wells

completed in the aquifer, one mile away from the Redwood Creek well and may be on the order of 5 to 6 feet up to four miles away. Use of the upper-end transmissivity results in a prediction of 4 to 5 feet of interference one mile away, and 3 to 4 feet at a distance of four miles away. The lower-end values lead to a prediction of 12 to 13 feet of interference one mile away and 7 to 11 feet of interference four miles away. As discussed in the methods section above, this analysis is conservative and is likely to over-estimate interference; the drawdown cone of depression from the pumping well would probably expand sufficiently to capture recharge equal to the pumping rate before 90 days, such that the pumping drawdown in the well would stabilize[15]. The Theis analysis assumes no recharge (water pumped by a well only comes from aquifer storage) and that a pumping well water level always continue to draw down. In reality (and observed many times, in our experience) the drawdown in a well pumped for 90 days in a hydrogeologic setting like that of the Redwood Creek well, typically levels off and remains relatively constant before 90 days of continuous pumping.

We consider the predicted interferences to be only an approximation because the Pierce Gulch Sand Aquifer system is not uniform. The actual drawdown that would occur with summer-long pumping will vary from our predictions, depending on the actual properties of the aquifer between the Redwood Creek well and a given point of interest. We used a uniform transmissivity of 140,000 gpd/ft in the prediction while calculated transmissivities ranged from 80,000 to more than 800,000 gpd/ft for the wells completed in other parts of the Pierce Gulch Sand Aquifer. Of course, monitoring of actual interference is preferred to theoretical predictions.

Conclusions

Based on the overview and analysis presented above, we make the following conclusions:

1. The Redwood Creek well is completed in the regional Pierce Gulch Sand Aquifer, in permeable coarse-grained sands.

2. Analyses of the pumped well and observation well data indicate the transmissivity of the Pierce Gulch Sand Aquifer near this well is 140,000 gpd/ft. The storativity was calculated at 1.8×10^{-4}, indicating a confined aquifer.

3. Interference drawdown from production of 1,000 gpm at the Redwood Creek well is predicted to cause drawdowns of about 4 to 5 feet at wells completed in the same aquifer, at a distance of mile away, after 90 days of continuous pumping. Interference drawdown at a distance of four miles, after 90 days of continuous pumping is predicted to be on the order of 3 to 4 feet.

13. The observation-well data-analysis by Scanlan Engineering appears to be in agreement with our results. Scanlan's analysis based on the pumping well was

[15] Water *levels*, however, may not necessarily stabilize if seasonal aquifer water level trends, interference from other wells and/or barometric effects are present.

about one-third the value HLI calculated by incorporating the effects of partial penetration.

Figure 32. Well Locations for Redwood Creek Eight-Hour Test

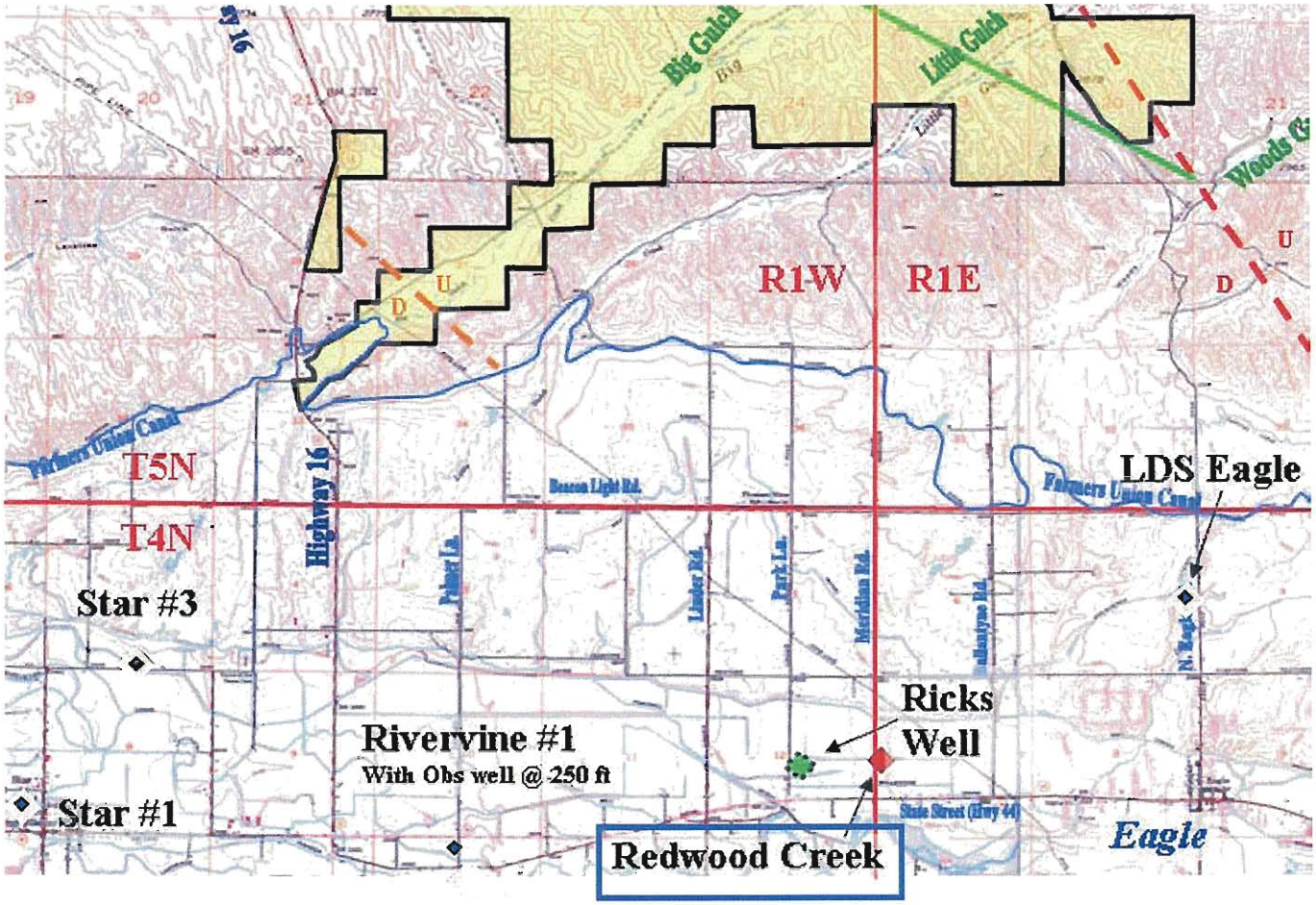
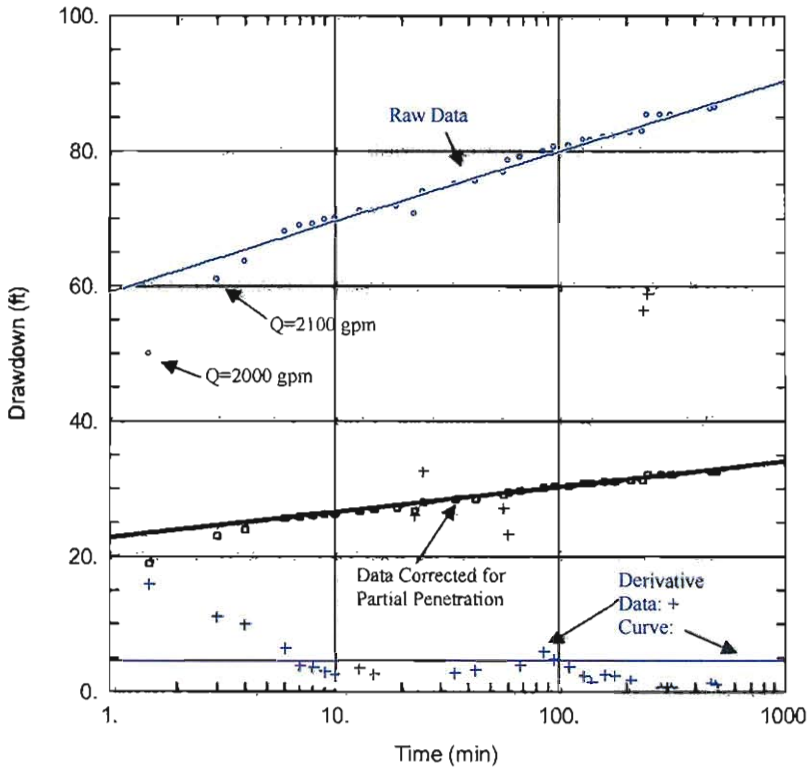


Figure 33. Cooper-Jacob Analysis for Redwood Creek Well Eight-Hour Test
Test Conducted: April 7, 1994



Redwood Creek Well
Screen = 298-401 ft
T = 54,000 gpd/ft
(no PP corrections)
T=140,000 gpd/ft
(with PP corrections)
S = Not Calculable
b =350 ft
t_c <1 min
r = 1 ft
Q = 2,100 gpm

Butler partial penetration correction makes calculated T for whole-aquifer thickness about 3 times greater than calculated value without PP correction.

Irregular pumping during first 5 minutes of test makes curve match impossible during this time.

Derivative curve match indicates method is applicable throughout test. No boundaries or leakage indicated.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

$u = 1.87r^2S/Tt$
t = time in days
r = effective radius of pumping well (ft)

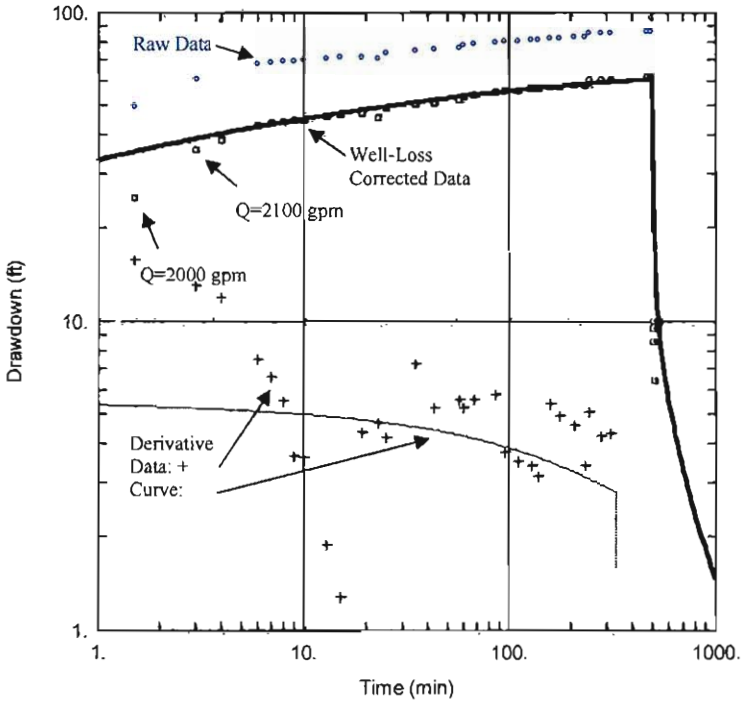
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

$s_{pp} = 0.266\ s_{observed}$ where:

s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Based on the analytical method of Cooper and Jacob (1946).
Partial penetration corrections from Butler (1957).

Figure 34. Theis Analysis for Redwood Creek Well Eight-Hour Test
Test Conducted: April 7, 1994



Redwood Creek Well
Screen = 298-401 ft
T=120,000 gpd/ft (raw data)
T=150,000 gpd/ft (corrected data)
S Not Calculable
Kv/Kh=0.1
b = 350 ft
r = 1 ft
Q = 2,100 gpm

Hantush partial penetration correction leads to aquifer transmissivity coefficient more than twice as large as analytical results without this correction. An estimated maximum likely well loss correction of 25 ft (subtracted from raw data) leads to transmissivity 20 percent larger than uncorrected data. See text for details.

Fair derivative curve match indicates method is generally applicable. Scatter is likely from discharge adjustments.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

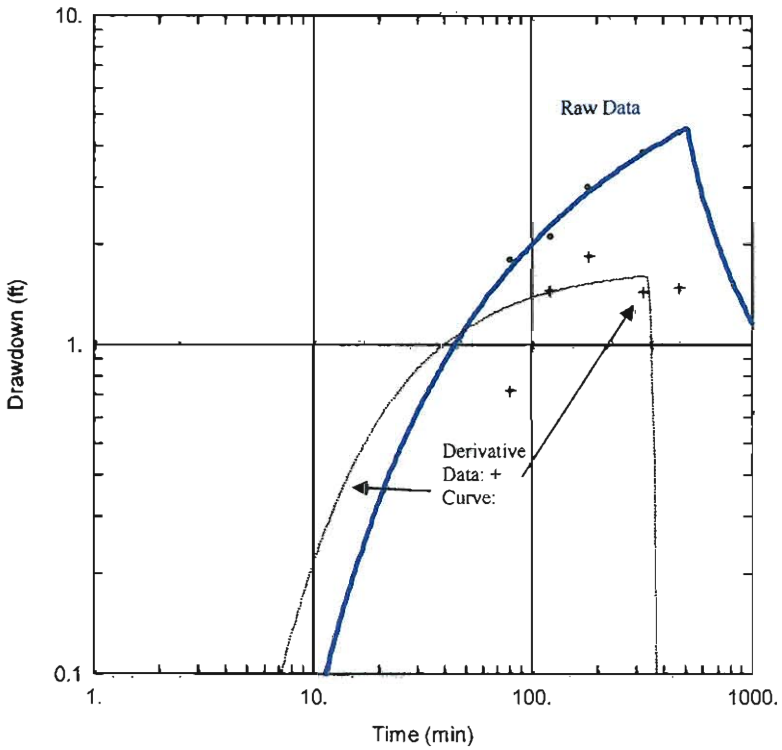
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown. Variations from "smooth," semi-log curve the result of Aqtesolv® generating type curve based on variations in reported pumping rate. Poor match during early time suggests flawed data.

Based on the analytical method of Theis (1935) with partial penetration corrections of Hantush (1961a and b).

Figure 35. Theis Analysis for Ricks Well: Redwood Creek Eight-Hour Test
Test Conducted: April 7, 1994



Ricks Well
Screen = 246-284? ft
T=140,000 gpd/ft
S = 1.8×10^{-4}
Kv/Kh=0.1
b =385 ft
r ≈ 2,500 ft
Q = 2,100 gpm
(at Redwood Creek Well)

Hantush partial penetration correction leads to no significant change in aquifer transmissivity coefficient. Ricks well sufficiently far from Redwood Creek well for horizontal flow.

Too few data points make derivative analysis unusable to indicate validity of method.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

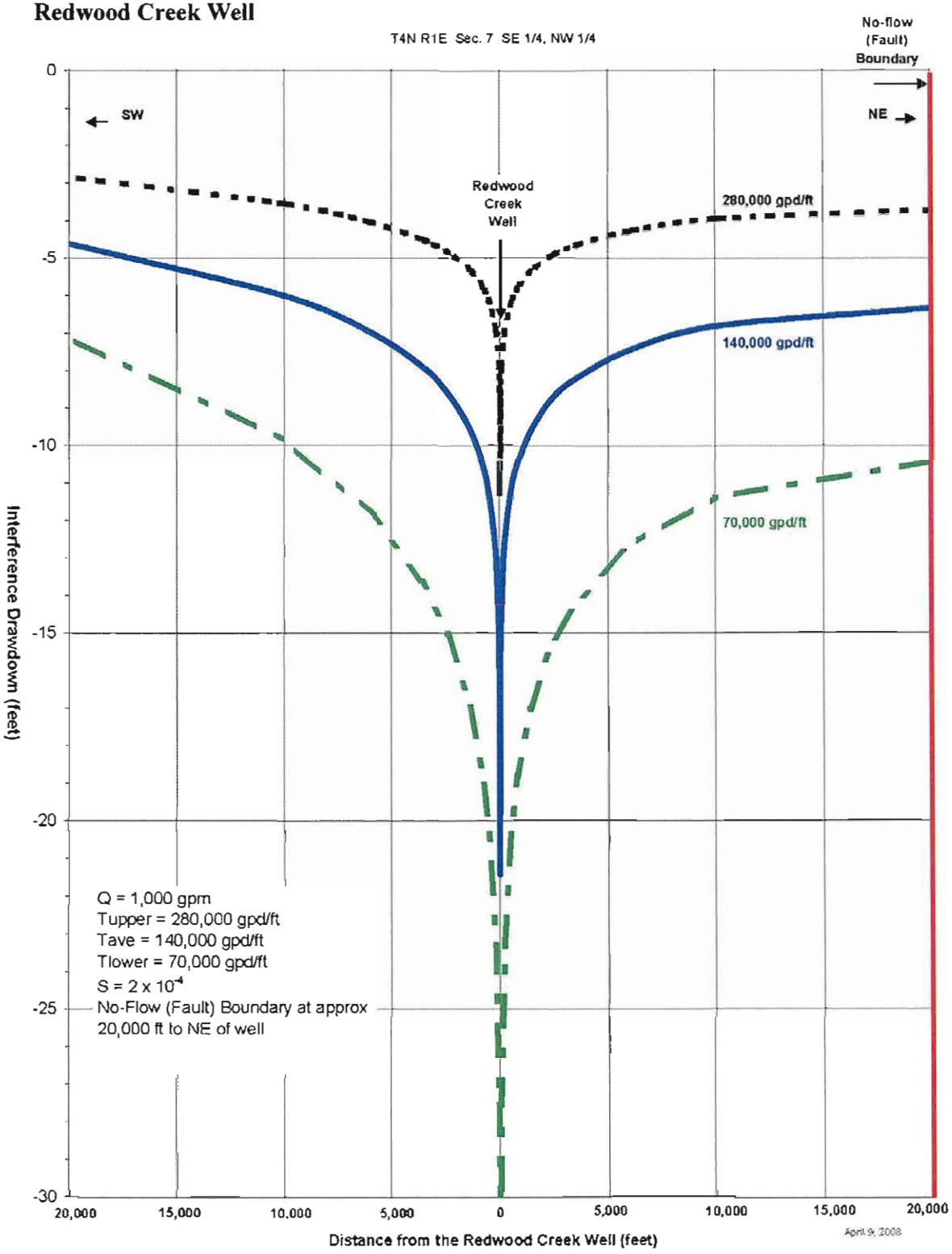
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 36. HLI's Predicted Interference at the End of Summer Pumping from the Redwood Creek Well



Star Sewer and Water District Well #1 Eight-Hour Test

Overview and Previous Analysis

Star Well #1 was drilled by Riverside Drilling using the reverse-circulation, mud-rotary method during February of 1995. Star Well #1 was drilled to a total depth of 565 ft bgl and completed with stainless steel well screen open to the aquifer between depths of 452 and 550 ft bgl. The pretest shut-in pressure was reported at 17.5 psi, equivalent to a water level of 40.6 ft above ground level which translates to an elevation of about 2,506 ft amsl. Personnel from Boise State University (Ed Squires and Roger Dittus) conducted an artesian flow test on February 27, 1995, for a period of 8 hours at an average flow rate of about 800 gpm. At the end of the test, the reported drawdown was 29.39 ft, for an end-of-test specific capacity of 27.2 gpm/ft. BSU personnel conducted the eight-hour "flow" test as part of an "opportunistic" research project[16], and not a part of testing for pump design.

Star Well #1 is completed in the Pierce Gulch Sand Aquifer between elevations of 1,915 ft amsl to 2,013 ft amsl. This well is located in Figure 37 (page 102) as a red diamond with a solid boundary. Star Well #1 is deeper than most other wells discussed in this report because the Pierce Gulch Sand Aquifer dips to the southwest and lies deeper beneath Star than it does beneath Eagle (HLI, 2007). No observation wells were monitored during the test. The well was discharged under existing artesian pressure; no pump was used. In other words, the difference between the measured above-ground potentiometric head of 40.6 ft agl (above ground level) and the level of the discharge pipe (just above ground level) was used to drive discharge. Constant flow was maintained by adjusting a flow valve and monitoring above-ground water level in the well. Flow was measured by measuring the time it took to fill a 55-gallon barrel. Water levels in the well were measured with a transparent, above-ground tube and measuring tape. The well had not been developed or pumped prior to testing, other than allowing the well to flow under artesian pressure. Data from the pumping test along with plots of the water levels were available in the files of Hydro Logic, Inc. To our knowledge, no previous analyses of aquifer properties have been published.

HLI Analysis

A Cooper-Jacob straight-line plot (Figure 38, page 103) and a Theis log-log plot (Figure 39, page 104) show drawdown data in the Star Well #1. The Cooper-Jacob plot shows that measured water levels followed a straight-line trend after about 20 minutes when the flow rate was (apparently) stabilized. It is generally more difficult to maintain a constant

[16] "Opportunistic" refers to the fact that the test was not commissioned by the well owner to generate information on pump sizing or aquifer characterizes; rather, because the well was available and the owner was willing, the test was conducted to generate more information on the aquifer to better understand the ground water system in the area. As such, the test may not have been as complete or as thorough as possible because of research-budget constraints or the need to accommodate the desires and schedule of the well owner.

flow rate when using a flow valve and artesian flow (and no pump) to maintain a constant rate as the pressure drops during the test. The Cooper-Jacob plot uncorrected for the effects of partial penetration (upper plot in Figure 38) indicates a transmissivity of 50,000 gpd/ft while the data corrected for partial penetration effects (lower plot) using the approximate method of Butler (1957) indicates a transmissivity of 120,000 gpd/ft.

The Theis plot (which includes Hantush (1961a and b) corrections for the effects of partial penetration but without adjustments for well loss (the upper curve in Figure 39) indicates a transmissivity of 100,000 gpd/ft. The Theis analysis with corrections for estimated upper end well loss (the lower curve in Figure 39) indicates a transmissivity of 120,000 gpd/ft based on an estimated maximum likely well loss of 9 ft. Since sufficient data were not available to calculate actual well loss, we conducted the analysis using an estimated maximum likely well loss of 9 ft. This value represents about one-half of the drawdown observed at two minutes into the test. The transmissivity calculated using drawdown data minus 9 ft was about 22 percent higher than that calculated using the raw data. Since a well loss of 50 percent may be too high for a well flowing at 800 gpm with 50 feet of screen opening (0.030-in slot size), we believe that actual well loss may have been less than the 9 ft used in our analysis. We believe that the "best" Theis-analysis transmissivity is likely to fall between the two analyses (with and without corrections for well loss) and may be therefore, about 110,000 gpd/ft. Considering all four analyses (Cooper-Jacob with and without partial penetration corrections and Theis with and without corrections for well loss), we believe the transmissivity in the vicinity of Star Well #1 is on the order of 100,000 to 120,000 gpd/ft.

The derivative analyses support the use of the Cooper-Jacob analysis of the pumping well data. The derivatives for the Theis analysis do not match as well but still indicate that the method is applicable. The mismatch is likely the result of adjustments made at the flow-valve which altered the amount of drawdown and thereby made the derivative vary. Thus, we believe the Theis analysis gives a reasonable approximation.

The absence of observation well data made calculating an accurate storativity impossible. Based on other tests in the area, we estimate a storativity on the order of 2×10^{-4}.

Well Interference and the Effects of Seasonal Pumping

No seasonal pumping test analysis was conducted for Star Well #1.

Conclusions

Based on the overview and analysis presented above, we make the following conclusions:

1. Star Well #1 is completed in the regional Pierce Gulch Sand Aquifer, in permeable, coarse-grained sands, at depths of 452 to 550 feet. This well is completed in the same aquifer as the production wells completed further to the east in Eagle, such as the Eaglefield and Lexington Hills wells.)

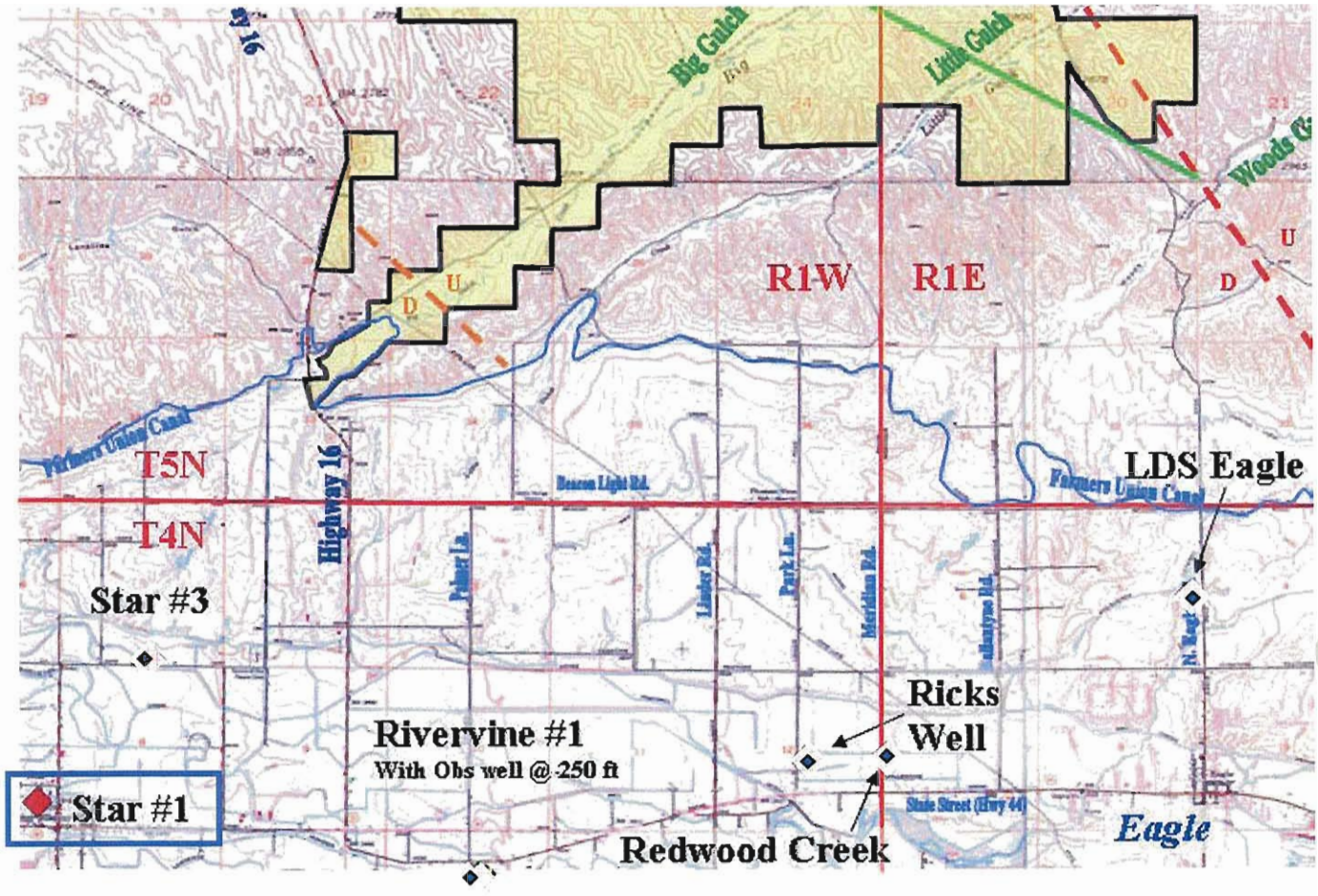
2. Drawdown analyses indicate the transmissivity of this portion of the Pierce Gulch Sand Aquifer, near this well, is on the order of 100,000 to 120,000 gpd/ft.

3. Storativity could not be calculated because no observation wells were monitored during the test.

4. The eight-hour test was insufficiently long to accurately address long-term aquifer behavior. A longer term-test (a week or more) with one or more nearby observation wells would be needed to better characterize the nature of the aquifer and to better quantify storativity at this location.

5. Star Well #1 had not been developed or pumped prior to flow testing and may therefore have indicated a different transmissivity had the aquifer section open to the well been developed and cleared of fine-grained aquifer material and drilling fluids ("mud"). A more representative long-term test conducted after well development, recovery to non-pumping ("static") conditions prior to testing and the use of a high capacity pump would give more meaningful test analyses.

Figure 37. Well Location for Star Well #1 Eight-Hour Test



November 29, 2007

Pumping Well Location

Approximate Northern Boundary of the Pierce Gulch Sand Aquifer

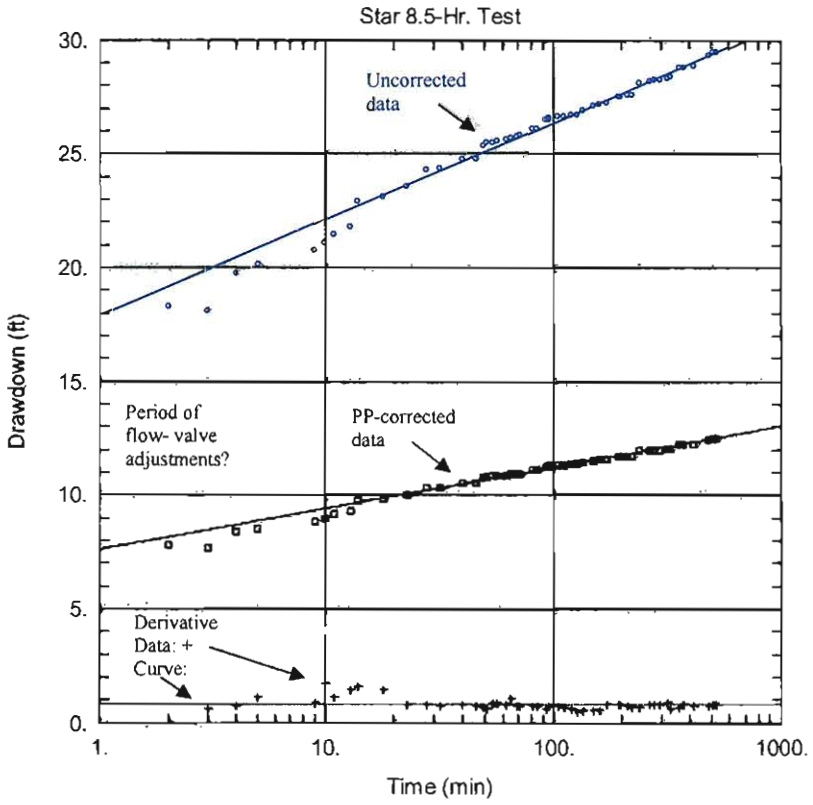
Fault located by magnetometer survey
D on down-dropped side
U on up-thrown side

Approximate position of the West-Boise-Eagle Fault
D on down-dropped side
U on up-thrown side

One Mile

N

Figure 38. Cooper-Jacob Analysis for Star Well #1 Eight-Hour Test
Test Conducted: February 27, 1995



Star Well #1
Screen = 452-550 ft
T = 50,000 gpd/ft
(no PP corrections)
T=120,000 gpd/ft
(with PP corrections)
S = Not Calculable
b = 285 ft
t_c <1 min
r = 1 ft
Q = 800 gpm

Butler partial penetration correction makes calculated T for whole-aquifer thickness about 2 to 3 times greater than calculated value without PP correction.

Good derivative curve match indicates method is applicable.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

$u = 1.87r^2S/Tt$
t = time in days
r = effective radius of pumping well (ft)

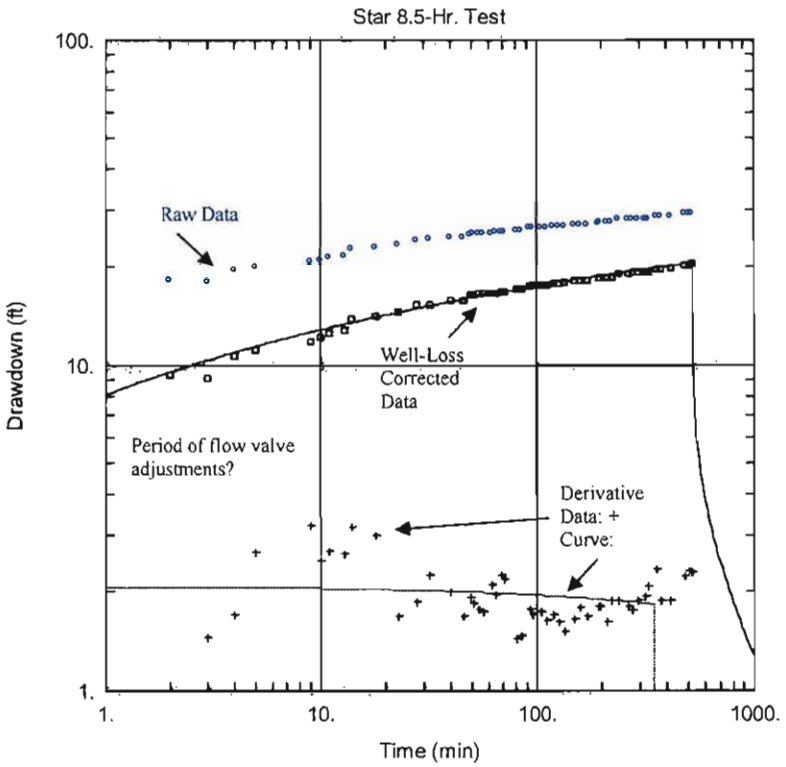
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

$s_{pp} = 0.425\ s_{observed}$ where:

s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Based on the analytical method of Cooper and Jacob (1946).
Partial penetration corrections from Butler (1957).

Figure 39. Theis Analysis for Star Well #1 Eight-Hour Test
Test Conducted: February 27, 1995



Star Well #1
Screen = 452-550 ft
T= 100,000 gpd/ft
(no Well Loss corrections)
T=120,000 gpd/ft
(with estimated maximum well loss corrections)
S = Not Calculable
Kv/Kh = 0.1
b = 285 ft
r = 1 ft
Q = 800 gpm (artesian flow)

Partial penetration correction leads to aquifer transmissivity coefficient twice as large as analytical results without this correction.

Analysis with estimated maximum likely well loss of 9 ft subtracted from raw data indicates Transmissivity 20 percent larger than analysis using uncorrected data.

Fair derivative curve match indicates method is generally applicable. Scatter is likely from flow-valve adjustments.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown. Variations from "smooth," semi-log curve the result of Aqtesolv® generating type curve based on variations in reported pumping rate. Poor match during early time suggests flawed data.

Based on the analytical method of Theis (1935) with partial penetration corrections of Hantush (1961a and b).

Star Sewer and Water District Well #3 Twenty-Four-Hour Test

Overview and Previous Analysis

Star Well #3 was drilled by Treasure Valley Drilling using the mud-rotary method during June through August of 2006. Star Well #3 was drilled to a total depth of 643 ft bgl and completed with stainless steel well screen open to the aquifer between depths of 544 and 643 ft bgl. The pretest shut-in pressure was reported at 13.5 psi, equivalent to a water level of 31.2 ft above ground level which translates to an elevation of about 2,499 ft amsl. On August 30-31, 2006, Layne of Idaho performed a 24-hour pumping test at an average rate of about 3,000 gpm. At the end of the test, the reported drawdown was 190.03 ft, for an end-of-test specific capacity of 15.8 gpm/ft. This well is located in Figure 40 (page 108) as a red diamond with a solid boundary.

Star Sewer and Water District well #3 is completed in the Pierce Gulch Sand Aquifer at elevations of 1,825 ft amsl to 1,924 ft amsl. Based on contouring of the bottom of the Pierce Gulch Sand Aquifer (HLI, 2007) and our interpretation of the top of the aquifer based on a geophysical log and the Well Driller's Report, the aquifer lies at elevations of about 1,780 ft amsl to 2,030 ft amsl. This well is the deepest of the Valley wells discussed in this report because the Pierce Gulch Sand dips to the southwest and lies deeper beneath Star than it does beneath Eagle. No observation wells were monitored as part of the test.

Prior to pumping, the well had been flowing with the flow-control valve "wide open" at an unknown rate under existing artesian pressure for a period of many days (D. Levitt, Treasure Valley Drilling, personal communication, September, 2006). This discharge was the equivalent of pumping the well for an unknown period at an unknown rate. By allowing this discharge many days to possibly weeks prior to testing, the well was not at "static" or non-pumping conditions prior to the initiation of the "24-hour" test. The changes in water levels observed during the tests were not therefore, true drawdowns from non-pumping conditions. There were, in effect, drawdowns from an arbitrary pretest water level. Treating this change in water level as a drawdown added an unquantifiable error to the analysis of the pumping-test data. Thus, the value of transmissivity we calculated (below) may be in error, if the pretest discharge resulted in a significant water level recovery superimposed over the drawdown from the pumping test. Since no pretest water levels were measured to quantify antecedent water level trends, the potential error from allowing the well to flow prior to testing, is unknown.

Data from the pumping test were available in the files of Treasure Valley Drilling. To our knowledge, no previous analyses of aquifer properties have been published and readily available.

HLI Analysis

A Cooper-Jacob straight-line plot (Figure 41, page 109) and a Theis log-log plot (Figure 42, page 110) show drawdown data from the Star #3 well test. The raw data in the

Cooper-Jacob plot (upper data points) show that water levels generally followed the straight-line trend after about 90 minutes of testing. The small steps in drawdown observed in the raw data on Figure 41, indicate either small adjustments in the pumping rate or poor resolution of the depths to water measured during the test. Prior to 90 minutes, it appears that the pumping rate varied significantly causing the drawdowns between 20 and 90 minutes to fall below the straight-line projection. Because only five water levels were reported for the first 90 minutes of the test (when typically 30 to 50 or more should be recorded), it is likely that the contractor-performed test was not thoroughly conducted. Therefore, our analyses were based on the data collected after 90 minutes of testing. The derivative analysis supports this conclusion with the derivatives falling near the type curve between 90 and about 600 minutes.

The late-time data (beginning about 600 to 1,000 minutes into the test) demonstrate a flattening of the drawdown plot. This flattening could indicate leakage to the aquifer or well development. The existing data are insufficient for us to be able to differentiate which of these possible causes of the flattening is likely. Since many of the wells reviewed by HLI as part of this project were not fully developed prior to testing, we believe that well development may be at least part of the cause of the flattened drawdown plot. However, the effects of leakage have been observed in other pumping tests performed on wells completed in the Pierce Gulch Sand Aquifer so these factors may also be a part of the cause of the flattened data plot.

The Cooper-Jacob plot based on raw data (uncorrected for partial penetration) indicates a transmissivity of about 100,000 gpd/ft (upper plot in Figure 41). The analysis using Butler (1957) corrections for partial penetration (lower curve in Figure 41) indicates a transmissivity of 180,000 gpd/ft.

We believe that the transmissivity indicated by the Cooper-Jacob analysis using the Butler approximations for partial penetration corrections is likely too high, probably because of the central placement of the well screen within the total thickness of the Pierce Gulch Sand Aquifer. The Butler corrections are based on the assumption that the well partially penetrates either the upper or lower portion of the aquifer and is therefore likely to over-estimate the effects of partial penetration when the well partially penetrates the central portion of the aquifer. When the well screen is located within the middle of the aquifer, the effects of partial penetration are less than those indicated by Butler (Walton, 1962).

The Theis method with partial penetration corrections of Hantush (1961a and b) is shown in Figure 42 (page 110). The analysis on the raw data (upper curve in Figure 42) indicated a transmissivity of 100,000 gpd/ft, while our analysis with a correction for maximum likely well loss indicated a transmissivity of about 140,000 gpd/ft. Sufficient data were not available to calculate actual well loss. Instead, we estimated a maximum likely well loss of 75 ft, a value which represents about one-half of the drawdown observed at the first recorded drawdown measurement (five minutes into the test. The transmissivity calculated using raw drawdown data minus 75 ft was about 11 percent larger than that calculated using the raw data. Since a well loss of 50 percent is likely to

be near the upper end of the range of possible well losses for a well pumped at 3,000 gpm with 99 feet of screen opening (0.015 to 0.040-in slot size), we believe that the actual transmissivity probably lies between the uncorrected-data value of 100,000 gpd/ft and the corrected-data value of 140,000 gpd/ft; possibly on the order of 120,000 gpd/ft.

We note that because of the uneven quality of the test (no pretest recovery to static conditions, poor flow control, possible measurement error and possible well development during the test), we only analyzed the later-time data. Early-time data from a properly conducted test on a fully developed well would have resulted in a more accurate analysis of transmissivity.

No observation well data were collected during this test making calculating storativity impossible. Based on other tests in the area, we estimate a storativity of about $2x10^{-4}$.

Well Interference and the Effects of Seasonal Pumping

No seasonal pumping test analysis was conducted for Star Well #3.

Conclusions

Based on the overview and analysis presented above, we make the following conclusions:

1. Star Well #3 is completed in the regional Pierce Gulch Sand Aquifer, in permeable, coarse-grained sands, at depths of 544 to 643 feet. This well is completed in the same aquifer as the production wells completed further to the east in the Eagle area, such as the Eaglefield and Legacy wells, discussed previously in this report.)

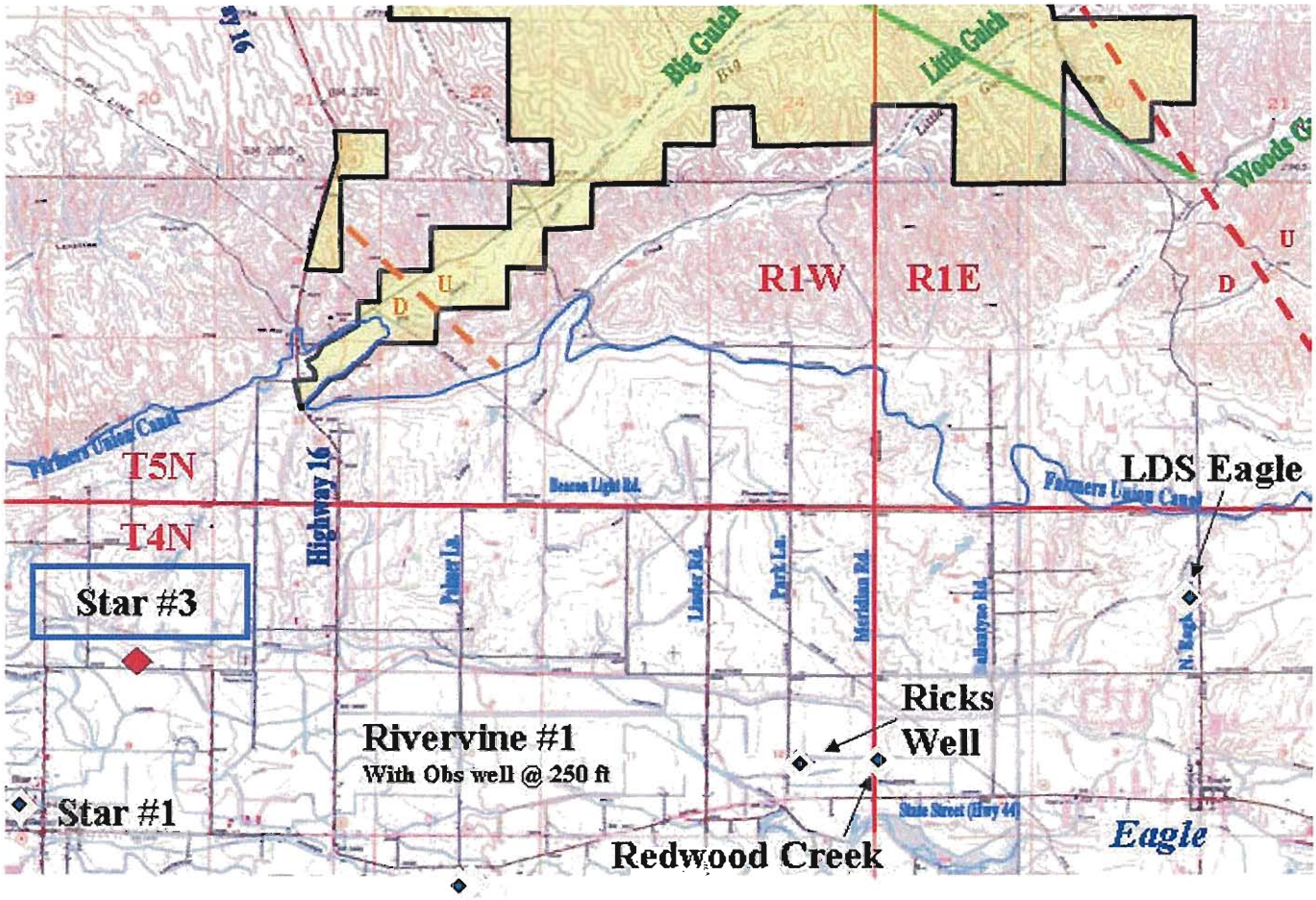
2. Drawdown analyses indicate the transmissivity of this portion of the Pierce Gulch Sand Aquifer, near this well, is about 120,000 gpd/ft. This transmissivity is only an approximation because of the uneven quality of the test.

3. Storativity was not be calculated because no observation wells were monitored during the test. However, because the aquifer is confined, we estimate a storativity on the order of $2x10^{-4}$ based on other tests conducted in the Pierce Gulch Sand Aquifer using observation wells.

4. A longer term-test (a week or more), at 3,000 gpm or more, with the well capped prior to testing to eliminate artesian flow and allow full recovery to non-pumping conditions, measurement of pretest water levels to assess antecedent water-level trends and barometric efficiency, along with monitoring in one or more nearby observation wells would be needed to better characterize the transmissivity of the aquifer and to quantify storativity.

5. Star Well #3 is capable of being pumped at rates higher that the 3,000 gpm rate used in the test. This well demonstrates the high-yield nature of the aquifer.

Figure 40. Well Location for Star Well #3 Twenty-Four-Hour Test



Pumping Well Location

Approximate Northern Boundary of the Pierce Gulch Sand Aquifer

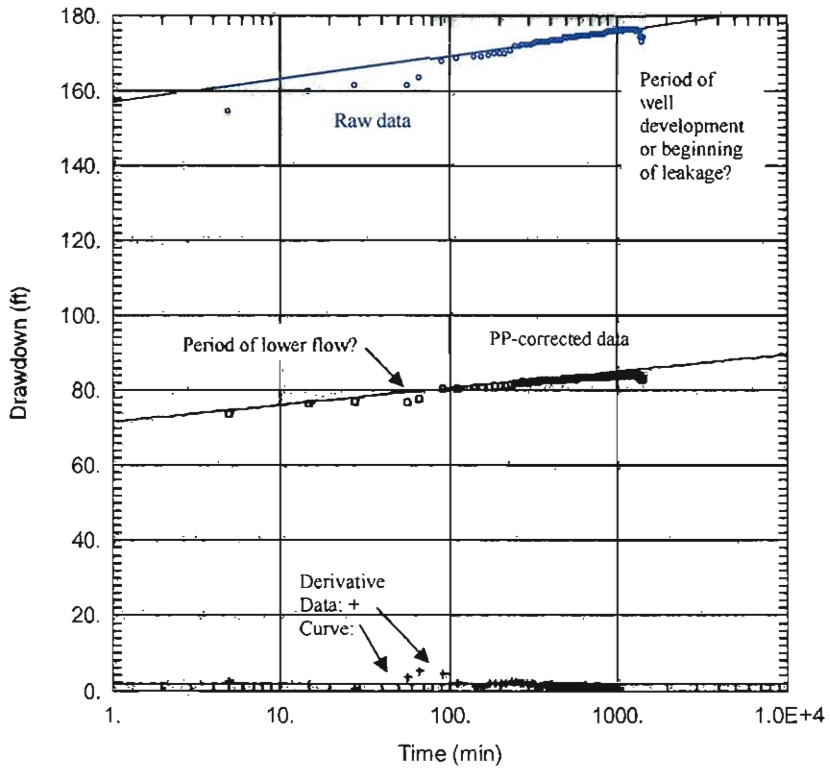
Fault located by magnetometer survey
D on down-dropped side
U on up-thrown side

Approximate position of the West-Boise-Eagle Fault
D on down-dropped side
U on up-thrown side

One Mile

N

Figure 41. Cooper-Jacob Analysis for Star Well #3 Twenty-Four-Hour Test
Test Conducted: August 30-31, 2006



Star Well #3
Screen = 544-643 ft
T=100,000 gpd/ft
(no PP corrections)
T=180,000 gpd/ft
(with PP corrections)
S Not Calculable
Kv/Kh=0.1
b = 250 ft
r = 1 ft
Q = 3,000 gpm

Central vertical placement of well screen suggests only minor need for partial penetration corrections as indicated by similar results between Cooper-Jacob analysis and Theis with Hantush corrections. However, using method of Butler (1957), partial penetration correction makes calculated T for whole-aquifer thickness almost 2 times greater than calculated value without PP correction. We believe that uncorrected value is more likely to be closer to actual value because of aquifer mid-depth screen placement. Derivative analysis supports validity of method.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

$u = 1.87r^2S/Tt$
t = time in days

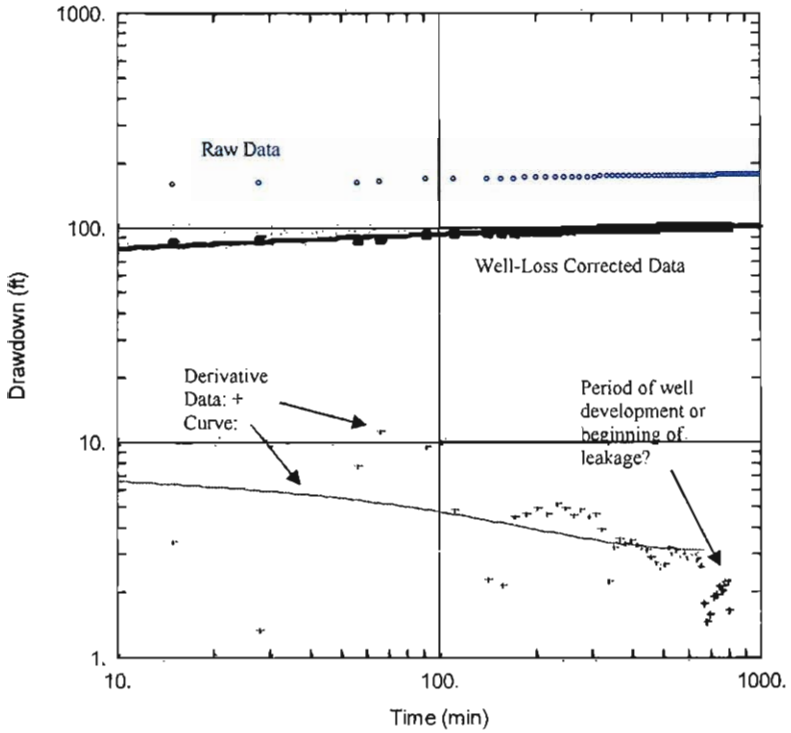
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
r = effective radius of pumping well (ft)

$s_{pp} = 0.475\ s_{observed}$ where:

s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Based on the analytical method of Cooper and Jacob (1946).
Partial penetration corrections from Butler (1957).

Figure 42. Theis Analysis for Star Well #3 Twenty-Four-Hour Test
Test Conducted: August 30-31, 2006



Star Well #3
Screen = 544-643 ft
T=100,000 gpd/ft
(no Well Loss corrections)
T=140,000 gpd/ft
(with Well Loss corrections)
S = Not Calculable
Kv/Kh=0.1
Estimated Maximum Likely Well Loss = 75 ft
b = 250 ft
r = 1 ft
Q = 3,000 gpm

Analysis with estimated maximum likely well loss of 75 ft subtracted from raw data indicates Transmissivity 10 percent larger than analysis using uncorrected data.

Derivative analysis supports validity of method

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935) with partial penetration corrections of Hantush (1961a and b).

LDS Eagle-Stake Center Well Four-Hour Test

Overview and Previous Analysis

The LDS Eagle-Stake Center domestic well was drilled by Pete Cope Drilling using the mud-rotary method during April and May of 1993. The LDS Eagle-Stake Center well was drilled to a total depth of 470 ft bgl and completed with stainless steel well screen open to the aquifer between depths of 387 and 465 ft bgl. The pretest water level was reported at 28.6 ft bgl which translates to an elevation of about 2,581 ft amsl. The LDS Eagle-Stake Center well was pump tested on May 20, 1994 for a period of 4 hours at rates of 80 and 90 gpm. At the end of the test, the reported drawdown was 17.52 ft, for an end-of-test specific capacity of 5.1 gpm/ft. This well is located in Figure 43 (page 114) as a red diamond with a solid boundary.

Boise State University personnel (Ed Squires) conducted the four-hour pumping test on the LDS Eagle Stake Center supply well with the permission of the well driller, on May 20th, 1994. The test was "opportunistic' and neither planned for, nor paid for by the owner. Rather, BSU personnel conducted the test as part of on-going research into the properties of the aquifers in the Eagle and Star area. The well was not developed prior to testing.

The LDS Eagle Stake Center well is completed in the Pierce Gulch Sand Aquifer at a elevations of 2,145 ft amsl to 2,213 ft amsl, deeper than some nearby supply wells in this area discussed in this report (such as the Lexington Hills well). This well, therefore, gives an indication of the properties of the lower portions of the Pierce Gulch Sand Aquifer in this area. Well logs in the area show layers of sands and clays overlie the zone tapped by the LDS well. No observation wells were monitored during the test. Water-level recovery after pumping was not measured in this "opportunistic" test. Data from the pumping test along with plots of the water levels were analyzed by BSU personnel. Their analyses, based on the Cooper-Jacob (1946) method indicated an aquifer transmissivity averaging 37,000 gpd/ft. No accurate analysis of storativity was possible because no observation wells were available for monitoring during the test.

HLI Analysis

A Cooper-Jacob straight-line plot (Figure 44, page 115) and a semi-log Theis log-log plot (Figure 45, page 116) show drawdown data for the LDS well. The Cooper-Jacob plot shows water levels followed the straight-line trend after about 5 minutes when the flow rate was (apparently) stabilized. The drawdown in the well then increased again, when the pumping rate was increased to 95 gpm, after 58 minutes into the test. A specific capacity analysis of the drawdown data indicates that the well developed during the test. At 40 minutes the specific capacity was 4.75 gpm/ft while pumping at 80 gpm. At 80 minutes, the specific capacity was 5.49 gpm/ft while pumping at 95 gpm. In a fully developed well when the pumping rate is increased, the specific capacity either remains

the same or decreases. An increase in specific capacity with an increase in pumping rate indicates well development.

The upper curve in Figure 42 shows a straight-line Cooper-Jacob plot through the raw data corresponding to the second pumping rate (95 gpm), when the well was more fully developed. The analysis indicates an approximate transmissivity of 60,000 gpd/ft. Using the Butler (1957) corrections for partial penetration (lower curve in Figure 43), a transmissivity of 90,000 gpd/ft is indicated. Our semi-log Theis analysis (Figure 43) indicates an approximate transmissivity of 70,000 gpd/ft. No corrections were applied for well loss in this Theis analysis. However, because the well was only pumped at 95 gpm and had almost 80 feet of well screen, well loss is likely to have been small and not a significant factor in the analysis.

The derivative analyses support the use of the Cooper-Jacob analysis of the pumping well data. The derivatives for the Theis analysis give only a fair to poor match but still indicate that the method may be applicable. The mismatch is likely the result of well development that occurred during the test.

Considering all three analyses, we believe that the transmissivity of the Pierce Gulch Sand Aquifer in the vicinity of the LDS Eagle Stake Center well is likely to be on the order of 75,000 gpd/ft. Because of well development during the test, none of these analyses should be considered accurate, however. We believe it is more realistic to present the analysis to one significant figure, or approximately 80,000 gpd/ft.

The lack of observation well data precluded the calculation of storativity. Based on the results calculated from the long-term testing of the Lexington Hills well and the similarity in geology reported on Well Driller's Reports from the area, we estimate a storativity of aquifer in this area to be around 10^{-3}.

Well Interference and the Effects of Seasonal Pumping

Because of its low pumping rate, no seasonal pumping test analysis was conducted for the LDS Eagle Stake Center well.

Conclusions

Based on the overview and analysis presented above, we make the following conclusions:

1. The LDS Eagle Stake Center domestic well is completed in a relatively deep portion of the regional Pierce Gulch Sand Aquifer, in permeable coarse sands, at depths of 397 to 465 feet.

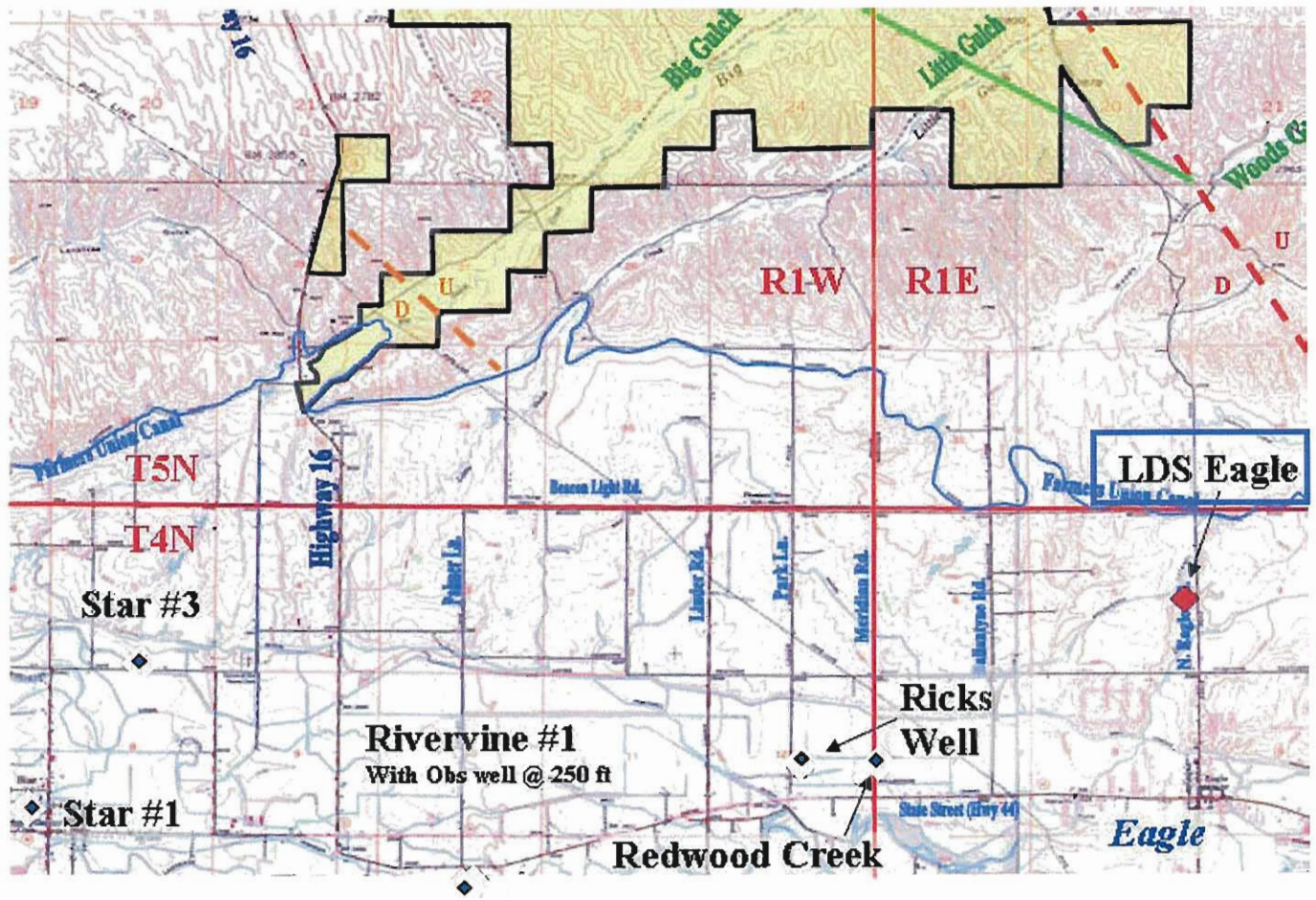
2. Drawdown analyses indicate the transmissivity of the Pierce Gulch Sand Aquifer near this well is 80,000 gpd/ft (to one significant figure). A more accurate calculation of transmissivity could not be made because of well development that

occurred during the test. Storativity could was not calculated because no observation wells were monitored during the test.

3. Based on the response of the aquifer during the 30-day test of the nearby Lexington Hills well, we believe the aquifer would likely behave as a confined aquifer with a storativity on the order of 10^{-3}.

4. A longer term-test (several days to a week or more) with one or more nearby observation wells would be needed to better characterize the nature of the aquifer in this area and to allow the quantification of storativity. Such a test would be more meaningful if the well were fully developed and then pumped with a higher-capacity pump that would cause larger water-level drawdowns than those reported for the existing test (less than 18 feet after pumping at 95 gpm for four hours).

Figure 43. Well Location for Eagle LDS Stake Center Four-Hour Test



November 29, 2007

Pumping Well Location

Approximate Northern Boundary of the Pierce Gulch Sand Aquifer

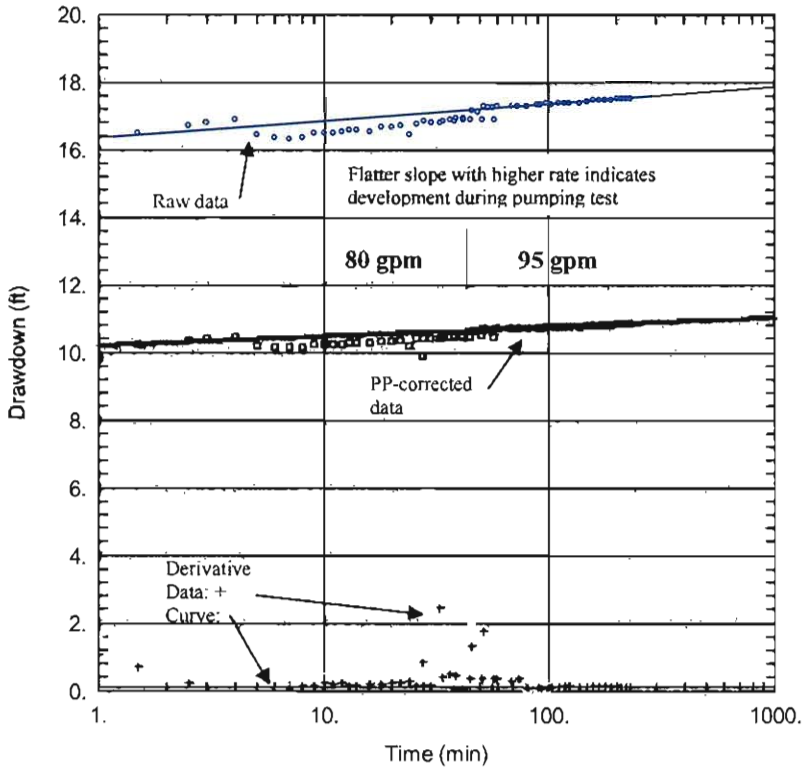
Fault located by magnetometer survey
D on down-dropped side
U on up-thrown side

Approximate position of the West-Boise-Eagle Fault
D on down-dropped side
U on up-thrown side

One Mile

N

Figure 44. Cooper-Jacob Analysis for LDS Stake Center Well Four-Hour Test
Test Conducted: May 20, 1993



LDS Stake Center Well
Screen = 387-465 ft
T= 60,000 gpd/ft
(no PP corrections)
T= 90,000 gpd/ft
(with PP corrections)
S Not Calculable
b = 380 ft
t_c < 1 min
r = 1 ft
Q = 80 and 95 gpm

Well development during test reduces validity of analysis.

Butler partial penetration correction makes calculated T for whole-aquifer thickness about 1/3 greater than calculated value without PP correction.

Derivative analysis supports validity of method.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

$u = 1.87r^2S/Tt$
t = time in days
r = effective radius of pumping well (ft)

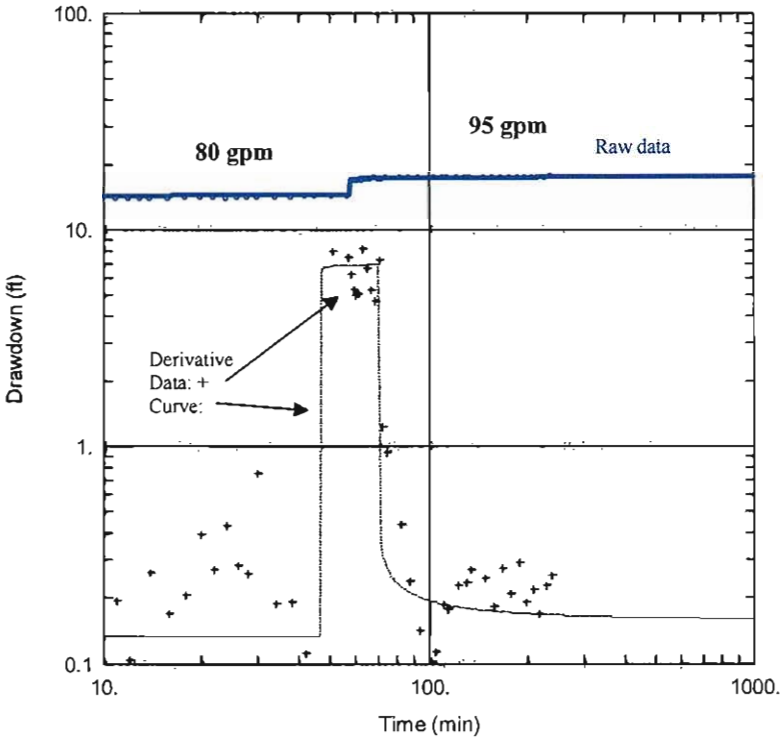
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

$s_{pp} = 0.62\ s_{observed}$ where:

s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Based on the analytical method of Cooper and Jacob (1946).
Partial penetration corrections from Butler (1957).

Figure 45. Theis Analysis for LDS Stake Center Well Four-Hour Test
Test Conducted: May 20, 1993



LDS Stake Center Well
Screen = 387-465 ft
T=70,000 gpd/ft
S Not Calculable
Kv/Kh=0.1
b = 380 ft
r = 0.5 ft
Q = 80 and 95 gpm

Partial penetration correction leads to aquifer transmissivity coefficient 80-percent larger than analytical results without this correction.

Well development during test reduces validity of analysis.

Derivative analysis shows only fair match indicating results only approximate.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown. Variations from "smooth," semi-log curve the result of Aqtesolv® generating type curve based on variations in reported pumping rate. Poor match during early time suggests flawed data.

Based on the analytical method of Theis (1935) with partial penetration corrections of Hantush (1961a and b).

Floating Feather 51-HourTest

Overview and Previous Analyses

A 51-hour pumping test was conducted by Scanlan Engineering (Scanlan, 1995) using the United Water Idaho, Floating Feather Well as the pumping well along with five observation wells. Pumping occurred over the period July 28-29, 1995 with pretest water levels measured several times during the day before pumping began with recovery water levels measured for about 13 hours after pumping ceased . The Floating Feather Well was pumped at an average rate of 1,500 gpm with a maximum drawdown of 30.16 feet, for an end-of-test specific capacity of 49.7 gpm/ft. Two observation wells showing response to pumping indicated maximum drawdowns of 12.83 to 1.4 feet. Interference drawdown at four other wells measured during the test could not be quantified because they were pumped during the test, masking any drawdowns that might have been caused solely by pumping at the Floating Feather Well. The Crandlemire Irrigation Well, located 65 feet to the southeast of the Floating Feather Well was pumped during the day before the test began. This pumping caused water levels to drop and then begin to recover in both the Floating Feather and Crandlemire wells. The test was started with water levels rising in both wells (caused by incomplete recovery from previous pumping), resulting in potential errors in the analysis (discussed below in the HLI analysis of the test).

Scanlan (1995) presented the collected data as linear and semi-log graphs and tables. Atmospheric pressure data were not collected although the Scanlan report noted that "variable weather pattern resulted in fluctuating barometric pressures which may have effected [sic] water levels somewhat." No corrections to the raw data were made to remove the effects of barometric fluctuations or antecedent water-level trends unrelated to pumping that may have affected water levels.

The data from the pumping well (Floating Feather) and the observation well (Crandlemire irrigation) were apparently analyzed for values of transmissivity and storativity but without definitive indication of which methods were used in the analyses. For the pumping well, Scanlan stated that the "semi-logarithmic plot indicates a short-term transmissivity of approximately 125,000 gpd/ft and a long-term transmissivity of 160,000 gpd/ft." He reported similar values of 125,000 to 160,000 gpd/ft from semi-log plots of the drawdown and recovery data from the Crandlemire well. Based on data from the Crandlemire well, he indicated a calculated storativity of $1x10^{-4}$. These results were also stated without supporting analysis. We suspect he used the Cooper-Jacob (1946) method as the data were plotted semi-logarithmically. He did not indicate whether the effects of partial penetration or well loss were considered in the analysis. Scanlan's results are included in our Table 3 (page 247).

Four other wells were measured during the test. One of these was the Vail domestic well (250 feet from the Floating Feather Well) which was reported as 110 to 120 feet deep, or about 63 feet above the completion interval of the pumped Floating Feather Well. Scanlan indicated that a Well Driller's report was not available for this well. The Vail

well responded to pumping during the test with a maximum drawdown of about 1.4 feet. Water level fluctuations during the test precluded any meaningful analysis for aquifer properties but (as discussed below) we believe that the initial drop in water level at the start of the test and a mirror-image rise when pumping stopped indicated that it was affected by the pumping at the Floating Feather Well. Three other wells, the Miller domestic, the Chase domestic and Chase irrigation wells were all pumped during the test, causing water level changes that masked any potential interference drawdowns that might have been caused by pumping at the Floating Feather Well.

HLI Analysis of Pumping Test

A 51-hour pumping test was conducted over the period July 28-29, 1995 by using the Floating Feather Well as the pumping well along with five observation wells. Pretest water levels were measured several times during the day before pumping began with recovery water levels measured for about 13 hours after pumping stopped. The Floating Feather Well was pumped at an average rate of 1,500 gpm with a maximum drawdown of 30.16 feet, for an end-of-test specific capacity of 49.7 gpm/ft. Two observation wells showing response to pumping indicated maximum drawdowns of 12.83 to 1.4 feet. Interference drawdown at three other wells measured during the test could not be quantified because they were pumped during the test, masking any drawdowns that might have been caused by pumping at the Floating Feather Well alone. The Crandlemire Irrigation Well, located 65 feet from the Floating Feather Well was pumped during the day before the test began. This pumping caused water levels to drop and then begin to recover in both the Floating Feather and Crandlemire wells. The test was started with water levels rising in both wells, resulting in potential errors in the analysis (discussed below).

The data presented as part of the Scanlan report were reanalyzed after careful review of geologic data and well construction information available from the Scanlan report and other sources. We also reviewed information on the elevation contours of the bottom of the Pierce Gulch Sand Aquifer in the overall study area included in HLI (2007). Our analysis of the geologic and elevation data indicates that the Floating Feather pumping well and the Crandlemire Irrigation Well both tap the Pierce Gulch Sand Aquifer. The details on well construction, pumping and aquifer depths for the Floating Feather (pumping) well and the Crandlemire irrigation (observation) well are included in Table 3 (page 247). Well locations are shown in Figure 46 (page 128). The table shows that the pumping well is completed in a portion of the Pierce Gulch Sand Aquifer between depths of 183 ft and 330 ft bgl while the Crandlemire Irrigation well is completed between depths of 176 and 316 ft bgl, essentially the same depth intervals within the Pierce Gulch Sand Aquifer.

Based on geophysical and lithologic logging of several wells in the area, the bottom contour of the Pierce Gulch Sand Aquifer (HLI, 2007) is estimated to lie at an elevation of 2100 ft amsl in the vicinity of the Floating Feather and Crandlemire wells. The top of the aquifer, based on lithologic descriptions on the Well Driller's Reports for the two wells, lies at depths of 111 to 113 ft bgl. Based on this understanding of the position of

the top and bottom of the aquifer, we estimate that the aquifer is approximately 386 feet thick in the vicinity of these two wells. Based on this aquifer thickness and the lengths of the well screens, each well is open to about 37 percent of the full aquifer thickness.

The Well Driller's Reports and geophysical logs for wells in this area indicate stratified sediments (layers of sand, silt and minor clay) throughout the aquifer. Because of this layering, we have assumed that the aquifer is anisotropic with vertical hydraulic conductivities less than horizontal conductivities. Because of this layering, we have assumed a bulk vertical-to-horizontal ratio (anisotropy) of 0.1 in our analyses for this well test, as we have for the analyses of the other Pierce Gulch Sand Aquifer tests discussed in this report.

The drawdown data from Scanlan for the Floating Feather pumping well and Crandlemire observation well are plotted in Figures 47 through 50.

Floating Feather Well

A semi-log Theis plot of drawdown data in the Floating Feather Well is shown in Figure 47 (page 129). The semi-log plot (as opposed to the more-typical log-log plot) was used to allow for a better fit between the data and the type curve. The initial pumping rate for this well varied significantly during the first 60 minutes of the test as shown by the rise, fall and rise again of drawdown levels during this period. Because of these variations, the traditional log-log curve match could not be effectively used to match the critical early-time data. Instead, a semi-log curve match was used to better observe and match data from the middle and later portions of the test. Data after 60 minutes generally fall on the Theis type-curve for the rest of the test but with some fluctuation, either caused by pumping of other wells in the area, unrecognized variations in the pumping rate of the Floating Feather Well or by inaccurate water level measurements. Even with these fluctuations, we believe the fit of the data to the Theis curve to be reasonable.

Figure 47 shows two plots for the pumped well. Raw ("uncorrected") data are shown as small blue circles in the upper portions of the plot, while drawdown data "corrected" for estimated maximum likely well loss are shown on the lower portion of the plot as black squares. Well loss was not directly measured or calculated as a step-test was apparently not conducted. Instead, we have estimated a maximum likely well loss that might have occurred to be able to bracket the results of the analysis for transmissivity. Without correcting for well loss, the analysis for transmissivity would likely under-estimate the actual value for the aquifer. With an assumed well loss that is too large, the analysis would likely over-estimate transmissivity. We believe that the actual, representative value for transmissivity will likely lie between results of the analyses conducted with and without estimated well loss.

In our analysis we have assumed the maximum possible well loss is on the order of 10 feet. This value was estimated based on one half of the amount of water level recovery that occurred during the first 30 seconds after the pump was shut off.

The semi-log Theis analysis using data uncorrected for well loss indicates a transmissivity (T) of 140,000 gallons per day per foot (gpd/ft.). With an estimated maximum well loss of 10 feet subtracted from each pumping water level drawdown data point, a transmissivity of 160,000 gpd/ft is indicated. The actual value may lie between these two values. We have included the mean of these two values (150,000 gpd/ft), rounded to two significant figures, in Table 3 (page 247). This value of 150,000 gpd is supported by the theoretical drawdown that we calculated using this transmissivity value and the storativity ($4x10^{-4}$) calculated below. Using these values we calculated a theoretical drawdown of 19.5 feet after 2 days of pumping at 1,500 gpm. This drawdown suggests that the actual well loss was about 10.7 ft (equivalent to the measured drawdown of 30.19 ft minus the theoretical drawdown of 19.5 ft.), a reasonable value for a well pumped at 1,500 gpm with almost 150 ft of well screen. This analysis supports the use of the mean of the uncorrected and corrected analyses to quantify transmissivity.

The type curve for the data plot with the assumed well loss is shown in Figure 47. This type curve was generated by Aqtesolv® and incorporates the hydraulic effects of the no-flow boundary of the West-Boise-Eagle Fault which lies approximately two miles from the pumping well. Although the effects are relatively small, they are included for completeness.

Figure 48 (page 130) shows two plots of residual drawdown (recovery) for the Floating Feather Well after pumping ceased. The upper curve (solid blue line) shows raw ("uncorrected") drawdown data while the lower curve (dashed black) shows data "corrected" for partial penetration following the method of Butler (1957). Both recovery plots show straight-lines between $t/t' = 5$ and 400, (the equivalent of 10 to 727 minutes after pumping stopped). During this recovery period, the residual drawdown data plot above and below the semi-log, straight line, apparently the result of other hydraulic impacts to the aquifer not related to the water level recovery in the pumped well (such as pumping at other wells and/or barometric effects). The uncorrected straight-line plot indicates a transmissivity of about 160,000 gpd/ft, while the Butler-method corrected-data plot indicates a transmissivity of 320,000 gpd/ft. The Butler corrections are based on the assumption that the well partially penetrates (is completed in) either the top or the bottom of the aquifer and not the middle. The Butler method tends to overcorrect drawdown when the partially-penetrating well is completed in the middle (vertically) of the aquifer (as is the Floating Feather Well) such that the calculated transmissivities using the corrected data are much too large. Because of this tendency to over-correct for wells completed near the middle of the aquifer, we believe that the actual transmissivity value is likely to be closer to (but larger than) the uncorrected-data analysis than the analysis based on the Butler-method-corrected data. Therefore, we estimate a recovery-based transmissivity on the order of 160,000 to 180,000 gpd/ft.

The match of the derivative type-curve and the calculated derivatives shown in Figure 47 is only fair, after about 50 minutes into the test. Prior to this time large changes in pumping rates caused relatively large changes in drawdown and therefore the derivatives. After 50 minutes, small variations in pumping rates caused derivatives that clustered just above and below the type curve, generally supporting the Theis method of analysis

Crandlemire Irrigation Well

The Crandlemire Irrigation well is located approximately 65 feet to the southeast of the Floating Feather Well. It was the nearest observation well monitored during the test. It is screened from 176 to 316 feet below ground surface, in approximately the same depth interval of the aquifer as the pumped well. The maximum drawdown experienced by this well during the test was 12.83 feet. These details are included in Table 3. Its location is shown in Figure 46 (page 128) as a labeled green diamond with a dashed boundary.

Figure 49 (page 131) shows HLI's semi-log Theis analysis for the Crandlemire Irrigation Well. The analysis indicates a transmissivity of 170,000 gpd/ft and a storativity of $3.7x10^{-4}$. This analysis was based on data uncorrected for possible antecedent water level trends or barometric effects (such pretest-data were not available). Our analysis included corrections for the effects of partial penetration, because the observation well lies very close (65 ft) to the pumped well and both wells are only open to 37 percent of the full-aquifer thickness. However, a sensitivity analysis for the effects of partial penetration on the Theis analysis indicated that partial penetration corrections did not significantly change the results of the analysis. The low sensitivity may be the result of scatter in the data making a type curve match less precise or it may be the result of both the pumping and observation wells being completed at: a) the same depth interval as each other, and b) within the middle depth-portion of the aquifer. The hydraulic effects of the no-flow boundary (the West-Boise-Eagle Fault shown in Figure 1, page 10) were small at the distance between the wells and the fault (two miles), as indicated in a sensitivity analysis, but are included in the analysis for completeness.

The Theis-curve match is not precise as there are many variations in the data, causing the data points to scatter above and below the near straight-line plot of the semi-log Theis type-curve. These variations may be related to pumping in other wells in the area and/or inaccurate water level measurements. As with the analysis of the pumping well data, variations in early-time pumping rates make a meaningful curve match during the early-time (and most critical) portion of the curve, difficult at best. Since the middle and later time data had to be used in the matching process, the semi-log plot was used to better allow the differences in late-time drawdowns to be more readily observed and therefore better matched. Nonetheless, the match is only approximate.

The match of the derivative type-curve and the calculated derivatives shown in Figure 49 is poor to fair. Small variations in pumping rates and possibly drawdowns caused by other pumping wells caused derivatives that are scattered. The derivative analysis does not generally support the analysis suggesting the results are only approximate.

The Theis analysis indicates a storativity of $3.7x10^{-4}$, a value considered representative of confined aquifers (Freeze and Cherry, 1979). No leakage or other boundary-type effects were observed in the plot of either the Crandlemire Irrigation or Floating Feather Wells.

The Theis recovery analysis (Figure 50, page 132) indicated a transmissivity of 170,000 gpd/ft and an S/S' of 3.5 for the Crandlemire Irrigation Well. An S/S' ratio of more than

1.0 typically indicates "early recovery" or "recharge to the aquifer system." In this test, however, a more likely explanation is that the water level recovery in the Crandlemire Well and the Floating Feather Well (which indicated a S/S' of 3.1, as shown on Figure 48) was caused, at least in part, by pumping in the Crandlemire Irrigation Well the day before the test began. Because of this recovery, the water level at the start of the test was still rising toward a true, pretest, non-pumping level. By using this lower level as the "static" water level in the analyses, the water levels in the two wells appeared to have "recovered" to their pretest levels when, in fact they needed to recover more to get to a true pretest or static level. For this reason, we believe that the S/S' ratios greater than 3.0 do not indicate a significant source of recharge to the aquifer, during the test.

Other Observation Wells

We believe that only one other well monitored during the test (the Vail domestic well) showed a drawdown plot that may have indicated the pumping effects of the Floating Feather Well. The Vail domestic well is located approximately 250 feet from the Floating Feather Well, but is completed at a much shallower depth - reportedly 110 to 120 feet bgl. This depth was not verified by a Well Driller's Report (which was reportedly not available) or other method such as down-hole camera. Since the lithologic logs on the Well Driller's reports for both the Floating Feather Well and the Crandlemire Well indicate that the top of the Pierce Gulch Sand Aquifer lies approximately 112 feet bgl, we believe that the Floating Feather could be completed in the same aquifer, but cannot say for certain. If so, drawdown should have been measurable during the test in the Vail well.

Water levels in the Vail well dropped about 1.4 feet starting about 15 to 20 minutes into the test. After about 300 minutes, water levels rose and fell in a periodic manner, indicating that pumping at some other non-identified well was likely interfering with the water levels in the Vail well. The periodic inference was on the order of 0.8 ft and the maximum drawdown that occurred in the Vail well was on the order of 1.4 ft (which included the 0.8 ft periodic interference from the unidentified well). The relatively large cyclic water level changes appear to have obscured the hydraulic effects of pumping the Floating Feather Well. Since no meaningful analysis of the data was possible beyond the documentation of a possible hydraulic connection, we have not included a drawdown plot or analysis in this report.

The Miller domestic well (another well monitored during the test), showed no well-defined response to pumping at the Floating Feather Well. The Miller well lies approximately 500 feet from the Floating Feather Well, is reportedly 60 feet deep and therefore *not* completed in the Pierce Gulch Sand Aquifer. Intermittent pumping of the Miller well during the test caused water-level drawdowns of about 12 feet. These large drawdowns caused by pumping in the Miller well effectively masked observation of any possible water level inference drawdowns caused by pumping at the Floating Feather Well which, we believe, would have been much smaller.

Two other wells, the Chase domestic and Chase irrigation wells were also pumped during the test and therefore yielded no data that would allow meaningful analysis of aquifer

properties. The Chase Irrigation well may have experienced a drawdown caused by pumping at the Floating Feather Well. The data, however, are scattered such that the apparent drawdown of about one foot, may only be a visual artifact of the data scatter which varied over a range of 2.5 ft during the test. Again, because no meaningful analysis was possible, no drawdown plot (or analysis) is included in this report.

Since the test occurred in 1995, the Floating Feather Well has been pumped regularly at rates of 2,100 to 3,100 gpm. The Vail and Miller wells were spot-monitored from June 1995, through April 1998, to help quantify the actual hydraulic impacts of production pumping of the Floating Feather Well. During this period, water levels measured for United Water Idaho varied over a range of almost 8 feet in the Vail well and almost 10 feet in the Miller well (Roger Dittus, personal communication, 2006). No real trend was apparent in a linear-trend analysis conducted by HLI on the data supplied by United Water Idaho. Our analysis shown in Figure 51 (page 132), indicated a slight decline in the Miller well (0.9 ft/yr) and a slight rise in the Vail well (0.6 ft/yr) but both analyses had an "R^{2}" (a statistical correlation coefficient) of less than 6 percent, indicating no significant correlation and no significant water level trend (a "perfect" R^2 correlation coefficient would be 100 percent). Therefore, the data from these wells indicate that overall water levels do not appear to have declined during this period. In addition, the levels measured over the three-year period are in the same range as those observed during the Floating Feather test suggesting that no significant drawdown interference caused by production pumping of the Floating Feather Well. The measured variations in water level in the Vail and Miller wells were on the order of 8 to 10 feet. These 8 to 10 foot variations, however, could have masked water level trends, were they much smaller, say on the order of 1 to 2 feet. Therefore, aquifer water levels could have been increasing or decreasing during this period but any small trend (on the order of 1 to 2 feet over the 3-year period) cannot be demonstrated by the data.

The timing of the responses in the Miller and Vail wells suggests a seasonal trend to water level variation. Figure 51 shows that the water levels in both wells were generally highest during the summer and lowest during the winter. The graph does not directly indicate the cause of the changers in water level. However, since the highest levels generally occurred during the irrigation season and the lowest levels occurred during winter (when there is no irrigation), it appears more likely that the variations were caused by irrigation water seeping down during the summer from the surficial zones where it is applied rather than pumping from the underlying Pierce Gulch Sand Aquifer which would be at lower rates during the winter (and therefore likely to cause smaller amounts of interference).

Unidentified Well Interference

During the test, all the observation wells showed the effects of the pumping of one or more wells, above and beyond the effects caused by pumping the Floating Feather Well. These effects were indicated by periodic rises and declines in the water levels in the observation wells. In many cases, these variations in water levels were much larger than the potential interference caused by the pumping at the Floating Feather Well. Such

interference effects from multiple wells are to be expected from an aquifer tapped by literally thousands of wells, especially during the summer when irrigation and municipal demands are high. Since there are many municipal and irrigation wells in the area, it would be almost impossible to conduct a test during summer that did not have interference from some well or wells in the area. The high potential for interference and documented hydraulic interconnection over large areas demonstrates that meaningful aquifer-testing requires coordination with well users in the area. In addition, a period of pretest water level data collection with analysis of these data to quantify antecedent water level trends and the likely range of interference effects that could occur during the test, is also required. The results of these types of analyses are needed to better design, conduct and analyze the pumping tests used to quantify aquifer parameters (as opposed to tests conducted to assess well performance and pump design).

Test Results Summary

In summary, the analyses of the Floating Feather Well and Crandlemire Irrigation Well indicate that the transmissivity of the Pierce Gulch Sand Aquifer in the vicinity of the Floating Feather Well is about 170,000 gpd/ft. This value is equal to the mean of analyses of the pumping well and the Crandlemire irrigation observation reported to two significant figures. This value is consistent with transmissivities calculated for this area (as shown on Table 3, Page 247).

Storativities calculated from the test data indicate that the Pierce Gulch Sand Aquifer is confined with a storativity of around $4x10^{-4}$.

Based on the transmissivities calculated for each well and the thickness of the aquifer as inferred from available Drillers' Reports and HLI (2007), representative aquifer hydraulic conductivities were calculated and are included on Table 3. These values are typical of "clean sands," which generally lie at the mid-point of the range of permeabilities for the "fine to coarse sands" indicated on the lithologic log portion of the Well Driller's Reports for the Floating Feather and Crandlemire wells.

Well Interference and the Effects of Seasonal Pumping

HLI used the representative transmissivity and storativity to predict inference effects in the aquifer at distances to almost 4 miles from the Floating Feather Well. In this simulation, the Theis method was used to generate drawdown curves as a function of distance from the Floating Feather Well pumping at 2,400 gpm which represents the mean pumping rate for June 2006 (Roger Dittus, personal communication, September, 2007). The Theis method was selected as it is generally conservative (tending to over estimate drawdown) as it does not consider leakage from overlying zones or the capture of recharge. A transmissivity of 170,000 gpd/ft was used in our analysis along with a storativity of $4x10^{-4}$ (values calculated from the test data). An image well was used to simulate the hydraulic effects of the no-flow boundary represented by the West-Boise-Eagle fault.

Our results are presented in Figure 52 (page 134) which shows that at the end of a 90-day summer pumping season of continuous pumping, interference drawdowns in the range of 14 to 17 feet are predicted for wells completed in the aquifer, one mile away from the Floating Feather Well and may be on the order of 9 feet up to four miles away. As discussed in the methods section above, this analysis is conservative and is likely to over-estimate interference; the drawdown cone of depression from the pumping well would probably expand sufficiently to capture recharge equal to the pumping rate before 90 days. When the pumping rate equals the rate of recharge capture, the drawdown caused solely by the pumping well stabilizes[17]. The Theis analysis assumes no recharge (water pumped by a well only comes from aquifer storage) and that a pumping water level *always* continues to draw down. In reality (and observed many times, in our experience) the drawdown in a well pumped continuously for 90 days in a hydrogeologic setting like that of the Floating Feather Well, typically levels off and remains relatively constant after a few weeks of pumping.

We consider the predicted interferences to be only an approximation because the Pierce Gulch Sand Aquifer system is not uniform. The actual drawdown that would occur with summer-long pumping will vary from our predictions, depending on the actual properties of the aquifer between the Floating Feather Well and a given point of interest. We used a uniform transmissivity of 170,000 gpd/ft in the prediction while calculated transmissivities ranged from 80,000 to more than 800,000 gpd/ft for the wells completed over a 10 to 11 mile width of the Pierce Gulch Sand Aquifer in the Eagle-Star vicinity. Of course, monitoring of actual interference is preferred to theoretical predictions. That is why the data collected from the Vail well better represents aquifer performance than the predictions made based on the assumptions required by the Theis method.

Conclusions from the Floating Feather Test

Based on the overview and analysis presented above, we draw the following conclusions:

1. The Floating Feather and Crandlemire wells are both completed in the Pierce Gulch Sand Aquifer, which we estimate to be about 386 feet thick near these wells. We interpret the top of the aquifer to lie at depths of 111 to 113 feet below land surface while the bottom lies at around an elevation of 2100 feet amsl or about 500 feet bgl.

2. The Floating Feather and Crandlemire wells are completed at similar depths with well screen tops at 183 and 176 ft bgl (respectively) and well screen bottoms at 330 and 316 ft bgl (respectively). Both wells partially penetrate the upper-middle portion of the Pierce Gulch Sand Aquifer

[17] The water level in the well can still change, however. Regional aquifer water level trends, interference from other wells, barometric effects and other factors can still cause water levels to rise or fall above the stabilized drawdown level. Drawdown represents the difference between the pre-pumping water level and the lowered water level caused by pumping.

3. The transmissivity of the Pierce Gulch Sand Aquifer is about 170,000 gpd/ft in the vicinity of the Floating Feather Well.

4. We calculated a storativity value of $4x10^{-4}$ for the Pierce Gulch Sand Aquifer in the vicinity of the Floating Feather Well indicating that the aquifer is confined.

5. The Pierce Gulch Sand Aquifer in the vicinity of the Floating Feather Well is highly productive with well yields of greater than 3,000 gpm possible from properly designed and completed wells.

6. Interference effects from a single production well pumping at 2,400 gpm from this portion of the Pierce Gulch Sand Aquifer is predicted to cause drawdowns of about 14 to 17 feet at wells completed in the same aquifer at a distance of one mile, after 90 days of continuous pumping. Interference drawdown in wells four miles away are estimated be on the order of 9 feet, but are likely to be less based on the conservative nature of our analysis.

7. A report prepared by Scanlan (1995) was likely directed toward design of a pumping plant for the newly constructed well, rather than for analysis of aquifer parameters. His report included "calculated" values for transmissivity and storativity. The report, however, did not include any analyses, straight-line plots or type curves to support the reported values. The Scanlan report did not include pretest data to allow for assessment of antecedent water level trends or the calculation of barometric corrections. The transmissivity values Scanlan presented were in range of (but smaller than) those calculate by HLI.

8. The effects of pumping wells other than the Floating Feather Well were detected in all of the observation wells monitored during the test. In three of the observation wells, pumping in each well itself during the test caused drawdowns that were many times greater than that likely to have been caused by the pumping from the Floating Feather Well. These drawdowns obscured and masked Floating-Feather-induced drawdowns, making meaningful analysis of the monitoring well data of no practical use.

9. Collection of spot water-levels over a three-year period from two domestic wells (Vail and Miller) show no statistical change in water level since the Floating Feather Well began pumping at rates of 2,100 to 3,100 gpm. A seasonal variation in water levels of 8 to 10 feet with the highest levels occurring during summer and the lowest during winter suggests that irrigation water seeping down from the surface may be the cause of the variations.

10. A better test of the Floating Feather Well is highly recommended as this well is screened over a relatively large portion of the aquifer (smaller partial penetration effects), is capable of pumping at 3,000 gpm or more, and is in a location with several significant and major wells known to be completed in the Pierce Gulch Sand Aquifer. Such a test would be best accomplished with coordination of all

major ground water pumpers within a few miles of the pumped well. It would be best to conduct the test outside of the irrigation season (during winter or very early spring) when water demand would be relatively low. Ideally, all significant groundwater pumping from the targeted Pierce Gulch Sand Aquifer would be curtailed before, during, and after the test to allow for collection and use of antecedent trend data to correct changes in water levels that are not caused by the pumping well. The test should be preceded by barometric and water level measurements during a non-pumping period to develop barometric efficiency corrections for the observation well data.

11. Coordination with all interested parties is highly recommended for all future well tests. The ability to coordinate and conduct such a test grows more difficult with time as more and more wells go into production. For municipal wells that cannot have their pumping curtailed during the test, it may be possible to hold pumping constant and well monitored such that the effects caused by pumping these wells can be incorporated into the analysis of the test data. It may be possible for municipal water providers to use wells further from the pumping well and monitored observation wells. None of these measures, however, are as effective as simply having the adjacent wells turned off during the test.

Figure 46. Well Locations for Floating Feather 51-Hour Test

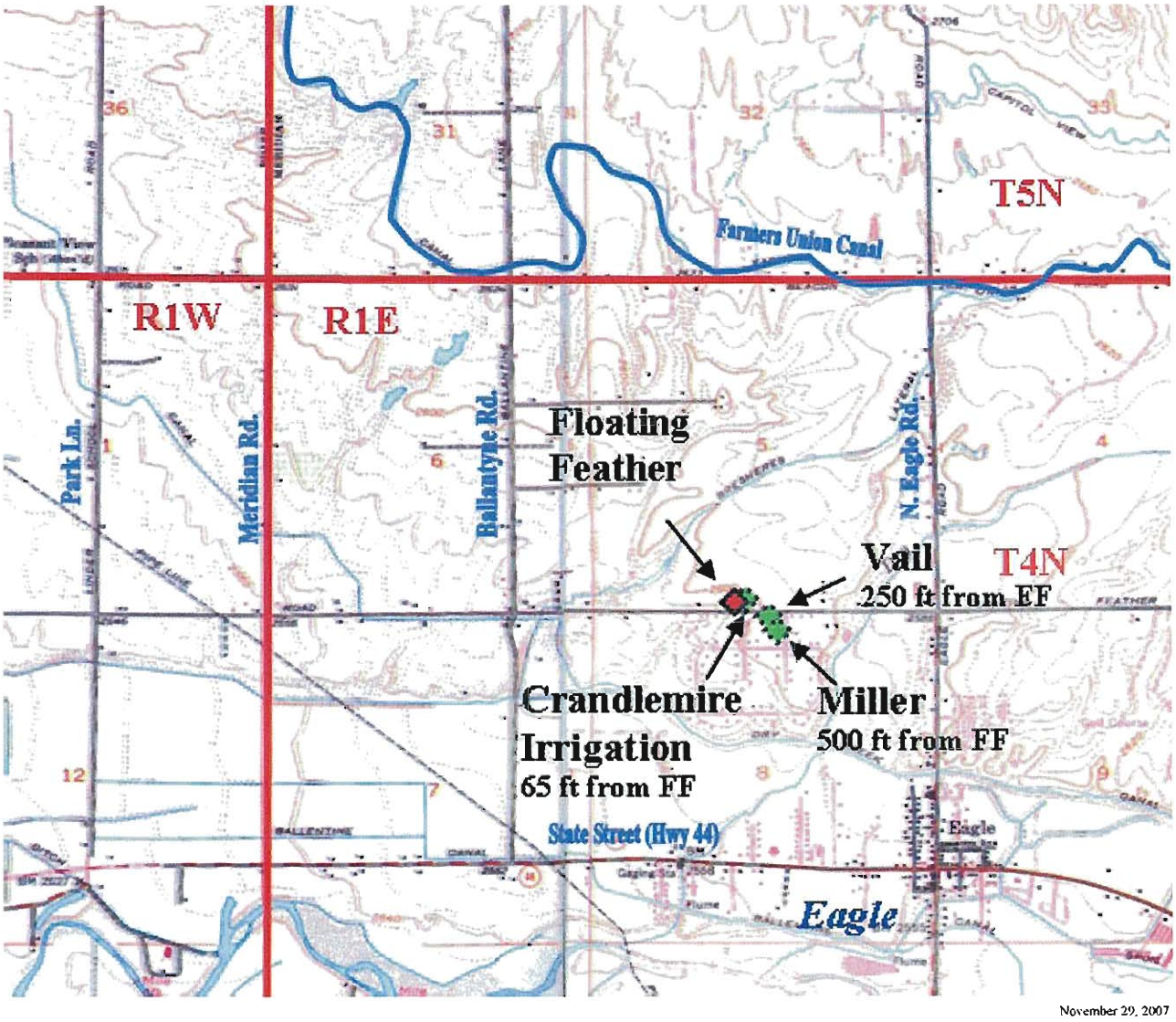
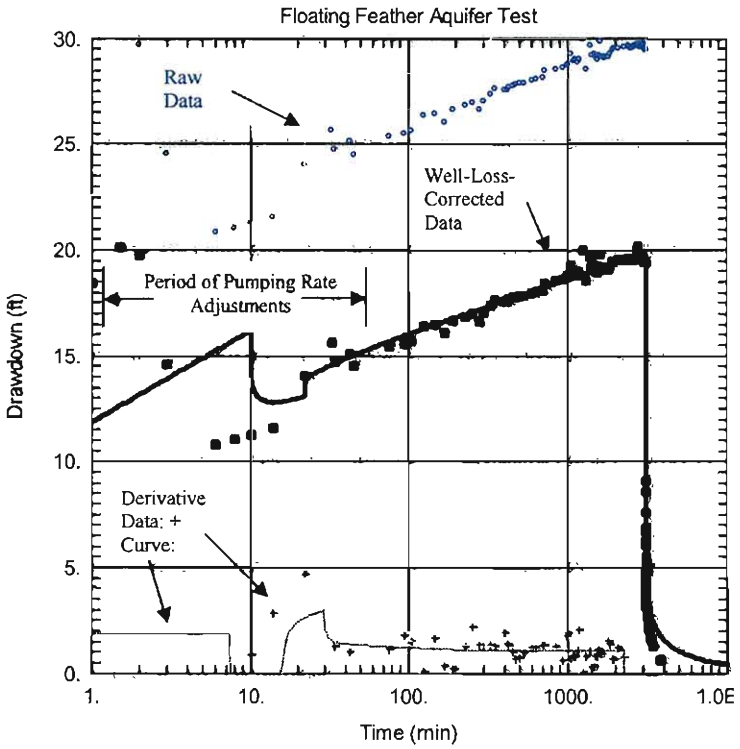


Figure 47. Semi-Log Theis Analysis for Floating Feather Well Floating Feather 51-Hour Test

Test Conducted: July 28-30, 1995



Floating Feather Well
Screen = 183-330 ft
T = 140,000 gpd/ft
(no well loss correction)
T = 160,000 gpd/ft
(w/ maximum well loss correction)
T = 150,000 gpd/ft
(mean of above to 2 sig. fig.)
S Not Calculable
Kv/Kh=0.1
Fault (no-flow) at 2 mi.
b = 386 ft
Estimated Maximum Likely Well Loss = 10 ft
r = 1.5 ft
Q = 1,500 gpm

Poor match before 50 minutes because of pumping rate variations. Approximate match 60 to 3,100 minutes. Water level variations apparently caused by local pumping (?) Derivative analysis shows fair match indicating reasonable support for method.

Estimated maximum likely well loss of 10 ft used in analysis based on first half minute of recovery (see text for details).

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

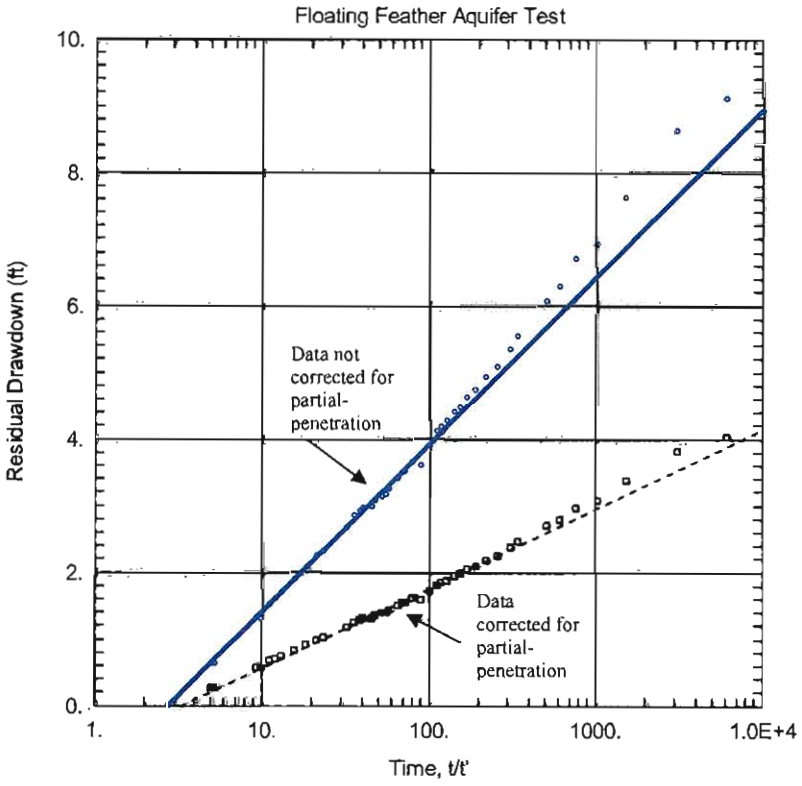
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown. Variations from "smooth," semi-log curve the result of Aqtesolv® generating type curve based on variations in reported pumping rate. Poor match during early time suggests flawed data.

Based on the analytical method of Theis (1935) with partial penetration corrections of Hantush (1961a and b).

Figure 48. Recovery Analysis for Floating Feather Well After the Floating Feather 51-Hour Test
Test Conducted: July 28-30, 1995



Floating Feather Well
Screen = 183-330 ft
T= 160,000 gpd/ft
(no PP corrections)
T= "320,000" gpd/ft
(with PP corrections)
S/S' = "3.1"
Kv/Kh=0.1
b = 386 ft
r = 1.5 ft
Q = 1,500 gpm

S/S' of 3.1 suggests early recovery but is more likely due to incomplete recovery from pumping of Floating Feather and Crandlemire Irrigation wells from previous day.

Partial penetration correction makes calculated T for whole-aquifer thickness about 2 times greater than for calculated value without PP correction –most likely too high because method designed for top or bottom penetration of aquifer and well completed in middle.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

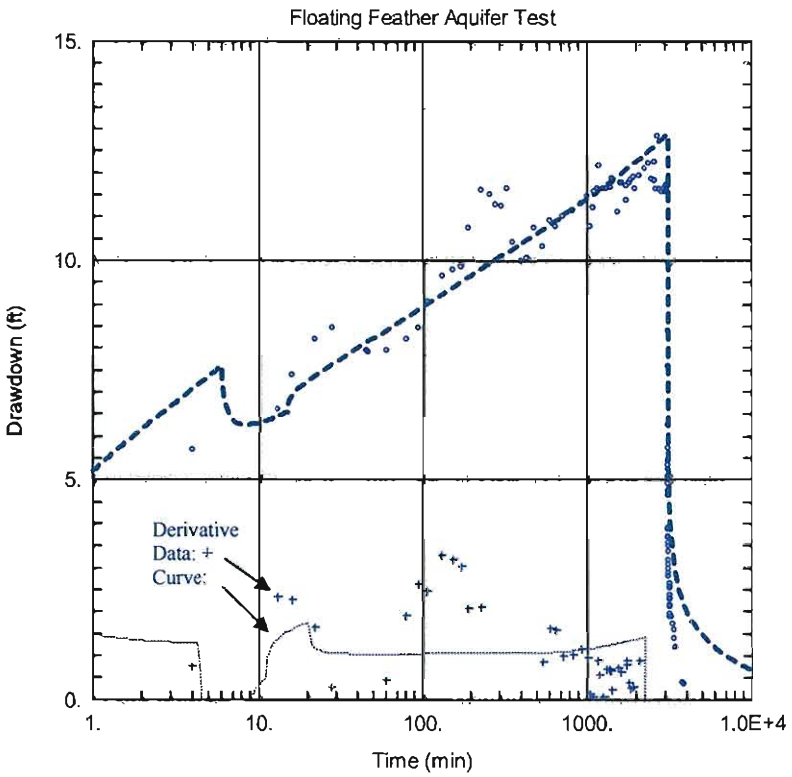
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
r = effective radius of pumping well (ft)

$s_{pp} = 0.2\ s_{observed}$ where:

s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Based on the analytical method of Cooper and Jacob (1946).
Partial penetration corrections from Butler (1957).

Figure 49. Semi-Log Theis Analysis for the Crandlemire Irrigation Well during the Floating Feather 51-Hour Test
Test Conducted: July 28-30, 1995



Crandlemire Irrigation Well
Screen = 176-316 ft
T = 170,000 gpd
S = 3.7 x 10^{-4}
Kv/Kh=0.1
Fault (no-flow) at 2 mi.
b = 386 ft
r = 65 ft
Q = 1,500 gpm
(at the Floating Feather Well)

No match before 60 minutes because of pumping rate variations. Approximate match 60 to 3,100 minutes. Water level variations apparently caused by local pumping (?).

Derivative analysis shows fair to poor match indicating only fair to poor support for method.

Semi-log Theis and Cooper-Jacob analysis (not shown) give similar results.

Comparison or Theis, Theis (w/ Hantush PP corrections) and Cooper-Jacob (uncorrected) indicate partial penetration effects not significant.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

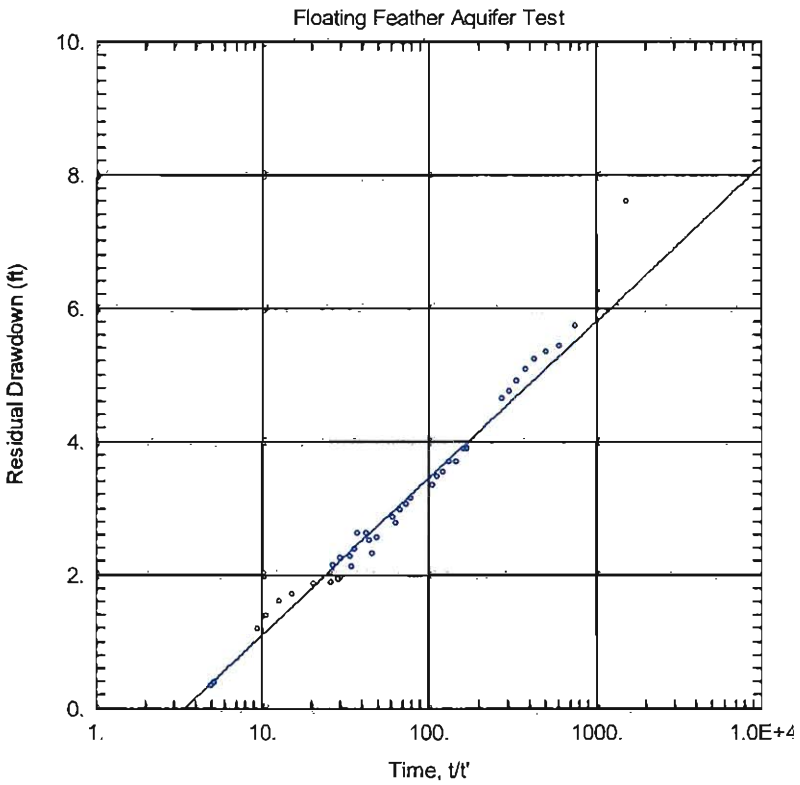
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown. Variations from "smooth," semi-log curve the result of Aqtesolv® generating type curve based on variations in reported pumping rate. Poor match during early time suggests flawed data.

Based on the analytical method of Theis (1935) with partial penetration corrections of Hantush (1961a and b).

Figure 50. Recovery Analysis for the Crandlemire Irrigation Well during the Floating Feather 51-Hour Test
Test Conducted: July 28-30, 1995



Crandlemire Irrigation Well
Screen = 176-316 ft
T= 170,000 gpd/ft
S/S' = "3.5"
Kv/Kh=0.1
b = 386 ft
r = 65 ft
Q = 1,500 gpm
(at the Floating Feather Well)

S/S' of 3.5 suggests early recovery but is more likely due to incomplete recovery from pumping of Floating Feather and Crandlemire Irrigation wells from previous day's pumping.

Partial penetration correction apparently not needed in analysis, based on comparison of pumping drawdown analyses with and without partial penetration corrections. Calculated transmissivity appears to best represent value for whole-aquifer thickness.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
r = distance from pumping well (ft)

Based on the analytical method of Theis (1935).

Figure 51. Water Levels in the Vail and Miller Wells 6/15/95 – 4/1/98

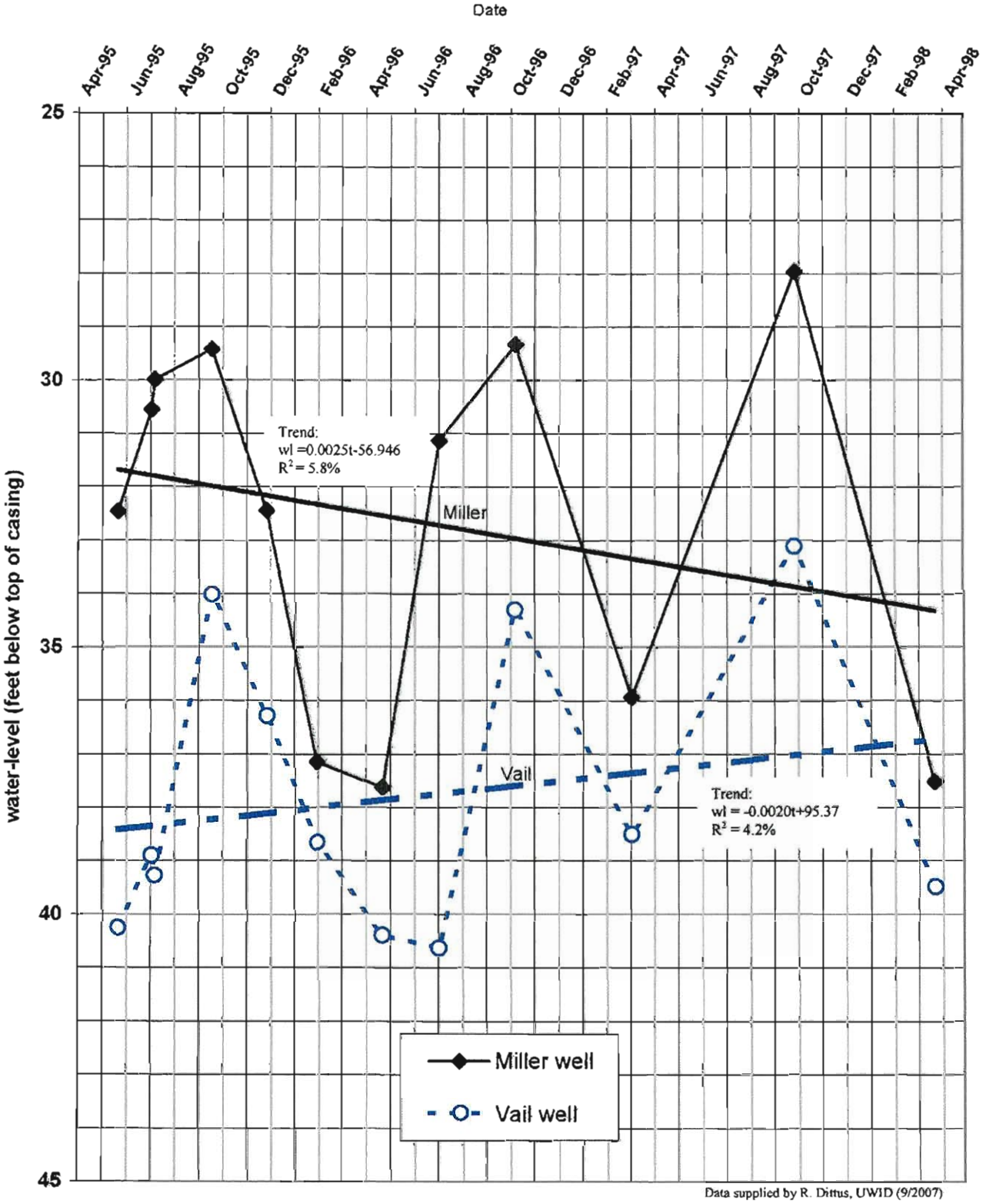
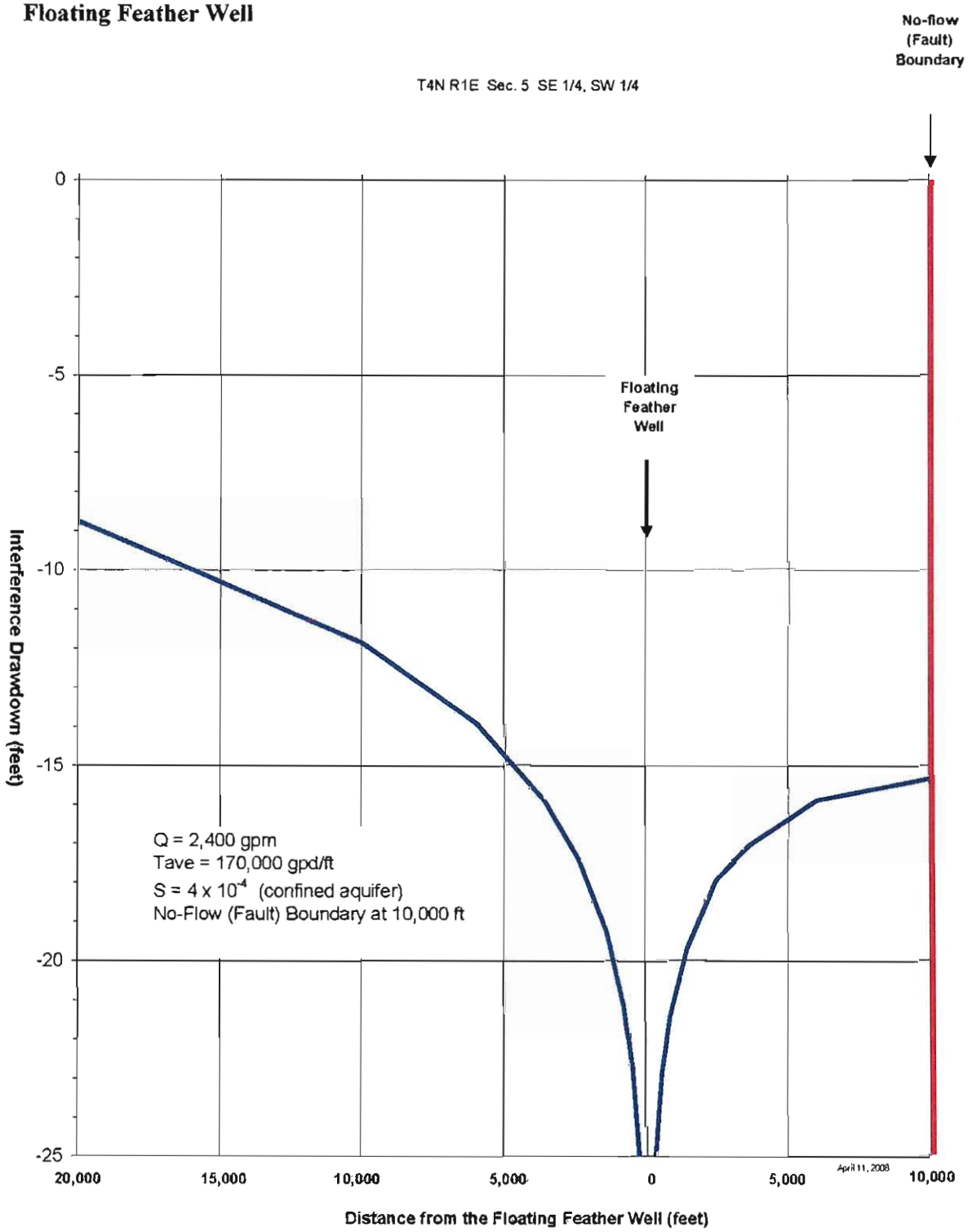


Figure 52. HLI's Predicted Interference at End of Summer Pumping from the Floating Feather Well



SECTION FOUR: FOOTHILLS WELL TESTS CONDUCTED BY OTHERS

In this section of the report, analyses from six well-tests are presented. Each of the four aquifers known to underlie the upland foothills that were discussed in the Hydrogeologic Overview sub-section of this report are represented by one or two well tests for each aquifer. These four aquifers are: the regional Pierce Gulch Sand Aquifer, the Willow Creek Aquifer, the Sandy Hill Aquifer and the mixed sediment/bedrock aquifer beneath Spring Valley lying beneath the area to the northeast of Eagle. The regional Pierce Gulch Sand Aquifer is the only aquifer of the four that is found beneath the Valley *and* Foothills areas. The Pierce Gulch Sand Aquifer beneath the upland Foothills is an extension of the same aquifer that underlies the Valley. Because of the dip of the strata toward the southwest at approximately 100 feet per mile in the vicinity of Star, and steeper beneath parts of the foothills, the Pierce Gulch Sand Aquifer is found at higher elevations beneath the foothill area. However, because the ground surface is higher, the well completion depths are coincidentally in ranges similar to those of Valley wells.

A series of upland-foothills test wells were drilled and tested under the direction of Scanlan Engineering (2003) and SPF Water Engineering (2004 a and b). The purpose of these wells was to characterize the hydrogeology and ground-water development-potential in the area north of Eagle, specifically parts of Townships T5N/R1W, T5N/R1E, and T6N/R1E targeted by SunCor for its Avimor development. Each test well was drilled, logged and pump-tested with pumping periods ranging from 2½ hours to one day. Two of the wells in the eastern part of the project (SVR #1 and SVR #2) were completed in an area where the geologic section comprises pockets of tuffaceous sediments overlying volcanoclastic rocks which in turn overlie granitic bedrock. These rocks are capable of producing small amounts of ground water to small domestic wells but not much more. They produced relatively small amounts of water during testing (about 50 gpm). SVR #1 and SVR #2 are discussed as "eastern upland mixed-bedrock wells." Scanlan informally named this water-bearing system as the "Spring Valley Aquifer."

Four test wells were completed in sand aquifers beneath the central upland project area on and near the M3 Eagle project area. Wells SVR #6 and SVR #10 tap a coarse-grained sand aquifer (informally named the "Willow Creek Aquifer" by Scanlan) which has water levels that are much deeper than those of wells SVR #7 and SVR #9 (completed in the Pierce Gulch Sand Aquifer). Wells SVR #6 and SVR #10 also report different water quality than that reported for SVR #7 and SVR #9; the latter pair having significantly higher concentrations of total dissolved solids, magnesium, bicarbonate, sulfate, and hardness, as well as lower concentrations of nitrate. The different geologic materials logged during drilling, different water levels within the aquifer and different ground-water geochemistry indicate that the Willow Creek Aquifer is separate and distinct from the Pierce Gulch Sand Aquifer.

We believe the Willow Creek Aquifer is an outlier of the sand facies of the Terteling Springs Member of the Idaho Group of Formations. The coarser-grained sand facies of the Willow Creek Aquifer likely represent near-shore delta or fan deposits on the margin of the large lake or lakes that formerly occupied the Boise River and Snake River Valleys. The fine-grained clays (mudstone facies of the Terteling Springs) were deposited off shore while the deltaic sand was being deposited along the margins of the lake. When the lake drained, the Pierce Gulch Sand was deposited unconformably on top of the Terteling Springs mudstone. The result is a rapid lateral transition from near-shore sands to finer-grained, off-shore clays to unconformable Pierce Gulch Sand, over a very short distance. The mudstone lying between the Willow Creek Aquifer and the Pierce Gulch Sand Aquifer acts as a low-permeability barrier, cutting off direct hydraulic connection between the two aquifers. The two aquifers, along with geologic cross-sections showing the relationships of the geologic materials separating them, are presented in HLI (2007) along with additional discussion of the "hydraulic disconnect" between the two aquifers.

Two other wells, SVR #3 and TPW#1, were also completed in the upland, foothills area, in a permeable but highly bounded aquifer informally called the "Sandy Hill Aquifer" by Scanlan (2004a). We believe the Sandy Hill Aquifer is also a sand-facies outlier of the Terteling Springs Member of the Idaho Group of Formations. The testing of TWP#1 along with the use of SVR #3 as an observation well led Scanlan to conclude that short-term potential yields of "several hundred" gpm or more would be possible from a properly designed and constructed production well. He also noted that elevated arsenic concentrations in the water along with poor water-level recovery after pumping would limit the Sandy Hill Aquifer for use as a significant supply aquifer, if treatment and artificial recharge were not applied. TPW#1 and SVR #3 are discussed as part of the Sandy Hill Aquifer section of this report.

Eastern Upland Mixed-Sediment/Bedrock Well SVR #1 Seven-and-One-Half-Hour Test

Overview and Previous Analysis

SVR #1 was drilled by Stevens and Sons Well Drilling using the direct mud-rotary method during October and November of 2002. SVR #2 was drilled to a total depth of 445 ft bgl and completed with borehole open to the aquifer between depths of 98 and 445 ft bgl. The pretest water level was reported at 16.8 ft bgl which translates to an elevation of about 3,373 ft amsl. SVR #1 was pump tested on March 23, 2004 for a period of 7½ hours at a rate of 51 gpm. At the end of the test, the reported drawdown was 102 ft, for an end-of-test specific capacity of 0.5 gpm/ft. This well is located in Figure 53 (page 140) as a red diamond with a solid boundary.

According to the Well Driller's Report, SVR #1 was completed in a "very fine sand," from depths of 98 to 140 ft bgl; "shale," "sandstone," and "gravel," from depths of 140 to 350; and "decomposed granite," between 350 to 445 ft bgl. Scanlan Engineering (2003) characterized these geologic materials as "lakebed sediments and volcanoclastic sediments from surface to approximately 340 feet" bgl and "decomposed granite" from 340 to 447 ft bgl. Scanlan Engineering informally named this unit the "Spring Valley Aquifer." Based on information provided to Scanlan Engineering by the well driller, they believed that "most of the water was being produced from above the top of the granite."

Scanlan Engineering reported a transmissivity value of 1,500 to 2,000 gpd/ft for SVR #1. Details on the analysis were not included in Scanlan Engineering, although the semi-log plots of drawdown data suggest he used the Cooper-Jacob (1946) method of analysis for transmissivity. As with all pumping tests using only the pumping well for data collection, accurate values for storativity could not be (and were not) calculated for the SVR #1 test.

HLI Analysis

We initially analyzed the SVR #1 data for the effects of well-bore storage. A log-log, radial flow analysis indicated that well bore storage effects were insignificant so methods of analysis not incorporating these effects were deemed acceptable. Drawdown was analyzed using the Cooper-Jacob method. Although this method does not accommodate the effects of partial penetration, no information is readily available to assess the depth of the bottom of the aquifer and therefore the overall thickness of the aquifer. Consequently, the degree of partial penetration could not be calculated. For the purpose of our analysis, we assumed the open well bore represented near full-penetration of the aquifer.

The Cooper-Jacob semi-log analysis for SVR#1 is presented in Figure 54 (page 141) while a semi-log Theis recovery analysis is presented in Figure 55 (page 142). A Cooper-Jacob analysis based on the first five data points (dashed blue line) suggest a near-well-bore aquifer transmissivity of about 340 gpd/ft. However, the derivatives for this time

period do not match well with the type curve (which would be horizontal) suggesting that the five points may not describe a straight-line plot. After 40 minutes, the drawdown curve flattens out and describes a straight-line. The analysis based on the after-40-minutes data indicates a transmissivity of 1,500 gpd/ft. The derivatives match the type curve and support the use of the Cooper-Jacob method.

Since the difference in the slopes between the two lines is much greater than 2:1, the apparent change in slope is not likely to be the result of a positive (recharge) boundary. A recharge source (like a lake or river) directly coupled to the aquifer would cause the slope of the drawdown curve to halve. It is more likely that the steeper initial data plot resulted from lower permeabilities near the well bore and/or variations in the pumping rate during the first 5 minutes of the test. The flat derivative plot after 40 minutes indicate that significant leakage did not occur.

The semi-log Theis recovery analysis (Figure 55, page 142) indicates a transmissivity of 2,300 gpd/ft. The figure shows the data plot as a straight-line at t/t' values of less than 20 (equivalent to 23 minutes after pumping stopped). The data plot from this time period indicate the bulk transmissivity of the larger zone surrounding the well in a manner analogous to the second, flatter, straight-line plot shown in the Cooper-Jacob plot (Figure 54). The two calculated transmissivities are in general agreement with each other, with a mean of 1,900 gpd/ft. The average of the values reported in Scanlan Engineering is slightly smaller at 1,700 gpd/ft, as shown in Table 3 (page 247).

The mean transmissivity 1,900 gpd/ft is considerably smaller than any reported for the non-bedrock (sedimentary) aquifers discussed in this report. These low values would be typical for a thin, fine-grained sand aquifer, as reported by the well driller for the zone 125 to 140 ft bgl, or for low-permeability sandstone as reported for deeper portions of the well. These low values indicate the aquifer (or aquifers, if the fine sand and the deeper sandstone represent separate aquifers) at this location cannot supply significant quantities of water beyond a limited domestic supply.

Storativity cannot be calculated from the data. One or more observation wells are needed as a pumping well alone cannot give meaningful data for storativity analysis. We speculate, however, that the storativity for the mixed-sediment/bedrock aquifer in the vicinity of this well ranges from 10^{-3} to 10^{-5}.

The recovery analysis indicates an S/S' of 1.0, indicating that no significant recharge was captured during the test. This lack of recharge supports the conclusion that the flattening of the drawdown curve that could appear to indicate a positive ("recharge") boundary, was more likely the result of the cone of depression from the pumped well encountering a zone of higher transmissivity within the aquifer away from the well bore. Total recovery to pretest levels did not occur before data collection stopped. Water levels were only collected for 2.5 hours after pumping ceased, a period far too short to allow for full water level recovery.

Since the potential yield, transmissivities and probable recharge area supplying water to the aquifer in the vicinity of SVR #1 are all relatively small, a production well at this location (or for that matter, any part of the mixed-sediment/bedrock aquifer in the eastern portions of the project area) cannot support development of significant quantities of water for more than individual domestic use or at most, a small limited water system supporting a few homes.

Well Interference and the Effects of Seasonal Pumping

The low yield of SVR #1 makes simulation of seasonal pumping of little use to a regional water-supply analysis. A simulation was not done.

Conclusions

Based on the overview and analysis presented above, we make the following conclusions:

1. The actual (and potential) yield of SVR #1 is too small for consideration for regional water supply. At best, only a very limited system supplying only a few homes appears feasible.

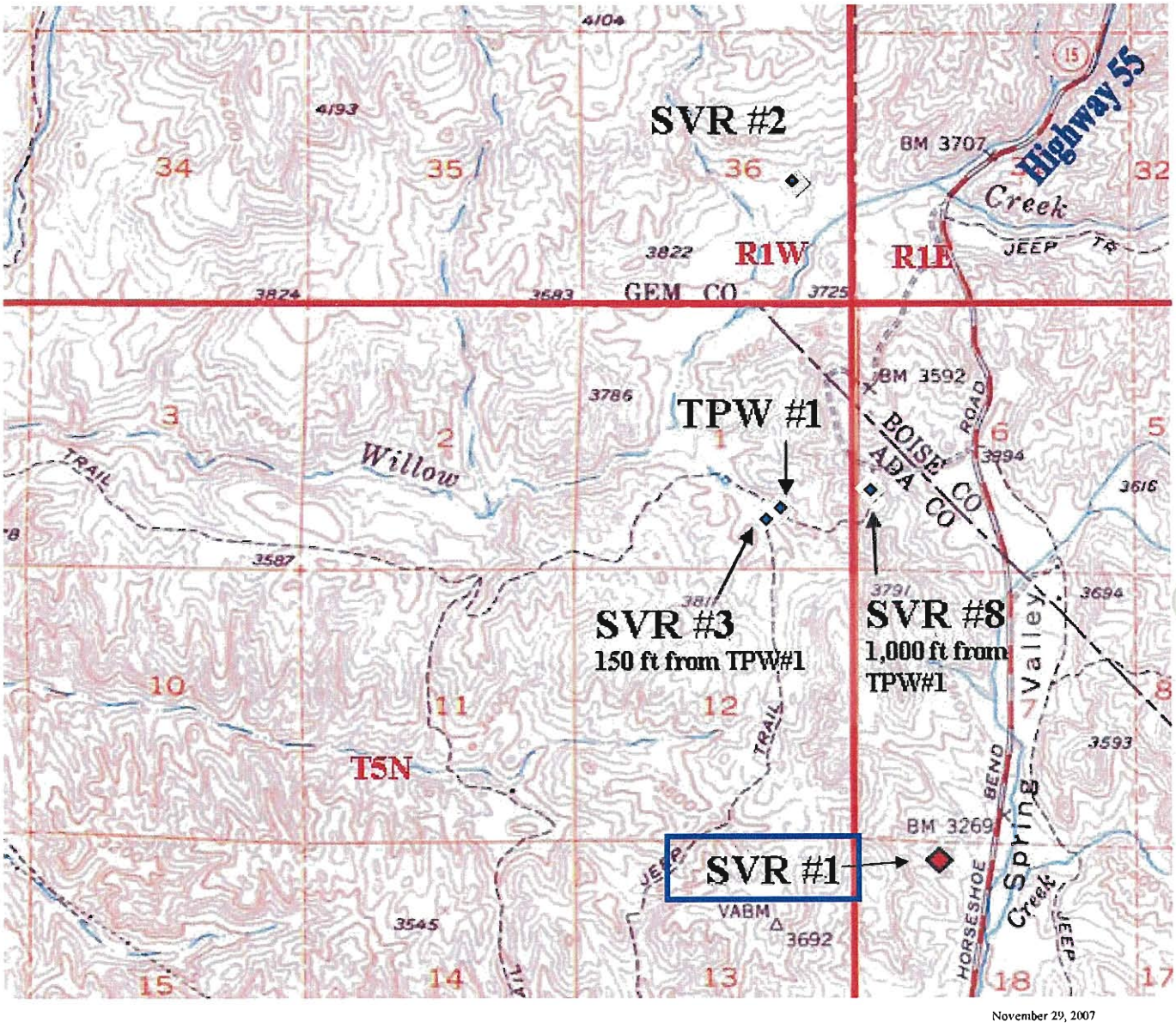
2. Previous analyses of aquifer transmissivity are consistent with those conducted as part of this study; values of 1,500 to 2,300 gpd/ft were calculated. The mean for our analyses was 1,900 gpd/ft.

3. Aquifer storativity could not be accurately analyzed from the existing data as no observation wells were measured during the test. We estimate that the aquifer has storativities on the order of 10^{-3} to10^{-5}.

4. A well field completed in the mixed-sediment/bedrock of the Eastern Upland cannot supply significant quantities of sustainable ground water for a regional supply. As with the test well SVR #1, only a very limited system supplying only a few homes appears feasible.

5. Volcanic and granitic bedrock can be considered a "no-flow boundary" for purposes of a regional supply-analysis, in comparison to the fluvial-lacustrine and alluvial sand and gravel aquifers in the region.

Figure 53. Well Location for SVR Well #1 Seven-Hour Test



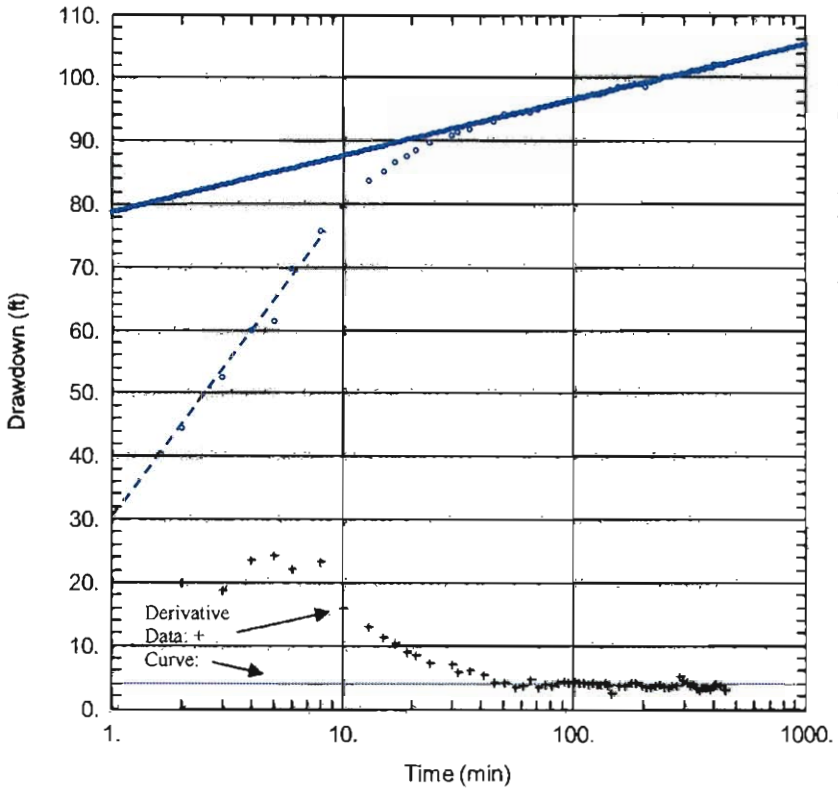
November 29, 2007

Pumping Well Location

One Mile

N

Figure 54. Cooper-Jacob Analysis for SVR Well #1 Seven-And-One-Half-Hour Test
Test Conducted: November 8, 2002



SVR Well #1
Open hole = 98-400ft
T = 1,500 gpd/ft
S Not Calculable
Kv/Kh= 1
b =275 ft
t_c < 1 min
r = 0.5 ft
Q = 51 gpm

Well bore storage analysis indicates no significant effects.

Derivative analysis supports method after 40 minutes into test. Later straight-line plot suggests more permeable region away from well bore.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

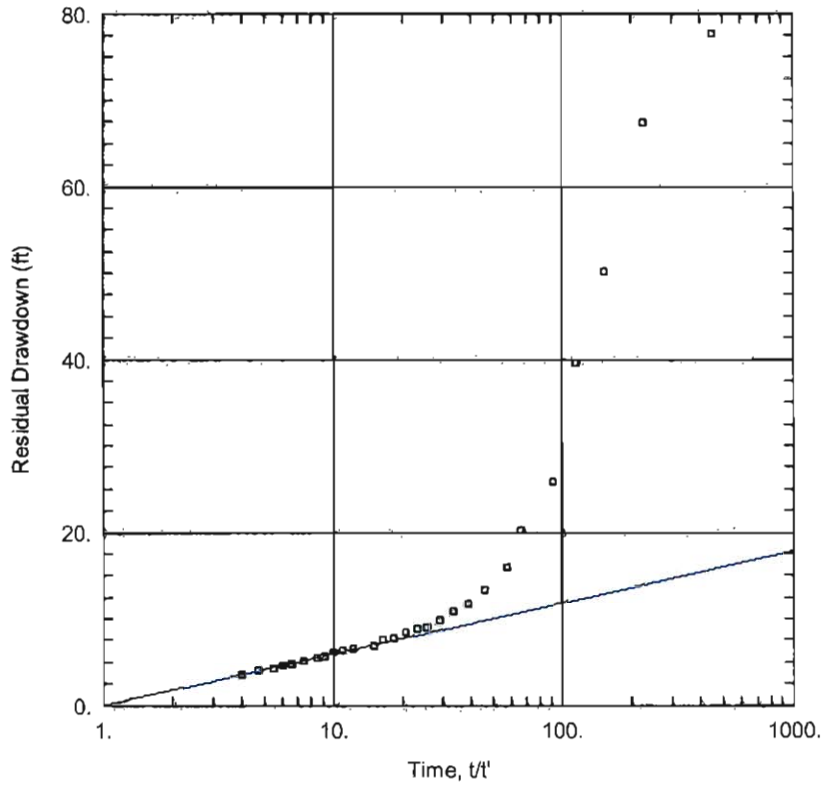
t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

$u = 1.87r^2S/Tt$
t = time in days

b = aquifer thickness in feet (ft), estimated from well log on Driller's Report.
r = effective radius of pumping well (ft)

Based on the analytical method of Cooper and Jacob (1946). No partial penetration corrections appear to be necessary for open bore-hole well.

Figure 55. Recovery Analysis for SVR Well #1 Seven-And-One-Half-Hour Test
Test Conducted: November 8, 2002



SVR Well #1
Open hole = 98-400ft
T= 2,300 gpd/ft
S/S' =1.0
Kv/Kh= 1
b =275 ft
Q = 51 gpm

S/S' = 1.0 implies no recharge or discharge boundaries encountered during test.

Transmissivity agrees with later-time Cooper-Jacob analysis.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Vertical to horizontal ratio of permeability (unitless), estimated from well logs in the area
b = aquifer thickness in feet (ft), estimated from well logs in the area
r = effective radius of pumping well (ft)

Based on the analytical method of Theis (1935). No partial penetration corrections appear to be necessary for open bore-hole well.

Eastern Upland Mixed-Sediment/Bedrock Well SVR #2 Two-and-One-Half-Hour Test

Overview and Previous Analysis

SVR #2 was drilled by Stevens and Sons Well Drilling using the direct mud-rotary method during November of 2002. This well is located in Figure 56 (page 146) as a red diamond with a solid boundary. SVR #2 was drilled to a total depth of 840 ft bgl and completed with borehole open to the aquifer between depths of 300 and 840 ft bgl. According to the Well Driller's Report it was completed in "clay," "sandstone," and "basalt" between 300 and 760 ft bgl and "decomposed granite" below 760 to 840 ft bgl. Scanlan Engineering (2003) informally named this unit the "Spring Valley Aquifer," as they did with the aquifer tapped by SVR #1. SVR #2 was pump tested twice. The first test conducted on November 22, 2005 at 40 gpm for 5½ hours, produced water of poor quality (hard water high in sulfate with arsenic exceeding primary drinking water standards and iron and manganese exceeding secondary drinking water standards). The upper portion of the open borehole was cased off above 300 feet bgl with 6-inch casing and a second test was conducted on March 23, 2004 for a period of 2½ hours at a rate of 50 gpm. The pretest water level of the second test was reported at 31 ft bgl which translates to an elevation of about 3,598 ft amsl, the highest of any of the wells discussed in this report. At the end of the second test, the reported drawdown was 159.9 ft, for an end-of-test specific capacity of 0.3 gpm/ft.

Scanlan Engineering (2003) reported transmissivities ranging from 280 to 695 gpd/ft for the tests based on straight-line Cooper-Jacob plots. Details on their analysis were not provided in their report. As with all pumping tests using only the pumping well for data collection, accurate values for storativity could not be (and were not) calculated for the test.

HLI Analysis

The methods of analysis for the SVR #2 test data from the March 23, 2004 50-gpm test were selected after a radial flow analysis indicated that the effects of well-bore storage may have affected data from the first four minutes of pumping. In a well that is pumped at a low rate in comparison to the amount of water standing in the well bore, the removal of this water causes water levels that do not match the theoretical levels assumed in the Cooper-Jacob or Theis method for an infinitesimally-small-diameter well. The discrepancy occurs because the water standing in the well bore supplies a significant portion of the water removed during the initial stages of pumping, compared to the proportion of water supplied by the aquifer. After a long enough pumping period, the aquifer supplies most, if not all the water pumped and these "well-bore storage" effects become relatively small. For this reason, analyses of later-time data (if not affected by other factors such as hydraulic boundaries) using a method that does not take well-bore storage effects into account (such as the Theis method) can yield results similar to that of the Papadopoulos-Cooper method which does compensate for well-bore storage effects.

We used two methods to analyze the drawdown data: the Cooper-Jacob, semi-log straight-line method and the Papadopoulos-Cooper log-log method that incorporates well bore storage. Both yielded similar results for calculated transmissivity: 720 gpd/ft (Cooper-Jacob – Figure 57) and 840 gpd/ft (Papadopoulos-Cooper – not shown). Each method has limitations. The Cooper-Jacob method cannot by itself accommodate the effects of well-bore storage while the Papadopoulos-Cooper is sensitive to effective well bore diameter. Neither method can accommodate the effects of partial penetration but since there is no available geologic information to suggest that the 460 ft open borehole draws from an aquifer that is significantly thicker than 460 ft, we believe that a partial penetration correction is not necessary. Because the radial flow analysis indicated that the data from after the first 10 minutes of pumping were not significantly affected by well-bore-storage effects, we believe that the Cooper-Jacob method is preferable to the Papadopoulos-Cooper method for analyzing and presenting the drawdown data. Also, the derivative analysis indicates a match to the type curve after 20 minutes of pumping. thus, the data from after 20 minutes are suitable for analysis by the Cooper-Jacob method.

We have also used the Theis recovery method to analyze recovery data from the SVR #2 test. Because well bore storage effects are only significant during the initial stages of recovery before the Theis recovery method yields a straight-line plot, well bore storage corrections are not needed in this method. The analysis (Figure 58, page 148) indicates a transmissivity of 270 gpd/ft.

The mean of the three analyses indicates a transmissivity of 600 gpd/ft, to one significant figure. This mean is within the range of the transmissivities reported by Scanlan. We consider this transmissivity to be too small to allow the aquifer to be considered for possible regional supply. Because of the averaging effect that occurs during well recovery, we consider the recovery analysis to better represent overall aquifer conditions. These very low values indicate that the aquifer at this location is only suitable for very development of small quantities of ground water for domestic or stock watering purposes and not the quantities needed for a regional supply.

Storativity could not be calculated from the data from either of these well test analyses. One or more observation wells is needed as a pumping well alone cannot give meaningful data for storativity analysis. We estimate a storativity in the range of 10^{-3} to 10^{-5} for the mixed sediment/bedrock in the vicinity of these wells. (See discussion for SVR #1.)

Since the calculated potential yields, transmissivities and assumed recharge area supplying water to the SVR #2 vicinity are all relatively small, wells in this aquifer are unlikely to yield more than a few ten's of gallons per minute..

Well Interference and the Effects of Seasonal Pumping

The low yield of SVR #2 makes simulation of seasonal pumping of little use to a regional water-supply analysis. A simulation was not done.

Conclusions

Based on the overview and analysis presented above, we make the following conclusions:

1. The actual and potential yields of SVR #2 are too small for consideration for regional water supply.

2. Calculated aquifer transmissivities ranged from 270 to 840 gpd/ft. These values are consistent with those presented in previous studies. We believe that the transmissivity of the aquifer near SVR#2 is on the order of 600 gpd/ft.

3. Aquifer storativity could not be accurately analyzed from the existing data as no observation wells were measured during the test. We estimate that storativity is on the order of 10^{-3} to10^{-5}.

4. Mixed-bedrock aquifer wells in the Eastern Upland area are unlikely to supply significant water for a regional supply.

5. Volcanic and granitic bedrock can be considered a "no-flow boundary" for purposes of a regional- supply analysis, in comparison to the sand and gravel aquifers in the region.

Figure 56. Well Location for SVR Well #2 Two-and-a-Half-Hour Test

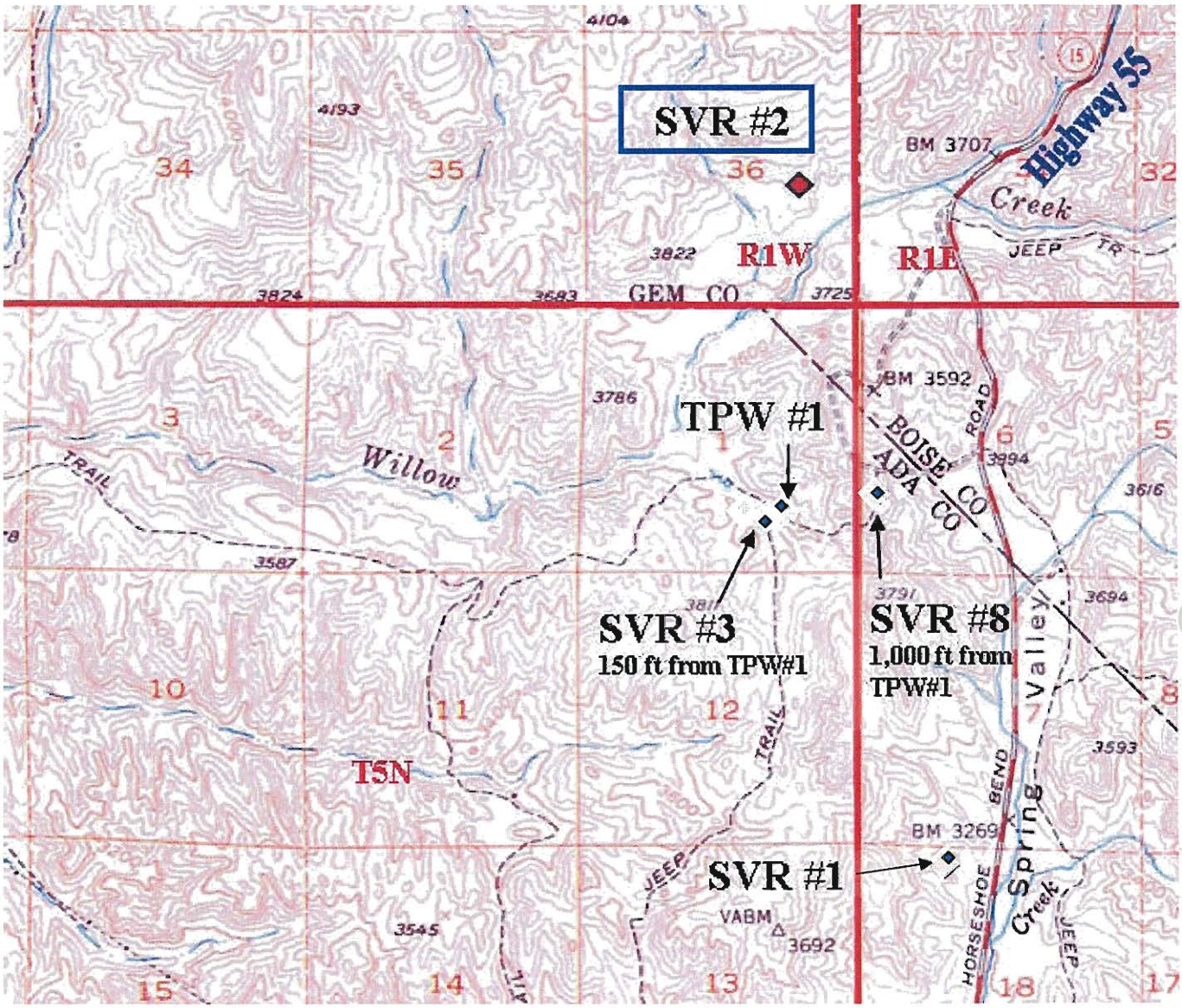
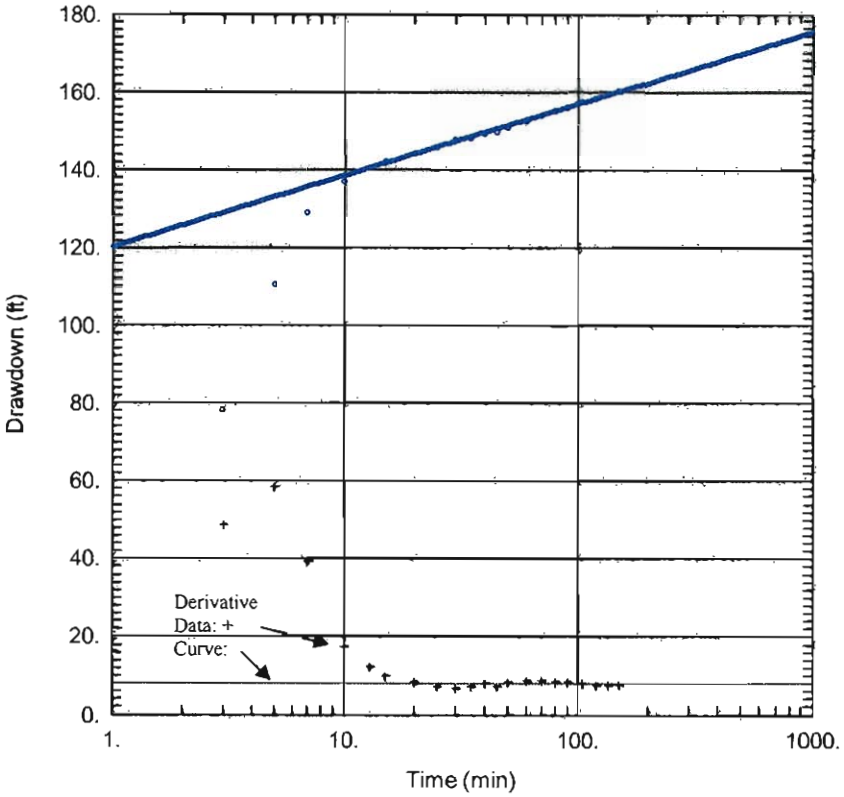


Figure 57. Cooper-Jacob Analysis for SVR Well #2 Two-and-a-Half-Hour Test
Test Conducted: December 19, 2002



SVR Well #2
Open hole = 300-760ft T= 720 gpd/ft
S Not Calculable
Kv/Kh= 1
b = 460 ft
r = 0.25 ft
t_c < 1 min
Q = 50 gpm

Well bore storage analysis indicates significant effects through eight minutes of pumping. Straight-line semi-log plot after eight minutes indicates data suitable for transmissivity analysis.

Derivative analysis supports method after 20 minutes.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

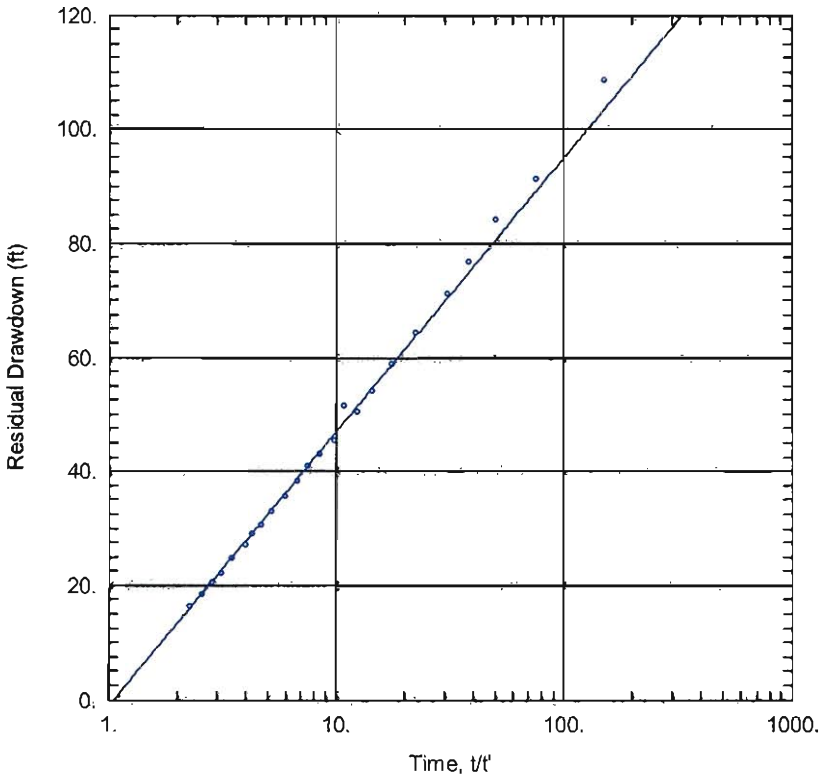
t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

$u = 1.87r^2S/Tt$
t = time in days

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
r = effective radius of pumping well (ft)

Based on the analytical method of Cooper and Jacob (1946)

Figure 58. Recovery Analysis for SVR Well #2 Two-and-a-Half-Hour Test
Test Conducted: December 19, 2002



SVR Well #2
Open hole = 300-760ft
T=270 gpd/ft
S/S' =1.0
Kv/Kh = 1
b =460 ft
r = 0.25 ft
Q = 50 gpm

S/S' = 1.0 implies no recharge or discharge boundaries encountered during test.

T = 264Q/Δs Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Vertical to horizontal ratio of permeability (unitless), estimated from well logs in the area
b = aquifer thickness in feet (ft), estimated from well logs in the area
r = effective radius of pumping well (ft)

Based on the analytical method of Theis (1935).

Willow Creek Aquifer Well SVR #6 Twenty-Four-Hour Test

Overview and Previous Analysis

SVR #6 was drilled by Adamson Pump and Drilling using the air-rotary method during January and February of 2004. This well is located in Figure 59 (page 153) as a red diamond with a solid boundary. SVR #6 was drilled to a total depth of 740 ft bgl. After the 8-inch casing was installed to a depth of 738 ft, a sand-and-cement mixture was placed from 730 to 740 ft bgl and the casing perforated with a star perforator between depths of 560 and 720 ft bgl. The pretest water level was reported at 450 ft bgl which translates to the lowest elevation (about 2,354 ft amsl) of any of the wells discussed in this report. SVR #6 was pump tested March 23, 2004.

SVR #6 was completed in a sand portion of the Willow Creek Aquifer between elevations of 2,070 and 2,390 feet. Based on the geologic log prepared by Feast Geosciences and the water level and log reported on the Well Driller's Report, the aquifer appears to be unconfined. A thick unsaturated zone of "dry" sand with some clay layers, overlies the water table at the SVR #6 well site and, according to the Well Driller's Report, extends to ground surface.

SVR #6 was pumped at an average rate of 358 gpm for 24 hours. During the test, water levels in the well dropped by 2.73 feet (from an initial level of 482 ft bgl) almost immediately. Over the next 2 ½ hours water levels rose and the drawdown actually reduced slightly to 2.71 ft suggesting well development (or errors in measurements). From 400 minutes through the end of the test drawdown water levels remained constant at 2.82 feet, resulting in an end-of-test specific capacity of 132 gpm/ft. Well development is also suggested by the constant drawdown for the last approximately 1,000 minutes of the test. An increase in drawdown would have been more typical. An increase in drawdown that might have occurred could have been offset by well development. Well development is the removal of drilling fluids and aquifer material near the well that should have taken place before the test. According to the driller, no development procedures were carried out prior to testing (Dave Adamson, personal communication, August 2007).

Analysis of the drawdown data by SPF (2004b) indicated a transmissivity of almost 2,000,000 gpd/ft with recovery data indicating 675,000 gpd/ft. In their report they summarized that transmissivity was "> 1,000,000 gpd/ft." Details of the transmissivity analysis were not presented but equations on the drawdown plots indicate the Cooper-Jacob (1946) method was used. As with all pumping tests using only the pumping well for data collection, accurate values for storativity could not be (and were not) calculated for the SVR #6 test.

HLI Analysis

We have re-analyzed the SVR #6 pumping test data. Figure 60 (page 154) shows a semi-log Theis (1935) analysis for unconfined-aquifer drawdown and recovery of SVR #6. The plot shows that several times during the test, drawdown decreased over time. Figure 60 shows this decrease in drawdown over the periods 8 to 18 minutes, 20 to 70 minutes and 80 to 200 minutes. During the period 40 to 1,440 minutes drawdown remained constant. It appears likely to us that the pumping rate may have been adjusted upward at the start of these intervals with subsequent well development causing the drawdown to decrease as the well developed.

A rough match of the data was made using the semi-log Theis method, with Hantush (1961 a and b) corrections for partial penetration. Because the initial drawdowns were also relatively constant, no curve match is possible using early time data. The curve match is only approximate because the well developed during pumping, causing drawdowns associated with well loss to reduce while drawdowns associated with head loss in the aquifer ("formation loss") increased.

Figure 60 presents both a raw-data plot (upper curve) and plot of the data corrected for an estimated maximum well loss of 2.5 ft (lower curve) which was subtracted from all the water levels that were measured during pumping. The estimated maximum well loss of 2.5 ft was based on the observation that drawdown was 2.72 ft below the initial non-pumping level almost instantaneously and remained near this level throughout the test and then rose almost immediately to 0.16 ft above, after pumping stopped and the water in the pump column drained, suggesting that most of the drawdown was the result of well loss. Based on the almost immediate drawdowns to 2.72 feet and almost immediate recovery to 0.16 ft, we believe that about 2.5 ft of the observed drawdown throughout the pumping portion of the test was the result of well loss.

The Theis analysis using the well-loss corrected data indicated a transmissivity of about 2,000,000 gpm/ft. A Theis curve could not be made to fit the raw data. Because the well was developing during the test, the curve match to the well-loss corrected data can only be considered approximate. As such, we believe that the transmissivity is greater than 1,000,000 gpd/ft but we cannot say by how much more.

The derivative analysis generally supports the use of the Theis method to calculate transmissivity. As shown on the figure, the calculated derivatives are close to the type curve except for the data collected between 200 and 500 minutes. The changes in drawdowns that occurred during this time period and the corresponding changes in derivatives suggest pumping rate adjustments or inaccuracies in water level measurements.

A Cooper-Jacob analysis (not shown) was also attempted using the drawdown data. However, because the drawdowns were constant throughout the last 1,000 minutes of the test, a meaningful straight-line plot could not be constructed.

No hydraulic boundaries were observed in the pumping test data. A boundary would have shown up as a change in slope in the data plot. Because the overall drawdown was so small, especially after well loss effects were removed, it is possible that boundary effects may have occurred but could not be detected within the resolution of the water level measurements. A test at a much higher discharge-rate and of longer duration might allow such effects to be measurable.

The semi-log Theis recovery method (Figure 61, page 155) indicates a transmissivity value of 650,000 gpd/ft using uncorrected data and 1,000,000 gpd/ft using data corrected for partial penetration using the method of Butler (1957).

We believe that neither the drawdown analyses nor the recovery analyses are very accurate. The test was performed on a well that was neither properly developed nor pumped at a high-enough rate to stress the aquifer sufficiently to generate good data. Considering the quality of the test data and the large variation in our analytical results, our best estimate of aquifer transmissivity is on the order of 1,000,000+ gpd/ft. Better testing would be needed to refine this estimate. SPF indicated similar transmissivity values.

The projection of the recovery line ("residual drawdown") shown in Figure 61 appears to project through a t/t' of 5.1. Any value greater than 1.0 indicates "early" recovery, typically a source of recharge. No recharge source is likely, however, since the aquifer is too deep to connect to any nearby body of surface water or to allow for pump-test discharge water to infiltrate to the aquifer during the test and be "recycled." It should also be noted that full recovery was not actually measured as the data were not collected sufficiently long after pumping shut down. It is not known what might have caused this projection of "early" recovery. It may be a relic of poor measurement technique, such as a data logger shift that was not corrected through the use of accurate hand measurements. (A data-logger shift-error or a hand-measurement error of only 0.1 feet would change the apparent "early" recovery into an apparent "late" recovery. Since such a small error is entirely possible, little stock should be placed in the "early" recovery).

Storativity could not be calculated from this well test. One or more observation wells are needed to generate meaningful data for storativity analysis. Based on the fact that the water levels define the top of the Willow Creek Aquifer, we believe that this aquifer is unconfined; during pumping, the upper portions of the aquifer would dewater. Based on the unconfined nature of the aquifer, a long term pumping storativity is estimated to be on the order of 10^{-2} to 10^{-1} and possibly higher.

Well Interference and the Effects of Seasonal Pumping

The Willow Creek Aquifer (in which SVR #6 is completed) appears to us to be highly transmissive but bounded in lateral extent. The contact of a clay layer to the south and west defines the southern boundary of the aquifer. Low-permeability bedrock to the north and east defines the northeast boundary of the aquifer. The bounded aquifer is therefore very limited in extent and appears to be disconnected from any significant source of

ground-water-underflow ("recharge") from the Pierce Gulch Sand Aquifer. Infiltration of direct precipitation and intermittent stream flow appears to be the only obvious sources of direct recharge to this aquifer. We believe these sources of recharge to be relatively small in quantity, a conclusion supported by SPF (2004b) who estimated total annual average recharge to the Willow Creek Aquifer to be about 4.5 cfs (about 2,000 gpm). Because of the physical limits to the aquifer and small amounts of recharge, seasonal and long-term pumping may be limited by recharge and not by interference effects to other wells outside the area. No simplified analytical modeling would give meaningful results and therefore no such analyses were conducted.

Conclusions

Based on the overview and analysis presented above, we draw the following conclusions:

1. SVR #6 is completed in the highly-transmissive Willow Creek Aquifer that is bounded in lateral extent by clay in the south and west, and bedrock in the north and east.

2. The hydraulic effects of the bounded aquifer were not observed in the pumping-test data, probably because the test put insufficient stress on the aquifer (pumping rate too low) and was too short in duration.

3. The Willow Creek Aquifer is deep and is composed of medium-to-coarse-grained-sand and occasional gravels, with water levels that are deep (450 ft bgl or more) beneath the M3 project area.

4. The lower elevation of the aquifer, the greater depth to water in the aquifer, and a distinctly different groundwater geochemistry, indicate the Willow Creek Aquifer is different and distinct from the Pierce Gulch Sand Aquifer tapped by upland wells SVR #7, SVR #9, and wells in the Boise River Valley in the Eagle and Star vicinity.

5. Our best estimate of transmissivity of the Willow Creek Aquifer near SVR #6, based on the available data, is 1,000,000+ gpd/ft.

6. Although the Willow Creek Aquifer is relatively deep, test data and Well Driller's Reports indicate that the top of the aquifer is defined by a water table, making the aquifer unconfined.

7. No meaningful storativity calculations were possible from the existing data. The unconfined nature of the aquifer indicates representative values of 10^{-2} to 10^{-1} or more are likely.

Figure 59. Well Location for SVR Well #6 Twenty-Four-Hour Test

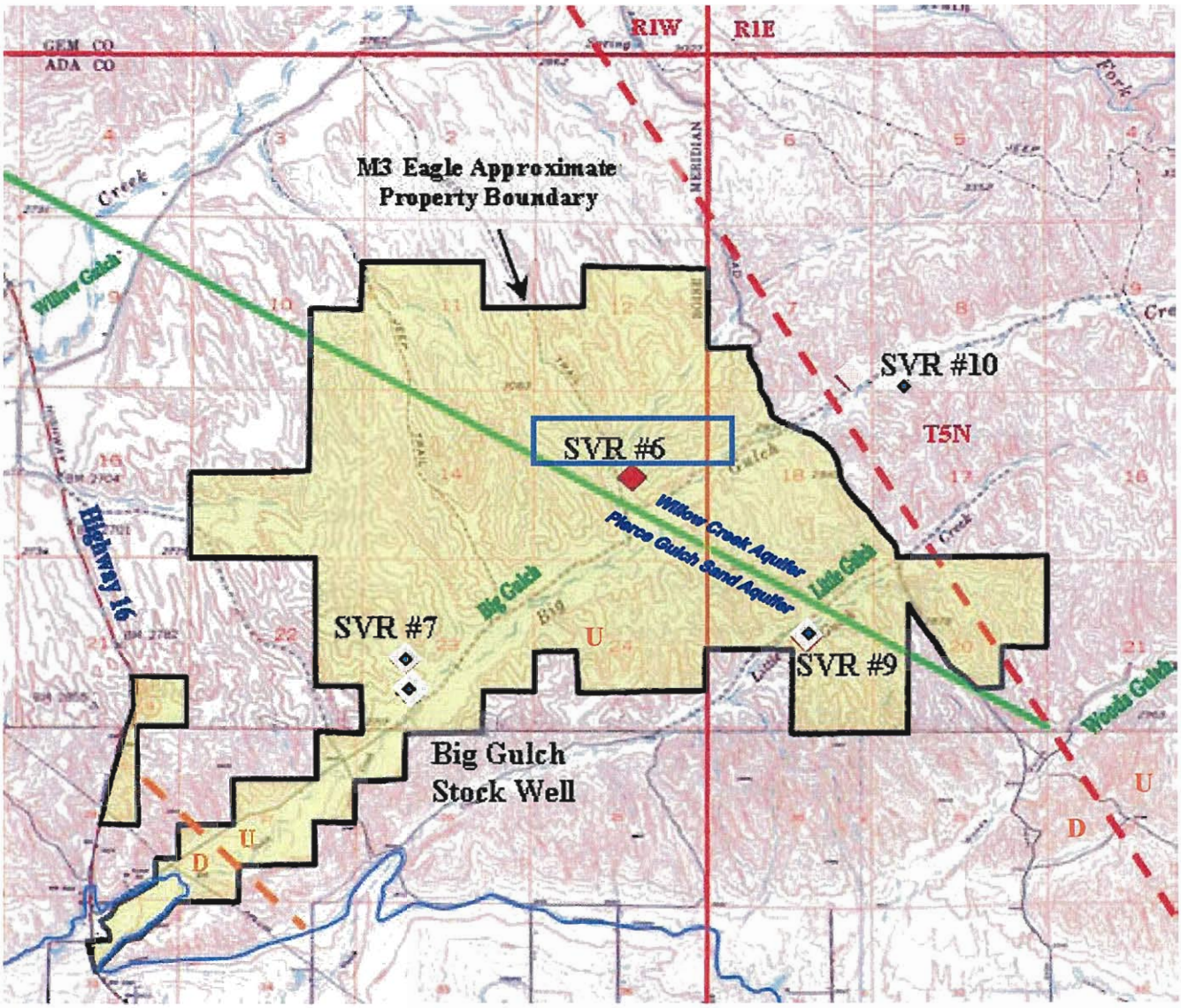
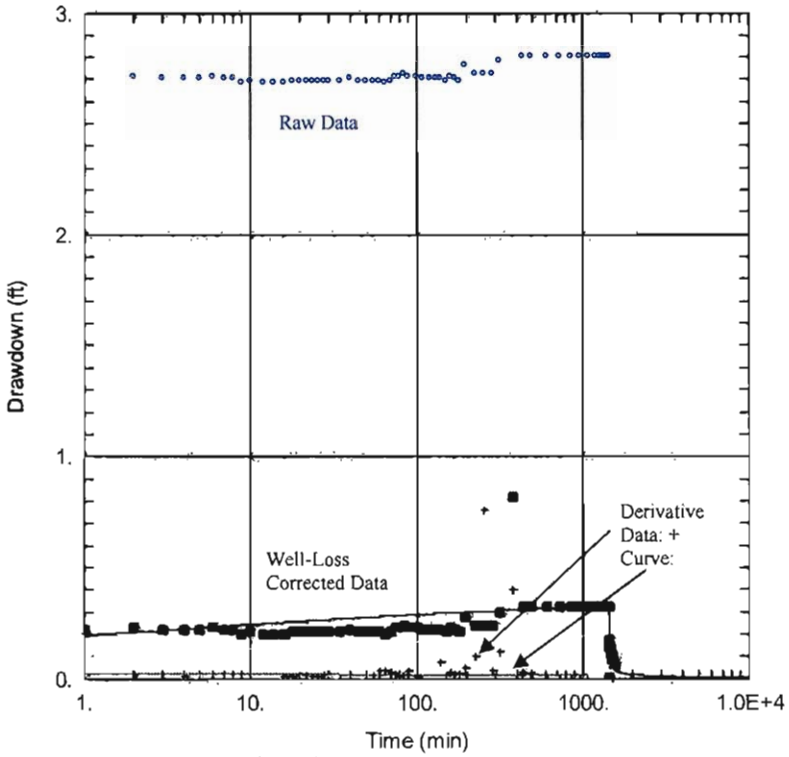


Figure 60. Semi-log Theis Analysis for SVR Well #6 Twenty-Four-Hour Test
Test Conducted: March 23, 2004



SVR Well #6
Screen = 560-720 ft
T > 1,000,000 gpd/ft
S = Not Calculable
Kv/Kh= 0.1
b = 290 ft
r = 0.5 ft
Q = 358 gpm

Results only approximate because the well developed during testing, affecting drawdown plot. Curve match only intersects very early and very-late-time data. An estimated maximum well loss of 2.5 feet was subtracted from raw data based on almost instantaneous initial drawdown of 2.5 ft. (See text for details).

Derivative type curve fit only approximate indicating transmissivity analysis is only approximate.

Partial penetration corrections applied (Hantush, 1961a and b).

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

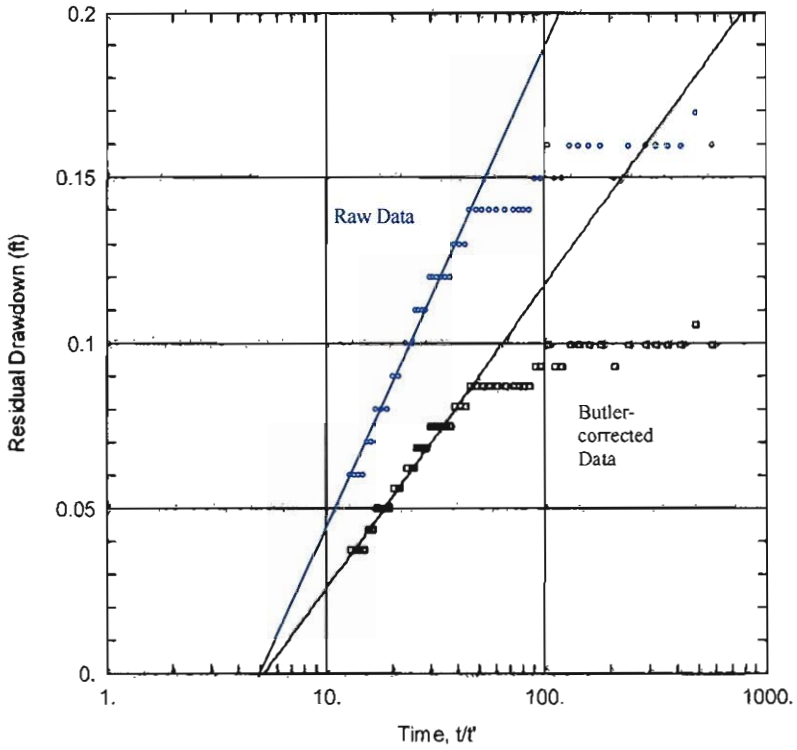
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer saturated thickness in feet (ft), estimated from log on Well Driller's Report.

Unconfined drawdown correction:
$s' = s - s^2/2b$ where
s' = corrected drawdown (ft)
s = measured drawdown (ft)

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935) with unconfined drawdown correction from Cooper-Jacob (1946) and partial penetration correction of Hantush (1961a and b).

Figure 61. Recovery Analysis for SVR Well #6 Twenty-Four-Hour Test
Test Conducted: March 23, 2004



SVR Well #6
Screen = 560-720 ft
T=650,000 gpd/ft
(no PP corrections)
T=1,000,000 gpd/ft
(with PP corrections)
S/S' = "5.1"
Kv/Kh= 0.1
b = 290 ft
r = 0.5 ft
Q = 358 gpm

High value of S/S' is likely incorrect as no significant nearby recharge source is likely. Data logger transducer may have shifted downward during test giving apparent "early recovery."

Partial penetration correction makes calculated T for whole-aquifer thickness about 50-percent larger than value calculated without PP correction.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer saturated thickness in feet (ft), estimated from log on Well Driller's Report.
r = effective radius of pumping well (ft)

$s_{pp} = 0.62\ s_{observed}$ where:
s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Based on the analytical method of Theis (1935).
Partial penetration corrections from Butler (1957).

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Willow Creek Aquifer Well SVR #10 Twenty-Four-Hour Test

Overview and Previous Analysis

SVR #10 was drilled by Adamson Pump and Drilling using the mud-rotary drilling method during June and July of 2004. SVR #10 was drilled to a total depth of 1,005 ft bgl and completed with stainless steel well screen open to the aquifer between depths of 630 and 640 ft bgl. This well is located in Figure 62 (page 160) as a red diamond with a solid boundary. The pretest water level was the deepest measured for any well discussed in this report at 482 feet below ground surface. SVR #10 was pump tested August 19, 2004. At the end of the test, the drawdown was 59.9 ft, resulting in an end-of-test specific capacity of 0.92 gpm/ft

SVR #10 is completed in a deep sand aquifer which lies between elevations of 2,200 and 2,390 feet. As with SVR #6, the water table appears to define the top of the aquifer, making the aquifer unconfined. Based on our interpretation of the Well Driller's Report, an unsaturated zone of "dry" sand overlies the water table in the Willow Creek Aquifer and appears to extend to the ground surface.

SVR #10 was pumped at an average rate of 55 gpm for 24 hours. During the test, water levels in the well dropped to within 0.1 foot of full drawdown of 59.9 feet within 8 minutes of pumping and remained at this level for the remainder of the 24-hour test period. If not for the effects of well-bore storage, we believe that the drop in pumping water levels to almost full drawdown would have occurred even sooner in the test. As with SVR #6, most of the 59.8 feet of drawdown is believed to be due to frictional well loss. Even though pumping at 55 gpm would not typically cause such a large well loss, it appears that unplanned and apparently uncorrectable partial exposure of the well screen during well construction lead to the large well losses.

The drilling and installation of SVR #10 was problematical. SPF (2004b) indicates that the initial borehole for SVR #10 was abandoned as a test well after the drill bit and several hundred feet of drive pipe were left in the hole and the well casing "broke or buckled at 520 ft." SPF (2004b) does not indicate whether the bore hole was completed as a water level monitoring point or abandoned. They do indicate that "it may be possible to use the well for measuring water levels but for all intents and purposes the original well was lost," suggesting that it was not abandoned.

A second borehole was then started 25 feet away from the original borehole that resulted in a well completion that was also different from that originally planned. According to SPF (2004b), the original intent was to expose both top and bottom screen sections to the aquifer. However, the screen assembly "became stuck during installation" and was installed with the upper portion of the screen still within the 8-in casing and the lower portion of the screen exposed to a zone "consisting primarily of clay" and not the original sand zone targeted through geophysical logging. We believe that it is likely that most of the water produced during pumping had to flow from the overlying clean sand through the clay zone (or the filled annulus surrounding the well casing) and therefore caused a

significant lowering of head (water level) during the test. Therefore, any calculated transmissivities are likely to be erroneous.

SPF did not calculate a transmissivity from the drawdown or recovery data. As with all pumping-well-only tests, storativity could not be (and was not) calculated from the SVR #10 test data.

HLI Analysis

Our reanalysis of the SVR #10 test data was problematical because the well was misconstructed, as discussed above. Figure 63 (page 161) presents a Cooper-Jacob plot which indicates a transmissivity value of about 300,000 gpd/ft. This transmissivity value is based on the relatively flat line shown on Figure 63 for data obtained after 10 minutes of pumping. Because the plot is so flat, a more accurate assessment could not be made. The mid-to-late-time data (after 10 minutes) were used in the analysis because the early-time data did not plot as a straight line. Even if they had plotted as a straight line, the transmissivity value of 700 gpd/ft indicated by this early-time plot would be unrealistically small for the more than 100 feet of "clean sand" and "sand and gravel" aquifer, as indicated in the Well Driller's Report. In actuality, the transmissivity for the Willow Creek Aquifer near SVR #10 is likely in excess of 300,000 gpd/ft, but not as large as that at SVR #6. The Driller's Report for SVR #10 indicates a significant part of the coarse grained-sand and gravel portion of the deposit lies *above* the saturated zone (and is therefore dry). It also indicates that the saturated portion of the sand aquifer is relatively finer at SVR #10 than it is at SVR #6. Therefore, the transmissivity in this area is very likely to be significantly less than it is at SVR #6, both because of lower permeability (from the relatively finer-grained deposits) and thinner aquifer (saturated portion of the entire deposit) thickness. The smaller saturated thickness at SVR #6 (compared to SVR #10) is probably because SVR #6 is located on the up-thrown side of the fault (shown on Figure 62) while SVR #10 is on the down-dropped side.

The recovery analysis presented in Figure 64 (page 162) yielded no meaningful results. The data show a steep initial recovery curve ($t/t' < 150$) followed by a flat line at "full recovery." Such a curve yields no data that can be meaningfully analyzed. The two lines are likely the result of the flawed well construction discussed above.

Because there were no observation wells for this test, storativity could not be calculated. One or more observation wells are needed to generate meaningful data for storativity analysis. As with SVR #6, we believe that the Willow Creek Aquifer in the vicinity of SVR #10 is unconfined. Based on the unconfined nature of the aquifer, we estimate a long-term storativity on the order of 10^{-2} to 10^{-1} and possibly larger.

Well Interference and the Effects of Seasonal Pumping

As with SVR #6, no analyses for well interference and long-term pumping impacts were conducted for SVR #10.

Conclusions

Based on the overview and analysis presented above, we draw the following conclusions:

1. SVR #10 is completed in the highly-transmissive and highly bounded Willow Creek Aquifer. The aquifer is bounded in lateral extent by clay in the south and west, and bedrock in the north and east. No boundary effects are apparent in the limited pumping-test data.

2. The hydraulic effects of the bounded aquifer were not observed in the pumping-test data, probably because: a) the well was misconstructed, b) the test did not sufficiently stress the aquifer (pumping rate too low), and c) the test was too short in duration.

3. Calculated transmissivity for the deep aquifer near SVR #10 is greater than 300,000 gpd/ft; a very high value. Misconstruction of SVR #10 that resulted in a highly inefficient well, makes a more exact analysis of transmissivity in the vicinity of SVR #10, problematic. Because the aquifer at SVR #10 is thinner and composed of finer-grained materials, we believe the transmissivity is likely to be much smaller at SVR #10 than it is at SVR #6.

4. Although the coarse-grained sand aquifer is relatively deep, Well Driller's Reports indicate that the top of the aquifer is defined by a water table making the aquifer unconfined.

5. No meaningful storativity calculations were possible from the existing data. The unconfined nature of the aquifer indicates representative values of 10^{-2} to 10^{-1} or more are likely.

Figure 62. Well Location for SVR Well #10 Twenty-Four-Hour Test

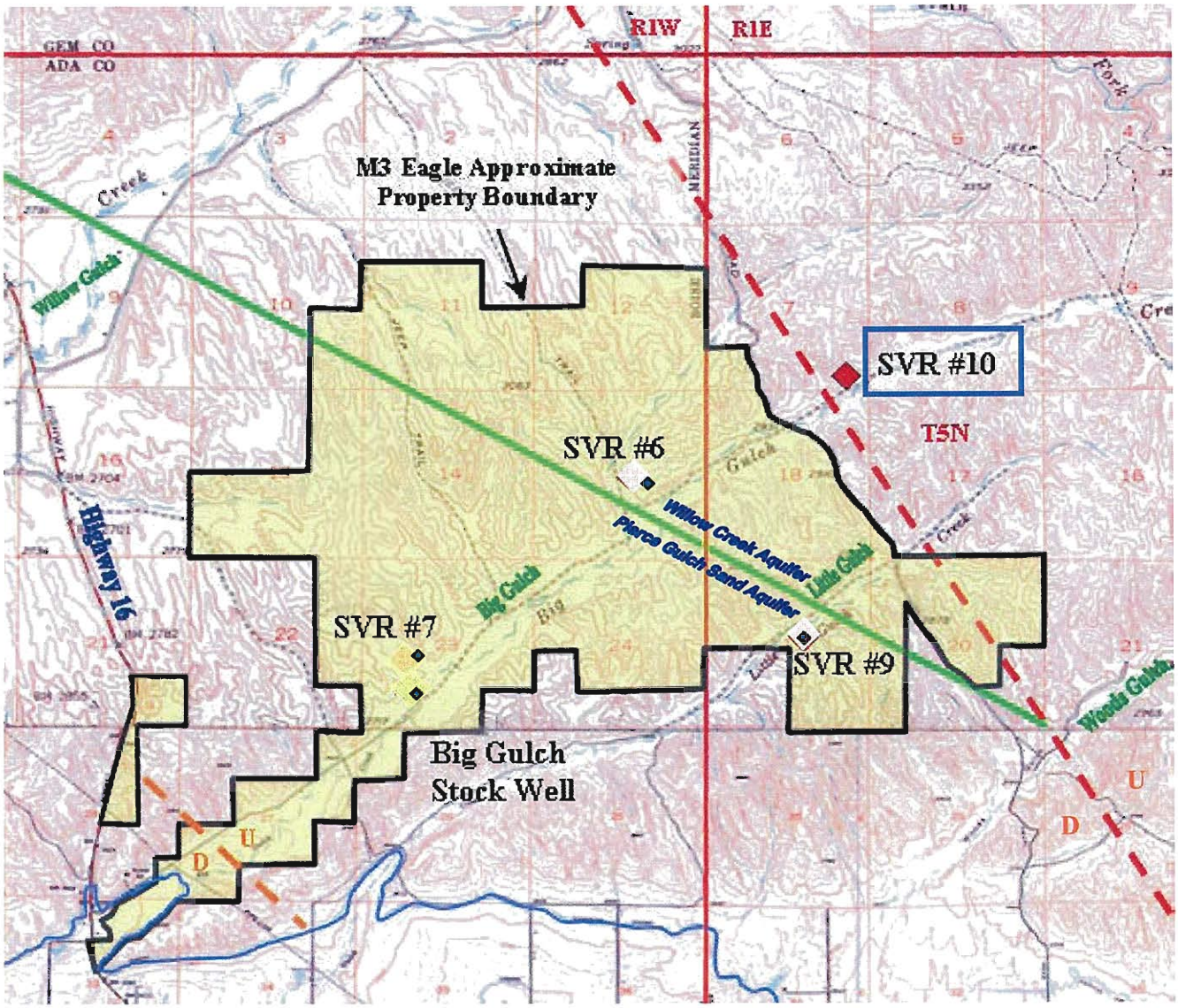
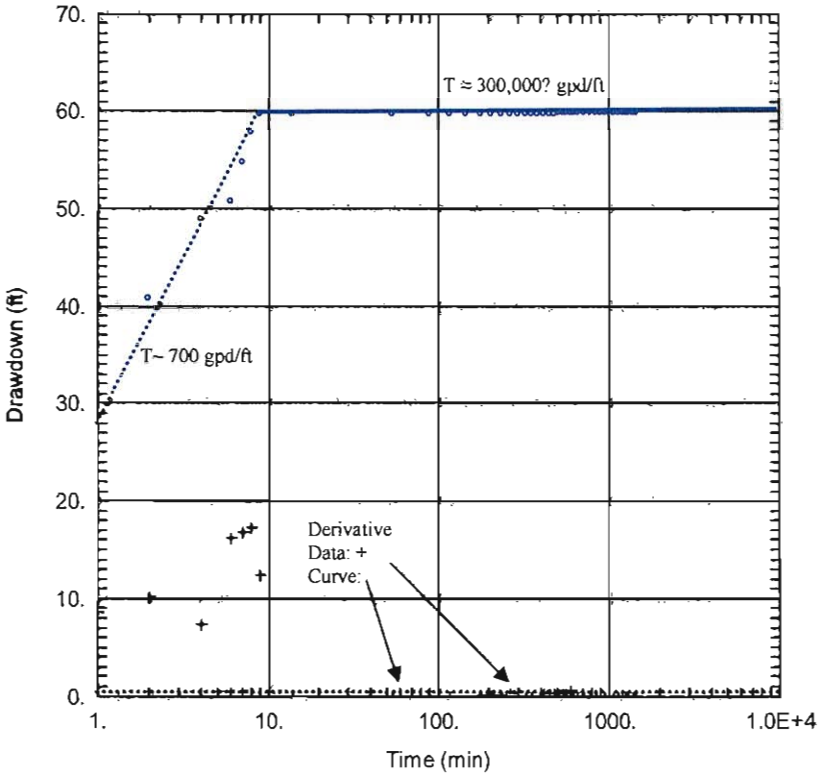


Figure 63. Cooper-Jacob Analysis for SVR Well #10 Twenty-Four-Hour Test
Test Conducted: August 19, 2004



SVR Well #10
Depth = 640 ft
T≈ 300,000? gpd/ft
S Not Calculable
Kv/Kh= 0.1
b = 190 ft
t_c < 1 min
r = 0.5 ft
Q = 55 gpm

T value only approximate. Early time data appears to represent lower zone screened in a clayey sand. Late-time data (after ten minutes) appears to represent leakage from upper zone where screen is cased off. Water appears to flow from upper zone to well through annular space along casing. See text for details.

Derivative type curve fit poor for early time, good for late time approximate indicating Cooper-Jacob analysis is only approximate.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

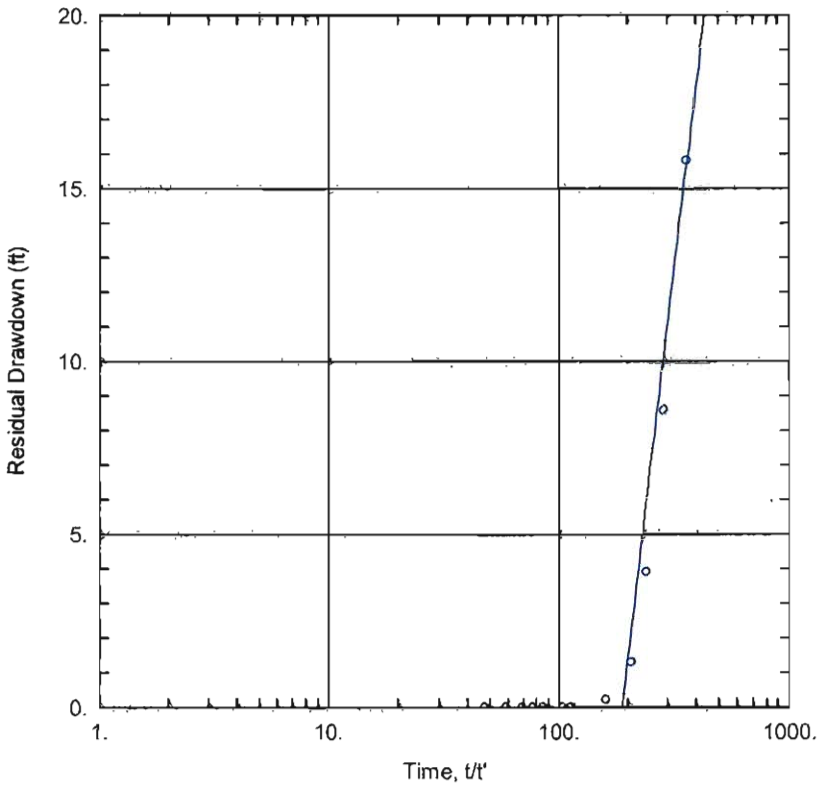
$u = 1.87r^2S/Tt$
t = time in days
r = effective radius of pumping well (ft)

b = aquifer saturated thickness in feet (ft), estimated from log on Well Driller's Report.

Unconfined drawdown correction:
$s' = s - s^2/2b$ where
s' = corrected drawdown (ft)
s = measured drawdown (ft)
b = aquifer saturated thickness (ft)

Based on the analytical method of Cooper and Jacob (1946).

Figure 64. Recovery Analysis for SVR Well #10 Twenty-Four-Hour Test
Test Conducted: August 19, 2004



SVR Well #10
Depth = 640 ft
T= no realistic value
S/S' = no realistic value
Kv/Kh= 0.1
b = 190 ft
r = 0.5 ft
Q = 55 gpm

Test invalid:
Early recovery curve is too steep and indicates a T of less than 300 gpd/ft. Late recovery (after 10 minutes) curve is flat and indicates infinite transmissivity. S/S' indicates "extremely early" recovery and therefore very large recharge boundary. These behaviors suggest flow from upper (cased-off) zone to lower zone. See text for details.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Vertical to horizontal ratio of permeability (unitless), estimated from well logs in the area
b = aquifer saturated thickness in feet (ft), estimated from log on Well Driller's Report
r = effective radius of pumping well (ft)

Based on the analytical method of Theis (1935).

Upland Pierce Gulch Sand Aquifer Well SVR #7 Twenty-Two-Hour Test

Overview and Previous Analysis

Well SVR #7 was drilled and tested in Big Gulch, within the upland project area. Adamson Pump and Drilling performed the work using the direct mud-rotary drilling method during March and April of 2004. This well is located in Figure 65 (page 169) as a red diamond with a solid boundary. SVR #7 was drilled to a total depth of 815 ft bgl and completed with a combination of torch-cut perforations in the well casing (340-350 ft bgl) and a louvered, steel-pipe, well-screen ((280-340 ft bgl). As shown in Table 3 (page 247), SVR #7 is completed in the middle portion of the Pierce Gulch Sand Aquifer which lies between elevations of 2,276 ft amsl and 2,536 ft amsl. According to the well driller (D. Adamson, personal communication, October 2007) the well was not developed prior to testing. The reported pretest-water-level was 160.54 ft bgl, equivalent to an elevation of about 2,555 ft amsl. SVR #7 was pump tested August 19, 2004. At the end of the test the maximum drawdown was 31.04 ft for an end-of-test specific capacity of 16.1 gpm/ft. The "Big Gulch stock well," a 4-in well used for observation 845 ft from the pumped well, had an end-of-test drawdown of 0.54 ft. This well is located in Figure 65 as a green diamond with a dashed boundary.

The Well Driller's Reports for SVR #7 indicate a water level that is slightly above the sand layer at the top of the aquifer suggesting a semi-confined to confined aquifer. During pumping significant enough to cause the water level near the pumping well to drop below the confining layer, we expect the aquifer would behave as an unconfined aquifer in the affected area.

SPF (2004b) reports that a 22.75-hour test was started on April 21, 2004, beginning as a stepped-rate test with rates of 300, 400 and 500 gpm. After the final increase to 500 gpm at 55 minutes into the test, water levels in the well dropped to 31.17 ft bgl and then rose slightly throughout the remainder of the test. We suspect that this rise was caused by the well continuing to develop as the well was pumped for the first time after only minor pre-test development. (SPF indicated that the well was air-lifted for two hours at rates far less than the pumping rate during the test.) This development makes test data analysis an approximation at best. Analysis of the drawdown data by SPF indicated a transmissivity of 270,000 gpd/ft with recovery data indicating 370,000 gpd/ft. A previously un-named well (referred to in our reanalysis as the "Big Gulch stock well") indicated a transmissivity of 240,000 gpd/ft for drawdown data and 307,000 gpd/ft for recovery data. No storativity value was given or discussed, even though an observation well was used to assess aquifer properties.

HLI Analysis

HLI reanalyzed the pumping test data from SVR #7 collected by SPF (2004b). Figure 66 (page 170) shows a Theis (1935) analysis for step-rate drawdown and recovery of SVR

#7. Because the curve is so flat and the drawdown actually *declines* during the later parts of the test, well development during the test is indicated. We have estimated a transmissivity of about 150,000 gpd/ft but because of well development, we consider this value to be only an estimate. This analysis does not include corrections for well loss which are likely to have been large, possibly in excess of 25 feet, as the well recovered to a "negative" residual drawdown (water level higher than before testing started) during the first minute of recovery. After three minutes of recovery, the residual drawdown was 1.6 ft indicating that most of the 31 ft of drawdown during pumping was caused by well loss. However, because of well development, we have not conducted an analysis with this well loss removed.

The derivative analysis generally does not support the use of the Theis method to calculate transmissivity. As shown on the figure, the calculated derivatives vary considerably with many negative values (caused by well development) that cannot be shown on a log-log plot. The results of the analysis, therefore, are only approximate.

A Cooper-Jacob (1946) analysis was not possible because a straight line through the data associated with any one of the pumping steps would have a negative slope, invalidating the method.

A Theis recovery analysis is shown in Figure 67 (page 171). The variations in levels above and below the straight line indicate that this analysis is also approximate, but possibly more likely to be representative than is the drawdown analysis because well development does not affect recovery analyses. We estimate a transmissivity of 300,000 gpd/ft from the recovery data. We have not applied partial penetration corrections to this analysis because the degree of penetration is not accurately known because of the well construction that includes both louvered well "screen" and torch-cut perforations. Partial penetration corrections would indicate a transmissivity larger than the 300,000 gpd/ft calculated above.

The Big Gulch stock well was used in the test to calculate aquifer transmissivity and storativity but the lack of any geologic, as-built construction details and/or Well Driller's Reports limits its value. Nothing is known about the geology of the drilled section penetrated by this well. (A search was made of IDWR files, but no Well Driller's Reports could be found.) Figure 68 (page 172) shows a Theis plot for the Big Gulch Stock Well.

A straight-line plot with a slope of one on a radial flow analysis (not shown) appeared to indicate that well-bore storage affected drawdown during the entire test. This type of response from a 4-in well in what should be a highly transmissive aquifer may suggest that the open-hole well was partially plugged with low-permeability material. The 4-inch pipe probably accumulated sand in-fill and pipe-scale over long periods of use which may have caused the observed effect. The low permeability material would slow the movement of water from out of the well into the aquifer in response to pumping. If the well was partially plugged, the results of the analysis are likely to be inaccurate. A comparison (not shown) of the results of the Theis analysis with the results generated using the Papadopoulos-Cooper (1967) method (a method that corrects for well-bore

storage effects) indicated no measurable difference. The apparent straight line on the radial flow analysis does not appear to be caused by well bore storage. Flow restriction or blockage in the well or well screen appears to be more likely.

Only an approximate match could be made using the Theis (or Papadopoulos-Cooper) methods. This may be because of partial plugging of the well or it may be because of careless water level monitoring. It was noted in the test data sheet that a "static" water level was not measured prior to the start of pumping. This may explain in part the poor curve match if initial water level indicated in the SPF report lead to incorrect drawdown calculations subsequently used in our analysis. It may also be that the observation well is completed in a portion of the aquifer slightly different from that of the pumped well. Finer-grained aquifer materials or partial completion in a zone coupled to the aquifer but partially separated by silt or clay layers may help explain the delayed and atypical response of the observation well. Our analysis indicates an approximate transmissivity of about 180,000 gpd/ft.

Figure 69 (page 173) shows recovery of the observation well after pumping stopped. The variation of the data from the straight line plot is similar to that observed in the pumping well. The drawdown curve indicates a transmissivity of 290,000 gpd/ft, a value that is similar to that indicated by the pumping well recovery data.

The drawdown data for the observation well (Figure 68) allow for only an approximation of the short-term storativity. The poorly fitting type curve indicates a storativity on the order of $1x10^{-2}$, a value that indicates an unconfined aquifer. With heavy pumping over the long term, we believe the water level in the aquifer could drop below the overlying confining bed and cause the upper portions of the aquifer to dewater possibly causing the storativity to become greater than 10^{-2}. These values are also considered approximations because: 1) the lack of well-construction information adds uncertainty, 2) the observation well may be partially plugged, 3) the observation well is completed higher in the aquifer than the pumping well and 4) clay layers lying stratigraphically between the elevations of the pumping and observation wells may have affected the short-term drawdown response in the observation well.

It should be noted that the stress on the aquifer at SVR #7 was not as large as would be desired. The well was only pumped at 500 gpm with most of the drawdown in the pumping well likely caused by well loss. (The well was completed with perforated casing and a louvered well "screen" with a smaller percentage of open area to the aquifer compared to a wire-wound screen. The smaller open area allows far less water to pass into the well and with considerably more well loss than that which would occur with a wire-wound screen.) Because well loss was so high and the test of limited duration (22 hours), drawdown stress within the aquifer was small. Consequently, only the pumping well and a nearby observation well were measured during the test. A larger pumping rate and a longer test would have allowed for better characterization of the aquifer through the use of more distal observation wells.

Well Interference and the Effects of Seasonal Pumping

SVR #7 is completed into the regional Pierce Gulch Sand Aquifer, as are the Kling Irrigation well and most other production wells in the vicinity of the Cities of Eagle and Star. Currently, no large-bore production wells are completed within this aquifer near SVR #7. Production wells are planned, however, in the general vicinity of the SVR #7 site so we simulated the distance-drawdown effects of a hypothetical well.

To compensate for any uncertainty in the results of our analyses, we have used a range of values for transmissivity, along with two different storativity values, in a simulation to predict interference effects in the aquifer at distances to almost 4 miles from a hypothetical production well at this location. In this simulation, the Theis method was used to generate a drawdown curve as a function of distance from a hypothetical well at the SVR #7 site pumping at 1,000 gpm which is a likely future pumping rate for a well in this area. The Theis method was selected as it is generally conservative (tending to over-estimate drawdown) as it does not consider leakage from overlying zones or the capture of recharge. The following transmissivities were used in three separate simulations: 500,000 gpd/ft (possible upper end), 300,000 gpd/ft (observed recovery test results) and 150,000 gpd/ft (results of pumping well drawdown analysis). We used the storativity calculated from the test data ($1x10^{-2}$) and a value calculated from other Pierce Gulch Sand Aquifer tests ($3x10^{-4}$) in separate simulations. An image well was used to simulate the hydraulic effects of the no-flow boundary represented by the edge of the aquifer as shown by the "green line" on Figure 65.

Our results are presented in Figure 70 (page 174) which shows that at the end of 90-days of continuous pumping, interference drawdowns in the range of 1 to 5 feet are predicted for wells completed in the aquifer at a distance of one mile away from the SVR #7 site and may be on the order of ½ to 1½ feet at a distance of four miles away. As discussed in the methods section above, this analysis is conservative and is likely to over-estimate interference because, we believe, the drawdown cone of depression from the pumping well would probably expand sufficiently to capture recharge equal to the pumping rate before 90 days, such that the pumping water level in the well would cease to draw down. The Theis analysis assumes no recharge (water pumped by a well only comes from aquifer storage) and that the pumping water level in a well will always continue to draw down. In reality (and observed many times, in our experience) the rate of drawdown in a well pumped for 90 days in an environment like that of the Pierce Gulch Sand Aquifer, typically declines or becomes unmeasurable before 90 days.

We consider the predicted interferences to be only an approximation because the Pierce Gulch Sand Aquifer system is not uniform. The actual drawdown that would occur with summer-long pumping will vary from our predictions, depending on the actual properties of the aquifer between the SVR #7 site and a given point of interest. We used a range of transmissivities and storativities to address the uncertainty of the properties of the aquifer at this, and other, locations within the Pierce Gulch Sand Aquifer. The prediction gives general guidelines for the amount of interference that could be caused by a large supply

well constructed near SVR #7, on other wells completed in the Pierce Gulch Sand Aquifer, near the M3 Eagle site.

Conclusions

Based on the overview and analysis presented above, we draw the following conclusions:

1. Based on elevation, water levels in wells, geophysics and geology, the sand aquifer beneath the upland area is a part of the same regional Pierce Gulch Sand Aquifer tapped by the production wells in the Boise River Valley in the Eagle-Star vicinity.

2. SVR #7 is completed in a highly-permeable portion of the aquifer. Our analysis of test data indicate a transmissivity of about 300,000 gpd/ft. the actual value may be higher as inefficient well construction and uncertainty in the data make an accurate analysis impossible.

3. Our analysis indicates a storativity of $1x10^{-2}$ representative of an unconfined aquifer. The lithologic log on the Driller's Report, though, suggests a semi-confined aquifer. Longer-term pumping (several weeks or more) at high discharge rates (several thousand gpm) might eventually dewater the upper portions of the aquifer near pumping centers causing the storativity to appear greater than $1x10^{-2}$, possibly to 0.20 or more.

4. A simulation of a hypothetical well pumping continuously at 1,000 gpm for 90 days indicated that interference drawdowns in wells completed one mile away would be on the order of 1 to 5 feet. At a distance of 4 miles, interference drawdowns on the order of ½ to1½ foot are predicted.

5. Long-term designated observation wells should be constructed near future production wells and monitored during testing and long-term production in order to provide data to better quantify the behavior of the aquifer system in response to prolonged pumping over time.

6. The hydraulic characteristics of the aquifer are not well known beneath this portion of the project area; the SVR #7 well test conducted in this area had several issues that compromise the test results and therefore an improved understanding of the aquifer. The test was of short duration, the well was poorly constructed with perforated casing and a louvered well screen (and therefore, highly inefficient) and the test was conducted before the well was properly developed.

7. Ideally, future aquifer tests should be conducted on wells that are properly completed in a significant portion of the aquifer and which are fully penetrating. In lieu of that, completing development of SVR #7 followed by a quality-controlled and well-orchestrated proper pumping test of two to seven days or more, at as high a rate as possible (900 gpm or more), monitoring all nearby

wells, could help to clarify aquifer properties in a portion of the Pierce Gulch Sand Aquifer that appears to be very transmissive.

Figure 65. Well Locations for SVR Well #7 Twenty-Two-Hour Test

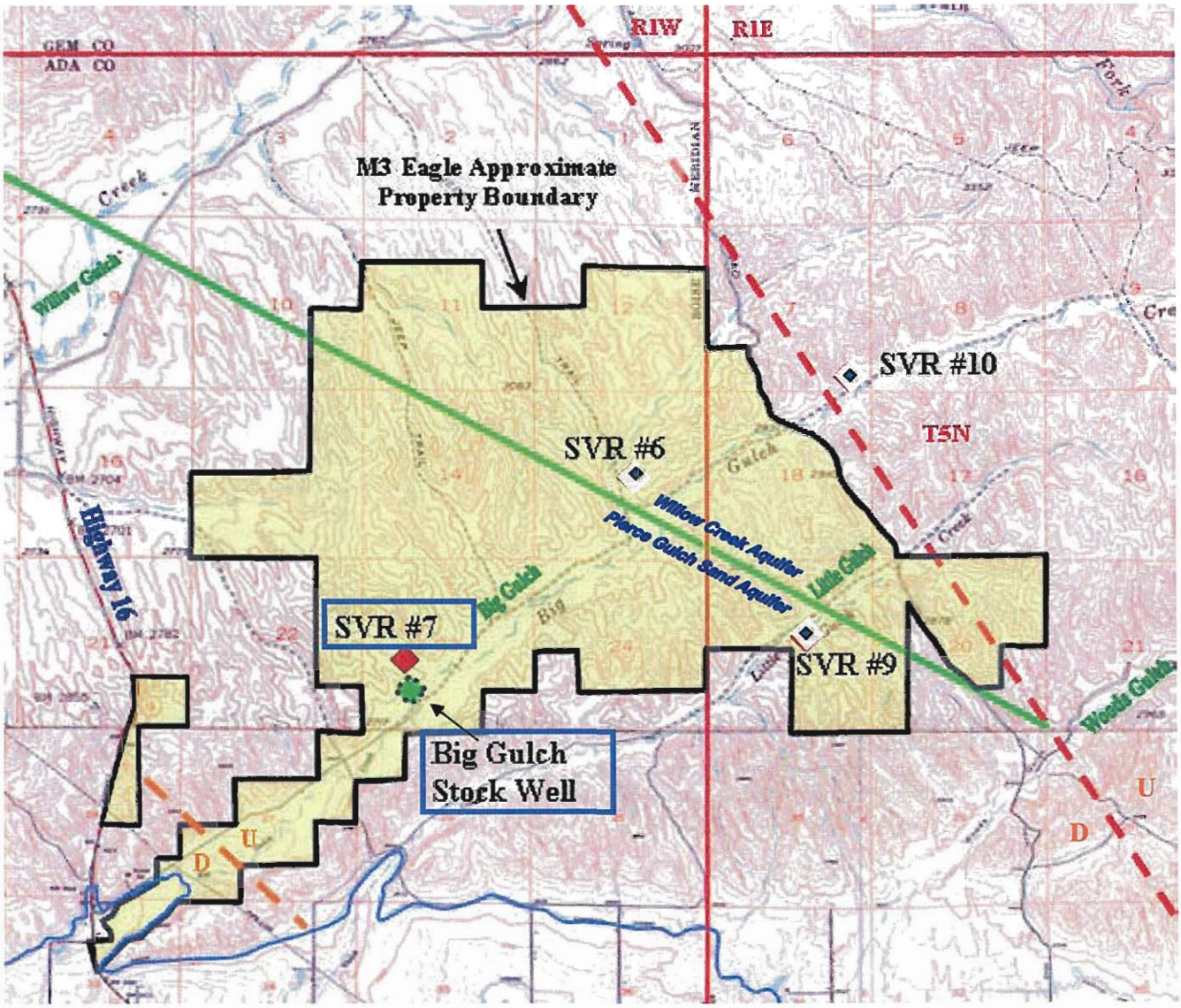
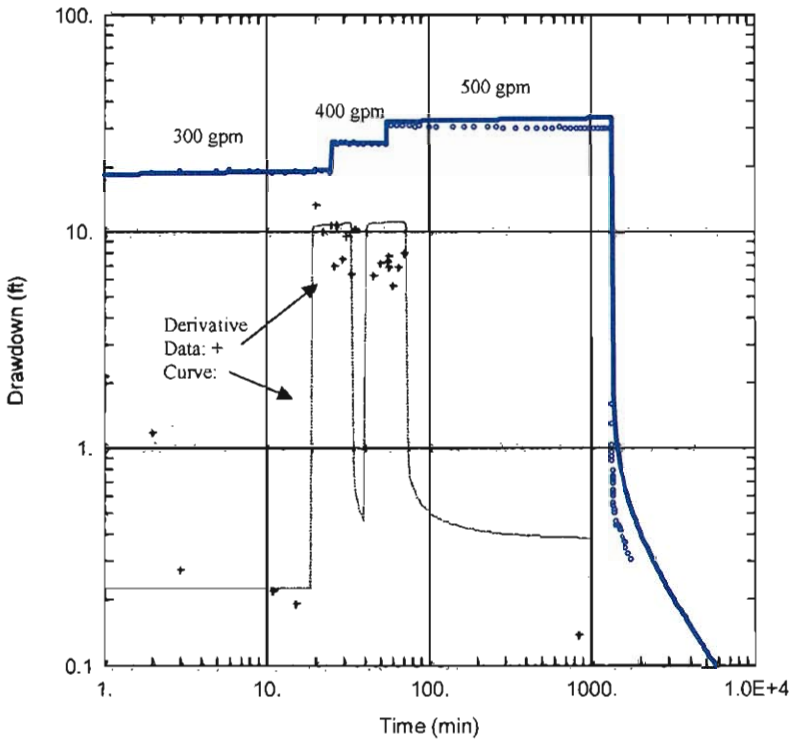


Figure 66. Theis Analysis for SVR Well #7 Twenty-Two-Hour Step-Rate Test
Test Conducted: April 21, 2004



SVR Well #7
Screen 280-350 ft
T≈ 150,000? gpd/ft
S Not Calculable
Kv/Kh= 0.1
b = 260 ft
r = 0.33 ft
Q = 300, 400 and 500 gpm

Curve match is only approximate. Curve too flat and actually declines during all three pumping stages (rates) such that good match not possible. Decline indicates development of well during pumping and therefore indicates an incorrect transmissivity value.
Partial penetration correction of Hantush (1961) applied.

Derivative type curve fit poor indicating transmissivity analysis is very approximate.

No well loss correction applied.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

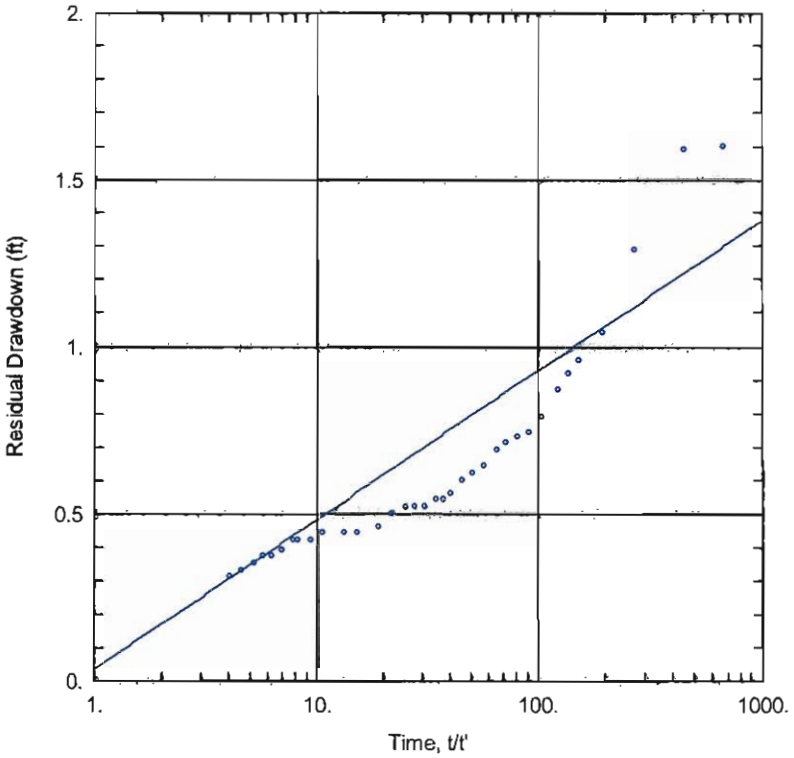
$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown. Variations from "smooth," semi-log curve the result of Aqtesolv® generating type curve based on variations in reported pumping rate. Poor match during early time suggests flawed data.

Based on the analytical method of Theis (1935) with partial penetration corrections of Hantush (1961a and b).

Figure 67. Recovery Analysis for SVR Well #7 Twenty-Two-Hour Test
Test Conducted: April 21, 2004



SVR Well #7
Screen 280-350 ft
T≈ 300,000 gpd/ft
S/S' = 0.85
Kv/Kh= 0.1
b = 260 ft
r = 0.33 ft
Q = 300, 400 and 500 gpm

Only late recovery time data (t/t' less than 10, equivalent to 2 hours and 20 minutes after pump shut off) plot as straight line. S/S' less than 1.0 suggests "late" recovery / no-flow boundary. Test too short for edge of aquifer to theoretically affect data, based on comparison of drawdown type curve generated with and without boundary.

T = 264Q/Δs Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

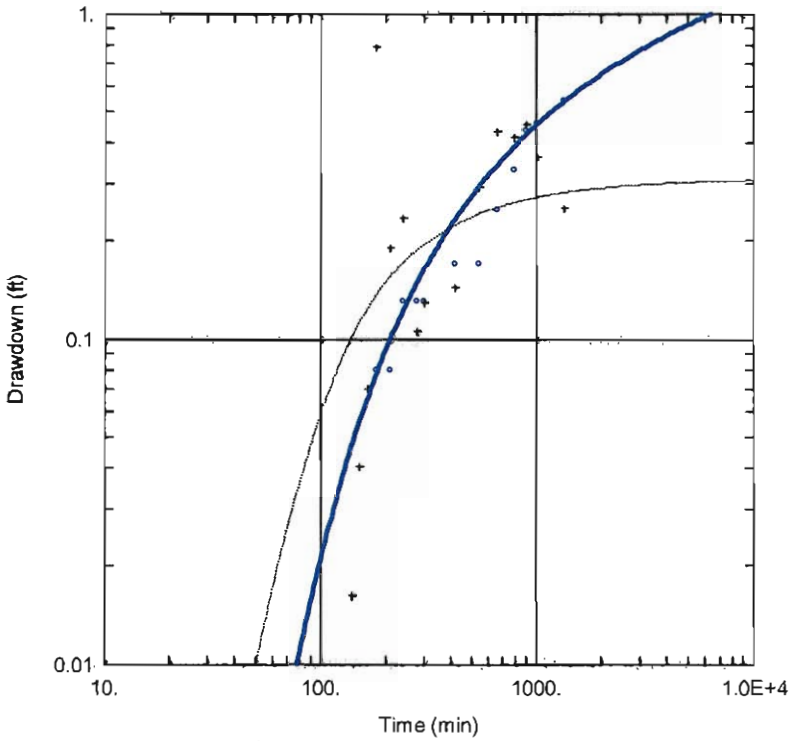
t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area
r = effective radius of pumping well (ft)

Based on the analytical method of Theis (1935)

Figure 68. Theis Analysis for Big Gulch Stock Well SVR#7 Twenty-Two-Hour Test
Test Conducted: April 21, 2004



Big Gulch Stock Well
Depth = 180 ft.
T≈ 180,000 gpd/ft
S ≈ $1x10^{-2}$
Kv/Kh= 0.1
b = 260 ft
r = 845 ft
Q = 300, 400 and 500 gpm
(at SVR #7)

Curve match is poor. Analytical results only approximate. Drawdown measurements are probably incorrect as original data collection assumed an unmeasured pretest water level. Radial flow analysis (not shown) suggested well-bore storage effects. However, Papadopoulos-Cooper method that incorporate well-bore storage yielded similar result to Theis. Well log is not available. Video of well indicates well completion in the top portion of the tested aquifer.

Derivative type curve fit poor indicating transmissivity analysis is only approximate.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

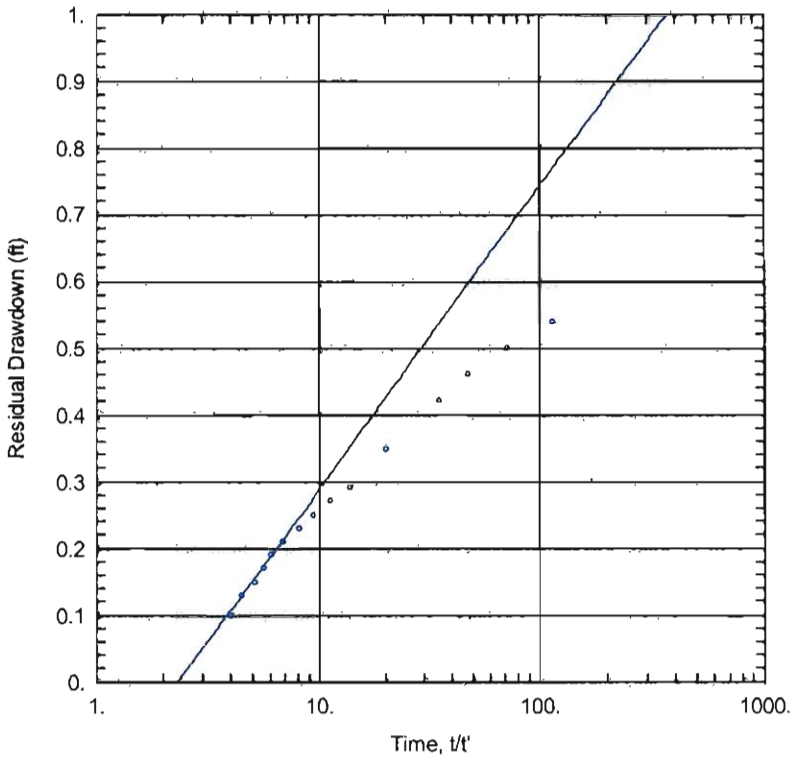
$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 69. Recovery Analysis for Big Gulch Stock Well SVR#7 Twenty-Two-Hour Test
Test Conducted: April 21, 2004



Big Gulch Stock Well
Depth = 180 ft.
T= 290,000 gpd/ft
S/S' = invalid
Kv/Kh= 0.1
b = 260 ft
r = 845 ft
Q = 300, 400 and 500 gpm
(at SVR #7)

Straight-line match may be valid (for T) but projection of line to residual drawdown = 0 (that indicates S/S') is invalid because pretest water level was not measured. Recovery plot is likely transposed downward by an unknown amount. Therefore, possible boundary and recharge effects are not indicated.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

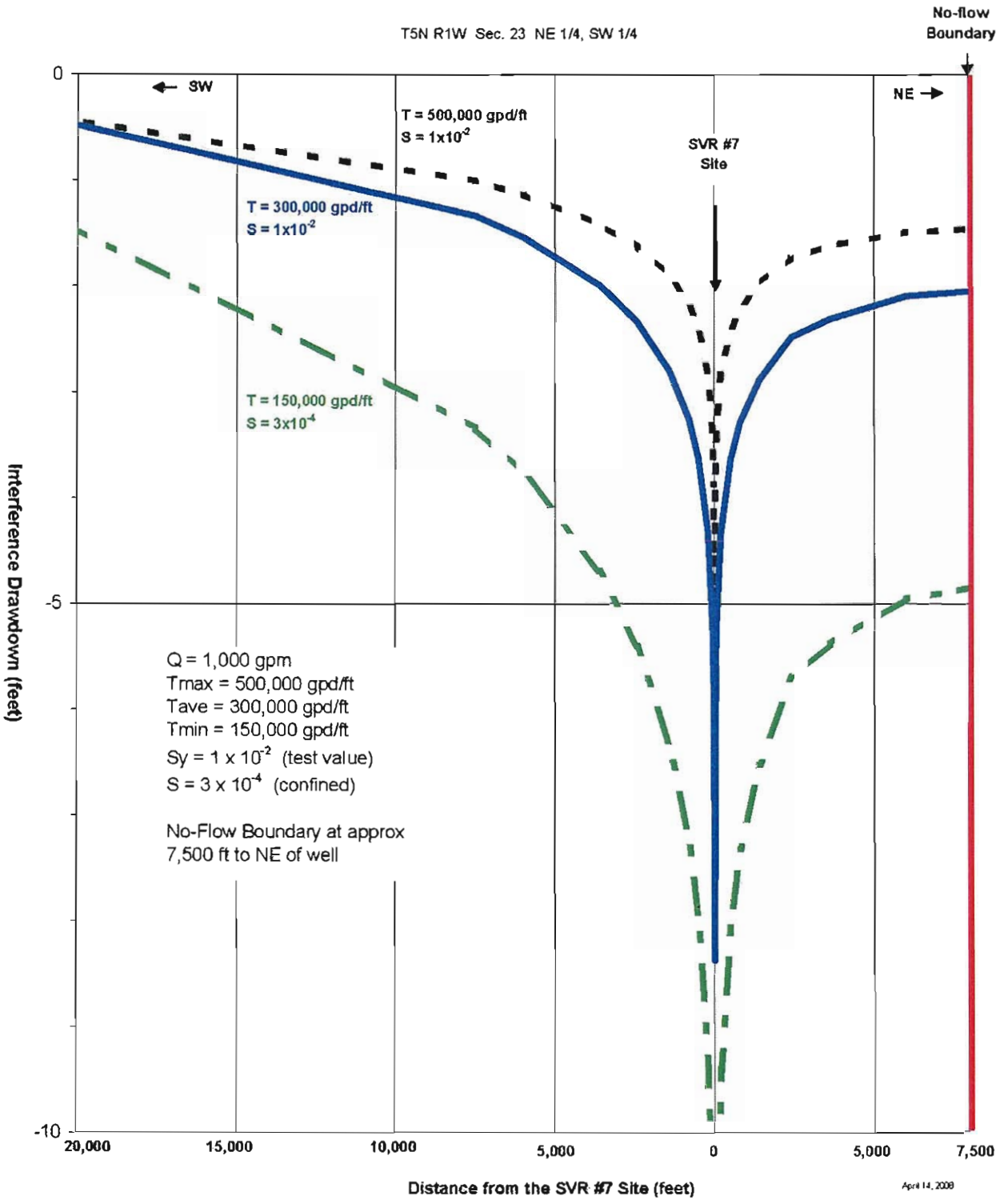
t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area
r = distance from pumping well (ft)

Based on the analytical method of Theis (1935).

Figure 70. HLI's Predicted Drawdown Interference at the End of Summer Pumping from a Production Well at the SVR#7 Location



Pierce Gulch Sand Aquifer Well SVR #9 Three-Hour Test

Overview and Previous Analysis

Well SVR #9 was drilled and tested in Little Gulch, by Stevens and Sons Well Drilling under the direction of Scanlan Engineering using the mud-rotary drilling method, during June of 2004. This well is located in Figure 71 (page 178) as a red diamond with a solid boundary. SVR #9 was drilled to a total depth of 806 ft bgl and completed with a 6-in stainless steel, well-screen open to the aquifer between 235 and 263 ft bgl. The lower portion of the borehole between 806 and 265 ft bgl was backfilled with bentonite chips. SVR #9 is completed within part of the Pierce Gulch Sand Aquifer which lies between elevations of 2,556and 2,483ft amsl beneath the site, as shown in Table 3 (page 247). According to Well Driller's Report (Appendix A), the upper portions of the Pierce Gulch Sand at this location are unsaturated ("dry") indicating that the aquifer is unconfined with the upper surface of the aquifer being defined by water table conditions. The pretest water level was 197.33 ft bgl, equivalent to an elevation of about 2,556 ft amsl. SVR #9 was pump tested June 23, 2004, for a period of 3.3 hours at a rate of 43 gpm. At the end of the test, the maximum drawdown was 13.8 ft, for an end-of-test specific capacity of 3.1 gpm/ft. A nearby well (Little Gulch Stock well) was not measured during the test.

Data from the SVR #9 pumping test are presented in SPF (2004b). Within the first 10 minutes of pumping, the water level in the well drew down to about 13.7 feet where it remained (with minor fluctuations) for the remainder of the test. Drawdown was relatively flat during the test and at some times even appeared to decrease. It is not known whether the apparent decrease was the result of pumping rate variations, errors in measurement, or well development. Because of the quick rise of the drawdown curve, we believe it is likely that a significant portion (10 feet or more) of the total drawdown was the result of well loss.

SPF did not calculate a meaningful transmissivity from the drawdown or recovery data. Their report presented blank log-log graph sheets for Theis analysis and blank semi-log graph sheets for Cooper-Jacob analysis with none of the data plotted. In the text they indicated an estimated range of 4,500 to 20,000 gpd/ft for transmissivity of the aquifer in the vicinity of SVR #9 but called their estimate "uncertain." As with all single-well pumping tests, storativity could not be calculated.

HLI Analysis

The pumping test data for the SVR #9 pumping tests were re-analyzed by HLI. A Cooper-Jacob straight-line analysis for SVR #9 is presented in Figure 72 (page 179). An approximate transmissivity of 120,000 gpd/ft was calculated. The Theis analysis presented in Figure 73 (page 180) also indicates a transmissivity of 120,000 gpd/ft.

A comparison of calculated transmissivities using the Theis method with and without partial penetration corrections of Hantush (196a and b) indicated only a five percent

difference, suggesting that partial penetration effects are small at this well. The low significance of partial penetration corrections is supported by a comparison of the well screen length and the thickness of the aquifer: The well is open to the middle 30 feet of the 73-foot thick sand aquifer pierced by the well, a condition where partial penetration effects would be relatively small according to Walton (1962). Thus, Cooper-Jacob analysis using data with Butler (1957) corrections were not made; only raw data were analyzed.

In both the Theis and Cooper-Jacob analyses, the data plots are relatively flat making the analytical results approximate. The relatively poor match of the derivative type curves and the derivative data in both analyses also indicate the results are only approximate. The lower transmissivity values for SVR #9 (in comparison to SVR #7) suggest the aquifer is thinner and/or less permeable at SVR #9 than it is near SVR #7. A thinner, less-permeable aquifer is also indicated by the geologist's logs (based on analysis of drill cuttings by Feast Geosciences and supported by an uncalibrated, analog down-hole, single point resistivity geophysical log) for these wells.

The lack of measurements from the nearby Little Gulch stock well during this test makes a meaningful calculation of storativity impossible. However, based on the geologic logs and the unconfined nature of the aquifer and the analysis of SVR #7, we estimate a storativity of about 0.20 or more.

Well Interference and the Effects of Seasonal Pumping

SVR #9 is completed near the edge of the regional Pierce Gulch Sand Aquifer. The aquifer is thinner at this location than it is at all other locations for well-tests reviewed in this report. This location is also close to the perceived edge of the aquifer, as indicated by the green line in Figure 69. The edge of the aquifer would act as a no-flow boundary during pumping, increasing the drawdown in a pumping well by as much as two times that which would occur without such a no-flow boundary. In addition, the water level is relatively low, resulting in a limited amount of available drawdown for pumping.

For the reasons above, placement of a production well near SVR #9 is not recommended. For this reason a simulation of distance-drawdown interference for a properly designed and completed production well was not specifically undertaken for this well site.

Conclusions

Based on the overview and analysis presented above, we draw the following conclusions:

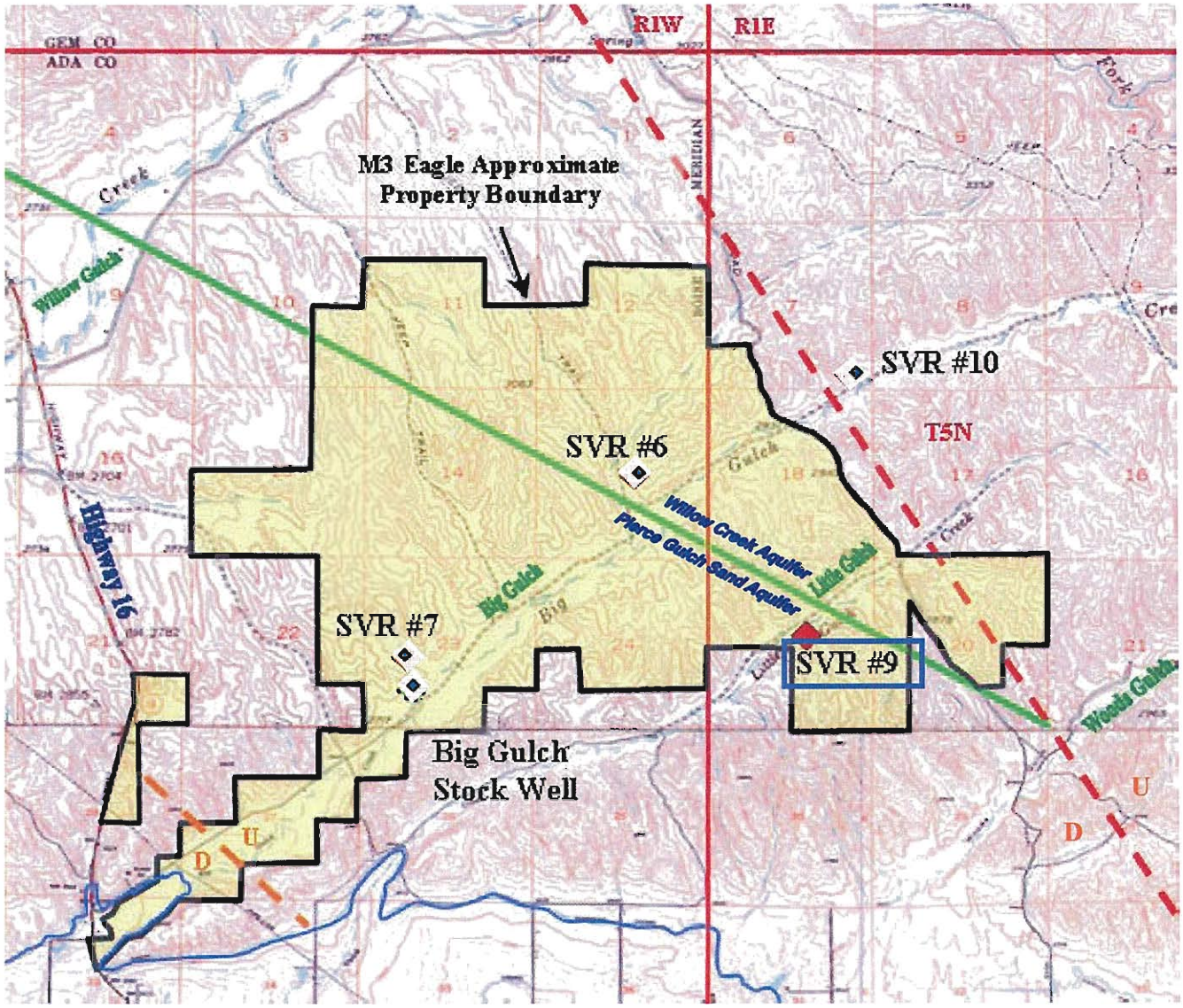
1. Based on elevation, water levels, geophysics and geology of the SVR#9 well, the sand aquifer beneath the SVR #9 site appears to be the bottom portion of the Pierce Gulch Sand Aquifer.

2. SVR #9 is completed near the edge of the highly-permeable Pierce Gulch Sand Aquifer with a transmissivity of about 120,000 gpd/ft.

3. The top of the aquifer appears to be defined by the water table in the vicinity of SVR #9. The Pierce Gulch Sand above the water table at this location is unsaturated ("dry"). The aquifer is therefore unconfined with an estimated storativity of 0.20 or higher.

4. The hydraulic characteristics of the aquifer are not well known beneath this portion of the project area; the well test conducted in SVR #9 had several issues that compromised the test results and therefore the understanding of the aquifer. The test was of short duration, the well was poorly developed prior to testing, and the pumping rate of only 43 gpm, is not considered high enough to adequately stress the aquifer. The low pumping rate resulted in a test-data plot that was relatively flat, making analyses only approximate.

Figure 71. Well Location for SVR Well #9 Three-Hour Test



Pumping Well Location

November 29, 2007

Approximate Northern Boundary
of the Pierce Gulch Sand Aquifer

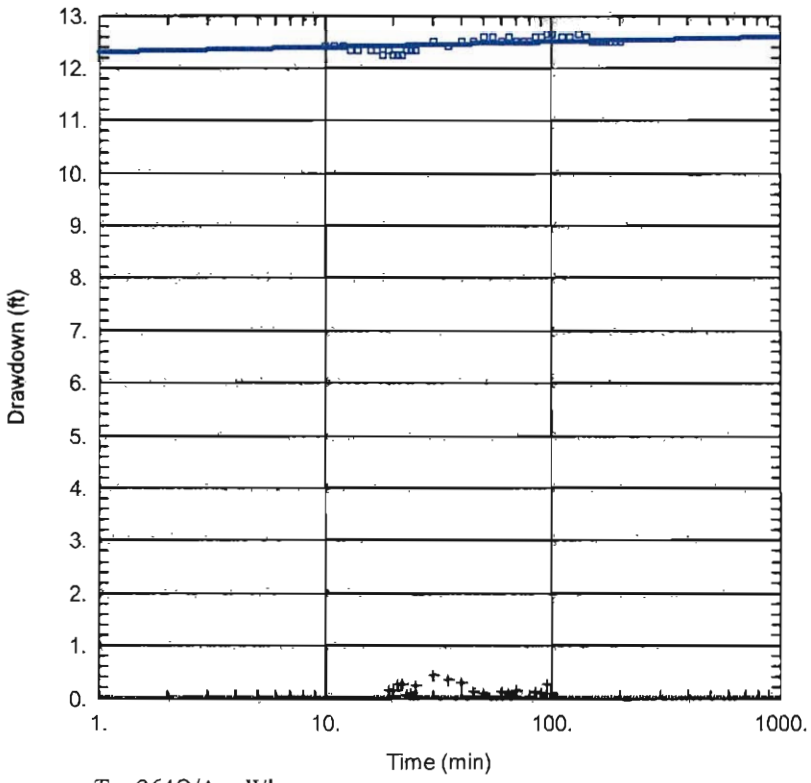
Fault located by
magnetometer survey
D on down-dropped side
U on up-thrown side

Approximate position of the
West-Boise-Eagle Fault
D on down-dropped side
U on up-thrown side

One Mile

N

Figure 72. Cooper-Jacob Analysis for SVR Well #9 Three -Hour Test
Test Conducted: June 23, 2004



SVR Well #9
Screen = 235-263 ft
T ≈ 120,000 gpd/ft
S Not Calculable
Kv/Kh= 0.1
b = 73 ft
t_c < 1 min
r = 0.5 ft
Q = 43 gpm

Line fit only approximate as data are variable. Probable well development during test likely caused drawdown plot that is misleading.

Derivative type curve fit only approximate indicating transmissivity analysis is only approximate.

No usable recovery data. The test was incomplete and poorly conducted.

Partial penetration corrections not critical. See text for details.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

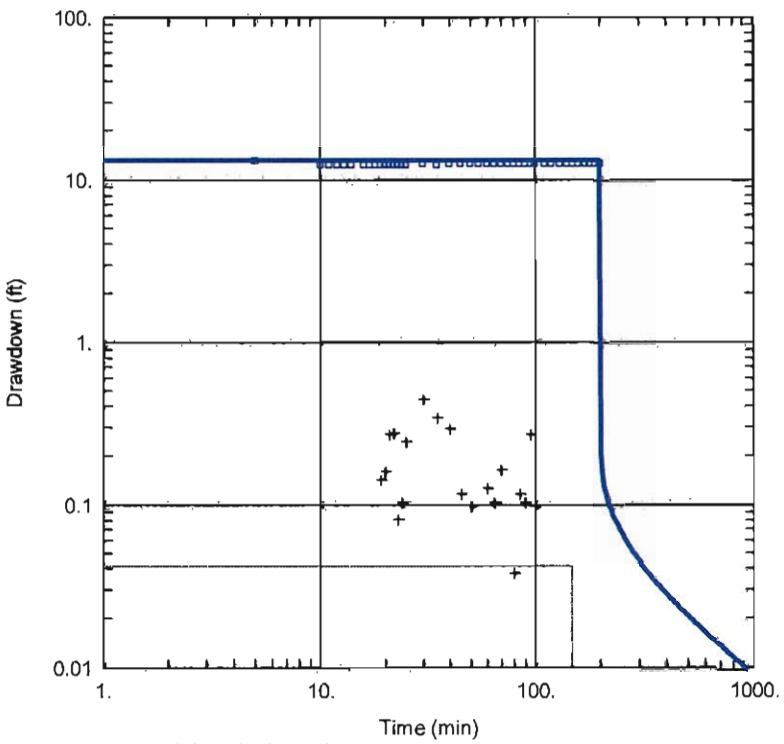
$u = 1.87r^2S/Tt$
t = time in days
r = effective radius of pumping well (ft)

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Unconfined drawdown correction:
$s' = s - s^2/2b$ where
s' = corrected drawdown (ft)
s = measured drawdown (ft)

Based on the analytical method of Cooper and Jacob (1946).

Figure 73. Theis Analysis for SVR Well #9 Three-Hour Test
Test Conducted: June 23, 2004



SVR Well #9
Screen = 235-263 ft
T ≈ 120,000 gpd/ft
S Not Calculable
Kv/Kh= 0.1
b = 73 ft
r = 0.5 ft
Q = 43 gpm

Curve fit only approximate as well developed during test causing drawdown curve that is too flat: Transmissivity only approximate. No usable recovery data.

Derivative type-curve fit is poor and does not support the analysis. Indicated results are only approximate.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer saturated thickness in feet (ft), estimated from log on Well Driller's Report

Unconfined drawdown correction:
$s' = s - s^2/2b$ where
s' = corrected drawdown (ft)
s = measured drawdown (ft)

Solid Line represents "type curve" where T and S best match observed drawdown
Based on the analytical method of Theis (1935) with unconfined drawdown correction from Cooper-Jacob (1946) and with partial penetration corrections of Hantush (1961a and b).

Sandy Hill Aquifer Well TPW #1 Seventy-One-Hour Test

Overview and Previous Analysis

Based on the results of a short-term, relatively-low-rate pumping-test on a small-diameter well, SPF (2004a) installed a test/production well (TPW #1) in a bounded upland aquifer located in the foothills upland northeast of Eagle. The aquifer, consisting of fine-to-coarse-grained sand, was informally called the Sandy Hill Aquifer by Scanlan (2003). It was apparently the hope of the land developer that the Sandy Hill Aquifer could be used as a regional water supply for the Avimor planned community, now under construction. Two wells, TPW #1 and SVR #8 were completed and tested in the Sandy Hill Aquifer to better characterize the ability of the aquifer to supply significant quantities of water on a sustainable basis from this upland area. A third well that identified the presence and initial characteristics of the Sandy Hill Aquifer, SVR #3, was also used in the testing program. These wells are located in Figure 74 (page 188) with the pumping well (TPW #1) as a red diamond with a solid boundary and the two observation wells (SVR #3 and SVR #8) as labeled green diamonds with dashed boundaries.

TPW #1 was completed by Riverside, Inc., using reverse-circulation, mud-rotary drilling methods during March, 2004. Its finished casing is 16-inches in diameter, completed to a depth of 292 feet with 0.040-inch-opening well screens from 238 to 290 feet below ground, and had a reported pretest water level of 177.84 ft bgl which equates to an elevation of about 3,422 ft amsl. TPW #1 was pump tested on April 14-17, 2004 for 71 hours at a rate of 2,050 gpm. At the end of the test, a total drawdown of 16.81 ft was reported for an end-of-test specific capacity of 122 gpm/ft.

Exploration/observation well SVR #8 was drilled and completed on April 12, 2004 approximately 1,000 feet east of TPW #1by Adamson Pump and Drilling using the air-rotary method. According to the Well Driller's Report, it is 6-inches in diameter, drilled to a depth of 141 feet, and completed with 0.040-inch slot well screens from 136 to 141 ft bgl, and had a reported pretest water level of 62 ft bgl. SPF reports that SVR #8 had about 0.7 ft of drawdown at the end of the test.

A third well, SVR #3, an observation well used during testing, is located approximately 150 feet west of TPW #1. According to the Well Driller's Report included in SPF (2003), SVR #3 was drilled by Stevens and Sons Well Drilling using direct mud rotary methods during November and December, 2002. It is 6-inches in diameter, was drilled to a depth of 970 feet, completed to a depth of 240 feet with 0.030 to 0.040-inch slot well screen from 165 to 240 ft bgl, and had a reported pretest water level of about 175 ft bgl which equates to an elevation of about 3,425 ft amsl. There is no indication on the Well Driller's Report whether the borehole below the well screen was backfilled or sealed. SPF reports that SVR #3 had about 0.9 ft of drawdown at the end of the test.

All three wells are completed in the Sandy Hill Aquifer. This aquifer apparently consists of fine-to-coarse-grained sand filling a small closed basin surrounded by volcanic rocks and granitic bedrock. The aquifer is unconfined with the upper surface of the aquifer defined by the water table; sediments above the water table are unsaturated ("dry"). The

lateral extents of the aquifer have not been delineated but as observed in the responses of the wells during testing (discussed below), the aquifer appears to be highly bounded hydraulically by bedrock and may be considered to be a "bathtub aquifer[18]." According to SPF, recharge from the underflow of ground water to the Sandy Hill Aquifer appears to be insignificant.

Pretest development of each well was apparently minimal. SPF (2004a) provides no details on development of TPW #1 and states that SVR #8 underwent one half hour of air-lift pumping prior to its use as an observation well. SPF (2003) indicates that SVR #3 was bailed and then pumped at 50 gpm for an unspecified time period.

A 71-hour pumping test was conducted over the period April 14 -17, 2004. Initially planned as a constant rate test, TPW #1 was pumped at 600 gpm for the first 8 minutes. After 8 minutes (and continued until the end of the 71 hour test), the rate was increased to a reported 2,050 gpm effectively resulting in a step-rate test. Water levels were measured in the pumping well and the two observation wells using electric probes and Stevens water-level float-and-cable chart-recorders. The drawdown in the pumping well at the end of the test was approximately 17 feet. The maximum drawdown in SRV #3 was about 0.9 feet with 0.6 feet observed in SVR #8. None of the wells completely recovered 40 hours after pumping ceased.

As shown in Table 3 (page 247), both TPW #1 and SVR #3 appear to be completed in the Sandy Hill Aquifer (as indicated by SPF) which lies between elevations of 3308 and 3425 feet amsl. SVR #8 was also apparently completed in the Sandy Hill Aquifer but since the data derived from this well yielded no meaningful analysis, it is not include in Table 3 nor discussed further in this report. A portion of the discharge flow from a local spring called the "Hillside Spring" by SPF, was occasionally measured during the test. The measured flow from this spring has been interpreted by SPF as being the sustainable yield of the aquifer although their reasoning behind this interpretation is not clear.

Barometric data were also collected, apparently with the intent of adjusting observation well data for changes in air pressure that, in turn, cause changes in well water levels that are unrelated to actual changes in water levels (potentiometric pressure levels) in the aquifer[19]. The relationship between changes in atmospheric pressure and the water level changes these induce in a well is termed "barometric efficiency," or "BE" for short. SPF estimated a BE of 58% for SVR #8, a value that is relatively high for a well completed in what appears to be an unconfined aquifer, based on SPF's review of the geologist's log included in SPF (2004a). Normally, barometric and water level data are collected for calculation of BE during a time period when water levels in the aquifer are not affected by well pumping. SPF does not make clear which data were used to generate their BE calculation. Their only indication of water level and barometric data being collected

[18] A "bathtub" aquifer is an aquifer surrounded by low-flow to almost impermeable bedrock with recharge only occurring through the infiltration of local precipitation.

[19] For a more detailed discussion of barometric effects and their corrections, please see the barometric efficiency discussion in Section Five on page 184 of this report.

when the well was *not* being pumped (or not recovering from being pumped) is found on a graph in their report that plots water level and barometric pressure collected over an 18-minute period, a period far too short, in our opinion, to generate sufficient data to calculate BE. No analysis was presented for BE corrections for SVR #3. SPF applied the 58%-barometric efficiency correction derived for SVR #8 to the data from SVR #3, based on the assumption that the BE's in these two wells would be approximately the same.

Straight-line plot analyses of the drawdown and recovery data from TPW #1 by SPF indicated a transmissivity of 361,000 gpd/ft. No storativity value was given or discussed. No analyses were presented for the observation wells (SVR #3 and SVR #8), although drawdown graphs of raw and corrected data were included in the report.

No analyses of boundaries were presented, although the changes in slope associated with boundaries are observable in the drawdown plots included in the SPF report. Instead, SPF used an average straight-line projection through the various data points (with and without boundary effects) to calculate transmissivity. SPF acknowledges the boundaries of the aquifer in their discussion of the limitations of the Sandy Hill Aquifer as a production aquifer; they state that high capacity wells (pumping at 2,000 gpm) would only be feasible with an artificial source of recharge, as they estimate a long-term average recharge rate to the Sandy Hill Aquifer on the order of 60 gpm (95 ac/ft annually). HLI believes that this estimate, although small for regional water supply, may even be optimistic, as discussed below in the HLI Analysis section, below.

HLI Analysis

Two Cooper-Jacob (1946) straight-line analyses for TPW #1 are presented in Figure 75 (page 189). The upper curve shows raw data while the lower curve shows data corrected for the effects of partial penetration using the approximates of Butler (1957). The semi-log plots shows drawdown in four distinct stages. The first occurs over the first 8 minutes of the test when the initial pumping rate was a reported 600 gpm. Fluctuating water levels suggest that the pumping rate varied and/or there were problems in measuring water levels. No meaningful analysis can be made with the observations reported for this first stage.

Between 10 and approximately 40 minutes (when the pumping rate was increased to a reported 2,000 gpm), the data plot in a relatively straight line, indicating the aquifer transmissivity in the vicinity of the pumping well. The Cooper-Jacob analysis for the raw data indicates a transmissivity of about 200,000 gpd/ft while the analysis using the Butler-corrected data indicates a transmissivity of 300,000 gpd/ft. From about 40 to 600 minutes the data plot on a straight line of flatter slope, indicating either that the drawdown cone of depression in the aquifer encountered a more permeable zone that in effect acted as a positive (recharge) boundary, or (less likely in our opinion, see below) that the aquifer dewatered through the process of "delayed yield." After this time (600 minutes) the rate of drawdown increased resulting in a steeper slope which indicates either that one or more no-flow boundaries were encountered by the drawdown cone of depression or (less likely, in our opinion) that the delayed yield portion of the test had

ended. The no-flow boundaries are highly likely to be the lateral edge of the aquifer where the sand contacts the bedrock that surrounds the aquifer.

The derivative analysis for the Cooper-Jacob plot shows that the derivatives did not match the type curve well. Several straights-line periods can be observed but the derivatives vary from the type curve because the slope of the data plot is not constant. In short, the derivative analysis support the use of the Cooper-Jacob method for the data collected from about 15 to 40 minutes.

We explored the possibility of delayed yield by analyzing the raw data following the method of Moench (1997). Figure 76 (page 190) shows our best match of the Moench type-curve to the raw data, which indicated a transmissivity of 300,000 gpd/ft. This value is similar to the transmissivity value calculated above using the Cooper-Jacob method, even though the data do not match well with the type curve for the period from 8 to 60 minutes, the period that appeared best for the Cooper-Jacob analysis. Figure 76 indicates that the plotted derivatives generally match the derivative type-curve, generally supporting the method. However, the observation well located 150 feet away (SVR #3) could not be matched to a Moench type-curve (see below), suggesting that the delayed yield did not occur. A delayed-yield response, if real, should have been observable in two wells so close to each other. The changes in slope of the straight-lines on the semi-log plot may better be explained by boundary effects.

A comparison of transmissivity indicated by the Moench method (which includes corrections for partial penetration) and the Cooper-Jacob method with partial penetration corrections of Butler (1957) shows similar results.

The recovery data were analyzed using the Theis (1935) straight-line recovery method (Figure 77, page 191) which indicates a transmissivity of 300,000 gpd/ft. The plot also shows an S/S' ratio of 0.5 which indicates that the well would recover "late," if at all. The last data point (t/t' = 1.67) indicates a residual drawdown of 0.92 feet after 40 hours of recovery. Projection of the straight line shows a residual drawdown of about 0.6 feet where it crosses the t/t' of 1 (equal to an infinitely long recovery period). The residual drawdown of 0.6 feet represents the water that was pumped from the aquifer that was not recharged during the recovery period. This residual and the small S/S' ratio support the conceptual model that one or more no-flow boundaries were encountered by the cone of depression during the test. Partial penetration corrections were not applied in this analysis.

Drawdowns in SVR #3 were analyzed using the Moench method, as shown in Figure 78 (page 192). The curve fit is poor as is the derivative analysis, suggesting that the method is unlikely to model the response of the aquifer during pumping. Neither a Theis curve nor a straight-line Cooper-Jacob plot could be constructed to match the data. The drawdown of 0.05 feet measured at 1 minute into the test apparently rose to around 0.3 feet sometime between the first measurement at (at 1 minute) and the second measurement (at 52 minutes). Since it appeared to remain at this level for the next 3 hours neither a straight-line on a semi-log plot nor a Theis curve on a log-log plot could be fit through both the first two points (1 minute and 52 minutes) and the data collected

from 56 through 423 minutes. It is possible that the water level data are in error but we can make no corrections or adjustments that can be justified based on our understanding of the test. The data from this well appear to be flawed and likely to lead to invalid analyses.

Residual drawdown data from SVR #3 were analyzed using the Theis recovery method (Figure 79, page 193). This analysis indicated an aquifer transmissivity of around 1,000,000 gpd/ft. which is much higher than that calculated using pumping-well data. The higher value may indicate that portions of the Sandy Hill Aquifer do indeed have higher transmissivity (as was indicated by the flattened drawdown curve in Figure 75). There is likely to be some inherent error in the analysis, however, as the data plotted in Figure 79 were not corrected for barometric effects. (Since no meaningful barometric efficiency data were collected for this well, we had no basis to make such a correction). In addition, since the drawdown during pumping data could not be analyzed in a meaningful way using the Cooper-Jacob, Theis or Moench methods, the recovery analysis is also suspect.

Figure 79 also shows the lack of water level recovery similar to that observed in the pumping well. SVR #3 had recovery water levels that were about 0.72 ft below the pretest levels at a t/t' of about 2.0 (equivalent to a recovery period of about a day and a half after pumping stopped). The apparent "residual drawdown" after this time then started to *increase* (water levels fell) after this time (possibly the result of changes in barometric pressure). Because of the lack of a barometric efficiency correction coefficient, no exact quantification of the removal of water from storage within the aquifer could be made. It does appear, however, that water was removed and that boundaries to the aquifer caused a "late" recovery.

We attempted to analyze data from a second observation well monitored during the test, SVR #8, using Theis, Cooper-Jacob and Theis recovery methods. No meaningful analyses could be made; the data plots do not make anything approximating a straight line on a semi-log plot nor could a meaningful fit be made for a Theis-type curve on a log-log plot. Consequently, no meaningful analyses for transmissivity were possible and plots are not included in this report.

Even though observation well data were collected from SVR #3 and SVR #8, no meaningful analysis for storativity was possible. No meaningful type curves could be generated to match the drawdown plots for either observation well. Therefore no calculated storativity was possible. Based on the fact that the Sandy Hill Aquifer appears to be unconfined (based on apparent delayed yield observed in the drawdown data from the pumping well and on our review of the Well Driller's Report), we estimate storativity could range from 0.02 to 0.3, values typical of an unconfined aquifer.

Well Interference, the Effects of Seasonal Pumping and Sustainable Yield

The Sandy Hill Aquifer, as characterized by SPF, is highly bounded with the exact positions of the boundaries unmapped and unknown at this time. Since production wells

developed in the Sandy Hill Aquifer would, then, only have measurable interference effects on wells also completed within the aquifer (where none other than TPW #1, now exist), no well interference or seasonal pumping effects were calculated.

SPF (2004a) suggested that the discharge from the Hillside Spring was an indicator of long-term sustainable yield. They indicated an average discharge of 60 gpm (95 ac-ft/yr) as the *minimum* that a well (or wells) completed in the Sandy Hill Aquifer could sustain over the long term without artificial recharge and that actual long-term yield would be "in excess" of this amount. Our calculations suggest that the sustainable yield could actually be less than 95 ac-ft/yr, as described below.

The sustainable yield will always be less than the total recharge to a groundwater system because not all recharge can be practically captured. From a practical and economical point of view, too many wells would be needed to capture every drop. Therefore, the total recharge to the Sandy Hill Aquifer defines the absolute maximum that could be sustained over the long term[20]. Sustainable yield will be less than this value.

Recharge to the Sandy Hill Aquifer is very limited. If recharge to the Sandy Hill Aquifer is solely through the infiltration of direct precipitation, then the capture area would be equal to the area (in map view) of the aquifer. SPF (2004a) estimated the area of the Sandy Hill Aquifer to be 175 acres. Their report also indicates that rainfall in this area is on the order of 21 in/yr and that recharge in the Boise Foot Hills ranges from 2 to 8 percent of precipitation. Using their values results in a total recharge to the Sandy Hill Aquifer of 4 to 15 gpm averaged annually. Even to equal the 60 gpm estimated by SPF as a *minimum* sustainable yield, the area recharging the Sandy Hill Aquifer would have to be 4 to 15 times greater than that estimated by SPF *and* 100 percent of recharge would have to be captured by a well or wells in the aquifer. Only if intermittent streams supplied 4 to 15 times the water locally recharged *and* all of the recharged water were extracted through production pumping would the SPF minimum be possible over the long term. These rough calculations suggest that the long-term sustainable yield without artificial recharge could be less than 60 gpm. They also suggest that the direct recharge area supporting the spring discharge may be larger than speculated by SPF and/or that other sources of ground water (such as bedrock underflow) recharge the aquifer and/or infiltrated stream flow from more distal areas recharges the Sandy Hill Aquifer.

Conclusions

Based on the overview and analysis presented above, we draw the following conclusions:

[20] In many situations, pumping can cause the capture zone for a well or well field to expand to capture more recharge than that which naturally occurs under non-pumping conditions. Therefore, calculated natural recharge does not typically indicate the maximum yield that is possible from a ground-water system, as indicated in Bredehoeft and others (1982). The Sandy Hill Aquifer is highly bounded, however, and little additional capture appears likely under pumping conditions. Therefore, pumping is unlikely increase the potential sustainable yield over non-pumping conditions in this aquifer.

1. TPW #1, SVR #3 and SVR #8 appear to be completed in the highly-transmissive and highly bounded Sandy Hill Aquifer. The aquifer appears to be bounded in lateral extent by low-permeability bedrock on all sides.

2. Calculated transmissivity for the Sandy Hill Aquifer near TPW #1 is on the order of 300,000 gpd/ft. Local, higher transmissivity zones may exist within the aquifer.

3. HLI's review of the Well Driller's Reports and SPF (2004a) indicate that the Sandy Hill Aquifer is unconfined with its top defined by a water table.

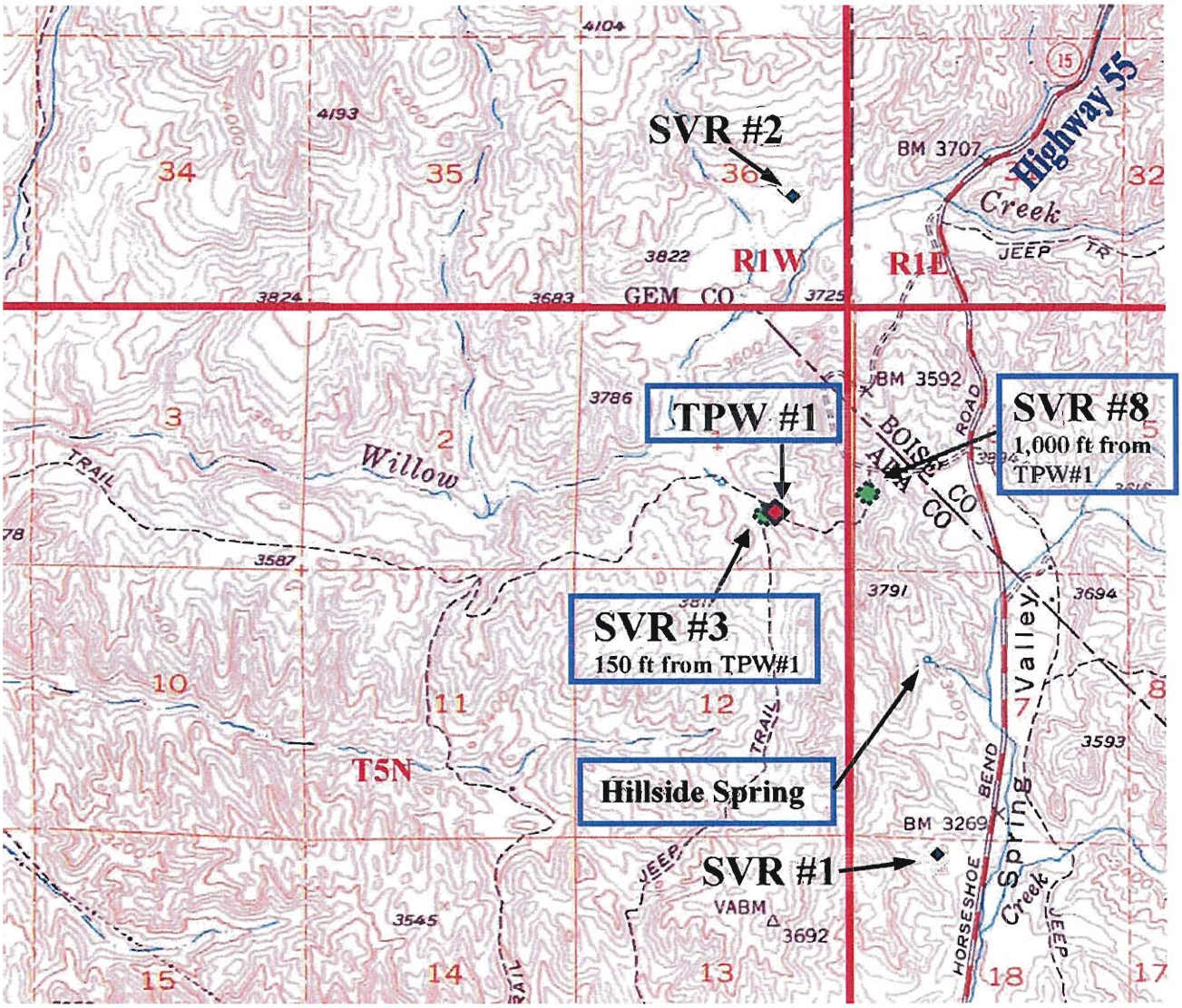
4. No meaningful storativity calculations were possible from the existing data. Based on the apparent unconfined nature of the aquifer, we estimate that values of approximately 0.02 to 0.2 or more are likely.

5. Natural recharge to the Sandy Hill Aquifer appears to be limited to the infiltration of local precipitation. The total amount of recharge to the aquifer cannot be quantified at this time as the lateral extent of the aquifer (and therefore the potential recharge area to the aquifer) is not known.

6. The long-term sustainable-yield from the Sandy Hill Aquifer is not known and cannot be calculated until the amount of natural recharge has been quantified. SPF estimated a yield "in excess of" 60 gpm (95 ac-ft/yr) based on what they believe to be the average discharge rate for the "Hillside Spring" which they indicate as a discharge point for the aquifer. Our calculations suggest that the sustainability of the aquifer may be less than this rate but we cannot accurately quantify the long-term sustainable-yield based on the existing information.

7. Longer-term and more highly controlled aquifer testing is needed to characterize the Sandy Hill Aquifer and environs.

Figure 74. Well Locations for TPW Well #1 Seventy-One-Hour Test



November 29, 2007

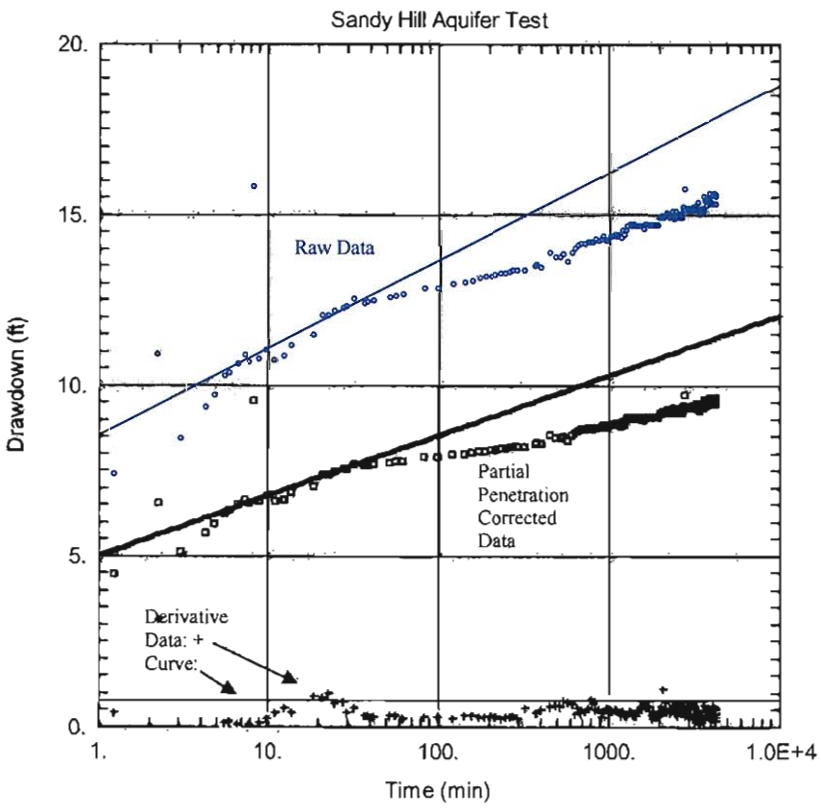
Pumping Well Location

Observation Well Location

One Mile

N

Figure 75. Cooper-Jacob Analysis for TPW #1 Seventy-One-Hour Step-Rate Test
Test Conducted: April 14-17, 2004



TPW #1
Screen = 238-290 ft
T=200,000 gpd/ft
(no PP corrections)
T=300,000 gpd/ft
(with PP corrections)
S Not Calculable
Kv/Kh= 0.1
b =114 ft
t_c < 1 min
r = 1 ft
Q = 2,050 gpm

Approximate match for t= 8 to 40 minutes only. Pumping for first 8 minutes at 600 gpm. After 40 minutes, two or more boundaries or delayed yield indicated. First boundary is "recharge" (higher T zone) second is "no-flow" (edge of aquifer?). More boundaries would likely be indicated with longer pumping.
Poor delayed yield match for obs well SVR#3 support boundaries.

Partial penetration correction makes calculated T about 50 percent without PP correction.

Poor derivative type curve fit does not support method. Therefore T values only approximate.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

$u = 1.87r^2S/Tt$
t = time in days
r = effective radius of pumping well (ft)

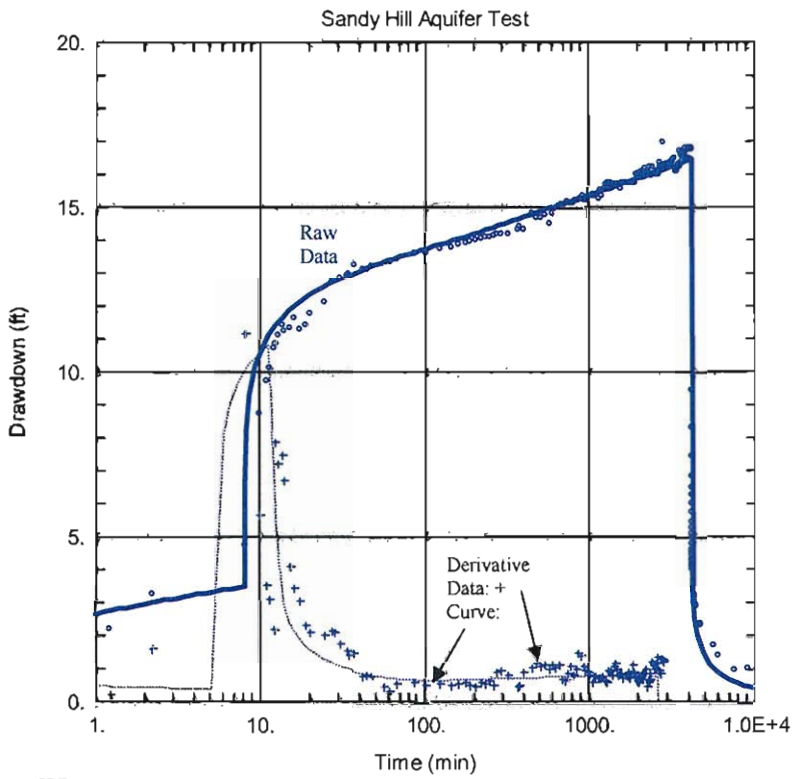
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Unconfined drawdown correction:
$s' = s - s^2/2b$ where
s' = corrected drawdown (ft)
s = measured drawdown (ft)

$s_{pp} = 0.2\ s_{observed}$ where:
s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Based on the analytical method of Cooper and Jacob (1946), Partial penetration corrections from Butler (1957).

Figure 76. Semi-log Moench Analysis for TPW #1 Seventy-One-Hour Test
Test Conducted: April 14-17, 2004



TPW #1
Screen = 238-290 ft
T=300,000 gpd/ft
S= Not calculable
S_y = Not calculable
Kv/Kh=0.1
s_w = -0.375
α= 0.04 min^{-1}
Q = 732 gpm (average)
b =114 ft
r = 1 ft
Q = 2,050 gpm

Fair match for derivatives suggest method may be valid. However, observation well 150 ft away (SVR#3) did not generate data that could be matched suggesting boundaries may be more likely explanation for flattening then steepening of drawdown curve.

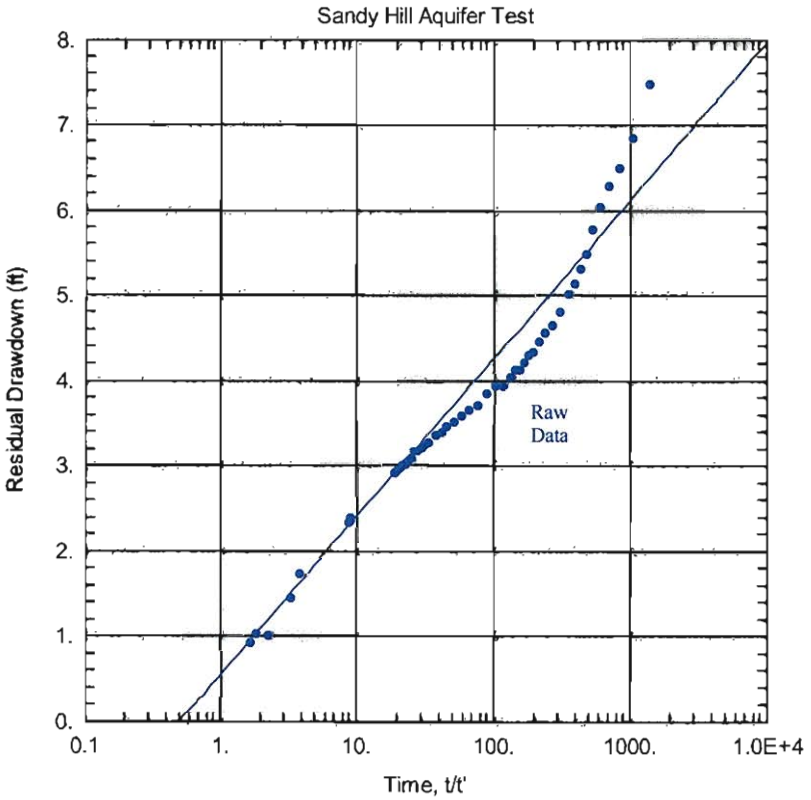
Where:

T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
S = Storativity (unitless)
S_y = Specific Yield (unitless)
s_w = Wellbore skin factor (unitless)
t = time in days
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
α = "empirical fitting parameter for non-instantaneous drainage" (min^{-1}) from curve adjustments

Solid Line represents "type curve" where T, S, Sy, Kv/Kh, s_w and α best match observed drawdown

Based on the analytical method of Moench (1997).

Figure 77. Recovery Analysis for TPW #1 Seventy-One-Hour Test
Test Conducted: April 14-17, 2004



TPW #1
Screen = 238-290 ft
T=300,000 gpd/ft
S/S' = 0.5
Kv/Kh= 0.1
b =114 ft
r = 1 ft
Q = 2,050 gpm

S S/S' = 0.5 indicates strongly bounded system (delayed/ incomplete recovery).

Longer duration test needed.

T = 264Q/Δs Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

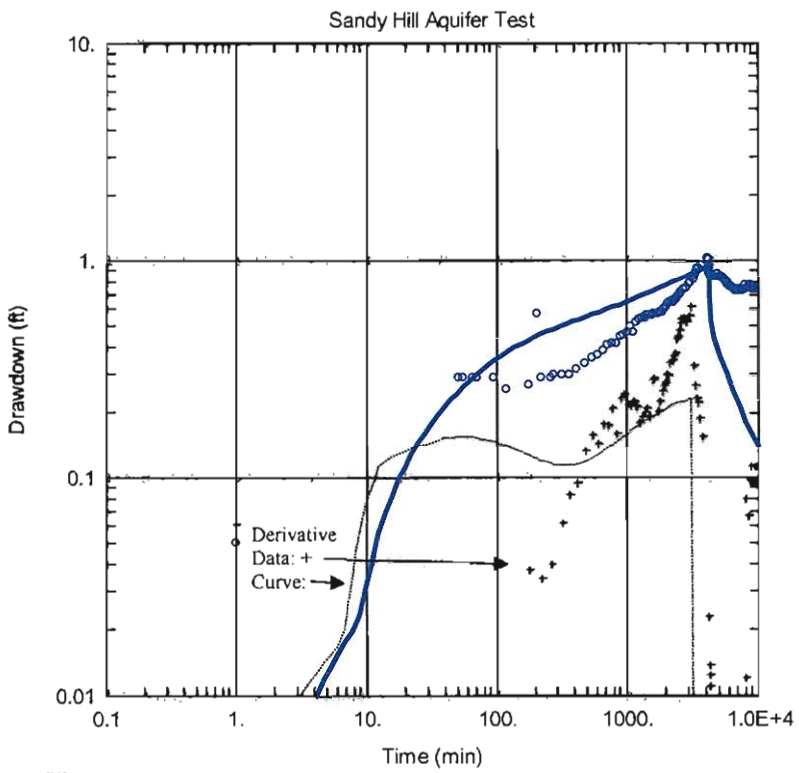
t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from well logs in the area
r = effective radius of pumping well (ft)

Based on the analytical method of Theis (1935).

Figure 78. Semi-log Moench Analysis for SVR#3 Seventy-One-Hour Test
Test Conducted: April 14-17, 2004



SVR #3
Screen = 175-240 ft
T = Invalid
S = Invalid
S_y = Invalid
s_w = Invalid
α = Invalid
ß = Invalid
Kv/Kh = 0.1
b = 114 ft
r = 150 ft
Q = 2,050 gpm
(at TPW#1)

No match for derivatives indicates method is invalid. No match possible for early-time data (<100 min, especially at t=1 min).

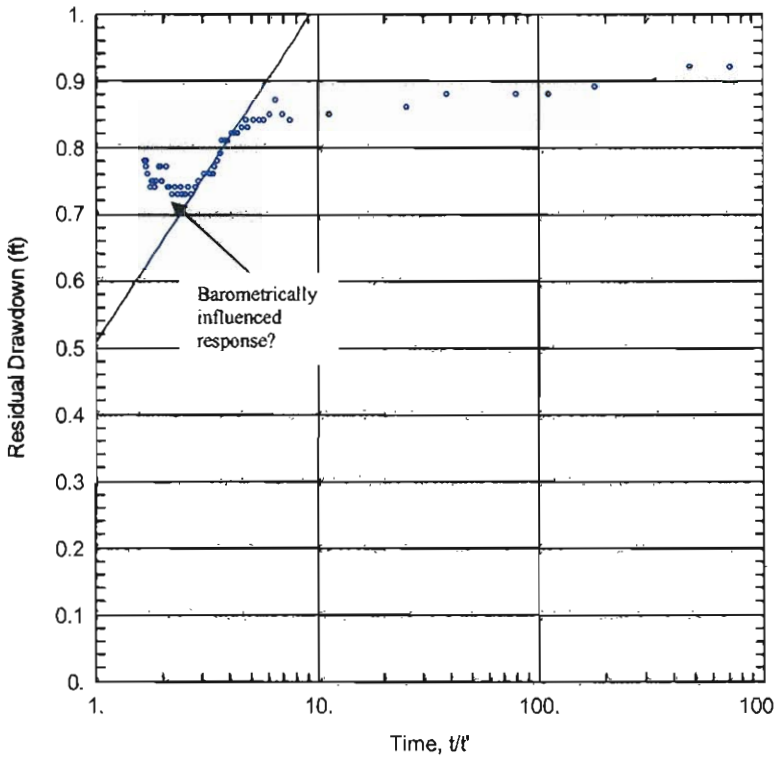
Where:

T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
S = Storativity (unitless)
S_y = Specific Yield (unitless)
s_w = Wellbore skin factor (unitless)
t = time in days
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
α = "empirical fitting parameter for non-instantaneous drainage" (min^{-1}) from curve adjustments

Solid Line represents "type curve" where T, S, Sy, Kv/Kh, s_w and α best match observed drawdown

Based on the analytical method of Moench (1997).

Figure 79. Recovery Analysis for SVR #3 Seventy-One-Hour Test
Test Conducted: April 14-17, 2004



SVR #3
Screen = 175-240 ft
T ≈ 1,000,000? gpd/ft
S/S' = 0.1
Kv/Kh= 0.1
b =114 ft
r = 150 ft
Q = 2,050 gpm
(at TPW#1)

S/S' = 0.1 indicates highly bounded system (delayed/ incomplete recovery).

T value unrealistically high: data are variable. End of recovery (t/t' < 3) indicates probable unaccounted for trend. T value likely invalid.

Poorly conducted test makes interpretations highly approximate.

T = 264Q/Δs Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Vertical to horizontal ratio of permeability (unitless), estimated from well logs in the area
b = aquifer thickness in feet (ft), estimated from well logs in the area
r = distance from pumping well (ft)

Based on the analytical method of Theis (1935).

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SECTION FIVE: ANALYSIS OF KLING IRRIGATION WELL AND AQUIFER TEST CONDUCTED BY HLI

Overview

An irrigation well located on the M3 Eagle property near the mouth of Big Gulch was inspected, re-developed and partially rehabilitated before a well-and-aquifer test was conducted to better assess the properties of the aquifer along the southwestern boundaries of the M3 project area. This 16-inch diameter well is located on the former Kling property in Township 5 North, Range 1East, in the southeast quarter of the southeast quarter of Section 28 (Figure 77). This well, known as the "Kling Irrigation well" was selected because it had reportedly been pumped at near 1,000 gallons per minute, is finished to a depth of 408 feet (70 feet into the regional Pierce Gulch Sand Aquifer), and is located near the Farmer's Union Ditch[21] which facilitated the removal of pumped water during the test. The well required rehabilitation before testing was possible, as is discussed below. Even after rehabilitation and redevelopment, the well was not as efficient as we would have hoped because the well screens remained partially plugged; however, the well did provide data that allowed for an improved understanding of the regional aquifer system beneath the M3 site and demonstrated that a supply well capable of a sustained production of more than 1,000 gpm (and probably 2,000 gpm or more) is possible from the southwest portion of the M3 Eagle property.

The aquifer test was conducted over the period January 8 through 18, 2007. Water level data were collected before, during and after a 3,000 minute pumping period that began at 09:50 hrs on January 9 and ended at 11:50 hrs, January 11, 2007. The data were collected from seven locations using electronic data loggers calibrated and backed up by hand measurements. Three of these locations had multi-completion wells (piezometer nests) monitoring two to five depth zones at each location for a total of 15 discrete data collection points. Post-pumping water level recovery data were collected until the afternoon of January 18, 2007, 9 days beyond the pumping period. Water quality samples collected near the end of the pumping period were submitted for geochemical analyses. During pumping, representatives of HLI were on-site continuously around the clock to collect hand data, monitor pumping discharge and work with the pumping contractor. In addition, representatives of the Farmers Union Ditch Co. made periodic visits to the site to inspect the canal receiving water pumped during the test.

The monitored wells consisted of the Kling Irrigation well (the pumping well) and six observation wells. The well locations are shown in Figure 80 (page 219). Each of these wells was located spatially using GPS instruments. The distances from the pumped well to each observation well were calculated to within 25 feet using these GPS coordinates. The three wells with multi-depth completions were M3-TW#1 (five zones), M3-TW#2

[21] As noted previously, the "Farmers Union Ditch" has been used in numerous reports and on many maps, as the "Farmers Union Canal." We use the name preferred by the owners of the Farmers Union Ditch in this report.

(two zones) and M3-TW#3 (four zones), all designed and installed under the supervision of HLI as part of the M3 Eagle Hydrogeologic Characterization project. Each TW-series well consisted of multiple-completion piezometers[22]; 2-inches in diameter, with well screens ranging from 10 to 50 ft in length, coupled to the aquifer with graded-silica sand, and sealed with bentonite grout between completion zones and from the uppermost completion zone to land surface. Three additional wells were also monitored: SVR#7, SVR#9 and the "Flack Corral" well. In total, water level data were collected from 15 discrete points ranging from 1,050 to 20,600 feet from the pumping well. Details about these wells are presented in Table 1 (page 217). In addition, atmospheric pressure was measured at two on-site stations during the test through the use of Solinst Barologgers. Data from two stations provided redundancy in case of Barologger failure (which did not occur). All electronic data were collected at one-minute intervals to facilitate test synchronization and data analysis. The collected data have been archived and are included on a CD attached to this report.

During the test, pumping caused water levels to change in only two wells: the pumped well and M3-TW#1, located 1,050 feet to the southwest of the pumped well. The change in water level (drawdown) in the Kling Irrigation well at the end of pumping was 93.70 feet for an end-of-test specific capacity of 9.6 gpm/ft. We estimate that about 40 to 45 feet of this drawdown may have been caused by well loss from the partially plugged well (as is discussed below). The mean of drawdowns measured in the four zones that responded to testing at M3-TW#1 (Zones 1 through 4) at the end of the 3,000-minute test was 8.97 feet. None of the other wells monitored during the test indicated a drawdown-response from the pumping at the Kling Irrigation well. They were apparently too far from the pumping well to respond.

Pumping Test Procedure

The test consisted of three parts:

1. pretest water level data collection
2. constant-discharge drawdown test, and
3. water-level recovery after pumping stopped.

The pretest data were collected to quantify the changes in water level that are caused by changes in atmospheric pressure and to quantify any antecedent water level trends that could have affected the data. We analyzed the data to develop equations to quantify the relationship between changes in water levels caused by changes in barometric pressure.

[22] Strictly speaking, a piezometer by definition is only open to a single point in an aquifer and not over an interval of many feet. Because the small-diameter PVC tubes have screen lengths of 10 to 50 feet, they should technically be termed "wells." However, to help distinguish them from the larger-diameter boring in which they are completed (such as well M3-TW #1 which has 5 small-diameter PVC tubes in the one well boring), we use the term "piezometers" to denote the difference. The effect of the longer screens is to "average" the aquifer heads or water levels present over the length of the screen as opposed to a piezometer which indicates the head at a single point. The difference between the point measurement of a piezometer and the average measurement indicated by the small-diameter PVC well with a screen 10 to 50 ft in length is small and therefore largely academic.

These equations were later used to adjust the water level data collected before, during and after pumping to remove the barometric "signal" from the water level data, leaving only water level changes caused by pumping.

The drawdown test consisted of pumping the Kling Irrigation well at a constant 900 gpm and measuring water levels in the pumped and all observation wells. Layne of Idaho, Inc. installed the line-shaft turbine test pump, the orifice weir used to measure flow, and all appurtenances associated with pumping the well. They also supplied and operated the truck-mounted diesel drive engine with right-angle drive that powered the pump. Water levels were measured in the pumping well through a dedicated water level sounding tube. Electronic data were collected using a Solinst™ data logger. Hand measurements were taken with a calibrated Powers™ well sounder and a steel tape. One sounding tube was used for both the hand measurements and the data logger after it was discovered that pump lubricating oil had seeped into a second tube originally planned for hand measurements. The electronic data logger collected data to the nearest 0.1 foot while hand data were measured to the nearest 0.01 foot. During pump shutdown, the rapidly-rising water level ("shut off surge") caused the data logger to shift upward in the sounding tube and the hand data were used to correct the electronic data by adding a constant 4.95 ft, the apparent amount of shift to the recovery data. The pumping rate was measured with a 10-inch diameter circular orifice weir and a 7-inch plate. A height of 19.5 inches of water above the center of the weir indicated a flow of 900 gpm. The pumping rate was measured and recorded every time a hand water level was measured. In addition, personnel from Layne checked the flow rate at least once every hour during the latter parts of the test and made slight discharge adjustments when necessary. The smoothness and continuity of the plotted electronic-drawdown-data verified that the pumping rate was maintained at a near-constant 900 gpm.

Water-level recovery data were collected after pumping stopped. These data were used to compare and support the analyses of the pumping drawdown-data. The recovery data were collected in all seven wells for the full test period (through the afternoon of January 18) with the exception of the pumped well (Kling Irrigation). The data logger for this well recorded water levels until 8:00 AM on January 12, 2007, when it was removed to allow Layne to remove the pump and pump column. The data collected during the test are included on the CD included with this report.

Analysis - Methods

The data from the test were analyzed to calculate the coefficients of transmissivity and storativity after extensive preprocessing. These values were then used to calculate theoretical drawdowns to verify the measured results at the observation wells and to estimate the well loss that occurred at the pumping well. Because the calculated-theoretical drawdowns are in close agreement with the observed drawdowns at the observation wells, we believe the calculated transmissivity and storativity values are supported. We attribute the difference between the calculated and observed drawdown at the pumping well almost entirely to well loss alone.

All data were preprocessed in MS Excel®. Spreadsheets were used initially to convert raw logger data into depth of water above the logger, then to depth to water, and eventually to barometrically-corrected drawdowns. Excel was also used to generate data plots and some figures.

The computer program *Aqtesolv® 4.50.002 Professional* software (HydroSOLVE, Inc., 2008) was then used to calculate the aquifer coefficients of transmissivity and storativity from the corrected data. Several methods were used to calculate transmissivity and storativity. Details on these methods are included in Appendix B. The Theis (1935) curve-matching method with corrections for partial penetration by Hantush (1961a and b) was used on logarithmic plots that included both pumping drawdowns and recovery ("residual drawdown"). Aqtesolv® generated a "type curve" that combines drawdown and recovery that we manually manipulated to obtain a best-fit match. This match indicated the transmissivity and storativity values used to generate the best-fit curve and therefore the best possible representative values for the test data[23]. The known geometry of the aquifer, details of well construction, along with pumping and drawdown data, were considered as additional input for these analyses. In addition, we used Aqtesolv® to generate type curves for data matching, both with and without the hydraulic effects of an inferred structural fault located about 1,500 ft northeast of the pumping well, identified by magnetometer survey (Wood, 2007). Comparison of the analytical results with and without a no-flow boundary (potentially caused by this fault - shown in Figure 77) allowed us to better assess the effects of pumping the Kling Irrigation well, as discussed below.

The Theis method applied to pumping well data can yield different results depending on the effective well radius used in the analysis and the amount of well loss that occurs during pumping. Neither of these was directly measured during the test. In some cases, the semi-log Cooper-Jacob method of analysis would be superior to the Theis/Hantush method because well loss and effective well diameter do not affect the calculations for transmissivity in the Cooper-Jacob method. However, in the case of the Kling Irrigation well, our calculations show that the effects of partial penetration strongly affect the calculated results. The pumping well only penetrates the upper 1/3 of the aquifer, as indicated by down-hole geophysical surveys in nearby M3-TW #1. (Even this amount of partial penetration may be too high if portions of the partially plugged well screen did not produce significant quantities of water during pumping.) Since Aqtesolv® has no built-in corrections for partial penetration for the semi-log methods, we believe that using the Theis method with Hantush corrections for partial penetration, coupled with sensitivity analyses for effective well radius and well loss, gives results that can be more representative of actual aquifer conditions than a Cooper-Jacob where partial penetration effects and/or aquifer anisotropy effects are significantly large. Our comparison of the Theis results with and without Hantush corrections indicated the relative effects of partial penetration. Therefore, we have applied the method of Butler (1957) to correct the raw

[23] Except for the pumped well. Storativity cannot be accurately calculated from the pumped well data because the effective radius ("r") of the pumped well cannot be known and storativity is highly sensitive to "r." Only observation well data can accurately indicate storativity.

data used in the pumped-well Cooper-Jacob analysis. These corrections are less accurate than the corrections of Hantush used in the Theis analysis. Nonetheless, they help to define the range of likely results. A discussion of these analyses for well loss, effective well diameter and partial penetration is included as part of the analyses for the pumped well.

The Theis (1935) straight-line, residual-drawdown, recovery method was used to analyze the response of each well after cessation of pumping. In this method the residual drawdown (drawdown remaining after pumping stops) is plotted against the ratio of time since pumping stopped divided by the time since pumping started (t/t'), on a semi-log plot. This method generates a straight line on a semi-logarithmic plot that is used to calculate the transmissivity. It also quantifies a storativity ratio that indicates whether the well is recovering "early" (indicating a source of recharge to the well) or "late" (indicating a hydraulic barrier to flow in the aquifer that delays water level recovery). The Theis semi-log, straight-line recovery method (like the Cooper-Jacob method), does not take into account the effects of partial penetration. Therefore, as discussed above, we have conducted two recovery analyses for the pumped well: one using raw data and one with data corrected for the effects of partial penetration using the Butler (1957) method. Because the observation wells are sufficiently far from the pumped well, partial penetration would typically be insignificant for these wells.

Because of the presence of thin, discontinuous clay and clayey-sand layers within the aquifer beneath the pumped well and within the aquifer at other locations, we attempted to analyze the data using the "leaky aquitard method" of Neuman and Witherspoon (1969) and the "ratio method" of Neuman and Witherspoon (1972). The analyses were performed in an attempt to better understand the system and to investigate whether the pumped well and the observation wells are completed in one aquifer or whether the system consists of two or more separate aquifers that are hydraulically connected through one or more leaky aquitards. (The Neuman-Witherspoon model assumes an aquifer overlain by a leaky aquitard which in turn is overlain by an aquifer. Pumping from the deeper aquifer eventually causes water to move from the overlying aquifer, to the pumped aquifer, via the leaky aquitard.)

At first glance, the vertical piezometer nest at TW-#1 appears almost ideal for either of the Neuman and Witherspoon methods. The well and aquifer setup for the Kling Irrigation test consisted of a pumped well completed in the upper portion of an aquifer with many discontinuous and/or leaky zones with observation wells screened at discrete points or zones at varying depths within the single aquifer. Unfortunately (for application of the Neuman-Witherspoon method), all piezometers are completed in permeable zones; none of the zones between the Zone 1 and Zone 4 piezometers appear to be proper aquitards, as required by the Neuman and Witherspoon methods. The geophysical log of M3-TW #1 (in Appendix A) shows that the clay zones are thin and variable. The discontinuous nature of the clay and sandy-clay zones was demonstrated by the responses of the Zone1 through Zone 4 piezometers; during the test, the deeper zones - much deeper than the pumped well - responded first, but the shallower zones (including the zone comparable to that of the pumped well) eventually responded *more* than the deeper zones.

(In addition, the shallowest piezometer (Zone 5) did not react at all to pumping and the aquitard between the Zone 4 and Zone 5 piezometers was not monitored.)

The initial response in the deeper zones could not have been the result of the drawdown cone of depression moving horizontally outward from the pumped well through the pumped aquifer, then vertically through a leaky aquitard, and eventually horizontally through the deep zone; such a response would have been indicative of Neuman-Witherspoon type conditions. Instead, the drawdown signal reached the deeper aquifer first at the M3 TW #1 site, apparently through a hydraulic pathway more tortuous than that assumed in the Neuman-Witherspoon model. Since a Neuman-Witherspoon type response was not observed, and the geophysical and geological logging do not indicate continuous aquitards, the Neuman-Witherspoon method could not be realistically applied; the minimum set-up of a well or piezometer in the pumped aquifer and a well or piezometer in the aquitard was not available for analysis. We believe that the model aquifer system assumed in the two Neuman and Witherspoon methods is inconsistent with the actual hydrogeology of the system.

Analysis - Preprocessing

Before the data could be analyzed with Aqtesolv®, the raw data had to be preprocessed. To preprocess the data we: 1) converted raw data to depth to water data, 2) calculated barometric efficiency of the aquifer at each well, 3) removed the barometric "signal" from the depth to water data, and 4) generated barometrically-corrected drawdown data. Each process is discussed below.

Raw Depth to Water

The general procedure used to preprocess the collected data is as follows: The first step was to convert the pressures recorded by the non-vented data loggers to *water level standing above the logger* by subtracting the barometric pressure recorded at the same time period as the water level logger. The next step was to convert the *water level above the logger* to a *depth to water* (dtw) by comparing the logger level to hand measurements which were recorded as depth below a datum (the top of the steel monument housing the well) along with the height of the monument above ground surface (casing "stick up"). In cases where a number of hand measurements were obtained, an average calibration was calculated that minimized the potential error. The compilation of the hand and logger measurements generated an average *depth of the logger below ground level* from which the water level above the logger was subtracted to generate a series of depth-to-water data. The *depth-to-water* plots for all of the wells monitored during the test are included in Appendix C, as Figures C-1 through C-7. In all cases except for the lower 4 zones of M3-TW#1 and the pumped well, the plots show water levels that closely mimicked atmospheric pressure, demonstrating the need to correct for the effects of atmospheric pressure change, or *barometric signal.*

Barometric Efficiency

The next step was to remove the *barometric signal.* This signal is the amount of water level change in a well that is caused solely by changes in atmospheric pressure. The ratio of the change in water level and change in atmospheric pressure is termed the "barometric efficiency" (BE). In a well with 100-percent barometric efficiency, an atmospheric pressure change equivalent to 1.0 foot of water[24] causes the water level to change in the well by 1.0 foot. In a well with a BE of 50-percent, the change would only be 0.50 feet. These changes in water level only occur because the well is open to the atmosphere and therefore is not a real change that would occur in the aquifer were there no well. A well sealed from the atmosphere would not show barometric effects nor need BE corrections as the changes in atmospheric pressure would load equally over the entire aquifer.

Barometric Efficiency was calculated using data when the only significant changes in water level would likely be from changes in atmospheric pressure following the method outline in the Ground Water Manual (US Department of the Interior, 1981). The pretest measurement period was used for this calculation. No significant pumping was occurring near any of the wells measured during the test and building high-pressure provided a significant change in atmospheric pressure for comparison of atmospheric pressure changes with changes in water levels. The BE for each well was calculated by plotting atmospheric pressure on the X-axis (horizontal) against the corresponding water level measured at the same time on the Y-axis (vertical). The points generated a "scatter" plot. A "best-fit" straight line was then calculated (using MS Excel) with the slope of the line indicating the BE and the R^2 indicating the statistical correlation of the best-fit line. The BE plots for all of the wells monitored during the test are shown in Appendix C Figures C-8 through C-16.

Water Levels Corrected for Barometric Efficiency

After the BE was calculated for each well, the water level data were corrected for BE effects. This correction was accomplished by multiplying the change in atmospheric pressure by the BE and subtracting the result from the water level data for each minute of data collection after pumping began. Subtraction was used to compensate for this inverse relationship because the water level goes up when the atmospheric pressure goes down and vice versa. The end result is a water level plot that is nearly free of water level changes caused by changes in atmospheric pressure.

The BE corrections are not perfect, however. The data loggers collect data by converting pressure on a diaphragm to a digital signal. The increments between steps in the recorded digital signal are a function of the range of the data logger. In high-range (300 foot) data loggers (such as that needed in a pumping well) the steps are 0.1 ft while in low-range (more sensitive) data loggers (such as used in many of the observation wells for this test)

[24] Atmospheric pressure can be measured in any unit of pressure. Typical units are millibars and inches of mercury but feet of water can also be used. The use of feet of water simplifies data logger corrections and corrections for barometric efficiency (BE) for our purposes here.

the range is 0.01 ft. Since the total change in atmospheric pressure during the pretest period was about 1 ft of water, the higher-range loggers generated a number of water levels that were the same even when the atmospheric pressure changed. They also generated different levels when the pressure was near the middle of the range between 0.1 ft increments (digital "flutter"). This situation generated "noise" in the data that made calculation of BE impossible for the pumping well[25] because the changes in atmospheric pressure during the measurement period were relatively minute. In addition, a small seasonal trend in the water levels and the rhythmic effects of "earth tides" added an additional increment of noise to the data from the other observation wells; noise that could have masked water level changes of a few hundredths of a foot that might otherwise have been attributable to pumping at the Kling Irrigation well. Based on the comparison of actual and theoretical drawdowns (discussed below) this masking was relatively academic and insignificant to the results and does not appear to be an issue.

BE Corrected Drawdowns

"True" water level drawdowns were calculated after the data were corrected for BE. Drawdown is the difference in the water level in the well caused solely by pumping. It was calculated by subtracting the depth to water just before pumping started from the depth to water after pumping started. In most cases, digital noise in the data required an averaging of the levels recorded from the 30 minutes before pumping started to represent the pre-pumped level. These drawdowns provided the data that were then used for analysis for the aquifer coefficients (properties of the porous-media matrix of the aquifer) of transmissivity and storativity. The plots of drawdowns corrected for BE (along with the measured atmospheric pressure) for all of the wells monitored during the test are shown in Appendix D Figures D-1 through D-16.

Analyses –Results

Water Levels

Appendix C Figures C-1 through C-7 show the actual water levels reported in all the 15 observation wells monitored during the test. The hydrographs for the pumped well and Zones 1-4 at M3-TW#1 show the classic response of a sharply lowering water level shortly after the commencement of pumping with a gradual flattening of the drawdown curve over time. When pumping stopped, a similar, but inverted, residual-drawdown curve was displayed as water level "recovered." The barometric pressure (plotted at a different scale) shows a general rise and then fall during the test. Because the relative drawdown effects caused by the pumping well are so much greater than the changes in water level caused by barometric effects, the barometric "signal" is effectively "masked" and not readily observed in the plots for Zones 1-4 or the pumping well.

All of the remaining observation wells show water level changes that are very similar to the plot of atmospheric (barometric) pressure. In these wells (Appendix C Figures C-3

[25] Data from late summer were also used in an attempt to calculate BE for the Kling irrigation well. However, during this time period, the atmospheric pressure did not appreciably change and pumping in the area generated small water level changes that helped to mask meaningful BE calculations.

through C-7) the scale ranges for water levels and barometric pressure are similar but inverted to better represent the cause-and-effect relationship. None of the other observation wells showed any measureable influence from the pumping of the Kling irrigation well. In other words, no drawdown curves typical of pumping followed by recovery (comparable to a reduced version of the curve observed for the data plot for the pumping well) are observable. Almost all of the changes in water levels measured in these wells appear to be directly attributable to atmospheric causes.

Many of the plots show what appear to be multiple, parallel curves for the same well; there appears to be two or even three water levels for any given time. These multiple levels are an artifact of the "digital flutter" of the recorded levels and the compression of many days worth of data collected at one-minute increments, into a plot only a few inches long. If the time scale were spread out, there would only be one level for each 1-minute increment. The spacing between the parallel lines indicates the resolution or digital step between levels recorded by the data logger as it converts the analog pressure (which can be of any value) in the data logger to digital values (which are in multiples of the digital step or conversion resolution). A running average of the recorded levels could eliminate the apparent multiple curves; however, since none of these wells indicated drawdown from the pumping of the Kling Irrigation well, we chose to plot the original, non-averaged data instead.

Barometric Efficiency

The calculated barometric efficiencies (BE) for all measured wells are included in Table 1 (page 217). These BE values, derived from plots on the figures presented in Appendix C (Figures C-8 through C-16), show the atmospheric pressure versus water level plots, the best-fit lines, the calculated BE and the degree of correlation (R^2). Most of the measured wells exhibit very high BE's (greater than 80-percent efficient). Only Zones 3 and 4 of M3-TW#1 had lower efficiencies of 52 percent. The BE in the pumped well could not be calculated with the existing data and was assumed to be comparable to that of the TW #1 Zone 4 well completed in the same zone. The barometric efficiencies indicate that almost all of the short-term water level changes that occur in the absence of nearby pumping wells are caused by changes in barometric pressure. The calculated high barometric efficiencies indicate a rigid aquifer framework whereby changes in the weight of the atmosphere are not readily transmitted to the ground water within the aquifer because the aquifer framework does not compress or easily distort. The atmospheric pressure changes are only transmitted to the surface of the water exposed in the well. In a well with low BE, the atmosphere effectively compresses the water in both the well and the aquifer, cancelling out change in water level caused by changes in barometric pressure. The relatively high BE values calculated for the M3 Eagle-area wells appear to confirm our conclusion that these sand aquifers are somewhat cemented and, certainly more so than the Driller's Reports for area wells would indicate.

Barometric efficiency could not be calculated for the pumping well (see Appendix C Figure C-9). There was too much "noise" in the data for a meaningful BE to be calculated. A BE correction of 50% was assumed based on the BE's calculated for M3-

TW#1 Zones 3 and 4 (52%). These piezometers are completed in the same portion (upper 100 feet) of the aquifer as the pumping well and likely have similar BE's.

Drawdowns After Barometric Effects are Removed

Figure D-1 (in Appendix D) shows the BE corrected drawdown and water level recovery in the Kling Irrigation well. The hydrograph shows that pumping at 900 gpm caused more than 45 feet of drawdown during the first two minutes of pumping. Drawdown continued to increase but at a predicable, logarithmically declining rate (i.e., a flattening curve) throughout the duration of the test, on the arithmetic plot. When plotted semi-logarithmically (Figure 78, page 192), the drawdown becomes a straight line after five minutes into the test. The straight line relationship remains at a constant slope through the duration of pumping. The lack of slope change after five minutes indicates that no significant hydraulic boundaries affected the response in the pumping well after five minutes of pumping. At the end of 3,000 minutes of pumping (50 hours), the total drawdown in the pumped well was 93.7 feet for a calculated fifty-hour specific capacity of 9.6 gpm/ft of drawdown.

After pumping was stopped, the residual drawdown in the Kling Irrigation well decreased significantly to about 32 feet within the first minute, a recovery of over 60 feet. This large recovery in a short period of time after pumping stopped is comparable to the 45 feet of drawdown observed during the first two minutes of pumping. These large values suggest that about half of the observed drawdown at the end of the test likely resulted from frictional well loss across the louvered openings, clogged openings, and a poorly developed well. We estimate that the well loss during pumping was about 45 to 50 feet resulting in an actual drawdown in the aquifer, just outside the well, on the order of about 40 to 50 feet. After the pumping stopped and well loss was no longer a factor, the water level rose in the Kling Irrigation well and continued following a predictable residual drawdown curve typical of a recovering well.

It should be noted that the BE-corrected drawdown plot in Figure D-1 includes a correction based on the hand-measured water levels which showed a 4.95 ft discrepancy after the pump was shut off. We believe that the sudden rise in water levels, by this amount, resulted from the shutdown of the pump caused the electronic data logger to be pushed upward in its monitoring tube and to become lodged 4.95 ft higher in the tube where it remained until it was removed at the end of the test. Before pump shutdown, hand-measured water levels showed very good agreement with the electronically acquired measurements as shown in the linear time series plot, Appendix C Figure C-1. For this reason, we have added 4.95 feet to the data logger readings after pump shut down to correct for the shift of the data logger.

Figures D-2 through D-6 (in Appendix D) show the BE corrected drawdown in Zones 1-4 in M3-TW #1 along with the composite water level drawdowns of these four zones. These figures show a typical drawdown curve during pumping and the inverted recovery curve after pumping stopped. The figures also show that the barometric correction has

removed the "signal" caused by the changes in atmospheric pressure that occurred during the test.

Water levels in Zones 3 and 4 of TW #1 (completed in the upper part of the Pierce Gulch Sand Aquifer), drew down by 10.7 ft and almost 12 ft, respectively, while the deeper piezometers, Zones 1 and 2, completed nearer to the bottom of the aquifer, responded much less, 6.5 ft and 6.7 ft, respectively.

The M3-TW #1 Zone 5 piezometer (Figure D-7) showed no response to pumping. Since the deeper wells at this site responded, the lack of response cannot be the result of distance. More likely, the clay layers overlying the Pierce Gulch Sand Aquifer are continuous in this area and act as a hydraulic barrier to limit short-term effects of pumping in the shallow unnamed alluvial aquifer that overlies the overlying Pierce Gulch Sand Aquifer.

The remaining curves for wells M3-TW#2 (all zones), M3-TW #3 (all zones), SVR #7, SVR #9 and Flack Corral (Figures D-8 through D-16) show no observable drawdown, only water levels staying within a range of about 0.1 to 0.2 feet of the pretest level, throughout the period of the test. Wells M3-TW #2, M3-TW #3, SVR #7, SVR #9 and Flack Corral appear to be too far from the pumped well to have responded at the rate and duration of the 50-hour test.

Heterogeneity of the Pierce Gulch Sand Aquifer

The timing and magnitude of the drawdowns measured in the various zones at TW #1 suggest ground-water flow paths that are different from those that would be expected in a homogeneous, isotropic aquifer. Figure 82 (page 221) shows the semi-logarithmic drawdown during pumping in all four piezometers plus the composite of the four piezometers. The figure shows the effects of heterogeneity within the aquifer. For example, the shallowest zone (Zone 4) responded after 30 minutes of pumping while the deepest zone (Zone 1) responded in less than 10 minutes. Yet by the end of the test, Zone 4 had almost twice as much drawdown than did Zone 1.

The *larger* response in the upper zones (3 and 4) and the smaller response in the lower zones (1 and 2) indicate that the Pierce Gulch Sand Aquifer is not homogeneous. In other words, permeability of the upper zone differs from that of the lower zone. Since the Kling Irrigation well and the Zone 3 and 4 piezometers are completed in the upper part of the Pierce Gulch Sand Aquifer, it would seem normal for the larger response to occur in the upper portion of the aquifer. However, since the distance between the pumping well and TW #1 is more than two times the thickness of the aquifer, flow gradients toward the Kling Irrigation well (under pumping) would be effectively horizontal, such that the upper and bottom portions of the aquifer would experience comparable drawdowns in a homogeneous aquifer. Drawdowns in the upper portions of the aquifer that were almost two times larger than those near the bottom indicate that that aquifer is not homogeneous.

The *timing* of the responses also indicates heterogeneity within the Pierce Gulch Sand Aquifer. Drawdown in the deeper zones (1 and 2) of the Pierce Gulch Sand Aquifer began 10 to 12 minutes after pumping began while drawdowns in the shallower zones (3 and 4) began 20 to 30 minutes into the test. The earlier response at the bottom of the aquifer (when pumping occurred within the top of the aquifer) also suggests a non-homogeneous system with smaller storativity in the bottom portions of the aquifer and larger storativity in the upper portion of the aquifer. This possible relationship is supported by the smaller BE's for the upper zone wells (3 and 4) and the larger BE's for the lower zone wells (1 and 2). The smaller BE's likely occurs because the upper part of the aquifer is less cemented and therefore more deformable while the bottom of the aquifer is more cemented and less deformable. We have observed a higher degree of cementation at the bottom of the Pierce Gulch Sand Aquifer at many locations throughout the greater project area, based on our review of drill cuttings and observations made during drilling.

A composite response based on an average (mean) of the drawdowns in Zones 1-4 is shown in Figure D-2. We believe this plot best approximates the drawdown that would likely have occurred in one observation well open over the entire interval represented by the four separate wells (equivalent to a well open between depths of 352 to 556 ft bgl). The composite drawdown at the end of the pumping period was a little less than 9.0 feet. By combining the drawdowns in this manner, the apparent effects inhomogeneity are reduced (but not eliminated), allowing for a more representative analysis of aquifer properties.

The shape of the drawdown curves also illustrates the effects of heterogeneity within the aquifer. The semi-log slope of the drawdown curves in the shallower Zones (3 and 4) began to flatten after 1,000 minutes of pumping and continued to do so through the end of pumping. However, the slope of the drawdown curves in the deeper Zones (1 and 2) continually steepened throughout the test. None of these four zones exhibited a straight-line relationship, as would be expected in a homogeneous aquifer. Conventional analyses for a uniform, homogeneous isotropic aquifer would indicate that the upper part of the aquifer was subject to recharge (so called "positive boundaries") while the lower part of the aquifer appears to have "no-flow hydraulic boundaries" such as a fault or lower-permeability region within the expanding cone of depression caused by the pumping well. Recharge to the upper zones (3 and 4) could occur as flow from the lower-permeability lower zones moving upward as the upward flow gradient became larger. The composite hydrograph of the four zones demonstrates a straight-line plot after about 1,000 minutes of pumping suggesting that the net, combined effect approximates a more uniform aquifer with no outside source of recharge and no indicated boundaries.

A no-flow hydraulic boundary could, in theory, have affected responses in the lower part of the aquifer. A steepening drawdown curve can be an indicator of a bounded system where the drawdown cone of depression intersects the no-flow boundary during pumping. A potential no-flow boundary may exist in the pumped aquifer. A structural geologic ("normal") fault has been inferred from magnetometer geophysical surveys. The fault lies about 1,500 ft northeast of the pumped well with the down-dropped block on the

southwest side of the fault (Figure 80, page 219). Such a fault could place low-permeability material adjacent to the fault at the depths of the lower zones, as has occurred with similar faults at other locations throughout this northern margin of the Snake River Plain. However, because the composite plot of the of the four M3-TW #1 piezometers demonstrates a response typical of a single well completed throughout the entire section of a homogeneous aquifer, we believe it is more likely that heterogeneity within the aquifer directs some vertical flow from the deep parts of the aquifer (and therefore appearing as if the bottom had no-flow or "negative" boundaries) transferring water to upper zones (and thereby acting as an apparent source of recharge or a "positive boundary"). In combination, there would be no net inflow or outflow of water to the aquifer (except through pumping) as suggested by the straight-line composite semi-log plot of the mean of the levels in all four responding wells.

The difference between the responses of the deeper zones (1 and 2) and the upper zones (3 and 4) of the aquifer *cannot* be explained by incomplete well development. The upper zones are not plugged by low-permeability, undeveloped aquifer materials that could generate a "skin-effect" that would delay responses to changes in water levels caused by pumping or the cessation of pumping. All five zones within well M3-TW #1 were developed using the same techniques of swabbing, air-lift pumping and injection of Aqua-Clear [tm] (a mud-dispersing agent) to breakdown drilling mud. All five piezometers produced 20 gpm of clear, sand-and-mud-free water under air-lift pumping after development was completed.

Aquifer Coefficients

Based on our analyses, a transmissivity of 39,000 gpd/ft and a storativity of about 0.001 (or $1x10^{-3}$) appear to best represent the aquifer in the region of the Kling Irrigation well. Figures 83 through 95 (pages 222 through 234) show the results of both Theis (1935) analyses of pumping and recovery as well as Theis (1935) straight-line recovery plots for the five wells that responded to pumping (Kling Irrigation well, Zones 1-4 in M3-TW #1, and the composite of Zones 1-4). The results of our analyses are summarized in Table 3 (page 247). The transmissivity indicated by M3-TW #1, however, appears to be on the order of 120,000 gpd/ft. Details of these analyses are presented below.

Pumped-Well Analysis for Transmissivity

Our analysis for the pumping well (below) suggests to us that the T for the aquifer at this location is on the order of 39,000 gpd/ft. The upper curve in Figure 83 (page 222) shows a Theis analysis for the pumped well uncorrected for well loss. The type curve used in the analysis includes the partial penetration corrections of Hantush (1961a and b) and the hydraulic effects of the fault (no-flow boundary) located 1,500 ft to the northeast shown in Figure 80 (page 219). The analysis indicates a transmissivity of 29,000 gpd/ft. A Theis analysis without the Hantush corrections (not shown) indicated a transmissivity of about 20,000 gpd/ft. Comparison of the two methods suggests that not correcting for partial-penetration generates a transmissivity that is about 70 percent of actual value.

The drawdown data points fall below the type curve for times less than 4 minutes. An analysis using the equation of Cooper and Papadopoulos (1967) indicates that well bore storage affected the pumping water levels during the first five minutes of pumping, causing the measured water levels to fall below the type.

The lower curve in Figure 83 shows our analysis for transmissivity using data corrected for maximum estimated likely well loss. In this analysis, the data have been "corrected" by the removal of 40 ft of drawdown that we have interpreted to represent well loss that appears likely to have occurred. This estimate of 40 feet for well loss is based on the amount of drawdown that occurred at the very beginning of the test after the water stored in the well casing had been removed (and well loss established) and the amount of water level recovery that occurred during the first minute after pumping was stopped (and well loss ceased). By the second minute of pumping, a drawdown of 45.86 ft was recorded and the pumping rate adjusted to 900 gpm. Well loss at this time had to be less than the total drawdown of 45 feet. At the end of the first minute of recovery after pumped had been stopped, the water level in the well recovered by about 62 ft. During the second minute it recovered only 3.7 feet, indicating that well loss (which would cease within seconds of the end of pumping) made up a large percentage of the recovery that occurred during the first minute of recovery. Based on these observations, we estimate that well loss was on the order of 40 ft or less. By subtracting 40 ft from the raw data we have calculated the transmissivity that would be indicated by a similar well without this well loss. The analysis corrected for well loss indicates a transmissivity of 37,000 gpd/ft, or about 28-percent larger than the analysis without this correction.

Figure 84 (page 223) shows two Cooper-Jacob (1946) analyses for the pumping well. The upper curve shows data uncorrected for the effects of partial penetration while the lower curve shows our analysis using data corrected using the method of Butler (1957) to correct for partial penetration. The analysis using the uncorrected data indicates a transmissivity of 20,000 gpm/ft while the analysis using the corrected data indicates a transmissivity of 36,000 gpm/ft.

Figure 85 (page 224) shows two plots of the recovery data and our analysis using the Theis (1935) straight-line recovery method. The upper plot (which does not include corrections for partial penetration) indicates a transmissivity of 27,000 gpd/ft. The lower plot based on data corrected using the Butler (1957) method, indicates a transmissivity of 45,000 gpd/ft.

In our opinion, a transmissivity around 39,000 gpd/ft best represents the actual transmissivity of the full thickness of the aquifer in the vicinity of the Kling Irrigation well. This value is the average (mean) of the value indicted by the two drawdown analyses corrected for partial penetration and well loss, and the recovery analysis corrected for partial penetration, rounded to two significant figures.

Storativity cannot be directly calculated from the pumped well but the recovery method indicated a ratio of S/S' of 1.2. When this value is greater than 1.0, a source of recharge

or the effects of an adjacent higher transmissivity zone (effectively acting as a source of recharge) is indicated. A nearby recharge source directly coupled to the aquifer such as a river or lake is not likely with the deep confined Pierce Gulch Sand Aquifer, since no such surface water source is located within many miles of the Kling Irrigation well. The Farmers Union Ditch is not a source of surface water in this area. Water levels in shallow domestic wells near the Farmers Union Ditch did not significantly change when flow ceased at the end of the 2006 irrigation season, indicating that leakage from the ditch is insignificant in this area. In addition, the ditch was dry before the test began. No recharge boundary was noted in the drawdown data for the pumping well indicating that the water discharged to the ditch was not "short circuiting" back to the pumping well. Also, no recharge was noted in the shallowest monitored well (Zone 5 in M3-TW #1).

The S/S' greater than 1.0 may have occurred because much of the aquifer adjacent to the Kling Irrigation well has much larger transmissivities (as shown in Figure 98, page 251). These higher-transmissivity regions, if encountered by the expanding cone of depression of the pumping well, would likely show up as a positive recharge boundary as seen in the test data.

M3-TW #1 Analyses

Two types of composite analyses for the four observation wells (piezometers) at M3-TW #1 are shown in Figures 86 and 87 (pages 225 and 226). Figure 86 presents a single plot of the mean of the drawdowns measured in Zones 1-4. In this plot, the drawdowns for each 1-minute time interval, from each of the four responding piezometers, were added with the sum divided by 4 to generate a mean drawdown for each time interval which was then analyzed using the log-log Theis (1935) method. Figure 87 shows the individual plots for each Zone (1-4) in a log-log Theis analysis with one best-fit match to the type curve, as calculated by Aqtesolv®. Typically, a composite analysis indicates time divided by the square of the distance on the x-axis – a method that allows comparison and analyses of wells at varying distances. These four piezometers represent a special case, however, because all four piezometers lie at the same distance from the pumped well. Therefore, a plot of time along the t (time)-axis (instead of t/r^2, as needed when the wells lie at different distances from the pumped well) is appropriate.

The Theis analysis of the averaged data (Figure 86) indicates a transmissivity of 120,000 gpd/ft, based on a "best-fit" type-curve match calculated by Aqtesolv® biased toward the first 100 minutes of the test. After this time, drawdown rose above the type curve indicating that heterogeneities within the aquifer and/or boundaries were affecting the drawdowns measured in the piezometers. The fit of the early time data is most likely to indicate the properties of the portion of the aquifer defined by the radial distance between the pumping and observations wells. The initial drawdown is caused by the passing of the leading edge ("front") of the cone of depression as it expands outward past the distance defined by the observation well. Therefore, data from this time are more likely to be representative of this near-well region of the aquifer than data from later times which represent the interaction of the "front" of the cone of depression as it expands outward

into portions of the aquifer further away (Butler, 1998). The best-fit, type-curve for the four-well-Theis analysis (Figure 87) indicates a transmissivity of 110,000 gpd/ft. As with the averaged-data plot, the best-fit curve match is biased toward the first 100 minutes of the test before boundaries or heterogeneities affected the data. The results of these two analyses are basically the same, with a mean (to two significant figures) of 120,000 gpd/ft. Calculated storativity values are $1.1x10^{-3}$ and $1.0x10^{-3}$, respectively, or an average rounded to one significant figure, of about $1x10^{-3}$.

Individual well data plots for Zones 1-4 for drawdown and recovery are shown in Figures 88-95 (pages 227 through 234). The individual values for the four zones vary, with low-end values of 87,000 and 92,000 gpd/ft for Zones 1 and 2 (respectively) and high-end values of 150,000 gpd/ft and 140,000 gpd/ft for Zones 3 and 4 (respectively). All four Theis analyses incorporate a no-flow (fault) boundary 1,500 ft from the pumped well. The plots for Zones 1 and 2 match the type curve. The derivatives fit the type cures supporting the applicability of the method. Theis curves for the shallower piezometers (3 and 4) only matched for the first 60 to 100 minutes into the test. After this time, the drawdowns increased significantly above the type curves, indicating either a bounded system or zones of much lower permeability acting as "discharge (no-flow) boundaries." The derivatives only match the type curve through about 30 to 40 minutes indicating that the Theis method is not valid after this time because of the boundary effects. The mean of these drawdown analyses was 120,000 gpd/ft, to two significant figures.

The apparent effects of low-permeability zones or no-flow boundaries within the aquifer are observed in the recovery analyses. These analyses indicate much lower transmissivities (compared with the drawdown analyses) ranging from a low of 24,000 gpd/ft for the shallowest piezometer (Zone 4) to 42,000 gpd/ft and 43,000 gpd/ft respectively for the deepest piezometers (Zones 1 and 2). These recovery analyses would typically indicate the "bulk" transmissivity of the aquifer, incorporating the heterogeneous nature of the aquifer with zones of higher and lower transmissivity. In contrast, the ratios of S/S' are greater than 1.0 for the shallow piezometers (Zones 3 and 4) suggesting a "recharge" source. At the same time, the pumping drawdowns greater than those predicted by the Theis type curve based on the early-time data suggest the opposite: a bounded system that would have S/S' ratios of less than 1.0. These apparent contradictions support the conclusion that the aquifer system is heterogeneous and does not match well with the simplified models envisioned for the analytical methods of analysis. The mean of these recovery analyses was 35,000 gpd/ft, to two significant figures.

The discrepancy between the drawdown and recovery analyses is significant. We believe that the effects of aquifer heterogeneity have affected the responses in the various depth-zones monitored at M3-TW #1. Because of the relatively good match between the mean of the pumping well analyses and the mean of the recovery analyses of the M3-TW #1 piezometers, we believe the recovery results may be more representative of the aquifer in the vicinity of the Kling Irrigation well.

Other Observation Well Analyses

The lack of measurable drawdowns in the other observation wells - M3-TW#2 (all zones), M3-TW #3 (all zones), SVR #7, SVR #9 and Flack Corral precluded analyses for transmissivity and storativity; no Aqtesolv® analyses were conducted.

Summary of Results

In summary, the Pierce Gulch Sand Aquifer in the region of the Kling Irrigation well is heterogeneous, with zones of higher and lower permeability. The representative transmissivity for the full thickness of the Pierce Gulch Sand Aquifer near the Kling Irrigation well is on the order of 39,000 gpd/ft. The storativity of the aquifer is around $1x10^{-3}$.

Verification of Aquifer Coefficients

The values for transmissivity and storativity derived from the test analyses were verified by comparing measured drawdowns with calculated drawdowns at the various wells monitored during the test. Small difference between the calculated and measured values of drawdown verified the analytical results. In our analysis we calculated theoretical drawdowns for three time intervals during the test (360, 1,440 and 3,000 minutes) using the Theis (1935) equation at distances of up to 22,000 feet which includes the various distances of all the measured wells. These curves are plotted on Figure 96 (page 235) along with actual measured drawdowns for the seven well sites. The analysis uses the aquifer coefficients calculated for the regions near the Kling Irrigation well (mean transmissivity of 39,000 gpd/ft and mean storativity of $1x10^{-3}$).

The graph shows that the theoretical and actual values agree well in all of the observations wells. In other words, using the aquifer coefficients derived from the Kling test to model the expected affect to the other wells monitored during this test, tells us that, except for the pumped well and M3-TW #1, we should not expect any effects because the other wells are located too far from the pumping center to show any measurable response at any of the three time intervals; theoretical and actual levels are all close to zero. Only the closest observation well, M3-TW #1 is theoretically close enough to show a response. The actual values for the composite draw downs of Zones 1-4 and calculated values match with a mean error of 0.39 feet, or about 6 percent.

The actual and the calculated theoretical drawdowns for the pumped well differ by about 46 feet. We believe that much of this 46 feet difference is attributable to well loss caused by the frictional loss in head from turbulent flow through the inefficient well construction and the partially-clogged well screen. This value of 46 ft is relatively close to the estimated well loss of 40 ft used our analyses above. The nearly instantaneous decline in water level just after pumping started and the almost immediate rise in water level just after pumping stopped support this conclusion.

The calculated drawdowns for the average drawdown at a distance comparable to M3-TW #1 only match the measured data when the values derived from the pumping well analysis are used in the prediction. When the higher transmissivity values derived from the analyses of M3-TW#1 data are used, a smaller drawdown is calculated. Since the Aqtesolv® analyses used to generate a curve match required the use of a fault acting as a no-flow boundary, and because other subsurface geophysical mapping by HLI suggests a buried fault trace, it appears likely that such a fault may be present in the vicinity of the Kling well and that it may control ground water movement in the aquifer to some extent.

Comparison with Other Regional Aquifer Tests

The results of the pumping test analyses indicate that the Pierce Gulch Sand Aquifer in the vicinity of the Kling Irrigation well may be significantly lower in transmissivity than it is at other locations both to the south and northeast. The calculated value of 39,000 gpd/ft is about 13 percent of the value calculated for a previous test of SVR #7 (transmissivity of about 300,000 gpd/ft or more), 9,900 feet to the northeast and about 20 percent of those calculated for some of the large production wells recently drilled in the Valley about 3 miles to the south and east, in the Eagle and Star area (Figure 98, page 251). However, we believe that the actual value for the aquifer in the vicinity of the Kling Irrigation well may be higher than the calculated 39,000 gpd/ft based on of uncertainty in the test data resulting from the construction of the Kling Irrigation well.

There is an element of uncertainty in the results of the Kling Irrigation aquifer test for two reasons. The first is the relative position of the well in the aquifer. The second is the degree of plugging of the well screen in the Kling Irrigation well. Table 1 shows that the intake for the Kling Irrigation well is open between elevations of 2,207 and 2,417 ft amsl while the regional aquifer at nearby M3-TW #1 lies at 2,012 to 2,287 ft amsl, as revealed in careful geological and geophysical logging. Since the wells are located about 1,050 feet from each other and because the Pierce Gulch Sand Aquifer is believed to slope at about 100 feet per mile to the southwest at this location, the aquifer should only be about 20 feet higher at the Kling well than it is at TW #1. Yet the Well Driller's Report for the Kling Irrigation well indicates it is completed in about the top 100 feet of what should be the Pierce Gulch Sand Aquifer and about 100 feet of some overlying zone.

This well construction suggests that the driller may have been unable to place the well screen assembly where he had originally planned. We speculate that the borehole began to collapse before the screen was installed and that, rather then pull the too-high screen, re-drill the hole and reinstall the screen (and bear the costs of these activities), the driller decided to leave the screen at a position 100 feet higher than planned. The partially-open borehole may also help to explain why the deeper zones of the aquifer at M3 TW #1 responded so quickly to pumping; the cone of depression produced by the pumping well did not have to pass downward through the shallow zones before it could move out laterally through the deep zones. Rather, the partially open borehole acted as a conduit connecting deeper portions of the aquifer to the shallower portions, allowing the cone of depression to pass simultaneously outward through all zones of the aquifer.

This unusually high placement of the well screens, coupled with the observed down-hole plugging in the well screens (observed through camera inspection that revealed that the louvered well screen is plugged at many locations), casts some uncertainty that the calculated transmissivity accurately represents a true value for the Pierce Gulch Sand Aquifer at this location. Normally a pumping well completed in only part of the aquifer (partial penetration) can be addressed when the observation well is sufficiently far from the pumped well (as is M3-TW#1). As discussed above however, the heterogeneity of the aquifer makes partial penetration effects difficult to accurately address. A better way to accurately know the overall aquifer coefficients in the area of the Kling Irrigation well would be to conduct a test with a new well that is properly designed and completed to tap the entire thickness of the aquifer. Such a well would give better representative values of transmissivity for the Pierce Gulch Sand Aquifer. Even with the inefficient well construction of the Kling Irrigation well, the derived storativity value appears typical of other short-term tests conducted on wells completed in the Pierce Gulch Sand Aquifer.

Well Interference and the Effects of Seasonal Pumping

Well interference effects from continuous pumping of the Kling well, or any supply well at this location, are calculated (and anticipated) to be small as the following analysis demonstrates. Two different values for transmissivity and storativity were used in two simulations to predict inference effects of a hypothetical well completed in the Pierce Gulch Sand Aquifer, at distances of almost 4 miles from the pumping well (Figure 97, page 236). In these simulations, the Theis method was used to generate a drawdown curve as a function of distance from pumping the general region of Kling Irrigation well for a properly designed and constructed replacement well at 1,000 gpm. In addition, an image well was placed to the north of the line representing the no-flow boundary to simulate its effects. The use of a no-flow boundary may be conservative as this portion of the aquifer is believed to be unconfined and, as such, may actually act more like a positive (recharge) boundary in how it affects water level changes caused by pumping. The mean calculated transmissivity of 39,000 gpd/ft and mean calculated storativity of $1x10^{-3}$ were used as one end point in the analysis. These values assume the results of the Kling well test accurately represent the Pierce Gulch Sand Aquifer near the Kling Irrigation well area.

A second endpoint was used to bracket the predicted interference drawdowns. Since other tests in the greater M3-Eagle area have indicated much larger values (such as the SVR #7 test which indicated a transmissivity of 300,000 gpd/ft), we have conducted our analysis using a transmissivity of 200,000 gpd/ft, a value that better represents the mean (to one significant figure of the Pierce Gulch Sand Aquifer tests.

The two curves represent a worst-case (Kling Irrigation test values) and a better-case (mean values) believed to be more representative of actual overall aquifer conditions. The actual interference-drawdown that would occur is likely to fall between the two curves shown in Figure 97.

The analysis shows that at the end of a 90-day summer pumping season, where the new well would be pumped continuously at a discharge rate of 1,000 gpm, interference draw downs in the range of 4 to 14 feet are predicted for wells completed in the Pierce Gulch Sand Aquifer one mile away from the well site and on the order of 3 to 12 feet up to 2 miles away. These analyses are conservative and are likely to over-estimate the actual interference that would occur under such conditions. In our view, the drawdown cone of depression from the pumping well would probably expand sufficiently to capture recharge (flow within the aquifer) before 90 days of continuous pumping. When the amount of captured recharge equals the pumping rate, drawdown caused by pumping in the well remains constant (and therefore "stabilizes"[26]). The Theis analytical method assumes no recharge, that water pumped by a well only comes from aquifer storage and that a pumping-well water-level never stabilizes. In reality (and observed many times, in our experience) the pumping induced drawdown in a well pumped for 90 days in a regional aquifer like that underlying the M3 Eagle area, typically "stabilizes" before 90 days. In addition, the portions of the aquifer away from the pumped well and toward the edge of the aquifer (near the green line on Figure 80) are unconfined. These regions would partially dewater under long-term pumping, supplying more water to the pumped well, in effect allowing for a much larger storage coefficient and therefore less drawdown than that calculated in this analysis.

Conclusions

Based on the overview and analysis presented above, we make the following conclusions:

1. The Kling Irrigation well is completed in the upper 109 feet of the Pierce Gulch Sand Aquifer which is about 275 feet thick at this location.

2. The already small open-area of the well screen in the Kling Irrigation well is significantly and irreversibly clogged, is subject to sand production, and is not suitable for long-term use as a regional supply well The Kling Irrigation well is poorly documented, poorly designed, and poorly constructed of marginal materials. Since the well was completed 19 years ago, a general deterioration of the well allowed by the marginal materials and caused partly by the inefficient design, has resulted in reduced well efficiency and yield. The proportion of water derived from various parts of the screen (and therefore the aquifer) is not known. The partial clogging of the well screen renders this analysis, and any future analysis, for aquifer coefficients uncertain.

3. The results of the Kling Irrigation well test indicate that high-capacity wells capable of yields of 1,000 to 2,000 or more are feasible on the M3 Eagle property. Indeed, high yield wells, (for example the Kling Irrigation well itself, albeit flawed), already exist on the property. We estimate that yields of 2,000 gpm or

[26] The pumping-induced drawdown in the aquifer remains constant but the water level in the well can still vary under the influence of regional water-level trends, changes in barometric pressure, changes in well loss caused by development or changes in the well screen and/or filter pack, and pumping in other wells.

more could be achieved from properly constructed fully penetrating wells on the M3 Eagle property.

4. Analyses of the pumped well data indicate the transmissivity of the Pierce Gulch Sand Aquifer near the Kling Irrigation well site may be on the order of 39,000 gpd/ft.

5. The transmissivity values derived from the analysis of the Kling Irrigation well aquifer test data are believed to be lower than actual. Because of problems related to well construction that may have led to erroneously small values for transmissivity (through incorrect partial penetration corrections), and because of much higher transmissivity values reported northeast and south of the Kling Irrigation well (300,000gpd/ft and more), we believe that the aquifer in the vicinity of the Kling Irrigation well either a) shares the higher transmissivities calculated for the aquifer from adjacent wells or b) that the Kling Irrigation well is completed into an anomalous and localized lower-permeability portion of the aquifer.

6. The mean storativity of the aquifer in the vicinity of the Kling well is calculated to be $1x10^{-3}$.

7. Well interference effects from high-yield pumping wells in the vicinity of the Kling Irrigation well (or from the Kling Irrigation well itself), are calculated to be relatively small. Using a lower-end transmissivity indicated from the test of 39,000 gpd/ft and an upper-end transmissivity of 200,000 gpd/ft, the storativity calculated during the test ($1x10^{-3}$), and an image well to simulate the no-flow boundary of the edge of the aquifer, two simulations were conducted to predict impacts from summer-long pumping at 1,000 gpm from a properly designed production well, on wells completed in the Pierce Gulch Sand Aquifer. The simulation indicated interference drawdowns on the order of 4 to 14 feet, at a distance of one mile from the well, and 3 to 12 feet, two miles from the well. Because these predictions bracket the likely range of aquifer parameters, the actual interference is likely to fall between these end-points of the ranges.

8. A properly designed and constructed high capacity well (1,000 to 2,000 gpm) and a pumping test lasting at least a week or more would be needed to better characterize the nature of the aquifer beneath the M3 site.

9. The barometric efficiencies of wells completed in the lower portion of the Pierce Gulch Sand Aquifer in the M3 Eagle vicinity are high, typically greater than 80 percent. The barometric efficiency in the upper portions is lower, but still relatively high. The high barometric efficiency suggests that the aquifer is partially cemented in its upper portions and highly cemented in its lower portions.

10. The value of the Kling Irrigation well test is limited because of poor design and/or construction of the pumping well and the relatively short duration of the test. The

test, however, does indicate the high productivity of the Pierce Gulch Sand Aquifer and the relatively small interference effects that a properly-designed-and-constructed, high-capacity production-well would have at this location. When a high-capacity production-well is constructed at this location, we believe it would be valuable to test it through at least one week of pumping while using the M3 TW #1 through #4 test wells along with SVR #7 and SVR #9 for monitoring. All wells monitored during the test should have barometric efficiency calculated and pretest and post test data collected to allow for the removal of water level changes not caused by the pumping well.

Table 1. Data for Wells Monitored During Kling Irrigation Well Test

Well Name	Aquifer Zone	Distance to Kling	Ground Elev.	Screen					Aquifer Elevation**		Pre-Test Water Level		Draw down: End of Test	Baro-metric Efficiency
				Length	Depth		Elevation							
					Top	Bottom	Top	Bottom	Top	Bottom	Depth	Elevation		
		ft	ft asl	ft	ft		ft asl		ft asl		ft bgl	ft asl	ft	percent
Kling Irrigation	-	0	2615	210	198	408	2417	2207	2315	2040	95.42	2519.58	94.39	-
TW#1	Composite***	1050	2612	204	352	556	2260	2056	2287	2012	90.23	2521.77	8.95	na
	1	1050	2612	42	514	556	2098	2056	2287	2012	88.72	2523.28	6.45	77%
	2	1050	2612	40	468	508	2144	2104	2287	2012	88.76	2523.24	6.76	84%
	3	1050	2612	30	396	426	2216	2186	2287	2012	91.44	2520.56	10.73	52%
	4	1050	2612	30	352	382	2260	2230	2287	2012	92.00	2520.00	11.84	52%
	5	1050	2612	40	98	138	2514	2474	2287	2012	90.13	2521.87	0	98%
TW#2	1	13,350	2785	50	270	320	2515	2465	2690	2415	213.53	2571.47	0	100%
	2	13,350	2785	20	230	250	2555	2535	2690	2415	213.71	2571.29	0	100%
TW#3	1	10,275	2769	10	432	442	2337	2327	2559	2284	258.19	2510.81	0	90%
	2	10,275	2769	20	399	419	2370	2350	2559	2284	258.31	2510.69	0	78%
	3	10,275	2769	10	369	379	2400	2390	2559	2284	258.36	2510.64	0	89%
	4	10,275	2769	20	334	354	2435	2415	2559	2284	258.53	2510.47	0	80%
	5	10,275	2769	20	238	258	2531	2511	2559	2284	Dry	Dry	Dry	Dry
SVR#7	-	9,900	2716	70	280	350	2436	2366	2455	2180	160.19	2555.81	0	95%
SVR#9	-	20,700	2758	28	235	263	2515	2487	2665	2390	193.95	2556.05	0	100%
"Flack Corral"	-	16,575	2768	151	249	400	2511	2360	2685	2410	210.25	2549.75	0	100%

*Note: Distance based on GPS coordinates. Accuracy estimated to 25 feet.

**Note: Aquifer elevation based on contour map in HLI, 2007 and geophysical logs indicating approximate aquifer thickness of 275 feet.

***Note: The "composite" well represents a mean of the zones that responded during the test (1-4), representing an equivalent well open to the entire interval represented by zones 1-4.

Table 2. Summary of Kling Irrigation Test Aquifer Analyses

Well Name	Zone	Method of Analysis	Figure No.	T gpd/ft	S (-)	S/S'	Boundary Type	Boundary Dist. ft	Comments
Kling Irrigation	3, 4, above	Theis	83	29,000	-		None		Poorly developed, partial penetrating, top of screen in aquitard? With partial penetration and well loss corrections.
		Cooper-Jacob	84	36,000	-		None		Without partial penetration (Butler), T = 20,000 gpd/ft .
		Recovery	85	45,000	-	1.2			S/S' indicates "early" recovery / recharge source? Partial penetration (Butler) corrections applied.
TW#1	Comp. of 1-4	Theis - Mean 4 wells	86	140,000	1.1E-03		None		Best fit to mean of water levels measured in each of four zones, for each minute of data collection.
		Theis Best-fit to 4 data sets	87	110,000	1.0E-03	1.1	Many		Best fit by Aqtesolv to early-time data on four-well plot
TW#1	1	Theis	88	87,000	1.0E-03		No-flow	1,500	In deeper potion of Regional Aquifer - Much deeper than pumping well
		Recovery	89	42,000		1.0			S/S' indicates "normal" recovery
TW#1	2	Theis	90	93,000	7.2E-04		No-flow	1,500	In deeper potion of Regional Aquifer - Much deeper than pumping well
		Recovery	91	43,000		1.0			S/S' indicates "normal" recovery
TW#1	3	Theis - early time	92	150,000	1.0E-03		No-flow		Top of zone equals bottom of pumped zone. Add'l boundaries needed to match data?
		Recovery	93	30,000		1.1			S/S' suggests slight "early" recovery / recharge source?
TW#1	4	Theis - early time	94	140,000	3.0E-03		No-flow		Overlaps bottom of pumped zone. Add'l boundaries needed to match data?
		Recovery	95	24,000		1.2			S/S' indicates "early" recovery / recharge source?
TW#1	5								
TW#2	all								
TW#3	all								
SVR#7	-								
SVR#9	-								
Flack Corral	-								

None of these wells indicated detectible drawdown during the test.

No analysis was possible.

	T (gpd/ft)	S (-)	S/S' (-)
Average of All responding zones:	75,000	1.3E-03	
Average of All recovery analyses:	31,000		1.1
Average of TW#1 Composites:	130,000	1.1E-03	
Average of TW#1 (individual wells):	80,000	1.0E-03	

NOTE: All results presented to 2 significant figures.

Figure 80. Well Locations for Kling Irrigation Two Day Test

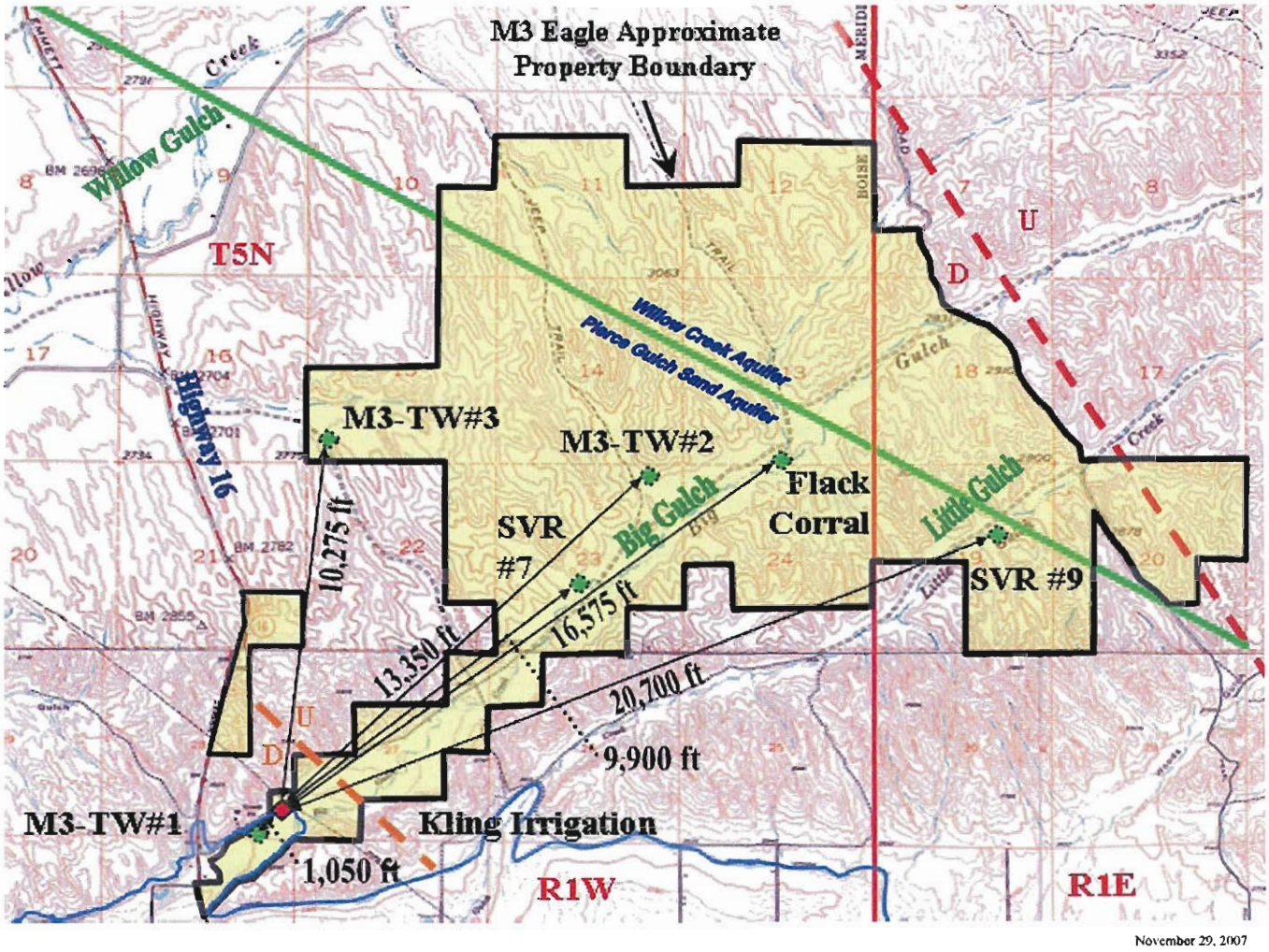


Figure 81. Kling Irrigation Well Barometric Efficiency Corrected Drawdown

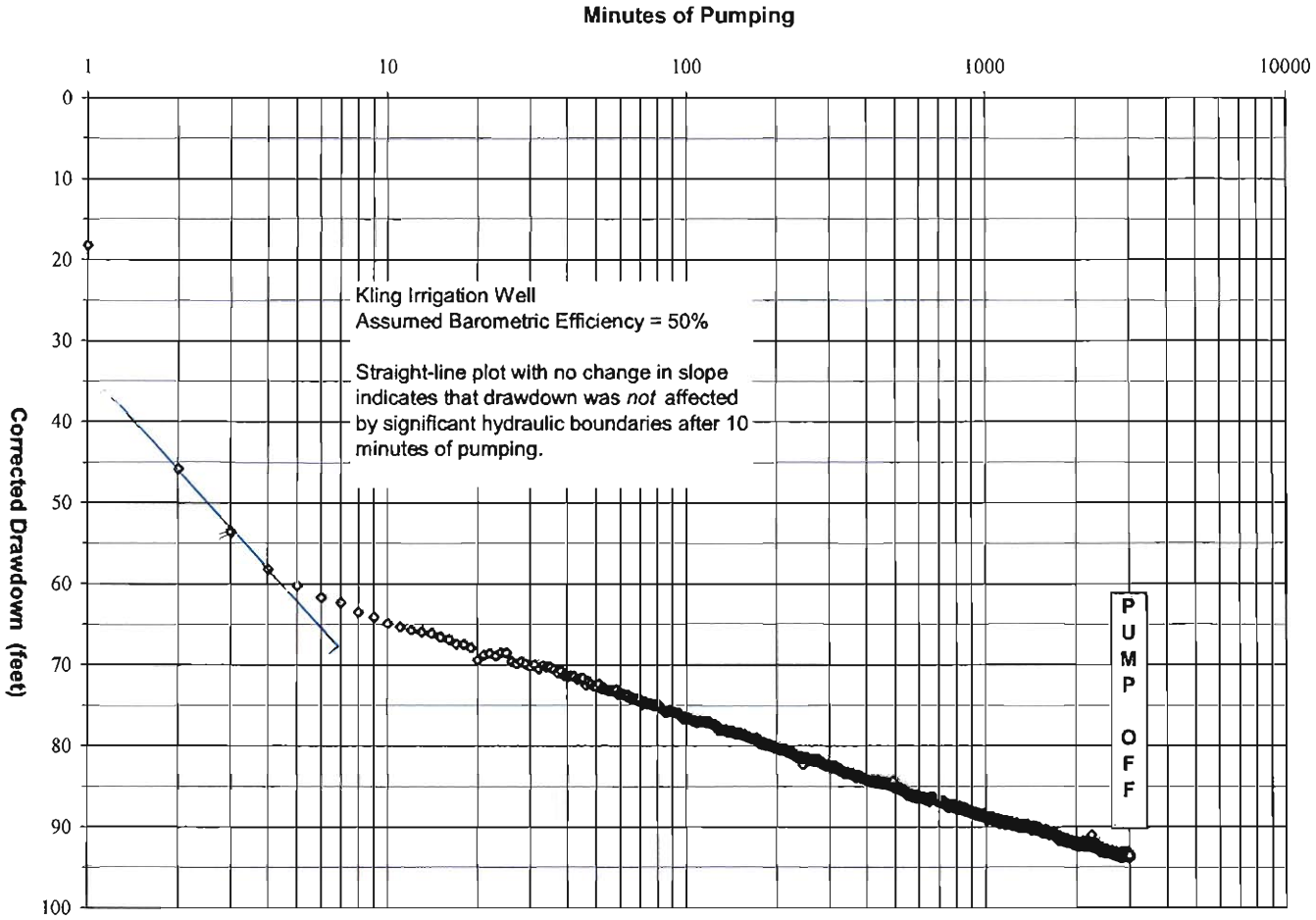


Figure 82. M3 TW#1 Barometric Efficiency Corrected Drawdown

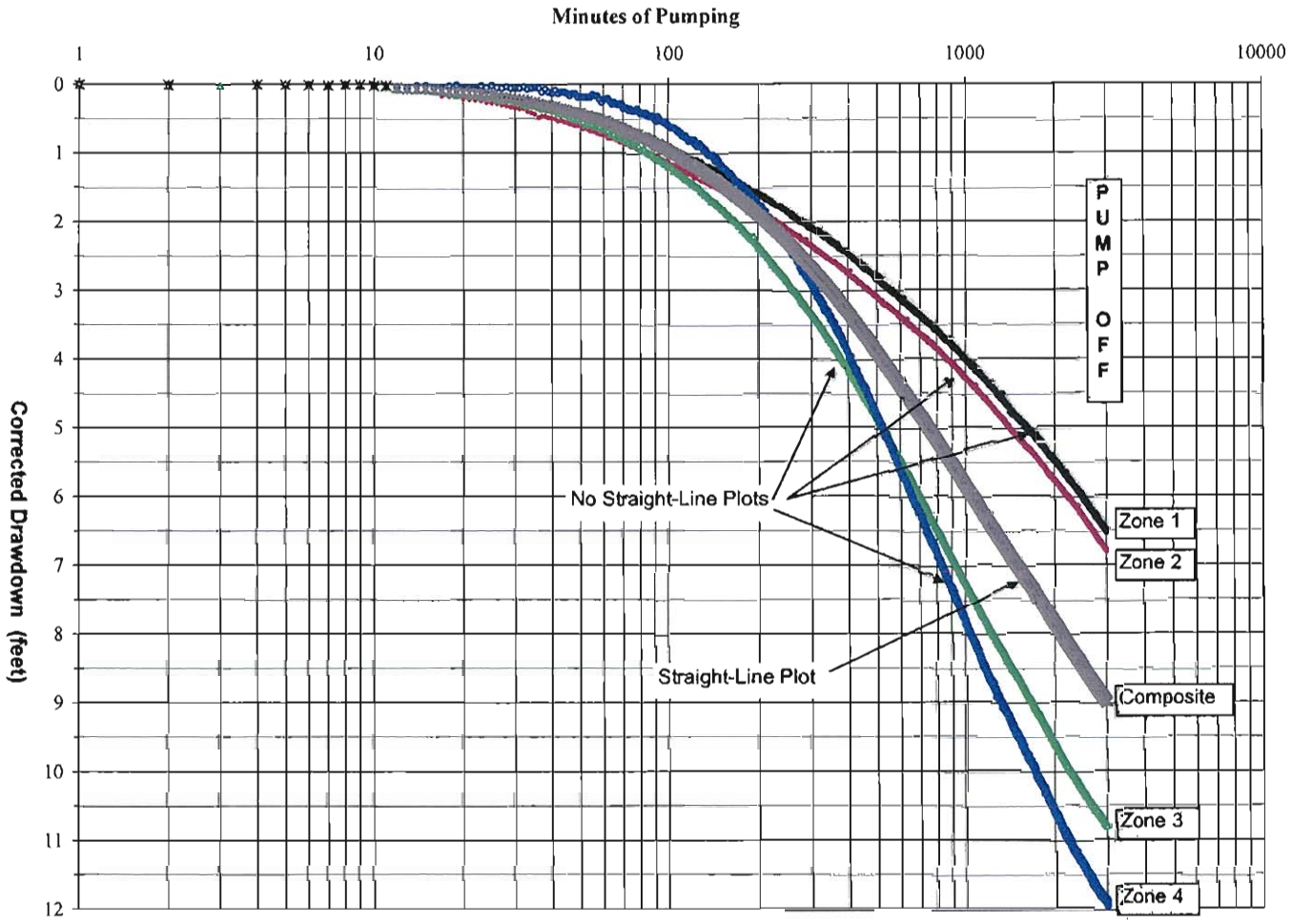
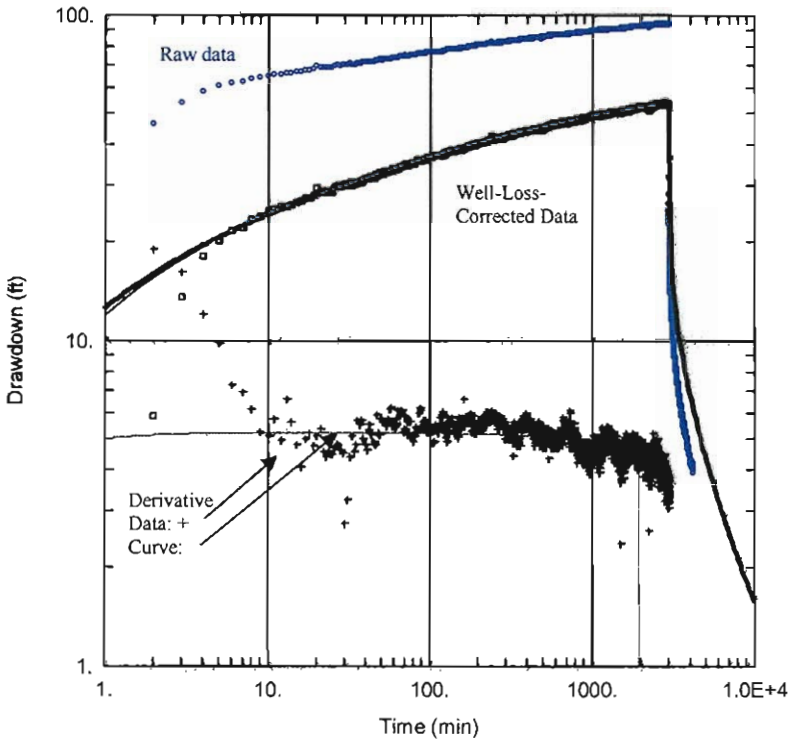


Figure 83. Theis Analysis for Pumping Well – Kling Irrigation 2-Day Test
Test Conducted: January 9-11, 2007



Kling Irrigation Well
Screen = 198-408 ft
T= 29,000 gpd/ft (raw data)
T= 37,000 gpd/ft (well loss removed)
S Not Calculable
Kv/Kh = 0.1
b ≈ 240 ft
r = 0.67 ft
Max Well Loss (est) **= 40 ft**
Q = 900 gpm

Good data fit after five minutes of pumping. Theis model appears representative. Analysis with estimated maximum well loss is 24 percent larger than analysis without. Analysis includes Hantush partial penetration corrections. Analyses without (not shown) indicate T values 30 percent smaller. Analysis with fault (no-flow boundary) at 1,500 ft.

Derivative analysis supports method after 8 minutes. Decrease in derivatives after 1,000 minute suggest influence of zones of higher transmissivity. The corresponding flattening of the drawdown curve cannot be seen on a log-log plot because of the compression of the vertical scale.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

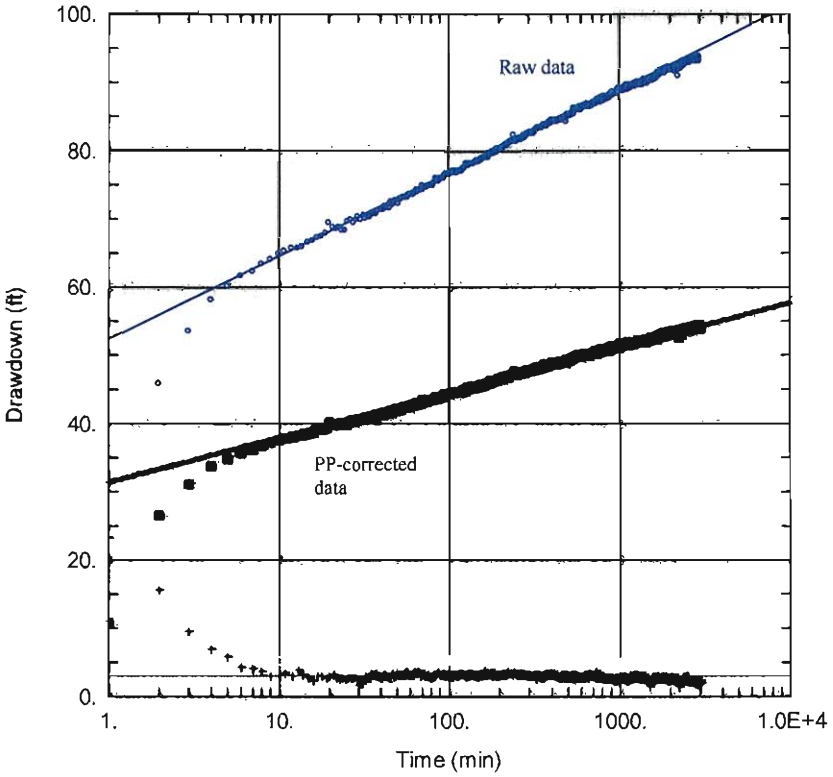
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935) with partial penetration corrections of Hantush (1961 a and b).

Figure 84. Cooper-Jacob Analysis for Pumping Well – Kling Irrigation 2-Day Test
Test Conducted: January 9-11, 2007



Kling Irrigation Well
Screen = 198-408 ft
T= 20,000 gpd/ft
(raw data)
T=36,000 gpd/ft
(with PP corrections)
S = Not Calculable
Kv/Kh=0.1
b ≈ 240 ft
t_c < 1 min
r = 0.67 ft
Q = 900 gpm

Partial penetration correction makes calculated T for whole-aquifer thickness about 75 percent greater than calculated value without PP correction. Transmissivity with PP correction agrees well with Theis analysis using well loss correction.

Derivative analysis supports method after 8 minutes. Decrease in derivatives after 1,000 minute suggest influence of zones of higher transmissivity. The corresponding slight flattening of the drawdown curve can be seen.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid

$u = 1.87r^2S/Tt$
t = time in days
r = effective radius of pumping well (ft)

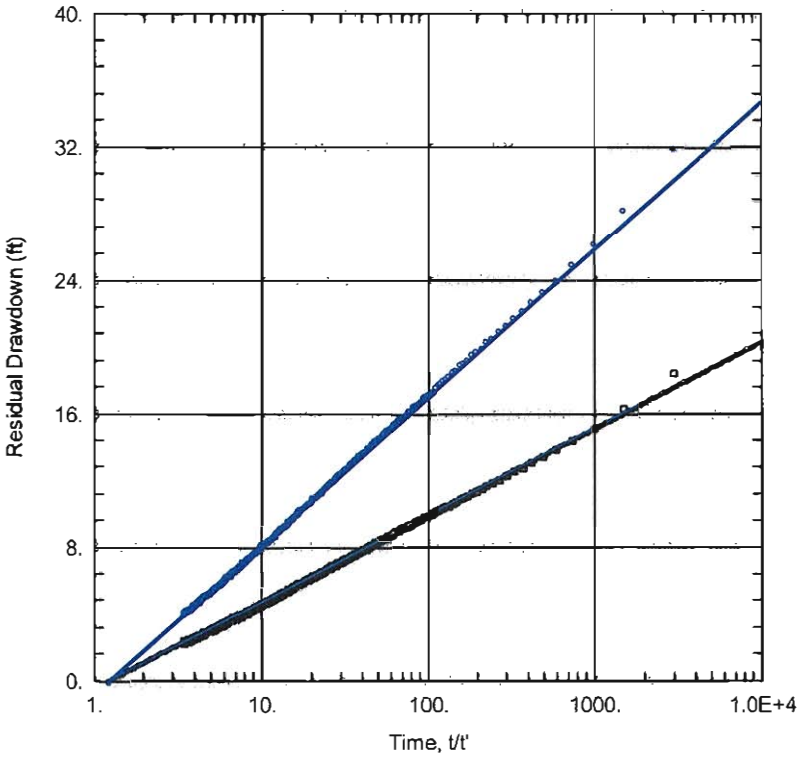
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

$s_{pp} = 0.58\ s_{observed}$ where:

s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Based on the analytical method of Cooper and Jacob (1946).
Partial penetration corrections from Butler (1957).

Figure 85. Recovery Analysis for Pumping Well – Kling Irrigation Two-Day Test
Test Conducted: January 9-11, 2007



Kling Irrigation Well
Screen = 198-408 ft
T=27,000 gpd/ft
(uncorrected data)
T=45,000 gpd/ft
(with PP corrections)
S/S' =1.2
Kv/Kh = 0.1
b ≈ 240 ft
r = 0.67 ft
Q = 900 gpm

Good recovery data fit. Theis recovery model appears representative. S/S' ratio of greater than 1 ("early" recovery) implies a recharge source; in this case, more transmissive portions of the aquifer are likely.

Partial penetration correction makes calculated T for whole-aquifer thickness about 2/3 greater than calculated value without PP correction.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

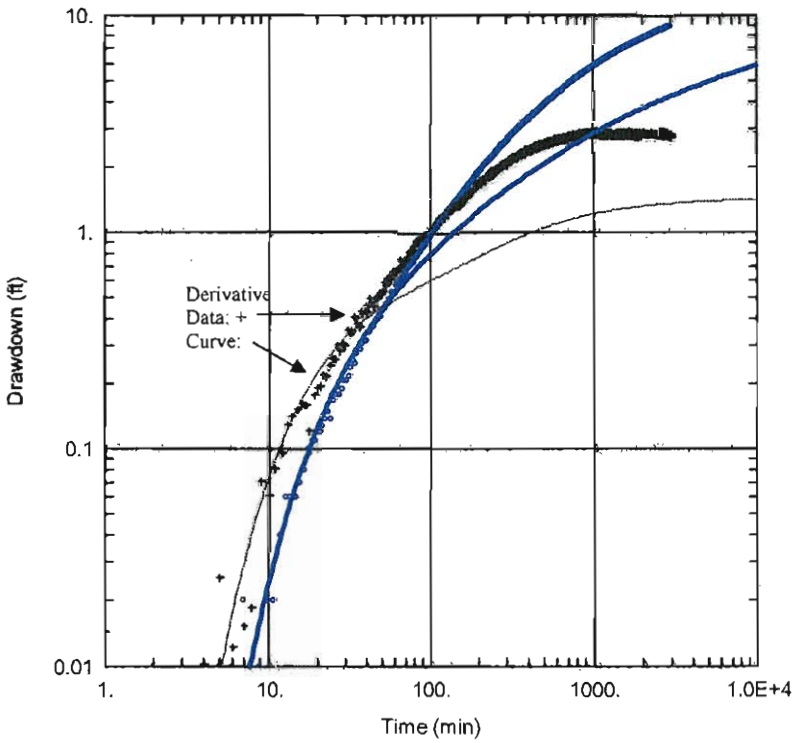
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from well logs in the area
r = effective radius of pumping well (ft)

$s_{pp} = 0.58\ s_{observed}$ where:

s_{pp} = Drawdown corrected for partial penetration
$s_{observed}$ = observed drawdown

Based on the analytical method of Theis (1935).
Partial penetration corrections from Butler (1957).

Figure 86. Theis Analysis for TW#1 Mean – Kling Irrigation 2-Day Test
Test Conducted: January 9-11, 2007



Test Well #1
Mean of Zones 1 - 4
Screens = 353-556 ft
T= 140,000 gpd/ft
S= 1.1×10^{-3}
Kv/Kh = 0.1
b = 240 ft
r = 1,050 ft
Q = 900 gpm
(at Kling Irrigation well)

Fit biased toward first 80 min of pumping. Good fit for first 80 minutes of test – Model with average (mean) of drawdowns in four wells gives reasonable approximation of aquifer behavior. Unaccounted for boundary effects after 100 minutes.

Model includes no-flow boundary (fault) at 1,500 ft from pumping well.

Derivative type curve fit only approximate through 40 minutes indicating transmissivity analysis is only approximate.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

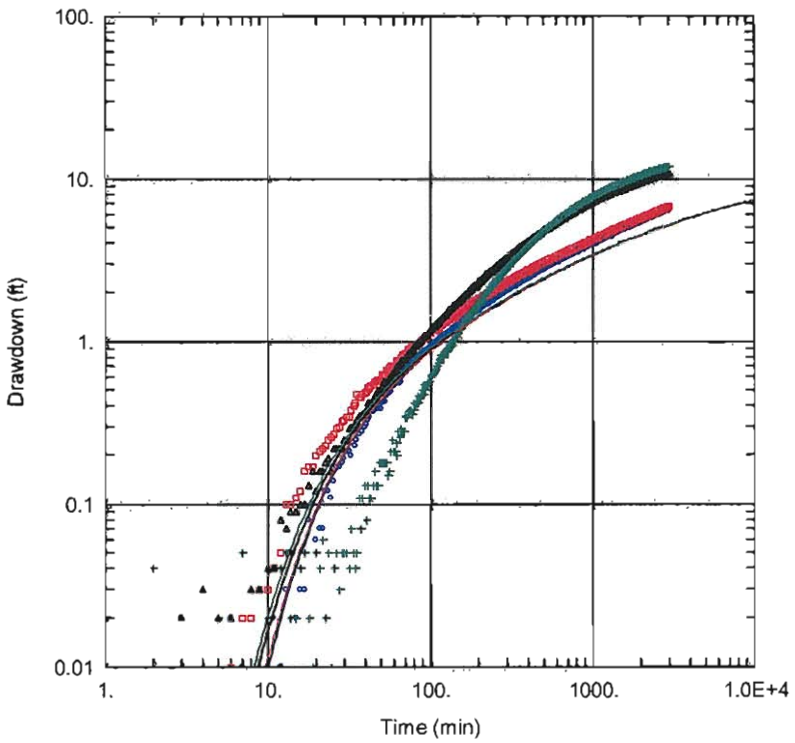
$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 87. Theis Analysis for TW#1 Composite – Kling Irrigation 2-Day Test
Test Conducted: January 9-11, 2007



Test Well #1
Best fit for Zones 1 - 4
Screens = 353-556 ft
T_{ave} = 110,000 gpd/ft
S_{ave} = $1.0x10^{-3}$
Kv/Kh = 0.1
b = 240 ft
r = 1,050 ft
Q = 900 gpm
(at Kling Irrigation well)

Fit biased toward first 100 min of pumping. Only approximate fit – Model with best-fit for all four wells gives approximation of aquifer behavior. Unaccounted for boundary effects after 100 minutes.
Model includes no-flow boundary (fault) at 1,500 ft from pumping well to achieve best fit.

o Zone 1 □ Zone 2
△ Zone 3 + Zone 4

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

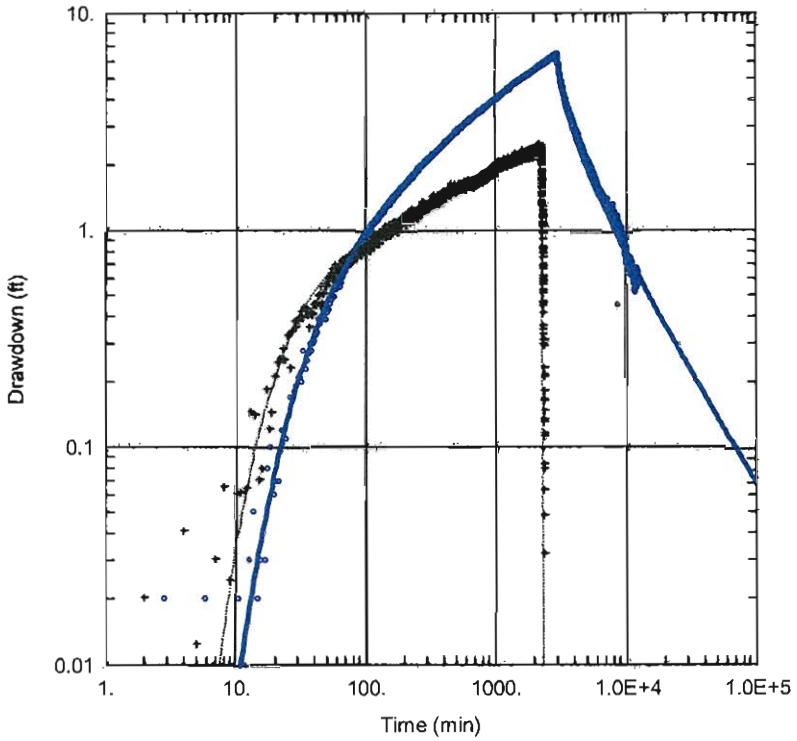
$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 88. Theis Analysis for TW#1 Zone 1 – Kling Irrigation Two-Day Test
Test Conducted: January 9-11, 2007



Test Well #1 Zone 1
Screen = 514-556 ft
T=87,000 gpd/ft
S=1.0x10^{-3}
Kv/Kh = 0.1
b = 240 ft
r = 1,050 ft
Q = 900 gpm
(at Kling Irrigation well)

Best fit with no-flow boundary 1,500 ft to northeast of pumping well.

Derivative analysis supports method. Good fit throughout entire test period.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

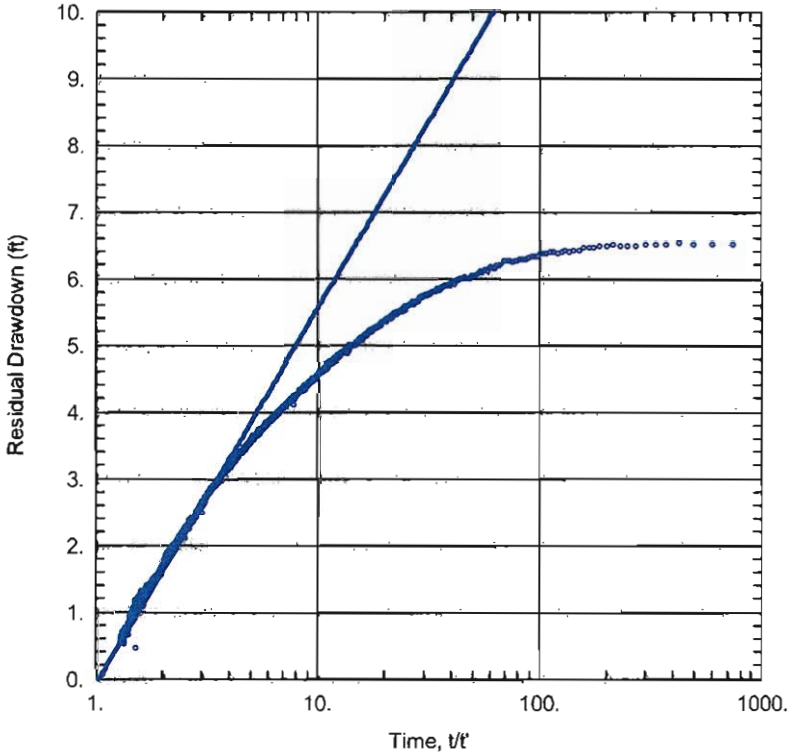
W(u) = 1.87r^{2}S/Tt Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 89. Recovery Analysis for TW#1 Zone 1 – Kling Irrigation Two-Day Test
Test Conducted: January 9-11, 2007



Test Well #1 Zone 1
Screen = 514-556 ft
T= 42,000 gpd/ft
S/S' = 1.0
Kv/Kh = 0.1
b = 240 ft
r = 1,050 ft
Q = 900 gpm
(at Kling Irrigation well)

S/S' = 1 indicates normal recovery.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

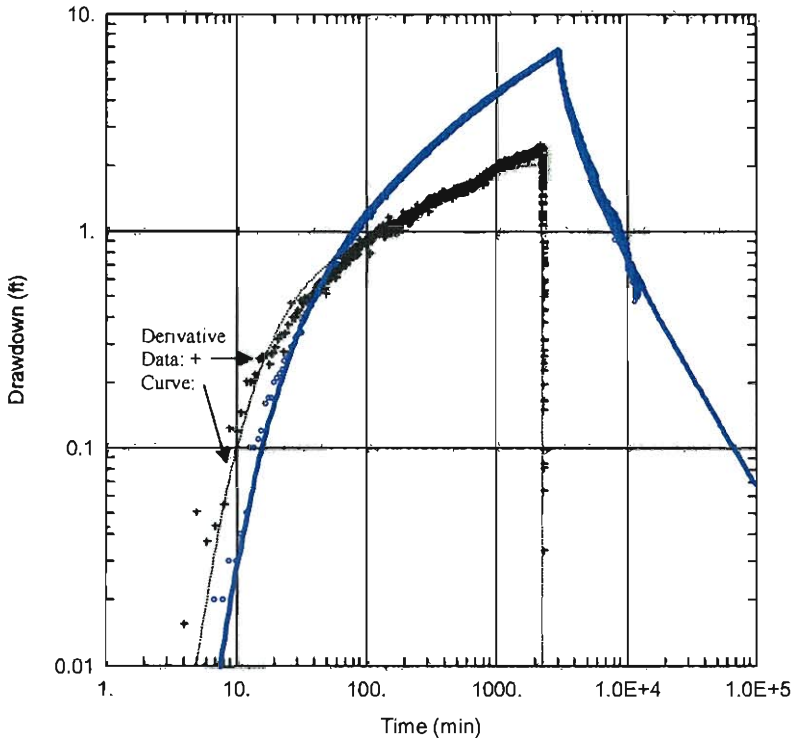
t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
r = distance from pumping well (ft)

Based on the analytical method Theis (1935).

Figure 90. Theis Analysis for TW#1 Zone 2 – Kling Irrigation Two-Day Test
Test Conducted: January 9-11, 2007



Test Well #1 Zone 2
Screen = 467-507 ft
T=93,000 gpd/ft
S=7.2x10^{-4}
Kv/Kh = 0.1
b = 240 ft
r = 1,050 ft
Q = 900 gpm
(at Kling Irrigation well)

Best fit with no-flow boundary 1,500 ft to northeast of pumping well

Derivative analysis supports method. Reasonable fit throughout entire test period.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

W(u) = 1.87r^{2}S/Tt Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

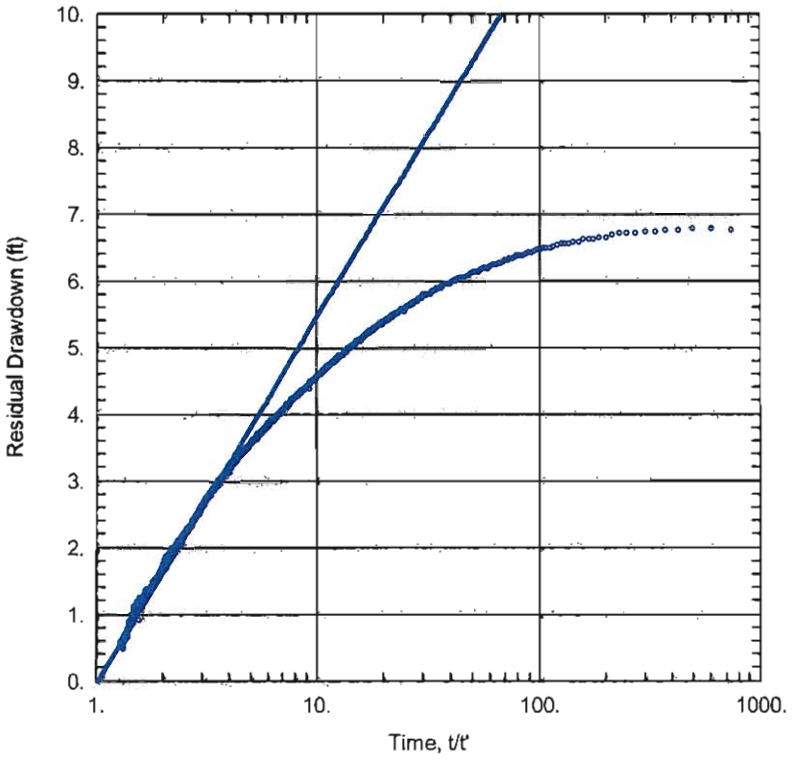
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 91. Recovery Analysis for TW#1 Zone 2 – Kling Irrigation Two-Day Test
Test Conducted: January 9-11, 2007



Test Well #1 Zone 2
Screen = 467-507 ft
T= 43,000 gpd/ft
S/S' = 1.0
Kv/Kh = 0.1
b = 240 ft
r = 1,050 ft
Q = 900 gpm
(at Kling Irrigation well)

S/S' = 1 indicates normal recovery.

T = 264Q/Δs Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

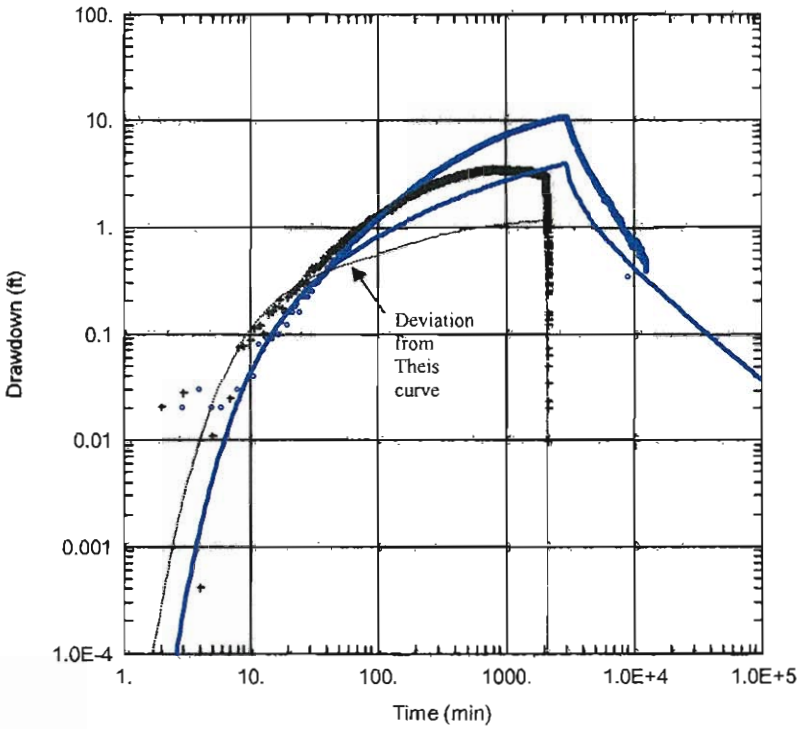
t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Vertical to horizontal ratio of permeability (unitless), estimated from well logs in the area
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
r = distance from pumping well (ft)

Based on the analytical method of Theis (1935).

Figure 92. Theis Analysis for TW#1 Zone 3 – Kling Irrigation Two-Day Test
Test Conducted: January 9-11, 2007



Test Well #1 Zone 3
Screen = 395-425 ft
T=150,000 gpd/ft
S=1x10^{-3}
Kv/Kh = 0.1
b = 240 ft
r = 1,050 ft
Q = 900 gpm
(at Kling Irrigation well)

Poor fit after 60 minutes. Multiple boundaries / variations in transmissivity suggested. Modeled with no-flow boundary at 1,500 ft. Theis model only approximates aquifer.

Derivative type curve fit good for first 40 minutes, only. Method not valid after 40 minutes.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
$W(u)$ = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

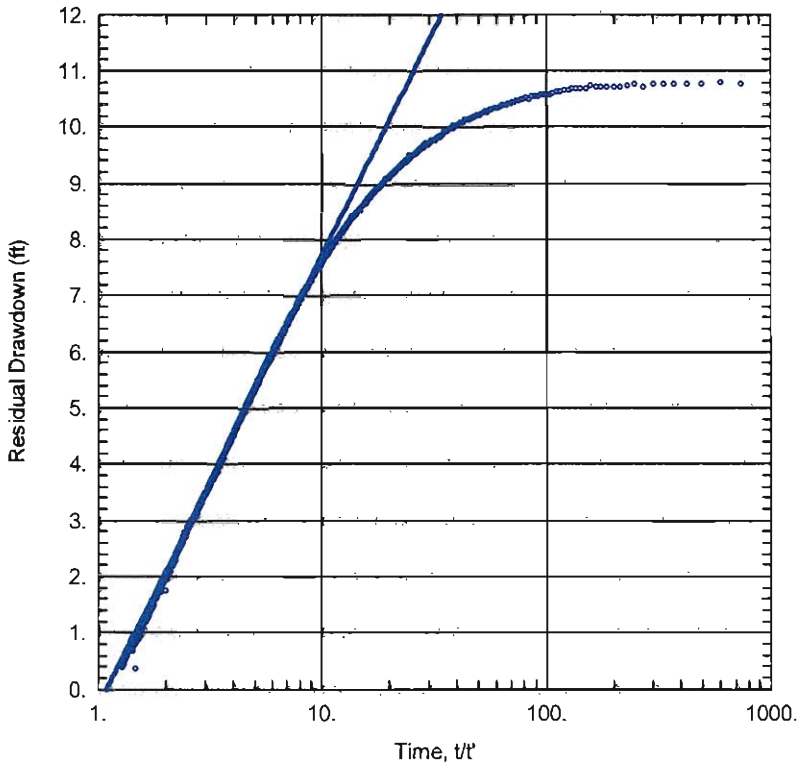
Kv/Kh = Vertical to horizontal ratio of permeability (unitless), estimated from well logs in the area

b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935).

Figure 93. Recovery Analysis for TW#1 Zone 3– Kling Irrigation Two-Day Test
Test Conducted: January 9-11, 2007



Test Well #1 Zone 3
Screen = 395-425 ft
T= 30,000 gpd/ft
S/S' = 1.1
Kv/Kh = 0.1
b = 240 ft
r = 1,050 ft
Q = 900 gpm
(at Kling Irrigation well)

Appears to be good recovery data fit. Theis recovery model appears representative. S/S' ratio of greater than 1 ("early" recovery) implies a recharge source; in this case, more transmissive portions of the aquifer are the likely source.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

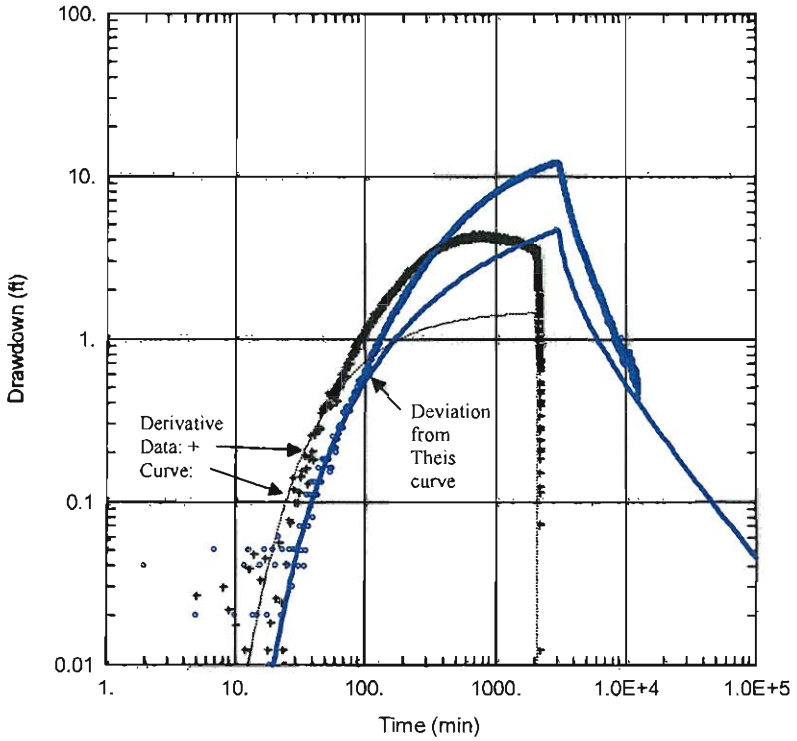
t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Vertical to horizontal ratio of permeability (unitless), estimated from well logs in the area
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
r = distance from pumping well (ft)

Based on the analytical method of Theis (1935).

Figure 94. Theis Analysis for TW#1 Zone 4 – Kling Irrigation Two-Day Test
Test Conducted: January 9-11, 2007



Test Well #1 Zone 4
Screen = 353-383 ft
T = 140,000 gpd/ft
S = $3x10^{-3}$
Kv/Kh = 0.1
b = 240 ft
r = 1,050 ft
Q = 900 gpm
(at Kling Irrigation well)

Poor fit after 100 minutes. Multiple boundaries / variations in transmissivity suggested. Modeled with no-flow boundary at 1,500 ft. Theis model only approximates aquifer.

Derivative type curve fit good for first 40 minutes, only. Method not valid after 40 minutes.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

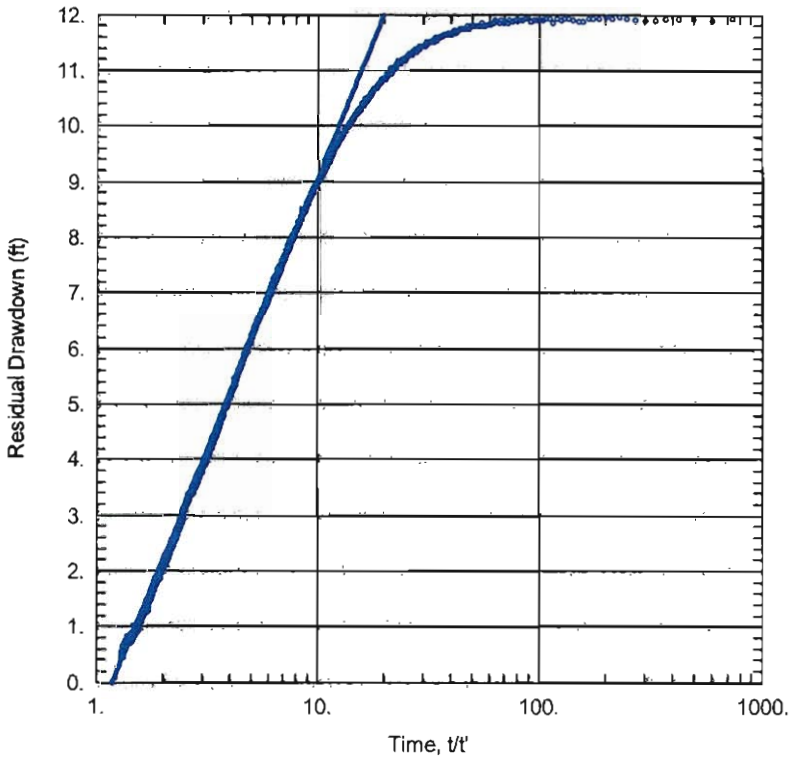
$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance from the pumping well, in feet (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown

Based on the analytical method of Theis (1935).

Figure 95. Recovery Analysis for TW#1 Zone 4– Kling Irrigation Two-Day Test
Test Conducted: January 9-11, 2007



Test Well #1 Zone 4
Screen = 353-383 ft
T= 24,000 gpd/ft
S/S' = 1.2
Kv/Kh = 0.1
b = 240 ft
r = 1,050 ft
Q = 900 gpm
(at Kling Irrigation well)

Appears to be good recovery data fit. Theis recovery model appears representative. S/S' ratio of greater than 1 ("early" recovery) implies a recharge source; in this case, more transmissive portions of the aquifer are the likely source.

T = 264Q/Δs Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs and well logs in the area
r = distance from pumping well (ft)

Based on the analytical method of Theis (1935).

Figure 96. Verification of Kling Irrigation Well Test Using Average T and S Calculated from Test

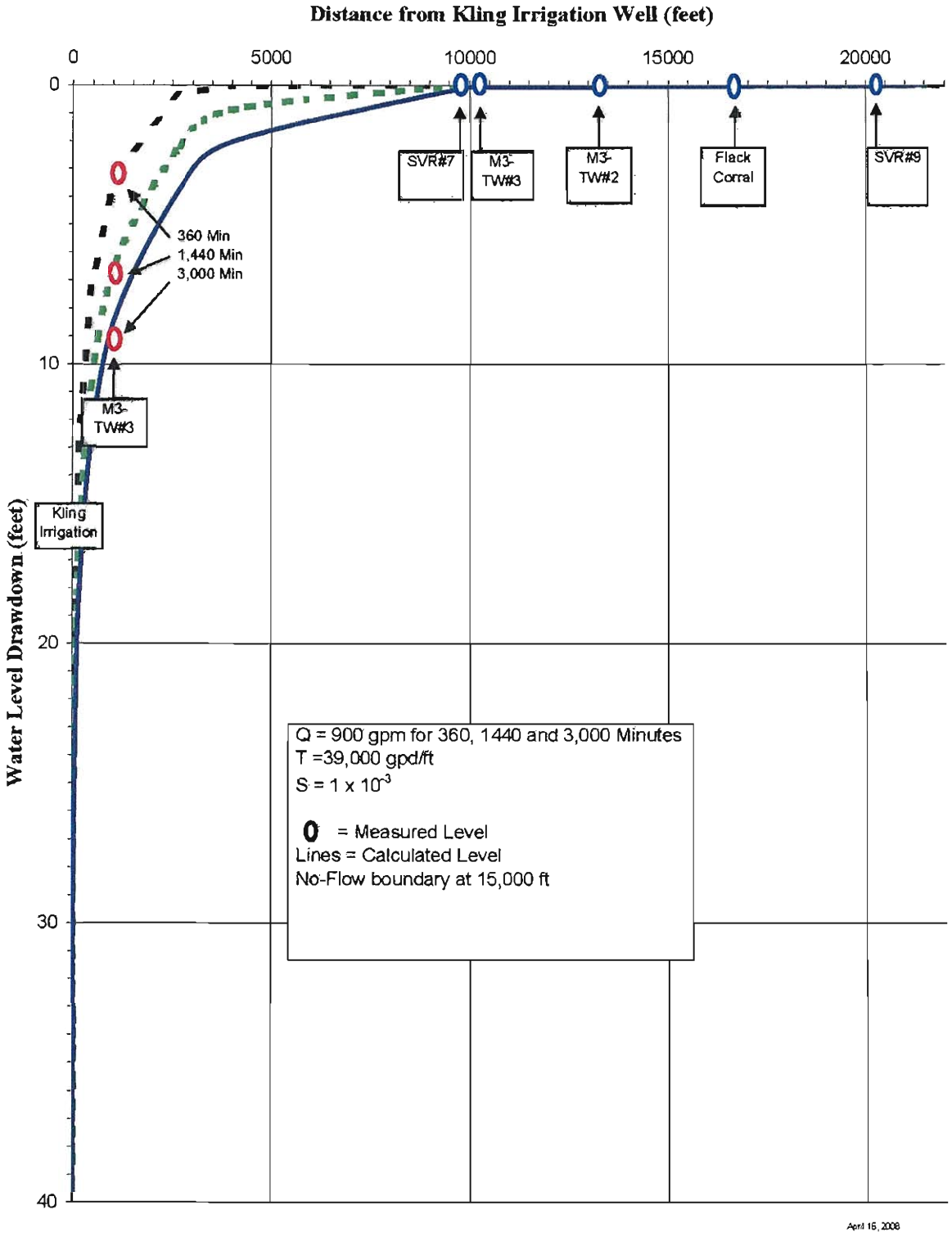
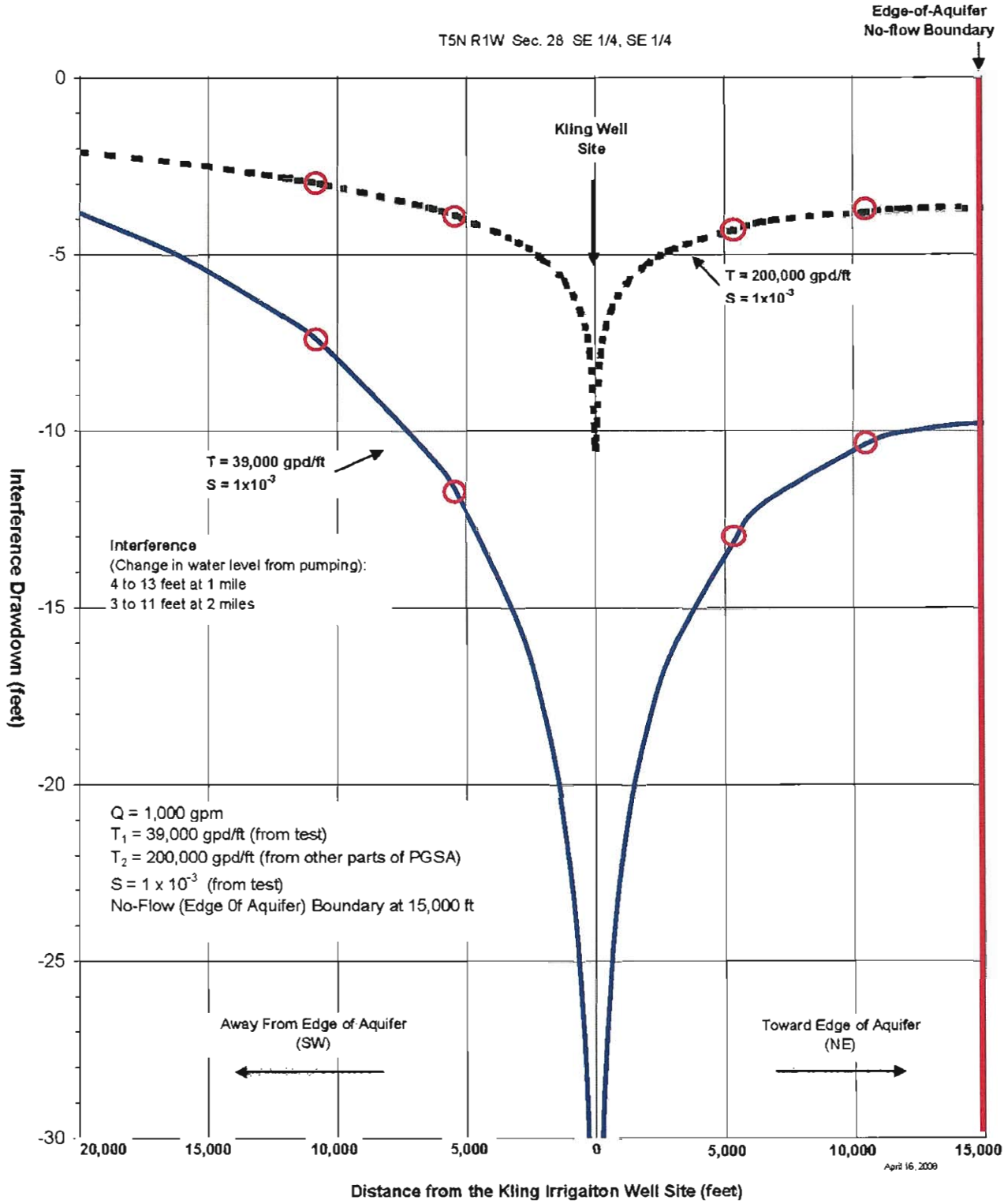


Figure 97. HLI's Predicted Interference at End of Summer Pumping from a Hypothetical Well at the Kling Irrigation Well Site



SECTION SIX: SUMMARY OF REGIONAL AQUIFER CHARACTERISTICS

Hydro Logic, Inc. analyzed sixteen separate well tests conducted within the greater M3-Eagle-Star area. Ten of the tests were conducted on the regional Pierce Gulch Sand Aquifer. One test was conducted on a shallow, unnamed aquifer overlying the Pierce Gulch Sand Aquifer in the Boise River Valley. Five tests were conducted on other minor aquifers; two of these were conducted on wells completed in undifferentiated sediment/mixed-bedrock aquifers that underlie the uplands northeast of Eagle, two were conducted on a sand aquifer of limited extent (informally called the Willow Creek Aquifer) located beneath the foothills north of Eagle, and one was conducted on a sand and gravel aquifer of very limited extent (informally called the Sandy Hill Aquifer) located beneath the foothills northeast of Eagle. The tests were conducted over the past 16 years by various entities and analyzed originally using a variety of techniques. In this study, HLI re-evaluated these tests using a unified and consistent approach. We combined our more-than-25-years of practical well and aquifer test experience with the multi-method computer program Aqtesolv® Pro, to generate a regional understanding of the aquifer parameters of transmissivity and storativity. We have also developed a series of conclusions and recommendations on the state of current and future aquifer testing in the region. The results of these analyses are presented in Table 3 (page 247) and Figure 98 (page 251). Based on the analyses and separate conclusions developed for each well and well test discussed above, we reach the following general conclusions on the Pierce Gulch Sand Aquifer and other aquifers present beneath the study area. Sections One through Five of the main body of the report should be consulted for information supporting these conclusions:

Conclusions:

1. The Boise River Valley in the Eagle-Star vicinity and portions of the Foothill Uplands to the north of Eagle which include the proposed M3 Eagle planned community development are underlain by a highly productive regional aquifer system consisting of stratified and partially cemented sand, silt and clay. The aquifer, named the Pierce Gulch Sand Aquifer (Hydro Logic, Inc., 2007), is typically 250 to over 300 feet thick. At some locations, however, the combined, water-bearing portions of the aquifer are over 500 feet thick.

2. Geophysical logging of thirteen wells in the greater project area (Hydro Logic, Inc., 2007) shows that the bottom of the Pierce Gulch Sand Aquifer slopes to the southwest at about 100 ft per mile in the Eagle-Star vicinity. The aquifer deepening to the southwest is consistent with the geologic history and paleo-topography of the area whereby large sand deltas and beaches were formed from rivers and streams flowing from the uplands to the north and east of what

is now Eagle, into a lake that stood in the present Boise River / Snake River Valley. The stratigraphy was tipped to the southeast mainly by basin down-warping and crustal uplift along the mountain front together with the deepening lake bed to the southeast; all imparting a southeastward "dip" to the sediments that now serve as the areas aquifers.

3. For the sake of understanding regional water supply, the previous conceptual model of a "lower confined aquifer" and an "upper confined aquifer" is better replaced by a conceptual model of a single regional aquifer, the Pierce Gulch Sand Aquifer. Based on borehole geophysical analyses and pumping test responses, the Pierce Gulch Sand Aquifer beneath the eastern edge of the study area beneath Lexington Hills lies between depths of about 100 feet bgl and 400 feet bgl. Further to the west in the Star vicinity, the Pierce Gulch Sand Aquifer lies between depths of about 400 and 700 feet bgl. Beneath the eastern portion of the M3 site, the Pierce Gulch Sand Aquifer rises to land surface while beneath the southwestern edge of the M3 site, it lies between 300 and 600 feet bgl. The difference in aquifer depths is the result of the dip of the aquifer which slopes at about 100 feet per mile to the southwest. Previous workers in the area were incorrect when they characterized the geologic section as "deep confined" aquifers (below 250 feet bgl) and "intermediate confined" (150 to 250 feet bgl) based strictly on depth and did not recognize that the aquifer supplying the City of Star wells was the same aquifer supplying the Eaglefield wells, and the Lexington Hills wells of the Eagle area.

4. The results of our analyses for transmissivity of the Pierce Gulch Sand Aquifer ranged from a low of around 40,000 gpd/ft to as high as 800,000 gpd/ft, depending on location. The average (mean) of all meaningful transmissivity values for the Pierce Gulch Sand Aquifer listed in Table 3 is 210,000 gpd/ft (rounded to two significant figures).

5. The effects of partial penetration were not evaluated by previous investigators; partial penetration corrections were not incorporated into their analyses. Consequently, many of the previously-calculated transmissivities represented only a portion of the full thickness of the Pierce Gulch Sand Aquifer. When the full thickness of the aquifer is considered in a partial penetration analysis, some of the calculated transmissivities are two to five times larger than values previously reported.

6. None of the previous investigators who conducted aquifer tests in the project area quantified the effects of delayed yield or leakage in their analyses. Consequently, some of the transmissivity values calculated by previous workers overestimated transmissivities when the flattening of a drawdown plot was misinterpreted as a higher transmissivity effect and not a delayed yield or leakage effect.

7. Previous workers did not evaluate the derivatives of the drawdown plots or the critical time when certain analytical methods (Cooper-Jacob) were valid. The derivative and critical time analyses indicated that some of the past analyses were invalid.

8. The Pierce Gulch Sand Aquifer beneath the upland area to the north has transmissivities that are comparable to those calculated from pumping tests of wells completed in the Pierce Gulch Sand Aquifer in the Eagle-Star area.

9. The Pierce Gulch Sand Aquifer is confined beneath the western parts of the study area but unconfined along the eastern margins (such as northeast Eagle or portions of the M3 property. Wells beneath the Lexington Hills area of northeast Eagle demonstrated relatively large storativities of 0.01 to 0.03 when pumped for an extended period. In some situations, the observed water level effects of delayed yield in relatively deep wells indicate that the Pierce Gulch Sand Aquifer is in hydraulic communication with the water table in this area.

10. Clay layers within and above the regional Pierce Gulch Sand Aquifer cause confined-aquifer responses to short-term pumping, but do not eliminate hydraulic connection to the upper water-bearing zones under longer-term pumping.

11. Production wells completed in the Pierce Gulch Sand Aquifer where it exists beneath the foothill uplands have the potential for yields from 1,000 gpm to above 2,000 gpm, as transmissivities and available drawdowns are similar to those for wells completed in the Valley.

12. Shallow aquifer(s) do overlie the Pierce Gulch Sand Aquifer at many locations beneath the Eagle-Star vicinity. Many domestic wells produce water from these overlying aquifers. The geologic deposits that comprise this shallow un-named aquifer in the lowland areas are unsaturated ("dry") beneath the upland foothills beneath much of M3 property.

13. A low-yield, mixed sediment and bedrock aquifer (not hydraulically or physically connected to the Pierce Gulch Sand Aquifer) underlies the northeastern portions of the study area. Transmissivities in this region are very low, generally 2,500 gpd/ft or less. Well yields are also small making this region unsuitable for development of a regional supply other than through a limited number of individual domestic water wells. This low-yield aquifer is not hydraulically connected to the Pierce Gulch Sand Aquifer.

14. A highly permeable, but isolated and bounded, sand unit with limited recharge, informally called the Willow Creek Aquifer, lies beneath the central part of the Upland. The southwestern boundary of this aquifer consists of a thick monotonous clay and mudstone unit (mudstone facies of the Terteling Springs Member) that also underlie the Pierce Gulch Sand Aquifer. The northeastern

boundary consists of low-permeability granitic bedrock and volcanic rocks. The Willow Creek Aquifer extends to, and couples with, high-permeability aquifers beneath the Payette Valley near Emmett. The Willow Creek Aquifer is not directly connected to the Pierce Gulch Sand Aquifer.

15. Potential well yields from the Willow Creek Aquifer are high but we expect that long term production could be severely constrained by small amounts of recharge and a bounded system that would significantly increase water-level drawdowns and large pumping lifts of 500 to 600 feet (and possibly more). Under longer-term pumping, the water table could conceivably be sufficiently lowered such that the ground water gradient would be reversed causing ground water in the Emmett area to move southeastwards through the Willow Creek Aquifer as a source of recharge.

16. We are not aware of available test data for the upland area northwest of the proposed M3 project site. To the best of our knowledge, no test data are available within the public domain from wells in this area. Consequently, no pumping test analyses are presented in this report for wells to the immediate northwest of the M3 Eagle site.

17. Another highly permeable, isolated and bounded sand unit with limited recharge, informally called the Sandy Hill Aquifer, has been reported on by SPF Water Engineering. This aquifer apparently lies beneath the foothills upland to the northeast of Eagle and is not hydraulically connected to the Pierce Gulch Sand Aquifer. This aquifer appears to be a large pocket of sand sitting on top of low-permeability bedrock; a stranded outlier of the sand facies of the Terteling Springs Member. Short-term, potential well yields from the Sandy Hill Aquifer appear to be high but long-term production would be severely limited by small amounts of natural recharge to the aquifer which SPF estimated to be about 60 gpm (based on the flow of a measured spring). SPF also asserts that artificial recharge would be needed for sustainable, long-term, high-volume use of the Sandy Hill Aquifer.

18. Available test data from all of the aquifers in the area are generally of uneven quality. The results and conclusion of previously issued consultant's reports of short-to-long-term testing reviewed in this report have technical limitations. In some cases, information on observation wells was incomplete (well logs were not available and no video or geophysical logging was conducted to confirm well construction and/or the current condition of the wells). In some cases, water level measurements had poor resolution. In other cases, the tests were conducted during a time of year when competing water users either pumped wells causing water-level interference or reduced value.

19. Construction of additional high-capacity wells in the Pierce Gulch Sand Aquifer appears feasible throughout much of the Eagle-Star M3 project area. These high capacity wells will cause drawdowns that will affect other wells. There are more

than 1,600 wells in the greater Eagle-Star-M3 area (as of August 2007), many of them poorly constructed. Development of additional municipal ground-water supplies, and associated watertable drawdowns, may require some existing wells to be deepened and/or replaced.

20. Development of additional wells and full development of existing municipal water rights will cause artesian pressures to decline over time throughout the Star-Eagle area. This decline of artesian pressures may cause some wells that flow at ground surface (or above) to cease doing so. Wells currently relying on artesian flowing conditions to provide water supplies may require pumps to produce water for use in the future.

21. The potential for development of ground water from the eastern part of the study area (east of the West-Boise-Eagle Fault and the Willow Creek Aquifer) is very limited and only low-yield wells are possible.

22. Subject to water quality concerns and very large pumping lifts, regional scale groundwater production may be possible from the Willow Creek Aquifer if pumping can reverse the very flat ground water flow gradient in the aquifer to induce flow from aquifers in the Payette River Valley. Pumping lifts of 600 to 700 feet may be required.

Recommendations:

Based on the conclusion presented above and details within the main body of this report, we offer the following recommendations:

1) Two major, regional pumping tests should be conducted.

We do not believe that these tests are necessary at this time (July 2008) to demonstrate that additional water is available from the Pierce Gulch Sand Aquifer. The large withdrawals that have been occurring over the past years along with the relative stability of water levels in the Eagle-Star-M3 area already have demonstrated that an overdraft situation has not occurred. Rather, these tests would help to better define aquifer properties, help to quantify the hydraulic interconnectedness across the aquifer, and asses the potential for mutual interference between the numerous supply wells in the area to better manage the ground-water resource in the future. We believe that *all* water right applications should be obliged to provide the data needed to understand and manage the resource. Properly designed and conducted pumping tests are part of the process that provides these data. We believe that all applicants for withdrawal of significant quantities of ground water be required to provide the rigorous and defensible aquifer-test data that would be generated following the recommendations below. *All* ground-water users in the region, present and future, would benefit were these recommendations to be followed and become standard procedure.

Following are our general recommendation for two aquifer tests:

a) Both tests should be undertaken during late winter or early spring before irrigation pumping or canal flow has begun and when municipal demand is relatively low.

b) One test should be conducted in the Valley near Eagle and the other should be conducted beneath the M3 project area.

c) All major water suppliers in the area should be contacted and coordinated to optimize data and minimize potential interference effects and uncertainties in the data.

d) Wells should be selected for the test based on location, position within the aquifer, well construction, availability of sound geologic and as-built construction information, ability to remove discharged water, and access. Observation wells should be selected strategically to allow for monitoring throughout the system with minimal interference from other water users. If wells cannot be kept from pumping, these wells should be manipulated to be held at a constant discharge throughout the test period.

e) The tests should be conducted using as large a pumping rate as is practical to generate as large a drawdown as possible to reduce the potential for the effects to be masked in more distal wells. Target rates of 2 to 6 cfs (approximately 900 to 2,700 gpm) or more, if possible, should be considered. Although the pumping rate should not theoretically affect the timing of the growth of the cone of depression, as a practical matter, water-levels are much more difficult to accurately measure when pumping rates are small.

f) Pumping for at least one week (and up to a month, if possible) is recommended, to allow for long-term storativity effects to become apparent and for delayed yield to become delineated (should it occur).

g) Upland wells completed in the Pierce Gulch Sand Aquifer should be included for observation as part of the Valley test. Valley wells should be included for observation as part of an upland well test.

h) Pre-pumping water levels along with barometric pressure should be measured changes in all monitored wells for at least a week during a period with both minimal regional water pumping and significant changes in atmospheric pressure, to develop a "barometric efficiency" correction so the effects of changing atmospheric pressure can be quantified.

i) Pre-pumping water levels along with barometric pressure should be measured, to determine antecedent water level trends for at least a week, in all wells. Depending on the time of year, there will be either a rising trend or a declining

trend. Data analysis will likely be more accurate if the testing is accomplished during a single trend and preferably when the trend is relatively constant.

j) At least a week of water level recovery data collection is recommended in order to assess aquifer properties based on recovery.

k) All measured wells should be surveyed or have GPS locations and elevations to within a few feet or better.

l) Data from the tests should be made available to all test participants and the Idaho Department of Water Resources.

m) The information from these tests (which grows increasingly harder to accomplish with each passing year) will allow for better future management of the water resources in the M3-Eagle-Star vicinity.

2) **A long-term water-level monitoring network should be established for the Eagle-Star-M3 area**

Monitoring can be the key to understanding the long-term performance of a ground-water system. It can also be a tool to detect changes before they become too large and therefore, more difficult to mange. The key to a properly designed, constructed and managed monitoring system is in part the selection (and possible construction, if necessary) of wells capable of indicating the water level in the target aquifer for a sufficiently long time (assured access).

The details of our recommendations are listed below:

a) The monitoring network should consist of designated wells that are non-pumping, of known (and verified) well construction and sealed with full-depth annular grouts into a single discrete aquifer zone. The wells should be preserved by long-term access agreements and, ideally, should be on publicly-owned land for monitoring in perpetuity. If existing wells are to be used, camera inspection of the inside wall of the well should be used to verify the details of well construction and the current condition of the well.

b) The wells should be strategically placed to measure water levels at many points within the Pierce Gulch Sand Aquifer and overlying water bearing zones.

c) All wells should be equipped with electronic data logging equipment backed by hand measurements to track water level changes.

d) The monitoring well network should be funded by local development and operated by a single entity with data made available to all interested parties.

e) M3 Eagle, United Water Idaho and others have installed monitoring wells that should be incorporated into the monitoring well network. M3 Eagle is currently monitoring water levels in 24 wells in the upland (foothills) area. While it is neither practical nor cost-effective to continue monitoring all of these wells in perpetuity, the monitoring wells that are known to generate high-quality data should be preserved. Great effort has been expended to ensure, to the extent possible, that the test wells sited and drilled by M3 Eagle will be in locations that will not be impacted by development. Monitoring of different wells over time, as wells are abandoned, is not the same as a single well record over a great length of time.

3) **Pumping tests of all future supply wells should be conducted with the intent of generating data for both evaluation of well performance *and* for providing a better understanding of the characteristics of the aquifer**

Each new supply well installed in the region presents an opportunity to generate additional information that will assist in the long-term management of the ground-water resources of the area. The IDEQ requires testing that will provide information on the performance of the newly installed well. With some modifications to the test, a significant amount of additional information can be generated to assist the long-term understanding and management of the aquifer system. We believe the additional effort of extending a "well test" into an "aquifer test" is highly worthwhile and recommend that all new major supply wells be required to provide this information as part of the IDWR permitting process.

The details on this testing are presented below:

a) Tests should be conducted with water level data collected before during and after the test to better assess the effects of antecedent trends, barometric effects and interference from other pumping wells.

b) Observation wells completed in the same depth interval of the aquifer, with a complete understanding of well construction and subsurface geology should be used whenever possible for analysis of aquifer parameters.

c) The pumping well and observation well(s) should be allowed to fully recover from previous pumping (to the extent possible) before the test is initiated. Flowing artesian wells should be capped with measured shut-in pressure and allowed to stabilize before starting the test.

d) Test reports should include accurate maps of well location and well details (including well logs) to support the data used in the analysis. Whenever possible, camera surveys of observation wells should be used to verify the details of well construction and current condition of the well to increase confidence in what is being measured.

e) Derivative and critical time analyses should accompany all data analysis plots to show when the data support the chosen method of analysis.

f) An understanding of the Pierce Gulch Sand Aquifer should be incorporated into the analysis to reflect the effects of aquifer boundaries, partial penetration, delayed yield, and potential effects from other pumping wells in the area.

1. Pumping tests should be conducted under the direction of a qualified hydrogeologist and not under the direction of a well driller, pump operator, or other unqualified personnel. Data should be field plotted as the test progresses to verify the test has been conducted sufficiently long to adequately characterize the well and aquifer behavior. Water levels should be measured carefully, using a combination of hand measurements with calibrated well sounders and electronic data loggers.

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Table 3 - Summary of Aquifer and Well Test Parameters

Well Test Well	Fig. No.	Well Elev.	Water Level DTW - =sgl	Water Level Elev.	Q	Max. DD	Screen top/bottom Depth	Screen top/bottom Elev	Entire Aquifer** top/bottom Depth	Entire Aquifer** top/bottom Elev	Thickness "b"	Dist. "r" to Well	Analysis	Analytical Results**** T (raw data)	T (corrected data)	S	Hydraulic Conductivity		Mat'l type based on Hydraulic Conductivity*	Comments
Map of Well Locations	1	ft amsl	ft	ft amsl	gpm	ft	ft	ft	ft	ft	ft	ft		gpd/ft	gpd/ft	ft²/day	ft/day	cm/sec		
Valley Wells																				
Eagle 7-Day Test - Pierce Gulch Sand Aquifer																				
Eaglefield Well #2 (pumping)	3	2514	-8.61	2523	1580	20.91	345	2169	181	2333	498	-	Cooper-Jacob	200,000	800,000	110,000	-	2.2E+02	7.8E-02	coarse sand	Match only valid: 20 to 80 minutes. Correction Includes PP (Butler) adjustment.
	4						425	2089	679	1835			Semi-Log Theis***	850,000	1,000,000	130,000	-	2.6E+02	9.2E-02	coarse sand	Match 20-80 min. Hantush PP correction. Correction for well-loss increases T by 18%
	5												Theis Butler PP corr.	200,000	760,000	100,000	-	2.0E+02	7.1E-02	coarse sand	Butler PP corrections yield similar results to Hantush supporting their validity
	6												Theis Recovery	200,000	800,000	107,000	-	2.1E+02	7.6E-02	coarse sand	No well loss to nlTest plot. Correction Includes PP (Butler) adjustment
Legacy #1	7	2513	-16.25	2529		2.73	282	2231	175	2338	500	1605	Theis/Hantush	no match	100,000	13,000	1.0E-02	2.6E+01	9.2E-03	clean sand	Trend correction needed for match before 500 min. No match after 500 min.
(observation)	8						352	2161	675	1838			Hantush-Jacob	no match	100,000	13,000	1.0E-02	2.6E+01	9.2E-03	clean sand	Leakage factor r/B = 4.6x10-4
UWID State and Linder #1A	9	2519	-12.83	2532		5.67	280	2239	210	2310	525	2405	Theis (early-time)	500,000	500,000	67,000	2.3E-03	1.3E+02	4.5E-02	clean sand	Theis gives average of near (pumping) and far (obs well) values.
(observation)	11						370	2149	735	1785			Butler (at obs well)	84,000	84,000	11,000	3.7E-03	2.1E+01	7.4E-03	clean sand	Butler method only gives approx. results as model does not strictly apply
UWID State and Linder #1B	10	2519	-12.53	2532		5.49	400	2119	210	2310	525	2405	Theis (early-time)	400,000	400,000	50,000	1.3E-03	9.5E+01	3.4E-02	clean sand	Theis gives average of near (pumping) and far (obs well) values.
(observation)	12						490	2029	735	1785			Butler (at obs well)	84,000	84,000	11,000	1.3E-03	2.1E+01	7.4E-03	clean sand	Butler method only gives approx. results as model does not strictly apply
Ricks Irrigation Well	13	2526	7.23	2519		1.09	234	2292	260	2366	416	3340	Theis/Hantush	no match	no match	-	-	-	-	-	Derivative analysis indicates no data match to type curve.
(observation)							395	2131	676	1850											
													Holladay means	187,000	187,000	25,000	5.0E-03				Mean based on 8 separate analyses
													SPF means	110,000	110,000	15,000	5.0E-03				Mean based on 24 separate analyses. SPF did not specify a mean.
Test summary ranges: PGSA near Eaglefield: Mean T = 460,000gpd/ft with a range of 200,000 to 800,000 gpd/ft, from UWID State and Linder: T = 80,000 to 400,000 gpd/ft, from Legacy T = 100,000? gpd/ft, S = 2x10 $^{-3}$																				***Analytical models only approximate assumptions required; therefore results only approximate. Pumping projections for individual wells will need PP corrections.***
Lexington Hills 30-Day Test - Pierce Gulch Sand Aquifer																				
Lexington Hills Well #1 (pumping)	17	2645	71.00	2574	732	81.00	215	2430	75	2570	326	-	Cooper-Jacob	15,000	50,000	6,700	-	2.1E+01	7.3E-03	clean sand	Early-time data. Includes PP (Butler) corrections. Delayed yield indicated
	18						385	2260	401	2244			Moench	80,000	80,000	10,700	-	3.3E+01	1.2E-02	clean sand	Good match to delayed-yield curve
													CH2M average	170,000	170,000	22,700	-	7.0E+01	2.5E-02	clean sand	CH2 average T too high. Delayed yield portion analyzed. Early time better
Holgate Well (observation)	19	2645	65.58	2579		3.85	?	?	89	2556	306	900	Theis (early time)	120,000	120,000	16,000	5.0E-04	5.2E+01	1.8E-02	clean sand	Only data for t<80 min match. Delayed yield indicated.
	20						171	2474	395	2250			Moench	96,000	96,000	13,000	1.2E-02	4.2E+01	1.5E-02	clean sand	Good match to delayed-yield curve
													CH2M averages	100,000	100,000	13,000	1.3E-02	4.2E+01	1.5E-02	clean sand	Good agreement with Moench
Carson Well (observation)	21	2630	62.48	2568		2.47	?	?	75	2555	305	1300	Theis (early time)	Analysis Likely Invalic		-	-	-	-	-	Well may be too shallow to properly indicate aquifer parameters
	22						90	2540	380	2250			Moench	77,000	77,000	10,000	3.5E-02	3.3E+01	1.2E-02	clean sand	Good match to delayed-yield curve
													CH2M averages	110,000	110,000	15,000	2.6E-02	4.9E+01	1.7E-02	clean sand	Average includes early time data does not considering delayed yield
Eagle Hills Golf Course Well	23	2610	55.59	2554		1.05	?	?	78	2532	302	2500	Theis (early time)	420,000	420,000	56,000	5.0E-03	1.9E+02	6.6E-02	coarse sand	Largest value in area. Poor derivative match. Results may be invalid
(observation)	24						175	2435	385	2230			Moench	400,000	400,000	53,000	8.0E-03	1.8E+02	6.2E-02	coarse sand	Good match to delayed-yield curve
													CH2M averages	280,000	280,000	37,000	1.2E-02	1.2E+02	4.3E-02	clean sand	Analyses do not take into account delayed yield
Floating Feather Irrigation Well	25	2670	86.80	2583		2.00	?	?	75	2595	315	5100	Semi-Log Theis	Analysis Likely Invalic		-	-	-	-	-	Poor data resolution. No derivative match. No analysis possible
(observation)							270	2400	390	2280			CH2M averages		-	-	-	-	-	-	Not presented in report.
Test summary: PGSA average near Lexington Hills #1 T = 160,000 gpd/ft, S = 3x10 $^{-3}$ (short-term pumping) and Sy = 0.02 (long-term pumping).																				***Analytical results indicate delayed-yield (unconfined) aquifer with high-rate, long-term pumping.***
Rivervine 6-Hour Test - Shallow Aquifer Overlying the Pierce Gulch Sand Aquifer																				
Rivervine (pumping)	28	2500	-1.75	2502	350	22.73	72	2428	4	2496	116	-	Cooper-Jacob	43,000	43,000	5,700	-	4.9E+01	1.7E-02	clean sand	Log suggests unconfined aquifer. Only upper portion of aquifer tested
	29						118	2382	120	2380			Theis/Hantush	48,000	48,000	6,400	-	5.5E+01	2.0E-02	clean sand	Recharge boundary indicated: river? canal? pond? delayed yield?
6-In Observation	30	2500	-2.25	2502		4.85	65	2435	4	2496	116	283	Cooper-Jacob	37,000	37,000	4,900	2.2E-04	4.2E+01	1.5E-02	clean sand	Obs well data better than pumping well data. No PP correction needed.
	31						75	2425	120	2380			Theis	36,000	36,000	4,800	2.5E-04	4.1E+01	1.5E-02	clean sand	Sensitivity analysis indicates PP correction not needed
Redwood Creek 8-hour Test - Pierce Gulch Sand Aquifer																				
Redwood Creek Well (pumping)	33	2545	-4.70	2550	2100	96.00	298	2247	295	2250	350	-	Cooper-Jacob	50,000	140,000	18,700	-	5.3E+01	1.9E-02	clean sand	Includes PP (Butler) corrections.
	34						401	2144	411	1900			Theis/Hantush	140,000	150,000	20,100	-	5.7E+01	2.0E-02	coarse sand	Includes PP (Hantush) correction. Well loss correction increased T by 7%.
													Scanlan	55,000	55,000	7,400	-	2.1E+01	7.5E-03	clean sand	No PP correction leads to under-estimate for T
Ricks Well (Observation)	35	2545	-12.00	2557		4.40	?	?	260	2285	385	2500	Theis/Hantush	140,000	140,000	19,000	1.8E-04	4.9E+01	1.7E-02	coarse sand	Obs well analyses agrees with Theis/corrected C-J analysis for pumped well.
(not same well as "Ricks Irrigation")							284	2261	404	1900			Scanlan	154,000	154,000	21,000	2.0E-04	5.5E+01	1.9E-02	coarse sand	Reasonable agreement.
Test summary: PGSA average near Floating Feather T = 170,000 gpd/ft, S = 4x10 $^{-3}$.																				

Table 3
Hydro Logic, Inc.
Boise, Idaho

Table 3 - Summary of Aquifer and Well Test Parameters (continued)

Well Test Well	Fig. No.	Well Elev.	Water Level DTW - *wgl*	Water Level Elev.	Q	Max. DD	Screen top/bottom Depth	Screen top/bottom Elev	Entire Aquifer** top/bottom Depth	Entire Aquifer** top/bottom Elev	Thickness "b"	Dist. "r" Well	Analysis	Analytical Results**** T		S	Hydraulic Conductivity		Mat'l type based on permeability*	Comments
		ft amsl	ft	ft amsl	gpm	ft	ft	ft	ft	ft	ft	ft		gpd/ft	ft^2/day		ft/day	cm/sec		
Floating Feather 51-hour Test - Pierce Gulch Sand Aquifer																				
Floating Feather (pumping)	47	2599	44.20	2555	1500	30.16	183	2416	113	2486	386	-	Semi-Log Theis	140,000	160,000	21,000	5.4E+01	1.9E-02	clean sand	Mean T = 160,000 gpd/ft from est. likley max. well loss of 0 to 10 ft
	48						330	2269	499	2100			Theis Recovery	160,000	320,000	43,000	1.1E+02	3.9E-02	clean sand	"Corrected" likley to be incorrect because well in middle of aquifer
													Scanlan averages	150,000	150,000	20,000	5.2E+01	1.8E-02	clean sand	Agreement with new analyses.
Crandlemire Irrigation (observation)	49	2599	45.30	2554		11.60	176	2423	111	2488	388	65	Semi-Log Theis	170,000	170,000	23,000	5.9E+01	2.1E-02	clean sand	Obs well data likely better than pumping well data. No PP correction needed.
	50						316	2283	499	2100			Theis Recovery	170,000	170,000	23,000	5.9E+01	2.1E-02	clean sand	Likely good T value. No PP correction needed.
													Scanlan averages	150,000	150,000	20,000	5.2E+01	1.8E-02	clean sand	Reasonable agreement.
Valley Single Well Tests - Pierce Gulch Sand Aquifer																				
Star #1 8-Hour Test	38	2512	-40.60	2553	800	29.39	452	2060	350	2126	310	-	Cooper-Jacob	50,000	120,000	16,000	5.2E+01	1.8E-02	clean sand	Includes PP (Butler) correction.
	39						550	1962	660	1816			Theis/Hantush	100,000	120,000	16,000	5.2E+01	1.8E-02	clean sand	Includes correction for estimated max. likely well loss.
Star #3 24-Hour Test	41	2476	-31.19	2507	3008	176.02	544	1932	390	2086	310	-	Cooper-Jacob	100,000	180,000	24,100	7.8E+01	2.7E-02	clean sand	PP (Butler) correction indicates 90% larger T.
	42						643	1833	700	1776			Theis/Hantush	100,000	140,000	18,700	6.0E+01	2.1E-02	clean sand	Includes correction for estimated max. likely well loss
LDS Eagle 4-Hour Test	44	2610	28.6	2581	95	17.52	397	2213	90	2520	380	-	Cooper-Jacob	60,000	90,000	12,000	3.2E+01	1.1E-02	clean sand	Development obscures true response. Includes PP (Butler) correction.
	45						465	2145	470	2140			Theis/Hantush	70,000	70,000	9,400	2.5E+01	8.7E-03	clean sand	Poor match. Sensitivity analysis indicates PP affects result by 80%
													BSU averages	37,000	37,000	4,900	1.3E+01	4.6E-03	clean sand	No PP corrections or recognition of well development effects
Upland Wells - Pierce Gulch Sand, Willow Creek, Sandy Hill and Eastern-Upland Aquifers																				
Pierce Gulch Aquifer Wells																				
SVR #7 22-Hour Test- Pierce Gulch Sand Aquifer																				
SVR #7 (pumping)	66	2710	160.54	2549	500	31.04	280	2430	180	2530	260	-	Theis Step	150,000	150,000	20,000	-	7.7E+01	2.7E-02	clean sand	Decline in PWL during test. Well developing. Analysis invalid
	67						350	2360	440	2270			Theis Recovery	150,000	150,000	20,000	-	7.7E+01	2.7E-02	coarse sand	Recovery better match than pumping. Max DD at 60 min, then decline.
													SPF averages	370,000	370,000	49,000		1.9E+02	6.7E-02	coarse sand	
Big Gulch Stock Well	68	2698	150.00	2548		0.54	?	?	170	2528	230	845	Theis/Hantush	180,000	180,000	24,000	1.0E-02	1.0E+02	3.7E-02	coarse sand	No log for obs well. Better match than pumping data
	69						180	2518	400	2298			Theis Recovery	180,000	290,000	39,000	-	1.7E+02	6.0E-02	coarse sand	General agreement with pumping well recovery.
													SPF averages	270,000	270,000	36,000	-	1.6E+02	5.5E-02	coarse sand	
SVR Well #9 3.3-Hour Test																				
	72	2753	197.33	2556	43	14.00	235	2518	197	2556	73	-	Cooper-Jacob	120,000	120,000	16,000	-	2.2E+02	7.7E-02	coarse sand	Log suggests unconfined aquifer
	73						263	2490	270	2483			Theis/Hantush	120,000	120,000	16,000	-	2.2E+02	7.7E-02	coarse sand	Test too short. Development makes results questionable
													SPF averages	13,0007	13,0007	-	-	-	-	-	No analysis presented in SPF, only range of results.
Kling Irrigation Well 50-Hour Test- Pierce Gulch Sand Aquifer																				
Kling Irrigation (pumping)	83	2614	95.42	2519	900	94.39	198	2416	341	2273	240	-	Theis/Hantush	29,000	37,000	4,900	-	2.0E+01	7.2E-03	clean sand	Includes correction for est. well loss and PP (Hantush).
	84						408	2206	581	2033			Cooper-Jacob	20,000	36,000	4,800	-	2.0E+01	7.1E-03	clean sand	Includes PP (Butler) corrections. Partially plugged screen.
	85												Theis Recovery	27,000	45,000	6,000	-	2.5E+01	8.8E-03	silty sand	Includes PP (Butler) corrections.
M3-TW #1 (composite: Zones 1-4)	86	2606	90.23	2516		8.95	353	2253	350	2253	240	1050	Theis (mean of 4 zones)	140,000	140,000	18,700	1.1E-03	7.8E+01	2.8E-02	clean sand	Composite (mean of 4 zones) averages anomalies in separate obs wells
	87						556	2050	590	2013			Theis 4-well plot	110,000	110,000	15,000	1.0E-03	6.3E+01	2.2E-02	clean sand	Best fit of 4 plots for 4 zones. General agreement with mean plot
M3-TW #1 Individual Zones 1-4	88,90,92,94												Mean of Theis Drawdown	120,000	120,000	16,000	1.4E-03	6.7E+01	2.4E-02	clean sand	In range of composite and single mean plot analyses
	89,91,93,95												Mean of Theis Recovery	35,000	35,000	4,700	-	2.0E+01	6.9E-03	clean sand	Recovery is consistent with pumped well analysis

Test summary: PGSA average near Kling irrigation well: T = 39,000 gpd/ft, S =0.0009. Higher average T of 110,000 to 140,000 gpd/ft in larger region of aquifer as indicated by obs wells at M3-TW #1.

Table 3
Hydro Logic, Inc.
Boise, Idaho

Table 3 - Summary of Aquifer and Well Test Parameters (continued)

Well Test Well	Fig. No.	Well Elev.	Water Level DTW -neg	Water Level Elev.	Q	Max. DD	Screen top/bottom Depth	Screen top/bottom Elev	Entire Aquifer** top/bottom Depth	Entire Aquifer** top/bottom Elev	Thickness "b"	Dirt. "r" Well	Analysis	Analytical Results*** T	Analytical Results*** T	Analytical Results*** S_{ss}	Hydraulic Conductivity		Mat'l type based on permeability*	Comments
		ft amsl	ft	ft amsl	gpm	ft	ft	ft	ft	ft	ft	ft		gpd/ft	ft^2/day		ft/day	cm/sec		
Willow Creek Aquifer Wells																				
SVR Well #6 24-Hour Test	60	2816	450.18	2366	358	2.82	560	2256	450	2366	290	-	Semi-Log Theis	1,000,000+	1,000,000+	100,000+	>300	>1E-01	coarse sand	Development during pumping: Indicated T likely too high.
	61						720	2096	740	2076			Theis Recovery	650,000	1,000,000	134,000	4.6E+02	1.6E-01	coarse sand	Better match than pumping analysis. Includes PP (Butler) correction.
													SPF averages	1,300,000	1,300,000	170,000	5.9E+02	2.1E-01	coarse sand	SPF best estimate for aquifer is 1,000,000+ gpd/ft.
SVR Well #10 24-Hour Test	63	2870	482.08	2388	55	59.90	630	2240	480	2390	190	-	Cooper-Jacob	300,000+	300,000+	7,000	4E+01+	1.E-02+	clean sand	Meter problems. Screen flaw. Flat DD. Analysis not accurate.
	64						640	2230	670	2200			Theis Recovery	-	-	-	-	-	-	No meaningful analysis possible. Poor test
													SPF averages	-	-	-	-	-	-	
Eastern Upland Mixed Sediment/Bedrock Wells																				
SVR Well #1 7.5-Hour Test	54	3390	16.80	3373	51	102.00	125	3265	125	3265	275	-	Cooper-Jacob	1,500	1,500	200	7.3E-01	2.6E-04	Bedrock/sediment	Low yield aquifer.
	55						400	2990	400	2990			Theis Recovery	2,300	2,300	310	1.1E+00	4.0E-04	Bedrock/sediment	
													Scanlan averages	1,700	1,700	230	8.4E-01	3.0E-04	Bedrock/sediment	
SVR Well #2 2.5-Hour Test	57	3630	32.10	3598	50	159.90	300	3330	300	3330	460	-	Cooper-Jacob	720	720	96	2.1E-01	7.4E-05	Bedrock/sediment	Low yield aquifer
	58						760	2870	760	2870			Theis Recovery	270	270	40	8.7E-02	3.1E-05	Bedrock/sediment	
													Scanlan averages	350	350	47	1.0E-01	3.6E-05	Bedrock/sediment	
Eastern Upland Sandy Hill Aquifer 71-Hour Test																				
TPW #1 (pumping)	75	3600	177.84	3422	2050	16.81	238	3362	178	3422	114	-	Cooper-Jacob	200,000	300,000	40,000	3.5E+02	1.2E-01	coarse sand	Includes PP (Butler) corrections. Highly bounded aquifer
	76						290	3310	292	3308			Moench	300,000	300,000	40,000	3.5E+02	1.2E-01	coarse sand	Reasonable match.
	77												Theis Recovery	300,000	300,000	40,000	3.5E+02	1.2E-01	coarse sand	Incomplete recovery suggests highly bounded aquifer.
SVR #3 (observation)	78	3600	175.38	3425		159.90	175	3425	175	3425	105	150	Moench	-	-	-	-	-	-	No fit. Invalid analysis
	79						240	3360	280	3320			Theis Recovery	1,000,000?	1,000,000?	134,000	1.3E+03	4.5E-01	coarse sand	Likly invalid analysis. Straight-line plot poor. Highly bounded system.

*Hydraulic conductivity (permeability) range from Freeze and Cherry (1979) - silty sand: k $5x10^{-4}$ to $5x10^{-3}$, clean sand: $5x10^{-3}$ to $5x10^{-2}$, coarse sand $5x10^{-2}$ to $5x10^{-1}$, gravel: $5x10^{-1}$ to $5x10^{0}$+

Ver: 7/6/2008

** Top of aquifer estimated from Well Driller's Reports may be inaccurate. Aquifer bottom depths estimated from geophysical contours are considered more accurate.

*** All Theis (1935) analyses of drawdown data include Hantush (1961a and b) corrections for Partial Penetration, even if not stated in this table. See text for further explanation.

**** If T for raw data = T for corrected data, then no correction applied.

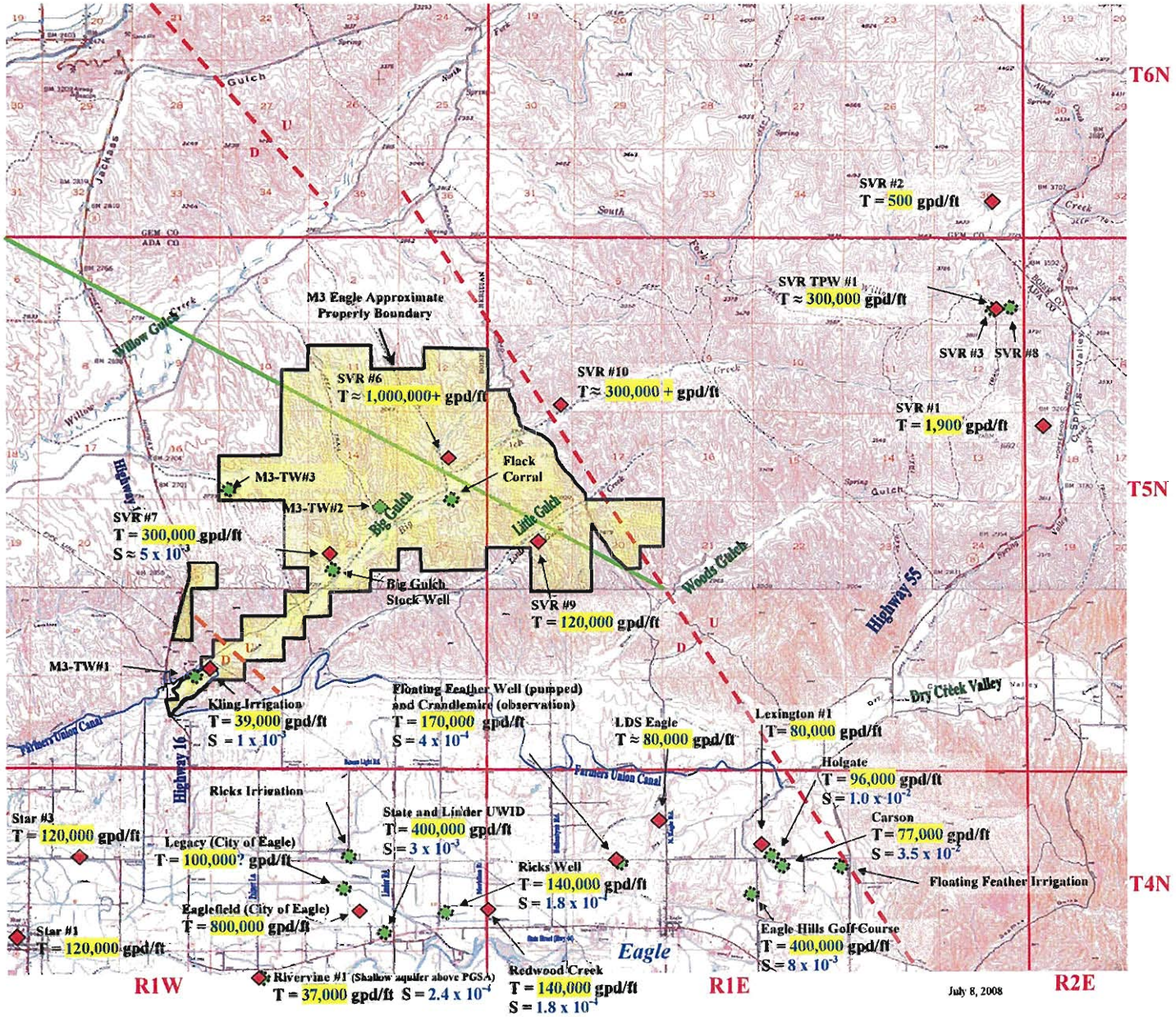

Figure 98. Calculated Values of Transmissivity and Storativity based on Analyses for Selected Wells in the Greater M3 Eagle Project Area

Location map for aquifer transmissivity values calculated from pump tests in the vicinity of the proposed M3 Eagle Development. The tests were conducted by various workers but all tests were reanalyzed by HLI with results presented here. See text of report for details.

Wells were surveyed using a GPS system. Base map is (1:62,500 scale) USGS 15 minute map

Figure 98.

Hydro Logic, Inc.
Boise, Idaho

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APPENDIX A – Well Information

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Appendix A Table of Well and Aquifer Support Information

Each well analyzed in this report has copies of its support data included in this appendix. The types/sources of the data are listed in this table. A "√" indicates that the source was available. A " " (blank) indicates that type of data was not available. "No Data Available" column indicates the only source of information was a brief description in the original report. Copies of the data grouped, by test, are presented in the order given on the table below.

			Sources of Original Data					
Test	Well	Well Location Figure	Composite Diagram	Geophysical Log	Geologist's Log	As-Built Diagram	Well Driller's Report	No Data Available
Eaglefield Seven-Day	Eaglefield Well #2 (pumping)	2		√		√	√	
	Legacy #1	2	√	√	√	√	√	
	UWID State and Linder #1 A/B	2	√	√	√	√	√	
	Ricks *Irrigation* Well	2				√	√	
Lexington Hills Thirty-Day	Lexington Hills Well #1	16	√	√	√	√	√	
	Holgate Well	16						√
	Carson Well	16						√
	Eagle Hills Golf Course Well	16					√	
	Floating Feather Irrigation Well	16						√
Rivervine Six-Hour	Rivervine Well	27	√		√			
	Nearby domestic 6" In Well	27						√
Redwood Creek Eight-Hour	Redwood Creek Well	32		√		√	√	
	Ricks Well (Not the Irrigation Well)	32						√
Star #1 Eight-Hour	Star Well #1	37		√	√		√	
Star #3 Twenty Four-Hour	Star Well #3	40	√	√	√		√	
LDS Four-Hour	LDS Eagle Stake Center Well	43	√	√	√	√	√	
Floating Feather Fifty One-Hour	UWID Floating Feather Well	46		√		√	√	
	Crandlemire Irrigation Well	46					√	
SVR #1 Seven-Hour	SVR Well #1	53	√	√	√	√	√	
SVR #2 Two-and-One Half-Hou	SVR Well #2	56	√	√	√	√	√	
SVR #6 Twenty Four-Hour	SVR Well #6	59	√	√	√	√	√	
SVR #10 Twenty Four-Hour	SVR Well #10	62	√	√	√	√	√	
SVR #7 Twenty-Two-Hour	SVR Well #7	65	√	√	√	√	√	
	Big Gulch Stock Well	65		√				
SVR #9 Three-Hour	SVR Well #9	71	√	√	√	√	√	
TPW #1 Seventy One-Hour	TPW #1	74				√	√	
	SVR Well #3	74	√	√	√	√	√	
Kling Irrigation Two-Day	Kling Irrigation Well	80	√		√	√	√	
	M3-TW #1	80	√	√	√	√	√	
	M3-TW #2	80	√	√	√	√	√	
	M3-TW #3	80	√	√	√	√	√	

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Form 238-7 6/02 (03)

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

Eaglefield Well #2 (pumping)

Twp ____ Rge ____ Sec ____
____ 1/4 ____ 1/4 ____ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 0042405
DRILLING PERMIT NO. 892605 - 837870
Water Right or Injection Well No. 63-32089, 63-32090

2. OWNER:
Name CITY OF EAGLE
Address 310 E. STATE ST.
City EAGLE State ID Zip 83616

3. LOCATION OF WELL by legal description:
You must provide address or Lot, Blk, Sub. or Directions to well. WELL #2 (EAGLEFIELD)
Twp. 4 North ☒ or South ☐
Rge. 1 East ☐ or West ☒
Sec. 11 ____ 1/4 (40 acres) NW 1/4 (40 acres) SE 1/4 (160 acres)
Gov't Lot ____ County ADA
Lat: : : Long: : :
Address of Well Site 50' W of INTERSECTION OF W TATLOCK DR + N GOLDEN CODION WAY (Give at least name of road + Distance to Road or Landmark) City EAGLE
Lt 83,84 Blk. 8 Sub. Name EAGLEFIELD ESTATES

4. USE:
☐ Domestic ☒ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☒ Other TEST

5. TYPE OF WORK check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other ____

6. DRILL METHOD:
☐ Air Rotary ☐ Cable ☐ Mud Rotary ☒ Other REVERSE

7. SEALING PROCEDURES

Seal Material	From	To	Weight / Volume	Seal Placement Method
CEMENT GROUT	0	320	24 YDS	PUMPED FROM BOTTOM TO TOP

Was drive shoe used? ☐Y ☒N Shoe Depth(s) ____
Was drive shoe seal tested? ☐Y ☐N How? ____

8. CASING/LINER: 280' 16"X12" REDUCER

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
16	+5	280	.375	STEEL	☒	☐	☒	☐
12	281	345	.375	STEEL	☒	☐	☒	☐
					☐	☐	☐	☐

Length of Headpipe ____ Length of Tailpipe 5'
Packer ☐Y ☒N Type ____

9. PERFORATIONS/SCREENS PACKER TYPE
Perforation Method ____
Screen Type & Method of Installation JOHNSON WIRE WRAP

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
345	425	.030		12	S.S.	☒	☐
						☐	☐
						☐	☐

10. FILTER PACK

Filter Material	From	To	Weight / Volume	Placement Method
#6-9 CSSI SAND	320	435	30,000	DRY POUR

11. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
____ ft. below ground Artesian pressure 8.1 lb.
Depth flow encountered ____ ft. Describe access port or control devices: ____
FLANGE CAP W/ 2- 1¼" PIPE PLUGS

12. WELL TESTS:
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time
1125 gpm		+5.2'	10 MIN

Water Temp. ____ Bottom hole temp. ____
Water Quality test or comments: ____
Depth first Water Encounter ____

13. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
28	0	3	TOP SOIL		
	3	28	RIVER GRAVEL		
	28	48	TAN CLAY		
	48	56	SAND		
	56	63	RUSTY TAN CLAY		
	63	135	SAND W/SM TAN CLAY STREAKS		
	135	183	BRN CLAY W/SAND STREAKS		
	183	189	FINE-MED SAND		
	189	194	TAN CLAY		
	194	215	SAND, SM GRAVEL		
	215	232	CLAY		
	232	290	SAND FINE-MED W/SM CLAY STREAKS		
20	290	297	SAND-FINE		
	297	329	BR. RUSTY, GREEN + GRAY CLAY		
	329	436	COARSE SAND, SOME FINE GRAVEL		
	436	444	BRN RUSTY CLAY		

RECEIVED
MAY 23 2006
WATER RESOURCES WESTERN REGION

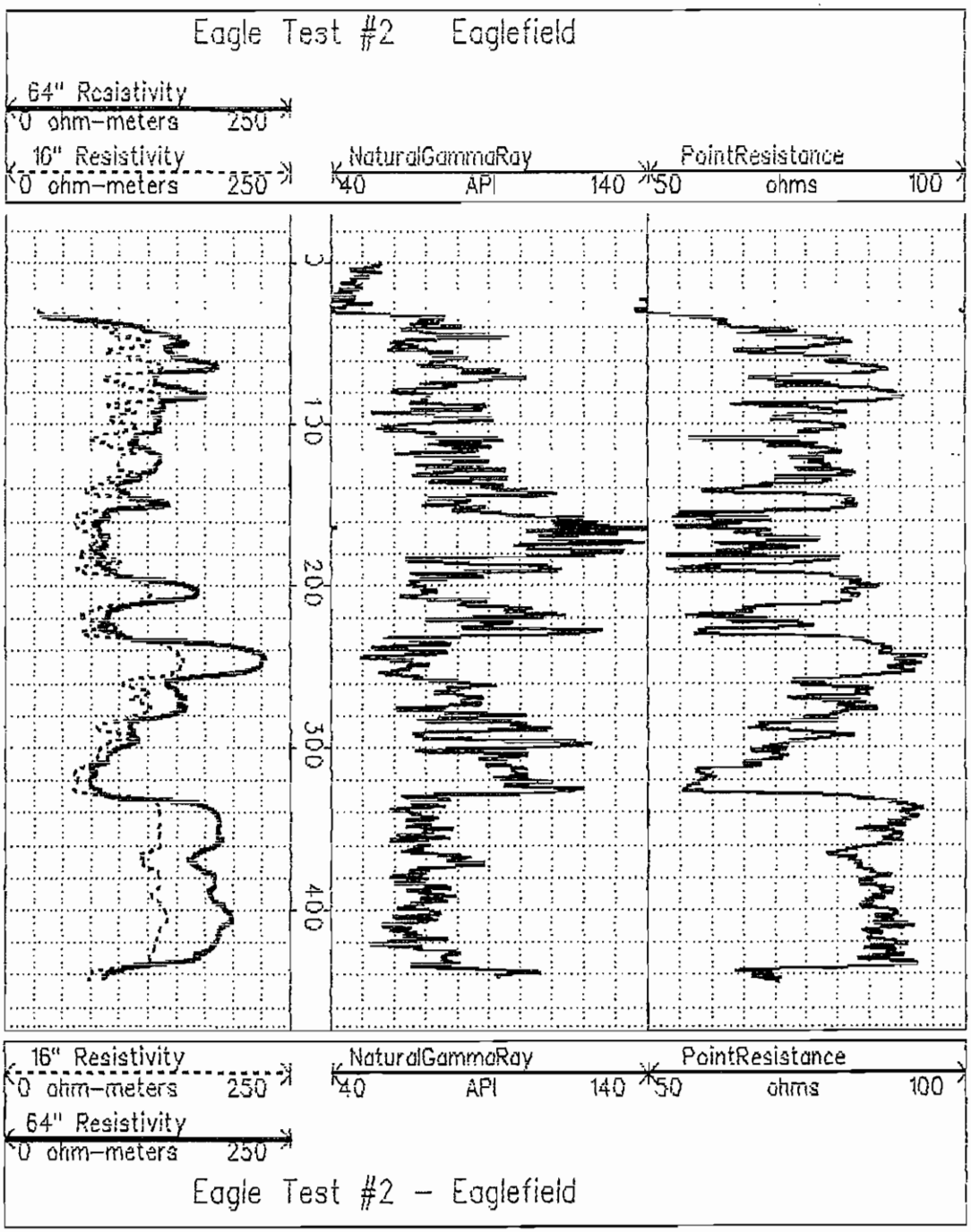
Completed Depth 430' (Measurable)
Date: Started 3-21-06 Completed 5-9-06

14. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name RIVERSIDE INC Firm No. 333
Principal Driller ____ Date 5-22-06
and
Driller or Operator II Justin Cleaver Date 5-22-06
Operator I ____ Date ____

Principal Driller and Rig Operator *Required.*
Operator I must have signature of Driller/Operator II.

FORWARD WHITE COPY TO WATER RESOURCES

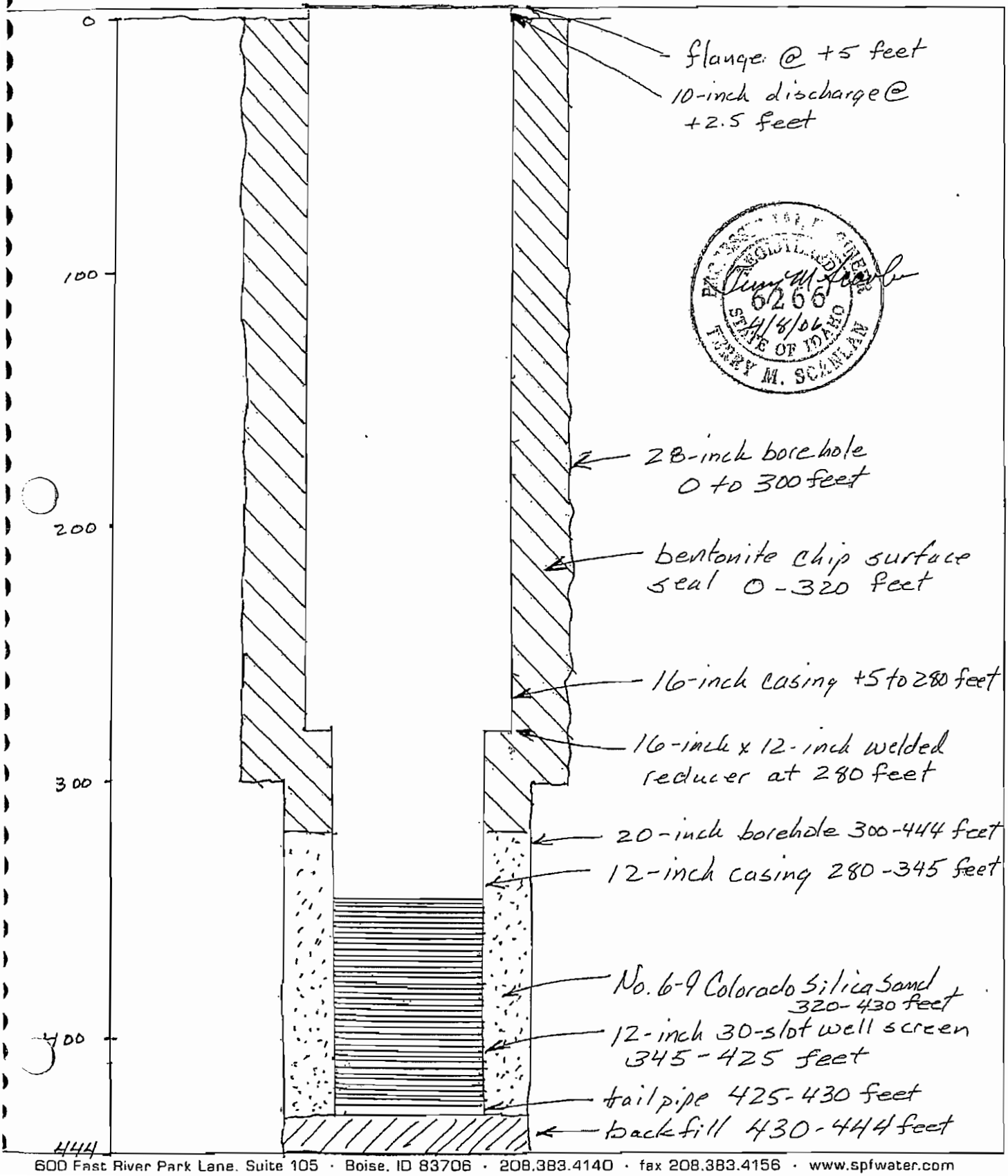

Eagle Test #2 Eaglefield
64" Resistivity
0 ohm-meters 250
16" Resistivity
0 ohm-meters 250
NaturalGammaRay
40 API 140
PointResistance
50 ohms 100
3
130
200
300
400
16" Resistivity
0 ohm-meters 250
64" Resistivity
0 ohm-meters 250
NaturalGammaRay
40 API 140
PointResistance
50 ohms 100
Eagle Test #2 - Eaglefield

SPF Water Engineering, LLC
water resource consultants

Eaglefield Well #2 (pumping)

By TS Date 4/4/06 Client Eaglefield Sheet 1 of 1

Chkd By _____ Description Final Well Design - Eagle Well #4 Job No 421.00 10



600 East River Park Lane, Suite 105 · Boise, ID 83706 · 208.383.4140 · fax 208.383.4156 · www.spfwater.com

63

Form 238-7
6/02

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

Legacy #1 (observation)

Twp ____ Rge ____ Sec ____
____ 1/4 ____ 1/4 ____ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 0041980
DRILLING PERMIT NO. 890994-835987
Water Right or Injection Well No. 63-32089 + 63-32090

2. OWNER:
Name CITY of EAGLE
Address P.O. Box 1520
City EAGLE State ID Zip 83616

3. LOCATION OF WELL by legal description: LEGACY WELL #1
You must provide address or Lot, Blk, Sub. or Directions to well.
Twp. 4 North ☒ or South ☐
Rge. 1 East ☐ or West ☒
Sec. 11 10 acres 1/4 SE 40 acres 1/4 NW 160 acres 1/4
Gov't Lot ____ County ADA
Lat: : : Long: : :
Address of Well Site QUARTER CIRCLE DJ RANCH, WEST OF EAGLE ROAD City EAGLE
(Give at least name of road + Distance to Road or Landmark)
Lt. ____ Blk. ____ Sub. Name ____

4. USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☒ Other TEST

5. TYPE OF WORK check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other ____

6. DRILL METHOD:
☐ Air Rotary ☐ Cable ☐ Mud Rotary ☒ Other REVERSE

7. SEALING PROCEDURES

Seal Material	From	To	Weight / Volume	Seal Placement Method
CEMENT GROUT	0	272	24 yds	PUMPED BOTTOM TO TOP
BENTONITE	360	415	12,000	DRY POUR

Was drive shoe used? ☐ Y ☒ N Shoe Depth(s) ____
Was drive shoe seal tested? ☐ Y ☒ N How? ____

8. CASING/LINER: 16" X 12" REDUCER @ 180' TO 181'

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
16	+4	180	.375	STEEL	☒	☐	☒	☐
12	181	282	.375	STEEL	☒	☐	☒	☐
					☐	☐	☐	☐

Length of Headpipe ____ Length of Tailpipe 5'
Packer ☐ Y ☒ N Type ____

9. PERFORATIONS/SCREENS PACKER TYPE
Perforation Method ____
Screen Type & Method of Installation JOHNSON WIRE WRAP

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
282	352	.030		12	S.S.	☒	☐
						☐	☐
						☐	☐

10. FILTER PACK

Filter Material	From	To	Weight / Volume	Placement Method
#8-12 SAND	272	360	24,000	DRY POUR

11. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
____ ft. below ground Artesian pressure 6 lb.
Depth flow encountered ____ ft. Describe access port or control devices: ____
FLANGED CAP W/ 1 1/4" PIPE PLUG

12. WELL TESTS:
☒ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time
1300 gpm	149'	135'	4 1/2 hrs

Water Temp. ____ Bottom hole temp. ____
Water Quality test or comments: ____
Depth first Water Encounter ____

13. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
24	0	4	TOP SOIL		
	4	7	CLAY		
	7	11	SAND		
	11	28	SAND, RIVER GRAVELS		
	28	60	BRN CLAY		
	60	63	SAND		
	63	72	BRN CLAY		
	72	92	SAND		
	92	94	BRN CLAY		
	94	166	SAND W/BRN CLAY STREAKS		
	166	174	CLAY		
	174	178	SAND		
	178	181	CLAY		
	181	183	SAND, CLAY STREAKS		
	183	257	SAND		
	257	264	CLAY		
	264	274	SAND W/CLAY STREAKS		
	274	353	SAND		
	353	360	BLUE CLAY		
20	360	384	BLUE CLAY		
20	384	387	SAND		
	387	419	BLUE-GRAY CLAY		
	419	444	SAND		
	444	459	BLUE-GRAY CLAY		
	459	493	SAND W/ CLAY LAYERS		
	493	501	BLUE-GRAY CLAY		
	501	505	CEMENTED SAND		
	505	573	BLUE-GRAY CLAY		
			NOTE: BORE HOLE ABANDONMENT FROM 415' TO 513' WITH DRILL CUTTINGS		

Completed Depth 357' (Measurable)
Date: Started 1-24-06 Completed 4-11-06

RECEIVED
MAY 17 2006
WATER RESOURCES WESTERN REGION

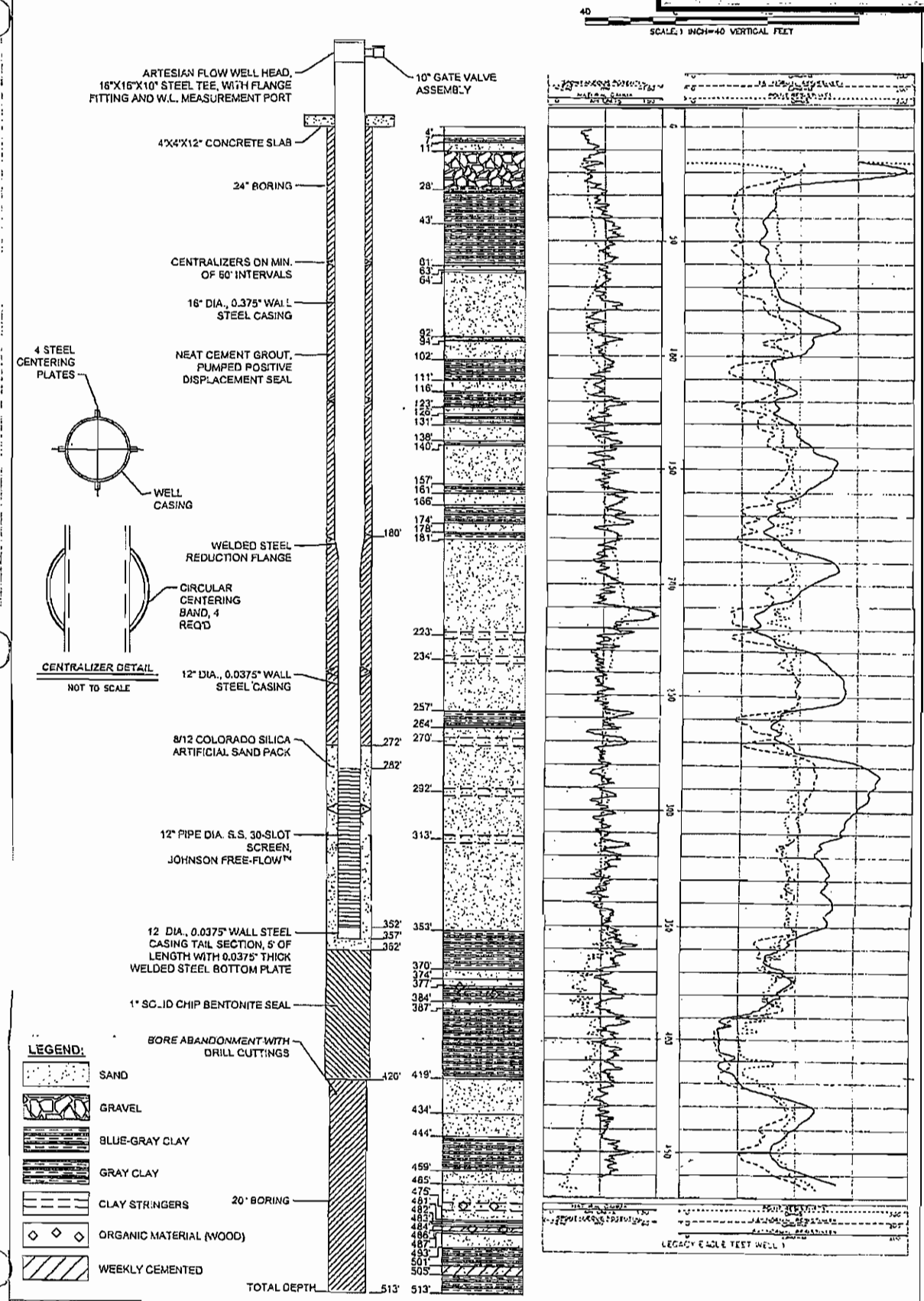
14. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name RIVERSIDE INC Firm No. 333
Principal Driller [signature] Date 5-15-06
and
Driller or Operator II ____ Date ____
Operator I Jeff Nash Date 5-15-06

Principal Driller and Rig Operator *Required.*
Operator I must have signature of Driller/Operator II.

FORWARD WHITE COPY TO WATER RESOURCES

Legacy #1 (observation)



AS-BUILT 2-17-06
EAGLE TEST WELL NO. 1
CITY OF EAGLE, IDAHO

HOLLADAY ENGINEERING CO.
ENGINEERS · CONSULTANTS

RECEIVED
OCT 28 1997
Department of Water Resources

Form 238-7
3/95

IDAHO DEPARTMENT OF WATER RESOU

WELL DRILLER'S REPORT

Use Typewriter or Ballpoint Pen

Tag #000019

UWID State and Linder 1A (observation)

67930

Inspected by _____
Twp____ Rge____ Sec____
____1/4____1/4 ____1/4
Lat: . : Long: : :

1. DRILLING PERMIT NO. 63-97-W-0633-801
Other IDWR No. _____

2. OWNER: Hope Lutheran Church
Name United Water Corp
Address PO Box 7488
City Boise State ID Zip 83707

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S

Twp. 4 North ☒ or South ☐
Rge. 1 East ☐ or West ☒
Sec. 11, NE 1/4 (10 acres) SE 1/4 (40 acres) ____ 1/4 (160 acres)
Gov't Lot ____ County Ada
Lat: : : Long: : :
Address of Well Site State St & Linder (Hope Luth Church) City Eagle
(Give at least name of road + Distance to Road or Landmark)
Lt. 7 Blk. 1 Sub. Name Brush Acres

4. USE:
☐ Domestic ☐ Municipal ☒ ~~Monitor~~ ☐ Irrigation
☐ Thermal ☐ Injection ☒ Other Test well

5. TYPE OF WORK check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other _____

6. DRILL METHOD
☐ Air Rotary ☐ Cable ☒ Mud Rotary ☐ Other _____

7. SEALING PROCEDURES

SEAL/FILTER PACK Material	From	To	AMOUNT Sacks or Pounds	METHOD

Was drive shoe used? ☐Y ☐N Shoe Depth(s) _____
Was drive shoe seal tested? ☐Y ☐N How? _____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Length of Headpipe _____ Length of Tailpipe _____

9. PERFORATIONS/SCREENS
☐ Perforations Method _____
☐ Screens Screen Type _____

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
						☐	☐
						☐	☐
						☐	☐

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
_____ ft. below ground Artesian pressure 6 lb.
Depth flow encountered 212 ft. Describe access port or control devices: caps

11. WELL TESTS:
☐ Pump ☐ Bailer ☐ Air ☒ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time

Water Temp. _____ Bottom hole temp. _____
Water Quality test or comments: _____
Depth first Water Encountered _____

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
10	1	6	topsoil		X
	6	31	sand & gravel		X
8	31	43	sand & sandy clay	X	
	43	68	cemented sand	X	
	68	71	clay		X
	71	93	sand	X	
	93	103	clay		X
	103	125	sand	X	
	125	140	clay		X
	140	200	sand & clay streaks	X	
	200	205	sand	X	
	205	212	clay		X
	212	485	sand	X	
	485	513	sand & cemented sand streaks	X	
	513	540	sand	X	
	540	845	blue clay		X
			~~see drawing for pipe information~~		

RECEIVED
OCT 23 1997
WATER RESOURCES WESTERN REGION

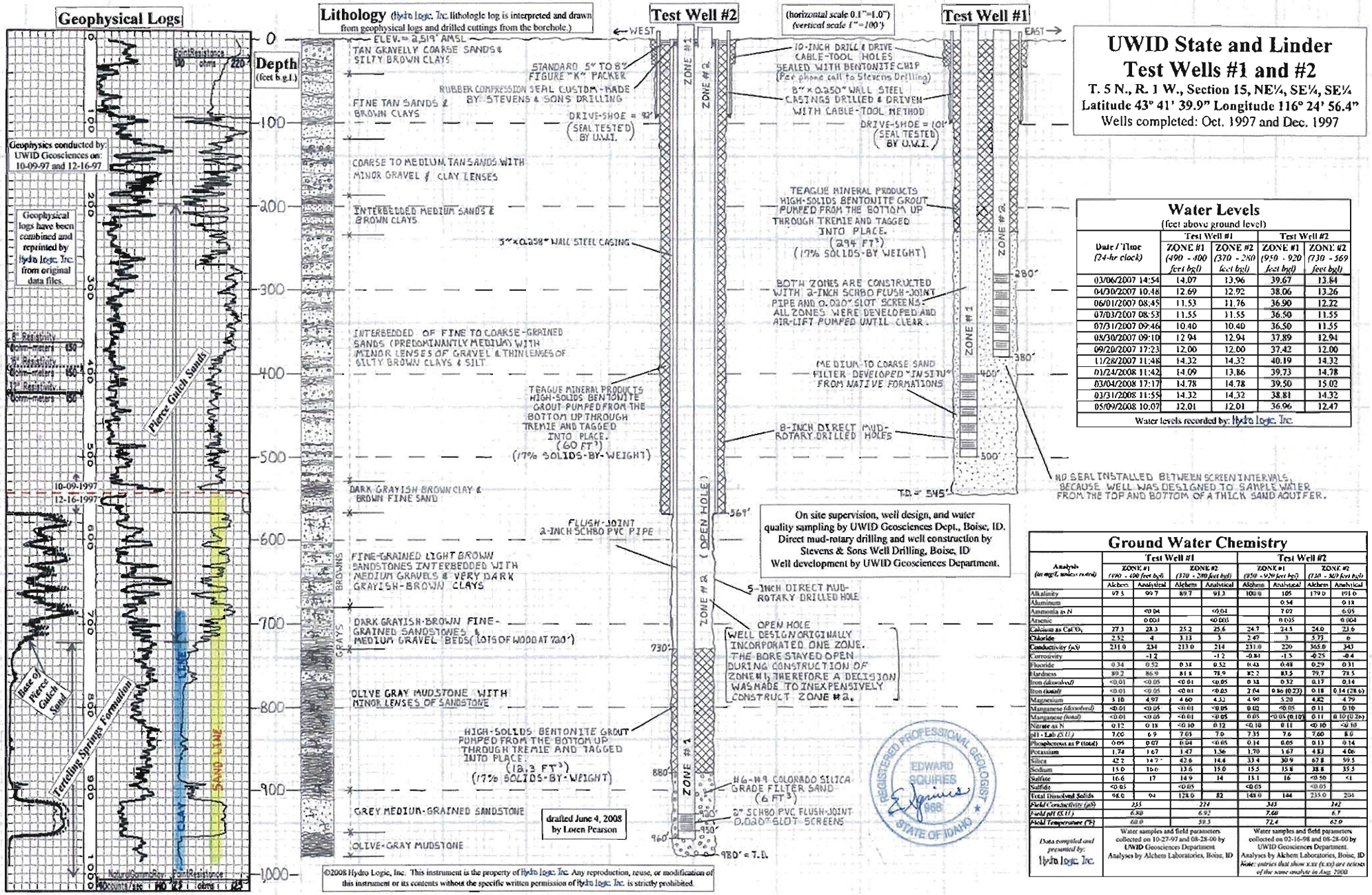
MICROFILMED
JAN 09 1998

Completed Depth 845 (Measurable)
Date: Started 9/25/97 Completed 10/13/97

13. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Firm Name Stevens & Sons Firm No. 153
Firm Official _____ Date _____
and
Supervisor or Operator Ron Stevens Date 10/20/97
(Sign once if Firm Official & Operator)

FORWARD WHITE COPY TO WATER RESOURCES



UWID State and Linder Test Wells #1 and #2

T. 5 N., R. 1 W., Section 15, NE¼, SE¼, SE¼
Latitude 43° 41' 39.9" Longitude 116° 24' 56.4"
Wells completed: Oct. 1997 and Dec. 1997

On site supervision, well design, and water quality sampling by UWID Geosciences Dept., Boise, ID. Direct mud-rotary drilling and well construction by Stevens & Sons Well Drilling, Boise, ID. Well development by UWID Geosciences Department.

Water Levels

(feet above ground level)

Date / Time (24-hr clock)	Test Well #1 ZONE #1 (490 - 400 feet bgl)	Test Well #1 ZONE #2 (370 - 280 feet bgl)	Test Well #2 ZONE #1 (950 - 920 feet bgl)	Test Well #2 ZONE #2 (730 - 569 feet bgl)
03/06/2007 14:54	14.07	13.96	39.67	13.84
04/30/2007 10:48	12.69	12.92	38.06	13.26
06/01/2007 08:45	11.53	11.76	36.90	12.22
07/03/2007 08:53	11.55	11.55	36.50	11.55
07/31/2007 09:46	10.40	10.40	36.50	11.55
08/30/2007 09:10	12.94	12.94	37.89	12.94
09/20/2007 17:23	12.00	12.00	37.42	12.00
11/28/2007 11:48	14.32	14.32	40.19	14.32
01/24/2008 11:42	14.09	13.86	39.73	14.78
03/04/2008 17:17	14.78	14.78	39.50	15.02
03/31/2008 11:55	14.32	14.32	38.81	14.32
05/09/2008 10:07	12.01	12.01	36.96	12.47

Water levels recorded by: Hydro Logic, Inc.

Ground Water Chemistry

Analysis (in mg/L unless noted)	Test Well #1 ZONE #1 (490 - 400 feet bgl) Alchem	Test Well #1 ZONE #1 (490 - 400 feet bgl) Analytical	Test Well #1 ZONE #2 (370 - 280 feet bgl) Alchem	Test Well #1 ZONE #2 (370 - 280 feet bgl) Analytical	Test Well #2 ZONE #1 (950 - 920 feet bgl) Alchem	Test Well #2 ZONE #1 (950 - 920 feet bgl) Analytical	Test Well #2 ZONE #2 (730 - 569 feet bgl) Alchem	Test Well #2 ZONE #2 (730 - 569 feet bgl) Analytical
Alkalinity	97.5	99.7	89.7	91.3	100.0	105	179.0	191.0
Aluminum						0.54		0.18
Ammonia as N		<0.04		<0.04		7.02		6.05
Arsenic		0.003		<0.003		0.035		0.004
Calcium as $CaCO_3$	27.3	28.3	25.2	25.6	24.7	24.5	24.0	23.6
Chloride	2.52	4	3.13	3	2.47	3	5.73	6
Conductivity (µS)	231.0	234	213.0	214	231.0	220	365.0	343
Corrosivity		-1.2		-1.2	-0.84	-1.5	-0.25	-0.4
Fluoride	0.34	0.52	0.31	0.52	0.43	0.48	0.29	0.31
Hardness	89.2	86.9	81.8	78.9	82.7	83.5	79.7	78.5
Iron (dissolved)	<0.01	<0.05	<0.01	<0.05	0.38	0.32	0.17	0.14
Iron (total)	<0.01	<0.05	<0.01	<0.05	2.04	0.86 (0.23)	0.18	0.14 (28.6)
Magnesium	5.10	4.97	4.60	4.32	4.99	5.20	4.82	4.79
Manganese (dissolved)	<0.01	<0.05	<0.01	<0.05	0.02	<0.05	0.11	0.10
Manganese (total)	<0.01	<0.05	<0.01	<0.05	0.05	<0.05 (0.10)	0.11	0.10 (0.2x)
Nitrate as N	0.12	0.18	<0.10	0.12	<0.10	0.11	<0.10	<0.10
pH - Lab (S.U.)	7.00	6.9	7.09	7.0	7.35	7.6	7.60	8.0
Phosphorous as P (total)	0.09	0.07	0.04	<0.05	0.14	0.05	0.13	0.14
Potassium	1.74	1.67	1.47	1.36	1.70	1.67	4.83	4.06
Silica	42.2	44.7	42.6	14.4	33.4	30.9	67.8	59.5
Sodium	15.0	16.0	13.6	15.0	15.5	15.8	38.8	35.5
Sulfate	16.6	17	14.9	14	15.1	16	<3.50	<1
Sulfide	<0.03		<0.03		<0.03		<0.03	
Total Dissolved Solids	98.0	94	128.0	82	148.0	144	235.0	204
Field Conductivity (µS)	255		224		343		342	
Field pH (S.U.)	6.80		6.92		7.68		6.7	
Field Temperature (°F)	60.0		59.5		72.4		62.0	
Data compiled and presented by: Hydro Logic, Inc.	Water samples and field parameters collected on 10-27-97 and 08-28-00 by UWID Geosciences Department. Analyses by Alchem Laboratories, Boise, ID				Water samples and field parameters collected on 02-16-98 and 08-28-00 by UWID Geosciences Department. Analyses by Alchem Laboratories, Boise, ID. Note: entries that show xx.xx (x.xx) are retests of the same analyte in Aug. 2000.			

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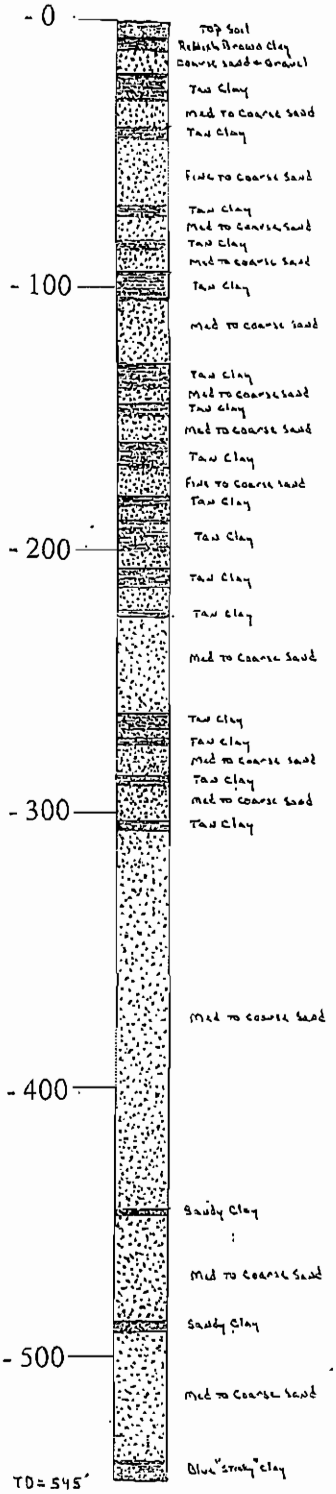
United Water Idaho State St. & L

T4N, R1W, NE 1/4, SE 1/4, SE

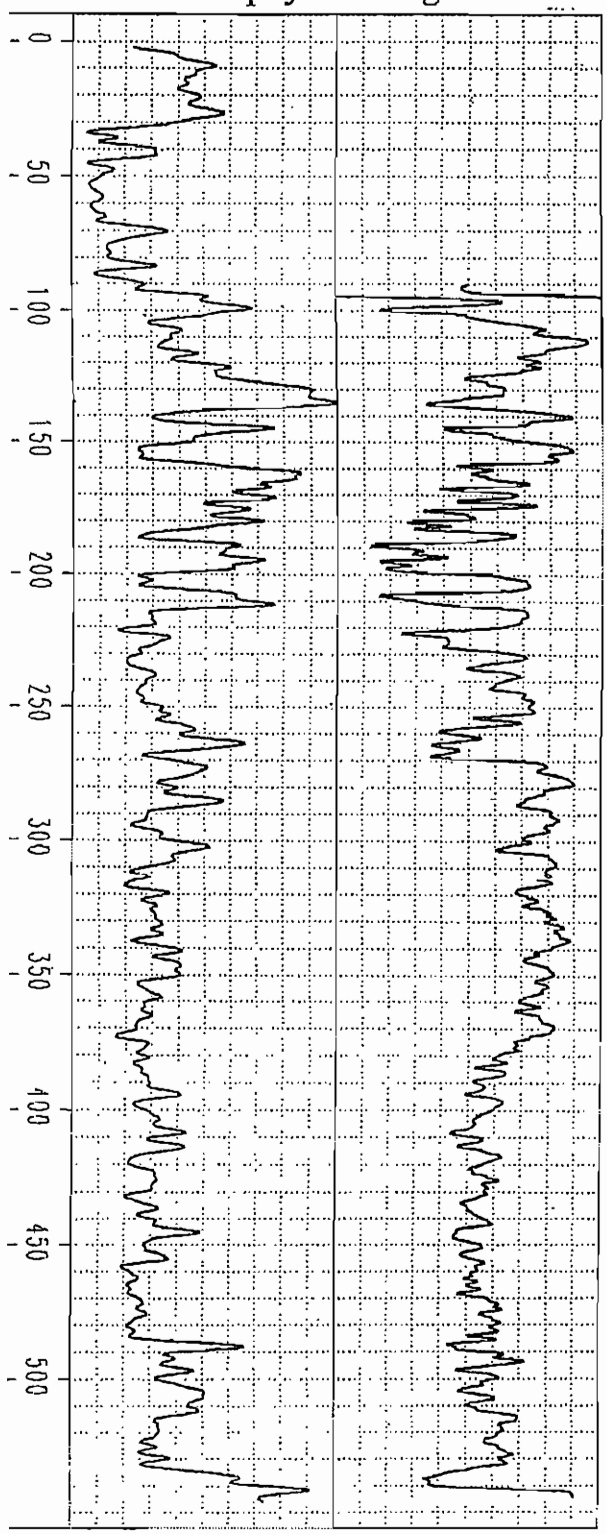
UWID State and Linder 1A (observation)

Lithology

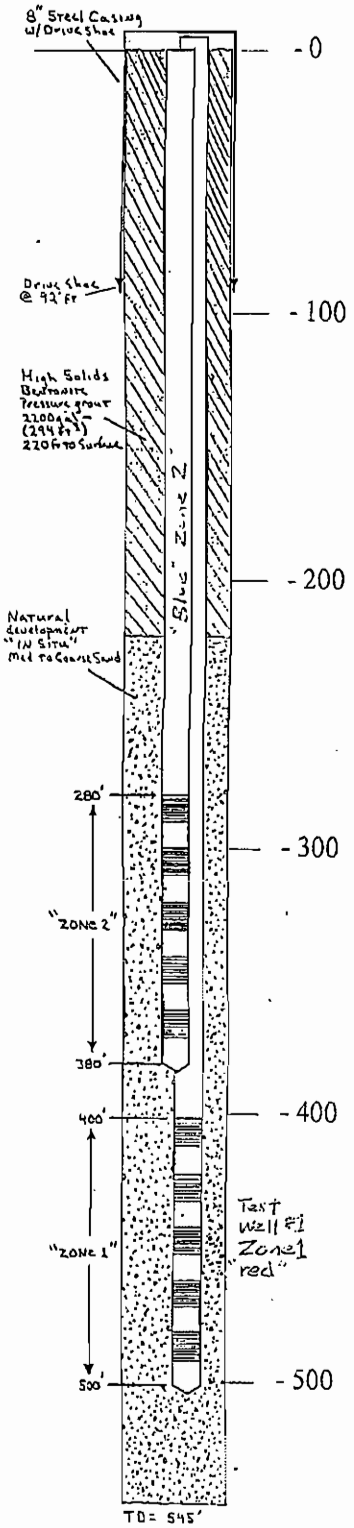


Lithology based on drill cuttings and geophysical logs

Geophysical Logs



Test Well Construction



completed 10-13-97
by Stevens & Sons Drilling

USE TYPEWRITER OR BALL POINT PEN

State of Idaho
Department of Water Administration

WELL DRILLER'S REPORT

Ricks Irrigation Well (observation)

State law requires that this report be filed with the Director, Department of Water Administration within 30 days after the completion or abandonment of the well.

1. WELL OWNER

Name Quarter Circle D,J. Ranch

Address Star, Idaho (Home Place)

Owner's Permit No.

2. NATURE OF WORK

☒ New well ☐ Deepened ☐ Replacement

☐ Abandoned (describe method of abandoning)

3. PROPOSED USE

☐ Domestic ☒ Irrigation ☐ Test ☐ Other (specify type)

☐ Municipal ☐ Industrial ☐ Stock ☐ Waste Disposal or injection

4. METHOD DRILLED

☒ Cable ☐ Rotary ☐ Dug ☐ Other

5. WELL CONSTRUCTION

Diameter of hole 16 inches Total depth 406 feet

Casing schedule: ☒ Steel ☐ Concrete

Thickness	Diameter	From	To
.250 inches	16 inches	0'8" feet	253 feet
.250 inches	10 inches	223 feet	406 feet
inches	inches	feet	feet
inches	inches	feet	feet
inches	inches	feet	feet

Was a packer or seal used? ☐ Yes ☒ No

Perforated? ☒ Yes ☐ No

How perforated? ☒ Factory ☐ Knife ☐ Torch

Size of perforation 3/16 inches by 3 inches

Number		From	To
5,152	perforations	234 feet	395 feet
	perforations	feet	feet
	perforations	feet	feet

Well screen installed? ☐ Yes ☒ No

Manufacturer's name

Type Model No.

Diameter Slot size Set from feet to feet

Diameter Slot size Set from feet to feet

Gravel packed? ☒ Yes ☐ No Size of gravel 3/8 minus 30 yds.

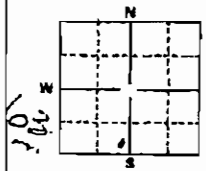
Placed from 223 feet to 406 feet

Surface seal depth 22 Material used in seal ☒ Cement grout ☐ Puddling clay ☐ Well cuttings

Sealing procedure used ☐ Slurry pit ☒ Temporary surface casing ☐ Overbore to seal depth

6. LOCATION OF WELL

Sketch map location must agree with written location.



Subdivision Name

Lot No. Block No.

County Ada

S/E ¼ S/W ¼ Sec. 2 T. 4 N/S R. I E/W

7. WATER LEVEL

Static water level feet below land surface

Flowing? ☒ Yes ☐ No G.P.M. flow

Temperature ° F. Quality

Artesian closed-in pressure p.s.i.

Controlled by ☒ Valve ☐ Cap ☐ Plug

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Discharge G.P.M.	Draw Down	Hours Pumped

9. LITHOLOGIC LOG

40055

Hole Diam.	Depth From	Depth To	Material	Water Yes	Water No
16"	0	3	Top Soil		X
"	3	12	Light clay and sand		X
"	12	27	Fine sand, some clay	X	
"	27	105	Blue clay		X
"	105	240	Sand with clay binder	X	
"	240	260	Sticky brown clay		X
"	260	295	Sand, some small layers of clay	X X	
"	295	318	Sticky brown clay		X
"	318	380	Sand, some small layers of clay	X X	
"	380	404	Sand, some clay	X	
"	404	406	Sticky light brown clay		X
			Gravel pack		
			30 yds. of 3/8 minus gravel		
			10" shoe on top of liner		
			15" shoe on bottom of liner		
			NOT TESTED AS OF 2/20/74		

10. Work started Nov. 28/73 finished Dec. 30, 73

11. DRILLER'S CERTIFICATION

Firm Name W. E. Stevens & Sons Firm No. 153

Address 3709 Hawthorne Drive Date 12/30/73

Signed by (Firm Official) Wayne E. Stevens

and

(Operator)

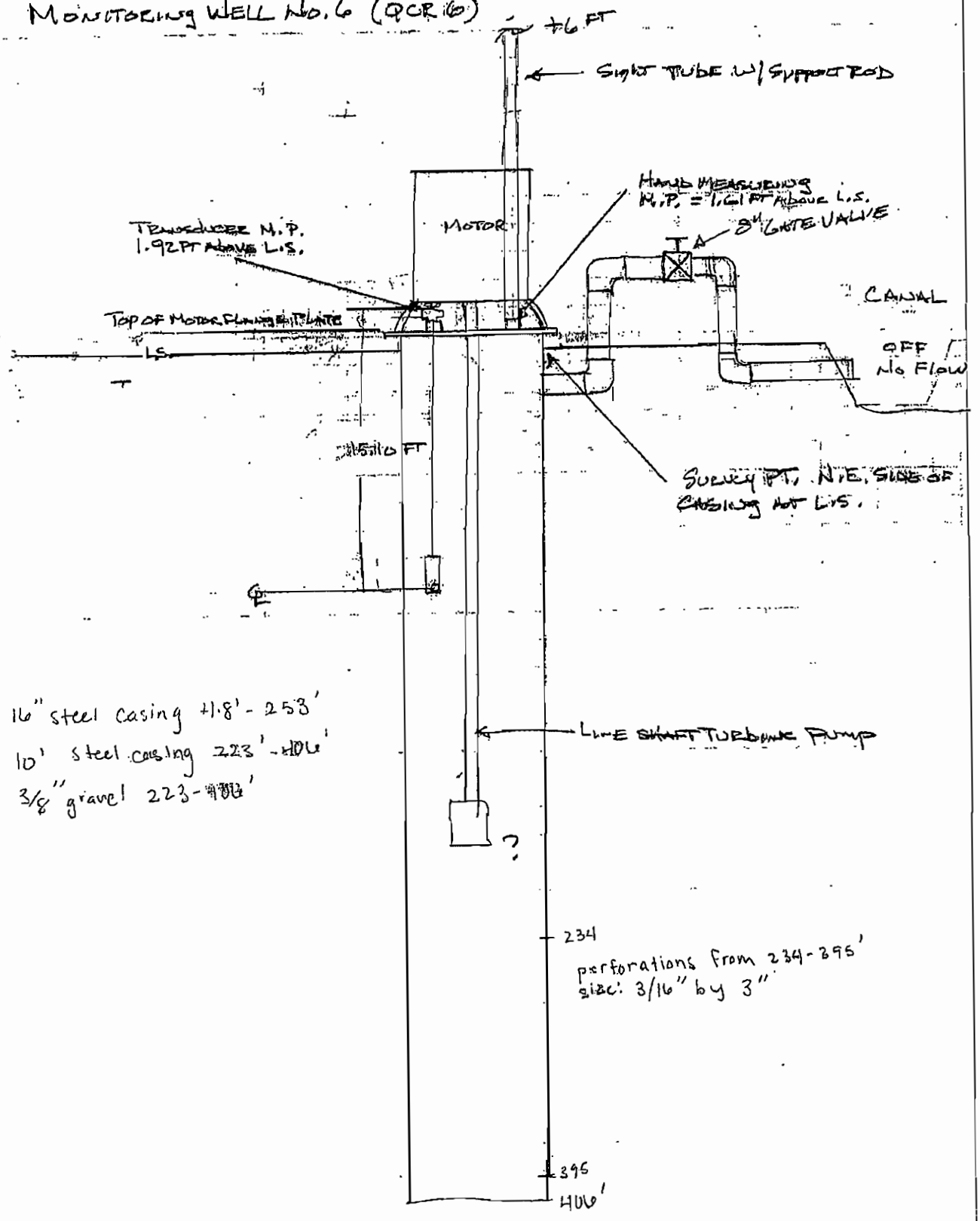
MICROFILMED

USE ADDITIONAL SHEETS IF NECESSARY FORWARD THE WHITE COPY TO THE DEPARTMENT

Ricks Irrigation Well (observation)

CITY OF EAGLE 7-DAY AQUIFER TEST
QUARTER CIRCLE WELL NO. 6
(RICK'S IRRIGATION WELL)

MONITORING WELL NO. 6 (QCR 6)



Form 238-7
6/89

STATE OF IDAHO
DEPARTMENT OF WATER RESOUI

WELL DRILLER'S REP

Lexington Hills Well #1 (pumping)

State law requires that this report be filed with the Director, Department of Water Resources within 30 days after the completion or abandonment of the well.

MAY 1 1991

Department of Water Resources
Western Regional Office

1. WELL OWNER

Name Floating Feather Hills, Inc.
Address 2417 Bank Drive-Suite 101 Boise, ID 83705
Owner's Permit No. 63-91-W-044 ~~63-11413 (App.Pending)~~

2. NATURE OF WORK

☒ New well ☐ Deepened ☐ Replacement
☐ Well diameter increase
☐ Abandoned (describe abandonment procedures such as materials, plug depths, etc. in lithologic log)

3. PROPOSED USE

☐ Domestic ☐ Irrigation ☒ Test ☐ Municipal
☐ Industrial ☐ Stock ☐ Waste Disposal or Injection
☐ Other _____ (specify type)

4. METHOD DRILLED

☐ Rotary ☐ Air ☐ Hydraulic ☒ Reverse rotary
☐ Cable ☐ Dug ☐ Other _____

5. WELL CONSTRUCTION

Casing schedule: ☒ Steel ☐ Concrete ☐ Other _____

Thickness	Diameter		From	To
.250 inches	16 inches	+	18" feet	215 feet
.250 inches	16 inches		265 feet	375 feet
.250 inches	16 inches		385 feet	405 feet
_____ inches	_____ inches		_____ feet	_____ feet

Was casing drive shoe used? ☐ Yes ☒ No
Was a packer or seal used? ☐ Yes ☒ No
Perforated? ☐ Yes ☒ No
How perforated? ☐ Factory ☐ Knife ☐ Torch ☐ Gun
Size of perforation _____ inches by _____ inches

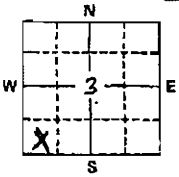
Number	From	To
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet

Well screen installed? ☒ Yes ☐ No
Manufacturer's name Roscoe Moss
Type Hvy.Stainless Steel Model No. Wirewrap
Diameter 16" Slot size .040 Set from 215 feet to 265 feet
Diameter 16" Slot size .040 Set from 375 feet to 385 feet
Gravel packed? ☒ Yes ☐ No ☐ Size of gravel 3/8-
Placed from 315 feet to 190 feet
Surface seal depth 90' Material used in seal: ☒ Cement grout
Sealed also at 190-180 ☐ Bentonite ☐ Puddling clay ☐ _____
Sealing procedure used: ☐ Slurry pit ☐ Temp. surface casing
☐ Overbore to seal depth
Method of joining casing: ☐ Threaded ☒ Welded ☐ Solvent Weld
☐ Cemented between strata
Describe access port 2"

6. LOCATION OF WELL

RECEIVED
JUL 0 8 1992

Sketch map location must agree with written location.



Subdivision Name _____
Lot No. _____ Block No. _____
County Ada
SW¼ SW¼ Sec. 3 , T. 4N N ☐ S ☐ R. 1E E ☐ W ☐

7. WATER LEVEL

Static water level 68 feet below land surface.
Flowing? ☐ Yes ☐ No G.P.M. flow _____
Artesian closed-in pressure _____ p.s.i.
Controlled by: ☐ Valve ☐ Cap ☐ Plug
Temperature ~~if~~ °F. Quality _____
Describe artesian or temperature zones below.

8. WELL TEST DATA

☐ Pump ☐ Baller ☐ Air ☐ Other _____

Discharge G.P.M.	Pumping Level	Hours Pumped

9. LITHOLOGIC LOG 075684

Bore Diam.	Depth From	Depth To	Material	Water Yes	Water No
28"	0	3	Top Soil		
	3	15	Sandy Loam		
	15	25	Coarse Sand & Pea Gravel		
	25	40	Med. to Crse. Sand		
	40	75	River Rock		
	75	85	Fine Sand		
	85	87	Lite Brn. Clay		
	87	106	Fine Sand		
	106	108	Lite Brn. Clay		
	108	124	Fine Sand		
	124	130	Lt. Brn. Clay		
	130	165	Fine Sand		
	165	175	Gldn.Fn./Med.Sand with some clay in spots.		
	175	182	Fine Sand		
	182	185	Lt.Brn.Clay & Fine Sand		
	185	189	Fine Sand		
	189	193	Fine to crse. Sand		
	193	195	Med./Crse. Sand & Clay Mxd.		
	195	198	Lt. Brn. Clay		
	198	205	Fine to Med. Sand		
	205	209	Fine/Crse.Sand & Lt.Brn. Clay Mxd.		
	209	211	Fine Sand		
	211	215	Fine/Med.Sand & Lt.Brn.Clay		
	215	225	Fine Sand		
	225	235	Sandwitched Sand & Clay (½)		
	235	265	Gray Sand		
	265	275	Sand-Clay (50-50)		
	275	282	Gray Clay		
	282	290	Fine Gray Sand		
	290	300	Gray Clay		
	300	305	Fine Gray Sand		
	305	311	Gray Clay w/sm.at.fine sand		
	311	315	Brn. & Gray Clay		

10.

Work started 2/26/91 finished 3/7/91

11. DRILLERS CERTIFICATION

I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

PETE COPE DRILLING CO., INC. Firm No. 213
Firm Name
Address 6505 W. Chinden Blvd. Meridian, ID Date 3/12/91
Signed by (Firm Official) _____
and
(Operator) Kevin Chastain

USE ADDITIONAL SHEETS IF NECESSARY — FORWARD THE WHITE COPY TO THE DEPARTMENT

CONTINUED - PAGE 2

Form 238-7
6/89

STATE OF IDAHO
DEPARTMENT OF WATER RESOUR

WELL DRILLER'S REP

Lexington Hills Well #1 (pumping)

State law requires that this report be filed with the Director, Department of Water Resources within 30 days after the completion or abandonment of the well.

MAY - 1 1991

Department of Water Resources
Western Regional Office

1. WELL OWNER

Name Floating Feather Hills, Inc.

Address _____

Owner's Permit No. _____

2. NATURE OF WORK

☐ New well ☐ Deepened ☐ Replacement
☐ Well diameter increase
☐ Abandoned (describe abandonment procedures such as materials, plug depths, etc. in lithologic log)

3. PROPOSED USE

☐ Domestic ☐ Irrigation ☐ Test ☐ Municipal
☐ Industrial ☐ Stock ☐ Waste Disposal or Injection
☐ Other _____ (specify type)

4. METHOD DRILLED

☐ Rotary ☐ Air ☐ Hydraulic ☐ Reverse rotary
☐ Cable ☐ Dug ☐ Other _____

5. WELL CONSTRUCTION

Casing schedule: ☐ Steel ☐ Concrete ☐ Other _____

Thickness	Diameter	From	To
_____ inches	_____ inches +	_____ feet	_____ feet
_____ inches	_____ inches	_____ feet	_____ feet
_____ inches	_____ inches	_____ feet	_____ feet
_____ inches	_____ inches	_____ feet	_____ feet

Was casing drive shoe used? ☐ Yes ☐ No
Was a packer or seal used? ☐ Yes ☐ No
Perforated? ☐ Yes ☐ No
How perforated? ☐ Factory ☐ Knife ☐ Torch ☐ Gun
Size of perforation _____ inches by _____ inches

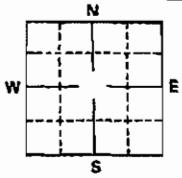
Number	From	To
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet

Well screen installed? ☐ Yes ☐ No
Manufacturer's name _____
Type _____ Model No. _____
Diameter ____ Slot size ____ Set from _____ feet to _____ feet
Diameter ____ Slot size ____ Set from _____ feet to _____ feet
Gravel packed? ☐ Yes ☐ No ☐ Size of gravel _____
Placed from _____ feet to _____ feet
Surface seal depth ____ Material used to seal: ☐ Cement grout
☐ Bentonite ☐ Puddling clay ☐ _____
Sealing procedure used: ☐ Slurry pit ☐ Temp. surface casing
☐ Overbore to seal depth
Method of joining casing: ☐ Threaded ☐ Welded ☐ Solvent Weld
☐ Cemented between strata
Describe access port _____

6. LOCATION OF WELL

Sketch map location must agree with

MICROFILMED
JUL 08 1992



Subdivision Name _____

Lot No. _____ Block No. _____

County _____

SW ¼ SW ¼ Sec. 3, T. 4N N ☐ S ☐ R. 1E E ☐ W ☐

7. WATER LEVEL

Static water level _____ feet below land surface.
Flowing? ☐ Yes ☐ No G.P.M. flow _____
Artesian closed-in pressure _____ p.s.i.
Controlled by: ☐ Valve ☐ Cap ☐ Plug
Temperature _____ °F. Quality _____
Describe artesian or temperature zones below

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Air ☐ Other _____

Discharge G.P.M.	Pumping Level	Hours Pumped

9. LITHOLOGIC LOG 075685

Bore Diam.	Depth From	Depth To	Material	Water Yes	Water No
28"	315	325	Brn. & Gray Clay Mix w/ streaks of fine sand.		
	325	335	Blue Brown clay w/ stks. of sand.		
	335	351	Fine Blue Sand		
	351	365	Blue Clay		
	365	385	Fine Blue Sand		
	385	388	Blue Clay		
	388	393	Blue Sand		
	393	405	Blue Clay		

10.

Work started _____ finished _____

11. DRILLERS CERTIFICATION

I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

PETE COPE DRILLING CO., INC.
Firm Name _____ Firm No. 213

Address _____ Date _____

Signed by (Firm Official) _____

and

(Operator) _____

USE ADDITIONAL SHEETS IF NECESSARY — FORWARD THE WHITE COPY TO THE DEPARTMENT

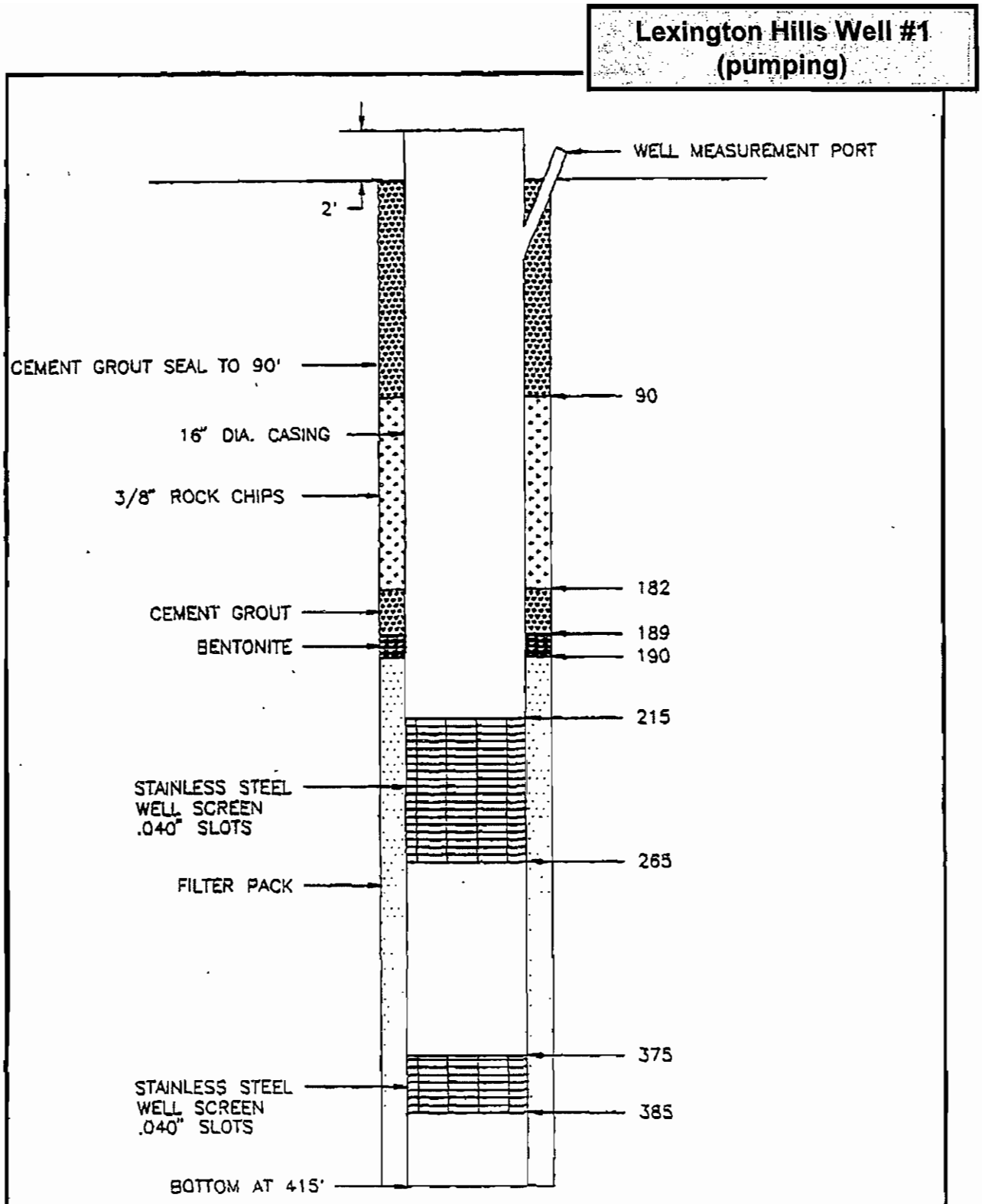
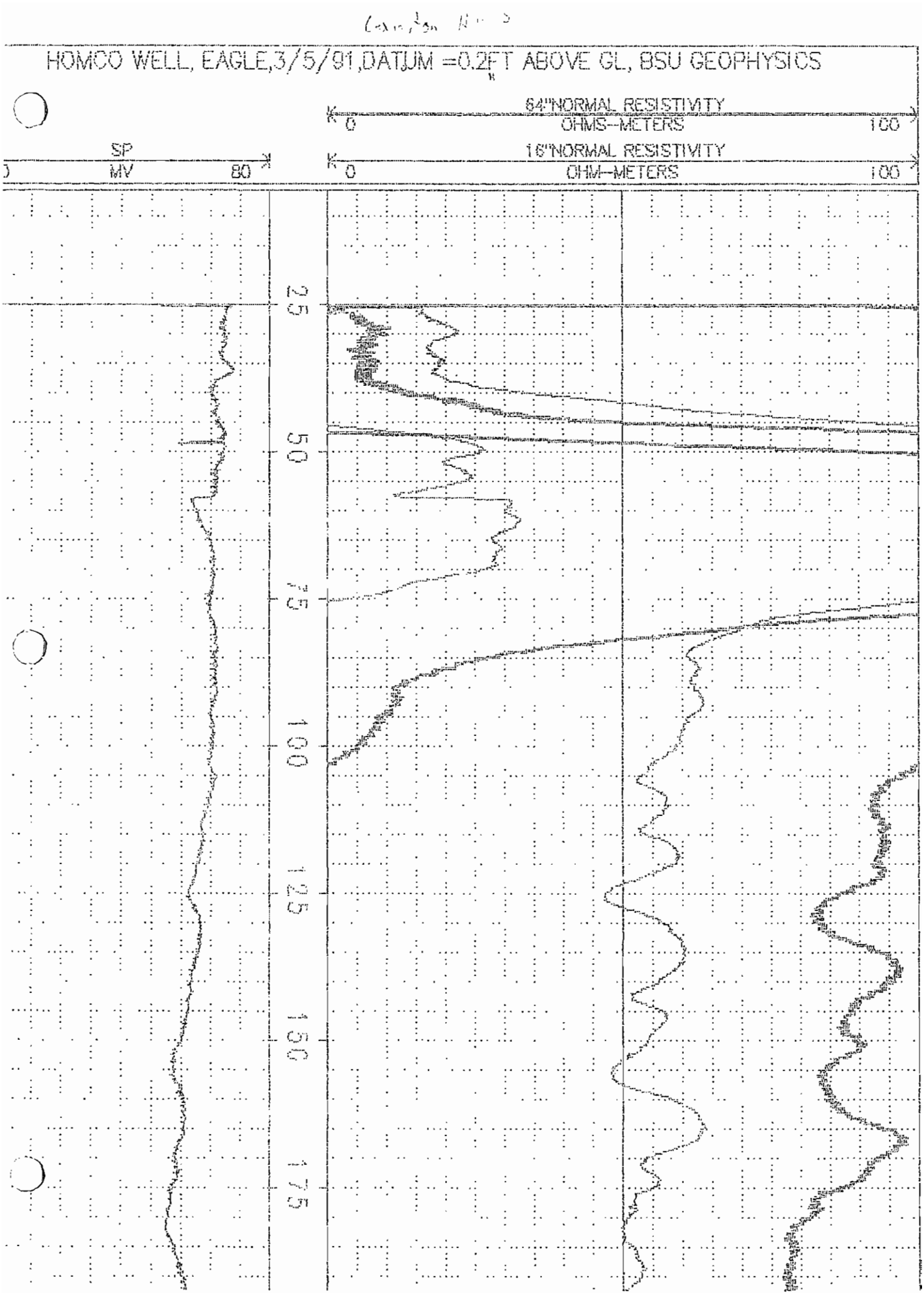


FIGURE 3
PRODUCTION WELL CONSTRUCTION
FLOATING FEATHER HILLS, INC.

CH2MHILL


HOMCO WELL, EAGLE,3/5/91,DATUM =0.2FT ABOVE GL, BSU GEOPHYSICS
64"NORMAL RESISTIVITY
OHMS-METERS
0
100
SP
MV
80
16"NORMAL RESISTIVITY
OHM-METERS
0
100
25
50
75
100
125
150
175

200
225
250
275
300
325
350
375
400

Eagle Hills Golf Course Well (not analyzed)

Form 238-7
4/92

STATE OF IDAHO
DEPARTMENT OF WATER RESOUR

WELL DRILLER'S REPORT

State law requires that this report be filed with the Director, Department of Water Resources within 30 days after the completion or abandonment of the well.

1. WELL OWNER
Name Eagle Hills Golf Course
Address 605 N Edgewood Lane Eagle
Drilling Permit No. 63-92-W-523
Water Right Permit No. 63-11872

2. NATURE OF WORK
☒ New well ☐ Deepened ☐ Replacement
☐ Well diameter increase ☐ Modification
☐ Abandoned (describe abandonment or modification procedures such as liners, screen, materials, plug depths, etc. in lithologic log, section 9.)

3. PROPOSED USE
☐ Domestic ☒ Irrigation ☐ Monitor
☐ Industrial ☐ Stock ☐ Waste Disposal or Injection
☐ Other _____ (specify type)

4. METHOD DRILLED
☐ Rotary ☐ Air ☐ Auger ☐ Reverse rotary
☒ Cable ☐ Mud ☐ Other _____ (backhoe, hydraulic, etc.)

5. WELL CONSTRUCTION
Casing schedule: ☒ Steel ☐ Concrete ☐ Other _____

Thickness	Diameter	From	To
.250 inches	12 inches	+ 1'6" feet	156'6" feet
.250 inches	8 inches	147 feet	157 feet
.250 inches	8 inches	162 feet	197 feet

Was casing drive shoe used? ☒ Yes ☐ No
Was a packer or seal used? ☒ Yes ☐ No
Perforated? ☐ Yes ☒ No
How perforated? ☐ Factory ☐ Knife ☐ Torch ☐ Gun
Size of perforation? _____ inches by _____ inches

Number	From	To
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet

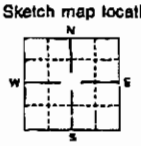
Well screen installed? ☒ Yes ☐ No
Manufacturer Johnson Type 304
Top Packer or Headpipe 143'
Bottom of Tailpipe 344'

Diameter 8 Slot size 30 Set from 157 feet to 162 feet
Diameter 8 Slot size 30 Set from 197 feet to 217 feet
Gravel packed? ☒ Yes ☐ No ☐ Size of gravel #8-12
Placed from 283 feet to 339 feet

Surface seal depth 60 Material used in seal: ☐ Cement grout
☒ Bentonite ☐ Puddling clay ☐ _____
Sealing procedure used: ☐ Slurry pit
☒ Temp. surface casing ☒ Overbore to seal depth
Method of joining casing: ☐ Threaded ☒ Welded
☐ Solvent Weld ☐ Cemented between strata

Describe access port well cap(no pump yet)

6. LOCATION OF WELL
Sketch map location must agree with written location.



Subdivision Name _____
Lot No. _____ Block No. _____
County Ada
Address of Well Site 605 N Edgewood Ln
(give at least name of road)
S/E ¼ N/E ¼ Sec. 9, T. 4 N ☒ or S ☐, R. 1 E ☒ or W ☐

7. WATER LEVEL
Static water level 49 feet below land surface.
Flowing? ☐ Yes ☒ No G.P.M. flow _____
Artesian closed-in pressure _____ p.s.i.
Controlled by: ☐ Valve ☐ Cap ☐ Plug
Temperature _____ °F. Quality _____
Describe artesian or temperature zones below.

8. WELL TEST DATA
☒ Pump ☐ Bailer ☐ Air ☐ Other _____

Discharge G.P.M.	Pumping Level	Hours Pumped
715	91	1
828	99'6"	1
851	103	1
961	108	30 min

9. LITHOLOGIC LOG 90228

Bore Diam.	Depth From	Depth To	Material	Water Yes	Water No
16	0	4	sandy brown clay topsoil		X
	4	22	light brown sandy clay		X
	22	78	cemented sand, gravel & boulders		X
12	78	169	cemented sand & gravel with streaks of brown clay	X	
	169	197	sticky brown clay		X
	197	217	fine to meddium sand	X	
	217	240	brown clay		X
	240	345	fine to medium sand	X	
	345		blue clay		
			casing:		
			.250 8" 217-282'		
			.250 8" 339-344'		

NOV 23 1992
Department of Water Resources
Western Regional Office
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NOV 20 1992
MICROFILMED
AUG 03 1993

10.
Work started 8/14/92 finished 10/20/92

11. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed:
Firm Name Stevens & Sons Firm No. 153
Address 3709 Hawthorne Dr Date 11/4/92
Signed by Drilling Supervisor Don Stevens
and
(Operator) _____ (if different than the Drilling Supervisor)

USE ADDITIONAL SHEETS IF NECESSARY — FORWARD THE WHITE COPY TO THE DEPARTMENT

USE TYPEWRITER OR BALL POINT PEN

State of Idaho
Department of Water Administration

WELL DRILLER'S REPO

Eagle Hills Golf Course Well (not analyzed)

State law requires that this report be filed with the State Reclamation Engineer within 30 days after completion or abandonment of the well.

1. WELL OWNER

Name Eagle Hills Golf Course

Address Eagle, Idaho

Owner's Permit No. _____

2. NATURE OF WORK

☒ New well ☐ Deepened ☐ Replacement

☐ Abandoned (describe method of abandoning)

_____

3. PROPOSED USE

☐ Domestic ☐ Irrigation ☐ Test

☒ Municipal ☐ Industrial ☐ Stock

4. METHOD DRILLED

☒ Cable ☐ Rotary ☐ Dug ☐ Other

5. WELL CONSTRUCTION

Diameter of hole 12 inches Total depth 485 feet

Casing schedule: ☒ Steel ☐ Concrete

Thickness	Diameter	From	To
.375 inches	12 inches	+1 feet	362 feet
_____ inches	_____ inches	_____ feet	_____ feet
_____ inches	_____ inches	_____ feet	_____ feet
_____ inches	_____ inches	_____ feet	_____ feet
_____ inches	_____ inches	_____ feet	_____ feet

Was a packer or seal used? ☐ Yes ☒ No

Perforated? ☐ Yes ☒ No

How perforated? ☐ Factory ☐ Knife ☐ Torch

Size of perforation _____ inches by _____ inches

Number	From	To
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet

Well screen installed? ☒ Yes ☐ No

Manufacturer's name Johnson

Type _____ Model No. _____

Diameter 6 Slot size 25 Set from _____ feet to _____ feet

Diameter ___ Slot size ___ Set from _____ feet to _____ feet

Gravel packed? ☒ Yes ☐ No Size of gravel No. 16 Sand

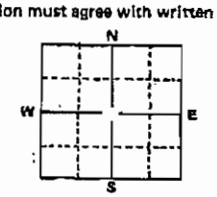
Placed from 330 feet to 480 feet

Surface seal? ☒ Yes ☐ No To what depth 60 feet

Material used in seal ☐ Cement grout ☒ Puddling clay

6. LOCATION OF WELL

Sketch map location must agree with written location.



36 R

County Ada

SE ¼ NE ¼ Sec. 9 T. 4N N/S, R. 1 E/W

7. WATER LEVEL

Static water level 60 feet below land surface

Flowing? ☐ Yes ☒ No G.P.M. flow _____

Temperature _____° F. Quality _____

Artesian closed-in pressure _____ p.s.i.

Controlled by ☐ Valve ☐ Cap ☐ Plug

8. WELL TEST DATA

☒ Pump ☐ Bailer ☐ Other

Discharge G.P.M.	Draw Down	Hours Pumped
400	100	

039004

9. LITHOLOGIC LOG

Hole Diam.	Depth From	Depth To	Material	Water Yes	Water No
12"	0	31	Dirt		
	31	59	Gravel cemented		
	59	120	Sandy clay cemented		
	120	170	Sandy clay courser sand		
	170	227	Sand fine with clay		
	227	279	Sandy clay		
	279	343	Brown clay		
	343	356	Brown sandy clay		
	356	383	Blue clay		
	383	410	Blue fine sand & thin clay stratas	X	
	410	420	Blue sand soft stone	X	
	420	425	Soft stone & blue clay		
	425	430	Blue clay & sand streaks		
	430	435	Blue clay		
	435	450	Blue sand & clay streaks	X	
	450	460	Blue sand & thin clay	X	
	460	470	Fine sand & blue clay	X	
	470	475	Blue clay thin streaks brown clay		
	475	480	Blue & brown clay		
	480	495	Blue clay	X	
	495	500	Muddy blue clay	X	

10.

Work started Aug. 1971 finished Oct. 1971

11. DRILLER'S CERTIFICATION

This well was drilled under my supervision and this report is true to the best of my knowledge.

Russel Cowe Drilling Co 65
Driller's or Firm's Name Number

Boise, Idaho
Address

Signed By Russel Cowe Date

USE ADDITIONAL SHEETS IF NECESSARY FORWARD THE WHITE, BLUE, AND PINK COPIES TO THE DEPARTMENT

SUBJECT PRELIMINARY GEOLOGIC LOG AND WELL CONSTRUCTION — BY C. FEAST — DATE 3/6/91
SHEET 1 OF 1
FLOATING FEATHER HILLS, INC. — PROJECT NO. B01 31684.A1

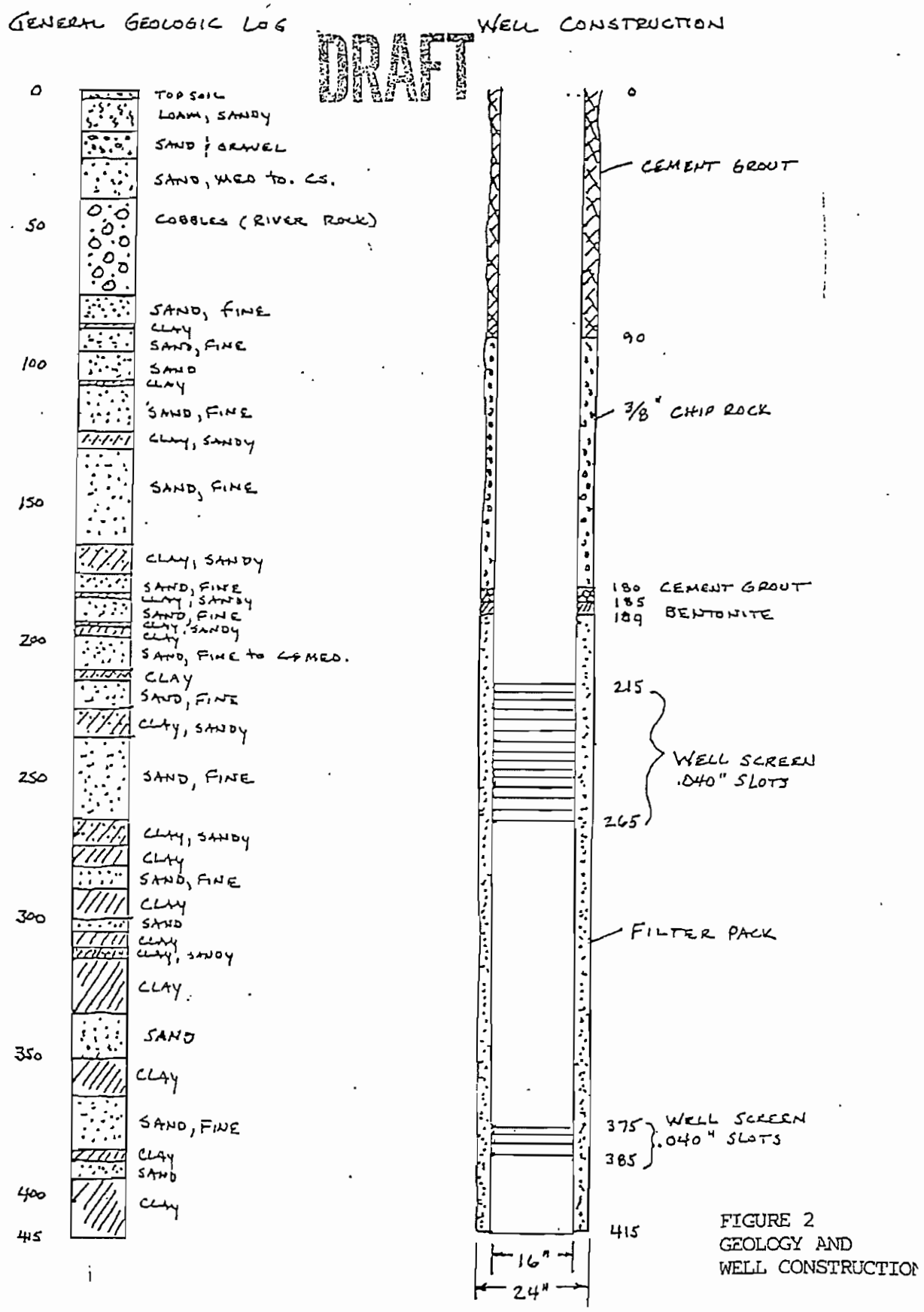


FIGURE 2
GEOLOGY AND
WELL CONSTRUCTION

Form 238-7 11/97 JGE 603

Ammended Log

IDAHO DEPARTMENT OF WATER RESOURCE

WELL DRILLER'S REPORT

Rivervine (pumping)

Twp ____ Rge ____ Sec ____
____ 1/4 ____ 1/4 ____ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 0031203
DRILLING PERMIT NO. ____
Other IDWR No. ____

2. OWNER:
Name Castle Rock Development
Address 1639 Lakemoor Way
City Eagle State ID Zip 83616

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S

Twp. 4 North [X] or South [ ]
Rge. 1 East [ ] or West [X]
Sec. 15 ____ 1/4 (10 acres) SW 1/4 (40 acres) NE 1/4 (160 acres)
Gov't Lot ____ County Ada
Lat: Long:
Address of Well Site Moon Valley Road (S. Side)
(Give at least name of road + Distance to Road or Landmark) City Star
Lt. ____ Blk. 1 Sub. Name Rivervine

4. USE:
[ ] Domestic [X] Municipal [ ] Monitor [ ] Irrigation
[ ] Thermal [ ] Injection [ ] Other ____

5. TYPE OF WORK: check all that apply (Replacement etc.)
[X] New Well [ ] Modify [ ] Abandonment [ ] Other ____

6. DRILL METHOD:
[ ] Air Rotary [ ] Cable [X] Mud Rotary [ ] Other ____

7. SEALING PROCEDURES:

Seal/Filter Pack Material	From	To	AMOUNT Sacks or Pounds	METHOD
Grout	0	73	420 gal	Pump
6x12 Sand	68	119	1 yd	Pour
3/4 Bentonite	119	145	680 #	Pour

Was drive shoe used? [X] Y [ ] N Shoe Depth(s) 73
Was drive shoe seal tested? [X] Y [ ] N How? Pressure

8. CASING/LINER:

Diameter	From	To	Guage	Material	Casing	Liner	Welded	Threaded
16	0	38	.250	steel	[X]	[ ]	[X]	[ ]
10	+16	73		PVC- SDR	[X]	[ ]	[X]	[ ]
12	+2	0	.250	steel	[X]	[ ]	[X]	[ ]

Length of Headpipe 68-85 Length of Tailpipe 0

9. PERFORATIONS/SCREENS:
[ ] Perforations Method ____
[X] Screens Screen Type Johnson *Tight Wound

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
68	85	.00	TW	4	SS	[ ]	[X]
85	104	.030		4	SS	[ ]	[X]
104	118	.035		4	SS	[ ]	[X]

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
±1 ft. below ground Artesian pressure 1/2 lb.
Depth flow encountered 80 ____ ft. Describe access port or control devices: Steel Plate

11. WELL TESTS:
[X] Pump [ ] Bailer [ ] Air [ ] Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time
400	21	60	10 hrs

Water Temp. 56 Bottom hole temp. 56
Water Quality test or comments: ____
Depth first Water Encounter 10

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
16	0	4	Top Soil		
16	4	36	Gravel & Sand	X	
16	36	40	Tan Clay		
16	40	67	Sand w/ Gravel	X	
16	67	73	Tan Clay		
15	73	79	Tan Clay		
15	79	124	Quartz Sand	X	
15	124	145	Sticky Tan Clay		

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SEP 27 2004
WATER RESOURCES
WESTERN REGION

Completed Depth 118 (Measurable)
Date: Started 5/16/2004 Completed 5/22/2004

13. DRILLER'S CERTIFICATION:
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Treasure Valley Drilling Firm No. 560
Firm Official and Driller or Operator Dan Rossitto Date 9/22/2004
(Sign once if Firm Official & Operator) Date 9/22/2004

FORWARD WHITE COPY TO WATER RESOURCES

Form 238-7
6/93

IDAHO DEPARTMENT OF WATER

WELL DRILLER'S REPORT

Redwood Creek Well (pumping)

Ball Point Pen

091012

1. DRILLING PERMIT NO. 63 93 C - 188 - 000
Other IDWR No. 63-11878

2. OWNER:
Name REDWOOD CREEK SUBDIVISION
Address 7188 SAN FERNANDO DRIVE
City BOISE State ID Zip 83704

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S

T. 04N North ☐ or South ☐
R. 01E East ☐ or West ☐
Sec. 7 SE 10 acres 1/4 NW acres 1/4 160 acres 1/4
Gov't Lot ____ County ADA

Address of Well Site CLOSE TO 2810 W STATE ST
(Give at least Direction + Distance to Road or Landmark)
Lot No. ____ Block No. ____ Subd. Name REDWOOD CREEK

4. PROPOSED USE: NON DOMESTIC
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other ____

5. TYPE OF WORK NEW WELL
☐ New Well ☐ Modify or Repair ☐ Replacement ☐ Abandonment

6. DRILL METHOD REVERSE ROTARY
☐ Mud Rotary ☐ Air Rotary ☐ Cable ☐ Other ____

7. SEALING PROCEDURES

SEAL/FILTER PACK			AMOUNT	METHOD
Material	From	To	Sacks or Pounds	
BENTONITE	265	0	380000#	POURED

Was drive shoe seal tested? YES NO How? ____

8. CASING/LINER:

Diameter	From	To	Guage	Casing	Liner	Steel	Plastic	Welded	Threaded
18	+1.5	281	.375			☐	☐	☐	☐
12	281	298	.375			☐	☐	☐	☐
12	313	361	.375			☐	☐	☐	☐
12"	401	411	.375			☐	☐	☐	☐

Final location of shoes ____
Top Packer or Headpipe ____ Bottom Tailpipe ____

9. PERFORATIONS/SCREENS
☐ Perforations Method ____
☒ Screens Type WIRE Material STAINLESS STEEL

From	To	Slot Size	Number	Diameter	Tele/Pipe Size	Casing	Liner
298	313	.40	304 STA	12"	PIPE	☐	☐
361	401	.40	304 STA	12"	PIPE	☐	☐
						☐	☐
						☐	☐

10. WELL TESTS: FLOWING ARTESIAN
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Depth	Time
2100	90'	831	8HRS

Temperature of water 58 Was a water analysis done? Yes ☐ No ☐
By whom? ANALETICAL LAB.
Water Quality (odor, etc.) GOOD
Bottom Hole Temperature 58

11. STATIC WATER LEVEL:
STATIC PLUS 7 ft. below surface Depth artesian flow found 297
Artesian pressure ____ lb. Describe access port 10"SIDE PIPE
Describe Controlling Devices: 10" VALVE

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	SWL
	0	5	TOPSOIL	
	5	10	SAND	
	10	19	BRN CLAY	
	19	20	FINE SAND, SOME SMALL GRAVEL	
	20	32	SAND, GRAVEL, RIVER ROCK	
	32	42	LITE BRN CLAY	
	42	58	SND, SND&CLAY MIX	
	58	65	LITE BRN CLAY	
	65	71	FINE TO MED SND	
	71	75	LITE BRN CLAY	
	75	84	FINE TO MED SAND	
	84	85	LITE BRN CLAY	
	85	95	FINE TO CRSE SAND&CLAY MIX	
	95	115	LT BRN CLAY W\SML AMNT SND	
	115	121	LTE BRN CLAY	
	121	130	FINE TO MED SAND& SML AMT CLAY	
	130	133	BRN CLAY W/ SAND MIX	
	133	137	FINE TO MED SAND W/ SOME CLAY MIX	
	137	155	BRN CLAY W/SOME SAND MIX	
	155	165	CLAY W\SOME SAND MIX	
	165	170	CLAY	
	170	175	CLAY W/SAND MIX	
	175	211	LT BRN CLAY W/SOME SAND MIXED	
	211	215	FINE TO MED SAND, SOME CLAY	
	215	255	LT BRN CLAY W\SOME SAND MIX	
	255	259	SAND W\SOME CLAY	
	259	275	CLAY W\SOME SAND MIX	

Date: Started 3/30/94 Completed 4/5/94

RECEIVED JUN 17 1994 Department of Water Resources

RECEIVED APR 20 1994 WATER RESOURCES WESTERN REGION

RECEIVED DEC 08 1995

13. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Firm Name PETE COPE DRILLING Firm No. 213
Firm Official Joseph Jones Date 4/18/94
and
Supervisor or Operator Karin Chastain Date 4/18/94
(Sign once if Firm Official & Operator)

FORWARD WHITE COPY TO WATER RESOURCES

Redwood Creek Well (pumping)

Form 238-7
6/93

IDAHO DEPARTMENT OF WATER R

WELL DRILLER'S REPORT

Pg 2 of 2

Ball Point Pen

091013

1. DRILLING PERMIT NO. 63 93 C - 188 -000
Other IDWR No. 63-11878

2. OWNER:
Name REDWOOD CREEK SUBDIVISION
Address
City State Zip

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S

T. ____ North ☐ or South ☐
R. ____ East ☐ or West ☐
Sec. ____, ____ 1/4 ____ 1/4 ____ 1/4
(10 acres, 40 acres, 160 acres)
Gov't Lot ____ County

Address of Well Site
(Give at least Direction + Distance to Road or Landmark)
Lot No. ____ Block No. ____ Subd. Name

4. PROPOSED USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other

5. TYPE OF WORK
☐ New Well ☐ Modify or Repair ☐ Replacement ☐ Abandonment

6. DRILL METHOD
☐ Mud Rotary ☐ Air Rotary ☐ Cable ☐ Other

7. SEALING PROCEDURES

SEAL/FILTER PACK Material	From	To	AMOUNT Sacks or Pounds	METHOD

Was drive shoe seal tested? YES NO How?

8. CASING/LINER:

Diameter	From	To	Guage	Casing	Liner	Steel	Plastic	Welded	Threaded
						☐	☐	☐	☐
						☐	☐	☐	☐
						☐	☐	☐	☐
						☐	☐	☐	☐

Final location of shoes
Top Packer or Headpipe Bottom Tailpipe

9. PERFORATIONS/SCREENS
☐ Perforations Method
☐ Screens Type Material

From	To	Slot Size	Number	Diameter	Tele/Pipe Size	Casing	Liner
						☐	☐
						☐	☐
						☐	☐
						☐	☐

10. WELL TESTS:
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Depth	Time

Temperature of water ____ Was a water analysis done? Yes ☐ No ☐
By whom?
Water Quality (odor, etc.)
Bottom Hole Temperature

11. STATIC WATER LEVEL:
____ ft. below surface Depth artesian flow found ____
Artesian pressure ____ lb. Describe access port
Describe Controlling Devices:

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	GPM	SWL
	275	295	LT BRN CLAY & SOME SAND		
	295	305	FINE TO CRS SND, SOME CLAY		
	305	315	FINE TO CRS SAND, SML GRVL, SOME CLAY		
	315	322	BRN CLAY W\SOME SAND MIX		
	322	325	CRS SAND & SMALL GRAVEL		
	325	355	BRN CLAY W\SOME SAND MIX		
	355	395	MED TO CRS SAND & SMALL GRAVEL		
	395	405	MED TO CRS SAND W\SMALL AMT CLAY		
	405	408	MED SAND		
	408	415	CLAY W\ SOME SAND MIX		

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JUN 17 1994
Department of Water Resources
FEB 08 1995

Date: Started ____ Completed

13. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Firm Name PETE COPE DRILLING Firm No.
Firm Official Date
and
Supervisor or Operator Date
(Sign once if Firm Official & Operator)

FORWARD WHITE COPY TO WATER RESOURCES

Rosewood Creek

– BSU

BOISE STATE UNIVERSITY

DEPARTMENT OF GEOLOGY AND GEOPHYSICS
PHONE: (208) 385–1631

WELL:

PROJECT: DATE:

CLIENT:

LOCATION:

STATE: COUNTY: ELEV: DEPTH REF:

BOREHOLE DATA

DRILLING CONTRACTOR:

RUN	BIT RECORD			CASING RECORD		
NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1			Surf.			
2						
3						
4						

HOLE MEDIUM: DRILL METHOD:

MUD TYPE: TIME SINCE CIRC:

VISCOSITY: WEIGHT: Rmf at Deg

GENERAL DATA

INSTRUMENTATION: UNIT/TRUCK:

LOGGING ENGINEER:

CLIENT REP:

OTHER SERVICES:

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR	SPACING		SOURCE		LOGGED INTERVAL		
		MODEL	PROBE S.N.	UPHOLE S.N.	DIG INT FEET	SPEED FT./MIN.	TYPE	Tx–Rx FEET	Rx–Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET

CALIBRATION FACTOR(S):

DIGITAL FILE NAME(S):

REMARKS:

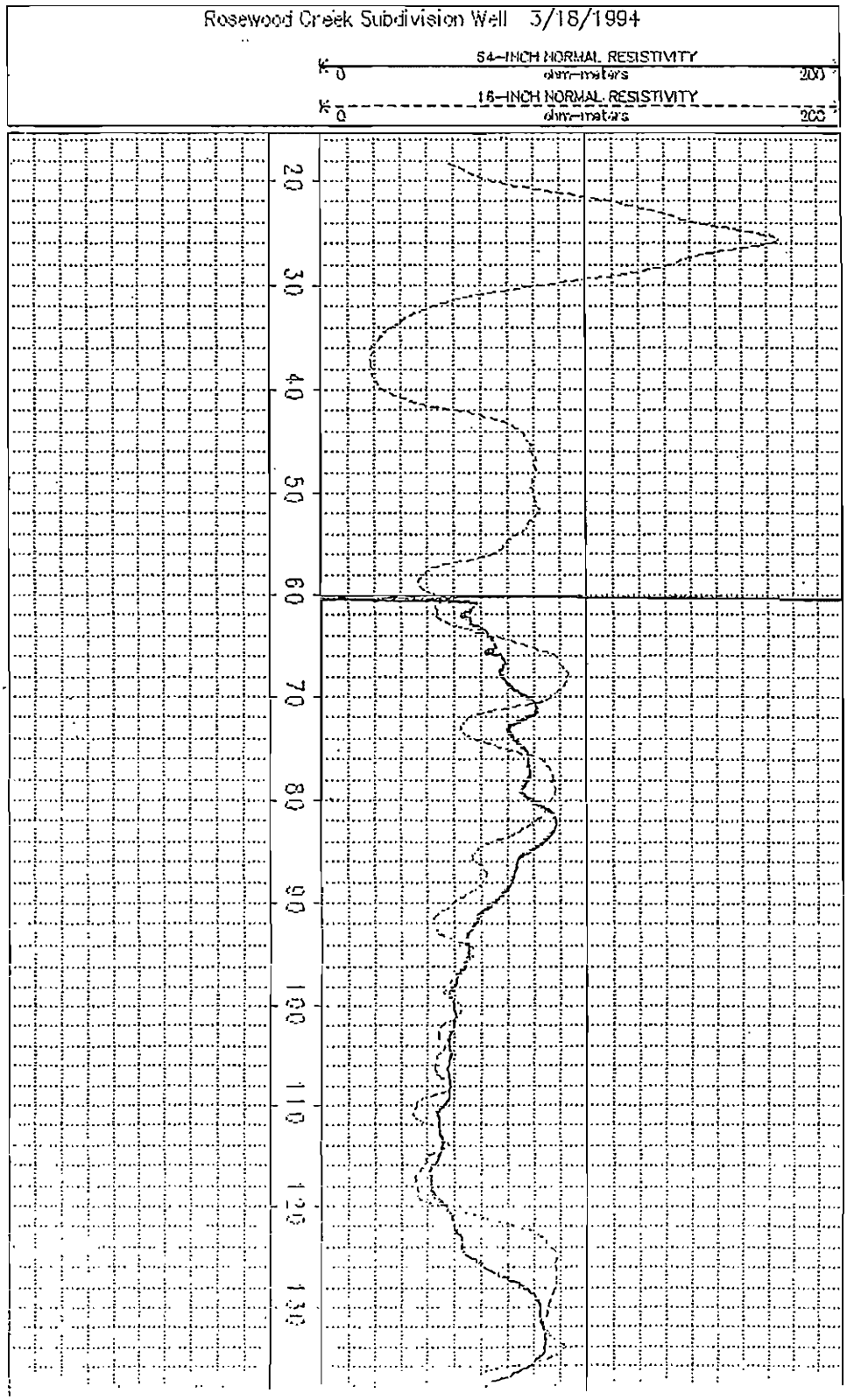
Rosewood Creek Subdivision Well 3/18/1994

64-INCH NORMAL RESISTIVITY

0 deflections 200

16-INCH NORMAL RESISTIVITY

0 deflections 200


Rosewood Creek Subdivision Well 3/18/1994
64-INCH NORMAL RESISTIVITY
0
ohm-meters
200
16-INCH NORMAL RESISTIVITY
0
ohm-meters
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70
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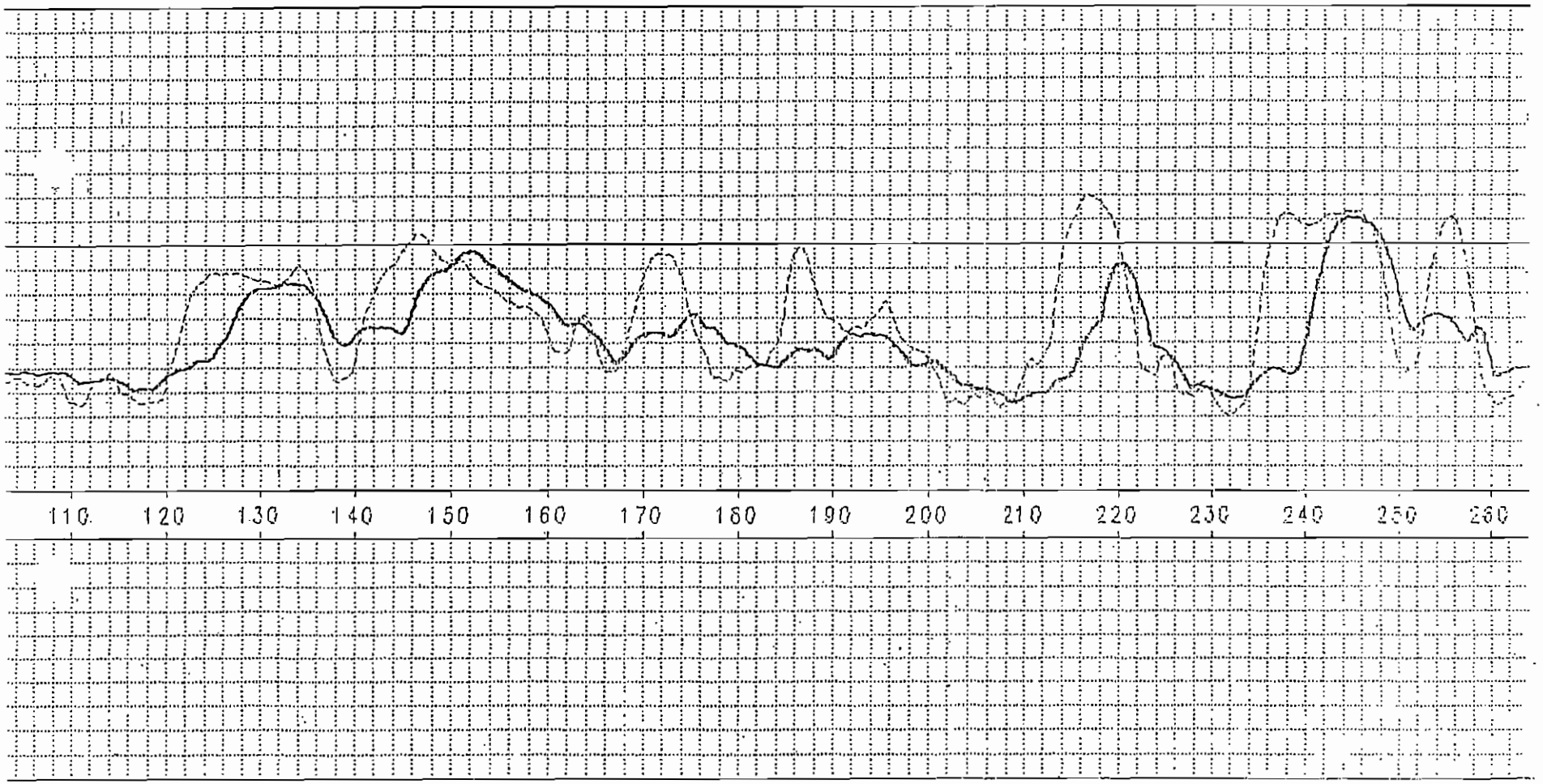
100
110
120
130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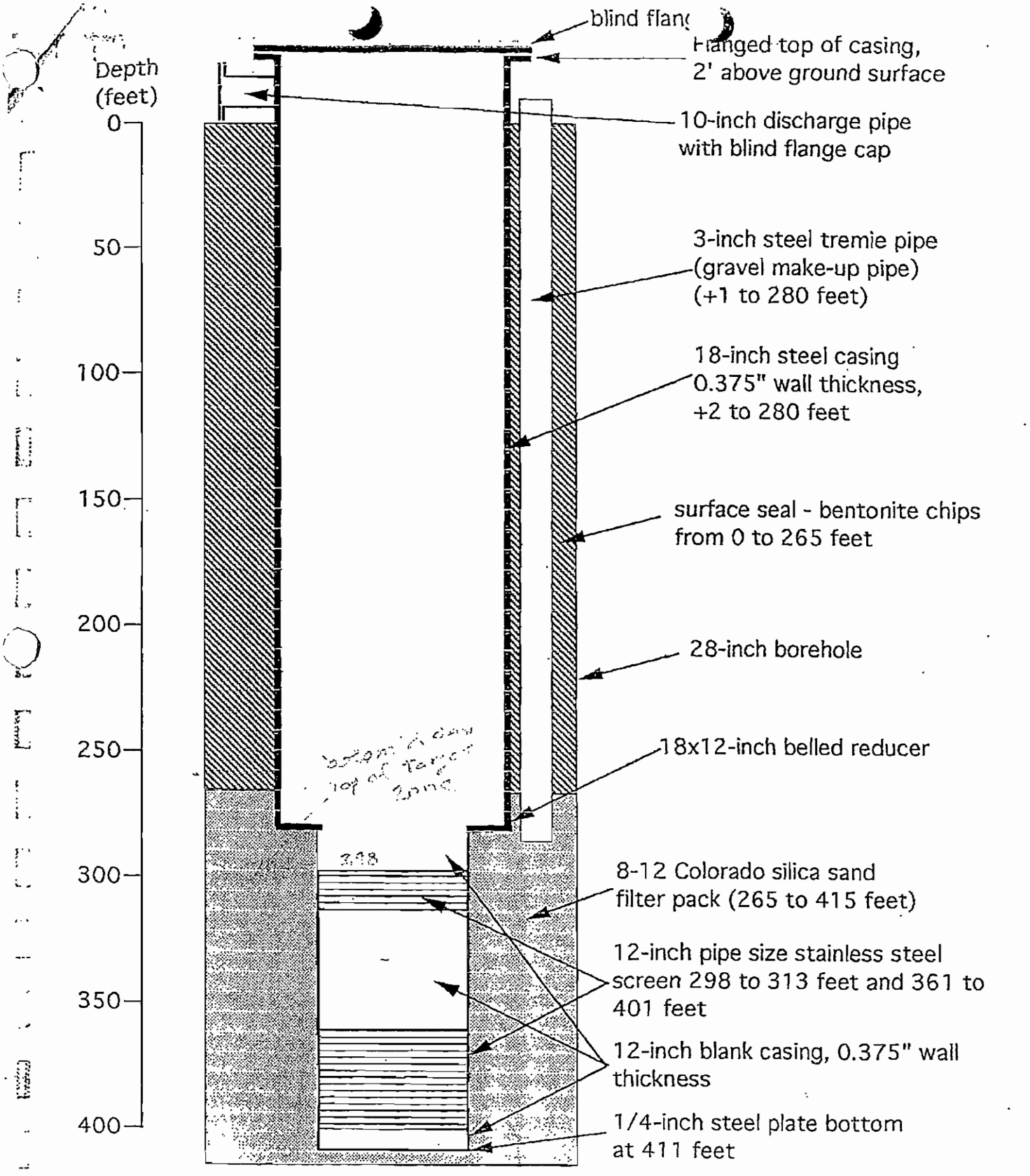
390
16-INCH NORMAL RESISTIVITY
ohm-meters
64-INCH NORMAL RESISTIVITY
ohm-meters



REDWOOD CREEK WELL NO. 1
AS BUILT

Form 238-7
7/94

Star #1

IDAHO DEPARTMENT OF WATER R... OF
WELL DRILLER'S REPORT

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Department of Water Resources

Ball Point Pen

53379

1. DRILLING PERMIT NO. 63 - 94 - W - 0972 - 000
Other IDWR No. 63-12100

2. OWNER:
Name City of Star
Address P.O. Box 277
City Star State ID Zip 83669

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S

Twp. 4 North XX or South ☐
Rge. 1 East ☐ or West XX
Sec. 8, ____ 1/4 SW (10 acres) 1/4 NW (40 acres) 1/4 (160 acres)
Gov't Lot ____ County Ada

Address of Well Site E. Side of Star Road City Star
(Give at least name of road + Distance to Road or Landmark)

Lt. ____ Blk. ____ Sub. Name ____

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4. PROPOSED USE:
☐ Domestic ☒ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other ____

5. TYPE OF WORK
XX New Well ☐ Modify or Repair ☐ Replacement ☐ Abandonment

6. DRILL METHOD
☐ Mud Rotary ☐ Air Rotary ☐ Cable XX Other Reverse Circ.

7. SEALING PROCEDURES

SEAL/FILTER PACK Material	From	To	AMOUNT Sacks or Pounds	METHOD
Granular	0	335	45,000	
Bentonite				
Co. Silica Sand	335	565	17.5yd	

Was drive shoe used? ☐ Y ☒ N Shoe Depth(s) ____
Was drive shoe seal tested? Y☐ N☐ How? ____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
16"	+3	335	.375	Steel	☒	☐	☒	☐
10"	335	452	.25	Steel	☒	☐	☒	☐
10"	472	495	.25	Steel	☒	☐	☒	☐
10"	515	540	.25	Steel	X		X	
10"	550	560	.25	Steel	X		X	

Length of Headpipe 10' Length of Tailpipe ____

9. PERFORATIONS/SCREENS
☐ Perforations Method ____
☒ Screens Screen Type Halliburton

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
452	472	.035		10"		☒	☐
495	515	.035		10"		X	
540	550	.035		10"		☒	☐

JAN 26 1995

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
____ ft. below ground Artesian pressure 17 lb.
Depth flow encountered ____ ft. Describe access port or control devices: 1/2" Plug in top

11. WELL TESTS:
XX Pump ☐ Bailer ☐ Air XX Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time
800		+12	8.5 hr.
1650	4	22.5	.5 hr.
1250	5	5	.5 hr.

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Water Temp. 63 Bottom hole temp. ____
Water Quality test or comments: ____

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
28	0	7	Topsoil		X
28	7	28	Sand, Gravel, & Rock	X	
28	28	35	Brown Clay		X
28	35	65	Brown Clay		X
28	65	80	Medium to Coarse sand	X	
28	80	88	Fine to Medium sand	X	
28	88	109	Brown Clay		X
28	109	119	Fine Brown Sand	X	
28	119	121	Light Brown Clay		X
			Mud @8.75#		
28	121	129	Ligt Brown Clay		X
28	129	139	Light Brown Clay		X
28	139	140	Light Brown Clay		X
28	140	143	Fine Brown Sand	X	
28	143	148	Light Brown Silty Clay		X
28	148	149	Med. to Coarse Brn Sand	X	
28	149	154	Med. to Carse Brn. Sand	X	
28	154	159	Silty Light Brn. Clay		X
28	159	160	Silty Light Brn. Clay		X
28	160	163	Fine to Coarse Brn. Sand	X	
28	163	169	Silty Lt. Brown Clay		X
28	169	174	Silty Lt. Brown Clay		X
28	174	179	Fine to Med. Brn. Sand	X	
28	179	189	Med. to Coarse Dark Brn.	X	
			Sand w/Pea Gravel		
28	189	193	Med. to Coarse Dark Brn.	X	
			Sand w/Pea Gravel		
28	193	197	Light Brown Clay		X
28	197	199	Fine to Coarse Brn. Sand	X	
28	199	205	Fine to Coarse Brn. Sand	X	
28	205	209	Blue Clay		X
28	209	210	Blue Clay		X
28	210	214	Fine Blue Sand	X	

Completed Depth 565 (Measurable)
Date: Started 2-7-95 Completed 2-20-95

13. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Firm Name Riverside, Inc. Firm No. 333
Firm Official [signature] Date 3/2/95
and
Supervisor or Operator [signature] Date 3-6-95
(Sign once if Firm Official & Operator)

FORWARD WHITE COPY TO WATER RESOURCES

Form 238-7
7/94

Star #1

IDAHO DEPARTMENT OF WATER
WELL DRILLER'S REPORT

MAR 8 1995 Ball Point Pen

Department of Water Resources 53380

1. DRILLING PERMIT NO. 63 - 94 - W - 0972 - 000
Other IDWR No. 63-12100

2. OWNER:
Name City of Star (Continued)
Address
City State Zip

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S

Twp. 4 North ☒ or South ☐
Rge. 1 East ☐ or West ☒
Sec. 8, 1/4 (10 acres) SW 1/4 (40 acres) NW 1/4 (160 acres)
Gov't Lot ____ County ADA

Address of Well Site
City
(Give at least name of road + Distance to Road or Landmark)

Lt. Blk. Sub. Name

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WESTERN REGION

4. PROPOSED USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other

5. TYPE OF WORK
☐ New Well ☐ Modify or Repair ☐ Replacement ☐ Abandonment

6. DRILL METHOD
☐ Mud Rotary ☐ Air Rotary ☐ Cable ☐ Other

7. SEALING PROCEDURES

SEAL/FILTER PACK			AMOUNT	METHOD
Material	From	To	Sacks or Pounds	

Was drive shoe used? ☐ Y ☐ N Shoe Depth(s)
Was drive shoe seal tested? Y☐ N☐ How?

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Length of Headpipe Length of Tailpipe

9. PERFORATIONS/SCREENS
☐ Perforations Method
☐ Screens Screen Type

JUN 26 1995

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
						☐	☐
						☐	☐
						☐	

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
____ft. below ground Artesian pressure ____lb.
Depth flow encountered ____ft. Describe access port or control devices:

11. WELL TESTS:
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time

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Water Temp. Bottom hole temp.
Water Quality test or comments:

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
28	214	219	Blue Clay		X
28	219	229	Blue Clay		X
28	229	239	Blue Clay		X
28	239	249	Blue Clay		X
28	249	257	Blue Clay		X
28	257	259	Fine Blue Sand	X	
28	259	269	Blue Clay 8.90# Mud		X
28	269	279	Blue Clay		X
28	279	301	Blue Clay		X
28	301	305	Fine Blue Sand	X	
28	305	308	Blue Clay		X
28	308	315	Coarse Blue Sand	X	
28	315	319	Gray Clay		X
28	319	321	Gray Clay		X
28	321	324	Fine Sand & Clay Mixed	X	
28	324	329	Gray Clay		X
28	329	334	Blue & Gray Clay w/streaks of brown Clay	X	
28	334	339	Blue Clay		X
20	339	375	Blue Clay		X
20	375	380	Fine Blue Sand	X	
20	380	382	Blue Clay		X
20	382	392	Fine Blue Sand	X	
20	392	401	Blue Clay		X
20	401	409	Fine Blue Sand		X
20	409	419	Gray Clay		X
20	419	429	Gray Clay w/Fine Sand		X
20	429	439	Dark Brown Clay		X
20	439	449	Dark Brown Clay		X
20	449	459	Fine to Med. Lt. Brn. Sand w/thin Clay layers	X	
20	459	469	Fine to Med. Sand	X	
20	469	473	Light Brown Clay		X

Completed Depth (Measurable)
Date: Started Completed

13. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Firm Name Rivas Tob Inc. Firm No. 333
Firm Official Date 3/6/95
and
Supervisor or Operator Date 3/6/95
(Sign once if Firm Official & Operator)

FORWARD WHITE COPY TO WATER RESOURCES

Star #1

Form 238-7
7/94

IDAHO DEPARTMENT OF WATER R

WELL DRILLER'S REPORT

Ball Point Pen

53381

1. DRILLING PERMIT NO. 63-94-W-0972-000
Other IDWR No. 63-19100

2. OWNER:
Name City of Star (Continued) Page 3
Address
City State Zip

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S

Twp. 4 North ☒ or South ☐
Rge. 1 East ☐ or West ☒
Sec. 8, 1/4 SW (10 acres) 1/4 NW (40 acres) 1/4 (160 acres)
Gov't Lot ____ County ADA

Address of Well Site
City
(Give at least name of road + Distance to Road or Landmark)

Lt. Blk. Sub. Name

4. PROPOSED USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other

5. TYPE OF WORK
☐ New Well ☐ Modify or Repair ☐ Replacement ☐ Abandonment

6. DRILL METHOD
☐ Mud Rotary ☐ Air Rotary ☐ Cable ☐ Other

7. SEALING PROCEDURES

SEAL/FILTER PACK			AMOUNT	METHOD
Material	From	To	Sacks or Pounds	

Was drive shoe used? ☐ Y ☐ N Shoe Depth(s)
Was drive shoe seal tested? Y☐ N☐ How?

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Length of Headpipe Length of Tailpipe

9. PERFORATIONS/SCREENS
☐ Perforations Method
☐ Screens Screen Type

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
						☐	☐
						☐	☐
						☐	☐

JUN 26 1995

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
ft. below ground Artesian pressure lb.
Depth flow encountered ft. Describe access port or control devices:

11. WELL TESTS:
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time

Water Temp. Bottom hole temp.
Water Quality test or comments:

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
20	473	475	Blue Clay		X
20	475	479	Fine to Med. Sand w/some Pea Gravel	X	
20	479	480	Fine to Med. Sand w/some Pea Gravel	X	
20	480	483	Blue Clay		X
20	483	486	Fine to Med. Blue Sand		X
20	486	492	Blue Clay		X
20	492	514	Fine to Med. Sand		X
20	514	539	Blue Clay & Sand		X
20	539	565	Sand & Gravel	X	

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MAR 8 1995
Department of Water Resources

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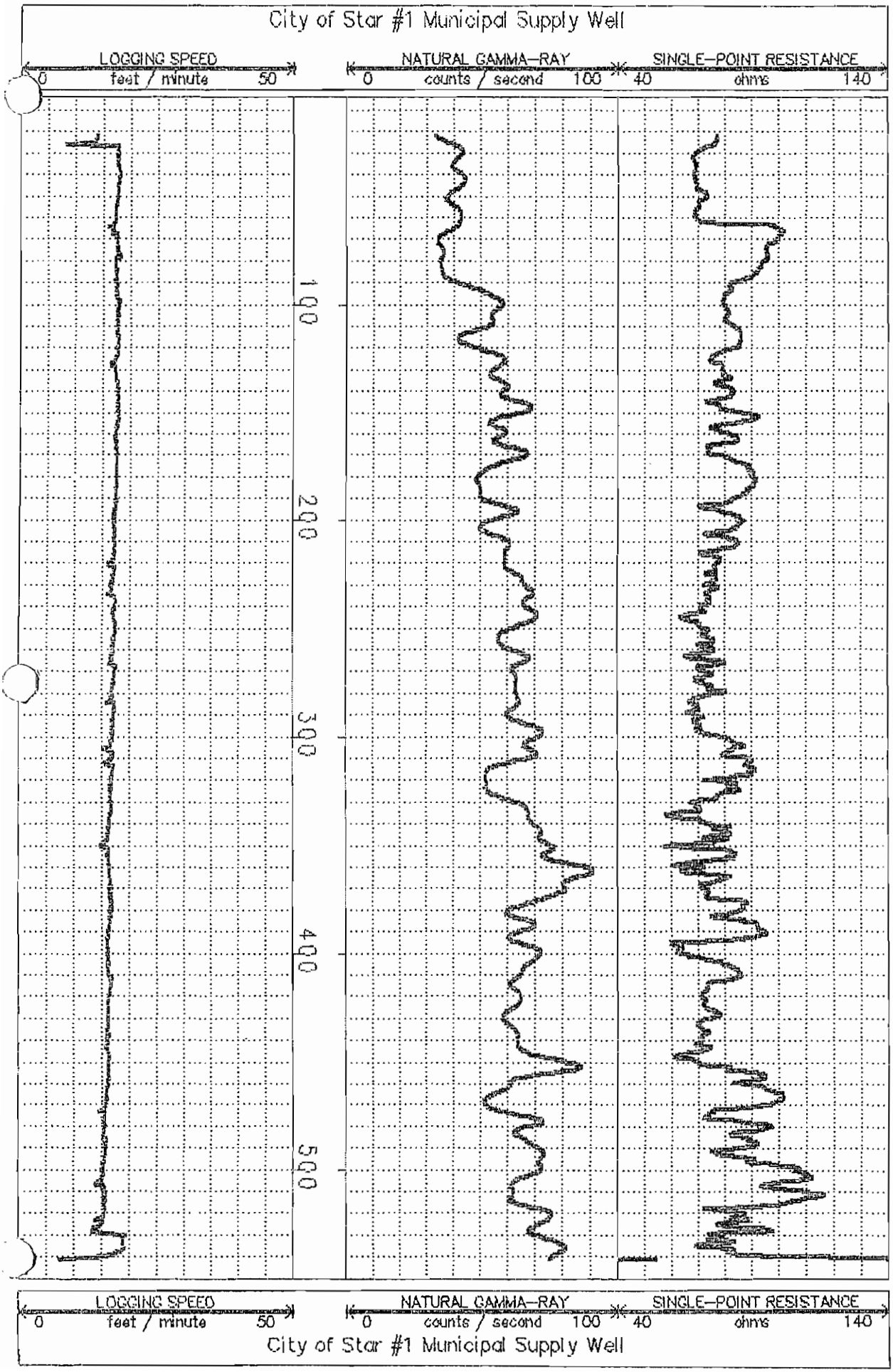
WESTERN REGION

Completed Depth (Measurable)
Date Started Completed

13. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

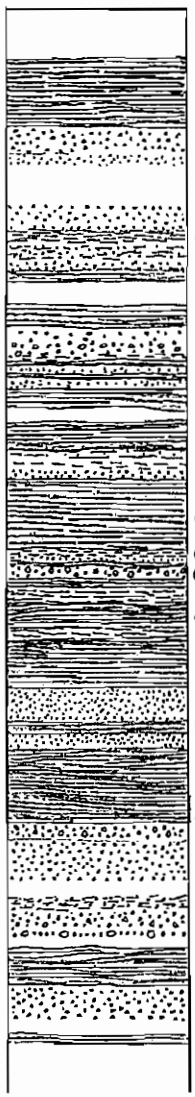
Firm Name RIVERS West Inc. Firm No. 333
Firm Official Date 3/6/95
and/or
Supervisor or Operator Date 3/6/95
(Sign one of Firm Official or Operator)

FORWARD WHITE COPY TO WATER RESOURCES


City of Star #1 Municipal Supply Well
LOGGING SPEED
0
feet / minute
50
NATURAL GAMMA-RAY
0
counts / second
100
SINGLE-POINT RESISTANCE
40
ohms
140
100
200
300
400
500
LOGGING SPEED
0
feet / minute
50
NATURAL GAMMA-RAY
0
counts / second
100
SINGLE-POINT RESISTANCE
40
ohms
140
City of Star #1 Municipal Supply Well

CITY OF STAR #1 WELL

Geologists Log based on drillers samples



Clayey silt, Light brown w/ small amount of fine sand

Coarse to very coarse sand, some fine brown w/ few oxidized grains, quartz 10% white feld, <1% biotite

Fine to med sand, darker brown

Med. sand, brown

Clayey silt, tan w/ oxidized streaks

Silt to Fine sand

Clay, light brown

Clay & silt, brown

Med to coarse sand, light brown w/ some gravel between 179-189 ft.

Brown sand, silt and clay beds, 189-205 ft.

Fine gray sand

Blue clay

Clay w/ some claystone, olive

Clayey silt gray-green

Med. sand, gray

Clay, green-brown to green-gray

Clayey silt, green-gray and fine sand, olive brown

Coarse to very coarse sand w/ some small gravel sized grains

Silt & clay, green-gray

Clay

Silt & clay green-gray w/ dark brown streaks/pieces

Clay, green-gray

Fine sand, some black wood fragments, gray

Clay, w/ claystone fragments, green-gray

Fine sand w/ biotite, dark gray

Clay, 2.5Y 3/2 very dark grayish brown 429-439

Unsorted med sand to gravel sized grains of quartz

Coarse sand w/ few black wood chips

abundant wood 483-486 ft.

Very Clayey sand, med to coarse, olive green

Coarse sand w/ wood & some small gravel sized qtz/Feldspar

few small rounded gravels

Clay

Clay, 5G 5/1 greenish gray to 5B 4/1 dark bluish gray

Medium to coarse gray-green sand

Medium to very coarse gray green sand

clay at bottom (570') 5G4/2 grayish green

STAR WELL
9-27-95
Geologists Log

31

Form 238-7
11/97 JGE

IDAHO DEPARTMENT OF WATER RESOURCES

WELL DRILLER'S REPORT

Star #3

Inspected by

Twp Rge Sec

1/4 1/4 1/4

Lat : : Long : :

1. WELL TAG NO. D 0046412

DRILLING PERMIT NO. 894262-839636

Other IDWR No. 63-31969

2. OWNER:

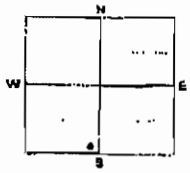
Name Star Sewer and Water District Well #3

Address PO Box 400

City Star State ID Zip 83669

3. LOCATION OF WELL by legal description:

Sketch map location must agree with written location.



Twp. 4 North X or South

Rge 1 East or West X

Sec. 5 SE 1/4 (10 acres) SE 1/4 (40 acres) SW 1/4 (160 acres)

Gov't Lot County Ada

Lat: Long:

Address of Well Site N of Floating Feather Rd, 1/2 mile East of Star Rd (Give nearest name of road + Distance to Road or Landmark) City Star

Lt. 6 Blk. 5 Sub. Name Lobo Creek

4. USE:

Domestic X Municipal Monitor Irrigation

Thermal Injection Other

5. TYPE OF WORK: check all that apply (Replacement etc.)

X New Well Modify Abandonment Other

6. DRILL METHOD:

Air Rotary Cable X Mud Rotary Other

7. SEALING PROCEDURES:

Seal/Filter Pack Material	From	To	AMOUNT Sacks or Pounds	METHOD
Bentonite Chips	0	35'	4.4 Yds	Overbore
Bentonite Chips	0	33'	1 Yd	Poured
Cement	530'	33'	25 Yds.	Pumped

Was drive shoe used? Y X N Shoe Depth(s)

Was drive shoe seal tested? Y X N How?

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
24"	+1'	35'	.250	Steel	X		X	
16"	+1.6'	530'	.375	Steel	X		X	
8"	509'	544'	.322	Steel		X	X	

Length of Headpipe Length of Tailpipe

9. PERFORATIONS/SCREENS:

Perforations Method

X Screens Screen Type Johnson

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
643'	630'	.020		8"	SS		X
630'	620'	.030		8"	SS		X
620'	584'	.040		8"	SS		X
584'	574'	.015		8"	SS		

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:

Flowing ft. below ground Artesian pressure 13.5 lb.

Depth flow encountered 543 ft. Describe access port or control devices 16" Weld on Flange, 16" Blind Flange, 8" Coup

11. WELL TESTS:

X Pump Bailer Air Flowing Artesian

Yield gal/min.	Drawdown	Pumping Level	Time
610 gpm		+2'	4 Hrs
1500 gpm		+2'	2 Weeks
3000 gpm	140'	160'	24 Hrs.

Water Temp. 57° Bottom hole temp. 61°

Water Quality test or comments:

Depth first Water Encountered 4'

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
36"	0	1	Top Soil		
36"	1	4'	Brown Clay		
36"	4'	18'	Gravel & Sand	X	
36"	18'	27'	Brown Sand	X	
36"	27	35'	Sticky Tan Clay		
22"	35'	46'	Sandy Tan Clay		
22"	46'	66'	Sticky Tan Clay		
22"	66'	74'	Sandy Tan Clay		
22"	74'	83'	Sticky Tan Clay		
22"	83'	121'	Sandy Tan Clay		
22"	121'	134'	Fine Brown Sand	X	
22"	134'	136'	Sticky Tan Clay		
22"	136'	141'	Medium to Coarse Sand	X	
22"	141'	169'	Sticky Tan Clay		
22"	169'	174'	Sticky Blue Clay		
22"	174'	261'	Sandy Blue Clay		
22"	261'	273'	Fine Blue Sand	X	
22"	273'	287'	Sticky Blue Clay		
22"	287'	292'	Coarse Quartz Sand	X	
22"	292'	295'	Sticky Blue Clay		
22"	295'	297'	Fine Blue Sand	X	
22"	297'	326'	Sticky Blue Clay		
22"	326'	328'	Fine Blue Sand	X	
22"	328'	401'	Sticky Blue Clay		
22"	401'	425'	Sandy Tan Clay		
22"	425'	429'	Sticky Blue Clay		
22"	429'	442'	Sandy Tan Clay		
22"	442'	446'	Fine Brown Sand	X	
22"	446'	462'	Sticky Blue Clay		
22"	462'	466'	Fine Blue Sand	X	
22"	466'	477'	Sticky Gray Clay		
22"	477'	486'	Fine Blue Sand	X	
22"	486'	507'	Sandy Blue Clay		

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WATER RESOURCES
WESTERN REGION

Completed Depth 643'

Date: Started 5/31/2006 Completed 8/16/2006

13. DRILLER'S CERTIFICATION:

I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Treasure Valley Drilling Firm No. 560

Firm Official Date 8/18/2006

and

Driller or Operator Date 8/18/2006

(Sign once if Firm Official & Operator)

FORWARD WHITE COPY TO WATER RESOURCES

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Form 238-7
11/97 JGE

IDAHO DEPARTMENT OF WATER RESOURCE

WELL DRILLER'S REPORT

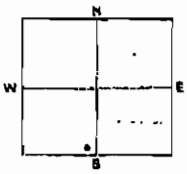
Star #3

Twp ___ Rge ___ Sec ___
___ 1/4 ___ 1/4 ___ 1/4
Lat: ___ Long: ___

1. WELL TAG NO. D 0046412 - 2
DRILLING PERMIT NO. 694262-839636
Other IDWR No. 63-31969

2. OWNER:
Name Star Sewer and Water Well #3
Address PO Box 400
City Star State ID Zip 83669

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.



Twp. 4 North X or South ___
Rge. 1 East or West X
Sec. 5 SE 1/4 SE 1/4 SW 1/4
Gov't Lot ___ County Ada
Lat: ___ Long: ___
Address of Well Site N of Floating Feather Rd., 1/2 mile East of Star Rd. City Star
Lt. 8 Blk. 5 Sub. Name Lobo Creek

4. USE:
___ Domestic X Municipal ___ Monitor ___ Irrigation
___ Thermal ___ Injection ___ Other ___

5. TYPE OF WORK: check all that apply (Replacement etc.)
X New Well ___ Modify ___ Abandonment ___ Other ___

6. DRILL METHOD:
___ Air Rotary ___ Cable X Mud Rotary ___ Other ___

7. SEALING PROCEDURES:

Seal/Filter Pack Material	From	To	AMOUNT Sacks or Pounds	METHOD
6-8 Sand	584'	643'	2.4 Yds	Poured
8-16 Sand	510'	584'	3.6 Yds	Poured

Was drive shoe used? ___ Y X N Shoe Depth(s)
Was drive shoe seal tested? Y X N How?

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded

Length of Headpipe ___ Length of Tailpipe ___

9. PERFORATIONS/SCREENS:
___ Perforations Method ___
X Screens Screen Type Johnson

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
574'	564'	.025		8"	SS		X
564'	554'	.015		8"	SS		X
554'	544'	.020		8"	SS		X

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
___ ft. below ground Artesian pressure ___ lb.
Depth flow encountered ___ ft. Describe access port or control devices: ___

11. WELL TESTS:
Pump Bailer Air Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time

Water Temp. ___ Bottom hole temp. ___
Water Quality test or comments: ___
Depth first Water Encounter ___

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
22"	507'	523'	Fine Blue Sand	X	
22"	523'	543'	Sticky Blue Clay		
16"	543'	553'	Fine Blue Sand	X	
16"	553'	561'	Medium Quartz Sand	X	
16"	561'	571'	Silty Blue Sand	X	
16"	571'	584'	Soft Sandy Blue Clay		
16"	584'	621'	Medium-Coarse Sand	X	
16"	621'	624'	Sandy Blue Clay		
16"	624'	643'	Silty Blue Sand	X	

Completed Depth 643' (Measurable)
Date: Started 5/31/2006 Completed 8/16/2006

13. DRILLER'S CERTIFICATION:
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Treasure Valley Drilling Firm No. 560
Firm Official ___ Date 8/18/2006
and
Driller or Operator ___ Date 8/18/2006
(Sign once if Firm Official & Operator)

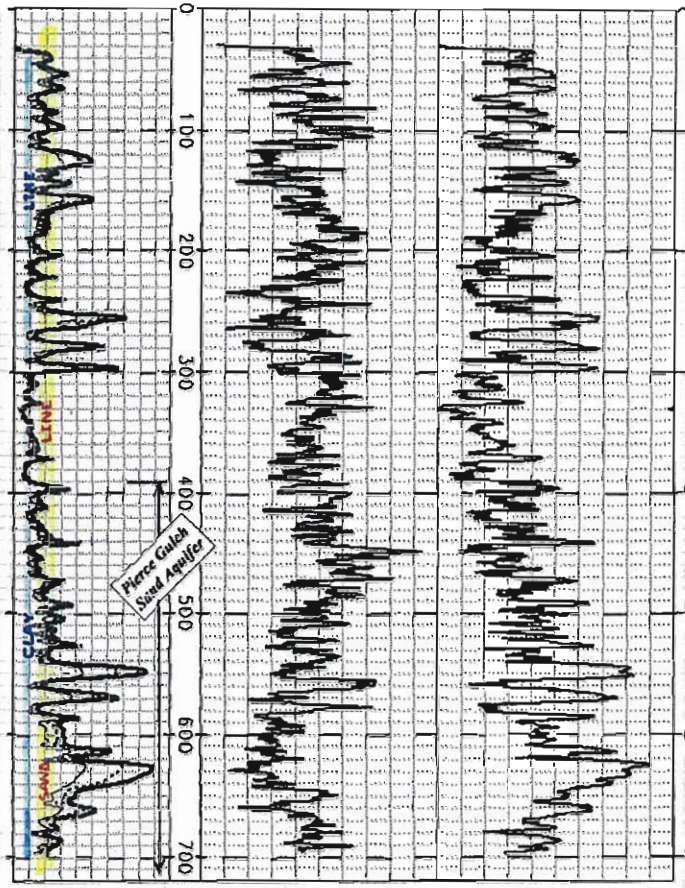
FORWARD WHITE COPY TO WATER RESOURCES

Star Sewer and Water District
Supply Well #3

T. 4 N., R. 1 W., Section 5, SE¼, SE¼, SW¼
Latitude N43° 42' 24.9" Longitude W116° 29' 1.0"
Well completed August 2006

Geophysical Logs

32" Resistivity 0 ohm-meters 200
16" Resistivity 0 ohm-meters 200
8" Resistivity 0 ohm-meters 200
Natural Gamma Ray 40 counts/sec 140
Point Resistance 40 ohms 100



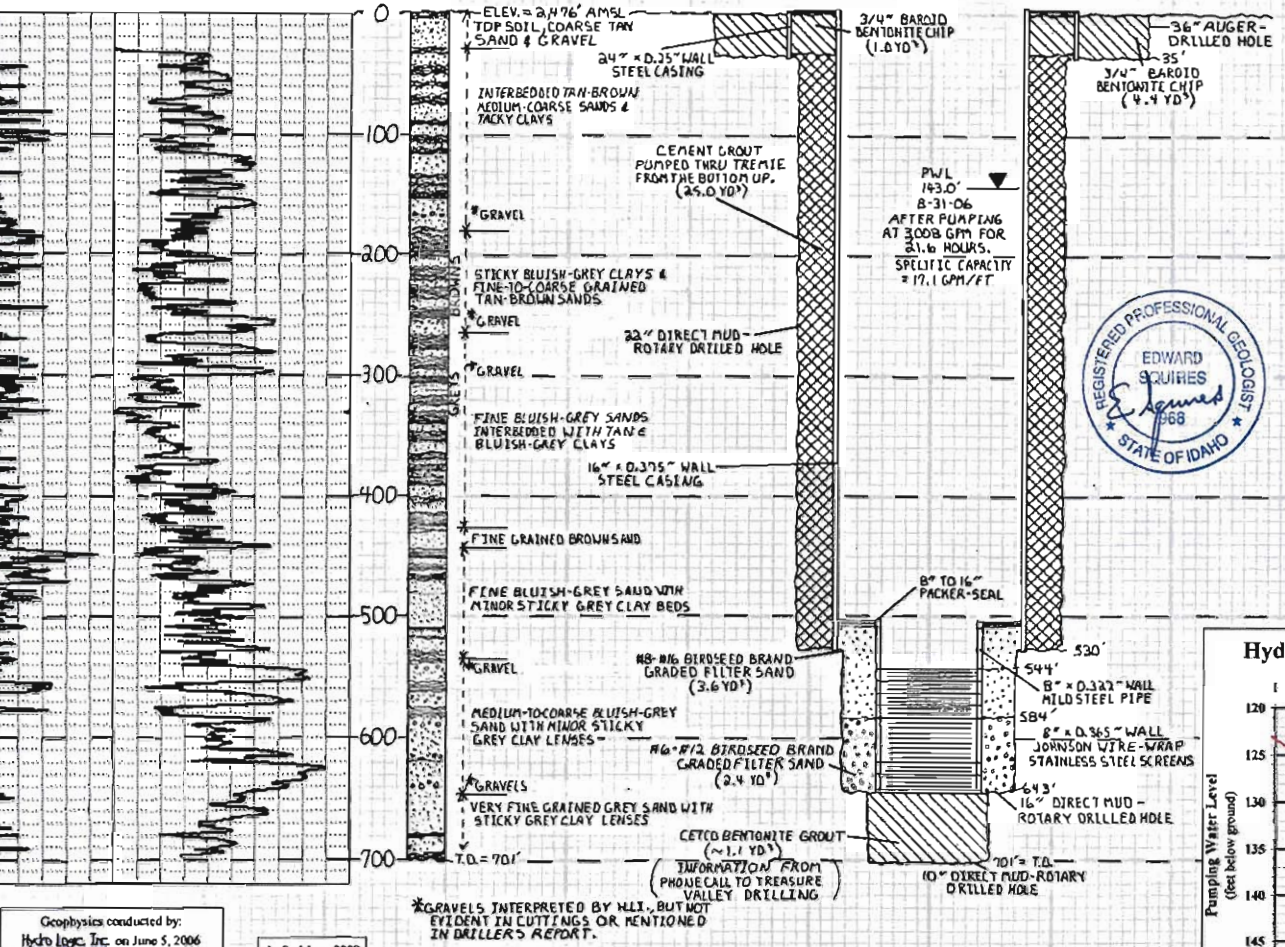
Depth (feet below ground level)

Lithology

Hydro Logic, Inc. lithologic log is interpreted and drawn from geophysical logs and drilled cuttings from the borehole.

As-Built Well Construction

(horizontal scale 0.1"=1.0")
(vertical scale 1"=100')



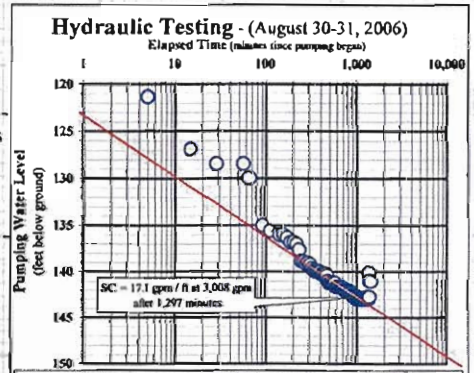
*GRAVELS INTERPRETED BY HLI., BUT NOT EVIDENT IN CUTTINGS OR MENTIONED IN DRILLERS REPORT.

Ground Water Chemistry

Analysis (in mg/L unless noted)	ZONE (643 - 544 ft bgl)
Alkalinity	82.0
Aluminum	<0.01
Ammonia as N	0.06
Arsenic	0.005
Calcium as $CaCO_3$	50.2
Chloride	1.60
Conductivity (µS)	184.0
Corrosivity	-0.65
Fluoride	0.55
Hardness	66.7
Iron (total)	0.20
Iron (dissolved)	0.20
Magnesium	4.03
Manganese (dissolved)	0.03
Nitrate as N	<0.10
Odor	<1
pH - Lab (S.U.)	7.64
Potassium	1.36
Silica	30.6
Sodium	13.6
Sulfate	9.03
Sulfide	<0.05
Total Dissolved Solids	123.0
Total Kjeldahl Nitrogen	0.15
Total Organic Carbon	<1.0
Field Conductivity (µS)	212
Field Dissolved Oxygen	0.35
Field pH (S.U.)	7.51
Field Temperature (°F)	66.5

Water samples and field parameters collected on August 30, 2006 by Hydro Logic, Inc.
Analyses by Alchem Laboratories, Inc., Boise, ID

Hydraulic Testing - (August 30-31, 2006)



Non-Pumping Water Level = +33.2 feet above ground (on 08/16/06)
Well pumped at 3,008 gallons/minute for 1,447 minutes by Layne of Idaho, Inc., Nampa, ID.
Well development consisted of allowing well to flow at 1,500 gallons/minute for approximately two weeks.

Geophysics conducted by: Hydro Logic, Inc. on June 5, 2006 immediately after removal of drill steel

drafted June 2008 by L. Pearson Hydro Logic, Inc.

On site supervision and direct mud-rotary drilling by: Treasure Valley Drilling and Pump, Inc., Weiser, ID
Well design by Clearwater Geosciences, LLP, Idaho Falls, ID with assistance from Hydro Logic, Inc., Boise, ID
Pump test design by Treasure Valley Drilling and Layne of Idaho.
Composite diagram developed by HLI from data of others. HLI did not work on this project.

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Form 238-7
4/92

RECEIVED STATE OF IDAHO
DEPARTMENT OF WATER RESOURCES
JUL 07 1993
Department of Water Resources

WELL DRILLER'S REPORT

POOR QUALITY

State Department of Water Resources must be filed with the Director, Department of Water Resources within 30 days after the completion or abandonment of the well.

LDS Eagle

pg 1 of 3

1. WELL OWNER L.D.S. CHURCH/EAGLE STAKE CENTR
Name _____
Address 2710 NW SUNRISE RIM. RD. SUITE200
63-93-W-0331-000
Drilling Permit No. _____
Water Right Permit No. 63-11992

2. NATURE OF WORK NEW WELL
☐ New well ☐ Deepened ☐ Replacement
☐ Well diameter increase ☐ Modification
☐ Abandoned (describe abandonment or modification procedures such as liners, screen, materials, plug depths, etc. in lithologic log, section 9.)

3. PROPOSED USE CULINARY WELL
☐ Domestic ☐ Irrigation ☐ Monitor
☐ Industrial ☐ Stock ☐ Waste Disposal or Injection
☐ Other _____ (specify type)

4. METHOD DRILLED MUD ROTARY
☐ Rotary ☐ Air ☐ Auger ☐ Reverse rotary
☐ Cable ☐ Mud ☐ Other _____ (backhoe, hydraulic, etc.)

5. WELL CONSTRUCTION
Casing schedule: ☒ Steel ☐ Concrete ☐ Other _____

Thickness	Diameter	From	To
0.25 inches	6" inches	+ 18 feet	387 feet
0.25 inches	6" inches	397 feet	421 feet
0.25 inches	6" inches	426 feet	432 feet

Was casing drive shoe used? ☐ Yes ☒ No
Was a packer or seal used? ☐ Yes ☒ No
Perforated? ☐ Yes ☐ No
How perforated? ☐ Factory ☐ Knife ☐ Torch ☐ Gun
Size of perforation? _____ inches by _____ inches

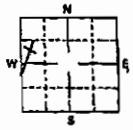
Number	From	To
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet

Well screen installed? ☒ Yes ☐ No
Manufacturer SEE ATTACH Type _____
Top Packer or Headpipe _____
Bottom of Tailpipe _____

Diameter ____ Slot size ____ Set from 387 feet to 297 feet
Diameter ____ Slot size ____ Set from 421 feet to 426 feet
Gravel packed? ☒ Yes ☐ No Size of gravel 8-12
Placed from 430 feet to 315 feet
Surface seal depth 315 Material used in seal: ☐ Cement grout
☒ Bentonite ☒ Puddling clay ☐ _____
Sealing procedure used: ☐ Slurry pit
☐ Temp. surface casing ☒ Overbore to seal depth
Method of joining casing: ☐ Threaded ☒ Welded
☐ Solvent Weld ☐ Cemented between strata

Describe access port WELL CAP

6. LOCATION OF WELL
Sketch map location must agree with written location.



Subdivision Name _____
Lot No. _____ Block No. _____
County ADA
Address of Well Site EAGLE RD BTWN BEACON LITE & Floating Feather Rd
(give at least name of road)
SW ¼ NW ¼ Sec. 4 T. 4N N ☐ or S ☐ R. 1E E ☐ or W ☐

7. WATER LEVEL
Static water level 28' feet below land surface.
Flowing? ☐ Yes ☒ No G.P.M. flow _____
Artesian closed-in pressure _____ p.s.i.
Controlled by: ☐ Valve ☐ Cap ☐ Plug
Temperature 65 °F. Quality Good
Describe artesian or temperature zones below.

8. WELL TEST DATA NOT AVAILABLE AT THIS TIME
☐ Pump ☐ Bailer ☐ Air ☐ Other _____

Discharge G.P.M.	Pumping Level	Hours Pumped
100	52'	4

9. LITHOLOGIC LOG

Bore Diam.	Depth From	Depth To	Material	Water Yes	Water No
10"	0	5	TOPSOIL		X
	5	10	CRSE SAND&SMALL GRAVEL		X
	10	45	SAND&RIVER GRAVEL	X	
	45	54	BRN SILTY CLAY		X
	54	56	SAND	X	
	56	58	BRN SILTY CLAY		X
	58	82	CLAY		X
	82	84	SAND	X	
	84	89	SILTY CLAY		X
	89	99	COURSE SAND	X	
	99	106	CLAY		X
	106	134	COURSE SAND	X	
	134	135	CLAY		X
	135	136	SAND-VERY COURSE	X	
	136	149	CLAY		X
	149	159	CLAY&COURSE SAND MIXED	X	
	159	159	S SAND		X
	159	160	CLAY		X
	160	164	SAND	X	
	164	171	CLAY		X
	171	200	SAND-CRSE-ROUNDED	X	
	200	206	CLAY		X
	206	224	FINE SAND&CLAY MIXED		X
	224	304	FINE SAND		X
	304	309	CLAY&SOME FINE SANDMIXED		X
	309	311	SAND		X
	311	318	CLAY		X
	318	329	FINE SAND	X	
	329	330	SAND	X	
	330	340	SAND&CLAY MIXED		X
	340	345	SAND		X
	345	377	FINE SAND&CLAY MIXED		X
	377	397	FINE SAND&HARD CLAY MIXED		X
	397	402	FINE SAND		X
	402	417	CLAY		X
	417	434	MED-FINE SAND	X	

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AUG 09 1993
Department of Water Resources

10. Work started 4/26/93 finished 5/7/93

11. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.
Firm Name PETE COPE DRILLING Firm No. 213
Address 6505W. CHINDEN Date 5/11/93
Signed by Drilling Supervisor Joseph Jones
and (Operator) Jerry Foster
(If different than the Drilling Supervisor)

USE ADDITIONAL SHEETS IF NECESSARY FORWARD THE WHITE COPY TO THE DEPARTMENT

Form 238-7
4/92

POOR QUALITY

STATE OF IDAHO
DEPARTMENT OF WATER RESOURCES

LDS Eagle

Department of Water Resources
Western Regional Office

WELL DRILLER'S REPORT

State law requires that this report be filed with the Director, Department of Water Resources within 30 days after the completion or abandonment of the well.

pg 2 of 3

1. WELL OWNER L.D.S. CHURCH
Name _____
Address 2710 NW SUNRISE RIM. RD. SUITE200
Drilling Permit No. 63-93-W-0331-000
Water Right Permit No. 63-11992

2. NATURE OF WORK NEW WELL
☐ New well ☐ Deepened ☐ Replacement
☐ Well diameter increase ☐ Modification
☐ Abandoned (describe abandonment or modification procedures such as liners, screen, materials, plug depths, etc. in lithologic log, section 9.)

3. PROPOSED USE CULLINARY
☐ Domestic ☐ Irrigation ☐ Monitor
☐ Industrial ☐ Stock ☐ Waste Disposal or Injection
☐ Other _____ (specify type)

4. METHOD DRILLED MUD ROTARY
☐ Rotary ☐ Air ☐ Auger ☐ Reverse rotary
☐ Cable ☐ Mud ☐ Other _____ (backhoe, hydraulic, etc.)

5. WELL CONSTRUCTION
Casing schedule: ☒ Steel ☐ Concrete ☐ Other _____

Thickness	Diameter	From	To
0.25 inches	6" inches	+ 437 feet	450 feet
0.25 inches	6" inches	465 feet	470 feet
.25 inches	10" inches	+18" feet	42 feet

Was casing drive shoe used? ☐ Yes ☒ No
Was a packer or seal used? ☐ Yes ☒ No
Perforated? ☐ Yes ☐ No
How perforated? ☐ Factory ☐ Knife ☐ Torch ☐ Gun
Size of perforation? _____ inches by _____ inches

Number	From	To
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet

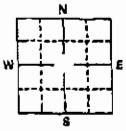
Well screen installed? ☒ Yes ☐ No
Manufacturer _____ Type _____
Top Packer or Headpipe _____
Bottom of Tailpipe _____

Diameter ____ Slot size ____ Set from 432 feet to 437 feet
Diameter ____ Slot size ____ Set from 450 feet to 465 feet
Gravel packed? ☐ Yes ☐ No ☐ Size of gravel _____
Placed from _____ feet to _____ feet

Surface seal depth 0' Material used in seal: ☐ Cement grout
☒ Bentonite ☐ Puddling clay ☐ _____
Sealing procedure used: ☐ Slurry pit
☐ Temp. surface casing ☒ Overbore to seal depth
Method of joining casing: ☐ Threaded ☒ Welded
☐ Solvent Weld ☐ Cemented between strata

Describe access port WELL CAP

6. LOCATION OF WELL
Sketch map location must agree with written location.



Subdivision Name _____
Lot No. _____ Block No. _____
County ADA
Address of Well Site EAGLE RD. ATWN BEACON LITE & Floating Feather Rd
(give at least name of road)
SW ¼ NW ¼ Sec. 4, T. 4N N ☐ or S ☐, R. 1E E ☐ or W ☐

7. WATER LEVEL
Static water level 28' feet below land surface.
Flowing? ☐ Yes ☒ No G.P.M. flow _____
Artesian closed-in pressure _____ p.s.i.
Controlled by: ☐ Valve ☐ Cap ☐ Plug
Temperature 65 °F. Quality Good
Describe artesian or temperature zones below.

8. WELL TEST DATA
☐ Pump ☐ Bailer ☐ Air ☐ Other _____

Discharge G.P.M.	Pumping Level	Hours Pumped

9. LITHOLOGIC LOG

Bore Diam.	Depth From	Depth To	Material	Water Yes	Water No
10"	436	443	CLAY		X
	443	444	SAND		X
	444	446	CLAY		X
	446	470	FINE SAND	X	

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JUL 07 1993
Department of Water Resources

APPROVED
AUG 09 1993

10. Work started _____ finished _____

11. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.
Firm Name PETE COPE DRILLING Firm No. 213
Address 6506W. CHINDEN Date 6/11/93
Signed by Drilling Supervisor _____
and
(Operator) _____ (if different than the Drilling Supervisor)

USE ADDITIONAL SHEETS IF NECESSARY

LDS Eagle

Department of Water Resources
Western Regional Office

pg 3 of 3

POOR QUALITY

CHURCH OF JESUS CHRIST OF LATTER DAY SAINTS
2710 NW SUNRISE RIM RD SUITE 200
BOISE ID 83705
PERMIT # 63-93-W-0331

6" CASING RECORD .250 WALL WELDED

1.5	-	380	381.5
			381.5 TOTAL 6" CASING

5" CASING RECORD .250 WALL WELDED

380		387	7
397		421	24
426		432	6
437		450	13
465		470	5
			55 TOTAL 5" CASING

6" TELESCOPE SCREEN RECORD .14 SLOT HOUSTON 304 STAINLESS

387	-	397	10
			10 SCREEN

6" TELESCOPE SCREEN RECORD .15 SLOT JOHNSON 304 STAINLESS

455	-	460	5
			5 SCREEN

6" TELESCOPE SCREEN RECORD .15 SLOT JOHNSON 304 STAINLESS

421	-	426	5
432	-	437	5
450	-	455	5
460	-	465	5
			20 SCREEN
			35 TOTAL SCREEN

471.5 TOTAL SCREEN + CASIN

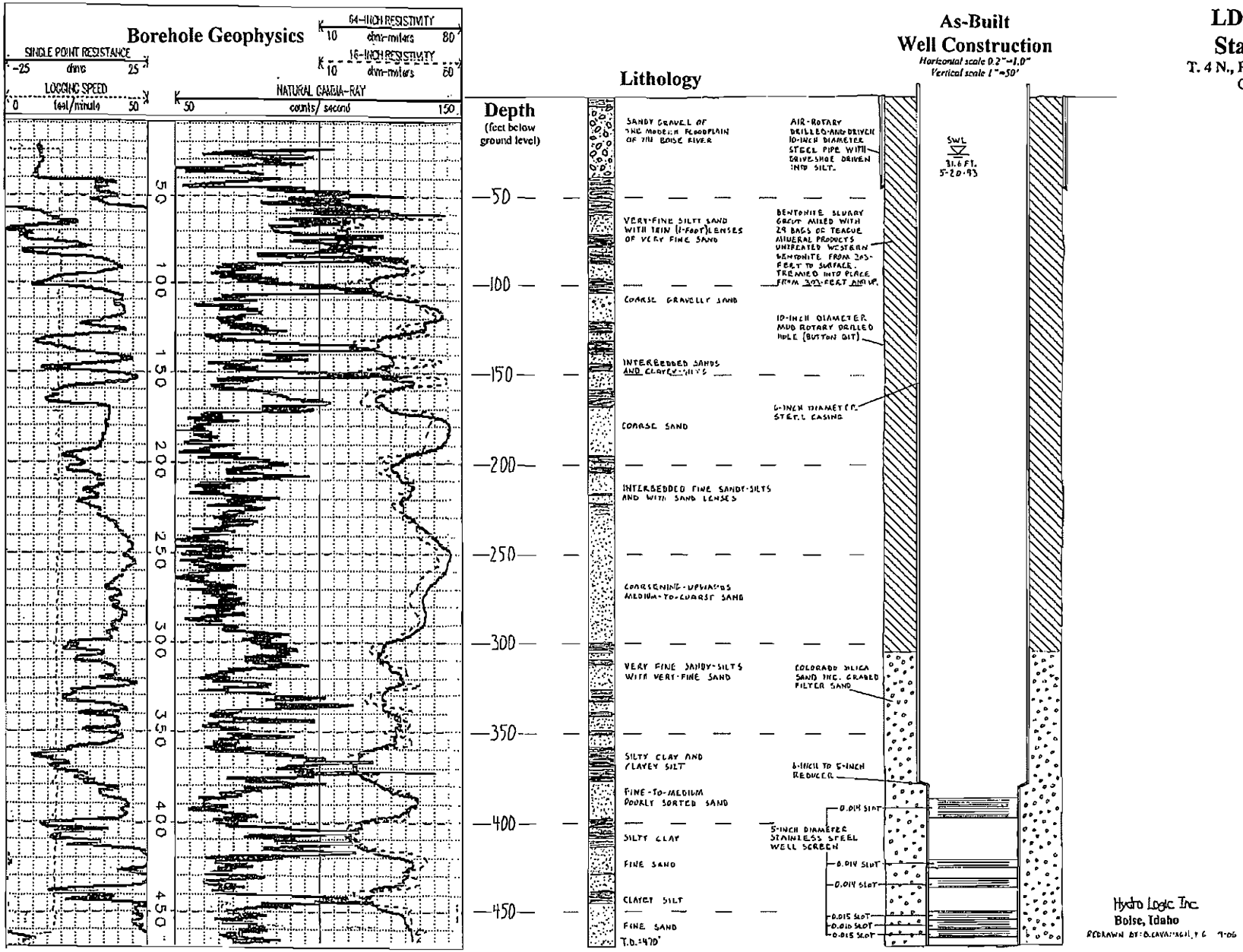
4N 1E Sec 4 SW 1/4 NW 1/4

MICROFILMED

AUG 0 9 1993

LDS Church Eagle
Stake Center Well

T. 4 N., R. 1 E., Sec. 4, SW 1/4, NW ¼
Completed: May, 1993



Hydro Logic Inc
Boise, Idaho
REDRAWN BY: B. LAVAGNINO, P.G. 7-06

RECEIVED JUL 20 1995

Form 238-7 7/94

UNITED WATER

FLOATING FEATHER

IDAHO DEPARTMENT OF WATER RESOURCES

WELL DRILLER'S REPORT

Use Typewriter or Ball Point Pen

1. DRILLING PERMIT NO. 63 - 95 - C - 0119 - 000
Other IDWR No.

2. OWNER:
Name UNITED WATER IDAHO, INC.
Address P.O. Box 7488
City Boise State ID Zip 83707

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S

Twp. 4 North ☒ or South ☐
Rge. 1 East ☒ or West ☐
Sec. 5, ____ 1/4 SE 1/4 SW 1/4 (10 acres / 40 acres / 160 acres)
Gov't Lot ____ County Ada

Address of Well Site Crandlemire site
Floating Feather Well City Boise
(Give at least name of road + Distance to Road or Landmark)

Lt. ____ Blk. ____ Sub. Name ____

4. PROPOSED USE:
☐ Domestic ☒ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other ____

5. TYPE OF WORK
☐ New Well ☐ Modify or Repair ☐ Replacement ☒ Abandonment

6. DRILL METHOD
☐ Mud Rotary ☐ Air Rotary ☐ Cable ☒ Other Reverse Rotary

7. SEALING PROCEDURES

SEAL/FILTER PACK Material	From	To	AMOUNT Sacks or Pounds	METHOD
Bentonite	0	171	30,000#	Pour from top
8&12Col.sand	171	346		Pour from top

Was drive shoe used? ☐ Y ☒ N Shoe Depth(s) ____
Was drive shoe seal tested? Y☐ N☐ How? ____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
18"	+2	171	.375	Steel	☒	☐	☒	☐
14	169	183	.375	Steel	☒	☐	☒	☐
14	193	204	.375	Steel	☒	☐	☒	☐

Length of Headpipe ____ Length of Tailpipe 10'

9. PERFORATIONS/SCREENS
☐ Perforations Method ____
☒ Screens Screen Type Houston wire wrap

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
183	193	.040		14	Stain.	☒	☐
204	214	.040		14	"	☒	☐
225	255	.040		14	"	☒	☐

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
55 ft. below ground Artesian pressure 5 lb.
Depth flow encountered ____ ft. Describe access port or control devices: ____

11. WELL TESTS:
☒ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time
1500 GPM.		67'	1 hr.
1000 GPM		54'	2 hr.

Water Temp. 55° Bottom hole temp. ____
Water Quality test or comments: ____

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
28	0	8	Top soil		
28	8	15	Coarse sand		
28	15	19	Hard pan, sand & gravel		
28	19	27	Coarse sand		
28	27	47	Sand, gravel & river rock		
28	47	49	Fine white sand		
28	49	50	Ligt brown clay		
28	50	53	Fine white sand		
28	59	113	Brown clay		
28	113	129	Fine to medium white sand		
28	129	131	Brown clay		
28	131	132	Fine sand		
28	132	138	Brown clay		
28	138	147	Fine to medium sand		
28	147	154	Brown clay		
22	154	167	Fine to medium sand		
22	167	174	Light brown clay		
22	174	176	Fine to coarse sand		
22	176	181	Brown clay		
22	181	258	Fine to coarse sand		
22	258	267	Brown clay		
22	267	279	Fine to medium sand		
22	279	313	Fine to coarse sand		
22	313	314	Brown clay		
22	314	317	Fine to coarse sand		
22	317	332	Fine to coarse sand		
22	332	346	Brown clay		

Completed Depth 340 (Measurable)
Date: Started 5/1/95 Completed 5/11/95

13. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

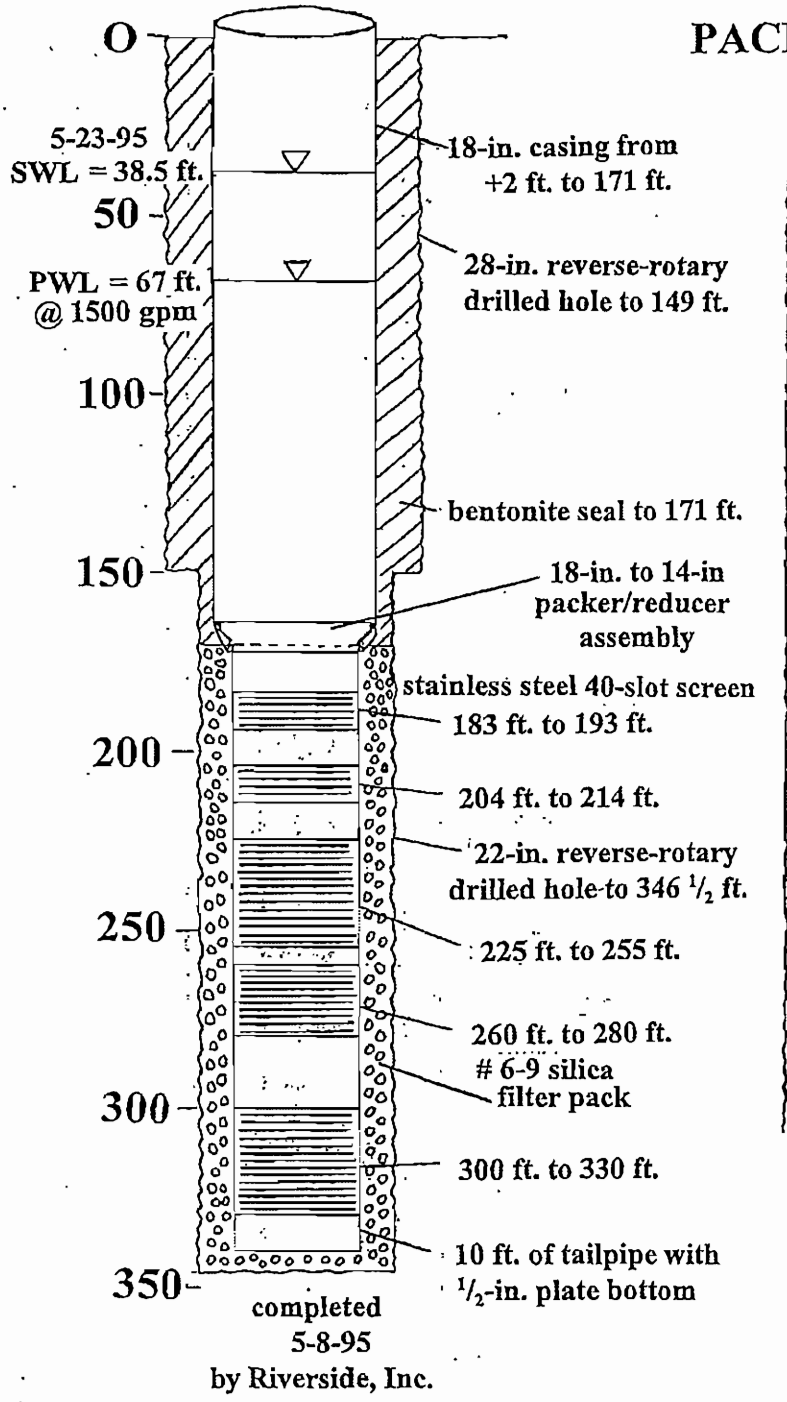
Firm Name Riverside, Inc. Firm No. 333
Firm Official ____ Date 7/19/95
and
Supervisor or Operator Jerry Dunfield Date 6/8/95
(Sign once if Firm Official & Operator)

FORWARD WHITE COPY TO WATER RESOURCES

UNITED W' \TER FLOATING FF 'THER WELL

5/8/95

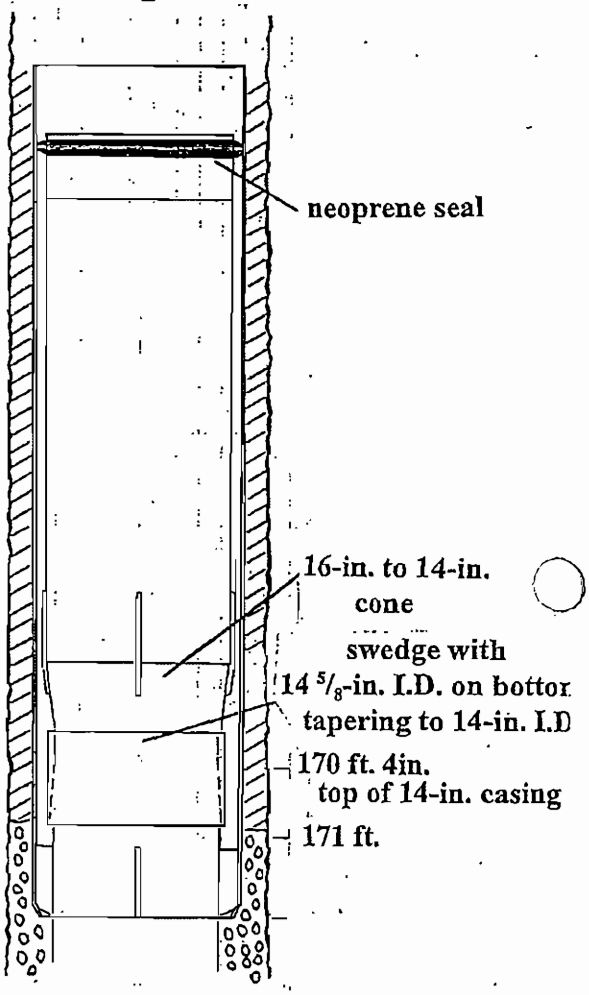
WELL CONSTRUCTION



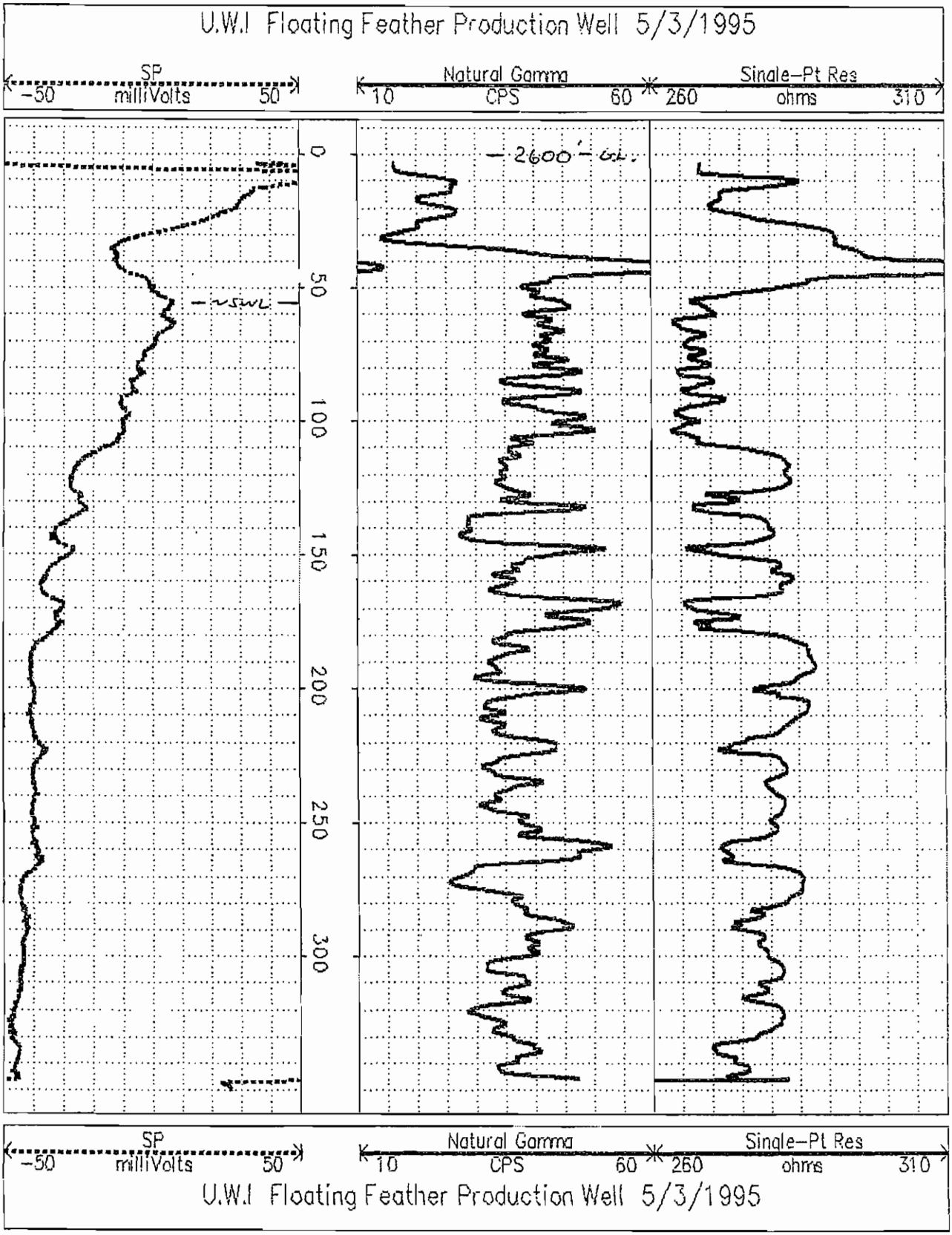
completed
5-8-95
by Riverside, Inc.

PACKER / REDUCER ASSEMBLY

total length 5'7"



5-10-95


U.W.I Floating Feather Production Well 5/3/1995
SP
-50
milliVolts
50
Natural Gamma
10
CPS
60
Single-Pt Res
260
ohms
310
0
50
100
150
200
250
300
U.W.I Floating Feather Production Well 5/3/1995

Form 238-7
7/94

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

RECEIVED JUL 20 1995
Department of Water Resources

Use Typewriter or Ball Point Pen

18872

1. DRILLING PERMIT NO. 63 - 95 - C - 0119 - ~~000~~ 200
Other IDWR No. Replacement of 63-90-W-0209-000 Water right # 63-11090

2. OWNER:
Name UNITED WATER IDAHO, INC.
Address P.O. Box 7488
City Boise State ID Zip 83707

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S

Twp. 4 North ☒ or South ☐
Rge. 1 East ☒ or West ☐
Sec. 5, ____ 1/4 SE 1/4 SW 1/4
Gov't Lot ____ County Ada

Address of Well Site Crandlemire site
Floating Feather Well City Boise
(Give at least name of road + Distance to Road or Landmark)

Lt. ____ Blk. ____ Sub. Name ____

4. PROPOSED USE:
☐ Domestic ☒ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other ____

5. TYPE OF WORK
☒ New Well ☐ Modify or Repair ☒ Replacement ☐ Abandonment

6. DRILL METHOD
☐ Mud Rotary ☐ Air Rotary ☐ Cable ☒ Other Reverse Rotary

7. SEALING PROCEDURES

SEAL/FILTER PACK Material	From	To	AMOUNT Sacks or Pounds	METHOD
Bentonite	0	171	30,000#	Pour from top
8&12Col.sand	171	346		Pour from top

Was drive shoe used? ☐ Y ☒ N Shoe Depth(s) ____
Was drive shoe seal tested? Y☐ N☐ How? ____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
18"	+2	171	.375	Steel	☒	☐	☒	☐
14	169	183	.375	Steel	☒	☐	☒	☐
14	193	204	.375	Steel	☒	☐	☒	☐

Length of Headpipe ____ Length of Tailpipe 10'

9. PERFORATIONS/SCREENS
☐ Perforations Method ____
☒ Screens Screen Type Houston wire wrap

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
183	193	.040		14	Stain.	☒	☐
204	214	.040		14	"	☒	☐
225	255	.040		14	"	☒	☐

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
55 ft. below ground Artesian pressure ____ lb.
Depth flow encountered ____ ft. Describe access port or control devices: ____

11. WELL TESTS:
☒ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time
1500 GPM		67'	1 hr.
1000 GPM		54'	2 hr.

Water Temp. 55° Bottom hole temp. ____
Water Quality test or comments: ____

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
28	0	8	Top soil		
28	8	15	Coarse sand		
28	15	19	Hard pan, sand & gravel		
28	19	27	Coarse sand		
28	27	47	Sand, gravel & river rock		
28	47	49	Fine white sand		
28	49	50	Ligt brown clay		
28	50	53	Fine white sand		
28	59	113	Brown clay		
28	113	129	Fine to medium white sand		
28	129	131	Brown clay		
28	131	132	Fine sand		
28	132	138	Brown clay		
28	138	147	Fine to medium sand		
28	147	154	Brown clay		
22	154	167	Fine to medium sand		
22	167	174	Light brown clay		
22	174	176	Fine to coarse sand		
22	176	181	Brown clay		
22	181	258	Fine to coarse sand		
22	258	267	Brown clay		
22	267	279	Fine to medium sand		
22	279	313	Fine to coarse sand		
22	313	314	Brown clay		
22	314	317	Fine to coarse sand		
22	317	332	Fine to coarse sand		
22	332	346	Brown clay		

RECEIVED AUG 02 1995 Department of Water Resources
RECEIVED JUL 21 1995 OCT 0 WATER RESOURCES WESTERN REGION

Completed Depth 340 (Measurable)
Date: Started 5/1/95 Completed 5/11/95

13. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Firm Name Riverside, Inc. Firm No. 333
Firm Official ____ Date 7/19/95
and
Supervisor or Operator Terry Dansby Date 6/8/95
(Sign once if Firm Official & Operator)

FORWARD WHITE COPY TO WATER RESOURCES

Form 238-7
11/97

IDAHO DEPARTMENT OF WATER RESOURC

WELL DRILLER'S REPORT

SVR Well #1

Inspected by
Twp ____ Rge ____ Sec ____
____ 1/4 ____ 1/4 ____ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 0025898 WELL #1
DRILLING PERMIT NO. 874391-788454
Other IDWR No.

2. OWNER:
Name Sun Cor Development
Address 80 East Rio Salado Pkwy. #410
City Tempe State AZ Zip 85281

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S

Twp. 5 North ☒ or South ☐
Rge. 2 East ☒ or West ☐
Sec. 18 1/4 (10 acres) N/E 1/4 (40 acres) N/W 1/4 (160 acres)
Gov't Lot ____ County Ada
Lat: : : Long: : :
Address of Well Site west side of hiway 55 in Spring Valley
(Give at least name of road + Distance to Road or Landmark) City

Lt. ____ Blk. ____ Sub. Name ____

4. USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other Test

5. TYPE OF WORK check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other

6. DRILL METHOD
☐ Air Rotary ☐ Cable ☒ Mud Rotary ☐ Other

7. SEALING PROCEDURES

SEAL/FILTER PACK Material	From	To	AMOUNT Sacks or Pounds	METHOD
bentonite grout	0	98	7 sk	pumped

Was drive shoe used? ☒Y ☐ N Shoe Depth(s) ____
Was drive shoe seal tested? ☐ Y ☐ N How? ____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
6	+2	98	250	steel	☒	☐	☐	☐
8	+1	5	250	steel	☐	☐	☐	☐
					☐	☐	☐	☐

Length of Headpipe ____ Length of Tailpipe ____

9. PERFORATIONS/SCREENS
Perforations Method ____
Screens Screen Type ____

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
						☐	☐
						☐	☐
						☐	☐

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
20 ft. below ground Artesian pressure ____ lb.
Depth flow encountered 20 ft. Describe access port or control devices: ____

11. WELL TESTS:
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time

Water Temp. ____ Bottom hole temp. ____
Water Quality test or comments: ____
Depth first Water Encounter ____

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
8	0	5	topsoil		X
	5	40	sandstone, brown		X
	40	85	sandstone, gray	X	
	85	125	shale like hard gray		X
	125	140	very fine sand	X	
	140	205	shale like, hard gray		X
	205	240	sandstone & gray clay		X
	240	260	shale like, hard gray		X
	260	270	sandstone, gravel, some clay		X
	270	340	granite, gravel, sandstone, rhyolite		
				X	
	340	350	clay w/ some sand & gravel	X	
	350	400	decomposed granite	X	
	400	445	increasingly harder		

SCANNED
JAN 27 2003

RECEIVED
JAN 15 2003
WATER RESOURCES
WESTERN REGION

Completed Depth 445 (Measurable)
Date: Started 10/21/02 Completed 11/27/02

13. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Stevens & Sons Firm No. 153
Firm Official Ron Stevens Date 12/20/02
and
Driller or Operator ____
(Signature of Firm Official or Operator)

FORWARD WHITE COPY TO WATER RESOURCES

Exploration Hole SVR 1
Spring Valley Ranch

Drilled by: Stevens and Sons, Inc.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Hydrologic, Inc.
Fluid level when logged: full
Casing when logged: 8" steel 0-5 ft, 8" open hole 5 - 445 ft.

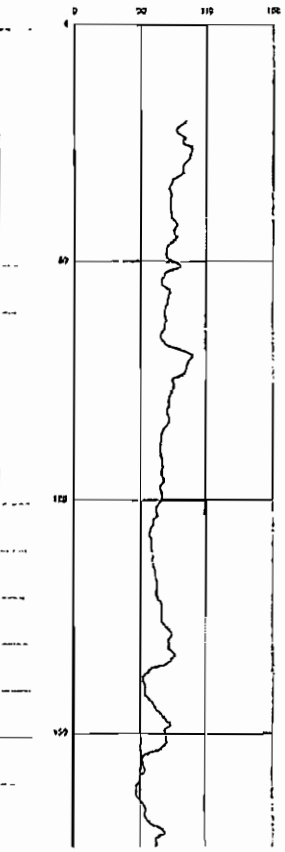
Drilled Dates: 10/30/02 - 11/05/02
Drilling Method: Mud Rotary
Borehole size: 8" (nom.) 0 - 445 ft.

Depth Drilled: 445 ft
Depth Logged: 428 ft.
Static WL: ~ 20 ft. bgl

Location: Ada County, Idaho
T5N, R2E, NE 1/4, NW 1/4, Sect 18
GL. Elevation: ~3260 ft. msl.

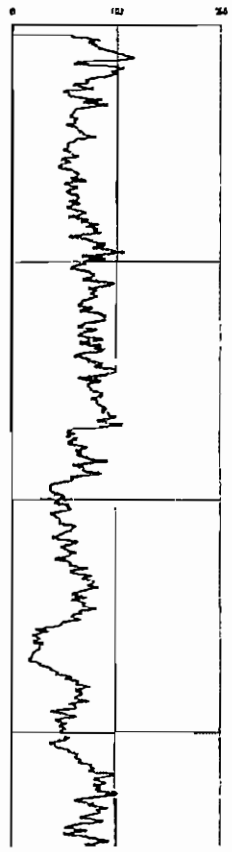
Depth (ft)	Geologic log from rotary cuttings
0	Top soil over well graded gravel fine-med., clasts of granite, qtz, and fine cemented SS, med. brown
10	Claystone, med-dark brown, hard, well cemented, fractured with FeMn coatings.
20	Claystone as above
30	Claystone as above, some poorly cemented ss and silicic ss, white veinlets and coatings on fractures.
40	Claystone as above, less mineralization on fractures, med-dark brn.
50	Claystone -tuff?, abundant white-yellowish white vein filling minerals and FeMn coating on fracture faces, v.hard, med-drk brn to 56 ft then dark gray
60	Claystone-tuff as above, v.fine, med-drk brn and gray, FeMn coatings on fractures, no bedding planes.
70	Claystone, tuffaceous, med. gray, softer than above, v.fine, massive, abundant white, elongated mineralilized frags (petrified wood?).
80	Claystone -tuff , med. gray, v. fine, med-hard cementation, occ. med. brn clay ball, sets, occ. white mineralization and petrified wood frag, massive.
90	Tuff, med-drk gray, v.fine grained, massive, occ. coarse qtz grain, mod-well cemented, hard
100	Tuff, as above, gray, hard, massive.
110	Tuff, as above, gray, hard, massive.
120	Tuff as above, larger grains
130	Sandstone, tuffaceous, silty -v. fine, as above, gray, hard, massive, soft @ 137-138.
140	Tuff as above, black glassy frags, aphanitic, rhyolite frags, arc shaped fractures, med-gray.
150	Tuff as above, mix of aphanitic glassy welded frags and rounded qtz grains.
160	Tuff, aphanitic groundmass with light xenoliths, hard @ 167m vugs with mineralization, med-dark gray.

Symb. Log

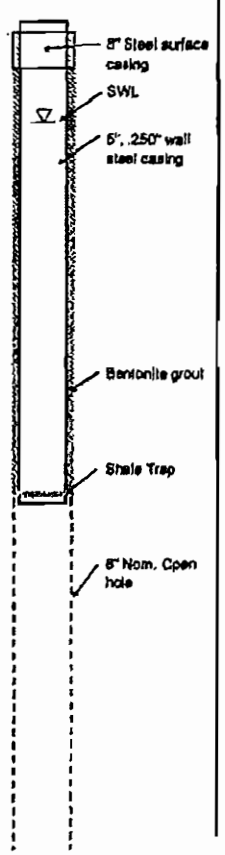


Pt. Res (Ohms)

Natural Gamma (CPS)



Well Construction



Exploration Hole SVR 1
Spring Valley Ranch

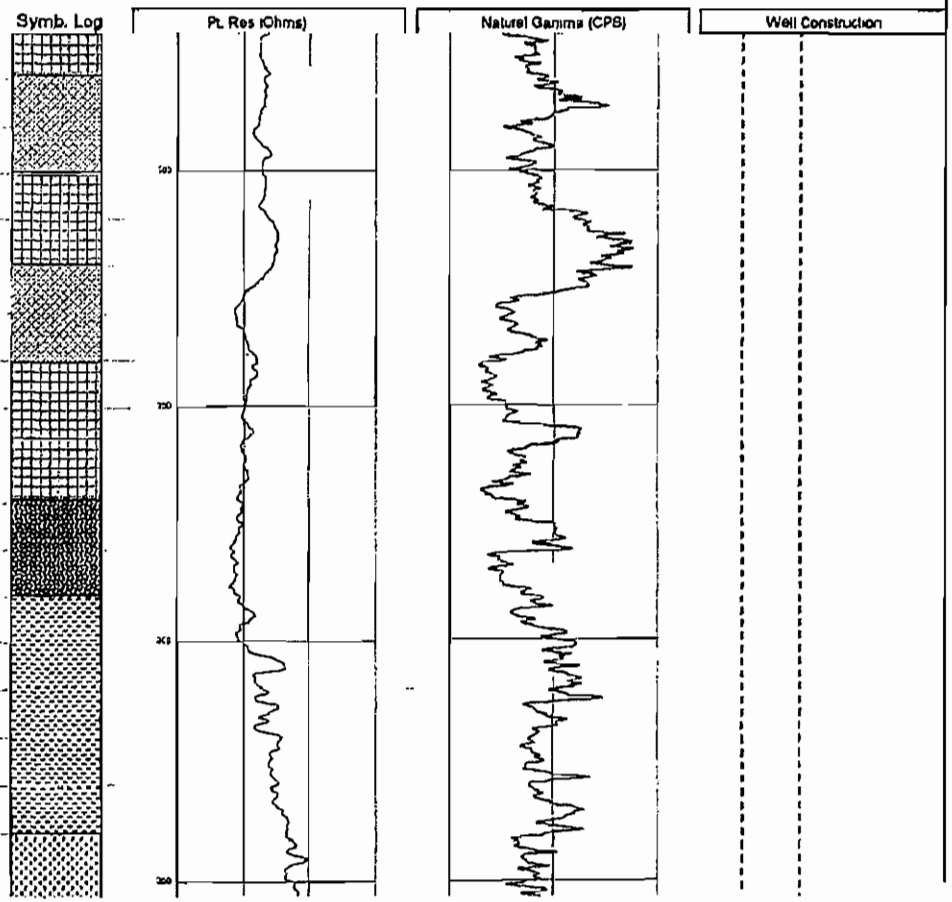
Drilled by: Stevens and Sons, Inc.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Hydrologic, Inc.
Fluid level when logged: full
Casing when logged: 8" steel 0-5 ft, 8" open hole 5 - 445 ft.

Drilled Dates: 10/30/02 - 11/05/02
Drilling Method: Mud Rotary
Borehole size: 8" (nom.) 0 - 445 ft.

Depth Drilled: 445 ft
Depth Logged: 428 ft.
Static WL: ~ 20 ft. bgl

Location: Ada County, Idaho
T5N, R2E, NE 1/4, NW 1/4, Sect 18
GL. Elevation: ~3280 ft. msl.

Depth (ft)	Geologic log from rotary cuttings
170	Tuff as above, aphanitic to v.fine sand, glassy, vugs, med-drk gray, occ. xenoliths.
180	Tuffaceous SS-Siltstone, occ. lighter gray, aglomerate of dark frags, occ rounded qtz grain
190	Tuffaceous SS-Siltstone as above, individual grains more apparent, occ qtz grain.
200	Tuff, as above, gray-brown.
210	Tuff, light and dark brownish gray, glassy, aphanitic tuff and gray clay.
220	Sandstone, light and dark gray, soft, fine, dirty, with clay balls.
230	Sandstone, gray, v. fine, with abundant clasts and inclusions of igneous rk frags, qtz grains
240	Tuff, aphanitic, dark gray, glassy, occ. frothy looking, lenticular black xtal inclusions.
250	Tuff as above, med-soft.
260	Sandstone, light gray, v.fine, soft, med and dark gray, hard at 267.
270	Breccia-gravel, mix of rock types incl. white granite with mica xtals, rhyolite and gray SS.
280	Gravel as above, more white lithic frags, soft @ 287.
290	Clay, gravelly and sandy, light gray, gravel frags predom. brick red rhyolite with qtz veins, sand is med gr, gray.
300	Clay and gravel as above, sticky clay, light grayish-brn, lithic frags of red rhyolite.
310	Clay, sandy and gravelly, sand is fine, salt and pepper, gravel s lithic frags of red rhyolite and gray ss.
320	Clay, gray, with fine gravel and coarse sand, clasts predom. qtz sand.
330	Clay, sandy to clayey sand, light gray, clay matrix is soft, plastic, sand is mix of decomp granite (qtz and feldspars) and black glassy balls., sandy at 336.
340	Decomposed granite, Grus, light gray, clayey, v. coarse, much less clay than above, Cs sand- to fine gravel is pred. qtz and feldspars, gray clay.



Form 238-7
11/97

IDAHO DEPARTMENT OF WATER RESOUR(

WELL DRILLER'S REPORT

SVR Well #2

0025899 WELL # 2

Inspected by _____
Twp ____ Rge ____ Sec ____
____ 1/4 ____ 1/4 ____ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D ~~874392-788455~~
DRILLING PERMIT NO. ____-____-____-_____-_____
Other IDWR No. _____

2. OWNER:
Name Sun Cor Development Co
Address 80 East Rio Salado Pkwy #410
City Tempe State AZ Zip 85281

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S

Twp. 6 North ☒ or South ☐
Rge. 1 East ☒ or West ☐
Sec. 36 ____ 1/4 (10 acres) N/E 1/4 (40 acres) S/E 1/4 (160 acres)
Gov't Lot ____ County Ada
Lat: : : Long: : :
Address of Well Site west side of hiway 55 in Spring Valley City _____
(Give at least name of road + Distance to Road or Landmark)

Lt. _____ Blk. _____ Sub. Name _____

4. USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other Test

5. TYPE OF WORK check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other _____

6. DRILL METHOD
☐ Air Rotary ☐ Cable ☒ Mud Rotary ☐ Other _____

7. SEALING PROCEDURES

SEAL/FILTER PACK Material	From	To	AMOUNT Sacks or Pounds	METHOD
bentonite grout	0	300	11 sk	pumped

Was drive shoe used? ☐Y ☐ N Shoe Depth(s) _____
Was drive shoe seal tested? ☐ Y☐ N How? _____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
6	+2	300	250	steel	☒	☐	☐	☐
8	+1	5	250	steel	☐	☐	☐	☐
					☐	☐	☐	☐

Length of Headpipe _____ Length of Tailpipe _____

9. PERFORATIONS/SCREENS
Perforations Method _____
Screens Screen Type _____

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
						☐	☐
						☐	☐
						☐	☐

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
31 ft. below ground Artesian pressure _____ lb.
Depth flow encountered _____ ft. Describe access port or control devices: _____

11. WELL TESTS:
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time

Water Temp. _____ Bottom hole temp. _____
Water Quality test or comments: _____
Depth first Water Encounter _____

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
8	0	6	topsoil		X
	6	20	brown clayw/ gravel		X
	20	29	granite sand		X
	29	35	sand, some water	X	
	35	60	sandy clay w/ gravel		X
	60	70	sandstone, some brown clay		X
	70	90	clay, less sand		X
	90	120	shale, green gray		X
	120	130	sandstone		X
	130	140	fine sand	X	
	140	150	sandy clay		X
	150	200	shale green-gray-blue		X
	200	210	sandstone		X
	210	240	clay, sandstone		X
	240	310	sandstone, some clay		X
	310	360	gray clay, some sand		X
	360	440	sandstone		X
	440	540	brown clay		X
	540	570	sandstone, some clay		X
	570	610	hard basalt		X
	610	640	sandstone		X
	640	660	cemented sand	X	
	660	670	gray clay		X
	670	760	sandstone		X
	760	840	decomposed granite		X

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WATER RESOURCES
WESTERN REGION

Completed Depth 846' (Measurable)
Date: Started 11/5/02 Completed 11/27/02

13. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Stevens & Sons Firm No. 153
Firm Official _____ Date 1/7/03
and
Driller or Operator _____ Date _____
(Sign once if Firm Official's Operator)

FORWARD WHITE COPY TO WATER RESOURCES

Exploration Hole SVR 2
Spring Valley Ranch

Drilled by: Stevens and Sons, Inc.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Hydrologic, Inc.
Fluid level when logged: 3 ft bgl
Casing when logged: 8" steel 0-5 ft, 6" open hole 5 - 705 ft., 6" open hole 705-846 ft.

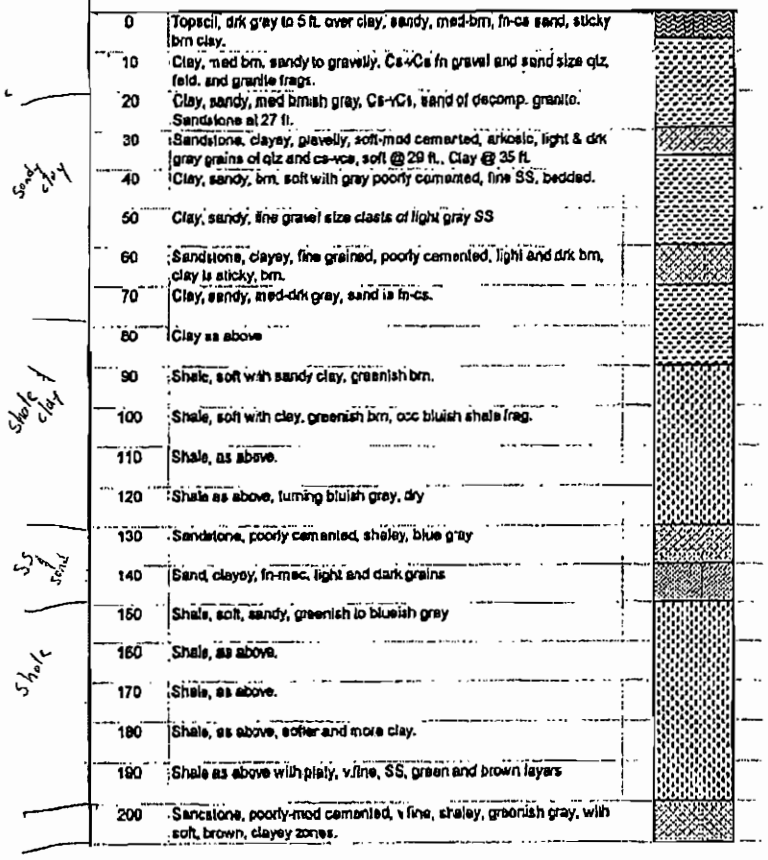
Drilled Dates: 11/12/02 - 11/22/02
Drilling Method: Mud Rotary
Borehole size: 8" (nom.) 0 - 705 ft.
Borehole size: 6" (nom.) 705 - 846 ft.

Depth Drilled: 840 ft
Depth Logged: 846 ft.
Static WL: ~31 ft. bgl

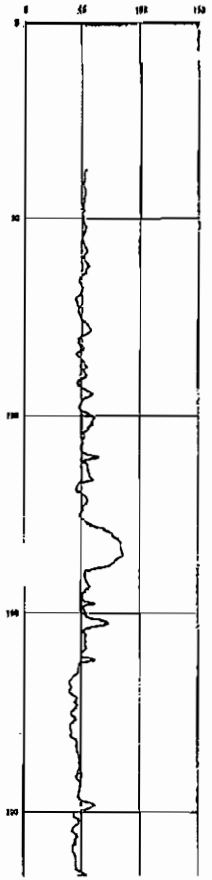
Location: Gem County, Idaho
T6N, R1E, SW 1/4, SE 1/4, Sect 36
GL. Elevation: ~3580 ft. msl.

Depth (ft)	Geologic log from rotary cuttings
0	Topsoil, drk gray to 5 ft. over clay, sandy, med-brn, fn-cs sand, sticky brn clay.
10	Clay, med brn, sandy to gravelly. Cs-vCs fn gravel and sand size qtz, feld. and granite frags.
20	Clay, sandy, med brnish gray, Cs-vCs, sand of decomp. granite. Sandstone at 27 ft.
30	Sandstone, clayey, gravelly, soft-mod cemented, arkosic, light & drk gray grains of qtz and cs-vcs, soft @ 29 ft., Clay @ 35 ft.
40	Clay, sandy, brn, soft with gray poorly cemented, fine SS, bedded.
50	Clay, sandy, fine gravel size clasts of light gray SS
60	Sandstone, clayey, fine grained, poorly cemented, light and drk brn, clay is sticky, brn.
70	Clay, sandy, med-drk gray, sand is fn-cs.
80	Clay as above
90	Shale, soft with sandy clay, greenish brn.
100	Shale, soft with clay, greenish brn, occ bluish shale frag.
110	Shale, as above.
120	Shale as above, turning bluish grey, dry
130	Sandstone, poorly cemented, shaley, blue gray
140	Sand, clayey, fn-mec, light and dark grains
150	Shale, soft, sandy, greenish to bluish gray
160	Shale, as above.
170	Shale, as above.
180	Shale, as above, softer and more clay.
190	Shale as above with platy, v.fine, SS, green and brown layers
200	Sandstone, poorly-mod cemented, v fine, shaley, greenish gray, with soft, brown, clayey zones.

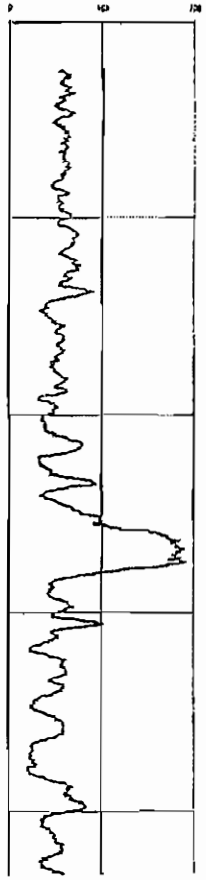
Symb. Log



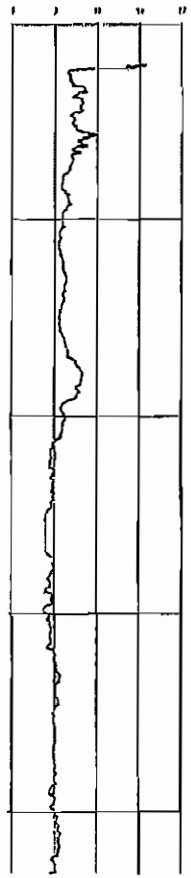
Pt. Res (Ohms)



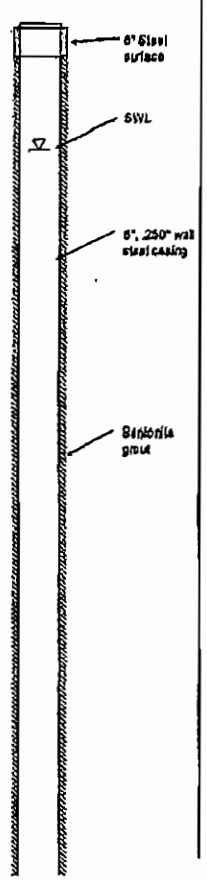
Natural Gamma (CPS)



Caliper (in.)



Well Construction



Exploration Hole SVR 2
Spring Valley Ranch

Drilled by: Stevens and Sons, Inc.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Hydrologic, Inc.
Fluid level when logged: 3 ft bgl
Casing when logged: 8" steel 0-5 ft, 8" open hole 5 - 705 ft., 6" open hole 705-848 ft.

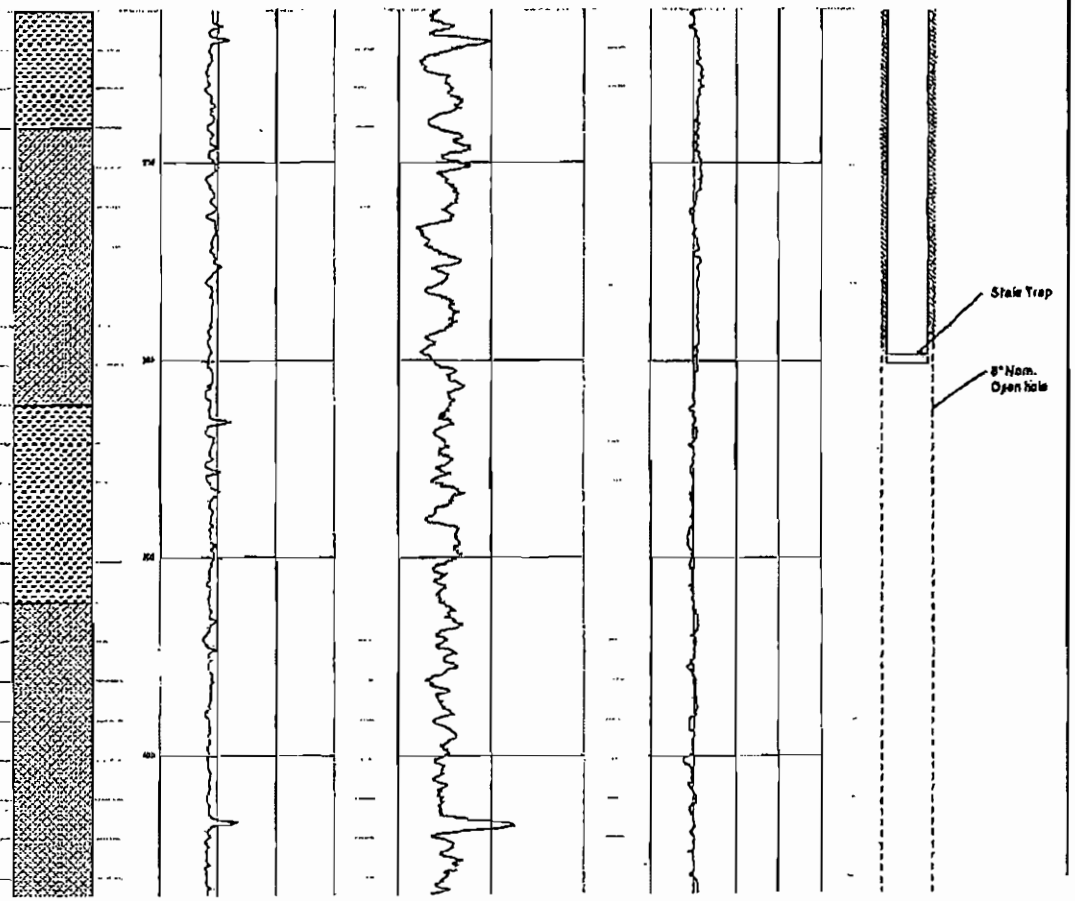
Drilled Dates: 11/12/02 - 11/22/02
Drilling Method: Mud Rotary
Borehole size: 8" (nom.) 0 - 705 ft.
Borehole size: 6" (nom.) 705 - 848 ft.

Depth Drilled: 840 ft
Depth Logged: 845 ft.
Static WL: ~ 31 ft. bgl

Location: Gem County, Idaho
T8N, R1E, SW 1/4, SE 1/4, Sect 36
Gl. Elevation: ~3580 ft. msl.

Depth (ft)	Geologic log from rotary cuttings
210	Clay, with thin sandstone streaks and stria, soft, greenish gray.
220	Clay, light brn to gray green, plastic, with thin fine sandstone stringers.
230	Clay, greenish gray with thin SS and shale stringers
240	Sandstone, silty and clayey, finly bedded, grayish green.
250	Sandstone, as above with brn clay.
260	Sandstone, as above, less clay.
270	Sandstone, as above, softer, more soft brown clay balls.
280	Sandstone, as above, less clay.
290	Sandstone, as above.
300	Sandstone, as above.
310	Clay, with shale and sandstone stringers, greenish gray.
320	Clay, as above
330	Clay, greenish brn as above, with white clay balls.
340	Clay, soft, greenish brown.
350	Clay, as above.
360	Sandstone, clayey to shaley, greenish gray and moderately cemented, gray ss and siltstone clasts, thinly bedded.
370	Sandstone, as above.
380	Sandstone, as above.
390	Sandstone, as above.
400	Sandstone, as above.
410	Sandstone, as above.
420	Sandstone, as above, more clay.

clay
sandstone
clay
sandstone



Exploration Hole SVR 2
Spring Valley Ranch

Drilled by: Stevens and Sons, Inc.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Hydrologic, Inc.
Fluid level when logged: 3 ft bgl
Casing when logged: 8" steel 0-5 ft, 6" open hole 5 - 705 ft., 6" open hole 705-846 ft.

Drilled Dates: 11/12/02 - 11/22/02
Drilling Method: Mud Rotary
Borehole size: 8" (nom.) 0 - 705 ft.
Borehole size: 6" (nom.) 705 - 846 ft.

Depth Drilled: 840 ft.
Depth Logged: 846 ft.
Static WL: ~31 ft. bgl

Location: Gem County, Idaho
T6N, R1E, SW 1/4, SE 1/4, Sect 36
GL Elevation: ~3580 ft. msl.

Depth (ft)	Geologic log from rotary cuttings
430	Sandstone, as above, less clay.
440	Sandstone, v fine-silty, finely bedded, with clay and shaley zones, med-greenish brown
450	Sandstone, as above.
460	Sandstone, as above.
470	Sandstone, as above.
480	Sandstone, as above.
490	Clay and fine bedded sandstone as above, brown.
500	Clay and fine bedded sandstone as above, abundant dark organic debris (bark?) at 498 ft, sticky gray clay.
510	Clay, as above, occ. shale and siltstone clast.
520	Clay, as above.
530	Clay, drk brn as above, more brn and gray sandstone stringers
540	Sandstone, light gray, fine grain, poorly cemented, brn clay balls.
550	Sandstone, clayey, v. fine, light gray.
560	Sandstone, as above, well indurated, some hard black basalt chips
570	Basalt, black, aphanitic with abundant small white porphorys and welded tuff
580	Basalt, as above, more tuff.
590	Tuff, welded and basalt, glassy, occ vug, med gray, very hard.
600	Tuff and basalt as above, glassy, more porphonitic, light and dark gray frags.
610	Tuff as above.
620	Sandstone, clayey, light gray and hard, aphanitic frags as above.
630	Sandstone, as above, less clay.
640	Sand, mix of lithologic frags as above sand grains, light gray.

Symb. Log | Pt. Res (Ohms) | Natural Gamma (CPS) | Caliper (in.) | Well Construction

Exploration Hole SVR 2
Spring Valley Ranch

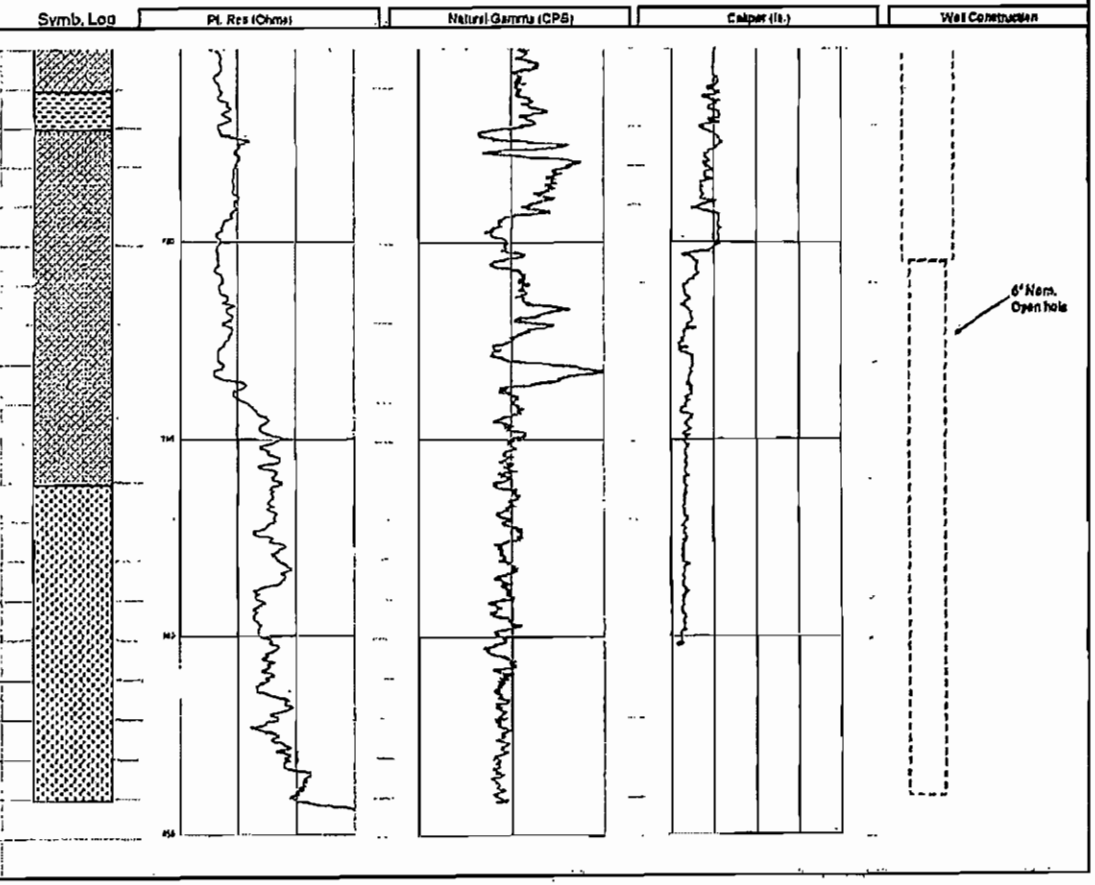
Drilled by: Stevens and Sons, Inc.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Hydrologic, Inc.
Fluid level when logged: 3 ft bgl
Casing when logged: 8" steel 0-5 ft, 6" open hole 5 - 705 ft., 6" open hole 705-846 ft.

Drilled Dates: 11/12/02 - 11/22/02
Drilling Method: Mud Rotary
Borehole size: 8" (nom.) 0 - 705 ft.
Borehole size: 6" (nom.) 705 - 846 ft.

Depth Drilled: 840 ft
Depth Logged: 846 ft.
Static WL: ~ 31 ft. bgl

Location: Gem County, Idaho
T6N, R1E, SW 1/4, SE 1/4, Sect 36
GL. Elevation: ~3580 ft. msl.

Depth (ft)	Geologic log from rotary cuttings
650	Sandstone, v. fine, soft, bedded clay, light gray.
660	Clay, sandy, light-blue gray, sticky.
670	Sandstone, fine-med, variable color light-dark gray and with shaley claystone.
680	Sandstone and siltstone, light, dark and greenish gray clasts, occ. chert and light gray shale frags.
690	Sandstone, variable colors and textures as above.
700	Sandstone, as above.
710	Sandstone, as above, with dark gray aphantic frags.
720	Sandstone, as above, less frags.
730	Sandstone, as above, driller indicates very soft.
740	Sandstone, as above
750	Sandstone, as above, abundant cs-vcs qtz grains.
760	Decomposed granite, grus?, vcs qtz and feldspar xtals, light gray
770	Decomposed granite, grus?, vcs qtz and felcspar xtals, light gray, drilled fast
780	Decomposed granite, grus?, vcs qtz and felcspar xtals, light gray, drilled fast
790	Decomposed granite, grus?, vcs qtz and feldspar xtals, light gray.
800	Decomposed granite, grus?, vcs qtz and feldspar xtals, light gray
810	Decomposed granite, grus?, vcs qtz and feldspar xtals, light gray
820	Decomposed granite, grus?, vcs qtz and feldspar xtals, light gray
830	Decomposed granite, grus?, vcs qtz and feldspar xtals, light gray
840	
850	



Form 238-7
6/02

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

SVR Well #6

Twp ____ Rge ____ Sec ____
____ 1/4 ____ 1/4 ____ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 0030892
DRILLING PERMIT NO. ____
Water Right or Injection Well No. ____

2. OWNER:
Name Spring Valley Development LLC
Address 485 E. Riverside Dr
City Eagle State Id Zip 83616

3. LOCATION OF WELL by legal description:
You must provide address or Lot, Blk, Sub. or Directions to well.
Twp. 5 North ☒ or South ☐
Rge. 1 East ☐ or West ☒
Sec. 13, 1/4 (10 acres) SE 1/4 (40 acres) NW 1/4 (80 acres)
Gov't Lot ____ County Ada
Lat: : : Long: : :
Address of Well Site 1 mile S/E of Willow Creek Rd
Big Gulch City Eagle
(Sub of least name of road - Distance - to Head of Locations)
Lt. ____ Blk: ____ Sub. Name ____

4. USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☒ Other test

5. TYPE OF WORK check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other ____

6. DRILL METHOD:
☒ Air Rotary ☐ Cable ☐ Mud Rotary ☐ Other ____

7. SEALING PROCEDURES

Seal Material	From	To	Weight / Volume	Seal Placement Method
Bentonite	0	105	3150 #	overbore

Was drive shoe used? ☒Y ☐N Shoe Depth(s) 738'
Was drive shoe seal tested? ☐Y ☒N How? ____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
8"	+2	738'	250	Steel	☒	☐	☒	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Length of Headpipe ____ Length of Tailpipe ____
Packer ☐Y ☐N Type ____

9. PERFORATIONS/SCREENS PACKER TYPE
Perforation Method STAR PERF. 4 ROWS @ JOINT 90 PERFS
Screen Type & Method of Installation None PER ROW

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
560	580	1/4	360	8"	.250 WALL	☒	☐
580	600	1/4	360	8"	CASING	☒	☐
600	620	1/4	360	8"	5	☒	☐
620-640		1/4	360	8"	5	☒	

Filter Material	From	To	Weight / Volume	Placement Method
Continued on page 2				

11. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
455 ft. below ground Artesian pressure ____ lb.
Depth flow encountered ____ ft. Describe access port or control devices: ____
Steel plate.

12. WELL TESTS:
☐ Pump ☐ Bailer ☒ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time
175			6 hours

Water Temp. 80° Bottom hole temp. ____
Water Quality test or comments: Iron .5 PH 7.5 Grams 7
Depth first Water Encounter 590'

13. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
12	0	10	sandy soil		
"	10	96	tan clay		
"	96	105	blue clay		
8	105	134	blue clay		
"	134	140	tan clay		
"	140	195	pea gravel & clay		
"	195	360	Lt gray sand & clay		
"	360	367	coarse sand & clay like pea gravel		
"	367	505	Fine & coarse sand		
"	505	540	larger pea gravel		
"	540	590	pea gravel w/ large Sand gaartz		
"	590	595	quartz sand	X	
"	595	605	Finer tan Sand		
"	605	620	quartz sand	X	
"	620	640	Finer sand	X	
"	640	645	quartz sand	X	
"	645	655	quartz sand & Some pea gravel	X	
"	655	660	gravel & quartz sand	X	
"	660	670	big sand		
"	670	680	big sand	X	
"	680	685	big sand		
"	685	690	big sand	X	
"	690	730	big sand	X	
"	730	740	big sand	X	
			Due to heaving sand - a mixture of sand & cement was placed from 730' to 740		

RECEIVED
MAR 19 2004
WATER RESOURCES (Measurable)
WESTERN REGION

Completed Depth 730'
Date: Started 01-26-04 Completed 02-27-04

14. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Adamson Pump & Drilling Rig No. 457
Principal Driller Dave Adamson Date 3-15-04
and
Driller or Operator II Dave Adamson Date 3-15-04
Operator I ____ Date ____
Principal Driller and Rig Operator *Required.*
Operator I must have signature of Driller/Operator II.

FORWARD WHITE COPY TO WATER RESOURCES

Form 238-7
6/02

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

SVR Well #6

Inspected by _____
Twp ____ Rge ____ Sec ____
____ 1/4 ____ 1/4 ____ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 0030892 pg 2
DRILLING PERMIT NO. _____
Water Right or Injection Well No. _____

2. OWNER:
Name Spring Valley Development LLC
Address 485 E. Riverside Dr
City Eagle State Id Zip 83616

3. LOCATION OF WELL by legal description:
You must provide address or Lot, Blk, Sub. or Directions to well.
Twp. 5 North X or South _
Rge. 1 East _ or West X
Sec. 13 _ 1/4 SE 1/4 NW 1/4
Gov't Lot _____ County Ada
Lat: : : Long: : :
Address of Well Site 1 mile SW of Willow Creek Rd
Big Gulch (Give distance to Road or Landmark) City Eagle
Lt. _____ Blk. _____ Sub. Name _____

4. USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection X Other test

5. TYPE OF WORK check all that apply (Replacement etc.)
X New Well ☐ Modify ☐ Abandonment ☐ Other _____

6. DRILL METHOD:
X Air Rotary ☐ Cable ☐ Mud Rotary ☐ Other _____

7. SEALING PROCEDURES

Seal Material	From	To	Weight / Volume	Seal Placement Method

Was drive shoe used? ☐Y ☐N Shoe Depth(s) _____
Was drive shoe seal tested? ☐Y ☐N How? _____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Length of Headpipe _____ Length of Tailpipe _____
Packer ☐Y ☐N Type _____

9. PERFORATIONS/SCREENS PACKER TYPE
Perforation Method STAR PERF. 4 ROWS @ JOINT 90 DEGREES
Screen Type & Method of Installation PER ROW (360)

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
640	660	1/4	360	8"	.250 WALL	X	☐
660	680	1/4	360	8"	CASING	X	☐
680	700	1/4	360	8"	"	X	☐
700 - 720		1/4	360	8"	"	X	

Filter Material	From	To	Weight / Volume	Placement Method
720 - 730				

11. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
_____ft. below ground Artesian pressure _____lb.
Depth flow encountered _____ft. Describe access port or control devices: _____

12. WELL TESTS:
☐ Pump ☐ Baller ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time

Water Temp. _____ Bottom hole temp. _____
Water Quality test or comments: _____
Depth first Water Encounter _____

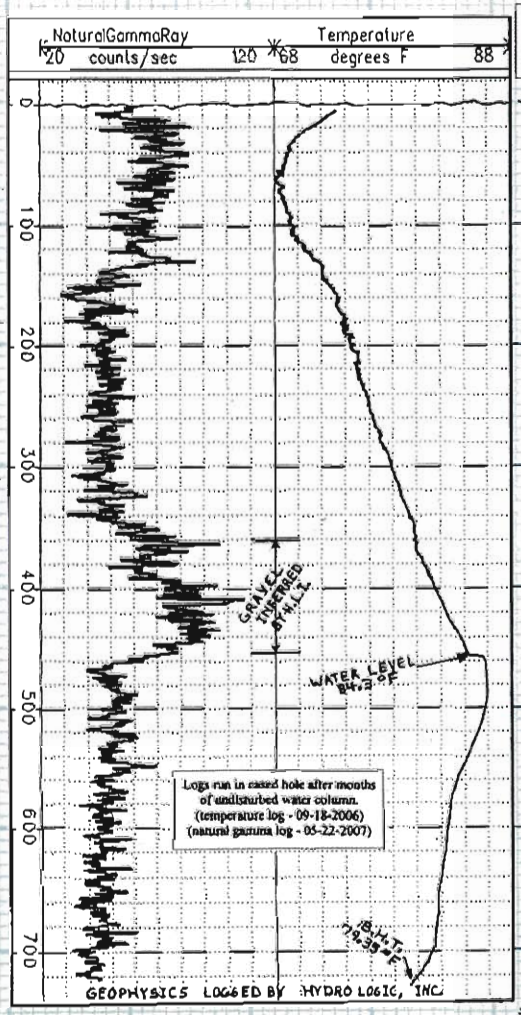
13. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N

M3 Eagle - S.V.R. Well #6

T5N R1W Section 13, SE¼, SE¼, NW¼
Latitude 43° 46' 19.8" Longitude 116° 24' 16.3"
Completed February 2004

Geophysical Logs

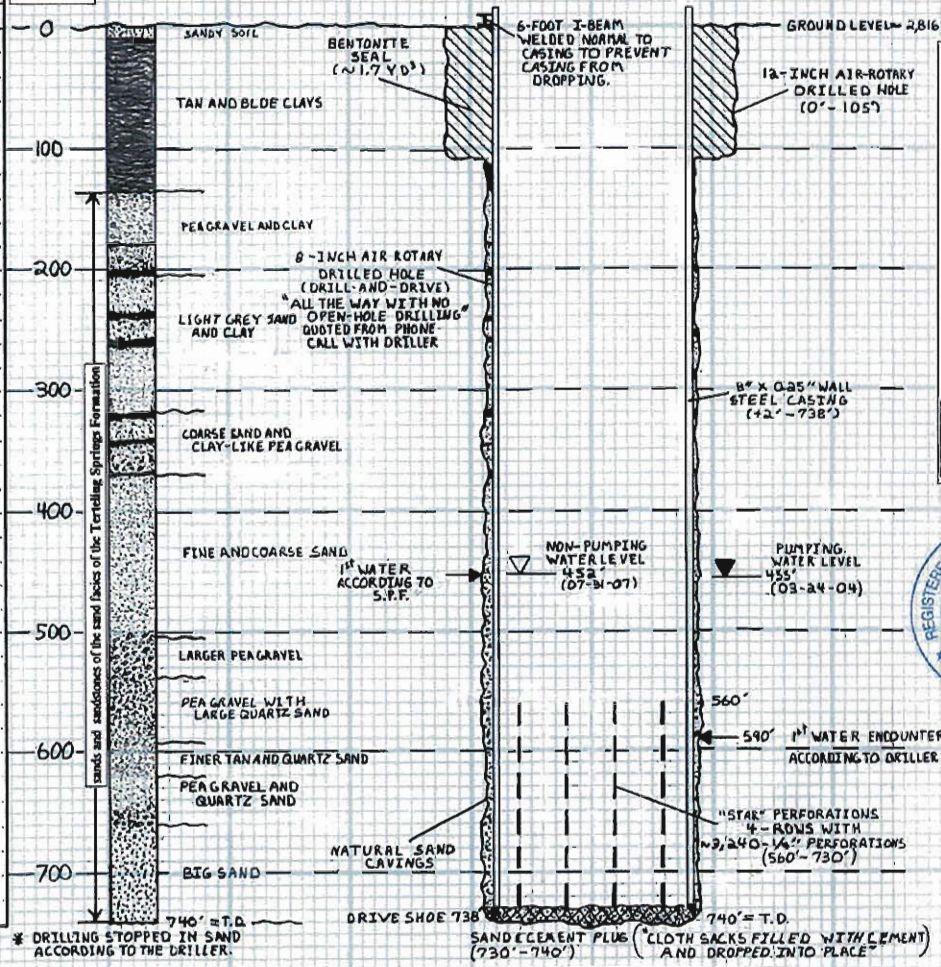


Depth (feet below ground level)

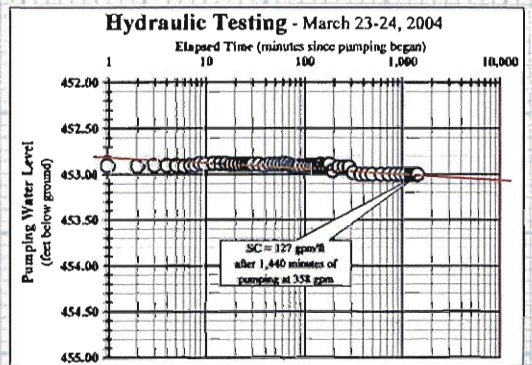
Driller's Lithology (from IDWR well log)

As-Built Well Construction

(horizontal scale 0.1"=0.5')
(vertical scale 1"=100')



Hydraulic Testing - March 23-24, 2004



Non-Pumping Water Level = 450.18 feet below ground (11:45 hrs on 03/23/04)
Test conducted by SPF Water Engineering, LLC and Adamson Pump & Drilling Co.
According to the driller, the well was not developed prior to pumping and is believed (HLI) to have been developing during the short-term test, imparting some uncertainty into the results.

REGISTERED PROFESSIONAL GEOLOGIST * EDWARD SQUIRES 988 * STATE OF IDAHO

Ground Water Chemistry

Lab Analyses	SPF Water Engineering Results (in mg/L unless noted) SCREENED (560'-730 feet bgl)
Alkalinity	58.8
Ammonia as N	0.13
Arsenic	0.067
Calcium as $CaCO_3$	9.71
Chloride	5
Conductivity (uS)	
Corrosivity	
Fluoride	0.95
Hardness	<5.0
Iron (total)	0.09
Magnesium	0.69
Manganese	<0.05
Nitrate as N	1.09
Nitrite as N	0.02
pH	
Potassium	1.5
Sodium	27.8
Sulfate	5.3
Sulfide	<0.05
Total Dissolved Solids	98
Field Analyses	
Field Conductivity (uS)	189.9
Field pH (S.U.)	7.67
Field Temperature (°F)	81.1

Water samples and field parameters collected on March 16, 2004 by SPF Water Engineering.
Analyses by Analytical Laboratories, Boise, ID.

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drafted August 15, 2007
by Loren Pearson,
Hydro Logic, Inc.

Well design, pump test design, and water quality sampling by SPF Water Engineering, LLC, Boise, ID
Air-rotary drilling, well construction, and pump testing by Adamson Pump & Drilling Co., Nampa, ID

Data compiled and plotted by Hydro Logic, Inc. from available data of others with the exception of the geophysical logs and a video inspection run in the completed well. HLI was not involved with the drilling project.

Form 238-7
6/02

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

SVR Well #10

Inspected by _____
Twp ____ Rge ____ Sec ____
____ 1/4 ____ 1/4 ____ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 00031493
DRILLING PERMIT NO. 815597
Water Right or Injection Well No. _____

2. OWNER:
Name SUNCOR
Address 485 EAST RIVERSIDE DR SUITE 300
City EAGLE ID State ID Zip 83616

3. LOCATION OF WELL by legal description:
You must provide address or Lot, Blk, Sub. or Directions to well.
Twp. 05 North ☒ or South ☐
Rge. 01 East ☒ or West ☐
Sec. 8, SW 1/4 (10 acres) SW 1/4 (40 acres) ____ 1/4 (160 acres)
Gov't Lot ____ County ADA
Lat: : : Long: : :
Address of Well Site 1/2 MILE NE OF WILLOW CREEK RD City EAGLE
(Give or attach Name of road + Distance to Road or Landmark)
Lt. ____ Blk. ____ Sub. Name ____

4. USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other TEST WELL

5. TYPE OF WORK check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other ____

6. DRILL METHOD:
☐ Air Rotary ☐ Cable ☒ Mud Rotary ☐ Other ____

7. SEALING PROCEDURES

Seal Material	From	To	Weight / Volume	Seal Placement Method
30% B. GROUT	1	500	4000 LB	PRESSURE GROUTED
30% B. GROUT	1000	770	1470 LB	PRESSURE GROUTED

Was drive shoe used? ☒Y ☐N Shoe Depth(s) ____
Was drive shoe seal tested? ☐Y ☒N How? ____
GRAVEL 3/8 FROM 770 TO 6666

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
8"	+2	600	.250	STEEL	☒	☐	☐	☐
6"	630	600	.250	STEEL	☐	☒	☒	☐
					☐	☐	☐	☐

Length of Headpipe 25 FT Length of Tailpipe 0
Packer ☒Y ☐N Type ____

9. PERFORATIONS/SCREENS PACKER TYPE
Perforation Method ____
Screen Type & Method of Installation STAINLESS STEEL

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
640	680	.40	—	6"	STAINLESS	☐	☐
600	580	.30	—	6"	STAINLESS	☐	☐
						☐	☐

10. FILTER PACK

Filter Material	From	To	Weight / Volume	Placement Method
NONE				

11. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
485 ft. below ground Artesian pressure ____ lb.
Depth flow encountered ____ ft. Describe access port or control devices: ____
well cap

12. WELL TESTS:
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time
AIR 50 GPM	—	—	—

Water Temp. ____ Bottom hole temp. ____
Water Quality test or comments: ____
Depth first Water Encounter ____

13. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
12	1	15	TOP SOIL & SAND		
	15	35	SANDY CLAY		
	35	360	COARSE SAND		
	360	380	COARSE SAND & CLAY		
	380	480	COARSE SAND & CLAY MIX		
	480	490	COARSE SAND & CLAY MIX		
	490	505	TAN CLAY		
	505	520	SAND & CLAY MIX		
	520	530	SAND		
	530	560	SAND & CLAY		
	560	590	MORE SAND LESS CLAY COARSE		
	590	620	CLAY TAN & WHITE		
	620	632	CLAY W/ SAND STREAKS		
	632	640	SHORT SAND STREAKS IN CLAY		
	640	660	TAN CLAY		
	660	670	TAN CLAY		
	670	680	SOFT WHITISH CLAY		
	680	687	WHITISH CLAY & BLUE CLAY - SAND		
	687	690	HARD CLAY BLUISH		
	690	715	BLUE CLAY - COARSE SAND		
	715	740	BLUE CLAY HARD & SOFT		
	740	760	BLUE CLAY		
	760	800	BLUE CLAY		
	800	825	BLUE CLAY SHORT SOFT SPOTS		
	825	835	BLUE CLAY		
	835	860	BLUE & WHITE CLAY		
	860	880	BLUE CLAY W/ COARSE SAND		
	880	920	SOFT BLUE CLAY		
	920	940	BLUE CLAY		
	940	980	BLUE CLAY		
	980	1005	BLUE CLAY		

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WESTERN REGION

Completed Depth 770' (Measurable)
Date: Started 6-7-04 Completed 7-29-04

14. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name ADAMSON PUMP & DRILLING Firm No. 457
Principal Driller Dave Adamson Date 7-30-04
and
Driller or Operator II Dave Adamson Date 7-30-04
Operator I ____ Date ____
Principal Driller and Rig Operator *Required.*
Operator I must have signature of Driller/Operator II.

FORWARD WHITE COPY TO WATER RESOURCES

Exploration Hole SVR 10

Spring Valley Ranch

Drilled by: Adamson Pump and Drilling.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Stevens and Son
Fluid level when logged: Surface
Casing when logged: 600 ft

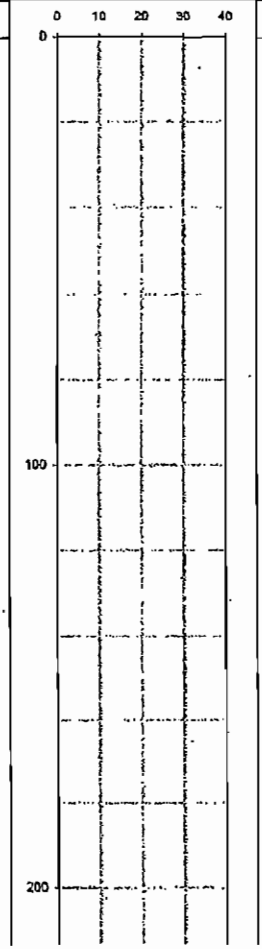
Drilled Dates: 6/7 - 7/29/04
Drilling Method: Mud Rotary
Borehole size: 12" (nom.) 0 - 1005 ft.

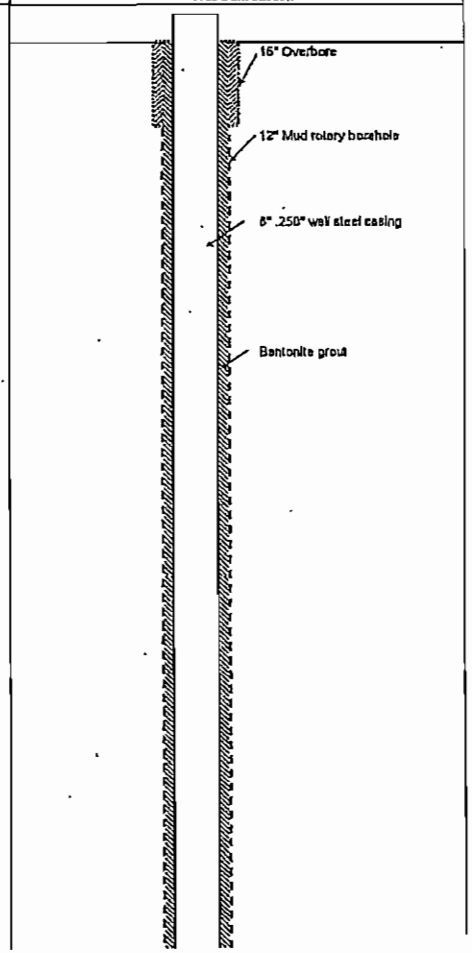
Depth Drilled: 1005 ft
Depth Logged: 960 ft.
Static WL: ~ 485 ft. bgl

Location: Ada County, Idaho
T 5 N, R 1 E, sw1/4, sw1/4, Sect. 8
GL Elevation: ~ 2,870 ft. msl.

Depth (ft)	Geologic log from rotary cuttings
0	Top soil over clay, soft, plastic, coarse qtz. sand grains, buff-yellow brown.
70	Sand and gravel, cs-vcs sand, fine gravel, clean, light gray
80	Sand, cs-vcs, clean, light gray
90	Sand, med-cs, minor fines, light brown
100	Sand and gravel, cs-vcs sand, med-cs gravel, clean, light gray
120	Sand and gravel, cs-vcs sand, med gravel, clean, light gray
130	Sand and gravel, cs-vcs sand, med-cs gravel, clean, light gray.
170	Sand and gravel, cs-vcs sand, fine gravel, clean, light gray
180	Sand, cs-vcs, clean, light gray
190	Sand and gravel, cs-vcs, fine gravel, clean, light gray

Symb. Log





Exploration Hole SVR 10

Spring Valley Ranch

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Logged by: C. Feast/Feast Geosolences, LLC
Geophysical logs by: Stevens and Son
Fluid level when logged: Surface
Casing when logged: 600 ft

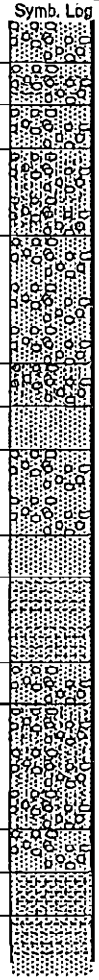
Drilled Dates: 6/7 - 7/29/04
Drilling Method: Mud Rotary
Borehole size: 12" (nom.) 0 - 1005 ft.

Depth Drilled: 1005 ft
Depth Logged: 960 ft.
Static WL: ~ 485 ft. bgl

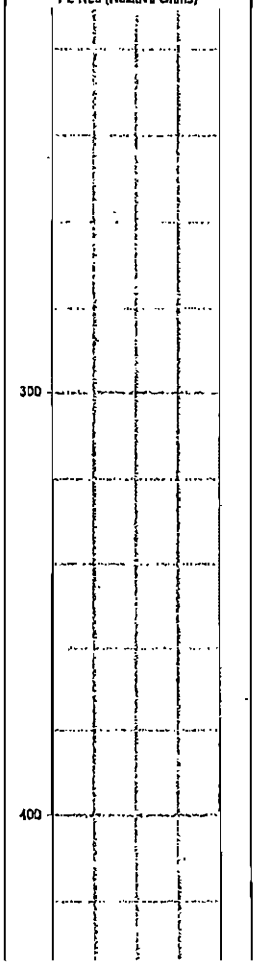
Location: Ada County, Idaho
T 5 N, R 1 E, sw1/4, sw1/4, Sect. 8
GL. Elevation: ~ 2,870 ft. msl.

Depth (ft)	Geologic log from rotary cuttings
210	
220	Sand and gravel, med-cs sand, fine gravel, minor clay, light brown
230	Sand and gravel, med-cs sand, fine gravel, clean, light brown
240	Sand and gravel, cs-vcs, sand, fine gravel, minor silt, light gray
250	
260	Sand and gravel, cs-vcs, fine gravel, clean, light gray
270	
280	
290	Sand and gravel, cs-vcs, sand, fine gravel, minor silt, light gray
300	Sand, cs-vcs, clean, light gray
310	Sand and gravel, cs-vcs, fine gravel, clean, light gray
320	
330	Sand, cs-vcs, clean, light gray
340	Sand, cs-vcs, clayey, gray
350	
360	Sand and gravel, cs-vcs, fine gravel, clean, gray
370	Sand and gravel, cs-vcs, fine to med gravel, clayey, gray
380	
390	
400	Sand and gravel, cs-vcs, fine gravel, clean, gray
410	Clay, sandy, gray
420	Sand, clayey, cs sand, gray

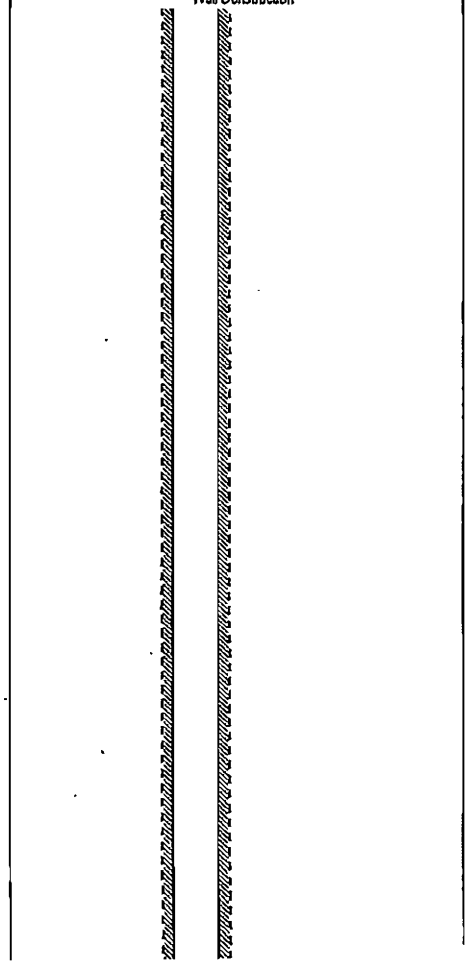
Symb. Log



Pt. Res (Relative Ohms)



Well Construction



Exploration Hole SVR 10

Spring Valley Ranch

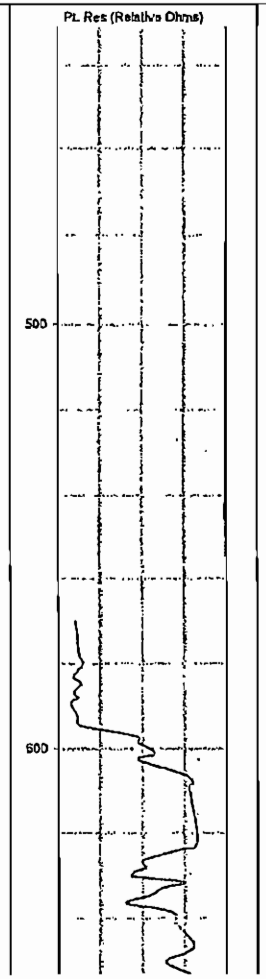
Drilled by: Adamson Pump and Drilling.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Stevens and Son
Fluid level when logged: Surface
Casing when logged: 600 ft

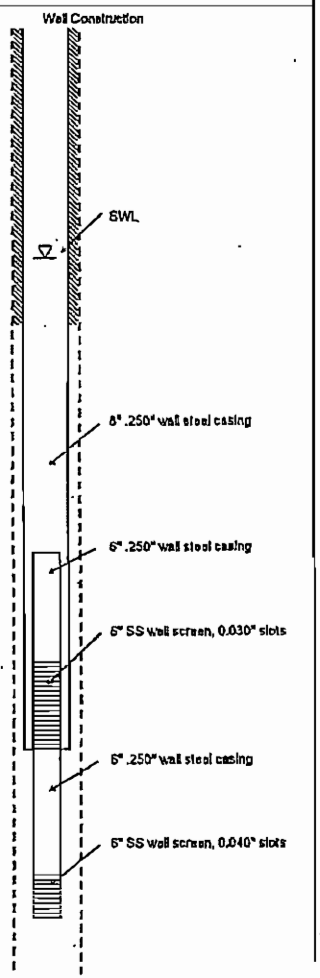
Drilled Dates: 6/7 - 7/29/04
Drilling Method: Mud Rotary
Borehole size: 12" (nom.) 0 - 1005 ft.

Depth Drilled: 1005 ft
Depth Logged: 960 ft.
Static WL: ~ 485 ft. bgl

Location: Ada County, Idaho
T 5 N, R 1 E, sw1/4, sw1/4, Sect. 8
GL. Elevation: ~ 2,870 ft. msl.

Depth (ft)	Geologic log from rotary cuttings
430	
440	
450	Sand, cs-vcs, clean, light gray
460	
470	Sand, clayey, cs sand, gray
480	Sand and gravel, cs-vcs, fine gravel, clean, gray
490	
500	
510	Sand, cs-vcs, clean, light gray
520	Clay, sandy, gray
530	Sand, cs-vcs, clean, light gray
540	Sand and gravel, cs-vcs, fine gravel, clean, gray
550	Sand, cs-vcs, clean, light gray
560	
570	
580	
590	
600	
610	
620	Sand, cs-vcs, clayey, light gray
630	
640	Clay, sandy, v. light gray, dries white





Exploration Hole SVR 10

Spring Valley Ranch

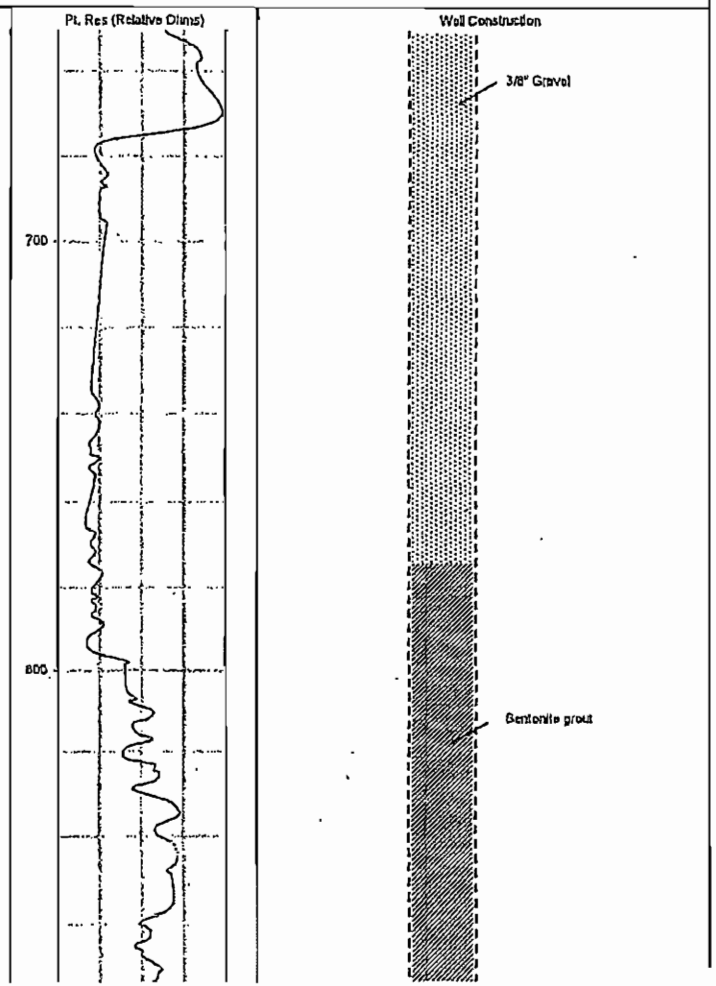
Drilled by: Adamson Pump and Drilling.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Stevens and Son
Fluid level when logged: Surface
Casing when logged: 600 ft

Drilled Dates: 6/7 - 7/29/04
Drilling Method: Mud Rotary
Borehole size: 12" (nom.) 0 - 1005 ft.

Depth Drilled: 1005 ft
Depth Logged: 960 ft.
Static WL: ~ 485 ft. bgl

Location: Ada County, Idaho
T 5 N, R 1 E, sw1/4, sw1/4, Sect. 8
GL. Elevation: ~ 2,870 ft. msl.

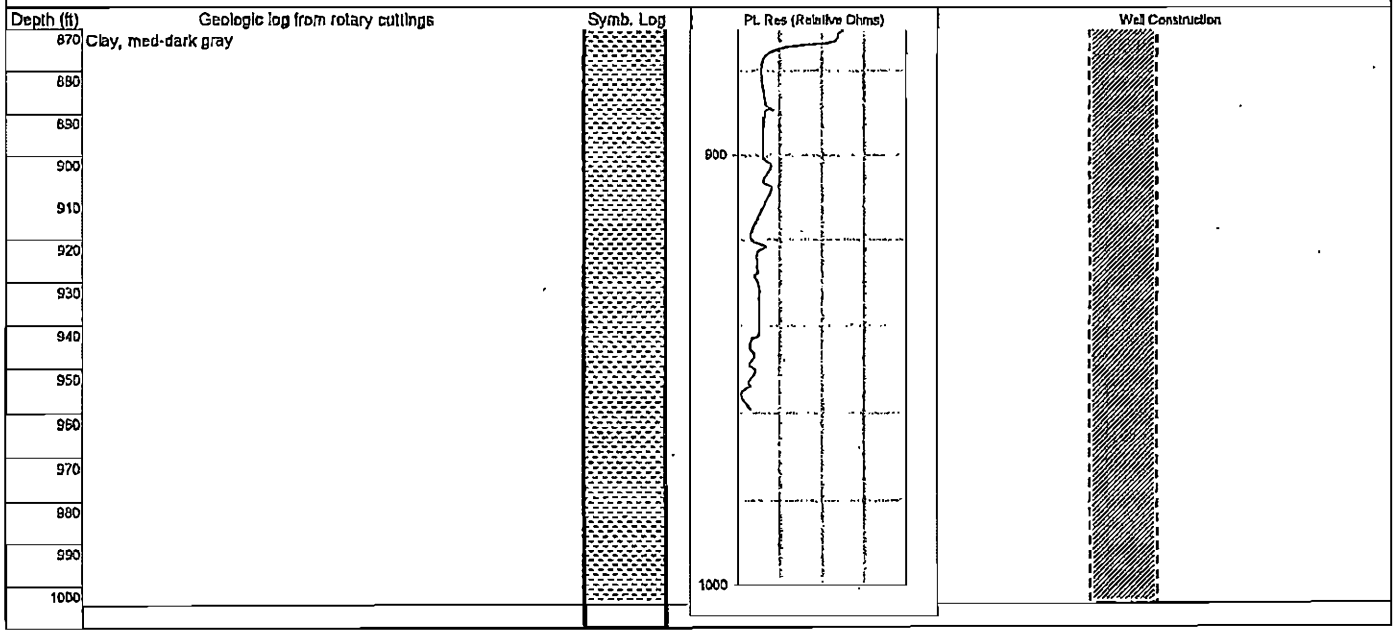
Depth (ft)	Geologic log from rotary cuttings
650	
660	
670	
680	
690	Clay, sandy, med - dark gray
700	
710	
720	Clay, med-dark gray
730	
740	
750	
760	
770	
780	
790	
800	
810	
820	Sand, clayey, cs sand, med-dark gray
830	
840	
850	
860	



Exploration Hole SVR 10

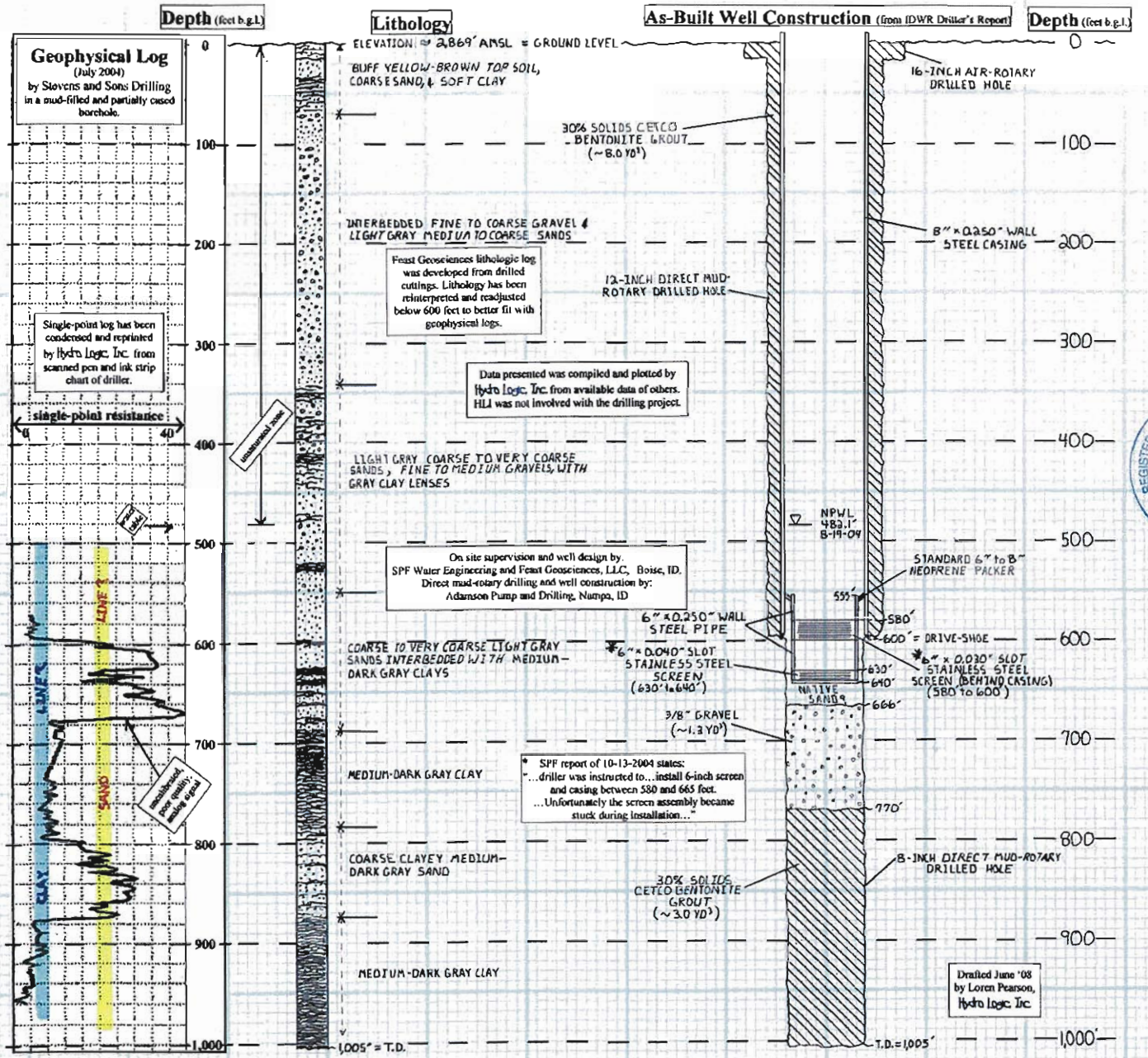
Spring Valley Ranch

Drilled by: Adamson Pump and Drilling.	Drilled Dates: 6/7 - 7/29/04	Depth Drilled: 1005 ft	Location: Ada County, Idaho
Logged by: C. Feast/Feast Geosciences, LLC	Drilling Method: Mud Rotary	Depth Logged: 960 ft.	T 5 N, R 1 E, sw1/4, sw1/4, Sect. 8
Geophysical logs by: Stevens and Son	Borehole size: 12" (nom.) 0 - 1005 ft.	Static WL: ~ 485 ft. bgl	GL. Elevation: ~ 2,870 ft. msl.
Fluid level when logged: Surface			
Casing when logged: 600 ft			



Spring Valley Ranch - Test Well #10

T.5.N R.1E. Section 8, SW¼, SW¼
Latitude N43° 46' 49.1" Longitude W116° 22' 23.2"
Completed July 2004



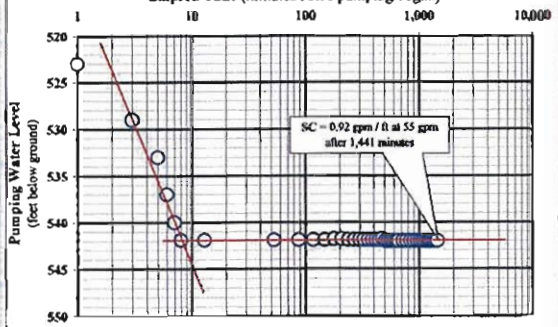
Ground Water Chemistry

Lab Analyses	SPF Water Engineering Results (in mg/L unless noted)
	SCREENED (630' - 640 feet bgl)
Ammonia as N	<0.04
Antimony	<0.005
Arsenic	0.012
Barium	<0.05
Beryllium	<0.0005
Bicarbonate	53.5
Cadmium	<0.0005
Calcium as $CaCO_3$	17.1
Chloride	2
Chromium	0.002
Fluoride	0.24
Hardness	51.8
Iron (total)	0.36
Magnesium	3.20
Manganese	<0.05
Mercury	<0.0002
Nickel	<0.02
Nitrate as N	5.2
Nitrite as N	<0.01
Potassium	2.4
Selenium	<0.005
Sodium	12.3
Sulfate	<1
Sulfide	<0.05
Thallium	<0.002
Total Dissolved Solids	70
Field Analyses	
Field Conductivity (µS)	160
Field pH (S.U.)	7.64
Field Temperature (°F)	75.9

SPF samples collected on August 19, 2004 by Feast Geosciences. Analyses by Analytical Laboratories, Boise, ID

REGISTERED PROFESSIONAL GEOLOGIST
EDWARD SQUIRES
968
STATE OF IDAHO

Hydraulic Testing - (August 19-20, 2004)



Non-Pumping Water Level = 482.1 feet below ground (11:30 hrs on 08/19/04)
Test conducted by Feast Geosciences and Adamson Pump and Drilling Co.
According to driller well development consisted of air-lift pumping at 50 gallons/minute for at least two hours.

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SVR #7

Form 238-7
6/02

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

Inspected by _____
Twp _____ Rge _____ Sec _____
_____ 1/4 _____ 1/4 _____ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 0031062
DRILLING PERMIT NO. _____
Water Right or Injection Well No. _____

2. OWNER:
Name Spring Valley Development LLC
Address 485 E. Riverside Dr Suite # 300
City Eagle State Id Zip 83616

3. LOCATION OF WELL by legal description:
You must provide address or Lot, Blk, Sub. or Directions to well.
Twp. 5 North ☒ or South ☐
Rge. 1 East ☐ or West ☒
Sec. 23, _____ 1/4 (10 acres) NE 1/4 (40 acres) SW 1/4 (160 acres)
Gov't Lot _____ County Ada
Lat: : : Long: : :
Address of Well Site Big Gulch Sw of Wilson Creek Rd (Give street and name of road + Distance to Road or Landmark) City Eagle
Lt. _____ Blk. _____ Sub. Name _____

4. USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☒ Other Test

5. TYPE OF WORK check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other _____

6. DRILL METHOD:
☐ Air Rotary ☐ Cable ☒ Mud Rotary ☐ Other _____

7. SEALING PROCEDURES

Seal Material	From	To	Weight / Volume	Seal Placement Method
30% Grout	815	380	—	Pressure Grout
30% Grout	240	0	—	Pressure Grout

Was drive shoe used? ☐Y ☐N Shoe Depth(s)
Was drive shoe seal tested? ☐Y ☐N How? _____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
8"	+2	278	250	Steel	☒	☐	☒	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Length of Headpipe _____ Length of Tailpipe _____
Packer ☐Y ☐N Type _____

9. PERFORATIONS/SCREENS PACKER TYPE
Perforation Method Perf. 8" Casing 10 FT
Screen Type & Method of Installation Shutter Screen 60 FT

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
280	340	1/8	Many	8"	Steel	☐	☐
340	350	1/8	60	8"	Steel	☐	☐
						☐	☐

10. FILTER PACK

Filter Material	From	To	Weight / Volume	Placement Method
5/16 Pea Gravel	380	242	—	Pour

11. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
161 ft. below ground Artesian pressure _____ lb.
Depth flow encountered _____ ft. Describe access port or control devices: _____
Well cap

12. WELL TESTS:
☐ Pump ☐ Bailer ☒ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time
100-200			1 hour

Water Temp. 72° Bottom hole temp. _____
Water Quality test or comments: From .5 PH 7.5 Grains 5 Depth first Water Encounter _____

13. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
12	0	3	top soil & clay		
"	3	30	Coarse sand		
"	30	55	brown clay		
"	55	60	sand		
"	60	70	brown clay		
"	70	120	soft & hard clay layers		
"	120	130	sand & clay		
"	130	135	Coarse sand		
"	135	150	clay		
"	150	190	clay w/some sand layers		
"	190	200	sand		
"	200	210	clay w/sand		
"	210	280	Coarse sand w/little clay		
"	280	290	Coarse sand		
"	290	340	Coarse sand		
"	340	350	bluish coarse sand w/some wood		
"	350	380	Coarse blue sand		
"	380	440	Coarse blue sand		
"	440	470	blue clay		
"	470	815	blue clay		

RECEIVED
APR 19 2004
WATER RESOURCES
WESTERN REGION

Completed Depth 350' (Measurable)
Date: Started 3/10/04 Completed 4-10-04

14. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Adamson Pump & Drill Firm No. 457
Principal Driller Dave Adamson Date 4-15-04
and
Driller or Operator II Dave Adamson Date 4-15-04
Operator I _____ Date _____
Principal Driller and Rig Operator *Required*.
Operator I must have signature of Driller/Operator II.

FORWARD WHITE COPY TO WATER RESOURCES

M3 Eagle - S.V.R Well #7

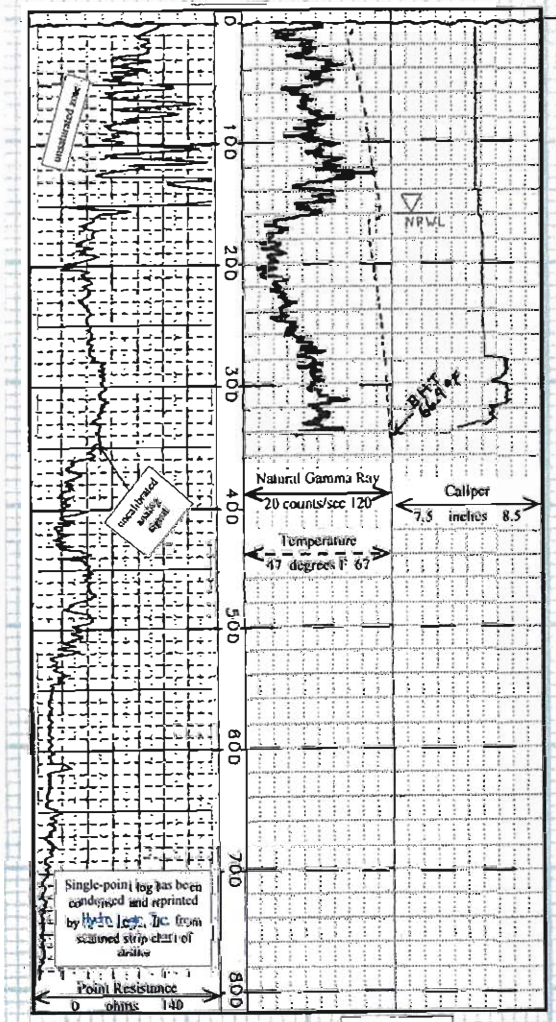
T5N R1W Section 23, NE¼, SW¼
Latitude 43° 35' 16.8" Longitude 116° 40' 18.0"
Completed April 2004

Geophysical Log

(March 2004)
by Stevens and Sons Drilling
in a mud-filled borehole.

Geophysical Logs

(April 27, 2007)
by Hydro Logic, Inc.
in a steel cased well.



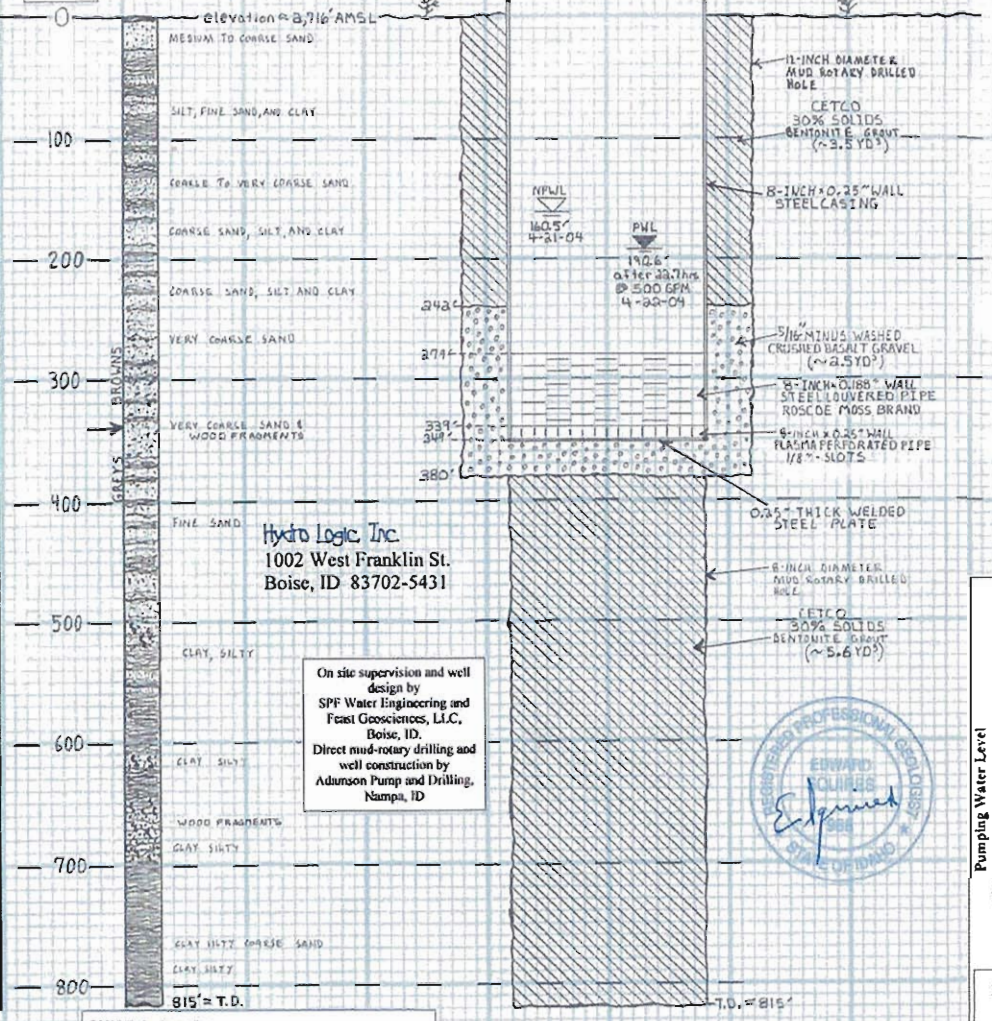
Drafted 02-15-08
by Loren Pearson,
Hydro Logic, Inc.

Lithology

Feast Geosciences lithologic log was developed from drilled cuttings. Lithology has been reinterpreted and readjusted to better fit with geophysical logs by Hydro Logic, Inc.

As-Built Well Construction

(from IDWR Driller's Report and Hydro Logic, Inc. downhole camera survey conducted on August 28, 2007)
(horizontal scale 0.1"=0.5")
(vertical scale 1"=100')



Hydro Logic, Inc.
1002 West Franklin St.
Boise, ID 83702-5431

On site supervision and well design by SPF Water Engineering and Feast Geosciences, LLC, Boise, ID.
Direct mud-rotary drilling and well construction by Adamson Pump and Drilling, Nampa, ID

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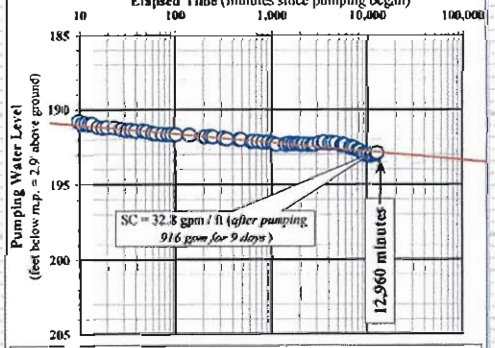
Ground Water Chemistry

Lab Analyses	SPF Water Engineering Results (in mg/L unless noted) SCREENED (279 - 349 feet bgl)	Hydro Logic, Inc. Results (in mg/L unless noted) SCREENED (279 - 349 feet bgl)
Alkalinity		120.0
Ammonia as N	<0.04	0.02
Arsenic	<0.005	0.0037
Calcium as $CaCO_3$	29.1	77.8
Chloride	5	4.42
Conductivity (uS)		305.0
Corrosivity		-0.35
Fluoride	0.41	0.43
Hardness	110	115.0
Iron (dissolved)		0.11
Iron (total)	0.11	0.11
Magnesium	8.19	8.91
Manganese	<0.05	0.02
Nitrate as N	0.31	0.34
Nitrite as N	<0.01	<0.01
Odor		<1
pH		7.63
Potassium	2.0	2.60
Silica		38.9
Sodium	22.9	23.2
Sulfate	24	23.5
Sulfide	<0.05	<0.05
Total Dissolved Solids	212	235.0
Total Kjeldahl Nitrogen		<0.10
Total Organic Carbon		3.36
Field Analyses		
Field Conductivity (uS)	300	382
Field Dissolved Oxygen		+1.37
Field Odor (describe)		minor H_2S
Field O.R.P. (mV)		+55
Field pH (S.U.)	7.00	7.40
Field Temperature (°F)	68.1	67.0
Field Visible Gas (yes or no)		yes

HLI samples collected on March 14, 2008 by Hydro Logic, Inc.
Analyses by Alchem Laboratories, Boise, ID
SPF samples collected on April 21, 2004 by Feast Geosciences.
Analyses by Analytical Laboratories, Boise, ID

Hydraulic Testing - (March 10-19, 2008)



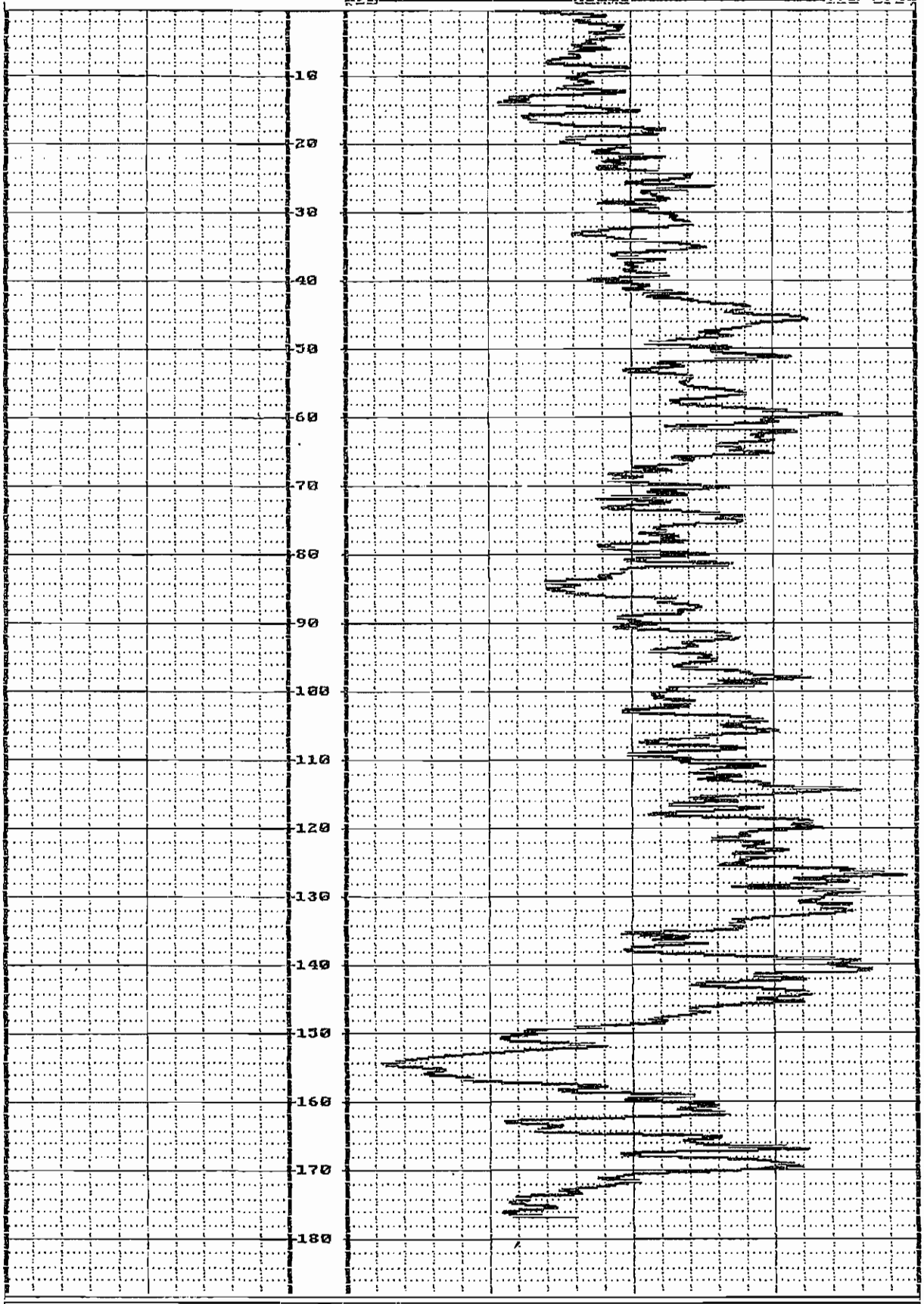
Non-Pumping Water Level = 165.00 feet below m.p. (16:00 hrs on 03/10/2008)
Testing conducted by Hydro Logic, Inc. and McLeran Well Drilling, LLC.
(no barometric or antecedent trend corrections applied to this plot.)

M3 4-inch (by SVR #7) 3/13/07

-743.22 43.75 9.38 7624.54 3884.14 4646.86 -22.44

Big Gulch Road

#20 Gamma 120 CPS



141.04 379.09 50.50 2.87 1.89 2.55 5.25

#20 Gamma 120 CPS

SVR Well #9

Form 238-7
6/02

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

Inspected by _____
Twp ____ Rge ____ Sec ____
____ 1/4 ____ 1/4 ____ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 0031492
DRILLING PERMIT NO. 815596
Water Right or Injection Well No. 386274

2. OWNER:
Name SUNCOR
Address 485 E Riverside Dr. #300
City Eagle State ID Zip 83616

3. LOCATION OF WELL by legal description:
You must provide address or Lot, Blk, Sub. or Directions to well.
Twp. 5 North ☒ or South ☐
Rge. 1 East ☒ or West ☐
Sec. 9, 10 acres 1/4 S/W 1/4 N/E 1/4
Gov't Lot ____ County Ada
Lat: : : Long: : :
Address of Well Site ½ mile SW of Willow Creek Rd
City Eagle
(Give a fixed feature of road + Distance to Road or Landmark)
Lt. ____ Blk. ____ Sub. Name ____

4. USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☒ Other test #9

5. TYPE OF WORK check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other ____

6. DRILL METHOD:
☐ Air Rotary ☐ Cable ☒ Mud Rotary ☐ Other ____

7. SEALING PROCEDURES

Seal Material	From	To	Weight / Volume	Seal Placement Method
bentonite grout	806	265	1250 gal	pumped
bentonite grout	215	0	300 gal	pumped

Was drive shoe used? ☐ Y ☐ N Shoe Depth(s) ____
Was drive shoe seal tested? ☐ Y ☐ N How? ____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
8"	+2	235	250	steel	☒	☐	☒	☐
6"	245	253	250	steel	☒	☐	☒	☐
					☐	☐	☐	☐

Length of Headpipe +2 Length of Tailpipe 0
Packer ☐ Y ☐ N Type ____

9. PERFORATIONS/SCREENS PACKER TYPE
Perforation Method ____
Screen Type & Method of Installation stainless

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
235	245	30		6"	stnls	☒	☐
253	263	30		6"	stnls	☒	☐
						☐	☐

10. FILTER PACK

Filter Material	From	To	Weight / Volume	Placement Method
#8-12 sand			3000#	

11. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
193'4 ft. below ground Artesian pressure ____ lb.
Depth flow encountered 198 ft. Describe access port or control devices: ____

12. WELL TESTS:
☒ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal/min.	Drawdown	Pumping Level	Time
43	14'	207	4½hr

Water Temp. ____ Bottom hole temp. ____
Water Quality test or comments: ____
Depth first Water Encounter ____

13. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
8	0	10	topsoil, sandy clay		X
	10	27	sand, brown clay		X
	27	60	tan gray clay		X
	60	90	sandy brown clay w/ gray streaks		X
	90	104	gray clay		X
	104	110	sandy brown clay		X
	110	155	coarse sand w/ gray streaks		X
	155	198	coarse to medium sand w/ clay streaks	X	
	198	210	reddish sand	X	
	210	243	fine sand w/ clay streaks	X	
	243	265	sand w/ wood, clay streaks	X	
	265	430	silty gray blue clay		X
	430	530	sticky gray blue clay		X
	530	531	hard shale		X
	531	780	gray blue clay		X
	780	781	hard shale		X
	781	806	gray blue clay		X
			topped with chips 20 sks		

RECEIVED
JUN 29 2004
WATER RESOURCES
WESTERN REGION

Completed Depth 806 drilled, 263 cased (Measurable)
Date: Started 6/1/04 Completed 6/25/04

14. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name Stevens & Sons Firm No. 153
Principal Driller ____ Date 6/28/04
and
Driller or Operator II ____ Date ____
Operator I ____ Date ____
Principal Driller and Driller Operator II signed.
Operator I must have signature of Driller/Operator II.

FORWARD WHITE COPY TO WATER RESOURCES

M3 Eagle - S.V.R. Well #9

T.5.N R.1E. Section 19, SW¼, NE¼
Latitude N43° 45' 33.3" Longitude W116° 22' 52.1"
Completed June 2004

Geophysical Log

(June 2004)
by Stevens and Sons Drilling in a mud-filled borehole.

Single-point log has been condensed and reprinted by Hydro Logic, Inc. from scanned pen and ink strip chart of driller.

0 single-point resistance 100

Depth (feet b.g.l.)

0
100
200
300
400
500
600
700
800

Unconsolidated zones
Sandline
Pierce Gulch Sand Aquifer
SANDLINE
CLAY LINE
Unconsolidated, poor quality, muddy layers
Terteling Springs Formation
BROWNS
GREYS

Lithology

Feast Geosciences lithologic log was developed from drilled cuttings. Lithology has been reinterpreted and readjusted below 120 feet to better fit with HLI's interpretation of the geology and the geophysical log.

ELEV. = 3753' AMSL = GROUND LEVEL

INTERBEDDED COARSE-GRAINED BROWN SANDS & TAN-TO-LIGHT GREY TACKY CLAYS

BROWN FINE-TO-COARSE GRAINED SAND WITH CLAY LENSES

REDDISH-BROWN ARKOSIC MEDIUM-COARSE SAND

LIGHT BROWN FINE-TO-COARSE GRAINED SANDS, CLAY LENSES, & ABUNDANT WOOD FRAGMENTS IN LOWER PORTION

LIGHT BROWNISH-GREY FINE-TO-COARSE GRAINED SANDS WITH MINOR CLAY BEDS & ABUNDANT WOOD FRAGMENTS IN UPPER PORTION

MEDIUM-GREY SILTY TACKY CLAY WITH SOME FINE GRAINED SAND

STICKY MEDIUM-GRAY CLAY

HARD STICKY MEDIUM-GRAY CLAY
(HARD SHALE NOTED BY DRILLER ON DRILLER'S REPORT:
- 530 - 531 FEET
- 780 - 781 FEET)

B10' = T.D.

Data presented was compiled and plotted by Hydro Logic, Inc. from available data of others. HLI was not involved with the drilling project.

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* SPF report of 10-13-2004 states:
"The driller measured the bottom-hole temperature (at 810 feet below ground surface) by running a bit to the bottom of the borehole, then pulling up and measuring the temperature of a chunk of clay attached to the bit. He recorded a temperature of 98°F in the clay. The actual temperature of the clay is probably higher (but cooled as the bit was retracted to ground surface)."

As-Built Well Construction

(horizontal scale 0.1"=1.0")
(vertical scale 1"=100')

Depth (feet b.g.l.)

GROUND LEVEL 0

BENTONITE CHIP (~14 FT³)
(From undocumented source. Presumed to be from Teague pits in Adrian, Oregon.

8"×0.250" WALL STEEL CASING

BENTONITE GROUT (~1.5 YD³)
(From undocumented source. Presumed to be from Teague pits in Adrian, Oregon.

12-INCH DIRECT MUD-ROTARY DRILLED HOLE

3/10/08 NPWL 195.3' BGL

PWL 6/23/04 AT 43GPM FOR 3 HOURS

#8-#12 GRADED COLORADO SILICA FILTER SAND (~1.5 YD³)

6-INCH STAINLESS STEEL 0.030" SLOT WIRE-WRAP SCREENS
(235 FT - 245 FT
253 FT - 263 FT)

6"×0.250" WALL STEEL PIPE (~245FT-253FT)

BENTONITE GROUT (~6.2 YD³)
(From undocumented source. Presumed to be from Teague pits in Adrian, Oregon.

8-INCH DIRECT MUD-ROTARY DRILLED HOLE

B10' = T.D.

Drafted June '08 by Loren Pearson, Hydro Logic, Inc.

On site supervision and well design by:
SPF Water Engineering and Feast Geosciences, LLC, Boise, ID.
Direct mud-rotary drilling and well construction by:
Stevens and Son Drilling Co., Nampa, ID

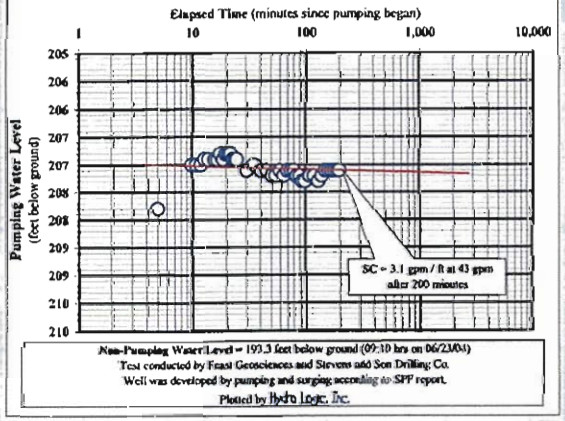
REGISTERED PROFESSIONAL GEOLOGIST
EDWARD SQUIRES
968
STATE OF IDAHO

Ground Water Chemistry

Lab Analyses (note: all samples with 0.45µm filter prior to analysis except sulfide)	SPF Water Engineering Results (in mg/L unless noted) SCREENED (235 - 263 feet bgl)
Ammonia as N	0.10
Antimony	<0.005
Arsenic	<0.005
Barium	0.10
Beryllium	<0.0005
Bicarbonate	107
Cadmium	<0.0005
Calcium as $CaCO_3$	24.9
Chloride	10
Chromium	<0.002
Conductivity (µS)	336
Fluoride	0.45
Hardness	102
Iron (dissolved)	0.60
Magnesium	10.4
Manganese	0.12
Mercury	<0.0002
Nickel	<0.02
Nitrate as N	<0.2
Nitrite as N	<0.01
pH (S.U.)	2.5
Potassium	2.0
Selenium	<0.005
Sodium	26.9
Sulfate	44
Sulfide (unfiltered)	<0.05
Thallium	<0.002
Total Dissolved Solids	216
Field Analyses	
Field Temperature (°F)	68

SPF samples collected on June 23, 2004 by Feast Geosciences.
Analyses by Analytical Laboratories, Boise, ID

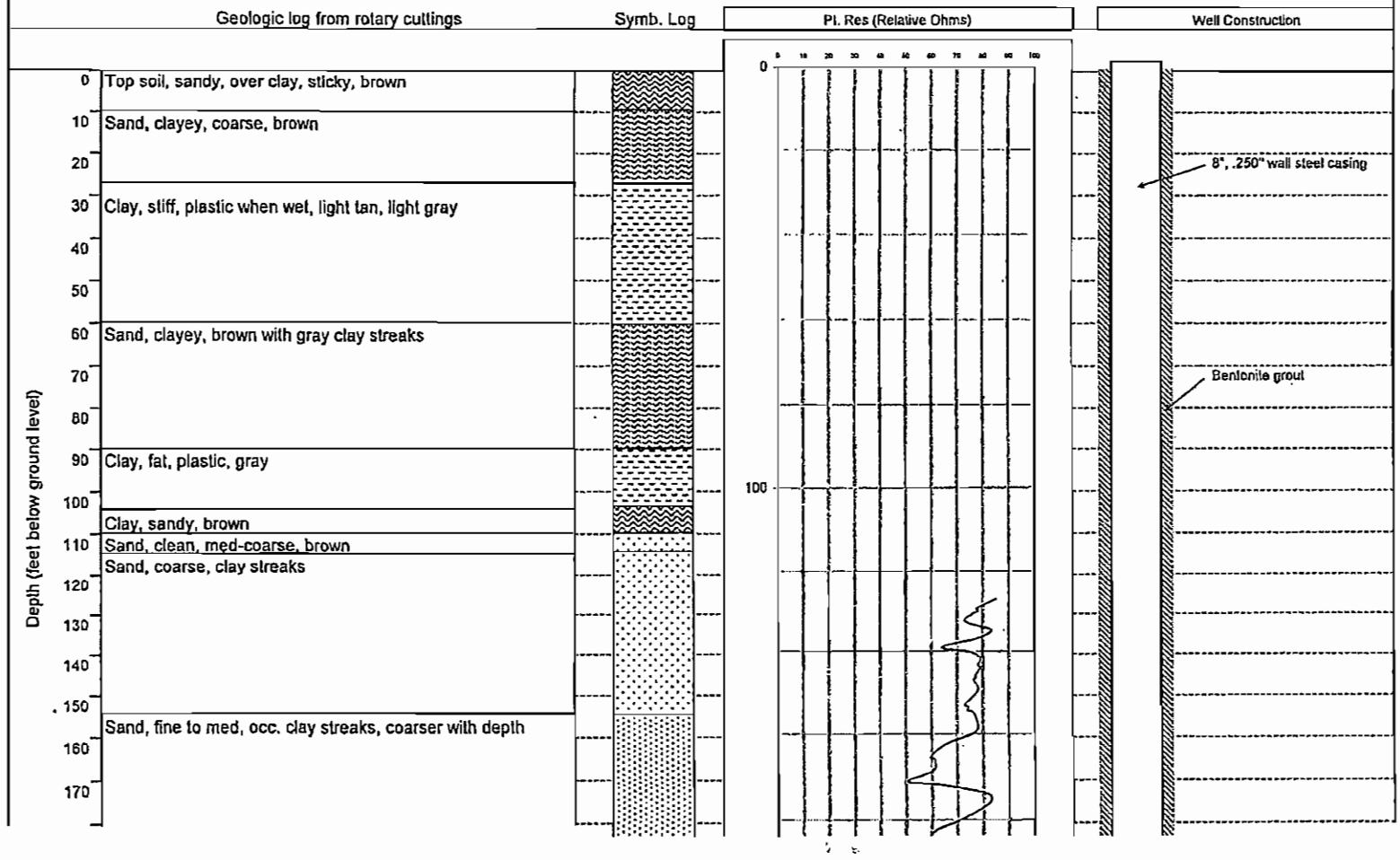
Hydraulic Testing - (June 23, 2004)



Non-Pumping Water Level = 193.3 feet below ground (09:10 hrs on 06/23/04)
Test conducted by Feast Geosciences and Stevens and Son Drilling Co.
Well was developed by pumping and surging according to SPF report.
Plotted by Hydro Logic, Inc.

Exploration Hole SVR 9
Spring Valley Ranch

Drilled by: Stevens and Son	Drilled Dates: 5/3-	Depth Drilled: 810 ft	Location: Ada County, Idaho
Logged by: C. Feast/Feast Geosciences, LLC	Drilling Method: Mud Rotary	Depth Logged: 805 ft.	T5N, R1W, 1/4, 1/4, Sect 9.
Geophysical logs by: Stevens and Sons Drilling	Borehole size: 8" (nom.)	Static WL: ~ 193 ft. bgl	GL Elevation: ~ 2700 ft. msl.
Fluid level when logged:	Borehole reamed to 12" for completion		
Casing when logged: 8" steel 0-5 ft, 8" open hole 5 - ft.			



Exploration Hole SVR 9

Spring Valley Ranch

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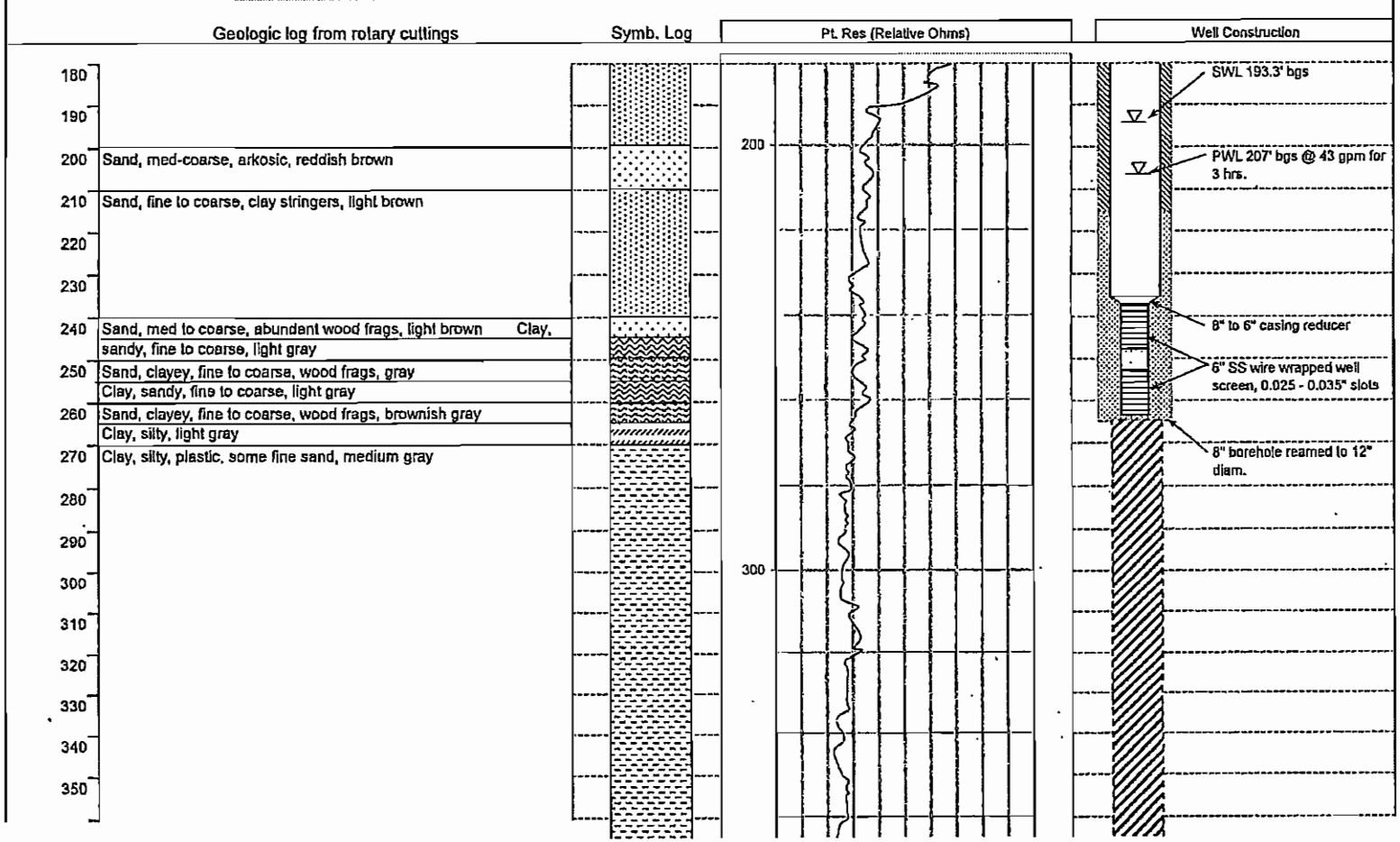
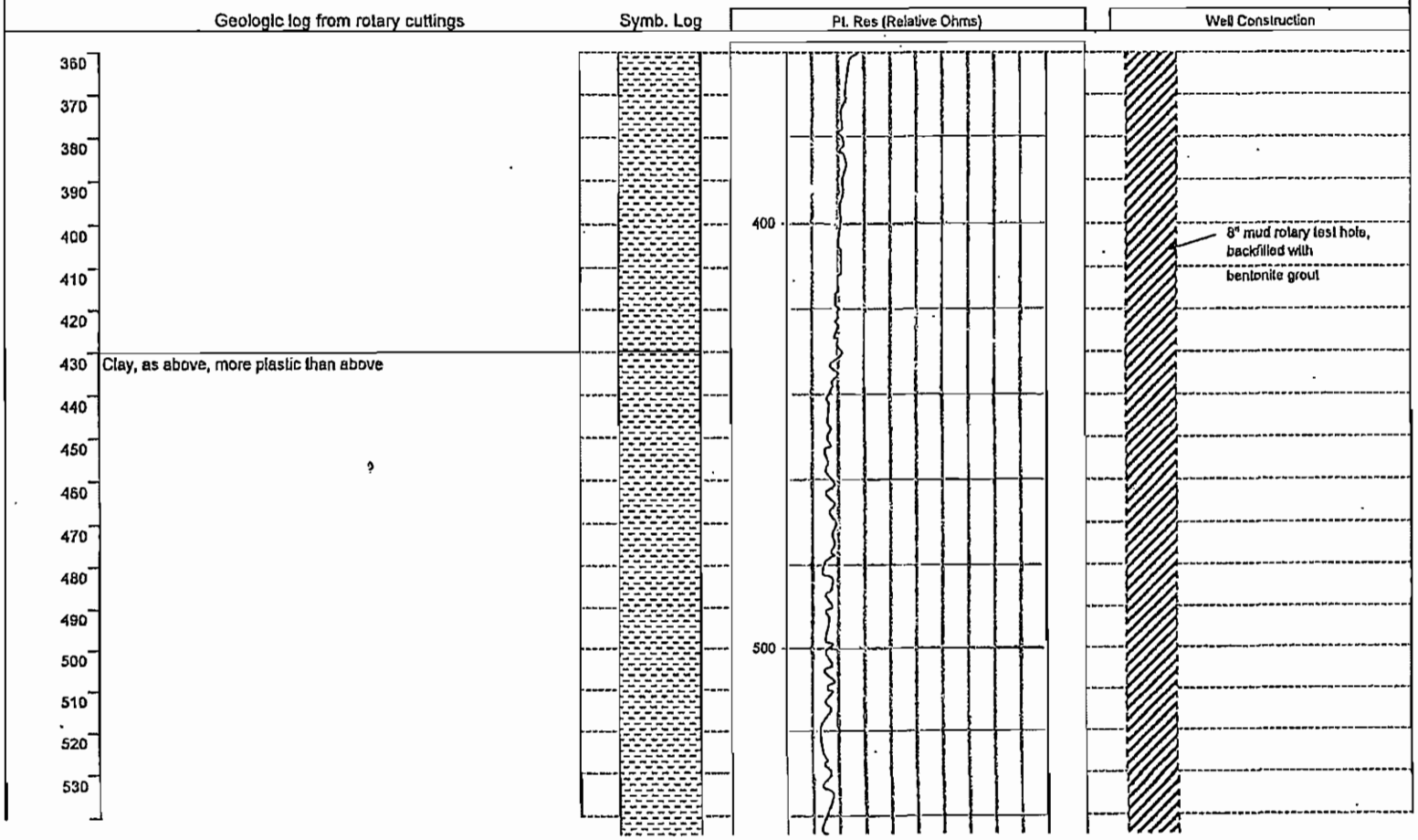
Logged by: C. Feast/Feast Geosciences, LLC	Drilling Method: Mud Rotary	Depth Logged: 805 ft.	T5N, R1W, 1/4, 1/4, Sect 9
Geophysical logs by: Stevens and Sons Drilling	Borehole size: 8" (nom.)	Static WL: ~ 193 ft. bgl	GL Elevation: ~ 2700 ft. msl.
Fluid level when logged:	Borehole reamed to 12" for completion		
Casing when logged: 8" steel 0-5 ft, 8" open hole 5 - ft.			



Exploration Hole SVR 9
Spring Valley Ranch

Drilled by: Stevens and Son	Drilled Dates: 5/3-	Depth Drilled: 810 ft	Location: Ada County, Idaho
Logged by: C. Feast/Feast Geosciences, LLC	Drilling Method: Mud Rotary	Depth Logged: 805 ft.	T5N, R1W, 1/4, 1/4, Sect 9
Geophysical logs by: Stevens and Sons Drilling	Borehole size: 8" (nom.)	Static WL: ~ 193 ft. bgl	GL Elevation: ~ 2700 ft. msl.
Fluid level when logged:	Borehole reamed to 12" for completion		
Casing when logged: 8" steel 0-5 ft, 8" open hole 5 - ft.			



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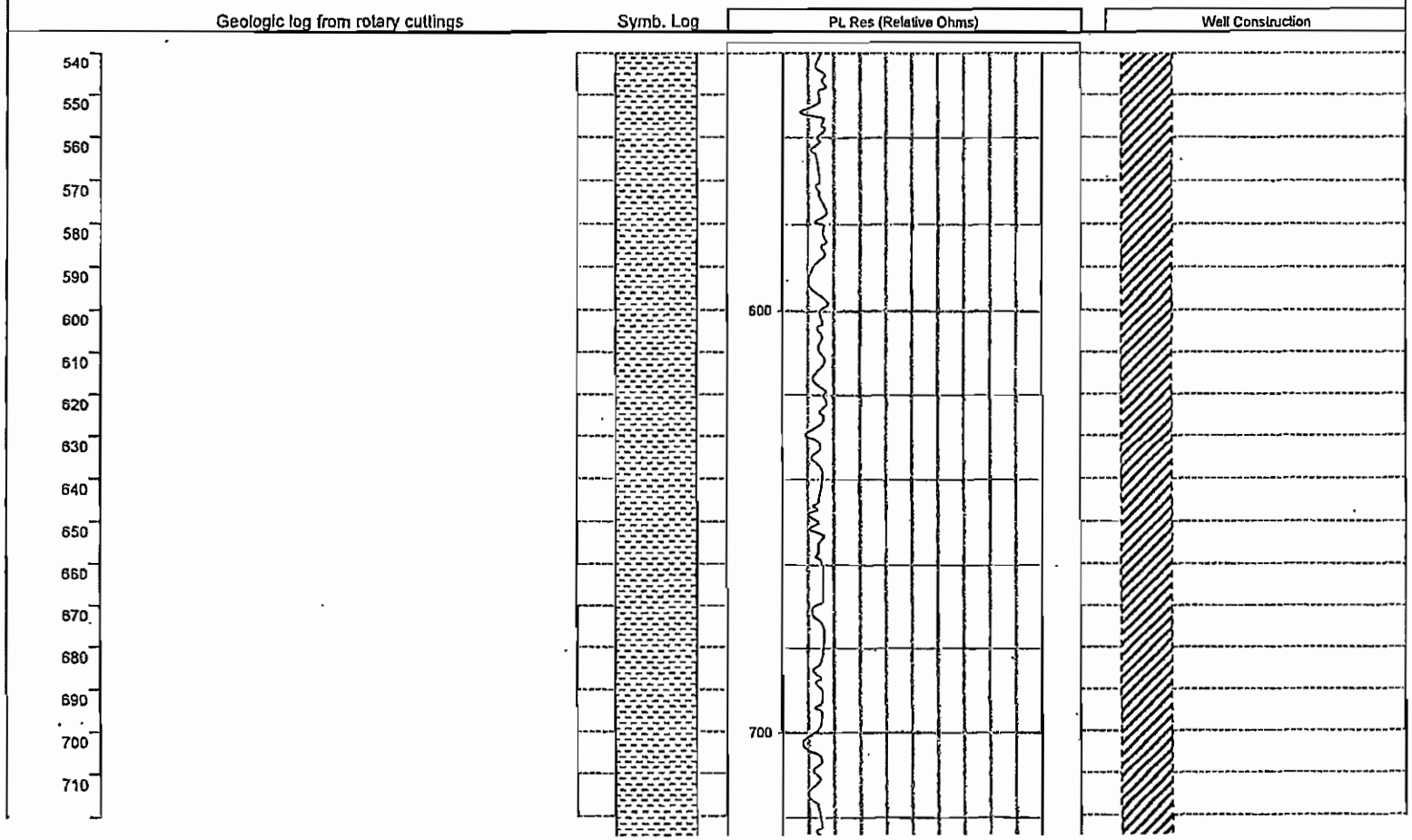
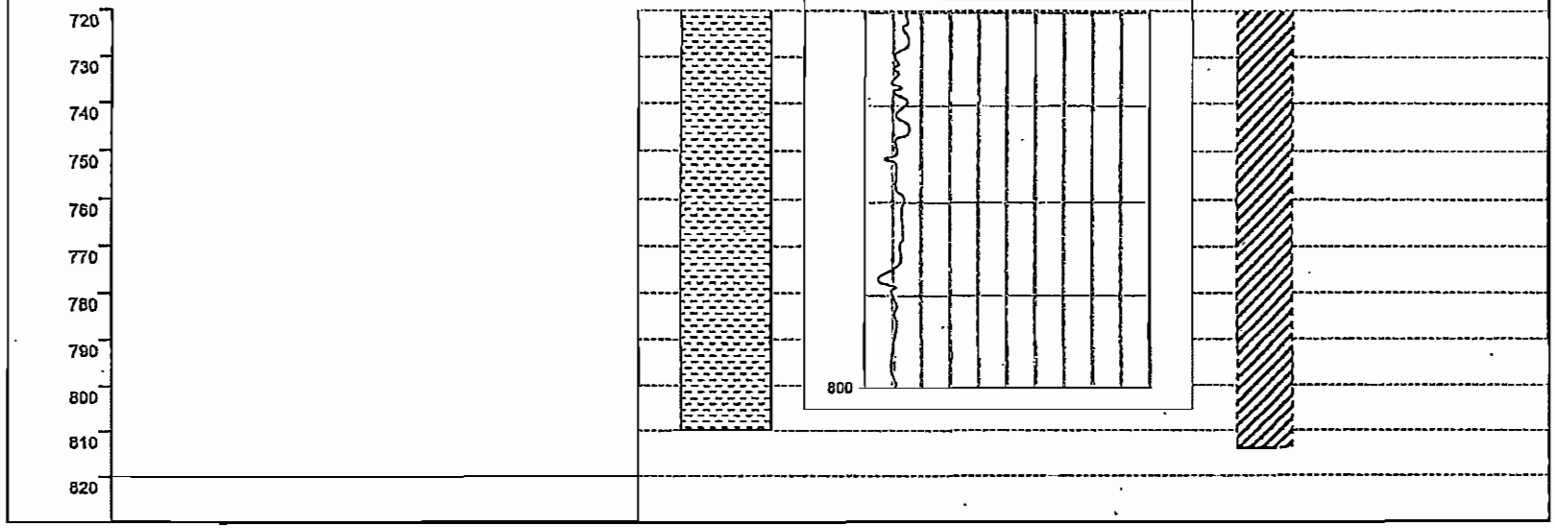
Geophysical logs by: Stevens and Sons Drilling	Borehole size: 8" (nom.)	Static WL: ~ 193 ft. bgl	GL Elevation: ~ 2700 ft. msl.
Fluid level when logged:	Borehole reamed to 12" for completion		
Casing when logged: 8" steel 0-5 ft, 8" open hole 5 - ft.			



Exploration Hole SVR 9
Spring Valley Ranch

Drilled by: Stevens and Son	Drilled Dates: 5/3-	Depth Drilled: 810 ft	Location: Ada County, Idaho
Logged by: C. Feast/Feast Geosciences, LLC	Drilling Method: Mud Rotary	Depth Logged: 805 ft.	T5N, R1W, 1/4, 1/4, Sect 9
Geophysical logs by: Stevens and Sons Drilling	Borehole size: 8" (nom.)	Static WL: ~ 193 ft. bgl	GL Elevation: ~ 2700 ft. msl.
Fluid level when logged:	Borehole reamed to 12" for completion		
Casing when logged: 8" steel 0-5 ft, 8" open hole 5 - ft.			



TPW #1 (pumping)

Form 238-7
6/02

IDAHO DEPARTMENT OF WATER RESOURCES
WELL DRILLER'S REPORT

Inspected by _____
Twp _____ Rge _____ Sec _____
_____ 1/4 _____ 1/4 _____ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 0030890
DRILLING PERMIT NO. _____
Water Right or Injection Well No. _____

2. OWNER:
Name Sunco Idaho LLC
Address 485 E. Riverside Drive Suite 300
City Eagle State Id Zip 83616

3. LOCATION OF WELL by legal description:
You must provide address or Lot, Blk, Sub. or Directions to well.
Twp. 5 North ☒ or South ☐
Rge. 1 East ☒ or West ☐
Sec. 1, _____ 1/4 (10 acres) SW 1/4 (40 acres) SE 1/4 (160 acres)
Gov't Lot _____ County Ada
Lat: : : Long: : :
Address of Well Site ½ mile West of Spring Valley Ranch (Give at least name of road + Distance to Road or Landmark) City Eagle
Lt. _____ Blk. _____ Sub. Name _____

4. USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☒ Other test

5. TYPE OF WORK check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other _____

6. DRILL METHOD:
☐ Air Rotary ☐ Cable ☐ Mud Rotary ☒ Other Reverse

7. SEALING PROCEDURES

Seal Material	From	To	Weight / Volume	Seal Placement Method
5% Bentonite	0	220	18.75 yd	dry pour

Was drive shoe used? ☐Y ☒N Shoe Depth(s) _____
Was drive shoe seal tested? ☐Y ☐N How? _____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
10"	+2	238	.365	steel	☒	☐	☒	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Length of Headpipe _____ Length of Tailpipe _____
Packer ☐Y ☐N Type _____

9. PERFORATIONS/SCREENS PACKER TYPE
Perforation Method _____
Screen Type & Method of Installation Johnson SS wire wrap

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
238	290	.040		10"	SST.	☒	☐
						☐	☐
						☐	☐

10. FILTER PACK

Filter Material	From	To	Weight / Volume	Placement Method
3/8 pea gravel	220	292	11.54 yd	dry pour

11. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
128' ft. below ground Artesian pressure _____ lb.
Depth flow encountered _____ ft. Describe access port or control devices: _____
1½" access port

12. WELL TESTS:
☒ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal/min.	Drawdown	Pumping Level	Time
2100 gpm	18'	146	72 Hrs

Water Temp. _____ Bottom hole temp. _____
Water Quality test or comments: _____
Depth first Water Encounter _____

13. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
24	0	2	Top Soil		
	2	38	Basalt Sand		
	38	52	Med. Sand		
	52	82	Coarse Sand w/some Clay mixed @ 73'-82'		
	82	134	Fine to med Sand + Brn Clay		
	134	227	Coarse Sand		
	227	292	Gray Clay w/coarse Sand @ 227'-289'		

RECEIVED
MAY 21 2004
WATER RESOURCES
WESTERN REGION

Completed Depth 292' (Measurable)
Date: Started 3-25-04 Completed 3-30-04

14. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.
Company Name Riverside Dlnc Firm No. 333
Principal Driller _____ Date _____
and
Driller or Operator II _____ Date 4-20-0
Operator I _____ Date _____
Principal Driller and Rig Operator *Required.*
Operator I must have signature of Driller/Operator II.

FORWARD WHITE COPY TO WATER RESOURCES

SCANNED
JAN 26 2004

TPW #1 (pumping)

JAN 15 2004
WATER RESOURCES
WESTERN REGION

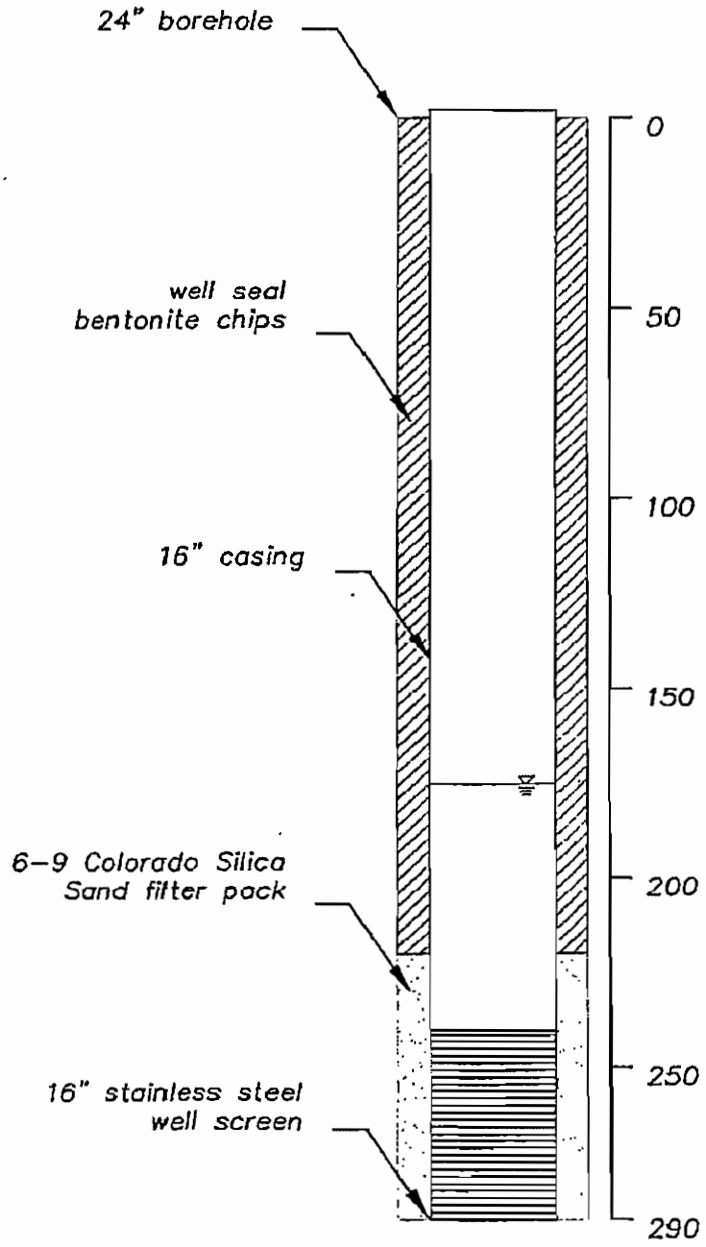


Figure 1

Test Production Well #1
Sandy Hill Aquifer

SCANLAN ENGINEERING

Form 238-7
11/97

IDAHO DEPARTMENT OF WATER RESOUR

WELL DRILLER'S REPORT

SVR #3 (observation)

Inspected by _____
Twp ____ Rge ____ Sec ____
____ 1/4 ____ 1/4 ____ 1/4
Lat: : : Long: : :

1. WELL TAG NO. D 0029004 WELL #3
DRILLING PERMIT NO. 874852-789296
Other IDWR No. _____

2. OWNER:
Name Sun Cor Development Co
Address 80 Rio Salado Pkwy #410
City Tempe State AZ Zip 85281

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S

Twp. 5 North XX or South ☐
Rge. 1 East XX or West ☐
Sec. 1 . ____ 1/4 S/W 1/4 S/E 1/4
Gov't Lot ____ County Ada
Lat : : Long: : :
Address of Well Site 3/4 mile west of hiway 55 City _____
(Give at least name of road + Distance to Road or Landmark)

Lt. _____ Blk. _____ Sub. Name Spring Valley Ranch area

4. USE:
☐ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other test

5. TYPE OF WORK check all that apply (Replacement etc.)
XX New Well ☐ Modify ☐ Abandonment ☐ Other _____

6. DRILL METHOD
☐ Air Rotary ☐ Cable XX Mud Rotary ☐ Other _____

7. SEALING PROCEDURES

SEAL/FILTER PACK Material	From	To	AMOUNT Sacks or Pounds	METHOD
bentonite grout	0	150	12 sk pumped	

Was drive shoe used? ☐Y ☐ N Shoe Depth(s) _____
Was drive shoe seal tested? ☐ Y☐ N How? _____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
8	+1	5	250	steel	XX	☐	XX	☐
6	+2	165	250	steel	☐	XX	XX	☐
6	175	195	250	steel	☐	XX	XX	☐

Length of Headpipe _____ Length of Tailpipe _____

9. PERFORATIONS/SCREENS
Perforations Method _____
Screens Screen Type Johnson v-wire

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
165	175	40		6	stnls	☐	XX
195	215	30		6	stnls	☐	XX
230	240	35		6	stnls	☐	XX

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
175' ft. below ground Artesian pressure ____ lb.
Depth flow encountered ____ ft. Describe access port or control devices: _____

11. WELL TESTS:
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time

Water Temp. _____ Bottom hole temp. _____
Water Quality test or comments: _____
Depth first Water Encounter _____

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
8	0	9	topsoil		X
	9	220	sand (water at 185)		
	220	280	sand, some organic		X
	280	360	green clay, some sand		X
	360	400	siltstone, some clay		X
	400	540	gray-brown clay, some sand		X
	540	570	siltstone		X
	570	600	brown-gray shale		X
	600	640	siltstone		X
	640	690	shale		X
	690	700	siltstone		X
	700	810	shale, hard clay, brown-gray		X
	810	860	basalt, hard		X
	860	930	siltstone		X
	930	940	gray clay		X
	940	950	siltstone		X
	950	970	sticky gray clay		X

Exploration Hole SVR 3
Spring Valley Ranch

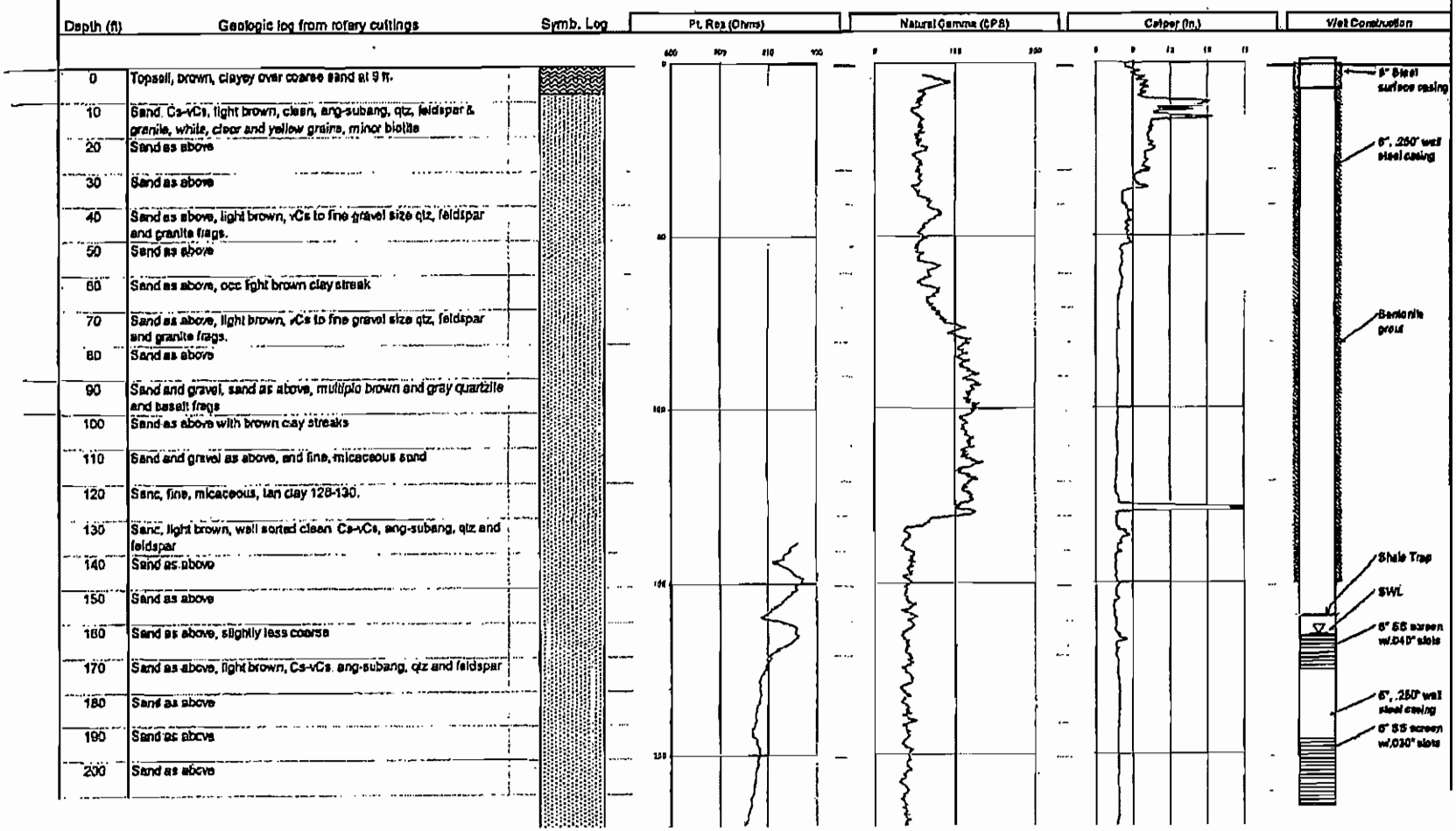
Drilled by: Stevens and Sons, Inc.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Hydrologic, Inc.
Fluid level when logged: 134 ft bgl
Casing when logged: 8" steel 0-5 ft, 8" open hole 5 - 967 ft.

Drilled Dates: 12/1/02 - 12/11/02
Drilling Method: Mud Rotary
Borehole size: 8" (nom.)

Depth Drilled: 970 ft
Depth Logged: 967 ft
Static WL: ~ 175 ft. bgl

Location: Ada County, Idaho
T5N, R1E, SE 1/4, SE 1/4, Sec 1
GL Elevation: ~ 3590 ft. msl.

Depth (ft)	Geologic log from rotary cuttings
0	Topsoil, brown, clayey over coarse sand at 9 ft.
10	Sand, Cs-vCs, light brown, clean, ang-subang, qtz, feldspar & granite, white, clear and yellow grains, minor biotite
20	Sand as above
30	Sand as above
40	Sand as above, light brown, vCs to fine gravel size qtz, feldspar and granite frags.
50	Sand as above
60	Sand as above, occ light brown clay streak
70	Sand as above, light brown, vCs to fine gravel size qtz, feldspar and granite frags.
80	Sand as above
90	Sand and gravel, sand as above, multiple brown and gray quartzite and basalt frags
100	Sand as above with brown clay streaks
110	Sand and gravel as above, and fine, micaceous sand
120	Sand, fine, micaceous, tan clay 128-130.
130	Sand, light brown, well sorted clean Cs-vCs, ang-subang, qtz and feldspar
140	Sand as above
150	Sand as above
160	Sand as above, slightly less coarse
170	Sand as above, light brown, Cs-vCs, ang-subang, qtz and feldspar
180	Sand as above
190	Sand as above
200	Sand as above



Exploration Hole SVR 3
Spring Valley Ranch

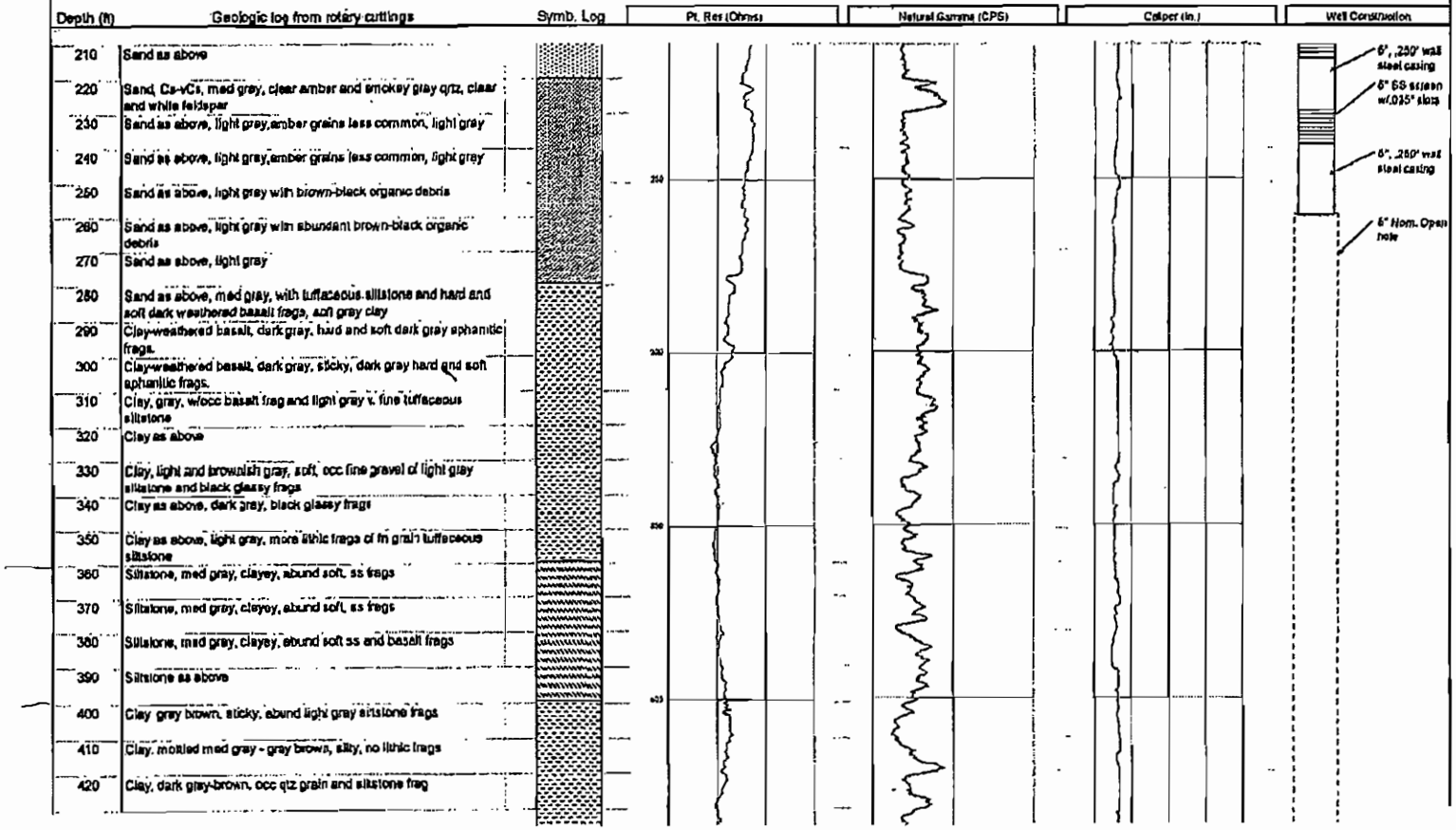
Drilled by: Stevens and Sons, Inc.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Hydrologic, Inc.
Field level when logged: 134 ft bgl
Casing when logged: 8" steel 0-5 ft, 6" open hole 5 - 957 ft.

Drilled Dates: 12/1/02 - 12/11/02
Drilling Method: Mud Rotary
Borehole size: 8" (nom.)

Depth Drilled: 970 ft
Depth Logged: 957 ft.
Static WL: ~ 175 ft. bgl

Location: Ada County, Idaho
T5N, R1E, SE 1/4, SE 1/4, Sect 1
GL Elevation: ~ 3590 ft. msl.

Depth (ft)	Geologic log from rotary cuttings
210	Sand as above
220	Sand, Cs-vCs, med grey, clear amber and smokey gray qtz, clear and white feldspar
230	Sand as above, light grey,amber grains less common, light gray
240	Sand as above, light grey,amber grains less common, light grey
250	Sand as above, light grey with brown-black organic debris
260	Sand as above, light grey with abundant brown-black organic debris
270	Sand as above, light gray
280	Sand as above, med gray, with tuffaceous siltstone and hard and soft dark weathered basalt frags, soft gray clay
290	Clay-weathered basalt, dark gray, hard and soft dark gray aphanitic frags.
300	Clay-weathered basalt, dark gray, sticky, dark gray hard and soft aphanitic frags.
310	Clay, gray, wocc basalt frag and light gray v. fine tuffaceous siltstone
320	Clay as above
330	Clay, light and brownish gray, soft, occ fine gravel of light gray siltstone and black glassy frags
340	Clay as above, dark gray, black glassy frags
350	Clay as above, light gray, more lithic frags of fn grain tuffaceous siltstone
360	Siltstone, med gray, clayey, abund soft, ss frags
370	Siltstone, med gray, clayey, abund soft, ss frags
380	Siltstone, med gray, clayey, abund soft ss and basalt frags
390	Siltstone as above
400	Clay gray brown, sticky, abund light gray siltstone frags
410	Clay, mottled med gray - gray brown, silty, no lithic frags
420	Clay, dark gray-brown, occ qtz grain and siltstone frag



Exploration Hole SVR 3
Spring Valley Ranch

Drilled by: Stevens and Sons, Inc.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Hydrologic, Inc.
Fluid level when logged: 134 ft bgl
Casing when logged: 8" steel 0-5 ft, 8" open hole 5 - 967 ft.

Drilled Dates: 12/1/02 - 12/11/02
Drilling Method: Mud Rotary
Borehole size: 8" (nom.)

Depth Drilled: 970 ft
Depth Logged: 967 ft.
Static WL: ~ 175 ft. bgl

Location: Ada County, Idaho
T5N, R1E, SE 1/4 SE 1/4, Sect 1
GL Elevation: ~ 3590 ft. msl.

Depth (ft)	Geologic log from rotary cuttings
430	Clay, mottled med gray - gray brown, silty, off-white and gray lithic frags
440	Clay, as above
450	Clay, greenish gray, sticky, occ fine gm ss frag
460	Clay, as above with light and dark gray fn ss frags
470	Clay as above, more lithic frags
480	Clay as above, more lithic frags
490	Clay, buff and gray with buff and grey siltstone frags
500	Clay, med gray, sticky, abundant ss and siltstone frags
510	Clay, with ss and siltstone frags as above
520	Clay, with ss and siltstone frags as above
530	Clay, brown, sticky, ss and siltstone frags as above with abundant dark brown organic debris
540	Siltstone, med gray, clayey
550	Siltstone as above
560	Siltstone as above, gray-brown
570	Shale, brown, platy with soft light graybrown ss frags
580	Shale, brown, platy less frags and more clay
590	Shale, med grey, clayey, soft
600	Siltstone, gray and brown, clayey
610	Siltstone, gray and white, clayey, occ Cs qtz grain
620	Siltstone, gray, clayey, no qtz grains
630	Siltstone, gray as above
640	Shale and siltstone, light brown, clayey

Symb. Log | Pt. Res (Ohms) | Natural Gamma (CPS) | Caliper (in.) | Well Construction

Exploration Hole SVR 3
Spring Valley Ranch

Drilled by: Stevens and Sons, Inc.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Hydrologic, Inc.
Fluid level when logged: 134 ft bgl
Casing when logged: 8" steel 0-5 ft, 8" open hole 5 - 967 ft.

Drilled Dates: 12/1/02 - 12/11/02
Drilling Method: Mud Rotary
Borehole size: 8" (nom.)

Depth Drilled: 970 ft
Depth Logged: 967 ft.
Static WL: ~ 175 ft. bgl

Location: Ada County, Idaho
T5N, R1E, SE 1/4, SE 1/4, Sect 1
GL Elevation: ~ 3590 ft. msl.

Depth (ft)	Geologic log from rotary cuttings
650	Siltstone, med gray, less clay than above
660	Shale and siltstone, gray with white bedding (ash beds?)
670	Shale and siltstone with white ash beds as above
680	Shale and siltstone with white ash beds as above
690	Siltstone, gray and brown shaley, sticky clay
700	Shale and claystone, med brown, clayey, hard claystone frags
710	Shale and claystone, med brown, clayey, hard claystone frags
720	Shale and claystone, med brown, clayey, hard claystone frags
730	Shale and claystone, med brown, clayey, hard claystone frags, finely bedded
740	Shale and claystone, med brown, less clay, hard claystone frags
750	Shale and claystone, med brown, less clay, hard claystone frags, qtz grains
760	Shale and claystone, med brown, less clay, hard claystone frags, no qtz grains
770	Shale and claystone, med brown, less clay, hard claystone frags, qtz grains
780	Shale and claystone, med brown, more clay, hard claystone frags
790	Shale and claystone, med brown, more clay, hard claystone frags
800	Shale and claystone, med brown, more clay, hard claystone frags
810	Tuff and basalt, dark gray, weathered, soft matrix with hard glassy frags
820	Tuff and basalt, dark gray, weathered, soft matrix with hard glassy frags
830	Tuff and basalt, dark gray, weathered, soft matrix with hard glassy frags
840	Tuff and basalt, dark gray, weathered, soft matrix with hard glassy frags
850	Tuff and basalt, dark gray, weathered, soft matrix with hard glassy frags
860	Siltstone, light gray, abundant qtz grains

Symb. Log | Pt. Res (Ohms) | Natural Gamma (CPS) | Caliper (in.) | Well Construction

Exploration Hole SVR 3
Spring Valley Ranch

Drilled by: Stevens and Sons, Inc.
Logged by: C. Feast/Feast Geosciences, LLC
Geophysical logs by: Hydrologic, Inc.
Fluid level when logged: 134 ft bgl
Casing when logged: 8" steel 0-5 ft, 5" open hole 5 - 867 ft

Drilled Dates: 12/1/02 - 12/11/02
Drilling Method: Mud Rotary
Borehole size: 8" (nom.)

Depth Drilled: 970 ft
Depth Logged: 867 ft.
Static WL: ~ 175 ft. bgl

Location: Ada County, Idaho
T5N, R1E, SE 1/4 SE 1/4, Sect 1
GL Elevation: ~ 3590 ft. msl.

Depth (ft)	Geologic log from rotary cuttings	Symb. Log	Pt. Res (Ohms)	Natural Gamma (CPS)	Caliper (in.)	Well Construction
870	Tuffaceous SS, dark gray, Cs qtz grains					
880	Tuffaceous SS, dark gray, Cs qtz grains					
890	Siltstone and claystone, med gray-brown					
900	Siltstone and claystone, med gray-brown					
910	Siltstone as above with dark gray glassy frags					
920	Siltstone as above with dark gray glassy frags					
930	Clay with siltstone frags, med gray, soft,					
940	Siltstone, med-light gray, less clay than above					
950	Clay with siltstone frags, med gray, soft,					
960	Clay with siltstone frags, med gray, soft,					
970						
980						
990						
1000						

Pg 1 of 3

Form 238-7
9/82

STATE OF IDAHO
DEPARTMENT OF WATER RESOURC

WELL DRILLER'S REPC

Kling Irrigation (pumping)

SEP 14 1989
Department of Water Resources
Western Regional Office

State law requires that this report be filed with the Director, Department of Water Resources within 30 days after the completion or abandonment of the well.

1. WELL OWNER Department of Water Resources

Name Don Jennings
Address P. O. Box 2663, Elko, NV 89801
63-88-W-150-000
Owner's Permit No. 63-10669

2. NATURE OF WORK

☒ New well ☐ Deepened ☐ Replacement
☐ Abandoned (describe abandonment procedures such as materials, plug depths, etc. in lithologic log)

3. PROPOSED USE

☐ Domestic ☒ Irrigation ☐ Test ☐ Municipal
☐ Industrial ☐ Stock ☐ Waste Disposal or Injection
☐ Other _____ (specify type)

4. METHOD DRILLED

☐ Rotary ☐ Air ☐ Hydraulic ☒ Reverse rotary
☐ Cable ☐ Dug ☐ Other _____

5. WELL CONSTRUCTION (See attached sheet)

Casing schedule: ☒ Steel ☐ Concrete ☐ Other _____

Thickness	Diameter	From	To
.250 inches	16 inches +	_____ feet	_____ feet
_____ inches	_____ inches	_____ feet	_____ feet
_____ inches	_____ inches	_____ feet	_____ feet
_____ inches	_____ inches	_____ feet	_____ feet

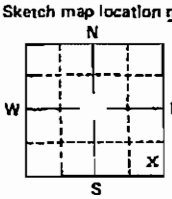
Was casing drive shoe used? ☐ Yes ☒ No
Was a packer or seal used? ☐ Yes ☒ No
Perforated? ☐ Yes ☒ No
How perforated? ☐ Factory ☐ Knife ☐ Torch
Size of perforation _____ inches by _____ inches

Number	From	To
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet

Well screen installed? ☒ Yes ☐ No
Manufacturer's name Roscoe Moss Hvy.
Type Wirewrap Model No. _____
Diameter 16" Slot size .040 Set from _____ feet to _____ feet
Diameter ____ Slot size ____ Set from _____ feet to _____ feet
Gravel packed? ☒ Yes ☐ No ☐ Size of gravel 3/8-
Placed from 50 feet to 415 (Bottom) feet
Surface seal depth 50' Material used in seal: ☐ Cement grout ☐ Bentonite ☒ Puddling clay ☐ _____
Sealing procedure used: ☐ Slurry pit ☐ Temp. surface casing ☒ Overbore to seal depth
Method of joining casing: ☐ Threaded ☒ Welded ☐ Solvent Weld ☐ Cemented between strata
Describe access port 2"

6. LOCATION OF WELL

Sketch map location must agree with written location.



Subdivision _____
Lot No. _____ Block No. _____
County Ada
SE SE¼ Sec. 28, T. 5N N/S, R. 3W E/W.

7. WATER LEVEL

Static water level 90 feet below land surface.
Flowing? ☐ Yes ☐ No G.P.M. flow _____
Artesian closed-in pressure _____ p.s.i.
Controlled by: ☐ Valve ☐ Cap ☐ Plug
Temperature ____ °F. Quality _____
Describe artesian or temperature zones below.

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Air ☐ Other _____

Discharge G.P.M.	Pumping Level	Hours Pumped

9. LITHOLOGIC LOG 103608

Bore Diam.	Depth From	Depth To	Material	Water Yes	Water No
28"	0	7	Topsoil		
	7	15	Clay & Sand		
	15	25	Coarse Sand		
	25	30	Brn. Clay		
	30	55	Coarse Sand		
	55	65	Sandy Brn. Clay		
	65	85	Sand Lt.Bn.Clay w/sme.sand		
	85	95	Gray Clay		
	95	102	Brn. Clay		
	102	105	Fine to Med. Sand	X	
	105	120	Gray Clay		
	120	125	Brn. Clay		
	125	155	Gray Clay		
	155	165	Gray Clay & Blue Shale		
	165	196	Gray Clay		
	196	210	Coarse Gray Sand	X	
	210	215	Gray Clay		
	215	235	Sandy Gray Clay w/stks.sand		
	235	240	Sandy Gray Clay	X	
	240	245	Gray Sand - Coarse	X	
	245	255	Gray Sand - Med.	X	
	255	260	Gray Sand - Fine	X	
	260	278	Gray Clay		
	278	283	Med. to Coarse Gray Sand		
	283	293	Blue Clay		
	293	298	Fine Blue Sand		
	298	301	Sandy Gray Clay		
	301	306	Fine Gray Sand	X	
	306	331	Gray Clay		
	331	338	Coarse Brn. Sand	X	
	338	343	Gray Clay		
	343	345	Gray Sand - Fine to Med.	X	
	345	355	Gray Clay & Fine Sand(50-50)	X	
	355	360	Gray Clay		
	360	365	Coarse Brn. Sand	X	
	365	375	Med. to coarse brn. sand w/sme. clay streaks.	X	

10. Work started 8/11/89 finished 8/14/89

11. DRILLERS CERTIFICATION DL

I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

PETE COPE DRILLING CO., INC.
Firm Name _____ Firm No. 213
6505 West Chinden Blvd.
Address Meridian, ID 83642 Date 8/14/89
Signed by (Firm Official) Pete Cope V.P.
and
(Operator) Joseph Jones

USE ADDITIONAL SHEETS IF NECESSARY — FORWARD THE WHITE COPY TO THE DEPARTMENT

Form 238-7
9/82

STATE OF IDAHO
DEPARTMENT OF WATER RESOUR(

WELL DRILLER'S REP(

Kling Irrigation (pumping)

State law requires that this report be filed with the Director, Department of Water Resources within 30 days after the completion or abandonment of the well.

1. WELL OWNER

Name Don Jennings.

Address

Owner's Permit No. 63-88-W-150-000

2. NATURE OF WORK

☐ New well ☐ Deepened ☐ Replacement
☐ Abandoned (describe abandonment procedures such as materials, plug depths, etc. in lithologic log)

3. PROPOSED USE

☐ Domestic ☐ Irrigation ☐ Test ☐ Municipal
☐ Industrial ☐ Stock ☐ Waste Disposal or Injection
☐ Other _____ (specify type)

4. METHOD DRILLED

☐ Rotary ☐ Air ☐ Hydraulic ☐ Reverse rotary
☐ Cable ☐ Dug ☐ Other

5. WELL CONSTRUCTION

Casing schedule: ☐ Steel ☐ Concrete ☐ Other

Thickness	Diameter	From	To
_____ inches	_____ inches +	_____ feet	_____ feet
_____ inches	_____ inches	_____ feet	_____ feet
_____ inches	_____ inches	_____ feet	_____ feet
_____ inches	_____ inches	_____ feet	_____ feet

Was casing drive shoe used? ☐ Yes ☐ No
Was a packer or seal used? ☐ Yes ☐ No
Perforated? ☐ Yes ☐ No
How perforated? ☐ Factory ☐ Knife ☐ Torch
Size of perforation _____ inches by _____ inches

Number	From	To
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet
_____ perforations	_____ feet	_____ feet

Well screen installed? ☐ Yes ☐ No
Manufacturer's name
Type _____ Model No. _____
Diameter ___ Slot size ___ Set from _____ feet to _____ feet
Diameter ___ Slot size ___ Set from _____ feet to _____ feet
Gravel packed? ☐ Yes ☐ No ☐ Size of gravel _____
Placed from _____ feet to _____ feet
Surface seal depth _____ Material used in seal: ☐ Cement grout
☐ Bentonite ☐ Puddling clay ☐ _____
Sealing procedure used: ☐ Slurry pit ☐ Temp. surface casing
☐ Overbore to seal depth
Method of joining casing: ☐ Threaded ☐ Welded ☐ Solvent Weld
☐ Cemented between strata
Describe access port _____

6. LOCATION OF WELL

Sketch map location must agree with written location.

N / W / E / S

Subdivision _____

Lot No. _____ Block No. _____

County ADA

SE ¼ SE ¼ Sec. 28, T. 5N N/S, R. 1W E/W.

7. WATER LEVEL

Static water level _____ feet below land surface.
Flowing? ☐ Yes ☐ No G.P.M. flow _____
Artesian closed-in pressure _____ p.s.i.
Controlled by: ☐ Valve ☐ Cap ☐ Plug
Temperature _____ °F. Quality _____
Describe artesian or temperature zones below.

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Air ☐ Other _____

Discharge G.P.M.	Pumping Level	Hours Pumped

103509

9. LITHOLOGIC LOG

Bore Diam.	Depth From	Depth To	Material	Water Yes	Water No
28"	375	378	Med. to coarse brn.sand	X	
	378	387	Brown Clay		
	387	400	Coarse Brn. Sand	X	
	400	402	Coarse Brn. Sand w/Clay	X	
	402	410	Coarse Brn. Sand	X	
	410	415	Brn. Clay		

RECEIVED
SEP 14 1989
Department of Water Resources

10.

Work started _____ finished _____

11. DRILLERS CERTIFICATION

I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Firm Name PETE COPE DRILLING CO., INC. Firm No. _____

Address _____ Date _____

Signed by (Firm Official) _____

and

(Operator) _____

JUN 21 1991

USE ADDITIONAL SHEETS IF NECESSARY — FORWARD THE WHITE COPY TO THE DEPARTMENT

Kling Irrigation (pumping)

CASING SCHEDULE 103610
DON JENNINGS WELL

16" Casing

+ 2'	-	198'	-	200' C
208'	-	238'	-	30' C
258'	-	298'	-	40' C
308'	-	328'	-	20' C
368'	-	398'	-	30' C
408'	-	414'	-	6' C
				326' C
				90' S
				416' Pipe

16" Screens - Roscoe Moss

198'	-	208'	-	10' S
238'	-	258'	-	20' S
298'	-	308'	-	10' S
328'	-	368'	-	40' S
398'	-	408'	-	10' S
				90' S

63-88-W-150-000

SN 1W Sec 28

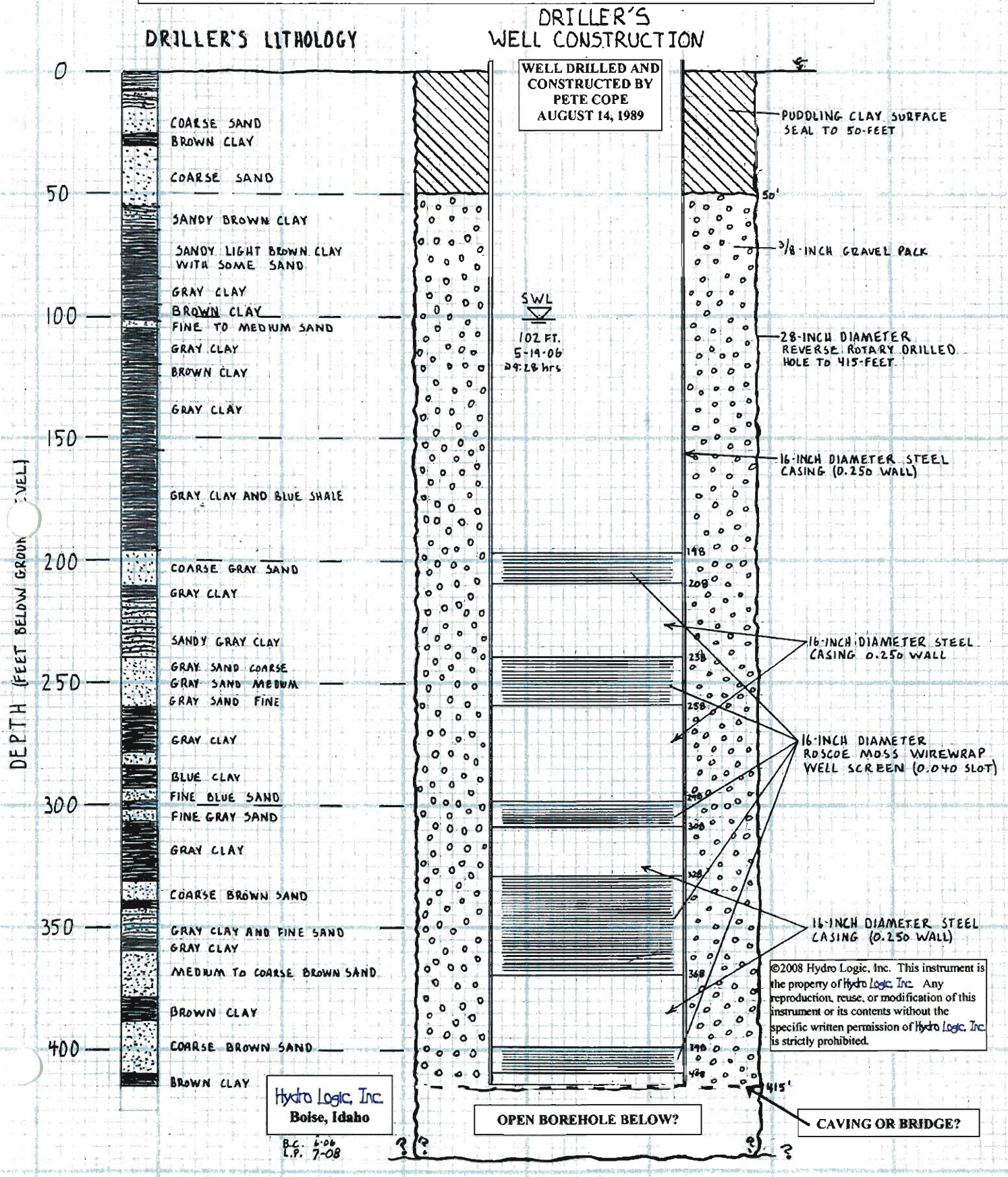
MICROFILMED
JUN 21

M3 Eagle - Kling Irrigation Well

T. 5 N., R. 1 W., Section 28, SE¼, SE¼

Latitude 43° 44' 15.81" Longitude 116° 27' 13.03"

Well completed August 1989



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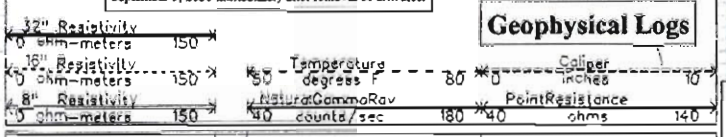
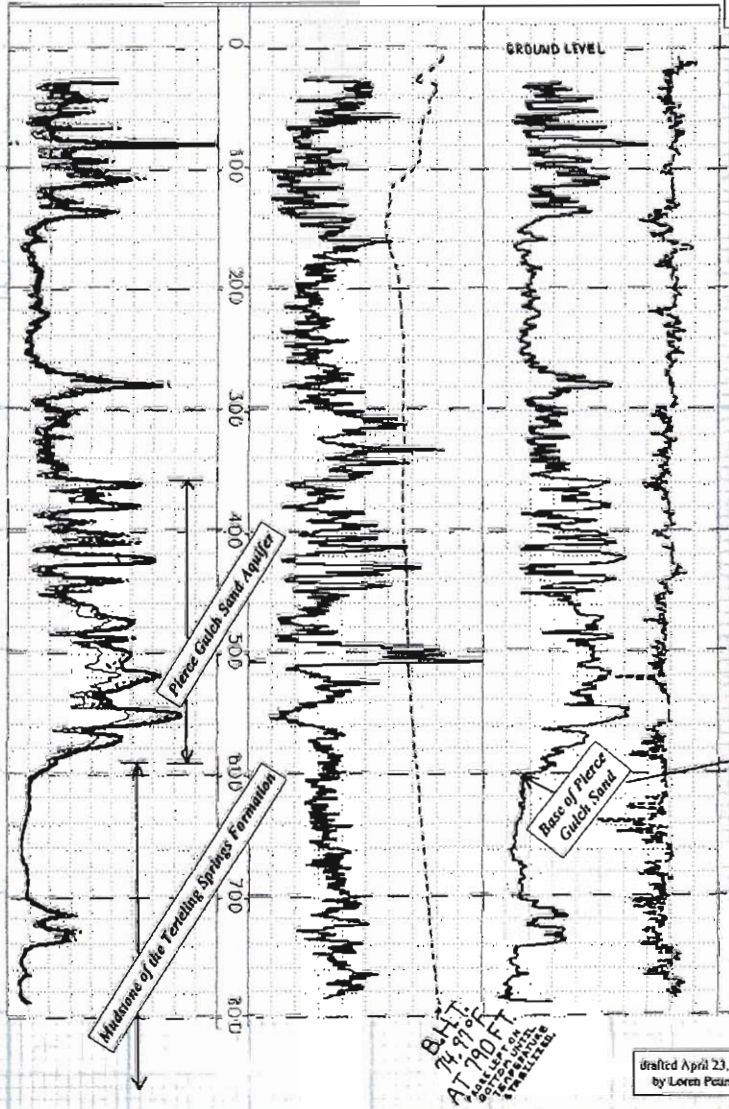
M3 Eagle - Test Well #1

T. 5 N., R. 1 W., Section 28, SE¼, SE¼
Latitude 43° 44' 12.37" Longitude 116° 27' 26.86"
Well completed September 2006

Geophysics conducted by: Hydro Logic, Inc. on September 9, 2006 immediately after removal of drill steel

Geophysical Logs



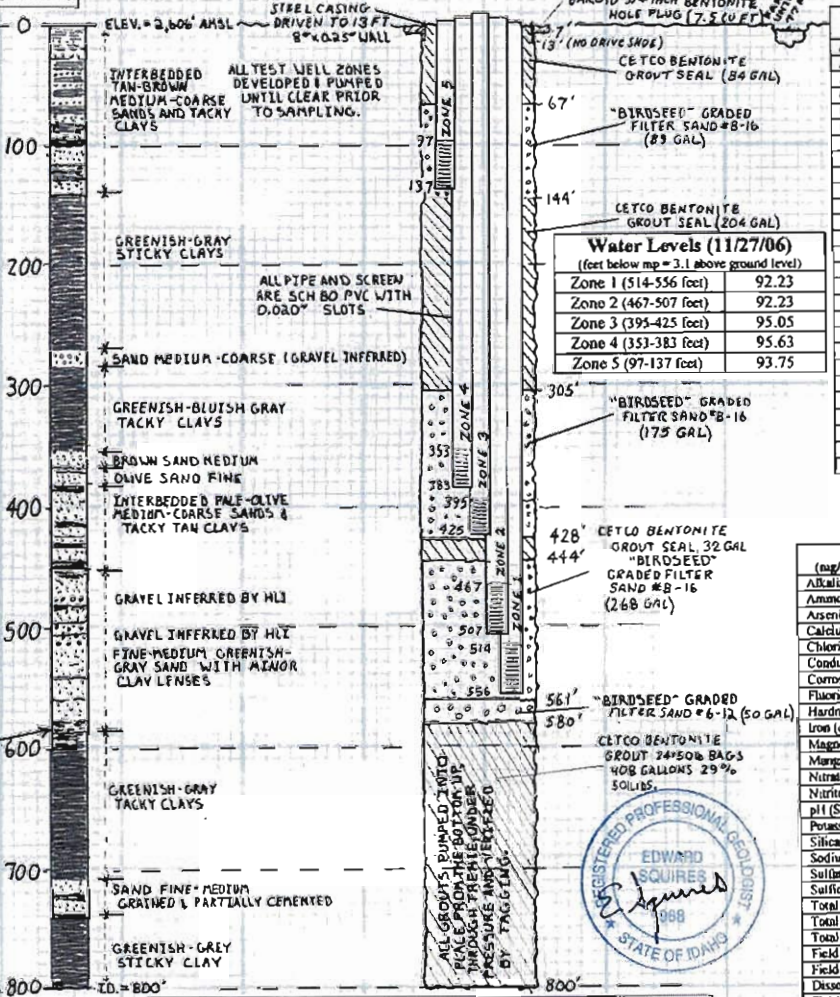


drafted April 23, 2008 by Loren Pearson

Depth
(feet below ground level)

Lithology
Hydro Logic, Inc. lithologic log is interpreted and drawn from geophysical logs and drilled cuttings from the borehole.

As-Built Well Construction
(horizontal scale 0.1"=1.0") (vertical scale 1"=100')



Water Levels (11/27/06)
(feet below mp = 3.1 above ground level)

Zone 1 (514-556 feet)	92.23
Zone 2 (467-507 feet)	92.23
Zone 3 (395-425 feet)	95.05
Zone 4 (353-383 feet)	95.63
Zone 5 (97-137 feet)	93.75

Water Chemistry

Analyte (mg/L unless noted)	Zone 1 514-556 feet	Zone 2 467-507 feet
Alkalinity	133.0	125.0
Ammonia as N	0.37	0.06
Arsenic	<0.003	<0.003
Calcium as CaCO3	84.4	85.5
Chloride	3.42	3.22
Conductivity (uS/cm)	302	297.0
Corrosivity	-0.40	-0.44
Fluoride	0.69	0.60
Hardness	111.0	109.0
Iron (dissolved/filtered)	0.23	<0.01
Magnesium	6.50	5.73
Manganese (dissolved)	0.10	0.02
Nitrate as N	<0.10	<0.10
Nitrite as N	<0.01	<0.01
pH (SU)	7.47	7.48
Potassium	2.26	2.21
Silica	31.8	30.7
Sodium	22.1	21.7
Sulfate	17.2	20.7
Sulfide	<0.05	<0.05
Total Dissolved Solids	173 .0	188.0
Total Kjeldahl Nitrogen	0.39	0.13
Total Organic Carbon	<1.0	<1.0
Field Temperature (°F)	67.1	66.0
Field Conductivity (uS)	305	295
Dissolved Oxygen	+1.7	+2.6
Field pH (S.U.)	7.19	7.19

Analyses by Alchem Laboratories, Boise, Idaho.
Zones 1 to 3 sampled 10/09/06. Zones 4 & 5 sampled 10/9/06.
Field measured parameters by Hydro Logic, Inc.

Analyte (mg/L unless noted)	Zone 3 395-425 feet	Zone 4 352-382 feet	Zone 5 98-138 feet
Alkalinity	119.0	114.0	119.0
Ammonia as N	0.04	<0.01	<0.01
Arsenic	<0.003	0.0049	0.0081
Calcium as CaCO3	77.7	81.3	85.9
Chloride	3.57	3.54	4.36
Conductivity (uS/cm)	282.0	285.0	281.0
Corrosivity	-0.50	-0.61	-1.16
Fluoride	0.60	0.50	0.24
Hardness	102.0	105.0	111.0
Iron (dissolved/filtered)	0.01	<0.01	<0.01
Magnesium	5.83	5.85	6.22
Manganese (dissolved)	<0.01	<0.01	<0.01
Nitrate as N	0.30	0.33	2.30
Nitrite as N	<0.01	<0.01	<0.01
pH (SU)	7.84	7.40	6.91
Potassium	2.07	2.10	2.74
Silica	29.5	28.7	38.0
Sodium	21.1	17.9	13.6
Sulfate	21.4	22.3	12.0
Sulfide	<0.05	<0.05	<0.05
Total Dissolved Solids	185.0	203.0	208.0
Total Kjeldahl N	<0.10	<0.10	<0.10
Total Organic Carbon	<1.0	<1.0	<1.0
Field Temperature (°F)	64.7	63.8	57.4
Field Conductivity (uS)	274	268	265
Dissolved Oxygen	+4.9	+2.63	+9.51
Field pH (S.U.)	7.27	7.07	6.72

On site supervision, well design and water quality sampling by Hydro Logic, Inc., Boise, ID.
Direct mud-rotary drilling and well construction by
Treasure Valley Drilling and Pump, Inc., Weiser, ID
Wells developed by McLeran Well Drilling, LLC, New Plymouth, ID.

REGISTERED PROFESSIONAL GEOLOGIST EDWARD SQUIRES 988 STATE OF IDAHO

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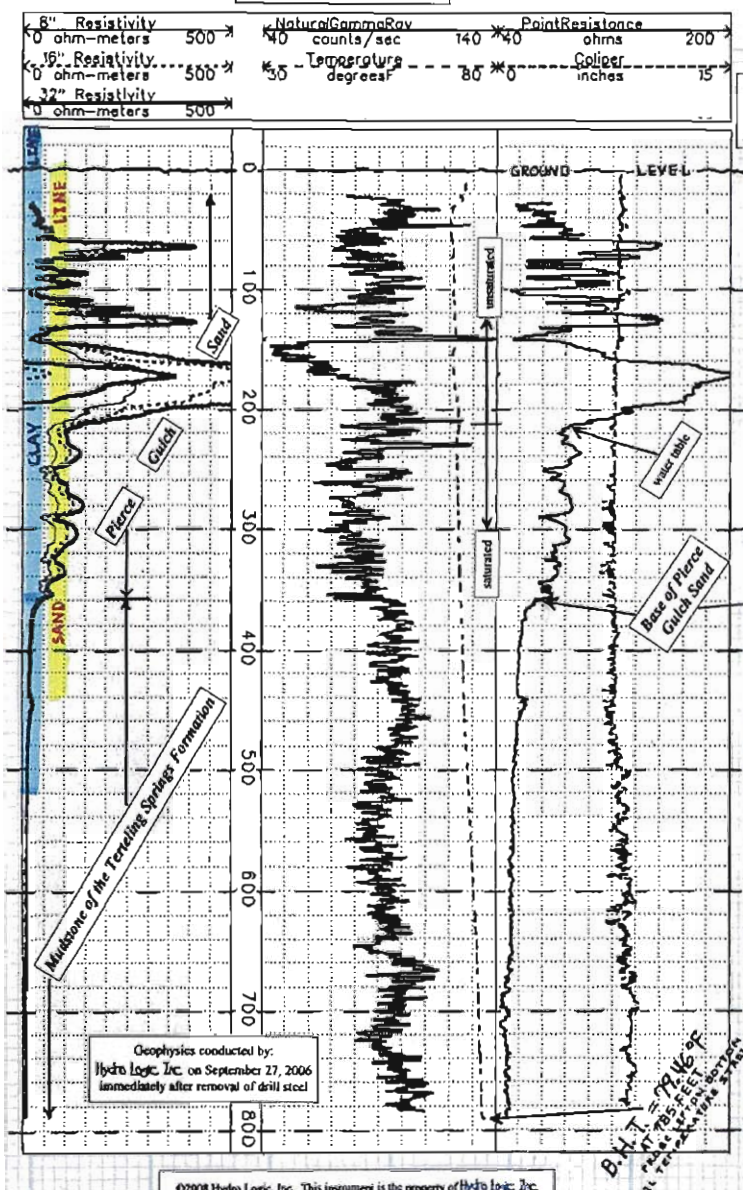
M3 Eagle - Test Well #2

T. 5 N., R. 1 W., Section 23, NE¼, NW¼, NE¼
Latitude 43° 45' 50.63" Longitude 116° 25' 6.58"
Well completed October 2006

Geophysical Logs



Geophysics conducted by:
Hydro Logic, Inc. on September 27, 2006 immediately after removal of drill steel

Lithology

Hydro Logic, Inc. lithologic log is interpreted and drawn from geophysical logs and drilled cuttings from the borehole.

- ELEV. = 2766' AMSL
- INTERBEDDED TAN TO BROWN SANDS & TACKY CLAYS & SILTS
- TAN VERY COARSE SAND WITH RUSTY PEA GRAVEL
- TAN COARSE SANDS AND TACKY BROWN CLAYS
- COLOR CHANGE
- GREY COARSE-MEDIUM SANDS WITH MINOR TACKY CLAY LENSES
- GREY SANDY STICKY CLAY
- DARK GREY SANDSTONE
- DARK GREY SILTY STICKY CLAY
- LIGHT TO DARK GREY MODERATELY CEMENTED INTERBEDDED MUDSTONE, SILTSTONE AND SANDSTONE
- DARK GREY STICKY CLAY
- T.D. = 800'

ALL BENTONITE GROUTS CONTAIN GREATER THAN 30 PERCENT SOLIDS BY WEIGHT AND WERE PUMPED FROM THE BOTTOM UP THROUGH TREMIE AND TAGGED INTO PLACE.

drafted March 2008 by Loren Pearson

As-Built Well Construction

(horizontal scale 0.1"=1.0") (vertical scale 1"=100')

- 3/4" BENTONITE CHIP (5.6 FT³)
- 8"x 0.25" WALL STEEL CASING
- 15-INCH HOLE TO 9'
- CETCO BENTONITE GROUT > 30% SOLIDS (1.2 YD³)
- 6-12 GRADED FILTER SAND "BIRDSEED" BRAND (0.3 YD³)
- CETCO BENTONITE GROUT > 30% SOLIDS (0.25 YD³)
- 6-12 GRADED FILTER SAND "BIRDSEED" BRAND (0.4 YD³)
- ALL WELLS ARE: 2-INCH SCH80 PVC FLUSH-JOINT RISER & 0.020" SLOT SCREENS
- BENTONITE GROUT > 30% SOLIDS (0.1 YD³)
- 6-12 GRADED FILTER SAND "BIRDSEED" BRAND (0.15 YD³)
- 8-INCH DIRECT MUD-ROTARY DRILLED HOLE
- ZONE #1, ZONE #2, ZONE #3
- 166', 180', 190', 192', 219', 230', 250', 259', 270', 320', 334', 788'
- INFILL
- T.D. = 800'

On site supervision, well design, pump test design, and water level monitoring by Hydro Logic, Inc., Boise, ID.
Direct mud-rotary drilling and well construction by Treasure Valley Drilling and Pump, Inc., Weiser, ID
Wells developed by McLerran Well Drilling, LLC, New Plymouth, ID.

Water Levels

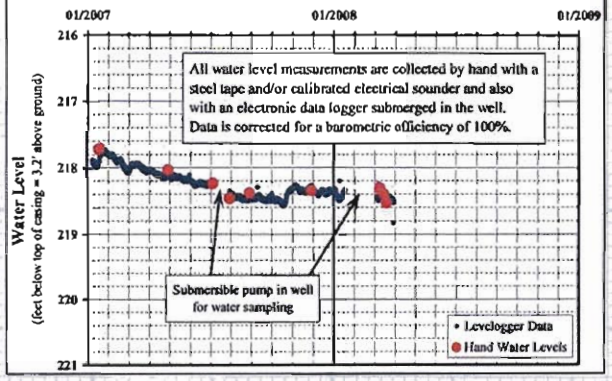
(feet below measure point = 3.0 feet above ground)

Date / Time (24-hr clock)	ZONE #1 (320 - 270 feet bgl)	ZONE #2 (250 - 230 feet bgl)	ZONE #3 (190 - 160 feet bgl)
10/10/06 13:05	216.87	-	unsaturated zone (installed to confirm water table depth)
11/07/06 12:00	217.23	217.36	
1/18/07 14:27	217.19	217.37	
4/30/07 15:25	216.97	215.76	
6/01/07 12:00	216.17	216.75	
7/24/07 12:30	-	217.11	
7/31/07 13:00	217.58	217.91	
8/30/07 12:20	217.60	217.93	
9/19/07 16:30	215.93	216.26	

Water levels recorded by Hydro Logic, Inc.

Water Level Monitoring - Zone #1

January 8, 2007 - March 31, 2008



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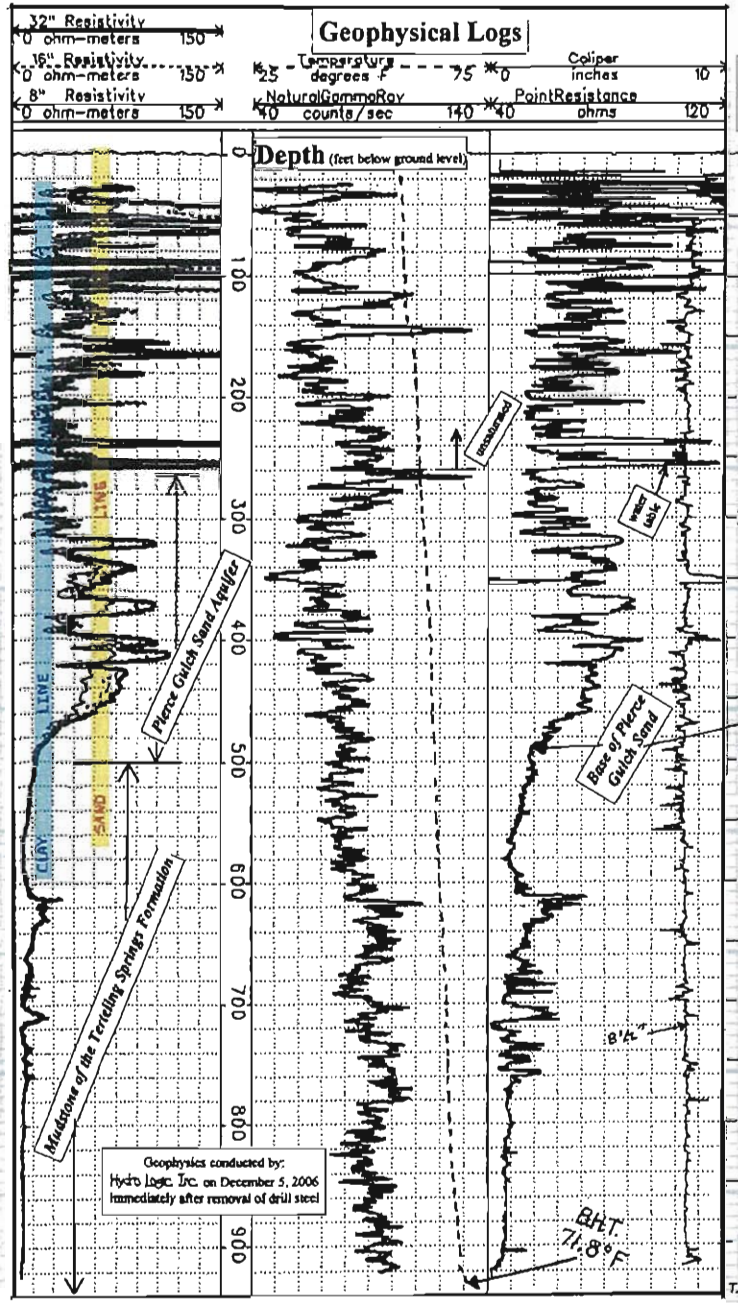
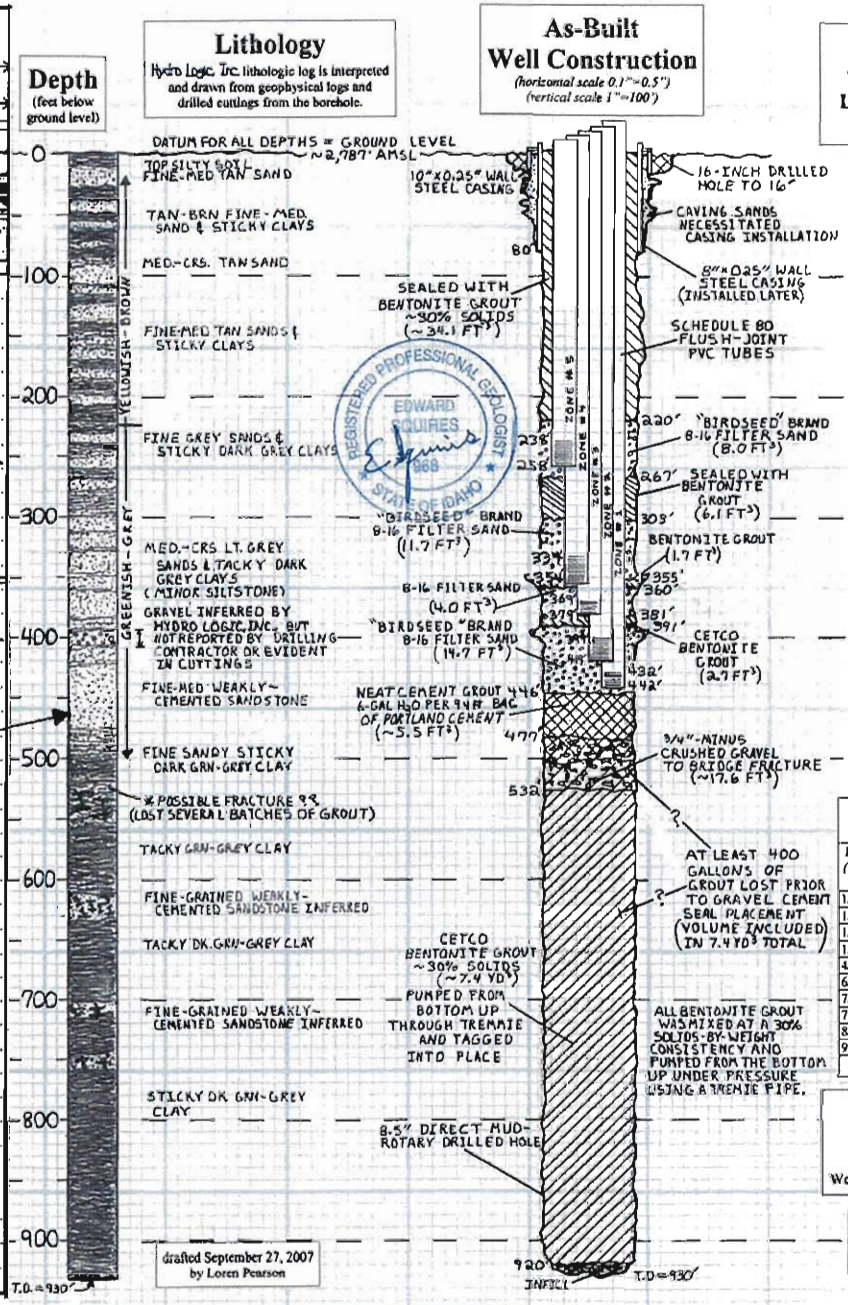
REGISTERED PROFESSIONAL GEOLOGIST EDWARD SQUIRES 668 STATE OF IDAHO

M3 Eagle - Test Well #3

T. 5 N., R. 1 W., Section 15, SW¼, SW¼, SW¼
Latitude 43° 45' 56.44" Longitude 116° 27' 8.35"
Well completed December, 2006





Ground Water Chemistry

Analysis (in mg/L unless noted)	ZONE #1 (442 - 432 feet bgl)	ZONE #2 (419 - 399 feet bgl)	ZONE #3 (379 - 369 feet bgl)
Alkalinity	136.0	123.0	117.0
Ammonia as N	0.28	0.14	0.05
Arsenic	0.008	0.005	0.009
Calcium as $CaCO_3$	69.8	74.8	86.5
Chloride	5.39	5.31	7.02
Conductivity (µS)	316.0	305.0	321.0
Corrosivity	-0.14	-0.46	-0.30
Fluoride	0.51	0.52	0.52
Hardness	98.4	106.0	118.0
Iron (dissolved)	0.16	0.09	0.03
Magnesium	6.94	7.48	7.47
Manganese (dissolved)	0.07	0.09	0.05
Nitrate as N	0.13	0.13	0.12
Nitrite as N	<0.01	<0.01	<0.01
Orthophosphate	0.477	0.270	0.276
pH - Lab (S.U.)	7.90	7.59	7.72
Potassium	2.90	2.54	2.53
Silica	43.5	41.2	35.8
Sodium	30.4	24.3	26.2
Sulfate	22.7	23.9	32.3
Sulfide	< 0.05	< 0.05	< 0.05
Total Dissolved Solids	253	235.0	238.0
Total Kjeldahl Nitrogen	0.35	0.23	0.18
Total Organic Carbon	1.34	< 1.0	< 1.0
Field Conductivity (µS)	310	307	321
Field Dissolved Oxygen	6.64	4.89	4.87
Field O.R.P. (mV)	+106	+6	+110
Field pH (S.U.)	7.62	7.22	7.46
Field Temperature (°F)	64.2	63.2	62.2

Analyses by Alchem Laboratories, Boise, ID
Samples collected on January 30, 2007 by Hydro Logic, Inc.

Water Levels

(feet below measure point = 3.5 feet above ground)

Date / Time (24-hr clock)	ZONE #1 (442 - 432 feet bgl)	ZONE #2 (419 - 399 feet bgl)	ZONE #3 (379 - 369 feet bgl)	ZONE #4 (354 - 334 feet bgl)	ZONE #5 (258 - 238 feet bgl)
1/05/07 13:05	261.42	261.48	261.68	261.79	unsaturated zone (installed to prove water table depth)
1/08/07 17:34	262.28	262.34	262.43	262.62	
1/18/07 10:07	263.30	263.34	263.42	263.60	
1/29/07 09:26	262.22	262.30	262.35	262.54	
4/30/07 11:39	262.62	262.63	262.71	262.90	
6/01/07 09:45	261.85	261.84	261.90	262.09	
7/03/07 09:54	262.34	263.74	263.81	263.99	
7/31/07 10:58	263.85	263.82	263.92	264.07	
8/30/07 10:01	263.93	263.95	263.96	264.18	
9/20/07 16:06	262.15	262.10	262.17	262.35	

Water levels recorded by Hydro Logic, Inc.

On site supervision, well design, pump test design, and water quality sampling by Hydro Logic, Inc., Boise, ID.
Direct mud-rotary drilling and well construction by Treasure Valley Drilling and Pump, Inc., Weiser, ID
Well development by McLeran Well Drilling, LLC, New Plymouth, ID.

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APPENDIX B – Pumping Test Methods of Analyses

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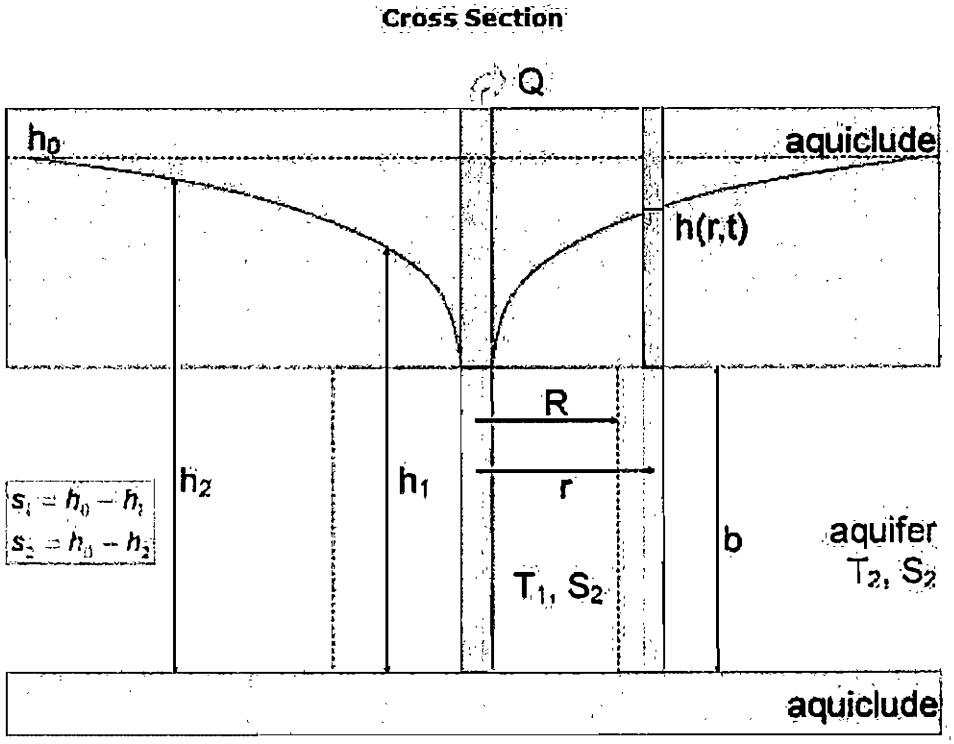
Details on the Method of Butler, J. J., Jr, 1988. (From Aqtesolv®)
Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is heterogeneous with a disk embedded in a matrix
- pumping well is fully penetrating
- flow to pumping well is horizontal
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head
- diameter of pumping well is very small so that storage in the well can be neglected

Equations:

$$\bar{s}_1 = \left(\frac{Q}{2\pi T_1}\right)\frac{K_0(Nr)}{p} + \left(\frac{Q}{2\pi T_1}\right)\frac{\left[K_1(NR)K_0(AR) - \frac{T_2}{T_1}\frac{A}{N}K_0(NR)K_1(AR)\right]I_0(Nr)}{p\left[\frac{T_2}{T_1}\frac{A}{N}I_0(NR)K_1(AR) + I_1(NR)K_0(AR)\right]}$$

$$\bar{s}_2 = \left(\frac{Q}{2\pi T_1}\right)\frac{\left[K_0(NR)I_1(NR) + K_1(NR)I_0(NR)\right]K_0(Ar)}{p\left[\frac{T_2}{T_1}\frac{A}{N}I_0(NR)K_1(AR) + I_1(NR)K_0(AR)\right]}$$

$$N = \sqrt{S_1 p / T_1}$$

$$A = \sqrt{S_2 p / T_2}$$

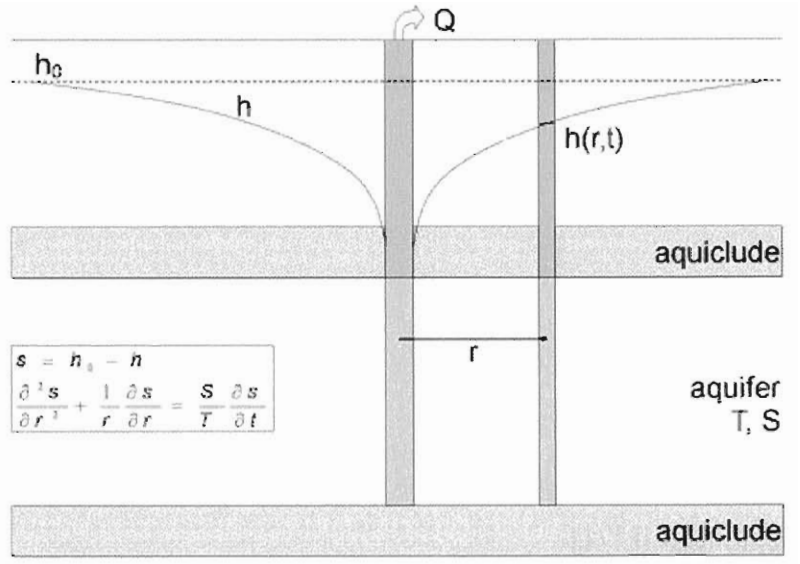
$$s_D = \frac{4\pi T}{Q}s$$

$$t_D = \frac{Tt}{r^2 S}$$

where

- I_i is modified Bessel function of first kind, order i
- K_i is modified Bessel function of second kind, order i
- p is Laplace transform variable
- Q is pumping rate [L^3/T]
- r is radial distance [L]
- R is radial distance to disk-matrix interface [L]
- s_1 is drawdown in the disk [L]
- s_2 is drawdown in the matrix [L]
- S_1 is storativity in the disk [dimensionless]
- S_2 is storativity in the matrix [dimensionless]
- t is time [T]
- T_1 is transmissivity in the disk [L^2/T]
- T_2 is transmissivity in the matrix [L^2/T]

Details on the Method of Cooper, H.H. and C.E. Jacob, 1946. (From Aqtesolv®)
Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous, isotropic and of uniform thickness
- pumping well is fully penetrating
- flow to pumping well is horizontal
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic
- diameter of pumping well is very small so that storage in the well can be
- values of u are small (i.e., r is small and t is large)

Equations:

For large values of time, Cooper and Jacob (1946) proposed the following equation for displacement in a confined aquifer in response to pumping:

$$s = \frac{2.303Q}{4\pi T}\log\left(\frac{2.25Tt}{r^2S}\right)$$

$$s_D = \frac{4\pi T}{Q}s$$

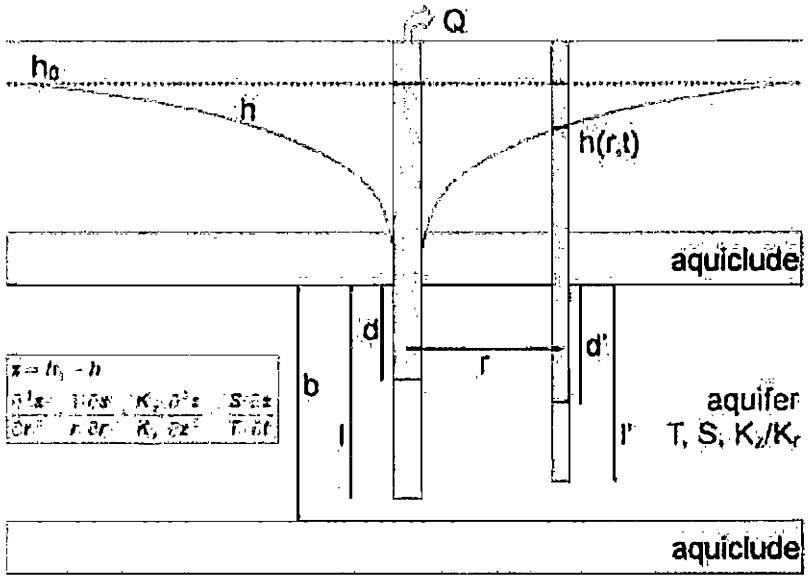
$$t_D = \frac{Tt}{r^2S}$$

where

- Q is pumping rate [L^3/T]
- r is radial distance [L]
- t is time [T]
- s is drawdown [L]
- S is storativity [dimensionless]
- T is transmissivity [L^2/T]

Details on the Method of Hantush, M.S. 1961a and b (From Aqtesolv®)

Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous and of uniform thickness
- pumping well is fully or partially penetrating
- flow to pumping well is horizontal when pumping well is fully penetrating
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head
- diameter of pumping well is very small so that storage in the well can be neglected

Equations:

Hantush (1961a, b) derived equations for the effects of partial penetration in a confined aquifer. For a piezometer, the partial penetration correction is as follows:

$$s = \frac{Q}{4\pi T}\left(W(u) + \frac{2b}{\pi(l-d)}\sum_{n=1}^{\infty}\frac{1}{n}\left[\sin\left(\frac{n\pi l}{b}\right) - \sin\left(\frac{n\pi d}{b}\right)\right]\cdot\cos\left(\frac{n\pi z}{b}\right)\cdot W\left(u,\sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b}\right)\right)$$

For an observation well, the following partial penetration correction applies:

$$s = \frac{Q}{4\pi T}\left(W(u) + \frac{2b^2}{\pi^2(l-d)(l'-d')}\sum_{n=1}^{\infty}\frac{1}{n^2}\left[\sin\left(\frac{n\pi l}{b}\right) - \sin\left(\frac{n\pi d}{b}\right)\right]\cdot\left[\sin\left(\frac{n\pi l'}{b}\right) - \sin\left(\frac{n\pi d'}{b}\right)\right]\cdot W\left(u,\sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b}\right)\right)$$

where

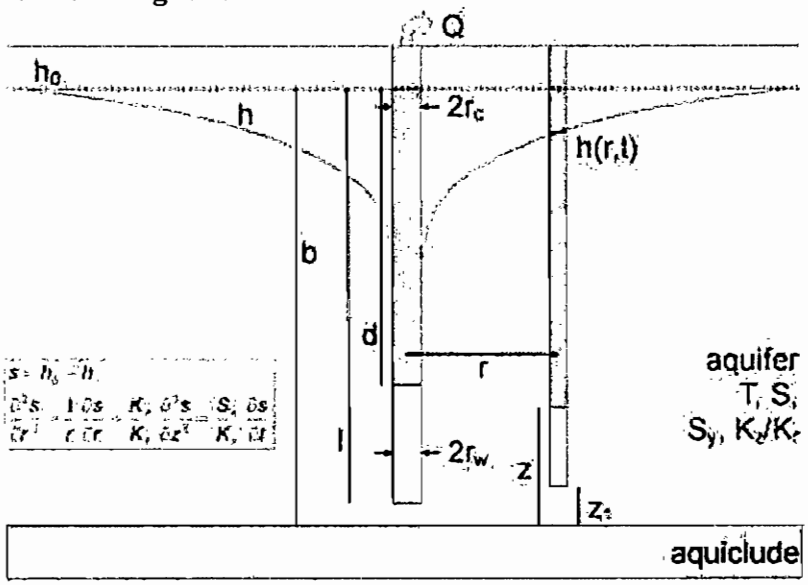
- b is aquifer thickness [L]
- d is depth to top of pumping well screen [L]
- d' is depth to top of observation well screen [L]
- l is depth to bottom of pumping well screen [L]
- l' is depth to bottom of observation well screen [L]
- K_z/K_r is vertical to horizontal hydraulic conductivity anisotropy [dimensionless]
- $w(u,\beta)$ is the Hantush-Jacob well function for leaky confined aquifers
- z is depth to piezometer opening [L]

At large distances, the effect of partial penetration becomes negligible when

$$r > 1.5b\Big/\sqrt{K_z/K_r}$$

Details on the Method of Moench, A.F. (From Aqtesolv®)

Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous and of uniform thickness
- aquifer potentiometric surface is initially horizontal
- pumping and observation wells are fully or partially penetrating
- flow is unsteady
- aquifer is unconfined with delayed gravity response

Equations:

$$\bar{h}_{wD} = \frac{2(A+S_w)}{p(l_D-d_D)[1+pW_D(A+S_w)]}$$

The following equation is the Laplace transform solution for dimensionless drawdown in a piezometer:

$$\bar{h}_D = \frac{2\bar{E}}{p(l_D-d_D)[1+pW_D(A+S_w)]}$$

The equation for dimensionless drawdown in an observation well is:

$$\bar{h}'_D = \frac{2\bar{E}'}{p(l_D-d_D)[1+pW_D(A+S_w)]}$$

$$A = \frac{2}{(l_D-d_D)}\sum_{n=0}^{\infty}\frac{K_0(q_n)(\sin[\varepsilon_n(1-d_D)]-\sin[\varepsilon_n(1-l_D)])^2}{\varepsilon_n q_n K_1(q_n)[\varepsilon_n+0.5\sin(2\varepsilon_n)]}$$

$$\bar{E} = 2\sum_{n=0}^{\infty}\frac{K_0(q_n r_D)\cos(\varepsilon_n z_D)\sin[\varepsilon_n(1-d_D)]-\sin[\varepsilon_n(1-l_D)]}{q_n K_1(q_n)[\varepsilon_n+0.5\sin(2\varepsilon_n)]}$$

$$\bar{E}' = 2\sum_{n=0}^{\infty}\frac{K_0(q_n r_D)[\sin(\varepsilon_n z_{2D})-\sin(\varepsilon_n z_{1D})][\sin[\varepsilon_n(1-d_D)]-\sin[\varepsilon_n(1-l_D)]]}{(z_{2D}-z_{1D})\varepsilon_n q_n K_1(q_n)[\varepsilon_n+0.5\sin(2\varepsilon_n)]}$$

$$W_D = \frac{\pi_o^2}{2\pi r_w^2 S_s(l-d)}$$

$$q_n = \sqrt{\varepsilon^2\beta_w + p}$$

$$q_n r_D = \sqrt{\varepsilon^2\beta + pr_D^2}$$

$$\beta_w = \frac{r_w^2 K_z}{b^2 K_r}$$

$$\beta = \frac{r^2 K_z}{b^2 K_r}$$

$$t_D = \frac{Kt}{S_s r_w^2}$$

$$h_D = \frac{4\pi Kb}{Q}(h_0 - h)$$

$$r_D = \frac{r}{r_w}$$

$$\sigma = \frac{S_s b}{S_y}$$

$$\gamma = \alpha_1 b S_y / K_z$$

ε_n are the roots of

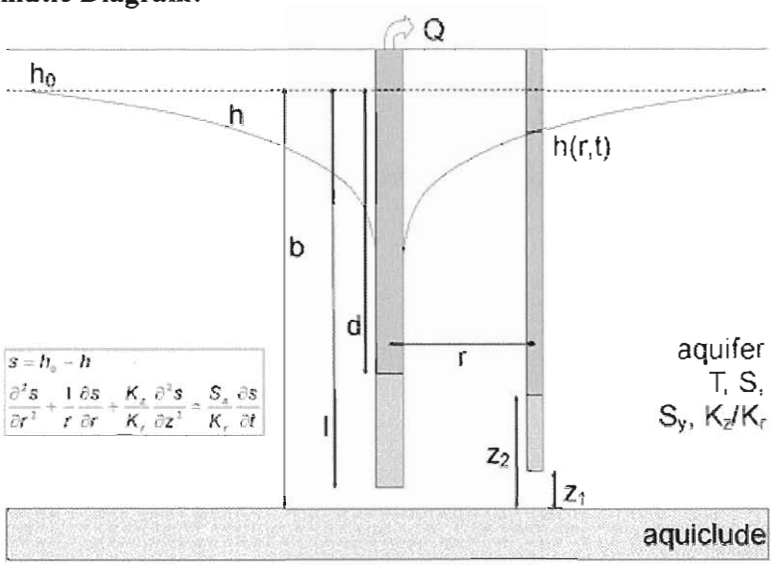
$$\varepsilon_n \tan(\varepsilon_n) = \frac{p}{(\sigma\beta + p/\gamma)}$$

where

- α_1 is an empirical constant (fitting parameter) for noninstantaneous drainage [1/T]
- b is aquifer thickness [L]
- d is distance from water table to top of pumping well screen [L]

- d_D is d/b
- K, K_r is radial hydraulic conductivity [L/T]
- K_z is vertical hydraulic conductivity [L/T]
- K_i is modified Bessel function of second kind, order i
- l is distance from water table to bottom of pumping well screen [L]
- l_D is l/b
- p is the Laplace transform variable
- Q is pumping rate [L^3/T]
- r is radial distance [L]
- r_c is casing radius [L]
- r_w is well radius [L]
- S_s is specific storage [1/L]
- S_w is wellbore skin factor [dimensionless]
- S_y is specific yield [dimensionless]
- t is time [T]
- z is elevation of piezometer above base of aquifer [L]
- z_D is z/b
- z_1 is elevation of bottom of observation well screen above base of aquifer [L]

Details on the Method of Neuman, S.P., 1974. (From Aqtesolv®)
Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous and has uniform thickness
- aquifer potentiometric surface is initially horizontal
- pumping well is fully or partially penetrating
- aquifer is unconfined with delayed gravity response
- flow is unsteady
- diameter of pumping well is very small so that storage in the well can be neglected

Equations:

$$s = \frac{Q}{4\pi T}\int_0^\infty 4yJ_0(y\sqrt{\beta})\left[u_0(y) + \sum_{n=1}^{\infty} u_n(y)\right]dy$$

$$\beta = \frac{r^2 K_z}{b^2 K_r}$$

$$\sigma = \frac{S}{S_y}$$

where

- b is aquifer thickness [L]
- K_r is radial hydraulic conductivity [L/T]
- K_z is vertical hydraulic conductivity [L/T]
- Q is pumping rate [L^3/T]
- r is radial distance [L]
- s is drawdown [L]
- S is storativity [dimensionless]
- S_y is specific yield [dimensionless]
- T is transmissivity [L^2/T]

The drawdown in a piezometer is found using the following equations:

$$u_0(y) = \frac{[1-\exp(-l_s\beta(y^2-\gamma_0^2))]\cosh(\gamma_0 z_D)}{[y^2+(1+\sigma)\gamma_0^2-(y^2-\gamma_0^2)^2/\sigma]\cosh(\gamma_0)} \cdot \frac{\sinh(\gamma_0(1-d_D))-\sinh(\gamma_0(1-l_D))}{(l_D-d_D)\sinh(\gamma_0)}$$

$$u_n(y) = \frac{[1-\exp(-l_s\beta(y^2+\gamma_n^2))]\cos(\gamma_n z_D)}{[y^2-(1+\sigma)\gamma_n^2-(y^2+\gamma_n^2)^2/\sigma]\cos(\gamma_n)} \cdot \frac{\sin(\gamma_n(1-d_D))-\sin(\gamma_n(1-l_D))}{(l_D-d_D)\sin(\gamma_n)}$$

The drawdown in a partially penetrating observation well is found using the following equations:

$$u_0(y) = \frac{[1-\exp(-l_s\beta(y^2-\gamma_0^2))][\sinh(\gamma_0 z_{2D})-\sinh(\gamma_0 z_{1D})]}{[y^2+(1+\sigma)\gamma_0^2-(y^2-\gamma_0^2)^2/\sigma]\cosh(\gamma_0)} \cdot \frac{\sinh(\gamma_0(1-d_D))-\sinh(\gamma_0(1-l_D))}{(z_{2D}-z_{1D})(l_D-d_D)\sinh(\gamma_0)}$$

$$u_n(y) = \frac{[1-\exp(-l_s\beta(y^2+\gamma_n^2))][\sin(\gamma_0 z_{2D})-\sin(\gamma_0 z_{1D})]}{[y^2-(1+\sigma)\gamma_n^2-(y^2+\gamma_n^2)^2/\sigma]\cos(\gamma_n)} \cdot \frac{\sin(\gamma_n(1-d_D))-\sin(\gamma_n(1-l_D))}{(z_{2D}-z_{1D})(l_D-d_D)\sin(\gamma_n)}$$

The gamma terms are the roots of the following equations:

$$\sigma\gamma_0\sinh(\gamma_0)-(y^2-\gamma_0^2)\cosh(\gamma_0)=0 \qquad \gamma_0^2 < y^2$$

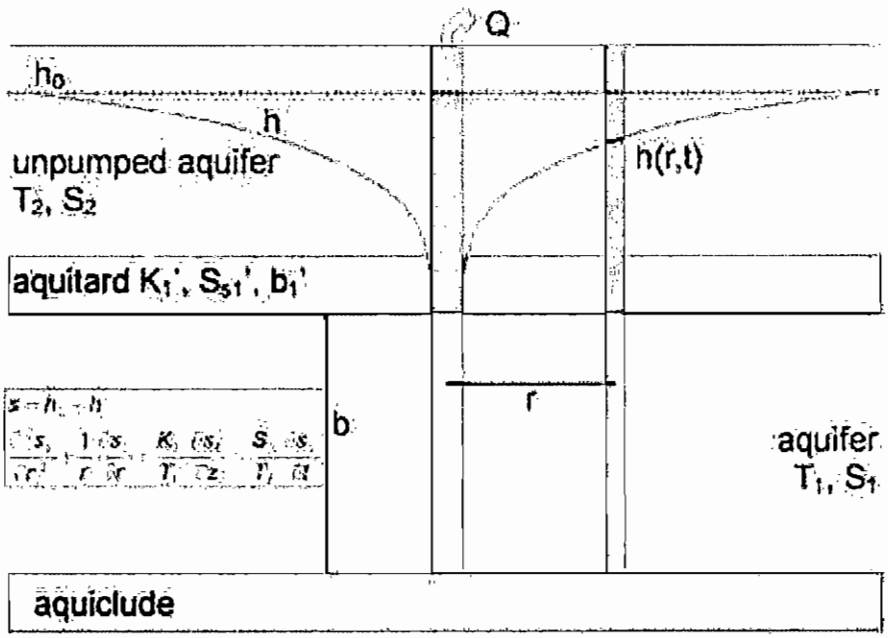
$$\sigma\gamma_n\sin(\gamma_n)+(y^2+\gamma_n^2)\cos(\gamma_n)=0 \qquad (2n-1)(\pi/2) < \gamma_n < n\pi \quad n \geq 1$$

where

- d_D is dimensionless depth to top of pumping well screen (d/b)
- J_0 is Bessel function of first kind, zero order

Details on the Method of Neuman, S.P., and Witherspoon, P. 1972. (From Aqtesolv®)

Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous, isotropic and of uniform thickness
- pumping well is fully penetrating
- flow to pumping well is horizontal
- aquifer is leaky confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head
- diameter of pumping well is very small so that storage in the well can be neglected
- confining bed(s) has infinite areal extent, uniform vertical hydraulic conductivity, storage coefficient and thickness
- flow is vertical in the aquitard(s)

Equations:

$$s_1 = \frac{Q}{4\pi T}\int_0^\infty (1-e^{-y^2 t_D})([1+G(y)]J_0(\omega_1(y))+[1-G(y)]J_0(\omega_2(y)))\frac{dy}{y}$$

$$s_1' = \frac{Q}{4\pi T}\frac{2}{\pi}\sum_0^\infty \frac{1}{n}\sin\frac{n\pi z}{b_1'}\int_0^\infty [1-e^{-n^2\pi^2 t_D} + \frac{e^{-n^2\pi^2 t_D} - e^{-y^2 t_D}}{1-y^2/(n^2\pi^2)}]([\frac{2(r/B_{21})^2(-1)^n y}{F(y)\sin y} - G(y) - 1]J_0(\omega_1(y))$$

$$-[\frac{2(r/B_{21})^2(-1)}{F(y)\sin y} - G(y) + 1]J_0(\omega_2(y)))\frac{dy}{y}$$

$$s_2 = \frac{Q}{4\pi T}\int_0^\infty (1-e^{-y^2 t_D})\frac{2(r/B_{21})^2}{F(y)}[J_0(\omega_1(y)) - J_0(\omega_2(y))]\frac{dy}{\sin y}$$

$$t_\alpha = \frac{T_1 t}{r^2 S_1}$$

$$t_\alpha = t_\alpha (r/B_{11})^4/(4\beta_{11})^2$$

$$r/B_{ij} = r\sqrt{K_i'/T_i b_j'}$$

$$\beta_j = \frac{r}{4b_j}\sqrt{\frac{K_j' S_s'}{K_i S_s}}$$

$$G(y) = M(y)/F(y)$$

$$\omega_1^2(y) = \frac{1}{2}[N(y) + F(y)]$$

$$\omega_2^2(y) = \frac{1}{2}[N(y) - F(y)]$$

$$F^2(y) = M^2(y) + \left[\frac{2(r/B_{11})(r/B_{21})y}{\sin y}\right]^2$$

$$M(y) = \left[\frac{(r/B_{11})^4}{(4\beta_{11})^2} - \frac{(r/B_{21})^4}{(4\beta_{21})^2}\right]y^2 - \left[(r/B_{11})^2 - (r/B_{21})^2\right]y\cot y$$

$$N(y) = \left[\frac{(r/B_{11})^4}{(4\beta_{11})^2} + \frac{(r/B_{21})^4}{(4\beta_{21})^2}\right]y^2 - \left[(r/B_{11})^2 + (r/B_{21})^2\right]y\cot y$$

$$s_D = \frac{4\pi T}{Q}s$$

$$t_D = \frac{Tt}{r^2 S}$$

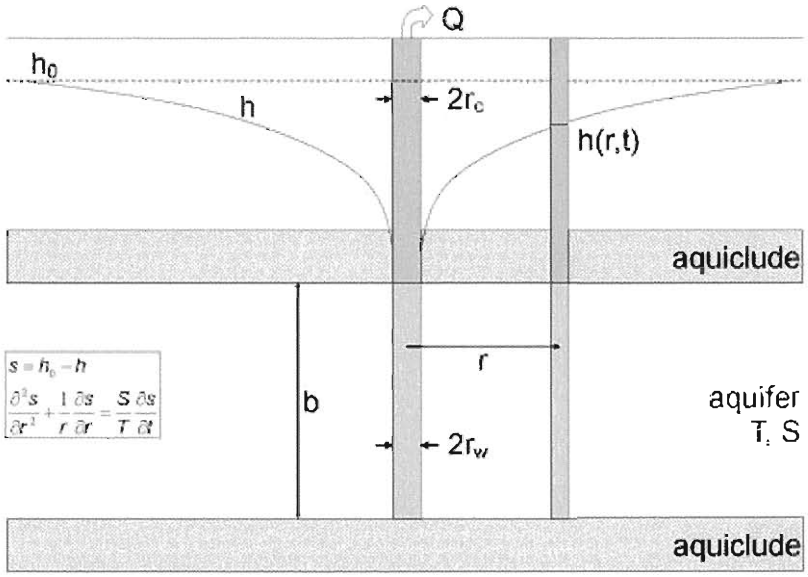
where

- b_i is thickness of aquifer i [L]
- b_j' is thickness of aquitard j [L]
- J_0 is Bessel function of first kind, zero order
- K_i is horizontal hydraulic conductivity in aquifer i [L/T]
- K_j' is vertical hydraulic conductivity in aquitard j [L/T]
- Q is pumping rate [L^3/T]
- r is radial distance [L]
- s_1 is drawdown in the pumped aquifer [L]

- s'_1 is drawdown in the aquit: ard [L]
- s_2 is drawdown in the unpun ıped aquifer [L]
- S, S_1 is storativity in the pu mped aquifer [dimensionless]
- t is time [T]
- T, T_1 is transmissivity in the pumped aquifer [L^2/T]

Details on the Method of Papadopulos, I.S. and H.H. Cooper, 1967. (From Aqtesolv®)

Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous, isotropic and of uniform thickness
- pumping well is fully penetrating
- flow to pumping well is horizontal
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head

Equations:

Papadopulos and Cooper (1967) derived a solution for a finite-diameter pumping well with wellbore storage in a confined aquifer as follows:

$$s = \frac{Q}{4\pi T} F(u, \alpha, r_D)$$

$$F = \frac{8\alpha}{\pi} \int_0^\infty \frac{(1 - e^{-\beta^2 u/4\alpha})[J_0(\beta r_D) A(\beta) - Y_0(\beta r_D) B(\beta)]}{([A(\beta)]^2 - [B(\beta)]^2)\beta^2} d\beta$$

$$A(\beta) = \beta Y_0(\beta) - 2\alpha Y_1(\beta)$$

$$B(\beta) = \beta J_0(\beta) - 2\alpha J_1(\beta)$$

$$u = \frac{r^2 S}{4Tt}$$

$$\alpha = \frac{r_w^2 S}{r_c^2}$$

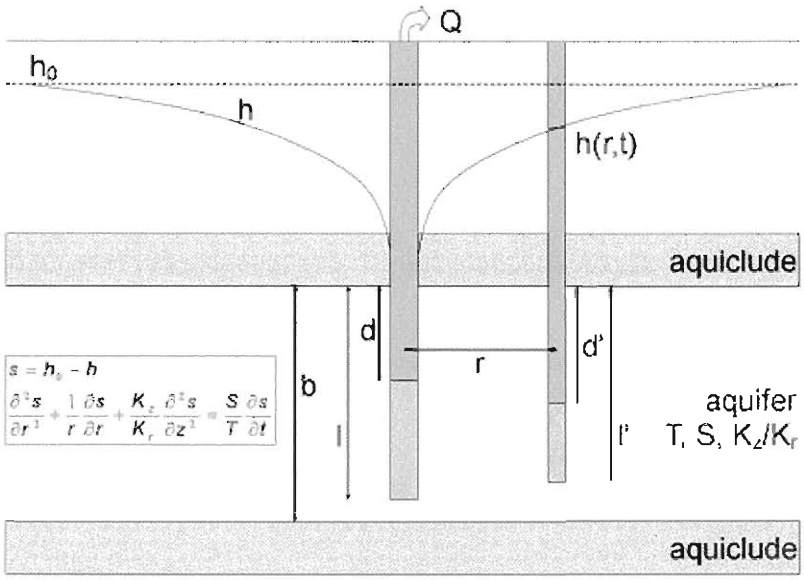
$$r_D = \frac{r}{r_w}$$

where

- J_i is Bessel function of first kind, order i
- Q is pumping rate [L^3/T]
- r is radial distance [L]
- r_c is casing radius [L]
- r_w is well radius [L]
- s is drawdown [L]
- S is storativity [dimensionless]
- t is time [T]
- T is transmissivity [L^2/T]
- Y_i is Bessel function of second kind, order i

Details on the Method of Theis, C.V., 1935. (Pumping) (From Aqtesolv®)

Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous and of uniform thickness
- pumping well is fully or partially penetrating
- flow to pumping well is horizontal when pumping well is fully penetrating
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head
- diameter of pumping well is very small so that storage in the well can be neglected

Equations:

$$s = \frac{Q}{4\pi T}\int_{u}^{\infty}\frac{e^{-y}}{y}dy$$

$$u = \frac{r^2 S}{4Tt}$$

where

- Q is pumping rate [L^3/T]
- r is radial distance [L]
- s is drawdown [L]
- S is storativity [dimensionless]
- t is time [T]
- T is transmissivity [L^2/T]

Hydrogeologists commonly refer to the exponential integral in the drawdown equation as the Theis well function, abbreviated as w(u). Therefore, we can write the Theis drawdown equation in compact notation as follows:

$$s = \frac{Q}{4\pi T}w(u)$$

Hantush (1961a, b) derived equations for the effects of partial penetration in a confined aquifer. For a piezometer, the partial penetration correction is as follows:

$$s = \frac{Q}{4\pi T}\left(w(u) + \frac{2b}{\pi(l-d)}\sum_{n=1}^{\infty}\frac{1}{n}\left[\sin\left(\frac{n\pi l}{b}\right) - \sin\left(\frac{n\pi d}{b}\right)\right]\cdot\cos\left(\frac{n\pi z}{b}\right)\ w\left(u, \sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b}\right)\right)$$

For an observation well, the following partial penetration correction applies:

$$s = \frac{Q}{4\pi T}\left(w(u) + \frac{2b^2}{\pi^2(l-d)(l'-d')}\sum_{n=1}^{\infty}\frac{1}{n^2}\left[\sin\left(\frac{n\pi l}{b}\right) - \sin\left(\frac{n\pi d}{b}\right)\right]\left[\sin\left(\frac{n\pi l'}{b}\right) - \sin\left(\frac{n\pi d'}{b}\right)\right]\cdot w\left(u, \sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b}\right)\right)$$

where

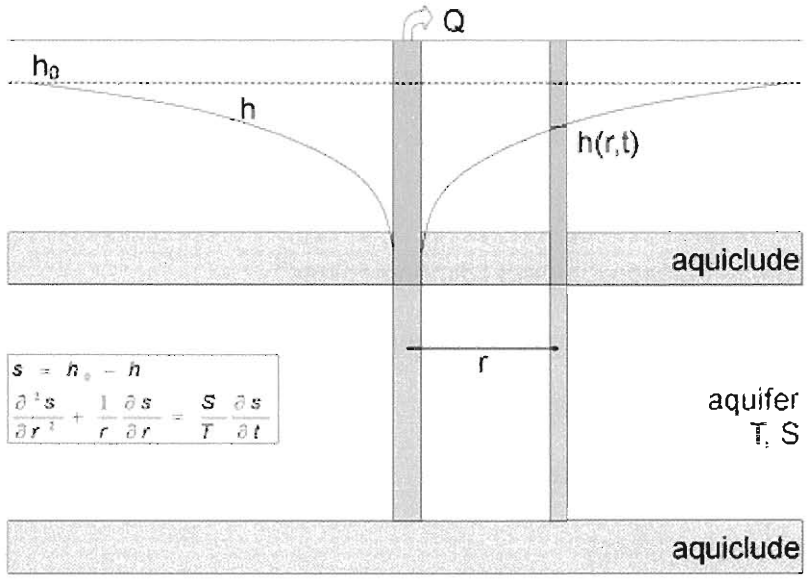
- b is aquifer thickness [L]
- d is depth to top of pumping well screen [L]
- d' is depth to top of observation well screen [L]
- l is depth to bottom of pumping well screen [L]
- l' is depth to bottom of observation well screen [L]
- K_z/K_r is vertical to horizontal hydraulic conductivity anisotropy [dimensionless]
- w(u,β) is the Hantush-Jacob well function for leaky confined aquifers
- z is depth to piezometer opening [L]

At large distances, the effect of partial penetration becomes negligible when

$$r > 1.5b/\sqrt{K_z/K_r}$$

Details on the Method of Theis, C.V., 1935. (Straight-Line Recovery) (From Aqtesolv®)

Schematic Diagram:



$$s = h_0 - h$$

$$\frac{\partial^2 s}{\partial r^2} + \frac{1}{r}\frac{\partial s}{\partial r} = \frac{S}{T}\frac{\partial s}{\partial t}$$

Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous, isotropic and of uniform thickness
- pumping well is fully penetrating
- flow to pumping well is horizontal
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head
- diameter of pumping well is very small so that storage in the well can be neglected
- values of u are small (i.e., r is small and t is large)

Equations:

$$s' = \frac{Q}{4\pi T}\left[\ln(t/t') - \ln(S/S')\right]$$

where

- Q is pumping rate [L^3/T]
- s' is residual drawdown [L]
- S is storativity during pumping [dimensionless]
- S' is storativity during recovery [dimensionless]
- t is time since pumping began [T]
- t' is time since pumping stopped [T]
- T is transmissivity[L^2/T]

APPENDIX C – Kling Irrigation Well Test Data: Water Levels and Barometric Efficiency

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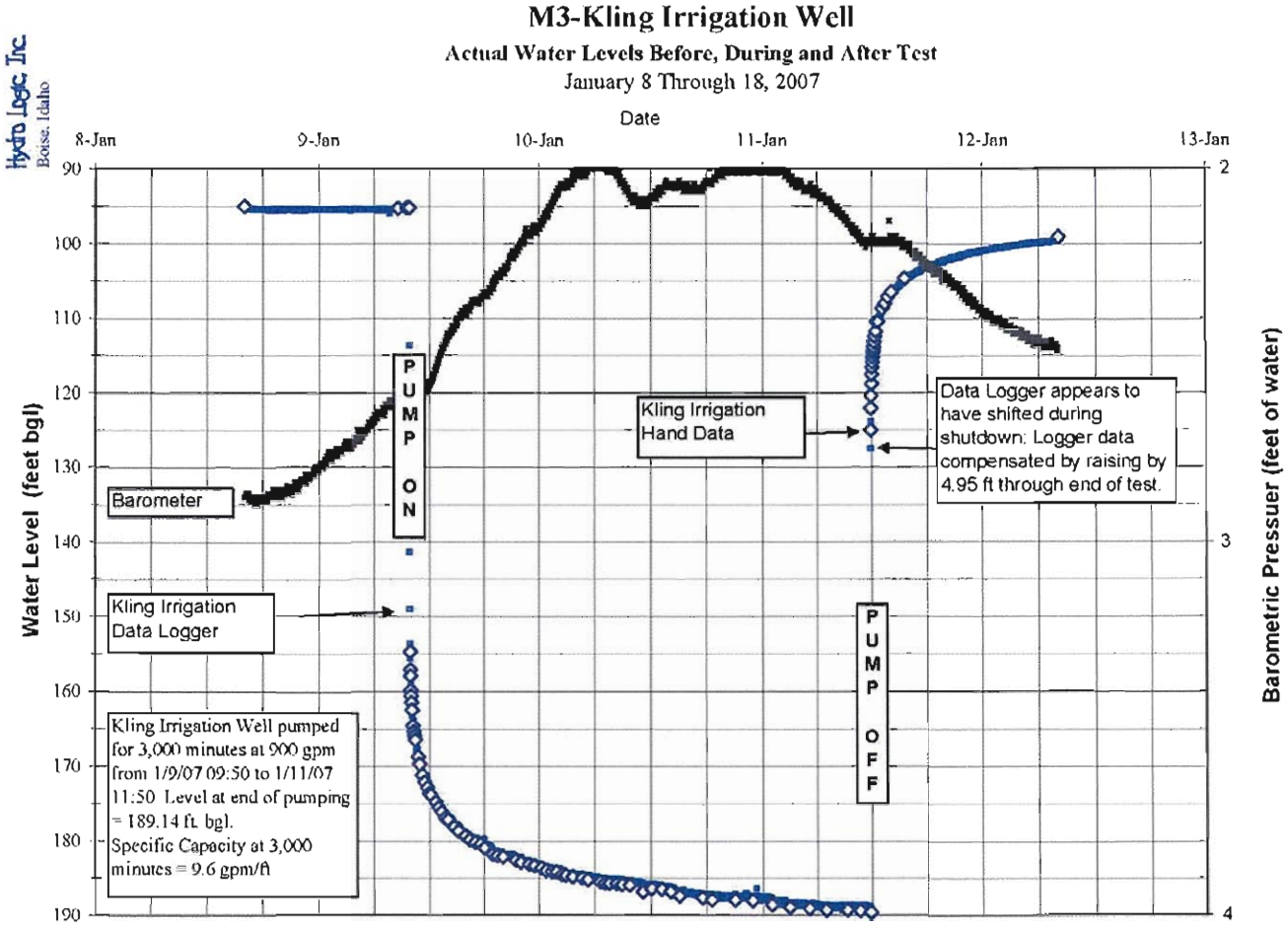
M3-Kling Irrigation Well
Actual Water Levels Before, During and After Test
January 8 Through 18, 2007
Hydro Logic Inc
Boise, Idaho
Date
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
Water Level (feet bgl)
Barometric Pressuer (feet of water)
90
100
110
120
130
140
150
160
170
180
190
2
3
4
PUMP ON
PUMP OFF
Barometer
Kling Irrigation Data Logger
Kling Irrigation Hand Data
Data Logger appears to have shifted during shutdown: Logger data compensated by raising by 4.95 ft through end of test.
Kling Irrigation Well pumped for 3,000 minutes at 900 gpm from 1/9/07 09:50 to 1/11/07 11:50 Level at end of pumping = 189.14 ft. bgl.
Specific Capacity at 3,000 minutes = 9.6 gpm/ft

Figure C-1.

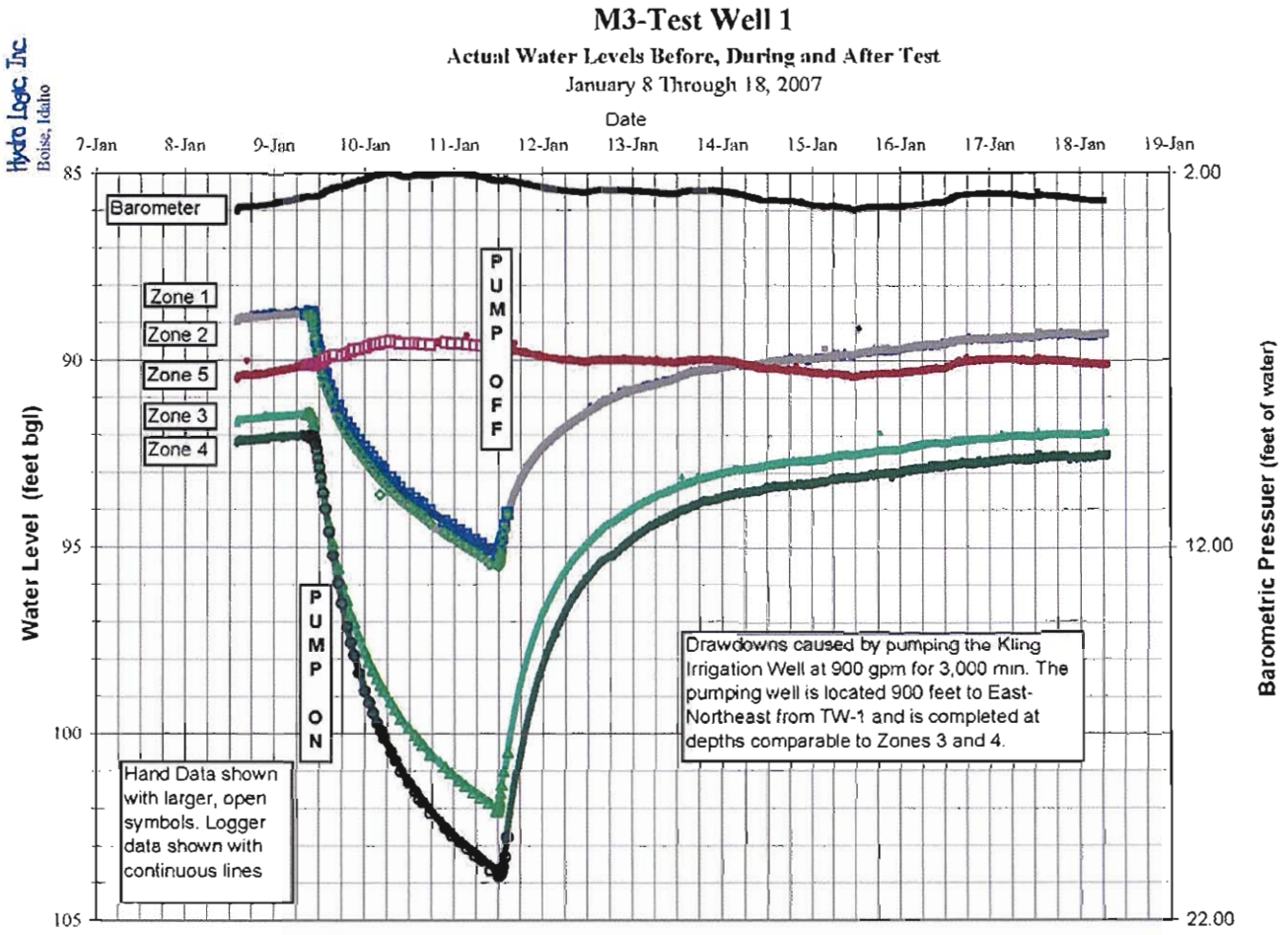
M3-Test Well 1
Actual Water Levels Before, During and After Test
January 8 Through 18, 2007
Hydro Logic, Inc.
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
Water Level (feet bgl)
85
90
95
100
105
Barometric Pressuer (feet of water)
2.00
12.00
22.00
Barometer
Zone 1
Zone 2
Zone 5
Zone 3
Zone 4
PUMP OFF
PUMP ON
Drawdowns caused by pumping the Kling Irrigation Well at 900 gpm for 3,000 min. The pumping well is located 900 feet to East-Northeast from TW-1 and is completed at depths comparable to Zones 3 and 4.
Hand Data shown with larger, open symbols. Logger data shown with continuous lines

Figure C-2

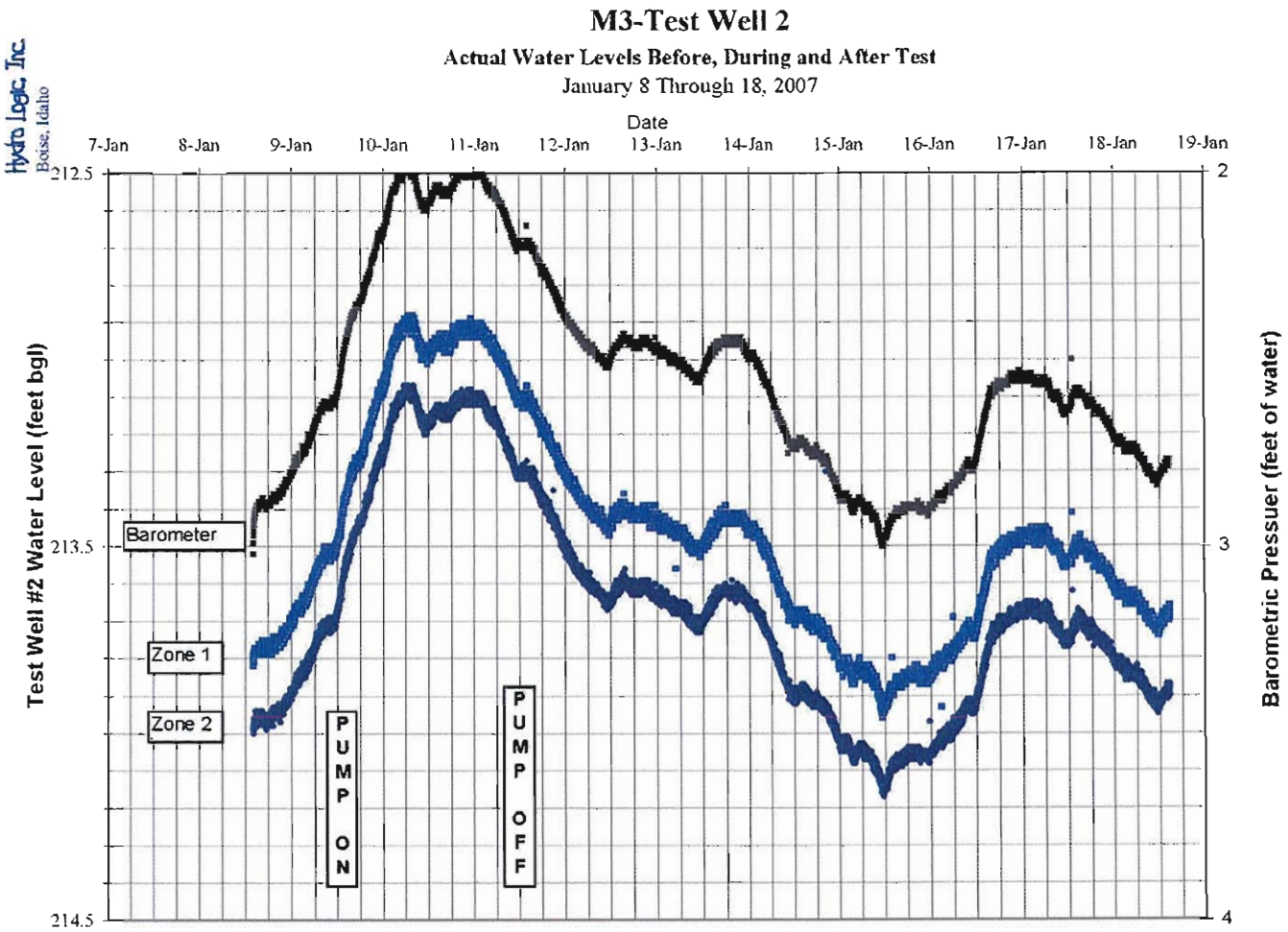
M3-Test Well 2
Actual Water Levels Before, During and After Test
January 8 Through 18, 2007
Hydro Logic Inc.
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
212.5
213.5
214.5
2
3
4
Test Well #2 Water Level (feet bgl)
Barometric Pressuer (feet of water)
Barometer
Zone 1
Zone 2
PUMP ON
PUMP OFF

Figure C-3.

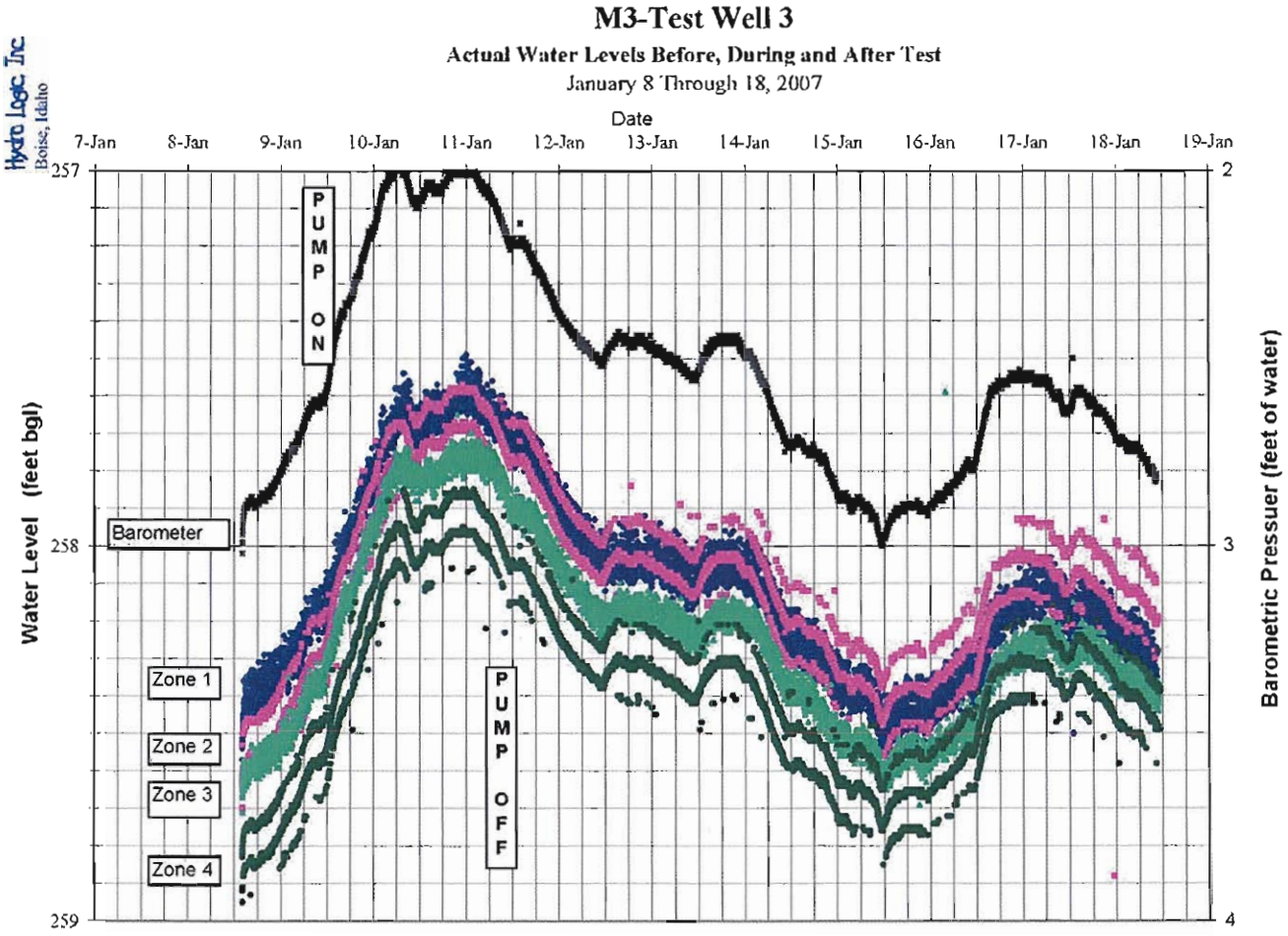
M3-Test Well 3
Actual Water Levels Before, During and After Test
January 8 Through 18, 2007
Hydro Logic Inc
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
257
258
259
2
3
4
Water Level (feet bgl)
Barometric Pressuer (feet of water)
PUMP ON
PUMP OFF
Barometer
Zone 1
Zone 2
Zone 3
Zone 4

Figure C-4.

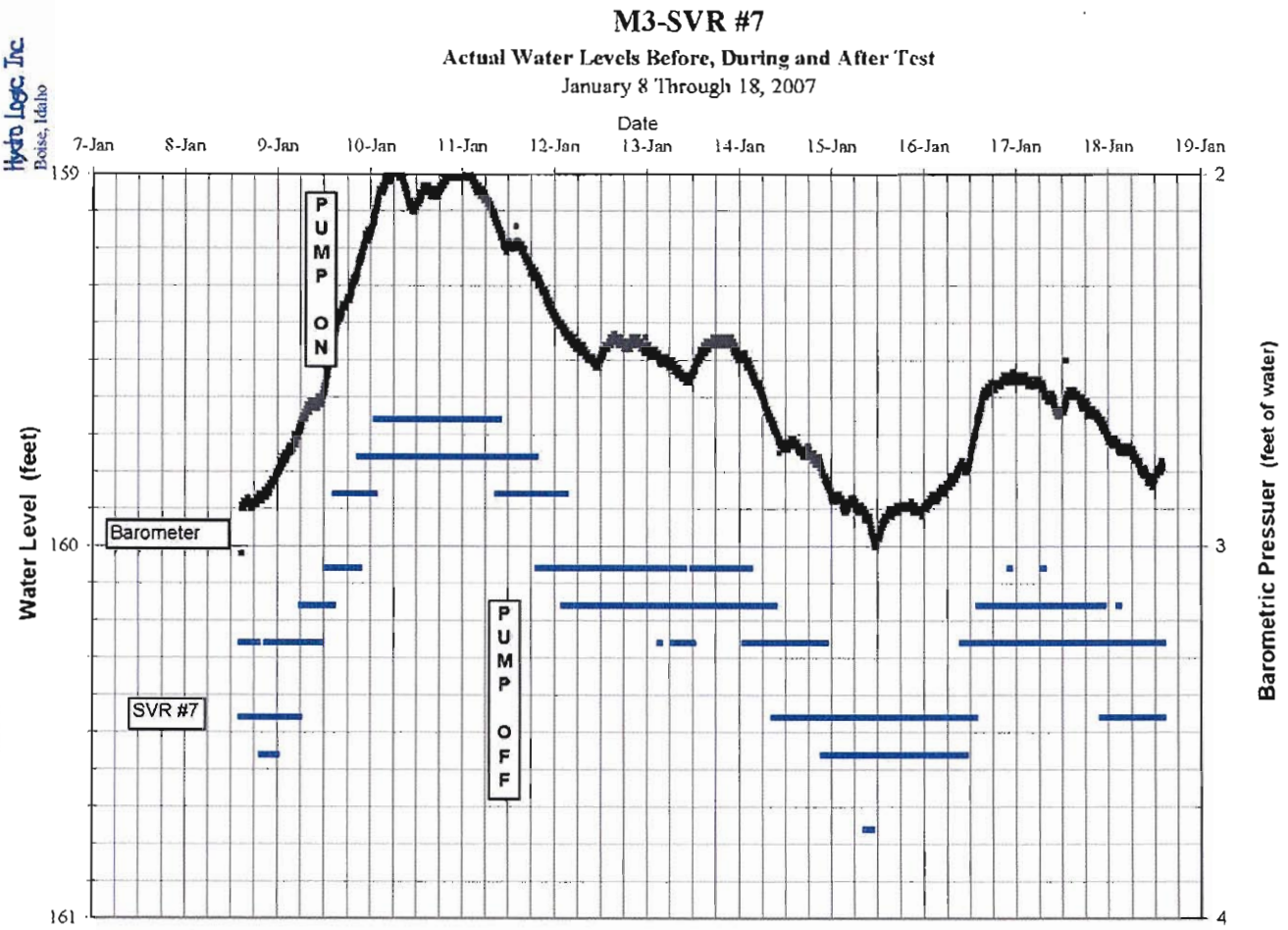
M3-SVR #7
Actual Water Levels Before, During and After Test
January 8 Through 18, 2007
Hydro Logic, Inc.
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
159
160
161
2
3
4
Water Level (feet)
Barometric Pressuer (feet of water)
PUMP ON
PUMP OFF
Barometer
SVR #7

Figure C-5.

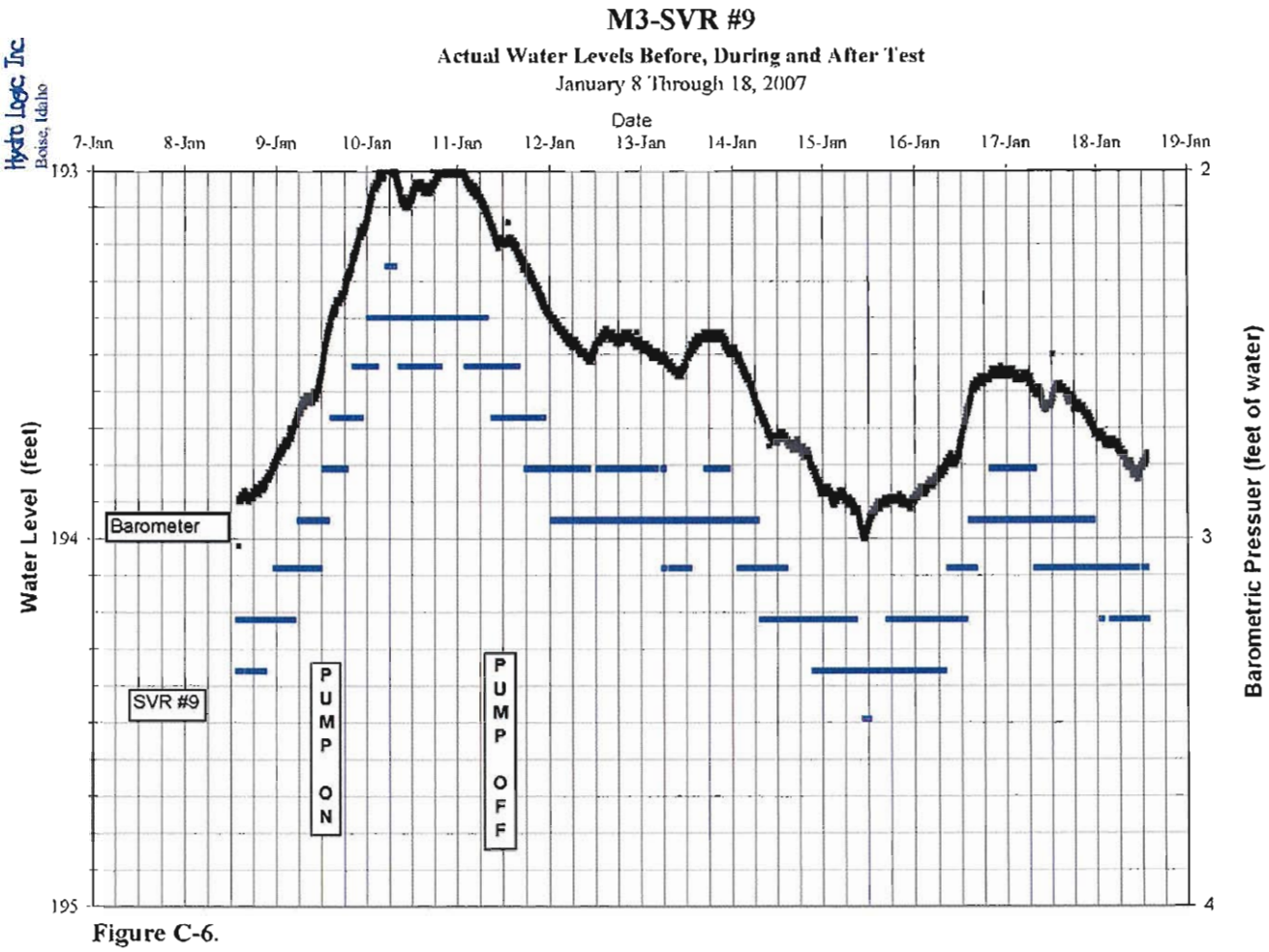
M3-SVR #9
Actual Water Levels Before, During and After Test
January 8 Through 18, 2007
Hydro Logic Inc
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
193
194
195
2
3
4
Water Level (feet)
Barometric Pressuer (feet of water)
Barometer
SVR #9
PUMP ON
PUMP OFF

Figure C-6.

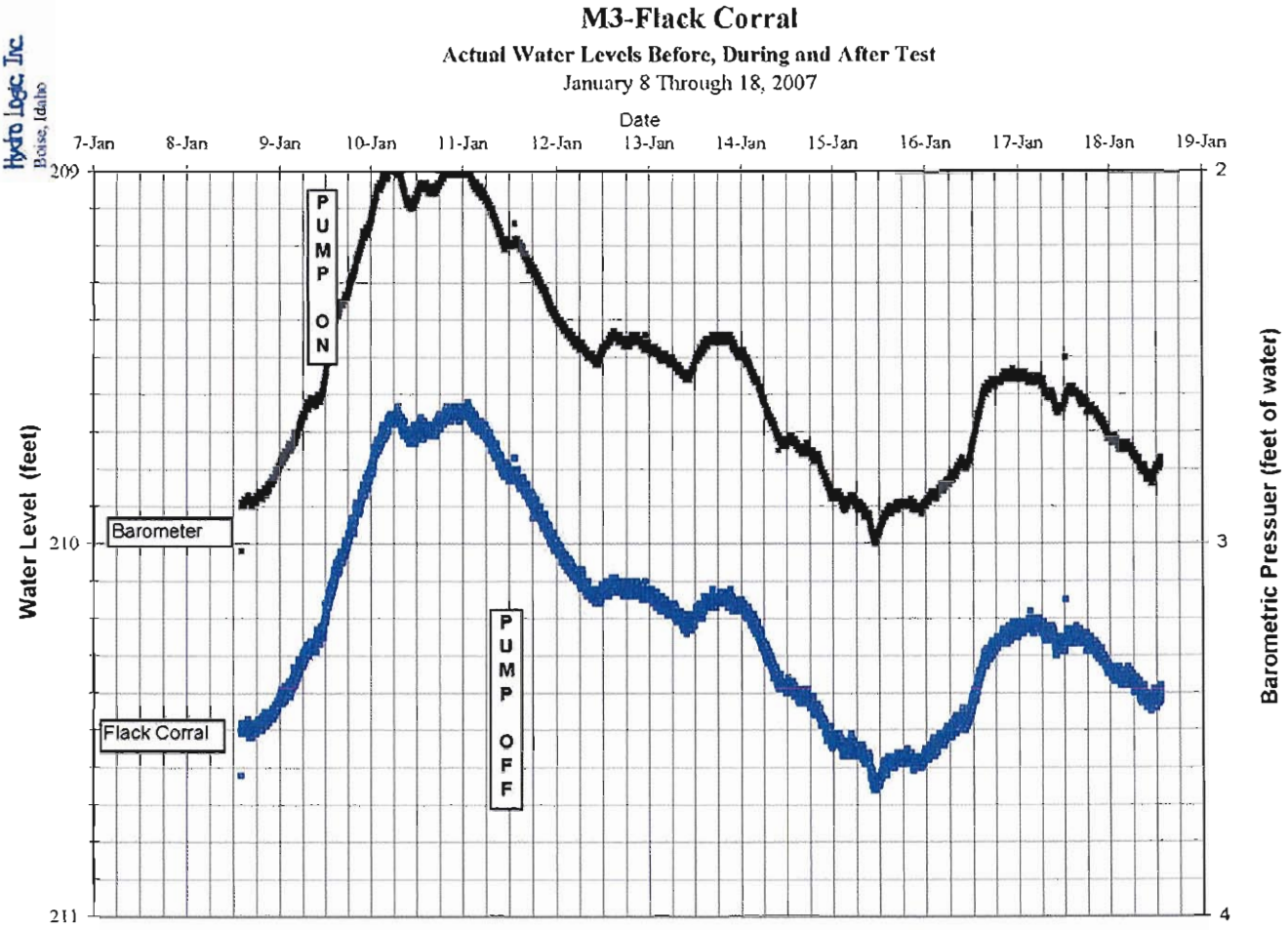
M3-Flack Corral
Actual Water Levels Before, During and After Test
January 8 Through 18, 2007
Hydro Logic Inc.
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
209
210
211
2
3
4
Water Level (feet)
Barometric Pressuer (feet of water)
PUMP ON
PUMP OFF
Barometer
Flack Corral

Figure C-7.

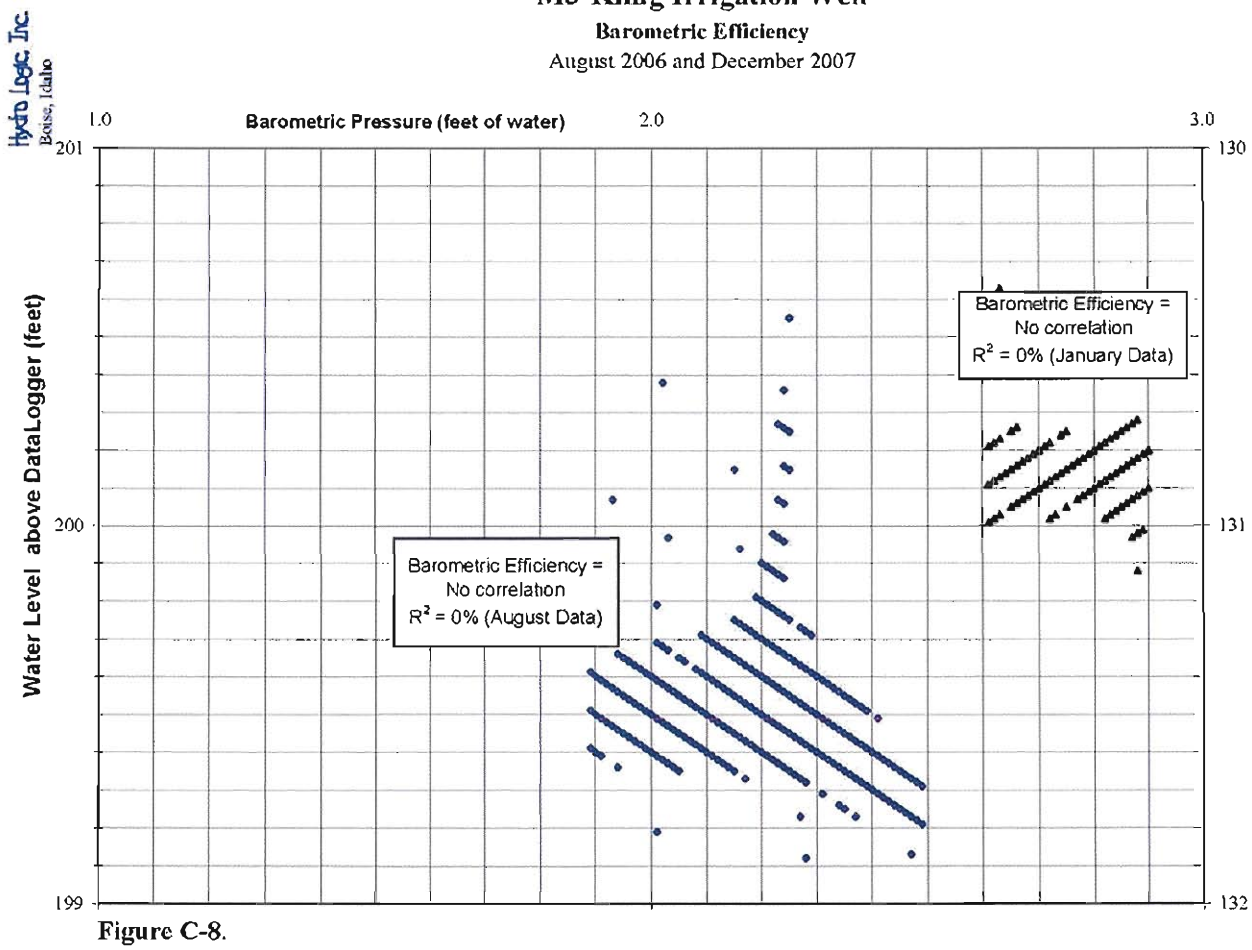
M3-Kling Irrigation Well
Barometric Efficiency
August 2006 and December 2007
Hydro Logic, Inc.
Boise, Idaho
Barometric Pressure (feet of water)
1.0
2.0
3.0
Water Level above DataLogger (feet)
201
200
199
130
131
132
Barometric Efficiency = No correlation
R² = 0% (August Data)
Barometric Efficiency = No correlation
R² = 0% (January Data)

Figure C-8.

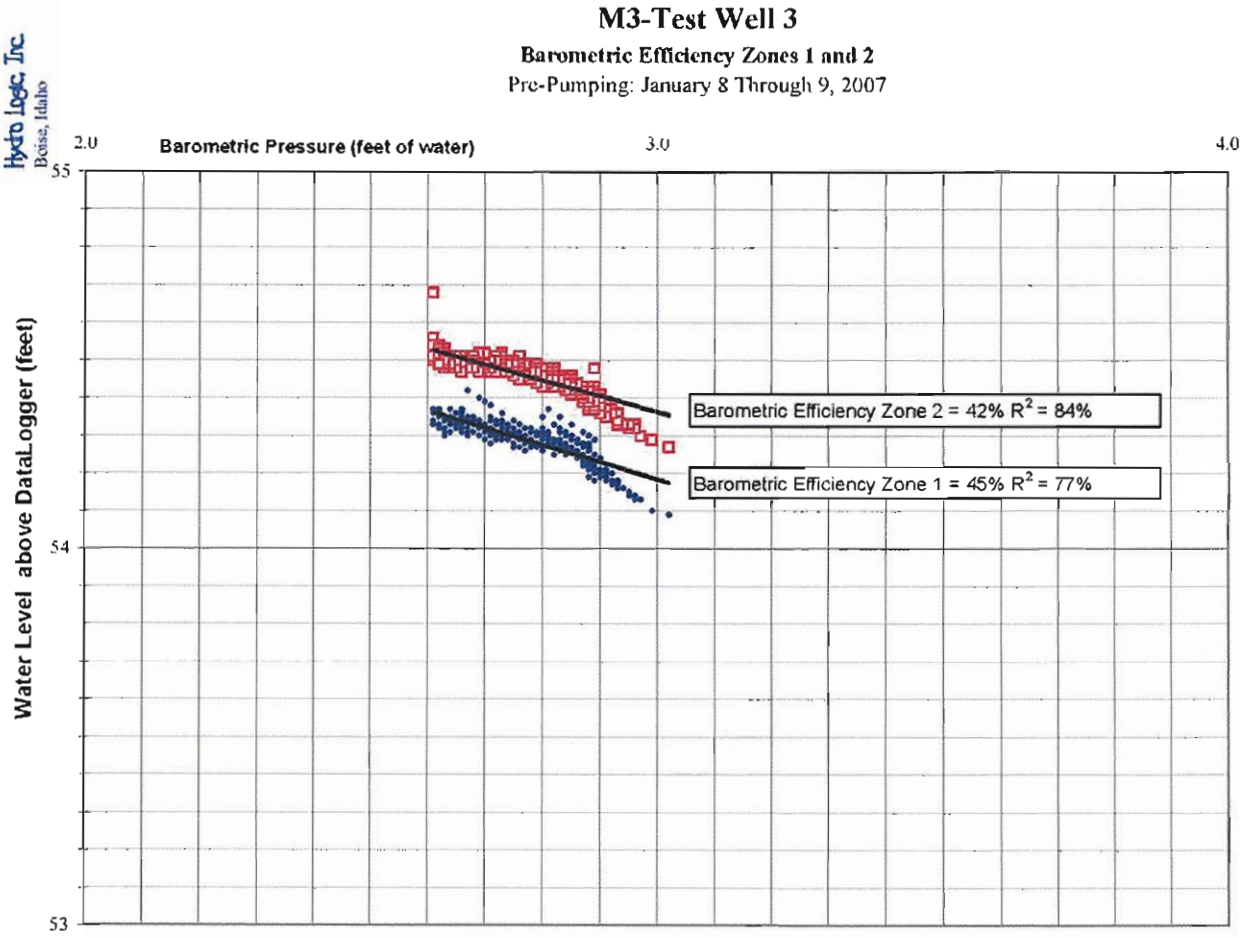
M3-Test Well 3
Barometric Efficiency Zones 1 and 2
Pre-Pumping: January 8 Through 9, 2007
Barometric Pressure (feet of water)
2.0
3.0
4.0
Water Level above DataLogger (feet)
55
54
53
Barometric Efficiency Zone 2 = 42% R2 = 84%
Barometric Efficiency Zone 1 = 45% R2 = 77%

Figure C-9.

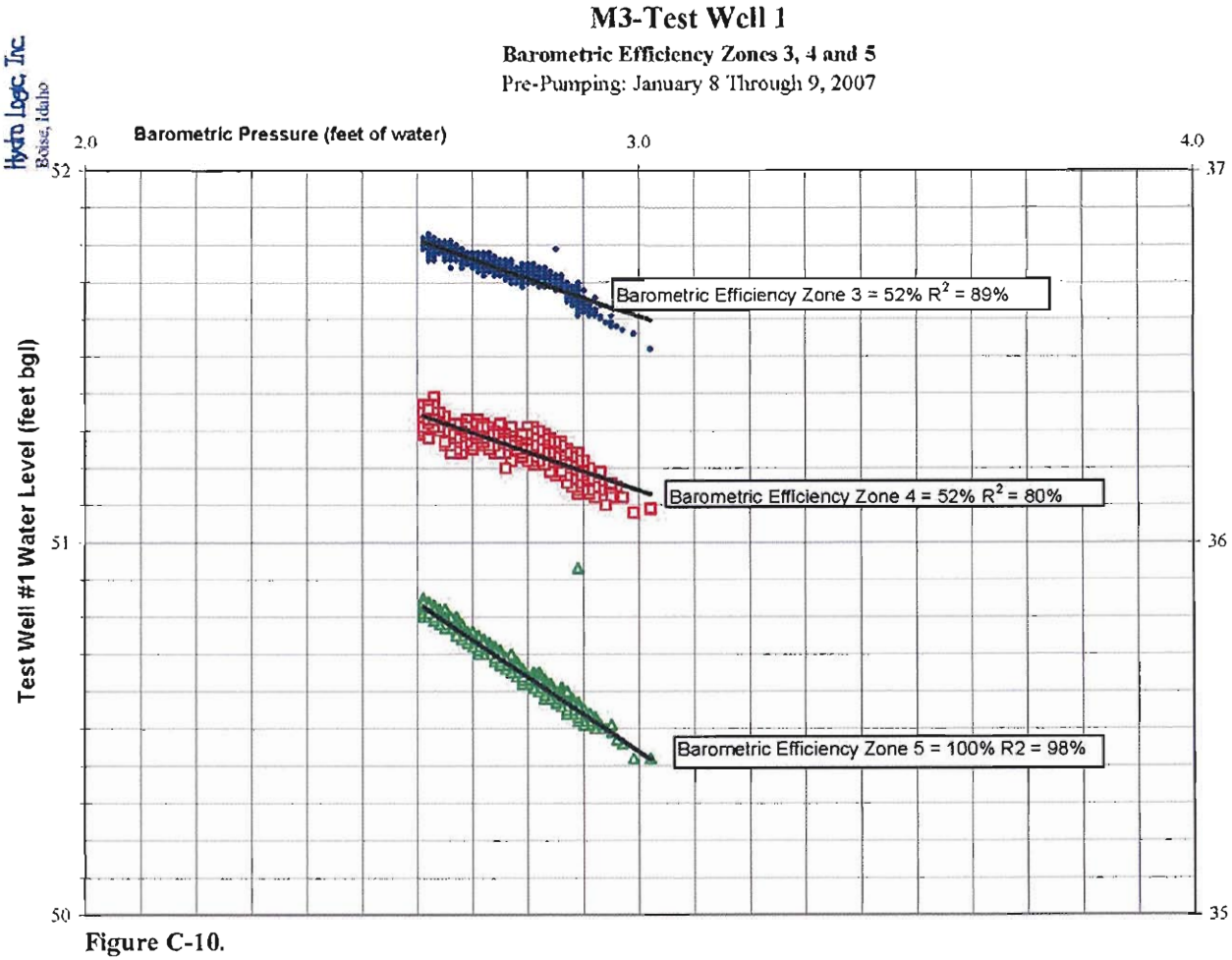
M3-Test Well 1
Barometric Efficiency Zones 3, 4 and 5
Pre-Pumping: January 8 Through 9, 2007
Hydro Logic Inc
Boise, Idaho
Barometric Pressure (feet of water)
2.0
3.0
4.0
52
51
50
37
36
35
Test Well #1 Water Level (feet bgl)
Barometric Efficiency Zone 3 = 52% R2 = 89%
Barometric Efficiency Zone 4 = 52% R2 = 80%
Barometric Efficiency Zone 5 = 100% R2 = 98%

Figure C-10.

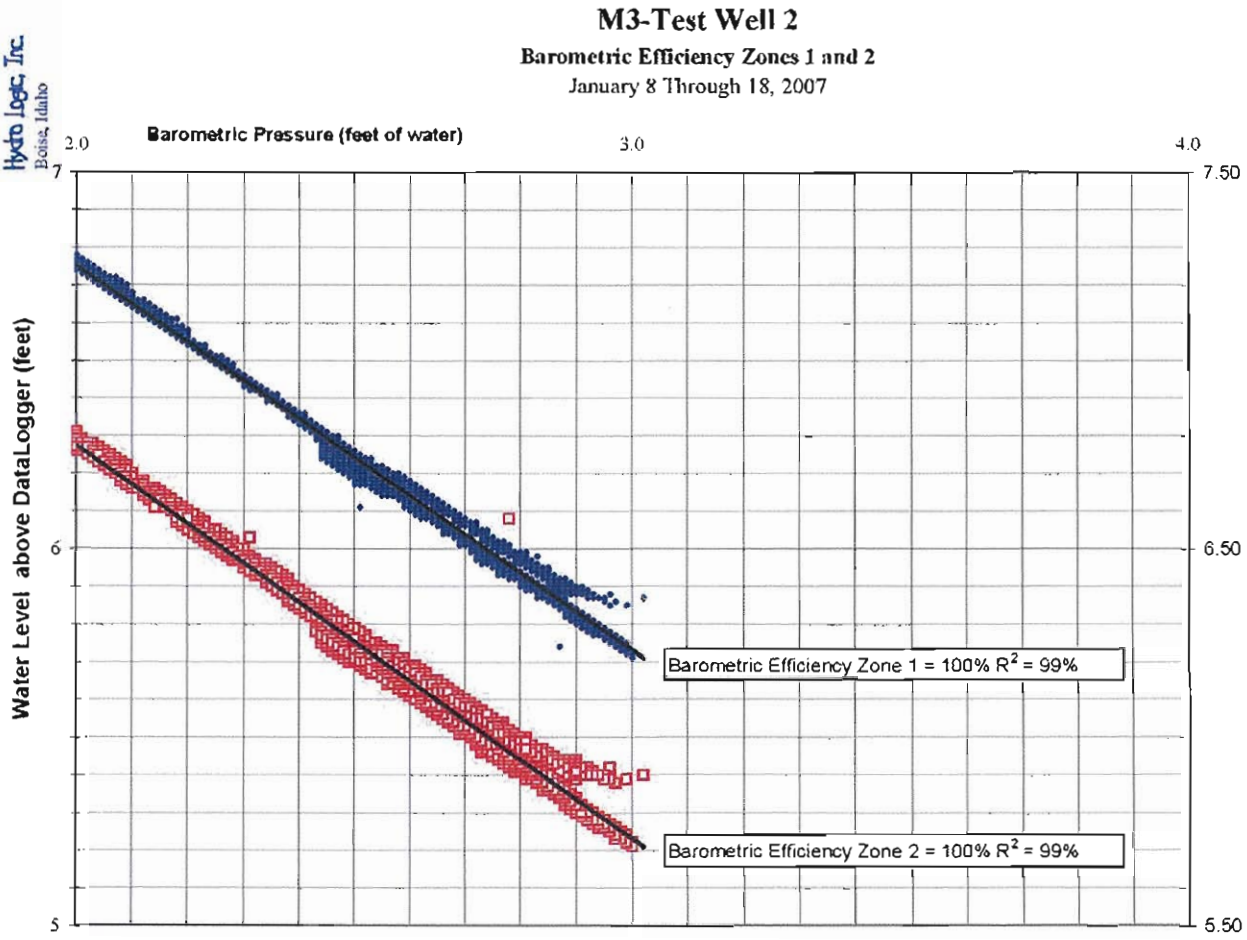
M3-Test Well 2
Barometric Efficiency Zones 1 and 2
January 8 Through 18, 2007
Hydro Logic Inc.
Boise, Idaho
Barometric Pressure (feet of water)
2.0
3.0
4.0
Water Level above DataLogger (feet)
7
6
5
7.50
6.50
5.50
Barometric Efficiency Zone 1 = 100% R2 = 99%
Barometric Efficiency Zone 2 = 100% R2 = 99%

Figure C-11.

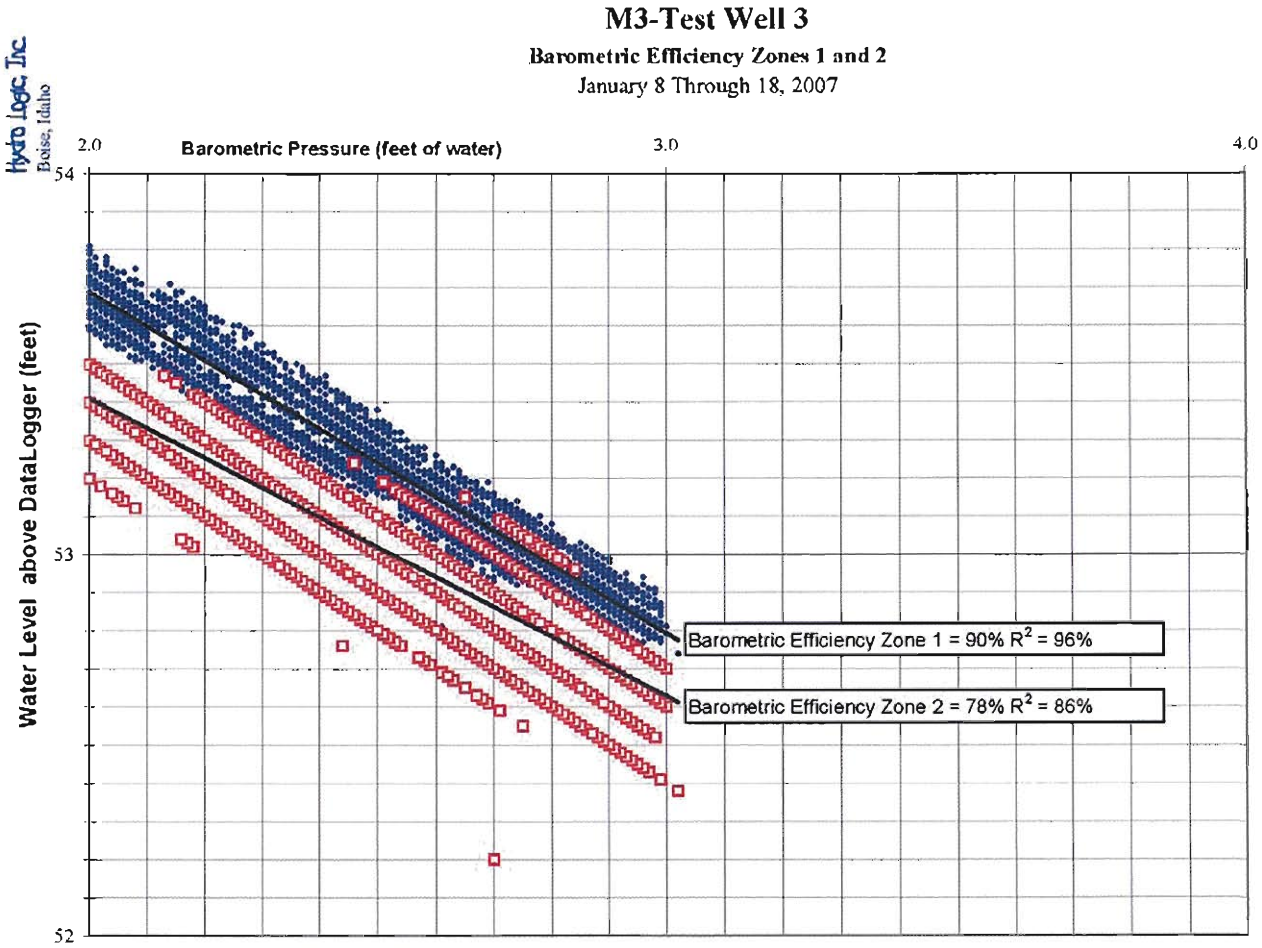
M3-Test Well 3
Barometric Efficiency Zones 1 and 2
January 8 Through 18, 2007
Hydro Logic Inc.
Boise, Idaho
Barometric Pressure (feet of water)
2.0
3.0
4.0
54
53
52
Water Level above DataLogger (feet)
Barometric Efficiency Zone 1 = 90% R2 = 96%
Barometric Efficiency Zone 2 = 78% R2 = 86%

Figure C-12.

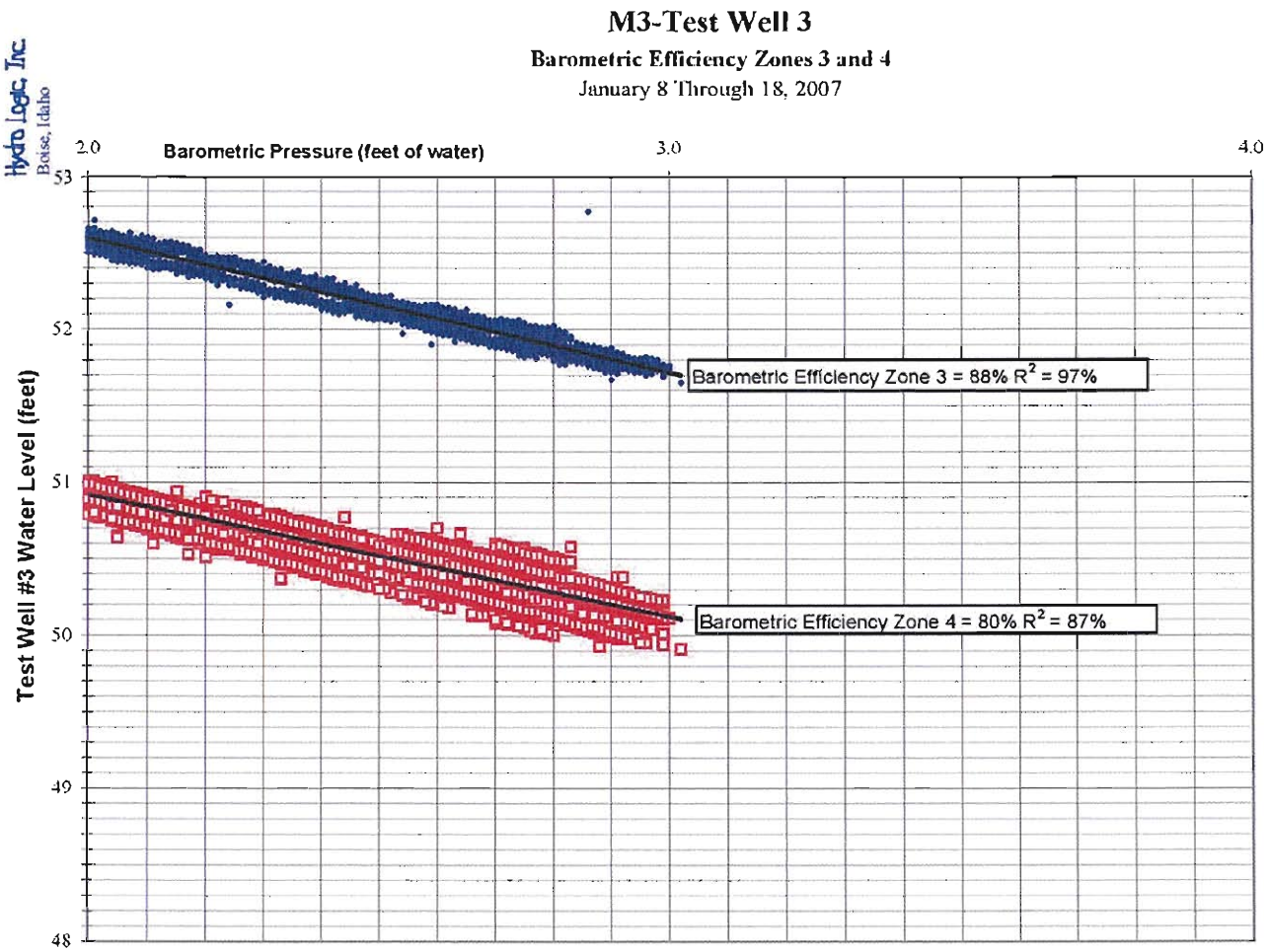
M3-Test Well 3
Barometric Efficiency Zones 3 and 4
January 8 Through 18, 2007
Hydro Logic Inc
Boise, Idaho
Barometric Pressure (feet of water)
2.0
3.0
4.0
Test Well #3 Water Level (feet)
53
52
51
50
49
48
Barometric Efficiency Zone 3 = 88% R2 = 97%
Barometric Efficiency Zone 4 = 80% R2 = 87%

Figure C-13.

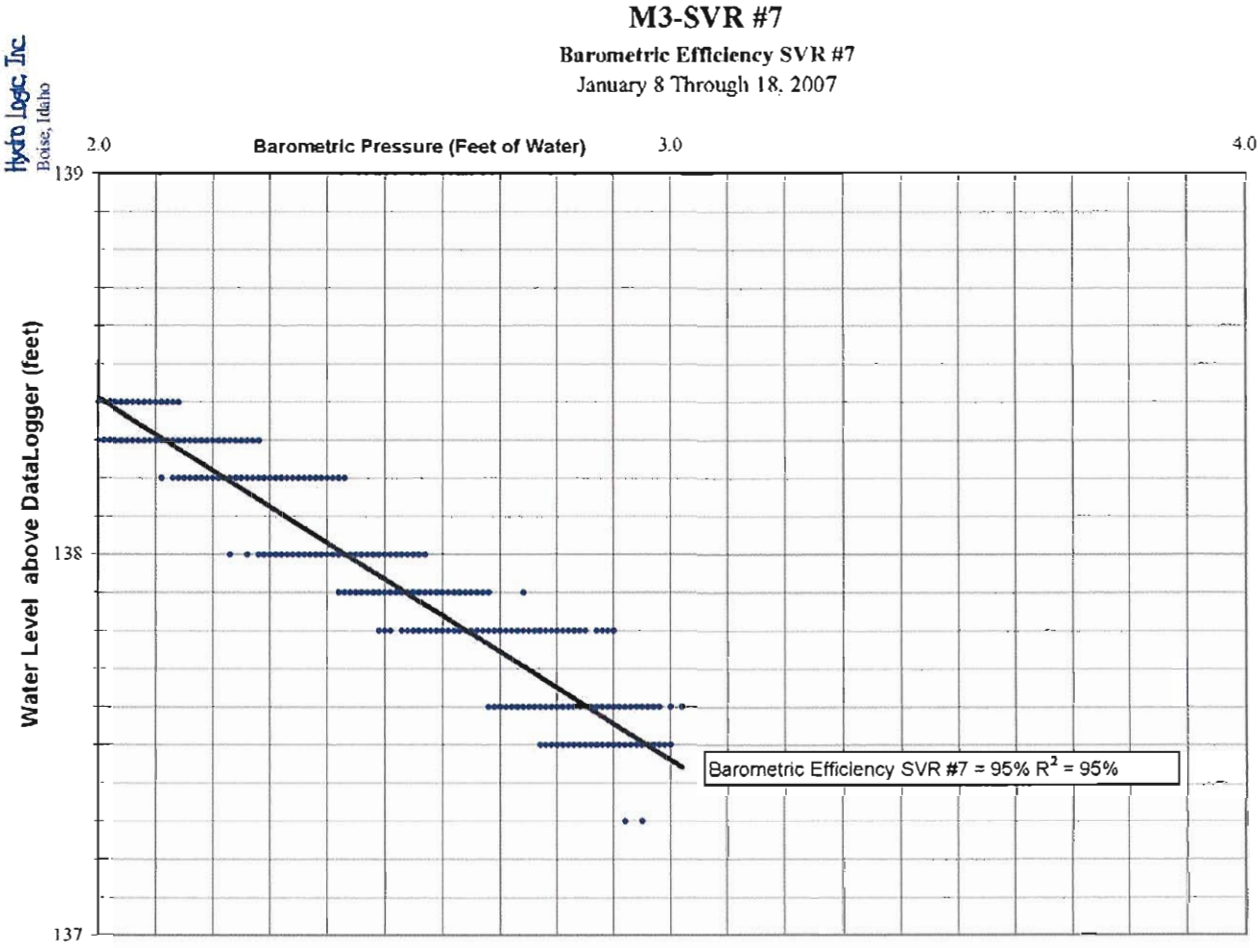
M3-SVR #7
Barometric Efficiency SVR #7
January 8 Through 18, 2007
Hydro Logic Inc
Boise, Idaho
2.0
Barometric Pressure (Feet of Water)
3.0
4.0
139
138
137
Water Level above DataLogger (feet)
Barometric Efficiency SVR #7 = 95% R2 = 95%

Figure C-14.

Hydro Logic Inc.
Boise, Idaho

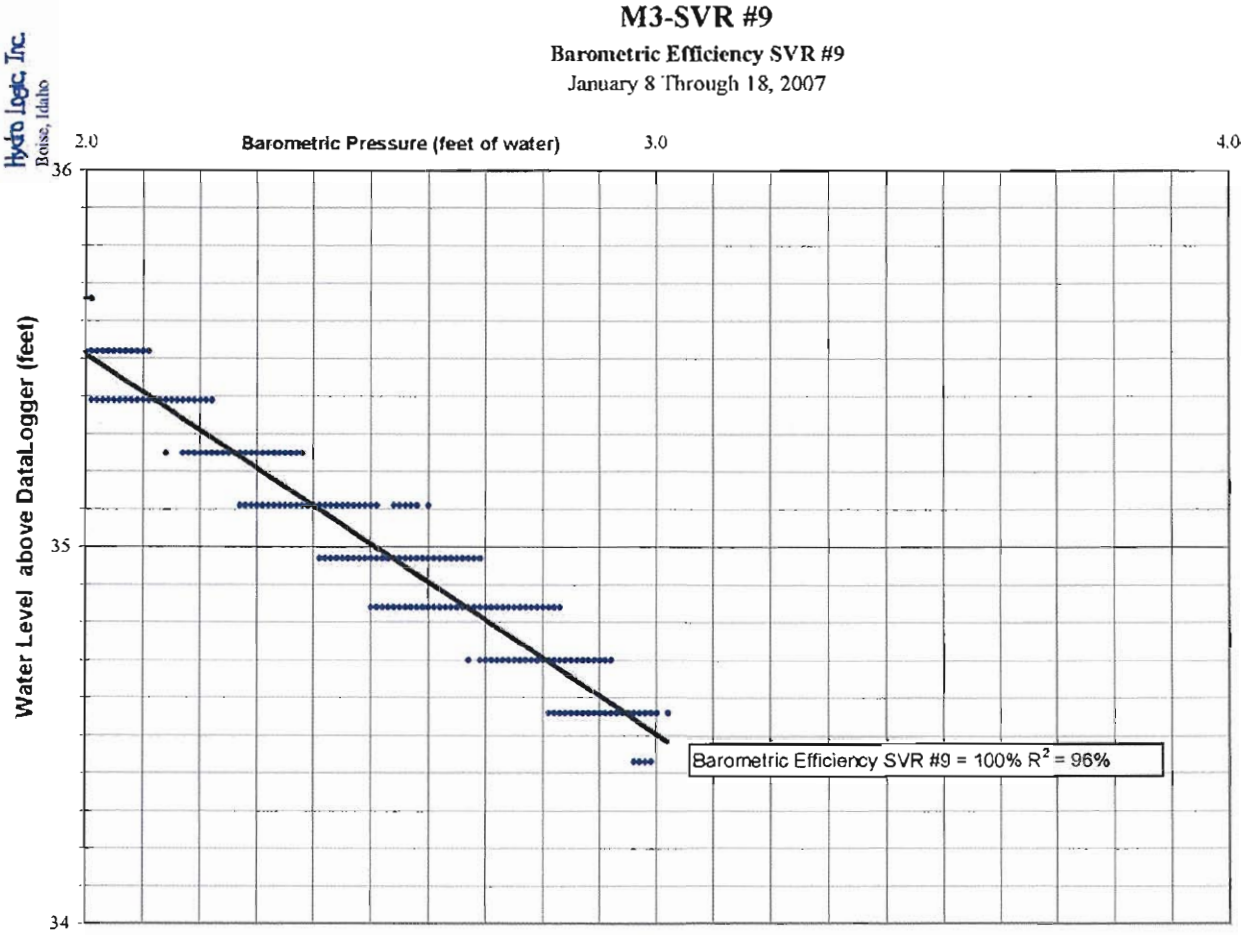

Figure C-15.

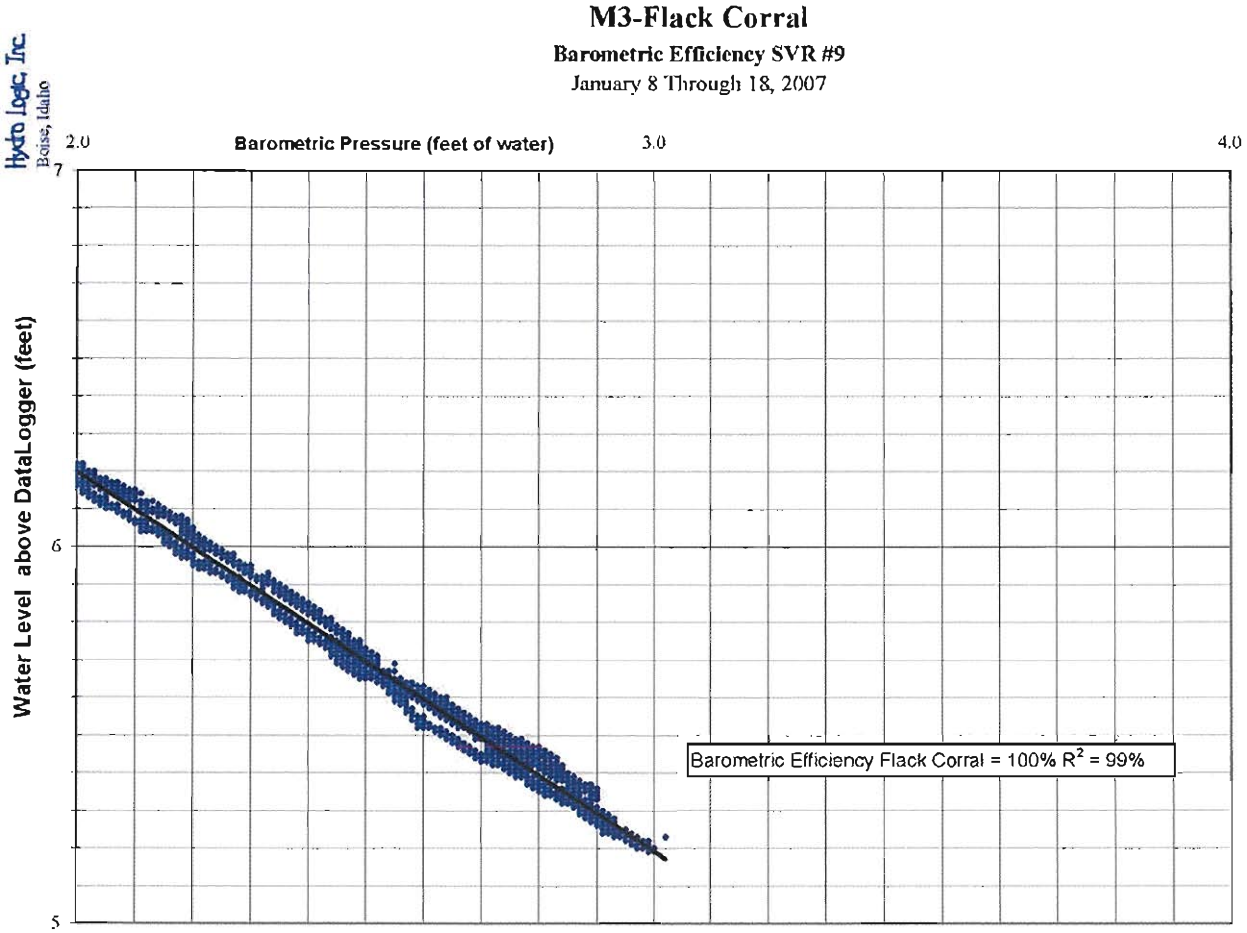
M3-Flack Corral
Barometric Efficiency SVR #9
January 8 Through 18, 2007
Hydro Logic Inc.
Boise, Idaho
Barometric Pressure (feet of water)
2.0
3.0
4.0
Water Level above DataLogger (feet)
7
6
5
Barometric Efficiency Flack Corral = 100% R2 = 99%

Figure C-16.

APPENDIX D – Kling Irrigation Pumping Test: Barometric Efficiency Corrected Drawdowns

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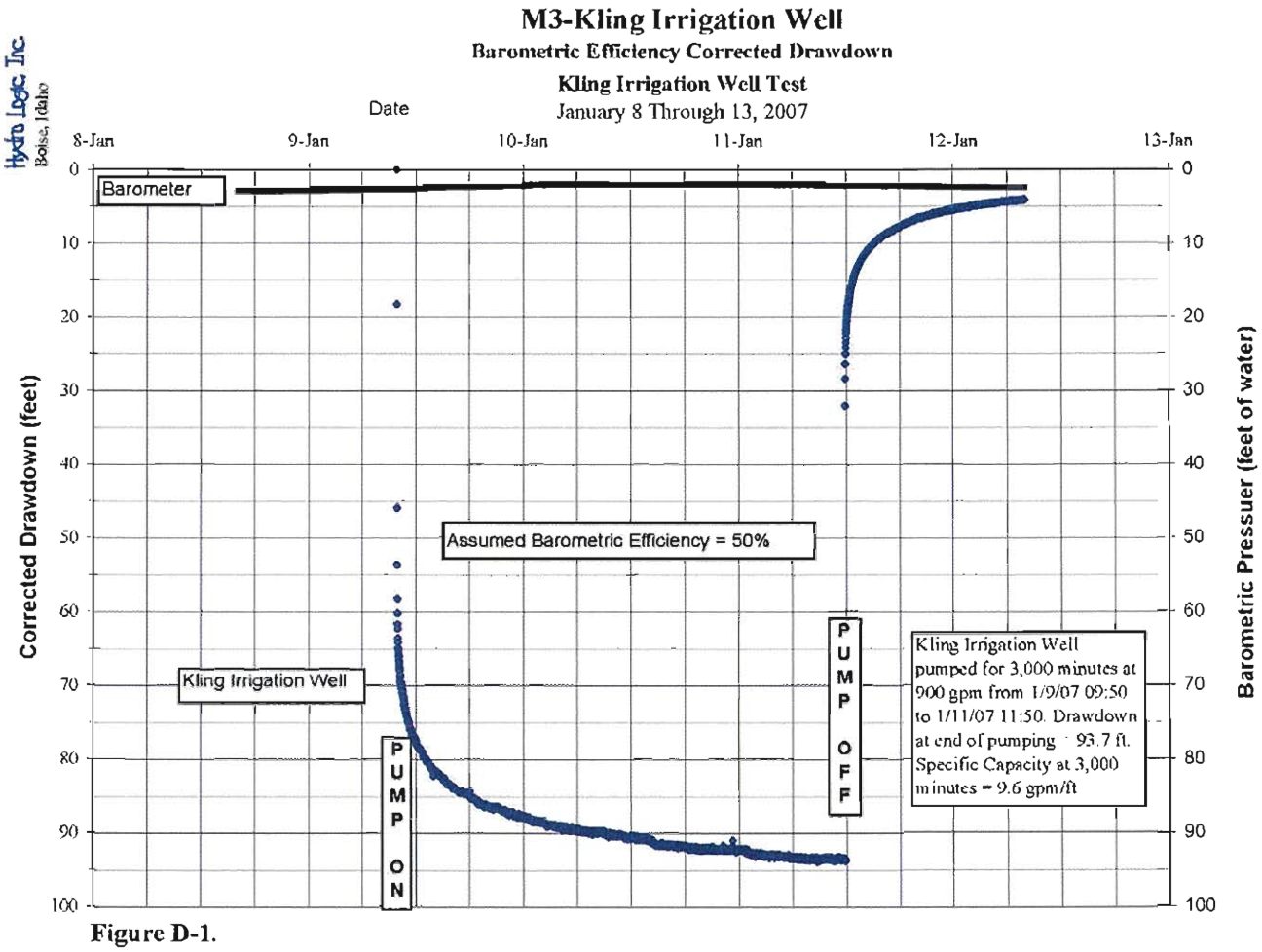

M3-Kling Irrigation Well
Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 13, 2007
Hydro Logic Inc
Boise, Idaho
Date
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
Barometer
Assumed Barometric Efficiency = 50%
Kling Irrigation Well
PUMP ON
PUMP OFF
Kling Irrigation Well pumped for 3,000 minutes at 900 gpm from 1/9/07 09:50 to 1/11/07 11:50. Drawdown at end of pumping = 93.7 ft. Specific Capacity at 3,000 minutes = 9.6 gpm/ft
Corrected Drawdown (feet)
Barometric Pressuer (feet of water)
0
10
20
30
40
50
60
70
80
90
100

Figure D-1.

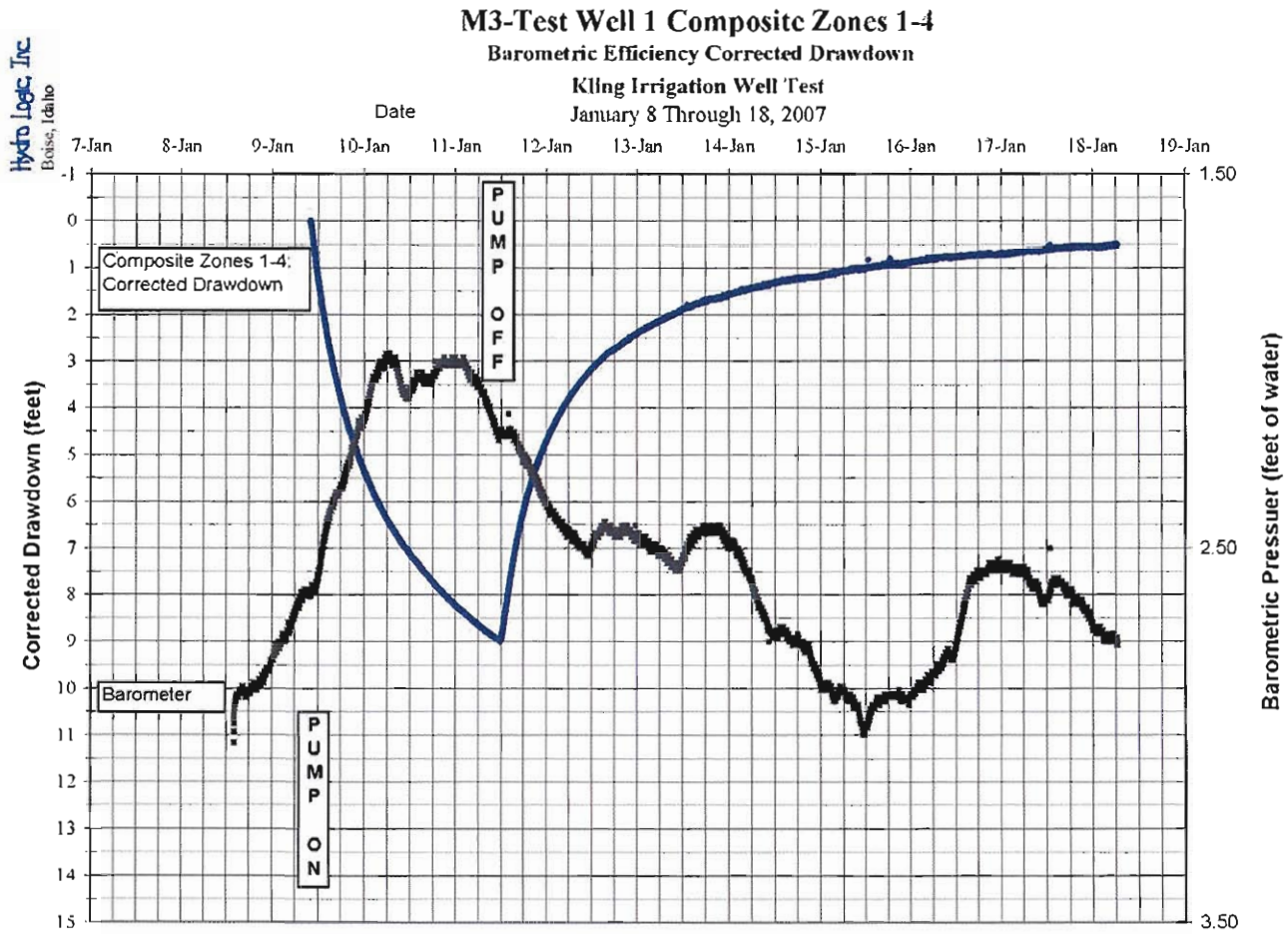

M3-Test Well 1 Composite Zones 1-4
Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Hydro Logic Inc
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
Composite Zones 1-4; Corrected Drawdown
Barometer
PUMP ON
PUMP OFF
Corrected Drawdown (feet)
Barometric Pressuer (feet of water)
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1.50
2.50
3.50

Figure D-2.

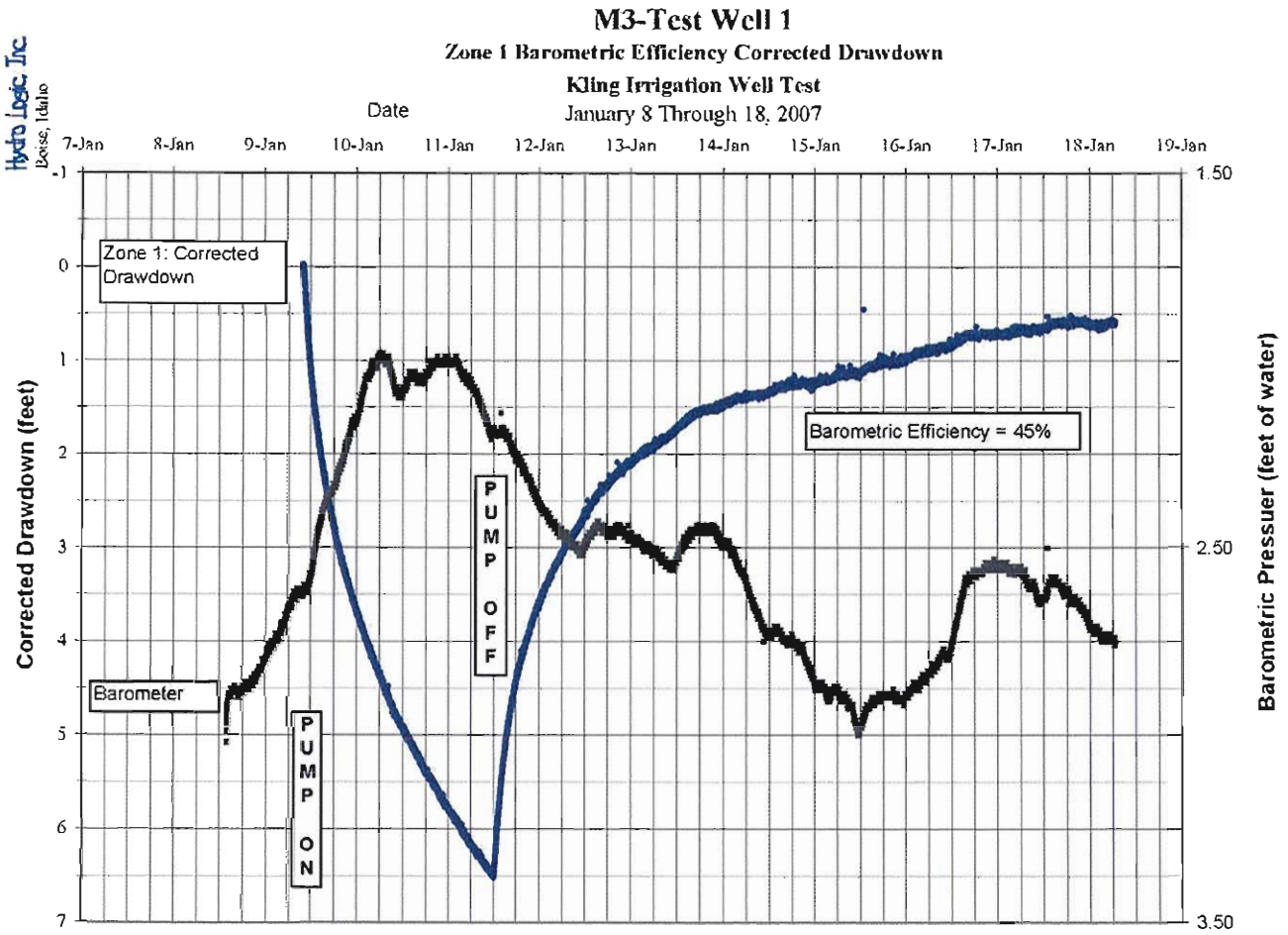

M3-Test Well 1
Zone 1 Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Hydro Logic, Inc.
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
-1
0
1
2
3
4
5
6
7
Corrected Drawdown (feet)
1.50
2.50
3.50
Barometric Pressuer (feet of water)
Zone 1: Corrected Drawdown
Barometric Efficiency = 45%
PUMP OFF
PUMP ON
Barometer

Figure D-3.

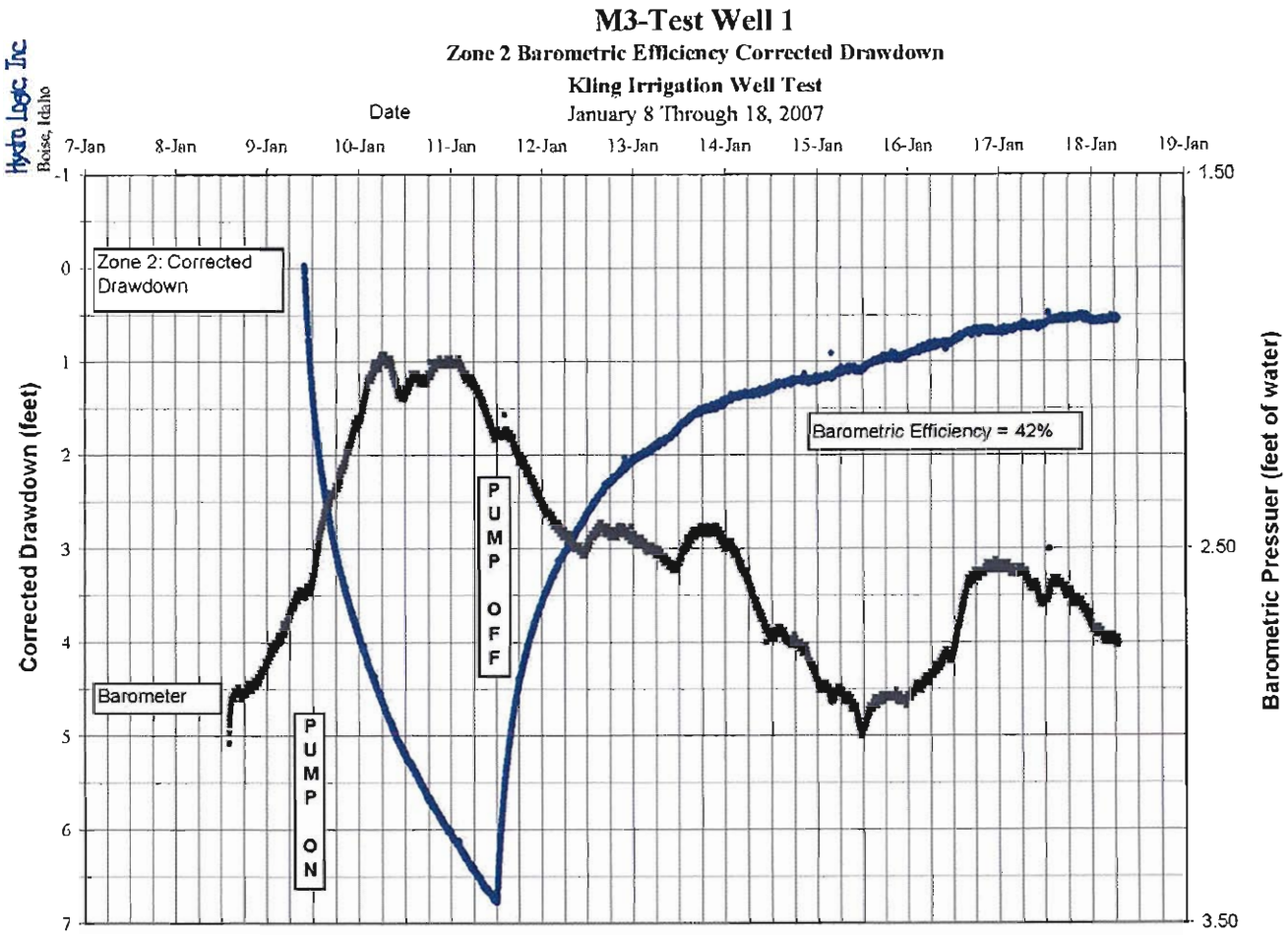

M3-Test Well 1
Zone 2 Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
Date
January 8 Through 18, 2007
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
Zone 2: Corrected Drawdown
Barometer
Barometric Efficiency = 42%
PUMP ON
PUMP OFF
Corrected Drawdown (feet)
Barometric Pressuer (feet of water)
-1
0
1
2
3
4
5
6
7
1.50
2.50
3.50

Figure D-4.

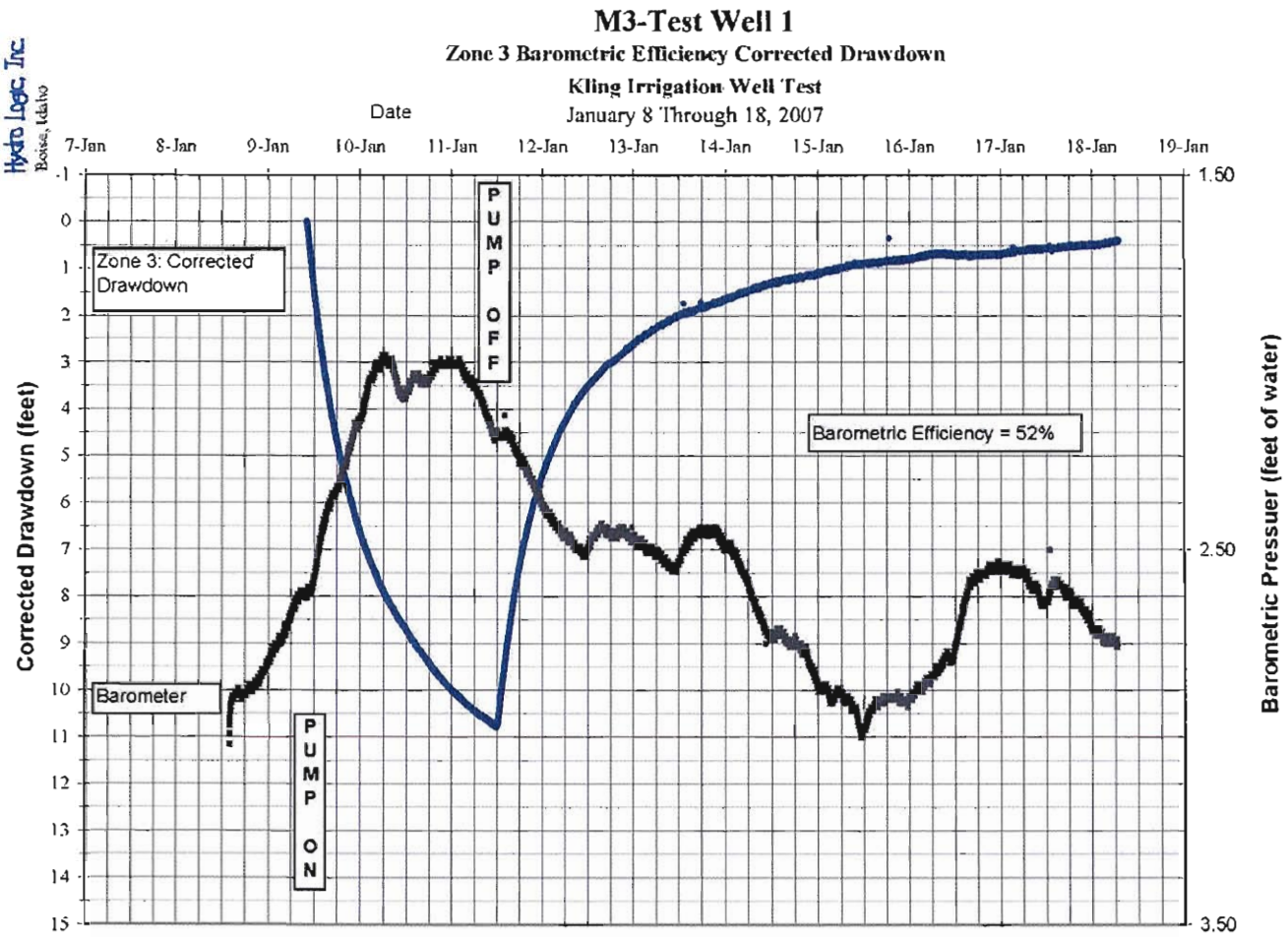

M3-Test Well 1
Zone 3 Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Hydro Logic, Inc.
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
Corrected Drawdown (feet)
Barometric Pressuer (feet of water)
Zone 3: Corrected Drawdown
Barometer
PUMP OFF
PUMP ON
Barometric Efficiency = 52%
1.50
2.50
3.50

Figure D-5.

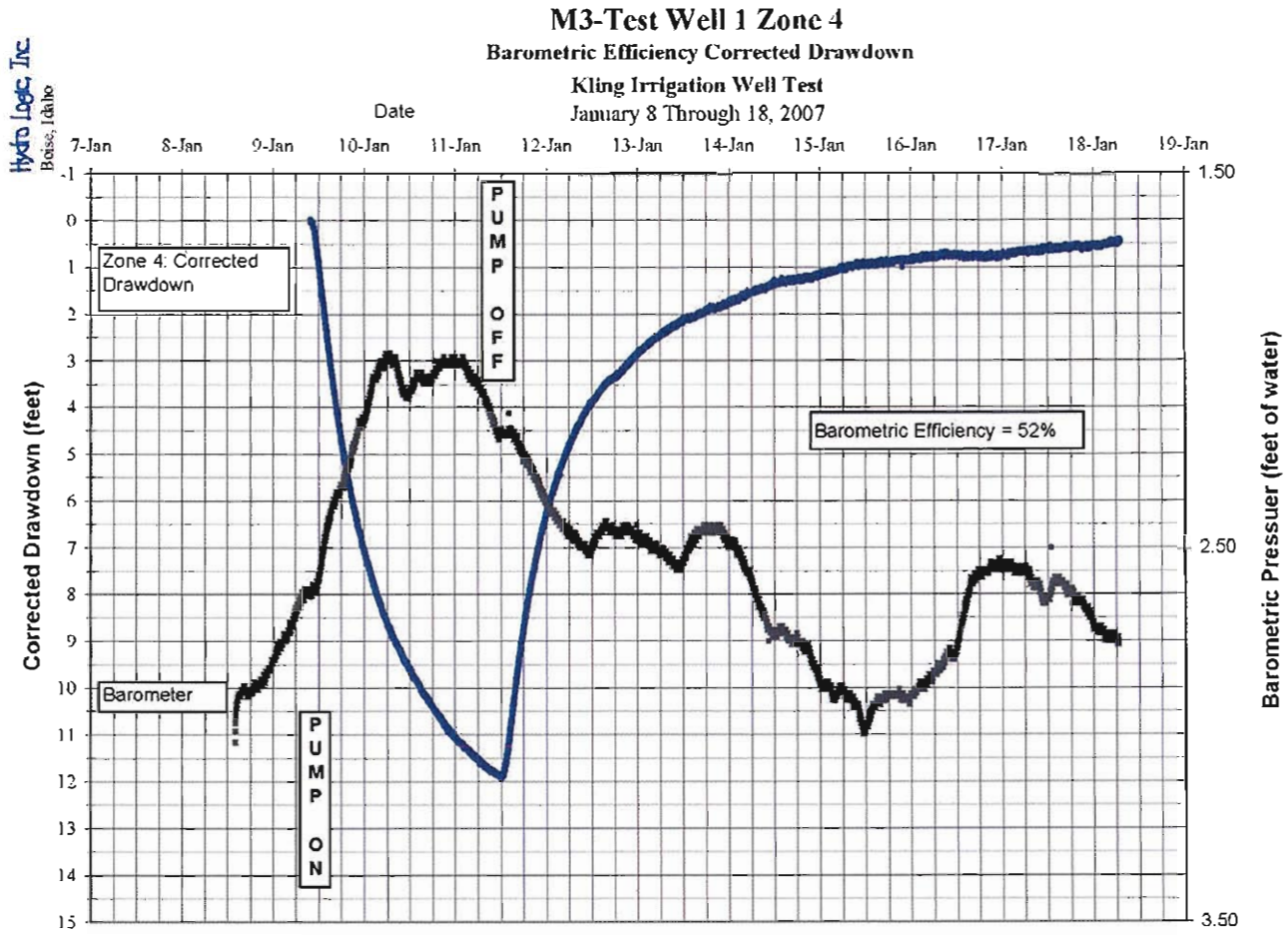

M3-Test Well 1 Zone 4
Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Hydro Logic, Inc.
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
Zone 4: Corrected Drawdown
Barometer
PUMP OFF
PUMP ON
Barometric Efficiency = 52%
Corrected Drawdown (feet)
Barometric Pressuer (feet of water)
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1.50
2.50
3.50

Figure D-6.

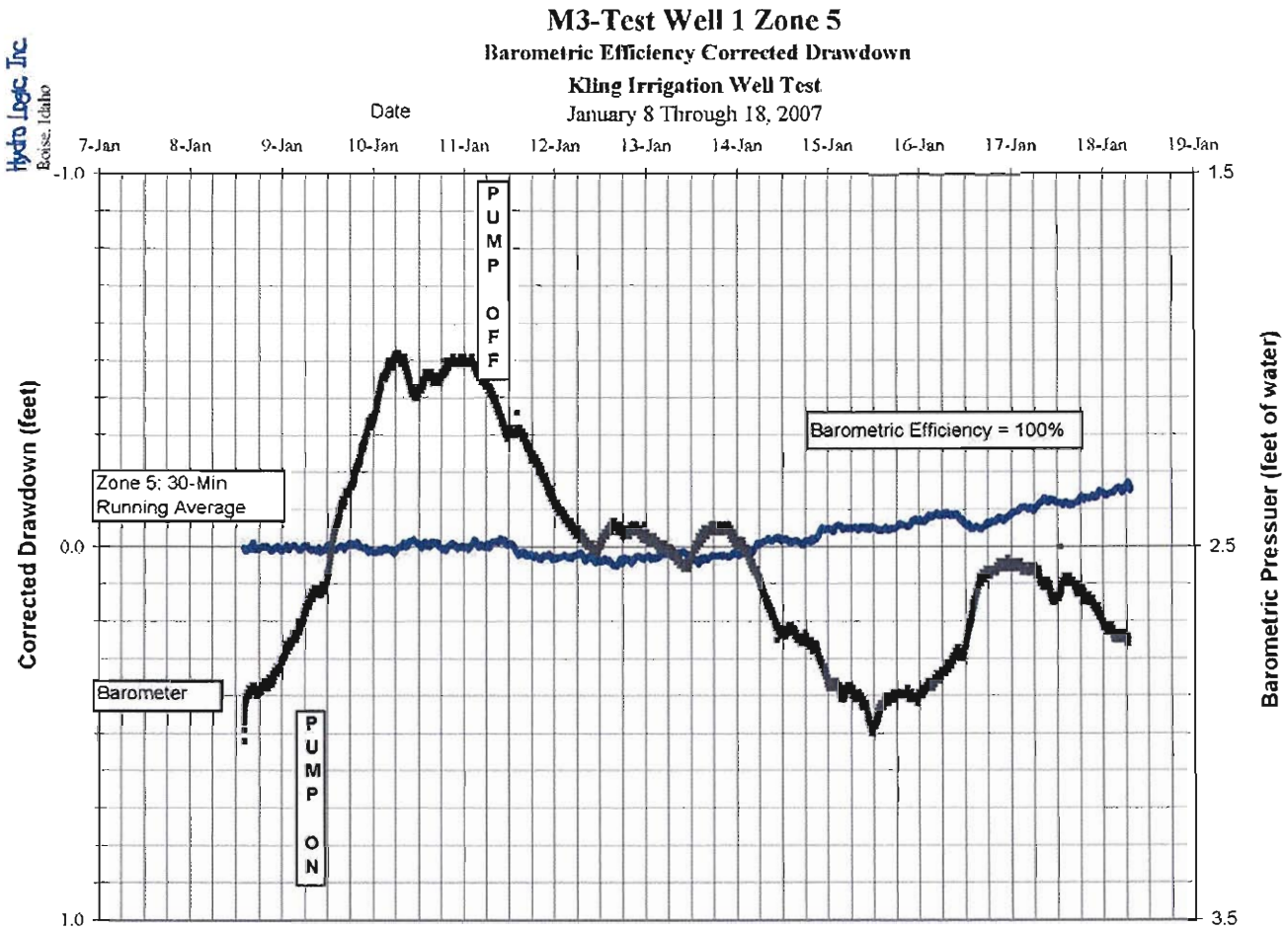

M3-Test Well 1 Zone 5
Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Hydro Logic Inc
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
-1.0
0.0
1.0
1.5
2.5
3.5
Corrected Drawdown (feet)
Barometric Pressuer (feet of water)
PUMP OFF
PUMP ON
Barometric Efficiency = 100%
Zone 5: 30-Min Running Average
Barometer

Figure D-7.

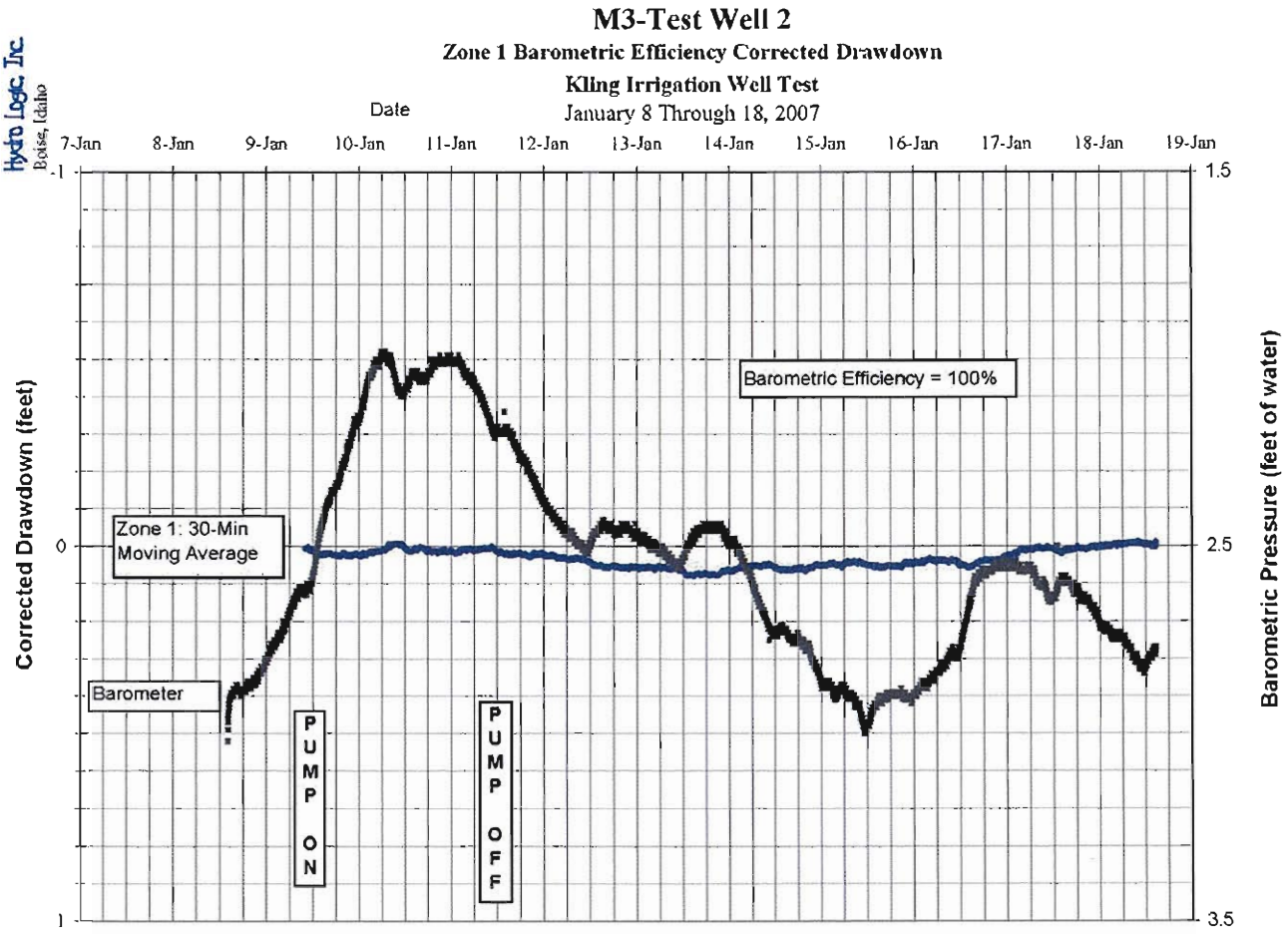

M3-Test Well 2
Zone 1 Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Hydro Logic Inc.
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
Corrected Drawdown (feet)
Barometric Pressure (feet of water)
-1
0
1
1.5
2.5
3.5
Barometric Efficiency = 100%
Zone 1: 30-Min Moving Average
Barometer
PUMP ON
PUMP OFF

Figure D-8.

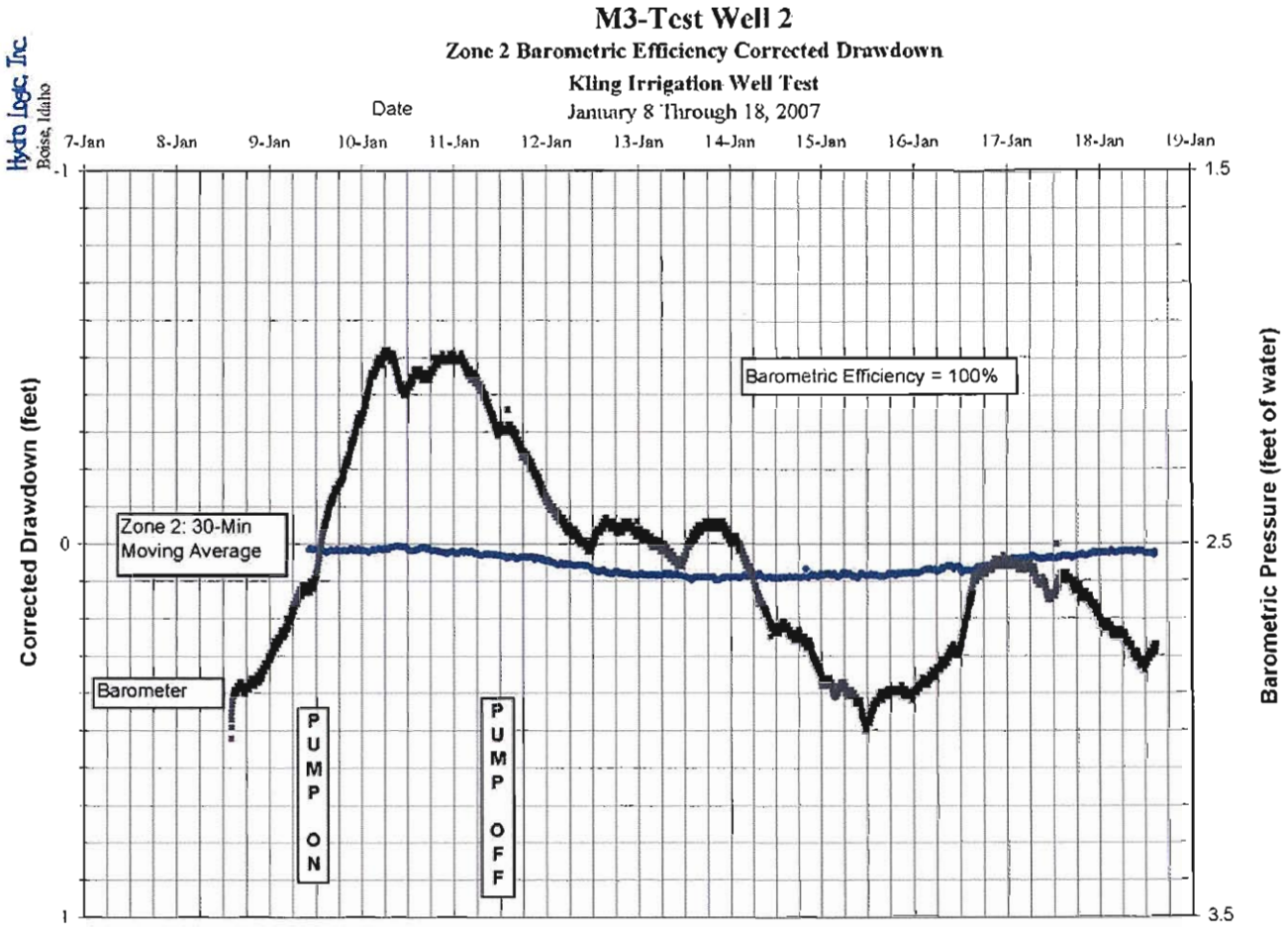

M3-Test Well 2
Zone 2 Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Hydro Logic, Inc.
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
Corrected Drawdown (feet)
Barometric Pressure (feet of water)
-1
0
1
1.5
2.5
3.5
Barometric Efficiency = 100%
Zone 2: 30-Min Moving Average
Barometer
PUMP ON
PUMP OFF

Figure D-9.

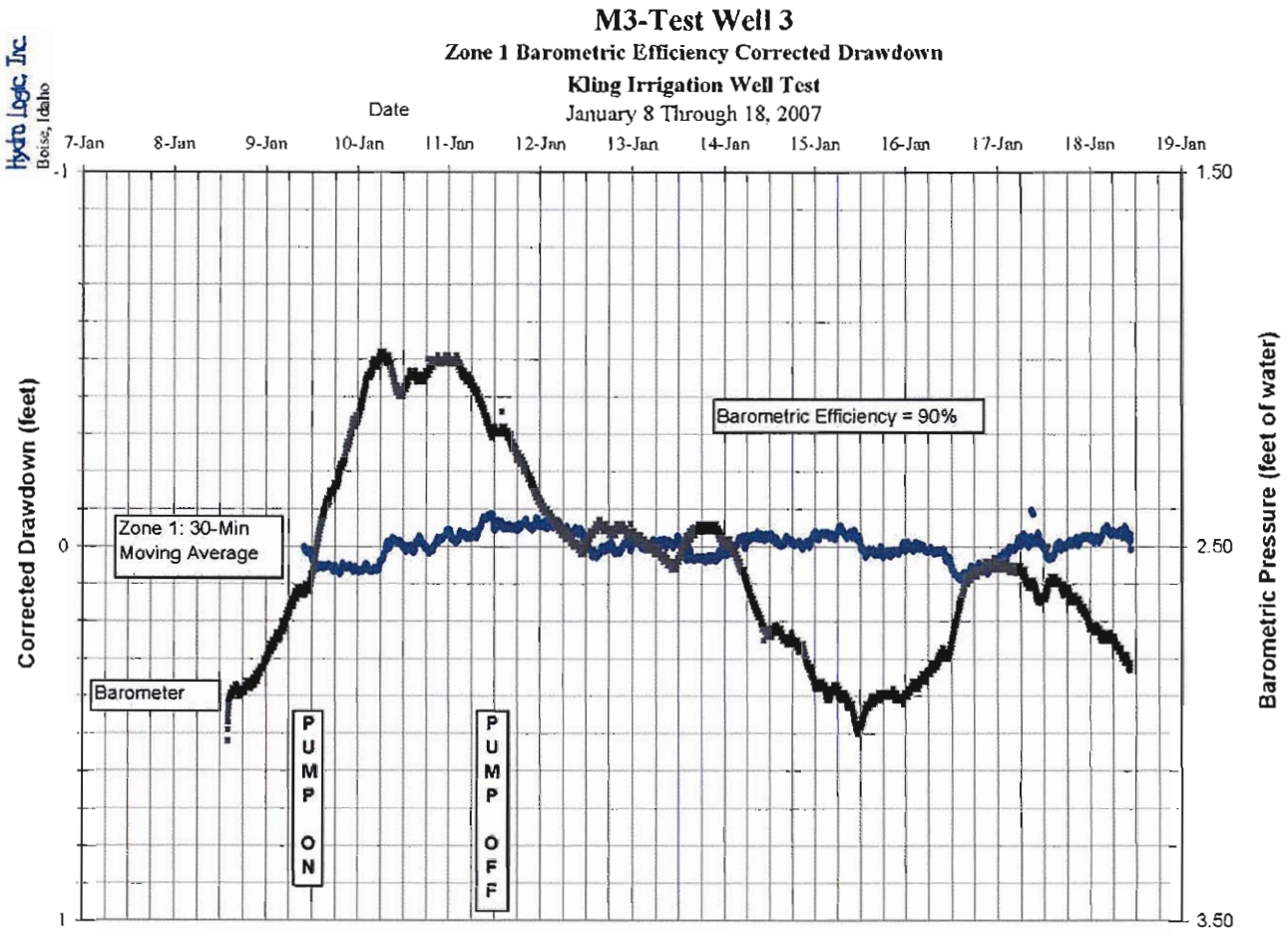

M3-Test Well 3
Zone 1 Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Hydro Logic Inc.
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
-1
0
1
1.50
2.50
3.50
Corrected Drawdown (feet)
Barometric Pressure (feet of water)
Barometric Efficiency = 90%
Zone 1: 30-Min Moving Average
Barometer
PUMP ON
PUMP OFF

Figure D-10.

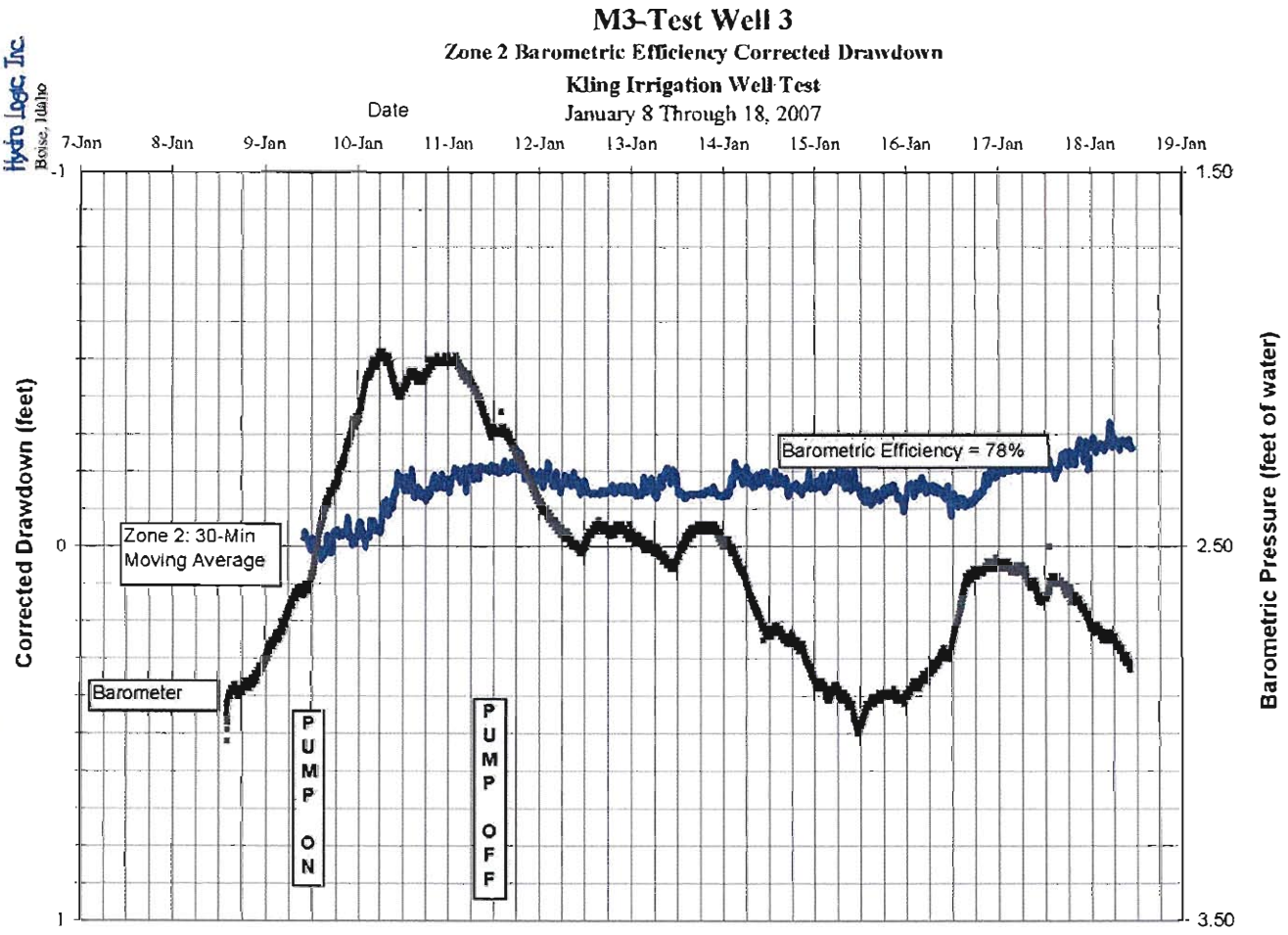

M3-Test Well 3
Zone 2 Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Hydro Logic Inc.
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
-1
0
1
1.50
2.50
3.50
Corrected Drawdown (feet)
Barometric Pressure (feet of water)
Barometric Efficiency = 78%
Zone 2: 30-Min Moving Average
Barometer
PUMP ON
PUMP OFF

Figure D-11.

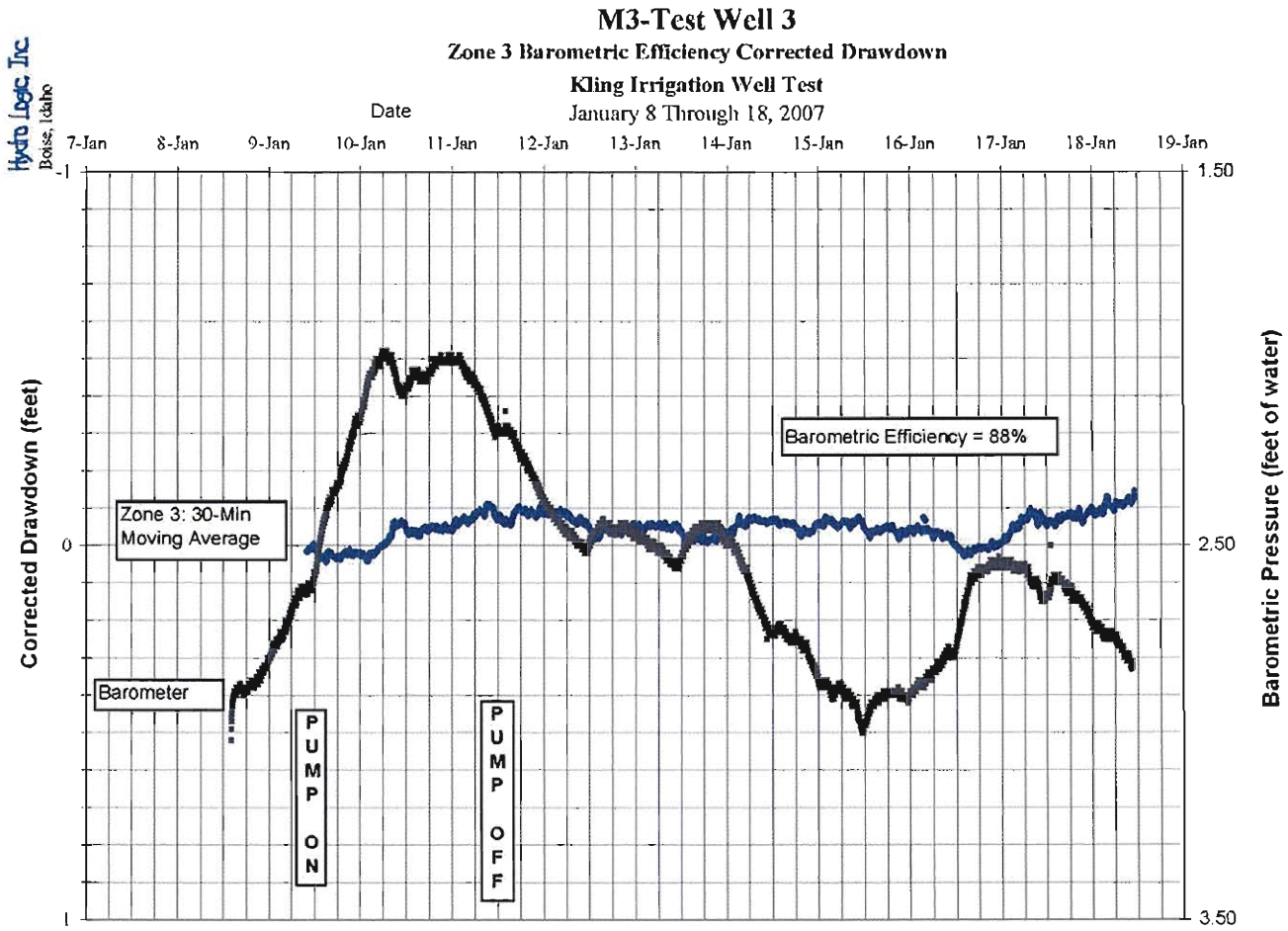

M3-Test Well 3
Zone 3 Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Hydro Logic, Inc
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
Corrected Drawdown (feet)
Barometric Pressure (feet of water)
-1
0
1
1.50
2.50
3.50
Zone 3: 30-Min Moving Average
Barometric Efficiency = 88%
Barometer
PUMP ON
PUMP OFF

Figure D-12.

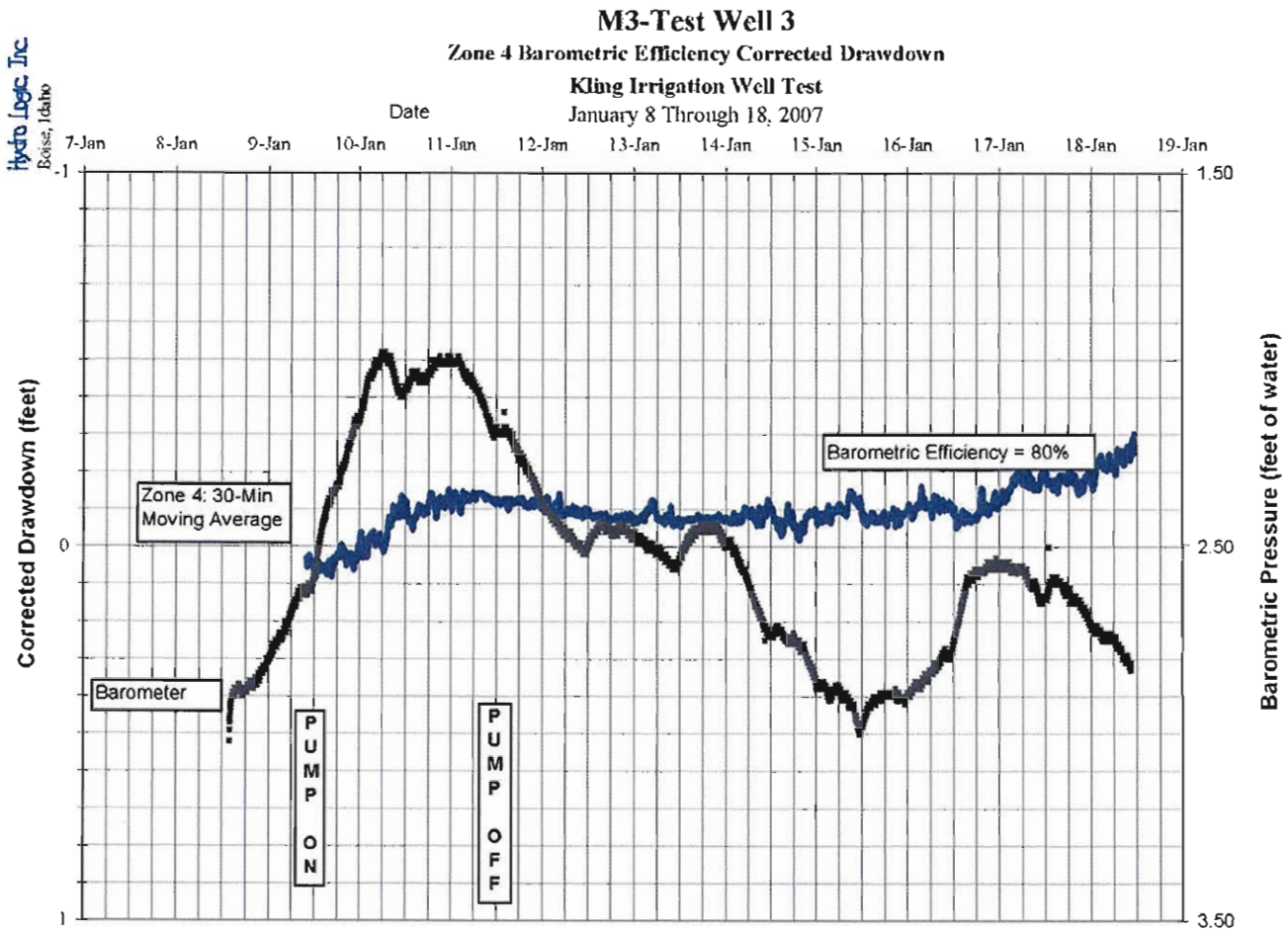

M3-Test Well 3
Zone 4 Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Hydro Logic Inc.
Boise, Idaho
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
-1
0
1
1.50
2.50
3.50
Corrected Drawdown (feet)
Barometric Pressure (feet of water)
Zone 4: 30-Min Moving Average
Barometric Efficiency = 80%
Barometer
PUMP ON
PUMP OFF

Figure D-13.

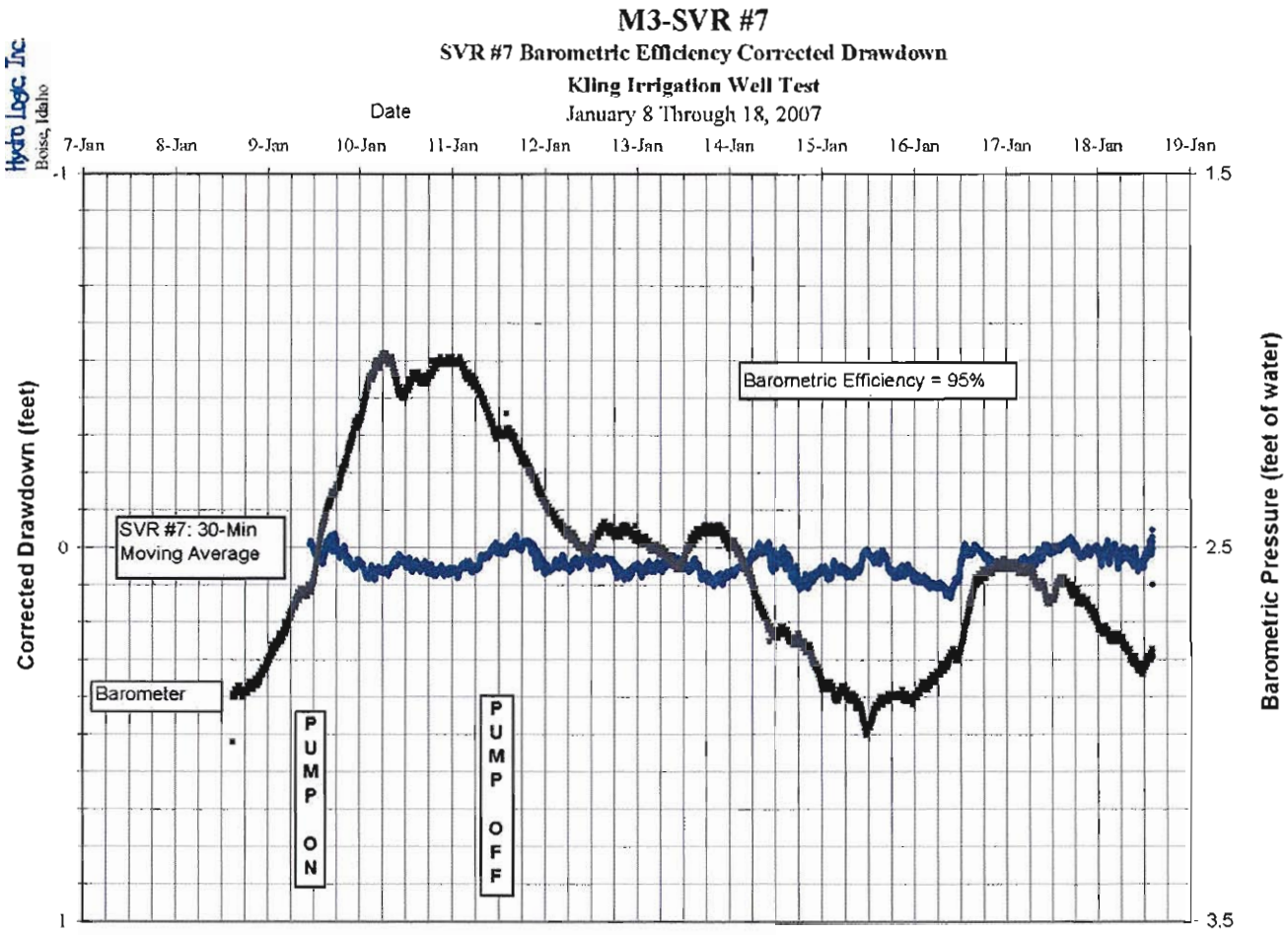

M3-SVR #7
SVR #7 Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
Corrected Drawdown (feet)
Barometric Pressure (feet of water)
-1
0
1
1.5
2.5
3.5
Barometric Efficiency = 95%
SVR #7: 30-Min Moving Average
Barometer
PUMP ON
PUMP OFF

Figure D-14.

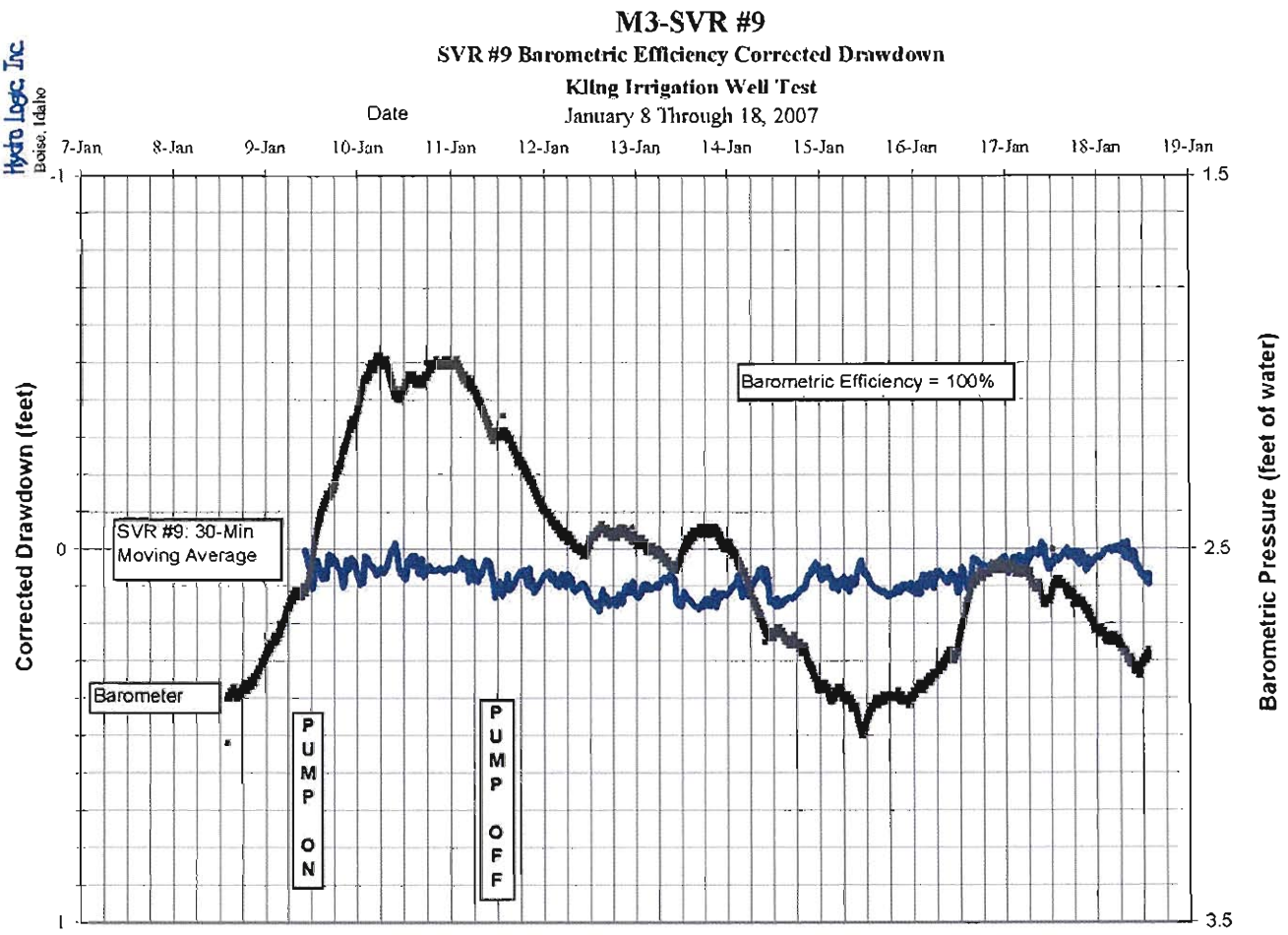

M3-SVR #9
SVR #9 Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
Date
January 8 Through 18, 2007
Hydro Logic Inc
Boise, Idaho
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
-1
0
1
1.5
2.5
3.5
Corrected Drawdown (feet)
Barometric Pressure (feet of water)
Barometric Efficiency = 100%
SVR #9: 30-Min Moving Average
Barometer
PUMP ON
PUMP OFF

Figure D-15.

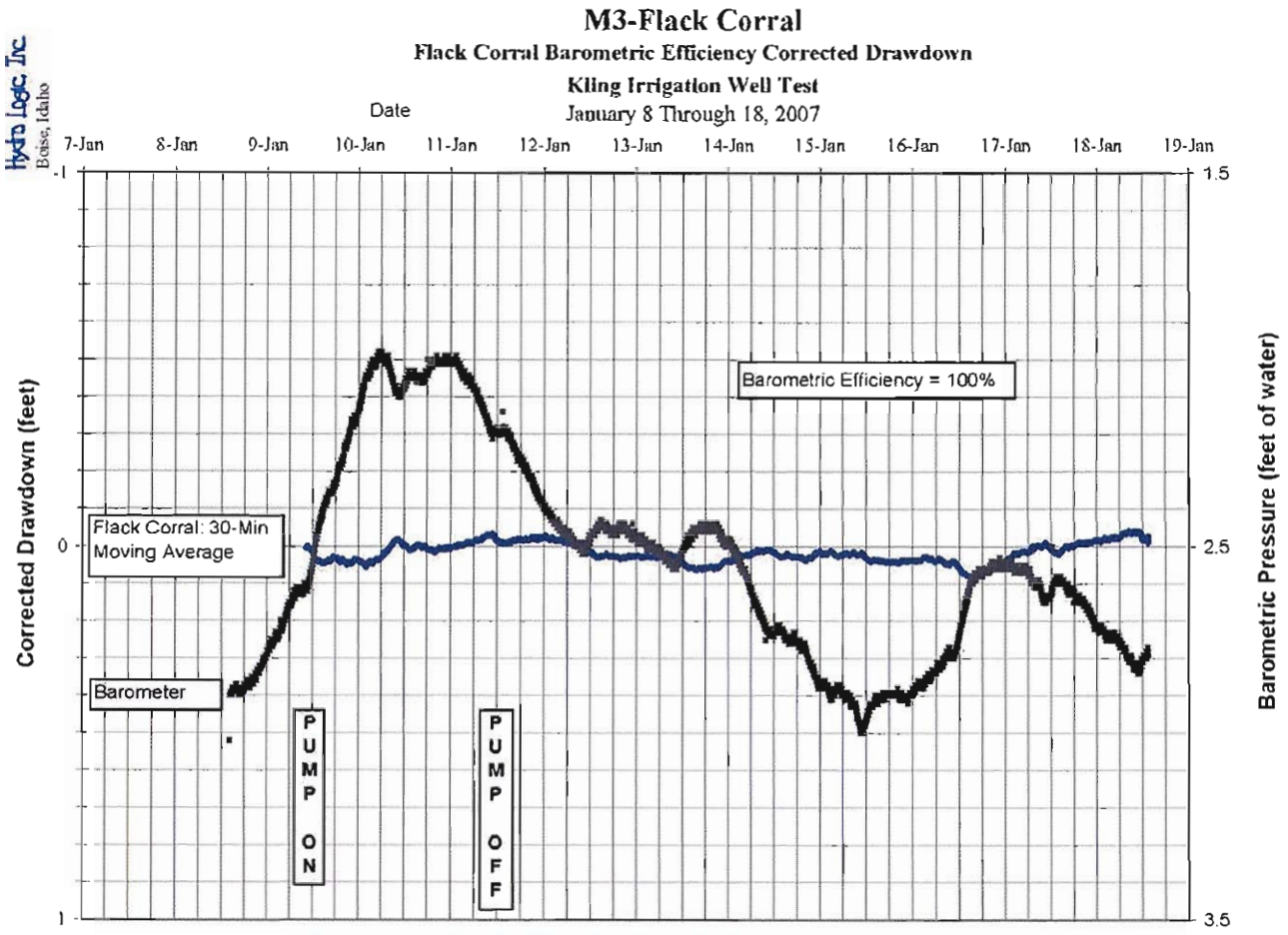
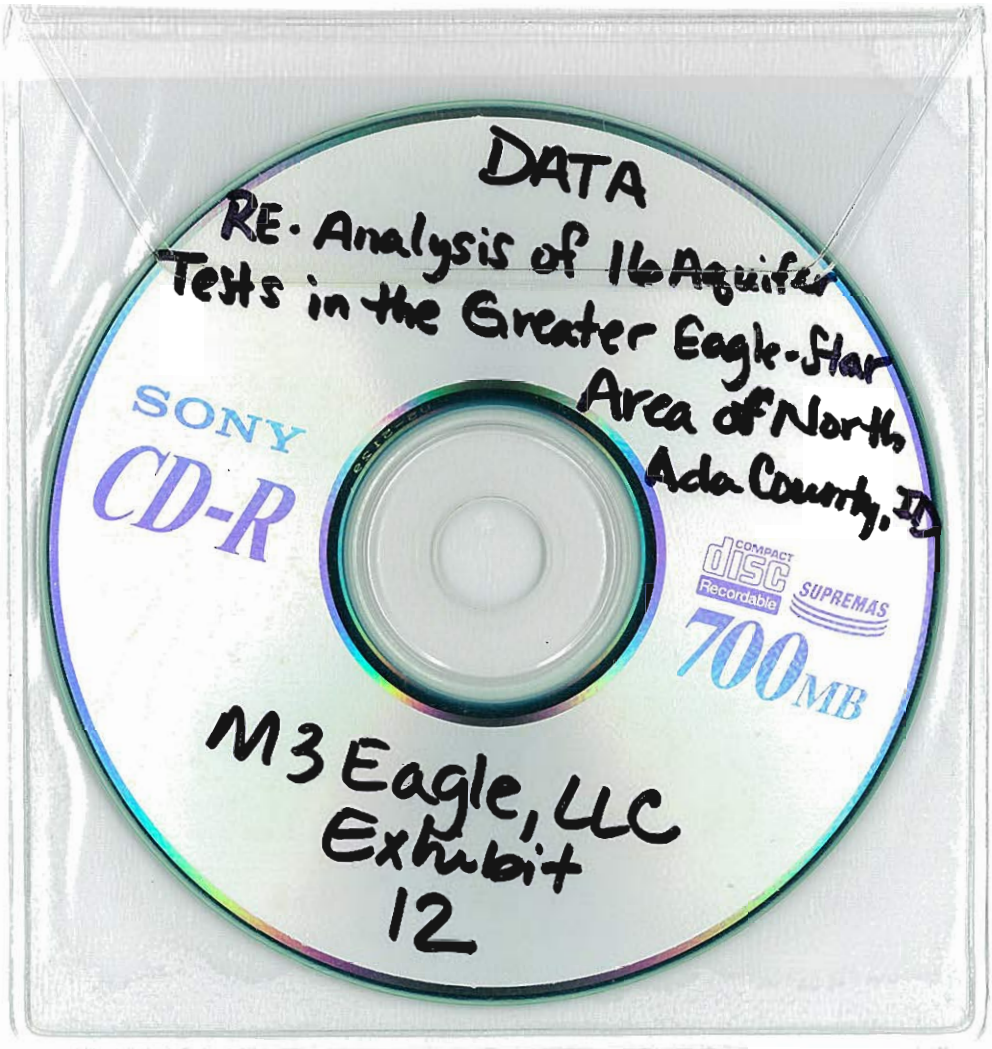

M3-Flack Corral
Flack Corral Barometric Efficiency Corrected Drawdown
Kling Irrigation Well Test
January 8 Through 18, 2007
Date
7-Jan
8-Jan
9-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
Corrected Drawdown (feet)
Barometric Pressure (feet of water)
-1
0
1
1.5
2.5
3.5
Barometric Efficiency = 100%
Flack Corral: 30-Min Moving Average
Barometer
PUMP ON
PUMP OFF

Figure D-16.

Emmett
by
Hydro Logic, Inc.
Boise, Idaho
M3 EAGLE
EAGLE IDAHO
S.V.R. #2
TPW #1
S.V.R. #10
S.V.R. #1
m3companies
S.V.R. #6
M3 TW #3
M3 TW #2
S.V.R. #7
S.V.R. #9
Big Gulch Stock
Kling Irrigation
M3 TW #1
LDS Eagle
Floating Feather
Lexington Hills #1
Star #3
16
Legacy #1
Redwood Creek
Eaglefield #2
State and Linder
West State Street
44
Star #1
Star
Rivervine #1
Eagle
55
© 2008 Tele Atlas
Image © 2008 DigitalGlobe
Google
20


DATA
RE. Analysis of 16 Aquifer Tests in the Greater Eagle-Star Area of North Ada County, ID
SONY
CD-R
COMPACT disc Recordable
SUPREMAS
700MB
M3 Eagle, LLC
Exhibit
12

13

Seismic Reflection Profiling in the Big Gulch Area

John H. Bradford
Center for Geophysical Investigation of the Shallow Subsurface (CGISS)
Boise State University
Boise, ID 83725-1536

Summary of completed work

On July 5, a crew from Boise State University mobilized to begin testing for a seismic reflection profile on the M3 Inc. properties located north of Star, Idaho. As noted in the work plan (Appendix A), the first objective of the testing was to ensure that the seismic source (a 500lb accelerated weight drop) and surface conditions were suitable to seismic reflection profiling - specifically, would our system likely achieve the experiment objectives.

The deep water table at the site (~150-450 ft) means that the seismic signal must propagate through a significant thickness of unsaturated sediments prior to reaching the primary target, which in this case is the stratigraphy associated with the fresh water aquifer and the fault that appears to traverse the property. Unsaturated sediments absorb the signal more than water saturated sediments or crystalline rock and this effect can have a detrimental impact on data quality.

After acquisition and analysis of data acquired at several shot positions located on the southwest end of the proposed seismic profile, we determined that our system would not likely produce data that would meet the survey objectives. Figure 1 shows the highest quality shot gather we obtained. While a number of wave modes are evident in the shot gather, these are primarily forms of coherent noise that would be removed in processing a reflection image. No seismic reflection events are evident in the data.

After observation of the poor data quality, in consultation with Hydro Logic Inc., and in accordance with the project work plan we chose to terminate acquisition as noted in the contract work plan.

Recommendations for future work

A more energetic seismic source may produce adequate data quality. For example, the 16,000 lb mini-vibe produce by Geosys Inc. may provide adequate energy. Completion of the project with the mini-vibe would add approximately $25,000 to the project. A gravity and magnetics survey could be completed at relatively low cost (< $5000) and would provide an image of the gross geometry of the system. This information could be used, for example, to constrain the position of the fault.

M3 EAGLE LLC
EXHIBIT
13

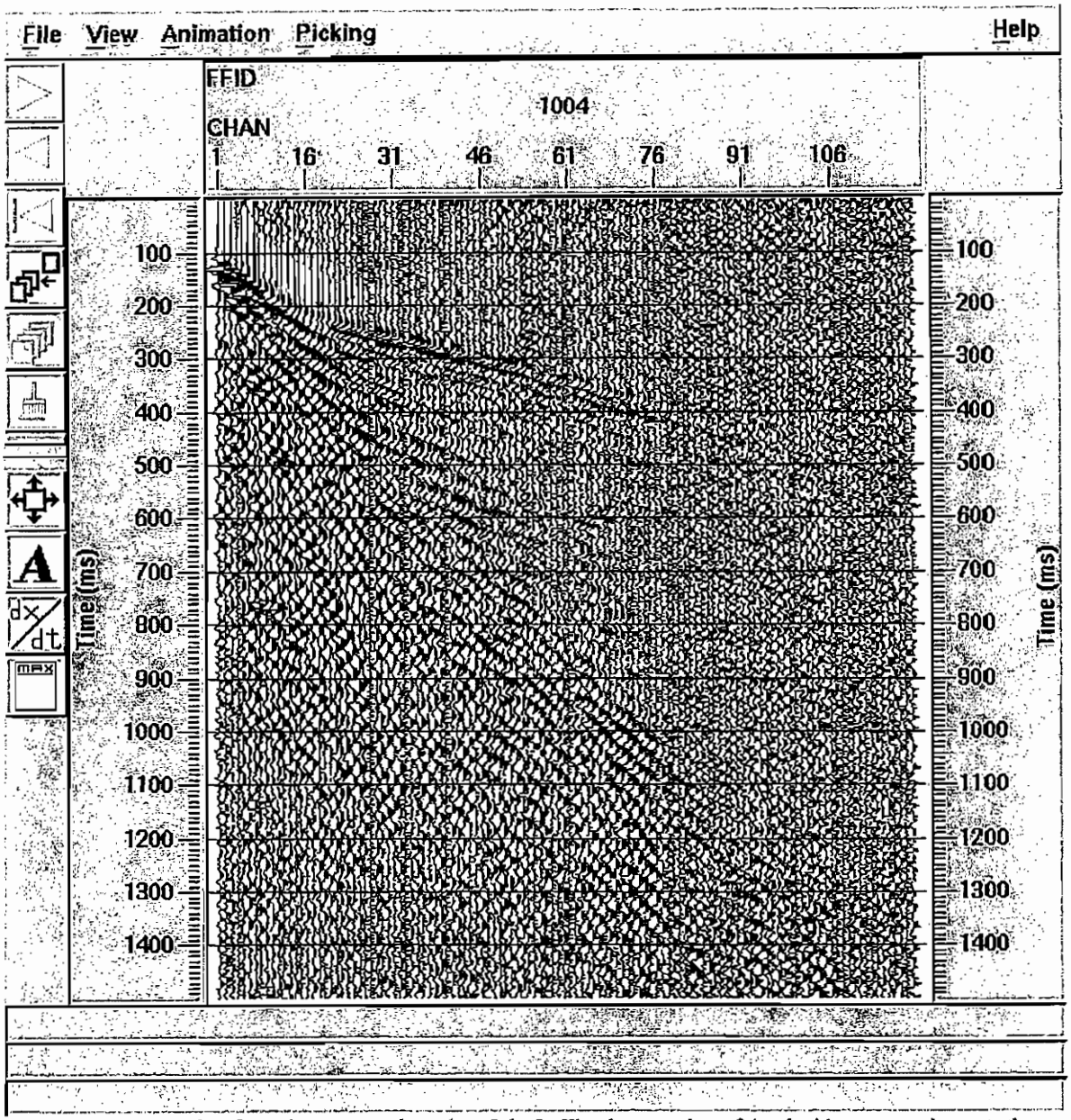


Figure 1. A shot gather from the tests conducted on July 5. The data consists of 4 coincident source impacts that were subsequently stacked to attenuate noise. A weak water table refraction is evident from channels 18-120 with respective times from 200 ms – 530 ms. Additional events that are evident are ground-roll and guided waves trapped between the water table and surface. No reflections are evident in the data.

APPENDIX A

Seismic Reflection Profiling in the Big Gulch Area

John H. Bradford
Center for Geophysical Investigation of the Shallow Subsurface (CGISS)
Boise State University
Boise, ID 83725-1536

1.0 Summary

We propose to acquire, process and interpret approximately 10 miles of seismic reflection data for Hydro Logic, Inc. north of Star, Idaho. The project objectives are

1. Perform noise tests to determine acquisition parameters and to evaluate the quality of the data acquisition.
2. Image shallow (to 1,000 feet bgl) sedimentary section and structures to delineate aquifers.
3. Image deeper volcanic bed rock and structural faulting.
4. Data to be plotted at client's preferred depth and distance scales.

The quality of the seismic reflection data may be adversely impacted by the deep water table at the site (~150 - 450 ft). The noise tests will be completed during the first two days of data acquisition. In consultation with Hydro Logic Inc. we will carefully evaluate data quality to ensure that the survey will satisfy project objectives. Should data quality be deemed inadequate, the project will be terminated with no additional costs charged to Hydro Logic Inc. In this case, total costs will include mobilization and demobilization and two days of field work.

The scope of work includes 1 day of mobilization, 1 day of demobilization and 10 days of seismic reflection field work. The costs include acquisition (~75% of total cost), processing and report preparation (~ 25% of total cost). Work will begin July 5, 2006 and be completed before September 1, 2006.

2.0 Site and Acquisition Details

The field site is located in the Boise Range foothills north of Star, Idaho. The seismic profiles will consist of one primary profile along the axis of Big Gulch. Additional cross profiles and an axis profile along Little Gulch will be acquired as time permits, not to exceed 10 field days. All profile locations will be established in consultation with Hydro Logic, Inc. We will use a 120-channel seismograph with geophones deployed every 5 m. The seismic source will be the CGISS trailer-mounted weight drop. We will use either a Topcon total station or Trimble differential GPS system for spatial control. Based on similar experiments we have conducted at a nearby location, we anticipate that we can complete 1 mile of seismic reflection imaging per full field day.

3.0 Data Processing and Report Preparation

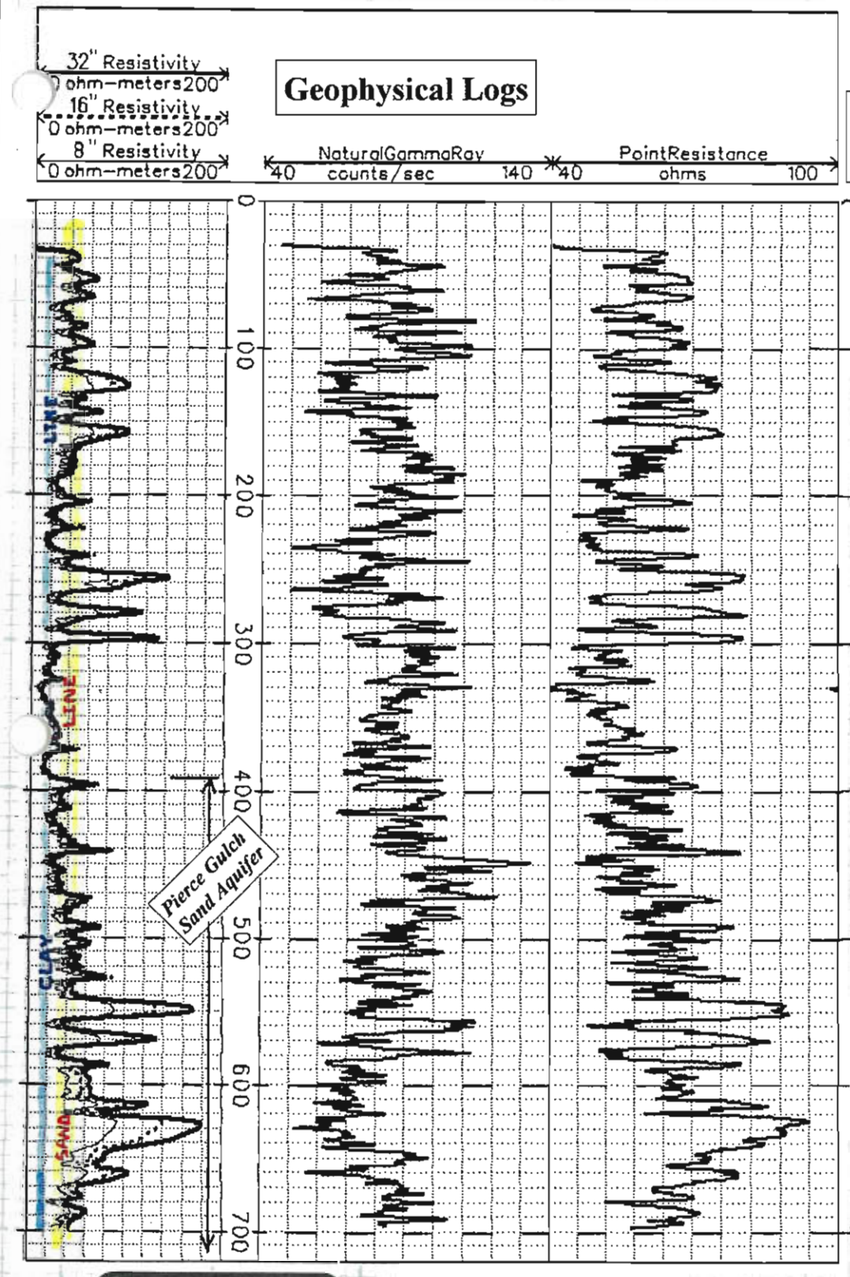
We will complete the seismic and survey data processing using the CGISS computing center and will collaborate with Hydro Logic, Inc. to complete a written report prior to the termination of the contract (September 1, 2006). Interpreted seismic sections will be presented in depth and horizontal position. Seismic data will be available for future CGISS publications.

14

Star Sewer and Water District
Supply Well #3

T. 4 N., R. 1 W., Section 5, SE¼, SE¼, SW¼
Latitude N43° 42' 24.9" Longitude W116° 29' 1.0"
Well completed August 2006

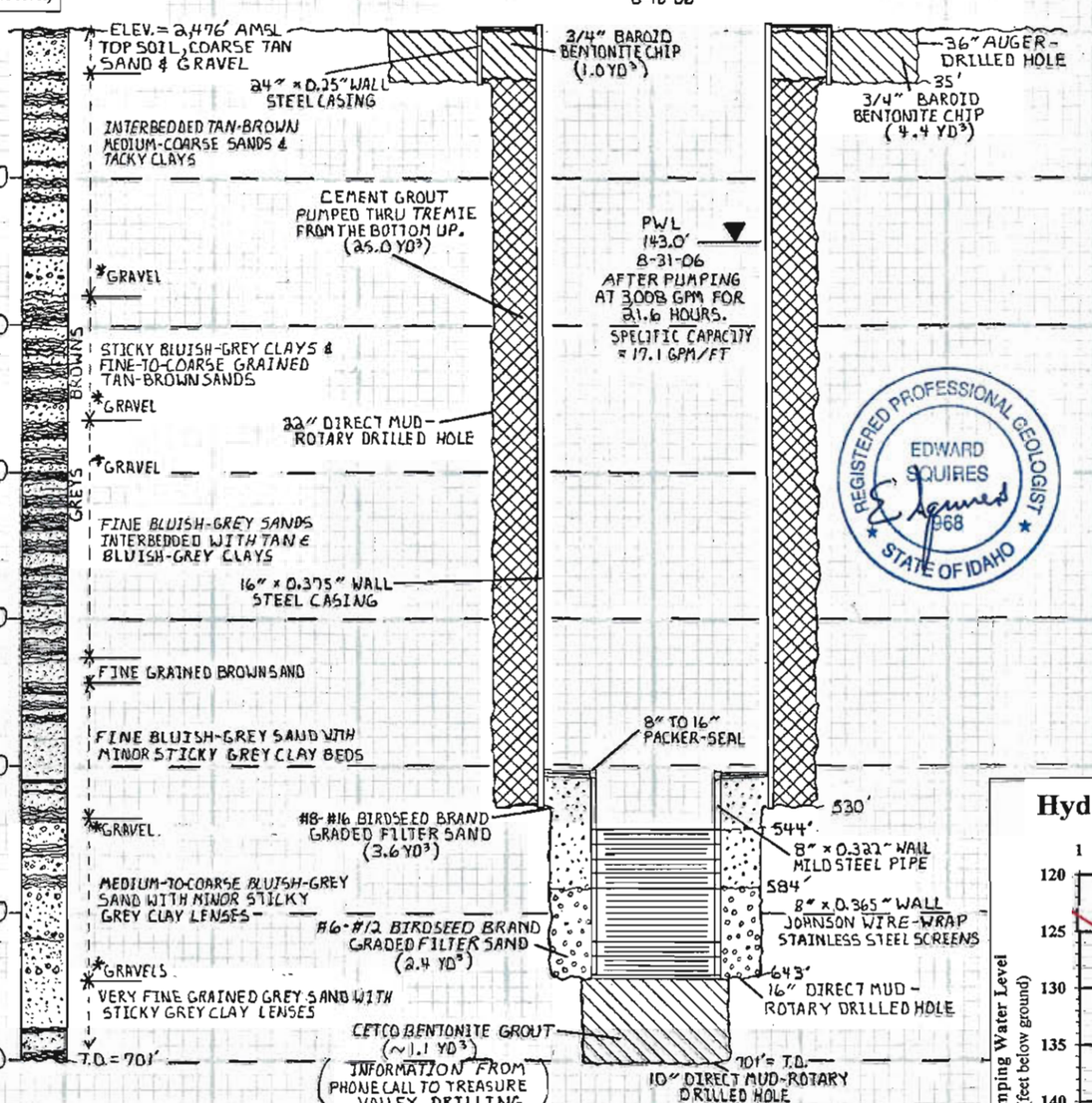
Geophysical Logs



Depth
(feet below ground level)

Lithology
Hydro Logic, Inc. lithologic log is interpreted and drawn from geophysical logs and drilled cuttings from the borehole.

As-Built Well Construction
(horizontal scale 0.1"=1.0")
(vertical scale 1"=100')



*GRAVELS INTERPRETED BY HLI., BUT NOT EVIDENT IN CUTTINGS OR MENTIONED IN DRILLER'S REPORT.

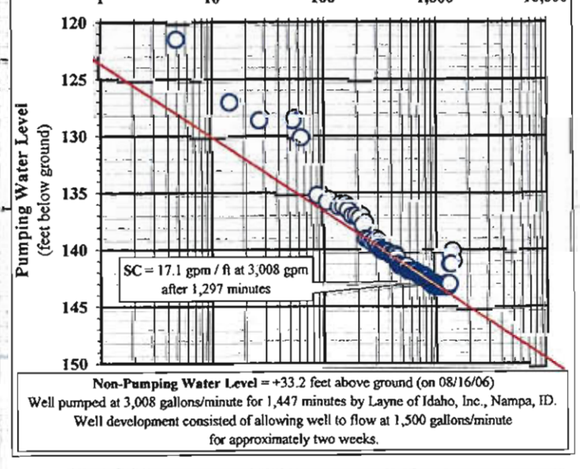
REGISTERED PROFESSIONAL GEOLOGIST
EDWARD SQUIRES
968
STATE OF IDAHO

Ground Water Chemistry

Analysis *(in mg/L unless noted)*	ZONE *(643 - 544 ft bgl)*
Alkalinity	82.0
Aluminum	<0.01
Ammonia as N	0.06
Arsenic	0.005
Calcium as $CaCO_3$	50.2
Chloride	1.60
Conductivity *(µS)*	184.0
Corrosivity	-0.65
Fluoride	0.55
Hardness	66.7
Iron *(total)*	0.20
Iron *(dissolved)*	0.20
Magnesium	4.03
Manganese *(dissolved)*	0.03
Nitrate as N	<0.10
Odor	<1
pH - Lab *(S.U.)*	7.64
Potassium	1.36
Silica	30.6
Sodium	13.6
Sulfate	9.03
Sulfide	<0.05
Total Dissolved Solids	123.0
Total Kjeldahl Nitrogen	0.15
Total Organic Carbon	<1.0
Field Conductivity (µS)	*212*
Field Dissolved Oxygen	*0.35*
Field pH (S.U.)	*7.51*
Field Temperature (°F)	*66.5*

Water samples and field parameters collected on August 30, 2006 by Hydro Logic, Inc.
Analyses by Alchem Laboratories, Inc., Boise, ID

Hydraulic Testing - (August 30-31, 2006)



Non-Pumping Water Level = +33.2 feet above ground (on 08/16/06)
Well pumped at 3,008 gallons/minute for 1,447 minutes by Layne of Idaho, Inc., Nampa, ID.
Well development consisted of allowing well to flow at 1,500 gallons/minute for approximately two weeks.

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Geophysics conducted by:
Hydro Logic, Inc. on June 5, 2006 immediately after removal of drill steel

drafted June 2008
by L. Pearson
Hydro Logic, Inc.

On site supervision and direct mud-rotary drilling by: Treasure Valley Drilling and Pump, Inc., Weiser, ID
Well design by Clearwater Geosciences, LLP, Idaho Falls, ID with assistance from Hydro Logic, Inc., Boise, ID.
Pump test design by Treasure Valley Drilling and Layne of Idaho.
Composite diagram developed by HLI from data of others. HLI did not work on this project.

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Spring Valley Ranch - Test Well #10

T.5.N R.1E. Section 8, SW¼, SW¼
Latitude N43° 46' 49.1" Longitude W116° 22' 23.2"
Completed July 2004

Geophysical Log

(July 2004)
by Stevens and Sons Drilling in a mud-filled and partially cased borehole.

Single-point log has been condensed and reprinted by Hydro Logic, Inc. from scanned pen and ink strip chart of driller.

single-point resistance
0 — 40

water table

unsaturated zone

uncalibrated, poor quality, analog signal

CLAY — LIKELY — SAND — LIKELY — CLAY

Depth (feet b.g.l.)

0, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1,000

Lithology

ELEVATION ≈ 2,869' AMSL = GROUND LEVEL

BUFF YELLOW-BROWN TOP SOIL, COARSE SAND, & SOFT CLAY

INTERBEDDED FINE TO COARSE GRAVEL & LIGHT GRAY MEDIUM TO COARSE SANDS

LIGHT GRAY COARSE TO VERY COARSE SANDS, FINE TO MEDIUM GRAVELS, WITH GRAY CLAY LENSES

COARSE TO VERY COARSE LIGHT GRAY SANDS INTERBEDDED WITH MEDIUM-DARK GRAY CLAYS

MEDIUM-DARK GRAY CLAY

COARSE CLAYEY MEDIUM-DARK GRAY SAND

MEDIUM-DARK GRAY CLAY

1,005' = T.D.

Feast Geosciences lithologic log was developed from drilled cuttings. Lithology has been reinterpreted and readjusted below 600 feet to better fit with geophysical logs.

Data presented was compiled and plotted by Hydro Logic, Inc. from available data of others. HLI was not involved with the drilling project.

On site supervision and well design by:
SPF Water Engineering and Feast Geosciences, LLC, Boise, ID.
Direct mud-rotary drilling and well construction by:
Adamson Pump and Drilling, Nampa, ID

* SPF report of 10-13-2004 states:
"...driller was instructed to...install 6-inch screen and casing between 580 and 665 feet.
...Unfortunately the screen assembly became stuck during installation..."

As-Built Well Construction (from IDWR Driller's Report)

Depth (feet b.g.l.)

0, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1,000

16-INCH AIR-ROTARY DRILLED HOLE

30% SOLIDS CETCO BENTONITE GROUT (~8.0 YD³)

12-INCH DIRECT MUD-ROTARY DRILLED HOLE

8" x 0.250" WALL STEEL CASING

NPWL 482.1' 8-19-04

STANDARD 6" to 8" NEOPRENE PACKER

555'

6" x 0.250" WALL STEEL PIPE

580'

600' = DRIVE-SHOE

6" x 0.040" SLOT STAINLESS STEEL SCREEN (630' to 640')

630'

640'

6" x 0.030" SLOT STAINLESS STEEL SCREEN (BEHIND CASING) (580 to 600')

NATIVE SAND?

666'

3/8" GRAVEL (~1.3 YD³)

770'

30% SOLIDS CETCO BENTONITE GROUT (~3.0 YD³)

8-INCH DIRECT MUD-ROTARY DRILLED HOLE

T.D. = 1,005'

Drafted June '08 by Loren Pearson, Hydro Logic, Inc.

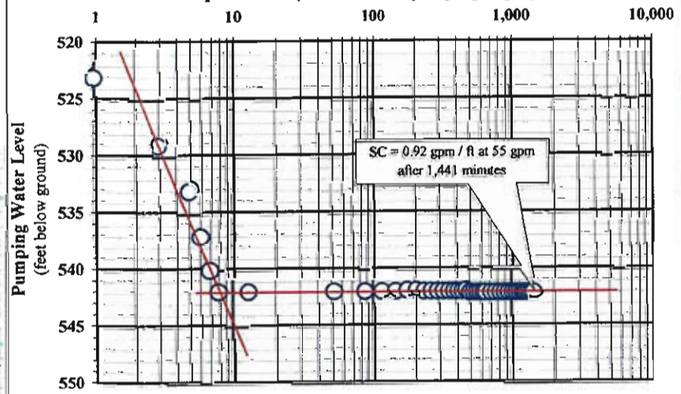
Ground Water Chemistry

Lab Analyses	SPF Water Engineering Results (in mg/L unless noted) SCREENED (630 - 640 feet bgl)
Ammonia as N	<0.04
Antimony	<0.005
Arsenic	0.012
Barium	<0.05
Beryllium	<0.0005
Bicarbonate	53.5
Cadmium	<0.0005
Calcium as $CaCO_3$	17.1
Chloride	2
Chromium	0.002
Fluoride	0.24
Hardness	51.8
Iron (total)	0.36
Magnesium	3.20
Manganese	<0.05
Mercury	<0.0002
Nickel	<0.02
Nitrate as N	5.2
Nitrite as N	<0.01
Potassium	2.4
Selenium	<0.005
Sodium	12.3
Sulfate	<1
Sulfide	<0.05
Thallium	<0.002
Total Dissolved Solids	70
Field Analyses	
Field Conductivity (µS)	160
Field pH (S.U.)	7.64
Field Temperature (°F)	75.9

SPF samples collected on August 19, 2004 by Feast Geosciences.
Analyses by Analytical Laboratories, Boise, ID

REGISTERED PROFESSIONAL GEOLOGIST — EDWARD SQUIRES — 968 — STATE OF IDAHO

Hydraulic Testing - (August 19-20, 2004)



Non-Pumping Water Level = 482.1 feet below ground (11:30 hrs on 08/19/04)
Test conducted by Feast Geosciences and Adamson Pump and Drilling Co.
According to driller well development consisted of air-lift pumping at 50 gallons/minute for at least two hours.

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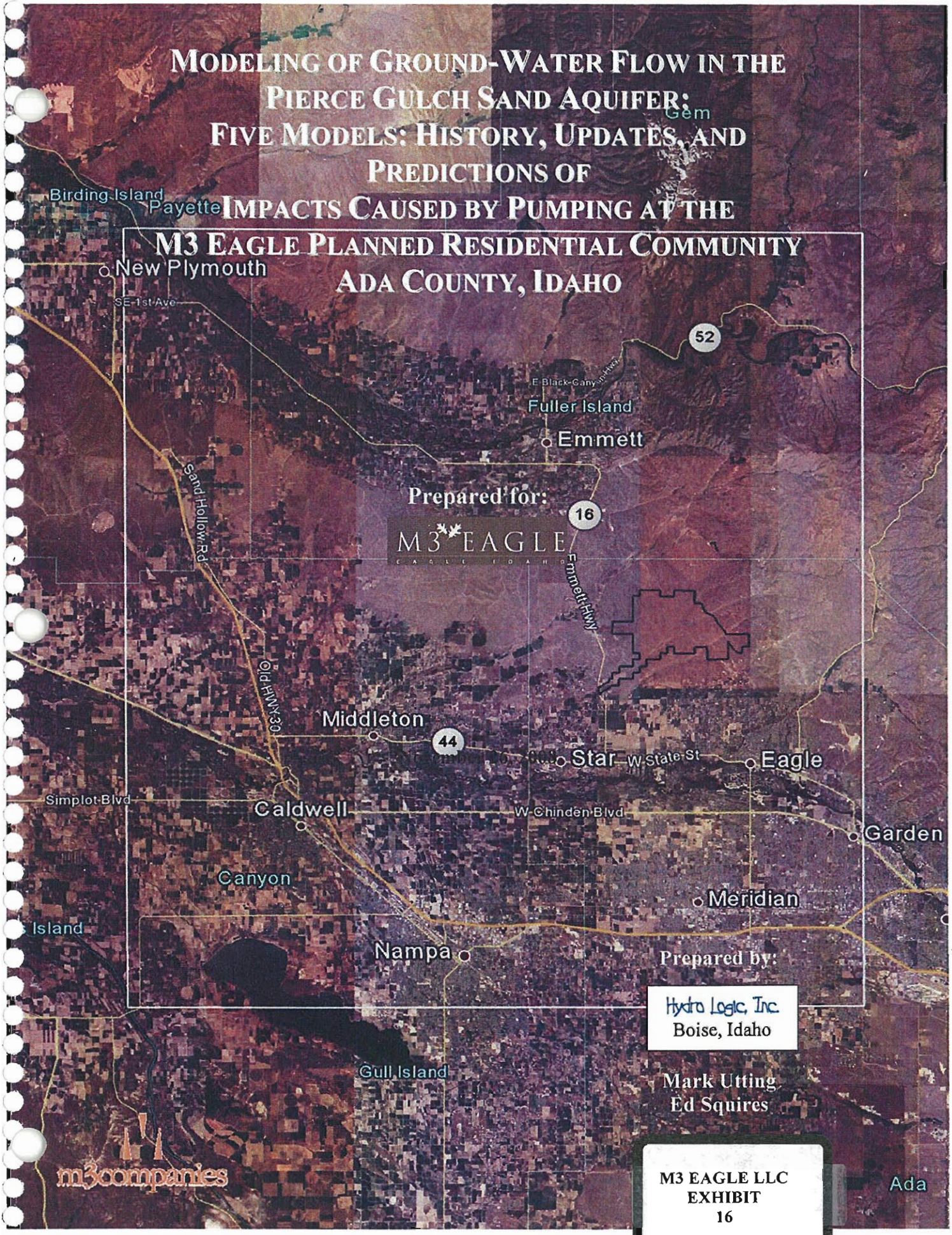
Modeling of Ground-Water Flow in the Pierce Gulch Sand Aquifer: Five Models: History, Updates, and Predictions of Impacts Caused by Pumping at the M3 Eagle Planned Residential Community Ada County, Idaho



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Modeling of Ground-Water Flow in the Pierce Gulch Sand Aquifer: Five Models: History, Updates, and Predictions of Impacts Caused by Pumping at the M3 Eagle Planned Residential Community Ada County, Idaho

Prepared for:
M3 Eagle, LLC

November 26, 2008

Prepared by:

Hydro Logic, Inc.
Boise, Idaho

Mark Utting
Ed Squires

EXECUTIVE SUMMARY

A recently developed three-dimensional, "Modflow" ground-water-flow model developed to include the greater M3-Eagle-Star vicinity, predicts that after 50 years of pumping from three wells at an average, continuous rate of 1,500 gallons per minute (gpm) from each well, drawdown impacts (water level declines) in wells completed in the Pierce Gulch Sand Aquifer one-half mile from the M3 Eagle property will be on the order of 10 to 20 feet. Drawdown impacts in wells completed in the shallower, unnamed alluvial aquifer overlying the Pierce Gulch Sand Aquifer are predicted to be about two-thirds of those predicted for the Pierce Gulch Sand Aquifer. To be conservative (likely to over-predict), the average annual volume of water pumped by the three wells in the simulation is about 10-percent greater than the amount of 6,535 acre-feet per year (equivalent to about 4,051 gpm or 9.02 cfs) requested by M3 Eagle to supply its Master Planned Community after full build-out (anticipated about 25 to 30 years after project start up).

The new model (called the "M3 model" in this report) supersedes four earlier ground-water flow models constructed by various entities over the past 26 years that included the greater M3-Eagle-Star vicinity ("Lindgren model"-1982, "USGS model"- 1991, "TVHP model"- 2004 and "U of I model"– 2007). The previous four models were unable to simulate and predict impacts to wells near the M3 Eagle property because these models were:

- Constructed with cell sizes that were too large (Lindgren, USGS and TVHP models),
- Developed with too few layers or layers not capable of modeling stratigraphic dip to realistically simulate the Pierce Gulch Sand Aquifer and overlying aquifers/aquitards (Lindgren, USGS, TVHP and U of I models),
- Set up with boundary conditions that did not allow ground-water flow in the Pierce Gulch Sand Aquifer (or for that matter, any modeled aquifers) to move to the Payette Valley as measured in the field (TVHP model), or
- Did not calibrate to transient conditions (U of I model).

The M3 model was constructed specifically to be able to predict ground-water flow in the greater M3-Eagle-Star vicinity while three of the four previous models were designed to consider flow over much larger areas and therefore, with much less detail. In addition, the M3 model does not have the problems associated with the previous four models because the team developing the model was able to learn from the previous models.

The new M3 model:

- covers 520 square miles,
- contains almost 82,000 active cells,
- comprises seven active layers
- has cell sizes as small as 330 feet on a side,
- was constructed with boundary conditions far from the M3-Eagle-Star vicinity that are unaffected by simulated pumping from the M3 site, and

- was calibrated to three long-term (one week to one month) aquifer tests.

The M3 model was developed by Pacific Groundwater Group (PGG) of Seattle Washington in close cooperation with Hydro Logic, Inc (HLI) in an interactive fashion. This collaborative effort allowed for efficient transfer of HLI's understanding of the hydrogeology of the project area in constructing and calibrating the model. Personnel at HLI have both developed numerical flow models in the past and have worked directly with key personnel at PGG over the past 20 years resulting in a strong, team-oriented, approach. This approach avoided the difficulties that often occur when models are generated without a strong understanding of field conditions or when regular interactions are limited between the modelers and personnel with direct knowledge of the hydrogeology of the modeled area. One of the goals of the M3 model was to accurately incorporate the real subsurface geologic section including the dip and thickness of sub-units as closely as possible, to create a realistic model that could be improved over time and serve as a useful tool in understanding the aquifer.

The M3 model was initially developed and calibrated to the Eaglefield and Lexington Hills aquifer tests, conducted near Eagle, Idaho. During the calibration process, it became apparent to the modeling team that water levels simulated by the model in the vicinity of the M3 Eagle property, were lower than those measured in the field during 2006 and 2007. As a result, two parallel models were developed: one that generally "honored" the aquifer transmissivities calculated from 17 pumping tests in the region (the "Tmatch" model) and one that allowed water levels to better match the field measured values (the "Hmatch" model). Both models met calibration criteria. Both models also generated predictions of drawdowns that would be caused by pumping from the M3 Eagle property that were generally similar (generally with a few feet of each other). By using the two parallel models for predictions, the results are presented as a range (e.g., "Predicted drawdowns one-half mile from the M3 property boundary range from 10 to 20 ft after 50 years of pumping."). Presenting a range of results brackets the uncertainty of the models. Uncertainty in the amount of pumping within the modeled area was also considered by calibrating both the Tmatch and Hmatch models with two estimates of total pumping: one smaller and one larger, resulting in a total of four separate predictions (Tmatch model based on the smaller pumping totals, Tmatch model based on the larger pumping totals, Hmatch model based on the smaller pumping totals and Hmatch model based on the larger pumping totals). In the end, the four predictions are all in close agreement, indicating that the uncertainty in the transmissivity and pumping data do not cause significant differences in model predictions.

Even though we consider the M3 model is the best predictive tool developed to date to assess changes to the ground-water system in the greater M3-Eagle-Star vicinity, we consider it a "work in progress." It was constructed such that it can be used for future simulations and can be updated as new information is obtained. In fact, the model presented in this report has been updated and revised three times since it was developed and presented in its original form in the one-year progress report included in Appendix A. Each of these updates (included in Appendix B) represents an improvement based on additional knowledge of the aquifer, water use or other features of the flow system.

Because the M3 model is an ongoing process and because it is best understood within the context of all four reports, this HLI model overview report combines and synthesizes the information from the four reports into one location and helps to explain the model in lay terms. Future update-information that should be considered includes: additional pumping-test data from new, high-quality aquifer tests of the Pierce Gulch Sand Aquifer; improved recharge analyses; improved analyses of leakage from canals, rivers and drains; and pumping test data from aquifers other than the Pierce Gulch Sand Aquifer (for example the Willow Creek Aquifer, the shallow unnamed alluvial aquifer and aquifers beneath the Payette River Valley).

The M3 model conservatively estimates ground-water underflow across the southeast boundary of the model (beneath the west Boise area) to be on the order of 102 to 115 cubic feet per second (cfs) from this region. This amount is at the lower end of the range quantified in several reports issued as part of the Treasure Valley Hydrologic Project which estimated 80 to 150 cfs of leakage from the New York Canal in the area east of Cole Road, and 21 to 110 cfs of leakage from the Boise River upstream from the Capital Bridge in Boise, for a combined total of 100 to 260 cfs (to two significant figures). The model was used to estimate the impacts of the reduction of flow from these two sources by simulating the decline in water levels that might result, if flow were to be reduced by twenty percent (through pave over or canal lining). The model predicted that water levels in the M3-Eagle-Star vicinity might decline by 2 to 5 ft north of the Boise River. Because the emphasis of the M3 modeling effort focused on the regions north of the Boise River and because of the closeness of the Meridian area to the model's southeastern boundaries, we do not consider predictions south of the river to be valid.

This modeling overview report discusses the history of numerical model development in the Treasure Valley. It includes key figures from three of the five models along with discussion of the improvements made with each model and what we consider to be their limitations in predicting pumping impacts in the M3 Eagle vicinity. We also include as Appendix A the original Pacific Groundwater report ("one-year progress report") that details model construction, initial calibration and the initial predictions when it was believed that seven wells might be needed to meet the initial, planned water requirements for the project. Three technical memoranda discussing updates and improvements to the model and the most recent simulations with the most up-to-date versions of the M3 model are also included in Appendix B. Appendix C contains the Conclusions and Recommendations sections from the two models (TVHP and U of I models) that preceded the M3 model.

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INTRODUCTION

This section of the report gives an overview of the work conducted, explains why the newest ground-water-flow model (the "M3 model") was developed, presents a very brief overview of the five models developed for the Treasure Valley area that include at least a portion of the greater M3-Eagle-Star vicinity, and outlines the structure of the report.

This report presents the results of a recently completed, "Modflow," three-dimensional, transient, computer-based, ground-water flow model of the greater M3-Eagle-Star vicinity (called the "M3 model" in this report). It also presents a summary and overview of the four ground-water flow models (that included this general geographic area) that preceded the latest model. The purpose of this report is to summarize the results and predictions of the new model, explain the significance of these results and show how this new model was built upon the recently-developed conceptual understanding of ground-water flow within the M3-Eagle-Star vicinity. A secondary purpose is to summarize the highlights of the results and recommendations of the previous models and to show the historical development of ground-water flow models pertinent to the M3-Eagle-Star vicinity.

The M3 model was developed by Pacific Groundwater Group (PGG) of Seattle, WA in close collaboration with Hydro Logic, Inc. (HLI) of Boise, ID. The PGG/HLI collaborative effort was calibrated to both a) water level data collected during 2007 ("steady-state" calibration) and b) three major Pierce Gulch Sand Aquifer tests conducted over the past seventeen years ("transient calibration"). This new, transient model simulates and predicts the potential impacts from pumping ground water from the regional Pierce Gulch Sand Aquifer in support of the municipal water-right application for up to 6,535 acre-feet per year, made by M3 Eagle for its Master Planned Community (Givens Pursley, 2008).

The M3 model predicts that impacts (interference reductions of well water levels) at full project build out, after 50 years of pumping from three on-site supply wells, each pumping at a continuous, annual average of 1,500 gpm (about 10-percent more than is currently planned) would be on the order of 10 to 20 feet, at some areas within one-half mile of the M3 property boundary. Since much of the M3 property is surrounded by BLM and or currently undeveloped lands, we expect impacts to existing wells completed in the Pierce Gulch Sand Aquifer outside of this "buffer zone" to be even less. Impacts to wells outside this buffer zone competed in the shallow unnamed aquifer directly overlying the Pierce Gulch Sand Aquifer in the Valley areas are predicted to be smaller.

The M3 model updates, and significantly builds upon, the two models that preceded it. A model developed by Douglas (2007) at the University of Idaho (the "U of I model"), the direct predecessor to the M3 model, was able to generally simulate water level data collected during 2006 ("quasi-steady-state" calibration), but was unable to accurately simulate previous aquifer tests. Because transient calibration was not possible for the U

of I model, it cannot be considered reliable and accurate to simulate and predict the impacts of ground water development from the M3 Eagle property.

The U of I model was highly significant, however, in that it verified the conceptual model in which ground water flows from the Boise River Valley to the Payette River Valley as described in HLI (2007a). It is important because it included the Pierce Gulch Sand Aquifer as a distinct hydrostratigraphic unit for the first time, based upon Douglas's review of both historical hydrogeologic data, and the more recent data presented in HLI (2007a). The U of I model is also significant because it updated the model that preceded it, the Treasure Valley Hydrologic Project ("TVHP model" – Petrich, 2004).

The TVHP model was the first "modern" (post millennial) ground-water flow model that included the greater M3-Eagle-Star vicinity along with a much wider modeled area. Because it covered a much wider area than the two more recent models, the TVHP model has a much coarser focus and did not consider the Pierce Gulch Sand Aquifer as a separate and distinct hydrostratigraphic feature. It also was set up with boundaries that forced the ground water within all the aquifers beneath the north Ada County foothills (including the M3 Eagle property) to stay within the Boise River Valley and flow toward the southwest contrary to what is now known (portions of the ground water in the Pierce Gulch Sand Aquifer flow toward the west and northwest toward the Payette River Valley) as indicated by recent hydrogeologic studies (HLI 2007a and b), USGS studies such as Parliman (1998) and Newton (1991), and by the two more recent models. The construction of the TVHP model *prohibited* the simulation of ground-water flow toward the Payette River Valley through the designation of the region between the Boise River Valley and the Payette River Valley as a no-flow boundary. Because of its regional focus, boundary conditions that forced ground water to flow toward the southwest, and the non-incorporation of the Pierce Gulch Sand Aquifer, it was not, and cannot now, be used to assess ground-water development from beneath the north Ada County foothills area.

Prior to the TVHP, two models were developed to simulate ground-water flow within the Boise River Valley. The first was the "Lindgren model," developed as part of a U of I master's thesis (Lindgren, 1982) while the second, the "USGS model" developed as part of the Regional Aquifer System Analysis (Newton, 1991) also simulated flow in the area. Because of the age and the relatively coarse focus of these models, the TVHP model was considered an update and a refinement to these older models.

Since the development of the first model (Lindgren), a considerable volume of detailed, technical information has been developed through test well drilling, geophysical surveys, aquifer tests, geochemical assessments, water level measurements and more. The newer, more-accurate, and more-complete data have allowed each subsequent model to be more detailed and more accurate than its predecessor. In addition, the need to predict impacts from projected ground water development in the north Ada County foothills area has resulted in the two most-recent models being more focused on, and more accurate for, analyses of this geographic region.

The four most-recent models were developed using the computer code "Modflow," developed by the USGS (McDonald-Harbaugh, 1988, 1996 and Harbaugh et al, 2002). Each model used the data as interpreted by the modeler, in the construction of a set of "cells," assembled as rows, columns and layers to represent an approximation of the subsurface hydrogeology of the modeled area. Each cell within the model was assigned hydraulic properties selected to allow the simulation of subsurface flow. The assigned properties for each cell were based upon the interpretation of the existing data available at the time.

The M3 model was prepared in stages. The model was originally functional in June of 2008. A report prepared by Pacific Groundwater Group (PGG) discussing the model and a predictive simulation of seven wells, each pumping at 1,000 gpm over a 26-year full-build-out period for the M3 Eagle Master Planned Community is included in its entirety as Appendix A. Since that time, PGG conducted additional calibration of the M3 model based on the data collected during a major nine-day aquifer test using well SVR #7 (located near the center of the M3 property). In addition, a more conservative model was developed to explore the uncertainty of pumping within the modeled area. This model increased overall pumping rates from numerous wells whose owners either do not measure or do not report the quantities of water pumped throughout the year. PGG then used the recalibrated model to predict pumping impacts that more accurately reflect the current projected development of ground water from beneath the M3 property, consistent with M3's revised water rights application. This simulation uses three wells, each pumping at 1,500 gpm over a 50-year period (representing the full potential impact about 25 years after full build-out). The additional calibrations and the additional predictive simulations were each summarized in a brief Technical Memorandum. Lastly, PGG was directed to consider the potential impacts to the ground-water-flow system should recharge originating as seepage from the Boise River and the New York Canal be reduced by twenty percent. All three reports (each presented as a Technical Memorandum) are included in their entirety in Appendix B. None of these four PGG reports have been previously issued or submitted to the Idaho Department of Water Resources (IDWR) prior to their inclusion in this HLI summary report.

Both the U of I and TVHP models have been documented in previously-issued reports submitted to IDWR. Since both of these reports are substantial in size, only the Conclusion and Recommendations portions of these reports along with a few selected figures are included in this report. Chapter Six (Conclusions and Recommendations) from the U of I model (Douglas, 2007) is included in Appendix C. A few key figures from Douglas are reproduced within our report. Appendix C also contains Chapter 12 (Conclusions and Recommendations) from the TVHP report (Petrich, 2004). Key figures from Petrich are also reproduced within our report. These figures have been modified slightly by adding the M3 Eagle project location and in some cases, ground-water-flow arrows as appropriate on figures showing water-level contours. These modifications were included to assist the reader in locating the M3 Eagle property and in understanding ground-water-flow directions.

The goal of this report is to explain ground-water models in a simplified, less-technical format, briefly summarize the history of ground-water-flow models that include at least a portion of the greater M3-Eagle-Star vicinity, assemble the pertinent information from the three most recent model reports, explain the results and significance of modeling in less-technical terms for the lay reader (who may be less likely to read a highly technical report on a ground-water model), explain the limitations of each model, and to recommend what we believe should be undertaken in support and improvement of the modeling effort.

Each section of this report works toward meeting this goal. The first section of this report is this introduction. The second section explains ground water modeling and particularly Modflow, as used by the four most-recent models. The third section of the report discusses the history and development of ground-water-flow models pertinent to the M3-Eagle-Star vicinity. The fourth section summarizes the development, calibration and predictive simulations of the M3 model. The fifth section of this report presents our recommendations for additional work to be done to support and improve the current M3 model.

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GROUND-WATER MODELS: WHAT THEY ARE, HOW THEY WORK AND MODLFOW

This section of the report explains that ground water models are a series of mathematical equations that represent a simplification of our understanding of how ground water flows. These equations can be solved by a computer in order to replicate historical hydraulic data and to predict the changes in water levels that would occur under different hydrologic situations, such as pumping from new wells. The four most-recent of the five models reviewed in this report were constructed using the computer code, "Modflow," developed by the USGS. Modflow consists of a series of modules or "building blocks" that can be assembled by a skilled modeler to represent the subsurface of the earth in a hydraulic simulation. A well-calibrated Modflow model can be used to predict the impacts from new wells and to explore many "what if" situations.

Description of a Ground Water Model

A ground water model is simply a series of mathematical equations representing ground-water flow. These equations can indicate water levels, flow rates and more. All ground-water models start with the very simple, but very powerful, ground-water flow equation

(developed in 1856 by Henry Darcy) that relates the quantity of flow to the change in the level (or pressure) of water as it flows through a porous zone of sand or gravel ("aquifer"). The Darcy equation relates the rate of flow through an aquifer, proportionally to the change in water level ("head") and a property of the aquifer that indicates its ability to allow water to flow through it ("permeability" or "hydraulic conductivity"). A very simple ground-water model may use only one Darcy equation and assume that all the properties of the aquifer are the same everywhere within the aquifer and that all the changes that are going to occur, have occurred. This situation is represented as a simple, one-dimensional, "steady-state," model of a homogeneous system, a situation that rarely occurs outside of a laboratory.

Because the real world is highly variable often with a lack of subsurface data and with changes that occur over time such as pumping, seasonal recharge, river flow, etc., a simplified, one-equation approach can only give a very rough approximation of how water flows through a subsurface system. Instead, a separate equation must be developed for each small portion of a water-bearing zone (aquifer) and for each zone where water is present but cannot be readily extracted by a well ("aquitard"). Each of these subsurface zones has different properties such that a series of equations becomes very complex and in many situations, impossible to solve directly. Changes over time must also be considered and are assessed using an equation that considers the change of water content (or "storage") within each cell. The real world is, in fact, far too complex and difficult to model using a few simple equations with simple solutions.

A computer model approximates the subsurface with a series of cells (or blocks), generally aligned as rows and columns within one or more layers. An equation[1] is developed for each cell. A model could be very simple with only one layer and a few dozen cells. A complex model could have many rows, columns and layers resulting in a hundred thousand or more cells. The computer "solves" all of the equations of the model when the solution of the equation in one cell balances with the solutions to the equations of the cells surrounding it. The computer takes tiny steps as it considers the solution in one cell and then compares it to the solutions in the surrounding cells, until the balance is achieved. Typically, millions of computations are needed for a model to generate results. Because the model must approximate the properties of each cell, the equations for each cell result in small errors – the difference between the model's calculated results and those that it might achieve, were it to run longer through additional iterations. The modeler specifies how small these errors must be for the results to be acceptable. After each step or iteration of a model run, the largest error observed within the model domain is compared with the maximum acceptable error specified by the modeler. When the largest observed error anywhere in the model is smaller than the specified largest-allowed error, the model is said to have "converged" with the resulting output (generally a water level or "head" specified for each cell) considered to be precise to within the specified acceptable error. When the model results are compared with, and are similar to, real-world data (such as water levels carefully measured in wells that have been accurately

[1] In the case of the Modflow models discussed in this report, the equation is a "finite-difference equation" whereby a complex differential equation is approximated by a simplified, linear equation. Some models use the "finite-element" technique which is not discussed in this report.

located and with accurately known well construction details) the model is said to be "calibrated."

Modflow

The US Geological Survey (USGS) developed a computer code called "Modflow" to assist in the modeling of ground-water flow. Modflow (and its earlier predecessors) is probably *the* most, widely accepted ground-water flow model code in use within the USA. The code is not specific to any one ground-water system. Rather it consists of a series of modules that allow the modeler to represent a wide variety of subsurface conditions, with a wide variety of model inputs and boundaries, solved with a wide variety of solution packages. Modflow is highly flexible and allows the modeler to represent many physical situations from vertical slices of a flow system; to a flat, two-dimensional approximation of a ground-water flow system; to a multi-layer, three-dimensional simulation of the ground-water flow system with rivers, wells, precipitation, drains and more. Modflow can simulate a flow system that has had as much time as it needs to reach equilibrium such that nothing is changing: water levels are constant, river flows are unvarying, and rainfall (considered as recharge) is constant. The result is a "steady-state" model. Modflow can also simulate a system where wells start and stop pumping, river levels rise and fall, seasonal rainfall varies, and other hydraulic changes occur. The result is a "transient" model. Modflow can be used to simulate simplified systems where the properties of an aquifer do not vary with position or direction of flow ("homogeneous and isotropic") to systems where properties are different at different locations within the system ("inhomogeneous") and/or vary, depending on the direction of ground-water flow ("anisotropic").

It is up to the modeler to determine which modules are needed and which data should be used in setting up the model. Modflow has modules allowing the simulation of varying aquifer and aquitard properties, wells, rivers, drains, recharge, inflow and outflow along model boundaries and more. Input data are needed for each of these modules. These data are typically: aquifer and aquitard properties, water levels, pumping rates, river and canal levels, river and canal bed properties, recharge rates, flow into and from the model from more distal areas and more. These data come from a variety of sources including field testing, historical data records, air photos (for land use assessment), computer data bases for Geographical Information Systems (GIS) and more. A skilled modeler must be able to evaluate the various sources of data, select the data that are appropriate and applicable. A good modeler must also be able to make sound, scientifically-based estimates of the data input values for regions where data are sparse or non-existent.

Because not every cell of the model has accurate data available, a modeler typically conducts a "sensitivity analysis" to assess which data are important to know and which data can be estimated with only small errors in the results when data-value estimates are incorrect. In a sensitivity analysis, the values of one selected portion of a data set (for example, river leakage) are changed, often by a power of ten (ten times larger or ten times smaller). All other parameters are held unchanged. When a parameter is changed by a power-of-ten and the change in model results is small (and acceptable), the model is

said to "insensitive" to that particular parameter. When the change in model results is large, the model is said to be "sensitive" to that parameter. By conducting a number of sensitivity analyses, the modeler can mathematically demonstrate which types of data are important to know accurately and which data types are less important and can be estimated based on sound hydrogeologic judgment (based on experience) with little resulting error.

Because of its power, flexibility and wide acceptance, the two most-recent models developed and reviewed in this report, were based on Modflow-2000 (Harbaugh et al, 2000). Both models used a form of graphical interface to assist in constructing the model and in viewing the results. The TVHP model started with older versions of Modflow: Modflow (McDonald and Harbaugh, 1988) and Modflow-96 (McDonald and Harbaugh, 1996) but was apparently run in its final version using Modflow-2000. It, too, was constructed and operated using various graphical interfaces. The USGS model also used an older version of Modflow in its construction.

A Ground-Water-Flow Model as One of Many Tools

All ground-water-flow models are just one of many tools used to understand ground-water flow and to predict what might happen under certain hydraulic conditions. No ground-water-flow model can ever be 100-percent accurate. There are always portions of the model that are based on best estimates for input data. We can never know with 100-percent certainty the properties of the geologic materials at all subsurface points. The estimates for various inputs may result in small errors in model predictions. They may also generate errors that are larger, especially in areas where the accuracy of the model is not considered as important compared with the areas of focus where an understanding of ground-water flow is important. Nonetheless, through sensitivity analyses, the modeler can develop an understanding of the relative significance of the predictive results.

A model is also an important tool to help indicate where it is important to develop additional information. Often data are collected that appear to be complete and only when input to the model, do data gaps become apparent. For this reason, the development of a model should be considered an on-going process and not a product that remains static and "final." Models are typically calibrated to show that they can replicate historical data. Over time, the model should be "verified" through the collection of additional data and rerunning of the model. When simulations do not match the actual hydraulic response of the system, the model needs to be adjusted. The adjustment (recalibration) allows the model to be improved, resulting in an increase in the confidence of the accuracy of the model. Through this iterative process the model becomes a more valuable tool.

In the end, all models will have some inaccuracies and therefore be at least partially "wrong." Even so, they are valuable as one of many tools. The model should not be considered the "be-all-and-end-all" understanding of a ground-water-flow system. However, when the physical, geochemical, and hydraulic data are all consistent with the results of a flow model, the confidence in the understanding of the system is increased.

AN OVERVIEW OF THE HISTORY OF GROUND-WATER-FLOW MODELS THAT INCLUDE THE M3-EAGLE-STAR VICINITY

Five transient, ground-water-flow models that have included at least a portion of the M3-Eagle-Star vicinity have been developed over the past 26 years. Each of these models has increased in its complexity and improved upon its predecessor. The latest model (the "M3 model") includes the most up-to-date hydrogeologic information, has the greatest detail and finest focus, and is the only existing model capable of predicting future impacts from pumping withdrawals (with relative accuracy) from beneath the north Ada County area that includes the M3-Eagle-Star vicinity. The M3 model was specifically developed and calibrated to allow for credible predictions of planned ground-water withdrawals from the Pierce Gulch Sand Aquifer in support of M3Eagle's municipal water rights application.

Older Models

The oldest computer-based, numerical, ground-water-flow model of the Treasure Valley was developed by Lindgren (1982) as part of a University of Idaho Master's thesis. This model (the "Lindgren model") was very simple in comparison to what has been developed since. It was designed to give a general understanding of ground-water flow in the Treasure Valley. The Lindgren model was two dimensional (one layer) and assumed (among other things) a system with only one aquifer up to 1,000 ft thick. It also assumed that the upland to the north of the Payette River was a no-flow, impermeable boundary. The Lindgren model was based upon a finite-difference model developed by de Sonneville (1972), originally designed for simulation of the Eastern Snake River Plain aquifer system. The model was calibrated to steady-state (1972) conditions but had difficulty in its transient calibration. It did not include the current understanding of ground-water flow through the Pierce Gulch Sand Aquifer to the Payette Valley beneath the north Ada County foothills. Because of its age, over-simplification of the ground water system in the north Ada County area, its coarse focus and difficulty in transient calibration, the Lindgren model was never designed to (and cannot) simulate future ground-water withdrawal from beneath the North Ada County area.

The second significant regional ground-water flow model that included the M3-Eagle-Star vicinity was developed by the USGS (Newton, 1991) as part of their Regional Aquifer System Analysis program. This regional simulation model used a very-coarse grid (with cells 2 miles on a side), consisted of three layers, and simulated the upper 500 feet of the model as a single unconfined aquifer bounded on top by a water table. The current understanding of the Pierce Gulch Sand Aquifer as a confined aquifer (with locally strong, upward flow gradients as high as 40 feet above ground surface) was not, and could not be simulated by the USGS model. Similarly to its predecessor, the USGS model was never designed to (and cannot) simulate future ground-water withdrawal from the North Ada County area.

TVHP Model

The third numerical model to incorporate at least a part of the greater M3-Eagle-Star vicinity within its model domain was developed as part of the Treasure Valley

Hydrologic Project (Petrich, 2004). This TVHP model was a significant update to its predecessors. It consisted of four layers with cells one-mile on a side. The domain of the model and its mile-on-a-side grid pattern (Figure 1), shows that the surface water divide (the crest of the foothills) defines the hydraulic boundary of the model in the M3-Eagle-Star vicinity. Similarly to its predecessor the TVHP model was designed to simulate regional flow and regional-scale impacts. Petrich states that "the direct use of the model for evaluating small-scale (e.g. individual wells) issues is limited." Our review supports this conclusion of Petrich's and indeed, our understanding of this model suggests that the mile-on-a-side cell size would make predictions on this scale to be only approximate.

The model divided the ground-water system into four layers. The upper portion of the ground-water-flow system was treated as a water table (unconfined) aquifer. This upper aquifer was assumed to be 200 feet thick with the top of the aquifer (the water table) defined as a plane connecting similar elevations of the Boise and Snake rivers. The modelers ruled out using direct geologic information (including the flood plain and terrace gravels of the present-day and ancestral Boise River) to define the upper aquifer. The TVHP model has an "intermediate" confined aquifer in the next 200 feet below the water table aquifer, with two more confined layers each 400 thick, lying below, for a total of 1,200 ft of saturated, water-bearing strata. The presence, distribution, and hydraulic role of the Pierce Gulch Sand Aquifer in ground-water flow toward the Payette River Valley were not incorporated into the TVHP model. Two representative cross-sections from the TVHP model report showing the vertical layout of the cells are shown in Figure 2. The details of the hydrostratigraphic layering now known to exist in the M3-Eagle-Star vicinity cannot be incorporated into this simplified layering system. The figure also shows leakage from the New York Canal and the Boise River as significant sources of recharge to the underlying ground-water system, an important contribution of the TVHP model. The recharge is indicated by the downward flow lines beneath the Boise River and the New York Canal.

The TVHP model assumed the surface water divide to be a "no-flow" (impermeable) boundary in the north Ada County area. Because of this no-flow boundary, ground-water flow in this area within all four layers is forced to flow to the south and west. Figure 3, reproduced from the TVHP report, shows ground-water potentiometric contours ("a water level map") with lower-elevation contours to the southeast of the M3 Eagle property and therefore all ground water flowing toward the southwest with none flowing toward the Payette Valley. [We have added flow arrows and the general location of the M3 property to assist the reader.]

The TVHP was not designed to, and therefore cannot, accurately simulate planned future withdrawals from beneath the M3 Eagle property or from the greater M3-Eagle-Star vicinity for three reasons. The first is the lack of inclusion of the Pierce Gulch Sand Aquifer as the regional water supply aquifer in this area. Using only two layers (one "water table" and one "confined") to simulate the upper 600 feet of the ground-water flow system is not adequate to properly simulate ground-water flow in the Pierce Gulch Sand Aquifer. The second reason is the no-flow boundary that forces all ground-water to flow to the southwest. Two series of water level data, one collected in 2006 and the other

in 2007, both show portions of the ground water in the North Ada County area flowing toward the west-northwest, to the Payette River Valley, as do two USGS reports (Parliman, 1998, and Lindholm, et al, 1983). The third reason is the coarse grid of the model. Simulations with grid cells one mile on a side can only show very coarse, approximate water-levels that would be inadequate for reliable predictions of future well-pumping impacts.

The TVHP model report lists a series of conclusions and recommendations (included in Appendix C). Many of the recommendations refer to additional modeling runs to assess various hydrologic situations. Other recommendations included: expanding monitoring (of water levels), the installation of multi-completion monitoring wells, and refining the grid size (smaller cells) in some areas. Since the model report was issued in 2004, monitoring has expanded in the M3-Eagle-Star vicinity, four multi-completion wells have been installed on the M3 Eagle property and two models with refined grids have been constructed.

U of I Model

The U of I model (Douglas, 2007) was the fourth numerical model developed to simulate ground-water flow within an area that includes the M3-Eagle-Star vicinity and the first attempt to specifically develop a model that could simulate planned withdrawals from the M3 Eagle property. Although it was not able to simulate the planned M3 ground-water withdrawals, it was a significant improvement upon its predecessors for analyzing ground-water flow in the M3-Eagle-Star vicinity. Some of the improvements include: a - refined (reduced) cell size, eight layers (although many played no significant role in the simulation of the greater M3-Eagle-Star vicinity), specific incorporation of the Pierce Gulch Sand Aquifer into the model, and boundary conditions that reflect the current understanding of ground-water flow from the Boise River Valley to the Payette River Valley. These improvements are discussed below.

The U of I model was calibrated to "quasi-steady-state conditions" in that it was able to generally replicate the water levels collected during summer of 2006. As such, it verified the feasibility of the conceptual understanding that ground water flows northward beneath the north Ada/Canyon county foothills, a significant advancement. It was not able, however, to replicate transient aquifer-pumping-test data. The U of I model is not, therefore, capable of predicting future well pumping scenarios from the M3 Eagle property.

The U of I model covers an area of 713 square miles, using a model grid of 62 by 46 cells, each one-half-mile on a side. Each cell is one-fourth the size of the cells in the TVHP model and 1/16 of the size of the USGS model, a significant improvement. The modeled area was much larger than the focus area of the M3-Eagle-Star vicinity in order to be able to incorporate natural boundaries to the system. As with most models, the focus area received more attention and detail in the incorporation of hydrogeologic information into the model. The model domain and grid outline reproduced from Douglas

(2007) are shown in Figure 4. The M3 Eagle property boundary is included in the figure to assist the reader.

The U of I model used eight layers, strictly defined by elevation, to simulate ground-water flow, as shown by the representative model cross section in Figure 5. Because of this definition by elevation, the upper three layers and the bottom layer played only a minor role in the simulation. In the eastern part of the model domain, the upper two layers represent the higher elevations (mostly bedrock and low-permeability sediments that we do not consider to be in significant hydraulic connection to the aquifers in the valleys). In the western part of the model domain, the top three layers lie above ground surface and therefore drop out of the flow simulation. The bottom layer represents 1,850 feet of low-permeability sediments (mostly clays) that are not an active part of the cold-water flow system of the region. Thus, most of the simulation takes place using four layers.

The Pierce Gulch Sand Aquifer is simulated within portions of Layers 5, 6 and 7 of the U of I model. However, since these layers are defined strictly by elevation, and the Pierce Gulch Sand Aquifer dips toward the southwest at approximately 100 feet per mile, the properties of each cell represent an average of the properties of the Pierce Gulch Sand Aquifer and the other sediments sharing the physical space of each cell. The inclusion of the Pierce Gulch Sand Aquifer into the model is an improvement over earlier models. In our opinion, however, the positioning of the layers based on elevation and not to the actual orientation of the Pierce Gulch Sand Aquifer reduces the ability of the model to specifically predict the effects of well pumping within the Pierce Gulch Sand Aquifer, alone.

The model uses a thin, low-permeability layer (between elevations of 2,500 and 2,503 ft above mean sea level) to force the Pierce Gulch Sand Aquifer and other aquifers shared by layers 5, 6 and 7) to act as confined aquifers. This three foot layer does not represent a layer existing in the "real world" although it does confine the deeper aquifers and keep the lower-elevation surfaces of the model from flooding and becoming lakes.

The U of I model used boundaries that allowed ground-water to flow from the Boise River Valley to the Payette River Valley as was indicated by water level data collected in 2006 (incorporated into the U of I model) and 2007(obtained after the model was substantially completed). The physical boundaries of the model are many miles from the focus area of the M3-Eagle-Star vicinity and do not, as with some previous models force all ground water in the Pierce Gulch Sand Aquifer to flow toward the Boise River from areas beneath the north Ada/Canyon County foothills. Each model cell along the boundaries was defined as "no-flow" (no ground water flowing into or out of the model) or "general head." (A general head is a specified water level at a specified distance from the boundary of the model along with a specified hydraulic term – "conductance," that controls the rate of flow. The effect of a general head boundary is to allow flow into or out of the model in areas where such flow is known to exist, but defined by water levels sufficiently far from the model's boundary such that pumping from a focus area within the model (away from the boundary) does not change the inflow or outflow. The modeler

picks the water level, distance and conductance that replicates the flow and then verifies that pumping from the focus area does not significantly affect the flow at the boundary.)

The U of I model report lists several recommendations to improve upon the model (All of which, are include in Appendix C). In broad categories, these included:

- additional monitoring,
- improved analysis of recharge,
- inclusion of all canals and ditches,
- improved analysis of water withdrawals,
- additional aquifer tests, especially from beneath the M3 Eagle property,
- inclusion of storage coefficients (for transient analysis), and
- inclusion of improved hydraulic information from zones above and below the Pierce Gulch Sand Aquifer.

These recommendations represent improvements that could be made to the existing model. The model *could* be updated by using the data generated through each of these improvements and by recalibrating the model. Undoubtedly, the updated model would be an improvement. However, we believe that the U of I model has limitations that ultimately would make it less valuable than a new model that took full advantage of the newly-developed information in its initial construction.

The timing of the construction and calibration of the U of I model and the timing of the ongoing HLI hydrogeologic investigation of the greater M3-Eagle-Star vicinity, limited the end results and usefulness of the model. The U of I modeling program had a "data cut-off" date of early summer 2007. Any data or new understandings of the ground-water system collected after this date could not be incorporated into the modeling process. However, considerable work *was* conducted during and after summer of 2007: additional water levels have been collected and analyzed; aquifer test have been conducted and analyzed; additional test wells have been constructed; geochemical samples have been collected, analyzed and modeled; additional borehole geophysical analyses have been conducted; and pumping tests from throughout the region have been reanalyzed. The information gathered since early summer 2007 has expanded the understanding of the flow system that would lead to an improved model. Unfortunately, the deadlines imposed through the Master's thesis process could not be stretched to match the timing of additional data collection. In an ideal world, the modeling would not begin until the data collection and analysis process was substantially complete. This was not possible, however.

In summary, the U of I model was an improvement over previous models. It used smaller cells and more layers, recognized and incorporated the Pierce Gulch Sand Aquifer, and recognized and incorporated model boundaries that better represent the flow system as it is now known. Since its completion, however, significant additional data have been collected and the understanding of the ground-water-flow system of the greater M3-Eagle-Star vicinity has increased. In addition, the limitations of the U of I model make it less useful as a model upon which to build a predictive tool.

For these reasons, a new model was needed for M3 to be able to simulate (with reasonable confidence) its planned water withdrawal from the Pierce Gulch Sand Aquifer beneath the M3 Eagle property. This new model (the "M3 model") was developed to build upon the improvements made by the U of I model, incorporate the additional hydrogeologic understanding gained after summer 2007, and learn from, and improve upon the limitations revealed through the U of I modeling process and all previous models. The M3 model is discussed in the following section of the report.

M3 MODEL

The fifth ground-water-flow model of the greater M3-Eagle-Star vicinity (the "M3 model"), developed by Pacific Groundwater Group of Seattle, WA in close collaboration with Hydro Logic, Inc. of Boise ID, was calibrated to both "steady-state" and "transient conditions." The M3 model consists of two separate models: one calibrated to best match existing water level data and one calibrated to best "honor" the transmissivities (a property of the aquifer) indicated through the analysis of 17 aquifer tests. The two models generate similar predictions and serve to bracket uncertainty in the data. The M3 model predicts that at full build-out of the M3 Master Planned Community, after 50 years of annual-average pumping at 1,500 gpm from each of three on-site supply wells, drawdown impacts to wells completed in the Pierce Gulch Sand Aquifer would be on the order of 10 to 20 feet, at some areas within one-half mile of the M3 property boundary. Impacts to wells at a similar distance competed in the shallow unnamed aquifer overlying the Pierce Gulch Sand Aquifer are predicted to be smaller. A mass-balance analysis indicates that currently, all the wells within the model domain pump only 9 to 14 percent of the ground water flowing into the system. Pumping from the M3 Eagle project at full build-out would increase this total by about 0.9 percent, a relatively small amount. The model calculates that about 102 to 115 cubic feet per second (cfs) flow into the Pierce Gulch Sand Aquifer from the southeastern regions beyond the model domain (Boise and Meridian). Field measurements made in this area as part of the Treasure Valley Hydrologic Project indicate a total of 100 to 260 cfs seeps from the Boise River and the New York Canal into underlying aquifers, supporting the conservative nature of the model-calculated inflow. The model predicts that water levels in the Pierce Gulch Sand Aquifer beneath the greater Eagle vicinity north of the Boise River would decline by about 2 to 5 ft (and probably by less than 1 foot beneath the M3 property), if flow entering the model from the southeast were to be reduced by 20 percent. Such a reduction might occur were the seepage from the New York Canal to be significantly reduced. The M3 model updates, and significantly builds upon the four models that preceded it.

Why the M3 Model was Developed

Because the U of I model could not serve as the predictive tool needed to assess the potential impacts of the development of the ground water needed for the completion of the M3 Eagle Planned Community, Hydro Logic, Inc. (HLI), through the authorization of M3 Eagle, LLC, hired Pacific Groundwater Group (PGG) to develop a transient, three-

dimensional, calibrated, numerical (computer based), ground-water-flow model, in close collaboration with HLI. The three-dimensional Modflow model was developed to simulate realistic and defensible predictions of impacts to existing wells that could be caused by municipal water-supply wells pumping from the Pierce Gulch Sand Aquifer beneath the M3 Eagle property,. The model predictions are made in support of the M3 Eagle Planned Community that has applied for a municipal water right of 6,535 acre-feet per year that it will require at full project-build-out, expected to take about 25 to 30 years, once construction begins (Givens Pursley, 2008).

Specifically, the M3 model was developed to:

- build upon the understanding and improvements made through the U of I modeling process,
- move beyond the limitations of the U of I model, and
- incorporate the improved on-going understanding of the hydrogeology of the greater M3-Eagle-Star vicinity provided by M3's hydrogeologic studies.

The model was developed as a tool to better understand the ground-water-flow situation in the greater M3-Eagle-Star vicinity. We do not consider it to be the ultimate understanding and definitive tool for ground water analyses. Rather it is one of many tools that help to clarify how ground water flows beneath the M3 Eagle property and in the North Ada County area. The predictions made by the model are unlikely to be 100-percent accurate. Rather, we believe that they give a reasonable range of likely impacts at various points within a few miles of the M3 property. Further away, where there was less emphasis on data collection and analysis, predictions are likely to be less accurate.

The M3 Model as an On-going Process

The M3 model was developed as a "living" model intended to be improved upon and refined over time as more data are collected and analyzed and new information becomes available. The model was initially developed, (and continues to be developed) as an on-going and evolving process and not a "final product." It has been, and will continue to be, improved and updated over time.

Because on its on-going nature of this project, PGG has issued several reports detailing the model at various points in its development. The first report was issued approximately one year after the modeling effort was started. This report, dated June 4, 2008 (included in Appendix A) detailed the initial model, its steady-state calibration, its transient calibration to two long-term aquifer tests ("Lexington Hills test" and Eaglefield test") and its 7-well simulation of what was initially believed to be M3's water requirements and the ability of the aquifer to supply only 1,000 gpm per supply well. As discussed, below this report presented the development of two parallel models (the Tmatch model and Hmatch model) to accommodate and explore uncertainties in the data and to allow a bracketed prediction of impacts to reflect these uncertainties.

A second update to the model was issued after HLI completed the analysis of a major aquifer test ("SVR #7 test"). The data obtained from this test, were the first for a long-term (9-day) aquifer test from beneath the M3 property and the first from the northern part of the model focus-area. Based on the SVR #7 test data, PGG recalibrated both the Tmatch and Hmatch models. The recalibration was presented in a Technical Memorandum dated July 26, 2008 (included in Appendix B).

A third update to the model was issued to revise the predictions of full-build-out pumping from beneath the M3 property using the recalibrated model, the reduced water requirements for the M3 property and the new understanding that individual supply wells with yields in excess of 2,000 gpm would likely be possible from the Pierce Gulch Sand Aquifer beneath parts of the M3 property. The revised predictive simulation was presented in a Technical Memorandum dated September 22, 2008 (included in Appendix B).

A fourth update to the model was issued after it was decided to make the model more "conservative" (likely to predict greater impacts from pumping) by exploring the uncertainty in well pumping data from supply wells within the model domain. Since very little record of actual well pumping amounts is available in the public record, estimates were made for the initial calibration and the calibration using the SVR #7 data. In this more conservative recalibration, larger amounts of pumping were assigned to various supply wells throughout the model domain, in order to explore whether the additional withdrawals would significantly affect predictions of impacts caused by pumping from beneath the M3 site. Both the Tmatch and Hmatch versions of the model were recalibrated using these higher pumping rates. The newly recalibrated model was then used to predict impacts caused by long-term pumping from the M3 property using both Tmatch and Hmatch versions of the model. The higher-existing-pumping-rate model was also used to explore possible changes to the ground-water-flow system that might be caused, were seepage from the New York Canal to be reduced. The revised calibration, the revised 50-year drawdown impacts and the possible changes to the ground-water-flow system from changes in New York Canal seepage were presented in a Technical Memorandum dated November 14, 2008 (also included in Appendix B).

Because the model is evolving and because the latest (November, 2008) version of the model can only be understood in the context of the previous versions, we summarize the process and development of the model with the perspective of having synthesized the initial report and the three memoranda, below.

M3 Model: Initial Development

Pacific Groundwater Group began developing a seven-layer, three-dimensional ground-water-flow model (the M3 model) in close collaboration with Hydro Logic, Inc., shortly after it was realized that all of the existing models (including the U of I model) could not accurately predict the impacts of the proposed pumping of ground water from beneath the

M3 Eagle site. HLI worked closely with PGG to help streamline the modeling process[2]. When PGG recognized that additional data were needed, HLI was usually able to collect, process, and analyze the data needed for the model. When HLI recognized data gaps from areas within the model domain, PGG was able through various modeling activities ("sensitivity analyses") to assess whether the data were critical to the model. In some situations when reviewing model output, PGG found results were best interpreted based on HLI's on-the-ground hydrogeologic experience within the model domain. Through this interactive process, the quality of the model was significantly improved.

The model was developed using Groundwater Vistas - Version 5 (ESI, 2007) which is a graphical interface for Modflow 2000. Solutions were obtained using the "Preconditioned Conjugate-Gradient Method" which is a mathematical solution package that solved the hundreds of thousand of equations within the model, in a timely and stable manner.

The M3 model covers a 520 square mile area, uses almost 100,000 cells (about 82,000 active), and has variable cell size (330 feet on a side in model focus areas and up to one-half mile at the model boundaries). The smaller cell sizes allows for the most-precise predictions to-date of water levels at specific areas within the model focus area. All cells are oriented north-south/west-east and positioned to lie within the public land survey system (township/range/section/quarter-section/quarter-quarter-section). The model domain is presented in Figure 6, while the model grid is shown in Figure 7, both reproduced from the initial M3 model report (PGG, 2008a).

The model has seven layers, oriented to represent the hydrogeology specific to the M3-Eagle-Star vicinity and greater modeled area. The Pierce Gulch Sand Aquifer is modeled in Layers 5, 6 and 7. The three layers are oriented to dip to the southwest as indicated in HLI (2007a) whereby the geophysical logs from 13 wells and 36 boring logs presented on Well Driller's Reports and other consultant's reports were used to construct a contour map of the bottom of the Pierce Gulch Sand Aquifer. Thus, the layers simulating the Pierce Gulch Sand Aquifer are oriented to our best understanding of the position of this hydrostratigraphic unit. Three layers were used to allow for partial penetration of both pumping and observation wells used to calibrate the model under transient conditions (discussed below) and to allow for future changes to the model to reflect differing properties of the aquifer as a function of depth, as we learn more about it.

The layers overlying the Pierce Gulch Sand Aquifer were constructed to best represent the aquifers and aquitards in the model domain. A lower-permeability layer (Layer 4) was assigned to overlie the Pierce Gulch Sand Aquifer and represents a confining layer present beneath much of the Boise River Valley and parts of the foothills. In areas where this confining layer is not present (such as in the Willow Creek Aquifer and beneath the Payette River Valley) the properties of the various aquifers present at the elevation of

[2] The collaboration between HLI and PGG was strong in part because of the history between the project manager at HLI (Mark Utting) and the project manager at PGG (Peter Schwartzman). Mr. Utting is a former principal at PGG, has produced several ground-water-flow models and worked with Mr. Schwartzman on dozens of projects over the past 19 years. Through this mutual experience and mutual understanding of the modeling process, the collaboration between HLI and PGG was strong and seamless.

Layer 4 were assigned based on various sources such as consultant's reports and Well Driller's Reports. In the Boise River Valley and parts of the upland, Layer 3 consists of a shallow, generally confined aquifer that represents the "shallow, unnamed alluvial aquifer" described in HLI, 2008b. In various PGG reports the term "middle aquifer" was adopted for Layer 3, as a simpler description. Layer 2 consists of a shallow, lower-permeability confining layer beneath much of the Boise River Valley and portions of the upland. In a manner similar to that of Layer 4, aquifer properties were assigned to Layer 2 where the Willow Creek Aquifer is present and beneath the Payette River Valley. Layer 1 represents the Boise River Gravels in the Boise Valley and unnamed alluvial gravels in the Payette Valley.

In the greater North Ada County area where extensive characterization through test well drilling and aquifer pumping test analyses has taken place, hydrostratigraphic properties were assigned based on relatively "hard" data. Outside of the main area of focus, layers were assigned properties as indicted by various sources including consultant's reports, the files at HLI, Well Driller's Reports and various IDWR sources. We believe that the layer properties in the North Ada County area are more likely to be accurate than those assigned to the parts of model domain in Canyon, Payette and Gem counties.

Modeling sensitivity runs demonstrated that an eighth layer below the Pierce Gulch Sand Aquifer to accommodate upwelling of geothermal water into the coldwater system (modeled with Layers 1 through 7), was unnecessary. Based on the known upward flow gradients and properties of the underlying Terteling Springs mudstone, modeling runs were conducted to calculate the significance of an "eighth layer" and the water it might contribute. The runs assumed a uniform upward flow gradient beneath the entire model domain based on field observations from wells completed within sand layers within the Terteling Springs mudstone, located in the southeast parts of the model domain. The differences between runs with and without this upward flow from beneath the Pierce Gulch Sand Aquifer were found to be so small (maximum increase in water levels in the Pierce Gulch Sand Aquifer of less than 0.1 foot) that an eighth layer was deemed unnecessary.

The M3 model made great use of Graphical Information System ("GIS") analyses and Digital Elevation Models ("DEM") for generating inputs for the model. Land-use GIS data were used to input recharge based on agriculture, rainfall and sources of irrigation water (surface water from canals versus ground-water from wells). GIS was also used to input leakage from canals and ditches and seepage in and out of rivers in the model domain, all based on digital data available from the USGS and other sources. GIS was also used to input recharge from septic drainfields in non-sewered areas.

Model boundaries were selected based in part HLI's field research and in part on the experience of the previous four models that indicated the surface water divides in north Ada and Canyon counties are *not* boundaries to ground-water flow. Boundaries used in the model consisted of "no-flow," "river," "constant-head," "recharge," and "general head." No-flow conditions were assigned where hydrogeological analysis indicated that ground water neither flowed in or out of the model boundary cell. River boundaries were

assigned based on the mean water levels in the Boise River, Payette River and Lake Lowell, estimated permeabilities and estimated thickness of the river or lake bottoms. Constant heads (fixed water levels) were assigned to parts of the southwestern, northwestern and northeastern portions of the model where water levels are known and assumed to lie too far away from, and therefore unaffected by, pumping within the model focus area. General heads (as explained on page 11, above) were initially assigned to the southeastern edge of the Pierce Gulch Sand Aquifer (at the model boundary) where ground-water flows into the model, originating from areas lying to the east of the model domain, as seepage from the Boise River and the New York Canal,. As part of a sensitivity analysis, these general head boundaries were converted to "constant flux" (flow) boundaries. This conversion maintained the inflow to the Pierce Gulch Sand Aquifer at the same rate as that calculated by the general-head boundary. The conversion did not alter the water levels calculated by the model during the initial simulation of pumping from the M3 Eagle property (seven wells pumping at 1,000 gpm each) demonstrating that the general-head boundary cells along the southeast corner of the model do not generate additional flow during the simulation of pumping. During the latest simulation (three new M3 supply wells pumping at 1,500 gpm each and total existing pumping increased throughout the model domain) the general head boundary was converted to a constant flux boundary to eliminate the possibility that pumping might artificially induce additional flow during the simulation. The constant flux boundaries were also used to explore the possible impacts in the future were flow to be reduced from lining the New York Canal (discussed below).

The properties and positions of the various hydrostratigraphic units were initially estimated based on analyses of pumping tests (for aquifer properties), and a combination of geophysical logs from HLI and the files of United Water of Idaho, and review of lithologic logs included with consultant's reports and Well Driller's Reports on file with IDWR (for aquifer position). Initial profiles at 13 locations with borehole geophysical logs and 36 locations with lithologic logs (a total of 49 wells) were then contoured to generate three dimensional spatial positioning of the aquifer and aquitards in the model domain. The contours were then modified, based on HLI's hydrogeologic knowledge of the area to accommodate known contacts between hydrostratigraphic units (such as between the Pierce Gulch Sand Aquifer and the Willow Creek Aquifer) as well as known structural boundaries (such as defined by the West-Boise-Eagle fault system).

In areas where little direct hydraulic data were available from pumping tests, we used best professional judgment to interpret the lithologic data to estimate aquifer properties using relationships between the type of deposit (sands, gravels, clays, etc.) and permeability, porosity and storativity (a property of the aquifer that relates the amount of water released during pumping). Because some of these initial estimates of aquifer and aquitard properties were uncertain, the effects of these uncertainties on the results of model simulations were investigated during the calibration process (discussed below).

M3 Model: Water Budget Input

A water budget analysis used as input to the model was conducted as a joint effort between HLI and PGG using a combination of new-data analyses and data reported and used in the Treasure Valley Hydrologic Project model. The water budget consisted of quantifying the various sources of water flowing into and out of the model domain through all of its boundaries. To begin with, an analysis prepared by HLI was used to set up the M3 model. As the model progressed, PGG and HLI realized that the model domain needed to be expanded in order to make sure that pumping simulations from beneath the M3 Eagle property were neither: **a**) affected by the model boundaries nor **b**) caused changes in inflow or water levels at the model boundaries. In order to quantify the various components of inflow and outflow in the expanded model domain, PGG took the various analyses conduced by HLI and used GIS methods of analysis to apply the concepts used in the initial HLI analyses, as is discussed below.

The water budget (discussed below) assessed the various sources of water flowing into and out of the model. Sources of inflow included recharge from: precipitation; irrigation; septic drainfields; and seepage from canals, ditches and rivers. Inflow also included "underflow" from ground water entering the model from aquifers along the boundaries of the model. Outflow from the model boundaries included: ground-water pumped from wells, ground water discharged to rivers and ditches and ground water leaving the model domain.

Well Pumpage

Well pumpage (the volume of water pumped) from within the model domain is poorly documented. Municipal suppliers typically monitor monthly pumpage totals but do not always report them to a central recording agency in a timely manner. Pumping rates from industrial, irrigation, stock, fisheries, housing-development and single-family domestic wells are rarely measured or reported. Because of the lack of "quality" data, HLI estimated the annual average pumping rates for supply wells in the model domain. The latest version of the model documented in the PGG Technical Memorandum dated November 14, 2008, resulted in a model calibration that used estimates of pumping within the model domain that were greater than those used in the previous versions of the model. In this most-recent model, the total pumping from within the model domain averaged over the year is 144 cfs which is about 60 percent greater than the 90 cfs yearly-averaged pumping used in the initial modeling efforts documented in the various reports and memoranda prior to the November 2008 Technical Memorandum. We consider the calibration and simulations conducted using the higher pumping rates to be more conservative and therefore better suited for use in the predictive simulations of long-term pumping from beneath the M3 property. The following discussion summarizes the method and assumptions used in the larger estimate (144 cfs) of pumping from the model domain.

Water withdrawals from municipal supply wells were estimated based on water-rights analyses. Average annual municipal pumping rates were assumed to be 15 percent of the allowed maximum (peak) pumping rate listed in all of the water rights for a municipal supplier. The 15-percent rate was based on a detailed comparison of actual pumpage and

water rights of the Eagle Water Company. During 2005, the Eagle Water Company's total pumping averaged over the year was 14.3 percent of their instantaneous water rights. During 2006, their average pumping was 15.3 percent of their instantaneous water rights. A review of other municipal suppliers in the area indicated a similar proportion of actual use to authorized, instantaneous permitted rates. Based on our analysis, we have assumed an average annual pumping rate equal to 15 percent of the instantaneous rate listed on the water rights for all of the municipal wells in the model domain.

This average-annual rate of 15 percent is a relatively small portion of the instantaneous water right rate for two reasons. The first is that municipal water rights are granted to allow a municipal supplier to meet their peak demand, a rate that occurs only for a few short periods during the year. At other times, water demand is much less and therefore the average pumping rate over the year is far less than the authorized peak rate. The second reason for the relatively small average rate is that municipal suppliers typically have water rights in excess of what they need today, in anticipation of future needs as their population base grows and service area expands. By having a water right in excess of today's needs, municipal suppliers are prepared for tomorrow's growth.

Domestic wells associated with residential developments were assumed to pump at an average of 30 percent of their peak water rights. A domestic water right was assumed to be for a multi-connection residential-development if the name listed on the water right was a corporation, partnership or company *and* the right was in excess of 0.2 cfs (about 90 gpm). It is likely that some water rights associated with residential-development wells were not identified using this method when the listed name on the water right was an individual. This type of error is considered "conservative" (i.e., indicating a rate likely to be too large and therefore likely to result in less water available for additional development). If not identified for residential development use, a domestic well with a yield greater than 0.2 cfs would be assigned an annual average, continuous, pumping rate equivalent to its instantaneous-water-right rate, a rate that is likely to be much higher than actual use.

Fisheries and wildlife enhancement supply wells were assumed to pump at their full annual water right allocation averaged over the year. If no annual limit was listed on the water right, we assumed that these type of wells pump at 30 percent of their listed peak water right rate.

Commercial and industrial wells were assigned pumping rates equal to their full annual volumetric limit averaged over the year. This rate is likely too high, but we found no basis for reducing this rate.

Wells associated with fire-protection water rights were assumed to pump so little over the course of a year that we assumed a resulting model-input of zero.

Irrigation well pumpage was estimated based on an application rate of 2.6 feet per year and a GIS analysis of irrigated acres. (We assumed that energy costs associated with ground-water pumping would limit over-application of irrigation water.) An initial

assessment assuming that irrigation wells used *all* of their allocated annual withdrawal water rights resulted in an estimated use that was unrealistically high, as some of these wells are only used to supplement surface water during drought years.

Domestic (individual home) well pumpage was estimated based on the IDWR well-record database and the assumptions of per capita consumption used in the TVHP model. The TVHP model assumed 230 gallons per day (gpd) per person and 2.9 persons per well (Urban, 2004). We counted the number of domestic wells listed in the IDWR well database on a per-quarter-section basis and then multiplied this total number of wells per quarter-quarter section by 667 gpd/well (230 gpd per person x 2.9 persons per well). When the model domain was extended to the south beyond the original model domain, a directly-counted, water rights analysis was not specifically conducted for the additional area added to the model domain. Rather, the average domestic well pumpage from the township lying directly to the north of the new area added to the model domain (which had a per-quarter-section accounting of domestic wells) was applied to the new area (in lieu of a per-quarter-section analysis). Because domestic pumping is such a small component of the overall water budget and because domestic pumping was assumed to be derived from the uppermost aquifer, the errors introduced by this method are considered to be small and insignificant to predictions of pumping from beneath the M3 property.

Other listed water right usages such as storage, recreational, diversion to storage, heating and cooling, etc, were generally listed as secondary uses on their water rights. Wells associated with these rights were assigned a pumpage based on their primary listing (first listing) on the water right.

Surficial Recharge: Precipitation and Irrigation

Recharge into the top active layer of the model was initially calculated based on rates used in the TVHP model and a land use analysis. Recharge for each type of land use was based on the total of precipitation plus irrigation minus runoff and evapotranspiration (water removed by plants and direct evaporation). Recharge rates from the TVHP project were quantified based on land use in Urban (2004) who presented seven land-use categories along with a recharge rate for each category. These rates varied from 0.0 feet per year (ft/yr) for "industrial" land use to 0.45 ft/yr for "surface-water irrigated farmland." The rates used in Urban were used in the recharge analysis for the M3 model.

A visual analysis of land use type by quarter section was initially prepared by Nimmer (2007) for input to the U of I model and later for used as input to the M3 model, with the results shown in Figure 8. In this analysis, Nimmer estimated the dominant land use within each quarter section based on visual analysis of land-use data downloaded from the USGS, based on the National Atlas (NA) land-cover map. A grid oriented to the Public Land survey system (PLS) was placed on top of the NA data (which had a different orientation) and one of the seven land-use categories (associated with recharge rates listed in Urban, 2004) was assigned by Nimmer to each quarter section using "best-professional judgment." In areas dominated by irrigated farmland, Nimmer assumed that farm lands lying topographically below nearby irrigation canals were irrigated with surface water and assigned the higher application rate associated with this irrigation

source, as listed in Urban. Nimmer assumed that water used to irrigate farmlands topographically above nearby irrigation canals originated from wells and applied the lower application rate associated with this source in Urban.

After the model domain was expanded southward, additional land use and associated recharge rates were needed for the added area. At this point, Pacific Groundwater Group updated the Nimmer analysis with a new GIS analysis of land use for the entire model domain. This analysis assessed land use on a model cell-by-cell basis. In cells with more than one land use type, a weighted average based on percentage of area for each land use was calculated and the appropriate rate applied. Based on instruction from HLI, PGG also assumed that irrigated farmlands topographically below a nearby irrigation canal were irrigated with surface water and not ground water. Although conceptually similar, this cell-by-cell computer-based GIS analysis is more accurate than the manual analysis initially conducted by Nimmer.

Surficial Recharge: Canals and Ditches

Recharge from canal and ditch leakage was also calculated for input to each active upper cell of the M3 model. Initially, Nimmer conducted a visual analysis of the major canals on a quarter-mile basis for input to the model. After the model domain was expanded, PGG conducted a GIS analysis for the entire model domain using data which included minor canal reaches and ditches along with the main canals. The PGG analysis also included surficial geologic materials with different leakage rates depending on the relative permeability of the materials (sands and gravels versus silts and clays). Based on the TVHP data included in Urban (2004), sands and gravels were assumed to have a leakage rate of 0.75 cfs per mile. Silts and clays were assumed to have leakage rates of 0.0 cfs/mile (no significant leakage).

Surficial Recharge: Septic Drainfields

Recharge from septic drainfields was calculated based on the presence of domestic wells. It was assumed that houses supplied by domestic well water supplies were unsewered and that each well indicated the presence of a septic drainfield. The number of wells per quarter section was tallied as part of Nimmer (2007). Based on Urban (2004), a drainfield recharge rate of 45 gpd per person along with the 2.9 people per household (as assumed in the domestic well pumpage analysis) was applied to the uppermost layer of the model. The total rate per quarter section was calculated as the number of wells in the quarter section times 45 gpd per person times 2.9 people per well.

M3 Model: Steady-State Calibrations

The M3 model was initially calibrated to steady-state conditions with the results reported in PGG, 2008a. Later, after several updates to the model, the steady-state calibration was revised as reported in PGG, 2008d. The following discussion pertains to the initial and revised steady-state calibrations presented in the appropriate PGG report, as indicated. Steady-state calibrations were based on matching water level data collected during summer of 2007 and presented in HLI (2007b). Although not a true steady state, these conditions represent a "snapshot" of the conditions of "today" before pumping from the

M3 site has occurred and therefore represent a quasi-steady-state condition from which to simulate future pumping. The water level data collected during the summer of 2007 were obtained from wells that were located (vertically and horizontally) through survey-grade GPS with estimated vertical accuracies of ±0.08 feet (HLI, 2008c). Geologic, geophysical and well-construction data from these wells were reviewed to identify the aquifer associated with each measured water level. Primarily, only wells that: a) were properly sealed, and b) had well screens identifiably within the Pierce Gulch Sand Aquifer, the Willow Creek Aquifer, or Payette Valley aquifers (an aquifer or aquifer system that appears to be contiguous with portions of the Pierce Gulch Sand Aquifer and the Willow Creek Aquifer), were used in the calibration. In addition, one well near the northwestern edge and one well near the southwestern edge of the model domain were used that were not surveyed. These wells were located using Google Earth with elevations estimated to be within ±10 feet. Because these wells lie so far from the model focus area, we believe potential errors introduced through the lack of survey are likely to be insignificant in the calibration process.

Development of Two Parallel Models through the Water-Level Calibration Process

Two parallel models were developed during the steady-state calibration process, after it became apparent that model-simulated water-levels beneath the M3 Eagle site were low, in comparison to measured levels. Either the aquifer system was more complex than originally set up in the model or the actual transmissivities of the various aquifers varied from the values initially input to the model (both tested and estimated). This realization led to the development of two parallel models: the "Hmatch model" and the "Tmatch model." The two models were used to "bracket" the predictions of impacts caused by pumping. As is discussed below, the difference between predictions made by the two models is relatively small, thereby helping to reduce possible concern about the differences between the two models.

The "Hmatch model" was developed to better match the predicted and measured ground-water levels ("heads"). The Hmatch model required that transmissivities of the Pierce Gulch Sand Aquifer be adjusted at some locations beyond the acceptable range of values originally selected for the calibration process. Since many of the input values were either estimated from lithologic information on Well Driller's Reports or from poorly conducted pumping tests, this departure from the original input values appears reasonable. The criteria for defining the range of allowable deviation within the Hmatch model was as follows: all wells within a transmissivity zone (of which there are 20) could have their transmissivity adjusted by no more than 0.33 to 3 times the log-average of the initial transmissivities for that zone. Only one value had to be adjusted outside of this range. The transmissivity associated with the Eaglefield #2 aquifer test had to be reduced by a multiplier of 0.2 in order to obtain the desired match. Because this zone also includes several well tests reporting transmissivities much lower than that of the well used in the calibration (UWID State and Linder test well) and because of the effects of an unknown pumping well and other problems associated with this test (as discussed in HLI, 2008), this adjustment is considered acceptable. It is probable that additional calibration focusing on this area would result in the single-transmissivity zone being divided into multiple zones with different average values for representative transmissivity. The water

levels generated by the Hmatch model were closer to the target values than those generated by the Tmatch model, as discussed below.

The "Tmatch model" was developed to better honor the initial transmissivity values input[3] to the model. In the Tmatch model, transmissivities were allowed to vary within a smaller range, during the calibration process. Transmissivity was allowed to be adjusted by no more than ± 50 percent of the log-average of the observed transmissivities for that zone. The water levels generated by the Tmatch model were not as close to the target values than those generated by the Hmatch model.

Initial Steady-Stated Calibration Statistics and Results

Both the Tmatch and Hmatch models met generally accepted calibration criteria, indicating that both models are statistically capable of modeling the ground-water-flow system. The models used three criteria (calculated by Groundwater Vistas) to quantify the degree of success in calibration:

- "residual mean" or "RM" (the average of the differences between the observed and calculated water levels,
- "absolute residual mean" or "ARM" (the average of the differences between the observed and calculated water levels, without consideration of whether the calculated water levels were above or below the measured levels), and
- "percentage standard deviation to the observed range" or "PSD/R" (a statistical analysis of the results that considers how the calculated values compare with the actual values in terms of the size of the range of target values).

The results for the initial Tmatch model were:

- RM = 2.71 feet (in other words, the average difference in the predicted values from the measured values was 2.71 ft,
- ARM = 13.99 feet (in other words, the average difference in the magnitude of predicted values from the measured values was 13.99 ft,
- PSD/R = 6.2% (in other words, the standard deviation of the predicted values was only 6.2 % of the range of the measured values).

The results for the initial Hmatch model were:

- RM = 2.82 feet (in other words, the average difference in the predicted values from the measured values was 2.82 ft,
- ARM = 9.75 feet (in other words, the average difference in the magnitude of predicted values from the measured values was 9.75 ft,

[3] Transmissivity is not directly input to the model. Rather, hydraulic conductivity is used instead, which is calculated by dividing transmissivity (calculated from pumping test data) by aquifer thickness (measured through geophysical logging or high-quality lithologic logging). Because transmissivity is directly calculated from pumping test data, we use this term in our discussion of the various models. In effect, the model calculates transmissivity using the hydraulic conductivity and the saturated thickness at each cell.

- PSD/R = 4.8 % (in other words, the standard deviation of the predicted values was only 4.8 % of the range of the measured values).

The target for the PSD/R for both models was 10%, a standard well met by both models. An RM of less than 3 feet for both models indicates the overall average errors in the predictions are small. An ARM of less than 15 feet is also good, but points out that the simulated water levels ("heads") beneath the M3 site were low, a situation we consider conservative in that calculated water-levels below those measured may indicate that additional water may be flowing into the model beyond that which is assumed. (In other words, more water may be "available" from the M3 Eagle area than indicated by the model.)

Figure 9 (reproduced from PGG, 2008a) shows that part of the ground water within the Pierce Gulch Sand Aquifer in the greater M3-Eagle-Star vicinity flows from the southeast to the northwest where it ultimately discharges to the Payette River basin. Another part of the ground water in the Pierce Gulch Sand Aquifer flows toward the northwest but then turns southwesterly and remains within the Boise River Valley. The initial model generated the ground-water level contours shown in Figure 9 while we have added the flow arrows in dark blue to indicate the flow paths toward the Payette River Valley and in light blue to show the flow paths where flow remains in the Boise River Valley. The flow path arrows are oriented based on the assumption that ground water flows at right angles to water-level contours. The figure also shows residual errors with values in blue indicating that the model-calculated levels are lower than those actually measured and red indicating that calculated levels are above those actually measured. The Hmatch model generates water levels (heads) that are closer to those actually measured during the summer of 2007, than those generated by the Tmatch model.

Most-Recent (November 2008) Steady-State Calibration Statistics and Results

Both the Tmatch and Hmatch models using the increased pumping from within the model domain (as presented in PGG, 2008d) met calibration criteria, indicating that both models are statistically capable of modeling the ground-water-flow system.

The calibration statistics for the revised Tmatch model were:

- RM = 8.92 feet,
- ARM = 15.16 feet
- PSD/R = 5.9%

The calibration statistics for the revised Hmatch model were:

- RM = 6.38 feet,
- ARM = 10.22 feet
- PSD/R = 4.6 %

The calibration statistics for the revised model are similar to those of the initial models. An RM of less than 9 feet for both models indicates the overall average errors in the predictions are slightly larger for the revised steady-state models (but, as discussed

below, allowed for better transient calibration). The ARM values for both models are similar to those of the previous model while the PSD/R values for the revised models are slightly better than those of the initial models.

Figure 10 (reproduced from PGG, 2008d) shows steady-state Hmatch-model and Tmatch-model ground-water flows that are similar to those of the initial models. These steady-state potentiometric contour maps also show that some of the ground water within the Pierce Gulch Sand Aquifer in the greater M3-Eagle-Star vicinity flows from the southeast to the northwest to the Payette River basin while some of it flows toward the northwest but then remains within the Boise River Valley. Similarly to the initial models, the revised Hmatch model generates water levels that are closer to those measured during 2007, than those generated by the revised Tmatch model.

Mass Balance: Amount of Water Pumped by Wells

The Tmatch and Hmatch steady-state calibrations for the initial and the revised models included mass balance analyses with resulting errors of less than 1 percent, an error that we believe, supports successful model calibration. In other words, when all of the sources of water going into the model are added up and compared with all the sources of water going out of the model, the difference is less than 1 percent of the total. (A steady-state model that does not have the input and output flows equal to within 1 percent is less likely to be properly calibrated, in our opinion.)

The mass balance analysis shown in Table 1 (next page) indicates that the total ground water pumped from the model domain (which includes, Eagle, Star, Meridian, Emmett, Caldwell and all the smaller communities within the area) represents about 9 to 14 percent of all the water flowing into the ground-water system within the model domain. The total average annual pumping from the entire model domain was calculated to be about 90 to 144 cfs, while the total input to the ground water system (recharge at the surface, seepage from the Boise River, New York Canal and other surface water sources) was calculated to be about 1030 to 1040 cfs. The relatively small proportion of pumping to total inflow is supported by water levels throughout the area that have remained generally stable[4] over the past decades, in spite of increased ground water development.

The model indicates that upon completion, the M3 Eagle Master Planned Community would pump about 1 percent of the total inflow to the model domain. This increase is relatively small and likely to be insignificant to overall flow within the system. For comparison, the average annual withdrawal of 9.03 cfs planned for full build-out of the M3 Eagle project, is small in comparison to the flow in many of the surface water ditches and canals in the area. For example the Farmer's Union Ditch (often called the Farmer's Union Canal) typically flows at well over 100 cfs during the summer. The combined flow of the Boise River and the New York Canal is more than 2,000 cfs during the summer.

[4] Although minor, some local, well-specific, water level declines have apparently occurred. We believe these declines are attributable to unsealed or poorly sealed wells that have allowed ground water to move along the annular space outside of the well casing, acting in effect, as a well that is continuously pumping. The continuous flow causes a local water level decline that is unrelated to overall aquifer water levels. The decline occurs as water flows from one aquifer (the Pierce Gulch Sand Aquifer) to overlying aquifers.

M3 pumping would represent about 6 to 9 percent of total pumping within the model domain area, based on the range of estimated total current pumping within the model domain. The smaller percentage of total pumping represented by M3's proposed pumping is based on the larger estimate of total pumping within the model domain, while the larger percentage is based on a comparison with the smaller estimate of total pumping.

Table 1 Mass Balance Comparison of Well Pumpage Volumes:

Initial Model Results -June 4 report (smaller estimate of total pumping)			**Revised Model Results** -November 14 Memo (larger estimate of total pumping)		
		% of total			% of total
INFLOW	cfs	Inflow	**INFLOW**	cfs	Inflow
Surficial Recharge	542	52.4%	Surficial Recharge	542	52.1%
Underflow via SE model corner	102	9.9%	Underflow via SE model corner	115	11.0%
Dry Creek	4	0.4%	Dry Creek	4	0.4%
Lake Lowell	17	1.6%	Lake Lowell	17	1.6%
Boise River Seepage	87	8.4%	Boise River Seepage	81	7.8%
Payette River Seepage	282	27.3%	Payette River Seepage	282	27.1%
TOTAL:	**1034**	**100.0%**	**TOTAL:**	**1041**	**100.0%**
WELL OUTFLOW			**WELL OUTFLOW**		
Domestic	14	1.3%	Domestic	60	5.8%
Municipal, Commercial, Irrigation	76	7.3%	Municipal, Commercial, Irrigation	84	8.1%
TOTAL:	**90**	**8.7%**	**TOTAL:**	**144**	**13.8%**
With M3			*With M3*		
Domestic	14	1.3%	Domestic	60	5.8%
Municipal, Commercial, Irrigation	76	7.3%	Municipal, Commercial, Irrigation	84	8.1%
M3	9	0.9%	M3	9	0.9%
TOTAL:	**99**	**9.5%**	**TOTAL:**	**153**	**14.7%**
M3 percentage of inflow:		***0.9%***			***0.9%***
M3 percentage of total pumping:		***9.1%***			***5.9%***

Mass Balance: Flow to the Pierce Gulch Sand Aquifer from Outside the Model Domain

The M3 model calculated that about 102 cfs to 115 cfs (about 65 to 74 million gallons per day – "mgd") of ground water flows into the southeast corner of the model through the Pierce Gulch Sand Aquifer. This rate of "underflow" was calculated through a series of "general head boundary" analyses based on measured water levels, "conductances" (based on transmissivities) and distances. In these general head boundary analyses, flow was calculated based on the water-level difference over a known distance, through which the ground water flows, through an aquifer with known transmissivity. In the analyses the transmissivities of the Pierce Gulch Sand Aquifer, as calculated from numerous pumping tests in the Meridian area, were assumed to also represent the region between the model's southeastern boundary and the region beneath the Boise River upstream from the Capital Bridge. The water levels reported in the Meridian and Boise areas (beneath the river and the New York Canal) were used to establish the water level differences. The distance was measured directly from USGS topographic maps. Using these input values, the model calculated inflow through the general head boundary.

Based on analyses included in the Treasure Valley Hydrologic Project (Petrich and Urban, 2005; and Urban, 2004), we assume that a significant portion of this general head flow into the model's southeastern boundary originated as seepage from both the Boise River and the New York Canal. Urban reported a Boise River loss to the underlying ground-water system of 15,000 ac-ft/yr (about 21 cfs) during 1996 and about 77,000 ac-ft/yr (about 110 cfs) during 2000. Both sets of measurements were made over the reach upstream from Capital Bridge. Urban also reported seepage from the New York Canal system over its whole length at an average rate of 13 percent of total diverted flow. Hutchings and Petrich (2002) indicate the New York Canal lost 80 to 150 cfs in a set of four measurements made in the reach upstream from Cole Road. The combined leakage to the underlying ground water system from these two sources therefore appears to range from about 100 to 260 cfs (to two significant figures). Based on the typical accuracy of methods to measure surface water flow rates (which range from ±5 to ±20 %) it is not possible to determine the proportion of water originating from the two identified sources. It appears possible that the underflow into the model from the southeast may originate from any combination of the two sources. The quantities of loss indicated in these three Treasure Valley Hydrologic Project reports are similar to, and therefore supportive of, the inflow calculated by the M3 model.

Mass Balance: Changes in Flow to the Pierce Gulch Sand Aquifer Caused by a Reduction of Seepage from the New York Canal

An analysis of changes in inflow to the model from the southeast indicated that water levels in the Pierce Gulch Sand Aquifer beneath greater Eagle vicinity could change by about 5 feet near Eagle and about 2 to 3 ft near the M3 property were inflow to the Pierce Gulch Sand Aquifer to be reduced by 20 percent. The 20-percent reduction of total inflow to the model from the southeast might occur should seepage be reduced from the New York Canal. We know of no current plans to line the canal or change its flow but since part of the recharge to the Pierce Gulch Sand Aquifer comes from outside of the model domain and because the TVHP analyses support the Boise River and the New York Canal as sources of recharge to the Pierce Gulch Sand Aquifer, we believe it is prudent to at least assess these potential changes.

The revised model was used in this analysis with the general head boundary from the original model converted to a constant flux (flow) boundary. In this analysis, the flows of 107 cfs (Tmatch model) and 115 cfs (Hmatch model) calculated through the general head boundary, were reduced by 20 percent to 86 cfs and 92 cfs (respectively) and represented as a constant flux boundary. The difference in water levels between the two model runs (100 percent of calculated inflow and 80 percent of calculated inflow) were calculated and plotted.

Changes in water level maps from PGG (2008d) excerpted in Figures 11 (Tmatch model) and 12 (Hmatch model) indicate that water levels in the greater M3-Eagle-Star vicinity will not change significantly even if recharge to the Pierce Gulch Sand Aquifer from the southeast is reduced by 20 percent through the lining of the New York Canal. These model figures indicate that Pierce Gulch Sand Aquifer water levels beneath the greater Eagle vicinity north of the Boise River would decline by 2 to 5 ft. Changes beneath the

M3 site are likely to 1 ft or less. Declines of this magnitude (1 to 5 ft) are unlikely to affect the overall yield of properly designed and constructed wells. Poorly constructed and inefficient wells that are marginal in their operation, could have yields affected, however, as they could be by other equally-possible factors, such as changes in seasonal recharge or changes in land use.

The M3 model simulates much larger changes in water levels in the south Meridian area. Such predictions, however, are likely to be inaccurate because of the proximity of the modeled constant-head boundary to this portion of the aquifer. The model's simulations in this area should only be used as a very general guideline.

M3 Model: Initial Transient Calibrations

After the Tmatch and Hmatch models were successfully calibrated to steady-state conductions, they were calibrated to transient conditions by replicating two long-term aquifer tests conducted in the greater Eagle area: the 30-day-Lexington Hills aquifer test and the 7-day Eaglefield aquifer test. Calibration was accomplished primarily by adjusting the storage parameters that control aquifer behavior ("storativity" and "specific yield"). These parameters quantify how much water is released from storage within an aquifer when water levels decline (for example through the pumping of a well). Transient calibration also included some changes in transmissivity along with verification that steady-state calibrations remained valid.

The transient calibrations consisted of comparing model-simulated and actual observation well drawdowns measured during the two tests. The transient calibration started from the steady-state model that was then allowed to simulate a 100-day period prior to the start of each test to allow the model to start off with pre-test water levels that were stable. The model was then allowed to simulate the duration of the test (7 or 30 days) with a pumping well placed within the cell at the location of the pumping well and the drawdown response noted at the cell representing the observation well (HLI, 2008b).

Figure 13a and 13b (reproduced from PGG, 2008a) show excellent agreement between the calculated and observed drawdowns from the two tests, for the Hmatch model. All of the simulations are within a few hundredths of a foot throughout much of the test periods. Because the measured drawdown-data were not corrected for barometric effects (CH2M-Hill, 1991; and Holladay, 2006) small differences between the calculated and measured levels are observed on the plots. These differences are smaller than potential unaccounted-for barometric effects.

Figure 13c shows that the Tmatch model did not accurately simulate the 7-day Eaglefield test. Better matches were achieved in trial calibrations by allowing larger changes in transmissivity and by the inclusion of a fault in the area. (A fault is suggested by the extension southward of a fault mapped on the M3 site.) However, because the Tmatch model was designed to "honor" the tested transmissivities with only minimal changes from the initial input values and because faults have yet to be mapped near the Eaglefield test and observation wells, the calibration shown in the figure was allowed to stand. The

good match generated by the Hmatch model and the small differences between Tmatch and Hmatch simulations of water level changes caused by pumping from beneath the M3 property (discussed below), indicate that the poor Tmatch-transient simulation of the Eaglefield test is not significant.

M3 Model: Transient Calibration to SVR #7 Test and Higher Total Pumping

Following completion of the initial transient calibrations to the 30-day Lexington Hills and 7-day Eaglefield aquifer tests, the Tmatch and Hmatch models were successfully calibrated to replicate the 9-day SVR #7 aquifer test, conducted during March of 2008. This test and resulting additional calibration are particularly valuable in that few reliable data were available from the northern portions of the Pierce Gulch Sand Aquifer lying beneath the M3 Eagle property, prior to the SVR #7 test. The additional calibration involved matching the measured response of two observation wells monitored during the SVR #7 test with simulations generated by both the Tmatch and Hmatch models, using the larger estimate of overall total pumping. In addition, the recalibrated Hmatch model was used to resimulate the Eaglefield #2 and Lexington Hills #1 aquifer tests. We believe that this set of calibrations (presented in the PGG, 2008d, included in Appendix B) is the most "conservative" (i.e., most likely to over-predict pumping impacts) model developed to date for assessing potential drawdown interference from pumping beneath the M3 property. The calibrations resulted in the recognition (and inclusion in the model) of higher transmissivities and somewhat lower storativities in the M3 Eagle property vicinity.

The simulated and measured drawdowns for the two observation wells (reproduced from PGG, 2008d and shown in Figures 14a and 14 b) are relatively close: within a 0.1 foot in the Big Gulch observation well (close to the pumping well) for much of the test and within a few hundredths of a foot for the beginning and end of the test for TW #4 Zone 2 well, located about 4,500 ft from the pumping well. The discrepancy between the calculated and observed data from the nearby Big Gulch observation well may be the result of discretization error. The model predicts water levels that represent the average water levels within each model cell. Only when the observation well and the pumping well lie exactly at the center of a cell do the calculated water levels equal the actual levels. Since neither well lies at the exact center of the cell in which it is located, a small error in drawdown predictions develops. This "discretization" error becomes smaller as the distance between the observation and the pumping wells becomes larger.

The discrepancy between the calculated and observed data from the further-away observation well (TW #4) may be the result of imperfect corrections to the raw data to remove the effects of atmospheric pressure changes. As seen in both hydrographs in Figure 14, the observed data show a drop and subsequent rise in drawdowns that would not normally be associated with a constant-rate aquifer test. This fall and rise in water levels is more likely a result of imperfect or incomplete corrections applied to the raw water level data.

A resimulation of the 30-day Lexington Hills #1 aquifer test (Figure 15a) and the 7-day Eaglefield #1 aquifer test (Figure 15b) using the recalibrated Hmatch model generated almost identical results to the simulations conducted with the initial Hmatch model. The differences between the older-calibration simulation and the newer-recalibration simulation were very small because the SVR-#7-calibrated model resulted in changes to only small portions of the Pierce Gulch Sand Aquifer lying several miles away from the area affected by the tests. This comparison demonstrates that the changes to the model made in the region of the M3 Eagle property have only limited effects on parts of the model lying miles far to the south.

The Tmatch model was not used to resimulate the Lexington Hills or Eaglefield tests because the changes to the Hmatch model produced only small changes in the simulated drawdowns associated with these two tests. Changes that were likely to be even smaller would have resulted in the Tmatch model because of its generally larger transmissivities. Because the Hmatch changes were so small a recalibration to the Tmatch model was not warranted.

M3 Model: Prediction of Impacts

The transient M3 Tmatch and Hmatch models predict that drawdown impacts to other wells completed in the Pierce Gulch Sand Aquifer at locations one-half mile from the M3 Eagle property boundary would be on the order to 10 to 20 feet. The model predicted these drawdowns based on simulations of three wells located on the southwest portion of the M3 Eagle property, each pumping continuously at an annual average rate of 1,500 gpm, 50 years after all wells had come on line, and the project completed (full build-out).

Four versions of the model were run resulting in four simulations to bracket the results. The four models included both smaller and larger total pumping versions of the Tmatch and Hmatch models. Having four simulations, all showing relatively similar results, helps to demonstrate that the uncertainty in the data (that led to the development of four separate model versions) is not considered significant. The range of values for the transmissivity of the aquifer and the range of values in the estimate of total pumping from within the model domain do not result in a large difference in drawdown predictions made by the M3 models.

The four predicted drawdowns predicted to be caused by pumping 1,500 gpm from each of three wells pumping from the Pierce Gulch Sand Aquifer beneath the M3 property are shown in Figures 16 and 17. Figure 16 (from PGG, 2008c) shows a) Tmatch and b) Hmatch models calibrated using the lower total pumping rates in the model domain while Figure 17 (from PGG 2008d) shows a) Tmatch and b) Hmatch models calibrated using the higher total pumping rates in the model domain. The four drawdown prediction figures show that most of the significant predicted drawdown occurs beneath the M3 property and within a buffer zone consisting of US Bureau of Land Management (BLM) land surrounding the M3 property. Beyond this buffer, the predicted drawdowns become smaller with distance from the pumped wells, located on figures.

The pumping rates used in the simulations are about 10 percent greater than the average pumping requested in the water rights application. Analyses for the annual average water demand indicate that the project will require 6,535 acre-feet per year (equivalent to 4,051 gpm, averaged over the year) at full build-out (Givens and Pursley, 2008). An average pumping rate of 1,500 gpm appears feasible from wells completed in the Pierce Gulch Sand Aquifer beneath the M3 property at the locations shown on the two figures. The 10-percent overage allows for predictions of drawdown effects that are more conservative than those that would occur at the actual requested total average rate of 4,051 gpm.

Short-term pumping rates would be higher during periods of peak water demand. However, during other times of the year wells would be pumped at a rate much lower than the 4,500 gpm total used in the simulation. Over the year, however, the combination of higher and lower pumping rates would result in an average equivalent to that used in the simulation.

Although drawdowns during periods of higher pumping near (and in) the M3 supply wells would be higher than those shown in the two figures, the higher-rate, short-term pumping is not expected to cause drawdowns at locations beyond the BLM buffer zone surrounding the M3 property that are more than a few feet higher than those shown in the figures. Because these peak pumping events would only last for a few days, distal wells would only be affected minimally (beyond the predicted long-term averages shown in the two figures) for two reasons. The first is that peak pumping would occur during summer when irrigation causes seasonal water levels in the Pierce Gulch Sand Aquifer to be at their higher levels (as demonstrated by long-term water-level monitoring). The larger drawdowns caused by the peak pumping would be offset by the higher water levels caused by irrigation. The second reason is that the short-term, larger drawdowns associated with peak pumping rates would take time to propagate outward from the pumping wells. The SVR #7 aquifer test demonstrated that drawdown effects ("expanding cone of water-level depression") took many days to become measureable several miles away. Short-term, high-rate well pumping lasting several days would be followed by reduced pumping rates after peak demand passed, allowing water levels in the aquifer to rise again.

The model shows that impacts to wells completed in the shallower un-named aquifer(s) overlying the Pierce Gulch Sand Aquifer will be smaller than those predicted for wells completed in the Pierce Gulch Sand Aquifer. The initial model predicted drawdowns in the shallower aquifer that are on the order of 2/3 of those predicted for the Pierce Gulch Sand Aquifer (PGG, 2008a). Because the model was not directly calibrated to the shallow aquifer, these drawdown predictions can only be considered an approximation. It is highly probable, however, that after 50 years of pumping from the Pierce Gulch Sand Aquifer, the drawdowns in the shallower aquifer will be less than those in the underlying, deeper Pierce Gulch Sand Aquifer. These predictions can only serve as guidelines until the shallow, un-named aquifer is directly included in model calibrations o r until long-term monitoring is implemented. Such calibration can only be made after several tests of this shallow aquifer have been completed and analyzed. No long-term shallow aquifer tests are known to have taken place as of this time (November, 2008). Direct monitoring

of the shallow aquifer (currently in process) will likely be a much better indication of how the shallow aquifer responds to pumping from the Pierce Gulch Sand Aquifer.

M3 Model: Overview of Results

The M3 Tmatch and Hmatch models recalibrated to steady-state and transient conditions and the larger estimate of total pumping from within the model domain, are the best models developed to date for predictions of impacts to wells completed in the Pierce Gulch Sand Aquifer in the greater M3-Eagle-Star vicinity. The M3 Hmatch model is especially able to replicate the three existing, long-term aquifer tests conducted in the greater M3-Eagle-Star vicinity over the past 17 years. Simulations of the planned ground-water development for the M3 Eagle project indicate drawdown impacts on the order of 10 to 20 feet in wells completed in the Pierce Gulch Sand Aquifer one-half mile from the M3 property. (Most existing wells, both those completed in the Pierce Gulch Sand Aquifer and those completed in other shallower aquifers, lie more than one-half mile away because much of the M3 property is surrounded by a buffer of BLM land along the south and east and mostly undeveloped lands to the north and west)

Water budget analyses indicate that current pumping from all wells within the entire model domain of 520 square miles represents about 9 to 14 percent of all of the water flowing into the ground-water system of the model. The addition of the planned pumping from M3 Eagle would increase this amount by about 0.9 percent, a relatively small increase.

The model estimates that about 102 to 115 cfs (about 65 to 74 mgd) flows into the Pierce Gulch Sand Aquifer from areas lying to the southeast of the model domain. This water is believed to originate as seepage from the Boise River and the New York Canal. Field measurements made as part of the Treasure Valley Hydrologic Project indicate a combined seepage rate of 100 to 260 cfs (to two significant figures) from these two sources in this area, supporting the inflow rate independently calculated by the M3 model.

Based on the model not being calibrated to replicate responses in the unnamed alluvial aquifer overlying the Pierce Gulch Sand Aquifer, the model estimates that wells completed in this aquifer may have drawdown impacts that are on the order of 2/3 of those predicted for wells completed in the Pierce Gulch Sand Aquifer at similar locations. However, because the M3 model was not calibrated to aquifers other than the Pierce Gulch Sand Aquifer, it cannot be used to accurately predict aquifer response from pumping in any aquifer besides the Pierce Gulch Sand Aquifer. Additional aquifer testing (to generate calibration data) followed by specific calibration for the Willow Creek Aquifer, the shallow unnamed aquifer and aquifers within the Payette River Valley would be necessary to use the M3 model for predictions in these aquifers.

Both the Hmatch and Tmatch models generated water levels that are somewhat lower than those actually measured during the summers of 2006 and 2007. Through the modeling process, several methods were attempted to increase the water levels in the

model. These methods included: allowing more water to flow into the Pierce Gulch Sand Aquifer from the southeast, increasing the transmissivity along the eastern portions of the Pierce Gulch Sand Aquifer, decreasing the transmissivities to the northwest of the M3 Eagle property, increasing seepage recharge in the Dry Creek area, increasing upward flow from beneath the Pierce Gulch Sand Aquifer (geothermal water upwelling), extending the fault mapped on the M3 Eagle property to the southeast to the Eaglefield area, and increasing surficial recharge. None of these methods could be totally justified based on the available existing data. Therefore, the modeled water-levels were allowed to remain somewhat low and the model considered conservative in that the lower water levels would result in less available drawdown and larger predicted impacts from pumping from wells completed on the M3 Eagle property.

The model indicates that a 20 percent reduction in the recharge from the area to the southeast of the model domain caused by reducing seepage from the New York Canal (should it occur) would cause water levels in the Pierce Gulch Sand Aquifer in the greater M3-Eagle-Star vicinity north of the Boise River, to drop by about 2 to 5 feet. These declines in water levels are unlikely to affect the predictions of drawdowns caused by pumping from beneath the M3 property, simulated by the model.

THE "BIG PICTURE" – THE ROLE OF MODELS AND RECOMMENDATIONS FOR ADDITIONAL WORK

The Role of Models

We believe it is important to note that a model is only a tool that is useful to understand and manage water use within a ground-water system. We believe that the M3 model is the best tool developed to date for the North Ada County area, to try to understand how future changes to the system such as additional pumping, changers in land use, or changes in recharge, might affect existing and future water supplies. Currently the M3 model has been used to predict impacts caused by ground-water development from the Pierce Gulch Sand Aquifer beneath the M3 Eagle property, that are likely to occur over a 50 year period, to existing wells. No other models or simplified analyses can provide better insight into changes in water levels and flow rates that might occur in the future. However, we wish to emphasize that the M3 model (or any other model, for that matter) cannot and should not be relied upon by itself to give exact answers to future "what if" questions. Models are based on our best understanding of the flow system but because much of what we need to know to construct the model lies underground where it cannot be directly seen, models can never be 100-percent accurate. Fortunately, general understandings and reasonable predictions of future behavior are often what we need to know in making water-resource planning decisions. If the model generally replicates our best understanding of a ground-water flow system (by simulating water levels that compare reasonably well with measured levels) and is able to replicate pumping events of the past (again, by replicating water levels, in this case drawdowns, that occurred during an aquifer pumping test), it gives us confidence that predictions of future pumping events

are likely to be similar to what would actually occur. Such is the case for the predictions made by the M3 model, which simulates both past water levels and past pumping tests.

Equally as important as model predictions, however, is the insight the model gives into key information and data gaps. Through sensitivity analyses, a model helps direct us toward the information that is more critical in predicting changes to ground-water flow and allows us not to be misdirected toward information that is less important. By increasing or decreasing the values of various data values within the model, we can see how much such changes make to predictions. When changing the values of a certain type of input parameter causes relatively large changes in the results, we learn that improving our understanding of the actual values of that parameter through more and improved data collection, would improve our understanding of the system and increase our confidence in future predictions. When changing an input parameter value causes only small changes in the results, we learn that a better understanding of the actual value is unlikely to improve our understanding of the system or increase our confidence in future predictions; we would be better off directing resources (time and money) toward developing an improved understanding of input data to which the model is more sensitive.

Also important, is how the model can be used to direct and make the most use of monitoring to allow for the best management of the system. Even with the development that has already occurred, water level data collected from many wells in the greater M3-Eagle-Star vicinity over the past 50 years, indicate that water levels have generally remained constant,[5]. Additional ground-water development is all but certain to occur in the future, while other factors such as changes in land use, lining of canals and global climate change are also likely. The best way to manage changes is to monitor water levels at key locations and revise management strategies accordingly. Because increases in pumping volumes tend to occur incrementally (as do other changes) the changes that would occur to water levels in wells, would also occur incrementally. A properly designed monitoring program should be able to identify changes as they occurred incrementally and allow for proper management changes *before* a crisis develops.

Such management options might include redirection of surface water resources. Should a decision be made to line the various canals and ditches affecting the model domain, the model could be used to assess where such action might significantly impact ground water use. Currently, surface water passes through the model domain at many thousands of cubic feet per second via the Boise River, New York Canal, Payette River, Farmer's Union Ditch and many other canals and ditches. Total average ground water use is currently only a few percent of this total. If the model indicated that canal seepage was important to maintain ground water supply, surface water rights might be acquired to allow for artificial recharge to maintain this recharge source. Likewise, if the model

[5] Most water levels measured in properly sealed wells in the greater M3-Eagle-Star vicinity have remained relatively constant. Some poorly sealed (or unsealed) wells have allowed water to flow from one aquifer to another, effectively acting as a continuously pumping well. Such a well causes a localized "cone of depression" that leads to the water level dropping over time, unrelated to an overall decline in aquifer water levels or ground water overdraft.

indicated that climatic change and a subsequent reduction of surficial recharge caused significant impacts to ground water use, a similar redirection of surface water rights or a redirection or retirement of irrigation rights at key locations, might be undertaken. The model could be used to help identify where such changes might be made and how large they should be.

In summary, the model is only one of many tools that should be used to best manage the ground water resources of the region. It is not the final and definitive oracle of ground water management. The M3 model should be in on-going and continuing development, and updated as new and improved information is acquired. It should be used to direct the collection of new information by identifying what information is important and where it is most critical. The model should also be used to help direct, design and assess ground water level monitoring programs.

Conclusions

The following summarizes the major conclusions of this report. The main body of the report should be consulted for additional details and information.

1. Five regional numerical groundwater flow models have been constructed over the past 26 years for the area that includes at least a portion of the greater M3-Eagle-Star vicinity. Only the most recent, the M3 model, is adequate to simulate potential drawdowns caused by the proposed pumping from beneath the M3 Eagle Master Planned Community property.

2. Four previous models (Lindgren, USGS, TVHP, and U of I) had some combination of: too few layers, layers not correlating to actual sub-surface geology, cell sizes that were too large, poor or no calibration to transient conditions, or non-representative boundary conditions, to allow them to be useful for predicting pumping impacts in the North Ada County area.

3. The M3 model consists of 7 layers, almost 80,000 active cells, covers 520 square miles and was calibrated to both steady-state conditions (water levels measured during the summer of 2007) and transient conditions (three aquifer tests lasting from one week to one month). The model was developed using Modflow and Groundwater Vistas. This model is, in our opinion, the preferred model for future updates as more hydrogeologic information becomes available.

4. Four versions of the M3 model were ultimately developed to address the uncertainty in the data. The four model predictions of potential pumping impacts were similar, indicating that the uncertainties in the data do not result in significantly different model predictions.

5. The M3 model in its most conservative version (the Hmatch model calibrated to the larger estimate of total existing pumpage) indicates that pumping at an annual average of 1,500 gpm from each of three supply wells completed in the Pierce

Gulch Sand Aquifer beneath the M3 Eagle property, would cause interference drawdowns (reduction in water levels) in wells completed in the Pierce Gulch Sand Aquifer at a distance of one-half mile from the M3 property boundary, of 10 to 20 ft. Interference drawdowns of 5 to 10 ft are predicted at a distance of 2 miles from the property boundary, in wells completed in the Pierce Gulch Sand Aquifer.

6. Simulations using the most conservative version (the Hmatch model calibrated to the larger estimate of total existing pumping) indicate that a 20-percent reduction in underflow originating in part from seepage from the Boise River and the New York Canal in the areas to the east and south of the model domain, would cause a reduction in water levels in the Eagle vicinity north of the Boise River, on the order of 2 to 5 ft and around 1 ft beneath portions of the M3 Eagle property.

Recommendations for Additional Work

During the review of the five models presented in this overview report, and especially after reviewing the M3 model, we became aware of uses of the M3 model and additional improvements that should be considered. Based upon our review, we offer the following recommendations:

1. Future modeling efforts to predict impacts to ground water in the greater M3-Eagle-Star vicinity should be based on the M3 model. This model has: sufficiently small cell size, sufficient layering, proper orientation and thickness of the layers in space to best represent the Pierce Gulch Sand Aquifer, boundaries that allow realistic flow within the Pierce Gulch Sand Aquifer and a demonstrated ability to adequately replicate both steady-state and transient conditions in the greater M3-Eagle-Star vicinity to make a viable model for the area. The M3 model overcomes the short comings of the previous four models in predicting impacts from ground water development in this part of the Treasure Valley.

2. The M3 model should be recalibrated as additional, high-quality aquifer test-data from the Pierce Gulch Sand Aquifer become available. These tests would help to refine the understanding of the aquifer parameters of transmissivity, storativity and specific storage for this regional aquifer.

3. Water budget inputs, especially surficial recharge, canal and drain leakage and river seepage should be refined and input to the model. The current model uses many values calculated and/or estimated as part of the Treasure Valley Hydrologic Project. Additional input based on high-quality field measurements would improve confidence in model predictions. Such data may be difficult and/or expensive to obtain.

4. Average and total pumping rates from major supply wells within the model domain are not well known. We recommend that monthly municipal pumping totals should be reported to a centralized location (such as IDWR) along with

details on well construction and location. We believe that the major water purveyors in the area are keeping records that would benefit overall water management, were this information made common knowledge. Irrigation pumpage is totally unknown. Few, if any, irrigation or industrial/commercial wells measure and report total pumpage – it is unknown whether these wells pump at, below, or above their allowed water rights.

5. If the model is to be used to predict impacts caused by pumping from wells completed in the Willow Creek Aquifer; shallow, unnamed alluvial aquifers; or the aquifers beneath the Payette River Valley; long-term aquifer tests should be conducted in these aquifers and the model recalibrated to reflect the new information generated from these tests. Water use information is also needed from these aquifers to allow for improved model calibration.

6. The model should be used to further assess the potential impacts to the ground water system supplying Eagle, Star, Meridian and (in the future) the M3 Eagle project, from changes in recharge originating as seepage from the numerous canals in the model domain. Possible changes in canal operations (such as lining to reduce seepage loss or changes in overall flow rates) may occur in the future. The model should give a general indication of the sensitivity of the ground-water-flow system to changes in these sources.

7. If the model is to be used to better predict impacts cause by pumping from the Eaglefield area, additional testing and calibration is recommended. The very high values of transmissivity generated from pumping test analyses at some locations and much smaller values at other nearby locations, suggests that the specific hydrogeology in this area is not fully understood. The presence of faulting and offsetting of the Pierce Gulch Sand Aquifer and the potential coupling of sand units not technically a part of the Pierce Gulch Sand Aquifer, but possibly coupled hydraulically, may have affected well response during the Eaglefield Well #2 aquifer test used in the calibrations discussed in this report. The lack of a clear understanding in the Eaglefield area does not appear to be necessary for predictions made for pumping from beneath the M3 property as demonstrated by the similarity of predictions made by the Tmatch and Hmatch versions of the model.

8. If additional high-quality geophysical and/or hydrogeologic information becomes available from within the greater M3-Eagle-Star vicinity, it should be incorporated into the model to help understand why the M3 model's simulations of water levels are below those actually measured in the vicinity of the M3 Eagle property. In addition, sensitivity analyses by changing aquifer properties using smaller zones within the model than are currently used, may help to indicate where the additional information might be sought. By identifying and simulating possible changes to the model that help to raise the water levels beneath the M3 Eagle site, these areas should be targeted for the collection of additional data.

9. All new production supply well drilling projects should have the benefit of professional hydrogeologic supervision and data acquisition which should be centralized to the public domain. M3 Eagle and UWID monitoring wells are good examples to follow.

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FIGURES

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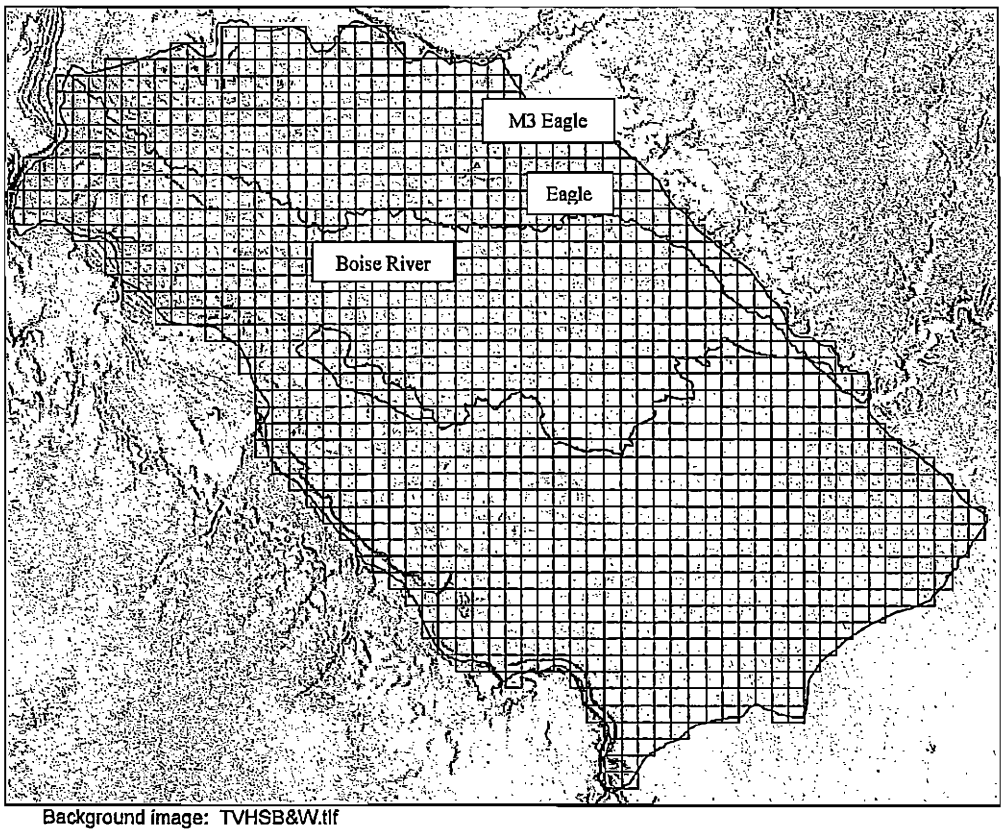
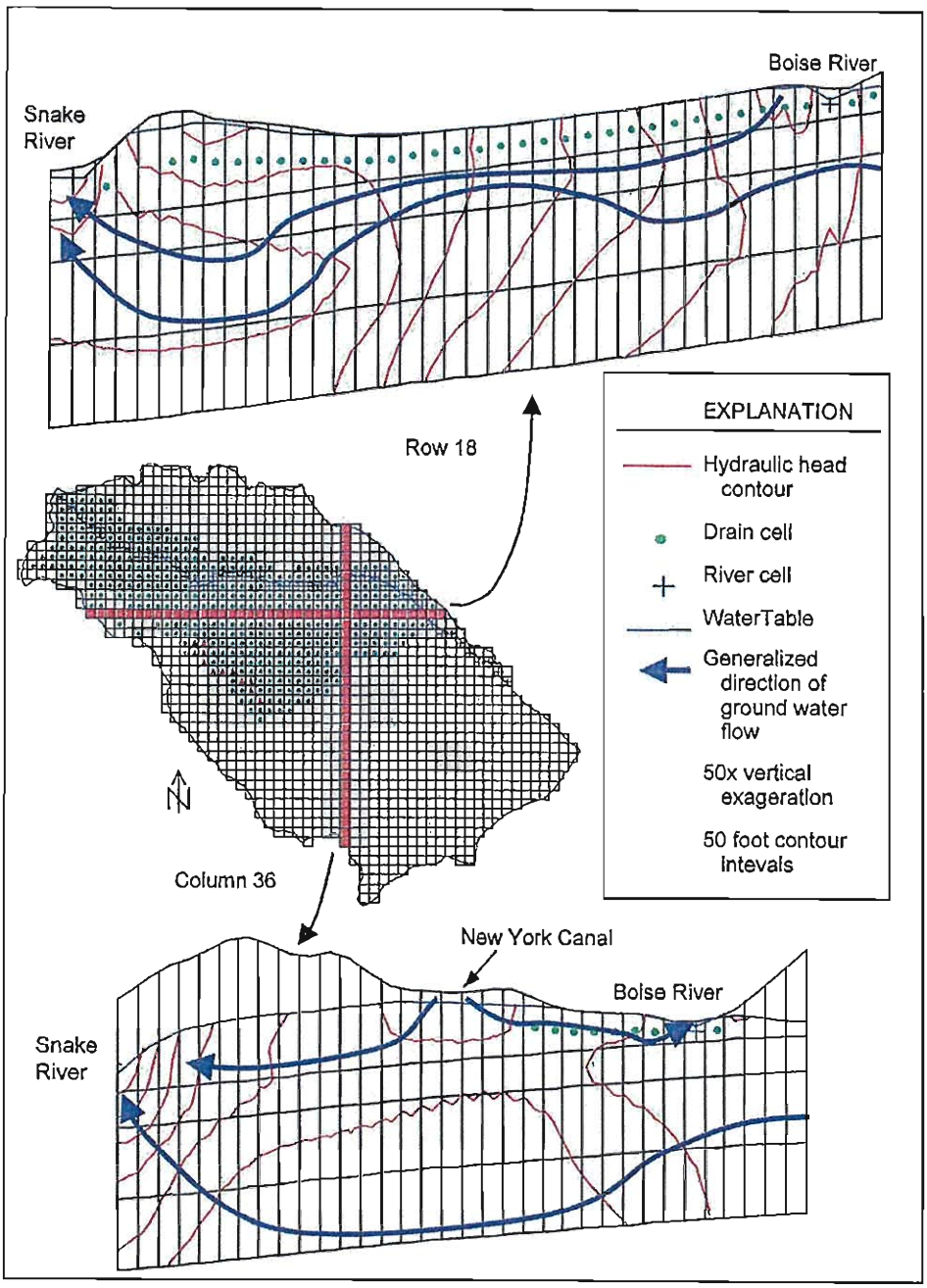
Figure 1. Domain of the TVHP Model



Background image: TVHSB&W.tif

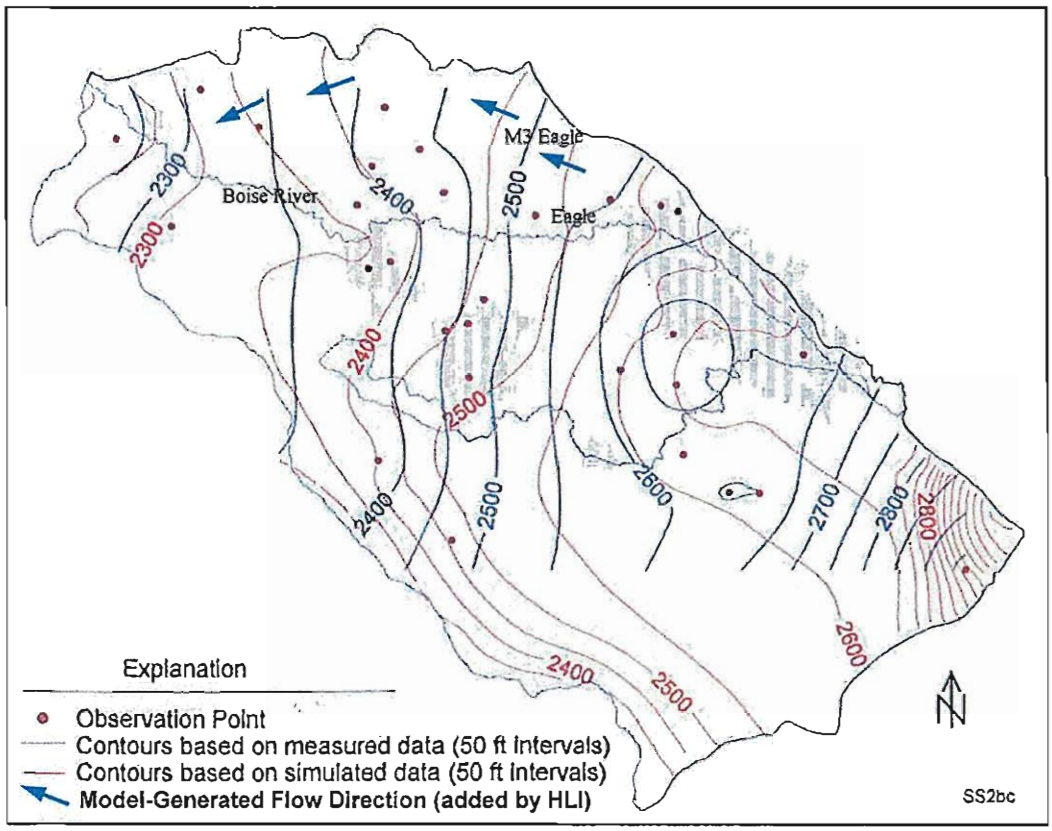
Domain of TVHP model from Petrich (2004) showing topographic divide in Foothills north of Eagle as northern boundary of model.

Figure 2. Two Representative Cross-Sections from the TVHP Model



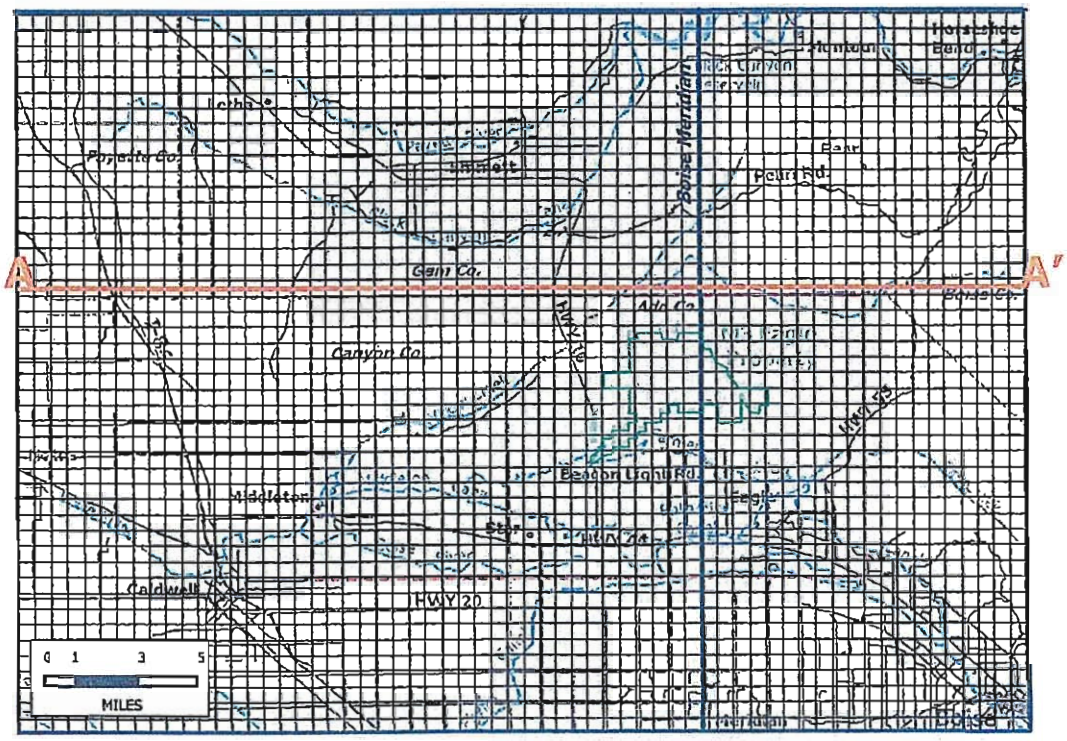
Two representative cross-sections from the TVHP model (Petrich, 2004) showing recharge from the Boise River (downward flow line in upper cross-section beneath the Boise River) and New York Canal (downward flow lines in lower cross-section).

Figure 3. Potentiometric Contours from the TVHP Model



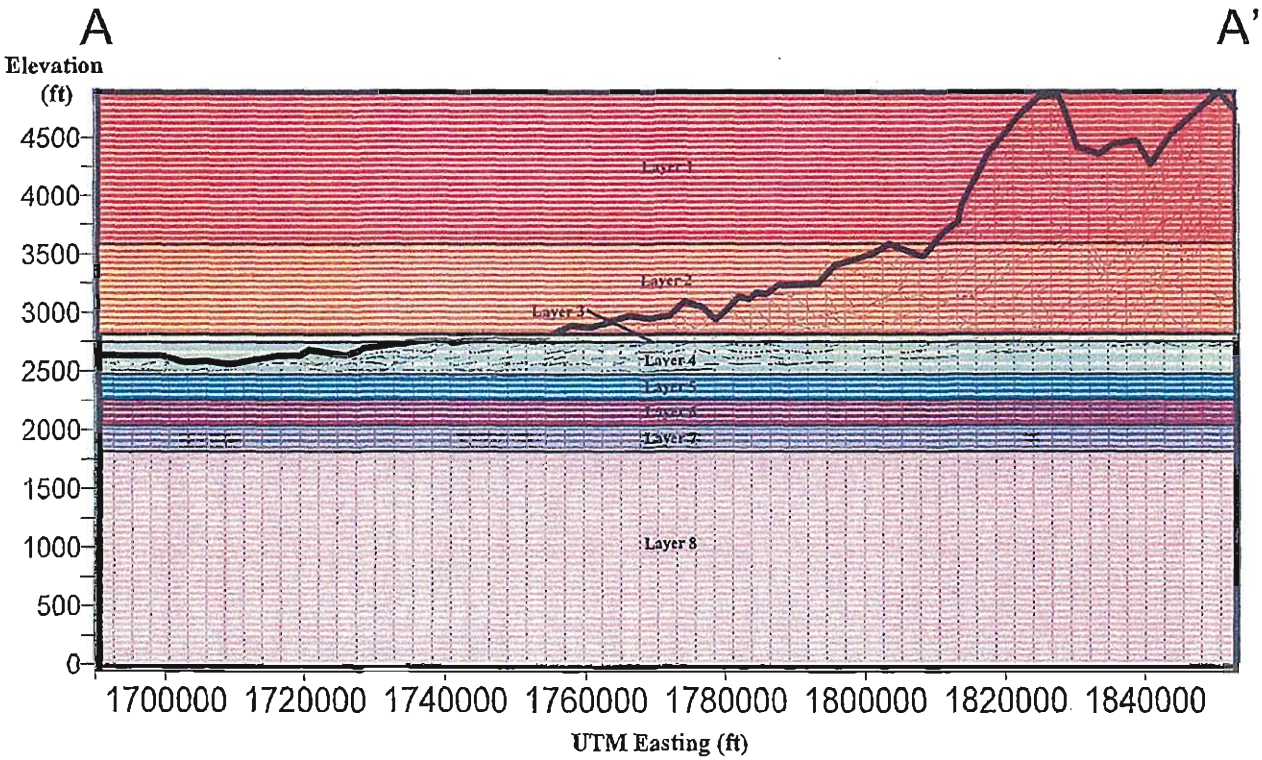
Model-based and measured-data-based contours from Layer 2 of the TVHP model (Petrich, 2004) showing flow direction in layer that would include the Pierce Gulch Sand Aquifer with flow direction forced toward southwest by model boundaries.

Figure 4. Model Domain and Grid Outline of the U of I Model



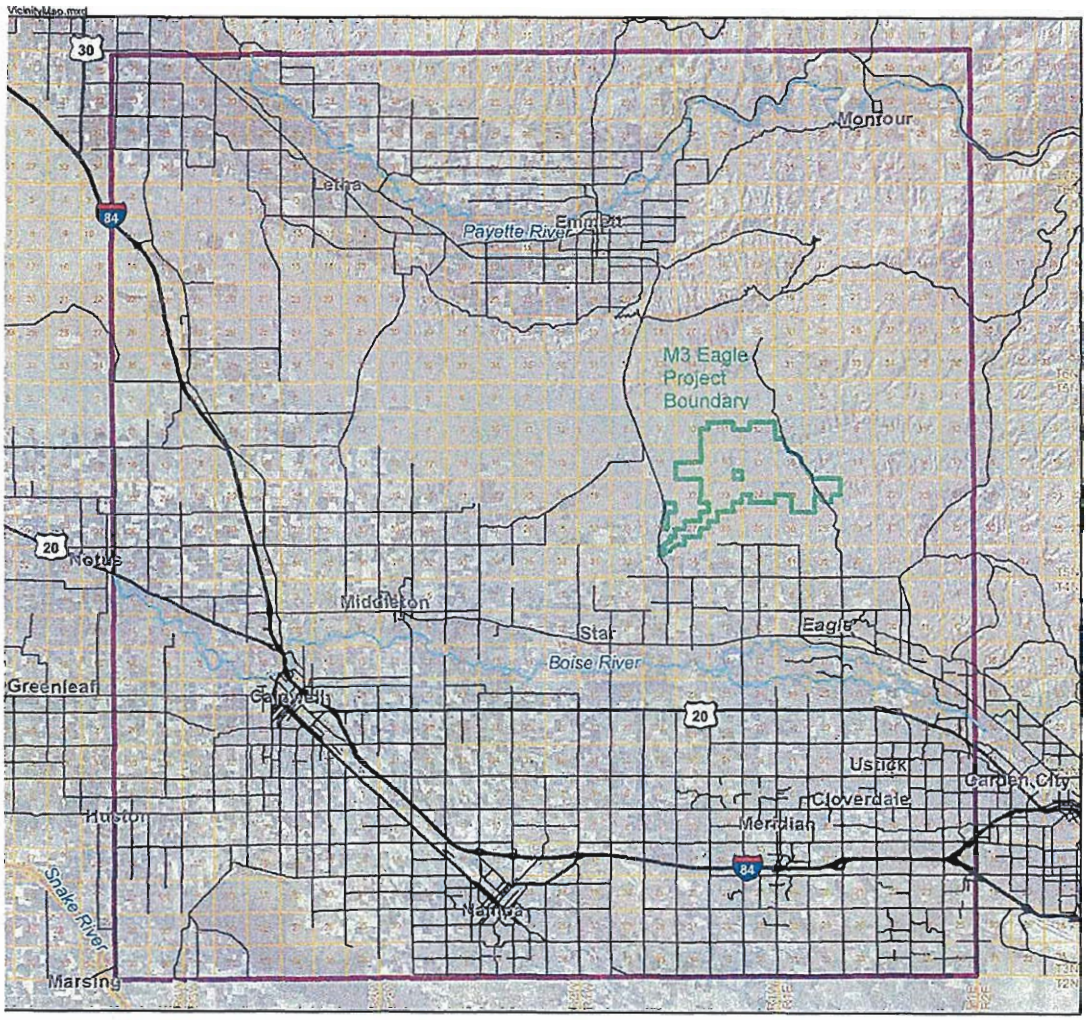
Domain of the U of I model showing that the northern boundary lies to the north of the Payette River and is therefore, unlikely to affect flow near the M3 Eagle project, from Douglas, 2007.

Figure 5. Representative Model Cross Section from the U of I Model



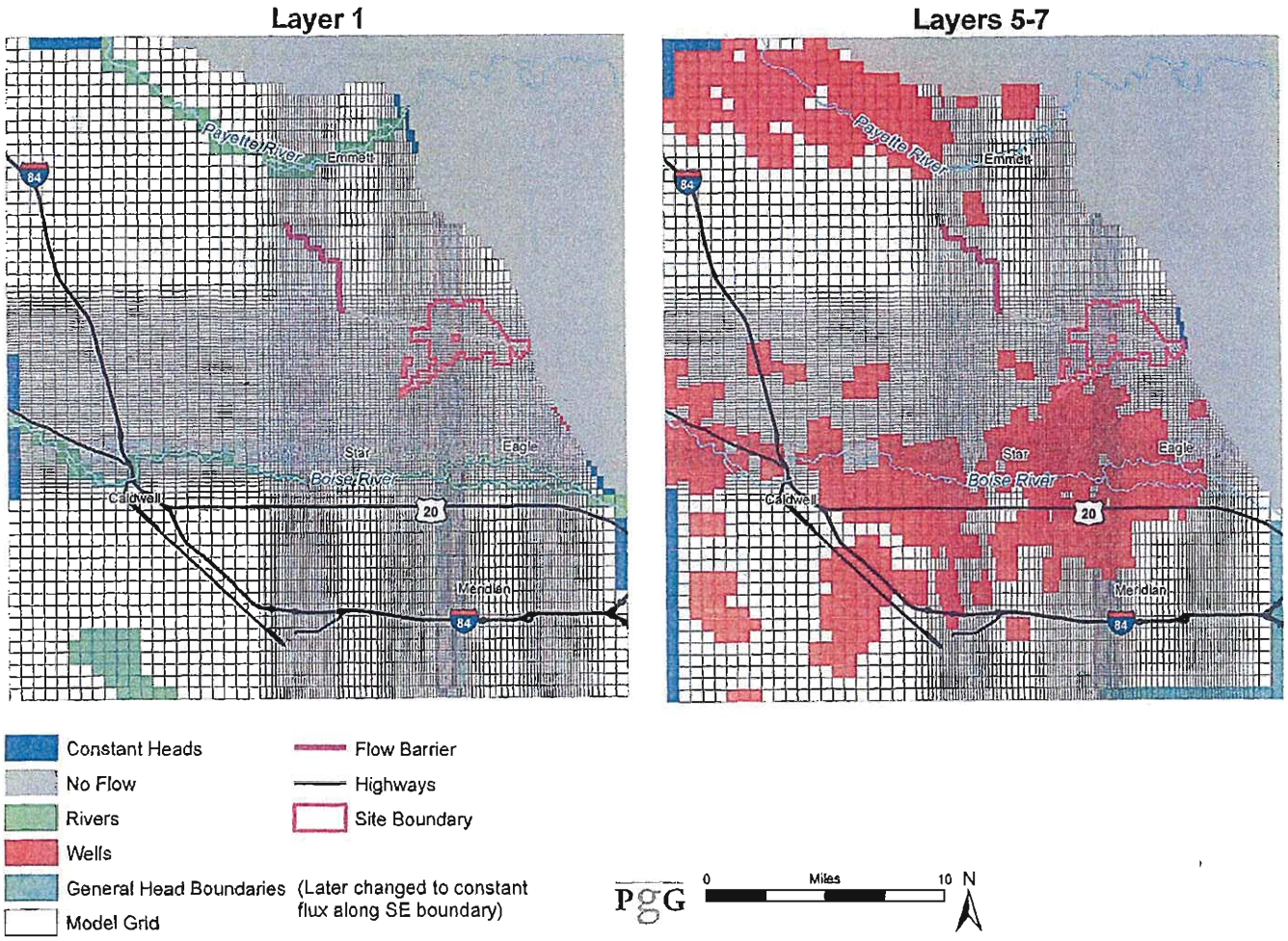
Representative cross-section from the U of I model (Douglas, 2007) showing: a) horizontal layering, b) Layers 1 and 2 representing uplands in the east and above ground (inactive) in the west, very thin Layer 3 (3 ft thick) to add confinement and d) large thickness of Layer 8 which represents Terteling Springs clays and mudstones.

Figure 6. Domain of the M3 Model



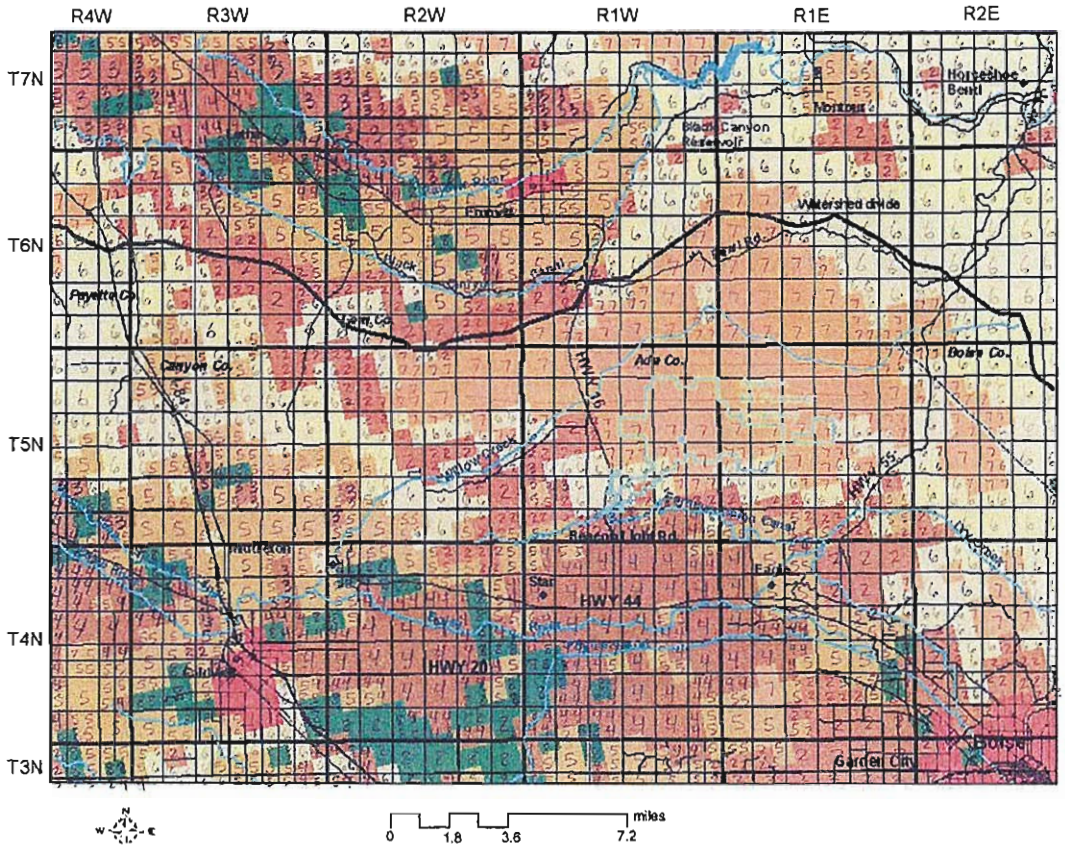
Domain of the M3 model showing boundaries well away from the M3 Eagle project, after PGG (2008a).

Figure 7. Model Grid and Cells in the M3 Model



Domain of M3 model showing variable cell size and boundary conditions, from PGG (2008a). Finer cell-size in M3 Eagle property and City of Eagle allows for better detail in transient calibration. Please see text for details.

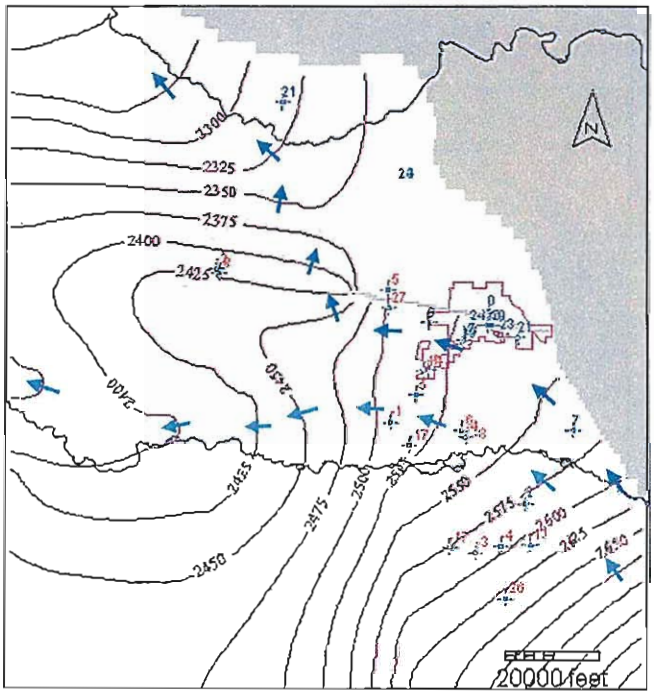
Figure 8. Land Use by Category in the M3 Model Area



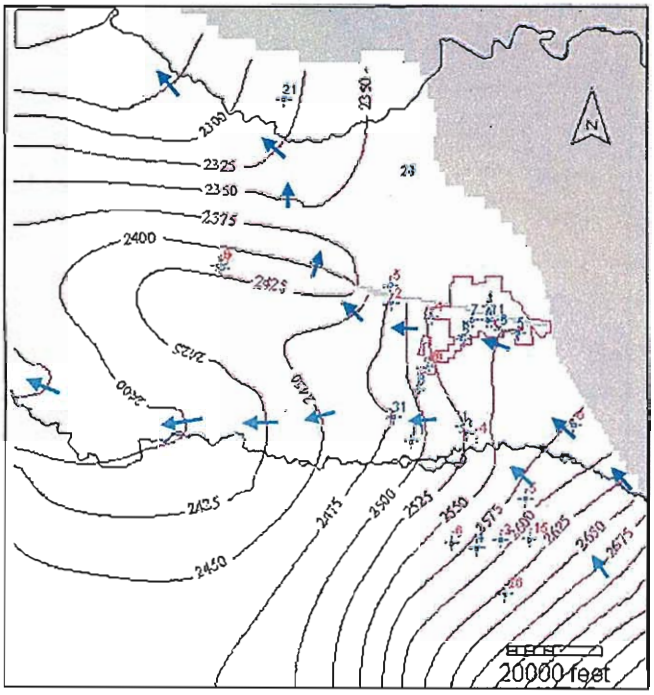
Land use manually categorized by quarter-section and reproduced from Nimmer (2007).

Figure 9. Potentiometric Contours and Ground-Water Flow-Directions from the Initial M3 Model

a) Tmatch model



b) Hmatch model



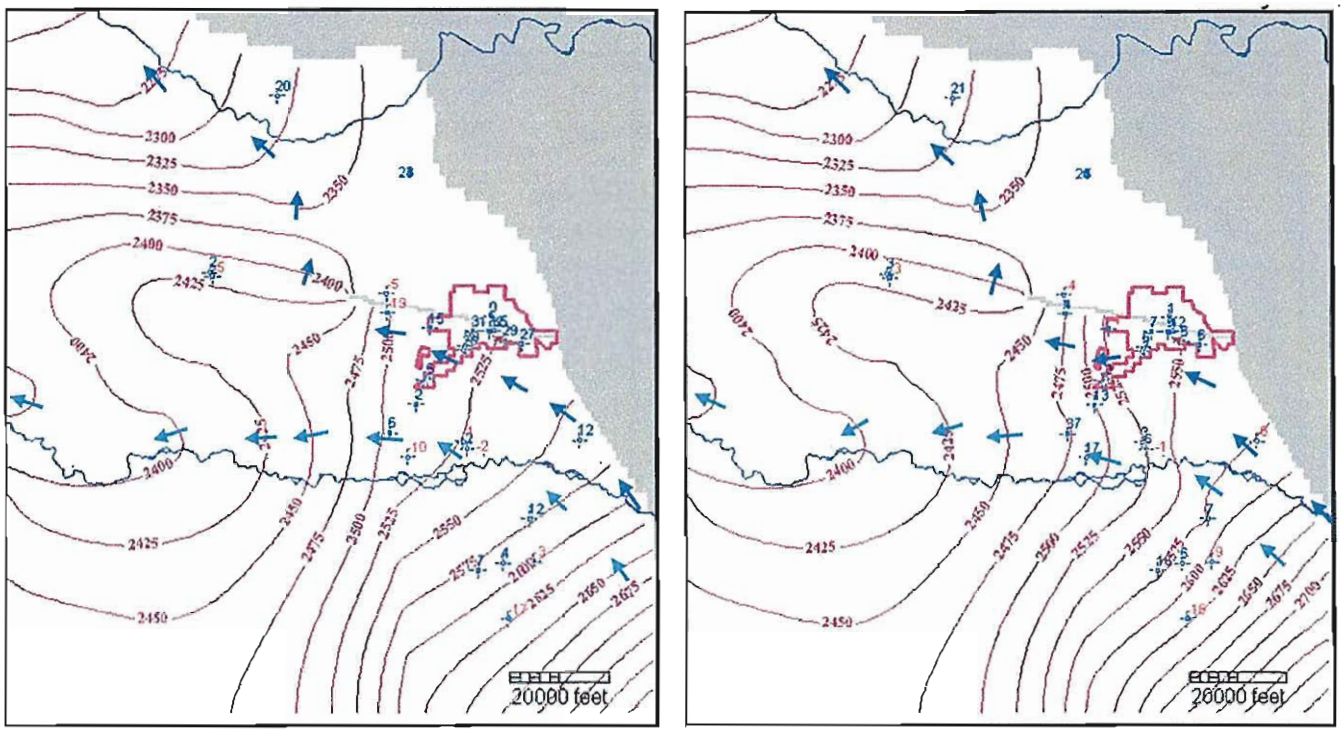
Steady-state potentiometric contours generated by initial M3 Tmatch and Hmatch models (with smaller overall estimates of well pumping within model domain) showing closer agreement to measured levels (smaller residuals) in Hmatch version, from PGG (2008a).

- Indicates flow in the Pierce Gulch Sand Aquifer that stays in the Boise River Valley
- Indicates flow in the Pierce Gulch Sand Aquifer that continues to the Payette River Valley

Figure 10. Potentiometric Contours and Ground-Water Flow-Directions from the Higher-Pumping Rate/ Recalibrated M3 Model

a) Tmatch model

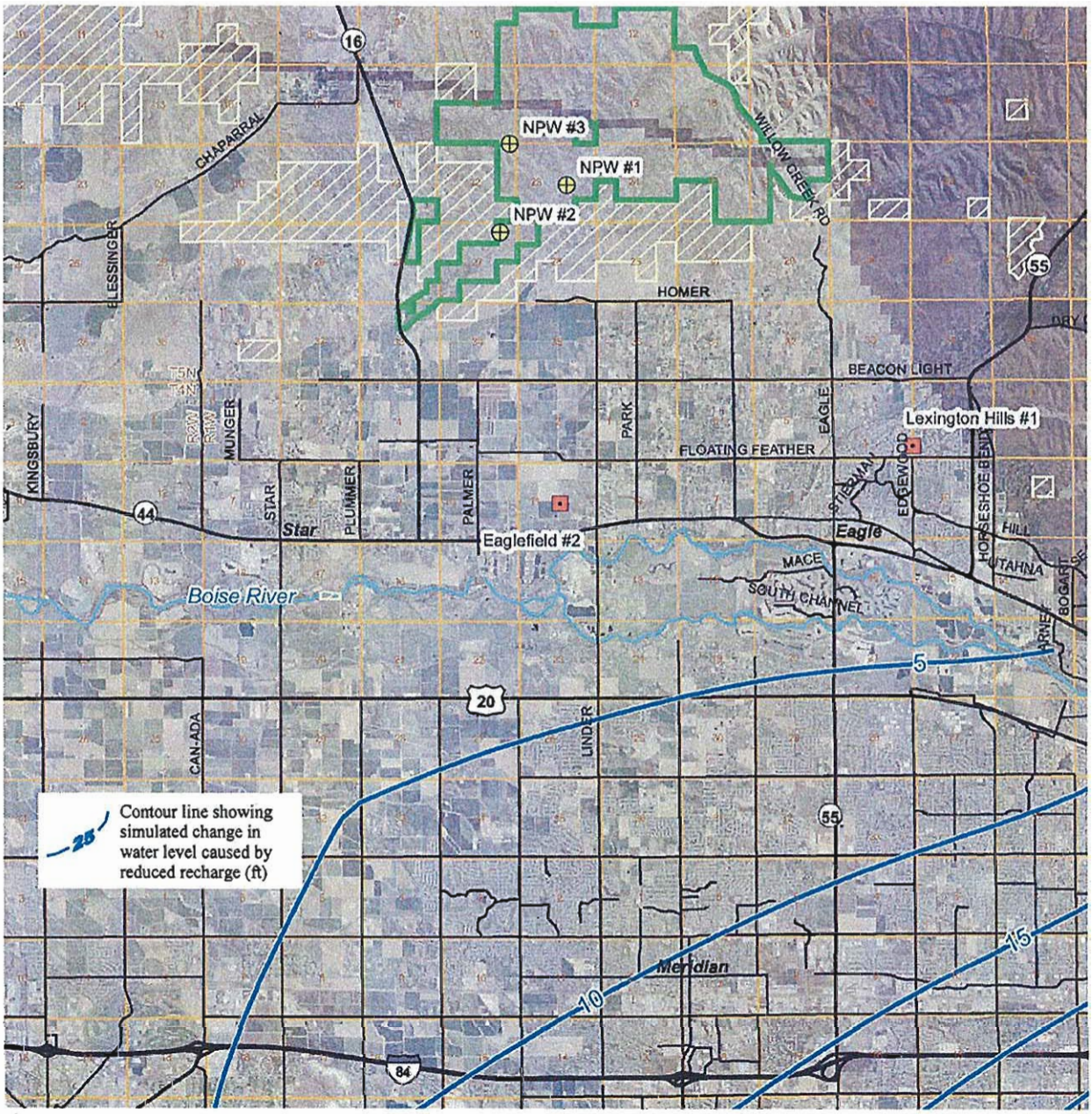
b) Hmatch model



Steady-state potentiometric contours generated by revised M3 Tmatch and Hmatch models (with larger overall estimates of well pumping within model domain) showing closer agreement to measured levels (smaller residuals) in Hmatch version, from PGG (2008d).

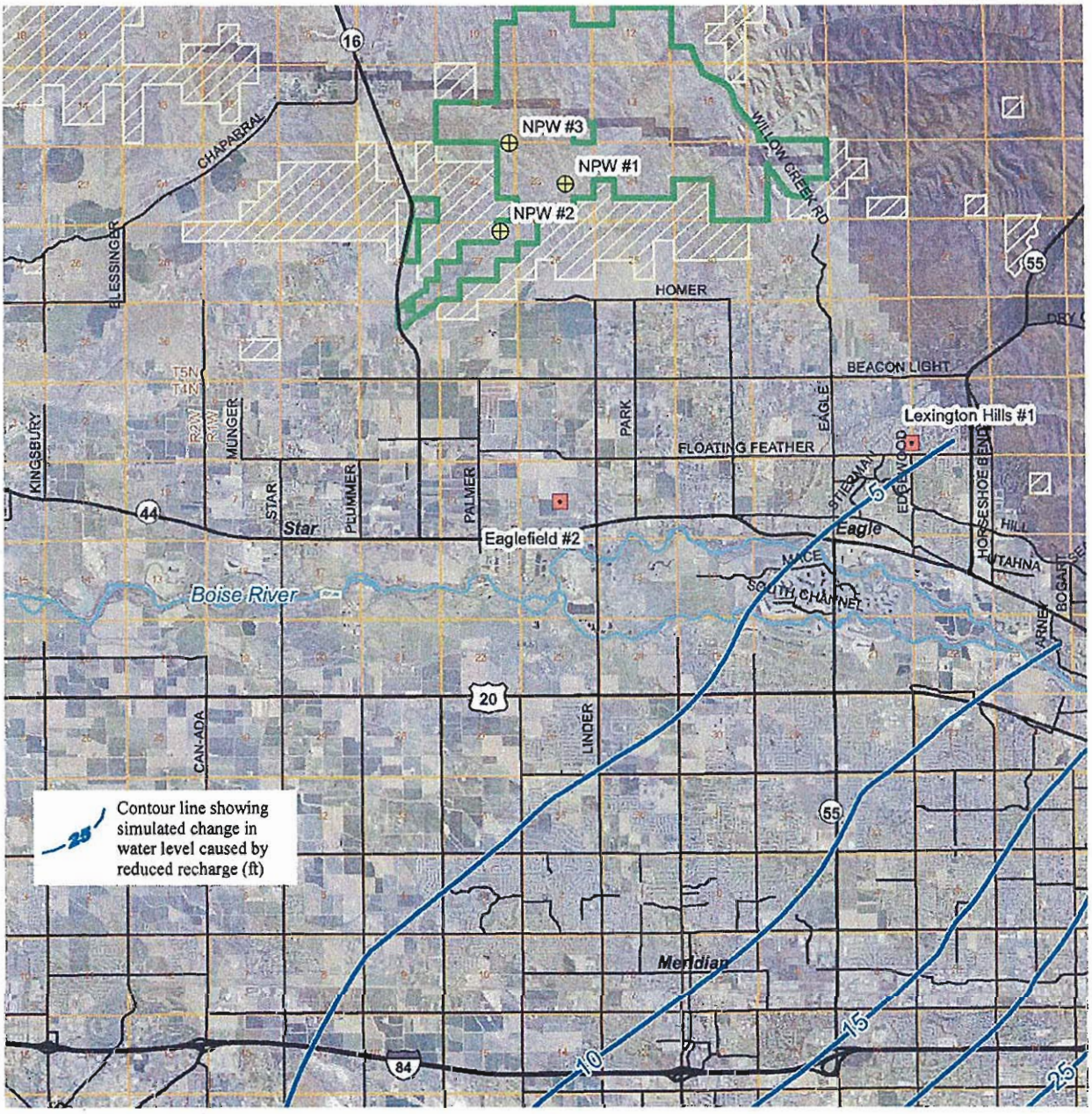
- Indicates flow in the Pierce Gulch Sand Aquifer that stays in the Boise River Valley
- Indicates flow in the Pierce Gulch Sand Aquifer that continues to the Payette River Valley

Figure 11. Tmatch Model-Generated Simulations of the Change in Water Levels Caused by a 20-Percent Reduction in Recharge from Southeast of Model Domain - Higher Pumping Rate Model



A prediction of water level changes caused by reduced recharge that might occur were the New York Canal to be lined to reduce seepage. Based on the Tmatch model with higher pumping rates within the model domain, from PGG (2008d).

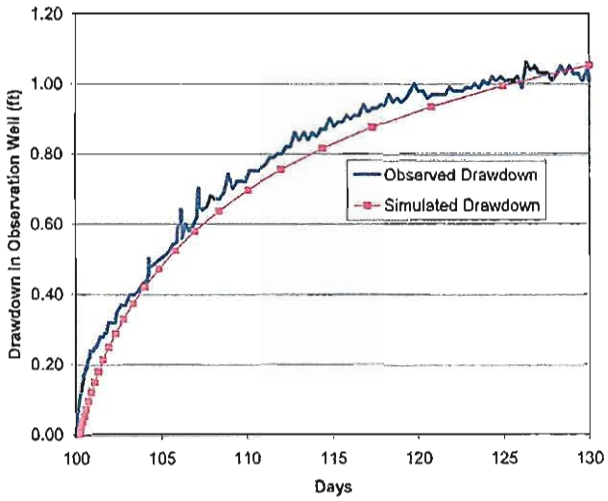
Figure 12. Hmatch Model-Generated Simulations of the Change in Water Levels Caused by a 20-Percent Reduction in Recharge from Southeast of Model Domain - Higher Pumping Rate Model



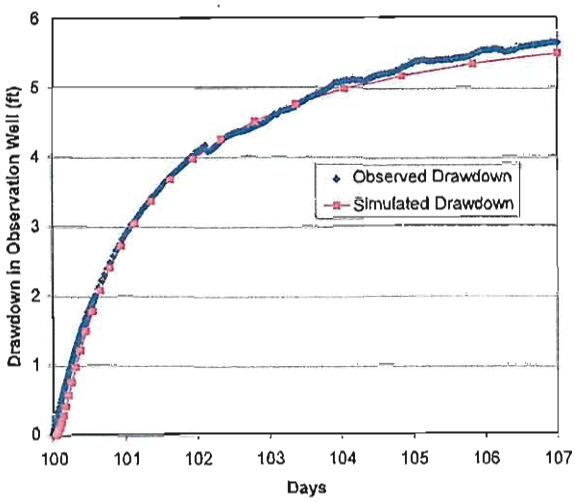
A prediction of water level changes caused by reduced recharge that might occur were the New York Canal to be lined to reduce seepage. Based on the Hmatch model with higher pumping rates within the model domain, from PGG (2008d).

Figure 13. Initial Transient-Calibration Hydrographs for Two Aquifer Tests - Lower Pumping Rate Model

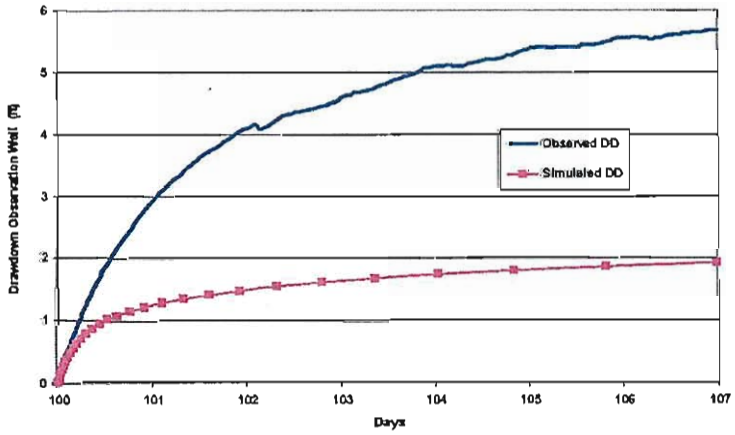
a) Lexington Hills Aquifer Test: Initial Hmatch Model



b) Eaglefield Aquifer Test: Initial Hmatch Model

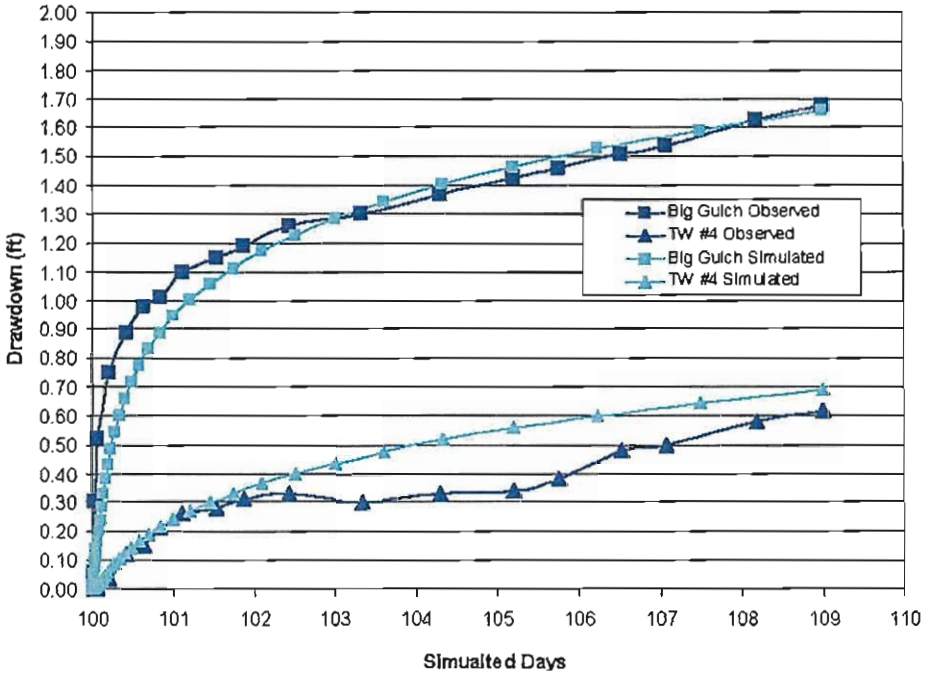


c) Eaglefield Aquifer Test: InitialTmatch Model

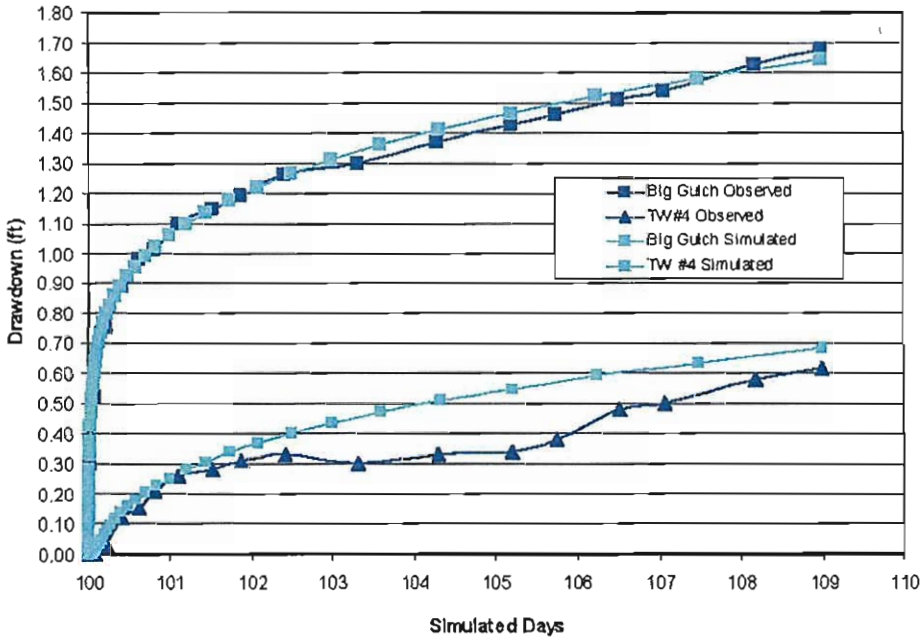


Transient calibration plots for observation wells from the Eaglefield and Lexington Hills aquifer tests, from PGG (2008a). Each simulation started after 100 days (with no pumping) to allow for equilibrium conditions before the test began. Plots show generally good match except for Tmatch model for Eaglefield test. Note that observed drawdowns from each test are not corrected for barometric effects or pre-test water level trends.

Figure 14. Transient-Calibration Hydrographs for SVR #7 from the SVR #7 Aquifer Test - Higher Pumping Rate Model



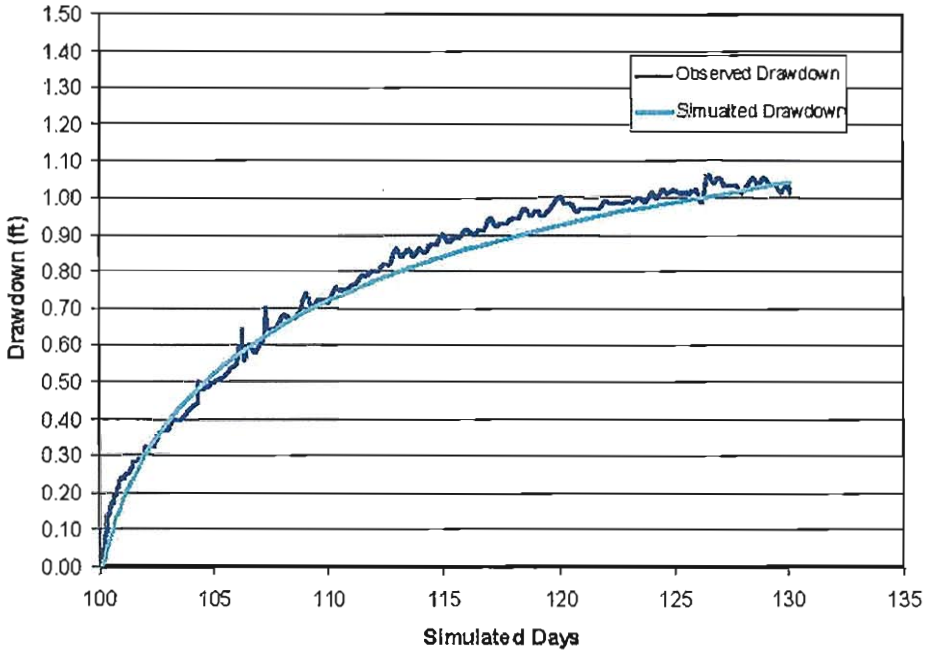
a) Tmatch model calibrated with higher total pumping in model domain.



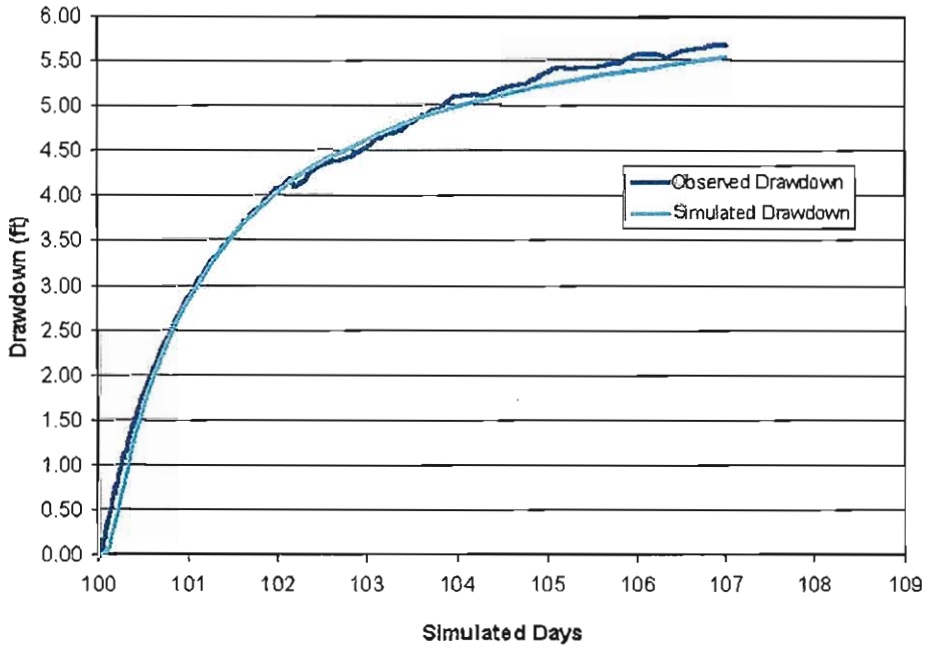
b) Hmatch model calibrated with higher total pumping in model domain.

Simulated and observed drawdowns for two observations wells during SVR #7 aquifer test, from PGG (2008d). Plots show generally good match. Decline in observed drawdown from "102" to "108" days for TW #4 (second through eighth day of test) likely caused by incomplete barometric and/or trend corrections. See text for details.

Figure 15. Transient-Calibration Hydrographs for Lexington Hills #1 and Eaglefield #2 – Higher Pumping Rate Hmatch Model



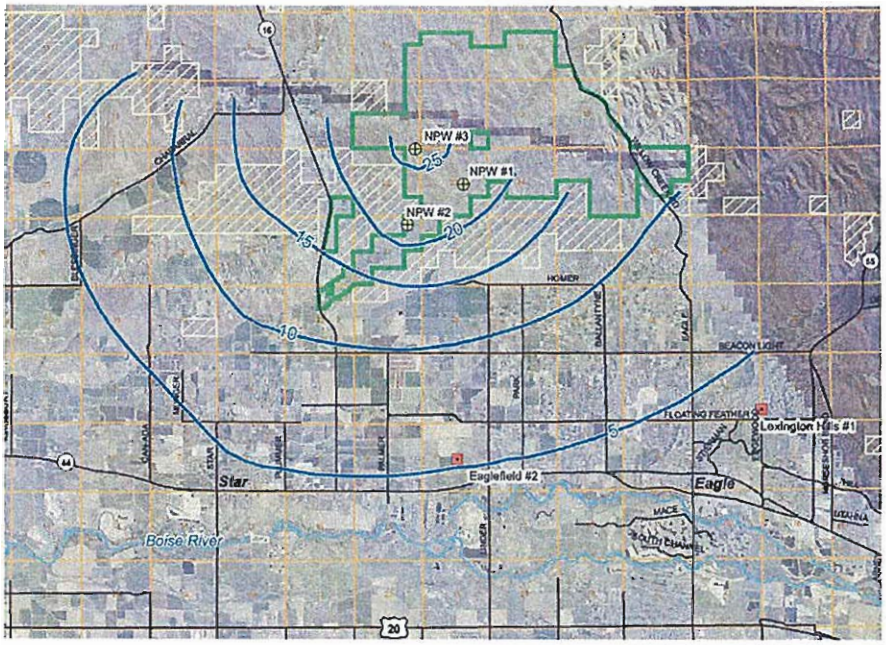
a) Lexington Hills #1 Observed and Simulated Drawdowns. Hmatch model calibrated with higher total pumping in model domain and SVR #7 Aquifer Test Data.



b) Eaglefield #2 Observed and Simulated Drawdowns. Hmatch model calibrated with higher total pumping in model domain and SVR #7 Aquifer Test Data.

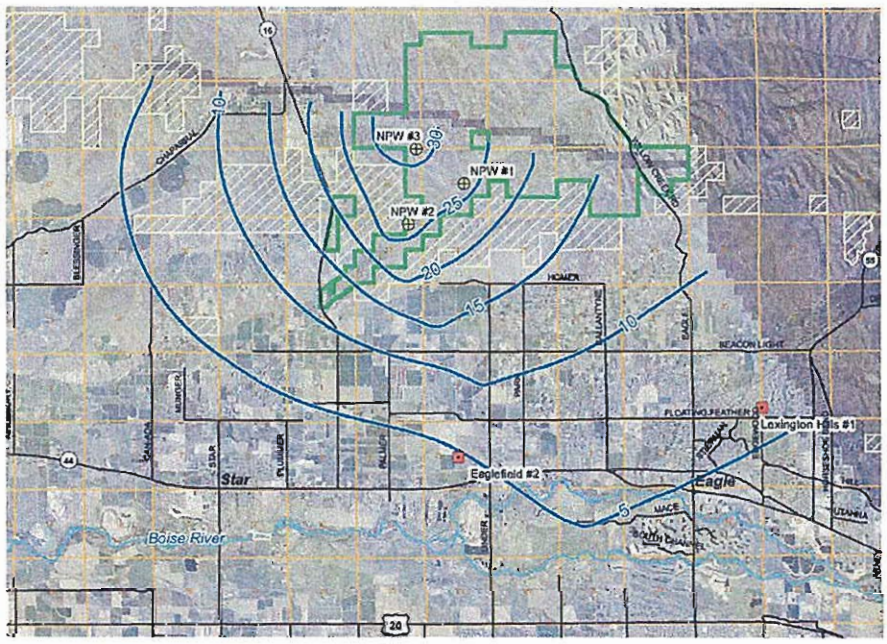
Simulated and observed drawdowns for two observations wells during SVR #7 aquifer test, from PGG (2008d). Plots show generally good match. Decline in observed drawdown from "102" to "108" days for TW #4 likely caused by incomplete barometric and/or trend corrections. See text for details.

Figure 16. Tmatch and Hmatch Model-Generated Drawdowns from Pumping at 4,500 gpm - Lower Pumping Rate Model



a) Tmatch Model after 50 years pumping at a combined 4,500 gpm at three proposed well locations ("NPW")

25 Contour line showing simulated drawdowns cause by pumping (ft)

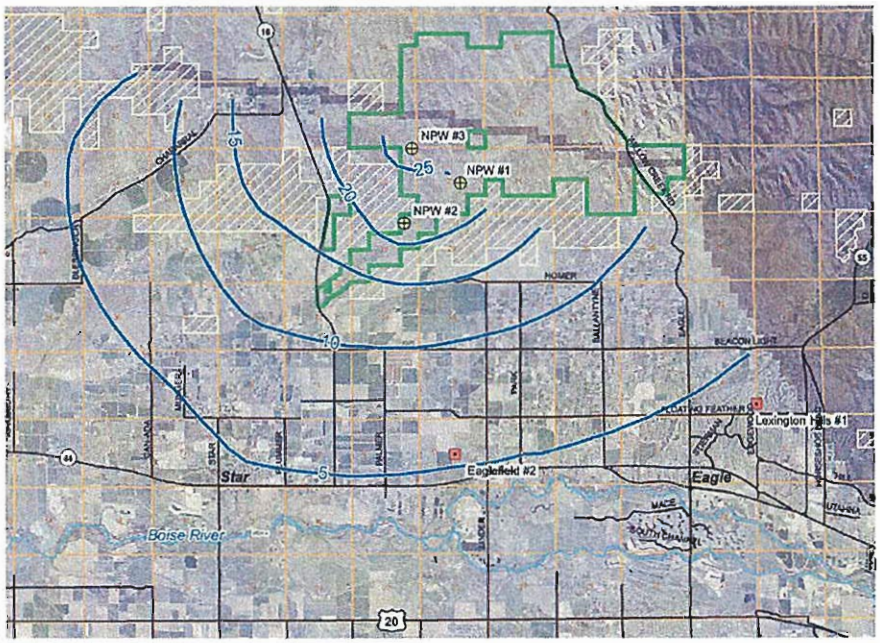


b) Hmatch Model after 50 years pumping at a combined 4,500 gpm at three proposed well locations ("NPW")

25 Contour line showing simulated drawdowns cause by pumping (ft)

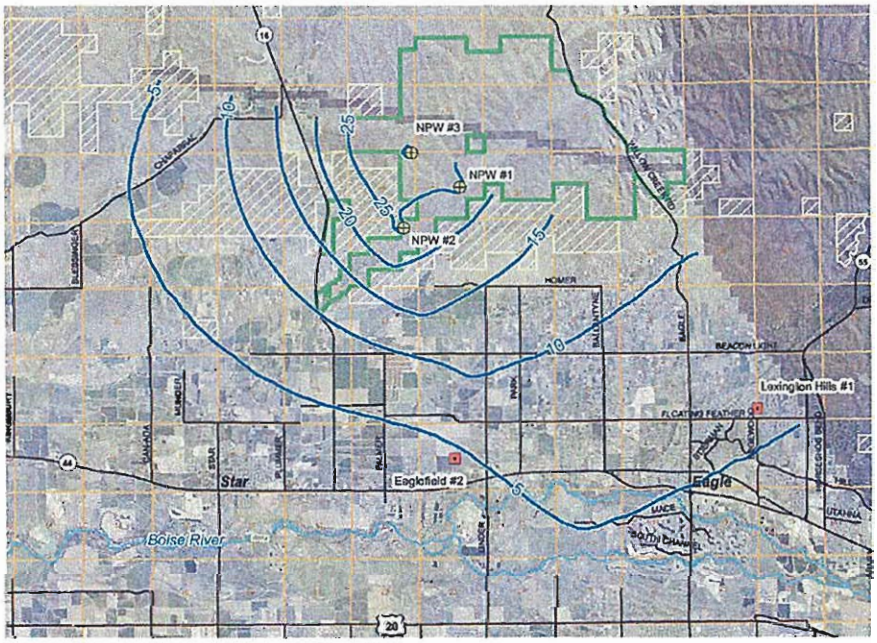
Two predictions of drawdown interference from pumping at 1,500 gpm from each of three wells using the two models (with lower pumping rates within the model domain) from PGG (2008c). (Drawdowns are smaller than those predicted from pumping at 7,000 gpm, shown in Figures 7-4 and 7-9 in PGG, 2008a, included in Appendix A).

Figure 17. Tmatch and Hmatch Model-Generated Drawdowns from Pumping at 4,500 gpm - Higher Pumping Rate Model



a) Tmatch Model after 50 years pumping at a combined 4,500 gpm at three proposed well locations ("NPW")

25 Contour line showing simulated drawdowns cause by pumping (ft)



b) Hmatch Model after 50 years pumping at a combined 4,500 gpm at three proposed well locations ("NPW")

25 Contour line showing simulated drawdowns cause by pumping (ft)

Two predictions of drawdown interference from pumping at 1,500 gpm from each of three wells using the two models (with higher pumping rates within the model domain) from PGG (2008d). Drawdowns beyond M3 property boundary are effectively the same as those simulated by the model with lower pumping rates within the model domain.

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APPENDICIES

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APPENDIX A – PACIFIC GROUNDWATER GROUP REPORT OF JUNE 4, 2008

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PACIFIC groundwater GROUP

M3 EAGLE GROUNDWATER FLOW MODEL AND ANALYSIS OF PUMPING IMPACTS - FIRST YEAR PROGRESS REPORT

June, 2008

M3 EAGLE GROUNDWATER FLOW MODEL AND ANALYSIS OF PUMPING IMPACTS – FIRST YEAR PROGRESS REPORT

Prepared for:

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June 4, 2008
JZ0705

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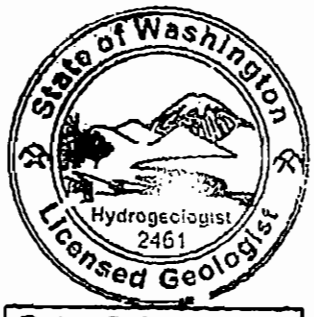
SIGNATURE

This report, and Pacific Groundwater Group's work contributing to this report, were reviewed by the undersigned and approved for release.



Peter Schwartzman

Peter Schwartzman
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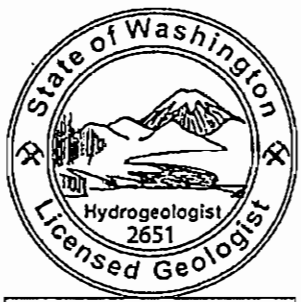
Washington State Hydrogeologist #2461



Dawn Chapel

Dawn Chapel
Senior Hydrogeologist
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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

A planned community by M3 Eagle, LLC in the foothills north of Eagle, Idaho proposes to install six new production wells in order to meet projected annual water demands of 6,535 acre-feet. As with any new groundwater withdrawal, pumping will cause some degree of local water level decline in the groundwater flow system over time. Groundwater level declines associated with M3 Eagle proposed pumping must be estimated to assess whether other nearby groundwater users would be impaired. The groundwater flow system in the M3 Eagle vicinity is complex, with multiple aquifers occurring at different depths, intervening aquitards, faulting, hydraulic connections between groundwater and surface water, multiple sources of recharge, and pre-existing groundwater withdrawals. Prediction of pumping drawdowns in a system of such complexity requires development of a groundwater flow model that represents all key components of the hydrogeologic system.

Hydro Logic, Inc. (HLI) characterized the hydrogeology of the M3 Eagle area, and retained and collaborated with Pacific Groundwater Group (PGG) to develop the numerical groundwater flow model. The project area and the model domain are shown on **Figure 1**. The model was calibrated to groundwater elevations measured in multiple wells, transmissivity estimates from multiple wells, and two aquifer tests. The model was then used to predict drawdown associated with proposed M3 Eagle groundwater withdrawals. Although the model presented in this report should be considered preliminary, we believe it is the best predictive tool developed to date to assess the impacts of groundwater development in the M3 Eagle vicinity. As time passes and additional data become available, the existing model will be improved through additional calibration and verification. These improvements and updates will be presented as addenda to this first-year progress report. This report, therefore, presents the status of the model one year into its development. We believe that this model as it is improved over time, will serve an important role in managing the groundwater resources of the M3 Eagle area.

1.2 PROJECT SCOPE

PGG's role in model development and prediction of pumping drawdown included the following:

- Development of a project geographic information system (GIS) that included roads, surface-water features, well distributions, irrigation ditches and canals, surficial geology, HLI's estimates of pumping and recharge distribution, land elevations and public land survey;
- Selection of a model domain of sufficient size to avoid undesirable boundary impacts during drawdown prediction, and discretization of the model grid to support accurate definition of drawdown throughout the domain;
- Development of model layering to represent hydrostratigraphic units and definition of hydraulic boundary conditions based on hydrogeologic interpretation by HLI;
- Delineation of surface-water bodies for representation in the groundwater flow model;
- Estimation of recharge from irrigation ditches and canals based on seepage rates provided by HLI;
- Compilation of pumping and recharge estimates into the groundwater flow model;
- Sensitivity analysis to identify model parameters that have the greatest influence on groundwater model results;

- Model calibration to groundwater elevations (steady state calibration) and aquifer test results (transient calibration) based on data provided by HLI;
- Consideration of model uncertainty; and,
- Use of the calibrated model to predict aquifer drawdowns over the course of M3 Eagle's proposed groundwater development.

It should be noted that some degree of uncertainty was identified during model calibration. Specifically, when PGG employed the best available estimates of aquifer transmissivity (provided by HLI) during model calibration, predicted groundwater elevations in the M3 Eagle vicinity were consistently too low. PGG was able to reproduce groundwater levels near the M3 site with sufficient departure from some of HLI's transmissivity estimates, In order to address this associated uncertainty, PGG developed two versions of the model: one that honored the transmissivity estimates ("Tmatch" model) and one that allowed departures from the transmissivity estimates in order to achieve a better match to measured water-level elevations ("Hmatch" model). Both versions of the model were used in the predictive analysis. Through the use of two models, we have effectively bracketed a range of drawdown impact-predictions. Since the differences in the drawdowns predicted by the two models were relatively small, we believe that the differences between the two models are relatively minor for the purposes of this investigation.

It should also be mentioned that development of the groundwater flow model was a collaborative effort between HLI and PGG. Model development almost always results in identification of data gaps and areas requiring further hydrogeologic interpretation. HLI collected additional data and performed additional hydrogeologic interpretation as questions arose during model design, construction, and calibration. Members of the HLI and PGG teams have worked together for almost 20 years. Because of this long-term relationship, the transfer of HLI's specific hydrogeologic understanding of the project vicinity needed to properly develop the model was greatly aided.

1.3 WARRANTY

The work was performed, and this report prepared using generally accepted hydrogeologic practices used at this time and in this vicinity for exclusive application to the study area and for the exclusive use of HLI. This is in lieu of other warranties, express or implied.

2.0 SUMMARY OF FINDINGS

1. **PGG developed a groundwater flow model in order to estimate drawdown associated with proposed pumping from M3 Eagle project.** The model represents the key components of the groundwater flow system, including: multiple hydrostratigraphic units (aquifers and aquitards), faulting, the Boise and Payette rivers, recharge from a variety of sources, and pumping for a variety of purposes. The model covers a sufficiently large domain (520 square miles) so that external boundaries do not affect estimation of drawdown.

2. **PGG worked closely with HLI to ensure that the structure of the computer model best matched the conceptual model of the groundwater flow system.** HLI provided maps and feedback regarding the structural surfaces of key hydrostratigraphic units, estimates of aquifer parameters from tested wells, and both groundwater elevation and aquifer test data to be used for calibration targets. HLI also provided interpreted data and guidance to facilitate model representation of pumping and recharge.

Finally, HLI provided input during the calibration progress, including supplemental data when data gaps were encountered.

3. **PGG calibrated the model to both steady-state and transient conditions.** The steady-state model was calibrated to observed groundwater levels in wells, whereas the transient model was calibrated to drawdown responses observed during aquifer tests. An iterative approach was used between the steady-state and transient calibrations. Both calibrations met standard criteria for successful calibration. Although the model represents the shallow, middle, and deep portions of the groundwater flow system, calibration emphasized conditions in the generally deep "Pierce Gulch Sand Aquifer" (PGSA) from which M3 Eagle proposes to withdraw groundwater.

4. **During calibration, some level of model uncertainty became apparent.** Specifically, when PGG employed the best available estimates of aquifer transmissivity (provided by HLI) during calibration, predicted groundwater elevations in the M3 Eagle vicinity were consistently too low. PGG was able to reproduce groundwater levels near the M3 site with sufficient departure from some of HLI's transmissivity estimates. In order to address this associated uncertainty, PGG developed two versions of the model: one that honored the transmissivity estimates ("Tmatch") and one that allowed departures from these estimates to achieve a better match to measured water-level elevations ("Hmatch"). Both of these model versions were used for predictive analysis, and thus bracket a range of predictive results.

5. **Both versions of the model met the criteria for successful steady-state calibration.** For steady state calibration, the ratio of residual standard deviation to the observed head range was less than the 10 percent calibration criteria. In addition, values of residual mean (RM) and absolute residual mean (ARM) ranged from 2.7 to 14 feet, which was considered reasonable compared to the head range in the area of PGSA calibration (about 200 feet),

6. **Successful transient calibration to two local pumping tests was achieved with the Hmatch model.** PGG also attempted to calibrate the Tmatch model to one of the tests, but could only achieve acceptable calibration by substantially decreasing (by a factor of five) the local transmissivity value in the area of the test. As the intent of the Tmatch model is to retain estimated transmissivity values (even at the expense of decreased matches to head or time-drawdown targets), the originally estimated transmissivity values were retained.

7. **PGG ran both models through 26 years of projected pumping at the M3 Eagle site in order to estimate both long-term and intermediate drawdowns throughout the project development.** At full build out, general drawdowns in the PGSA in the M3 pumping center are estimated to reach 30 to 50 feet (not including well-loss drawdowns specific to individual wells). PGSA drawdown is predicted to rapidly decline with distance outward from the pumping center, with only 5 feet of drawdown predicted 4 miles away at the Boise River. Drawdown in the Middle Aquifer[1] is predicted to be less than in the PGSA depending on location within the aquifer system. Drawdown maps are presented on **Figures 7-2** through **7-11.**

8. **The groundwater flow model was developed to estimate drawdown in the Pierce Gulch Sand Aquifer and the overlying Middle Aquifer, caused by pumping associated with the M3 project.** While the model includes all key elements of the shallow and intermediate portions of the groundwater flow system (e.g. alluvial aquifers along the Boise and Payette Rivers, the rivers themselves, the

[1] The Middle Aquifer (layer 3) is also referred to as the "shallow, unnamed, alluvial aquifer overlying the Pierce Gulch Sand Aquifer"

Middle Aquifer), the model was not calibrated to conditions in these portions of the system. Therefore, the model should not be used to simulate stresses and responses within those aquifer systems without further data review, possible design refinements and calibration.

3.0 CONCEPTUAL HYDROGEOLOGIC MODEL

The hydrogeology of the study area is described in the main body of this report. Key features of the conceptual hydrogeologic model represented by the groundwater flow model include:

- The Pierce Gulch Sand Aquifer (PGSA), which occurs close to the land surface near the M3 Eagle site and dips downwards to the southwest;
- The Willow Creek Aquifer (WCA), which occurs north and northeast of the M3 Eagle site;
- The West Boise-Eagle Fault, which hydraulically separates the PGSA and overlying shallow aquifers present to the southwest of the fault from low-permeability units lying to the northeast of the fault;
- The low-permeability sediments separating the PGSA from the WCA beneath the northeastern portions of the M3 Project site;
- The Boise River sand and gravel aquifer, an alluvial aquifer which occupies the extensive present-day floodplain of the Boise River;
- A regional aquitard that separates the Boise River alluvial aquifer from the PGSA;
- Water-bearing deposits within the regional aquitards, described by HLI as the "shallow, unnamed, alluvial aquifer overlying the Pierce Gulch Sand Aquifer, but for the purpose of this report, heretofore known as the "Middle Aquifer";
- Valley-fill deposits of the Payette River, including both water-bearing units and low permeability units. Occurrence of low permeability units creates confined conditions in the deeper portions of these deposits. PGG also assumed that the shallow valley-fill deposits include an alluvial aquifer, similar to the Boise River sand and gravel aquifer;
- Bedrock hills ("North Eagle Foothills") that effectively function as a "no-flow" boundary for the groundwater flow system in the unconsolidated sediments;
- Groundwater recharge based on precipitation, land cover, irrigation applications, and seepage losses from irrigation ditches;
- Pumping withdrawals for domestic, municipal, industrial, and irrigation uses;
- An overall west-northwest flow direction for groundwater in the PGSA with a potentially substantial source of recharge outside of the model domain (upstream on the Boise River) where the PGSA comes into close hydraulic contact with the river.

4.0 MODEL CONSTRUCTION

4.1 MODEL CODE

The three-dimensional, finite difference code "MODFLOW" (McDonald and Harbaugh, 1988; Harbaugh et al., 2000) was selected for this model because it has been thoroughly validated and is in common use by government agencies and consultants. Groundwater Vistas Version 5 (GV) (ESI, 2007) was used as

platform to organize input data, run the model, and view results. MODFLOW comes with several solver options: Slice-Successive Over-Relaxation (SSOR), Strongly Implicit Procedure (SIP), and the Preconditioned Conjugate-Gradient Method (PCG2). Different solvers may work better for different problems. The PCG2 solver was successful in solving the M3 model simulations.

4.2 MODEL DOMAIN AND DISCRETIZATION

The model domain occupies an area of 20 by 26 miles, including portions of the Boise Foothills, Payette River Valley, and Boise River Valley (**Figure 1-1**). The outer boundaries of the model domain were set at significant distances from the M3 site to minimize boundary effects on the estimation of drawdown. The M3 site is located in the northeast portion of the model domain near natural "no-flow" (bedrock) conditions in the Boise Foothills. The model represents the Willow Creek Aquifer (WCA) and Payette Valley Aquifer (PVA) in the north, and Pierce Gulch Sand Aquifer (PGSA), an unnamed alluvial aquifer overlying the Pierce Gulch Sand Aquifer (termed the "Middle Aquifer" in this report), the gravel aquifer that occupies the Boise River Valley in the south, and an alluvial aquifer beneath the Payette River valley to the north.

The model domain was discretized into a seven-layer, variable-spacing grid. The grid contains a total of 99,568 cells, 81,958 of which are active. Variable grid spacing included minimum spacing of 330 ft near the M3 site gradually increasing to a maximum of 2,640 ft (a half mile) at the outer model boundaries (**Figure 4-1**). This variable grid spacing allows detailed representation of hydrogeologic conditions and pumping drawdown in the M3 vicinity while covering a geographically extensive area and providing computational efficiency in running the model. The grid spacing was set so that single model cells, or multiple model cells, fit evenly within a quarter of a square-mile public land survey (PLS) "section". This allowed various data indexed to the PLS system (e.g. pumping, water rights) to be readily calculated and distributed among model cells. The model grid was aligned in an east-west direction, generally parallel to the major rivers.

Model layers were defined based on the hydrostratigraphic units discussed in Section 3 and HLI's hydrogeologic report. The top of the model domain (land surface) was defined based on a USGS digital elevation model (DEM). Model layer surfaces were defined relative to the top/bottom of the PGSA (and the WSA to the north), as represented in 13 borehole geophysical logs and 36 boring logs. Top/bottom PGSA surfaces dip to the southwest, and were defined based on contouring and interpolation between logs. A discontinuity was represented between the top/bottom elevations of the PGSA and the WPA in a manner consistent with the stratigraphic understanding of these units. The materials between the top and bottom surfaces of the PGSA were divided evenly into three model layers (5, 6, and 7). The PGSA top/bottom surfaces were extended beneath the Payette River Valley where the PGSA is absent. The top/bottom surfaces were also extended across the West Boise-Eagle Fault into the region occupied by the WCA. Model layering includes a discontinuity across the fault to represent its displacement. **Figure 4-2** contours the top and bottom reference surfaces, and shows the contact elevations for 36 boring logs interpreted to define these surfaces.

Above the top-of-layer-5 reference surface, the overlying 4 layers were divided in the following manner:

- Model layer 1 was generally assigned a uniform thickness of 50 ft, except in portions of the Payette River valley where the top reference surface is relatively shallow.
- Areas with thinner material above top reference surface primarily occurred just north of the cliffs which flank the Payette River floodplain. In this area, if 50 ft were allocated to model layer 1, the

remaining thickness would be too small for layers 2 through 4. Therefore, the thickness above the PGSA top was divided evenly between layers 1 through 4.

- In all areas where layer 1 was assigned a thickness of 50 feet, the materials between the bottom of layer 1 and the top reference surface (top of layer 5) were divided evenly into three, equal thickness layers (2, 3 and 4).

4.3 BOUNDARY CONDITIONS

Boundary conditions included no-flow, constant head, general head, recharge, wells, rivers, and a vertical low-permeability barrier. **Figure 4-1** shows the boundary conditions for layer 1 and layers 5, 6, and 7 (same for all three layers). Boundary conditions in layers 2 through 4 are limited to pumping wells and the vertical low-permeability barrier which penetrates the entire model domain.

4.3.1 No-Flow Boundaries

No-flow boundaries vary by model layer based on expected flow conditions in the shallow and deep portions of the groundwater flow system, and the intended use of the model. In all layers, no flow occurs in the region designated as "inactive" due to the presence of low-permeability bedrock. All layers also include an internal no-flow boundary in the location where the bottom of the Pierce Gulch Sand Aquifer reaches the surface and the underlying contact with low-permeability clay and mudstones of the Terteling Springs Formation crop out. These low-permeability sediments cause a hydraulic disconnect between the aquifers on either side (PGSA and WCA). The use of a no-flow condition was computationally advantageous for ensuring no transfer in the contact vicinity. While the PGSA and WCA are hydraulically separated by the contact in the eastern model domain, they become hydraulically continuous toward the middle and the western portions of the domain.

In layer 1, portions of the model's exterior boundaries are specified as no flow. Specifically, the southern model boundary (southeast, south, and southwest) and the northern half of the western model boundary. Although these boundaries may not occur along groundwater divides, they are designated as no flow because:

1. Flow through the shallow system is dominated by conditions in the alluvial aquifers (along rivers), which *are* simulated with constant head boundaries along the exterior model boundaries. Heads along the entire boundary are therefore somewhat set by the alluvial constant head cells.

2. The no-flow portions of these external boundaries are far from the M3 pumping center, and actual conditions at this distance are not critical for the intended purpose of this model. More importantly, a highly accurate replication of shallow alluvial aquifer conditions is not necessary for the purpose of this model – to estimate drawdowns in the deep and shallow domestic aquifers associated with pumping at the M3 site.

3. Treating these values as no-flow is conservative, as it will tend to overestimate predicted drawdowns associated with pumping.

The exterior boundaries in layers 2 through 4 are all treated as no-flow. Horizontal flow is generally negligible in aquitards (layers 2 and 4); therefore, alternative representations are not needed. Surrounding the middle aquifer (layer 3) with no-flow conditions again provides conservative estimates of drawdown, which is the intended use of the model.

Layers 5, 6 and 7 all have the same boundary conditions with the exception that layer 7 has a no-flow boundary along the bottom of the layer. (Note: Section 5.3 discusses a sensitivity run where model simulation of layer 7 included upwelling from deep geothermal aquifers.) No-flow conditions are specified along the eastern half of the southern model boundary and the northern half of the western model boundary. Both of these external boundaries also include head-dependent boundary conditions (constant head and general head) which define inflows and out flows to the deep aquifer system. It was not necessary to specify head-dependent conditions along the entire length of the model's external boundaries to simulate the groundwater flow field. As described in Section 7, model predictions were performed in a conservative manner that maximizes drawdown and does not allow *any* additional flow to cross any of the model's exterior boundaries due to M3 pumping impacts.

4.3.2 Constant Head Boundaries

Constant head boundaries (CHB's) are specified in layer 1 and layers 5-7 (same in all three layers). The CHB's in layer 1 correspond to the upstream and downstream intersection of the stream alluvium with the external model boundaries, thus representing subflow into and out of the model domain. Head values were set based on river elevations in these locations. CHB's in layers 5-7 were positioned on the southern half of the western boundary and on the northwest corner of the model domain to represent subflow out of the PGSA and the Payette Valley aquifer, respectively. A small group of CHB cells was also placed against the no-flow cells representing bedrock to simulate inflow to the WCA. Head values at these locations were adjusted during calibration to match observed heads within the model domain. PGSA subflow into the model domain was simulated with a general head boundary (discussed below).

4.3.3 General Head Boundary

A general head boundary (GHB) was used to represent subflow into the PGSA along the southeast corner of model layers 5, 6 and 7. The GHB was preferred over a CHB due to the proximity of this external model boundary to the proposed M3 pumping center. The GHB places the location of the fixed head beyond the outer edge of the model domain. The GHB was conceptualized as a southwest-northeast trending line which is nearest to the model domain at the southeast corner of the grid. Distances from the exterior boundary of the grid to the "fixed head" simulated by the GHB ranged from around 2,500 feet at the southeast corner of the domain to as much as 34,000 feet at the GHB cells farthest from the corner. The "fixed head" location of the GHB represents an upstream location in the Boise River Valley where the PGSA has a stronger hydraulic connection to the river, its associated alluvium, and leakage from the New York Canal. The value of the fixed head was adjusted during calibration, and the hydraulic conductivity of the sediments between the GHB cells and the fixed head was maintained at or close-to the nearby hydraulic conductivity of the PGSA within the model domain (within a factor of 2). These adjustments were made to allow the model to generally match water levels measured across the City of Meridian in selected wells in the southeast portion of the model.

4.3.4 Recharge

Primary sources of recharge include precipitation, irrigation applications, seepage from ditches and canals, and effluent from septic systems. MODFLOW's recharge package was used to simulate areally distributed recharge over the uppermost aquifer in the model domain. Recharge was estimated for the primary sources and combined prior to model input. Total recharge is presented on **Figure 4-3**. The recharge input does not include seepage from the Boise and Payette rivers, which is simulated as a head-dependent boundary based on MODFLOW's river package.

Septic Recharge

Septic recharge was estimated based on well densities and the water budget evaluation of Urban (2004). The analysis assumed that there are 2.9 people per house at a recharge rate of 45 gal/day/person. For most of the model domain, HLI estimated septic recharge rates per quarter section based on well densities and the (conservative) assumption of only one house per well. After calculating recharge per quarter section, these values were distributed among the model grid cells using GIS (multiple cells may occupy the same quarter section in more refined portions of the grid). Initially, all quarter sections in the proposed model domain were analyzed for septic recharge. After a while it became apparent that a larger model area would reduce potential errors associated with pumping impacts reaching the boundaries of the model. A larger model was then constructed. Since an inventory of wells and septic drain field users had not been conducted in the newly added peripheral portions of the model, actual numbers were estimated. In these peripheral areas outside HLI's well-density accounting, recharge values were assigned (estimated) based on similar areas that were included in the well density analysis. Assigned values and the areas from which they were derived are listed on **Table 4-1.**

Ditch and Canal Recharge

Ditch/canal recharge estimation is based TVHP Water Budget Data (Urban, 2004). GIS analyses used the distribution of ditches, canals and surficial geology to calculate ditch recharge rates for high-permeability surficial geologic units. In the Boise River valley, a recharge rate of 0.75 cfs/mi was assigned to ditches/canals overlying high-permeability geologic deposits and 0 cfs/mi for ditches/canals overlying low-permeability geologic deposits. Geologic deposits were defined based on mapping by Othberg and Stanford (1992), with low-permeability units including Qbgc, Qs, Qwgs, Qwig, Tgf, and Ts and high-permeability units including the remaining mapped area. Outside the area mapped by Othberg et al, other areas with high-permeability deposits, including areas along the Payette River valley, received recharge values of 0.75 cfs/mile. HLI guided PGG in identifying these other high permeability areas, and PGG used GIS to calculate recharge per model cell based on the total length of ditches/canals in each cell.

Landuse Recharge

Landuse recharge includes recharge from incident precipitation and from irrigation applications. HLI estimated recharge rates based on the study by Urban (2004) as listed on **Table 4-2.** The landuse types in the model domain were identified based on GIS analyses. For model cells composed of more than one landuse type, weighted average recharge rates were computed. For areas without available landuse information, a minimal recharge rate (0.02 ft/yr) was applied as scrubland or grassland.

4.3.5 Wells

Groundwater withdrawals consist of water that is pumped from municipal, industrial, agricultural, and domestic wells. Domestic wells are typically shallower than water-supply wells for the other uses, and this analysis assumes that domestic wells withdraw from model layer 3 ("Middle Aquifer") whereas municipal, industrial, agricultural uses withdraw from layers 5-7 (PGSA). MODFLOW's well package was used to represent groundwater withdrawals.

Municipal and industrial groundwater withdrawals were estimated based on water right records by assuming that 15% of the allowable water-right amounts were actually used on an average annual basis. The 15%-use factor was based on review of consumption and water rights data for the Eagle Water Company (no other water use data were available from other municipal systems in the study). Water rights were compiled per quarter section and then distributed among associated model cells using GIS. In addition, for each model cell, pumping was distributed evenly between PGSA layers 5, 6, and 7. Details on pump-

ing rates for municipal and industrial groundwater withdrawals are available digitally on a CD provided with selected copies of this report.

Groundwater withdrawals for irrigation were estimated based on typical irrigation application rates, the distribution of irrigated acres, and whether a cell was likely to be irrigated from groundwater or surface-water sources. A linear application rate of 2.6 ft/year was estimated for irrigated areas of the model domain and the distribution of irrigation was identified based on irrigated areas stated in the water rights ("AFA"). In order to differentiate irrigated areas served by groundwater from those served by surface water, PGG used GIS to evaluate land-surface elevations relative to nearby ditch elevations. For the irrigated areas where land surface elevations exceeded nearby ditch/cannel elevations, all the water used for irrigation was assumed to be withdrawn from the PGSA. For irrigated areas where land surface elevations were below the ditch/cannel elevations, the areas were considered primarily irrigated by surface water, and only 10% of the irrigation application was assumed to be extracted from aquifer. Similar to the municipal and industry withdrawals, withdrawals were evenly distributed vertically throughout the three PGSA layers. Details on pumping rates for irrigation withdrawals are available digitally on a CD provided with selected copies of this report.

Domestic well pumping was estimated based on data derived from Treasure Valley Hydrologic Project (Urban, 2004, page: 3-9) which referenced an average household of 2.9 people using an average of 230 gal/day/person. HLI provided PGG with estimates of numbers of wells per quarter section based on Well Driller's Records on file with the Idaho Department of Water Resources (IDWR). PGG estimated domestic pumping by assuming a single household per well, and defined associated model withdrawals from the "Middle Aquifer" in layer 3. Similar to estimation of irrigation recharge, there were portions of the model domain that did not receive HLI's formal analysis after the model domain was enlarged. Instead, domestic pumping rates (cfs per quarter section) were assigned based on similar areas within the model domain. These assignments are summarized in **Table 4-1**. Details on pumping rates for domestic groundwater withdrawals are available digitally on a CD provided with selected copies of this report.

MODFLOW's well package was also used to "inject" water into the shallow groundwater system along the eastern model boundary, where Dry Creek enters the model domain and loses its water to streambed seepage. A cluster of small model cells can be seen along the bedrock (inactive cell) boundary in layer 1 (**Figure 4-1**), from which 8 cfs of water was injected into the aquifer. The value of 8 cfs was based on mean stream flow derived from USGS monitoring records from the Dry Creek stream gauge.

4.3.6 Rivers

MODFLOW's river package was used to simulate groundwater exchanges (gains and losses) with the Boise and Payette rivers. The rates of flow between rivers and an underlying aquifer are calculated in each simulation based on river stage, surrounding groundwater levels, the footprint of the riverbed, and riverbed conductance characteristics. Groundwater moves into the rivers if surrounding groundwater levels are higher than the river stage and vice versa if the groundwater levels are lower than the river stage. Major canals (e.g., New York Canal) were not simulated as river features because seepage from these channels was included in the recharge estimates.

GIS analyses were used to determine the length of the river segment within the model cell. A river width of 80 feet was applied to both Boise River and Payette River. River stage elevations were defined based on topographic contour elevations. The riverbed was assumed to be 4 feet less than the river stage. The riverbed hydraulic conductance is defined as:

$$COND = M/K_R L_R W_R$$

where K_R is the hydraulic conductivity of the riverbed material, L_R is the reach length, W_R is the river channel width, and M is the riverbed thickness (McDonald and Harbaugh, 1988). While K_R, and M may vary throughout the model domain, PGG generalized these to uniform parameters for each river. M for both rivers was assumed to be 5 feet. Values of K_R were adjusted during calibration, and ultimately ranged from 10 to 225 feet/day.

MODFLOW's river package was also used to simulate Lake Lowell in model layer 1 (**Figure 4-1**). The lake elevation (2,520 feet above mean sea level) was derived from the USGS topographic map. A lakebed thickness of 5 feet was assumed, and the hydraulic conductivity of the lakebed was adjusted to 0.01 feet/day during calibration to achieve a reasonably low rate of seepage loss. According to Freeze and Cherry (1979), this value represents the permeability of silt.

4.3.7 Vertical Low Permeability Boundary

A vertical low permeability boundary ("flow barrier") was used to extend the hydraulic disconnect where the contact between the bottom of the Pierce Gulch Sand Aquifer and the underlying clays and mudstones of the Terteling Springs Formation crops out at or near ground surface. No significant quantities of groundwater can flow across this contact because of its low permeability and the unsaturated nature of the Pierce Gulch Sand Aquifer at this location. The flow barrier extends through all model layers, and is shown on **Figure 4-1** as a purple line. Whereas the no-flow cells that directly represent the contact allow no groundwater flow to cross the contact, the flow barrier cells to the northwest allow limited flow in the region where the Pierce Gulch Sand Aquifer and WCA begin to co-mingle. The flow barrier was assigned a thickness of 1 feet and a hydraulic conductivity of 0.005 ft/day (equivalent to a 10 foot thick barrier with a permeability of 0.05 ft/day or according to Freeze and Cherry (1979), equivalent to silty sand).

4.4 AQUIFER AND AQUITARD PROPERTIES

The hydraulic properties of aquifers and aquitards are specified in the model using hydraulic conductivity (K), storage coefficient (S), and specific yield (S_y). Hydraulic conductivity can be further separated into its horizontal and vertical components (K_h and K_v). PGG used a method of zonation, where zones of like aquifer properties are distributed over continuous regions of active model cells. Groundwater Vistas calculates the transmissivity of a model layer based on its thickness and its K_h.

4.4.1 Hydraulic Conductivity

Zones of like K_h and K_v were sometimes designated across entire hydrostratigraphic units and sometimes designated as sub-regions within a given hydrostratigraphic unit. **Figures 4-4** through **4-6** show the K zonation throughout all of the model layers, and **Table 4-3** summarizes K values per zone for both versions of the model. Uniform, homogeneous K_h/K_v combinations were assigned to all aquifers and aquitards with the exception of the PGSA. This apparent simplification is justified where little information is available about hydrostratigraphic units. Not adding unwarranted complexity is referred to as the "principal of parsimony". The PGSA was assigned several zones based on analysis of aquifer test data in multiple wells. Values of K_h and K_v for individual zones were adjusted during calibration, and the boundaries of various sub-regions were sometimes shifted within the PGSA during calibration. Hydrostratigraphic units represented with a single zone include:

- The WCA is represented by Zone 10 in all layers from the land surface to the bottom of the model. The WCA occurs in the northeast portion of the model domain north and northwest of the contact be-

teen the Pierce Gulch Sand Aquifer and the underlying clays and mudstones of the Terteling Springs Formation. As with most aquifers, Zone 10 was assumed to have an anisotropy ratio (K_h/K_v) of 10, which remained constant during model calibration.

- Payette River shallow alluvium is represented by Zone 9 in layer 1 and parts of layer 2 (where layer 1 is thin). Zone 9 was assumed to have an anisotropy ratio of 10, which remained constant during calibration.
- Payette River valley fill is represented by Zone 6 in layers 2 through 7 with an anisotropy ratio of 1000. This high anisotropy reflects the fact that the valley fill contains both aquifers and aquitards (which significantly retard vertical flow). The anisotropy of Zone 6 was varied between 100 and 1000 during calibration.
- Boise River alluvial sand and gravel deposits are represented by Zone 7 in model layer 1. Zone 7 was assumed to have an anisotropy ratio of 10, which remained constant during calibration.
- Upland surficial aquifer deposits are represented by Zone 4 in the higher-elevation portions of model layer 1. Zone 4 was assumed to have an anisotropy ratio of 10, which remained constant during calibration.
- Aquitards separating the surficial aquifers from the PGSA are represented by Zone 1 in layers 2 and 4. The aquitards are assigned relatively low K values, and were also assigned an anisotropy ratio of 10.
- The "Middle Aquifer", between the surficial aquifer and the PGSA, was represented by Zone 2 in layer 3 with a constant anisotropy value of 10.
- The PGSA is represented by multiple zones with the same zone distribution in layers 5, 6 and 7. Most zones were assigned anisotropy ratios of 10; however, Zone 11 was assigned a value of 100 during calibration. This higher value represents the hydraulic effects of thin and discontinuous clay layers interbedded within the Pierce Gulch Sand Aquifer which are more numerous and form a larger percentage of the aquifer in the western portion of the modeled area (as compared to the eastern portion of the modeled area).

Model layers 1 through 5 were all specified as MODFLOW layer type "3", which allows unconfined conditions if the layer is not fully saturated and "dry" conditions if the layer falls above the regional water table. Beneath the uplands, portions of the top several layers are expected to be dry for this reason. Model layers 5, 6 and 7 are designated as MODLFOW layer type "0", which is always saturated.

4.4.2 Aquifer Transmissivity

Transmissivity (T) was calculated for each layer by Groundwater Vistas as the product of K_h and thickness. Therefore, T was not directly assigned to the model layers. T values for the PGSA and the WCA were previously estimated based on aquifer testing in various production and irrigation wells, and are summarized in **Table 4-4**. During calibration, K values were varied to achieve the best matches with available data. For the Hmatch model, acceptable ranges of K values were chosen such that the average simulated T values for each zone were within a range of one-third to three-times the average of the values estimated from aquifer tests within that zone. For the Tmatch model, PGG attempted to employ K values such that average simulated T values for each zone were within +/-50% of the average of the values estimated from aquifer tests within that zone (note that PGG employed log-averages for all averaging associated with T values, as T variations typically occur along a logarithmic distribution). Final distributions of PGSA T values from both versions of the model are discussed in Section 5.4.1.

4.4.3 Aquifer Storage Parameters

Values of storage coefficient (S) and specific yield (S_y) were adjusted during calibration. Acceptable values of S ranged from $5x10^{-3}$ to $5x10^{-5}$, whereas acceptable values of S_y ranged from 0.01 to 0.1 over short durations (e.g. 24-hour aquifer tests) and from 0.01 to 0.3 over longer durations (e.g. 30-day aquifer tests). Final calibrated values were S and S_y are discussed in Sections 6.4 and 6.5.

5.0 STEADY STATE MODEL CALIBRATION

Calibration is the process of adjusting model parameters (e.g. K_h, K_v) within acceptable, representative ranges to achieve the best match between model predictions and actual observations from the groundwater flow system. Flow system observations fall into two categories: "targets" and "prior information". Targets can be actual measurements of groundwater levels ("heads"), drawdowns in response to pumping, and/or gains or losses to surface water features ("streamflow seepage"). During steady state calibration, targets consisted primarily of head targets from water level elevations measured in wells. PGG also checked the model mass balance to ensure that predictions of streamflow seepage losses/gains were within reasonable orders of magnitude. Prior information includes knowledge gained from interpretation rather than direct measurement. Examples may include HLI's interpreted aquifer transmissivity values from pumping tests and associated hydraulic influence of boundaries within the flow system. During calibration, PGG referenced such transmissivity values to constrain K values assigned to the PGSA.

During calibration, it became apparent that not all of the head targets could be matched while honoring the prior-information transmissivity values estimated from aquifer testing. Specifically, the model tended to predict heads in the M3 vicinity lower than observed water-level elevations. In order to maximize confidence in observed head targets, HLI had the wellheads of key observation points surveyed to obtain better estimates of elevation. The model's difficulty in predicting heads near the M3 site suggest that either interpreted T values for the PGSA are not representative, or that the groundwater flow system contains additional complexities not indicated by the currently available data. In order to address the uncertainty associated with these possibilities, PGG expanded our calibration analysis to include two versions (realizations) of the model:

1. The "Tmatch" model realization maintained T values associated with the PGSA K zones that best honored prior-information T values.
2. The "Hmatch" model realization allowed larger departures from the prior-information T values in order to obtain better matches to water-level targets in the M3 Eagle vicinity.

Both model realizations are included in descriptions of steady-state and transient calibration. Both model realizations were used for predicting drawdowns associated with proposed M3 Eagle pumping.

5.1 TARGETS AND PRIOR INFORMATION

Table 5-1 presents a summary of the water-level targets used during steady-state calibration. Of the 37 wells, 13 are completed in the PGSA[2], 3 are completed in undifferentiated sediments above the PGSA, one is completed in the WCA, and 5 are completed in sediments interpreted to be laterally continuous with the PGSA and/or WSA. These 5 wells are located near Emmett in the Payette River valley, where hydrogeologic units have not been explicitly defined. However, the completion elevations and high

[2] PGSA completion is uncertain for two of these wells.

transmissivities of these wells are similar to both the PGSA and WCA, and hydrogeologic interpretation by HLI suggests that the sediments in which they are completed are likely hydraulically connected to both aquifers. The accuracy of target elevations is a function of accuracy of well head elevation and accuracy of depth to water. Surveyed well heads had elevation accuracies of 0.±08 ft. In the cases of monitoring wells under the control of HLI, water level accuracies were on the order of ±0.03 ft. In wells that were not surveyed and elevations were derived from the combined use of Google^{tm} Earth and USGS topographic maps the well head accuracies were on the order of ±20 ft. In domestic or other pumping wells were water levels may have been recovering from undetected pumping prior to measurement (and water levels may have been recovering) water levels representative of non-pumping conditions have an estimated accuracy of ±20 ft. At the extremes, we believe surveyed monitoring wells had water level elevations with a combined accuracy of about ±0.1 ft, while a non-surveyed supply wells had a combined accuracy of ±40 ft. HLI provided estimates of seasonal groundwater level fluctuations, which have been observed to range from 5 to 15 feet within the Eagle-Star-M3 vicinity.

Table 4-4 presents prior-information T values for wells tested in the PGSA and the WCA. Based on HLI's interpretation, T values in the PGSA range from about 5,000 to 110,000 ft^2/day. Interpreted T values for wells tested in the WCA range from 7,000 ft^2/day to 130,000 ft^2/day. Confidence in the reported T values varies, as some of the aquifer tests were not optimally conducted or showed complex responses.

Summary statistics are used to assess the "match" between observed and modeled heads and to evaluate whether the model is well calibrated. A well calibrated model strives to minimize the difference between observed and modeled heads (residual). Three statistics are generally used to evaluate the minimization of residual values. The residual mean (RM) is the sum of all residuals divided by the number of targets. Some residuals are positive and some negative and a well calibrated model that balances the two would result in a low RM-value. The Absolute Residual Mean (ARM) is the sum of the absolute values of the residuals divided by the number of targets. The ARM statistic is a measure of the overall average error. Finally, a comparison of the residual standard deviation to the overall range in target values throughout the model is assessed, with a value less than 10% generally considered good. The statistics indicate acceptable calibration results for both model realizations, as discussed in Section 5.4.2.

5.2 CALIBRATION PARAMETERS

Parameters varied during steady state calibration included K_h values of aquifers and aquitards, riverbed hydraulic conductivity (K_r) for the Boise and Payette rivers, and head values for the CHB's and the GHB.

Table 4-3 presents the acceptable ranges of K_h and K_v considered during calibration. Acceptable K_h ranges were based on sedimentary texture and conform with typical published values (e.g. Freeze and Cherry, 1979). The anisotropy values shown on **Table 4-3** were all held constant during calibration, except for the Payette River valley fill where anisotropy was allowed to range from 100 to 1000. These relatively high anisotropy values reflect the fact that the Payette River valley fill contains silty zones that were not explicitly simulated as aquitards, but were instead implicitly represented in the bulk properties of the unit. **Table 4-3** also presents the final values of K_h and K_v derived during the steady state calibration. As previously noted, the spatial distributions of parameter zones are presented in **Figures 4-4** through **4-6.**

Head values for the CHB's and GHB were adjusted manually to improve head matches near the boundaries and throughout the model domain.

5.3 STEADY STATE SENSITIVITY ANALYSIS

During the early phases of steady state calibration, PGG performed an initial sensitivity analysis to evaluate which model parameters had the greatest influence on calibration residuals (heads). Parameters considered in the initial sensitivity analysis included: Kv of aquitards (Zone 1 and anisotropy in Zone 6), Kr of riverbeds and lakebeds, head and conductance for GHB, and Kh for four zones within the PGSA. The sensitivity analysis provided the following insights:

- Calibration residuals were much more sensitive to the Kv of the regional aquitards than the anisotropy within the Payette River valley fill sediments (Zone 6). Relative to other parameters considered, aquitards Kv had a relatively large influence on calibration residuals.
- The model showed relatively low sensitivity to values of riverbed Kr. This is likely due to the fact that the shallow aquifer systems that are hydraulically connected to rivers are separated from the deeper PGSA by two aerially extensive aquitards, and because most of the calibration targets occur in the deep aquifer system.
- Calibration residuals showed relatively low sensitivity to the conductance value specified for the GHB, but very high sensitivity to the GHB head value. By inference, calibration residuals will also be quite sensitive to the CHB head values for the PGSA in layers 5 through 7.
- Calibration residuals showed low to high sensitivities to PGSA Kh zones, depending on the location of the zone. In general, zones that connected portions of the aquifer system (with calibration targets) to CHB's and GHB's had the highest sensitivities.

PGG also evaluated model sensitivity to upwelling into the PGSA from a deeper (hydrothermal) aquifer. Inflow from upwelling was estimated with Darcy's Law (Freeze and Cherry, 1979) assuming aquitard materials between the PGSA and an underlying geothermal aquifer with a Kv representative for clay of 1e-8 cm/sec (0.00003 ft/day). The hydraulic gradient into the PGSA was 0.05, based on measurements at UWID State and Linder wells. Inflow from upwelling was applied to the bottom of the PGSA (layer 7) by placing "injection wells" in each model cell, where flows were calculated based on flux (Darcy's Law) and the areal footprint of the cell. Including upwelling from the deeper aquifer caused an insignificant change in modeled head in the PGSA (maximum increase less than 0.1 feet). For this reason, upwelling was not carried forward in subsequent model calibration. Not simulating upwelling was also considered to be conservative for estimating drawdown due to proposed M3 Eagle pumping, as leakage from a deeper aquifer would tend to slightly reduce PGSA drawdowns associated with PGSA pumping.

5.4 CALIBRATION RESULTS

5.4.1 Calibration to Observed Transmissivity

The spatial distribution of transmissivity (T) values within the PGSA for the Tmatch and Hmatch models are shown in **Figure 4-7** (associated calibrated hydraulic conductivity values are reported on **Table 4-3).** HLI's T value estimates from pumping tests are also plotted on the figure for comparison. Estimated T values are limited to areas within the vicinity of the M3 project site and southward. Twenty-five estimated values are available for comparison and range from about 5,000 ft^2/day to 130,000 ft^2/day with a log-average of about 21,000 ft^2/day.

The T estimates are fairly well represented in the Tmatch model, with values ranging smoothly from about 12,000 ft^2/day to 53,000 ft^2/day within the project site area and southward. A moderately high T zone ranging from 30,000 to 60,000 ft^2/day is represented within a portion of the M3 project site (Zone 12

in **Figure 4-6**). This slightly higher zone is based on an estimated value from two pumping tests at that location. The final log average T values for each zone are within the acceptable range of +/-50% of the observed log average T value in each zone, except for Zone 13 where the simulated log average T value is about 80% above the observed value.

Model T values show greater departure from the estimated vales in the Hmatch model (The basis for the Hmatch model calibration is discussed in the following section). The final log average T values for each zone are within the acceptable range of one-third to three-times the observed log average T value in each zone. Simulated T values in the Hmatch model also show stronger contrasting T zones with log average zone values ranging from about 5,800 ft^2/day to 46,000 ft^2/day. The stronger contrasts in values in the Hmatch model are due to low and high permeability zones added to the Hmatch model during calibration to improve the match between simulated and observed head targets. Both models; however, simulate log average T values within the range of values estimated from pumping tests.

5.4.2 Calibration to Observed Heads

Target residual values (observed minus modeled head) and calibration statistics for both models are summarized in **Table 5-1. Figure 5-1** provides a graphical comparison of observed versus modeled heads, and **Figure 5-2** shows the spatial distribution of calibration residuals for both models. Both models match the observed heads fairly well throughout the model domain except in the area of the M3 project site, where the Tmatch model simulated heads that are about 25 ft below the target heads. In order to achieve a better match to head targets in this area, the hydraulic conductivity zones in the PGSA were slightly modified. This was accomplished by extending a high hydraulic conductivity zone (Zones 3 and 5 in **Figure 4-6**) south of the project site along the eastern margin of the model domain. Zones 13 and 15 immediately west of these higher zones were also reduced by 2.5 to 5 times their values in the T Match model, a change supported by the conceptual model for the stratigraphy of the area. This change resulted in additional groundwater influx towards the project site and a subsequent higher simulated head value. Head targets within the M3 project site of the Hmatch model are within 10 ft of the observed values. Recent magnetometer data suggest there may be a northwest-southeast trending fault in the vicinity of the boundary between the high and low hydraulic conductivity zones represented in the Hmatch model. A low-permeability fault would have the same effect of focusing additional groundwater influx to the project site, although such a fault was not included in this modeling effort.

The residual calibration statistics for both models are summarized in **Table 5-1**. The residual mean (RM), absolute residual mean (ARM) and percentage of the residual standard deviation to the observed head range (RSD/R) are 2.71 feet, 13.99 feet, and 6.25% respectively for the Tmatch model and 2.82 feet, 9.75 feet, and 4.84% respectively for the Hmatch model. Based on the calibration criteria discussed above and the overall accuracy of the head targets shown on **Table 5-1**, these statistics indicate acceptable model calibration. The lower ARM and RSD/R values in the Hmatch model indicate a superior match to the observed heads.

5.4.3 Mass Balance

Table 5-2 presents a water budget summary for both the Tmatch and the Hmatch models. Water budget components are expressed as net inflow to the model, with negative values symbolizing model outflows. The water budget was reviewed during calibration, with attention primarily focused on the PGSA components. Primary components of inflow to the model include recharge, upgradient "subflow" in the alluvial sediments along the Payette River, and PGSA inflow from the GHB located in the southeast corner of the model. Primary components of outflow from the model include the Boise and Payette Rivers and groundwater pumping. Total groundwater pumping represents about 7 percent of the total model inflow.

The model ultimately represented several boundary conditions first conceptualized as "outflow" or "in-flow" boundaries with flow in the opposite direction. Specifically, the PGSA CHB along the southwest model boundary and the Payette River valley fill aquifer CHB along the northwest model boundary both showed small inflows after calibration was complete, and the WCA CHB along the northeast model boundary showed a small outflow. The latter two boundaries could have been adjusted during calibration to achieve the expected flow directions; however, their influence on PGSA conditions was too small to be concerned with during calibration and in fact, the WCA CHB could have been removed altogether. In-flow or outflow are both acceptable from the PGSA CHB along the southwest model boundary, as this boundary was designated to help match observed heads in this vicinity.

Model predicted groundwater inflow to the Boise and Payette Rivers is on the order of 570 and 390 cfs, respectively. These values appear to be on the high side, and may reflect higher-than-actual K_h values for the alluvial aquifers associated with these rivers. PGG did not attempt to calibrate the model to shallow flow-system conditions. Our goal during calibration was to ensure that a shallow flow system was both *represented* and *connected* to the deeper flow system via an aquitard portrayed with a reasonable estimate of K_v. The fact that the model predicts much of the water introduced to the shallow flow system to *re-main* in the shallow flow system and discharge to the rivers rather than flow vertically downward to the deep system suggests that the K_v assigned to the aquitards (0.02 ft/day or $7x10^{-6}$ cm/sec) is likely conservative in restricting induced seepage during predictive simulations of proposed M3 pumping.

6.0 TRANSIENT MODEL CALIBRATION

The steady-state calibration described above strives to adjust model parameters so that long-term average conditions are well represented in the model. A transient calibration, on the other hand, strives to adjust model parameters so that time varying stresses (e.g. seasonal changes in recharge or pumping rates) and corresponding responses to the aquifer system are well represented in the model.

A transient calibration was performed for both the Tmatch and Hmatch models to match simulated groundwater drawdown responses to observed responses from aquifer testing conducted in the field. Adjustments to model parameters included changes within acceptable ranges to values of K, S and S_y within the PGSA aquifer. Two pumping tests conducted in the PGSA with observed drawdown over time in relatively nearby observation wells were available as calibration drawdown targets: a 7-day pumping test at Eaglefield #2 and a 30-day pumping test at Lexington Hills #1. Note that the transient calibration for the Tmatch model only involved a single simulation of the 7-day pumping test, while the transient calibration for the Hmatch model involved two simulations; one of the 7-day pumping test and one of the 30-day pumping test. Additional transient calibration is possible in the future using the 30-day test with the Tmatch model and/or the results of a recent 9-day long test on M3 Well SVR-7

An iterative calibration approach between the transient and steady state models was necessary to ensure a good calibration match to both steady state target values and transient target values. This involved, through trial and error, adjustments to K values within the PGSA that would provide a good fit to both steady state and transient target values.

6.1 TRANSIENT STRESS PERIODS AND INITIAL HEADS

Each aquifer pumping test simulation consisted of two stress periods. A stress period is a duration of time during which hydraulic conditions (e.g. groundwater pumping) are considered to be constant. Each stress period is further divided into time steps for which a solution to the groundwater model is solved. The first

stress period for both transient simulations consisted of 100 days divided into 30 time steps with no changes to hydraulic conditions (pumping, recharge, etc) imposed. This stress period was applied to ensure that the initial heads were stable in the transient model. The second stress period for both transient simulations consisted of the aquifer pumping test duration; 7-days with 40 time steps and 30-days with 30 time steps. Initial heads for both simulations were the steady-state calibrated head solution for each model.

6.2 SIMULATED PUMPING AND OBSERVATION WELLS

HLI used geologist's lithologic logs, borehole geophysics and Well Driller's Reports to estimate which layers the pumping well is screened within the PGSA aquifer. The Lexington Hills #1 was assigned to the upper PGSA aquifer (layer 5) with a pumping rate of 732 gallons-per-minute (gpm) applied over the 30-day test period. The drawdown observation well for the Lexington Hills test, the Eagle Hills Golf Course well, was placed in the middle PGSA aquifer (layer 6). The Eaglefield #2 was assigned to layer 6 of the PGSA aquifer with a pumping rate of 1580 gpm applied over the 7-day test period. The drawdown observation well for the Eaglefield #2 test, monitoring well "UWIDState&Linder1A", was placed in the middle PGSA aquifer (layer 6). **Figure 6-1** shows the locations of these pumping and observation wells.

6.3 AQUIFER TEST RESULTS (TARGETS)

The observed drawdowns for the 7-day and 30-day tests and the final calibrated simulated drawdown using the Hmatch model are shown in **Figure 6-2**. The 7-day pumping test at the Eaglefield #2 resulted in about 5.5-ft of observed drawdown in the observation well after 7-days of pumping. The 30-day pumping test at the Lexington Hills #1 resulted in a little over 1-ft of observed drawdown in the observation well after 30-days of pumping. The final calibrated Hmatch model matches the observed drawdown for both tests fairly well (**Figure 6-2**). The 7-day pumping test simulated with the Tmatch model (**Figure 6-3**) was not as favorable without substantially decreasing the local transmissivity value of the aquifer as discussed below.

Calibration parameter adjustments, results, and the limitations of the Tmatch model to simulate the local 7-day pumping test are discussed below.

6.4 CALIBRATION PARAMETERS

Parameters adjusted during the transient calibration were K, S, and S_y within the PGSA. K-value zones 12, 13, 14, and 15 within the Tmatch model and K-value Zones 3, 5, 13, and 14 within the Hmatch model were adjusted within reasonable ranges during the calibration process (see **Figure 4-6** for zone maps). The calibration required an iterative trial and error process to achieve the best match to both steady-state and transient target values.

Simulated drawdowns were fairly sensitive to S values and it became necessary to create two zones of S-values in order to simulate the 7-day and 30-day pumping tests with the Hmatch model (**Figure 4-8**). A lower storage coefficient value (S=0.00035) was required to achieve a match to the 7-day pumping test and a higher value (0.005) was required to achieve a match to the 30-day pumping tests using the Hmatch model. The higher S-value boundary was chosen to correspond to the higher K-value Zones 3 and 5 extended in the Hmatch model. The same S-values and zonation were used in both the Hmatch and Tmatch models.

6.5 CALIBRATION RESULTS

The results of the transient calibration are plotted in hydrographs of observed and simulated drawdown (**Figures 6-2** and **6-3**). A fairly good match was achieved within acceptable ranges of aquifer parameter values for both pumping tests using the Hmatch model (**Figure 6-2**). The local transmissivity value required to match the 7-day pumping test and still maintain a good match to observed groundwater elevations in the Hmatch model was 7,700 ft^2/day. This is about 3 times less than the average transmissivity estimated from aquifer tests for this general area of the model (27,000 ft^2/day) and about 6 times less than the average transmissivity estimated from aquifer tests in the immediate vicinity of the 7-day pumping test (50,000 ft^2/day)

The Tmatch model also required a similarly low value of the local transmissivity to match the 7-day pumping test (from 41,000 ft^2/dy obtained during the steady state calibration to 7,500 ft^2/day). Since the Tmatch model was developed to emphasize a match to field estimates of transmissivity, the steady-state calibration values were honored over matching local aquifer conditions to the 7-day pumping test. The resulting Tmatch model under-predicts the 7-day final drawdown by about 35% (**Figure 6-3**). An attempt to simulate more drawdown by decreasing the S-value from 0.00035 to 0.0001 did not make a significant difference in the final simulated drawdown value. Therefore the same S and Sy zonation and values were left the same for both models.

Final calibrated aquifer property values for both models are summarized in **Table 4-3**. The mass balance error for all transient simulations was less than 0.02% and the additional pumping represented in the transient simulations is less than 0.5% additional mass flux in the model compared to the steady state models.

7.0 PREDICTIVE ANALYSIS

The two calibrated models were used to evaluate potential impacts from future water supply wells proposed at the M3 site. Transient simulations were performed to assess the impacts from adding progressively more water supply wells to the site. Impacts were evaluated by observing aquifer drawdown responses over time. Details of the predictive analysis are described below.

7.1 PREDICTIVE PUMPING RATES AND POINTS

The predictive simulations consisted of a 26 year (2009 to 2035) transient simulation with six proposed water supply wells progressively added every 4 years during the simulation. The locations of the six proposed water supply wells (PW #1, PW #3, PW #4, PW #5, PW #6 and PW #7) and schedule are shown in **Figure 7-1**. The locations were chosen by HLI and represent the approximate locations for future pumping wells. The exact locations may vary, depending on site specific topography, lot layouts and road designations. In the simulation, wells P1 and P4 begin operation in 2009, followed by P5 in 2013, P6 in 2017, P7 in 2021 and P3 in 2025. Each well operates at a constant rate of 1000 gpm once in operation and is assumed to fully penetrate the PGSA aquifer (layers 5 through 7). The model continues to run for another 10 years after the last well is added in order to observe maximum drawdown responses in aquifer.

A final steady-state simulation at full build-out pumping was performed to confirm that drawdown predicted at the end of the transient simulation is representative for long-term prediction.

7.2 PREDICTIVE DRAWDOWN

Figures 7-2 through **7-9** show "snapshot" maps of predicted drawdown in the PGSA after 4, 8, 16 and 26 years of pumping for both the Tmatch and Hmatch models. Steady state calibrated heads were used as the initial heads in the predictive simulations and the drawdown values shown in the figures are calculated as the change in the simulated heads over time compared to these initial heads. The series of snapshots shows how drawdown in the aquifer progresses with time during the 26 year simulation.

The predictive simulations indicate the drawdown at the end of the 26 year simulation in the PGSA aquifer occurs within the project site boundary near the proposed water supply wells with the largest drawdown centered on PW #3. In the general pumping vicinity, drawdowns of about 30-ft and 50-ft are (respectively) predicted by the Tmatch and Hmatch models. Larger drawdowns caused by well loss and aquifer conditions adjacent to the well screen are expected at the actual pumping wells, and will need to be evaluated during production-well installation and testing. Drawdown values decrease with distance from the M3 site, with both models predicting a maximum drawdown of about 5-ft in the vicinity of the Boise River (about 4 miles south of the project site).

Both predictive models were also run as steady state with all six proposed water supply wells pumping at 1000 gpm to evaluate the long term equilibrium drawdown. The results were essentially identical to the final drawdown at the end of the 26 year transient simulation, indicating the aquifer system has nearly approached equilibrium 10 years after the last well is brought into operation. In addition, PGG ran one of the predictive models in steady state with the PGSA GHB boundary (closest PGSA boundary to the M3 site) converted to a constant flux boundary, using the same flux as the steady state calibration (zero pumping from the M3 site). This formulation caused no significant change in predicted drawdown, thereby showing that the boundary is not inappropriately limiting drawdown by increasing model inflow.

Figures 7-10 and **7-11** show maps of predicted drawdown in the middle aquifer overlying the PGSA (layer 3) at the end of the 26 year simulation. The maximum drawdown in layer 3 at the end of the simulation is 20-ft for the Tmatch model and 25-ft for the Hmatch model. Note that in both models most of layer 3 is dry beneath the project site both before and after the proposed water supply wells are added to the models.

Figures 7-12 through **7-17** show hydrographs of simulated drawdown in the PGSA over time at the location of the proposed water supply wells and at six observation points south of the project site. Results from both the Tmatch and Hmatch models are shown in the figures. The location of the six observation points (M3 Site, Star #3, Eaglefield #2, Floating Feather, Lexington Hills #1, and Homer Road) are shown in **Figures 7-2** through **7-9**. Except for the Eaglefield #2 and Star #3 the simulated drawdowns are consistently higher in the Hmatch model. However, the differences between the two models are fairly small. Differences in predicted drawdown at the off-site wells range from 0.7 feet at Eaglefield #2 to 2.7 feet at Homer Road. The higher drawdown simulated at Eaglefield #2 and Star #3 with the Hmatch model is due to the lower K-value assigned in this area. Wells at on the M3 site exhibit 6 feet difference in simulated drawdown due to proximity to the pumping center.

8.0 MODEL USES AND LIMITATIONS

The following bullets summarize the appropriate uses and limitations of the model:

- Two model "realizations" were developed to bracket hydrogeologic representation of site conditions ("Hmatch" and "Tmatch"). Both models predict similar ranges of drawdown associated with pro-

posed M3 pumping within the PGSA. If future simulations are performed to estimate pumping drawdowns in the PGSA, both models should continue to be used to represent a range of predicted conditions.

- The model realizations are well suited for the designed purpose of predicting drawdown due to proposed M3 pumping from the PGSA. If a different pumping center not on the M3 site is simulated, model users should be careful to ensure that the pumping center is sufficiently far from CHB's and GHB's, so that pumping is not satisfied predominantly from these boundary conditions. As noted above, PGG confirmed that induced inflow from the GHB located immediately southeast of the M3 site does not inappropriately reduce predicted drawdown.

- Transient model calibration resulted in a specific zonation of S values within the PGSA. Calibration to additional aquifer tests could support further refinement of S zonation. Model users requiring highly accurate transient simulations should recognize that further refinement of the S zonation could effect the prediction of time-responses to pumping. PGG confirmed that transient predictions were approaching a steady state solution at late time (26 years of simulation).

- The model (i.e. both realizations) was not calibrated to hydrogeologic conditions in the shallow and middle aquifer systems. Model realizations should not be used to simulate hydraulic responses in either system without further calibration, nor should the water budget developed for these portions of the system be construed as accurate.

- The model (i.e. both realizations) was not calibrated to conditions in the WCA. PGG does not recommend using the model realizations for drawdown predictions in the WCA without additional WCA data collection and calibration. A CHB, positioned on the eastern (upgradient) extent of the CHB, has very little influence on the model. This CHB could be removed.

- Model calibration was performed to best available estimates of recharge, pumping, and target groundwater level elevations. Changes in the recharge estimates are unlikely to affect existing model calibration, as most of the recharge introduced to the model remains in the upper flow systems. Changes in PGSA pumping could affect model calibration, as could additional information data to be used for water level targets.

9.0 REFERENCES

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Table 4-1 Assigned Values of Recharge and Domestic Pumping in Peripheral Regions of the Model Based on Values from Similar Areas

Assigned to Section	Domestic Pumping Rates (cfs/Q Section)	Recharge Rates (cfs/Q Section)	Section Used to Originate the Average
T3NR1E	1.70E-04	3.33E-05	T4NR1E
T3NR1W	7.72E-05	1.51E-05	T4NR1W
T3NR2E	8.90E-07	1.74E-07	T4NR2E
T3NR2W	8.08E-05	1.58E-05	T4NR2W
T3NR3W	8.08E-05	1.58E-05	T4NR3W
T3NR4W	8.08E-05	1.58E-05	T4NR4W
T7NR3W, R4W, R1W	1.93E-05	3.78E-06	T7NR2W
T7NR1E	0.00E+00	0.00E+00	HLI direction
T6NR4W, R3W	5.32E-05	1.04E-05	T6NR2W
T5NR4W, R3W	4.93E-05	9.65E-06	T5NR2W
T4NR4W, R3W	8.08E-05	1.58E-05	T4NR2W
T6NR2E	0.00E+00	0.00E+00	HLI direction
T7NR3E	0.00E+00	0.00E+00	HLI direction

Table 4-2 Landuse Recharge for Combined Irrigation and Natural Precipitation

Recharge Rate (ft/yr)	Land Use No. (by HLI)	Dominant use within quarter mile
0.25	1	Urban/ Residential. Assumes mostly residential and that irrigation "excess" leads to recharge.
0.02	2	Dryland cropland pasture. Assumes AET uses almost all of "surplus" RF.
0.2	3	Irrigated cropland pasture - probable *ground* water source. Assumes power costs limit overwatering to quantities actually needed.
0.45	4	Irrigated cropland pasture - probable *surface* water source. Assumes flood irrigation and over watering.
0.11	5	Grassland/cropland mosaic. Assumes 50% each of 3 and 6.
0.02	6	Grassland. Assumes AET uses almost all of "surplus" RF.
0.02	7	Shrubland. Assumes AET uses almost all of "surplus" RF.
0.25	8	Evergreen needle/leaf forest. Assumes mostly Public/Recreational lands in Urban. Much is irrigated.

* Note: recharge values from the Treasure Valley Hydrologic Project (Urban, 2004)

Table 4-3 Summary of Calibrated Aquifer Property Zones

Zone Number	Description	Layers	Acceptable K or T Range During Calibration	"Tmatch" Model				"Hmatch" Model			
				Kh (ft/day)	Kv (ft/day)	Kh/Kv	S, Sy	Kh (ft/day)	Kv (ft/day)	Kh/Kv	S, Sy
1	Regional Aquitard	2 and 4	Kv range 0.003 to 0.3 ft/day	0.28	0.02	10	0.00035, 0.1	0.28	0.02	10	0.00035, 0.1
2	Middle Aquifer	3	K not varied during calibration	28.35	2.84	10	0.00035, 0.1	28.35	2.84	10	0.00035, 0.1
4	Upland Surficial Aquifer	1	Kh range 20 to 200 ft/day	100	10	10	0.00035, 0.1	100	10	10	0.00035, 0.1
6	Payette River Valley Fill	2 to 7	Kh 20-200 ft/day, Kh/Kv range from 100 to 1000	110	0.11	1000	0.00035, 0.1	110	0.11	1000	0.00035, 0.1
7	Boise River Alluvial Sand and Gravel	1	Kh range 1000 to 5000 ft/day	2834	283	10	0.00035, 0.1	2834	283	10	0.00035, 0.1
9	Payette River Shallow Alluvium	1 to 2	Kh range 1000 to 5000 ft/day	2000	200	10	0.00035, 0.1	2000	200	10	0.00035, 0.1
10	Willow Creek Aquifer (WCA)	1 to 7	Kh range 20 to 200 ft/day	110	11	10	0.00035, 0.1	110	11	10	0.00035, 0.1
11	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Hmatch: 1/3x to 3x zone avg T (5,092 ft2/d); Tmatch: +/- 50% of zone avg T (see note)	18.29	0.1879	100	(see note)	18.28	0.1879	100	0.00035, 0.1
12	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Tmatch: +/- 50% of zone avg T (40,000 ft2/d) (see note)	200	20	10	(see note)	n/a	n/a	n/a	n/a
13	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Hmatch: 1/3x to 3x zone avg T (17,087 ft2/d); Tmatch: +/- 50% of zone avg T (see note)	80	8	10	(see note)	15	1.5	10	0.00035, 0.1
14	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Hmatch: 1/3x to 3x zone avg T (33,194.66 ft2/d); Tmatch: +/- 50% of zone avg T (see note)	85	8.5	10	(see note)	35	3.5	10	0.00035, 0.1
15	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Tmatch: +/- 50% of zone avg T (17,345 ft2/d) (see note)	95	9	10	(see note)	n/a	n/a	n/a	n/a
3	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Hmatch: 1/3x to 3x zone avg T (23,465 ft2/d)(see note)	n/a	n/a	n/a	(see note)	125	12.5	10	0.005, 0.1
5	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Hmatch: 1/3x to 3x zone avg T (17,395 ft2/d)(see note)	n/a	n/a	n/a	(see note)	220	22	10	0.005, 0.1
A	Riverbed K for the Boise River	1	10 - 1000 ft/day	n/a	10	n/a	n/a	n/a	10	n/a	n/a
B	Riverbed K for the Payette River	1	10 - 1000 ft/day	n/a	225	n/a	n/a	n/a	225	n/a	n/a

Notes:
Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity; T = transmissivity
The Tmatch model employs the same S/Sy zonation as the Hmatch model. These zones are shown for the PGSA on Figure 4.8.
Zone averages of T used for PGSA calibration are based on per-well T values presented on Table 4-4 (averages based on log averages)

Table 4-4 Summary of Prior Information Transmissivity Values from Aquifer Tests

Well ID	X	Y	Aquifer	Interpreted T Value (ft^2/d)	Interpreted T Value (gpd/ft)	Associated K Zone in Hmatch Model	Associated K Zone in Tmatch Model
KlingIrrigation	15888710	1784767	PGSA	4,900	36,750	13	13
M3-TW#1	15888355	1783754	PGSA	9,100	68,250	13	13
CarsonWell	15877225	1817228	PGSA	10,000	75,000	5	15
LexingtonHillsWell#1	15878263	1807674	PGSA	11,000	82,500	5	15
Legacy#1	15875774	1792090	PGSA	13,000	97,500	13	13
HolgateWell	15877828	1816709	PGSA	13,000	97,500	5	15
Star#1	15875728	1774447	PGSA	13,000	97,500	11	11
Star#3	15877429	1776912	PGSA	13,000	97,500	13	13
LDSEagle	15880313	1811730	PGSA	13,000	97,500	5	15
SVRWell#9	15896687	1803861	PGSA	16,000	120,000	5	15
RedwoodCreekWell	15875081	1801823	PGSA	17,000	127,500	3	15
RicksWell	15875081	1799323	PGSA	19,000	142,500	3	13
Meridian24-TEST	15849772	1795443	PGSA	23,000	172,500	14	14
UWIDStateandLinder1A	15872994	1794909	PGSA	27,000	202,500	13	13
FloatingFeatherIrrigationWell	15877591	1808490	PGSA	27,000	202,500	5	15
Meridian18-TEST	15851570	1806763	PGSA	32,000	240,000	14	14
Meridian19-TEST	15850820	1789997	PGSA	37,000	277,500	14	14
Meridian20-TEST	15851236	1800500	PGSA	37,000	277,500	14	14
SVR#7	15895143	1792303	PGSA	40,000	300,000	3	12
Meridian21-TEST	15839973	1801638	PGSA	40,000	300,000	14	14
EagleHillsGolfCourseWell	15875901	1816284	PGSA	60,000	450,000	5	15
EaglefieldWell#2(pumping)	15874442	1792983	PGSA	110,000	825,000	13	13
SVRWell#10	15904062	1805937	WCA	6,700	50,250	10	10
EmmettTW#9D	15934945	1778313	WCA	21,000	157,500	10	10
SVRWell#6	15901348	1797647	WCA	130,000	975,000	10	10

Note: Coordinate data, aquifer assignment and interpreted T values provided by HLI

Table 5-1 Summary of Target Values, Calibration Residuals, and Statistics

Well ID	Aquifer	X	Y	Row/Col/Layer	Observed Target Head (feet msl)	Weight	"Tmatch" Modeled Head (feet msl)	"Tmatch" Residual (feet)	"Hmatch" Modeled Head (feet msl)	"Hmatch" Residual (feet)
BIG-GULCH-STOCK	PGSA	1792066	15894335	44 / 74 / 6	2546	1	2527	19	2543	3
CityofEagle-Eaglefield	PGSA	1792983	15874442	74 / 75 / 6	2530	1	2534	-4	2527	3
CityofEagle-Legacy	PGSA	1792090	15875774	72 / 74 / 6	2525	1	2532	-6	2525	1
COLTONLaneBondCampbell	WCA	1776053	15905744	27 / 51 / 6	2358	1	2363	-5	2362	-5
EWC-WELL-3	PGSA	1815959	15876182	72 / 102 / 6	2570	1	2564	7	2577	-6
FLACK-4IN	PGSA	1797322	15898384	38 / 82 / 6	2555	1	2530	26	2547	8
FLACK-6IN	PGSA	1798272	15898438	38 / 83 / 6	2559	1	2530	29	2548	11
LITTLE-GULCH	PGSA	1800297	15896424	41 / 85 / 6	2556	1	2533	23	2550	6
M3-TW#1	PGSA	1783754	15888355	53 / 61 / 6	2504	1	2519	-14	2515	-10
M3-TW#2	PGSA	1793979	15898370	38 / 77 / 6	2551	1	2527	24	2544	7
M3-TW#3	PGSA	1785043	15898897	37 / 63 / 6	2528	1	2520	8	2531	-4
Meridian18-TEST	PGSA	1806763	15851570	92 / 90 / 6	2596	1	2606	-11	2610	-15
Meridian20-TEST	PGSA	1800500	15851236	92 / 85 / 6	2590	1	2594	-4	2592	-2
Meridian21-TEST	PGSA	1801638	15839973	97 / 86 / 6	2604	1	2630	-26	2630	-26
Meridian24-TEST	PGSA	1795443	15849772	93 / 78 / 6	2586	1	2589	-3	2582	4
Meridian26-TEST-1	PGSA	1805810	15860301	89 / 89 / 6	2583	1	2580	2	2587	-5
Meridian19-TEST	PGSA	1789997	15850820	92 / 70 / 6	2559	1	2576	-17	2565	-6
MOYLE	PGSA?	1780976	15872589	77 / 57 / 6	2503	1	2520	-17	2492	11
RIO-LOBO	PGSA	1740258	15908909	23 / 18 / 6	2413	1	2421	-8	2419	-7
RIVERBIRCH-GOLF	PGSA	1782324	15883356	61 / 59 / 6	2513	1	2518	-5	2504	8
S/L-EAST	PGSA	1794909	15872994	77 / 78 / 6	2530	1	2538	-8	2533	-4
S/L-WEST	PGSA	1794900	15872992	77 / 78 / 6	2530	1	2538	-8	2533	-4
SHALAKO	PGSA?	1739660	15909757	22 / 18 / 6	2416	1	2418	-2	2416	0
STAR-3	PGSA	1776912	15877429	70 / 52 / 6	2509	1	2510	-1	2478	31
SVR#6	WCA	1797644	15901350	34 / 82 / 6	2361	1	2361	0	2361	1
SVR#7	PGSA	1792303	15895143	43 / 74 / 6	2549	1	2527	23	2543	6
SVR#9	PGSA	1803869	15895751	42 / 88 / 6	2558	1	2538	21	2553	5
WILLOWBROOK	PGSA	1776266	15901879	33 / 51 / 6	2477	1	2504	-27	2479	-2
EmmetWell#9	WCA? / PGSA?	1778533	15928534	15 / 54 / 6	2383	1	2360	23	2360	23
EmmettTW-9S	WCA? / PGSA?	1778535	15928284	15 / 54 / 1	2383	0.02	DRY	N/A	DRY	N/A
EmmettTW-9M	WCA? / PGSA?	1778533	15928534	15 / 54 / 3	2383	0.2	2360	23	2360	23
EmmettTW-9D	WCA? / PGSA?	1778533	15928534	15 / 54 / 6	2384	1	2360	24	2360	24
EmmettWell#10	WCA? / PGSA?	1753130	15945710	8 / 24 / 6	2339	1	2318	21	2318	21
Caldwell#17Test	Above PGSA?	1726460	15842469	95 / 12 / 3	2430	0.2	2451	-21	2450	-20
NagelBev.Test	Above PGSA?	1753746	15841986	96 / 24 / 3	2460	0.2	2474	-14	2471	-11
Caldwell#19Test	Above PGSA?	1737638	15859014	89 / 17 / 3	2450	0.2	2423	27	2421	29
KLING-IRR	PGSA	1784767	15888710	53 / 63 / 6	2519	1	2520	-1	2520	0
CALIBRATION STATISTICS										
Residual Mean								2.71		2.82
Absolute Residual Mean								13.99		9.75
Range								265.34		265.34
Residual SD								16.58		12.83
Res SD/Range								6.2%		4.8%

Table 5-2 Water Budget for Steady State Model Calibrations

Water Budget Component	Boundary Type	Model Layer	Tmatch Net Inflow (cfs)	Hmatch Net Inflow (cfs)
Recharge	Recharge	Uppermost Active	542.44	542.44
Boise River Seepage	River	Layer 1	-573.27	-567.18
Payette River Seepage	River	Layers 1, 2, 3	-388.20	-387.58
Lake Lowell Seepage	River	Layer 1	16.59	16.73
Dry Creek Seepage Inflow	Wells	Layer 1	3.95	3.95
Domestic Pumping	Wells	Layer 3	-13.94	-13.93
Municipal, Industrial & Irrigation Pumping	Wells	Layers 5-7	-75.83	-75.83
Boise River Alluvial Aquifer Inflow	CHB	Layer 1	86.51	80.12
Boise River Alluvial Aquifer Outflow	CHB	Layer 1	10.76	10.91
Payette River Alluvial Aquifer Inflow	CHB	Layer 1	282.45	282.46
Payette River Alluvial Aquifer Outflow	CHB	Layer 1	-1.94	-1.93
PGSA Inflow from SE Model Boundary	GHB	Layers 5-7	102.79	101.86
PGSA Outflow at SW Model Boundary	CHB	Layers 5-7	6.33	6.52
Payette River Valley Fill Outflow	CHB	Layers 5-7	1.93	1.94
Willow Creek Aquifer Along NE Model Boundary	CHB	Layers 5-7	-0.46	-0.37
Model Mass Balance Error			*<1%*	*<1%*

VicinityMap.mxd

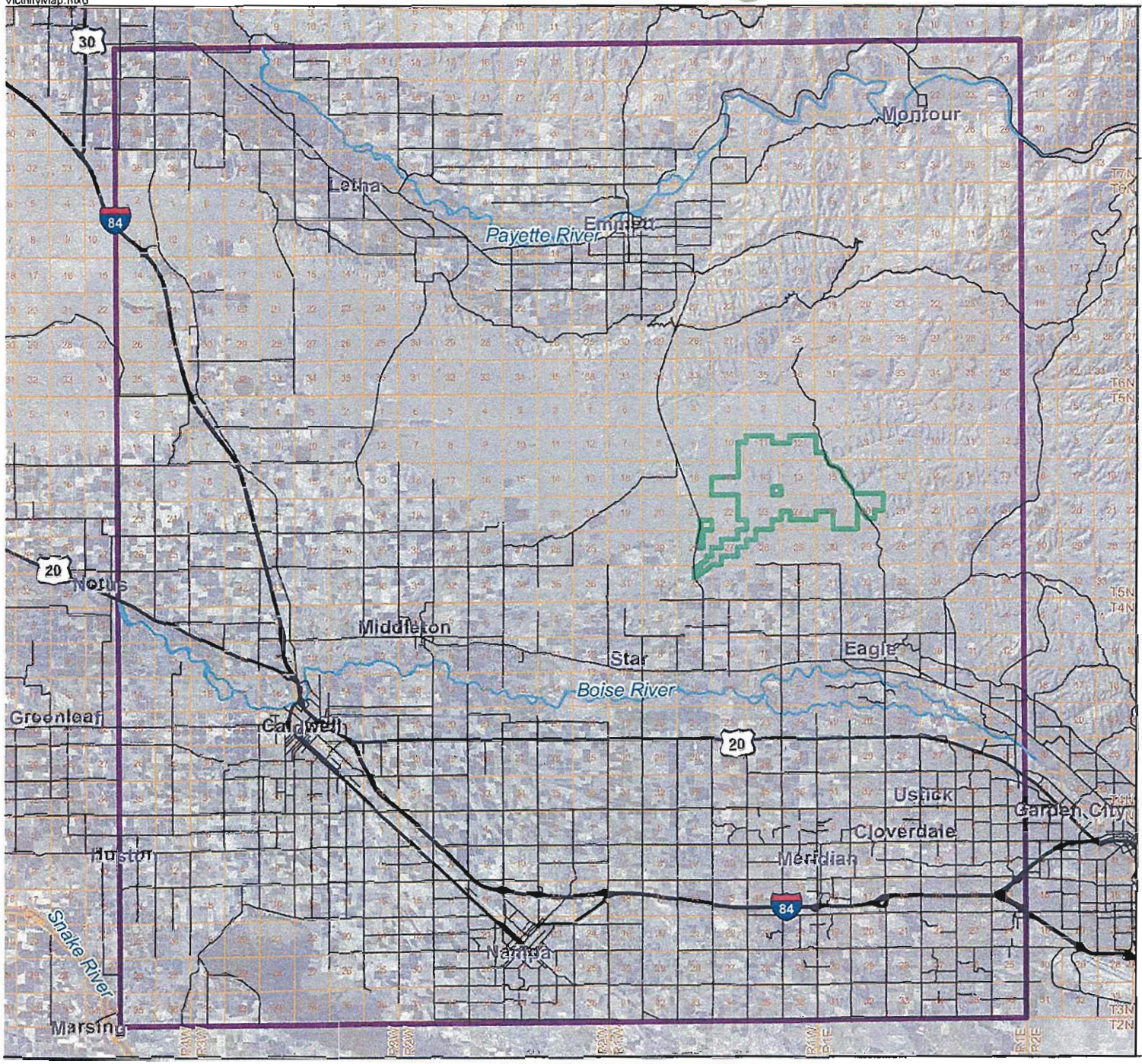


Figure 1-1

Vicinity Map

M3 Eagle Model
JZ0705

M3 Eagle Site Boundary

PGG Model Domain

PGG

0 Miles 5

1:250000

N

ModelGrid.mxd

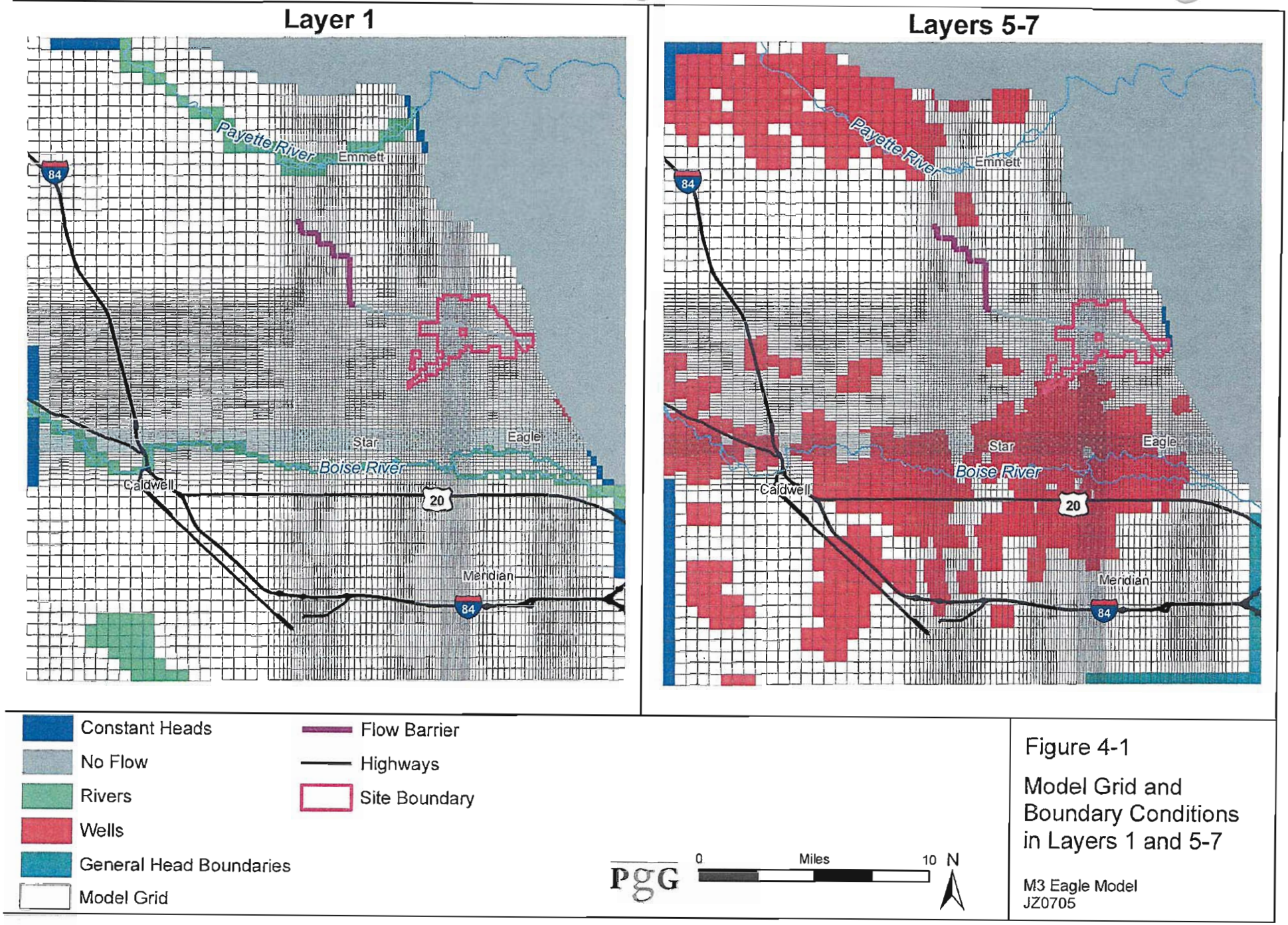
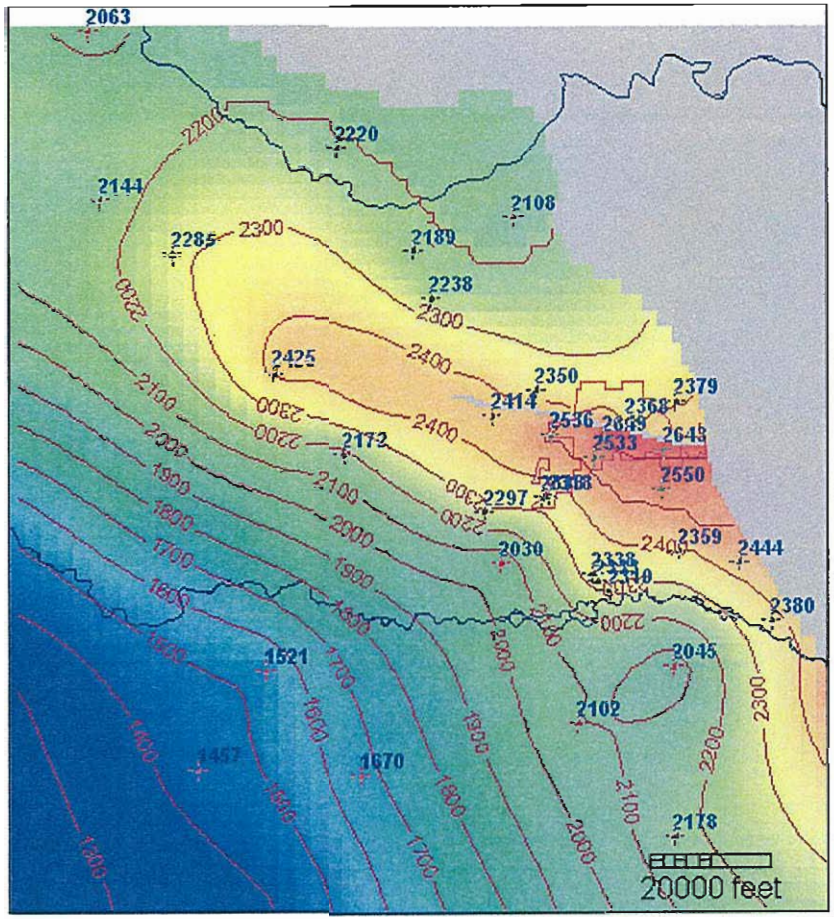


Figure 4-1

Model Grid and Boundary Conditions in Layers 1 and 5-7

M3 Eagle Model
JZ0705

Top of Layer 5



Bottom of Layer 7

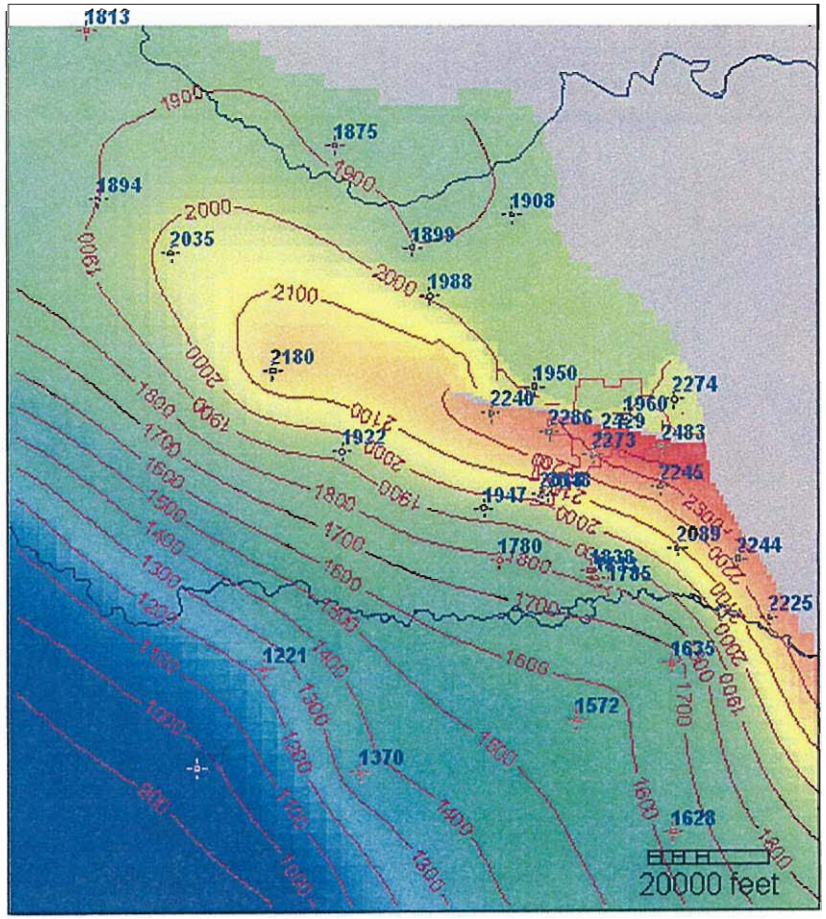


Figure 4-2
Reference Surfaces Used in Model Construction

M3 Eagle Model
JZ0705

PgG

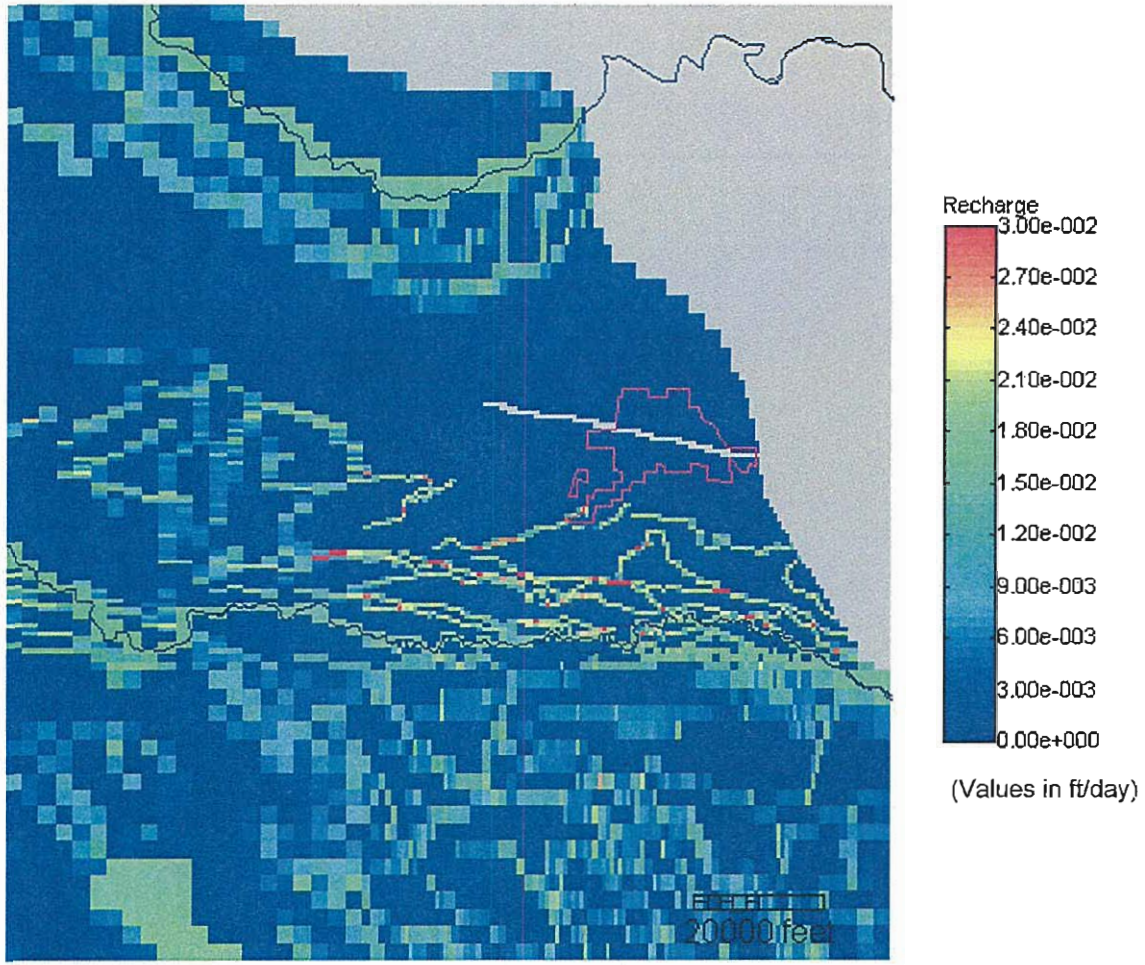
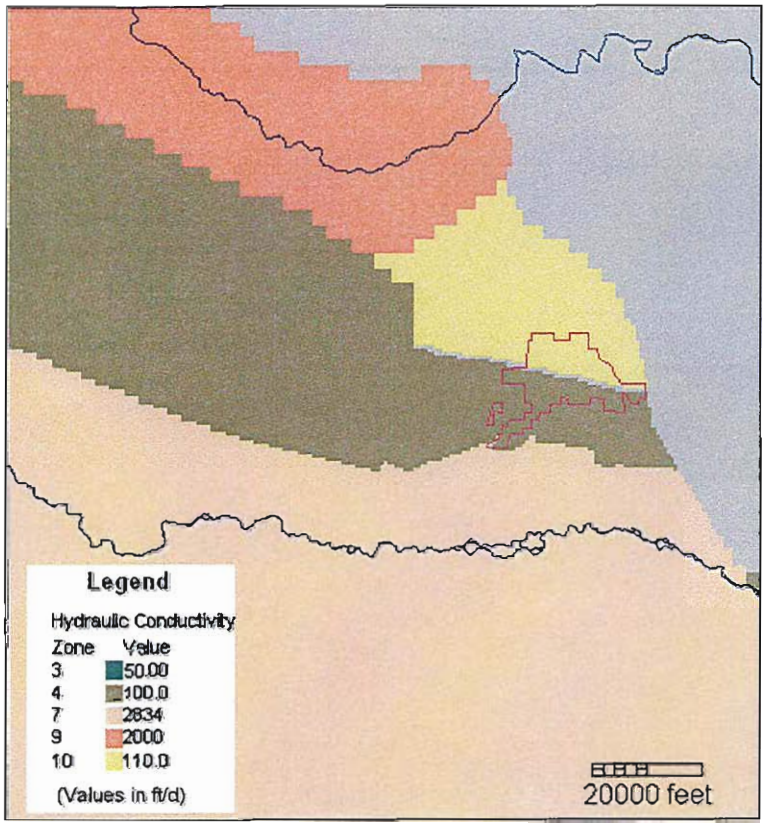


Figure 4-3
Distribution of Recharge

M3 Eagle Model
JZ0705

PgG

Layer 1



Layer 2

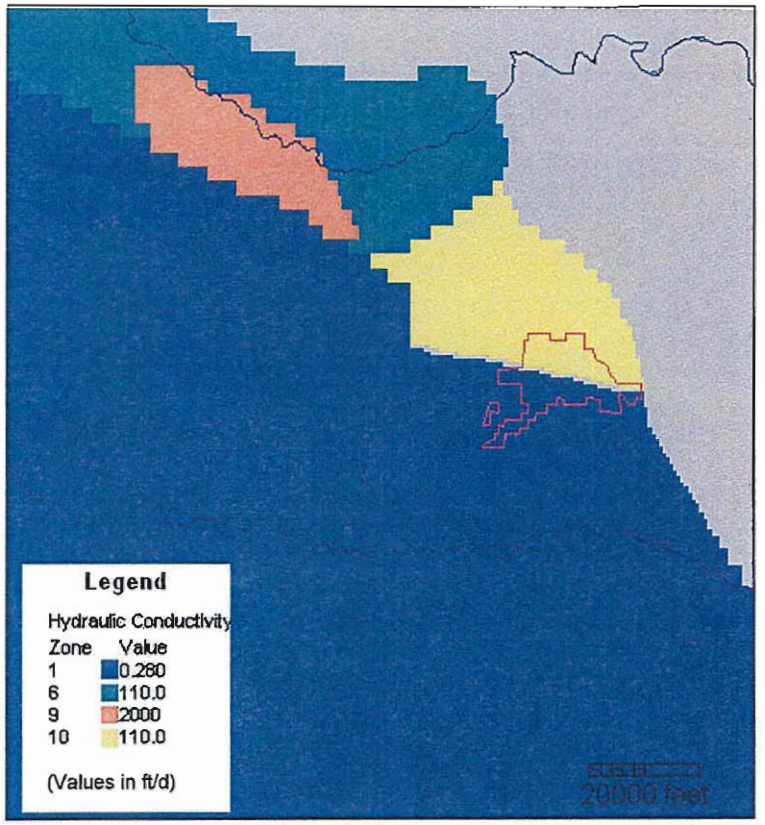
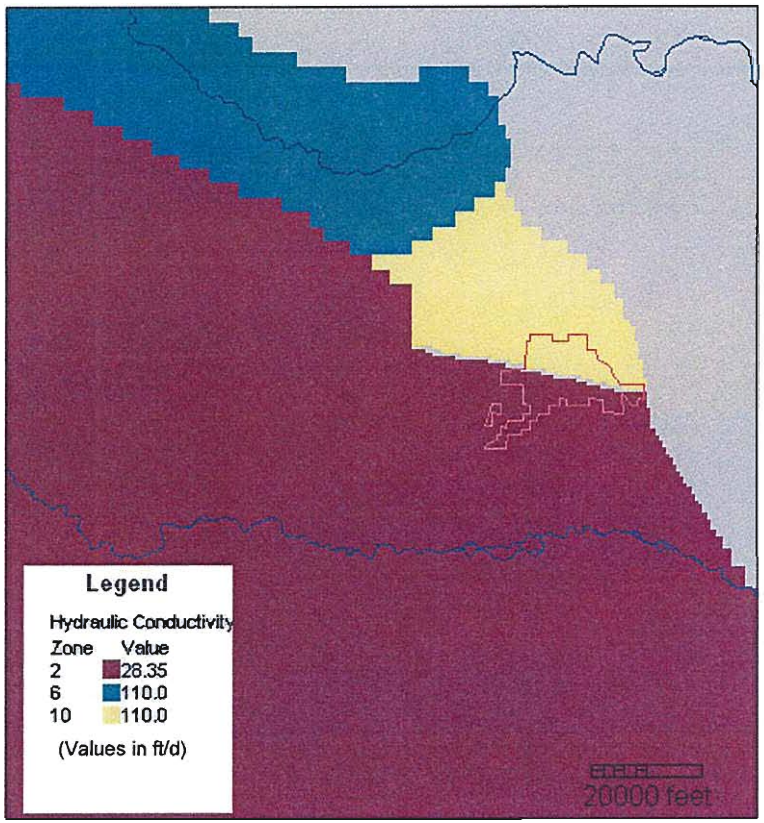


Figure 4-4
Hydraulic Conductivity Zones for Layers 1 and 2

M3 Eagle Model
JZ0705

PgG

Layer 3



Layer 4

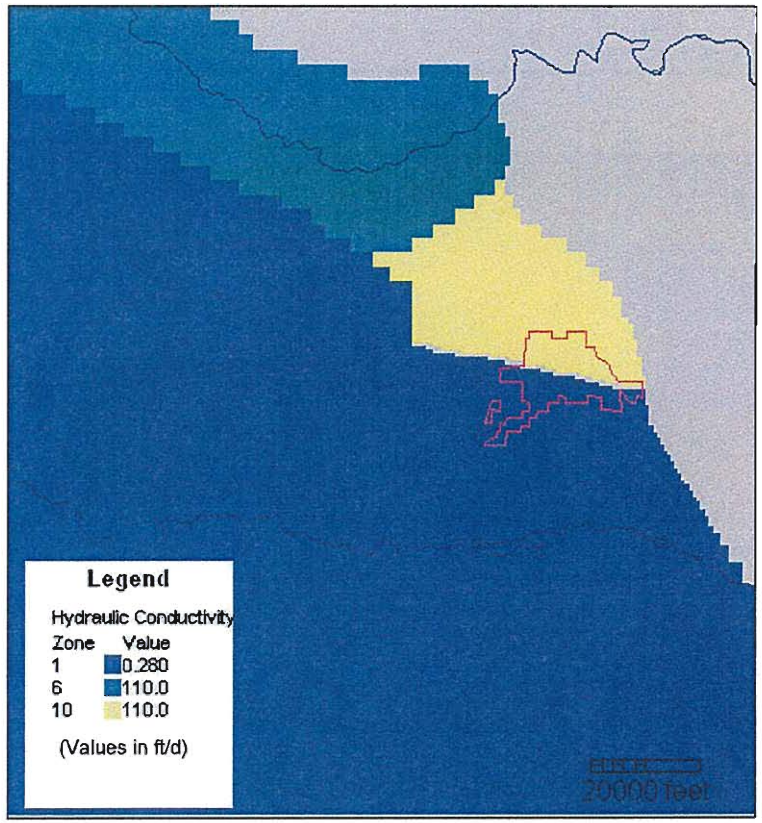


Figure 4-5
Hydraulic Conductivity Zones for Layers 3 and 4

M3 Eagle Model
JZ0705

PgG

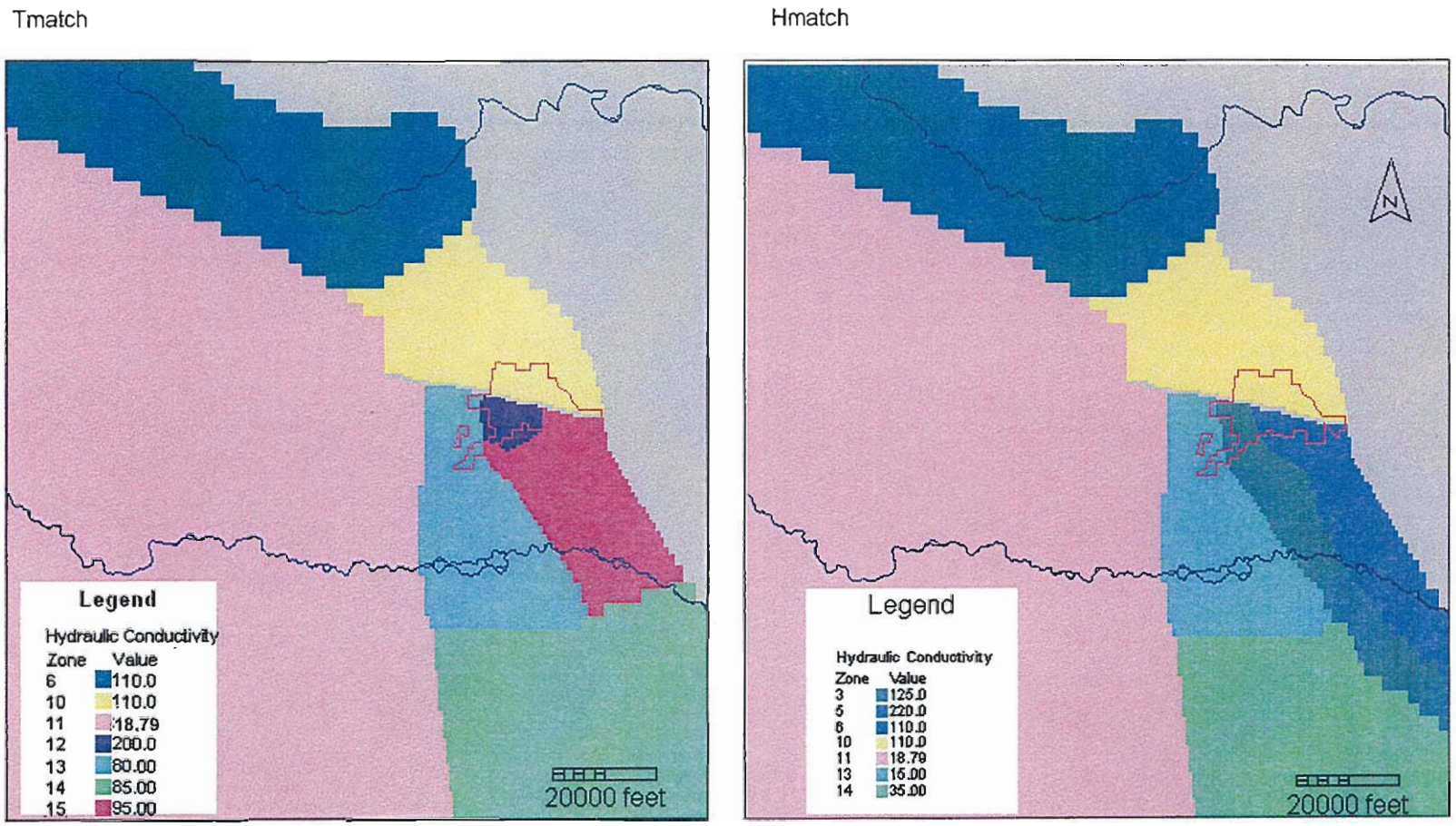
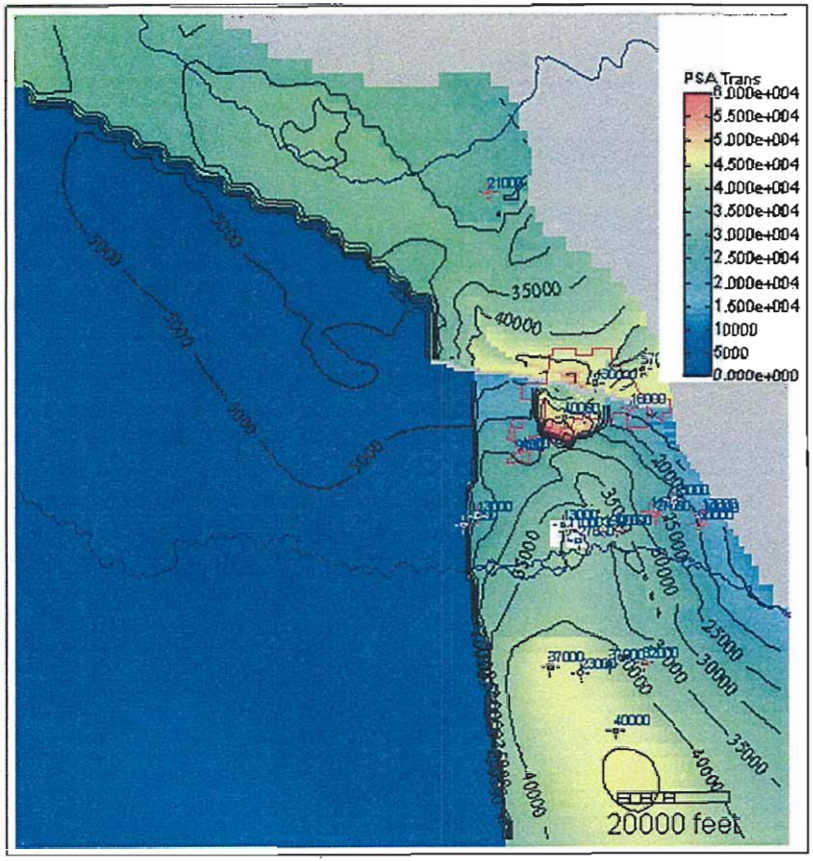


Figure 4-6
Hydraulic Conductivity Zones for Layers 5/6/7

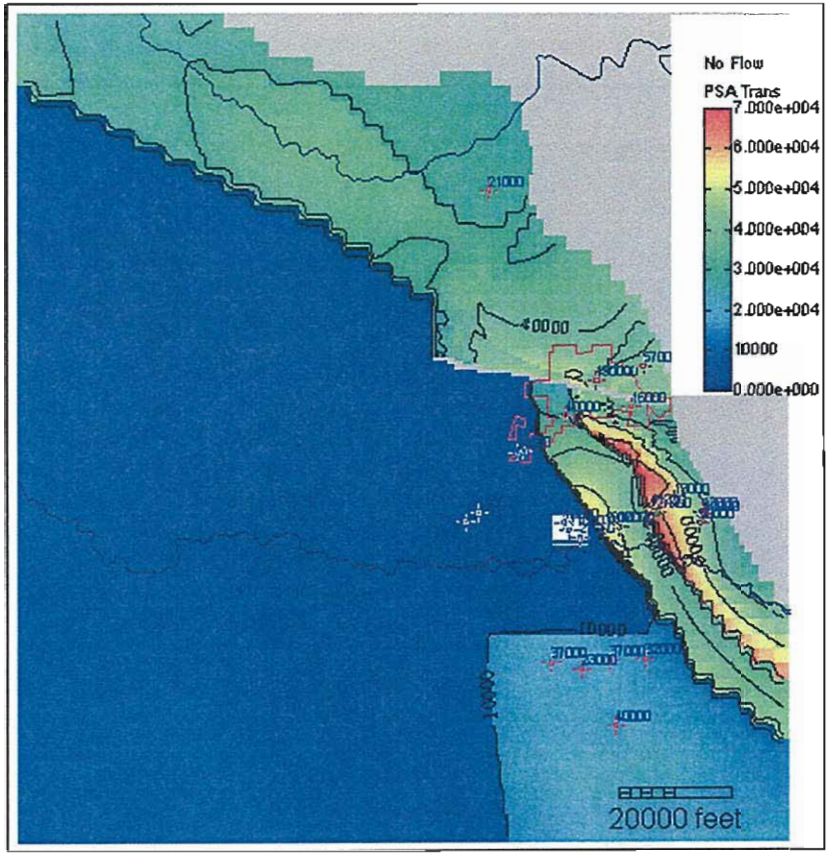
M3 Eagle Model
JZ0705

PgG

Tmatch



Hmatch



NOTE: Transmissivity estimates from aquifer tests summarized on Table 4-4. Values in ft^2/day.

Figure 4-7
Modeled PGSA Transmissivity and Estimates from Aquifer Tests

M3 Eagle Model
JZ0705

PgG

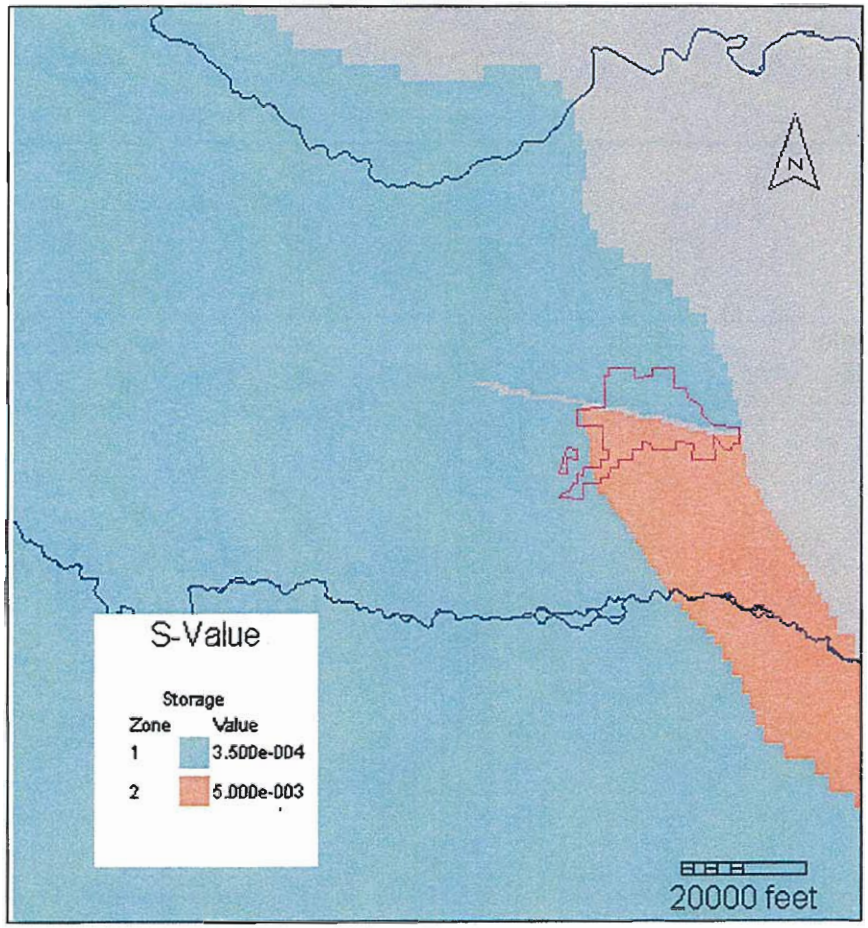
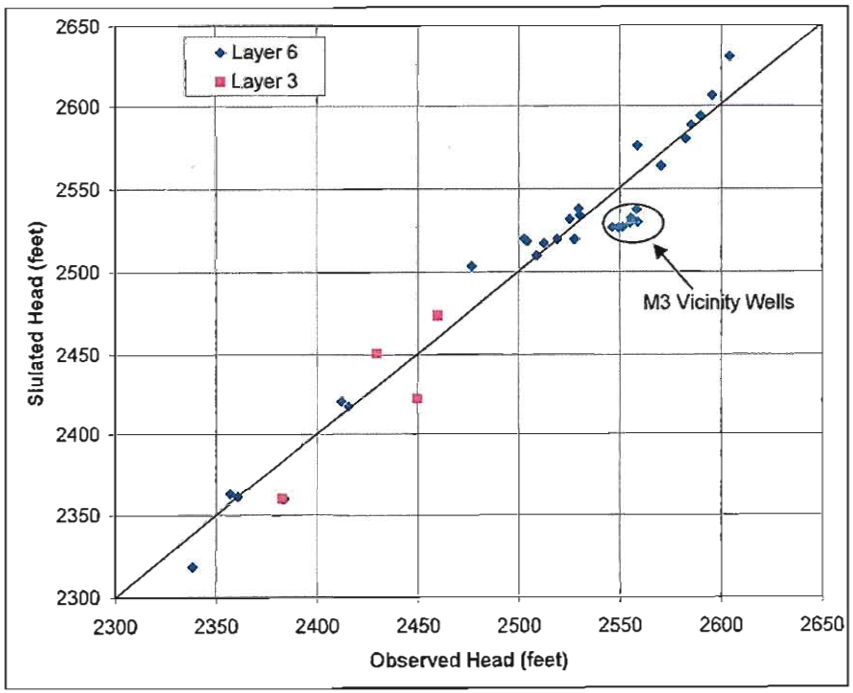


Figure 4-8
Modeled Storage Coefficient Zones (PGSA)

M3 Eagle Model
JZ0705

PgG

Tmatch Model



Hmatch Model

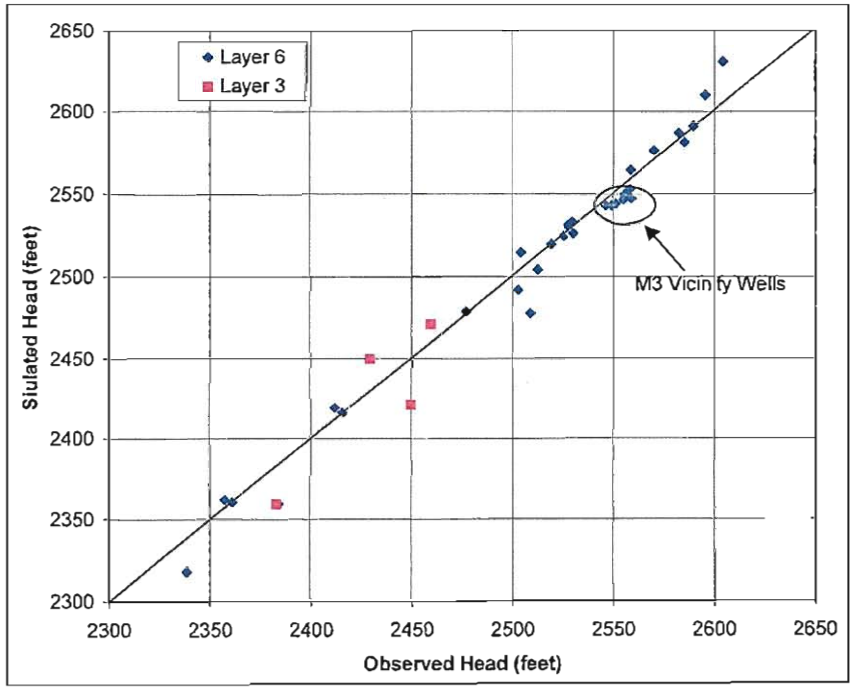
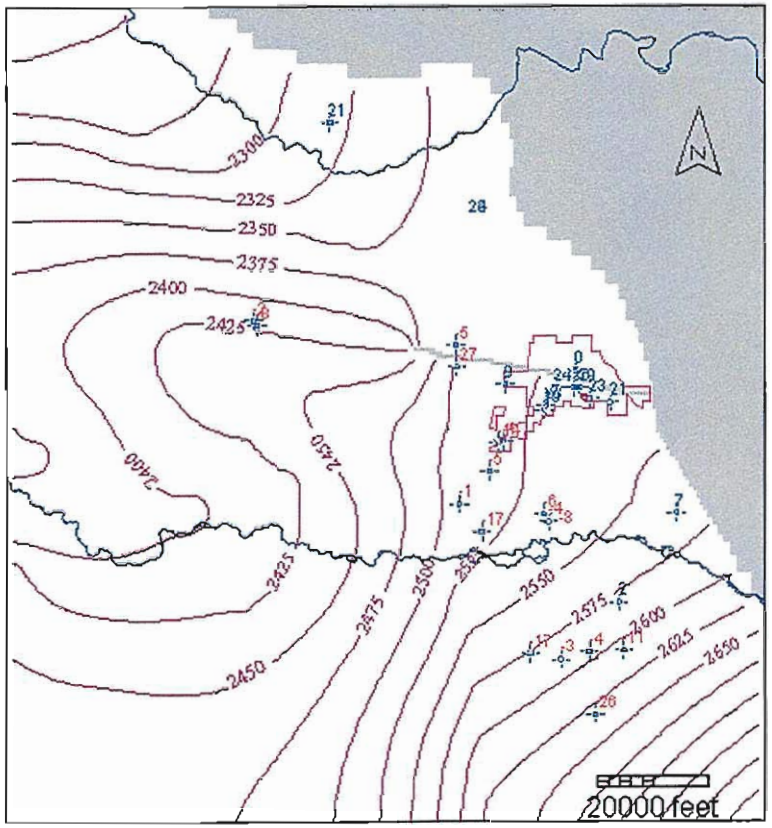


Figure 5-1
Observed versus Simulated Heads

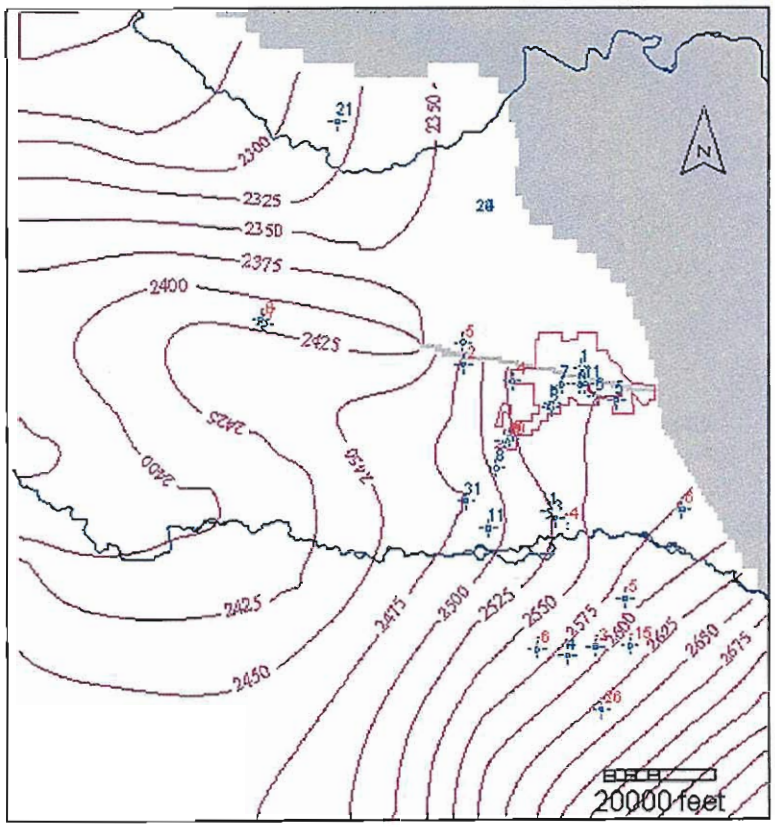
M3 Eagle Model
JZ0705

PgG

Tmatch



Hmatch



NOTE: Target values and residuals listed on Table XX.

Figure 5-2
Modeled Heads and Residuals in Layer 6 (PGSA)

M3 Eagle Model
JZ0705

PgG

Pumping_and_Obs_Wells.mxd

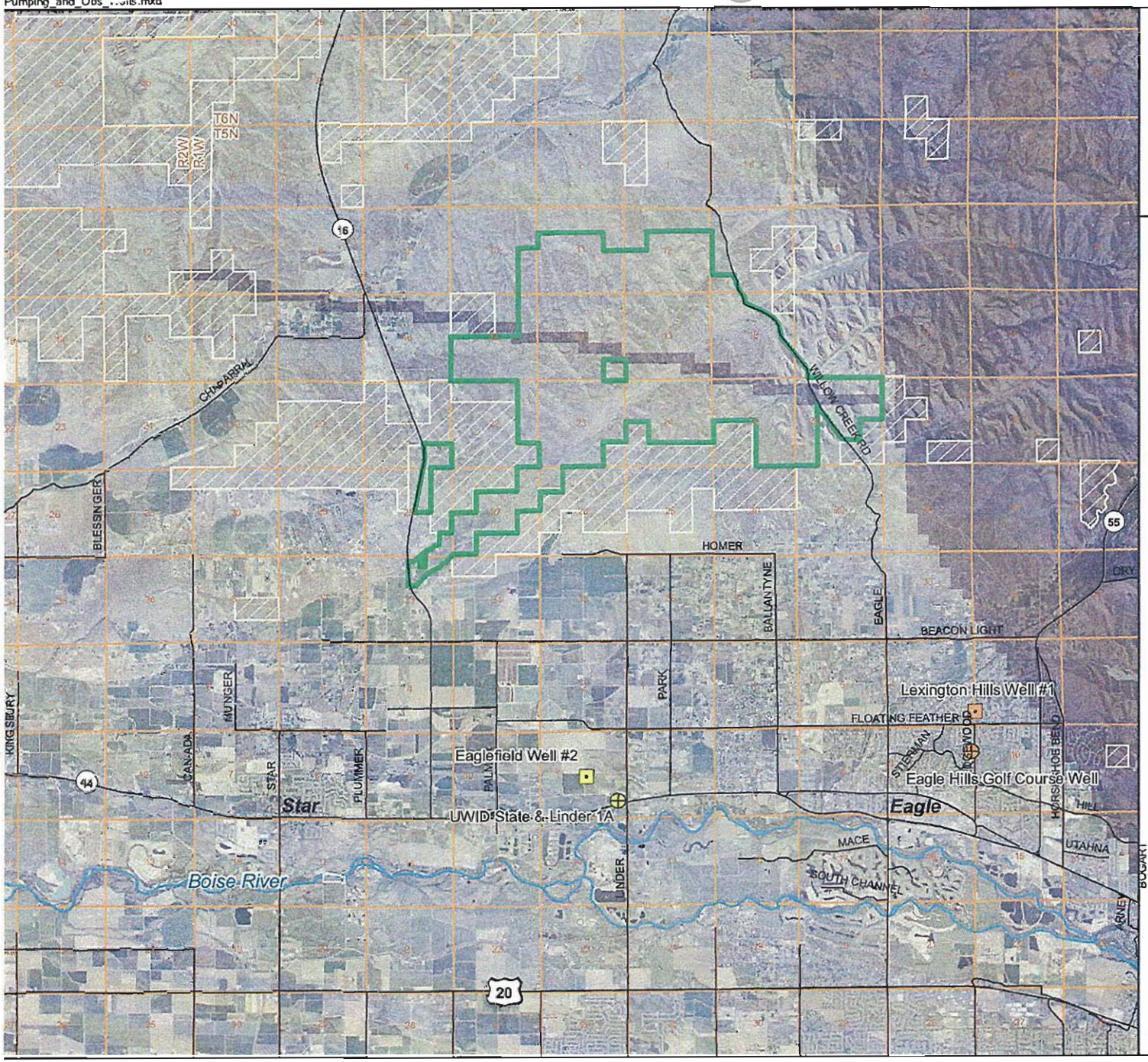


Figure 6-1

Locations of Pumping and Observation Wells (Transient Calibration)

M3 Eagle Model
JZ0705

- 30-Day Test Observation Well
- 30-Day Test Pumpnig Well
- 7-Day Test Observation Well
- 7-Day Test Pumping Well
- No Flow Zones
- M3 Eagle Site Boundary
- BLM
- sections

pgG

0 Feet 8,000

2006 Orthophoto

N

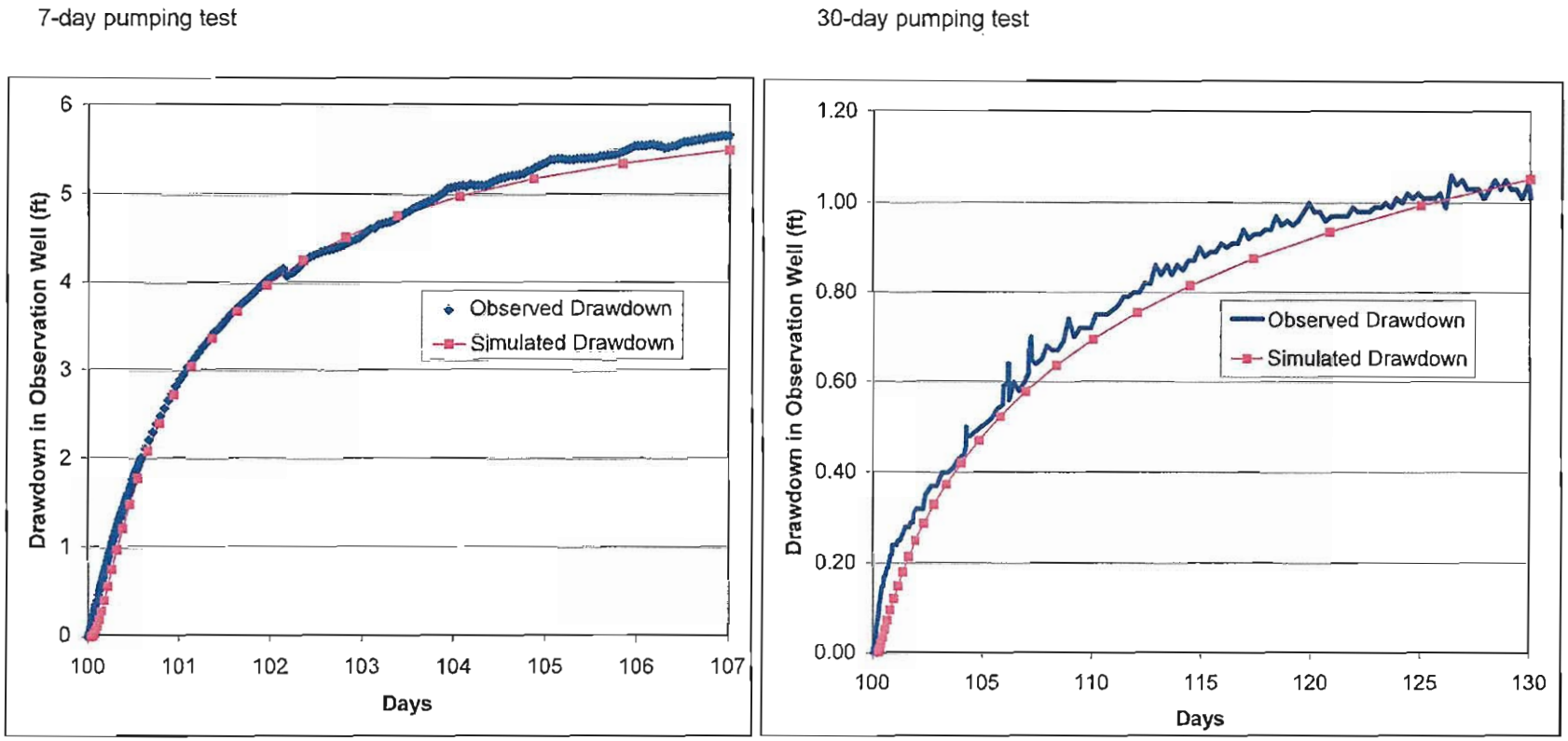


Figure 6-2
Modeled Drawdown in Hmatch Model (7-day and 30-day pumping tests)

M3 Eagle Model
JZ0705

PgG

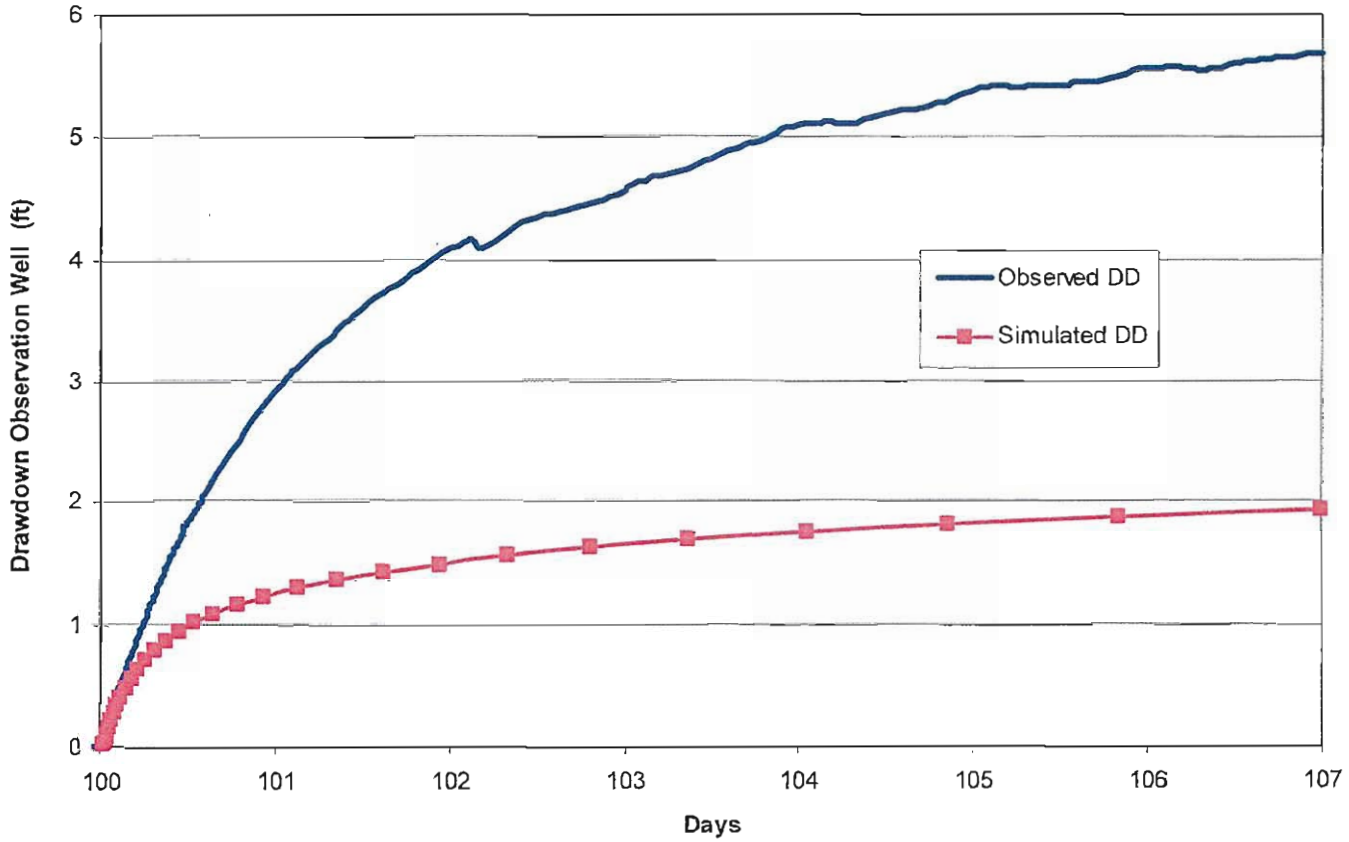


Figure 6-3
Modeled Drawdown in Tmatch Model (7-day pumping test)

M3 Eagle Model
JZ0705

PgG

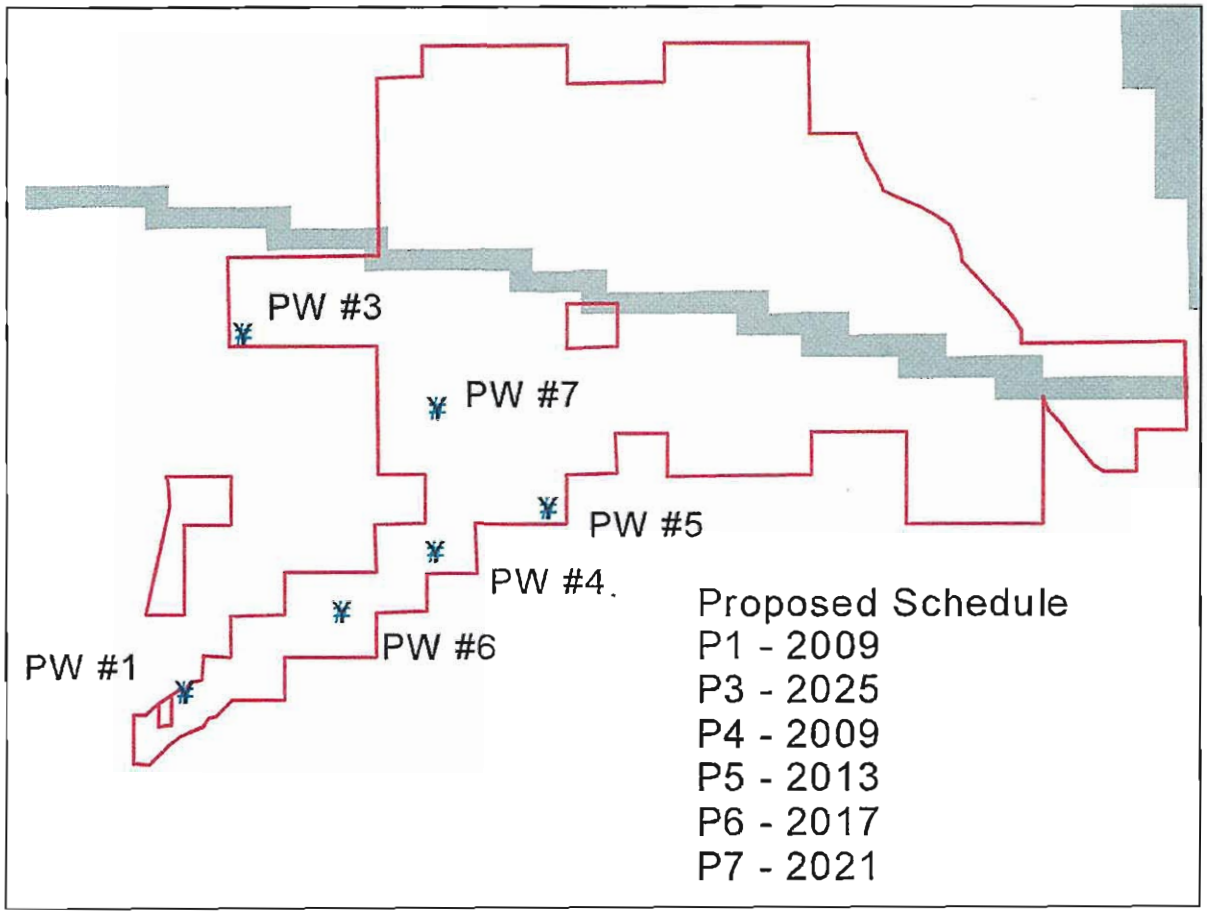


Figure 7-1
Proposed Supply Wells (M3 Site)

M3 Eagle Model
JZ0705

PgG

DrawDown_6.mxd

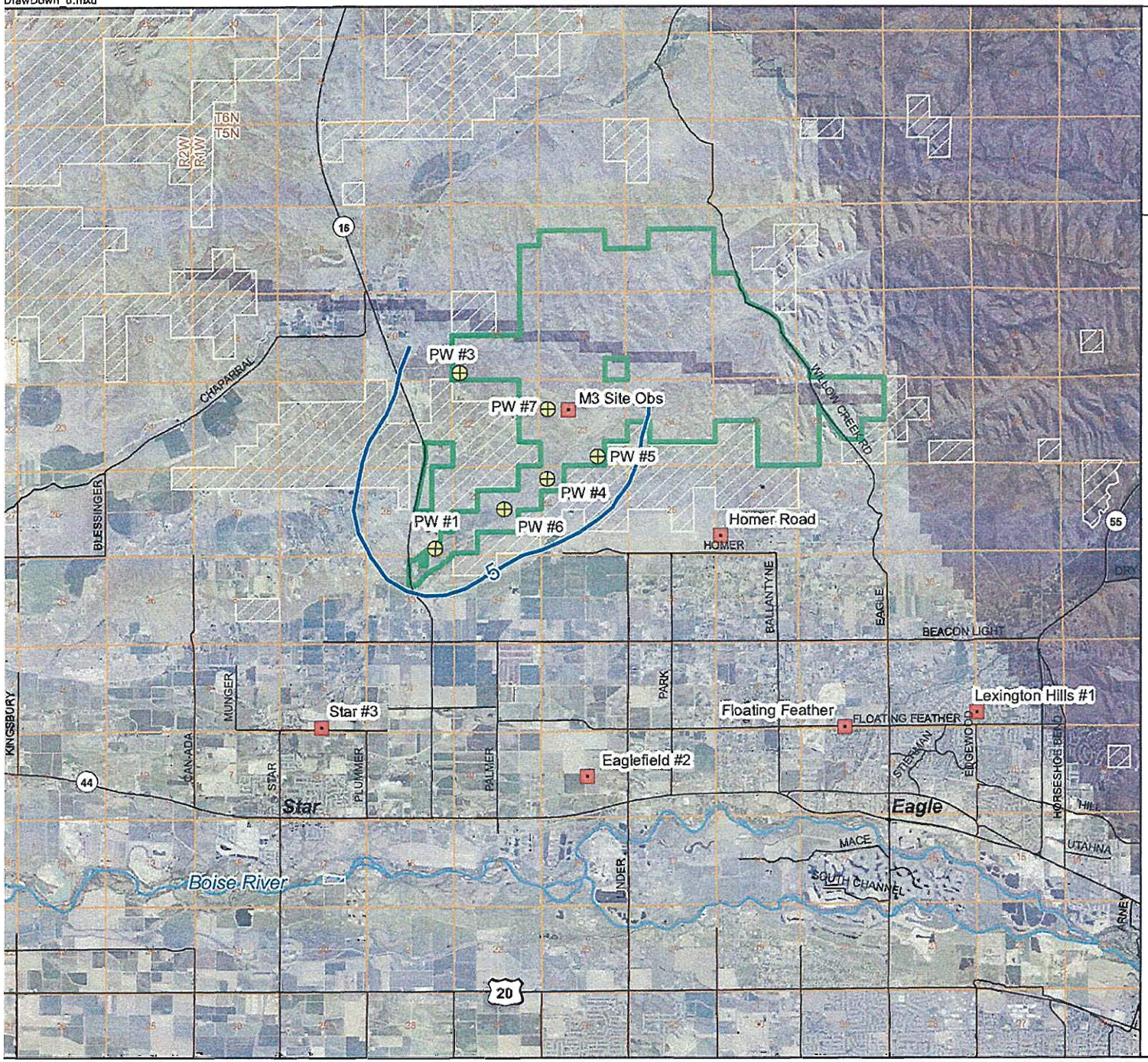


Figure 7-2

Simulated PGSA Drawdown After 4 Years (2013) - Tmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	**1000**	**2009**
PW #4	**1000**	**2009**
PW #5	1000	2013
PW #6	1000	2017
PW #7	1000	2021
PW #3	1000	2025

PGG

0 Feet 8,000

2006 Orthophoto

N

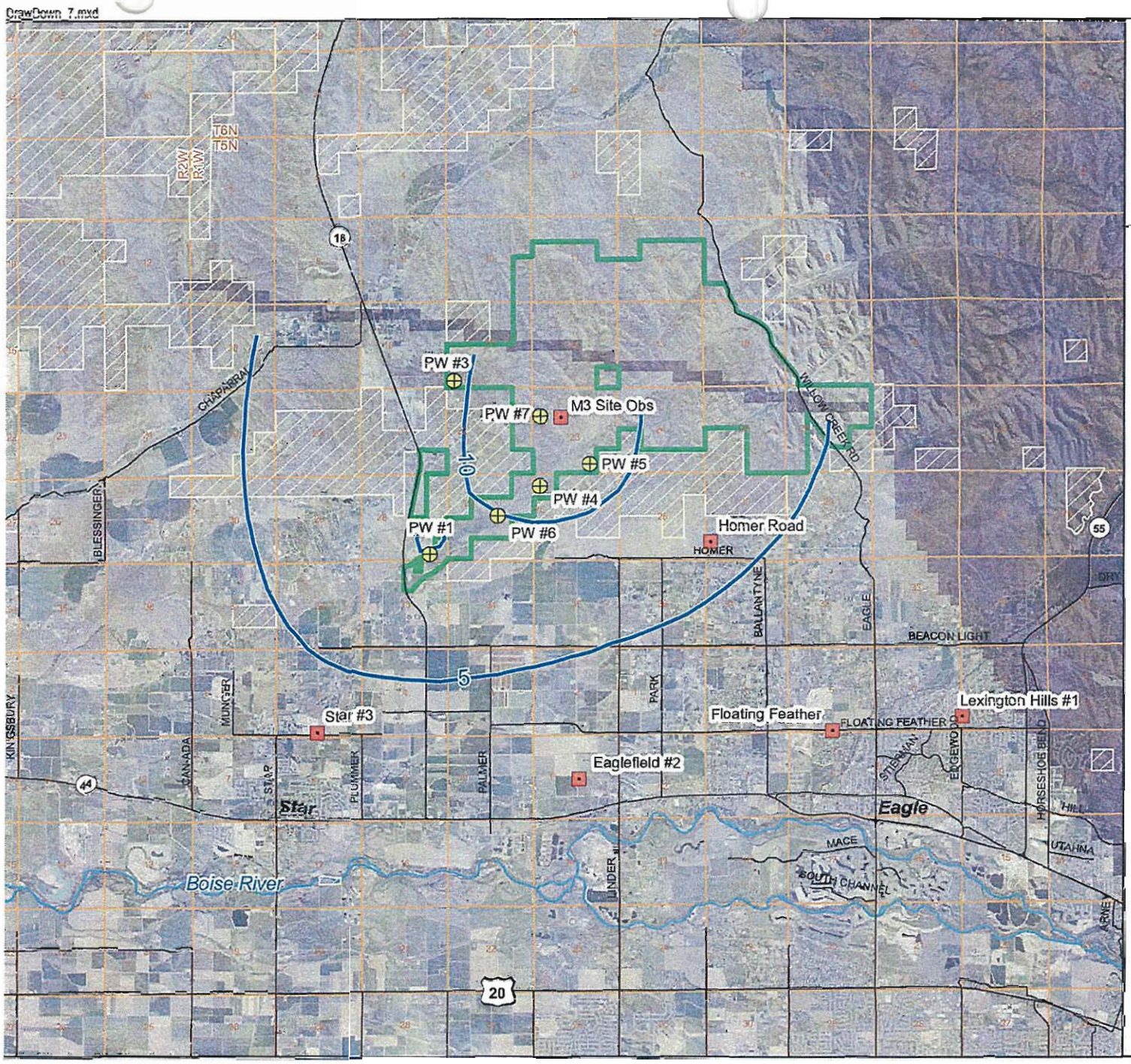


Figure 7-3

Simulated PGSA Drawdown After 8 Years (2017) - Tmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown In feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	**1000**	**2009**
PW #4	**1000**	**2009**
PW #5	**1000**	**2013**
PW #6	**1000**	**2017**
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_8.mxd

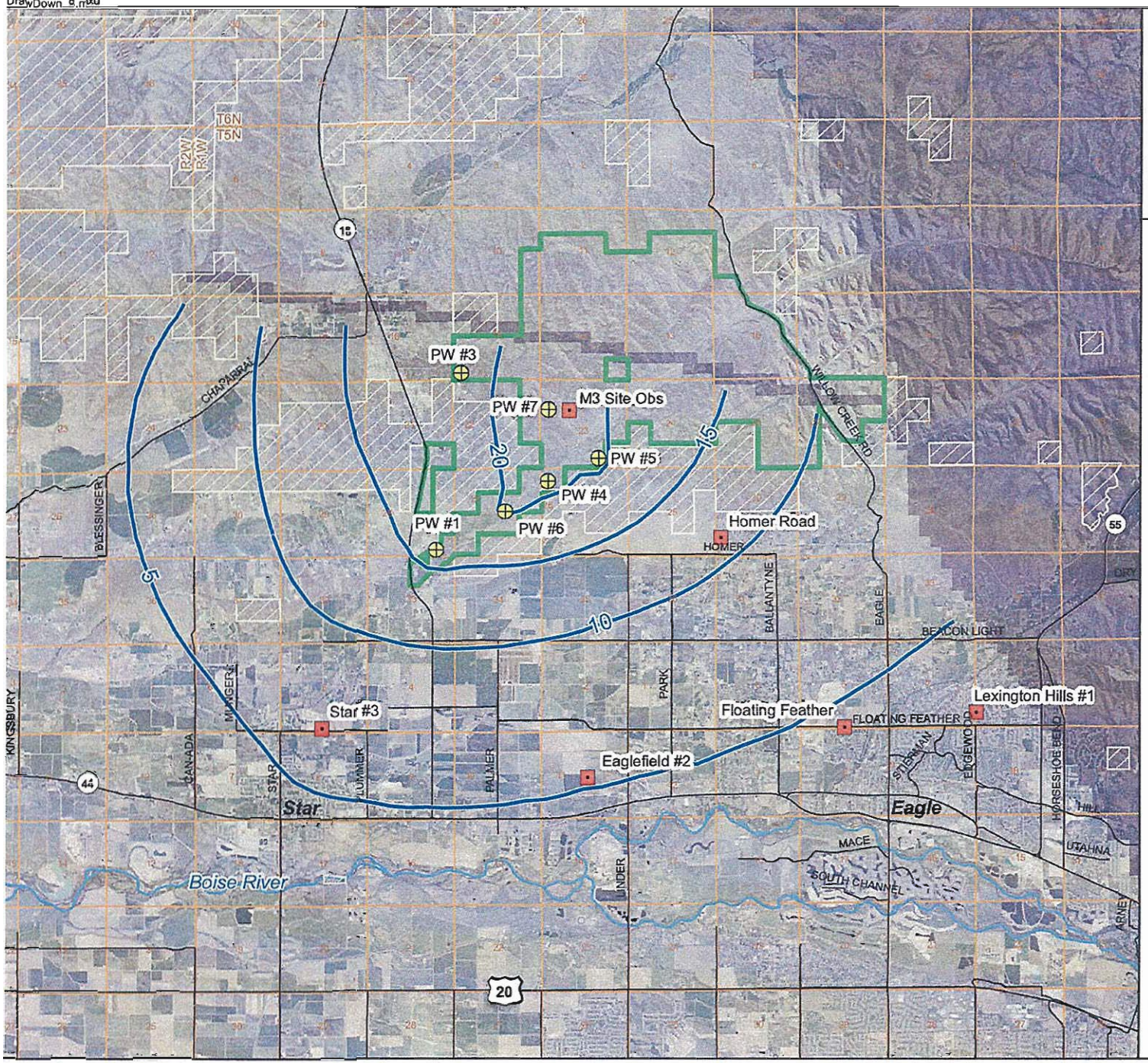


Figure 7-4

Simulated PGSA Drawdown After 16 Years (2025) - Tmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	1000	2009
PW #4	1000	2009
PW #5	1000	2013
PW #6	1000	2017
PW #7	1000	2021
PW #3	1000	2025

PGG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_9.mxd

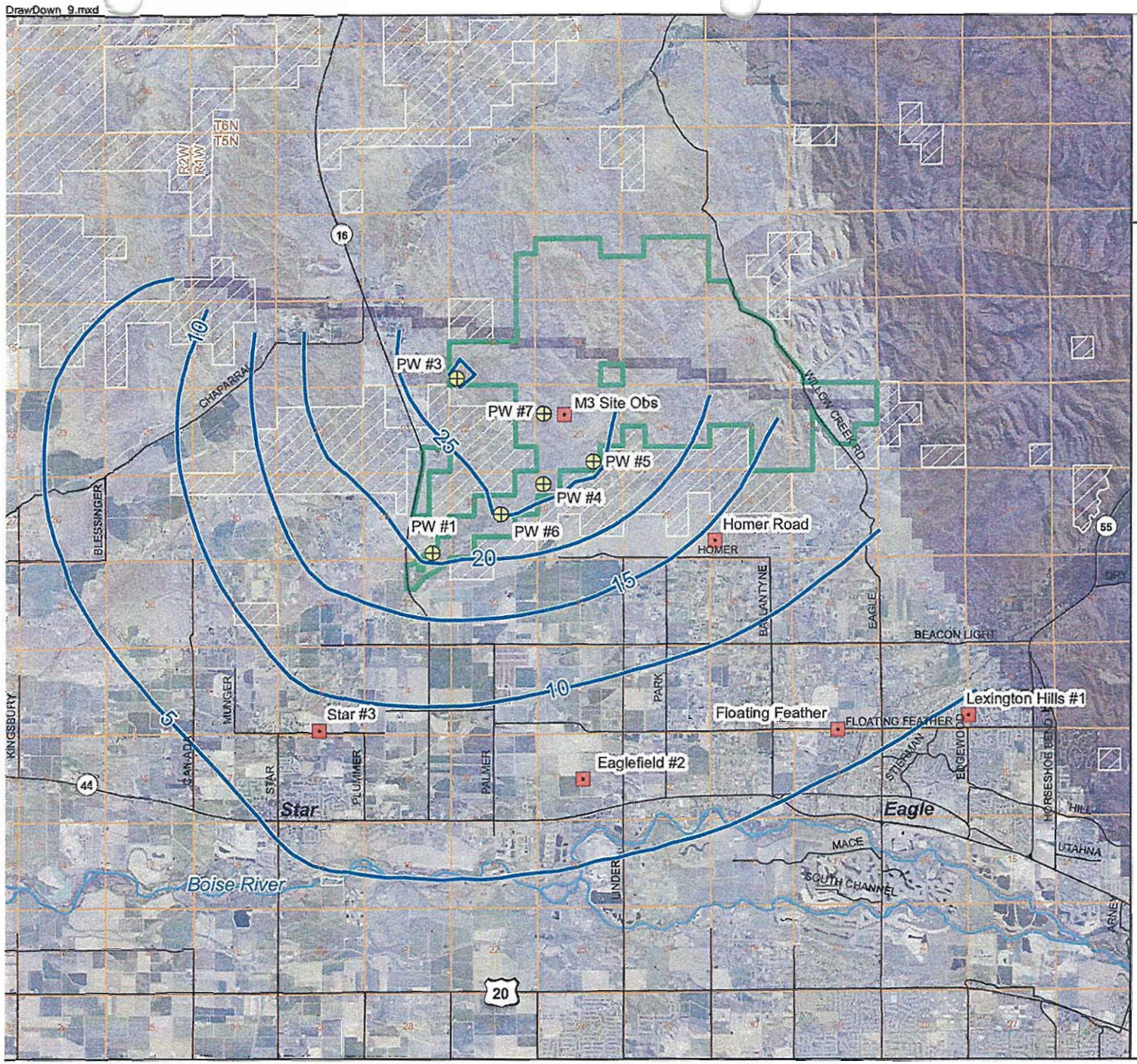


Figure 7-5

Simulated PGSA Drawdown After 26 Years (2035) - Tmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	1000	2009
PW #4	1000	2009
PW #5	1000	2013
PW #6	1000	2017
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_1.mxd

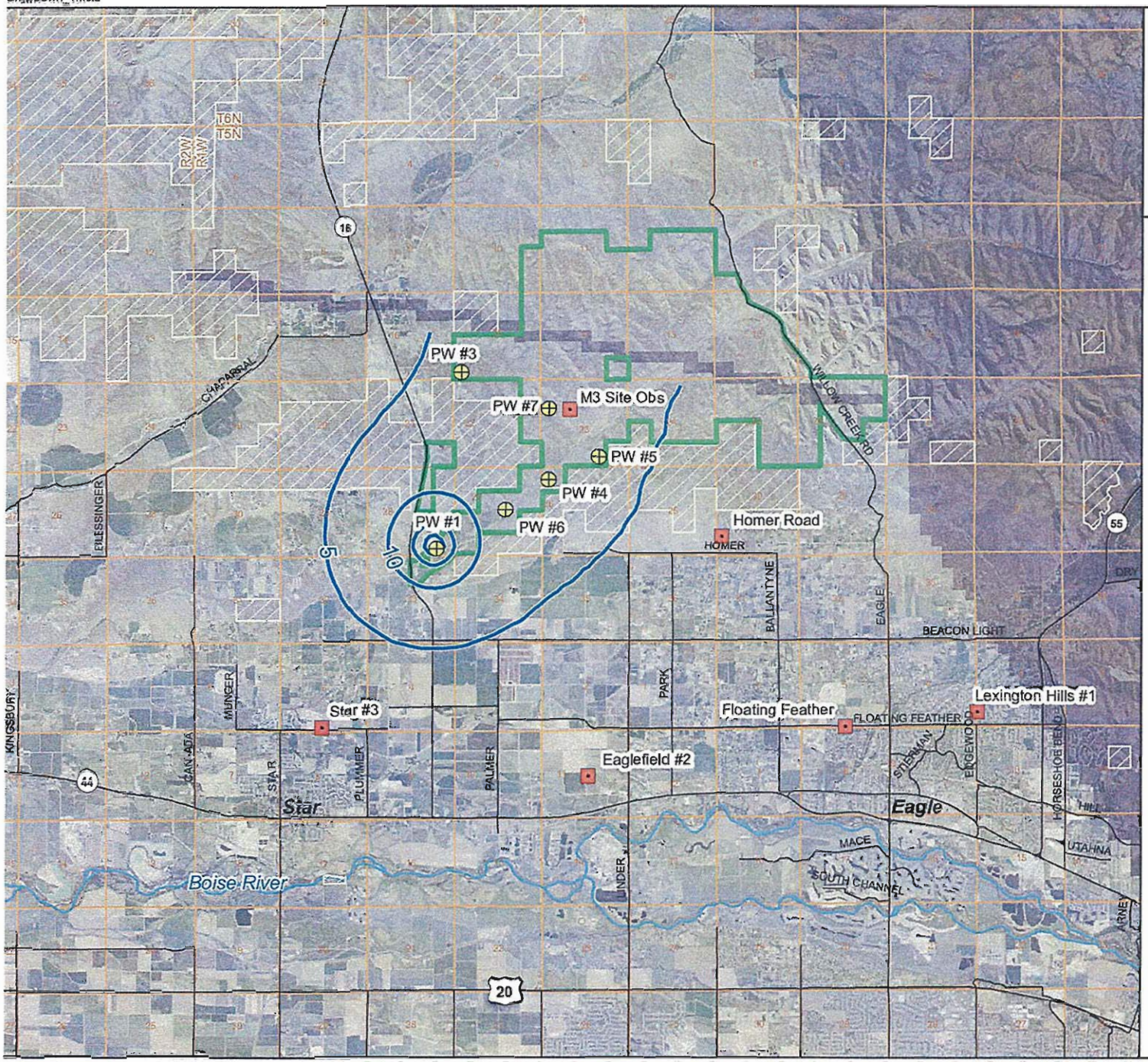


Figure 7-6

Simulated PGSA Drawdown After 4 Years (2013) - Hmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	**1000**	**2009**
PW #4	**1000**	**2009**
PW #5	1000	2013
PW #6	1000	2017
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_2.mxd

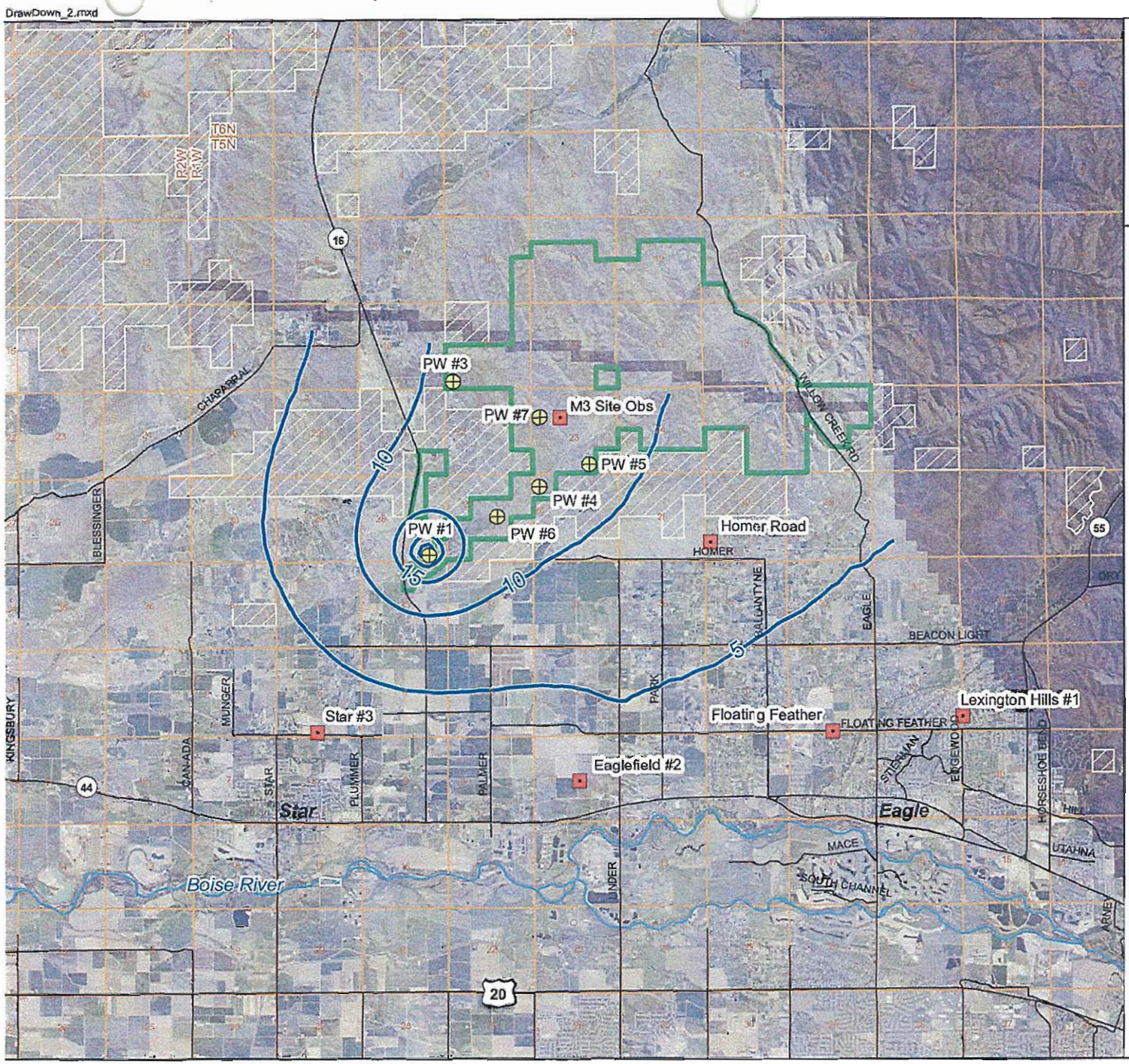


Figure 7-7

Simulated PGSA Drawdown After 8 Years (2017) - Hmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	**1000**	**2009**
PW #4	**1000**	**2009**
PW #5	**1000**	**2013**
PW #6	**1000**	**2017**
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_3.mxd

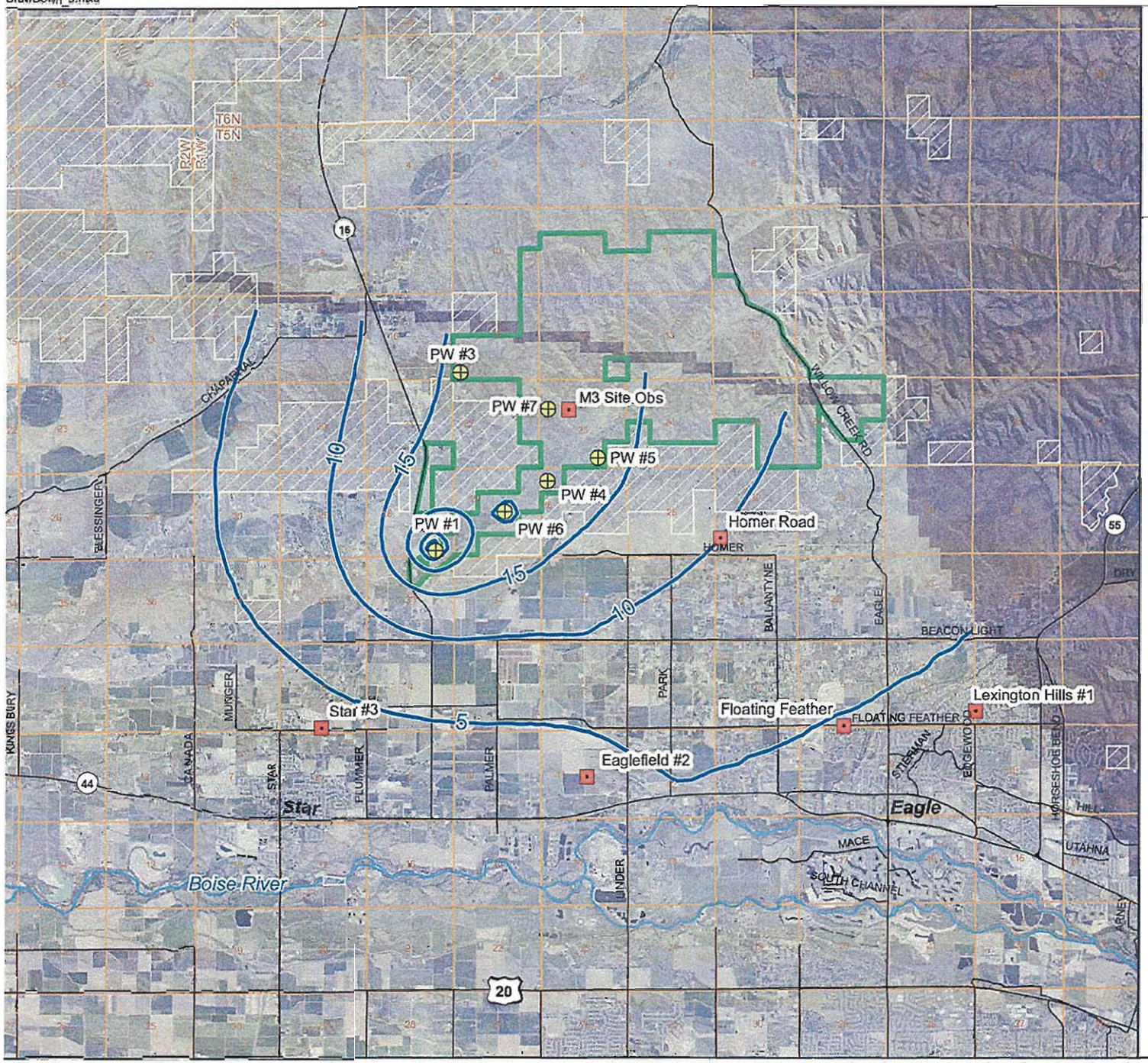


Figure 7-8

Simulated PGSA Drawdown After 16 Years (2025) - Hmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	1000	2009
PW #4	1000	2009
PW #5	1000	2013
PW #6	1000	2017
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_4.mxd

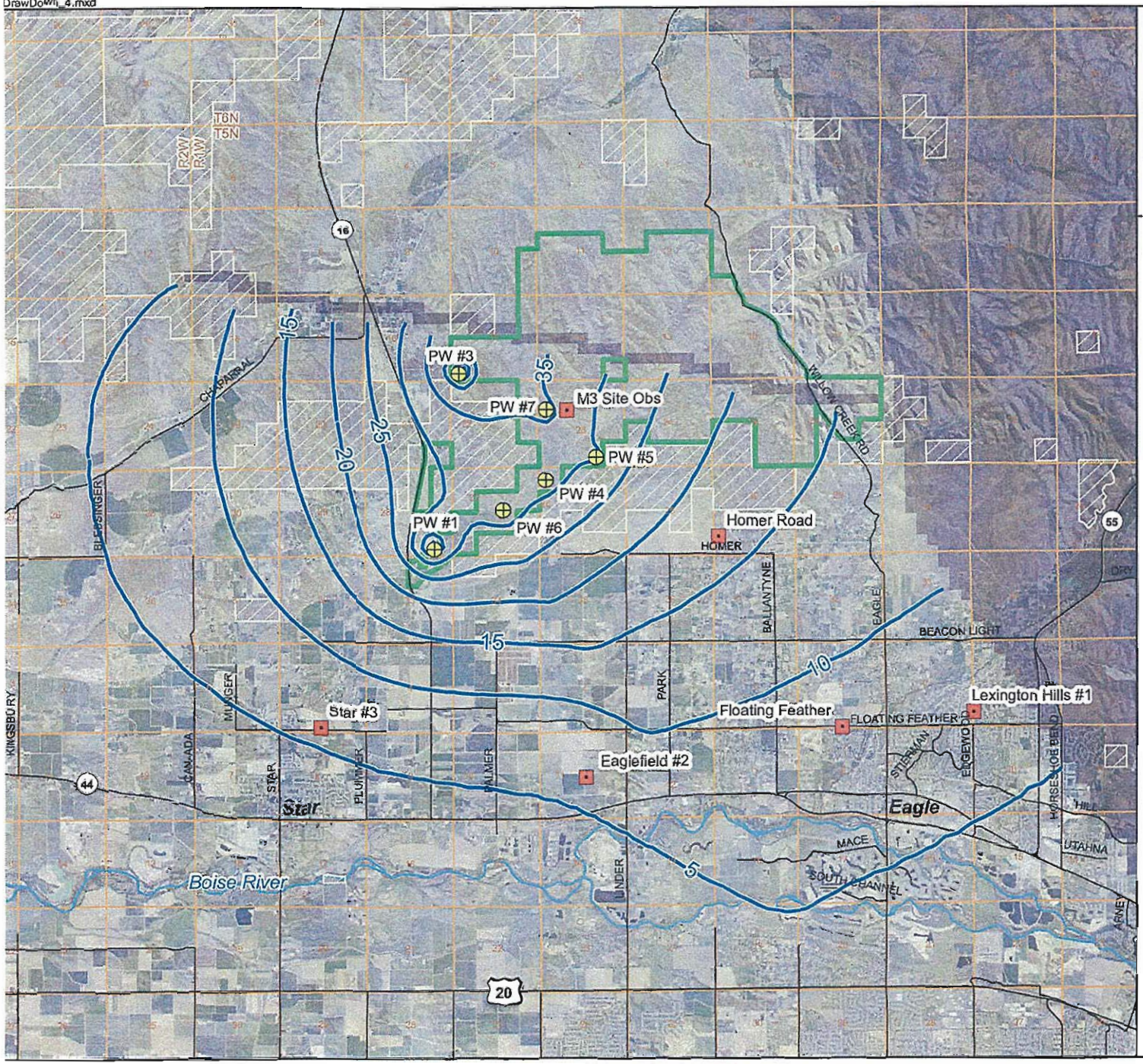


Figure 7-9

Simulated PGSA Drawdown After 26 Years (2035) - Hmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	1000	2009
PW #4	1000	2009
PW #5	1000	2013
PW #6	1000	2017
PW #7	1000	2021
PW #3	1000	2025

PGG

0 Feet 8,000

2006 Orthophoto

N

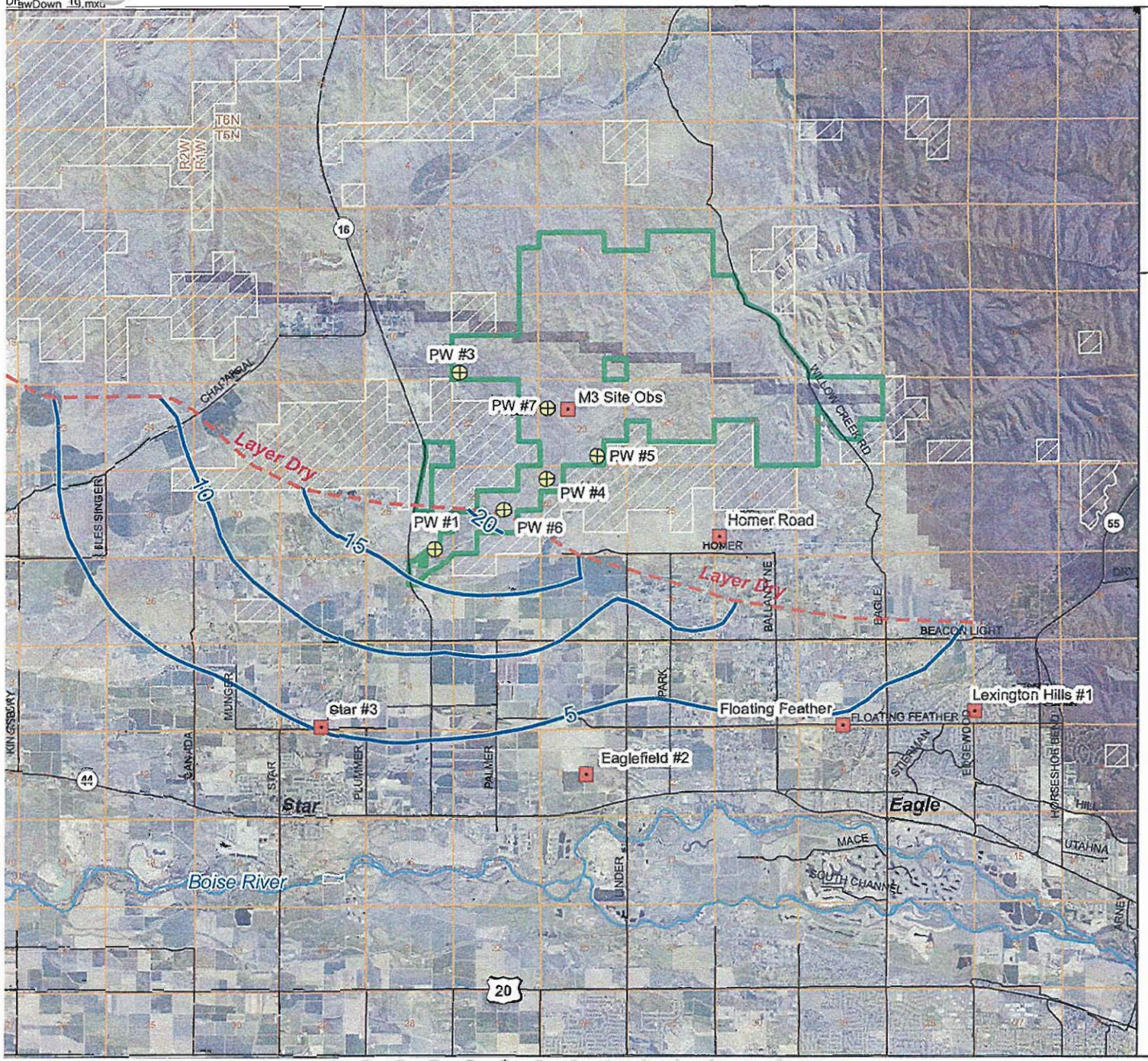


Figure 7-10
Simulated Drawdown in Middle Aquifer After 26 Years (2035) - Tmatch Model

M3 Eagle Model
JZ0705

- ⊕ Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	1000	2009
PW #4	1000	2009
PW #5	1000	2013
PW #6	1000	2017
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_5.mxd

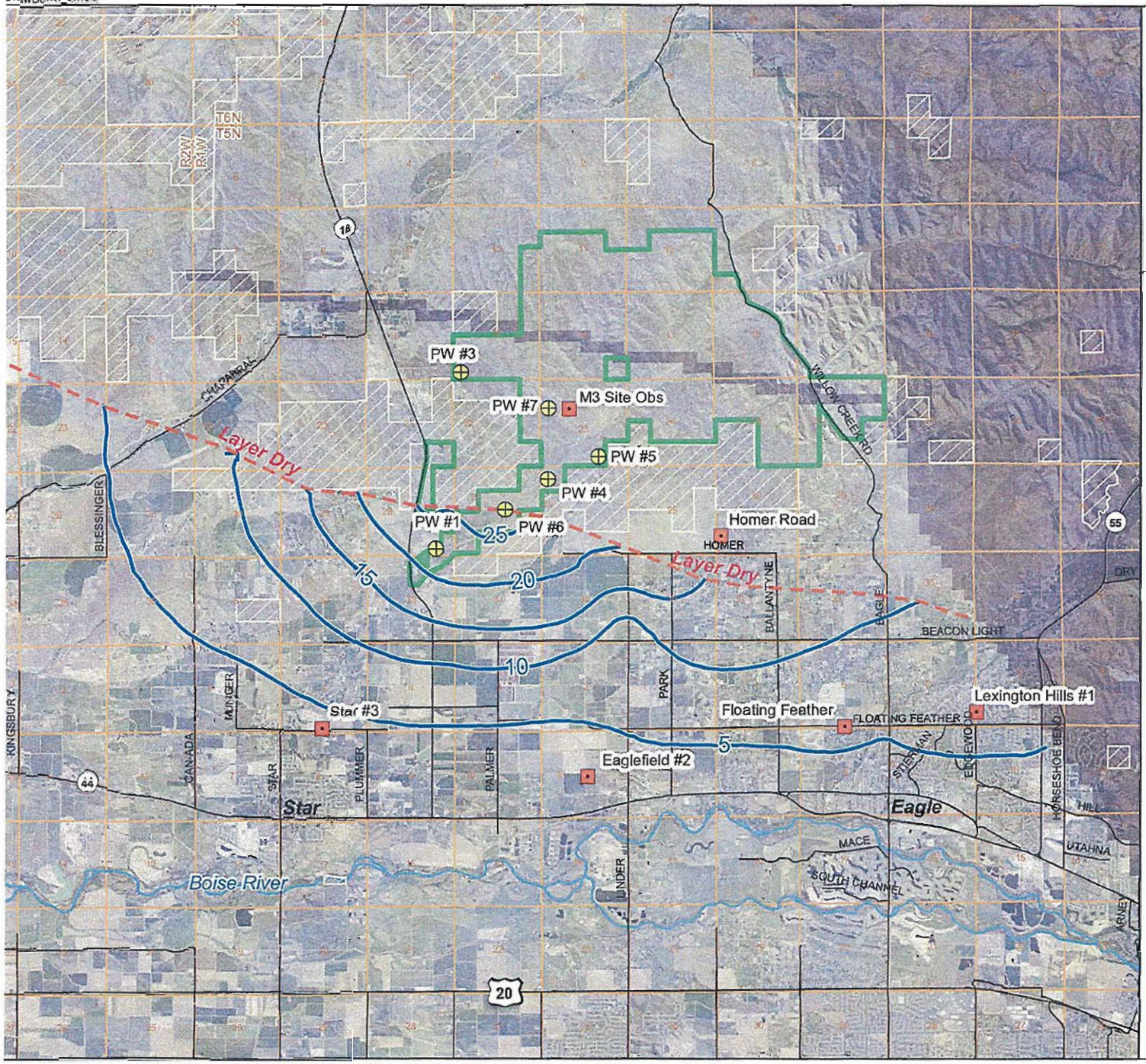


Figure 7-11
Simulated Drawdown in Middle Aquifer After 26 Years (2035) - Hmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	1000	2009
PW #4	1000	2009
PW #5	1000	2013
PW #6	1000	2017
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

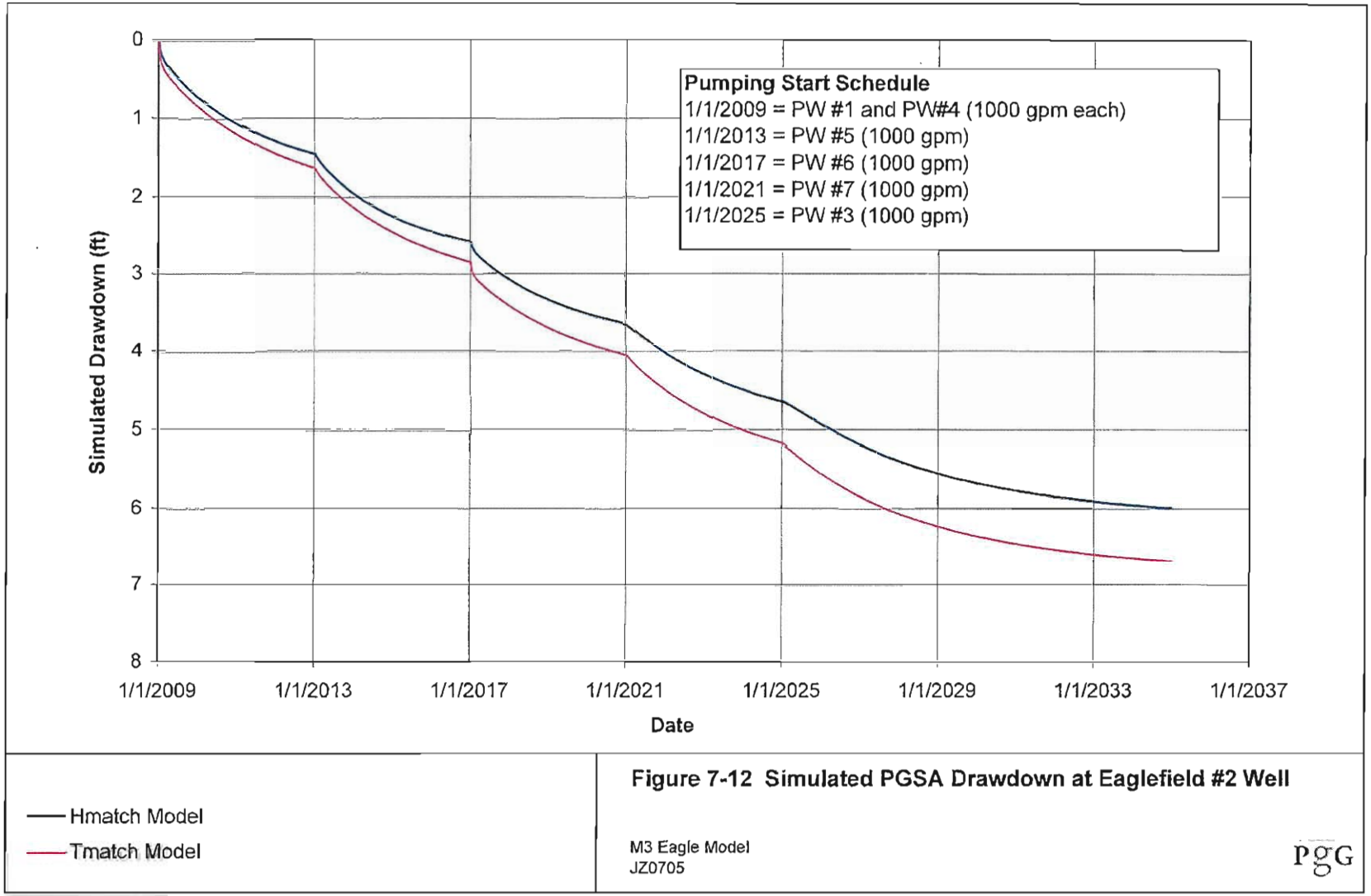


Figure 7-12 Simulated PGSA Drawdown at Eaglefield #2 Well

M3 Eagle Model
JZ0705

PgG

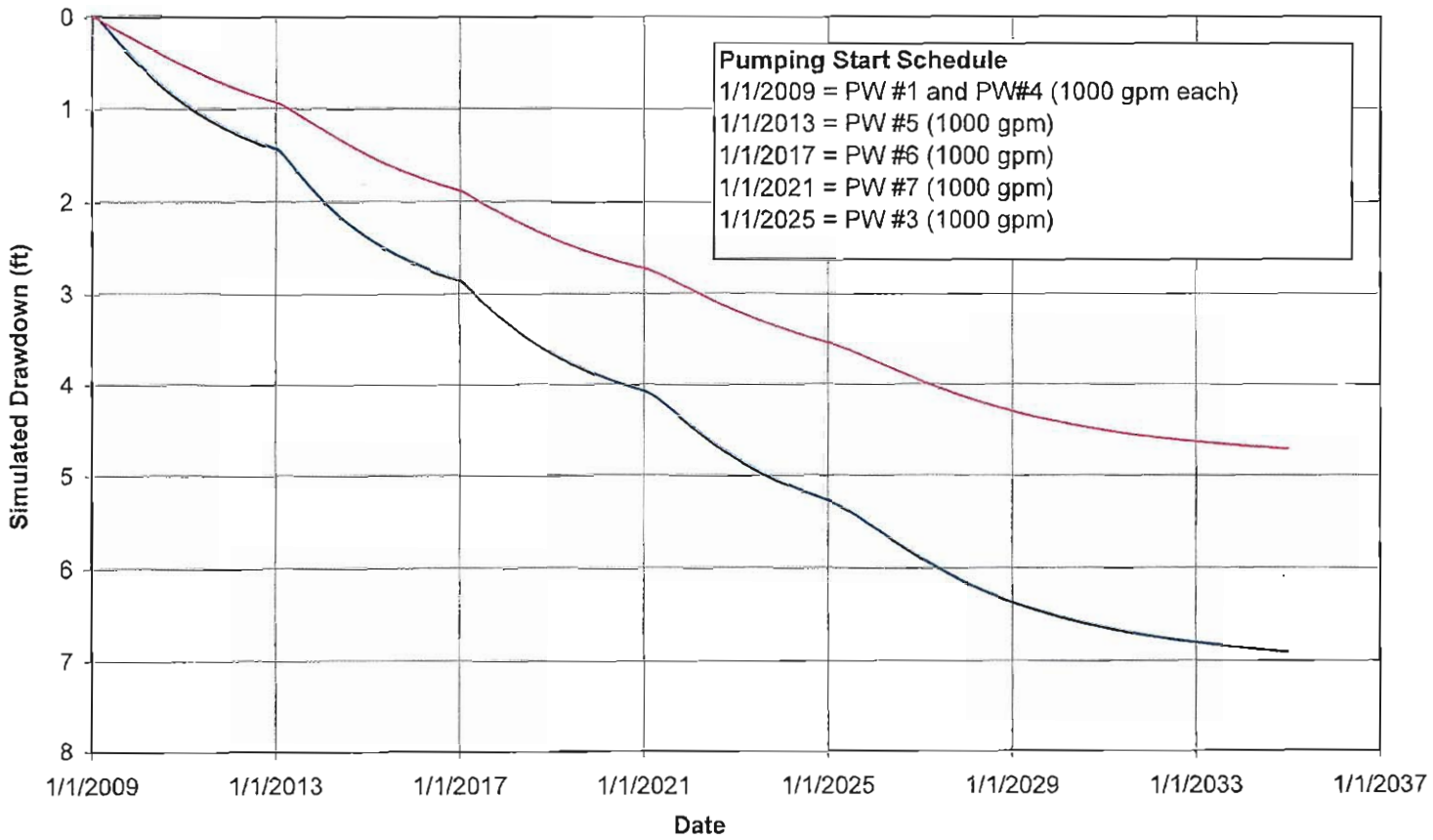


Figure 7-13 Simulated PGSA Drawdown at Lexington Hills #1 Well

M3 Eagle Model
JZ0705

PGG

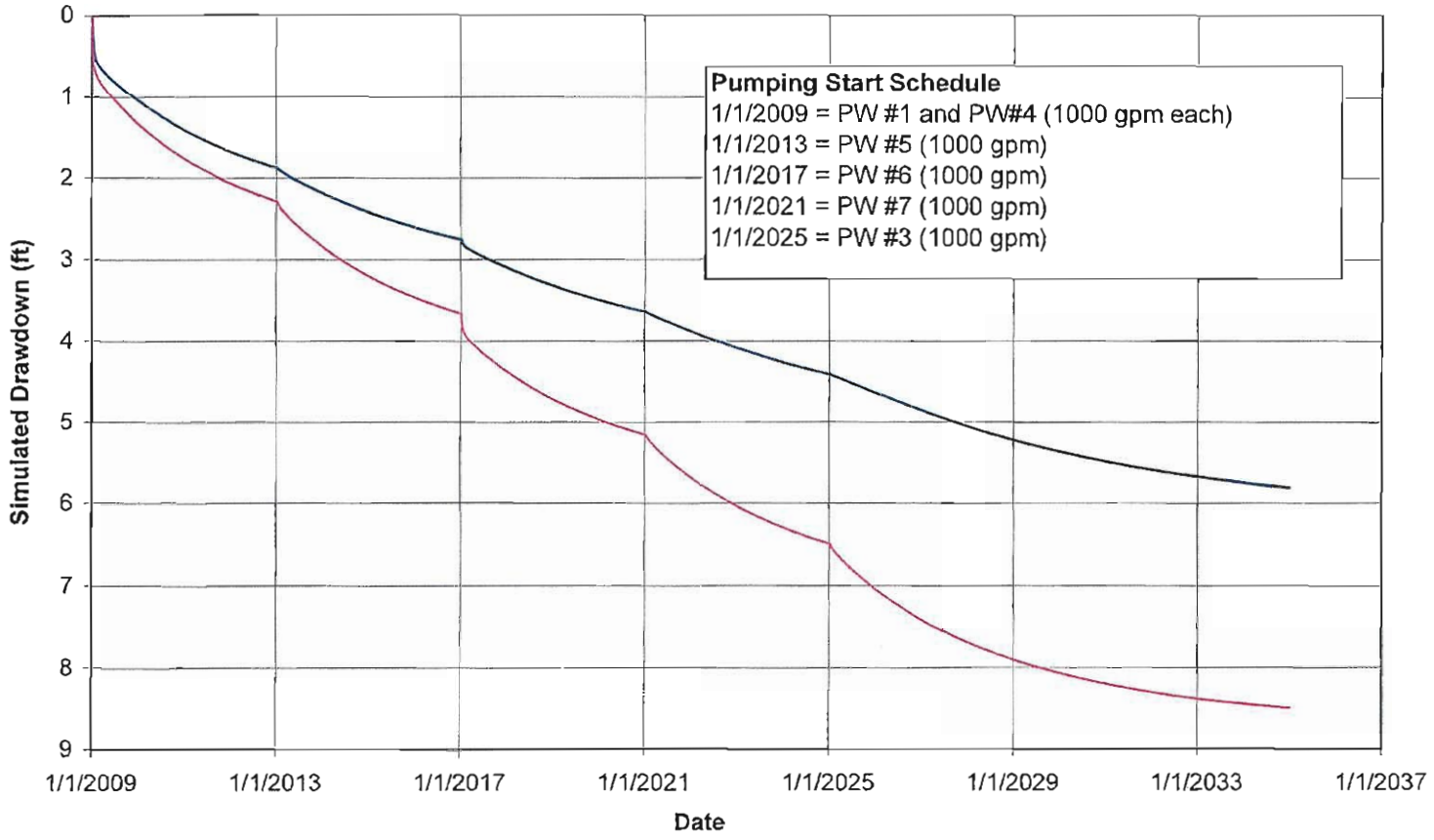
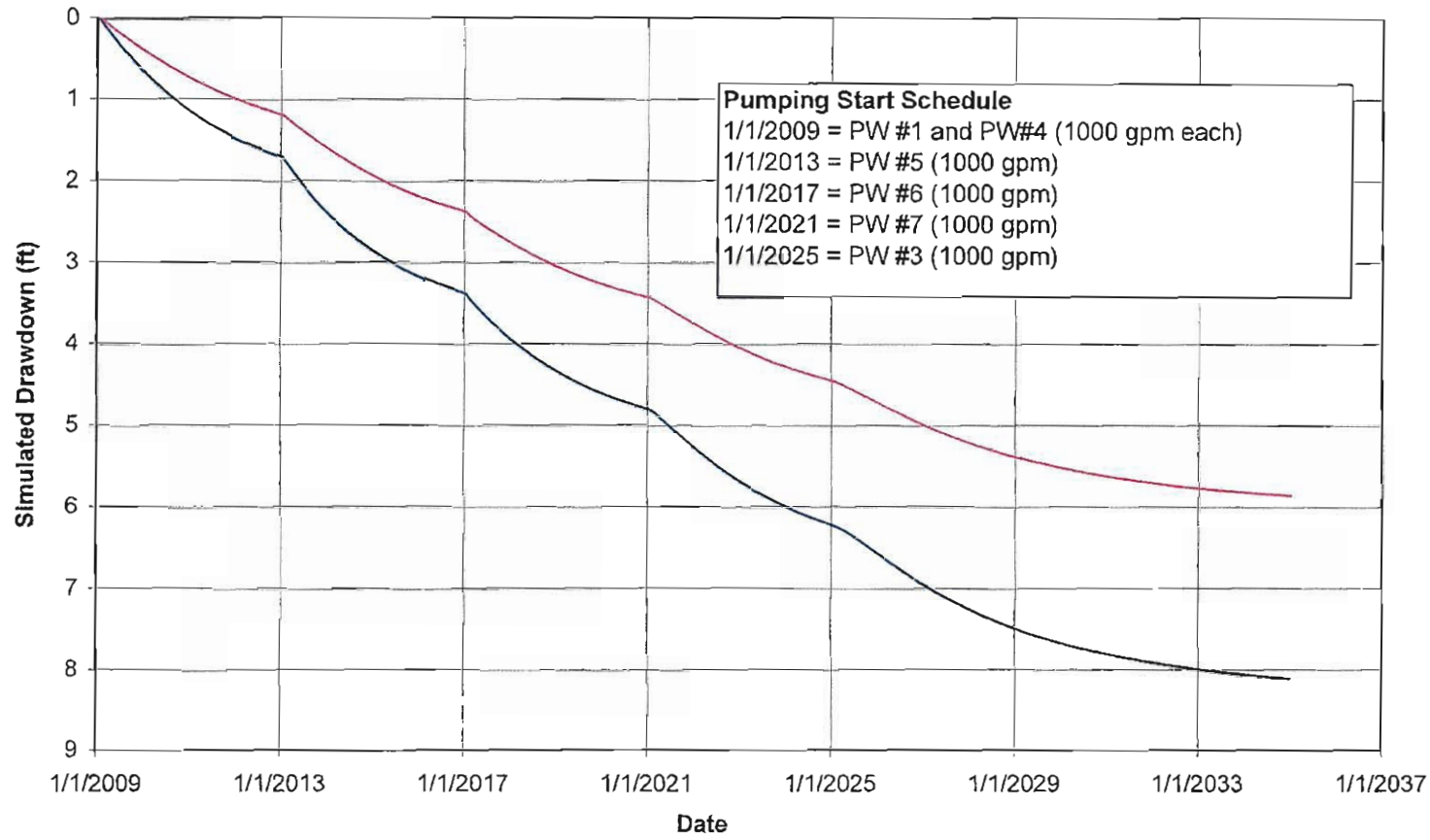


Figure 7-14 Simulated PGSA Drawdown at Star #3 Well

M3 Eagle Model
JZ0705

PgG



Hmatch Model

Tmatch Model

Figure 7-15 Simulated PGSA Drawdown at Floating Feather Well

M3 Eagle Model
JZ0705

PgG

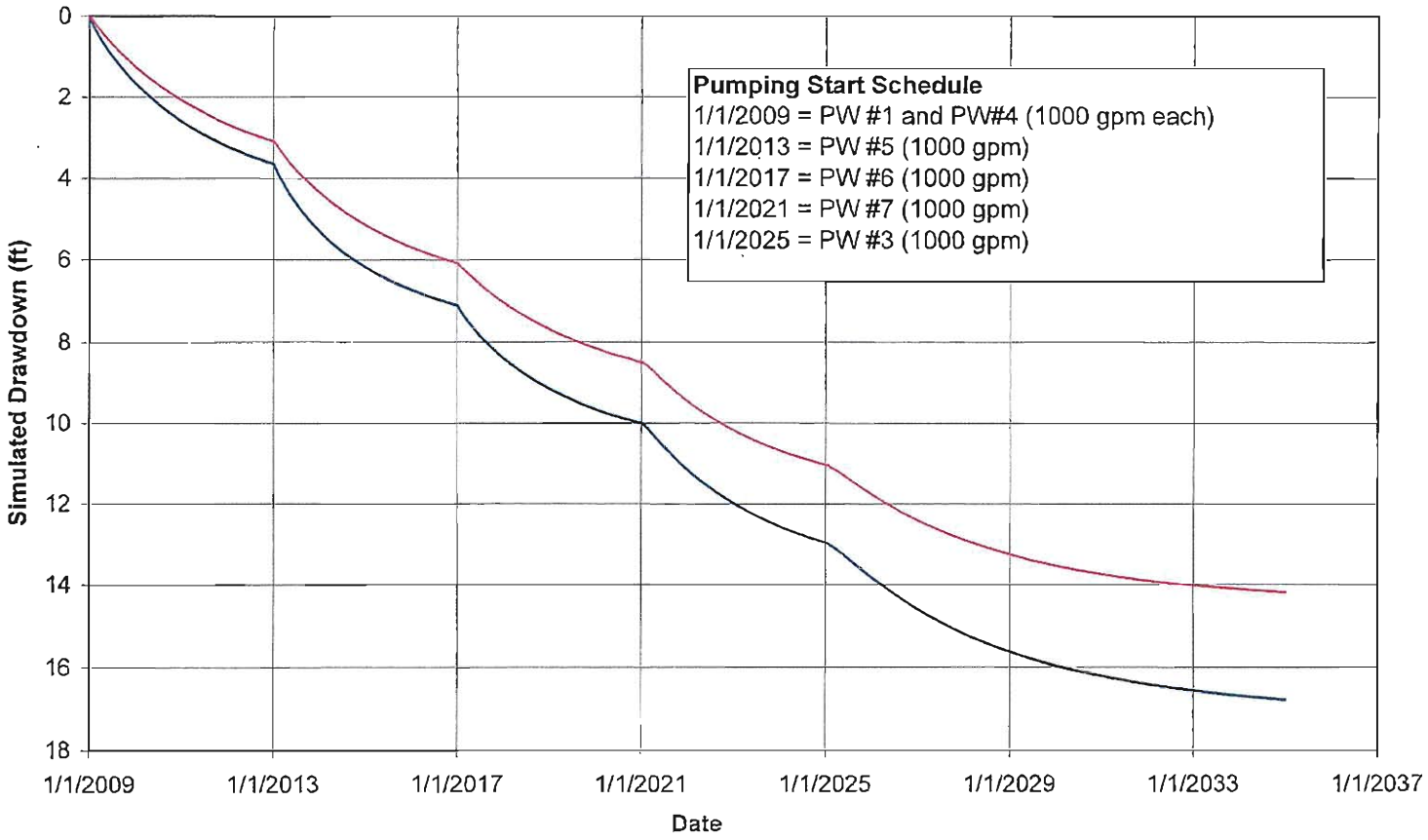
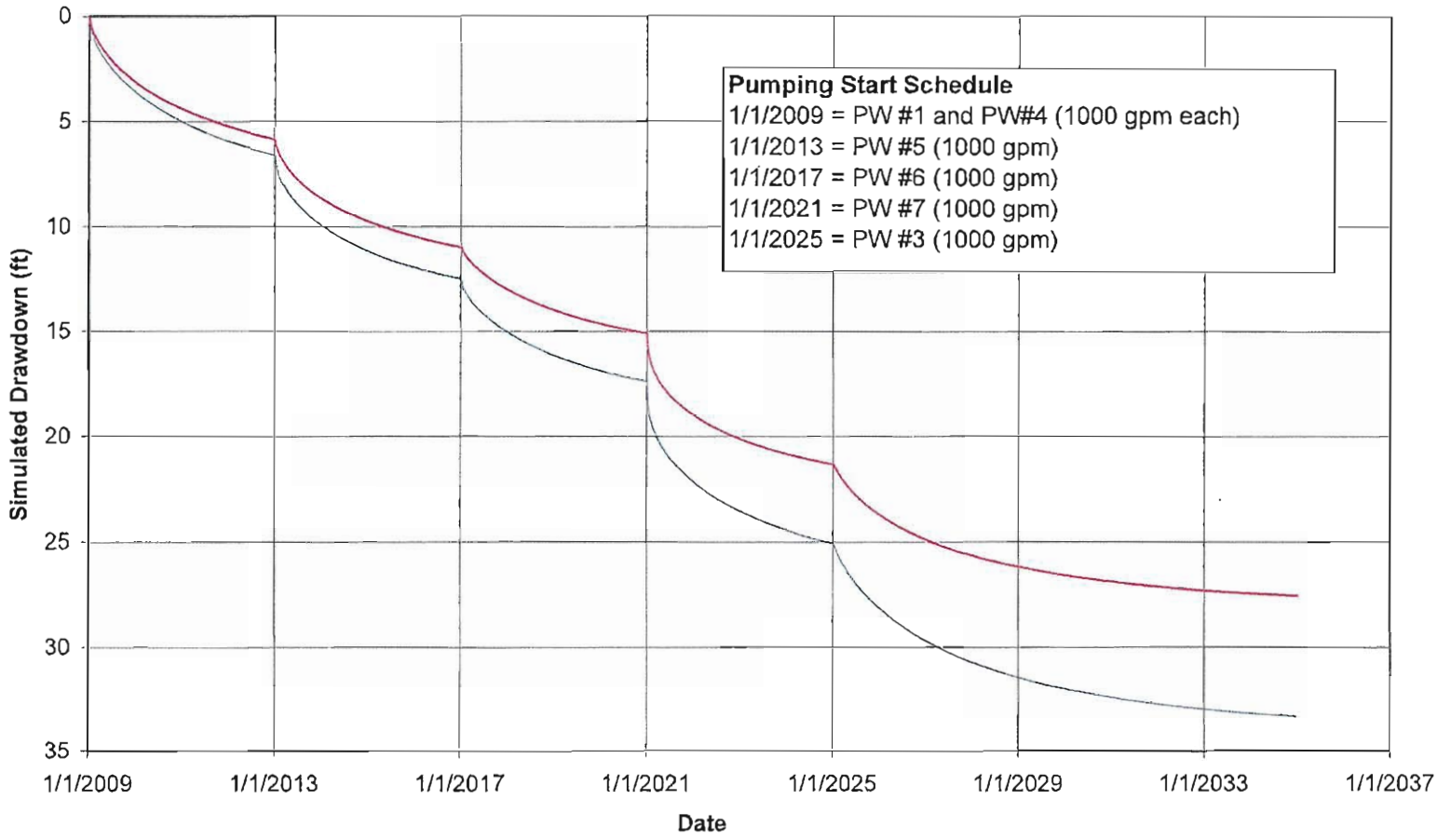


Figure 7-16 Simulated PGSA Drawdown at Homer Road

M3 Eagle Model
JZ0705

PGG



Hmatch Model

Tmatch Model

Figure 7-17 Simulated PGSA Drawdown at M3 Property

M3 Eagle Model
JZ0705

PGG

APPENDIX B –PGG MEMORANDA

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PACIFIC groundwater GROUP

Technical Memorandum

To:	Mark Utting (Hydro Logic, Inc.)
From:	Dawn Chapel and Peter Schwartzman (Pacific Groundwater Group)
Re:	Transient Calibration to the SVR #7 Pumping Test (M3 Eagle Groundwater Flow Model)
Date:	July 26, 2008

This memo summarizes the results of Pacific Groundwater Group's (PGG's) transient calibration of the M3 Eagle groundwater flow model to a recent hydraulic analysis of the 9-day SVR #7 constant rate pumping test in the Pierce Gulch Sand Aquifer (PGSA). The M3 Eagle model was previously developed and calibrated to both steady-state and transient conditions. The additional calibration effort was requested to see how well the current model simulates hydraulic responses observed at this more recent test and to perform a local model calibration if necessary. The following sections summarize the original model calibration effort, our transient calibration to the SVR #7 pumping test, and our assessment of this new calibration.

ORIGINAL MODEL DEVELOPMENT AND CALIBRATION

The M3 Eagle model was previously developed and calibrated to both steady-state and transient conditions. Two steady-state calibrations were developed with favorable results – one that emphasized best fit to interpreted aquifer transmissivity values ("Tmatch") and the other that emphasized best fit to observed groundwater levels ("Hmatch"). Transient calibrations included simulation of drawdown responses observed during the 30-day Lexington Hills #1 and the 7-day Eaglefield #2 pumping tests. The location of these test wells are shown in **Figure 1**. The Hmatch model was calibrated to both the Eaglefield #2 and Lexington Hills #1 pumping test with favorable results. A transient calibration of the Tmatch model was attempted for the Eaglefield #2 pumping test but was less favorable without a substantial reduction to the steady state calibrated transmissivity value. Since the Tmatch model was developed to emphasize a best fit to transmissivity, the transmissivity values developed in the steady-state calibration (i.e. close to values interpreted from pumping tests) were used for the predictive simulations.

Predictive simulations were run with both models to predict the effects on the groundwater flow system from proposed pumping at the M3 site. Results of the two model predictions were similar. The original model development, calibration, and predictive simulations were documented in the *M3 Eagle Groundwater Flow Model and Analysis of Pumping Impact* report to Hydro Logic, Inc. (PGG, 2008).

TRANSIENT CALIBRATION TO SVR #7 PUMPING TEST

Hydro Logic Inc. (HLI) requested that PGG perform model runs to ascertain whether the existing model(s) readily simulate the SVR #7 pumping test. Favorable results were achieved with the both the Hmatch and Tmatch models with local model refinements. The following sections describe the SVR #7 pumping tests, observation data, and PGG's transient calibration.

SVR #7 PUMPING TEST

HLI provided PGG with the pumping rate and observed aquifer drawdown values for the 9-day SVR #7 constant rate pumping test in the PGSA. Drawdown hydrographs were provided for two observation wells, the Big Gulch Stock well and the TW #4 Zone 2 well. The location of the SVR test wells are shown in **Figure 1**. HLI provided 20 representative drawdown values over the course of the 9-day test for each well. Big Gulch is located approximately 900-ft southwest of SVR #7 and TW #4 is located approximately 4,500-ft southwest of SVR #7. SVR #7 was pumped at a constant rate of 916 gallons-per-minute over the 9-day period.

Based on well completion elevations and screen lengths, HLI estimated SVR #7 well to be completed in the middle portion of the PGSA (model layer 6); the Big Gulch Stock well to be completed in the top of the PGSA (model layer 5); and the TW #4 well to be completed through the entire PGSA (model layers, 5, 6, and 7).

CALIBRATION AND SIMULATION OF THE SVR #7 PUMPING TEST

PGG used the Hmatch and Tmatch models to simulate the SVR #7 pumping test. Wells were placed in aquifer layers as described above. The transient simulation consisted of two stress periods; the first stress period consisting of 100 days of simulation with no pumping followed by the second stress period consisting of 9 days of simulation with pumping[1]. The model also simulates long term average pumping rates for irrigation, municipal, and domestic use, which were included in the initial Hmatch and Tmatch model calibrations as described in the PGG's original report (PGG, 2008).

A limited calibration effort was employed to match the observed drawdowns by adjusting model parameters within acceptable ranges in the vicinity of the SVR #7 pumping test.

The result of the calibration effort for the Hmatch model was a slight increase in local hydraulic conductivity in the PGSA such that a portion of Zone 3 (125 ft/day) was replaced with Zone 20 (160 ft/day) as shown on **Figure 1** and a decrease in local PGSA storage coefficient (S-value) such that a portion of Zone 2 (0.005) was replaced with

[1] PGG commonly employs this practice to establish that, prior to imposing new stresses, the transient model exhibits quasi steady state behavior. Steady state heads are used as initial conditions for the transient model.

Zone 3 (0.0005) as shown on **Figure 3**. The result of the calibration effort for the Tmatch model was also a slight decrease in the local hydraulic conductivity in the PGSA from 200 ft/day to 160 ft/day (Zone 12) as shown on **Figure 2**, and the same decrease in the local PGSA S-value performed on the Hmatch model (**Figure 3**). In addition, storage coefficient Zone 3 was assigned an Sy value of 0.025 rather than the value of 0.1 used in the Hmatch model. The reduction in the Sy-value for the Tmatch model was required due to nearby model cells in the Tmatch model within the PGSA converting to unconfined as described below.

The location of these localized model adjustments are shown in **Figures 1 through 3.** Additional documentation of model property zonation is presented in PGG, 2008.

The calibration for both models involved a balance between matching the observed drawdown at the Big Gulch well and the observed drawdown at the TW #4 well (**Figures 4 and 5**). Simulations of the observed drawdowns for both models were sensitive to the storativity value and required an order of magnitude decrease from the original S-value of 0.005 (Zone 2) to a new value of 0.0005 (Zone 3). This value is similar to the S-value of 0.00035 to the west (Zone 1) in the original model and reflects the spatial heterogeneity of aquifer properties within the PGSA. The Tmatch model also required a reduction in the local Sy-value from 0.1 (Zone 2) to 0.025 (Zone 3) due to nearby cells converting to unconfined. The SVR #7 pumping test is located in an area of the model where the PGSA is not fully saturated; unsaturated conditions occur in the overlying cells. When a model cell is not fully saturated, MODFLOW converts to using the Sy-value for storage calculations during a transient simulation. In the Tmatch model partial saturation cells within the PGSA are located in the immediate vicinity of the SVR #7 pumping well, whereas they are located further north in the Hmatch model. The simulated drawdown with the Tmatch model is therefore more sensitive to the value of Sy-value assigned in this area of the model. The required reduction of Sy from 0.1 to 0.025 to match the observed drawdown in the Tmatch model suggests a more "semi-confined" aquifer response. Sediment cementation has been observed in the PGSA in this area and therefore supports the interpretation of a locally semi-confined response.

The simulated drawdowns in both wells using the parameters described above provide a reasonable fit to the observed drawdowns (**Figures 4 and 5**). The maximum simulated drawdown at the end of the 9-day test in the nearby Big Gulch observation well was within 12% of the observed drawdown for the Hmatch model and 2% for the Tmatch model. During the middle time of the test, the two versions of the model bracket the observed drawdown at the Big Gulch observation well, with the Hmatch model simulated drawdown being about 7% lower than the observed drawdown and the Tmatch model simulated drawdown being about 5% higher than the observed drawdown.

The simulated drawdown in the more distant TW #4 observation well was almost identical for both versions of the model, with the maximum simulated drawdown being within 4% of the observed drawdown for the Hmatch model and within 6% of the observed drawdown for the Tmatch model (**Figures 4 and 5**)

ASSESSMENT OF NEW CALIBRATION AND FUTURE WORK

Our calibration involved a refinement of aquifer parameter values within the vicinity of the SVR #7 pumping test. Localized changes to aquifer properties provided a reasonable calibration to the observed drawdowns. To assess the effects of these localized model changes in other areas of the model domain, PGG used the newly calibrated Hmatch model to simulate the 7-day Eaglefield #2 pumping test (4 miles south of the SVR #7 site) that was used in the original calibration. The results, shown in **Figure 6,** indicate the localized refinements have little to no effect on the original calibration. The simulated and observed drawdowns for the Eaglefield #2 match very well – as they did in the original calibration.

The newly calibrated model was not used to assess the effects of the localized model refinements on the 30-day Lexington Hills #1 pumping test; although, given it's location of approximately 5.5 miles to south, it is our opinion that the effects are likely insignificant.

The newly calibrated models were also not used to assess changes to the PGSA drawdowns associated with proposed M3 Eagle pumping that were previously predicted by PGG (PGG, 2008). However, based on the facts that long term (26-year) predicted drawdowns were very similar to steady-state drawdown predictions (thus making long-term predictions insensitive to "S") and that changes to the model were small and local, PGG expects similar drawdown predications of long-term drawdown associated with the M3 Eagle project. While changes in long-term drawdowns are expected to be minimal, the time-evolution of the drawdown distribution may proceed faster than originally estimated due to the lower S/Sy values. Therefore, PGG recommends that both newly calibrated model versions are used to update existing long term PGSA drawdown predictions from proposed pumping at the M3 site.

Figure 1: Local PGSA K-Zones and Location of Pumping Test Wells (Hmatch Model)

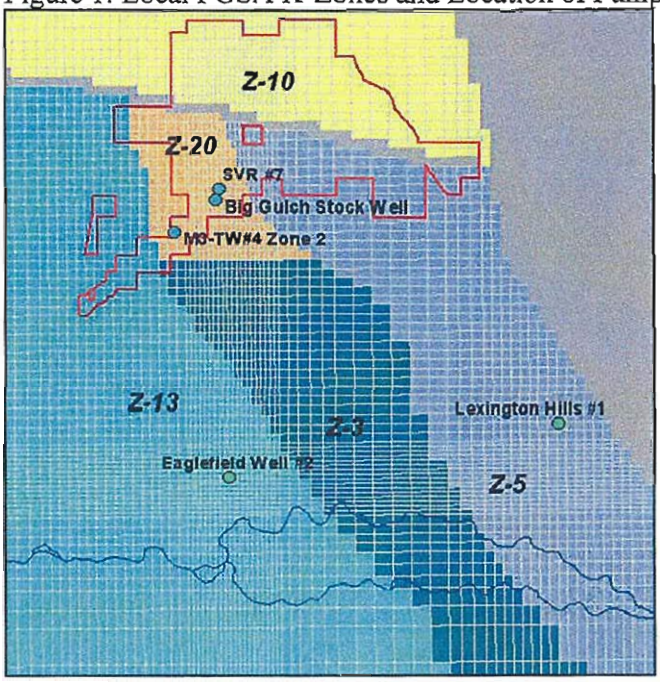


Figure 2: Local PGSA K-Zones and Location of Pumping Test Wells (Tmatch Model)

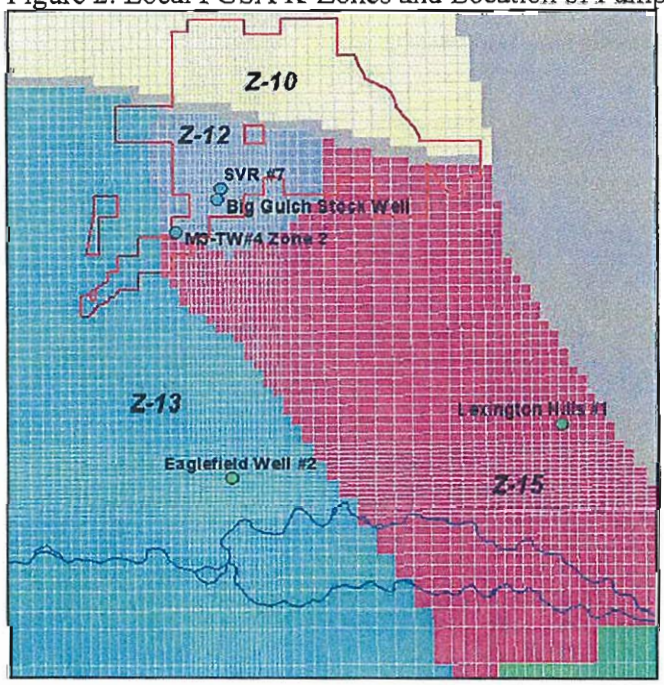


Figure 3: Local PGSA S-Zones and Location of Pumping Test Wells (Both Models)

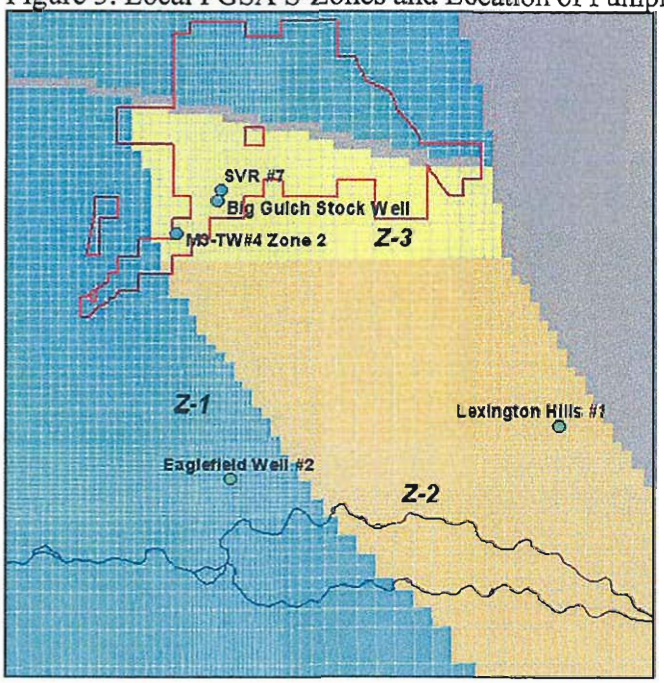


Figure 4: Simulated and Observed Drawdown SVR #7 Pumping Test (Hmatch Model)

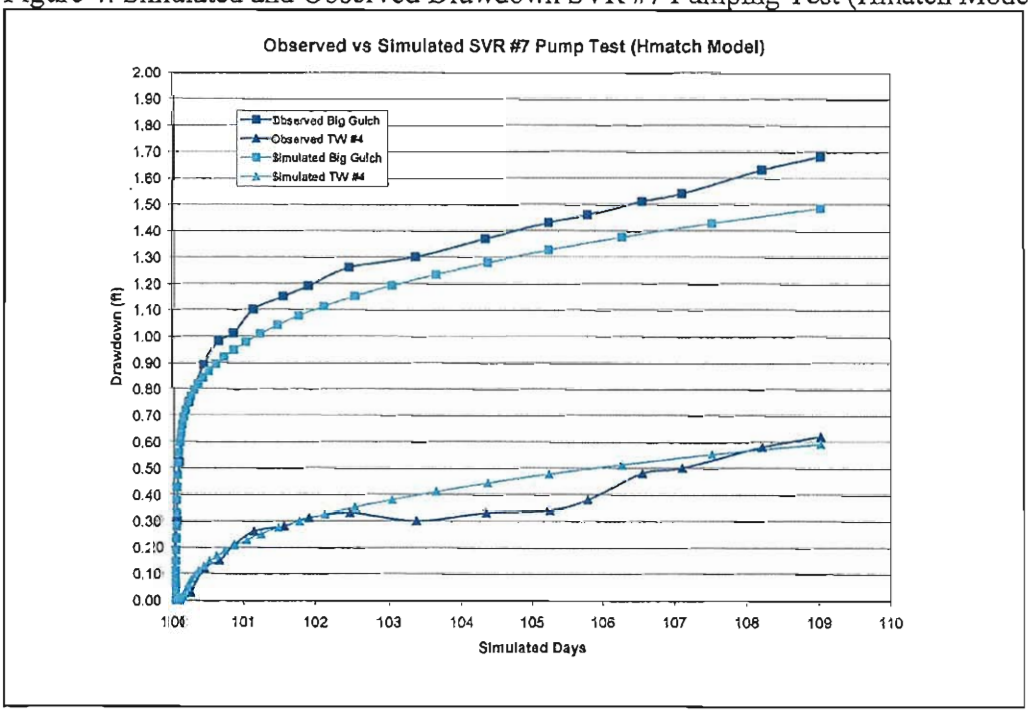


Figure 5: Simulated and Observed Drawdown SVR #7 Pumping Test (Tmatch Model)

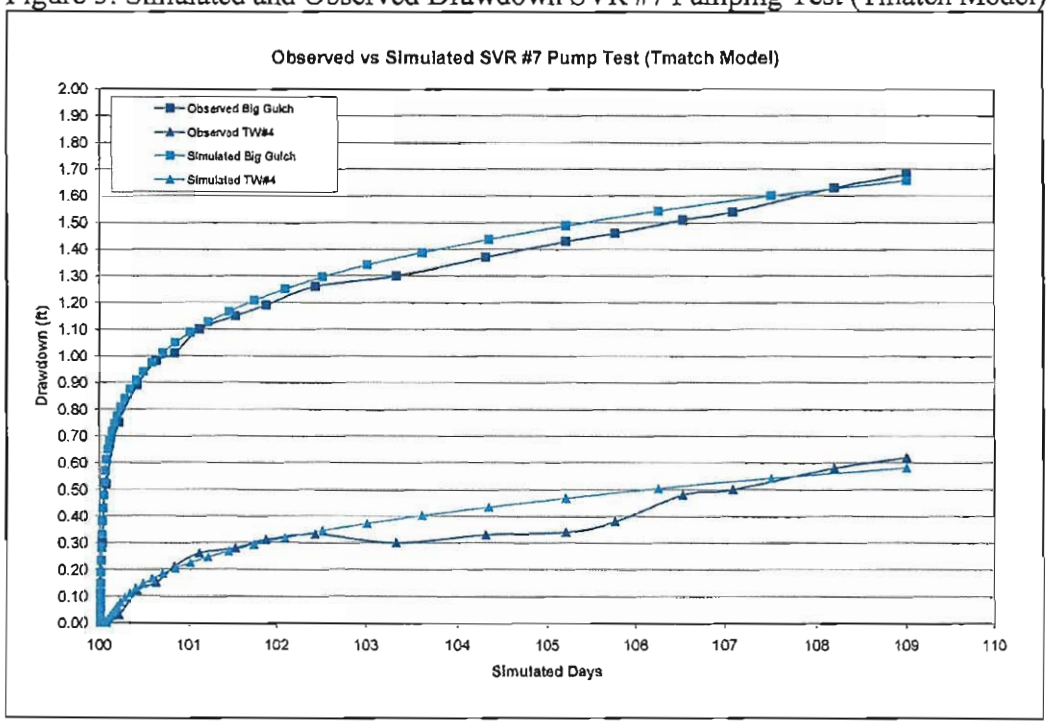
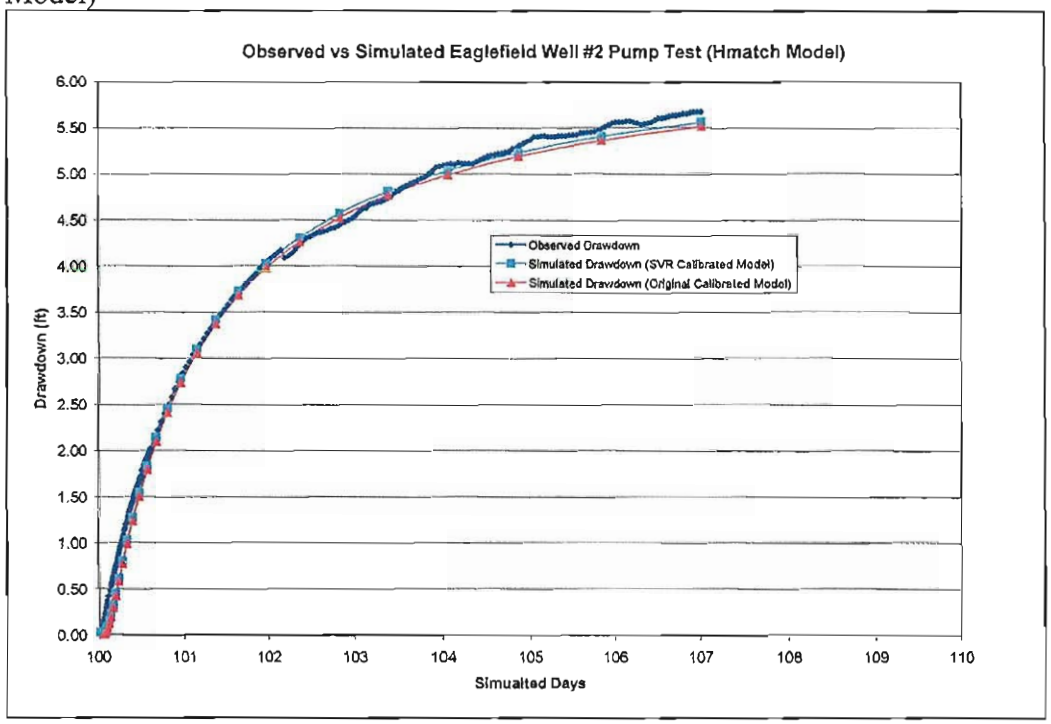


Figure 6: Simulated and Observed Drawdown Eaglefield Well #2 Pumping Test (Hmatch Model)



PACIFIC groundwater GROUP

Technical Memorandum

To:	Mark Utting (Hydro Logic, Inc.)
From:	Dawn Chapel and Peter Schwartzman (Pacific Groundwater Group)
Re:	50-Year Drawdown Simulation with Proposed NPW wells (M3 Eagle Groundwater Flow Model)
Date:	September 22, 2008

This memo summarizes the results of Pacific Groundwater Group's (PGG's) simulation of drawdown from three proposed wells (NPW #1, #2, and #3) using the M3 Eagle groundwater flow model.

The M3 Eagle model was originally developed and calibrated to both steady-state and transient conditions and resulted in two model versions – one that emphasized best fit to interpreted aquifer transmissivity values ("Tmatch") and the other that emphasized best fit to observed groundwater levels ("Hmatch"). Using the two models in predictive simulations allows for a bracketing of results with the Hmatch model more "conservative" (likely to predict larger impacts) than the Tmatch model which is likely to predict smaller impacts.

Local refinements were later made to both models for an additional transient calibration to data recently generated from the SVR #7 pumping test in the Pierce Gulch Sand Aquifer (PGSA). The results of the later calibration were favorable and PGG and Hydro Logic Inc. (HLI) agreed that the newly calibrated models should be used to update predictive drawdown at the M3 site.

The following sections summarize these prior calibration efforts and the results of the simulated drawdown associated with the proposed NPW wells using the newly calibrated models.

ORIGINAL MODEL DEVELOPMENT AND CALIBRATION

The M3 Eagle model was previously developed and calibrated to both steady-state and transient conditions. Two steady-state calibrations were developed – one that emphasized best fit to interpreted aquifer transmissivity values ("Tmatch") and the other that emphasized best fit to observed groundwater levels ("Hmatch").

Transient calibrations included simulation of drawdown responses observed during the 30-day Lexington Hills #1 and the 7-day Eaglefield #2 pumping tests. The location of these test wells are shown in **Figure 1.** The Hmatch model was calibrated to both the

Eaglefield #2 and Lexington Hills #1 pumping test with favorable results. A transient calibration of the Tmatch model was attempted for the Eaglefield #2 but was less favorable without a substantial reduction to the steady state calibrated transmissivity value. Since the Tmatch model was developed to emphasize a best fit to transmissivity, the transmissivity values developed in the steady-state calibration (i.e. close to values interpreted from pumping tests) were used for the predictive simulations.

Predictive simulations were run with both models to predict the effects on the groundwater flow system from proposed pumping at the M3 site. Results of the two model predictions were similar. The original model development, calibration, and predictive simulations are documented in the *M3 Eagle Groundwater Flow Model and Analysis of Pumping Impact* report to Hydro Logic, Inc. (PGG, 2008).

TRANSIENT CALIBRATION TO SVR #7

HLI later requested that PGG perform additional calibration to simulate the 9-day SVR #7 constant rate pumping test. Favorable results were achieved with local refinements to both models. Well SVR #7 and nearby observation wells are shown in **Figure 1** and locally refined distributions of aquifer properties are shown in **Figures 1 through 3.**

The result of the SVR #7 transient calibration effort for the Hmatch model was a slight increase in local hydraulic conductivity in the PGSA such that a portion of Zone 3 (125 ft/day) was replaced with Zone 20 (160 ft/day) as shown on **Figure 1** and a decrease in local PGSA storage coefficient (S-value) such that a portion of Zone 2 (0.005) was replaced with Zone 3 (0.0005) as shown on **Figure 3.** The result of the calibration effort for the Tmatch model was also a slight decrease in the local hydraulic conductivity in the PGSA from 200 ft/day to 160 ft/day (Zone 12) as shown on **Figure 2,** and the same decrease in the local PGSA S-value performed on the Hmatch model (**Figure 3**). In addition, storage coefficient Zone 3 was assigned an Sy value of 0.025 rather than the value of 0.1 used in the Hmatch model. The reduction in the Sy-value for the Tmatch model was required due to nearby model cells in the Tmatch model within the PGSA converting to unconfined as described in the original technical memorandum (PGG, July 26, 2008). The reduction in Sy is consistent with HLI's interpretation of the PGSA being cemented beneath the M3 Eagle property along with a corresponding reduction in both porosity and Sy.

The effects of the local refinements on previous calibrations were also assessed with the new changes and we found little to no effect on the original calibration. The results of the SVR #7 calibration was documented by PGG in a technical memorandum *Transient Calibration to the SVR #7 Pumping Test (M3 Eagle Groundwater Flow Model)* dated July 26, 2008.

50 YEAR DRAWDOWN SIMULATION

PGG used the SVR #7 calibrated Hmatch and Tmatch models to simulate transient drawdown from three proposed wells operating for 50 years. HLI provided PGG with the location of the three proposed wells (NPW #1, #2, and #3) which are assumed to be fully screened within the PGSA (layers 5, 6, and 7). The locations of the three wells are shown in **Figure 4**. Each well was assigned an average constant pumping rate of 1500 gallons per minute. The transient simulation consisted of two stress periods; the first stress period consisting of 100 days of simulation with no pumping followed by the second stress period consisting of 50 years of simulation with pumping. The results of the simulations are discussed below.

50 YEAR DRAWDOWN RESULTS

The results of the 50 year simulation show that most of the drawdown occurs within the first 5 years of pumping and that relative equilibrium in the area of the pumping wells is achieved after about 20 years (**Figures 5 and 6**).

As was the case with the original model development, the Hmatch model simulates slightly higher drawdown than the Tmatch model. The maximum 50 year drawdown simulated in the PGSA (**Figures 7 and 8**) was 33-ft for the Hmatch model and 27-ft for the Tmatch model in the vicinity of Well NPW #3[1]. Drawdown values decreased to 5-ft or less in the vicinity of Boise River (approximately 4 miles south of the site) for the Hmatch model and 4-ft or less for the Tmatch model.

The maximum 50 year drawdown simulated in the Middle Aquifer[3] (layer 3) above the PGSA was 22-ft for the Hmatch model and 16-ft for the Tmatch model with drawdown values decreasing to 2-ft or less in the vicinity of the Boise River for both models (**Figures 9 and 10**). Note that in both models most of layer 3 is dry beneath the project site (north of the NPW wells) both before and after the proposed water supply wells were added to the model.

Small scale numerical noise in the drawdown distribution in the Middle Aquifer can be seen in **Figure 9** (isolated 5-ft drawdown contour between the continuous 10-ft and 5-ft contour intervals). This is due to predictive simulations of drawdown in the shallow portions of the model (layers 1 through 4) being affected by the variability of saturation in the upper layers of the model. This variable saturation is expressed as dry cells, and additional dry cells are created during the predictive simulations of NPW pumping. Creation of new dry cells in the shallowest layers cause some degree of "noise" in the distribution of predicted drawdown in underlying cells, in which simulated drawdown may be somewhat under predicted in isolated areas. This occurs when a model cell in the uppermost

[1] Note that the models cannot be used to estimate the drawdowns in the pumping wells because drawdown is averaged over the entire associated model cell (The cell dimensions at NPW #3 are 660-ft x 660-ft).
[3] The Middle Aquifer (layer 3) is also referred to as the "shallow, unnamed, alluvial aquifer overlying the Pierce Gulch Sand Aquifer"

layer (layer 1) becomes dry during the simulation and recharge gets apportioned to the next lowest layer. Layer 2 is an aquitard, and direct apportionment of recharge can raise the head locally in the receiving cell and the underlying cell in layer 3, thus causing an apparent reduction in local drawdown. This relic noise can be seen in **Figure 9** with the isolated 5-ft drawdown contour between the continuous 10-ft and 5-ft contour intervals. While local areas influenced by such relic noise tend to underpredict drawdown, the order of magnitude of model drawdown predictions in this general region of the model is still believed to be reasonable and representative.

Figure 1: Local PGSA K-Zones in PGSA (Hmatch model)

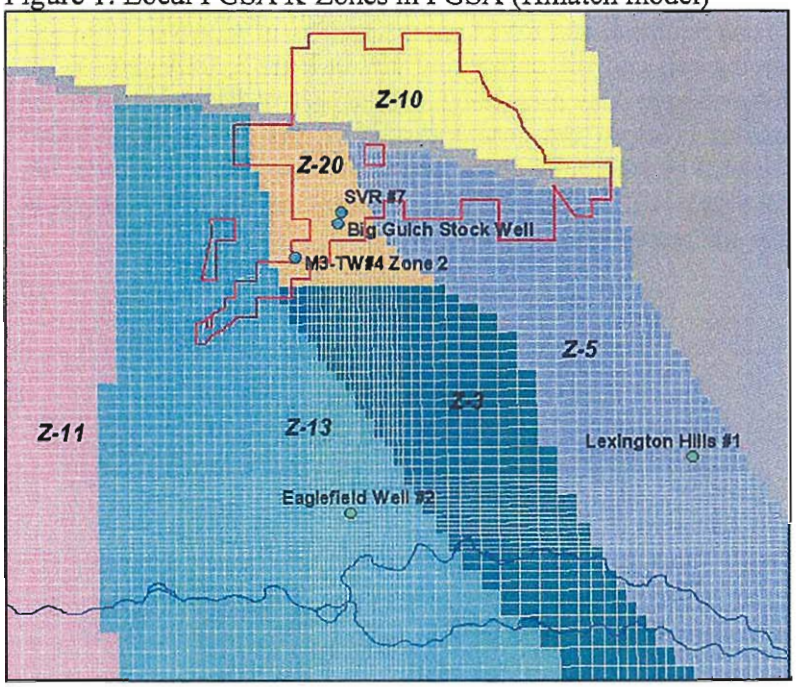


Figure 2: Local PGSA K-Zones in PGSA (Tmatch model)

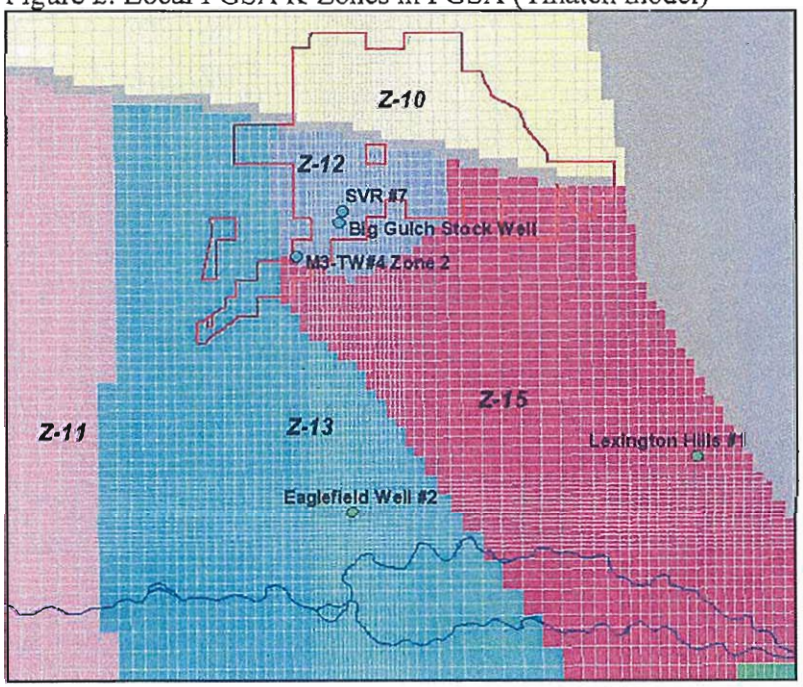


Figure 3: S-Zones in PGSA (Both models)

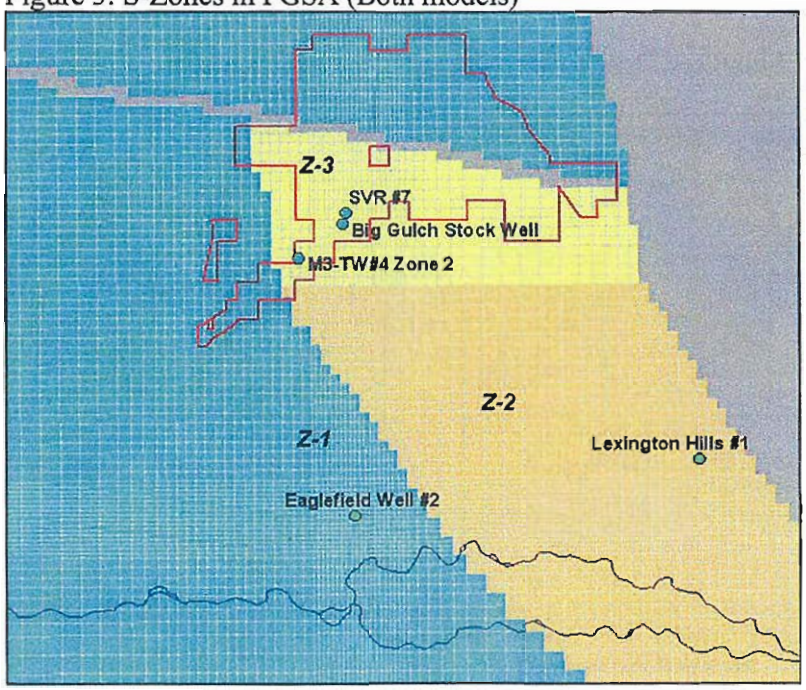


Figure 4: Location of Proposed NPW Pumping Wells

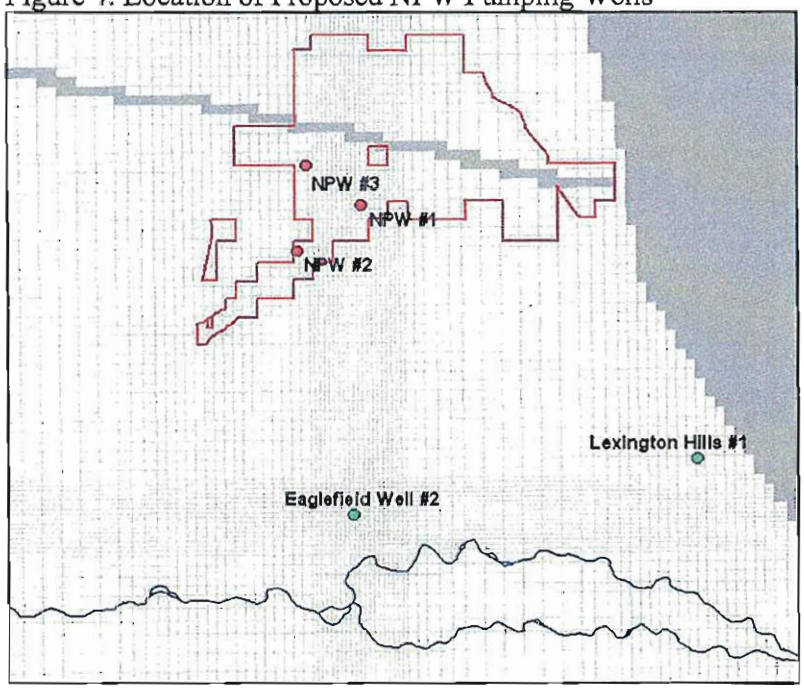


Figure 5: Percent of Total Simulated Drawdown at Pumping Wells (Hmatch)

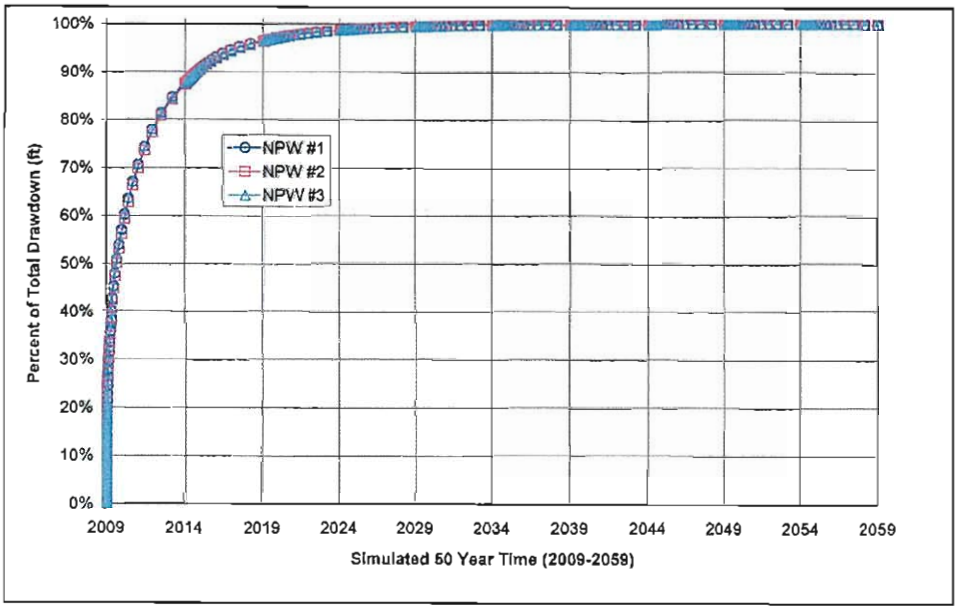
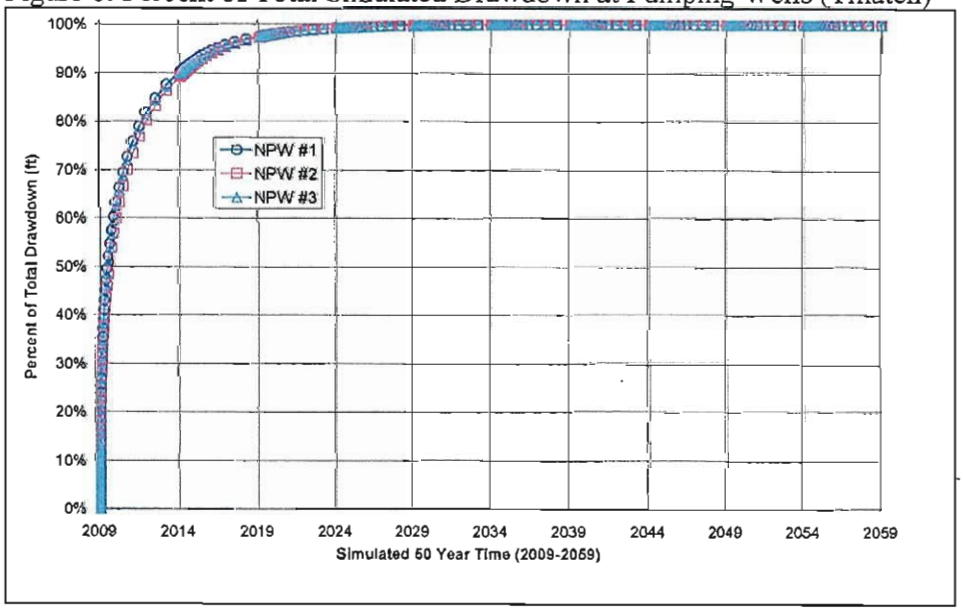


Figure 6: Percent of Total Simulated Drawdown at Pumping Wells (Tmatch)



NPWwells_DD_PGSA_50_Hmatch.mxd

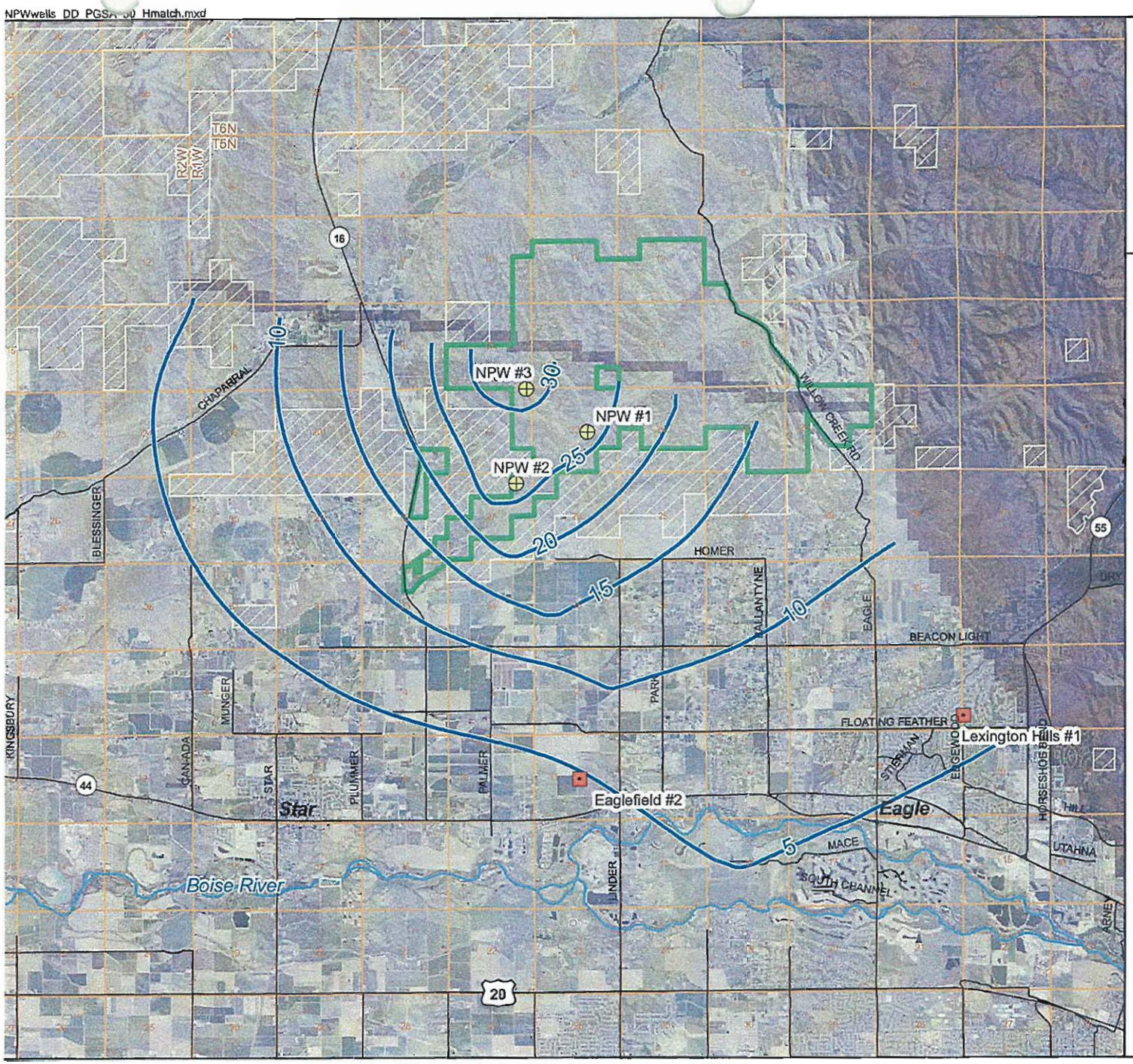


Figure 7

Simulated PGSA Drawdown After 50 Years (NPW wells) - Hmatch Model

M3 Eagle Model
JZ0705

- NPW Wells (Pumping at 1500 GPM)
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

PGG

0 Feet 8,000

2006 Orthophoto

N

NPWwells_DD_Plot_50_Tmatch.mxd

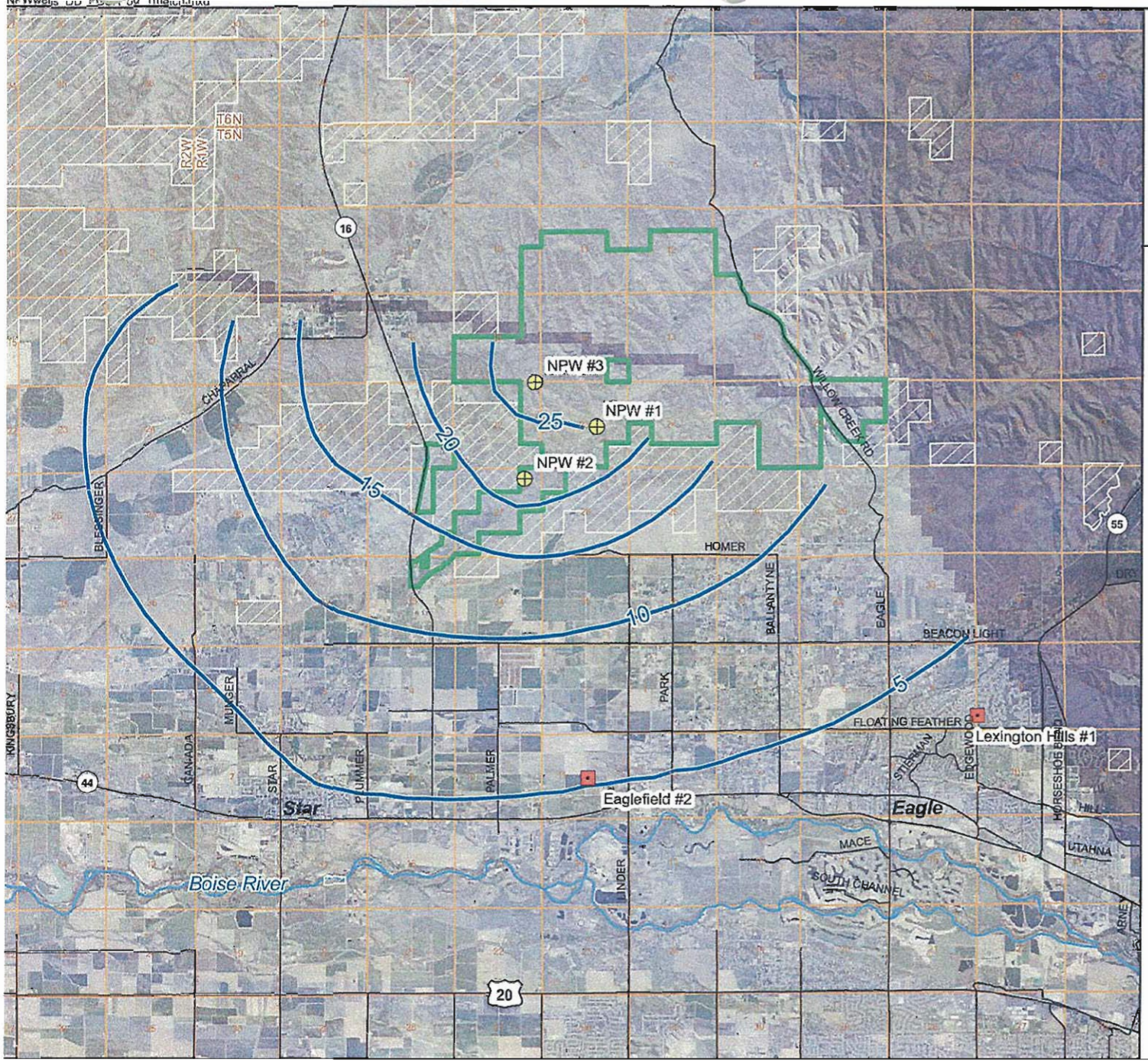


Figure 8

Simulated PGSA Drawdown After 50 Years (NPW wells) - Tmatch Model

M3 Eagle Model
JZ0705

- NPW Wells (Pumping at 1500 GPM)
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

PgG

0 Feet 8,000

2006 Orthophoto

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NPWwells_DD_Middle_50_Hmatch.mxd

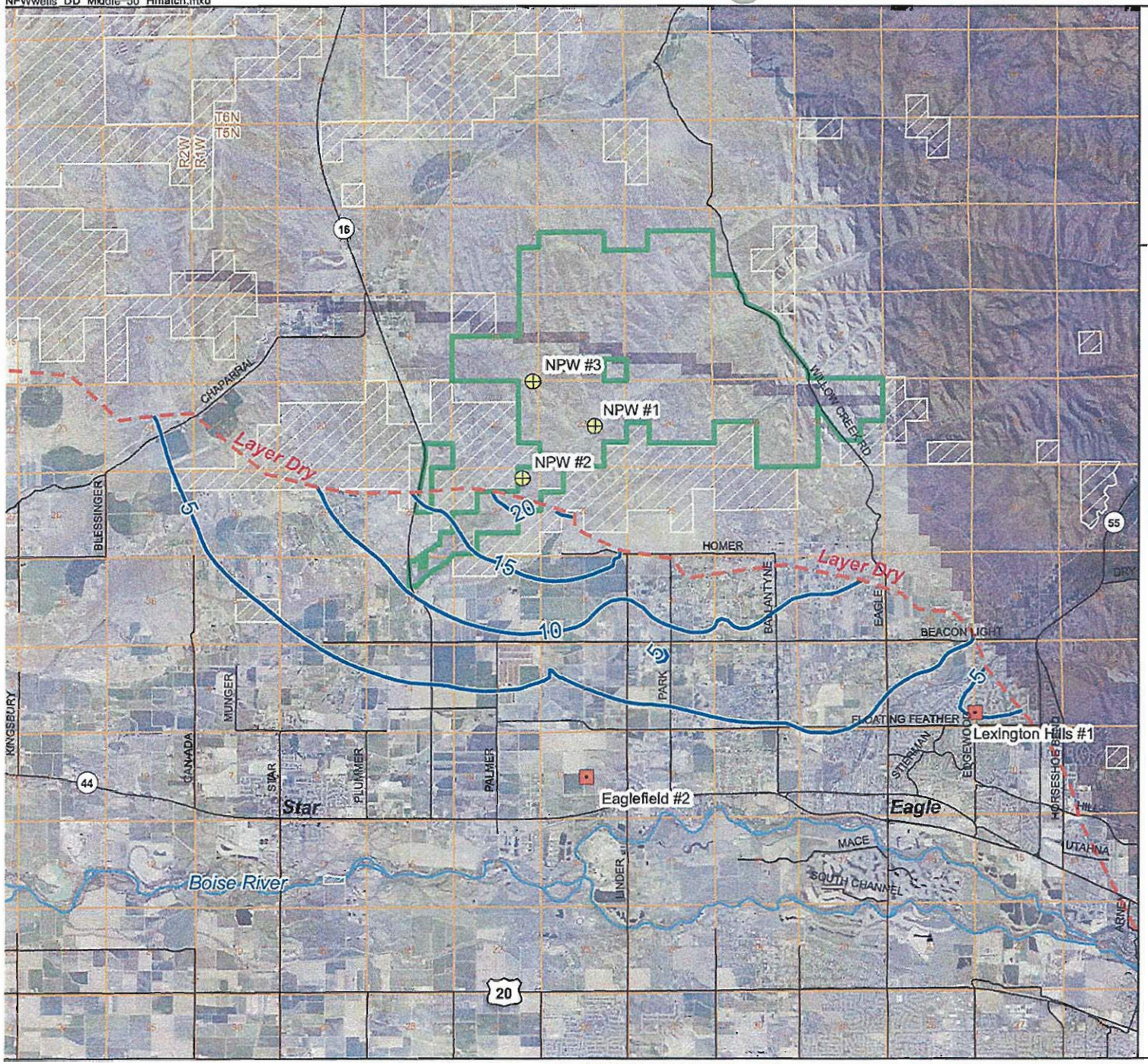

Figure 9

Simulated Middle Aquifer Drawdown After 50 Years (NPW wells) - Hmatch Model

M3 Eagle Model
JZ0705

- NPW Wells (Pumping at 1500 GPM)
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
  - Isolated 5-ft contour reflects numerical noise associated with overlying model cell going dry.
- No Flow Zones
- Site Boundary
- BLM Lands

PGG

0 Feet 8,000

2006 Orthophoto

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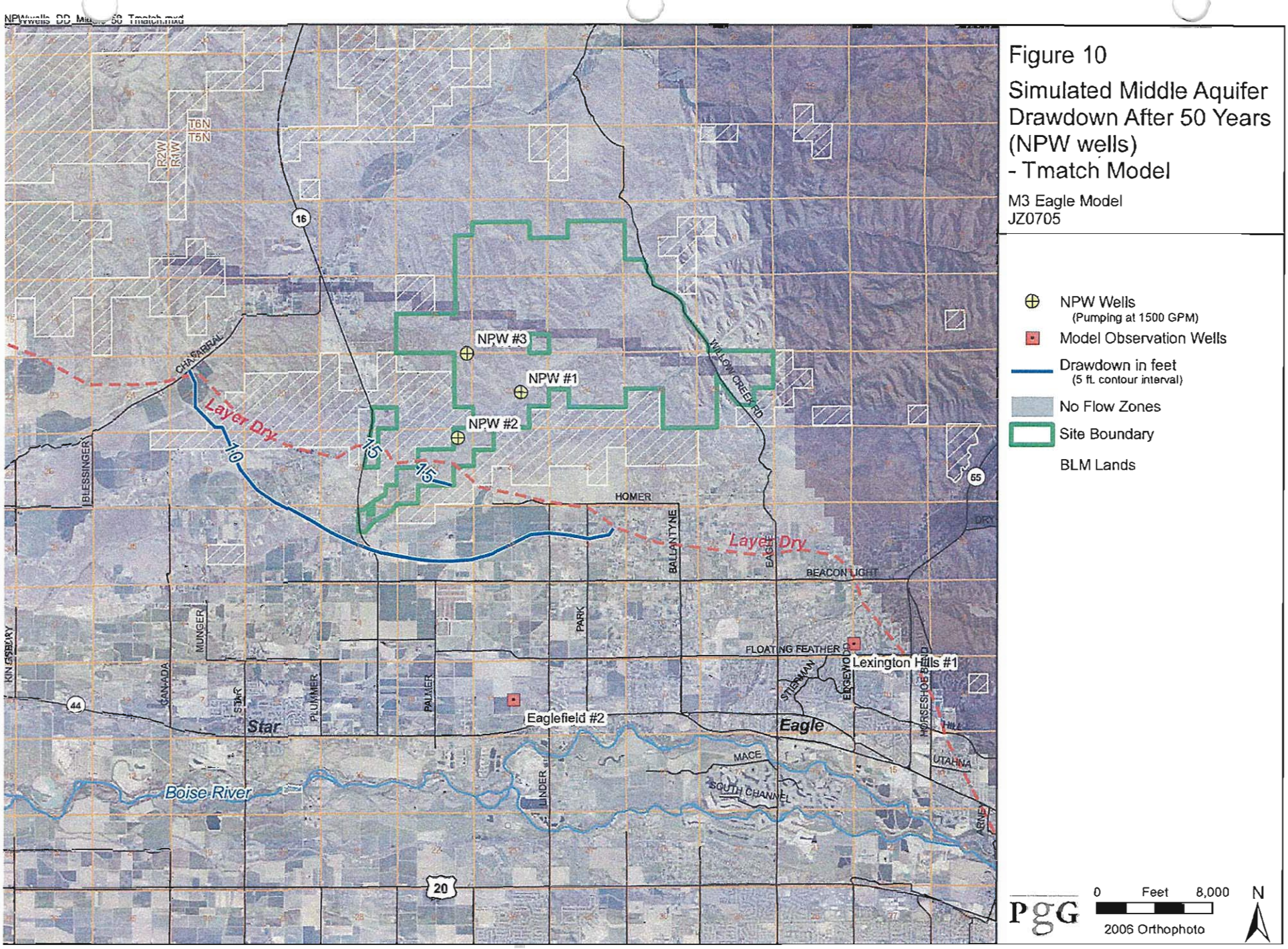


Figure 10

Simulated Middle Aquifer Drawdown After 50 Years (NPW wells) - Tmatch Model

M3 Eagle Model
JZ0705

- NPW Wells (Pumping at 1500 GPM)
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

PgG

0 Feet 8,000

2006 Orthophoto

N

PACIFIC groundwater GROUP

Technical Memorandum

To:	Mark Utting (Hydro Logic, Inc.)
From:	Dawn Chapel and Peter Schwartzman (Pacific Groundwater Group)
Re:	Model Refinement and Recalibration; Re-simulation of 50-year Drawdown; and Assessment of Affects of Reduced Canal Leakage (M3 Eagle Groundwater Flow Model)
Date:	November 14, 2008

This memo summarizes Pacific Groundwater Group's (PGG's) results for model refinement and recalibration associated with additional pumping introduced to the M3 Eagle groundwater flow model. The memo also presents new simulation results of drawdown from three proposed wells (NPW #1, #2, and #3) at the M3 Site using the refined model. Finally, the effects from a 20% reduction in recharge to the Pierce Gulch Sand Aquifer (PGSA) from reduced leakage in the New York canal are evaluated with the model. These topics are preceded by a review of prior development of the groundwater flow model.

PRIOR MODEL DEVELOPMENT

The M3 Eagle model was originally developed and calibrated to both steady-state and transient conditions and resulted in two model versions – one that emphasized best fit to interpreted aquifer transmissivity values ("Tmatch") and the other that emphasized best fit to observed groundwater levels ("Hmatch") The original modeling effort included predictive simulations of drawdown from progressively more pumping wells at the M3 Site over a 26 year period. The original model development, calibration, and predictive simulations are documented in the *M3 Eagle Groundwater Flow Model and Analysis of Pumping Impact* report to Hydro Logic, Inc. (PGG, 2008).

Local refinements were later made to both versions of the model for an additional transient calibration to the SVR #7 pumping test. The results of this calibration were favorable and PGG and HLI agreed that the newly calibrated models should be used to update predictive drawdown at the M3 site. HLI provided PGG with new well locations and associated maximum pumping rates, for which PGG performed a 50-year full pumping simulation. The results of the SVR #7 calibration were documented by PGG in a technical memorandum *Transient Calibration to the SVR #7 Pumping Test (M3 Eagle Groundwater Flow Model)* dated July 26, 2008. The results of the 50-year drawdown simulation (updated for the SVR #7 calibration) were documented by PGG in a technical memorandum *50-Year Drawdown Simulation with Proposed NPW wells (M3 Eagle Groundwater Flow Model)* dated September 22, 2008.

MODEL REFINEMENT AND RECALIBRATION

HLI recently determined that additional information on pumping from housing developments, fisheries and industrial uses was available and should be incorporated into the groundwater flow model. Additional information on pumping from the Cities of Meridian, Nampa and Caldwell were also incorporated into the model, thus resulting in increased pumping from both the Middle Aquifer and the PGSA. The following sections summarize model refinement through introduction of new pumping, re-calibration of both model versions, and associated predictive simulations of drawdown over 50 years of pumping at the M3 Site.

MODEL REFINEMENT

HLI provided PGG with additional groundwater withdrawal information to be added to the model. The information consisted of estimated pumping and construction information for individual wells operated by specific municipalities (e.g. Meridian, Nampa, Caldwell) along with estimates of groundwater withdrawals for housing developments, fisheries and industrial users grouped per quarter section for multiple wells. The grouped pumping estimates were assumed to represent withdrawals from the Middle Aquifer (layer 3 in the model); whereas the pumping estimates for municipalities were assigned to model layers based on the location and completion elevations of individual wells[1]. The total pumping added to the Middle Aquifer was 46 cfs (about a 30% increase from the original modeled Middle-Aquifer pumping and the total additional pumping added to the PGSA (layers 5, 6 and 7) was 8.3 cfs (about a 10% increase from the original modeled pumping from the PGSA). Pumping from all wells with completions in the PGSA was distributed across the entire thickness of the PGSA (layers 5-7).

MODEL RECALIBRATION

Model recalibration consisted of steady-state and transient recalibrations. As described in the original model report, steady-state recalibration for the Hmatch model emphasized achieving the best model matches to observed groundwater elevations within the PGSA whereas steady-state recalibration for the Tmatch model emphasized maintaining a match to estimated transmissivities within the PGSA. Transient recalibration focused on matching both models to the observed 9-day drawdown from the SVR #7 aquifer test at the M3 Site. Both original models had been successfully calibrated to the SVR #7 aquifer test. A transient recalibration to the 7-day Eaglefield #2 and 30-day Lexington Hills #1 aquifer tests was also performed for the Hmatch model. The original Hmatch model had been successfully calibrated to both these tests.

An iterative calibration approach between the transient and steady-state models was necessary to ensure a good calibration match to both steady-state target values and transient

[1] HLI provided spatial coordinates for the wells, PGG estimated wellhead elevations from the project Digital Elevation Model, and PGG compared completion interval elevations to model layer elevations to distribute wells over associated model layers.

target values. This involved, through trial and error, adjustments to hydraulic conductivity (K), storage coefficient (S) and specific yield (Sy) values within the PGSA that would provide a good fit to both steady state and transient target values.

The following sections summarize the steady-state and transient recalibration results

Steady-State Model Recalibration Results

The steady state calibration for the Hmatch model resulted in a slight increase in the hydraulic conductivity by 20% in PGSA Zone 5 (from 220 to 264 ft/day) and PGSA Zone 3 (from 125 to 150 ft/day) (**Figure 1**). The steady-state calibration for the Tmatch model resulted in a slight increase in the hydraulic conductivity by 25% in PGSA Zone 12 (from 160 to 200 ft/day) (**Figure 2**). The changes in local aquifer properties for the PGSA zones shown on **Figures 1** and **2** among the original model, the calibration to the SVR #7 aquifer test, and the current refined model are summarized in **Table 1** below.

Table 1: Local Changes to PGSA Hydraulic Conductivity, Storage Coefficient, and Specific Yield

Local Horizontal Hydraulic Conductivity (Kh) in PGSA							
Tmatch Model				Hmatch Model			
Local PGSA Zone Number	Kh (ft/day) Original Model	Kh (ft/day) Original SVR #7	Kh (ft/day) New Model	Local PGSA Zone Number	Kh (ft/day) Original Model	Kh (ft/day) Original SVR #7	Kh (ft/day) New Model
12	200	160	200	3	125	125	150
13	80	80	80	5	220	220	264
14	85	85	85	20	NA (was zone 3)	160	160
15	95	95	95	13	15	15	15
				14	85	85	85
Note: Kh/Kv = 10 for all zones listed above							

Local Storage Coefficient (S) and Specific Yeild (Sy) in PGSA							
Tmatch Model				Hmatch Model			
Local PGSA Zone Number	S/Sy Original Model	S/Sy Original SVR #7	S/Sy New Model	Local PGSA Zone Number	S/Sy Original Model	S/Sy Original SVR #7	S/Sy New Model
1	0.00035/0.1	0.00035/0.1	0.00035/0.1	1	0.00035/0.1	0.00035/0.1	0.00035/0.1
2	0.005/0.1	0.005/0.1	0.005/0.1	2	0.005/0.1	0.005/0.1	0.004/0.1
3	NA (was zone 2)	0.0005/0.025	0.0002/0.01	3	NA (was zone 2)	0.0005/0.1	0.0005/0.05

See Figures 1-3 for distribution of PGSA zones

The increase in the hydraulic conductivity for Zone 12 in the new Tmatch model and Zones 3 and 5 in the new Hmatch model were needed to both match target groundwater elevations and to match simulated drawdown values in the transient recalibrations (see below).

Final modeled heads and target residuals in the PGSA (layer 6) for the Hmatch and Tmatch models are shown in **Figures 4 and 5**. The target residuals were fairly similar to the original steady-state model calibration.

The residual mean (RM), absolute residual mean (ARM) and percentage of the residual standard deviation to the observed head range (RSD/R) for the original models and the newly calibrated models are summarized below in **Table 2** and are considered acceptable calibration results for both model realizations. Summary residual statistics are discussed in more detail in the original report (PGG, 2008).

Table 2: Summary of Head Target Statistics for Steady State Calibration

Statistic	Tmatch (Original)	Tmatch (New)	Hmatch (Original)	Hmatch (New)
RM	2.71	8.92	2.82	6.38
ARM	13.99	14.16	9.75	10.22
RSD/R	6.25%	5.93%	4.84%	4.64%

The final transmissivity values in the PGSA for both models were also within the acceptable ranges defined for the Hmatch and Tmatch calibrations, as described in the original report.

Transient Model Recalibration Results

The Hmatch and Tmatch models were both recalibrated to the 9-day constant rate SVR #7 aquifer test. The Hmatch model was also recalibrated to the 7-day Eaglefield #2 aquifer test and the 30-day Lexington Hills #1 aquifer test. Associated test wells are shown in **Figure 1.** In additional to the slight local modifications in hydraulic conductivity described above, the transient recalibration work required some slight local modifications to the storage coefficient (S) and specific yield (Sy) for both models. For the Hmatch model, a decrease in Sy from 0.1 to 0.05 in Zone 3 was required to match the 9-day SVR #7 aquifer test and a decrease in S from 0.005 to 0.004 in Zone 2 was required to match the 30-day Lexington Hills #1 aquifer test. For the Tmatch model, a decrease in the S from 0.0005 to 0.0002 and Sy from 0.025 to 0.01 in Zone 3 was required to match the 9-day SVR #7 aquifer test. **Figure 3** shows a map of the different S and Sy zones and **Table 1** summarizes these modifications.

As described in the original SVR #7 transient calibration memo (dated July 26, 2008), Sy is relevant to the transient calibration because the SVR #7 aquifer test occurs in an area where portions of the PGSA sediments are not fully saturated (unconfined). Furthermore, the reduced values of Sy suggest a more "semi-confined" aquifer response, which is consistent with cementation observed in the PGSA. Unconfined conditions in the PGSA are associated with unsaturated conditions in overlying model cells. In the original SVR #7 transient calibration the reduction in Sy was only required for the Tmatch model. With the addition of 30% more groundwater withdrawal in the Middle Aquifer (layer 3), more local cells in the uppermost layers of both models have drained to unsaturated and underlying areas of the PGSA represented as unconfined have therefore expanded.

Simulated versus observed drawdown for the Hmatch and Tmatch models for the two observation wells associated with the SVR #7 aquifer test (Big Gulch and TW #4) are shown in **Figures 6 and 7**. As shown in the figures, the newly modified models provide a reasonable match to the observed drawdown.

Simulated versus observed drawdown for the Hmatch model for the observations wells associated with the 30-day Lexington Hills #1 and the 7-day Eaglefield #2 aquifer tests are shown in **Figures 8 and 9.** As shown in the figures, the newly modified Hmatch model provides a reasonable match to the observed drawdown.

As described in the original report, the Tmatch model did not calibrate favorably to the 7-day Eaglefield #2 aquifer test without a substantial decrease in the local hydraulic conductivity of the PGSA. The Tmatch model underpredicted the maximum measured drawdown by about 35%. It should be noted, however, that HLI reported in its reanalysis of the 7-day Eaglefield #2 test, that pumping from an unidentified, nearby well (or wells) may have caused drawdowns that were not representative of aquifer response caused solely by pumping of the Eaglefield #2 well. Because of this uncertainty in the representativeness of the measured drawdowns and because the Tmatch model was developed to emphasize a match to field estimates of transmissivity, these transmissivity values were honored over matching local aquifer conditions to the 7-day aquifer test. As such, a recalibration effort to the 7-day aquifer test was not attempted with the newly modified Tmatch model.

NEW PREDICTIVE SIMULATIONS

PGG used the newly modified and recalibrated Hmatch and Tmatch models to simulate transient drawdown from three proposed wells operating for 50 years. HLI provided PGG with the location of the three proposed wells (NPW #1, #2, and #3) as shown in **Figure 10**. The wells are assumed to be fully screened within the PGSA (layers 5, 6, and 7). Each well was assigned an average constant pumping rate of 1500 gallons per minute. The transient simulation consisted of two stress periods; the first stress period consisting of 100 days of simulation with no pumping followed by the second stress period consisting of 50 years of simulation with pumping.

For the predictive simulations the general head boundary (GHB) used in both models to represent subflow into the PGSA along the southeast corner of the model in layers 5, 6, and 7 was converted to a constant flux boundary based on the steady-state calibrated solutions (**Figure 11**)[2]. The total constant-flux inflow was 114.77 cfs for the Hmatch model and 106.82 cfs for the Tmatch model. As described in the original report, the GHB represents an upstream location in the Boise River Valley where the PGSA has a stronger hydraulic connection to the river, its associated alluvium, and leakage from the New York Canal. Conversion to a constant flux boundary based on the steady-state solution takes a conservative approach for the predictive simulations in that additional flux from the boundary can not be induced during the simulations. Addition flux into the model from a general head boundary could result in less predicted drawdown.

HLI also requested that PGG perform sensitivity simulations with the model to assess pumping drawdown in the PGSA if the influx from the southeast boundary was reduced by 20%; the reduction representing reduced leakage from the New York Canal. The 20% reduction resulted in a total constant flux of 91.82 cfs assigned for the Hmatch model and 85.46 cfs for the Tmatch model. PGG simulated the reduction with both versions of the model in steady state to assess the long-term effects on groundwater levels caused by the reduced canal leakage.

[2] Model boundary conditions are described in more detail in the original report (PGG, 2008).

The results of the 50-year predictive simulation and the reduction of leakage from the New York Canal are summarized below.

NEW 50-YEAR PREDICTIVE SIMULATION

The results of the 50-year simulation are similar to the original predictive simulations and show that most of the drawdown occurs within the first 5 years of pumping and that relative equilibrium in the area of the pumping wells is achieved after about 20 years for both model versions (**Figures 12 and 13**).

As was the case with the original model, the Hmatch model simulates slightly higher drawdown than the Tmatch model. The 50-year maximum drawdown simulated in the PGSA was 31-ft for the Hmatch model and 27-ft for the Tmatch model in the vicinity of Well NPW #3 (**Figures 14 and 15**)[3]. Drawdown values decrease to 5-ft or less in the vicinity of Boise River (approximately 4 miles south of the site) for the Hmatch model and 4-ft or less for the Tmatch model. These results are very similar to the previous 50-year predictive simulations documented by PGG in a technical memorandum *50-Year Drawdown Simulation with Proposed NPW wells (M3 Eagle Groundwater Flow Model)* dated September 22, 2008. However, the new Hmatch model predicts about 2-ft less drawdown in the vicinity of the NPW pumping wells than the original Hmatch model. This is likely related to the 20% increase in local hydraulic conductivity required for the recalibration discussed above.

The use of a constant flux boundary for the southeast corner of the model in layer 5-7 versus the use of a general head boundary, as was done in the original 50-year predictive simulation, did not make a significant difference in the predicted drawdown values. Drawdown near the boundary was about 1-ft higher with the constant flux boundary for both versions of the model.

Tables 3 and 4 present water budget summaries for the Tmatch and the Hmatch models both with and without NPW pumping. The difference in mass balance with and without pumping indicates that more than 90% of the proposed NPW pumping are capturing water that would have discharged to the Boise River or that entered the model as subflow within the Boise River alluvium.

[3] Note that the models cannot be used to estimate the drawdowns in the pumping wells because drawdown is averaged over the entire associated model cell (The cell dimensions at NPW #3 are 660-ft x 660-ft).

Table 3: Water Budget for Steady-State and 50-Year Transient Hmatch Simulation

Water Budget Component	Boundary Type	Model Layer	Hmatch (SS No Pumping) Net Inflow (cfs)	Hmatch (50 Year Pumping) Net Inflow (cfs)	Hmatch (Difference) Difference[1] 50yr-SS (cfs)	Hmatch (Difference) Percent Contribution to NPW Pumping
Recharge	Recharge	Uppermost Active	542.44	542.44	0.00	0.00%
Boise River Seepage	River	Layer 1	-530.53	-521.58	8.95	89.27%
Payette River Seepage	River	Layers 1,2,3	-386.91	-386.72	0.19	1.92%
Lake Lowell Seepage	River	Layer 1	17.49	17.51	0.01	0.14%
Dry Creek Seepage Inflow	Wells	Layer 1	3.95	3.95	0.00	0.00%
Middle Aquifer Pumping (Domestic, Industrial)	Wells	Layer 3	-59.68	-59.51	0.17	1.72%
PGSA Pumping (Municipal, Industrial & Irrigation Pumping)	Wells	Layers 5-7	-84.00	-94.12	-10.03	NA
Boise River Alluvial Aquifer Inflow	CHB	Layer 1	80.95	81.57	0.62	6.21%
Boise River Alluvial Aquifer Outflow	CHB	Layer 1	11.76	11.78	0.02	0.20%
Payette River Alluvial Aquifer Inflow	CHB	Layer 1	282.48	282.49	0.01	0.07%
Payette River Alluvial Aquifer Outflow	CHB	Layer 1	-1.92	-1.91	0.00	0.01%
PGSA Inflow from SE Model Boundary	GHB[2]	Layers 5-7	114.77	114.77	0.00	0.00%
PGSA Outflow at SW Model Boundary	CHB	Layers 5-7	7.61	7.62	0.01	0.14%
Payette River Valley Fill Outflow	CHB	Layers 5-7	1.98	1.98	0.00	0.02%
Willow Creek Aquifer Along NE Model Boundary	CHB	Layers 5-7	-0.30	-0.27	0.03	0.31%
Model Mass Balance Error			<1%	<1%		

1. Negative number indicates more outflow simulated in the transient model. Positive number indicates more inflow
2. For the 50 year pumping simulation the boundary type was constant flux

Table 4: Water Budget for Steady-State and 50-Year Transient Tmatch Simulation

Water Budget Component	Boundary Type	Model Layer	Tmatch (SS No Pumping) Net Inflow (cfs)	Tmatch (50 Year Pumping) Net Inflow (cfs)	Hmatch (Difference) Difference[1] 50yr-SS (cfs)	Hmatch (Difference) Percent Contribution to NPW Pumping
Recharge	Recharge	Uppermost Active	542.44	542.44	0.00	0.00%
Boise River Seepage	River	Layer 1	-529.18	-520.05	9.13	88.60%
Payette River Seepage	River	Layers 1,2,3	-387.02	-387.00	0.01	0.14%
Lake Lowell Seepage	River	Layer 1	17.38	17.38	0.02	0.23%
Dry Creek Seepage Inflow	Wells	Layer 1	3.95	3.95	0.00	0.00%
Middle Aquifer Pumping (Domestic, Industrial)	Wells	Layer 3	-59.52	-59.39	0.14	1.33%
PGSA Pumping (Municipal, Industrial & Irrigation Pumping)	Wells	Layers 5-7	-84.09	-94.40	-10.30	NA
Boise River Alluvial Aquifer Inflow	CHB	Layer 1	88.50	88.84	0.34	3.35%
Boise River Alluvial Aquifer Outflow	CHB	Layer 1	11.81	11.84	0.04	0.37%
Payette River Alluvial Aquifer Inflow	CHB	Layer 1	282.49	282.47	-0.01	-0.14%
Payette River Alluvial Aquifer Outflow	CHB	Layer 1	-2.18	-1.92	0.26	2.48%
PGSA Inflow from SE Model Boundary	GHB[2]	Layers 5-7	106.82	106.82	0.00	0.00%
PGSA Outflow at SW Model Boundary	CHB	Layers 5-7	7.42	7.45	0.03	0.28%
Payette River Valley Fill Outflow	CHB	Layers 5-7	1.75	1.97	0.22	2.14%
Willow Creek Aquifer Along NE Model Boundary	CHB	Layers 5-7	-0.39	-0.34	0.05	0.48%
Model Mass Balance Error			<1%	<1%		

1. Negative number indicates more outflow simulated in the transient model. Positive number indicates more inflow
2. For the 50 year pumping simulation the boundary type was constant flux

Note that model results show a small (0.14-0.17 cfs) reduction in pumpage from the Middle Aquifer (model layer 3). This reduction is well within the bound of error associated with estimation of pumping in layer 3. It arises because cells within a small portion of layer 3 (e.g. south of the fault) become dry with the additional NPW pumping. However, PGG did not attempt to calibrate the model to the distribution of saturation in the Middle Aquifer, and predictions of change in saturation should be taken in the context of a non-calibrated portion of the model.

AFFECTS OF REDUCTION FROM NEW YORK CANAL LEAKAGE

The results of the steady state simulation with 20% reduced flux from the southeast boundary show decreases in groundwater elevations (**Figures 16 and 17**) within the PGSA. The simulation shows decreases in groundwater elevations near the M3 Site of about 3-ft for the Hmatch model and about 2-ft for the Tmatch model. Groundwater elevations near the Boise River also decreased from about 15-ft closest to the boundary to 2-ft near the Eaglefield #2 well for the Hmatch model and about 7-ft closest to the boundary to 3-ft near the Eaglefield #2 well for the Tmatch model.

The contours of groundwater level declines on **Figures 16 and 17** show a steep gradient leading from the southeast corner boundary towards the Boise River. The magnitude and

gradient of groundwater elevation reductions near the southeast boundary is affected, to some degree, by the modeled location of the general head boundary that provides inflow to the model. As actual inflow may enter the model more diffusely over a somewhat larger area, the associated decrease in flux may be distributed over a somewhat larger area. A more diffuse distribution would result in reduced but more spread-out drawdowns near the southeast corner of the model; but would likely have little effect on predicted groundwater-elevation declines closer to the project area. In other words, the modeled reduction in water levels near the modeled boundary should be considered to be an approximation.

Figure 1: Local PGSA K-Zones and Location of SVR #7 Test Wells (Hmatch Model)

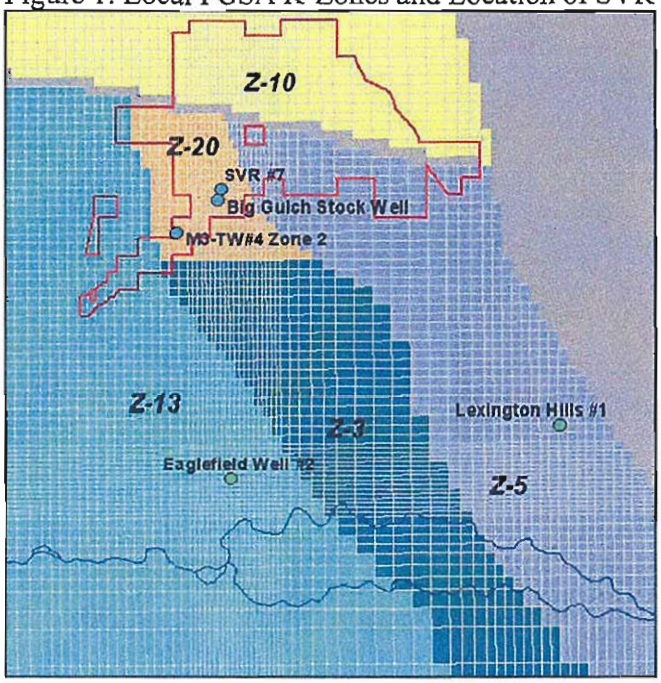


Figure 2: Local PGSA K-Zones and Location of SVR #7 Test Wells (Tmatch Model)

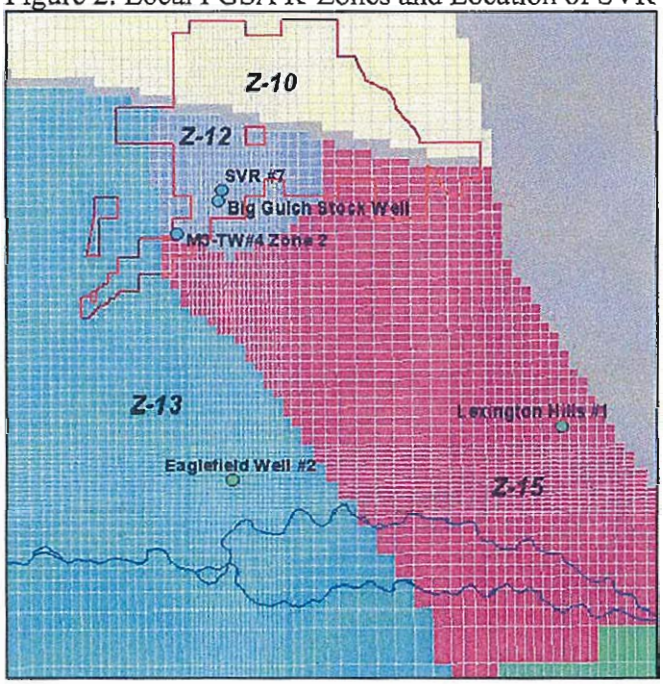


Figure 3: Local PGSA S-Zones and Location of SVR #7 Test Wells (Both Models)

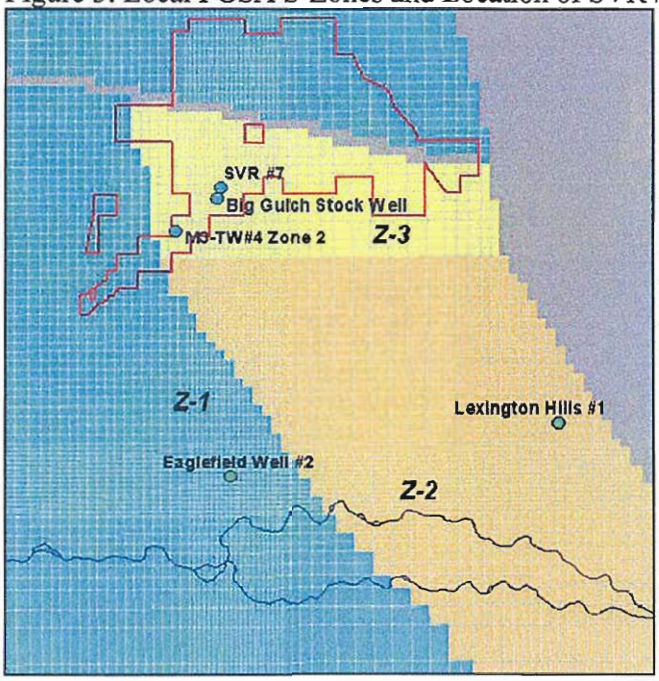


Figure 4: Modeled Heads and Residuals in Layer 6 (PGSA) – New Hmatch Model

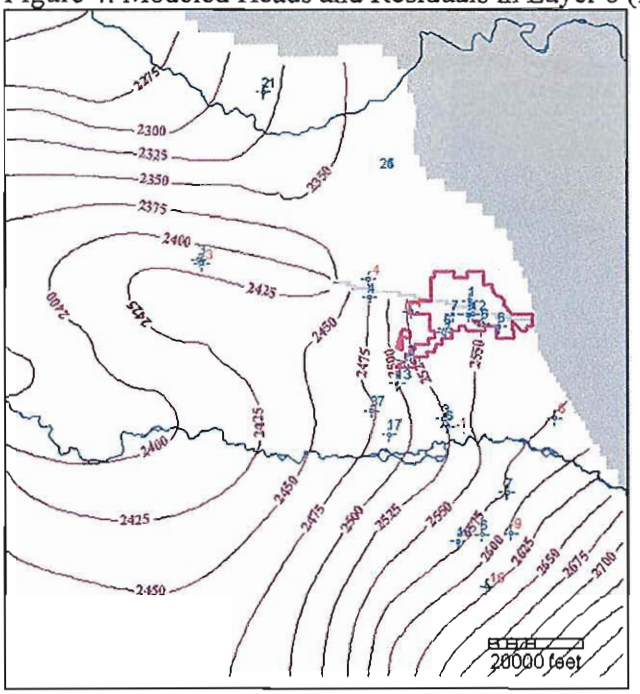


Figure 5: Modeled Heads and Residuals in Layer 6 (PGSA) – New Tmatch Model

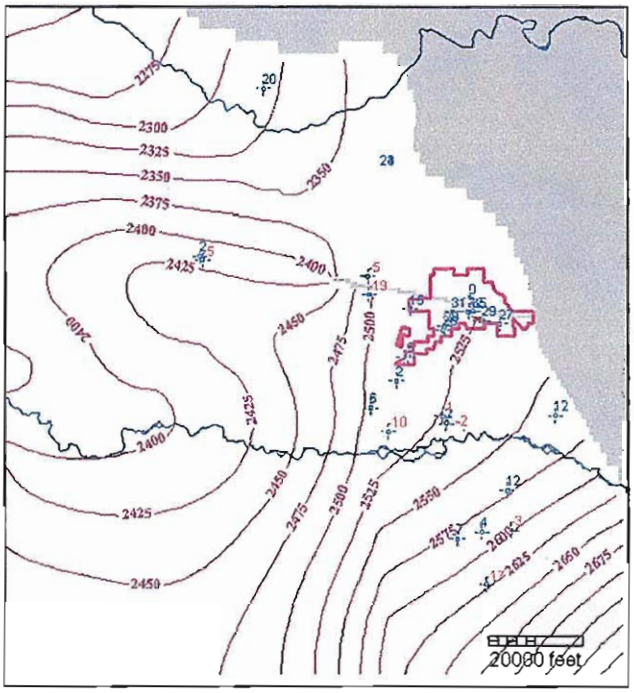


Figure 6: Simulated vs Observed Drawdown SVR #7 Aquifer Test (New Hmatch Model)

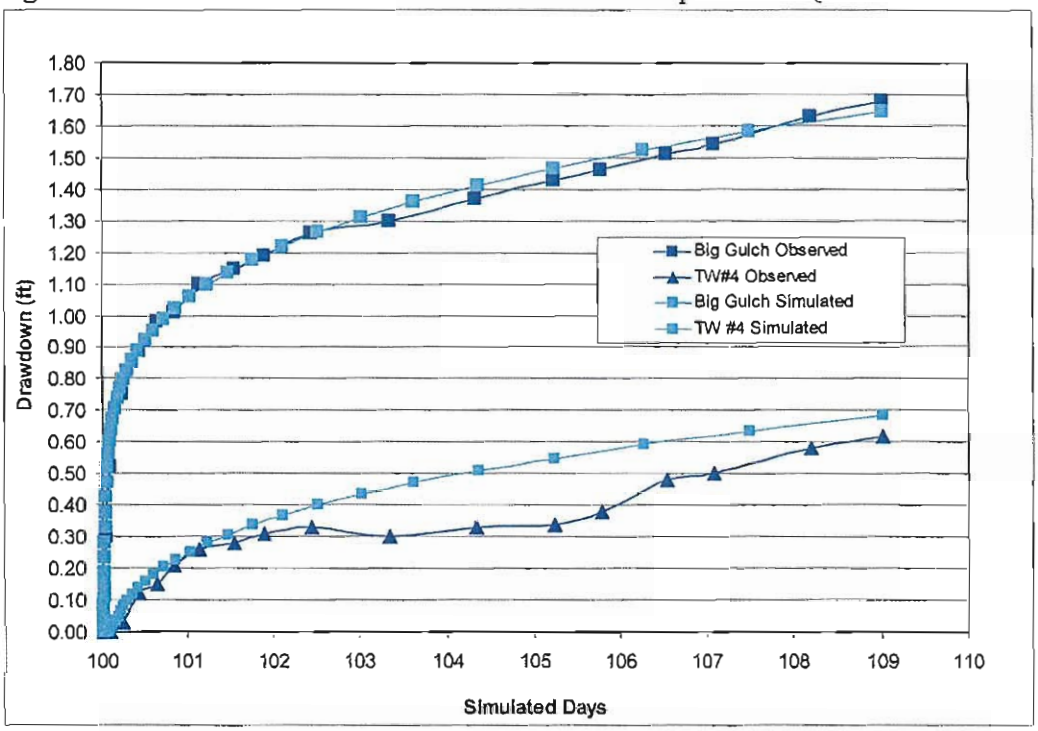


Figure 7: Simulated vs Observed Drawdown SVR #7 Aquifer Test (New Tmatch Model)

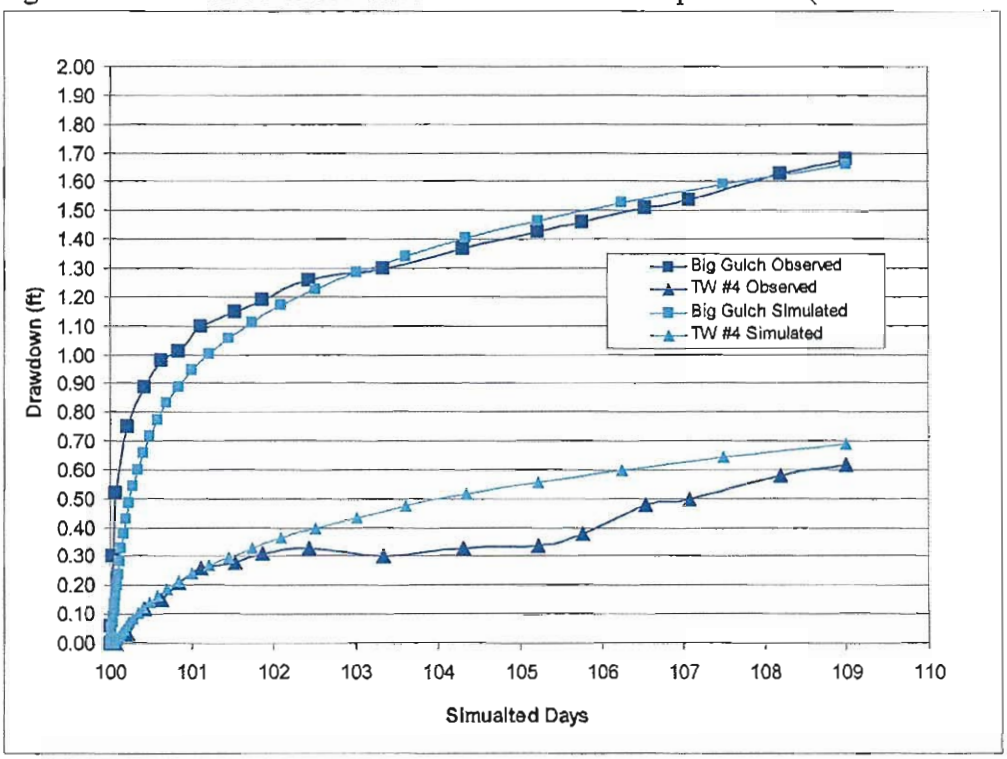


Figure 8: Simulated vs Observed Drawdown Lexington Hills #1 Aquifer Test (New Hmatch Model)

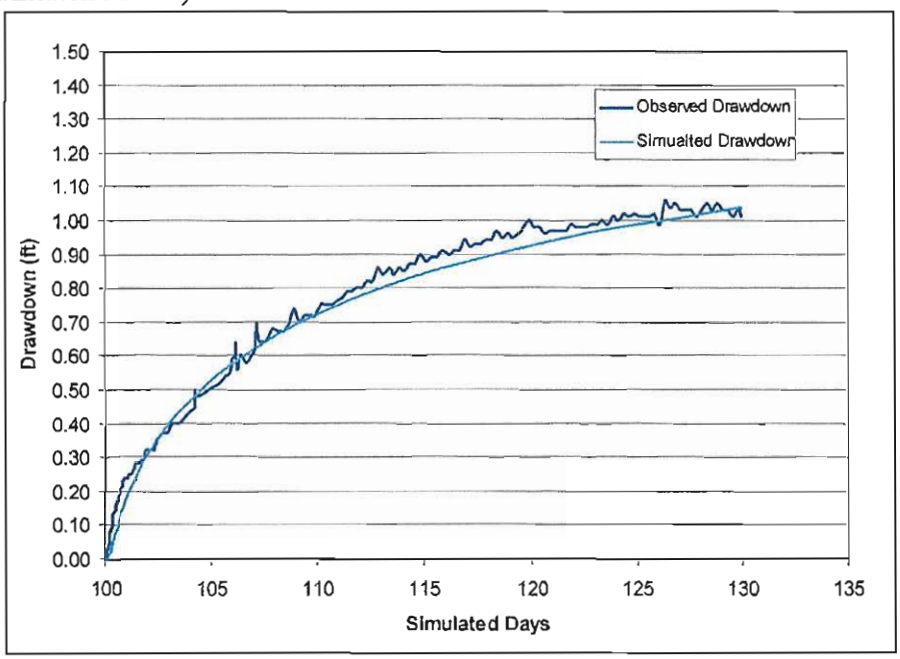


Figure 9: Simulated vs Observed Drawdown Eaglefield Well #2 Aquifer Test (New Hmatch Model)

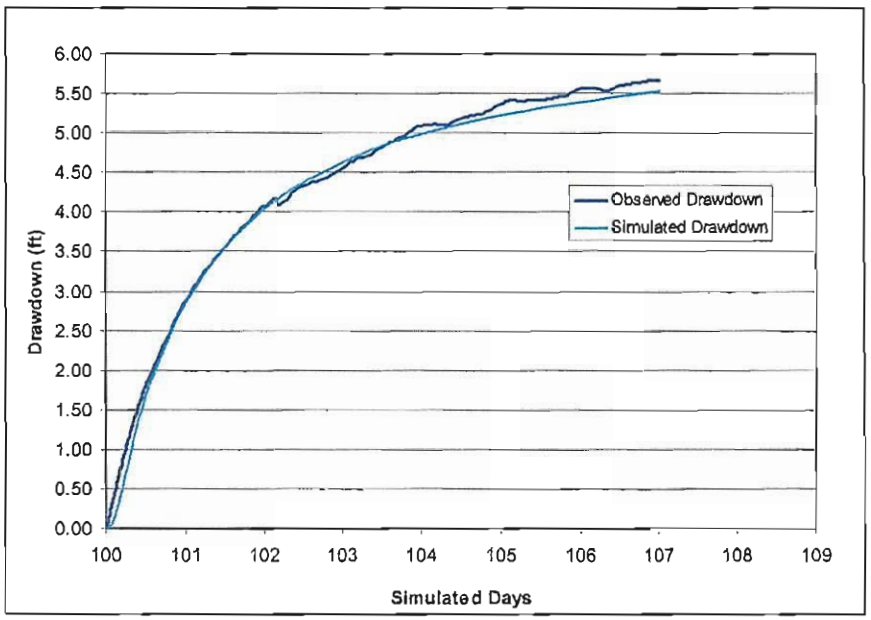


Figure 10: Location of Proposed NPW Pumping Wells

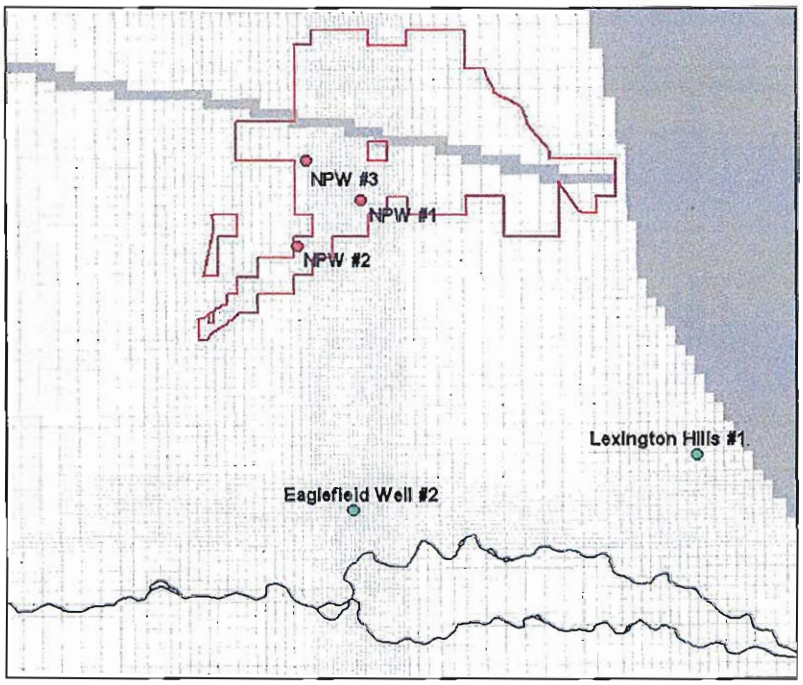


Figure 11: Location of General Head Boundary in southeast corner of model converted to Constant Flux Boundary for Predictive Simulation

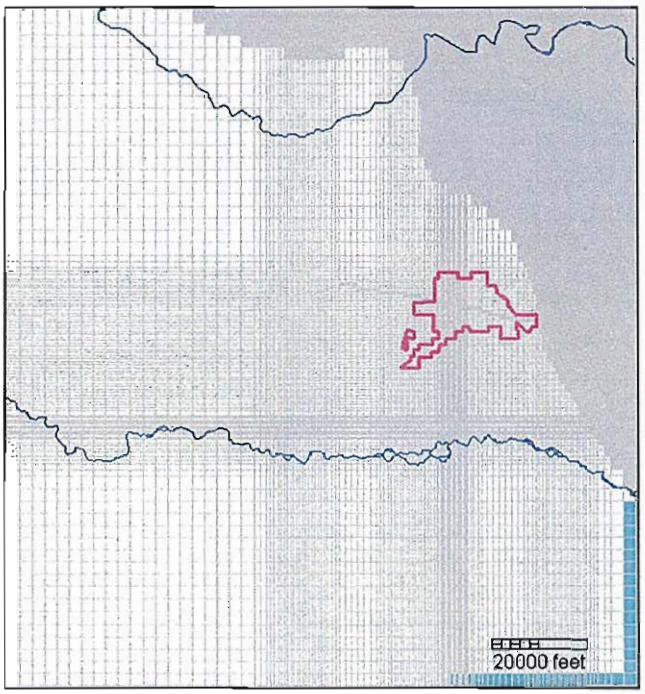


Figure 12: Percent of Total Simulated Drawdown at Pumping Wells (New Hmatch Model)

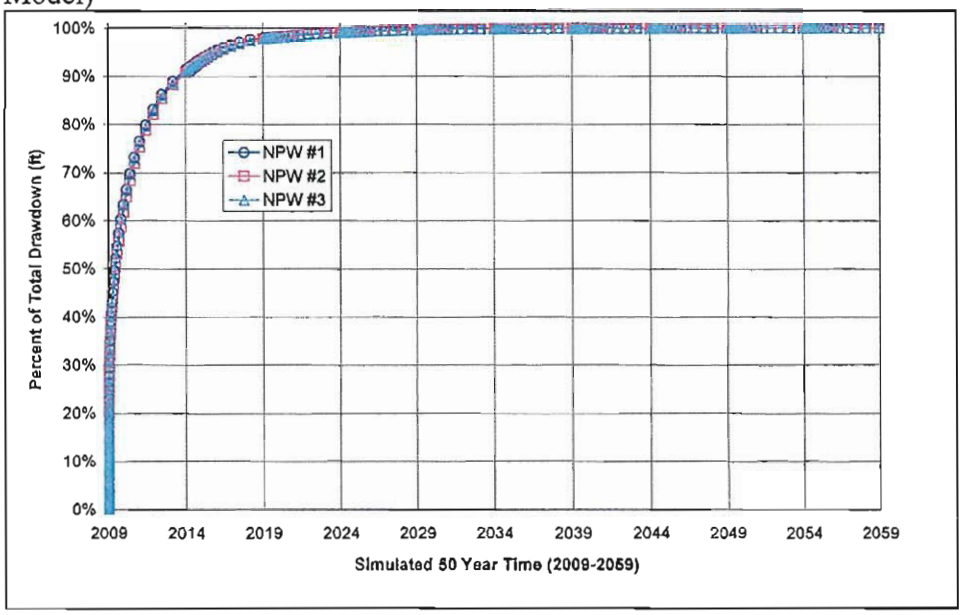
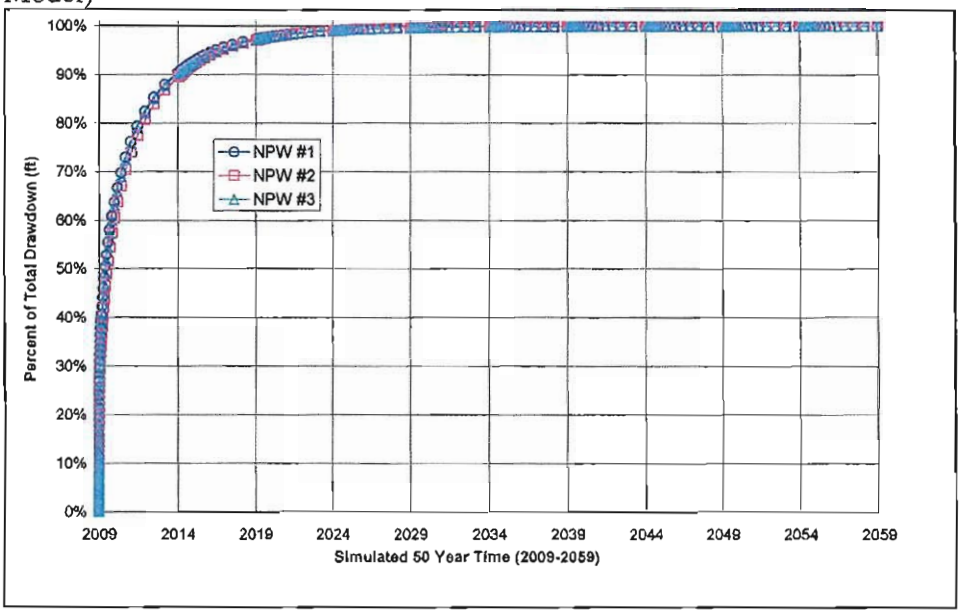


Figure 13: Percent of Total Simulated Drawdown at Pumping Wells (New Tmatch Model)



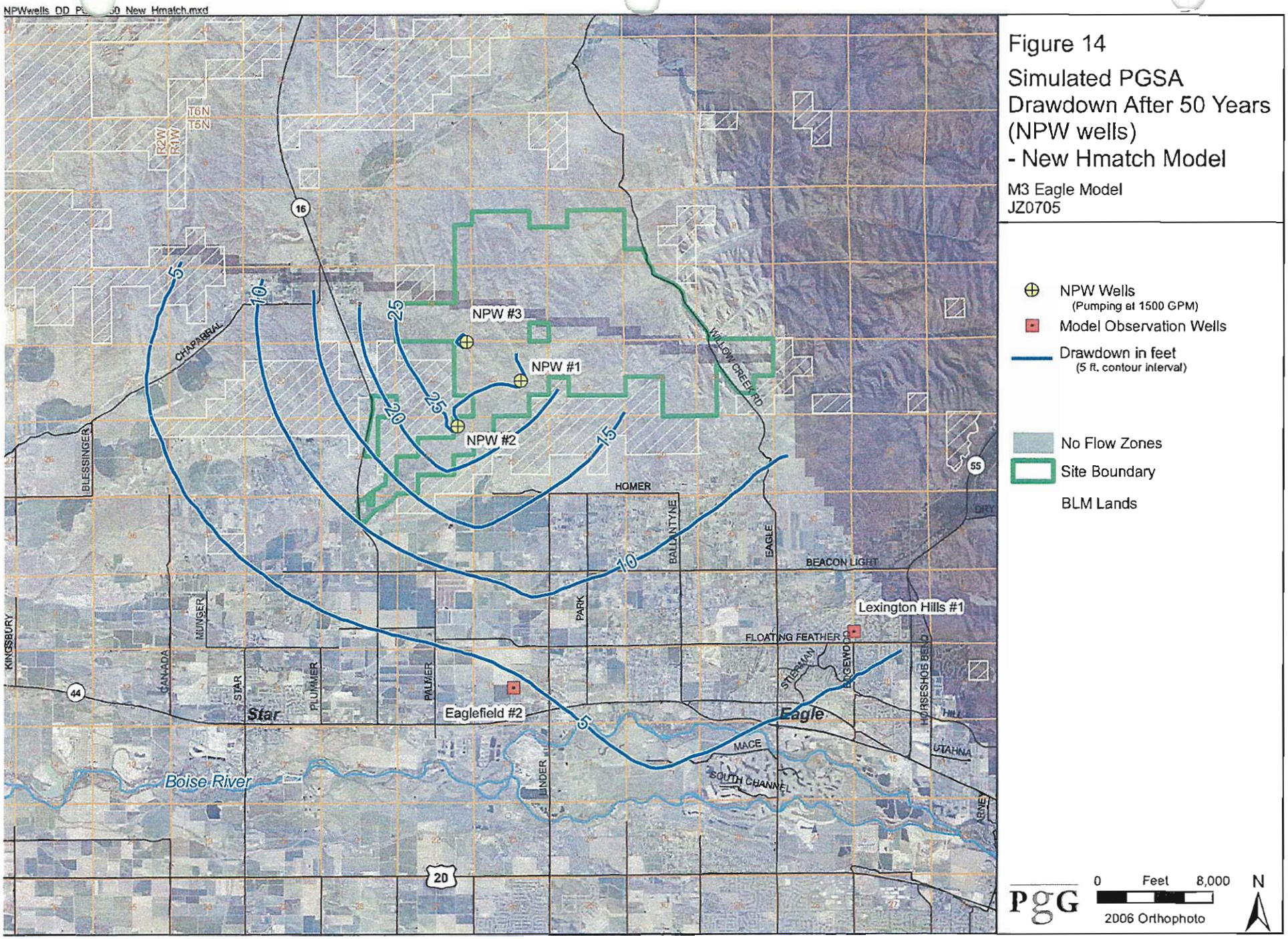


Figure 14

Simulated PGSA Drawdown After 50 Years (NPW wells) - New Hmatch Model

M3 Eagle Model
JZ0705

NPWwells_DD_PGSA_50_New_Tmatch.mxd

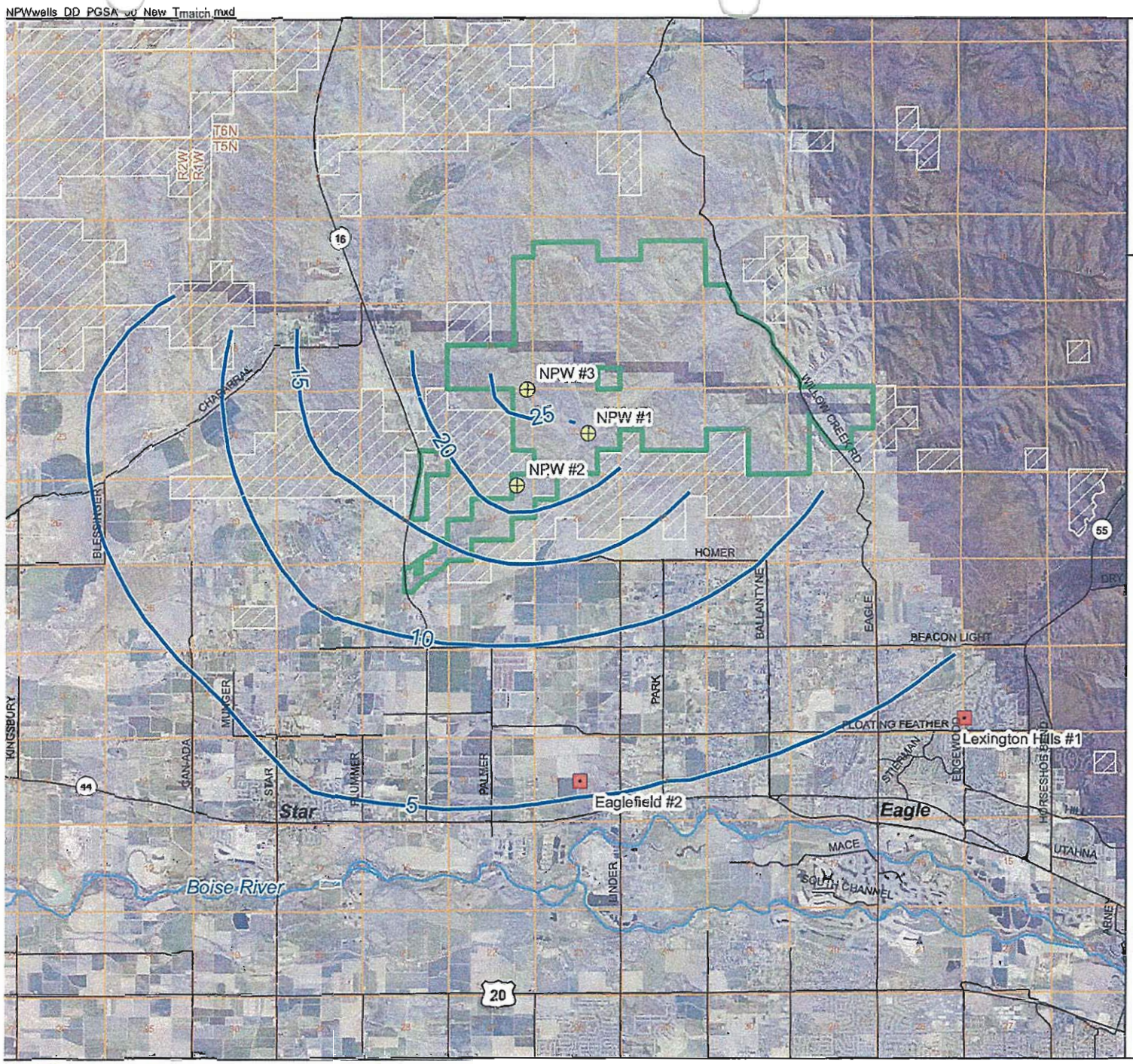


Figure 15

Simulated PGSA Drawdown After 50 Years (NPW wells) - New Tmatch Model

M3 Eagle Model
JZ0705

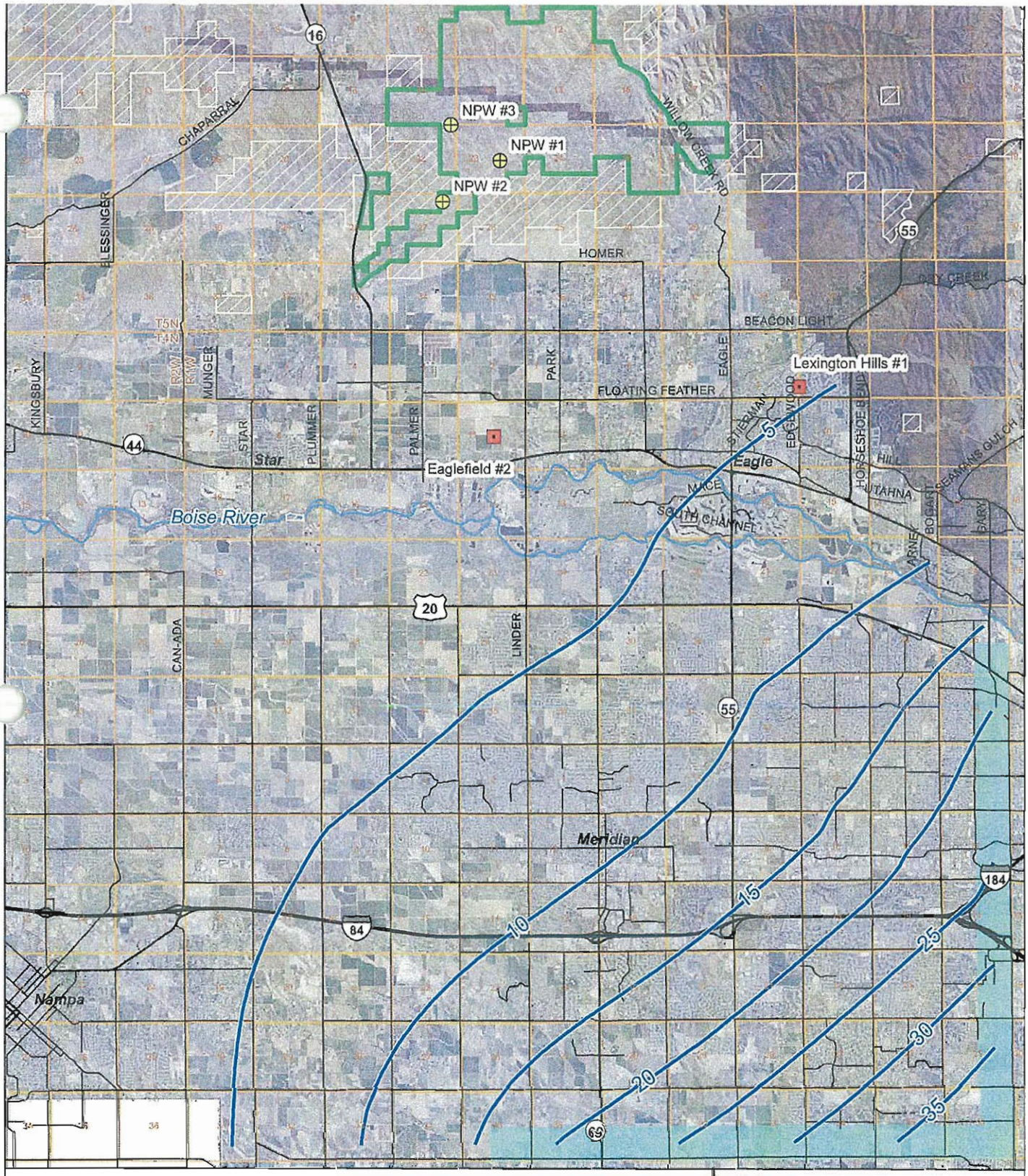
- NPW Wells (Pumping at 1500 GPM)
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

PGG

0 Feet 8,000

2006 Orthophoto

N



NPW Wells
(Pumping at 1500 GPM)

Model Observation Wells

Reduced Groundwater Level Contours, in feet
(5 ft. contour interval)

Constant Flux Boundary

No Flow Zones

Site Boundary

BLM Lands

PGG

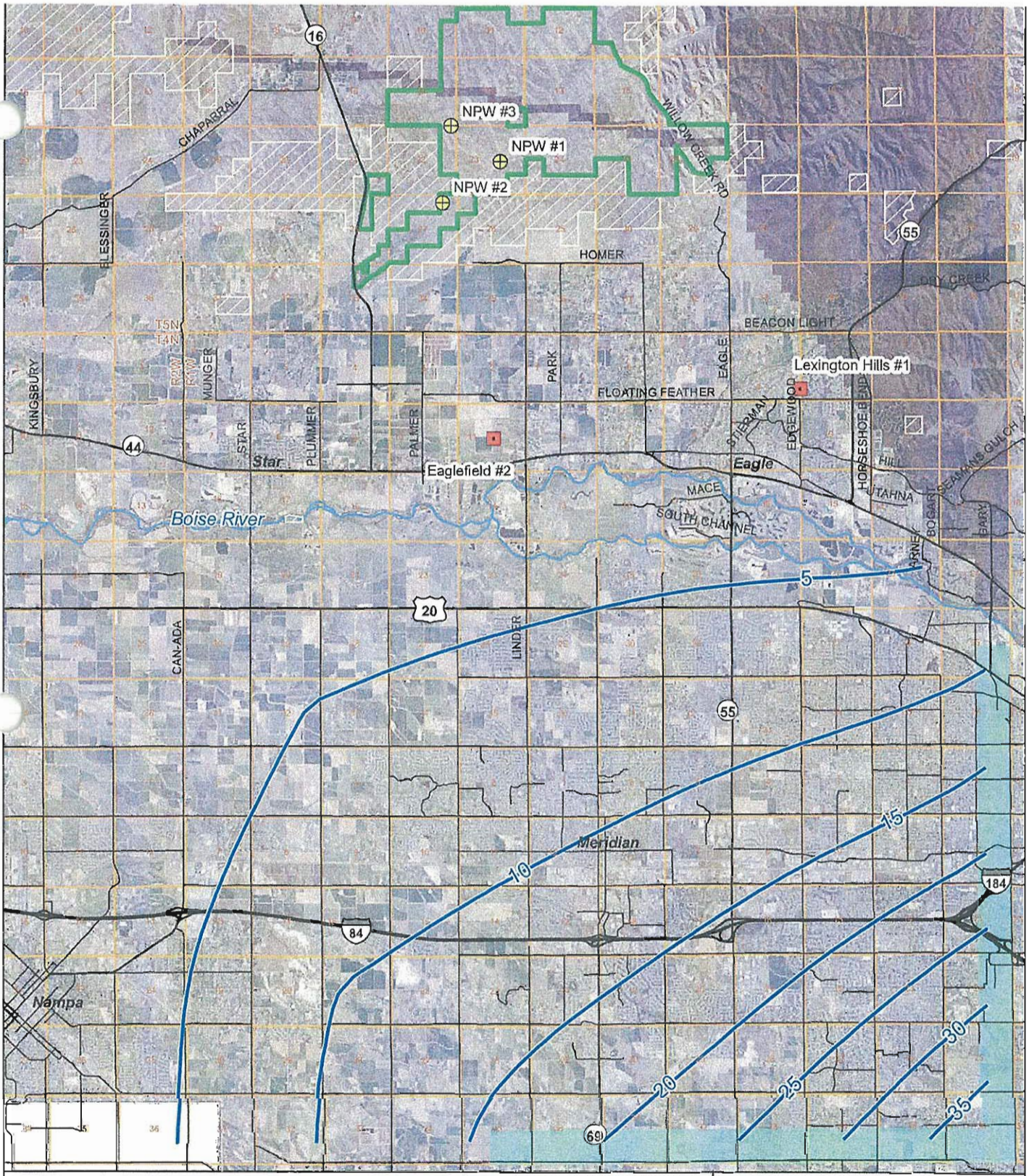
0 Feet 10,000

2006 Orthophoto

N

Figure 16
Simulated PGSA Steady State Reduction in Groundwater Levels (Reduced Canal Leakage) - New Hmatch Model

M3 Eagle Model
JZ0705



NPW Wells
(Pumping at 1500 GPM)

Model Observation Wells

Reduced Groundwater Level Contours, in feet
(5 ft. contour interval)

Constant Flux Boundary

No Flow Zones

Site Boundary

BLM Lands

PGG

0 Feet 10,000

2006 Orthophoto

N

Figure 17
Simulated PGSA Steady State Reduction in Groundwater Levels (Reduced Canal Leakage) - New Tmatch Model

M3 Eagle Model
JZ0705

APPENDIX C - CONCLUSIONS AND RECOMMENDATIONS FROM TVHP AND U OF I REPORTS

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12. CONCLUSIONS AND RECOMMENDATIONS

A numerical model was constructed to simulate regional-scale, steady-state, ground water flow in the Treasure Valley of southwestern Idaho. Conclusions from simulations using this model consist of the following:

1. PEST-calibrated parameter values indicate relatively higher K_h values in the uppermost aquifer zones, corresponding with known areas of coarser-grained sediments. PEST-calibrated parameter values also indicate relatively higher K_h and K_v values in areas of the eastern and central portion of the valley associated with fluvial deltaic deposition.
2. Simulated fluxes between model layers in the base calibration indicates a relatively small amount of water moving vertically between model layers, especially in the lower layers. Based on simulation results, most recharge occurring in shallow aquifer zones does not reach lower zones.
3. A 10% increase or decrease in recharge led to minimal changes in water levels or parameter value estimates. This is because shallow ground water levels in central portions of the basin are controlled, in part, by elevations of surface water channels. Decreased or increased recharge resulted in changes in the rates of water discharging to model drain, general head boundary (Lake Lowell), constant head (Snake River), and river (Boise River) cells.
4. Underflow does not appear to be consistently distributed along the Boise Front. The model experienced difficulty in applying rates as high as 8,000 ft^3/day/cell (similar to water budget estimates) in some model areas, especially in the far eastern portions of the model domain.
5. Simulated minimum water levels (maximum impact) indicated that some ground water level declines might occur with a 20% increase over 1996 levels. Simulated modest declines were observed in the Boise area in layers 1 and 2. Greater simulated declines were observed in the central portion of the valley (especially in the Lake Lowell area) in layers 3 and 4. Simulated water level declines and/or changes in mass balance components reflect a combination of parameter uncertainty and response to a changed hydraulic stress.
6. The simulated 20% increase in ground water withdrawals resulted in increased losses from the Boise River (23%), decreased discharge to agricultural drains (62%), and decreased discharge to the Snake River (9%). Again, simulated water level declines and/or changes in mass balance components reflect a combination of parameter uncertainty and response to a changed hydraulic stress.
7. Uncertainty in the model calibration limits a more precise description of responses to changes in recharge and/or withdrawals.
8. Changes in land use that lead to decreases in shallow-aquifer recharge may not have a substantial effect on shallow ground water levels until the water table elevations remain below those of nearby surface channels.

Additional simulations should be considered to better define aquifer system characteristics or scenario predictions. These include the following:

1. Maximum and minimum hydraulic head predictions with no changes in model stresses from the base simulation. Use the results from these simulations for comparisons in scenario predictions.
2. Increases and decreases of 30% (over 1996 levels) in aquifer recharge.
3. Across-the-board withdrawal increases and decreases in aquifer withdrawals over 1996 levels.
4. Increased local withdrawals in various locations in the valley to test responses in water levels and in recharge rates to lower model layers.
5. Simulations with reductions in recharge and increases in withdrawals to estimate at what point shallow ground water levels drop below drain elevations in the central portion of the valley.
6. Horizontal and vertical variations in underflow along the Boise Front.
7. Conduct additional simulations to refine the understanding of ground and surface water interaction in the Boise River corridor using a more refined grid than, and/or submodel of, the current model .
8. Develop response ratios for the interaction between ground water extractions and seepage from or discharge to surface channels.

Additional recommendations include the following:

1. Expand monitoring in areas showing recent ground water level declines.
2. Consider incorporating new monitoring data into the model as they become available.
3. Better define discharge rates to surface water channels to allow more constraint on simulated discharge.
4. Better define temporal diversion and return rates for transient simulations.
5. Refine model based on newly compiled diversion and return data.
6. Install additional multi-completion monitoring wells to expand vertical gradient data.
7. Search for opportunities to enhance ground water level monitoring in portions of the valley with relatively few current data.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.0 INTRODUCTION

The M3 Eagle Big Gulch Model provides a preliminary mathematical representation of a new, conceptual hydrogeologic model for ground water flow in the region between the Boise River near Eagle, Idaho and the Payette River near Emmett, Idaho. Although this preliminary ground water model is a work in progress, it provides a user-friendly, visual tool to help test and refine conceptual understanding of the ground water flow conditions that exist within the model domain. This chapter presents conclusions and recommendations developed during an 18-month investigation.

6.0.1 Conclusions

6.0.1.1 Hydrogeologic conclusions of the investigation

The following conclusions are derived from interpretation of hydrogeologic data presented by Squires et al. (2007), independent evaluation of well driller's reports, available water level data, aquifer test data summarized by HLI, and general accepted hydrogeologic theory:

(1) Ground water flow between the Boise River valley and the Payette River valley occurs primarily through sediments of the Pierce Gulch Sand aquifer system. The Pierce Gulch Sand aquifer system is 150 to 275 feet thick (possibly thicker in other areas) consisting of stratified granitic sand layers with interbedded layers of silt and clay. It is bounded on the north side by a southeast-northwest trending normal fault known as the West Boise-Eagle fault (Wood and Anderson, 1981). The Pierce Gulch Sand aquifer is generally underlain by clays and mudstones of the Terteling Springs

Formation and dips at an angle of about 1° to the southwest in the model domain. The aquifer system is truncated at by the unsaturated water table in the vicinity of Black Canyon Canal southwest of Emmett, the West Boise-Eagle fault northwest of Boise, and by the mudstones of the Terteling Springs Formation underneath in the vicinity of the fault.

(2) The Willow Creek aquifer (SPF, 2004) exists mostly on the north side of the West Boise-Eagle fault and extends from the foothills to the Payette River near Emmett, Idaho. The Willow Creek aquifer consists primarily of high hydraulic conductivity gravels and sands; however, the aquifer appears to be isolated from the regional ground water flow system in the Pierce Gulch Sand aquifer system by the West Boise-Eagle fault and mudstones of the Terteling Springs formation. Granite of the Idaho batholith, and overlying tertiary volcanics bound the Willow Creek aquifer on the eastern side of the model domain.

(3) The Pierce Gulch Sand aquifer system constitutes the primary ground water source for the cities of Star and Eagle, and the proposed M3 Eagle planned community. The aquifer system is believed to be moderately to highly productive based on the existence of many large production supply wells completed in the aquifer, and aquifer tests conducted in the vicinity of Eagle and the M3 Eagle Development property.

(4) Ground water recharge to the Pierce Gulch Sand aquifer system originates southeast of the model domain from seepage from the Boise River downstream of Diversion Dam, and from the dense network of canals in the Boise-Meridian area; ground water flows northwesterly under the Boise River in the Eagle, Idaho area in the direction of

the hydraulic gradient toward the natural ground water discharge areas in the Payette River valley near Letha, Idaho and the Snake River valley to the west.

6.0.1.2 M3 Eagle Big Gulch Model conclusions

The M3 Eagle Big Gulch Model is based predominantly on the conceptual hydrogeologic model developed for the model window area by HLI, water levels measured within the model window during the summer/fall of 2006, and water levels derived from the IDWR Ground Water Level Database for the rest of the model domain. The following conclusions are derived from the many simulations performed during development of the numerical model:

(1) The M3 Eagle Big Gulch Model is limited by the lack of a comprehensive database for model input.

(2) Preliminary results strongly support the conceptual model developed by HLI that ground water flows from the Boise River valley to the Payette River valley throughout the lower Boise River basin and the southern half of the proposed M3 Eagle development property.

(3) The general direction of ground water flow through the Pierce Gulch Sand aquifer system is from areas of higher head (water level) in the Boise River valley to areas of lower head in the Payette River valley. Seepage from the Boise River upriver from the modeled area and the New York canal is the primary source of recharge to the Pierce Gulch Sand aquifer.

(4) Based on model calibration of hydraulic conductivity and recharge, driving heads (higher heads) in the Pierce Gulch Sand aquifer system originate in the south and east Boise areas. However, canal seepage and surface irrigation just north of the Eagle

and Star areas contribute significant recharge to the shallow water table aquifer near the southwestern edge of the proposed M3 Eagle development property.

(5) Calibrated model values for hydraulic conductivity in the Eagle-Star vicinity are lower than previously expected based on results from aquifer tests conducted in the area.

(6) Based on model calibration of hydraulic conductivity and canal seepage, recharge estimates for the model window area are underestimated.

(7) Simulation of the steep water level contours between the outcrop of the Pierce Gulch Sand and the West Boise-Eagle fault zone is difficult. Additional work is needed to adequately define the ground water flow conditions in this area.

(8) Changes in land use and/or development that reduce canal leakage and/or irrigated areas are expected to reduce local recharge and cause ground water levels in domestic wells in the vicinity of Eagle to decline.

6.0.2 Recommendations

The M3 Eagle Big Gulch Model provides a useful tool for the mathematical evaluation of evolving conceptual, hydrogeologic models of the regional ground water flow conditions between the Boise River valley and the Payette River valley. The present model must be considered preliminary in nature, and more data and more simulations are required to calibrate the model. The following recommendations are suggested to improve the predictive capability of the M3 Eagle Big Gulch Model and are ranked according to priority with the first recommendation being the most important:

(1) Establish a water level monitoring network comprised of wells in the Pierce Gulch Sand aquifer system and other aquifers within the model domain. Monitor on a

regular basis to document seasonal changes that may occur and incorporate average water level conditions when simulating the model in steady-state conditions.

(2) Expand the monitoring network to acquire more water level measurements outside the model window.

(3) Incorporate new monitoring data into the model as it becomes available.

(4) Develop a detailed water budget for the model domain.

(5) Perform a more detailed analysis on recharge to incorporate better estimates into the model.

(6) Update recharge estimates as land use changes and as certain areas become more developed.

(7) Locate and map all canals within the model domain that were not previously simulated (specifically in the northwestern area of the model window) and incorporate all new data into the model.

(8) Improve the canal and river seepage estimates.

(9) Improve discharge estimates for municipal entities (cities and towns) in the model domain by acquiring year-to-year seasonal pumping estimates.

(10) Update domestic discharge estimates by documenting actual well withdrawals from the wells known to exist in each cell.

(11) Better define temporal conditions such as irrigation diversion rates, urban and rural domestic water use, periods of canal use, and seasonal water levels in wells.

(12) Conduct long-term aquifer tests in the M3 Eagle property vicinity to better understan the effects of increased water development in the area.

(13) Estimate storage coefficients for all layers in the model throughout the model domain to prepare for transient model simulations.

(14) Conduct additional aquifer tests near the West Boise-Eagle fault to better understand the effects caused by pumping near that zone, and determine the best way to simulate the fault in MODFLOW.

(15) Obtain hydrogeologic data on the layers above and below the Pierce Gulch Sand aquifer system.

[End of Report]

M3 EAGLE
EAGLE IDAHO
Gem
Birding Island
Payette
New Plymouth
SE 1st Ave
52
E Black Canyon Hwy
Fuller Island
Emmett
Sand Hollow Rd
16
Emmett Hwy
Old HWY 30
Middleton
44
Star
W State St
Eagle
Simplot Blvd
Caldwell
W Chinden Blvd
Garden
Canyon
Meridian
ks Island
Nampa
Gull Island
Prepared by:
Hydro Logic, Inc.
Boise, Idaho
Ada

17

Well Density Map

Number of Wells by Section and Quarter Section in the North Ada County Area

The total number of wells in each Section is shown by the larger numerals at the center of each Section. The number of wells within each Quarter-Section is indicated by the smaller numerals on the grid. Data were derived from the Idaho Department of Water Resources microfiche and hard copy Driller's Report files from the Western Regional Office and the IDWR on-line database as of July 2007. Some wells may be missing and others may be mislocated.

Township and range boundaries are denoted in red, and the approximate boundary of the proposed M3 Eagle development is gray with yellow shading.

USGS 15 -minute (1:62,500 scale) quadrangle base map.

T6N

T5N

T4N

R1W R1E R2E

Star Eagle

M3 PROPERTY BOUNDARY

Boise Front Geothermal Ground Water Management Area – (1987)

Hydro Logic, Inc.
Boise, ID

M3 EAGLE LLC
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17

Well Density by section and Quarter Section 09-13-2007

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Hydro Logic, Inc
1002 W. Franklin Street, Boise ID 83702 (208) 342-8369, (Fax) 342-3100, hydrologic@qwest.net

March 19, 2008

Mr. Dennis E. Owsley
Hydrology Section
Technical Services Bureau
Idaho Department of Water Resources
322 East Front Street
Boise, ID 83702-5431

Re: Update on Hydro Logic, Inc. Ground Water Level Measurements the Northern Ada County Area Including the Proposed M3 Eagle Planned Community

Dear Dennis:

Under cover of this letter, I transmit an updated version of the Northern Ada County June 2006 water level measurements we provided to IDWR on March 7, 2007. The report and data table are also being sent to you electronically for your use and for posting to the IDWR's North Ada County web site, should you desire to do so.

If you have any questions, please give me or Mark Utting a call.

Sincerely,
Hydro Logic Inc.

Ed Squires E Squires

M3 EAGLE LLC
EXHIBIT
18

Hydro Logic, Inc
1002 W. Franklin Street, Boise ID 83702 (208) 342-8369, (Fax) 342-3100, hydrologic@qwest.net

TECHNICAL MEMORANDUM

TO: Dennis Owsley/ Hydrology Section / Technical Services Bureau / Idaho Department of Water Resources / 322 East Front Street / Boise, ID 83702-5431

FROM: Ed Squires/ Hydro Logic, Inc. / 1002 W. Franklin St., Boise, Idaho 83702

DATE: March 17, 2008

SUBJECT: Surveyed Water Level Measurements of Wells in the Northern Ada County/Eagle Area, for the M3 Eagle Hydrogeologic Characterization

This technical memorandum presents the results of a water level survey conducted during June and July 2007. The results of the survey are included in Table 1 (attached). The purpose of the survey was to update the information provided in 2006 year by collecting a set of water levels at generally the same time of year, from surveyed wells located in and around the greater M3 Eagle project area. This information, and the accompanying water level contour map, are aimed toward the goal of improving the hydrogeologic characterization and analysis of the ground water system of the area. The water level data have been used as input for the 3-D MODFLOW computer model in progress under the direction of Hydro Logic, Inc., (HLI). The measured water levels are included in Table 1 and Figure 1. The locations of the monitored wells are shown by name in Figure 2.

Water levels were measured over the period June 1 through July 31, 2007, by personnel from HLI. We measured water levels in wells that had been used during our 2006 survey and other wells that were identified as lying in key locations needed for additional information required for our characterization study. Wells measured during our 2007 water level measurement program were subsequently surveyed using high-precision Global Positioning System (GPS) survey by the Idaho Survey Group (ISG) over the period August 14-15, 2007. ISG indicated an elevation accuracy to within a few hundredths of a foot.

We measured a total of 59 water levels during this water level survey compared to the 165 wells measured during the summer of 2006. The wells surveyed were chosen after careful review of geologic reports, Well Driller's Reports and/or geophysical logs to identify wells that are completed in the Pierce Gulch Sand Aquifer. Some wells were also selected that are completed in different aquifers. Aquifer designations were based on elevations, lithologic descriptions and water levels.

Table 1 includes the survey information for the measured wells. Data new to the 2007 program are highlighted in bold. Information is presented as latitude/longitude and GPS coordinates in UTM US feet for Zone 11. Wellhead elevations presented to one one-hundredth of a foot indicate the wells that were surveyed by ISG. Elevations presented to

one foot were generated using the computer program TOPO. Horizontal accuracies are also included in the table.

Wells were measured using a steel tape and chalk to the nearest 0.01 foot. The tape was first cleaned and sanitized using chlorine bleach. Chalk was then applied to the lower few tens of feet of the marked-and-calibrated steel-tape. The tape was inserted into the well access port and lowered until the end of the tape reached below the surface of the water, wetting a portion of the chalk. The depth to water was calculated by subtracting length of the wetted portion of the chalk from the total tape length below the top of the well head casing. In general, the tape was lowered multiple times in order to arrive as a "confirmed" water level. Electrical well sounders were not used because of the potential for snagging the tip of the well sounder line on the down-hole wiring or couplings of domestic wells and because of the preferred accuracy of the steel tape method.

The field hydrogeologist attempted to assess whether the well was pumping, had recently been pumped, was being affected by some other nearby well, or in some other way might give misleading (non-"static") levels. In some cases a deep submersible pump and the potential for the water to be used at some distal location made it impossible to know for sure whether the pump was in use in these deep wells.

Table 1 also includes selected information included on well driller's reports on file with the Idaho Department of Water Resources (IDWR). Driller's Reports were available for some, but not all, of the measured wells. The information included on Table 1 includes the IDWR number (if noted on the log), the depth to water reported by the well driller, the well completion date and well completion interval information (depth to top and bottom of the well screen assembly or perforated sections). In cases where no completion interval information was available on the log, we have assumed that the well was completed as an "open-hole" well with no screen or perforations. Well completion information is also shown as elevations above sea level by subtracting depths from the estimated ground surface elevation. All measurements (except for latitude and longitude) are in feet.

Figure 1 presents our revised 2007 contour map for water levels in the Pierce Gulch Sand Aquifer and the Willow Creek Aquifer. The contours were initially generated using SURFER®. Contouring was done with a contour-interval of 25 feet and the use of a fault to exclude the influence of water levels within non-Pierce Gulch Sand Aquifer aquifers. The SURFER® -generated contours were then modified by hand using best-professional judgment to account for edge effects and the interaction between the water levels in the Pierce Gulch Sand Aquifer and the Willow Creek Aquifer in the Payette Valley. All contours for the Willow Creek Aquifer were generated by hand using best-professional judgment. Contours presented as dashed lines in Figure 1 are approximate and based on fewer and/or less-accurate data.

The 2007 contours in Figure 1 show are more accurate than the contours developed in 2006 and presented in our Year-One Progress report (HLI, 2006) using a "shotgun"

approach with more wells and less-accurate hand-held instruments for survey positions and elevations. The new contours continue to indicate and support the general flow patterns in the greater Eagle-Star-M3 project area that we presented in 2006. Some of the perturbations shown on the 2006 contour map were apparently the result of the inherent errors associated with using all of the water level data, even from wells that were completed in overlying aquifers, were pumping (or recovering from pumping) at the time of measurement, and/or may have been inaccurately located. The 2007 contour map (Figure 1) shows that ground water flows from the Boise Valley toward the Payette Valley, with a generally northwest component beneath the Eagle-Star-M3 vicinity.

We initiated this study to confirm our previous work and because the relatively flat water level gradients were within the error range of our hand-held instruments. In other words, we felt a more accurate measurement of well head elevations were necessary to confirm the true direction of ground water flow beneath the area. Our survey-grade measurements not only confirmed the ground water flow direction but is showed a slightly higher gradient toward the Payette River basin causing us to estimate somewhat lower aquifer transmissivity values for the Pierce Gulch Sand Aquifer.

We are still monitoring on a continuous basis at several locations in greater Eagle-Star-M3 area. These data will be made available at a future date.

Figure 1. 2007 Regional Ground Water Level Contours and Flow Directions

Water Level Data Sources:

M3 Project Area, Eagle, Star and Meridian: Measurements and Survey - Summer of 2007 by HLI

Emmett and Caldwell Areas: Wells from IDWR Data Base. Locations / Elevations From Google Earth®, MapQuest® and TOPO®

Data contoured by Surfer® with manual contouring near Emmett and Caldwell. Dashed contours where sparce or approximate data appear to yield contours that may or may not be representative.

+ Well: surveyed ◆ Well: estimated location

Approximate Ground Water Flow Directions:

Pierce Gulch Sand Aquifer

"Willow Creek Aquifer" and Payette Valley Aquifer

Water Level Contour Elevation in Feet MSL

2400

(Dashed Where Inferred)

West Boise-Eagle Geologic Fault System

(Dashed Where Inferred)

Contact between bottom of Pierce Gulch Aquifer and underlying mudstone facies of the Terteling Springs Formation (inferred location, dashed where speculative)

Scale: = 1 Mile

North

September 17, 2007

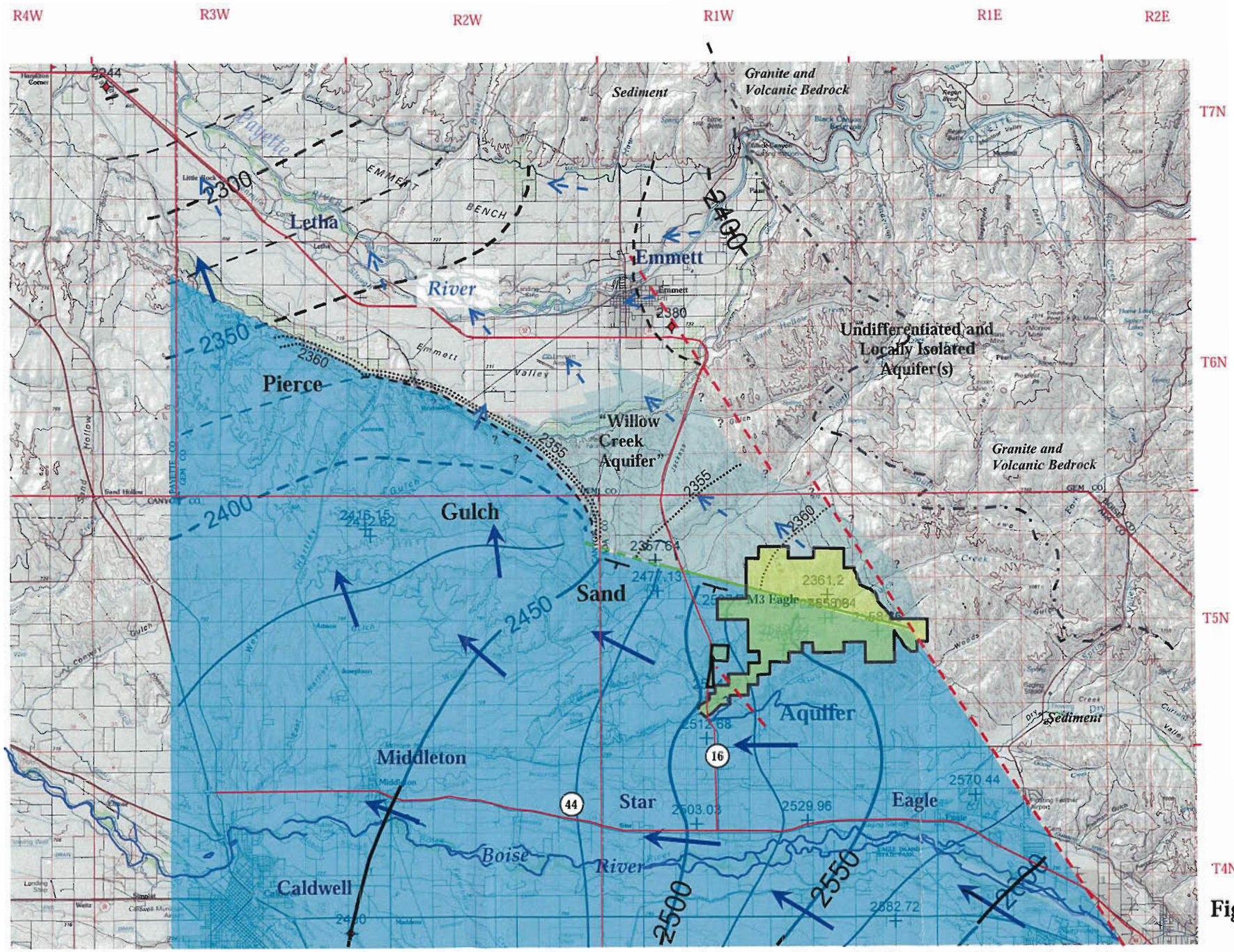


Figure 1.

The black-colored, 50-foot water level contours inside blue shading indicate the northwesterly movement of ground water from the Boise Basin to the Payette Basin north of the Cities of Star, Eagle, and Middleton through the Pierce Gulch Sand Aquifer. The dotted 5-foot water-level contours inside the turquoise area illustrate the relatively flat ground water gradient within the recharge-limited informally named "Willow Creek Aquifer" isolated between low-permeability sediments of the uplands lying to the east of the M3 site and by stratigraphic layering (a day-lighting clay stratum) on the southwest (green solid and dashed line). The boundaries of this aquifer have not been defined as indicated by the "?" symbol.

Hydro Logic, Inc
Boise, Idaho

Figure 2. Locations For Wells Measured During 2007 Regional Ground Water Level Survey

M3 Project Area, Eagle, Star and Meridian: Wells located by GPS Survey Summer of 2007 by HLI and Idaho Survey Group

Emmett and Caldwell Areas: Wells located from maps in HLI files.

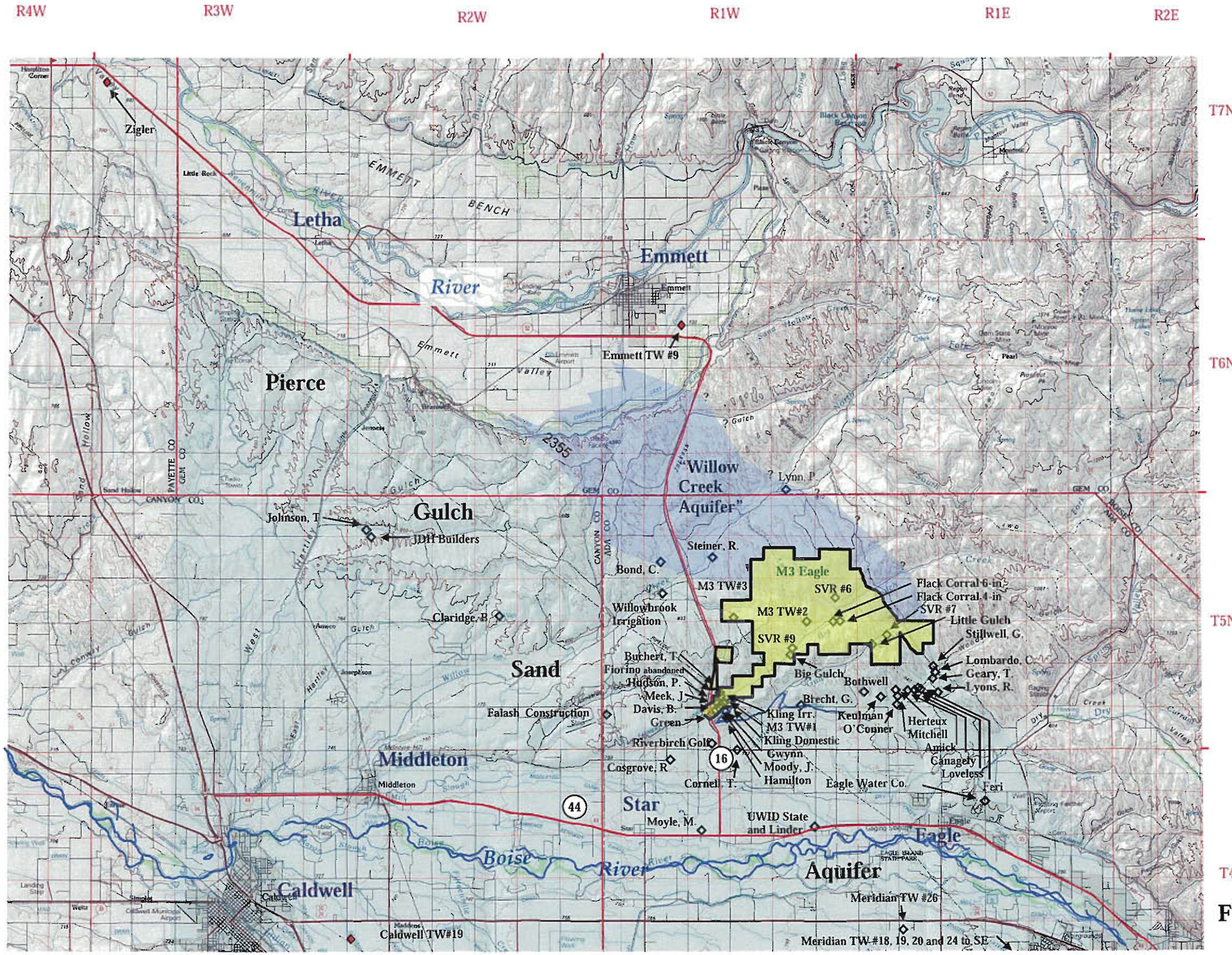
Northwest Area: Well located using well log address, MapQuest®,and Google Earth®.

◆ Well water level measured Summer 2007

◆ Well water level from previous periods

Scale: ⌐¬ = 1 Mile

North ↑



September 19, 2007

Figure 2.

Hydro Logic, Inc
Boise, Idaho

Hydro Logic, Inc
1002 W. Franklin Street, Boise, ID 83702 (208) 342-8369, (Fax) 342-3100, hydrologic@qwest.net

Table 1 - Regional Well and Water Level Survey 2006 and 2007

Well Owner	Time (24 Hour Clock)	Depth to Water (DTW) 2007	Time (24 Hour Clock)	Depth to Water (DTW) Previously Reported	DTW Change - = level getting deeper with time	Water Level Elevation 6/2007 - 7/2007	Water Level Elevation 6/2006 - 7/2006	Casing Stickup	Depth to Water from Driller's Report	Well Completion Date	Well Depth	Opening Top (depth)	Opening Bottom (depth)	Opening Top (elevation)	Opening Bottom (elevation)	1 = open interval from log 2 = open hole	Aquifer Designation	Comments
name of current, previous, or original owner (if applicable)		feet below ground		feet below ground	feet	(feet above mean sea level)	(feet above mean sea level)	feet above ground	feet		feet below ground	feet below ground	feet below ground	(feet above mean sea level)	(feet above mean sea level)	#	(see end notes)	notes
Allred, Keith and Christine			07/25/2006 10:10	38.48			2577	0	39									
Amick, Dave	06/15/2007 14:59	206.61	06/22/2006 14:15	205.51	-1.10	2538	2539	1.36	190	Feb - 1992	256	256	256	2487	2487	1		
Anderson, Gloria			06/24/2006 19:05	146.39			2553	1.01										
Bailey, Gene			06/13/2006 11:30	163.14			2484	1.65										
Ballard, Patrick and Lori			06/13/2006 13:15	22.27			2504	1.5	40									
Baramore, Kagathaleen			06/12/2006 15:43	199.58			2502	1.8	221	Nov - 2006	417	407	417	2293	2283	1		
Barfuss, Ray			06/20/2006 11:45	60.50			2496	1.6										
Barker, Byron			06/19/2006 16:33	167.21			2544	1.2										
Barsby			06/25/2006 14:25	33.02			2710	1.39	17	Dec - 1996	58	18	58	2724	2684	1		
Big Gulch - Stock Well (owned by M3 Eagle)	07/03/2007 13:37	152.90				2546.32	-	1			180					2	PGSA	
Boatiglia (sp?)			06/12/2006 13:00	67.01			2508	0.3										
Bodily La Thare, abandoned			06/19/2006 16:07	154.00			2563	1.76										
Bodily La Thare, domestic			06/19/2006 15:32	139.05			2553	2										
Bothwell, Glenn	06/15/2007 11:05	211.14	06/18/2006 14:24	206.74	-4.40	2550	2554	1.15	200	Feb - 1991	293	292	292	2468	2468	1		
Brecht, George and Leigh	06/19/2007 14:41	85.49	06/15/2006 11:15	86.53	1.04	2546	2545	1.05	88	Jul - 2006	178	168	178	2462	2452	1		
Brookside (Unknown Owner)			06/25/2006 13:15	20.54			2656	1.37										
Buchert, Troy	06/14/2007 15:39	286.4	06/03/2006 00:00	279.60	-6.80	2480	2486		264	Dec - 2006	460	450	460	2316	2306	1		
Burke, Tim and Mary			06/23/2006 14:40	164.81			2541	0.63										
Caldwell #17 Test 3N/3W 10ADD**			07/11/2006 15:30	37.25			2420	2.9	21	Nov - 2002	480	369	429	2085	2025	1	above PGSA?	
Caldwell #19 Test 4N/2W 30 BC**			05/24/2005 13:14	-18.70			2442	2.65	-19	May - 2005	582	550	570	1871	1851	1	above PGSA?	DTW from 5/24/05
Campbell, Morris			06/20/2006 13:40	51.52			2478	1.4										
Canegaly, Paul & Karen	06/20/2007 12:57	140.3	06/22/2006 13:55	139.44	-0.86	2551	2552	1.24	134	Feb - 1995	223	211	221	2479	2469	1		Pumping starts during measurement
Capps, Eric & Heather			06/20/2006 16:15	266.45			2501	2.2	280	Jun - 2006	436	431	436	2334	2329	1		
Chukar (Ray Irving)			06/12/2006 16:08	209.22			2480	2	204	May - 2006	368	368	368	2319	2319	2		
City of Eagle - Legacy	08/17/2007 11:05	-9.24					2525	3.23		Apr - 2006	513	282	352	2231	2161	1		
City of Eagle - Eaglefield	08/18/2007 10:37	-13.28					2530	3		May - 2006	444	260	395	2254	2119	1		
Clark, Lynnwood			06/23/2006 11:00	228.36			2543	1.5										
Colton Lane Bond Campbell	08/08/2007 16:22	394.04				2357.64	-	2.25	380	Feb - 2003	503	503	503	2246	2246	2	WCA	
Cornell, Thomas and Vickie	06/19/2007 13:17	48.98	06/13/2006 13:46	36.65	-12.33	2529	2541	2.55	2	Dec - 1967	245	245	245	2330	2330	2		Nearby irrigation well pumping
Cosgrove, Ralph	06/14/2007 14:53	53.18	06/20/2006 13:14	52.52	-0.66	2494	2495	0.65	45	Jul - 1987	197	197	197	2350	2350	2		
Cunningham - domestic			08/08/2006 12:45	93.09			2747	0										
Cunningham - irrigation			08/08/2006 12:35	97.70			2739	1.5	82	Sep - 1967	237	237	237	2598	2598	2		
Cunningham - new domestic			08/08/2006 13:10	122.24			2800	2.1										
Curtright			06/13/2006 16:00	58.15			2511	1.05										
Davis, Bob	06/19/2007 10:33	78.87	06/02/2006 13:00	78.78	-0.09	2519	2519	2.2	80	Mar - 1999	160	149	149	2447	2447	1		
Decker, Charles			08/01/2006 12:06	4.04			2492	1	2	Nov - 1971	57	57	57	2438	2438	2		
Densmore, Jackie (original owner)			06/12/2006 10:55	64.93			2482	2.35	50	Apr - 1997	206	150	160	2395	2385	1		
Dubie, Gaylord				24.20			2555	0.73										
Eagle Family Worship Center			08/01/2006 13:50	16.76			2533	1.4	14	Jun - 2002	85	85	85	2463	2463	2		
Eagle Water Co. - Well #3		65.80				2570.44	-	1.55									PGSA	
Edmunson, Johnny			06/17/2006 17:00	101.58			2555	1.4	92	Dec - 1970	175	116	116	2539	2539	1		
Edwards, Stephen			06/27/2006 16:15	41.64			2563	2.19										
Eiguren, Tony & Tara, domestic			06/25/2006 15:35	90.54			2649	1.54	100	Apr - 2006	420	420	420	2318	2318	2		
Eiguren, Tony & Tara, irrigation			06/25/2006 15:45	96.05			2635	1.52				30	30	2700	2700	1		
Fahrner, Sharon			08/01/2006 10:55	24.85			2488	0.7										
Falash Construction	06/20/2007 15:19	190.31	06/28/2006 10:20	185.97	-4.34	2441	2445	1.16	195	Jun - 1995	285	285	285	2345	2345	2		
Ferri, Frank & Linda	06/15/2007 14:11	155.38	06/22/2006 16:55	152.53	-2.85	2547	2550	2.3	147	Jun - 1999	235	223	233	2477	2467	1		15 minutes into recovery when measured
Fiorino, 1 Chris, domestic			06/02/2006 15:00	222.80			2499	1.65	215	Nov - 1994	608							
Fiorino, 2 Chris, abandoned	06/14/2007 11:35	266.24	06/02/2006 15:30	272.80	6.56	2494	2487		260	Oct - 1993	487	463	485	2297	2275	1		
Flack Corral 4-inch (owned by M3 Eagle)	07/03/2007 14:44	207.37				2555.06	-	2.2									PGSA	
Flack Corral 6-inch (owned by M3 Eagle)	07/03/2007 14:56	214.11		213.74	-0.37	2558.94	2549	2.8	-	Jun - 1905	400	400	400	2360	2360	2	PGSA	
Flack Rental Property, domestic			06/13/2006 14:57	52.49			2533	1.25				132	132	2452	2452	1		
Flack Rental Property, irrigation			06/13/2006 14:52	52.74			2533	0.83	38	May - 1961	72.5	69	69	2516	2516	1		
Floating Feather (UWID)																	PGSA	
Fry, Diane			06/15/2006 10:35	71.74			2520	1.89	68	Oct - 2006	98	93	98	2497	2492	1		
Fry, Phillip			06/15/2006 12:10	106.85			2549	1.13	110	Sep - 1996	181	165	165	2490	2490	1		
Fuller				error			error	1.7	310	Sep - 2000	471	459	469	2391	2381	1		
Gallia, J and L			06/12/2006 14:45	149.40			2557	1.8										
Geary, Tim	06/15/2007 15:49	141	06/24/2006 16:40	144.59	3.59	2556	2552	1.84	130	May - 1997	229	219	229	2476	2466	1		
Gillis, Bert			06/12/2006 11:58	91.50			2465	1.95										
Gonzales, Curtis			08/01/2006 14:35	12.78			2521	1.6	12	Jun - 2002	98	98	98	2434	2434	2		
Green, Jay and Kim (owned by M3 Eagle)	06/14/2007 16:11	96.51	06/02/2006 14:00	93.19	-3.32	2492	2495	1.55	75	Nov - 1970	135	130	135	2457	2452	1		
Grupe, Robert			06/20/2006 17:00	58.34			2491	0.95	50	Oct - 1974	76	76	76	2472	2472	2		
Gwynn (owned by M3 Eagle)	06/14/2007 13:31	111.86	06/02/2006 13:30	109.49	-2.37	2500	2502	1.8	110	Jun - 1998	320	314	319	2296	2291	1		
Hamilton 1, Ken and Linda	06/14/2007 14:15	190.92	06/03/2006 15:30	191.54	0.62	2520	2520	1.3	190	Mar - 2006	415	405	415	2305	2295	1		
Hamilton 2, Ken and Linda			06/03/2006 15:00	182.28			2527	1.3										
Haws, Scott			06/28/2007 14:30	196.95			2444	1.4	173	Mar - 1994	344	339	339	2301	2301	1		
Heck, Bill			07/25/2006 09:15	7.64			2544	0	6	Apr - 1977	50	39	39	2513	2513	1		
Hendricks, John			06/17/2006 19:50	84.42			2555	0.95										
Herteux, Darrick and Carrie	06/22/2007 10:06	231.77	06/19/2006 10:50	226.89	-4.88	2538	2543	1.81	217	Jun - 2000	341	337	337	2431	2431	1		
Hinkley, Clint & Regina			06/28/2006 11:30	173.15			2440	1.38										
Hondo (Unknown Owner)			06/23/2006 15:20	224.84			2551	1.14										
Howarth, Charles			08/01/2006 16:08	-12.01			2510	3	12									
Hudson, Paul	06/14/2007 12:20	220.9	06/03/2006 00:00	219.45	-1.45	2517	2518	1.94	202	Jun - 1998	469	463	468	2255	2250	1		

Hydro Logic, Inc
1002 W. Franklin Street, Boise, ID 83702 (208) 342-8369, (Fax) 342-3100, hydrologic@qwest.net

Table 1 - Regional Well and Water Level Survey 2006 and 2007

Well Owner	Time (24 Hour Clock)	Depth to Water (DTW) 2007	Time (24 Hour Clock)	Depth to Water (DTW) Previously Reported	DTW Change - = level getting deeper with time	Water Level Elevation 6/2007 - 7/2007	Water Level Elevation 6/2006 - 7/2006	Casing Stickup	Depth to Water from Driller's Report	Well Completion Date	Well Depth	Opening Top (depth)	Opening Bottom (depth)	Opening Top (elevation)	Opening Bottom (elevation)	1 = open interval from log 2 = open hole	Aquifer Designation	Comments
name of current, previous, or original owner (if applicable)		feet below ground		feet below ground	feet	(feet above mean sea level)	(feet above mean sea level)	feet above ground	feet		feet below ground	feet below ground	feet below ground	(feet above mean sea level)	(feet above mean sea level)	#	(see end notes)	notes
Hudson, Richard & Cheryl			06/20/2006 14:52	41.13			2481	1.3	40	Jun - 1998	144							
Hutton, C. Hank			06/20/2006 14:35	42.02			2483	2.05	20	Jun - 2006	115							
Jackson, Milan			06/25/2006 12:35	64.61			2657	1.4										
Jones, Robert			06/19/2006 17:06	105.78			2556	1.35	34	Oct - 1973	124	114	124	2546	2536	1		
Kallbrier, John				297.78			2508	1.75	184	May - 1963	628	492	492	2312	2312	1		
Keulman, Gloria	06/19/2007 15:13	205.74	06/19/2006 13:44	201.69	-4.05	2554	2558	1.54	200	Jan - 1990	324	312	322	2446	2436	1		
Kinder, Richard and Tracy			06/20/2006 12:53	51.60			2487	0.83										
Klein, Milton			06/21/2006 15:30	48.94			2470	1.32										
Kling - Irrigation well (owned by M3 Eagle)	08/30/2007 12:14	95.42	06/02/2006 10:39	103.04		2521	2512	1	90	Aug - 1989	415	198	408	2417	2207	1	PGSA	
Kling Domestic Well (owned by M3 Eagle)	06/11/2007 15:37	111.6	06/02/2006 11:13	112.65	1.05	2506	2505	1.45	105	May - 2006	285	285	285	2331	2331	2		
Koeppen, Dave			06/03/2006 00:00	94.35			2577	1.25	105	Aug - 1993	223							
Kuck, Lonn - domestic			06/21/2006 16:05	49.37			2470	1.15										
Kuck, Lonn - irrigation			06/21/2006 16:20	51.80			2468	1.61										
Lane, K. and Tina			06/27/2006 14:18	12.84			2552	2.15	6	Sep - 1999	101	96	101	2467	2462	1		
Langdon, Ken and Joan			06/13/2006 14:18	83.62			2535	1.1										
Langley, B			06/15/2006 09:54	42.81			2528	1.1										
Lansing (27750 Lansing Lane) Bob Claridge	08/08/2007 12:38	236.36				2504.37	-	2.13										Pumping before measurement
LDS Church / Eagle Stake Center			08/01/2006 13:01	41.55			2561	1.7	28	May - 1993	470	397	465	2204	2136	1		Very difficult to measure
Lexington Hills #1							-										PGSA	
Little Gulch 6-inch Stock Well	06/01/2007 14:02	174.58		182.14	7.56	2577	2569	1.5			224.2	224	224	2526	2526	2		
Lombardo, Chris & Carey	06/20/2007 13:34	178.67	06/24/2006 15:54	176.52	-2.15	2542	2545	1.15	163	May - 1997	244	234	244	2486	2476	1		Pumping before measurement
Longhi, Michael and Christl			06/12/2006 12:39	85.33			2472	2										
Loveless, Brent	06/20/2007 12:30	177.25	06/22/2006 17:30	172.80	-4.45	2544.10	2549	1.35	170	May - 2006	354	344	354	2376	2366	1		Pumping before measurement
Lynn, Corbett			06/16/2006 11:17	396.20			2368	1.2										
Lynn, Mark			06/16/2006 14:26	384.24			2338	2.14	395	Oct - 1993	620	543	573	2177	2147	1		
Lynn, Phil	06/19/2007 09:50	431.24	06/16/2006 12:06	431.19	-0.05	2372	2372	1.58	360	May - 2000	600	600	600	2202	2202	2		
Lyons, Robert	06/15/2007 13:22	259.81	06/24/2006 17:50	258.72	-1.09	2536	2537	0.6	280	Sep - 1976	Nov-00	310	320	2485	2475	1		
M3 Eagle - Test Well #1	07/03/2007 11:42	105.17				2504.37	-	3.15									PGSA	
M3 Eagle - Test Well #2	07/31/2007 13:00	217.58				2551.43	-	3									PGSA	
M3 Eagle - Test Well #3	07/03/2007 09:54	262.34				2527.75	-	3.46									PGSA	
Maddox, Kenneth	06/15/2007 12:36	93.11	06/27/2006 11:00	97.65		2570	2566	1.48	80	Sep - 1992	245	235	245	2427	2417	1		Pumping before measurement
Mallot, Karl			08/01/2006 09:54	13.70			2559	0.7										
Martinez, Jorge			06/19/2006 11:40	249.31			2555	2.47	239	Jul - 1998	338	400	410	2402	2392	1		
Mc Peak, Orval			06/27/2006 14:00	40.23			2554	0.9										
McLeod			08/01/2006 16:30	2.20			2518	1.2										
Meek, Janis	06/19/2007 11:58	202.36	06/02/2006 12:06	201.97	-0.39	2488	2488	1.88	220	Aug - 2006	415	398	398	2290	2290	1		
Meridian #18 - Test Lower Zone	06/25/2007 16:36	16.90	06/01/2006 13:33	14.56	-2.34	2595.68	2598.02	1.95		Dec - 1995	700	575	695	2036	1916		PGSA	
Meridian #19 - Test	06/25/2007 15:17	0.70	06/01/2006 12:50	-1.26	-1.96	2558.74	2560.70	2.2	-6	May - 1997	1043	250	390	2307	2167	1	above PGSA?	
Meridian #20 - Test Zone 4	06/25/2007 16:16	6.82	06/01/2006 13:20	2.92	-3.90	2589.93	2593.83	4.96		Nov - 1997	1012	890	960	1702	1632	1	PGSA	
Meridian #21 - Test	06/25/2007 14:42	20.97	06/01/2006 12:16	18.63	-2.34	2604.34	2606.68	1.9	10	Jan - 1999	905	837	897	1786	1726	1	PGSA	
Meridian #24 - Test		-13.70		-	-	2585.56	-	1.96	-20	Feb - 2002	935	820	850	1750	1720	1	PGSA	
Meridian #26 - Test Zone #1	06/25/2007 16:54	24.77	06/01/2006 16:53	18.37	-6.40	2582.72	2589.12	1.55	21	Jun - 2004	1005	792	872	1814	1734		PGSA	
Michaud, Dan and Terry			06/17/2006 19:20	144.24			2558	0.66	150	Apr - 1994	240	230	240	2472	2462	1		
Mike			06/13/2006 09:55	62.52			2492	1.3										
Milam, Margie & Ben			06/22/2006 12:50	143.72			2539	1.6										
Mingus, Gary and Heather - domestic			06/17/2006 17:40	86.24			2557	1.15	75	Jun - 1992	160	150	160	2492	2482	1		
Mingus, Gary and Heather - irrigation			06/17/2006 18:00	82.81			2557	2										
Mitchell, James & Eileen	06/15/2007 11:54	177.2	06/23/2006 11:36	171.14	-6.06	2542	2548	1.63	180	Jan - 1991	385	279	289	2439	2429	1		Pumping before measurement
Moi, Obert			06/27/2006 12:20	95.12			2556	0.88	85	Jun - 1992	194	191	191	2459	2459	1		
Monroe, Troy and Yvette			06/13/2006 10:43	68.13			2494	1.65	76	Jan - 2006	154	149	154	2411	2406	1		
Moody, John and Betty (owned by M3 Eagle)	06/19/2007 11:03	101.12	06/03/2006 00:00	98.42	-2.70	2508	2511	2.1	110	Apr - 1996	302	339	359	2268	2248	1		
Moore, Steve and Sue			06/17/2006 16:30	177.45			2548	0.73	170	Aug - 1993	267	254	264	2471	2461	1		
Morton, Del and Robin			06/13/2006 15:40	69.38			2503	0										
Moyle	07/23/2007 12:24	-15.34				2503.03	-	1.4										
Moyle, Rex and Marjorie			06/13/2006 09:00	63.34			2494	1.2	53	May - 1984	98	98	98	2458	2458	2		
Nahas, Robert and Kelly			06/15/2006 11:40	127.25			2555	1.57										
O'Connor, Mike & Cindy	06\22\2007 09:33	131.86	06/23/2006 17:00	128.82	-3.04	2555	2558	1.39	115	Mar - 2000	269	252	267	2433	2418	1		
Olson, L			06/20/2006 17:30	61.04			2492	1.3										
Palmore, Dennis and Judy			06/28/2006 15:05	231.70			2440	1.24	232	Oct - 1994	432							
Prescott, William			06/19/2006 12:20	233.78			2560	1.86										
Prin, J and V			06/17/2006 18:20	86.49			2555	1.14										
Purdy, Carol			08/01/2006 15:38	9.30			2528	1.1	5	Mar - 1991	100	100	100	2436	2436	2		
Purdy, Pat & Debra			06/25/2006 12:10	32.07			2649	0.22										
Purdy, Vickie and Dane, dairy			08/01/2006 11:39	12.35			2514	1.6										
Purdy, Vickie and Dane, rental			08/01/2006 11:14	29.96			2491	0.6										
Redfern, Dennis			06/17/2006 18:50	92.22			2558	1.77										
Reich, Norman			06/28/2006 13:40	199.57			2442	1.62										
Reimbolt, Tom - Well #2			06/18/2006 16:05	257.98			2544	0.37	250	Sep - 2006	284	274	285	2528	2517	1		
Reimbolt, Tom -Well #1			06/18/2006 15:05	163.73			2540	1.38	162	Oct - 1997	403	391	401	2311	2301	1		
Richardson, Bruce and Jean			06/27/2006 09:55	42.35			2559	0.92										
Rid			06/18/2006 13:45	181.56			2562	3.81										
Rio-Lobo (11494 Rio Lobo) JDH Builders 5N/2W 6DC 207	08/08/2007 09:40	184.36				2412.62	-	1.3	170	Jul - 2004	421	411	421	2185	2175	1	PGSA	
River Birch Golf Course - domestic			06/12/2006 10:00	50.74			2510	1.1	67	Apr - 1968	220	220	220	2340	2340	1		
River Birch Golf Course - irrigation (old Jensen #8)	06/15/2007 10:10	69.25	06/12/2006 10:27	74.21	4.96	2512.68	2500	0.8	70	Jan - 2006	500	500	500	2073	2073	2	PGSA	

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Table 1 - Regional Well and Water Level Survey 2006 and 2007

Well Owner	Time (24 Hour Clock)	Depth to Water (DTW) 2007	Time (24 Hour Clock)	Depth to Water (DTW) Previously Reported	DTW Change - = level getting deeper with time	Water Level Elevation 6/2007 - 7/2007	Water Level Elevation 6/2006 - 7/2006	Casing Stickup	Depth to Water from Driller's Report	Well Completion Date	Well Depth	Opening Top (depth)	Opening Bottom (depth)	Opening Top (elevation)	Opening Bottom (elevation)	1 = open interval from log 2 = open hole	Aquifer Designation	Comments
name of current, previous, or original owner (if applicable)		feet below ground		feet below ground	feet	(feet above mean sea level)	(feet above mean sea level)	feet above ground	feet		feet below ground	feet below ground	feet below ground	(feet above mean sea level)	(feet above mean sea level)	#	(see end notes)	notes
Rodgers, Steve and Cheri			07/25/2006 11:23	160.45			2469	0.7	100	Aug - 1994	594	594	594	2035	2035	2		
Rose, Edward							-											
Schirmer, Doris			06/03/2006 00:00	211.44			2516	1.94	190	Jul - 1980	247	96	101	2629	2624	1		
Shalako (11509 Shakalo Rd) = Tosha Johnson 5N/2W 6CD	08/08/2007 10:54	156.12				2416.15	-	1.83	168	Feb - 2006	272	257	272	2313	2298	1	PGSA?	
Shervik Builders			06/21/2006 14:10	53.87			2489	1.71	52	Feb - 1996	122	122	122	2419	2419	2		
Shrum, Gary and Karen			06/13/2006 15:15	56.06			2530	1.2										
Smith, David			06/24/2006 15:00	200.20			2561	1.4										
Snyder, Garry & Joyce			06/23/2006 12:10	149.58			2556	1.74										
Spano, Joe and Jennifer			06/18/2006 13:10	166.99			2534	1.23	150	Feb - 1997	350	340	350	2360	2350	1		
Spencer, Brent & Joan			06/28/2006 10:55	190.04			2421	1.24										
Star #1			02/27/1995 00:00	-38.37			2513	3.3	-39	Feb - 1995	565	452	550	2019	1921	1	PGSA	" 06" DTW from 2/95
Star #3			08/30/2006 00:00	-31.19			2509	1.6	-31	Aug - 2006	643	544	643	1932	1833	1	PGSA	" 06" DTW from 8/06
Steiner, Richard	06/14/2007 10:30	224.42	06/20/2006 18:10	273.71	49.29	2498	2449	2.3	300	Feb - 1995	600	570	600	2150	2120	1		Pumping before measurement
Stillwell, Gary & Merry Lou	06/19/2007 16:17	228.19	06/24/2006 14:30	234.64	6.45	2525	2518	2.77	212	Sep - 1997	293	283	293	2467	2457	1		
Stillwell, Glenn			06/02/2006 14:30	175.50			2516	1.25	175	Jun - 1978	230	221	221	2469	2469	1		
Strickland			07/25/2006 12:30	-5.30			2514	1.5	2	Nov - 1991	185	158	158	2360	2360	1		
Sutro Corp			06/21/2006 14:35	47.71			2491	1.14										
SVR #01			11/08/2002 09:33	19.80			3219	3	20	Nov - 2002	445	98	400	3138	2836	1		
SVR #02			11/26/2002 11:45	18.00			3603	3	31	Nov - 2002	840	300	840	3318	2778	1		
SVR #03			12/16/2002 00:00	175.00			3425	3	175	Dec - 2002	240	165	240	3433	3358	1		
SVR #04			03/06/2003 10:00	43.40			3249	2.5	75	Mar - 2003	295	250	290	3040	3000	1		
SVR #05			02/05/2004 10:00	22.97			3220	4	226	Jan - 2004	147	38	140	3201	3099	1		
SVR #06 (owned by M3 Eagle)	07/03/2007 15:30	455.36	05/05/2006 11:03	453.22	-2.14	2361.27	2352	1	455	Feb - 2004	740	560	730	2244	2074	1	WCA	
SVR #07 (owned by M3 Eagle)	07/31/2007 12:35	163.40	07/10/2006 15:42	163.06	-0.34	2549.44	2556	3	161	Apr - 2004	815	280	350	2436	2366	1	PGSA	
SVR #08			04/14/2004 10:00	66.70			3426	2.5	62	Apr - 2004	141	238	290	3252	3200	1		
SVR #09 (owned by M3 Eagle)	07/31/2007 15:03	196.50	05/05/2006 12:19	195.95	-0.55	2558.36	2556	1.8	193	Jun - 2004	806	235	263	2515	2487	1	PGSA	
SVR #10			06/26/2006 12:30	483.61			2389	2.28	485	Jul - 2004	1005	580	640	2290	2230	1	WCA	
Swank, Jim			07/25/2006 12:07	26.15			2557	1	35	Jun - 1991	170	155	165	2427	2417	1		
Taylor, Jerry			06/25/2006 16:40	75.82			2504	0.78										
Thompson			06/19/2006 14:30	240.87			2554	1.38										
Treasure Valley Turf - domestic			06/20/2006 10:00	47.45			2514	1.45										
UWID State and Linder MW #1 (East Well)	06/01/2007 08:45	+11.53				2529.96	-	-0.55		Oct - 1997	545	400	490	2119	2029	1	PGSA	
UWID State and Linder MW #2 (West Well)	06/02/2007 08:45	+12.22				2529.91	-	-0.55		Dec - 1997	845	560	730	1959	1789		PGSA	Deeper of test well pairs
VanHouten, Jay			06/29/2006 10:45	8.68			2484	0.56										
Walker, Brandon			06/17/2006 15:10	64.44			2574	2.48										
Watson, Thomas and Lumia			06/17/2006 15:55	93.11			2566	0.91										
Welton, Stu			08/01/2006 10:38	37.00			2483	1.9	30	Oct - 1998	174	174	174	2344	2344	2		
West, Robert			06/22/2006 16:08	226.02			2545	0.99										
Willow Creek (Unknown Owner)			06/26/2006 14:40	183.11			2584	2.55										
Willowbrook - irrigation	08/14/2007 10:26	168.25				2477.13	-	2.42									PGSA	
Woods			06/12/2006 15:20	204.70			2472	2.05	230	Jun - 1998	371	371	371	2304	2304	2		
Yeakly			06/29/2006 12:30	47.50			2460	1.15										

Mean change in Depth To Water (DTW) measurements acquired by HydroAll Wells: *-0.22*

Note: some wells were pumping or recovering in 2006 and 2007 at time of measurement. Changes may or may not reflect changes in overall aquifer conditions and are subject to an annual groundwater

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Documentation Provided

by

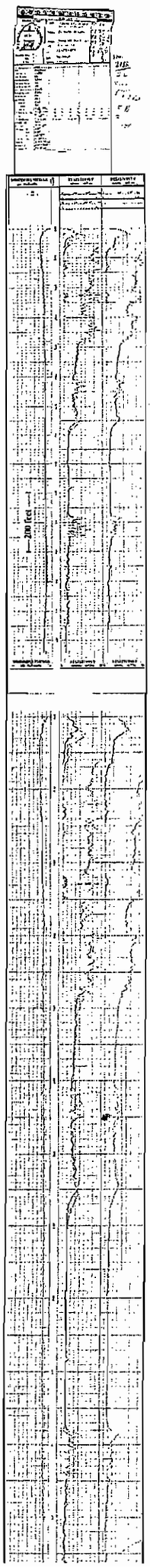
S. H. Wood, PhD.
Professor Emeritus

M3 EAGLE LLC
EXHIBIT
19

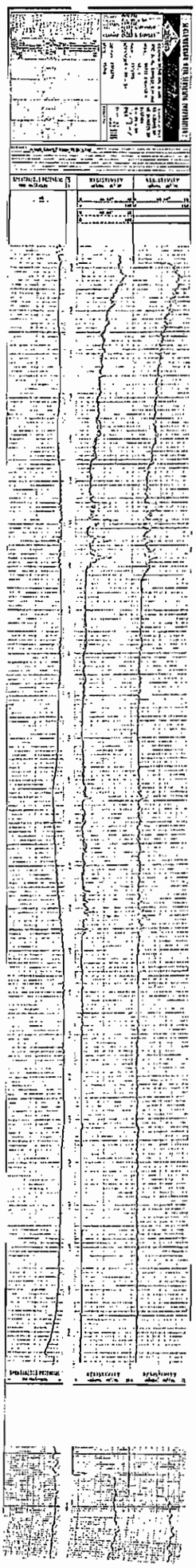
A

19A

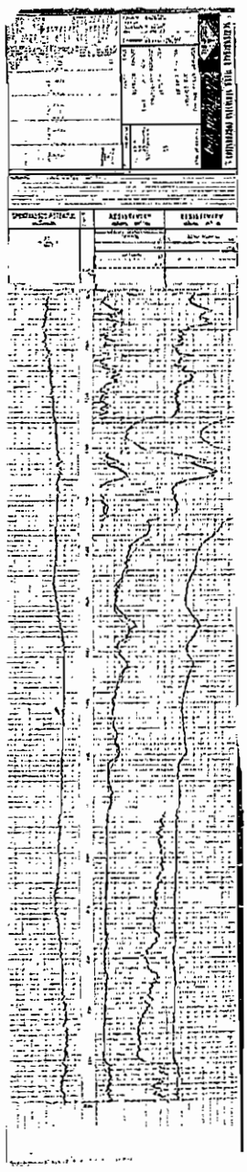
RB1



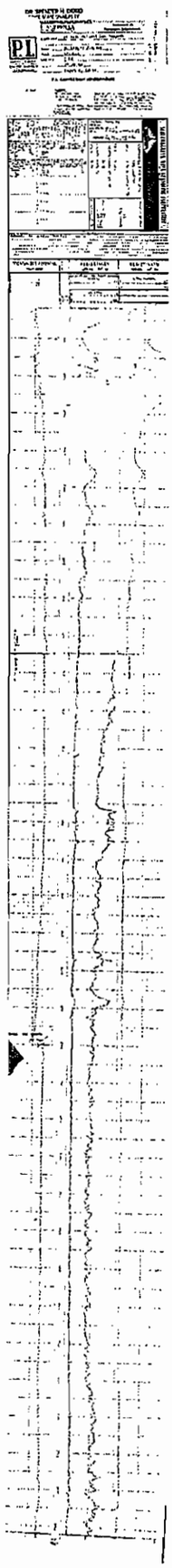
BC1

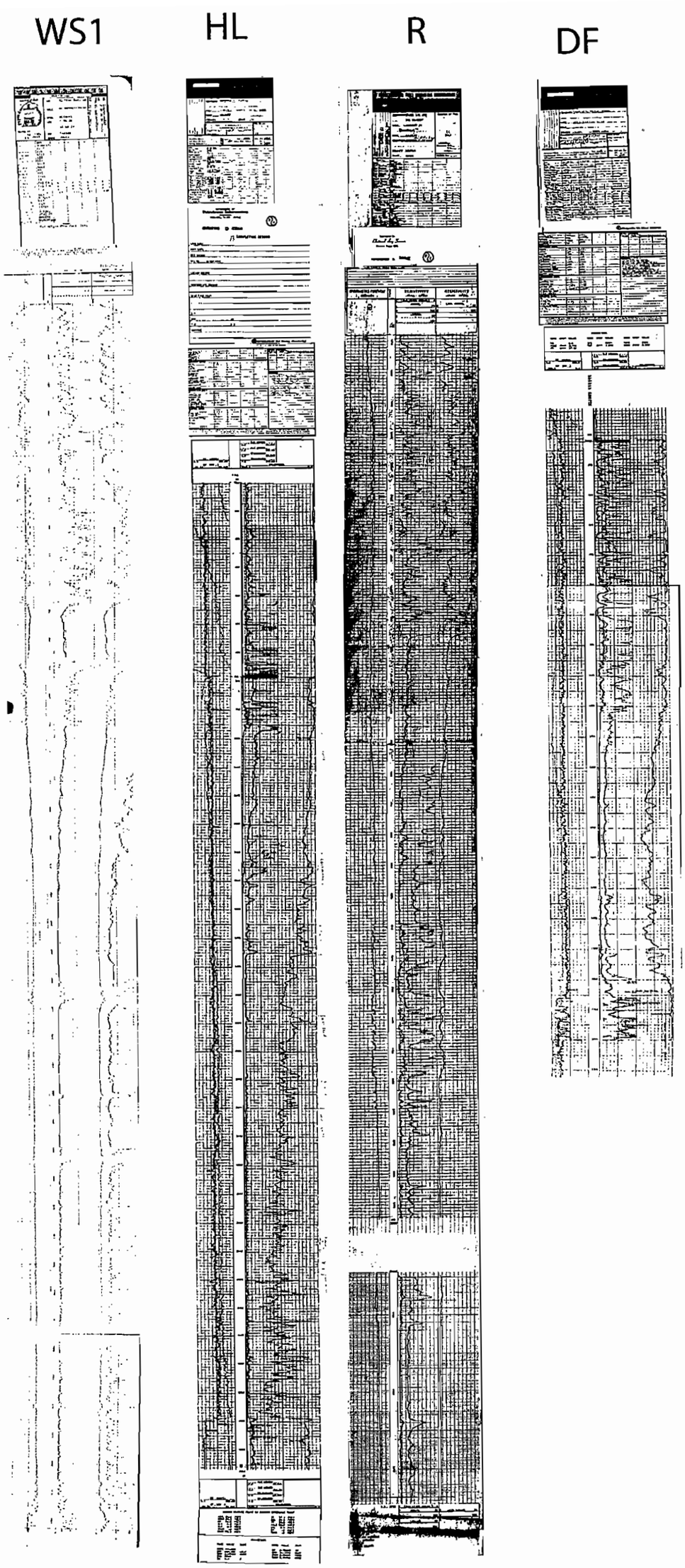


TD1



VJ1




WS1
HL
R
DF

19B

Qualitative Interpretation of Magnetic Anomalies and Progress Report on Geologic Mapping in the Foothills North of Eagle, Ada and Gem Counties, Idaho

Report prepared for HydroLogic, Inc. (May 20, 2007)

by

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MAGNETOMETER SURVEY

Summary: The survey clearly identifies a down-to-SW fault along Willow Creek Road (Fig.1), and width of the anomaly suggests the sediment section over volcanics is at least 3,000 feet deep (a surprisingly deep estimate, which if important, needs verification by more detailed survey and interpretation). The fault aligns with the NW extension of the previously identified West Boise – Eagle fault. Another major down-to-SW fault is identified near the mouth of Big Gulch, and crude estimate of thickness of sediment section over faulted volcanics is 2,300 to 4,600. Better definition of faulting on the M3 properties could be obtained by a long magnetometer line (14 km), along ridgetop roads between Willow Creek and Big Gulch, with close supervision of data quality.

Measurements: Data was acquired under the supervision of Dr. Paul Donaldson, mostly by graduate student Carlyle Miller.

The first data set was acquired in about June, 2006 as lines along Little Gulch and Big Gulch. The data set is generally of good quality with a noise level of ± 5 nanoTeslas (nT).

A second set of data was acquired later in the summer of 2006 along Willow Creek and Chaparral Road ("north line"), along the Farmers Union Canal ("south line"), an extension of the Big Gulch Line to the southwest, and a short line near Highway 16 between Big Gulch and Willow Creek (Figs. 2 and 3). This data set is quite noisy with a level of ± 15 nT, and many unexplained excursions exceeding 80 nT. It is likely that the magnetometer malfunctioned intermittently. The instrument was subsequently sent to Geometrics for repair by Lee Liberty, and a number of problems were repaired. However, the majority of measurements cluster along a trend, so that the larger anomalies were measured. Nevertheless, it is recommended that anomalies detected by the second data set be verified by running an additional line between Willow Creek and Big Gulch, along the ridge top roads through the northern M3 properties and as far SW and NE, as is possible on other lands. The fluctuation in altitude along such a line, greater than 20 m along such should be noted, but it is not likely to significantly affect the measurement of anomalies arising from buried volcanics over 300 m deep (see for example Figs. 5 and 6), which shows that elevation (depth) difference from 300 to 400 m causes a diminishment of 80 to 60 nT, or 20 nT. These anomalies also have an associated long wavelength, greater than 600 m, and should be easily distinguished from elevation effects. However,

for shallow anomalies, shallower than 300 m depth, the effect is greater, and elevation effect over a few hundred meters distance could be mistaken for a shallow anomaly if not noted or corrected.

The instrument used is a Geometrics G-858 cesium magnetometer with two sensors spaced one meter apart, on a vertical staff, the lower sensor about 1 meter off of the ground. This instrument measures the total magnetic field of the earth on each sensor to a precision of 1 nanoTesla (nT. The field values ranged from 53,600 to 53,900 nT. The survey was made by walking and continuously recording. Locations were obtained by simultaneous recording from a GPS unit with an accuracy of ± 8 m. No base stations measurements were made, but tie lines on the Big Gulch and Little Gulch lines gave agreement measurements, indicating no drift or large secular variation in the first set of data. It is possible that gradual diurnal variation of up to 60 nT may occur over a period of 12 hours. I was not provided with detailed field notes showing times of measurement – so one cannot evaluate that source of error – when splicing data together taken at very different times of day.

Source of magnetic anomalies: Magnetic anomalies arise from faulted rock sequences or topographic variation in rocks having a substantial magnetic susceptibility (k), i.e. greater than 0.0001 SI units. (note: SI values are 4π times cgs units, and both are dimensionless). Anomalies may also arise from spatial variation in k of rocks. Basaltic volcanic rocks range from 0.001 to 0.05, dependent largely upon the percent and grain size of the mineral magnetite. For example, a rock with 7 per cent magnetite will have a volume susceptibility of 0.038 SI units (Breiner, 1999). In addition to the magnetism induced in rocks by the prevailing magnetic field, basaltic rocks in particular may have a frozen remnant magnetism set by crystallization of magnetite when the lava cooled. Polarity of the frozen magnetism may be of different or opposite polarity from the induced magnetism, on account of reversed polarity of the earth's magnetic field at the time of crystallization. Remnant effects are difficult to predict without detailed sampling and modeling. For this qualitative interpretation, it is assumed that anomalous magnetism is entirely caused by induced magnetism of the present earth's field.

Qualitative interpretation of anomalies of this survey is based on an assumption that most of the magnetic features are faulted volcanic rocks beneath the Idaho Group sediments. Mapping the in the Pearl area by Clemens (1993) indicates that above the granitic rocks is about 100 m thick section of basalt, locally overlain by as much as 120 m of rhyolite, which is in turn overlain by another 25 m of basalt. Overlying this volcanic section are the Idaho Group sediments which are at least 200 m thick over most of the area. The faulted basalt and rhyolite would produce magnetic anomalies. The deeper granite may produce broad anomalies of longer wavelength and lower amplitude than the volcanics. Very low k of sediments indicate they to not contribute to the field. A reasonable model is 100 to 200 meter thick slab of volcanic rock, overlain by sediments and faulted by normal faults.

Models of faulted volcanic rocks at depth:

Analytical models of the total-field magnetic anomalies for a 2-dimensional faulted slab are published int Telford et. al. (1990). The model is for a cross section of a plate of

thickness, t, extending infinitely in the 3rd dimension. The formula on p. 100, Eqn 3.59b was calculated to visualize the effect of depth, thickness and susceptibility, for offset volcanic rocks. Figures 5 and 6 show a simplified version, of just the upthrown block, assuming an offset of 100 m, of a 100 meter thick section of volcanic rocks of susceptibility of 0.003 SI.

$$F(x) = +2\,k\,t\,F_e\,\{1/(d^2 + x^2)\}\{d \sin 2I \sin\beta - x(\cos^2 I \sin^2\beta - \sin^2 I)\}.$$

In terms for EXCEL:

F(x) =+2*(*k*)*(*t*)**Fe***((1/((*d*^2)+A5^2))*(*d**(SIN(2*RADIANS(*I*)))* (SIN(RADIANS(*strike*))) - A5*(((COS(RADIANS(*I*)))^2)*((SIN(RADIANS(*strike*)))^2) - ((SIN(RADIANS(*I*)))^2)))).

Where
k = magnetic susceptibility, SI units
t = thickness of slab of magnetic rock, in meters.

F(x) = total field measured by the magnetometer.
F_e =Approximate total field of the earth in the area, which induces the anomalous field in susceptible rocks. i.e., the background value, estimated to ± 1000 nT (used a value of 54,000 nT) for model calculations,

d = depth to top of slab
x = horizontal distance from fault edge (parameter A5 in EXCEL code above) (assumed vertical fault plane)
I = inclination of the earth's magnetic field, which for this area is 60 degrees.
β = strike angle between magnetic north, and the strike of the fault. For a fault with strike of N45W, and down to SW, use 45 degrees. For a fault N45W and down to NE use 225 degrees. Telford et. al. (1990) are not clear on their conventions, and to make their formula reproduce their Fig. 3.22b on page 103, I had to change the sign of the equation above from – to a +.

In all formulas for 2D bodies of uniform cross section, the amplitude varies as $2\,k\,t\,F_e$, so that for any given fault depth and offset, at a given orientation to the earth's magnetic north, the anomaly varies linearly with the thickness of the magnetic slab (t) and the susceptibility (k).

Figures 5 and 6 show results of calculation for NW-SE trending faults with vertical planes. The model is appropriate, since faults in the area generally trend NW-SE. The anomaly shape is the same, and changes sign, if faulting sense is opposite (i.e., up to southwest, or up to northeast)

Figure 5 shows that a down-to-SW fault, with 100 m of displacement on the volcanic section will have a positive bulge in the field of 100 to120 nT, if top of upthrown block is 200-m deep, the width of anomaly will be about 600 m. If top of the block is 600-m deep, the anomaly will diminish to 20 to 40 nT, and width will be about 1200 m.

Figure 6, is the anomaly of a down-to-NE fault, and is just the negative value of Figure 4. This calculation for a 700-m deep anomaly show a width of about 1700 m, and an anomaly of 20 to 40 nT for the 100 m thick volcanic section, offset 100 m.

To re-iterate again, the strength of the modeled anomaly is linearly related to the magnetic susceptibility and thickness of the section of volcanic rocks, and diminishes with depth as 1/d.

Specialized and costly software exists for more exact modeling of anomalies (QUICKMAG-PRO $2850 from Rockware), however it was not immediately available for this study. However, I just became aware of a freeware GEOMODEL, also from Rockware, that allows 2.5 D modeling, and that will be done subsequent to this report.

Simple estimates of depth to anomalous features: Because distance breadth of the anomaly increases with increasing depth of the anomalous feature, the width is an indicator of depth to rock feature or susceptibility giving rise to the change in the earth's field. A rule of thumb is that depth is about ½ the width of the anomaly. For example, if an anomaly is 1200 m wide, the depth is about 600 m. Such depth estimates are crude and may be off by 50 per cent (Breiner, 1999).

Another simple measure is to measure the map distance, x_z, of the straight portion of the slope of one of the limbs of an anomalous bulge or depression in field values. "Straight portion" is the distance between the inflection point (i.e.curvature changes from concave upward to convex upward, for positive anomalies). In this estimate, the depth, z, is simply calculated from:

$$z = C\ x_z$$

where C varies from 0.5 to 1.5 (Breiner, 1999).

Discussion of observed anomalies along survey lines. All survey lines trend approximately SW-NE, so that they will yield profiles perpendicular to strike of SW-NW trending faults, believed to be the dominant structures in the area (Fig. 1). Their location will be discussed in terms of UTM km easting coordinate for easy reference on profiles and map. Because the lines are oriented mostly SW-NE, the easting km coordinate separation is multiplied by 1.4 to determine the width of anomaly along the SW-NE oriented survey line. Anomalies are labeled by circled letters on Figure 1, and the following sections discuss the profile lines in terms of those lettered anomalies.

North Line (Chaparral Road – Willow Creek Valley), 9 km long

A: A +20 nT positive anomaly, with a (600-m x 1.4) = 840-m width can be discerned from the rather noisy data at the NE end of the line, centered at 546.15 east (Fig. 2). Anomaly is not well defined, and large excursions of 100 nT in the data are probably

instrument malfunction – indicating the data should be re-run if this anomaly is of interest.

B: Field values rise to the SW to point 544.0, 30 to 40 nT, and then fall off sharply to the SE to point **C**. Interpretation of point B is uncertain. Elevation drop of 33 ft between point is not enough to explain rise in values.

C: Most profound anomaly along this 9-km line is a negative anomaly centered at UTM km 543.0, of -60 to -80 nT, and a width of (1.2 km x 1.4) = 1700 m. The negative value indicates a down-to-SE fault, with more than 100 m displacement, and at an estimated depth to volcanic section on the upthrown block of (½ x 1700 m) = 850 m (2,800 ft).

D: Values rise irregularly from edge of the point **C** anomaly to the end of the line, 60 nT, over a distance of 2.5 km. Data is so noisy (±20 nT) that shape of any individual anomalies, if they exist, cannot be discerned.

Big Gulch Line and the SW extension, 12-km long.

E: A positive +50 nT anomaly, centered at 550.5 east, has a width of (1.4 x 3 km) = 4.2 km (Fig. 2). The same anomaly is larger on the Little Gulch line (Fig. 3), and the tie line (Fig.4), where its magnitude is + 100 to + 180 nT, and breadth is 3 to 4 km. The positive value and width suggest a down-to-SW faulted volcanic section, perhaps 1.5 to 2 km (4,800 to 6,000 ft) deep. Magnitude of the anomaly suggests large displacement (>200 m). The depth estimate seems large, and it is possible that the diminishing NE limb may be a thinning of the volcanic section, and the anomaly width due to faulting is less.

F: A well defined low of -20 nT, with a width of (1.4 x 2 km) = 2800 m. Possibly a down to NE fault at depth, but associated with anomaly at E, may indicate complicated geometry of faulted volcanics.

G. Slight rise and decline with amplitude of about 20 nT, and width of less than (1 km x 1.4) = 1.4 km may indicate a down to SW fault of small displacement (< 100 m).

H: A + 80 nT anomaly centered at 544.5 east with a width of at least (1.4 x 2 km) = 2.8 km, suggests a large down to SW fault, with top of upthrown block about 1.4 km (4,600 ft) deep; however, the SW definition is very noisy due to malfunction of the magnetometer when that SE extension data of this line was obtained (i.e., data SW of 545.0 east). The "south line" point **M**, indicates a 2,300 to 3,300 ft sediment section over the volcanics here, but in both cases the data is very noisy, and needs to be re-run for more precise estimates.

Little Gulch line

I: The largest and best defined anomaly of the survey is this +100 nT, (1.4x 2km) 2.8 km wide positive anomaly, centered at 550.8 east (Fig 3). The positive value suggests a large-displacement (>200 m), down-to-SW fault, with top of faulted volcanics on the upthrown block of about 1.4-km (4,600-ft depth. As discussed above under point E, depth estimate seems much larger than expected, and none of the lines fully defines the full NE limb of the anomaly. NE extension of line could allow better modeling, and also tie to the known volcanic section in upper Little Gulch area drilled by Conolley's wells about 1000 ft deep, 4 km west of here, and the exposed volcanic contact about 4 km to the NE (Fig. 1).

J: A negative anomaly of about -20 nT and a width of (1.2 x 1.2 km) = 1.4 km is centered at 547.3 east, suggesting a small displacement fault at a depth of 700 m (2,300 feet).

K: The rise from anomaly J, at end of line, may be the NE limb of the larger positive anomaly detected by the SW end of the "south line". That SW continuation is shown on this profile, and defines a + 80 nT anomaly centered at about 544.8 east.

South Line (Farmers' Union Canal)

L: Values rise at the east end of the line at 551.7, and are likely the west limb of the anomaly I on the Little Gulch line (Fig 3).

M: Values rise continuously to the west along this line, and then jump up sharply at 547.2 (Fig. 3). The sharp jump may be a splice of data taken at different times, and a result of diurnal variation and of no geologic significance. The peaking of values at 545.5 suggest a large displacement, down-to-SW fault, shown by a positive anomaly of at least + 100 nT, and a width of (2 to 3 km x 0.7) = 1.4 to 2 km. Because this is an EW line, the width of the anomaly, measured perpendicular to a NW-SE strike fault, is reduced by multiplying by 0.7. This same feature is also defined on the Big Gulch line at point **H** (Fig.2) confirming its NW-SE trend, and together suggest a volcanic-section feature at least ½ x 1.4 to 2 km (2,300 to 3,300 ft) deep beneath the sedimentary section.

Willow Creek Road Line ("perpendicular tie line")

N: Data on this line is displayed on both the northing coordinate and the easting coordinate, to better define this large (+200 nT) anomaly centered at 550.4 east (Fig. 4). This is the same feature detected on the Little Gulch line at point **I** (Fig. 3), and probably also at lesser magnitude as point **E** on the Big Gulch line (Fig. 2), and defines a large down-to-SE fault with NW-SE strike.

GEOLOGIC MAPPING PROGRESS & DISCUSSION OF FAULTS

Mapped geologic features are compiled on Fig. 1. Thorough geologic mapping is shown in the northeast corner of the area from Clemens (1990). Mappable faults shown in Fig. 1 are from a number of unpublished mapping projects by S.H.Wood.

Oolitic sands: Occurrence of oolitic sands has been mapped as a part of this project, because they are one of the few cemented rock outcrops in the sedimentary section. Oolitic sands are carbonate coated grains of lake shore deposits, and their origin and significance is discussed in Swirydczuk et al (1980), Wood and Clemens (2002), Wood (2004), Wood and Squires (2007). Significant to this study is the observation that these carbonate-cemented sands occur over a stratigraphic interval, limited to a few hundred feet, in the upper part of the Terteling Springs Formation, on the north side of the western Snake River Plain. Therefore these outcrops are considered a rough geologic marker bed, and the elevation of their occurrence a rough indicator of the tectonic tilting or faulting across the area. Elevations of oolite outcrops are posted on the map (Fig. 1). In the SE Pearl area, their elevation is 3,100 to 3,200 feet. Along Willow Creek, near Lynn's Ranch they occur at 2,900 to 3,000 feet, and along the Old Freezeout Hill Road they occur at 2,700 to 2,750. From these elevations, it is concluded that the vertical-fault offset combined with tectonic tilt of the sedimentary section is about (3,200 - 2,700), 500 ft, from the Pearl area (NE corner of map) to Old Freezeout Hill Road.

Oolitic sands and the Terteling Springs Formation: The oolite deposits are also an identifying feature of sand facies of the Terteling Springs Formation, a facies that lies within several miles of the contact with the Idaho batholith, and grades basinward to the SW to the mudstone faceies (Wood and Clemens, 2004). Therefore, the thick sand section observed along the Old Freezeout Hill Road is Terteling Springs Formation, and is not the overlying Pierce Gulch Sand.

Pierce Gulch Sand: Apparently the Pierce Gulch Sand, with a significant thickness in the western part of the M3 properties, is in a downfaulted section exposed along the bluffs of the Payette River Valley, west of the Old Freezeout Hill Road. I believe the strata in the bluffs in Section 28, T2W, R6N is the Pierce Gulch Sand, because a characteristic white volcanic ash bed (locally 2-ft thick) occurs at elevation 2,610 ft within the dominantly coarse sand deposits. A similar volcanic ash bed occurs in the bluffs of sand sediment along the north side of the Payette River near Birding Island, 18 miles to the northwest. However mapping of the section exposed along the Payette River is in the very preliminary stages, and these correlations are tentative.

Faults: Exposures of strata in the M3 area are scarce; however faint stratification lines are apparent on Google-earth imagery and BLM aerial photography. The faults indicated by the magnetometer survey do not have obvious surface expression, except for one small fault exposed in the roadcut along Willow Creek Road in the hill just north of Big Gulch (Fig.1). That fault is associated with the major down-to-SW fault along Willow Creek Road detected by the magnetometer survey (points **E, I, L,** and **N**), and also known in the southwestern part of the map area from drillers logs and geophysical logs (Fig. 1). Width of the magnetic anomaly suggests a thick sediment section over the volcanics here; however these depth estimates of 4,800 ft are crude. If one uses the formula $z = Cx_z$, and

x_z = (1.4 x 1.5 km) = 2000 m, and a constant for C of 0.5, the depth of sediment over volcanics computes to 1000 m (3,300 ft). The fault is a NW extension of the West Boise – Eagle fault system identified by Squires (1992).

It is puzzling that the down-to-SW fault exposed in the Highway 16 roadcut at Freezeout Hill (Fig. 1) does not have a strong expression on the magnetometer survey (as noted above, that data on the "north line" is very poor in quality on account of instrument malfunction, and another traverse is needed to understand this puzzle). Because the exposed fault shows strata that cannot be matched up in the 60 ft vertical exposure, the offset on this down-to-SW fault must exceed 60 ft. However I believe that the sands at this exposure are entirely the Terteling Springs Formation sand facies. The fault projects SE to the oolite bed exposures on the north side of Willow Creek, near Lynn's Ranch, but the oolite beds are not faulted; therefore, if it is a significant fault, it must project to the SW or to the NE of these beds.

The magnetometer survey of Big Gulch and the "south line" shows a major down-to-SE fault at the western M3 property, labeled points **H, K**, and **M** (Fig. 1). Thickness of sediment over the volcanic section is crudely estimated at 2,300 ft based on width of magnetic anomaly. This fault could be better defined by a survey along the ridgetop roads between Big Gulch and Willow Creek, west of Highway 16 (not M3 property).

The fault indicated by point **C** on the "north line" has an unexpected down-to-NE magnetic signature (negative anomaly) (Figs 1 and 2). Data is very noisy along this line, and the data between points **C** and **D**, while suggestive of complicated faulting, need to be repeated before a more confident interpretation can be made.

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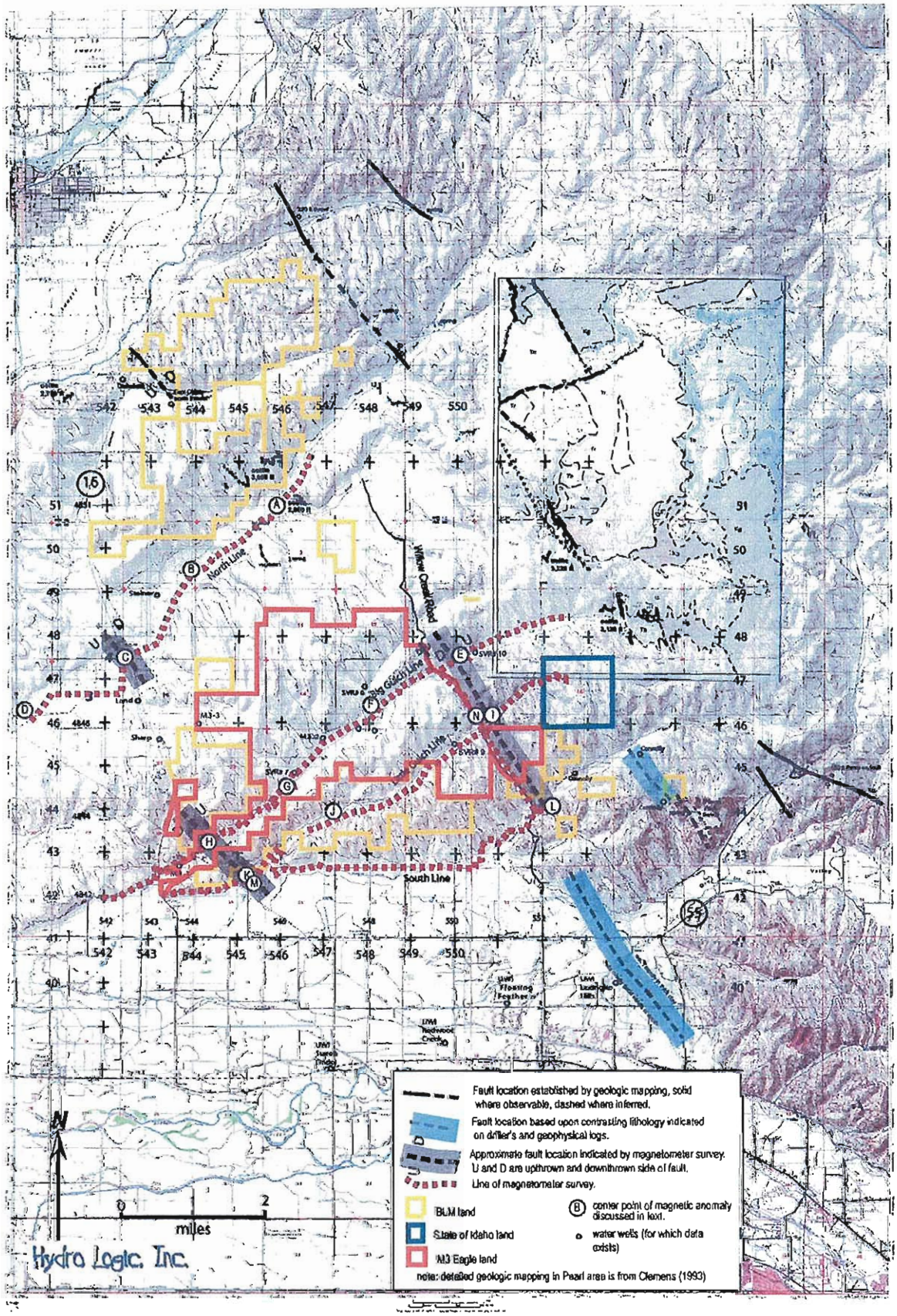

Figure 1. Map showing M3 property, geologic mapping in progress, and location of magnetometer lines. Center point of magnetic anomalies are circled - refer to text for discussion.

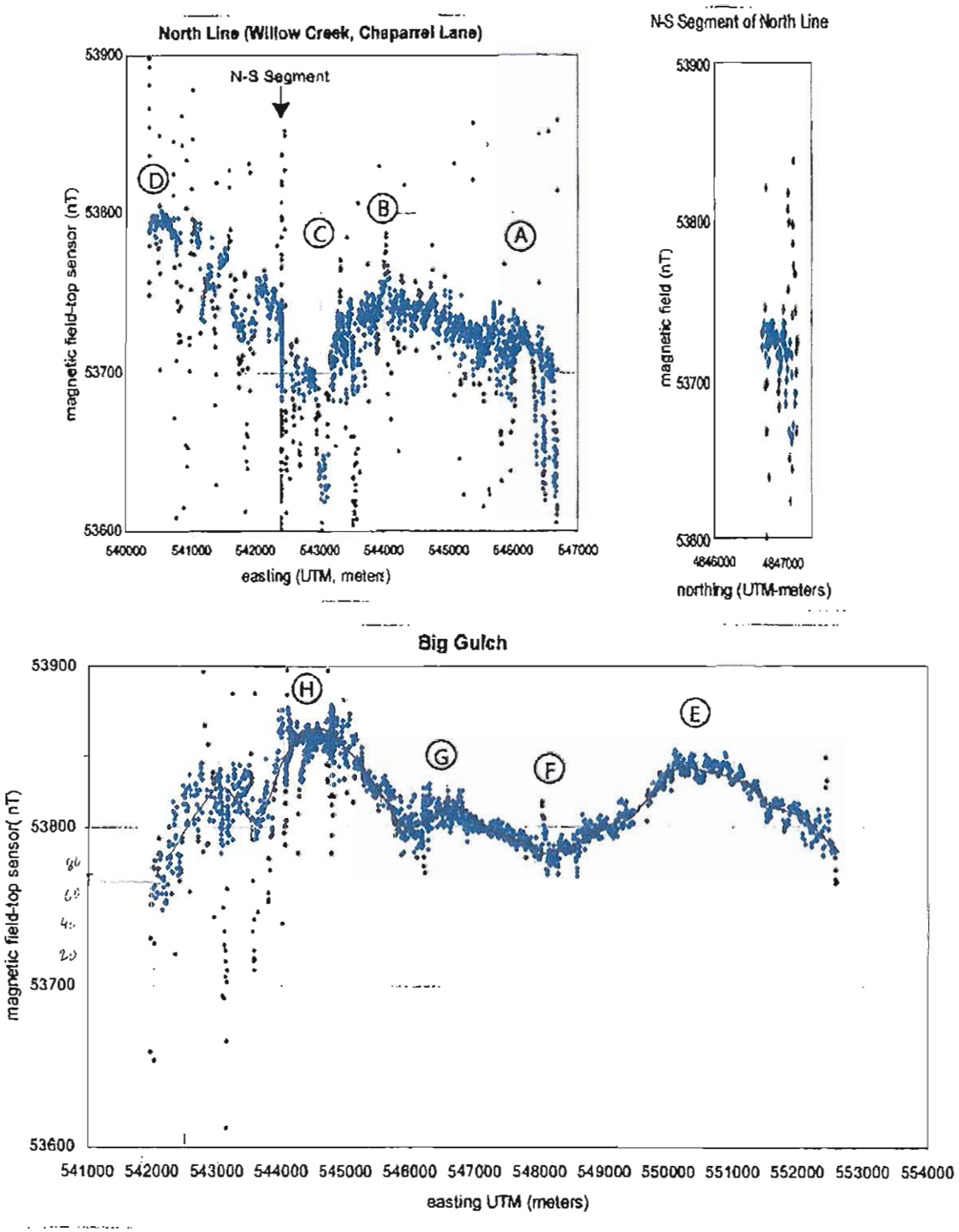

Figure 2. Magnetometer lines along Willow Creek - Chaparral Lane and Big Gulch

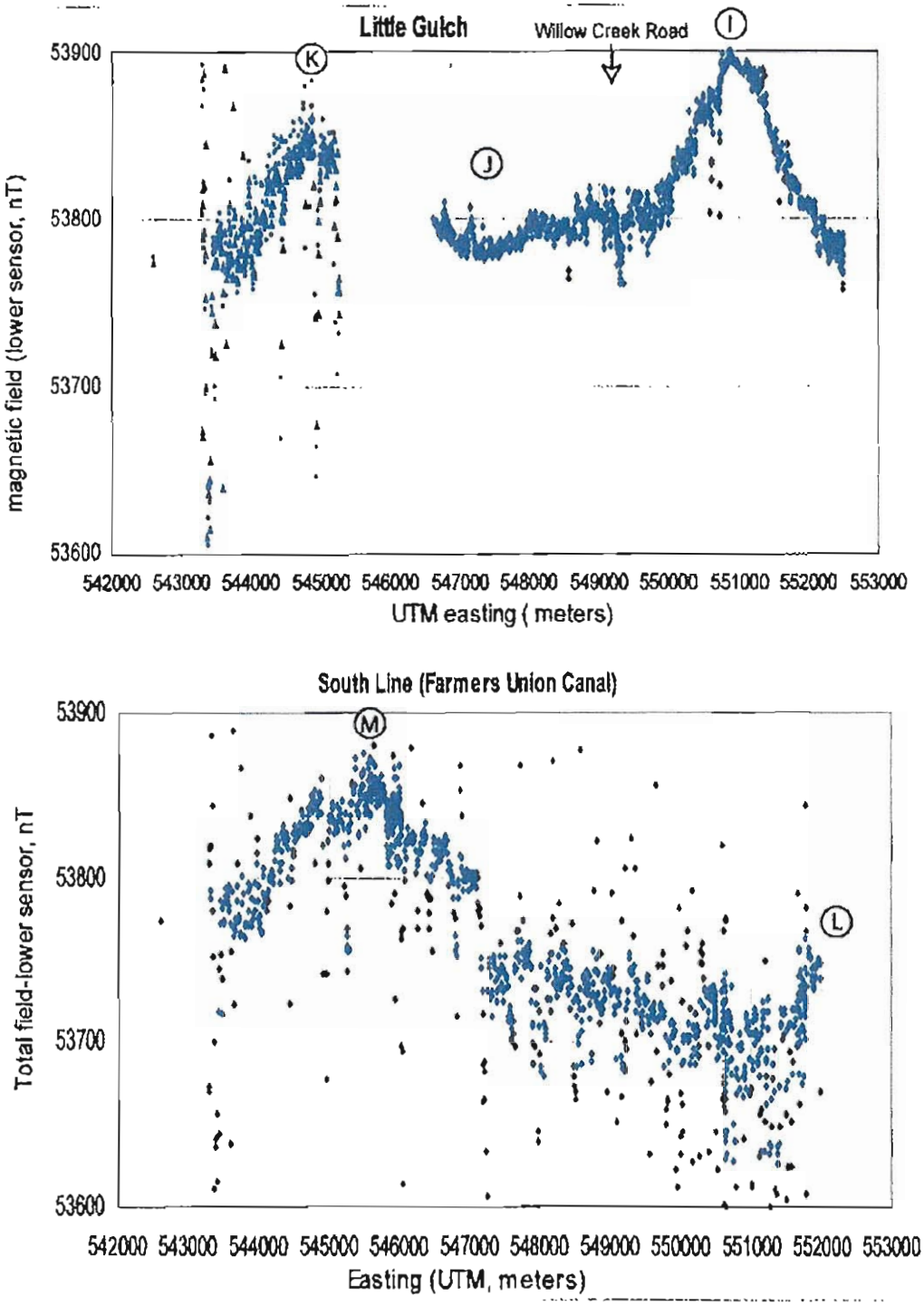

Figure 3. Magnetometer lines along Big Gulch and the Farmers' Union Canal.

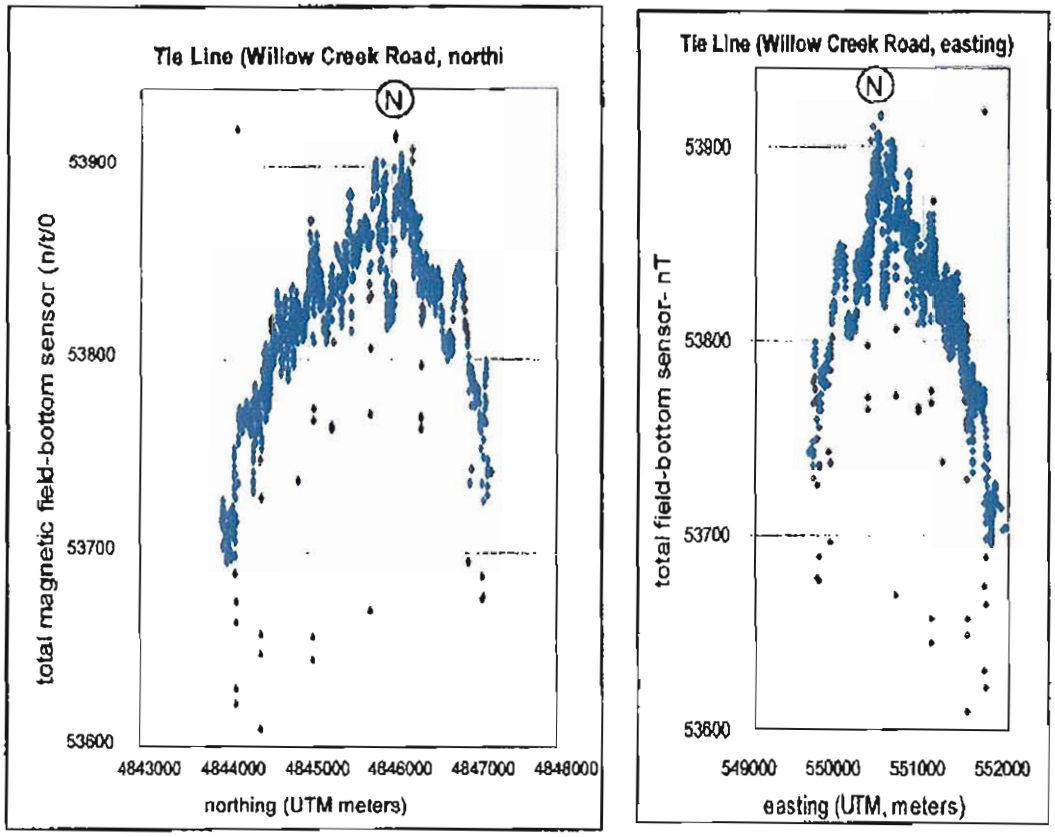

Figure 4. Magnetometer line along Willow Creek Road.

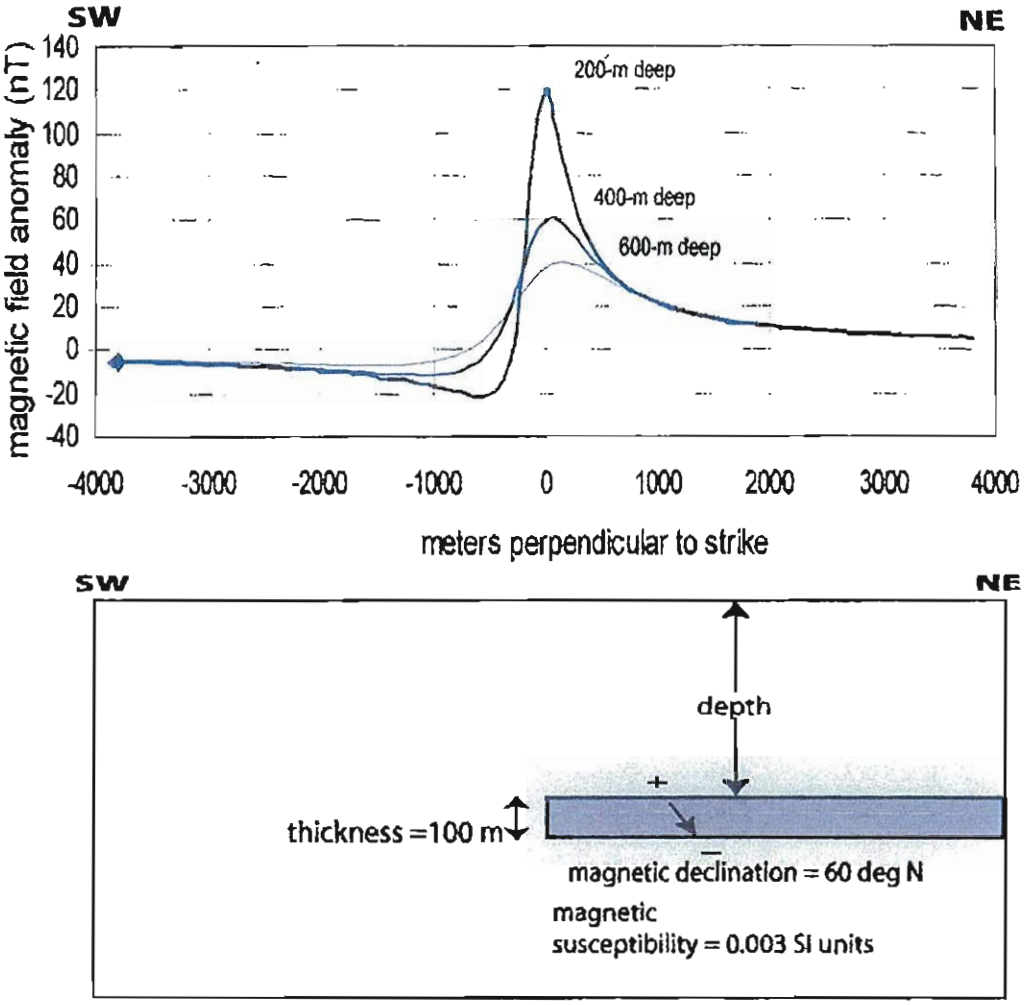

Figure 5. Model calculation of a down-to-SW faulted volcanic slab, fault with a NW-SE strike - simplified to show only the upthrown block.

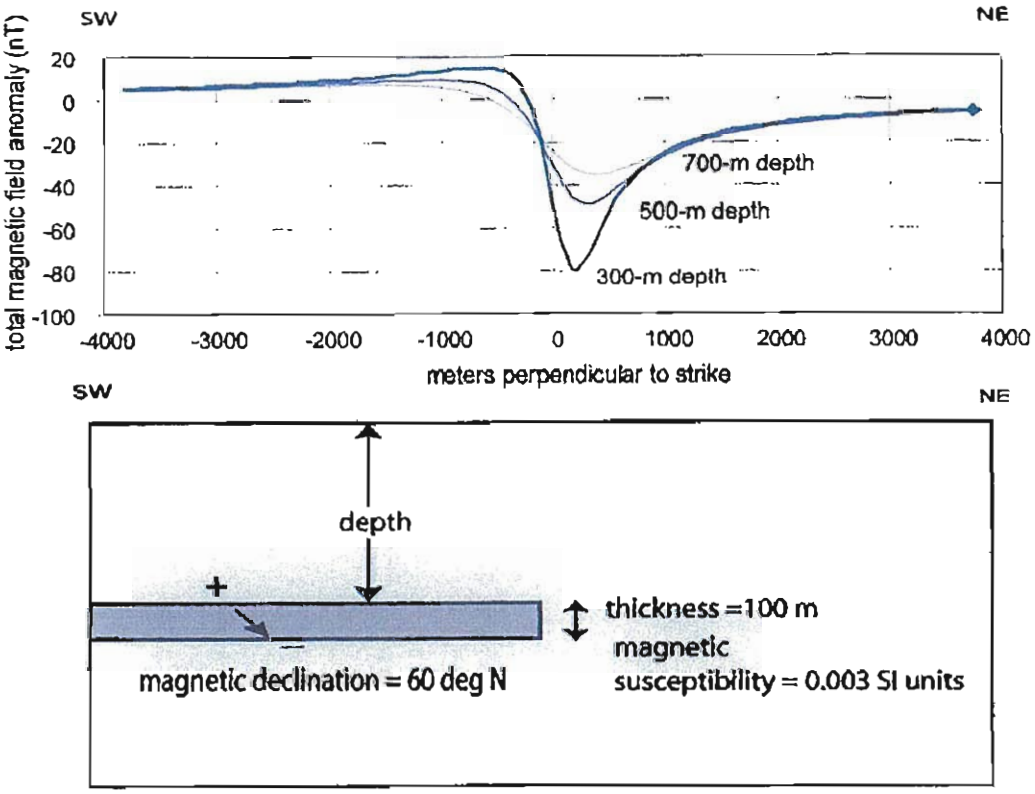

Figure 6. Model calculation of a down-to-NE faulted volcanic slab, fault with a NW-SE strike - simplified to show only the upthrown block.

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Geological Field Trips in Southern Idaho, Eastern Oregon, and Northern Nevada

Edited by Kathleen M. Haller and Spencer H. Wood

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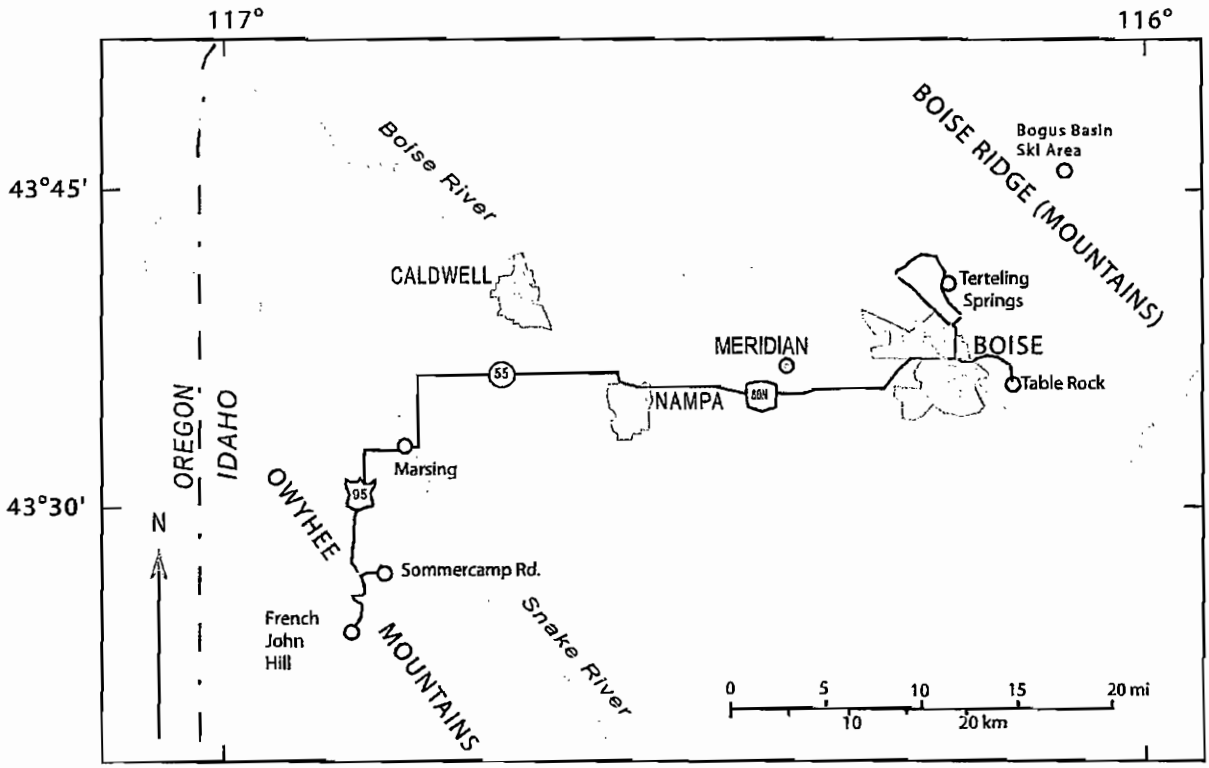

Figure 1. Field-trip route from Boise to the Owyhee Mountains and back to points of interest in the Boise foothills.

Geology Across and Under the Western Snake River Plain, Idaho: Owyhee Mountains to the Boise Foothills

By Spencer H. Wood

Introduction

This 1-day field trip is a transect across the western Snake River Plain (fig. 1). The western plain is a continental-rift structure, 300 km long and 70 km wide. It is bounded and internally faulted by northwest-trending normal faults. The western Snake River Plain has a different orientation and structure than the eastern plain. The eastern plain is a curious downwarp related to magmatism and extension along the track of the Yellowstone hot spot (fig. 2). The faulted basin of the western plain began forming about 12 m.y. ago, and much of the relief was completed by 9 Ma. This timing corresponds with the passage of the hot spot located to the south about 11 Ma. Wood and Clemens (2002) suggest that softening of the lithosphere by the passing hot spot triggered extension and basin formation. The hot spot passage was accompanied by voluminous rhyolite volcanism to the south and by eruptions of rhyolite at or near the margins of the western plain (Bonnichsen and others, 2004; Perkins and Nash, 2002; Pierce and Morgan, 1992). Northwest of the western plain and in southeastern Oregon voluminous eruptions of the Columbia River and Steens Mountains flood basalts occurred between 16.1 and 15.0 Ma (Hooper and others, 2002a, 2002b; Camp and others, 2003). Earliest Columbia River basalts are as old as 17.5 Ma (Baksi, 2004)

Understanding of the sedimentary record builds upon earlier work in the central and southern part of the western plain by Malde and Powers (1962) who defined many of the stratigraphic units. Work of Squires (1992) improved our knowledge of the subsurface near Boise. The sediments record

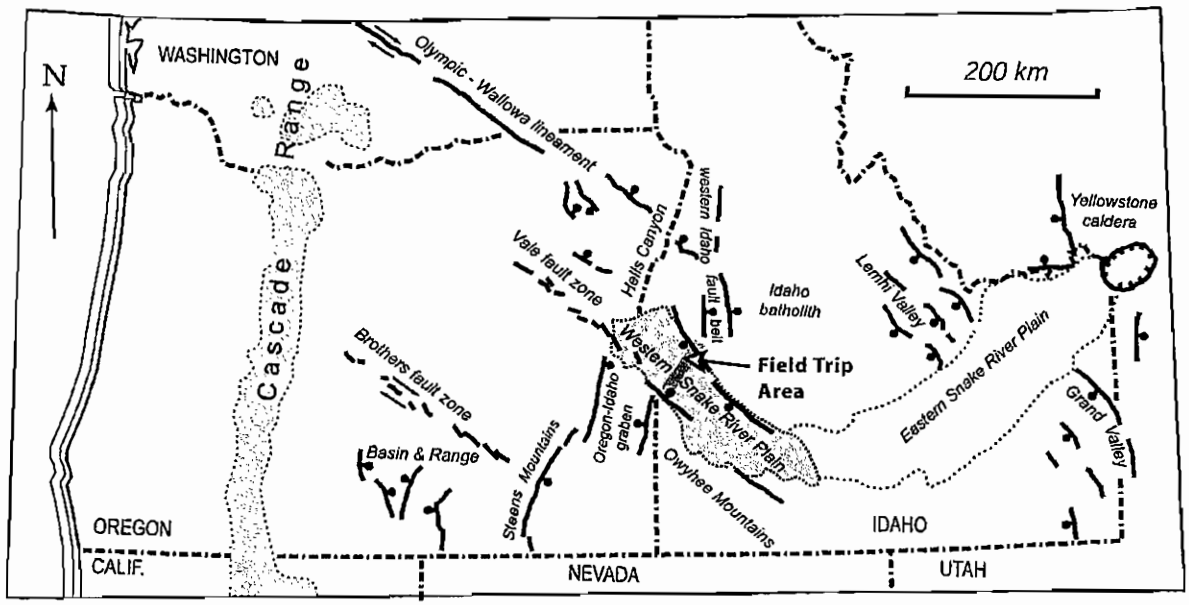

Figure 2. Western and eastern Snake River Plain and late Cenozoic geologic features of the northwestern United States. The western plain was a lake basin in the late Miocene to late Pliocene, usually referred to as "Lake Idaho" (after Wood and Clemens, 2002).

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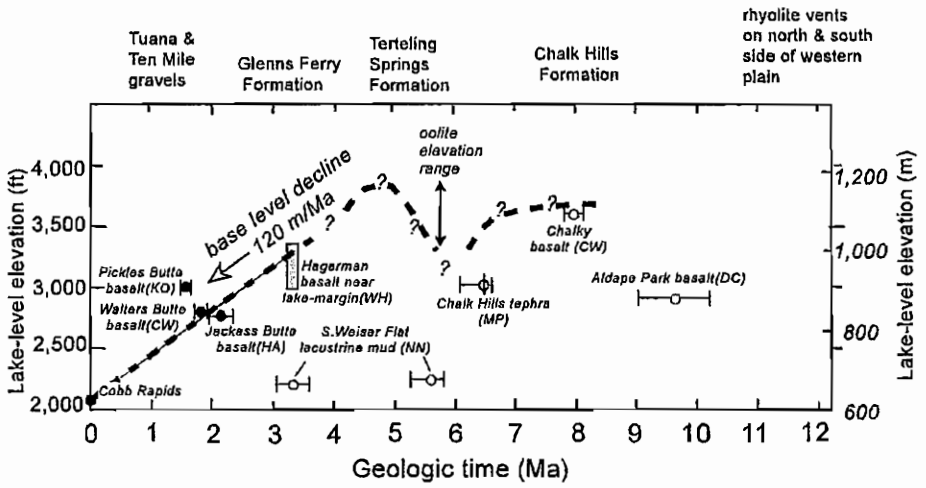

Figure 3. Plot of elevation of the lake deposits versus time. This plot does not take into account tectonic deformation that may have altered the elevation of lake deposits. Most localities are on the margin of the plain, which has not been so much affected by tectonic movement or compaction subsidence (Wood, 1994). Points on the graph are dates on lacustrine sediment, or basalt associated with or overlying the lacustrine section: K-Ar dates on basalt are: DC (Clemens and Wood, 1993), HA (Amini and others, 1984), Zircon fission-track ages on silicic ash are NN (Nancy Naeser, published in Thompson, 1991); $^{40}Ar/^{39}Ar$ ages on basalt are: CW (White and others, 2004), and KO (Othberg and others, 1995), WH (Hart and others, 1999), and tephrochronology from MP (Perkins and others, 1998).

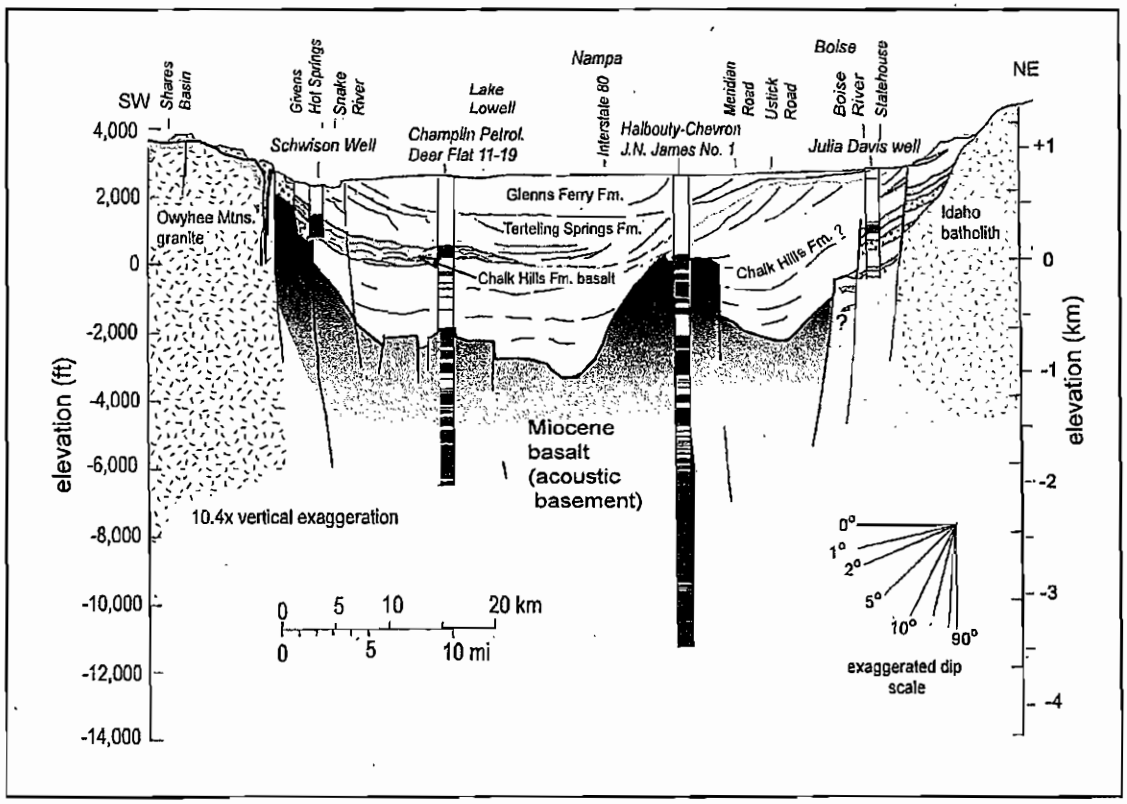

Figure 4. Section across the western plain showing major stratigraphic units, based upon seismic-reflection and well data. Dark patterns on well columns are basalt intervals: dotted pattern is rhyolite: no pattern is sediment.

two major episodes of large lakes that filled the basin (figs. 3 and 4). The Chalk Hills Formation records the first deposition of sand, lacustrine muds, and intercalated volcanics. Subsequently the level of the "Chalk Hills lake" declined, or perhaps the lake completely drained. Sediments and volcanics of the Chalk Hills Formation are deformed by tilting and faulting. The lake system then refilled and transgressed over eroded Chalk Hills Formation. The transgressive lake sediments grade upward and shoreward to calcareous muds and oolites; this sequence is called the Glenns Ferry Formation on the south side of the plain, and the Terteling Springs Formation on the north side (figs. 3 and 4). This last lake system is popularly known as "Lake Idaho". The calcareous sediments indicate increased alkalinity of a lake within a closed basin. The lake then overtopped its spill point into ancestral Hells Canyon and, as it lowered, the drained basin filled with mostly sandy delta-plain units that are important aquifers.

The field trip starts in a rhyolite field in the Owyhee Mountains: the 11-Ma Jump Creek Rhyolite (fig. 5). We then look at the high gravels overlying the rhyolite at elevation 1,100 m. Descending onto the plain, we will examine the basal lacustrine sediments along Sommercamp Road, mapped as the Chalk Hills Formation. The lower Chalk Hills Formation contains numerous volcanic ash beds and an unusual pumice-block layer. Several basalt fields occur in the subsurface and in exposures along the margins. Along the Owyhee Mountains front, the transgressive sequence overlying the deformed and eroded Chalk Hills Formation is readily identified by an angular unconformity with a locally occurring ledge of nearly horizontal, brown, coarse, pebbly sandstone laying upon the

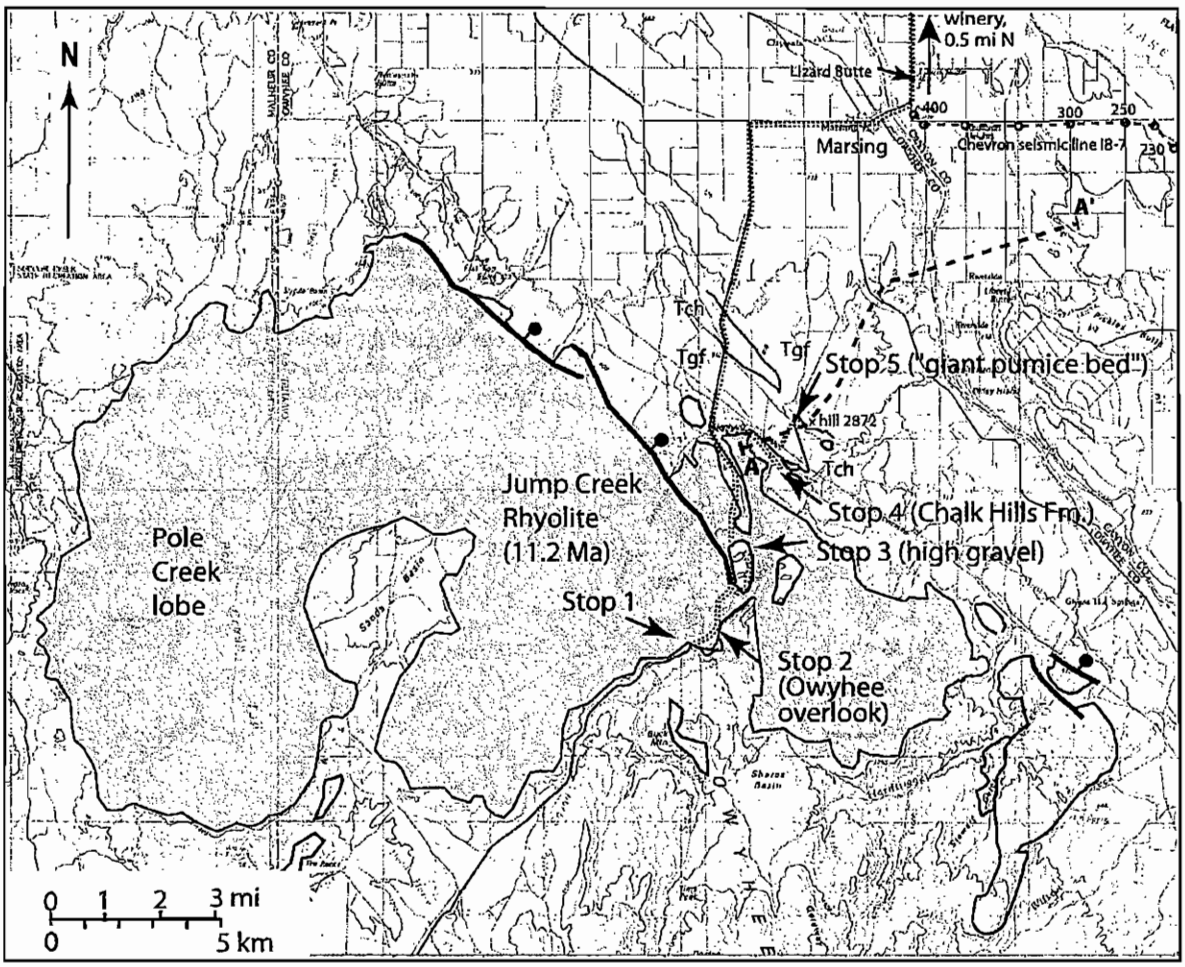

Figure 5. Map showing field-trip route along the Owyhee Mountains front near Marsing, Idaho, distribution of the 11-Ma Jump Creek Rhyolite, and associated geologic features along the edge of the western Snake River Plain. Location of cross-section A-A' (fig. 16), seismic line (fig. 12), field-trip route (shaded line), and Stops 1-5 are shown.

tilted mudstone. This sandstone ledge is overlain by mudstone of the Glenns Ferry Formation.

Over most of the plain, we rely on seismic data and deep wells for information on the subsurface. From Marsing, we will drive across the plain through the towns of Nampa and Meridian to Boise. Squires and others (2003) describe a 15-km-long seismic line from Meridian to Boise from which we can interpret the episodes of lake filling and sedimentation as seen on the plain margins.

The angular unconformity between the Chalk Hills Formation and the Glenns Ferry Formation is not exposed along the Boise foothills; however, a section containing oolite bars is interpreted as the upper part of the transgressive sequence named the Terteling Springs Formation. Overlying the transgressive sequence is a massive Gilbert-style delta sequence of coarse sand that is interpreted as the response to regression of the lake after the lake overtopped the spill point at Hells Canyon. Downcutting of the outlet resulted in a slowly declining lake level and delta progradation over the basin. The basin filled and rivers flowed across the plain. Along the field-trip route, we observe valleys of the Snake and Boise Rivers that are incised about 150 m into the lake sediments.

FIELD-TRIP ROAD LOG

Mileages for this first leg of the trip are based upon the ***green milepost signs,*** *posted every mile on the northbound side of the highway.*

Milepost	Inc.	
13.8	0.0	We travel north on U.S Highway 95 toward Boise. Starting point for mileage is at the south end of a large road cut at the crest of the highway at French John Hill, 14 mi south of Marsing, Idaho. Parking area is on the north side of highway, or continue south about 0.1 mi to large pullout on south side, where one can make a U-turn with good visibility.

Stop 1. Road Cut with Deformed Sediments and Pyroclastics at the Base of the Jump Creek Rhyolite, French John Hill, Owyhee Mountains

Road cuts here expose a jumble of rhyolite vitrophyre breccia and older sediments beneath the flow-banded and sheeted stoney rhyolite flows on the skyline (fig. 6). The Jump Creek Rhyolite covers 275 km² and is one of the younger rhyolites erupted along the margin of the western Snake River Plain (fig. 5). Neill (1975) obtained a K-Ar age of 11.2±0.2 Ma on sanidine. The rhyolite has many lobate flows, one upon another, and in this area is up to 250-m thick. Volume is estimated at 70 km³. Bonnichsen and others (2004) consider this a rhyolite field made up of many segments. They report $^{40}Ar/^{39}Ar$ and K-Ar ages ranging from 10.6 to 11.7 Ma.

Rocks of the Jump Creek Rhyolite are identified by abundant (12–23 percent), conspicuous (up to 4 mm) phenocrysts of plagioclase. Sanidine and quartz vary in abundance up to 4 percent and are up to 2 mm in size. Microphenocrysts of ferrohypersthene and clinopyroxene are present (Ekren and others, 1981, 1982). A single analysis of this rock, on a water-free basis, shows 71 percent silica making it truly a rhyolite (analysis published in Ekren and others, 1984).

In the valley southeast of U.S. Highway 95, Squaw Creek has cut through the rhyolite into a 130-m-thick section of ashy stratified sediments mapped by Ekren and others (1981) as the Sucker Creek Formation. In the lower part of this section is an 8-m-thick, ledge-forming ash-flow tuff. The section rests upon 500 m of older Miocene basalt.

Directly beneath the rhyolite flow rock is about 20 m of dismembered silicic-ash beds and mud and ashy sediments, basalt breccia, beds of rounded stream gravels, and rhyolite

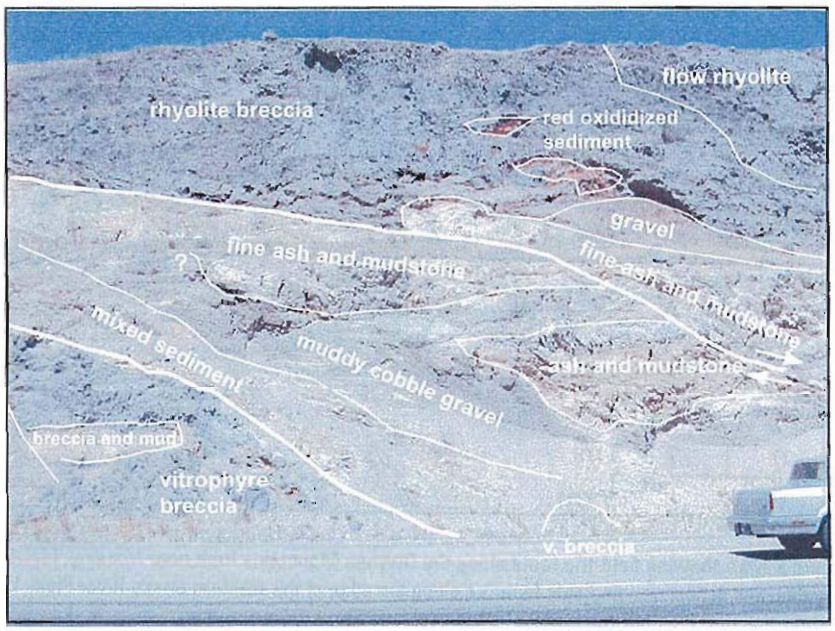

Figure 6. Deformed sediment and rhyolite at the base of the Jump Creek Rhyolite, Stop 1, west side of road cut on U.S Highway 95 (milepost 13.8).

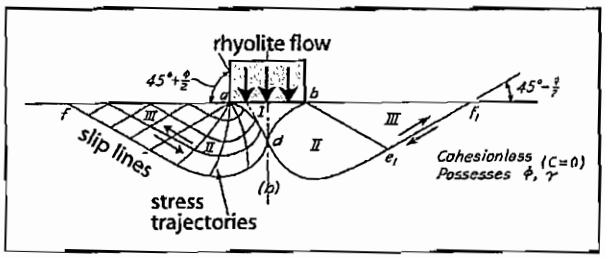

Figure 7. Diagram showing model of bearing-failure slip lines for fairly dense or stiff soil with frictional strength and no cohesion. This type of failure, with low-angle slip lines may have occurred as the thick flows of the Jump Creek Rhyolite piled up over wet sediments of the underlying Sucker Creek Formation (drawing after Terzaghi and Peck, 1967).

breccia. Such structural complexity originally suggested to me that this is a near-vent area of the rhyolite. Low-angle faulting cuts through the section exposed in the road cut which suggested sliding of near-vent volcanic topography (fig. 6). However, the low-angle faults are more likely analogous to bearing failures produced by loading the area with the thick rhyolite flows (fig. 7). The complex structures here are similar to larger scale features in the Absaroka volcanics described by Decker (1990) and which he attributed to liquefaction of saturated epiclastic and pyroclastic rocks in response to loading by lava flows. In this area, the overlying rhyolite lava was up to 200-m thick and imposition of such a great load over a short period of time (perhaps days to decades) could well have liquefied and deformed these materials.

Ekren and others (1984) suggested the Jump Creek Rhyolite may have been a rheomorphic tuff, but Bonnichsen and Kauffman (1987) have shown that thick breccias and features seen here are typical of large rhyolite flows. This area warrants a detailed description and study as few areas of the large hot-spot related rhyolite flows are so well exposed as here in Squaw Creek Canyon.

The older Miocene volcanic rocks of the Owyhee Range host major silver-gold deposits (*e.g.*, the Delamar Mine), about 30 mi due south of here (Halsor and others, 1988). The volcanic rocks rest upon Cretaceous (62 to 70 Ma) granitic rocks exposed at several places in the mountains southeast of here, which Taubeneck (1971) called the southern extension of the Idaho batholith.

Milepost	Inc.	
		Walk north 0.5 km through the road cut to see the deformed sediments and rhyolite. Continue walking north, and the vans will be moved to the Owyhee Mountains Viewpoint, to pick you up.
14.1	0.3	Park for Stop 2.

Stop 2. Owyhee Country Viewpoint

Large parking area on the east side of road. The sign explains that the origin of the name "Owyhee" is not an Indian name as it would seem. It is an antiquated spelling of Hawaii, as used by Captain Cook. In 1819, Donald MacKenzie of the Canadian Northwest Company sent a group of trappers into these mountains. Among the party were several native Hawaiians who were never seen again, and so the mountains are named for those lost "Owyheeans".

The hill to the west of here is called French John Hill, named for "French" John Carrey who built a road in the early 1870s parallel to the present U.S. Highway 95 (Boone, 1988). From the view point, one looks across the deep rhyolite gorge of Squaw Creek and the north flank of the Owyhee Mountains to the western Snake River Plain. Across the plain are the Idaho batholith mountains north of Boise. Rimrock basalt along the north side of the Snake River Canyon overlies gravels, which are underlain by lake beds of the Pliocene Glenns Ferry Formation. Pickles Butte is a basalt vent area $^{40}Ar/^{39}Ar$ dated by Othberg (1994) at 1.58±0.085 Ma, which is the minimum age usually quoted for the complete withdrawal of Lake Idaho from this area. Basalts in this area, including Lizard Butte, are the westernmost extent of young basalt that overlies lakebeds.

About 14,500 yr ago, floodwaters of the Bonneville flood roared 60-m (200–ft) deep through the Snake River canyon below, but were confined to the canyon below 755-m (2,480-ft) elevation (O'Conner, 1993).

Milepost	Inc.	
15.0	0.9	Turn east at milepost 15 on a paved road, that turns to gravel within 0.1 mi. Proceed for 0.3 mi, and continue straight at the Y to the old Highway 95 grade, and follow the abandoned highway north for a total of 1.1 mi from the turnoff at milepost 15. The road cuts are in the high gravel deposit of Stop 3.

Stop 3. High Gravels of the Owyhee Mountains and an Overlook of the Chalk Hills Formation-Glenns Ferry Formation Contact

From this abandoned grade of U.S. Highway 95, there is a good view over the western plain and the area of the next stop, Stop 4 (fig. 8). The road cuts are in an alluvial-fan gravel perched high in the Owyhee Mountains. Ekren and others (1981) mapped these high gravels (figs. 5 and 9) but did not comment on their significance. The gravels clearly overlie the Jump Creek Rhyolite, but their relationship to the lake deposits is unclear. The elevation here is 1,100 m (3,600 ft), which is the highest elevation of most lake deposits around the plain margin. It is likely this is an old alluvial fan sequence

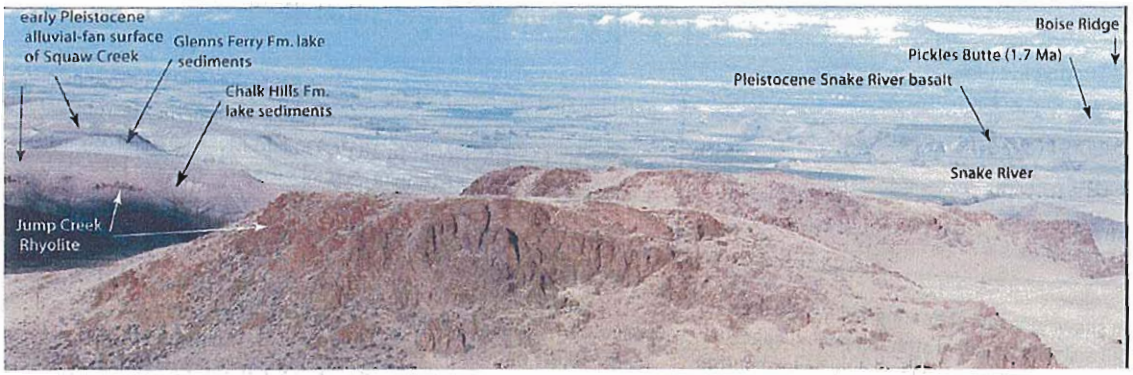

Figure 8. Overlook of the western Snake River Plain, looking north from Stop 3.

that graded to Lake Idaho, but we do not know the age of the gravels or the amount of vertical faulting that displaced the gravel downward to the north. We will see a thinner, but very similar, gravel overlying the top of the Chalk Hills Formation in the Sommercamp Road cut at the next stop (see fig. 10).

The road is blocked at a distance of 1.3 mi, so turn around, park, examine the gravels and the view (fig. 8), and then return by the same route back to the new U.S. Highway 95.

Mile-post	Inc.	
15.0	1.1	Turn north toward Boise on U.S Highway 95 and proceed down the grade.
16.8	1.8	Road cut to the west side of the road exposes the contact between vitrophyre and overlying stoney rock of the Jump Creek Rhyolite. The vitrophyre contains abundant spherulites and stretched lithophysae. These features in the glassy part of the flow are attributed to pockets of higher vapor content that cause crystallization and devitrification emanating from the vapor-filled voids. These stoney-rhyolite spherulites form in the hot glass (Lofgren, 1971; Cas and Wright, 1988).
16.9	0.1	Road cut on west side of road exposes a northwest-trending fault, with a 1.5-m-thick fault breccia. Bentonitic claystone of the lower Chalk Hills Formation is faulted down to the northeast against the Jump Creek Rhyolite.
18.4	1.5	Turn east from Highway 95, just past the weigh station, on to Sommercamp Road. Travel east on Sommercamp Road for 0.9 mi to the top of the grade and road cut.

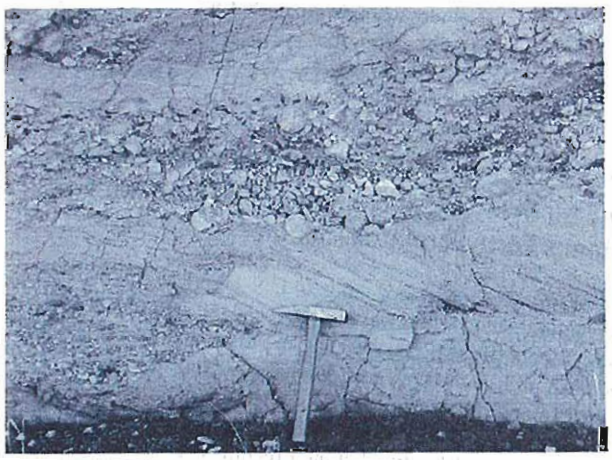

Figure 9. High gravels at Stop 3 (see fig. 5 for location). Mudstone overlain and interbedded with cross-bedded coarse sand and subangular gravel. Rock pick handle is 30 cm, for scale.

Stop 4. Chalk Hills Formation Along Sommercamp Road

We will walk down the grade and examine the road cut of deltaic sediments and then return to vans at the top of the grade on Sommercamp Road.

The Chalk Hills Formation represents sediments of the earliest large lake in the western Snake River Plain rift. The age of the formation is poorly constrained. In their review of radiometric ages on the formation, Wood and Clemens (2002) place its age between 10 and 6 Ma. The road cut along Sommercamp Road exposes a section of foreset and topset beds of a delta (fig. 10). These sediments are near the base of the formation and rest upon a section of clay-altered vitrophyre of the Jump Creek Rhyolite (fig. 11).

The delta sediments in the road cut are unconformably overlain by a gently-west-dipping, grey cobble gravel, similar to that seen at Stop 3. The gravel is faulted at the west end of

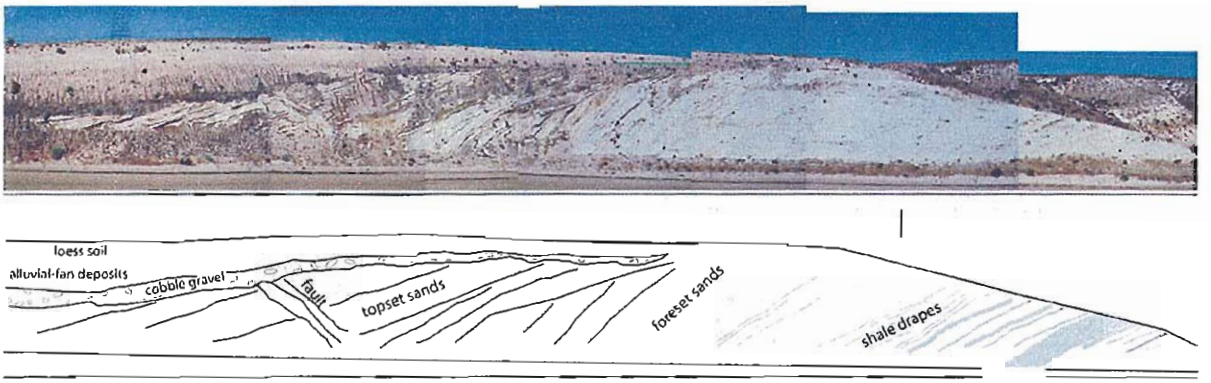

Figure 10. Delta foreset and topset beds of the Chalk Hills Formation along road cut of Sommercamp Road at Stop 4. The basalt ash marker bed in figure 11 is about 50 m west of photo along road cut.

the road cut and is overlain by unfaulted alluvial fan deposits and a loess soil. The Glenns Ferry Formation is missing in this road-cut exposure. One kilometer north of this road-cut exposure, 10 m of lacustrine sediment of the Glenns Ferry Formation unconformably overlies the Chalk Hills Formation with an angular discordance of about 8°.

The Chalk Hills Formation is about 110 m thick in this area (fig. 11). We will be looking at the sediment and volcanic features at two outcrop areas, here along Sommercamp Road, and another in a gulch 1.6 km (1.0 mi) northeast of here. The formation here is mostly claystone with an arkosic sandstone bed near the base, abundant intercalated silicic-ash layers, and delta sands that are mostly coarse silicic ash. Topset beds have well-preserved ripple marks. The foreset beds are mostly coarse sand ash with mud drapes, typically 0.1–0.5 m thick. Mud drapes form on the foreset sand beds in the time intervals between sand avalanche and deposition on the foreset slopes, or when a particular depositional delta lobe is temporarily abandoned by a distributary.

Exposed along Snake River Plain margins and also detected on seismic sections and wells beneath the plain, 10 km (6 mi) north of here (figs. 12 and 5) are intercalated local basalt fields within the Chalk Hills Formation. Many of these basalt fields erupted into water (Bonnichsen and others, 1997). At this locality, basalt occurs as one or two layers of scoriaceous ash and lapilli beds about 0.5-m thick at the west end of the road cut and indicated in the upper part of the stratigraphic section (fig. 11).

At the top of the Sommercamp Road grade, take the dirt road to the north through the barbed-wire gate and follow the track that parallels the power transmission line to the southeast. Travel 0.3 mi to a road that turns left (north) and follows the wooden-pole power line to the northeast. Travel 0.7 mi to the edge of the mesa and park.

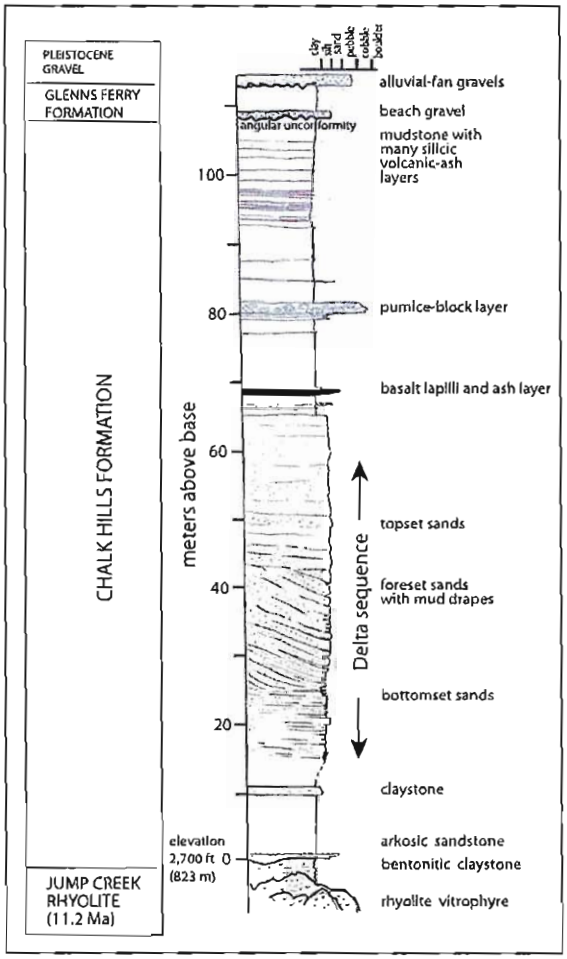

Figure 11. Graphic stratigraphic column of the Chalk Hills Formation at Stops 4 and 5.

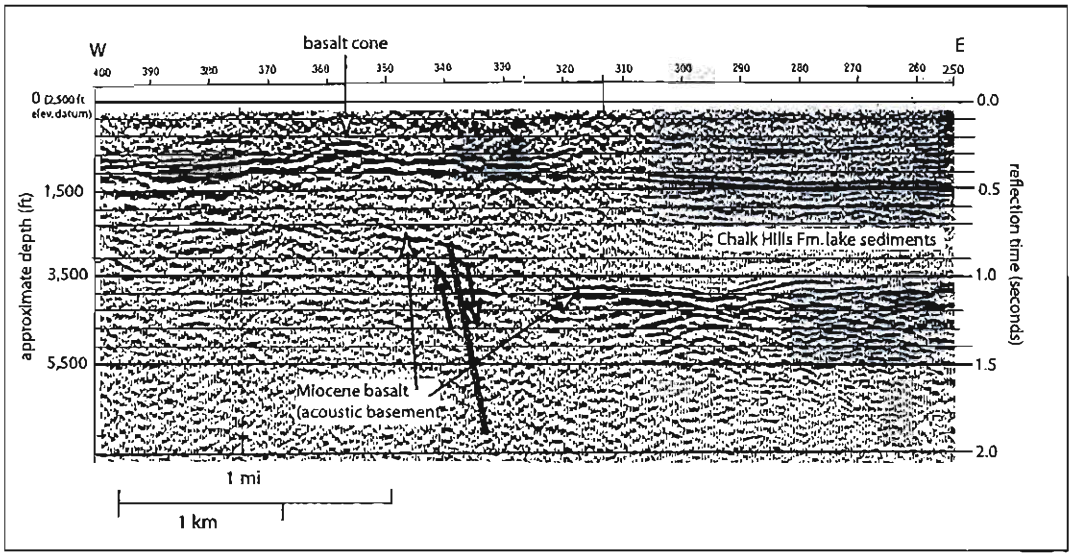

Figure 12. Seismic-reflection section showing a subsurface basalt field in the Chalk Hills Formation, between Marsing and Lake Lowell Reservoir (shotpoint locations shown on fig. 5, Chevron Seismic Line IB-7, shot points 250–400). The basalt field is 305–460 m (1,000–1,500 ft) below the surface. The top of the basalt appears as high-amplitude reflections from the sediment-basalt interface. The basalt field has relief due to cones with slopes of 23°. On the west end of the section, at a depth of 670 m (2,200 ft), is the surface of the older Miocene basalt beneath the Chalk Hills Formation. This older basalt surface is faulted down to the northeast to a depth of 1,070 m (3,500 ft,) or a displacement of 400 m (1,300 ft). Faulting of the basalt field within Chalk Hills Formation appears to be less than 90 m (300 ft).

Stop 5. Giant-Pumice Bed of a Sublacustrine Rhyolite-Dome Eruption Within the Chalk Hills Formation Sediments

There is a rough road over the rim and down to the valley below, on which we will walk 300 m northeast to exposures of the "giant-pumice bed".

A remarkable layer of large (up to 1 m) pumice blocks, about 1.5-m thick, is exposed in a gulch in the SW quarter of section 32, T. 2 N., R. 5 E. The pumice blocks are radially fractured, but the broken pieces are intact, indicating they were deposited before they fractured (fig. 13). Post-deposition fractures indicate the blocks were still hot when emplaced and then cracked upon cooling. This unusual type of deposit also has been described at La Primavera Volcano, Mexico, by Clough and others (1982) and Cas and Wright (1988). The blocks are interpreted as pieces of the pumiceous carapace of a rhyolite dome that erupted beneath a lake and then floated and shoaled while still hot and intact (fig. 14). Also in this gulch, is the continuation of the section above the basalt ash seen in the road cut of Stop 4. Here the section contains many silicic volcanic ash layers within claystone, and is locally overlain by

Figure 13. Large fractured pumice block in pumice-block layer within the upper Chalk Hills Formation at Stop 5.

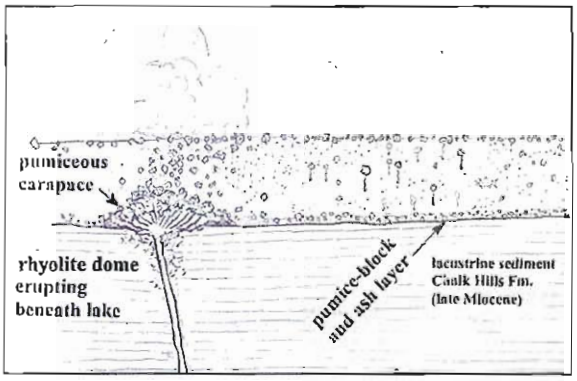

Figure 14. Sketch of a pumice dome eruption beneath the lake. It seems unlikely the large blocks waterlogged and sank, because they must have been hot and intact when emplaced. More than likely, the large blocks were steaming hot and still intact and then fractured in place upon further cooling.

a 1-m-thick horizontal ledge of pebbly sandstone and 10 m of massive lacustrine mudstone of the Glenns Ferry Formation (figs. 15 and 11).

The Glenns Ferry Formation dips a few degrees to the north, and the section is much thicker north of here (fig. 16). About 0.5 km (0.3 mi) south of this valley along the dirt road that climbs the north mesa is a sequence of silicic volcanic ashes, one of which is about 1-m thick and can be traced for several miles to the north (fig. 16). The lowest part of the Glenns Ferry Formation contains veins of selenite gypsum suggesting local lagoons along the lake shore that dried intermittently. However, none of the formation here is calcareous. It does become very calcareous in its upper part, about 3 km north of here (fig. 16). Much of the lacustrine mud in a 670-m (2,200-ft) deep well beneath Caldwell, 22 km north of here, is also calcareous (Wood, 1994).

Optional 0.25-mi walk is a 180 ft climb to the mesa to the east (hill 2872), for a good view and photo of the angular unconformity. In this valley, at the bottom of the mesa to the north is the contact of the Glenns Ferry Formation over the Chalk Hills Formation; however, the prominent rusty-colored sandy gravel visible on the south side of the valley is missing here. The lower 7 m of the Glenns Ferry Formation contains selenite gypsum veins (satin spar), and the 70-m-thick section here is a monotonous mudstone with several volcanic-ash beds.

Mile-post	Inc.	
		Return to vans at top of the south mesa and retrace the route back west to U.S. Highway 95.
18.4		Turn right (north) on to the new U.S. Highway 95.
19.8	1.4	The angular unconformity is in the road cut on the west side of the highway. A horizontal ledge of brownish-orange pebbly sandstone of the basal Glenns Ferry Formation overlies the slightly tilted claystone and ash layers of the Chalk Hills Formation.
24.0	4.2	Junction of U.S. Highway 95 and State Route 55. Turn right (east) on to State Route 55 toward Marsing.

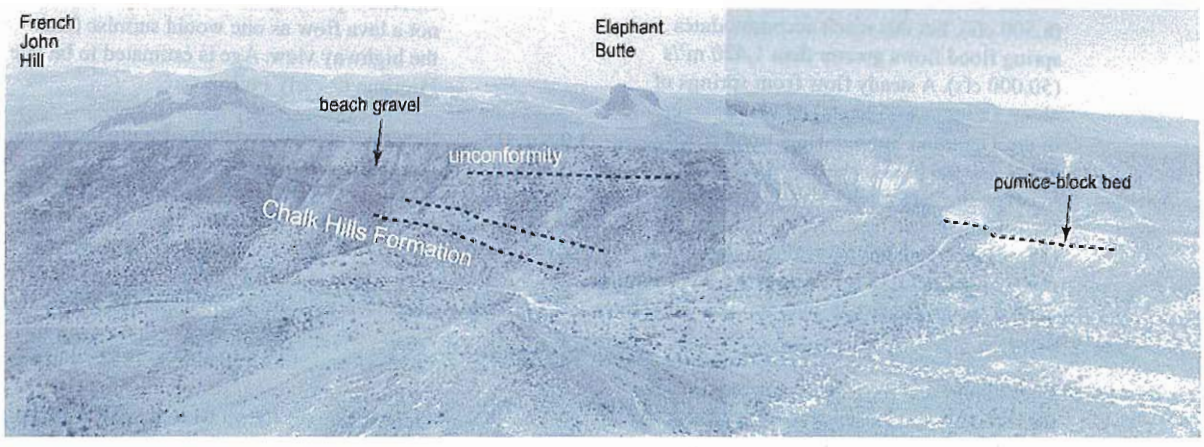

Figure 15. Angular unconformity between the tilted Chalk Hills Formation and the Glenns Ferry Formation. Base of the Glenns Ferry Formation is an 1-m-thick discontinuous sandstone, interpreted as a beach sand. Overlying the sandstone is 10 m of mudstone. Mudstone thickens to the north as shown in figure 19. View is looking south from mesa north of Stop 5.

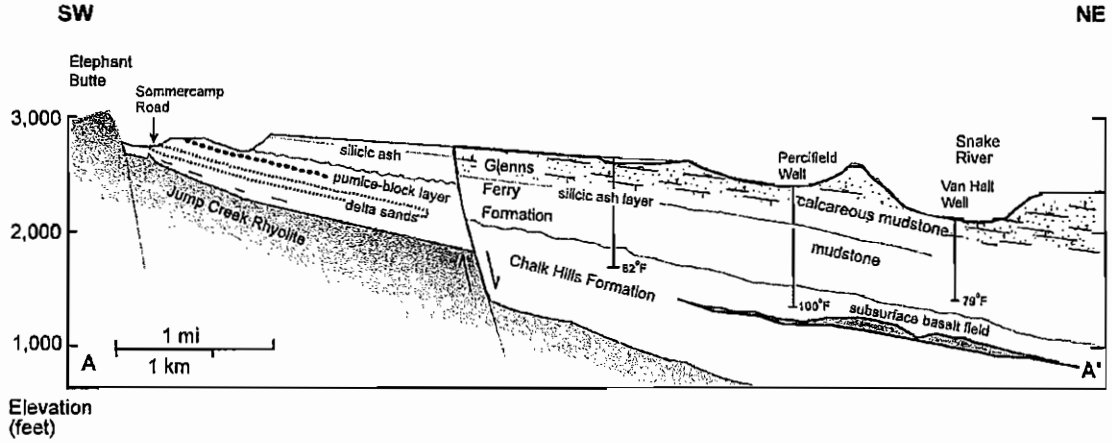

Figure 16. Stratigraphic cross section showing the position of calcareous mudstones of the upper Glenns Ferry Formation. Section is from Sommercamp Road area to the Marsing Hills. Location of section line A-A' is shown on figure 5.

Mileposts on State Route 55 start at 0.0 at this junction

Mile-post	Inc.	
0.0	0.0	Junction U.S. Highway 95 and State Route 55, traveling east on State Route 55.
1.7	1.7	Marsing
2.7	1.0	Snake River bridge at Marsing. The river at Marsing flows in a natural low-gradient reach. The valley of the river is about 120 m (400 ft) below the surrounding plain. When the Bonneville flood roared through here 14,500 yr ago, the raging river was about 60-m (200-ft) deep over Marsing (O'Conner, 1993). Today, the average flows are about 240 m^3/s (8,500 cfs), but this reach accommodates spring flood flows greater than 1,420 m^3/s (50,000 cfs). A steady flow from springs of about 127 m^3/s (4,500 cfs) enters the river in the Thousand Springs-Hagerman reach, about 250 km (155 mi) away. This reach between the backwaters of Brownlee Dam in Hells Canyon and Swan Falls Dam, 56 km (35 mi) upstream has an average gradient of 0.00025 m/km (1.32 ft/mi), making this a long natural reach of the river without hydroelectric dams. The ecology and physical characteristics of the riverbank have been studied recently to provide information for legal proceedings between the U.S. Department of Fish and Wildlife and the State of Idaho over claims for Federal water rights to protect wildlife refuges on the islands (Ostercamp and others, 2001; Ostercamp, 1998; and Dixon and Johnson, 1999).
3.4	0.7	Lizard Butte east of the highway is the eroded remnant of a complex basalt volcano having many features of hydrovolcanism. The volcano erupted through the wet lacustrine sediment of the Glenns Ferry Formation. The deposits include deformed stream gravels, steeply dipping bomb-and-lapilli beds of scoria and surge deposits. The cap rock is a hard basalt agglutinate with chunks of white sediment, which is interpreted as a welded basalt spatter (Craig White, personal communication, 2003). Although the cap rock displays columnar jointing, it is welded spatter and not a lava flow as one would surmise from the highway view. Age is estimated to be late Pliocene or early Pleistocene.
3.9	0.5	Several light-colored hills forming the north rim of the Snake River valley are at about 10:00. These also are called the Chalk Hills, but they are not the Chalk Hills of the type locality of the Miocene Chalk Hills Formation. These "Chalk Hills" are sand and calcareous mudstone of the upper Glenns Ferry Formation and are of the floodplain and marsh facies (Reppening and others, 1994). They contain an important vertebrate fauna of early Pleistocene age (latest Blancan-earliest Irvingtonian), known as the Froman Ferry fauna. Important fossils, collected by local resident George R. Scott, are microtine rodents, early Pleistocene horse, puma, and an archaic

rabbit. Sediments are of reversed magnetic polarity (Van Domelen and Rieck, 1992), and estimated age is 1.5-1.7 Ma (Reppening and others, 1994).

4.8 0.9 **STOP FOR PICNIC LUNCH.** Ste. Chappelle Winery is the first post-prohibition winery in Idaho. Experimental vineyards were first planted in 1972, and the winery established in 1976 by the Symms Fruit Ranch. Well-drained loess soils, the microclimate of south-facing slopes of the Snake River valley, and the late growing season combine to produce Riesling, Chardonnay, Merlot, and other varietal grapes. There are now eight wineries in this area of which Ste. Chappell is the largest, shipping 200,000 cases per year. Figure 17 is a view from the winery.

6.8 2.0 Going north and then due east on State Route 55, we leave the Snake River valley and travel across the broad western plain.

9.2 3.6 Between Huston and the Lake Lowell turnoff is the "Lower Deer Flat channel", a 3-km-wide, northwest-trending, gravel-mantled, middle-Pleistocene channel incised about 30 m into an upland surface of Glenns Ferry Formation capped by the Tenmile Gravel (Othberg, 1994). This probably is an old channel of the Snake River that was blocked to the southeast by the basalt fields of Kuna Butte and other large shield volcanoes. Eruptions of these lavas forced the river south to its present course on the south side of the plain.

16.2 7.0 Continue straight east through the stoplight at the intersection of State Route 55 and Caldwell Boulevard. This easterly continuation is named Karcher Boulevard, and there are no more mileposts. You will cross over the railroad tracks and the Interstate heading toward the Amalgamated Sugar Refinery.

18.0 1.8 Just past the sugar beet refinery, turn right (south) on Northside Boulevard and then left (east) to enter Interstate 84, heading east to Boise.

Mileages are now based upon mileposts of Interstate 84.

Milepost	Inc.	
38.0	3.0	Just before Exit 38, the Interstate Highway descends over a basalt-mantled surface (one of the Amity or Deer Flat surfaces). This lava can be traced to Caldwell where it was $^{40}Ar/^{39}Ar$ dated by Othberg (1994) at 0.799±0.095 Ma and has a reversed magnetic polarity. From here east, the Interstate is on the Sunrise Terrace surface.
46.0	8.0	From Exit 46 (Eagle Road) the Interstate heads east, along a route for which we have a high-resolution seismic line all the way to Boise (about 8 mi east). Because of urbanization and traffic in this area, we used a route along the Union Pacific Railroad right-of-way, one mile south of the Interstate.
49.0	3.0	Take signs to CITY CENTER, as you negotiate the "Flying Y" complex of freeway overpasses.
49.5	3.5	About 0.5 mi beyond the Interstate "Flying Y" intersections, the highway descends to the Whitney Terrace surface.
51.8	2.3	Four lanes descend from the Whitney terrace onto the modern flood plain of the Boise River and downtown Boise. The Interstate Connector merges with city streets at Front Street. Continue east on Front Street.

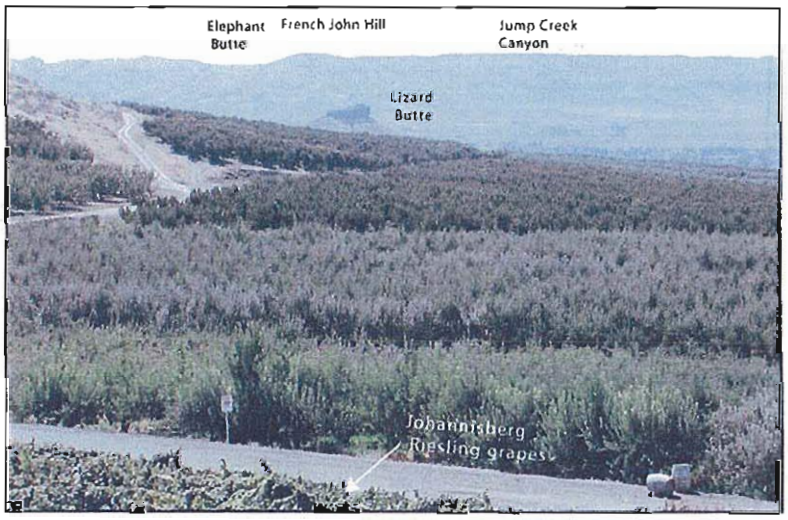

Figure 17. View to the south across the Snake River valley to the Owyhee Mountains from the Ste. Chappelle vineyards (Lunch Stop).

53.5	1.7	At the Capitol Boulevard stoplight, turn left (north-northeast), and the State Capitol Building should be in sight about 5 city blocks ahead.
53.8	0.3	At the Idaho State Capitol Building, turn left one half block in front of the capitol, and then right on 8th Street to the northwest corner of the State Capitol. The 1920 State Capitol building is constructed of Miocene Boise Sandstone from the Table Rock Quarries (Stop 9).

Reset mileages at the 8th Street and State Street intersection.

WESTERN BOISE FOOTHILLS LEG OF FIELD TRIP

Mileage Cum.	Inc.	
0.0	0.0	This leg of the field trip starts at 8th and State Street, the northwest corner of the State Capitol grounds (fig. 18). Continue 3 blocks northeast on 8th Street and turn left (northwest) on Hays Street.
0.0	0.2	Hays Street and 8th Street. Travel 0.6 mi northwest on Hays Street.

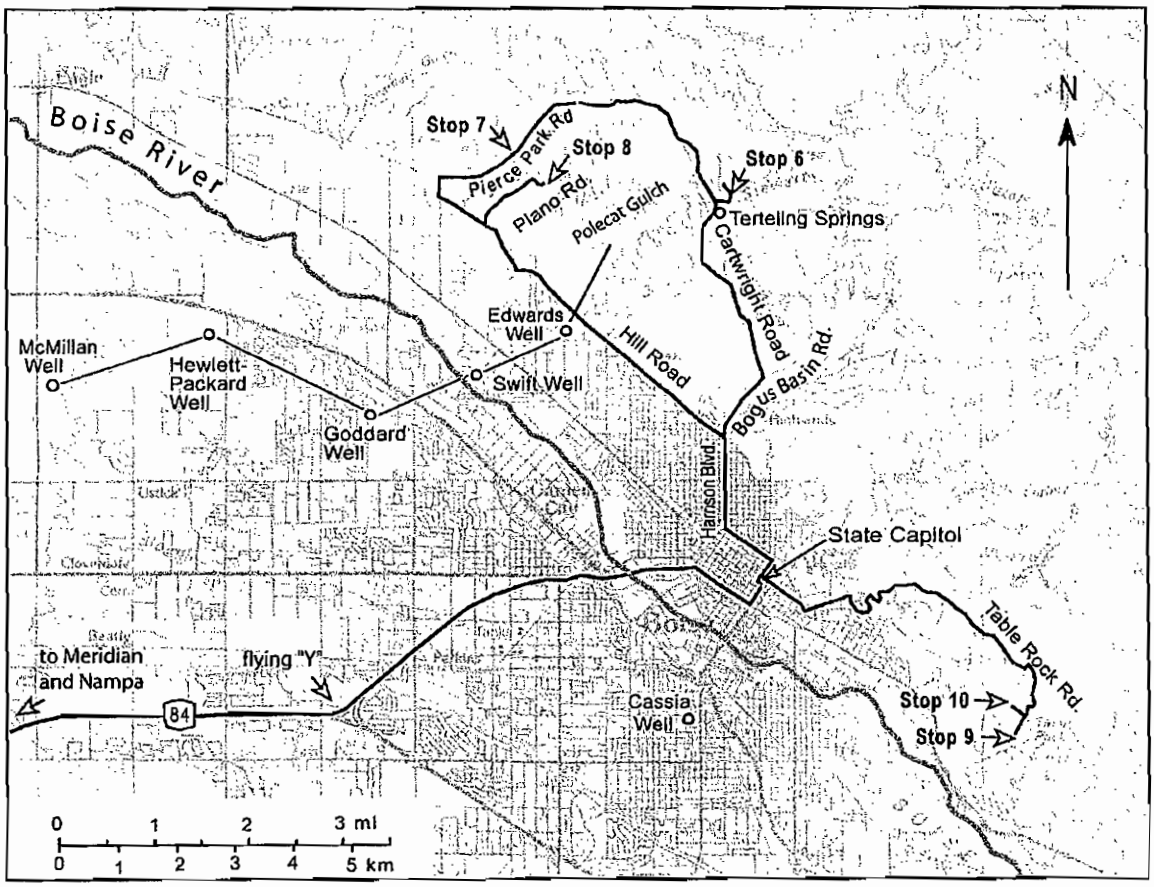

Figure 18. Map showing route of trip through the Boise foothills.

0.8 0.6 Bear right (north) and merge with Harrison Boulevard. Continue straight ahead (north) to the Hill Road intersection.

1.8 1.0 Hill Road stoplight. Continue straight ahead. Harrison Boulevard turns into Bogus Basin Road.

2.1 1.0 In the road cuts behind the buildings, on the left (west), is fine- and medium-grained sand with hummocky cross stratification (HCS) (Gallegos and others, 1987). HCS is produced by currents near the wave base, induced by storm waves. This type of cross stratification indicates near shore sedimentation, and under oceanic conditions within a 10–20-m depth (Walker and Plint, 1992).

2.6 0.5 Turn left (northwest) onto Cartwright Road. This turn is beneath the green-lawn-covered hill of the J.R. Simplot Mansion. Sediment along the road is mostly nearshore muds and sand of the Terteling Springs Formation.

3.3 0.7 Crest of hill. Ahead are hills with the conspicuous contact between mudstone of the Terteling Springs Formation and the overlying coarse Gilbert-style delta sands of the Pierce Gulch Sand (fig. 19). The mudstone is grass covered because of good moisture retention of the fine soil, whereas the Pierce Gulch Sand has only dark bitterbrush clumps with roots that reach deeper into the ground for moisture on dry sandy slopes. This vegetation contrast is seen on most south-facing slopes of these lithologies. North-facing slopes in the foothills have a substantial mantle of loess soil, 1–4-m thick, which supports bitterbrush and sage thickets.

4.6 1.3 Sediments dipping 28° W. in the road cut are inferred to be the Chalk Hills Formation. Sediments of the overlying Terteling Springs Formation, at the gate to the Owyhee Motorcycle Club, 0.2 mi to the northeast, are dipping only 12°. Generally, it is inferred that an unexposed angular unconformity exists between these units. This is the only place where existence of an angular unconformity can be demonstrated within the lacustrine sequence in the foothills. Possibly, it compares with the unconformity at Stop 5 along the Owyhee Mountains front.

4.8 0.2 Park for Stop 6.

Stop 6. Oolites and Fossil Clams of Lake Idaho, Owyhee Motorcyle Club in Stewart Gulch

Park at the entrance to the Owyhee Motorcycle Club. View the foreset beds at the gate, go through the gate, and walk around the hill to the northeast, observe the sediments in the excavated cut at the bleachers on the racetrack, and then proceed about 200 m up the gulch to the oolites. Coarse sand foreset beds of a Gilbert-style delta are overlain by Terteling Springs Formation mudstone at the entrance gate of the motorcycle club (figs. 20 and 21). This contact is interpreted as a "flooding surface" caused by a rise in lake level. Alternatively, one might argue it is the result of lobe switching of delta distributaries, but mass-failure deposits into deep water seen around the hill to the east suggest deepening of waters. The foreset-bedded sand unit at the entrance gate crops out again as cemented sandstone in the canyon of Dry Creek, about 1 mi north of here. In Dry Creek valley, this sand is one layer of foreset-bedded sandstone about 25-m (80-ft) thick. It is believed that Terteling Springs, just below the road here, is

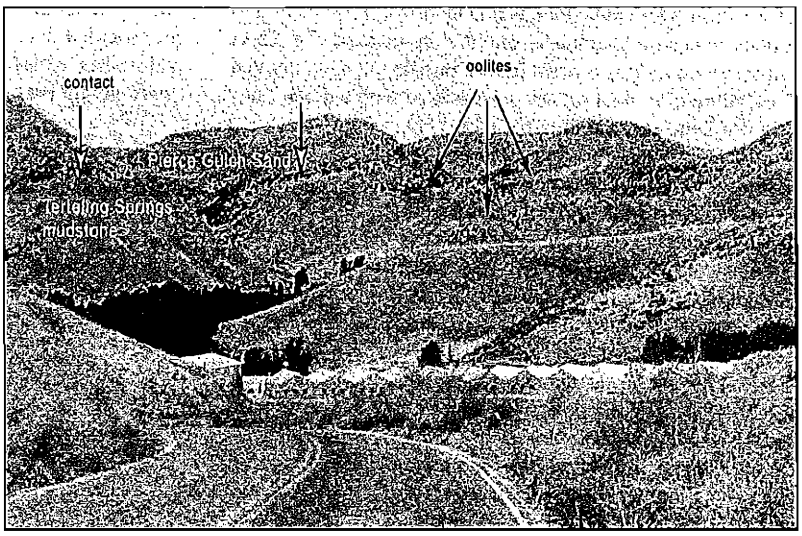

Figure 19. Contact of the Pierce Gulch Sand overlying mudstone and oolite bars of the Terteling Springs Formation. View is to the northwest from the Cartwright Road across Stewart Gulch. Greenhouses in the foreground are heated by geothermal water.

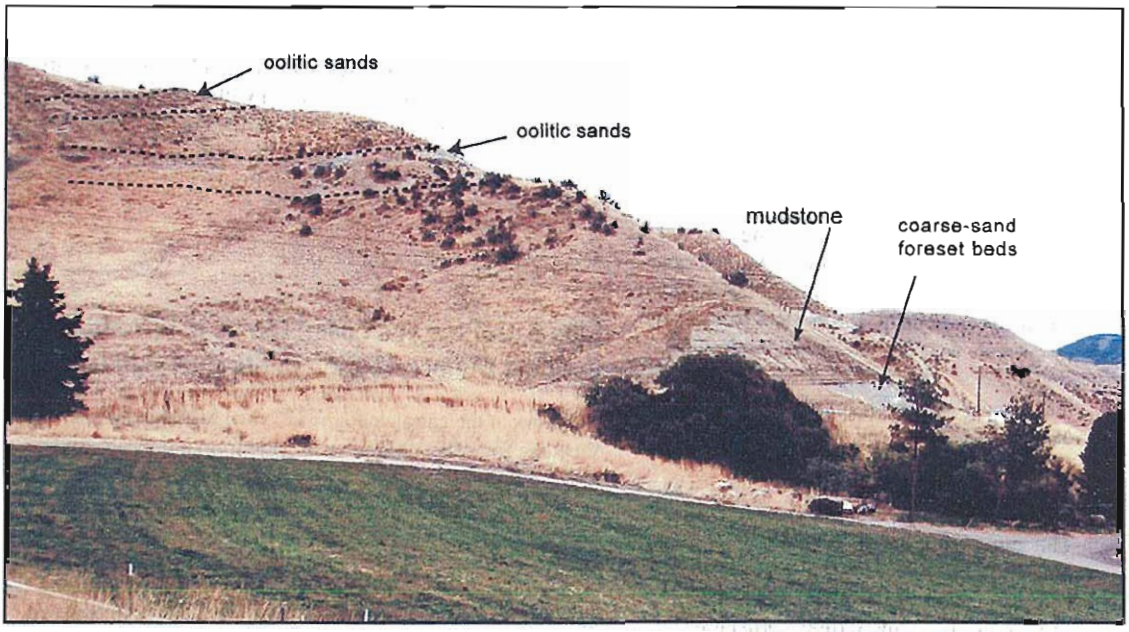

Figure 20. Coarse sand of a Gilbert delta overlain by mudstone and the oolite bars at Terteling Springs in Stewart Gulch. View is to the northeast from Cartwright Road.

discharge from this permeable sand unit intercalated within mudstones of the Terteling Springs Formation.

Walk through the gates and continue left around the hill about 200 m past the bleachers to the beer and pop stand. In the excavated cut behind the stand is a bed of coarse orange sand, over 3-m thick, and fine beds contorted by soft sediment deformation. The sand contains abundant white shells of gastropods and clams chaotically oriented in the sand (fig. 22A). I interpret the sand as a mass-failure into deep water, derived from failure of a shoal or beach associated with a delta. The sand was deposited rapidly on the lake bottom causing soft sediment deformation of the fine beds.

Continue walking up the gulch about 100 m beyond the racetrack and through an unmaintained fence to a smooth rock ledge at the foot of the hills. This rock ledge is made up of carbonate-coated sand grains, commonly called "oolites" (fig. 22B). Formation of lacustrine oolites occurs in wave-agitated waters of beaches and shoals. Origin of ooids is still debated, but precipitation of concentric microlayers from carbonate-saturated waters onto grains of fine sand seems clear here. Davaud and Giradclos (2001) show that biofilms act as a catalyst or substrate for submicron-sized calcite crystals forming on oolites in temperate, freshwater Lake Geneva (Switzerland), at depths of 1–5 m.

Several lenses of oolitic sand occur here over a stratigraphic interval of 120 m (fig. 23). On the south side of the western plain, these oolite occurrences have been interpreted as a transgressive unit at the base of the Glenns Ferry Formation (Malde and Powers, 1962; Swirydczuk and others, 1979, 1980a, 1980b, Reppening and others, 1994). Wood and Clemens (2002) agree they are a transgressive unit, and propose that the oolites are an indication that Lake Idaho was a closed-lake basin of increasing alkalinity. The closed-basin environment is confirmed by a ^{13}C isotopic analysis of del^{13}C

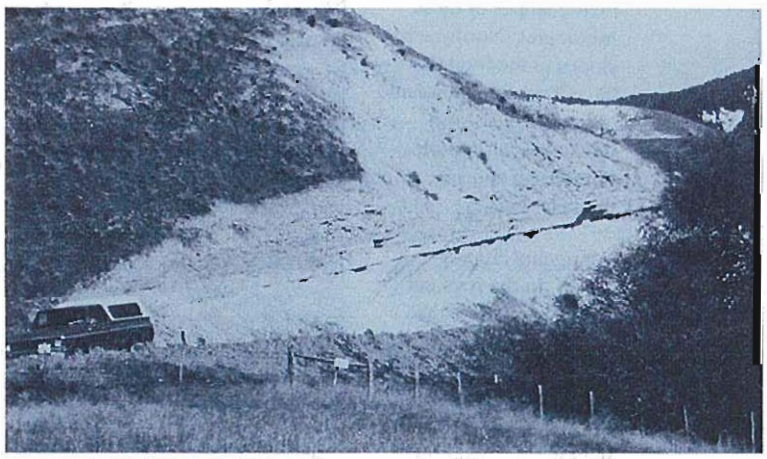

Figure 21. Closeup of foreset-bedded coarse sand overlain by mudstone of the Terteling Springs Formation.

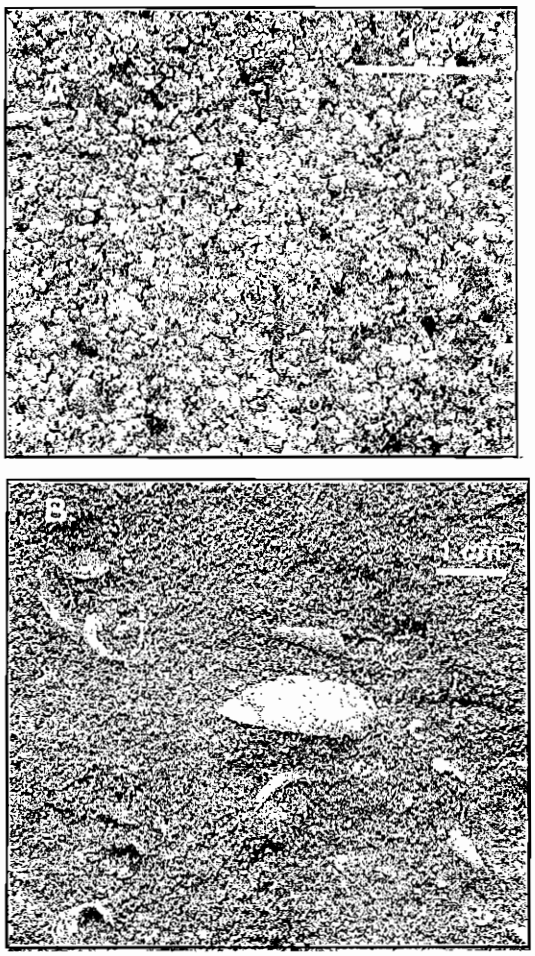

Figure 22. (A) Carbonate-coated grains (oolites), mostly about 0.8 mm in size from the outcrop at the Owyhee Motorcycle Club. (B) Fossil clams and snails in a coarse sand at the Owyhee Motorcycle Club. Shells are scattered without orientation indicating this may be a mass-wasting deposit collapsed from a delta front and not a beach deposit.

= +2.0 for carbonate in oolites collected from drill cuttings from a depth of 40 m in the Cassia Street water well in central Boise (fig. 18), about 8 km (5 mi) south of here (Cavanagh, 2000). Worldwide, the del^{13}C of closed-lake carbonates range from -2 to +5, whereas open-lake carbonate ranges from -5 to -15 (Talbot, 1990).

Mileage Cum.	Inc.	
		Walk back to the vans parked at the entrance to the motorcycle club. Continue driving northwest on Cartwright Road.
5.8	1.0	Crest of the hill. The road traverses the contact of the Pierce Gulch Sand over the Terteling Springs Formation.
6.3	0.5	Pierce Park Road. Bear left (southwest) on Pierce Park Road.
6.7	0.5	Many springs occur at the contact of the base of the permeable Pierce Gulch Sand upon mudstone along this road, as indicated by the abundant black locust, cottonwood, and willow trees and blackberry thickets.
7.6	0.9	Mudstone of the Terteling Springs Formation with a 2-cm-thick white silicic volcanic ash. Near here, visible when the grader cleans the road cut, is a white sand hummock within the mudstone, probably storm-wave reworked sands that avalanched from a delta edge.
7.9	0.3	Pull off on the right side of road and park at the entrance to the sand quarry in the Pierce Gulch Sand. Walk down the road (south) to the road cut in Terteling Springs Formation.

Stop 7. Pierce Park Road: Pierce Gulch Sand Over Mudstone of the Terteling Spring Formation

The quarry exposes 20-m-thick foreset beds of the Pierce Gulch Sand. The sand is a Gilbert–style delta of coarse sand. Walk down the road (about 150 m) just past the high road cut in Terteling Springs Formation mudstone, on the west side of road, to see the 20-cm-thick, white silicic volcanic ash near the top of the mudstone unit. The coarsest grains at the base

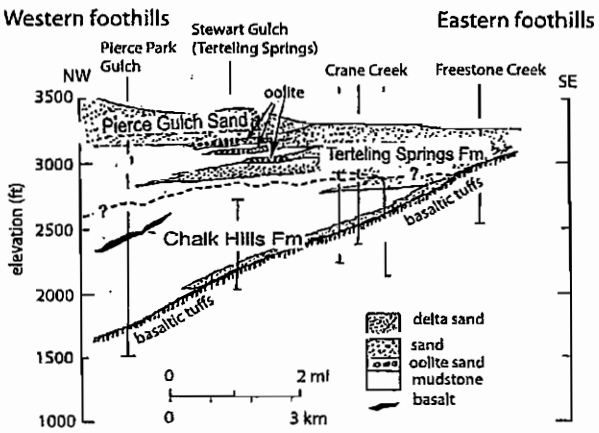

Figure 23. Stratigraphic diagram showing relation of the Chalk Hills Formation with the overlying Terteling Springs Formation and the Pierce Gulch Sand (from Wood and Clemens, 2002).

of this ash layer consist of 0.15- to 0.2-mm shards of white pumice and very light-gray glass. This size suggests it came from a volcanic source within several hundred kilometers. This relatively thick ash occurs in many places in the western foothills and is a good marker near the top of the Terteling Springs mudstone.

Mileage
Cum. Inc.

After this stop, return to vans and continue down Pierce Park Road.

9.1 1.2 Pierce Park Road and Hill Road. Turn left (east) onto Hill Road.

9.7 0.6 North Plano Road and Hill Road. Turn left (north) on North Plano Road, and continue northeast. We will travel 1.4 mi up this road.

0.1 End of pavement. Continue on North Plano Road. It is uncertain whether this is still a private road, despite the abundance of "no-trespassing notices" on the side of the road. The road serves several residences at the top of the hill. I think it now is a public county road.

0.8 Turn around and park at the switchback, which is a posted entrance to private sand quarries. Walk back about 150 m to the road cut on the south side of the road.

Stop 8. North Plano Road: Base of the Pierce Gulch Sand

The road cut on this dirt road into the foothills is the only good exposure of the base of the Pierce Gulch Sand over mudstone of the Terteling Springs Formation. The contact is so easily mapped on air photos by contrast in vegetation and soil that one might believe it is an unconformity. However, at this locality the deposition appears continuous, and the boundary between these two different lithologic units is simply that of a coarse-sand delta prograding and downlapping over prodelta mudstone. On a large scale, when viewed from a distance, the lower sand crossbeds shallow downward in slope and appear tangential to the contact.

Geophysical logs of water wells west of here show a major delta unit in the upper section (fig. 24). At the McMillan Well, 10 km (6 mi) west of here, the delta sand thickens to 210 m (700 ft). The delta unit is built out into a deeper lake basin and is thicker there because of "greater accommodation depth".

In this road cut, a 1.5-m-thick bed of coarse sand overlies mudstone, and the sand is overlain by yet another mudstone. The main thick body of coarse sand lies just a few meters above the road cut (fig. 25). Mudstone fingers and lenses penetrate the sand, suggesting the muds were semisoft when overlain by the sand. Small sand dikes also wedge upward about 0.3 m into the overlying mudstone. The boundaries are quite sharp and appear conformable, suggesting that sand prograded rapidly over the mud bottom of the lake.

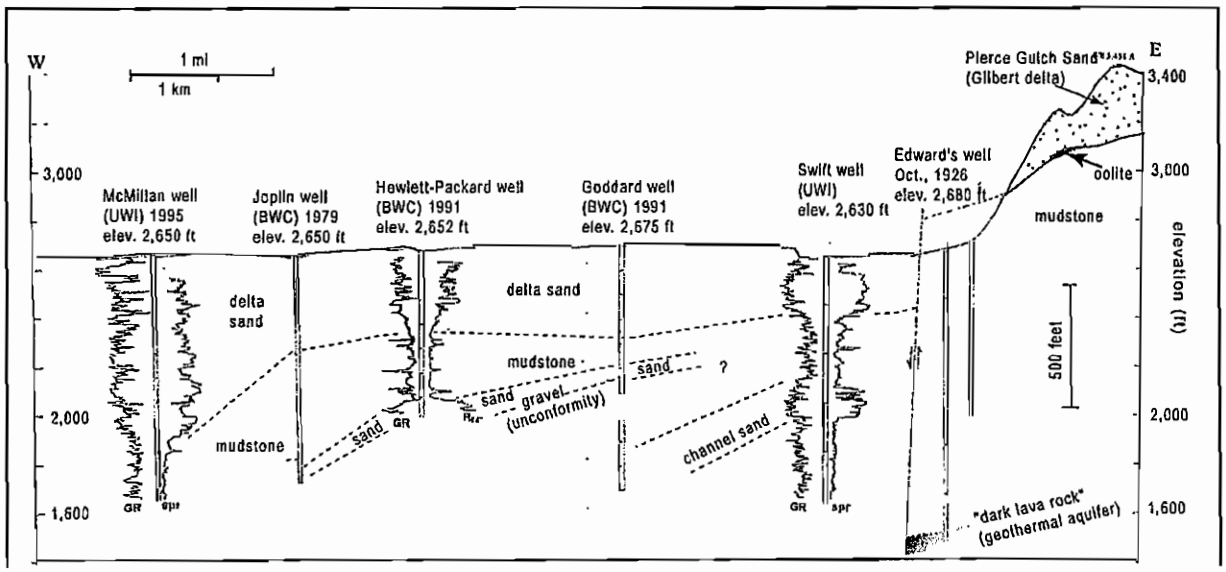

Figure 24. Stratigraphic section and well logs from Polecat Gulch in the foothills to west Boise, showing the Pierce Gulch Sand and equivalent delta facies in the subsurface. Well locations shown in figure 18. GR, natural gamma log; spr, single-point resistance log; and R_{64}, 64-inch normal-resistivity log. Well logs courtesy of United Water Idaho, Inc. (UWI), and its predecessor, Boise Water Company (BWC).

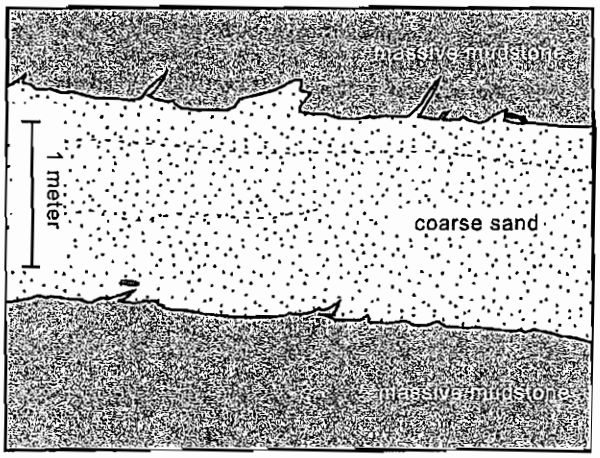

Figure 25. Tracing of photo showing an bed of coarse sand interbedded within mudstone, just beneath the base of the massive Gilbert-style delta of the Pierce Gulch Sand at North Plano Road. The sand bed is interpreted to be a sublacustrine avalanche out on to the muddy lake bottom, formed as the main foreset sand body was advancing basinward.

Mileage Cum.	Inc.	
		After viewing this stop, drive 1.4 mi back to Hill Road.
9.7	1.4	Return to the intersection of Hill Road and North Plano Road and turn left (east) on Hill Road.
11.1	1.4	Hill road makes a 90° turn to the left (east).
11.9	0.8	To the right (south) is the road to Edward's Greenhouse, a highly successful geothermally-heated greenhouse operation raising garden plants and decorative flower baskets of all sorts for the Boise market. Location of the Edward's well is shown in figure 18. The geothermal system here is of historical importance in Idaho groundwater law, because in 1931, the Idaho Supreme Court issued a landmark decree (Silkey v. Tiegs) on the doctrine of "the illegality of mining of an aquifer". The court interpreted the declining pressure and artesian-well flows of hot water to be the result of discharge exceeding recharge of an aquifer. In those situations, the rights of the junior appropriators (those owners of the later wells) to produce water are curtailed. The wells are about 350-m (1,150-ft) deep, into a "dark volcanic rock", probably a rhyolite, and produce 47° C (117° F) water (Young and others, 1988).
12.4	0.53	6th Street and Hill Road stoplight, continue southeast on Hill Road.
13.8	1.4	Bogus Basin Road and Hill Road and Bogus Basin Road (Harrison Boulevard) intersection. Turn right (south) on Harrison Boulevard, and travel 1.0 mi to where Harrison merges with the east-bound lane of Hays Street, follow east on Hays Street for 0.8 mi to 9th Street.
15.6	1.8	9th Street and Hays Street. Turn right (south) on 9th Street.
15.8	0.2	State Street and 9th Street. Turn left (east) on State Street.
15.9	0.1	Idaho State Capitol Building, 8th and State Street.

Reset mileages at the 8th Street and State Street intersection.

EASTERN BOISE FOOTHILLS LEG OF FIELD TRIP

Mileage Cum.	Inc.	
0.0	0.0	This leg of the trip starts at the intersection of 8th Street and State Street, the northwest corner of the State Capitol Building grounds. Travel east on State Street.
0.1	0.1	Intersection of Fort Street and State Street. Bear right (east) onto Fort Street.
0.4	0.3	Turn left (north) on Reserve Street.
0.6	0.2	Intersection of Mountain Cove Road and Reserve Street, continue north on Reserve Street. The dike on the northwest (left) side of the street was built in 1998 to increase the volume of the sediment retention reservoir where Cottonwood Creek flows from the foothills. The September 1996 foothills fire focused awareness on potential debris flows out of the foothills gulches, particularly after major fires in the watersheds.
0.9	0.3	Main road bears right and uphill (east) and changes name to Shaw Mountain Road at this intersection with San Felipe Way. Three hundred feet northwest along a gated gravel

road is the Boise Geothermal, Inc. Well No. 1, drilled to a depth of 634 m (2,080 ft). Idaho batholith granite is at a depth of 512 m (1,680 ft) in this well (Burnham and Wood, 1983).

1.0	0.1	The basalt of Aldape Heights crops out along Shaw Mountain Road to about this intersection with Santa Paula Place. This basalt is intercalated with sands of the Chalk Hills Formation. Clemens and Wood (1993) obtained a whole-rock K-Ar age of 9.5±0.6 Ma. They

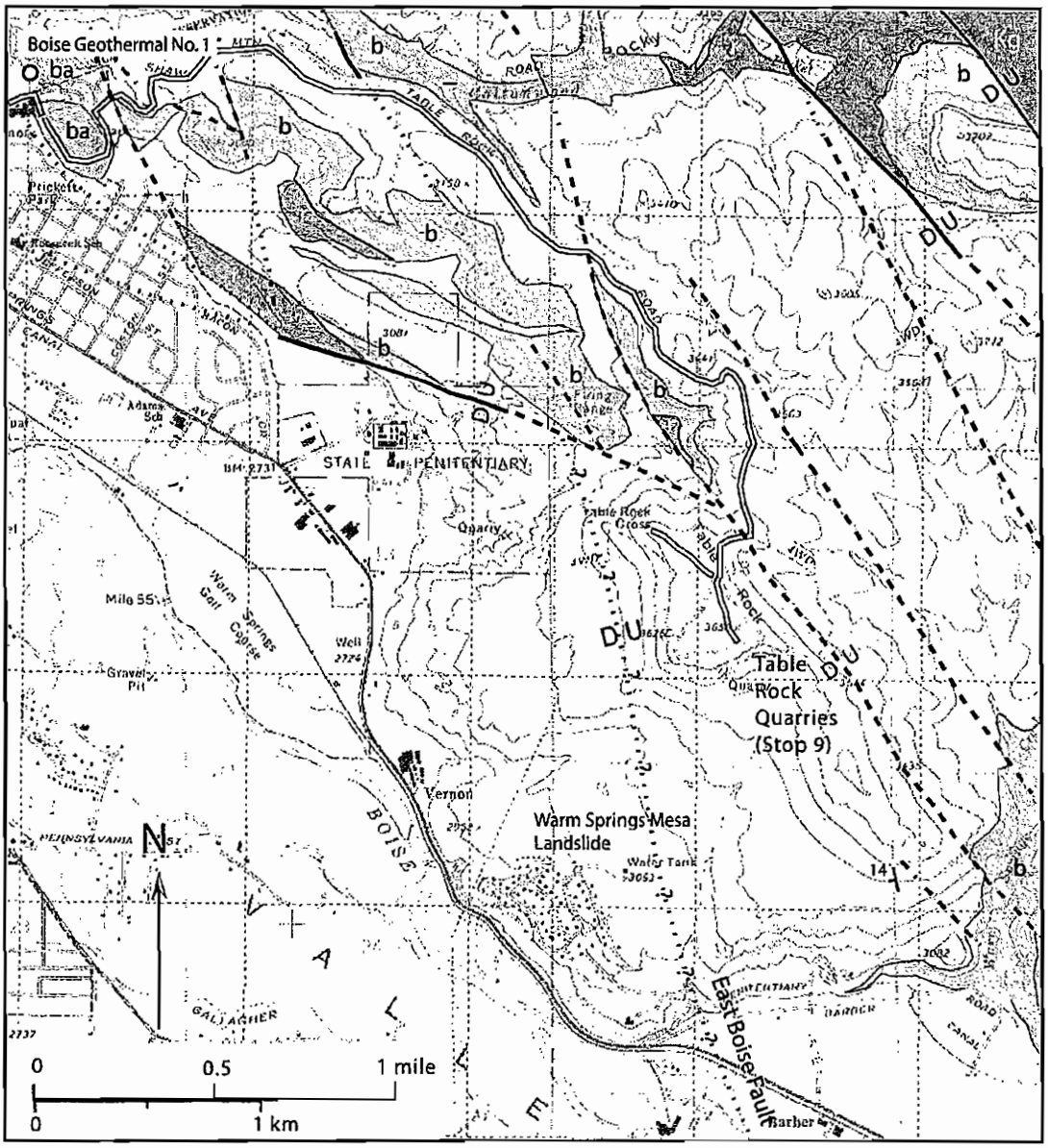

Figure 26. Geologic map showing the route to Table Rock. The Table Rock area is a downfaulted block, with respect to the foothills on the north. Because it is structurally lower, it contains one of the more complete stratigraphic sections in the foothills of 210 m (700 ft) of fluvial and lacustrine sediment over the Miocene rhyolite and basalt. Symbols on map: Kg, granodiorite of the Idaho batholith; r, Quarry View Park and Cottonwood Creek rhyolite (11.8±0.6 and 11.3±0.3 Ma, respectively); b, basalt and basaltic tuffs; ba, basalt of Aldape Park; and unshaded areas are fluvial and lacustrine sediment (after Clemens and Wood, 1993).

show that this rock petrochemically matches basalt that occurs in the Capitol Mall Geothermal wells by the Statehouse, at a depth of about 223 m (730 ft), indicating vertical separation due to dip of beds and offset along faults is about 260 m (850 ft) between the outcrop and the wells by the Statehouse.

2.0	1.0	Turn right (east) on Table Rock Road at this intersection of Shaw Mountain Road and Table Rock Road.
4.0	2.0	Bear right (south) on Table Rock Road at this intersection with E. Wildhorse Lane (private lane).
4.2	0.2	Gate unlocked between 1 hour before sunrise and 1 hour after sunset. This point is in a saddle between hills and is the location of the normal fault (fig. 26) that down drops the Table Rock section of sediments to the southeast relative to the foothills to the north.
4.5	0.3	Park for Stop 9.

Stop 9. Table Rock Quarries

Park here and procede 0.25 mi to the southeast along a deeply-rutted road to the rim of the mesa and the quarries for the "Boise Sandstone".

Table Rock is a mesa capped by silica-cemented sandstone, forming a prominent landmark above east Boise. The mesa is comprised of younger lake and stream sediments faulted down relative to the northern foothills, about 300 m (1,000 ft), thus preserving a 200-m (700-ft) section of sedimentary strata (Wood and Burnham, 1987; Clemens and Wood, 1993) (fig. 26). The 15-m-thick sandstone layer at the top (fig. 27) has been quarried for over 100 yr and widely marketed as a dimension stone. It is the stone of which the Idaho State Capitol Building was constructed in 1920. This "Boise Sandstone" also is a standard for many rock mechanics and petroleum reservoir experiments (Wong and others, 1997). Porosity of 0.27 and a permeability of 910 mD (9.6×10^{-4} cm/s, hydraulic conductivity) are reported by Kovscek and others (1995).

The massive character of this sandstone makes it a good stone for sculptors and for dimension stone. I have puzzled over how a 15-m-thick layer of sand, of such uniform grain size ($D_{10} = 0.2$, $D_{50} = 0.35$, $D_{95} = 0.7$ mm), was deposited. Gallegos and others (1987) suggested it was a gravity-driven mass flow beneath the lake based on the character of its basal scour surface. Above the massive sandstone is 5 m of bedded sandstone with 0.5 mm coated grains (ooids) and rip-up slabs of coarse sandstone mixed with ooids (fig. 27 and 28). Above the bedded sand is thin-bedded mudstone and uncemented sand and sandy gravel.

Silica cementation of the sand occurred as silica-saturated geothermal waters percolated through permeable beds and cooled allowing the dissolved silica to precipitate. Silica-cemented sandstone around the western plain commonly occurs within several kilometers of fault systems. The faults were conduits for upward flow of silica-bearing hot water from depths of a few kilometers.

From the quarries is the best view of the Pleistocene terrace sequence of the Boise River Valley (fig. 29). Othberg (1994) established a chronology for the four terraces observed

Figure 27. Massive medium-grained sandstone at the Table Rock Quarries. This 15-m-thick layer is the "Boise Sandstone" sold throughout the United States as a dimension stone during the early 20th Century. The layer can be traced laterally for at least 800 m. Sedimentary architecture of this sand has not been studied, and its origin remains uncertain. It is overlain by bedded sands that contain up to 30 percent coated grains, that look very much like carbonate coated oolites, but do not effervesce. The sands also contain rip-up clasts of oolite-bearing coarse sand (fig. 28). The upper bedded sands display low-angle, tangential cross stratification. Above the sandstone is mudstone and pebbly sands.

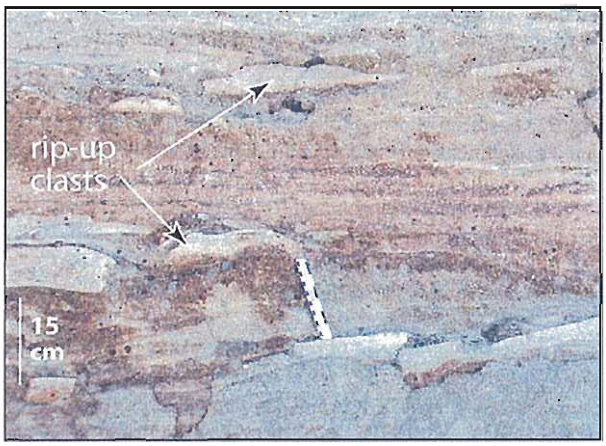

Figure 28. Rip-up clasts (light colored) of cemented coarse sand with 0.5 mm coated grains within bedded coarse and small-pebble sandstone. Locality shown in figure 27 at the Table Rock Quarries.

here by dating the basalt layers that lay upon the terrace surfaces. He also recognized the much older (but undated) Bonneville gravels on the southeastern skyline of figure 29. The terraces are typically overlain by 15 to 30 m of gravel on a strath surface of eroded lacustrine sand or mudstone (Squires, 1992). Downward erosion of the Boise Valley leaving this sequence of abandoned flood plains was in response to lowering of base level and related downcutting by the Snake River. During the late Pliocene and the Quaternary, the Snake River was downcutting the entrance to upper Hells Canyon as shown by the "base-level decline" of figure 3. This is a good place to address the question of why rivers incise episodically leaving broad terrace remnants. Othberg (1994) indicated that climate fluctuation in the Quaternary likely was the cause that triggered incision. However, questions remain about whether it was related to a change in sediment load or discharge characteristics associated with glaciation in the headwaters of the Boise River or related to overall climate change. Pazzaglia and Brandon (2001) present a model for coastal streams where they associate fill and flood plain deposition with the increased load accompanying deglaciation. In this model, strath incision occurs during periods of alpine glacial advance. Their study of coastal streams, however, also is complicated by sea-level fluctuation. At this time, the factors tht controlled or triggered downcutting and terrace formation in this region are unknown.

Mileage Cum.	Inc.	
		After viewing the quarries return to the parked vans and proceed west toward the group of radio towers and continue on to the parking area at the large white cross.
4.7	0.2	Park for Stop 10.

Stop 10. Table Rock Cross Viewpoint: View to the West Over Boise and the Western Plain

This final stop of the trip looks west over the city of Boise (fig. 30). Directly below us are the grounds of the 1860 Idaho Territorial Penitentiary and the Boise Warm Springs geothermal area. The prison buildings were constructed by prisoners from sandstone quarried from the hill below. The area now is a public park and houses the Idaho Museum of Mining and Geology. From this area, one can embark on short hikes on well-marked trails into the foothills. City bus service along Warm Springs Avenue leaves every 30 minutes from downtown at 8th and Idaho Street and takes you to within

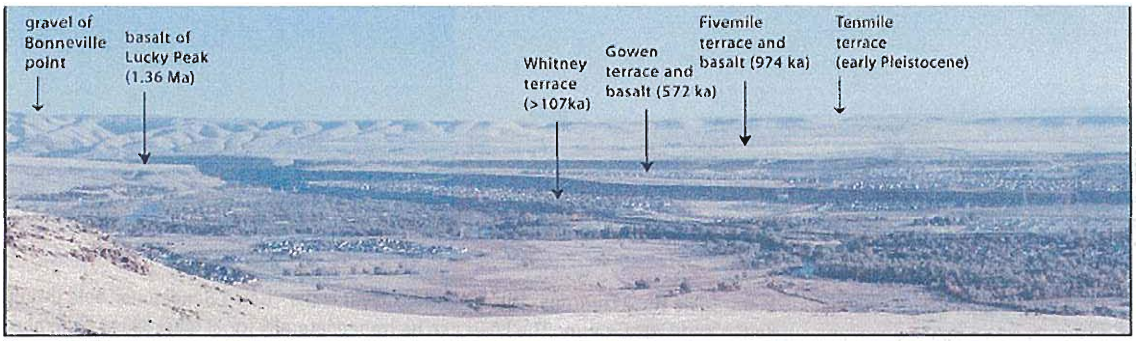

Figure 29. View to the southeast from the Table Rock Quarries. Othberg (1994) obtained Pleistocene ages on the several basalt units that flowed over the successively lower braided floodplains of the Boise River. The early Pleistocene Tenmile terrace surface forms the skyline. This surface is 150 m (500 ft) above the modern Boise River.

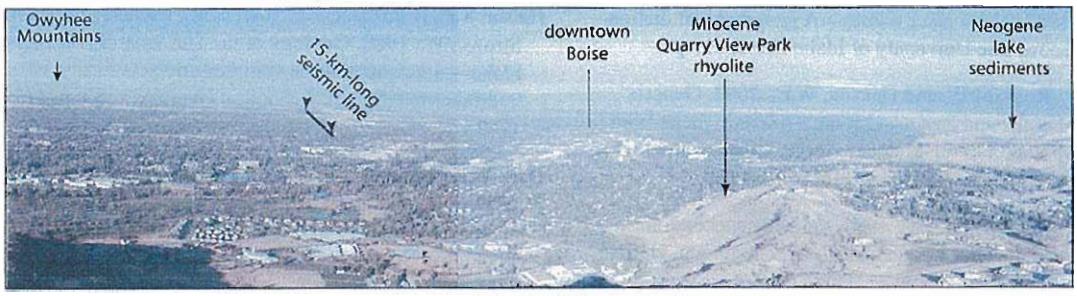

Figure 30. View to the west over the Boise Valley and the western Snake River Plain. Building area at the bottom of the hill, beneath this viewpoint, are the grounds of the 1860 Idaho Territorial Penitentiary and the Boise Warm Springs area.

300 m (0.2 mi) of the park on weekdays; however, there is currently no weekend service.

The outcrop of the Quarry View Park rhyolite is described by Wood and Burnham (1987) and shown by the arrow in fig. 30. Clemens and Wood (1993) report a K-Ar age of the rhyolite of 11.8±0.6 Ma on andesine plagioclase separates. The rhyolite is overlain by basalt, which is in turn overlain by a ledge of cemented conglomeritic sandstone. The overlying lacustrine and fluvial sediments dip generally west-southwest 4–10°. Several northwest-trending normal faults trace through the foothills and beneath downtown Boise (Liberty, 1998). Despite our high elevation at the Table Rock viewpoint, 1,108 m (3,636 ft), we are on a down-thrown block relative to the hill below containing the Miocene rhyolite (figs. 26 and 30). Throw on the fault between the rhyolite and the flat area below is about 210 m (700 ft)(Wood and Burnham, 1987).

All of the state office buildings, many commercial buildings in downtown Boise, and many of the older homes in northeast Boise are heated by hot water from wells. The original two hot water wells were drilled 123-m (404-ft) deep in the warm springs area by the Penitentiary in the early 1900s. They initially had an artesian flow of 351 l/s (550 gallons/minute) of 77° C (170° F) water, but pressure has declined, and the wells must be pumped. The Warm Springs Water District is the oldest geothermal heating district in the United States. The State of Idaho, the U.S. Veterans Hospital, and the city of Boise since the 1980s, produce water from wells 600–920-m (2,000–3,000-ft) deep beneath downtown Boise and along the edge of the foothills. A reinjection well was drilled in 1994 near the State Historical Museum, 5 blocks south of the Convention Center to a depth of 975 m (3,200 ft). Location was based on a seismic reflection survey by Liberty (1998) that imaged the faulted basalt above the rhyolite. Flow from the rhyolite aquifers below 670 m (2,200 ft) was about 57 l/s (900 gallons per minute) of 77° C (170° F) water, and these aquifers have a shutin artesian hot-water-column head of 13 m (43 ft) above ground level. It is the most successful production well, but due to its location at the tail end of the building-heat-circulation system, it is used as a reinjection well. The geothermal aquifer system is in the same fractured rhyolite rock exposed on the upthrown fault block in the foothills below. Production is just now increasing for the city of Boise system to serve new buildings, but it is uncertain whether aquifer pressure and temperature will sustain continued exploitation in this downtown area. The area south of the Boise River has never been explored by deep wells. It is likely the downfaulted aquifer is deeper and hotter immediately to the south.

This is the end of the trip, and vans will return back to the Convention center.

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19D

Geologic and Tectonic History of the Western Snake River Plain, Idaho and Oregon

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ABSTRACT

The western Snake River Plain is a Neogene-aged intracontinental rift basin, about 70 km wide and 300 km long, trending northwest across the southern Idaho batholith. Its southeastern end merges with the northeast-trending eastern plain, a structural downwarp associated with extension along the track of the Yellowstone hot spot. Orientation of the western plain rift is parallel to several regional northwest-trending crustal discontinuities, such as the Olympic-Wallowa lineament and the Brothers fault zone, suggesting that the rift failed along zones of lithospheric weakness, as the lithosphere was softened by the passing hot spot. Crustal refraction data and gravity show that the rift is not simply underlain by granitic rock, despite its appearance of having broken and extended the southern end of the Idaho batholith. Instead, the crust beneath 1 to 2 km of basin fill is mostly of mafic composition down to the top of the mantle, about 42 km deep beneath the plain. North and south of the plain, the upper crust has velocities more typical of granitic rock. South of the plain, beneath the 9-11 Ma Bruneau-Jarbidge eruptive center of silicic volcanics, is a zone of slightly high seismic velocity at a depth of 23 km that could be restite or an underplate of basalt related to formation of the silicic magma.

In this paper we show that some (12-10 Ma) rhyolite flows and domes erupted near the margins of the plain, but that thick rhyolite does not occur in deep wells in the subsurface of the plain northwest of Boise. For this reason, we suspect that much of the area of the plain was an upland and not a large depositional basin during the period of silicic volcanism.

Geochronology of volcanic rocks on both sides indicate major faulting began about 11 Ma and was largely finished by 9 Ma. Since about 9 Ma, slip rates have been low (less than 0.01 mm/year) with the exception of a short (about 10-km) segment of late Quaternary faulting in the Halfway Gulch-Little Jacks Creek area on the south side.

Earliest sediment of the plain is associated with basalt volcanism and high rates of faulting. Interbedded arkose, mudstone, and volcanic ash constitute this earliest sediment mapped as the Chalk Hills Formation. Local basalt lava fields (dated 10-7 Ma) occur at several levels in the Chalk Hills Formation. An active rift environment is envisioned with lakes interconnected at times by a river system.

The faulted and tilted Chalk Hills Formation is dissected by an erosion surface at the basin margins, indicating a regression of lakes to the deeper basins. Depositional records of the regression are generally absent from the margins, but we suggest that the east Boise fan aquifer sediments and deep basin fill might be such a record. Nothing is known of the cause of the regression of the Chalk Hills lake.

A transgressive lacustrine sequence encroached over slightly deformed and eroded Chalk Hills Formation on the plain margins, locally leaving basal coarse sand, or a thin beach pebble layer now iron-oxide cemented. The upper part of this transgression deposited shoreline oolitic sand deposits, indicating increased alkalinity of a closed lake. In the Boise foothills, much of the exposed sediment appears to be this transgressive lacustrine sequence

Editors' note: The manuscript was submitted in July 1998 and has been revised at the authors' discretion.

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where it is mapped as the Terteling Springs Formation, with shoreline sands and small deltas interfingering basinward with lake muds. The lake rose to its highest elevation of about 3,600 feet (1,100 m) in a period of less than a few million years. At that highest level, it overtopped the spill point into ancestral Hell's Canyon and the Columbia-Salmon river drainage. Reliable geochronology constrains the time of overflow between 6.4 and 1.7 Ma and is in need of better resolution. The rise in lake level may have been indirectly caused by regional tectonic movement of the migrating uplift of the Yellowstone hot spot, as an associated Continental Divide migrated about 200 km eastward from the Arco area to its position in Yellowstone National Park over the period 6 Ma to present. In doing so, the catchment area of the Snake River may have increased as much as 50,000 square km. Captured runoff associated with the shifting topographic divide is hypothesized to have caused the level of Lake Idaho to rise to its spill point about 4 million years ago.

Downcutting of the outlet was apparently slow (about 120 m/Ma) during which time sandy sediment eroded from the basin margins and filled the remaining lake basin with interbedded mud and sand of lacustrine delta systems. This sedimentary sequence of a slowly lowering base level constitutes most of the Glenns Ferry Formation and the main sand-bearing aquifer section of the western plain. It is represented in the Boise foothills by a 60-m-thick unit of coarse sand with Gilbert-type foreset bedding called the Pierce Park sand. Subsequently, fluvial systems with gradients necessary to produce braidplain sandy gravel deposits flowed to the outlet region near Weiser. These gravel deposits should decrease in age and altitude to the northwest, and at Weiser these oldest gravels occur at elevation 2,500 feet.

During the late stages of the draining of Lake Idaho, basalt volcanism resumed in the western plain, focusing along a line of vents that trends obliquely across the plain at about N. 70° W., named here the Kuna-Mountain Home volcanic rift. Both sublacustrine and subaerial volcanoes erupted and built a basalt upland with elevations of highest shields to 3,600 feet over the last 2.2 million years. Aligned vents and fissures of these volcanoes indicate the present orientation of the principal tectonic stress is N. 70° W., contrasting with the N. 45° W. boundary of the plain and the N. 30° W. alignment of vents in the eastern plain. This N. 70° W. alignment is similar to the same vent features of Quaternary basalt fields in eastern Oregon, suggesting that a province of similar tectonic stress orientation includes the western plain and much of eastern Oregon.

Key words: rift, Cenozoic faulting, lacustrine sediments, Quaternary volcanoes

INTRODUCTION

The western part of the Snake River Plain is an intracontinental rift basin about 70 km wide and 300 km long. It is a normal-fault bounded basin with relief due to both tilting toward the center of the basin and evolving normal fault systems. Maximum depth of Neogene sedimentary fill in the basin is 2-3 km. The offset of older volcanic rocks exceeds 4 km in places. We show here that the rift-basin structure evolved mostly within the last 9.5 million years contrary to estimates by others (Mabey, 1982; Malde, 1991) who have loosely stated the basin began forming 16 to 17 million years ago.

The contiguous lowland of the eastern and western Snake River Plain confused geologists for many years who tried to ascribe a common structural origin to the entire arcuate lowland of southern Idaho (called the "smile face" of Idaho as it appears on physiographic maps). Lindgren (1898) and Kirkham (1939) described the plain as an arcuate structural downwarp. They did not recognize the fault boundaries of the western plain. Malde (1959) was first to report the normal fault boundaries of the western plain.

The eastern part of the plain is not a tectonic rift because it is not fault bounded. Instead, it is a downwarp forming a spectacular low topographic corridor across the actively extending northern Basin and Range Province (Parsons and others, 1998). By all measures, the eastern plain is an unusual lowland formed perhaps by a curious interplay of magmatism and extension (Parsons and others, 1998; McQuarrie and Rodgers, 1998).

The western plain can be more simply explained as a basin and range structure whose formation was triggered by the magmatism of the migrating Yellowstone hot spot (Clemens, 1993). Its orientation is the same as the many northwest-trending half grabens that flank the eastern plain and developed in the "wake" of the northeast-migrating hot spot. In contrast to those half-graben systems, however, the western plain is a much larger feature, 70 km wide compared to less than 30 km wide for the Grand Valley or Lemhi Valley grabens. The western plain lies north of the track of the hot spot. In the hot-spot tectonic model proposed by Anders and others (1989) and Pierce and Morgan (1992), one might expect symmetrically disposed half-graben systems formed beyond the parabolic-shaped "wake" as the hot spot passed by. No corresponding major graben system of similar proportions and age occurs south of the track in the northwestern Utah area.

As shown in Figure 1, the western plain cuts obliquely across an older north-trending Oregon-Idaho graben dated 15.5 to 10.5 Ma (Cummings and others, 2000). It also truncates the south end of the west-central Idaho fault belt identified by Hamilton (1963), a relatively young

system of north-trending normal faults. Early in its history the western plain underwent rapid subsidence and became the locus for the major lacustrine system of Lake Idaho, which persisted from about 9.5 to 1.7 Ma. The lake system underwent a substantial lowering about 6 Ma and then refilled. The 7.8-Ma duration of the lake system is long but typical of other rift lakes, such as east African Lake Malawi discussed by Johnson and Ng'ang'a (1990).

The western plain rift basin is similar in dimensions and structure to intracontinental rifts elsewhere in the world, such as those in east Africa, the Baikal Rift in eastern Russia, and the Rio Grande Rift in southwestern United States. The structure is a complex of half grabens and full grabens similar to that reported by Bosworth (1985) in other continental rift settings. The volcanism of the western plain differs from those rifts by its association with a migrating continental hot spot indicated by a pattern of time-transgressive silicic volcanism.

Practical geological interest in the western plain is largely inspired by the great ground-water resources in the sedimentary fill, and to a lesser extent by the geothermal ground water in the deep volcanic rocks. These resources are essential to the economy of semiarid southwestern Idaho. Recent pumpage has been about 0.3 million acre-feet/year (0.37 cubic km/year; Newton, 1991). Ground-water development has been mostly within the upper 800 feet (250 m) of section and has been spectacularly successful with some wells in sand aquifers producing 3,000 gallons/minute (1,600 cubic m/day; Squires and others, 1992). Many wells, however, are drilled into thick mudstone sections with poor production. The distribution of sand aquifers in the fluvial-lacustrine section is complex, but in just the last few years we are gaining a clearer understanding of the depositional history and gross features of the sedimentary architecture (Squires and others, 1992; Wood, 1994). Toward this end, we have turned the unsuccessful oil and natural gas exploration in the basin to our advantage. We have examined the scattered data on deep holes drilled by petroleum companies mostly in the years between 1950 and 1985 (Wood, 1994). This information and recent studies have improved the groundwater models now being developed for managing the resource and averting conflicts over ground-water use.

In this study, we review geophysical data on the western plain and interpret seismic-reflection data and deep drill-hole data to understand both the tectonic framework of the basin and the sedimentary facies of the basin fill. We incorporate available K-Ar and $^{39}Ar/^{40}Ar$ ages of volcanic rocks and paleomagnetic data for a chronology of events that produced the plain. We elucidate features of the sedimentary fill pertinent to the location of sand aquifers in the predominantly mud sediments of the lake system. From these data and geomorphological considerations, we propose a model for the history of the great lake system that filled the basin and its eventual overflow into ancestral Hell's Canyon. We also discuss Qua-

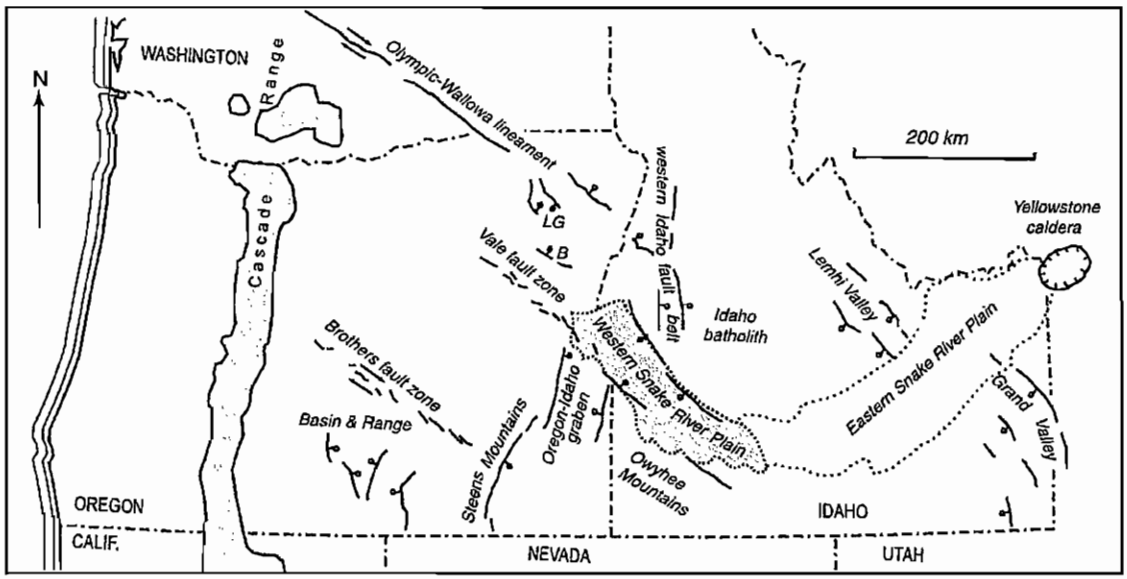


Figure 1. Regional setting of the western Snake River Plain showing related geologic features and emphasizing northwest-trending, late Cenozoic fault structures in Oregon and Idaho. LG—La Grande graben, B—Baker Valley.

ternary geomorphic features of the fluvial system that followed the draining of the lake and tectonic aspects of the Quaternary basalt fields that cover part of the western Snake River Plain.

CRUSTAL STRUCTURE AND TECTONICS

Basic to understanding the origin of the western plain is the following question. What is it about the earth's crust that causes a wide northwest-trending sag and graben just here in southern Idaho? The upper crust extended several kilometers to form this 50- to 70-km-wide rift. The northwest trend of the western plain cuts across north- to south-trending older Miocene extensional structures. The northwest trend, however, is the same as that of several smaller late Cenozoic graben basins northwest of the plain (La Grande Valley, Baker Valley). These basins show late Quaternary faulting on their margins (Pezzopane and Weldon, 1993). Several major lineaments of the northwest United States also have the same northwest-southeast trend (the Olympic-Wallowa lineament, Vale fault zone, and the Brothers fault zone). The lineaments are spaced 70 to 200 km apart through eastern Oregon (Figure 1). Parts of some lineaments are expressed by normal faults. Many of the lineaments show small amounts of late Cenozoic right-lateral movement expressed as *en echelon* normal faults or pull-apart basins. Displacements are but a few kilometers, thought to accommodate differences in extension across the lineament structures (Lawrence, 1976). The pervasive northwest structural trends suggest an orientation for zones of lithosphere weakness that have responded to late Cenozoic stress systems. While inherited zones of weakness might explain the orientation of the western plain, it does not explain the geographic position or width.

The western plain cuts across the southern part of the Mesozoic Idaho batholith, with the Owyhee Mountains segment (Taubeneck, 1971) split off to the south of the main outcrop (Figure 2). The elevation of most of the batholith mountains to the north, as well as the crest of the Owyhee Mountains, is about 8,000 feet (2,440 m). Southwest of the Owyhee Mountains is the Owyhee Plateau, a region of low relief (elevation about 5,500 feet, 1,680 m) extending into northern Nevada and southeastern Oregon. Flows of hot-spot rhyolite and basalt that form the plateau are relatively little deformed by faulting or tilting, and little is known of the underlying crust.

If the western plain is an ordinary graben, it should be underlain by downfaulted granitic rocks of the Idaho batholith. According to Hill and Pakiser's (1967) interpretation of deep crustal refraction data, a significant layer of rock having the velocity of granite (V_p of 5.5-6.4 km/s) does not underlie the plain. Prodehl (1979) reinterpreted the refraction data and concluded similarly that granitic-rock velocities are restricted beneath the western plain. Instead, the plain is underlain below 8-km depth by high-velocity material, V_p = 6.6-6.8 km/s (Figure 3). This contrasts with crust south of the plain (Mountain City to Elko), where 6.1 km/s material extends down to an 18-km depth. We have no refraction data north of the plain; however, the very existence of the extensive Idaho batholith north of the plain indicates granitic crust. The depth to the base of the batholith has not been gravity modeled to our knowledge, although Cowan and others (1986) illustrate it in their cross section to extend to 8 to 10 km. The thickness of most great granite batholiths is probably not more than 15 km, and the erosion of roof rock has probably reduced the depth to the base of the granite of exposed batholiths to less 10 km (Bott and Smithson, 1967; Leake, 1990). By analogy with the Sierra Nevada batholith, granitic rock there extends to a depth of 10 to 15 km and appears to be underlain by a root of low velocity (6.5 km/s) material to a depth of 40 km (Fliedner and others, 1996). In addition, a relatively low-velocity upper mantle material is detected to a 60-km depth. It is reasonable to assume that at one time granite beneath the plain was 8 to 10 km thick, but has been intruded by significant quantities of basaltic rock.

A large positive gravity anomaly is associated with the western plain (about +100 milligals) relative to the bordering batholith regions (Mabey, 1982). The anomaly has two peculiar features (Figure 4). It is composed of a broad positive anomaly paralleling the margins of the plain (N. 40° W.). Superposed on this is a narrow (30-km-wide) feature of about +25 milligals that trends obliquely (N. 70° W.) across the plain, south of Mountain Home, for a distance of 140 km (shown in Figure 4 by the southeastern region enclosed by the -105 milligal contour). The narrow anomaly can be accounted for by the Quaternary basalt field, but the broad anomaly must arise from a deep high-density body. Mabey (1982) modeled a single gravity profile perpendicular to the plain, near Mountain Home, and reproduced the gravity data with a deep body of density 2.9 g/cm^3 from 9 to 18 km and a shallow body of the same density from 3 to 6 km depth. A density of 2.9 g/cm^3 is appropriate for solid basalt or gabbro in contrast to a density of 2.65 g/cm^3 for granitic rocks, and less than 2.3 g/cm^3 for sedimentary rocks. Both the seismic refraction data and gravity data indicate that the sediment and volcanic fill are underlain by material in the intermediate crust having appropriate velocity and density of diabase or gabbro intrusive rocks, and not material typical of granite.

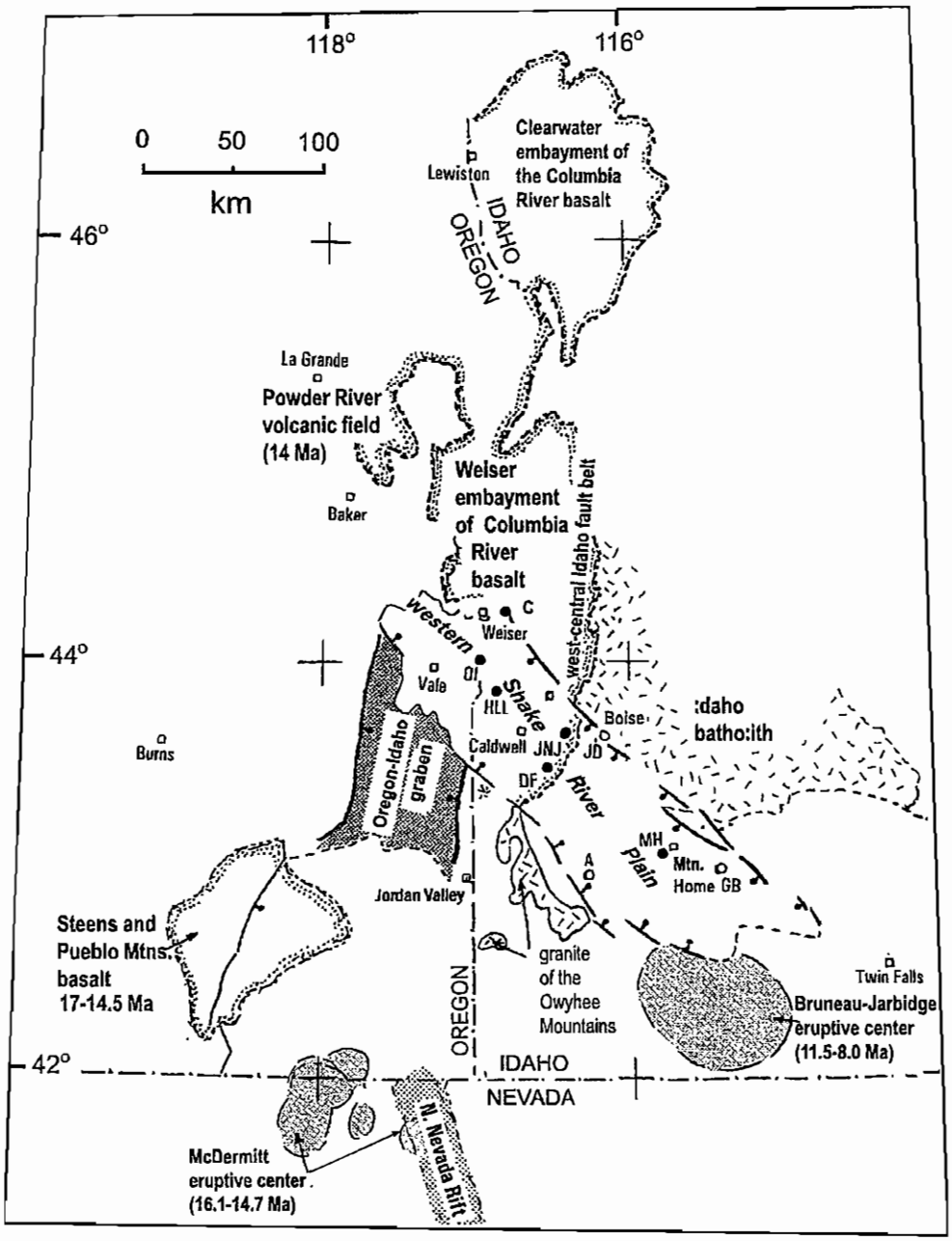


Figure 2. Map showing tectonic features surrounding the western Snake River Plain and locations of deep wells into volcanic basement. Wells only in deep basalt are shown with a solid circle: C—Chrestesen No. A-1; OI—Ore-Ida Foods No. 1; HLL—Highland Land and Livestock No. 1; JNJ—J.N. James No. 1; DF—Deer Flat No. 1; and MH—Mountain Home Air Force Base Geothermal Test. Wells in deep rhyolite are shown with an open circle: JD—Boise Julia Davis Park; A—Anschutz Federal No. 1; and GB—Griffith-Bostic No. 1. Tectonic feature locations and reference sources: northern Nevada rift (Zoback and others, 1994); Oregon-Idaho graben (Cummings and others, 2000); rhyolite-field eruptive centers (Bonnichsen, 1982; Pierce and Morgan, 1992; McCurry and others, 1997); and the Columbia River and Steens Mountain basalt areas (Hooper and Swanson, 1990; Lees, 1994; Hooper and others, 2002a, 2002b.).

A substantial accumulation of Miocene basalt lava lies beneath the sediments of the western plain. We show a hypothesized contact of lavas with underlying intrusive basalt (Figure 3). The deepest drill hole in the plain at Meridian (J.N. James well, 4.3 km deep) penetrates a thick basalt section and bottoms in basalt flows having a geochemical affinity with the Columbia River Basalt Group (Clemens, 1993; Figure 5). No inclusions of deep crustal rocks are known from western plain basalt, so we can only speculate on the geophysical results that either the underlying crust contains insignificant remnant granite greatly intruded by Cenozoic diabase and gabbro, or it is entirely filled with mafic intrusives.

Extension could have thinned the granite, but as we

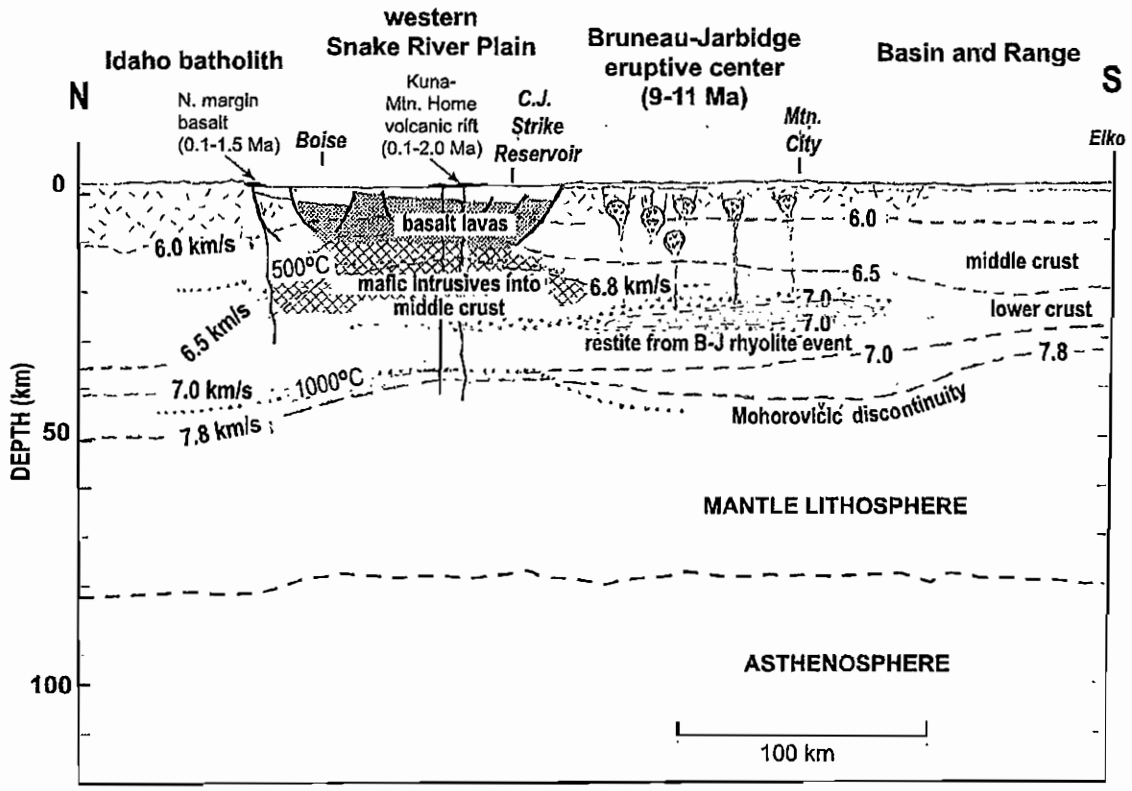


Figure 3 (A)

Figure 3. (A) Lithosphere structure interpreted principally from crustal structure beneath the western Snake River Plain and adjacent areas. Interpretation is based on the seismic refraction line of Hill and Pakiser (1967) and the reinterpretation by Prodehl (1979). Location of seismic line shown on map. Noteworthy is the upward bulge of material, with $V_p > 6.6$ km/s beneath the western plain believed to be mafic rock, and the overlying thin (~5 km) layer with velocity between 6.0 and 6.5, believed to be basalt flows or granite intruded by basalt. Prodehl's interpretation shows a high velocity layer ($V_p > 7.0$ km/s) that lies in the deep crust beneath what is now recognized as the Bruneau-Jarbidge rhyolite eruptive center along the track of the hot spot. We suggest the high-velocity layer might be restite remaining from the partial melt and extraction of rhyolite melt. It is important to realize that the crustal refraction velocities shown beneath the plain are obtained from arrivals into a string of detectors, south of Boise, and are an average of the crust between Boise and C.J. Strike. No experiments have explored structure beneath the Idaho batholith. The batholith structure shown is inferred from a section by Hyndman (1978) and Cowan and others (1986) and by analogy to the Sierra Nevada batholith shown by Fliedner and others (1996). Mafic intrusives in the intermediate crust were first suggested by Mabey (1976) from gravity data. Diagrammatic diapirs of silicic melts beneath the B-J area were suggested by Leeman (1989). Dotted-line isotherms are from heat-flow models of Brott and others (1978). One can only guess the depth of the asthenosphere at about 90 km (see Smith and Braile, 1993, Figure 35, for the eastern plain, and by analogy to the Rio Grande Rift, Baldridge and others, 1984, Figure 2).

(B) Prodehl's (1979) reinterpretation of refraction data and crustal structure from Boise to Elko.

(C) Map showing the location of the seismic refraction line. Labeled triangles are shot points, and circles are detector positions.

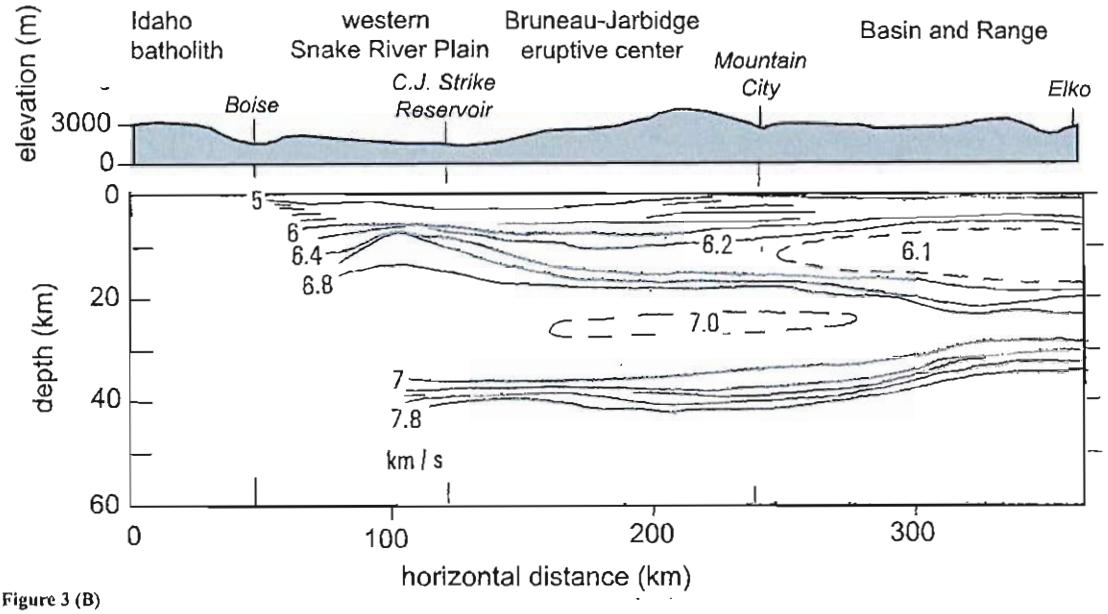


Figure 3 (B)

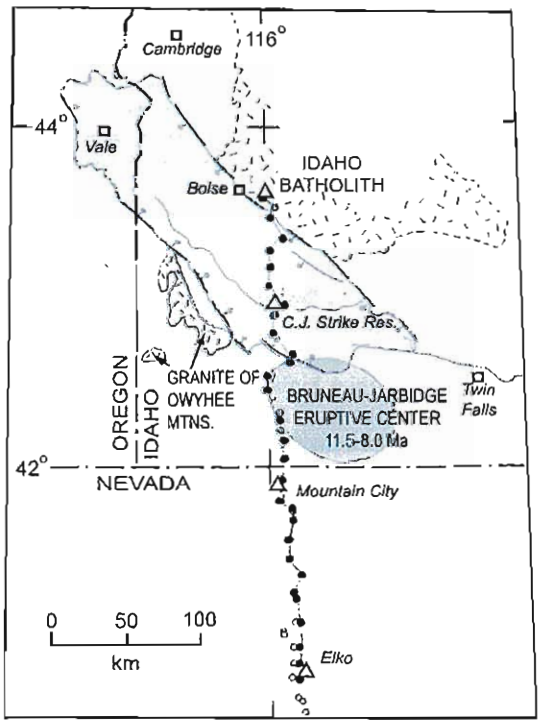


Figure 3 (C)

will show, it is unlikely that this process has greatly altered the thickness of the granite. To evaluate extension, we have added up the vertical dip-slip fault offset of the basement volcanic rock, shown on Figure 5, and assuming 45-degree dipping normal fault planes, we obtain only about 2 km of vertical offset and therefore a corresponding 2 km of horizontal extension of the 60 km width, or about 3 percent extension. Such an evaluation using only fault offset does not take into account the component of basin extension expressed by subsidence due to downwarping. If, instead of faulting, we consider the volume of the basin to have been created by extension of the upper 10 km of crust, we obtain an extension of about 10 percent. This value of extension is comparable to the 7 to 14 percent extension determined for the east African rift basins by Rosendahl and others (1992) and around 10 percent for the Rhine and Baikal rifts (Park, 1988, p. 84). It seems unlikely that extension of 10 percent could thin the granite so that it is undetectable from seismic refraction velocity measurement.

Although the western plain would not be regarded as strongly extended, with about 10 percent extension, the modification of the composition of the middle and lower crust below 8-km depth is considerable. Our preferred explanation is that the middle and lower crust under the western plain has been so invaded by mafic intrusives that it has a seismic velocity (6.6 km/s) similar to that indicated for diabase by Christiansen and Mooney (1995). Dense, high-velocity rock could also form in the middle

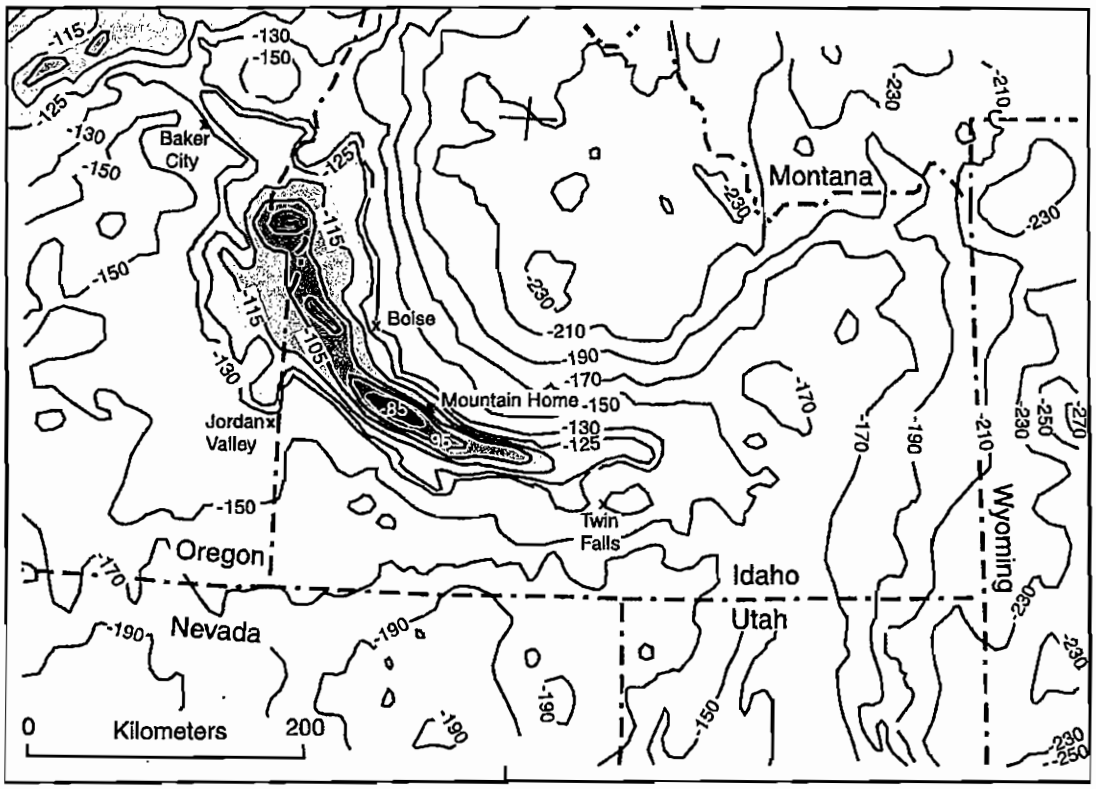


Figure 4. Map of Bouguer gravity anomalies of the western Snake River Plain region. Noteworthy is the high gravity anomaly of the western plain indicating rock of high density beneath the plain. Contour interval is 20 milligals, except for values more positive than -130 milligals. The areas of more than -125 milligals are shaded and contoured every 10 milligals. Map is from the Gravity Anomaly Map Committee (1987). Values are terrain corrected in areas of high relief. Bouguer anomalies are calculated by subtracting the theoretical attraction of rock mass above sea level using a standard crustal density of 2.670 g/cm^3. This attempts to remove the effects of varying topographic relief. Thus Bouguer anomalies result from masses above sea level with densities different from 2.67 g/cm^3, or from any lateral variation of density below sea level. In continental regions, the regional values are negative because topography is usually isostatically compensated by low density crust extending below sea level. Theoretically, corrected gravity will be zero only at sea-level measuring points.

crust by magmatic differentiation or by partial melting and eruption of the silicic component, leaving a residual mafic material; however, the volume of silicic volcanics erupted from the plain area appears to be too small (less than 500 cubic km) to account for a residual volume of high velocity rock in the intermediate crust. Most of the silicic magma of the region erupted from vents south of the western plain.

Crustal velocities in the western plain are different from those in the eastern plain, where such large lateral variations in velocity of the upper and middle crust are not detected. This led Braile and others (1982) and Wendlandt and others (1991) to infer that rising basalt may not have yet significantly modified the middle crustal composition of the eastern plain.

From the reinterpretation of the western-plain seismic refraction profile by Prodehl (1979), one might infer from his velocity model that granitic material lies south of the plain, between depths of 6 to 15 km, and that an anomalous 10-km-thick high-velocity layer of 7.0 km/s lies deep in the crust from 20 to 30 km (Figure 3). The location of that layer coincides with the roots of the large Bruneau-Jarbidge rhyolite eruptive center identified by Bonnichsen (1982) and located along the track of the Yellowstone hot spot (Figure 2). A deep-crustal high-velocity layer in this position supports the idea of a remnant of deep crustal underplate of plume basalt suggested by Leeman (1989). Alternatively, the layer could be the mafic residual of deep crust from which 2,000 cubic km of rhyolite is estimated by Pierce and Morgan (1992) to have erupted from the Bruneau-Jarbidge area.

Thus, rifting by downwarping and normal faulting

along northwest-trending boundary faults initiated extension of the western-plain crust, cutting through the south end of the batholith. It is possible that a pre-existing lithosphere structure along this trend was particularly vulnerable to weakening by heating and extension caused by the passing hot spot 10 to 11 million years ago. The rifting process involved the injection of large amounts of basaltic magma into the middle crust beneath the western plain, and that process may have greatly extended the early rift, more so than is estimated by our examination of the basin volume or faulting of the Miocene basalt basement. Basaltic magma may have been injected into the downfaulted block of granite. Humphreys and others (1999) suggest that much of the subsidence of the eastern plain is caused by the weight of added basalt to the crust, and that explanation invoked by Baldridge and others (1995, p. 455) for other continental rifts, may also apply to the western plain. Again, we point out that the actual track of the hot spot adjacent to the south side of the western plain appears to correlate with a high-velocity (7.0 km/s) body in the deep crust that may contain injected basalt or mafic residue from hot-spot volcanism. In contrast, beneath the western plain the high velocities and inferred injected basalt extend upward to a much shallower depth (8 km). These interpretations of older seismic refraction data indicate that deep-crustal seismic experiments and a reevaluation of gravity data using modern methods would contribute to our knowledge of the Bruneau-Jarbidge eruptive center, the western plain, the batholith, and the effect of the migrating hot spot on the crust.

Because the plain is the product of extension and has clear evidence of high-angle, normal faulting at the surface, it is appropriate to question whether these high-angle faults shoal in dip at depth and merge with low-angle detachment faults. Recently proposed models of extended terrane show such detachments at the brittle ductile transition at depths of 15 to 30 km beneath the Basin and

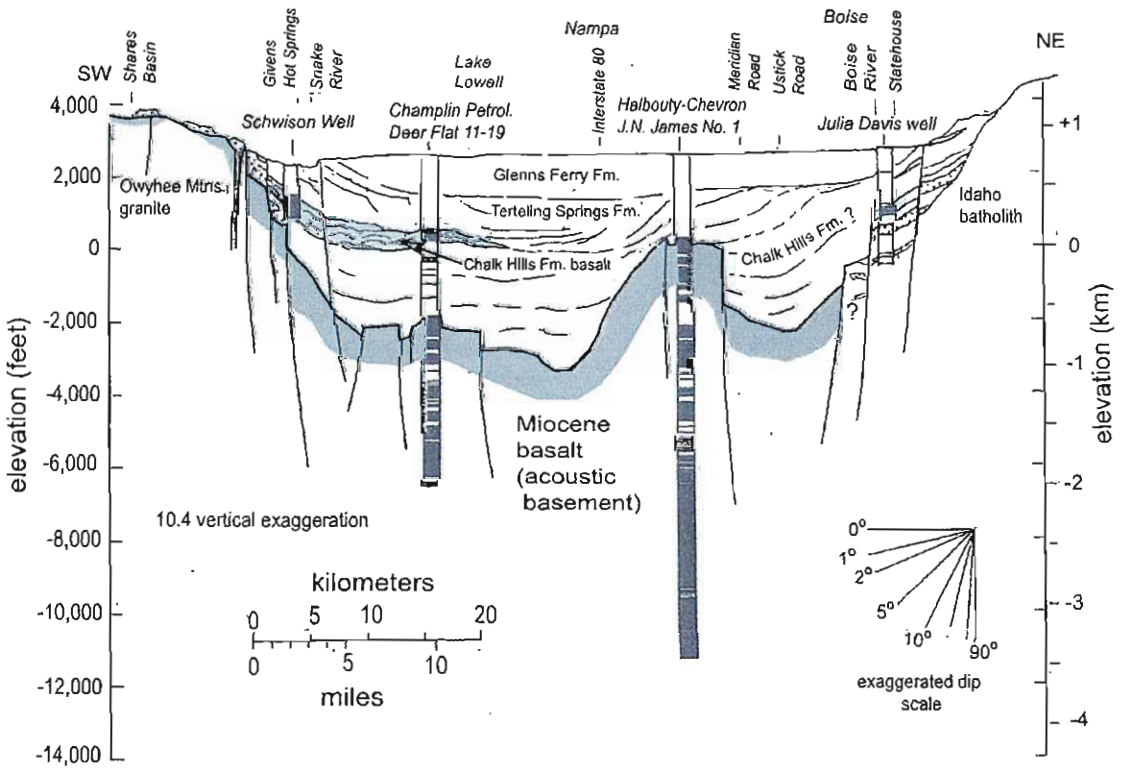


Figure 5. Section across the western plain showing the basalt occurrence (dark pattern) in the deep wells and the configuration of sedimentary fill and associated basalt from seismic reflection data. Shaded outline is the top of Miocene basalt. Stippled pattern is rhyolite that occurs in wells only at the margins of the plain.

Range Province (Wernicke, 1992). Fault block rotation, indicating the curvature of some faults at depth, occurs only along the northeast margin faults at the west end of the Mount Bennett Hills. Wood (1989) shows that the blocks have rotated to northeast dips of 12 to 25 degrees. We have no geophysical observations on the nature of faults deeper than 6 km, but certainly we allow that they could greatly decrease in dip and merge with detachments at depth as they approach the ductile middle crust. The crust is considered ductile below about 13 km because that is the limiting depth of earthquakes in this region.

THE BEGINNING OF THE WESTERN SNAKE RIVER PLAIN BASIN

We address here the time at which the western Snake River Plain first became a depositional basin. Previous workers have loosely assumed it began about 17 to 16 Ma (Mabey, 1982; Malde, 1991), associating the western plain graben with the beginning of large-scale extension in the Basin and Range Province to the south. We believe that the graben basin did not begin forming until 11 Ma. Our presumption is that evidence for the formation of the incipient plain must be (1) northwest-oriented normal faulting and downwarping of the western plain area and (2) accumulation of sediments in a basin.

STRUCTURES BEFORE THE WESTERN PLAIN GRABEN

Before formation of the western plain, extensional-fault and dike structure had a more north-south trend (Figure 1). Extensional faults and dikes were a north-south orientation during the eruption of Columbia River basalt north of the plain in the interval 17 to 14 Ma (Hooper and Swanson, 1990), in the Steens Mountains (Minor and others, 1987), and in the northern Nevada rift from 18 to 14 M (Zoback and others, 1994). The north- to south-trending Weiser embayment of the Columbia River Basalt Group was a basin that accumulated at least 2.1 km of basalt prior to formation of the western plain (well logs from 1978 Phillips Petroleum Chrestesen No. A-1). Columbia River basalts onlap the batholith at the eastern margin of the embayment. It is not known whether this margin is a result of basin downwarping or if it is partly a fault boundary. The Weiser embayment is oriented north to south similar also to the Clearwater embayment (Figure 2). From surface mapping, other workers have reported that the Weiser embayment contains up to 0.7 km of Imnaha Basalt (17.2-16.5 Ma), as much as 0.2 km of Grande Ronde Basalt (16.5-15.6 Ma), and 0.3 km of the younger (< 15 Ma) but undated Weiser Basalt (Hooper and Swanson, 1990; Fitzgerald, 1982; Hooper and Hawkesworth, 1993).

South of the western plain, Cummings and others (2000) have discovered a north- to south-trending basin they have named the Oregon-Idaho graben (Figures 1 and 2). The bounding faults on this graben formed 15.5 to 10.5 Ma. The basin filled with bimodal (rhyolite and basalt) volcanic assemblages and sediments over 2 km thick. Dike orientations in the basin generally trend north to northeast (Ferns and others, 1993). The basin was later truncated by the northwest faulting that formed the western plain. The east side of the Oregon-Idaho graben and the east side of the Weiser embayment coincide with a north-trending zone of steep gravity gradient, where the Bouguer value increases about 25 milligals from the area on the east underlain by granitic batholith to the basalt-filled basin on the west (illustrated in Figure 4 and in more detail by Figure 2-1 of Wood and Anderson, 1981). Though rhyolite eruptives are more conspicuous at the surface of the Oregon-Idaho graben, the gravity data suggest a thick graben fill of dense basalt that contrasts with lower density granitic rock to the east (illustrated just north of Jordan Valley, in Figure 4).

The spatial arrangement of the Weiser embayment basin across the western plain from the Oregon-Idaho graben tempts one to correlate these two north-northeast trending structures (Figure 2). The ages of basalt fill of the Weiser embayment span the time of the pre-Ore-Ida-graben accumulation of at least 0.6 km of tholeiitic basalt and latite and also the accumulation of 2 km of lava flows and volcaniclastic sedimentary fill in the graben. Pre-graben tholeiitic basalt also occurs in a 1-km-thick section to the adjacent east in the Owyhee Mountain upon which Pansze (1974) obtained a whole-rock K-Ar age of 17 Ma (Ekren and others, 1982; Cummings and others, 2000). Basalt dikes within this Owyhee Mountains section trend north-south (Ekren and others, 1981). Therefore, it seems likely that north- and north-northeast-trending basins were the dominant structural-basin pattern before the western Snake River Plain graben formed.

Several deep wells (greater than 2.7 km deep) in the northwestern part of the western plain penetrate thick sections of basalt and tuffaceous sediment beneath the lacustrine sediment (Clemens, 1993). Figure 2 shows a western group of deep wells, drilled only in basalt at depth, that did not intersect rhyolite. The J.N. James No. 1 well was drilled by the Halbouty-Chevron group to a depth of 4.3 km in the center of the western plain at a site 25 km west of Boise. Beneath 0.7 km of lacustrine sediment, the well contains a 1.59-km-thick section of basalt lying upon a 1.37-km-thick sequence of mostly basaltic tuff,

and a bottom section of 0.2-km-thick basalt (Figure 5). The chemistry of five samples of bottom basalt cuttings from 4.08 to 4.11 km in depth were analyzed for major, trace, and REE elements (Clemens, 1993) and fall within the range of Columbia River basalts, being most like the olivine tholeiites of the Powder River volcanic field (Figure. 2) that erupted 14 Ma in the La Grande and Baker grabens (Hooper and Conrey, 1989), but also having some characteristics of the Imnaha Basalt (Peter Hooper, written commun., 1993; Clemens, 1993). We have not yet analyzed the other basalts in the well. The most one can conclude is that no significant rhyolite occurs in this well and that the lower basalt is similar to the basalt in the Weiser embayment.

The Highland Land and Livestock No. 1 well (3.64 km deep) and Ore-Ida No. 1 well (3.06 km deep) drilled through similar sections of interbedded basalt and sediment to a total depth beneath the upper 1.1 km and 1.4 km of lacustrine sediment, respectively. Samples from the Ore-Ida well were submitted for K-Ar dating by participating companies. The resulting dates are known, but laboratory details are not available. Basalt cuttings from a depth of 2.18 km in the Ore-Ida well yielded a whole-rock age of 16.2 ± 1.8 Ma, and core from a depth of 2.50 km a whole-rock age of 9.0 ± 1.8 Ma. The stratigraphic contradiction in the ages suggests that either the apparently older sample has gained radiogenic argon or the older age is correct. The apparently younger and deeper sample could have lost argon by the hydrothermal alteration of the basalt, and therefore the sample could be older. Nevertheless, the 9.0 Ma age can be regarded as a minimum age for this basalt.

THE INCEPTION OF SILICIC VOLCANISM AND UPLIFT

It is widely advocated that the Yellowstone hot spot was first manifested in eruptions of the Imnaha Basalt about 17.5 Ma along north and north-northwest-trending fissures in the Hell's Canyon area (Hooper and Swanson, 1990), as eruptions of the Steens Basalt (16.1 Ma), as eruptions and caldera collapse of several rhyolite centers near McDermott, Nevada, and as basalt dike emplacement along the N-NW-trending northern Nevada rift about 17 Ma (Pierce and Morgan, 1992; Zoback and others, 1994). During the inception of silicic volcanism (17-14 Ma), the rhyolite erupted from vents scattered over a broad region encompassing most of southwest Idaho south of the western plain and adjacent parts of Nevada and Oregon. By 11 Ma, silicic volcanic vents were centered mostly in the Bruneau-Jarbidge region (Bonnichsen and others, 1989) but were also distributed to the northwest along the future site of the western plain graben (Figure 6). The actual vent areas for many of the larger volume tuffs and flows have not been located, but many emanated from the Bruneau-Jarbidge region. Rhyolite vents are evident along the margins of the western plain. Jenks and others (1993) mapped a thick rhyolite breccia with unbrecciated dikes and sills, near Little and Big Jacks Creek, which they called the rhyolite of Horse Basin. They suggest it erupted from a buried NW-trending fissure near the edge of the plain. A faulted 1-km-diameter dome occurs south of Givens Hot Springs at the southwest edge of the plain and edge of the Owyhee Mountains (S.H. Wood, unpub. mapping). Clemens and Wood (1993) and Clemens (1993) have obtained K-Ar ages on near-source rhyolite lava flows of 11.8 to 11.0 Ma near and west of Boise on the north margin. It appears that eruptions of domes and small flows may have accompanied the beginning of the active phase of northwest-trending faulting, but that rhyolite volcanism had largely ceased by the time the basin began to form.

Most of the 12-10 Ma rhyolite accumulations on the margins of the western plain are without significant sedimentary interbeds (Wood and Gardner, 1984). The only known exception is from recent drilling in the subsurface beneath north Boise (City of Boise, Julia Davis Park well; Figure 5) where two rhyolite flows are separated by 130 m of coarse arkosic sand and batholith-derived gravel. The lowest flow is underlain by 60 m of similar coarse sediment at the bottom of the 0.98-km-deep well (P.N. Naylor, written commun. 1998). This sediment occurrence might be explained by local downfaulting associated with the eruptions adjacent to the batholith mountains. Perhaps this was the site of early basin initiation accompanying the rhyolite eruptions, but lack of a fine-grained lacustrine facies in the deep section precludes association with a deep basin. Likewise, the 2.3-km section of rhyolite in the Anschutz-Federal well on the south margin of the plain is without significant sedimentary interbeds (McIntyre, 1979). Elsewhere around the western plain, the lack of sediment in the nearly continuous pile of rhyolite eruptives suggests that during time of silicic volcanism the area was an upland. One would expect to find caldera basins; however, Ekren and others (1984) were impressed by the lack of conspicuous caldera features associated with silicic volcanism south of the plain in the region east of the Oregon border.

We believe it is significant that the deep wells in the center of the western plain, discussed above, have not drilled sections of rhyolite, despite abundant and thick rhyolite on the northeast and southwest margins. The lack of rhyolite beneath the plain is indeed surprising, and we can only conclude that the center of the present plain was formerly an upland of older basalt.

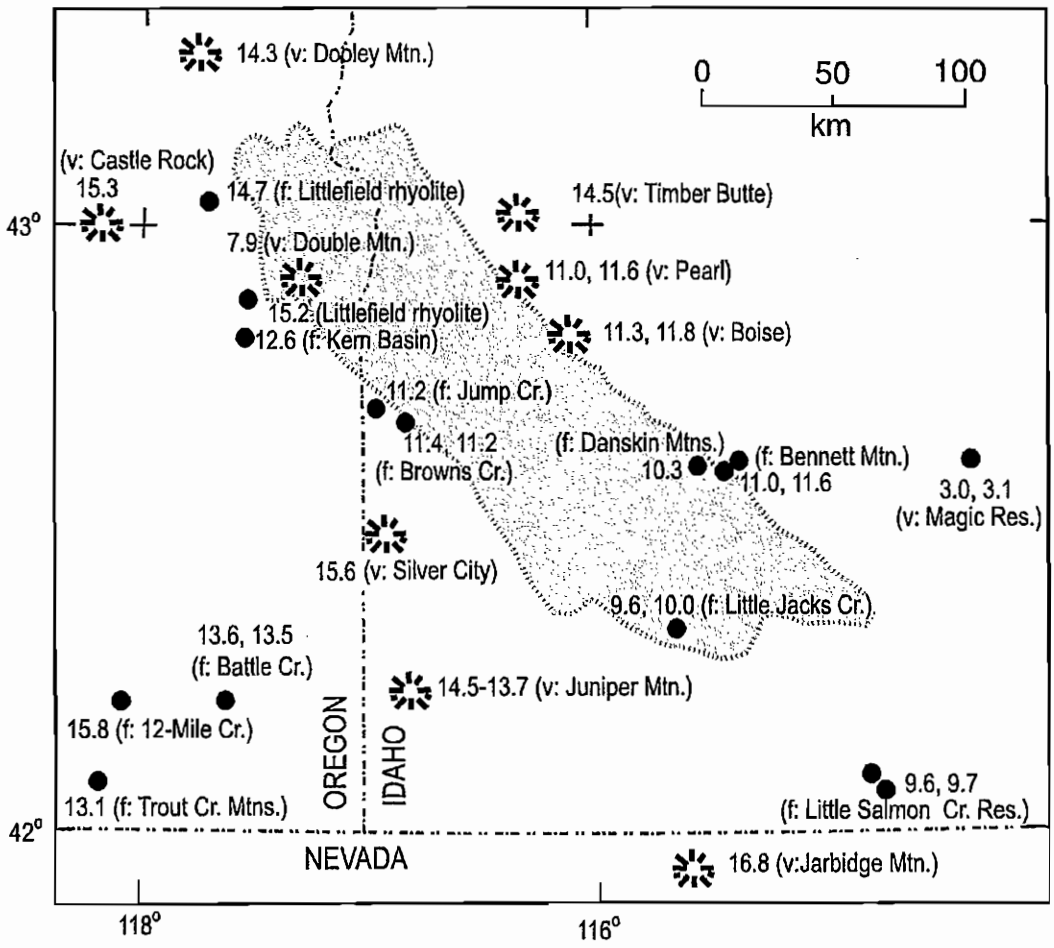


Figure 6. K-Ar ages (Ma) of rhyolite vents (v) and tuffs or lava flows (f) adjacent to the western Snake River Plain from Neill (1975) and Armstrong and others (1980) quoted in Ekren and others (1981, 1984), Clemens (1993), and Clemens and Wood (1991, 1993a, 1993b), Walker and others (1974), Dalrymple and others (1967), MacLeod and others (1975), Ferns and Cummings (1992), Rytuba and Vander Meulen (1991), and Ar-Ar ages from Lees (1992), and Manley and McIntosh (1999). All K-Ar ages calculated using 1976 constants except Trout Creek, 12 Mile Creek, Battle Creek, Salmon Creek, Jarbidge, and Silver City, which may be 0.1 to 0.4 Ma older than shown if recalculated.

East of Boise are two wells that drilled deep rhyolite near the margins of the plain (Anschutz-Federal and Griffith-Bostic). Rhyolite beneath sediment and basalt in the Griffith-Bostic well east of Mountain Home shows that the faulting has displaced rhyolite erupted 10.3 Ma to a depth of 2.0 km (Clemens and Wood, 1993). There the well bottomed in rhyolite at least 0.9 km thick, and the total rhyolite thickness is judged to be about 2.3 km (Wood, 1989). The Anschutz-Federal well (45 km southwest of Mountain Home) drilled through 2.2 km of rhyolite and bottomed in granite (McIntyre, 1979; Ekren and others, 1981). The center of the western plain southeast of Boise has not been explored by deep drilling, so we cannot be certain that rhyolite is absent from the subsurface there. The deepest well is 1.3 km deep at Mountain Home Air Force Base (elevation 3,022 feet, 921 m). This well drilled through 0.75 km of basalt beneath 0.55 km of lacustrine sediment (Lewis and Stone, 1988), a section similar to those in the center of the western plain shown in Figure 5.

Pierce and Morgan (1991) emphasized the broad uplift of 0.5-2.0 km that occurs as the hot spot migrates, and it is shown most graphically by their Plate 1 of topography. Others have suggested that simple vertical expansion due to heating the crustal lithosphere can account for uplift of that order, followed by cooling subsidence

after passage of the hot spot (Brott and Blackwell, 1978). Blackwell (1989) estimates the thermal effect to be 200-250 km wide. This estimate can be projected back in time to the western plain region to suggest that the area was on the north edge of a volcanic highland at 14-11 Ma and not a basin. Before eruption of rhyolite in the western plain area, the geologic evidence discussed earlier shows only north-trending basins laying generally west of the batholith that accumulated basalt. Mapping the rhyolite flow directions in the future should help to reconstruct the topographic picture and confirm or refute the presence and nature of the uplift as the hot spot passed by the position of the western plain.

HISTORY OF GRABEN FAULTING IN THE WESTERN PLAIN

The geochronology of the major graben that forms the western plain has been determined at two localities by correlating dated surface volcanic units to their subsurface equivalents (Figure 7). The offset of volcanic units at the south side of the Bennett Mountains show that most of the 2.8 km offset occurred between 11 and 9.5 Ma. Offset units on the north side of the Owyhee Mountains indicate the 2.2 km of offset was largely completed by 9 Ma, but the date for the onset of vertical movement is not well constrained.

A history of faulting in eastern Idaho along northwest-trending basin and range structures associated with hot-spot migration can be compared with that for the western plain. Anders and others (1989) determined that the rapid rate of faulting south of the eastern plain was constrained in time between 2 and 3 Ma, with vertical slip rates of about 1 mm/year (Figure 7). For the western plain, we derive somewhat smaller slip rates of 0.5 mm/year for the two boundary faults on either side of the plain. Basin relief formed by hot-spot-triggered normal faulting seems to evolve over just a few million years, and then vertical slip rates become very slow (less than 0.01 mm/year). From these fault histories, we argue that most of the western-SRP basin relief was formed in a rather short geologic time between 11.0 and 9.5 Ma. This is not to imply that these normal fault systems become totally inactive after the main period of displacement, but only to note that the average long-term slip rates become very low following the main episode of activity.

The only segment of western-SRP faults shown to have late Quaternary activity is the Owyhee Mountain front 55 km southwest of Mountain Home in the Halfway Gulch-Little Jacks Creek area (Beukelman, 1997). The Halfway Gulch fault trends N. 60° W. to N. 75° W.

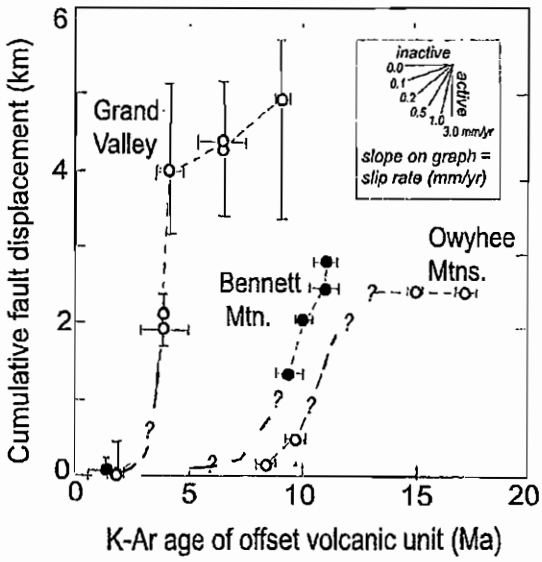


Figure 7. Displacement histories of normal faults bounding the western plain graben (Bennett Mountain is north of and includes the Griffith-Bostic well shown as GB in Figure 2; Owyhee Mountains-Anschutz well is shown as A in Figure 2; modified after Clemens, 1993) and of the Grand Valley fault oriented perpendicular to the eastern plain. Location of Grand Valley fault shown in Figure 1 (after Anders and others, 1989). Illustration shows that basin relief from normal faulting evolves rapidly over a very few million years and that vertical slip rates sharply wane afterwards.

A mappable, late Quaternary scarp occurs along the mountain front for a very short length of only 5.3 km, with a maximum scarp height of 7.7 m. The total length of the system of mappable young faults is less than 12 km, which is unusually short for such large vertical displacement. Scarp-degradation age estimates are about 20,000 years. An associated fault (Water-Tank fault), 7.6 km northeast of the mountain front, strikes N. 35-50° W. and has a 3.6-m Quaternary scarp. A trench-stratigraphic study on the Water-Tank fault shows five episodes of surface rupture within an estimated 26,000 years and estimated average vertical slip rates within these time periods of 0.08 to 0.2 mm/year (Beukelman, 1997). These Quaternary vertical slip rates greatly exceed the long-term slip rates shown in Figure 7 for the Owyhee Mountain front just 20 km to the northwest. This difference in slip rates suggests that episodic reactivation may occur on suitably oriented faults (Beukelman, 1997).

THE EARLIEST SEDIMENT IN THE WESTERN PLAIN: BANBURY BASALT AND THE CHALK HILLS FORMATION

Throughout the western plain margins, a section of basalt flows and pyroclastic layers interbedded with tuffaceous mudstone commonly rests unconformably upon the granite of the Idaho batholith, the late Miocene rhyolite, or the basalt of the Miocene Columbia River Group. At the south margin of the Weiser embayment near Emmett, coarse sand and tuffaceous sediment rest unconformably on Weiser basalt of the Columbia River Basalt Group. Near the plain margins, the lower basaltic material may be interbedded with gravels and sands derived from the batholith. Some of these basaltic rocks have been called the Banbury Basalt. The formation name has been incorrectly applied to any basalt within the sedimentary sequence of the plain. It is unlikely that the Banbury Basalt is a continuous unit or that basalts of identical age occur along the margins and beneath the plain. Basalt eruptive centers probably occurred sporadically in many places and spanned a considerable time after rhyolite volcanism ceased. Bonnichsen and others (1997, p. 401) make a crucial observation that the period of western-plain basalt volcanism following the rhyolite is confined to about 2 million years from 9 to 7 Ma, although we believe that the inception of basalt volcanism extends back to about 10 Ma for reasons indicated in the following discussion.

In some places, sediments may dominate in the basal section, and geologists might call the section the Chalk Hills Formation or the Banbury Basalt with interbedded sediment. We recommend that the term Banbury Basalt be restricted to the basalt field in the vicinity of Banbury Hot Springs, and not be extended to other basalt fields intercalated with sediment of the Chalk Hills Formation. We further recommend that each contiguous basalt field be given a separate name, and each be considered as a member of the Chalk Hills Formation.

In its type area, the Banbury Basalt is about 330 m thick (Malde and Powers, 1961). Armstrong and others (1980) reviewed the age of this basalt section, where it overlies Idavada rhyolite dated 10.1 and 11.0 Ma and encloses a silicic ash K-Ar dated at 10.2 Ma (sample KA 830, whole-rock on coarse ash; Evernden, 1964). Armstrong and others (1980) report two whole-rock K-Ar age determinations of 13.8 ± 1.5 and 8.1 ± 0.7 Ma. These disparate ages were then averaged and reported as 9.4 ± 0.6 Ma, although the validity of averaging such ages is questionable. Ekren and others (1981) report that all the flows they measured had normal magnetic polarity, which suggests the Banbury Basalt erupted during the normal interval between 10.1 and 8.8 Ma.

In the Boise area, a basalt tuff-dominated unit resting on rhyolite or granite is about 200 m thick in drill holes beneath the city, and thinner discontinuous patches occur in the foothills upon the batholith on both the north and south sides of the plain. Clemens (1996) has reported on an undated 4-m-thick rhyolite ash in the lower part of this unit in the Boise foothills.

In the Boise area, the beginning of fluvial-lacustrine sedimentation is dated at before 9.5 Ma by the basalt of Aldape Park intercalated with sediment that crops out in the foothills, and is correlated to the subsurface in geothermal wells. This basalt yields a modified whole-rock K-Ar age of 9.5 ± 0.6 Ma and has a normal magnetic polarity (Clemens and Wood, 1993). A whole-rock K-Ar age of a basalt might be open to question, but the age is within the normal polarity episode from 8.8 to 10.1 Ma, and the other normal episodes are either younger than 8.2 Ma or older than 11.3 Ma, leading us to believe it is a valid age. This basalt layer overlies 150 m of fluvial-lacustrine sediment beneath which is about 200 m of basalt, tuff, and sediment resting upon rhyolite or granitic rocks. Therefore, 150 m of basin sediment was deposited in the Boise area before 9.5 Ma but after emplacement of an earlier basal basalt. We do not have reliable radiometric dates or magnetic polarity on the basalt tuff unit, but it lies on rhyolite dated 11.3 and 11.8 Ma (Clemens and Wood, 1993). We conclude that the 150 m section of sediment beneath the dated basalt marks the beginning of the basin in the western plain between 11.3 and 9.5 Ma.

Sediment that rests on the older basalts, rhyolite, or the Idaho batholith is usually mapped as the Chalk Hills Formation or in some localities as the arkosic sands of the Poison Creek Formation. These formation distinctions are poorly defined and not useful because the arkosic sands are just a fluvial facies that may have a lacustrine equivalent. These sediments are the first clear evidence of the basin in the western plain. Systematic mapping and study of these rocks are yet to be done, but we will review here our present knowledge of the Chalk Hills Formation. The bottommost sediments are usually coarse sand and pebble gravel derived mostly from the Idaho batholith and older volcanics. These sands are interbedded with mudstones which become more prevalent upwards in the section. Within the first 100 m, the section grades upward into tuffaceous muds and clays and many volcanic ash beds, predominantly gray silicic ash and lapilli, but with some basaltic ash beds. Some ash and lapilli beds exceed 20 m in thickness. Pillow basalts occur within these sediments south of Walters Ferry and over an area called the Teapot volcanic complex by Bonnichsen and others (1997) and mapped by Ekren and others(1981) as

basalt of the Murphy area.

We have mapped and measured a 100-m section just south of Walters Ferry in the vicinity of Chalky (sec. 35, T. 2 S., R. 3 W.) and show the complexity of the basal sediments and volcanics of the Chalk Hills Formation in Figure 8. The rhyolite of Browns Creek (11.1 Ma) is overlain by reddish pahoehoe basalt erupted subaerially. The basalt is then overlain by noncalcareous silts with channel arkosic sands in a 50-m sequence that fines upward. Upon this sequence is 30 m of cliff-forming gray silicic ash, mostly silt size, that fines upward. Over the ash are basalt lapilli layers and palagonite tuff. The top of the section here is a 15-m-thick complex of pillow basalt and dikes, called the "Teapot volcanic complex" with a $^{40}Ar/^{39}Ar$ age of 7.95 ± 0.2 Ma (Craig White, written commun., 1997; Bonnichsen and others, 1997). The section beneath the pillow basalt is faulted down to the northeast about 20 m by a northwest-trending normal fault that does not appear to cut the pillow basalt unit.

Swirydczuk and others (1982), Kimmel (1982), and Middleton and others (1985) describe sections of the Chalk Hills Formation on the south margin of the plain. None are measured with respect to the base of the formation. Most are within 50 m of the top of the formation as defined by an oolitic sand and a slight angular unconformity. Kimmel (1982) had some success in tracing ash layers in the formation and obtained nine fission-track ages on glass from the ash layers. Ages ranged from 6.1 to 9.1 Ma with standard deviations of 0.5 to 1.2 Ma. Some question exists regarding the reliability of glass fission track ages, but they are within the range of two whole-rock K-Ar ages on basalt in the lower part of the unit reported by Armstrong (1975) at 8.2 ± 0.7 and 8.6 ± 0.5 Ma.

Perkins and others (1998) examined Kimmel's (1979) stratigraphic section no. 14 (SE ¼, sec. 19, T. 7 S., R. 4 E.). From trace and major element chemistry, they were able to correlate the ash layers within this Chalk Hills Formation section to regional volcanic ash falls. Ages of these ashes range from 7.49 to 6.4 Ma. The 6.4-Ma ash correlates to the Walcott Tuff on which several whole-rock K-Ar ages, ranging between 6.3 ± 0.3 and 6.5 ± 0.1 Ma, are reported by Morgan (1992). The age of this ash is important because it establishes the youngest known age for Chalk Hills Formation deposition before the formation was partly eroded during a regression of the lake system.

Kimmel's (1979) section no. 14 was examined in this study. The sediments rest upon the subaerial flow basalt of Al Sadie Ranch that rests upon the rhyolite of Horse Basin mapped by Jenks and others (1993). The lower 25 m of sediment is a nonlacustrine sequence of fluvial deposits and paleosols overlain by basalt tuff. The top of the basalt tuff is reworked in part and shows hummocky cross-stratification of shoreline storm waves. The cross-stratified tuff is overlain by 50 m of lacustrine deposits containing the volcanic ashes and fish fossils. From this reexamination and from Perkins and other's (1998) ash chronology, we conclude that the Chalk Hills Formation lake transgressed over this area at some time before 7.49 Ma and that basalt eruptives preceded the lake transgres-

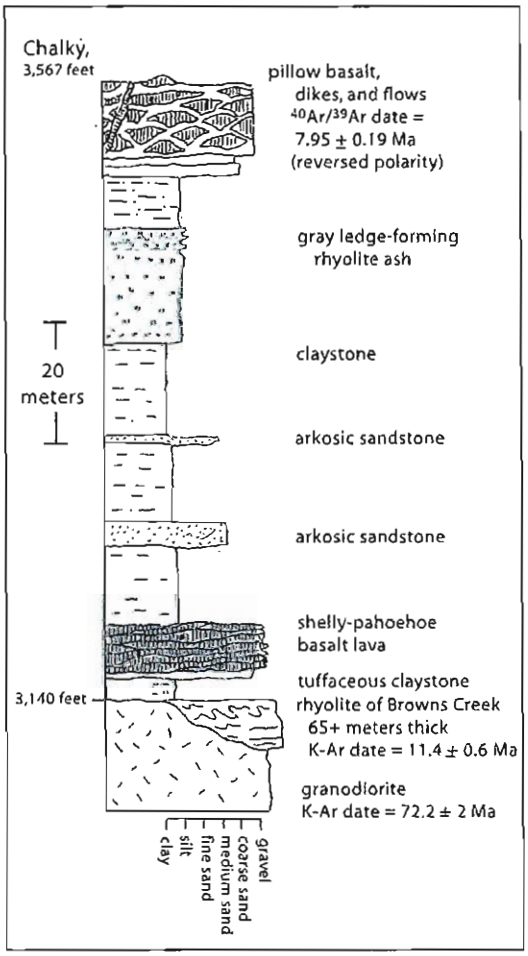


Figure 8. Columnar section of the Chalk Hills Formation at "Chalky" on the south side of the western plain near Walters Ferry (sec. 35, T. 2 S., R. 3 W.). This section was called a reference section (PC-2) for the Poison Creek Formation by Ekren and others (1981), but we regard the Poison Creek as a facies of the Chalk Hills Formation (see text). Section contains two sequences of basalt separated by claystone and a thick rhyolite ash bed. $^{40}Ar/^{39}Ar$ age of 7.95 Ma on the upper basalt is from Craig White (written commun., 1997), and the K-Ar dates on rhyolite and granite are referenced in Ekren and others (1981, 1984). Recalculated age on the Reynolds Creek flow of the Browns Creek rhyolite from Bill Bonnichsen (written commun., 2000).

sion at this locality. The lake then regressed from this site at some time after 6.5 Ma.

The Chalk Hills Formation is relatively thin, about 100 m, along the margins of the plain. It is much thicker beneath the plain (Figure 5). In the type area at the head of Little Valley, Malde and Powers (1962) report the Chalk Hills Formation to be about 90 m thick where it overlies the Banbury Basalt. Ekren and others (1981) report a thickness over 100 m. Sheppard (1991) describes a 100-m-thick section near Oreana that rests on the rhyolite of Little Jacks Creek. The rhyolite of Little Jacks Creek is K-Ar dated at 9.6 ± 1.5 and 10.0 ± 2.0 Ma by Neill (1975; ages recalculated by Bill Bonnichsen (written commun., 2000). The Oreana section contains a 13-m-thick marker gray rhyolite ash, about 35 m above the base, and at least twenty other ash layers interbedded with fine sediment. Sheppard (1991) noted several thin (less than 25 cm) basalt ash layers in the upper part of the formation. The occurrence of one thick (more than 10 m) gray ash within the Chalk Hills Formation and of basaltic ash near the top appears to correlate with our 100-m section (Figure 8) at Chalky near Walters Ferry, about 38 km to the northwest. Thick ash could have erupted from sources to the east; however, at a locality 10 km south of Marsing (SE¼ sec. 32, T. 2 N., R. 4 W.) is a 100-m section that contains a 1.5-m layer of rhyolite pumice blocks up to a meter in diameter, 80 m above the base. The layer can only be from a local eruption of a rhyolite dome beneath the lake water (Wood and Wood, 1999), and it shows that at least one rhyolite system continued to erupt near the southeast margin of the western plain during deposition of the formation.

Sheppard (1991) discusses the chemistry of the "Chalk Hills lake," drawing information from an examination of ostracodes by R.M. Forester. The ostracode fauna indicate that at one time the lake-water salinity was greater than 300 mg/l and less than 3,000 mg /l and had a pH about 8 to 9. The water chemistry, though somewhat alkaline, is consistent with lake water supporting the freshwater fish fauna described by Smith and others (1982), not unlike many of the fish-populated Great Basin lakes of today.

Smith and Patterson (1994) show that the water of the "Chalk Hills lake" produced carbonates that are extremely depleted in the heavy oxygen isotope (^{18}O). This suggested to them that the lake was maintained by tributaries of high elevation watersheds and that the waters were little affected by evaporation. They also report that the lake had an unusual mix of fish fauna. Cold-water fish (Salmon and trout species) occur with warm-water species of catfish and sunfish. The lake contained no sculpins or whitefish (cold-water species). It has not yet been resolved if any of the fish were anadromous (Gerald Smith, oral commun., 1995).

Much of the Chalk Hills Formation sediment is noncalcareous mudstone. We are unaware of any significant carbonate facies in the formation. Kimmel (1979) does not describe any calcareous sediment in the many stratigraphic sections he measured. Gypsum partings and veins occur locally near the base of Chalk Hills Formation mudstones. Within thick siltstone layers is a 0.3-m gypsum layer in sec. 23, T. 21 S., R. 46 E., Malheur County, Oregon (Kimmel, 1979, p. 262) and gypsum is associated with volcanic ash layers in Owyhee County, Idaho (sec. 19, T. 7 S., R. 4 E.; Kimmel, 1982). We have noted selenite and satin spar as veins and partings in laminated bentonitic mudstone at the base of the formation north of Marsing (sec. 4 and 5, T. 1 N., R. 4 W.). Kimmel (1979) interpreted these as "displacement gypsum" probably formed by shallow ground-water precipitation in the lake muds. Veins and partings of gypsum in mudrocks suggest that shallow ground water was enriched in sulfate and calcium, and this probably occurred beneath local areas of restricted lake waters that underwent seasonal evaporation. However, we wish to emphasize that the gypsum occurs early in the history of deposition and not in the bulk of the later Chalk Hills Formation.

Kimmel (1982) puzzled (as we have also) over the fall in lake level at the end of Chalk Hills Formation deposition and the subsequent rise in lake level and deposition of the transgressive unit and the Glenns Ferry Formation. He gave several alternate hypotheses for the major lake fluctuation, which we believe reached its lowest elevation at some time after 6.4 Ma. One of these hypotheses involves both tectonic movement and downcutting of the outlet to produce a low lake level, and then basalt volcanism blocking the outlet. Tectonic movement was significant based upon the faulted and slightly tilted nature of most of Chalk Hills Formation and our analysis of rates of faulting (Figure 7). Therefore, it is possible that the basin and its outlet were tectonically lowered. There is no evidence in the sediments of major evaporation in the upper part of the formation to suggest climate change or reduced inflow; however, the stratigraphy of the formation is in need of review to understand the lowering of the lake level. We know nothing of the location of the outlet, but basalt volcanism blocking an outlet in the western plain region is an unlikely cause of the subsequent rise in lake level because Bonnichsen and others (1997) do not find significant basalt volcanism in the western region for the interval between 7 and 2.2 Ma. Rhyolite volcanism, however, was active in what is now the eastern plain region, and that volcanism combined with uplift of the hot-spot region could account for blocking an eastern outlet, if it existed there.

We visualize an environment of a large basin with sporadic basalt volcanism and high rates of basin-relief formation by faulting. At many localities around the plain, basalt volcanic rocks underlie the basal fluvial or lacustrine sediments and are also intercalated with the sediments. From Kimmel's (1982) work, the interconnected Chalk Hills lakes apparently extended from the Bruneau area to the Oregon border, a distance of at least 110 km. From Smith and others' (1982) and Sheppard's (1991) work, the lakes were at times slightly alkaline, but they supported a fresh-water fish fauna. This suggests a system of river interconnections through the evolving topography in the basin, but perhaps not as great a flow-through as the present Snake River discharge. From the above discussion of stratigraphy in the Boise area, the "Chalk Hills lake system" is younger than 10.1 Ma and includes basalt dated 9.4 Ma in the Boise foothills and a pillow basalt complex on the south side of the plain dated at 7.95 ± 0.19 Ma. For the youngest date on the Chalk Hills, we go to the south side of the plain and use Kimmel's (1982) glass fission-track ages between 6.1 and 9.1 Ma, but accepting the uncertainty of these ages. Identification of the Walcott tuff (6.4 Ma) by Perkins and others (1998) in the upper part of the formation establishes a maximum age for the drop in lake level at the end of "Chalk Hills Time." The top of the formation has been removed by erosion marked by a slight unconformity at most localities. Future research should focus on finding a complete upper section in order to better understand events leading to the drop in lake level and the resulting unconformity.

DROP IN LAKE LEVEL AT THE END OF "CHALK HILLS TIME"

A key problem is defining the top of the Chalk Hills Formation. Swirydczuk and others (1979, 1980) show convincingly that a lacustrine shoreline sequence transgresses over beveled, gently tilted strata of the Chalk Hills Formation in the Oreana area. Kimmel (1982) concluded that the Chalk Hills lake lowered or completely drained at the end of the Miocene, and then filled again. Smith and others (1982) suggest that about 1 million years of geologic record is missing in the hiatus between the beveled lake deposits of the Chalk Hills Formation and the transgressive shoreline deposits, and that the missing time is somewhere in the 6 to 4 Ma interval. In some places, the contact is an unconformity with underlying Chalk Hills Formation dipping 4 to 12 degrees basinward, overlain by lake beds dipping less than 4 degrees. At these localities, the upper part of the Chalk Hills Formation has been eroded away. If lakes persisted in the deeper parts of the basin, sediment preserved in the subsurface may contain a more complete sedimentary record. Figure 5 shows the seismically imaged deep sediment that is thought to be the upper part of the Chalk Hills sedimentary record. Because part of the Chalk Hills Formation has been eroded from the margins and we have not, as yet, identified this unconformity in the subsurface, the decline in lake level at the time of the upper Chalk Hills is poorly understood. Apparently, the duration of a lake system could be from 10.1 to about 6 Ma as illustrated in Figure 9.

The transgressive sequence marked by the lowest occurrence of oolitic shoreline sand has been used as the definition of the base of the Glenns Ferry Formation (Malde and Powers, 1962). In the Boise foothills area (Figure 10), lenses of oolitic sand occur over a 120-m-vertical section within the upper part of a shoreline facies that W.L. Burnham and S.H. Wood (written commun., 1992) have named the Terteling Springs Formation. We regard most of the Terteling Springs Formation as a transgressive unit. We have not been able to find a clear indicator in the Boise area of the top of the Chalk Hills Formation. We have found a record of lake-level rise but have not found a record of lake-level drop similar to the unconformity on the south side of the plain.

Possibly, the subsurface alluvial fan deposits of southwest Boise, delineated by Squires and others (1992) and shown in Figure 11, are a record of lake-level fall in Chalk Hills Formation time because the base of the fan rests upon clayey sediments at a subsurface elevation of 2,000 to 2,400 feet (610 to 730 m). The subsurface fan is overlain by lake deposits at about elevation 2,700 feet (820 m). Ed Squires (written commun., 1990) has mapped an outcrop of oolitic sands in the Mayfield area to the east at elevation 3,600 feet overlying the fan deposits. From these relationships, he concludes a lake transgressed over the alluvial fan deposits. If so, then the subsurface alluvial fan deposits are much older than we have previously thought and are contemporaneous with the upper Chalk Hills Formation.

THE TRANSGRESSIVE LACUSTRINE SEQUENCE

A history of the major water-level fluctuations of Lake Idaho is hypothesized in Figure 9. Some event caused the lake level to rise and transgress over the Chalk Hills Formation. The upper part of this transgressive sequence contains oolite lenses marking shoreline regions. Repenning and others (1994, p. 72) thoroughly reviewed

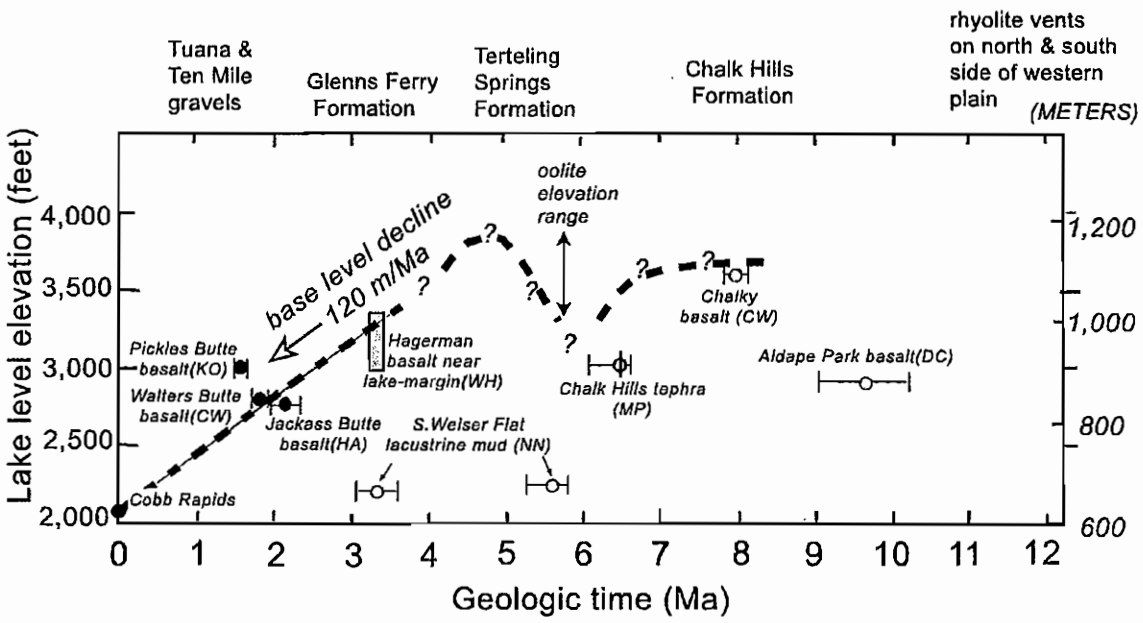


Figure 9. Plot of elevation of lake deposits versus time. This plot does not take into account tectonic deformation that may have altered the elevation of lake deposits. Most localities are on the margin of the plain, which has not been so much affected by tectonic movement or compaction subsidence (Wood, 1994). Points on the graph are dates on lacustrine sediment, or basalt associated with or overlying the lacustrine section: K-Ar dates on basalt are from DC (Clemens and Wood, 1993) and HA (Amini and others, 1984); zircon fission track ages on silicic ash are from NN (Nancy Naeser, published in Thompson, 1991); $^{40}Ar/^{39}Ar$ ages on basalt are from CW (Craig White, written commun., 1997), KO (Othberg and others, 1995), and WH (Hart and others, 1999); and tephrochronology is from MP (Perkins and others, 1998).

previous work on the Glenns Ferry Formation. They proposed that the locally oolitic, rusty-stained sandstone, taken by Malde and Powers (1962) as the base of the Glenns Ferry Formation, be given separate formational recognition. Our mapping on the north side of the plain supports that proposal, for we see at least 120 m of an oolite lens-bearing section up to elevation 3,800 feet (1,160 m). The stratigraphic diagram (Figure 12) shows this relationship in the Boise foothills with oolite lenses up to 3,200 feet (975 m). The lower elevation (3,200 feet) shown in the section is because of the southwest dip of the strata. In principle, this transgressive sequence should have an equivalent open lake facies that may be quite thick. We believe the mudstone facies of the Terteling Springs Formation to be that open lake facies. Consequently, the basinward equivalents of oolite facies on the south side of the plain need to be reexamined because there should be a substantial correlative section of mudstone. Only the 30 m beneath the oolite is described in the literature on this section (Swirydczuk and others, 1980a, 1980b, 1982).

An important implication of a transgressive or rising lake-level sequence is that sand and coarse clastics will be deposited near the shoreline and that deltas will not prograde significantly into the lake basin. Therefore, much of the incoming sand is stored as nearshore sediment, and not deposited in the open lake where only muds are deposited. The rising lake level also suggests that the lake does not have a spillway. A closed basin might have been forming. A steadily filling closed basin perhaps explains the oolites in the upper part of the section. The lake was becoming increasingly alkaline from evaporation as it rose to higher levels, thus favoring precipitation of calcium carbonate. Swirydczuk and others (1980b) compare the lake chemistry at the time of oolite deposition with that of Pyramid Lake, Nevada (pH of 9, and 4,700 mg/l total dissolved solids, but supporting a healthy trout population). Finally, the lake overtopped a spill point and began to slowly drain. As soon as drainage was established, the lake would have become less alkaline.

THE LAKE-LEVEL FLUCTUATION AT 6-4 MA AND A PLAUSIBLE EXPLANATION

The history of lake levels shown in Figure 9 ignores the effects of differential tectonic movement, which with

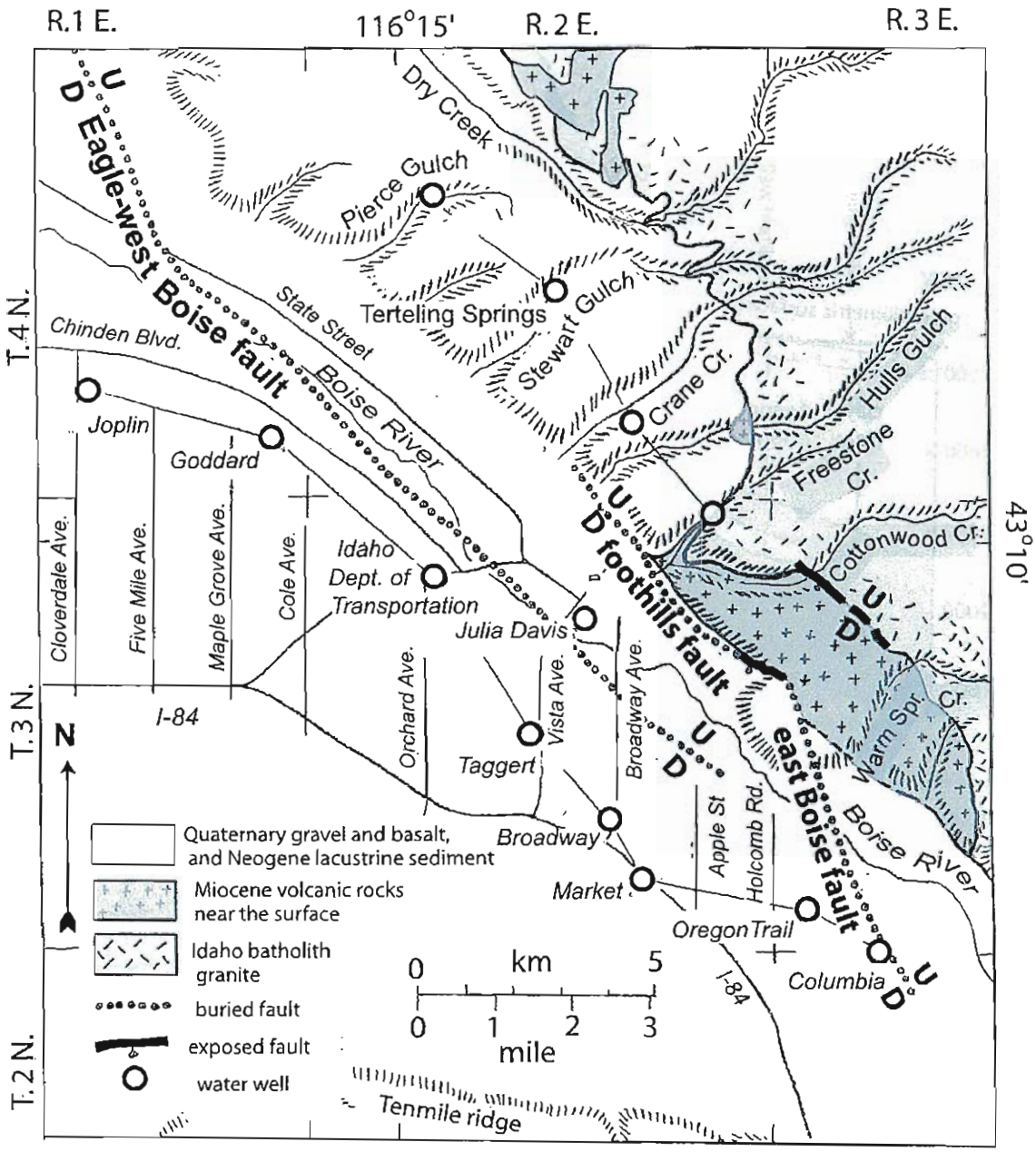


Figure 10. Geologic map of the Boise area showing locations of stratigraphic cross sections of Figure 11 and Figure 12.

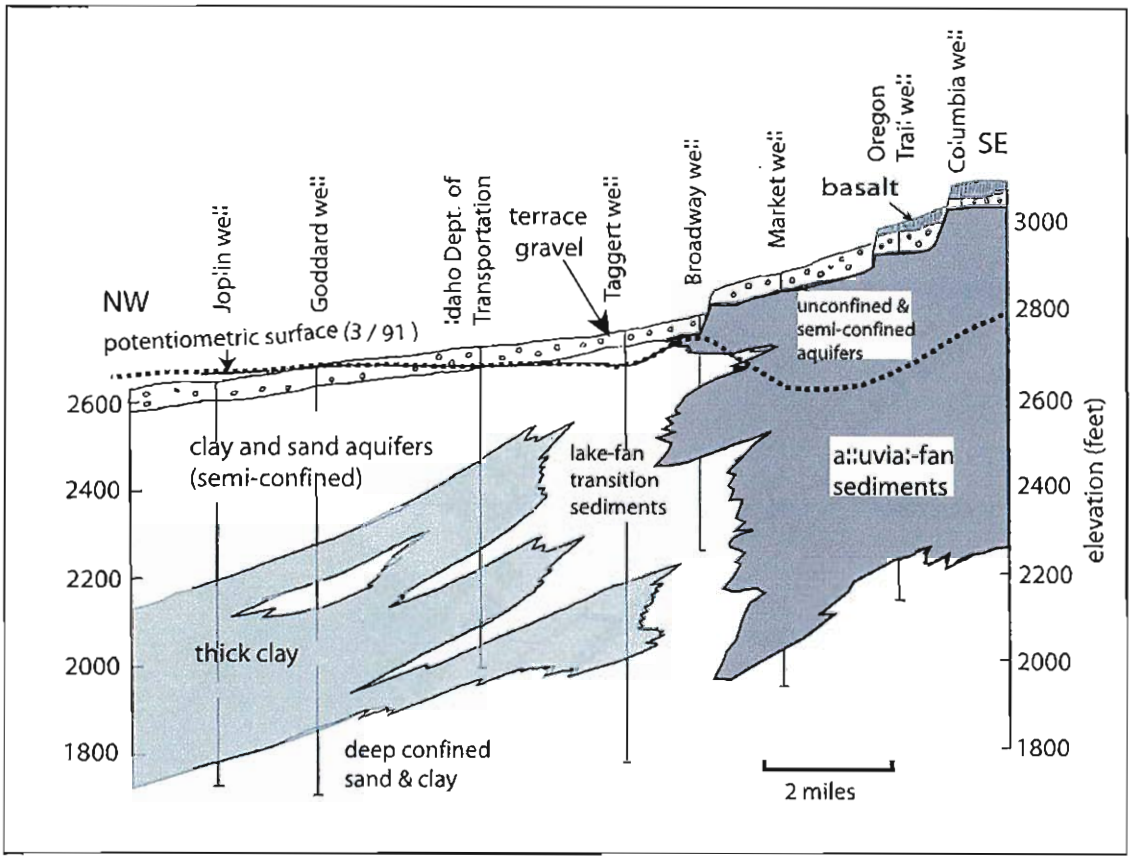


Figure 11. Cross section showing stratigraphy of alluvial fan and lake sediment aquifers beneath Boise (from Squires and others, 1992).

the present knowledge is difficult to unravel from other causes of lake-level fluctuation. We list the possible causes of secular lake-level fluctuations (Table 1) but will pursue only our favored mechanism to keep the discussion short. At the outset, we must state that our study of the Chalk Hills Formation is very limited. The accumulation of the formation is likely a result of continued tectonic foundering of the basin area. The subsequent fall in lake level, about 6 to 7 Ma, is poorly documented and without a satisfactory explanation. The rapid tectonic foundering of the basin, the change to a more arid climate, or the establishment of a lower outlet are all favored possible explanations.

The lake-level rise, marked by the transgressive sequence (oolite section and the upper Terteling Springs Formation), is well documented (Swirydczuk and others, 1980a, 1980b). We propose that the major lake-level fluctuation at about 6 Ma was caused by new stream inflows associated with the migrating Yellowstone hot-spot

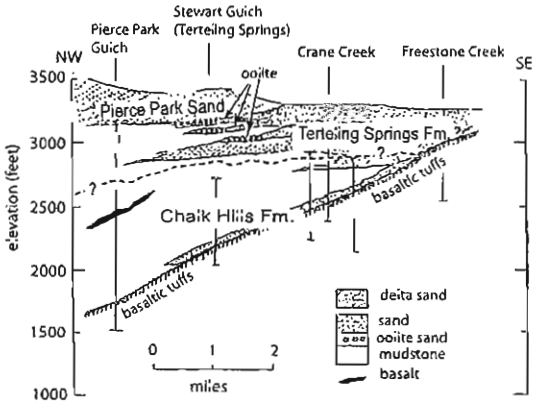


Figure 12. Stratigraphic cross section showing lake margin facies in the Boise foothills and the distribution of oolitic sands. Location of section shown in Figure 10.

Table 1. Causes of lake-level fluctuations.

RISE IN LAKE LEVEL
Increased inflow
Increased runoff
Increased precipitation
Decreased evapotranspiration in catchment
Diversion of major stream into basin by capture or damming
Decreased evaporation from lake surface
Decrease in surface area
A climate change, colder or more humid
Filling of lake basin by sediment
Rise in elevation of the outlet
Landslide, glacier-ice, or lava-flow damming
Relative tectonic warping or faulting of outlet area
DECLINE IN LAKE LEVEL
Decreased inflow
Decreased runoff
Precipitation decrease
Increase in evapotranspiration in catchment region
Diversion of a major tributary stream from basin by capture or damming
Increase in evaporation from lake surface
Warmer or dryer climate
Increase in lake surfacearea
Sediment compaction
Fall in the level of the outlet
Progressive downcutting of outlet
Breaching of a landslide, glacier-ice, or lava-flow dam
Spillover and establishment of a new and lower outlet
Tectonic lowering of outlet by warping or faulting

uplift. An uplifted region about 400 km across with a maximum uplift of 0.5 to 1 km is currently centered on the locus of rhyolite volcanism at Yellowstone (Pierce and Morgan, 1992). The hot-spot model implies a broad northeast-migrating continental uplift region. A migrating uplift also implies an eastward-migrating drainage divide (Figure 13).

Anderson (1947) proposed that the Continental Divide had shifted eastward about 160 km in late Tertiary time. He was intrigued by the peculiar shift in directions of the Salmon River and drainages north of the eastern plain. We realize now that the hot-spot uplift provides a mechanism for his observations. Taylor and Bright (1987) also suspected that the migrating uplift was responsible for drainage changes in the region. Cox (1989) suggested this has been a characteristic of continental hot spots. The Continental Divide may have shifted about 200 km from a position near Arco, where it was associated with the Heise Volcanic field about 6 Ma, to its present position in Yellowstone National Park.

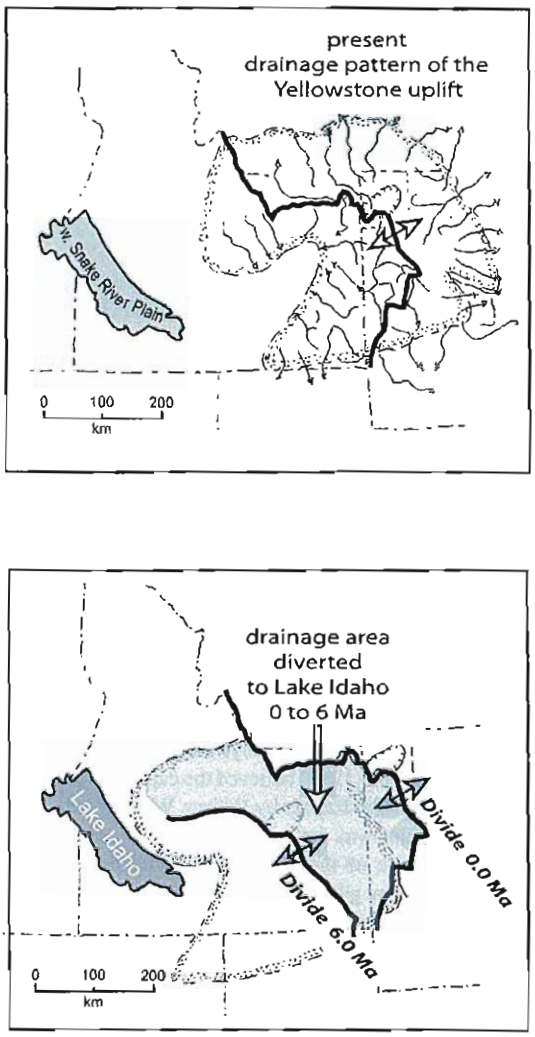


Figure 13. Map showing the area that may have diverted drainage to Lake Idaho, 6 to 0 Ma, on account of eastward-migrating uplift associated with the Yellowstone hot spot.

The idea of a shifting drainage divide could explain a part of the history of lakes in the western plain. About 6 Ma, the lake that was depositing the Chalk Hills Formation declined to a low level. The shifting drainage divide does not offer a simple explanation for the decline to a low level; however, some earlier spillover into another lower elevation basin, a climate change decreasing inflow and increasing evaporation, or an increase in the rate of subsidence could account for the lake-level lowering. Then, about 4.5 Ma the lake began to rise, transgressing over the older Chalk Hills lacustrine deposits. We propose here that the eastward-migrating uplift with

a west slope captured major rivers or allowed major drainage diversions into the western plain basin (Figure 13). We suggest that drainages that had formerly flowed east to the Missouri or Colorado drainages, or into Basin and Range dead ends, now flowed down the west slope of the uplift into Lake Idaho. Such major diversions could have increased the inflow into Lake Idaho causing it to rise to its spill point about 4.0 Ma.

THE SPILLOVER OF LAKE IDAHO INTO HELL'S CANYON AND THE DEPOSITION OF THE GLENNS FERRY FORMATION

Wheeler and Cook (1954) published a key concept in deciphering the history of Lake Idaho. They propose that headward erosion to the south by a tributary to the Salmon-Columbia river system captured the waters of Lake Idaho in the late Cenozoic. Although we differ in the details, the spillover into ancestral Hell's Canyon seems certain. They believed spillover and capture occurred at the Oxbow because of the peculiar bends of the Snake River. The Oxbow and its trend are more satisfactorily explained by diversion of the downcutting river by the resistant northeast-trending mylonite zone in the pre-Tertiary rocks. Wood (1994) believed the capture occurred near the present Cobb Rapids by Weiser. We now believe the spillover point was a divide about 5 km above the present confluence of the Burnt River with the Snake River through a low gap between the present Slaughterhouse Range and Dead Indian Ridge (Figure 14). Our observations are mostly from topographic maps: the area has not been systematically mapped and searched for remnant patches of lake sediment and gravel to test these ideas. We hypothesize a former low divide at about 3,600 feet (1,100 m) in elevation at the headwaters of a steep-gradient, north-draining tributary. The lake, which lay to the south, rose and overtopped this divide. A similar divide exists today at Henley Basin (Figure 14), 8 km to the northeast, a gap similar to that which must have existed at the spillover. This gap is the 3,200-foot (980-m) elevation divide between the north-flowing Rock Creek and the south-flowing Hog Creek. It is a gap through which rising lake water also could have flowed over into ancestral Hell's Canyon, had it not already done so in the gap to the southwest, presumed to have been slightly lower at the time of spillover. That this gap is presently 3,200 feet (989 m) is not really a problem, since in the past several million years, it could have been lowered by erosion 400 feet (120 m; this assumes a reasonable denudation rate of the divide area of 200 feet/Ma or 6 cm/Ka). Note also on Figure 15, that the river gradient steepens in the 20-mile (32-km) reach from the mouth of Rock Creek to Cobb Rapids, suggesting that the smoothed remnant of the former knickpoint created by the spillover has migrated about 10 miles (16 km) above the spillover point.

We hypothesize that most streams on the south side of the Blue Mountains formerly flowed to the south-southeast into the lake. The Burnt River and many nearby creeks have this direction; however, the Burnt River turns sharply northeast in its lowest 4-km reach below Huntington, where we believe it was captured and diverted from its southerly course by the downcutting Snake River.

Repenning and others (1994, p. 71-72) and Van Tassell and others (2001) suggest that the spillover occurred in the early Pliocene, rather than with the onset of the ice ages of the late Pliocene as previously suggested by Othberg (1988) and Wood (1994). Repenning and others (1994) propose that much of the Glenns Ferry Formation deposition occurred after the lake had found the Hell's Canyon outlet, which they believe happened between 3 and 4 million years ago. Othberg (1994) also suggests that the basin may have filled earlier than late Pliocene. He further suggests that the lake drained slowly while flood-plain aggradation continued in the basin. He does associate the beginning of widespread gravel deposition over the plain with a change in stream regimen caused by late Pliocene climates. From his study of gravel terraces and deposits of the Boise Valley, he indicates that basin aggradation gave way to valley cutting in the early Pleistocene.

The time when spillover occurred is not well constrained. Lacking is accurate geochronology tied to traceable marker beds and detailed stratigraphic work in the upper Glenns Ferry Formation. The timing of spillover assumed by other workers rests upon magnetic polarity changes in sedimentary section determined by Neville and others (1979) and Conrad (1980) in scattered stratigraphic sections that were not tied to radiometrically dated ashes or flows or by geologic mapping. We believe the reliable geochronology is as follows: (1) the 6.4-Ma date near the top of the Chalk Hills Formation determined by Perkins and others (1998); (2) the Ar-Ar ages obtained by Hart and others (1999) on basalt at Hagerman and paleomagnetism of sediment determined by Neville and others (1979) and the volcanic ash correlations of Izett (1981) that indicate ages between 3 and 4 Ma for the Hagerman section; and (3) the Ar-Ar age of 1.67 Ma for the subaerially erupted basalt at Pickles Butte obtained by Othberg (1994). These dates reliably set the maximum age for the beginning of the transgressive sequence, the age when the lake shore was near Hagerman, and the age when the lake basin filled with sediment and river gravel

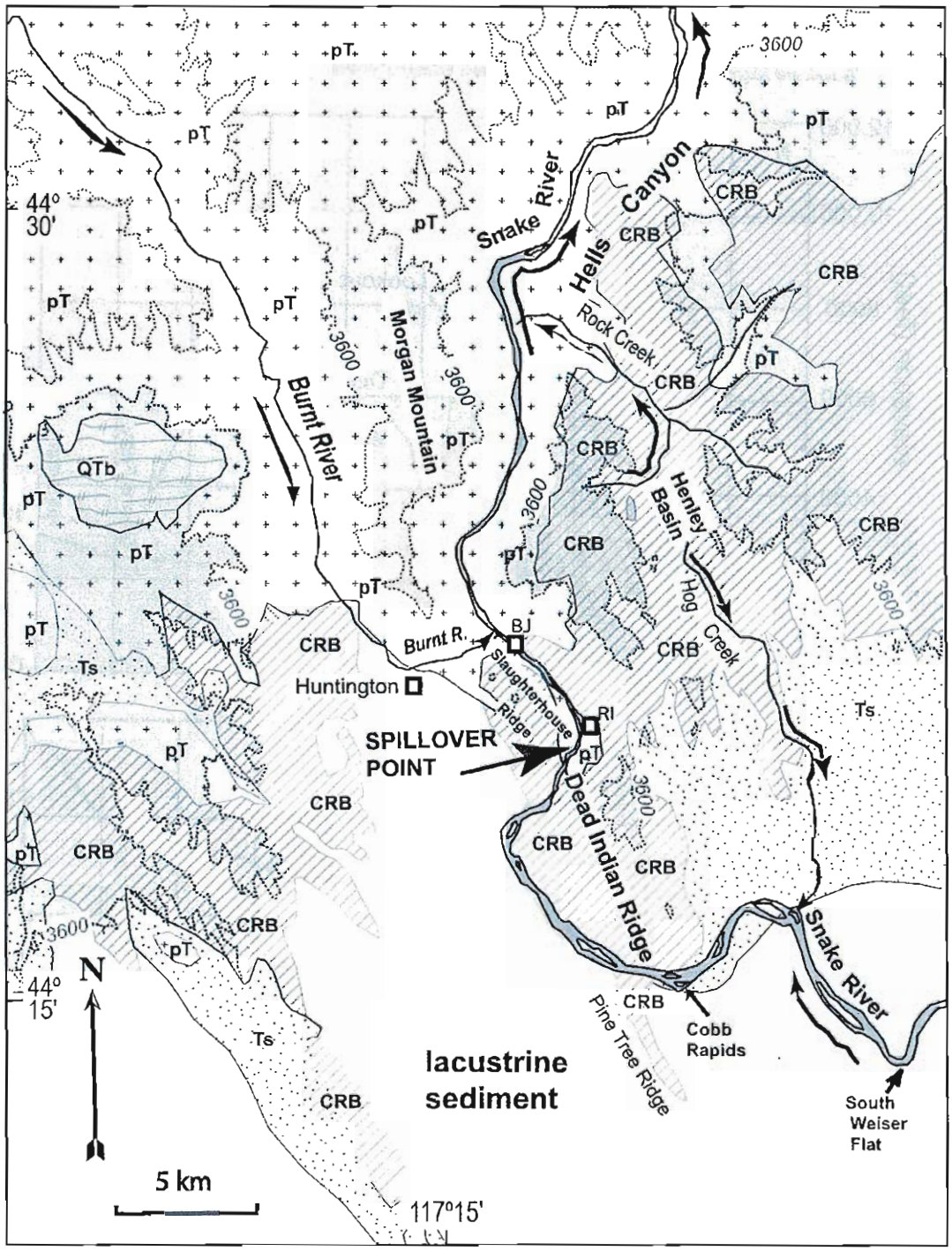


Figure 14. Present topography above 3,600 feet (shaded area) and geology at the upper end of Hell's Canyon showing the proposed spill point of Pliocene Lake Idaho. We hypothesize that the headwaters of a north-flowing tributary of ancestral Hell's Canyon were between Blakes Junction (BJ) and Rock Island Station (RI). The Pliocene divide between the Columbia-Salmon River system and Lake Idaho was between the present Slaughterhouse Ridge and Dead Indian Ridge. That divide was overtopped when the lake rose to about 3,600 feet. Henley Basin is a similar divide that still exists between north-flowing Rock Creek and south-flowing Hog Creek. The knickpoint formed by the capture has subsequently migrated 9 km up to Cobb Rapids (see Figures 15 and 17). As the river canyon lowered, a tributary creek on the west captured the lower part of the south-flowing Burnt River. Geologic units are pT—pre-Tertiary rocks of the Olds Ferry terrane (Vallier, 1998); CRB—Columbia River Basalt Group; Ts—older deformed lacustrine and fluvial sediment, probably equivalent to Sucker Creek and Chalk Hills Formations; QTb—cinder cone and basalt flows of probable Pliocene age; lacustrine sediment—younger sediment of Lake Idaho.

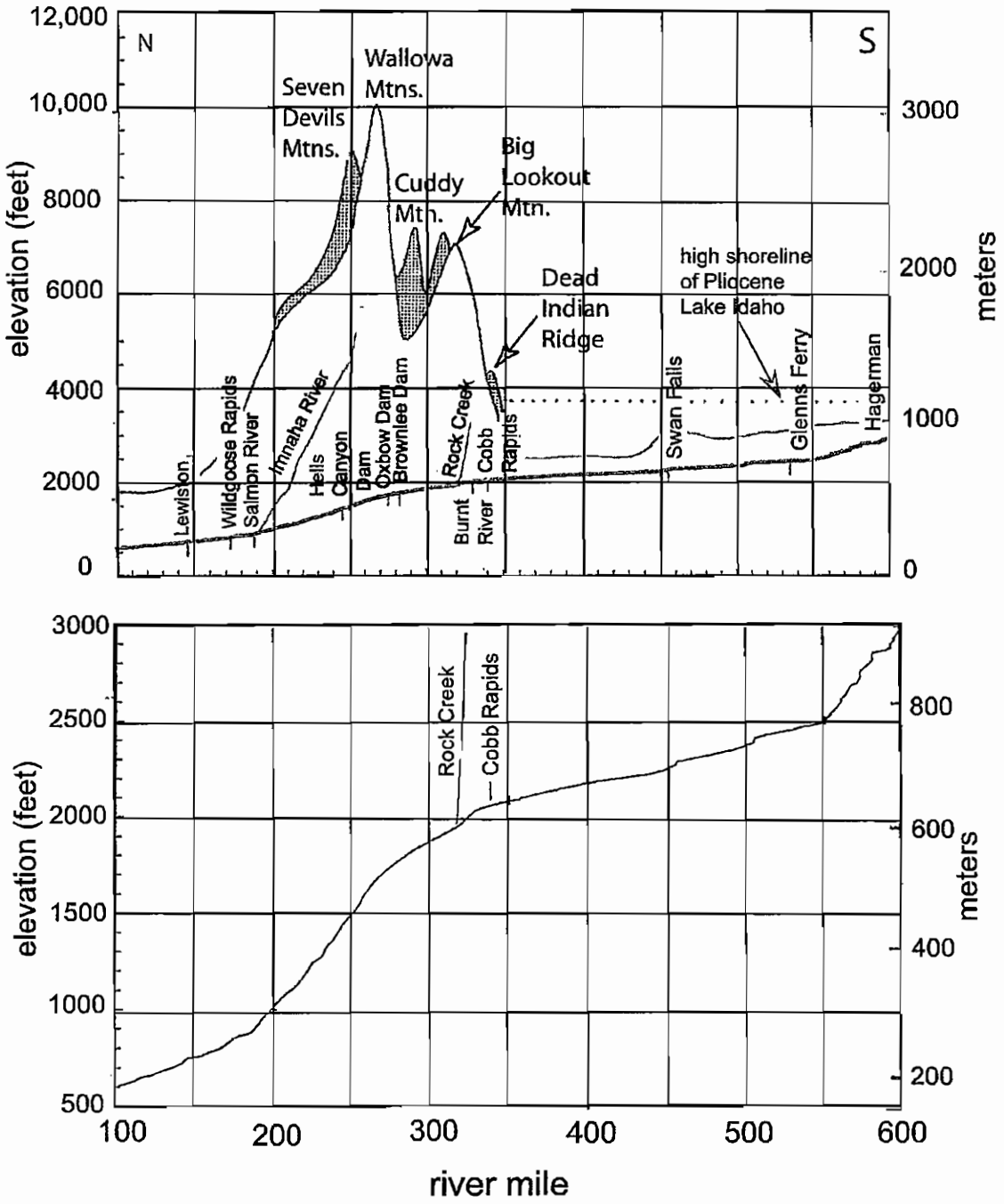


Figure 15. Longitudinal profile of the Snake River showing the change in gradient from Hell's Canyon to the Snake River Plain. Included is the profile of the Imnaha River, which has a source in the high Wallowa Mountains, and Rock Creek, which has headwaters at a divide similar to the proposed spillover location shown in Figure 14. It is thought the ancestral upper Snake River had a similar high-gradient profile at the time it breached the divide into the western plain and began draining Lake Idaho.

deposited over lake sediment near Marsing, respectively. Therefore the rise, spillover, fall, and sediment infilling of the lake occurred at sometime between 6.4 Ma and 1.67 Ma. Van Tassell and others (2001) and Smith and others (2000) provide new geochronological and paleontological evidence suggesting that Lake Idaho connected to the Columbia River drainage at some time between 3.8 and 2 Ma.

It will be important to establish whether the Hagerman section represents a transgressive sequence of lacustrine deposits over beach deposits, deposits of a highstand of the lake, or fluvial deposits over lacustrine deposits. We believe the facies at Hagerman could be the transgressive stage, the highstand, or a facies of the early stages of draining an alkaline lake. Our contention is that the medium and fine sand interbedded with calcareous silt and clay throughout the 250- to 400-foot (75-120 m) sections described by Malde (1972) at Fossil Gulch and Peters Gulch indicate lake conditions of a closed alkaline lake, or one just beginning to drain. Wood (1994) described 1,000 feet (300 m) of very calcareous claystone overlain by 800 feet (240 m) of interbedded fluvial and deltaic sand interbedded with moderately calcareous silt in a geothermal well beneath Caldwell. South of Marsing, the lacustrine sediments above the Chalk Hills Formation and beach gravels are composed of 300 feet (90 m) of noncalcareous mudstone (with gypsum cemented ashes and gypsum veins) conformably overlain by 1,000 feet (300 m) of very calcareous mudstone interbedded with fine and medium sand in the upper part (S.H. Wood, unpub. mapping). We believe the thick calcareous sediments are a record of an alkaline lake of a closed basin.

We constructed the diagram of Figure 9 without knowing that Hearst (1999) had published a similar hypothetical diagram of lake-level elevations over time. She shows the spillover as having occurred about 2.7 to 2.5 Ma, based upon a re-evaluation of the geochronology of Kimmel (1982), Neville and others (1979), and Repenning and others (1994). She accepts the glass fission-track ages of Kimmel (1982) and finds that they concur reasonably with paleontological age estimates of fauna in the Glenns Ferry Formation. Her work has caused us to rethink the ages in our Figure 9. Kimmel's (1982) dates are on volcanic ash within 17 m of the base of the Glenns Ferry Formation. The ages range from 2.2 to 3.3 Ma, and since they are based upon fission tracks in glass and not in zircon, and because they are near the base of the formation, we suspect they may be too young for that part of the section. The ages of 5.5 ± 0.4 Ma and 3.3 ± 1.0 Ma at south Weiser Flat, shown in Figure 7, are fission-track ages on zircons from volcanic ash within lacustrine sediments, but we are uncertain of their correlation to the Glenns Ferry Formation. These ages on ash date a time of deposition of noncalcareous lacustrine mudstone at that site at the northwest end of the western plain basin. Future work should focus on better dates on volcanic ashes in the section explored by Hearst (1999) and the section in the Boise foothills where major sand units prograde over lacustrine muds in the upper part of the section and are an indication of falling lake level after the lake spilled over the outlet into Hell's Canyon.

We realize now that the slow downcutting of the bedrock outlet and deepening of Hell's Canyon are good explanations for features of the final phase of Lake Idaho. Helpful to our understanding were the typical rates of downcutting of bedrock canyons by major rivers (Schumm and others, 1991). Rates are typically about 150 m/Ma. We have added comparative data from other studies that support these relatively slow rates (Table 2). A reconstructed history of lake levels (Figure 9) suggests that the lake level lowered at a rate of about 120 m/Ma. Although climate change may have affected the stream regimen, the rates of downcutting of Hell's Canyon, and the lake levels, we do not think that climate change is necessary to explain the sequence of major events in the late history of Lake Idaho.

A slow lowering of base level would have caused the erosion of sands from the lake margins and delivered sand into the basin by delta progradation, a feature noted in the center of the basin by Wood (1994) but its significance not clearly understood at the time. The abrupt change from deep lake mudstone to prodelta and delta deposits occurs over much of the western plain where it is detected by geophysical logs (Figure 16). We believe this change is a result of the slowly lowering lake level and of sandy sediment prograding into and filling the basin. Wood (1994) calculated from the relief of prodelta slopes that the lake water into which the deltas prograded was at least 255 m deep. Not until the entire western part of the lake was filled did streams flow across the plain to the outlet. At Weiser, the highest gravel deposits are about elevation 2,500 feet (762 m), and we believe these record the time at which the lake basin completely filled with sediment and stream gradients had aggraded across the plain so that braided streams transported gravel across the plain to the outlet area, leaving deposits known as the Tuana Gravel and the Tenmile Gravel (Sadler and Link, 1996; Othberg, 1994). The ages of the gravels must decrease across the plain to the west, but it is believed that the streams were continuous to the outlet near Weiser by about 1.7 Ma (Othberg, 1994). These highest gravels have subsequently been incised by the Snake River and tributaries about 120 m. Cobb Rapids of the Snake River at elevation 2,080 feet (635 m; Figure 17) is the present knickpoint in Miocene basalt as the river changes grade

Table 2. Rates of river incision into bedrock canyons (after Schumm and Ethridge, 1994).

Rate (cm/1,000yr)	Rock Type	Location	Reference
4.0	granite	SE Australia	*Brittlebank, 1900
9.6	basalt	SE Australia	*Brittlebank, 1900
9.5	conglomerate	Arizona	*Rice, 1980
24.8	sandstone	Arizona	*Rice, 1980
30.0	sedimentary rock	Colorado	*Larsen et al., 1975
7.0	metamorphic rock	Colorado	*Scott, 1975
37.0	limestone and basalt	Utah	*Hamblin et al.,1981
2.6	limestone and basalt	Utah	*Hamblin et al., 1981
8.7	granite	Sierra Nevada, west slope, California	*Huber, 1981
50.0	unknown	Dearborn River, Montana	Foley, 1980
5 to 10	granite	Boise River, Idaho	Howard, et al., 1982
30 to 70	Quaternary intracanyon basalt	South Fork Boise River, Idaho	Howard, et al., 1982
15 to 16	Eocene lacustrine sediment	Wind River, Wyoming	Chadwick et al., 1997
11 to 16	granite and metamorphic rock	Middle Fork Salmon River, Idaho	Meyer and Leidecker, 1999

*Schumm and Ethridge's (1994) table contains references to data prior to 1981, which are not referenced in this paper.

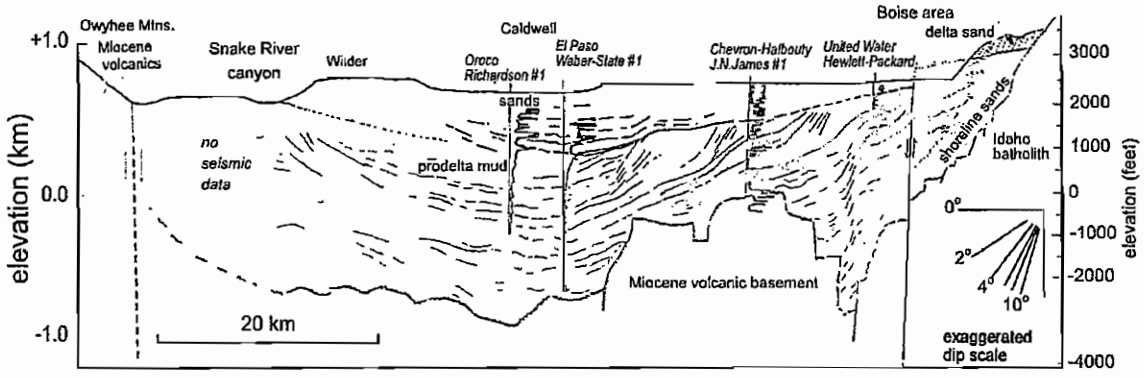


Figure 16. Tracing from seismic reflection section across the western Snake River Plain showing the upper sequence of fluvial-deltaic sediments and character of resistivity logs in wells. Resistivity-log excursions to the right are fresh-water aquifer sands, and the monotonous, near zero, resistivity values are indicative of mudstones. Notice the abrupt change upward from pro-delta muds to the sandy section of the delta systems, delta plain, and fluvial sands in the Caldwell area. Deposition may have been continuous in the center of the plain, but beds appear truncated by erosion to the east, and this surface to the east may be the unconformity at the top of the Chalk Hills Formation. The deltaic deposits in the Richardson well are discussed by Wood (1994). Line of section extends from Terteling Springs in Stewart Gulch shown in Figure 10 westward through the J.N. James well to the Caldwell area shown on Figure 2.

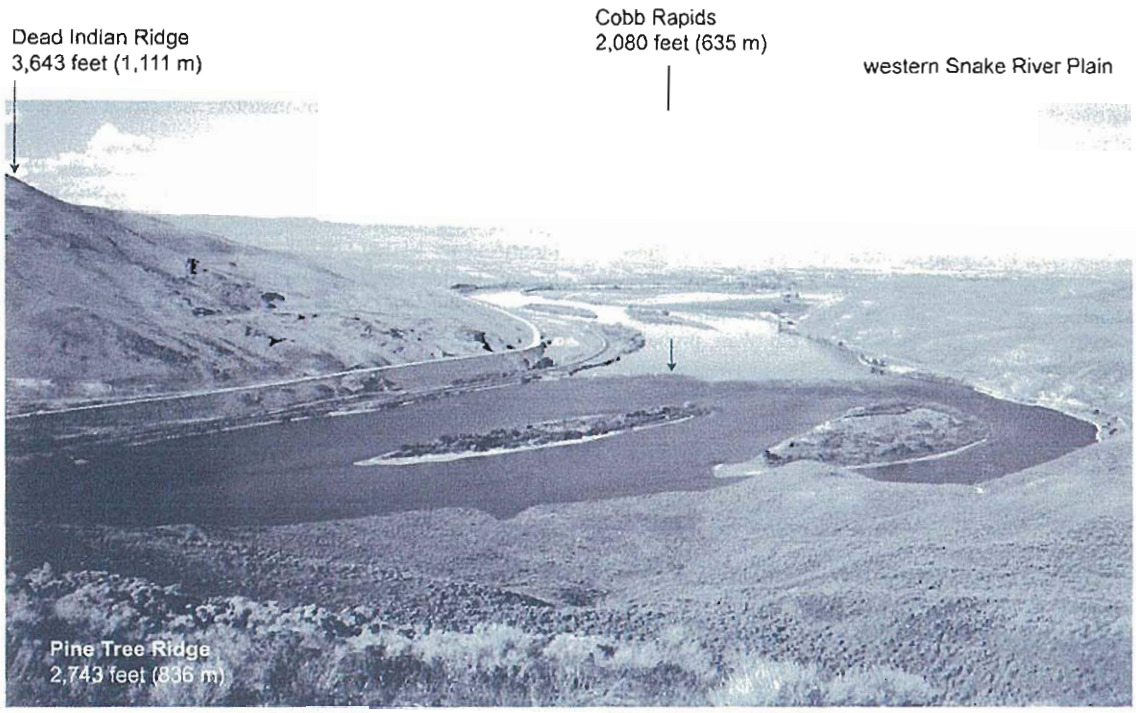


Figure 17. Photograph looking east and upriver of Cobb Rapids of the Snake River near Weiser. Cobb Rapids is the knickpoint of the river profile between the low gradient plain and the high gradient Hell's Canyon reach.

from the plain (1.6 feet/mile, 0.0003) and descends at steeper gradient (4.9 feet/mile, 0.0009) and a convex profile into Hell's Canyon (Figure 15).

LATE PLIOCENE AND QUATERNARY VOLCANISM IN THE WESTERN PLAIN

The resumption of basalt volcanism in the western plain region began around 2.2 Ma. At the western side of the plain, Lees (1994) obtained $^{40}Ar/^{39}Ar$ dates and subdivided the late Cenozoic basalts into two groups. On the older group of olivine basalts, shown by Walker and MacLeod (1991) as Pliocene and Miocene, Hooper and others (2001b) obtained dates ranging from 8 to 13 Ma, which they called the Sourdough and Keeney sequences. The younger group with dates of 1.9 to 0.8 Ma, they named the Kivett sequence. This basalt chronology of Hooper and others (2001b) is roughly consistent with that of Bonnichsen and others (1997) who show a 9-7 Ma basalt episode in the western plain, followed by a 5-Ma-long hiatus in basalt volcanism and then a second episode from about 2.2 Ma to as recently as 100,000 years ago.

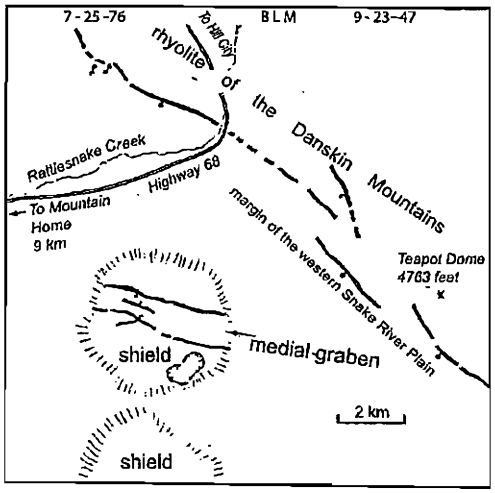
Hooper and others (2001b) also dated Malheur Butte, a volcanic neck that is higher (elevation 2,661 feet, 811 m) than Lake Idaho sediment in the surrounding hills (elevation 2,300-2,550 feet, 670-780 m). Fine-grained, blue-gray andesite (about 2 percent plagioclase) yielded a whole-rock $^{40}Ar/^{39}Ar$ date of 0.8 ± 0.7 Ma. We have determined that the andesite is intrusive into an older bentonitic claystone, but we cannot determine from field relationships if it intrudes into or is overlain by the Glenns Ferry Formation. Lees (1994) suspected that flows of Malheur Butte lay buried beneath the lake sediment, but we find it is clearly intrusive into uplifted older sediment.

Basalt volcanism in the western plain beginning about 2.2 Ma erupted a volume of about 300 cubic km (see basalt-isopach map by Whitehead, 1992) from a group of vents with an alignment that is oblique to the orientation of the plain and its boundary faults (Figure 18). We call this basalt field of the western plain the Kuna-Mountain Home volcanic-rift zone. Although small in volume compared to the total late Neogene and Quaternary basalt of the eastern plain (estimated to be 40,000 cubic km

by Kuntz, 1992, p. 231), the western plain basalt field shares characteristic forms of basalt fields of the eastern plain. The vents are marked by numerous shield volcanoes distributed from near Mountain Home to the Kuna-Melba area. Other vents of this age also occur along the north margin of the plain near Boise (Othberg, 1994; Othberg and others, 1995) and within the Idaho batholith north of the plain (Howard and Shervais, 1982; Vetter and Shervais, 1992). Some intracanyon flows from these vents traveled down stream valley, up to 75 km distance, and spilled onto the plain, but their total volume is substantially less than the vents within the plain, probably less than 10 cubic km. A number of basalt vents erupted into the declining stages of Lake Idaho along the south side of the plain (Godchaux and others, 1992), and we used ages on Walters Butte and Pickles Butte to help date the level of the lake in Figure 9. Bonnichsen (written commun., 2000) has pointed out to us that some vents lie off the main line of shields, but we believe the bulk of the volume erupted from the zone shown in Figures 19.

Basalt eruptions from the volcanic rift zone constructed an upland of coalescing large shield volcanoes, generally higher than 3,100 feet (945 m) in elevation, that has confined the Snake River to a southerly course through the plain. Big Foot Butte shield is fully 8 km in diameter, and elevation at the top is 3,535 feet (1,078 m). The Initial Point shield is 10 km in diameter and has built up to an elevation of 3,240 feet (988 m). Most of the lava field erupted upon a surface that is 2,400 to 2,500 feet (730-760 m) in elevation (Wood, 1997). In the area of Little Joe Butte, Whitehead (1992) shows Quaternary basalt down to 1,300 feet (400 m) in elevation, where the basalt is determined to be 1,500 feet (460 m) thick on the basis of resistivity soundings. Two water wells drilled the basalt column down to elevation 1,880 feet (573 m), where they are still in the basalt section (Cinder Butte Farms Well, sec. 27, T. 2 S., R. 4 E.; and Big "D," Inc. Well, sec. 28, T. 2 S., R. 4. E.). The deep basalt in this area appears confined to a zone about 10 km wide over the main vent area and may be partly composed of dikes and sills; however, the driller of the Cinder Cone Butte well described red cinders at elevation 2,048 feet (624 m), and the driller of the Sabin well (sec. 25) described subsurface red lava at the 2,108-foot (647-m) elevation. The red color suggests these are subaerially erupted basalt cinders. In most other wells, basalt rests upon gravel and sand sediment at and above elevation 2,050 feet (625 m). The deep basalts here are poorly understood, particularly the low elevation of the sediment surface upon which most of basalt rests in this local area (i.e., about 2,050 feet, 625 m). We do not believe that the lake deposits of the western plain were incised to that depth before the eruption of basalt lavas. The present Snake River elevation just southeast of this area is 2,340 feet (713 m). Probably, this area of low-elevation basalt-sediment contact has experienced relative downfaulting associated with the basalt volcanism.

An ancestral canyon of the Snake River (filled by basalt) trends northwestward in the subsurface from Swan Falls to near Melba and Bowmont, a feature originally identified by Malde (1987) and called the "Canyon 3 Stage." Malde (1991) estimates the floor of the canyon at elevation 2,150 feet (655 m) on the basis of well data



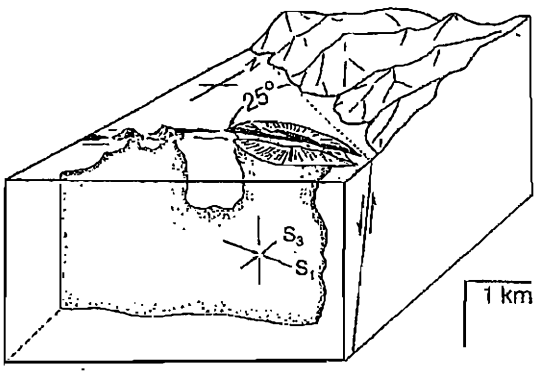


Figure 18. The air-photo tracing shows the northeast margin of the western plain 9 km northeast of Mountain Home. Tracing shows the N. 70° W. trend of fissures in the Pleistocene shield volcano and the N. 45° W. trend of the faults on the margins of the plain. Block diagram shows the inferred direction of principal stress-controlling feeder dike systems for the Kuna-Mountain Home volcanic rift zone. S_1 is the maximum principal stress, and S_3 is the minimum principal stress.

in the Melba area. He believed the canyon went through to the Boise River drainage to the north. We are unable to find the well data cited by Malde. Wood (1981, unpub. mapping) found water wells that drilled basalt down to 2,330 feet (710 m) in elevation near Nampa and U.S. Highway 30, but not down to 2,150 feet (655 m). There is evidence for the incision of the older lake deposits and infilling intracanyon basalt down to 2,330 feet (710 m) in elevation, but not to 2,150 feet (655 m) as suggested by Malde (1991). Determining elevations of the base of gravels overlain by subsurface intracanyon basalt is important to understanding the evolution of the Quaternary deposits and the history of incision of lake deposits (Othberg, 1994). The river at Swan Falls is now at 2,285 feet (697 m) in elevation. It is unlikely the river previously had a lower base level. Base level is established by the bedrock knickpoint at Cobb Rapids (elevation 2,080 feet, 634 m) 100 miles (160 km) downstream (Figures 14 and 15). Incision below 2,300 feet at Swan Falls would require the eroding stream to have had a lesser gradient than now (1.7 feet/mile, 0.0003), or that the Cobb Rapids area has been significantly uplifted in the Quaternary, neither of which seems likely. An elevation range of 2,300 to 2,400 feet (700-730 m) appears to be the deepest level of Quaternary incision in the Swan Falls-Nampa area of the plain.

The western plain basalt field has characteristics identical to the individual volcanic rift zones of the eastern plain, as defined by Kuntz (1992) to be linear arrays of basalt volcanic landforms and structures. The landforms include fissures, spatter ramparts, tephra cones, lava cones, shield volcanoes, and dikes at depth. The structures include noneruptive fissures, faults, and small grabens. The term "rift" needs clarification because we regard the western plain as a tectonic or continental rift, but we define here a volcanic rift zone that cuts obliquely across the western plain. A tectonic rift is a large graben structure not necessarily associated with volcanism. Kuntz (1992) shows that volcanic rift zone alignments are collinear with the strike orientation of active basin-range normal faults on both sides of the eastern plain. The length of the Kuna-Mountain Home volcanic rift zone is about 100 km, similar to typical 80-km lengths of zones in the eastern plain.

Fissures and faults within shield volcanoes of the western plain have the same alignment as the volcanic vents, about N. 70° W., indicating structural control of magma vents related to the regional tectonic stress system. This alignment is about 25 degrees counterclockwise from the bounding fault systems of the western plain (Figure 18). Nakamura and Uyeda (1980), Zoback and Zoback (1991), and Conner and Conway (2000) show such features are reliable indicators of tectonic stress direction whereby the volcano alignment is perpendicular to the least principal stress direction.

Remarkably, the alignments within volcanic rift zones change from the eastern plain to the western plain. Eastern plain zones are mostly aligned N. 30° W., whereas the one zone in the western plain is N. 70° W., and this change in orientation occurs over a distance of 80 km from the Richfield-Burley Butte zone (Shoshone lava field) to the easternmost group of vents near Mountain Home. That general trend N. 70° W. is also characteristic of eastern Oregon Quaternary basalt fields (aligned vents and fissures) and to the distribution of Quaternary basalt fields across the state westward to the Cascade Range (Figure 19). These Quaternary volcanic trends may indicate a province of relatively uniform stress orientation east of the Cascades and including the western plain, that is a different province from the eastern plain region.

CONCLUSIONS

The western Snake River Plain is a normal-fault bounded basin, 70-km wide and 300-km long. The amount of extension that formed the western-plain sedimentary basin is about 10 percent, similar to intracontinental rift basins elsewhere in the world such as Lake Baikal and those in east Africa. Exposed strata on the margins and seismic reflection data show as much as 2 km of basin relief formed by both faulting and by downwarping toward the basin axis. Fault structures are both half and full grabens. The western plain structure contrasts greatly with the northeast-trending eastern plain where extension is not expressed by faulting at the margins but solely by downwarping associated with basalt intrusion in fissure systems oriented perpendicular to the axis of the eastern plain.

Previously published seismic refraction data show that the intermediate and deep crust beneath the western plain is mafic rock, whereas the margins of the plain are granitic rock. The basin sediments are underlain first by basalt lavas which are underlain by middle crustal rock so invaded by mafic intrusives that the original granite is no longer recognizable by seismic refraction-derived velocities. This indicates the plain is not a simple graben of downfaulted granitic crust. The data also show a high velocity layer at a depth of 23 km restricted to the area beneath the Bruneau-Jarbidge eruptive center southeast of the plain. This layer could be restite or an underplate of basalt related to the formation of silicic magma.

The northwest orientation of the western plain basin appears to follow a pre-existing lithosphere weaknesses or megafabrics of the northwestern United States. This

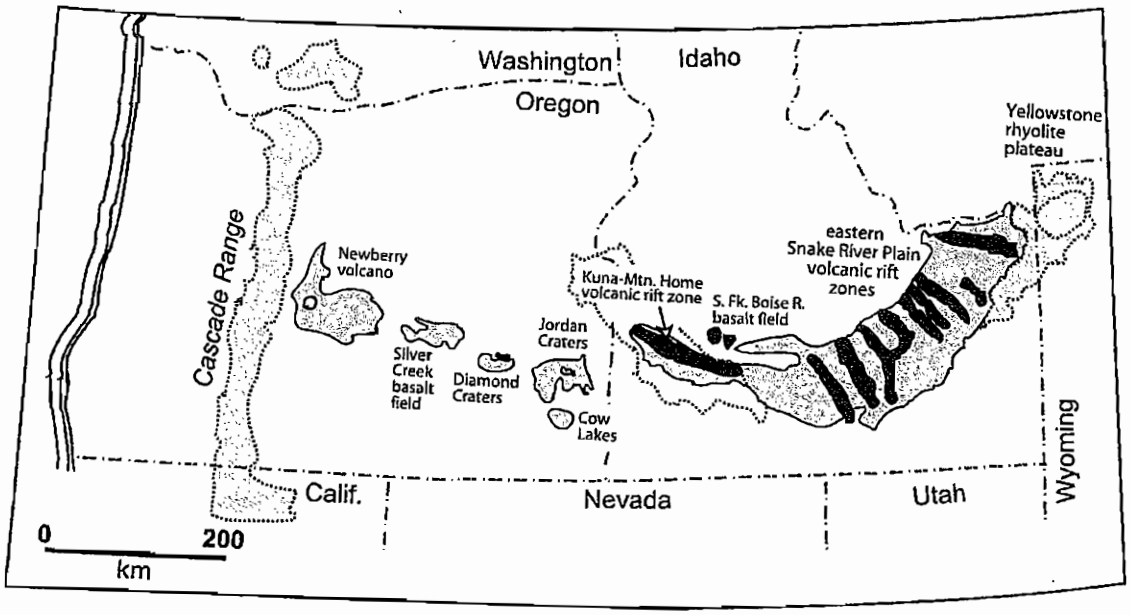


Figure 19. Map showing Quaternary basalt fields of eastern Oregon and southwest Idaho. Darkest shading is the basalt vent area. Note the contrast in the orientation of the volcanic rift zones between the eastern and the western plain. Orientation of the Kuna-Mountain Home volcanic rift zone of the western plain parallels those of eastern Oregon basalt fields, suggesting a similar orientation of tectonic stress direction in the Quaternary but a direction that differs markedly from the eastern Snake River Plain.

orientation is expressed in other structures such as the Olympic-Wallowa lineament, the Brothers fault zone, and the Baker-La Grande grabens.

The geologic and tectonic history of the western Snake River Plain is intimately involved with magmatism as shown by the following sequence of events and features:

(1) Before the basin formed, widespread and voluminous rhyolite volcanism occurred south of the plain, and the early Columbia River and Steens basalt erupted over Mesozoic rocks north and south of the plain, 17-13 Ma. Local eruptions of rhyolite occurred along the fault margins of the plain as the basin began to form about 12-11 Ma.

(2) Timing of the beginning of the basin coincides with the lodging of the hot spot at the Bruneau-Jarbidge rhyolite eruptive center, 11.5-8 Ma, southeast of the western plain. We suggest that heating of the lithosphere initiated the structure and also caused basalt magma intrusion as the basin extended.

(3) Deep wells in the center of the western plain drilled through sediments to basalt flows and basalt tuff exceeding 2.5 km in thickness, and have not drilled through rhyolite. Rhyolite sequences without significant sedimentary interbeds, as much as 2-km thick, occur on the margins of the plain. Lack of rhyolite in deep drill holes suggests that much of the plain area was an upland during the early eruptions of rhyolite from the Bruneau-Jarbidge center.

(4) Normal faulting that formed the western plain basin began about 11 Ma and amounted to over 2 km of offset by 9 Ma. Since that time, long-term average rates of vertical slip have been low (<0.01 mm/year), except for an active fault segment 55 km southwest of Mountain Home. Broad downwarping toward the center of the basin and compaction subsidence of the thick sedimentary fill have since lowered the center of the basin about 0.3 km with respect to the margins.

(5) Earliest sedimentation in the western plain is accompanied by eruptions of local basalt fields dated 10 to 7 Ma. The sediments are mapped as the Chalk Hills Formation. We find that the Poison Creek Formation of arkosic sand and the Banbury Basalt are local features and should be considered as facies and local basalt fields within the Chalk Hills Formation.

(6) The lake systems that deposited the Chalk Hills Formation declined in lake level at some time between 6 and 4 Ma, resulting in erosion of the Chalk Hills Formation from the margins of the lake. Reasons for the decline in lake level are not known.

(7) On the basis of fault history, we assume that elevations of lake-level features preserved as shoreline fea-

tures on the margins of the lake have changed little in the past 6 million years. This assumption allows reconstruction of the history of Lake Idaho as the basin refilled, overflowed, and the outlet was downcut.

(8) Between 6 and 4 Ma, lake levels rose and deposited a transgressive sequence over an unconformity surface on the Chalk Hills Formation. The shoreline transgressive sequence is identified by pebbly sands and oolitic-sand deposits in its upper part. We interpret the oolite occurrence as a product of increasing alkalinity in the lake water, as lake levels rose in a closed basin. We speculate that the lake-level rise was caused by captured drainages associated with the eastward-migrating hot-spot uplift.

(9) The lake overtopped a spill point into ancestral Hell's Canyon at a point between Huntington and Weiser. The spill point appears to be near Dead Indian Ridge at about elevation 3,600 feet (1,100 m). The time when the lake began to drain is poorly constrained, but we speculate it was about 4 Ma.

(10) Overtopping of the spill point connected the Snake River to the Columbia-Salmon River system and to the sea. Recent work by Van Tassel and others (2001) suggests the connection was established between 3.8 and 2 Ma. An implication is that once the lake began to drain, the alkalinity of lake water should have decreased, and this perhaps explains the lack of calcareous muds in the uppermost part of the Lake Idaho stratigraphic section.

(11) In the subsurface of the northwestern part of the western plain, an abrubt transition occurs upward in the section from thick mudstone to overlying deltaic sands. We interpret these sands to be the result of lowering lake level, erosion of lake-margin sands, and delivery of sand to the unfilled basin. The resulting upper section of deltaic sands and fluvial deposits is as much as 400 m thick, and these interbedded sands and muds constitute the main freshwater aquifer section of the western plain.

(12) Ages and elevations of basalt deposited over flood-plain sediment and gravel near the margins of the western plain indicate erosion of the outlet resulting in lake-level decline at an average rate of 120 m/Ma over the past 4 Ma.

(13) The process of filling of the remaining lake basin from southeast to the northwest outlet implies that flood-plain and stream-channel deposits should become younger to the northwest. The lake basin filled with sediment by about 1.6 Ma, and braided stream systems depositing cobble gravel flowed to the outlet.

(14) The resumption of basalt volcanism in the western plain began about 2.2 Ma. Much of the volcanism is expressed as a field of shield volcanoes that trends obliquely across the plain from Mountain Home to Kuna with an orientation of N. 70° W. Fissures and faults within the shields have similar orientations, suggesting the vents are controlled by a regional stress system such that the maximum principal stress is similarly oriented and that the least principal stress is aligned perpendicularly at N. 20° E.

(19) Late Quaternary fault activity occurred on a segment of the southeastern boundary fault system, 55 km southwest of Mountain Home, that trends N. 30° W. to N. 70°W. The N. 70° W. orientation of some active faults is parallel to the Quaternary Kuna-Mountain Home volcanic rift zone, which suggests that episodic reactivation may occur on faults oriented suitably with respect to the present system of tectonic stress.

Examining the history of the western Snake River Plain brings up a number of questions for future research. Is the basalt crust beneath the western plain a product of early injection of basalt magma, similar to processes thought to be presently occurring in the eastern plain? Is the deep-crustal high-velocity zone beneath the Bruneau-Jarbidge center related to the rhyolite volcanism? These two questions might be answered by deep-crustal seismic exploration and a reevaluation of gravity data. Additionally, such a project might give new data on the way in which hot-spot magmatism has altered the lithosphere.

Other aspects of the western plain that should be a focus of research are as follows: The paleotopography and implied uplift of the region during eruption of rhyolite might be reconstructed if flow directions of rhyolite were mapped. Chronology of the "Chalk Hills" lake is poorly constrained, particularly the time of the lake level decline. Better stratigraphic study and chronology are needed of this formation to understand the processes that affected the lake. Further, the chronology of the lake level rise and overtopping of the spill point is poorly known. Detailed stratigraphy and geochronology combined with an interpretation of lacustrine-sediment geochemistry may significantly contribute to knowledge of the history of Lake Idaho.

We have suggested that the principal tectonic stress orientation indicated by Quaternary basalt vents and active faulting is about N. 70° W., and that a similar orientation is expressed by basalt fields in eastern Oregon. More detailed study of the vents throughout the region is needed to verify this. Also borehole breakouts as indicators of tectonic-stress orientation in future deep wells should be studied with compass-oriented borehole imaging or 4-arm caliper logs.

ACKNOWLEDGMENTS

Our studies of the western plain have been supported at various times by the Idaho Department of Water Re-

sources, United Water Idaho, Idaho State Board of Education, Los Alamos National Laboratory, J.R. Simplot Company, and Boise State University faculty research grants. This study contains new information developed for the Treasure Valley Hydrologic Study of the Idaho Department of Water Resources. Our ideas have been shaped through discussion and data shared by many colleagues. We would like to thank Ed Squires, Dan Brown, Terry Scanlon, Patrick Naylor, David Hawk, Lee Liberty, Dora Gallegos, Gregg Beukelman, Kurt Othberg, Craig White, Ken Pierce, Grant Meyer, and the late Will Burnham. A special thanks to Bill Bonnichsen for an insightful review and information on areas he has explored far more than any other person. Many thanks also to Gary Fuis for reviewing and clarifying parts of the manuscript.

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19E

Stratigraphic Studies of the Boise (Idaho) Aquifer System Using Borehole Geophysical Logs With Emphasis on Facies Identification of Sand Aquifers

Report to the Treasure Valley Hydrologic Study
Idaho Department of Water Resources

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Introduction

The cold-water aquifer system beneath the City of Boise is composed of sandy sediments interbedded with claystone and mudstone that were deposited near the shores of lakes which filled the western Snake River Plain during the late Miocene and Pliocene epochs (10 to 1.7 million years ago) (Figures 1 and 2). The sand layers are the deposits of stream channels, beach sands winnowed by wave action, deltas built out into the lake, and possibly density-flows across the lake bottom from collapse of parts of the delta shelf. These depositional environments do not produce broadly distributed sand layers. Instead the sand layers are typically restricted in their horizontal and vertical continuity by interbedded mudstone or lateral termination into mudstone. The difficulty here lies with correlation of sand layers and determination of their shapes. Important is to predict whether sand layers found in wells have some sort of hydraulic connection, and which are not interconnected. By analogy to modern sedimentary environments and subsurface studies by others, our goal is to obtain at least a partial understanding of the three-dimensional geometrical shapes of sand aquifers.

Structural downwarping coupled with normal faulting along the margins of the plain further complicates deciphering the stratigraphic section. For example, a 4-degree dip of strata (370 feet per mile), results in strata identified in one well, being 370 feet deeper in a well one mile away in the down dip direction (Figure 2). Stratigraphic offset along down-to-basin normal faults (up to 800 feet of vertical throw on some faults) pose additional complexity, because in the older strata, faulting was contemporaneous with deposition.

For this report, we have compiled available geophysical logs (natural gamma, single-point resistance, or normal-resistivity logs at a scale of 1 inch equals 200 feet for the wells shown in Figure 3. Most of the logs are owned by United Water Idaho, Inc. and we have been permitted to use other data by the City of Boise, Micron Technology, and the Idaho Department of Transportation. On many of the United Water Idaho (UWID) wells, drill cuttings were examined by geologists, and the grain size of sands are known. On other wells, the driller's descriptions are the only record of lithology, and the grain-size of sands is not consistently reported. We explain our attempts to correlate geologic strata and identify depositional facies for the line of wells from Claremont Subdivision (end of 8th Street in the foothills) to the Cassia Street well, and for the line of wells from " Hill 3431" above Stewart Gulch in the foothills to the McMillan well of west Boise. Correlation from the Micron Technology plant area to Cassia Street are still preliminary, and not included. Correlation from Idaho Street well to the Bethyl Street well and west to the St. Lukes well (at east Meridian) is currently being evaluated using seismic reflection data acquired by the Boise State University CGISS group this summer of 2000.

Methods

Facies interpretations of geophysical logs are discussed in Rider (1996), Berg (1986); and Galloway and Hobday (1996); however, examples from lacustrine basins are few. Most of the examples from Rider's interpretations (shown in Figure 4) are from marine environments; however, his examples of a channel-point bar, delta-border progradation, transgressive shelf, and prograding shelf are probably applicable to the lacustrine setting. The study of the Pliocene lacustrine Ridge Basin in California by Link and Osborne (1978) is helpful, because they interpret logs of a mouth bar complex overlying a delta

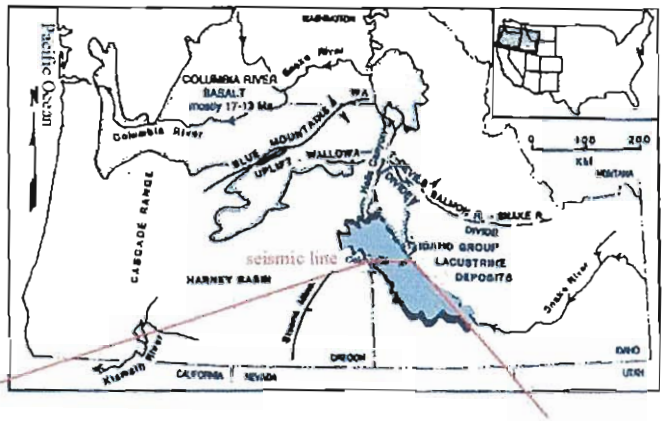


Figure 1. Location of Neogene Lake Idaho deposits in the northwest United States (from Wood, 1994)

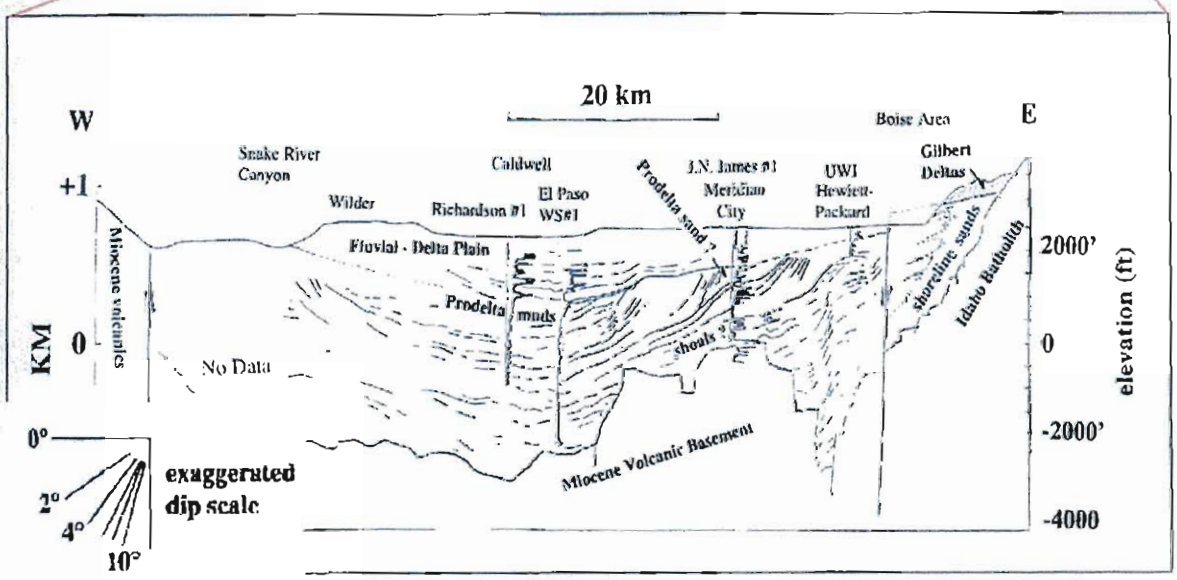


Figure 2. Interpreted cross-section from seismic lines across the western Snake River Plain, showing the geometry of strata that reflect seismic waves within lake and stream deposits and the resistivity response of borehole geophysical logs of deep wells. Drawn from petroleum industry seismic reflections lines which were focused on the deeper strata and did not image the strata shallower than 700 ft depth (i.e., the main cold-water aquifer section).

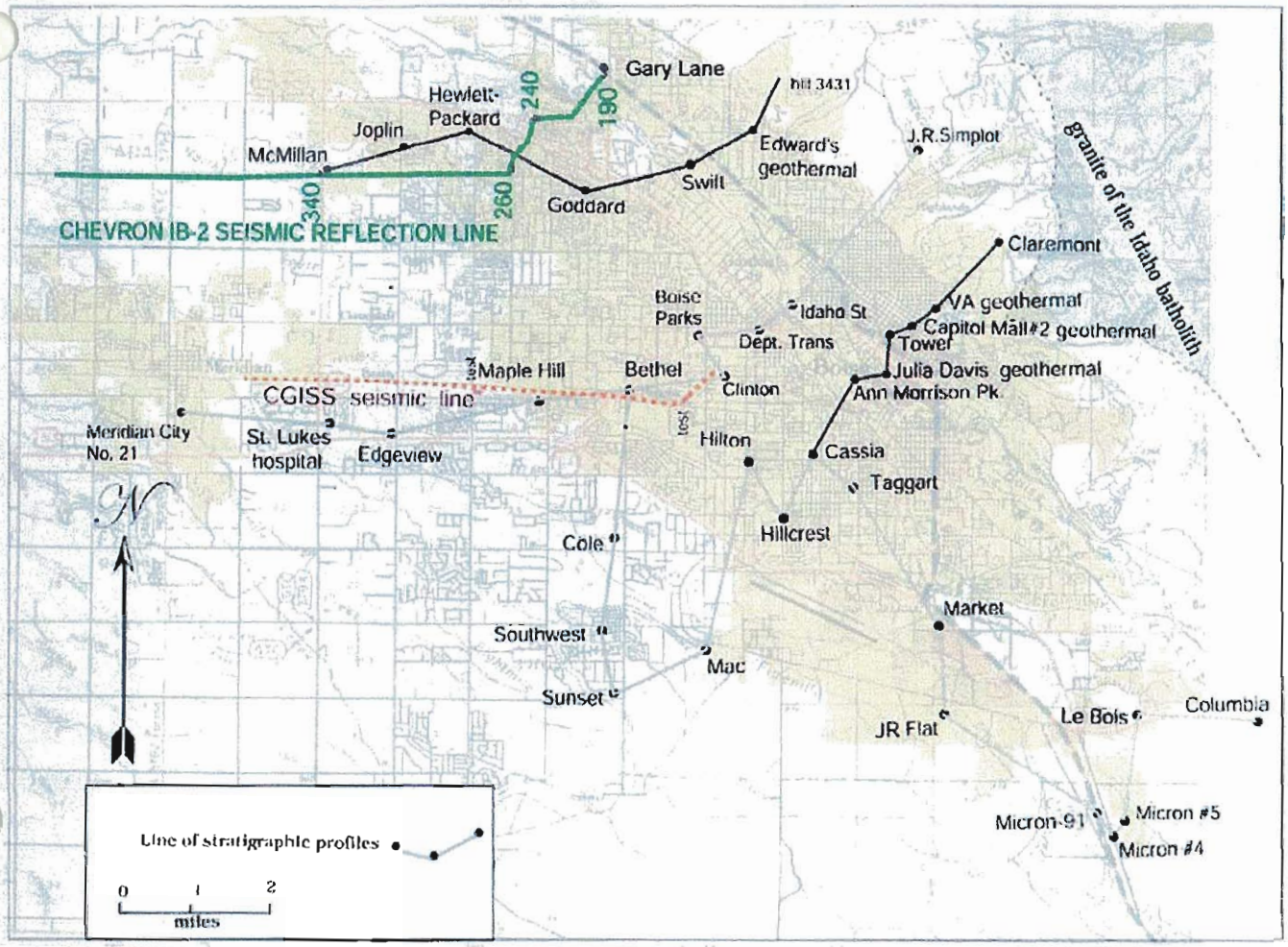


Figure 3. Map showing deep wells in the Boise area and locations of seismic lines. Profiles of Figures 9 and 10 are highlighted lines.

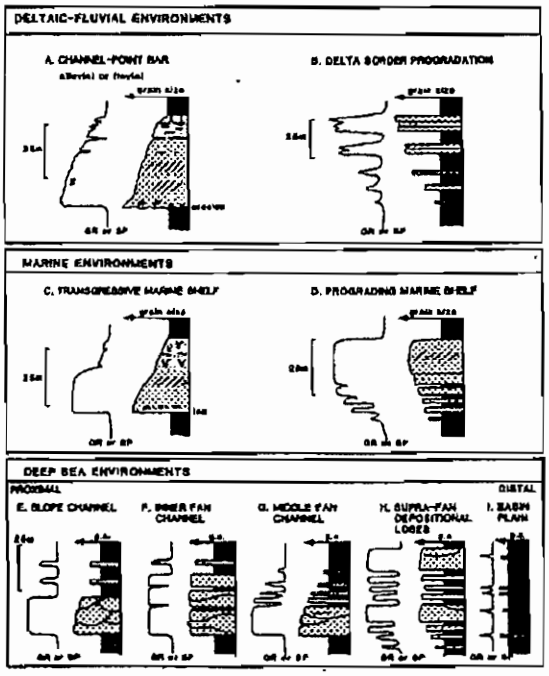


Figure 4. Idealized well log shapes (gamma or SP, or mirror image of resistivity) for sedimentary facies (From Rider, 1996).

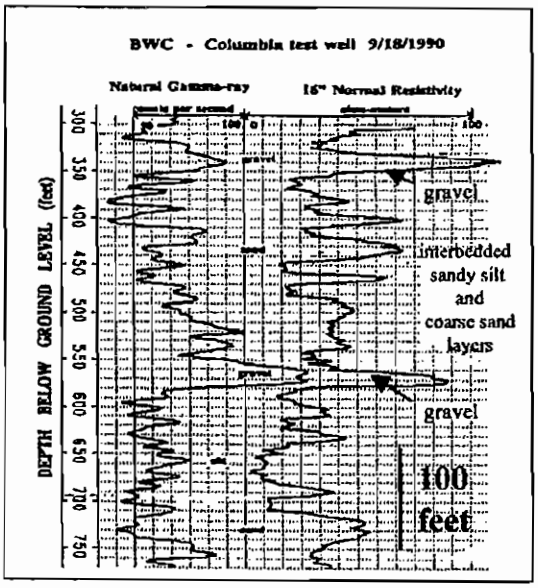


Figure 5. Geophysical log character of the mixed alluvial-fan - braided-stream facies beneath southeast Boise. Gravel layers are typically 20 feet thick and have higher radioactivity (high counts/sec on the natural gamma log) on account of a large percentage of cobbles of high-potassium porphyritic felsite. Gravels show a tendency to be more silty upwards (fining of matrix upward), and have abrupt bases typical of channels. Sands are typically 20 feet thick with abrubt bases and fining upward. Silty beds show a "spiky" character on the natural gamma log. (From Squires and others, 1992).

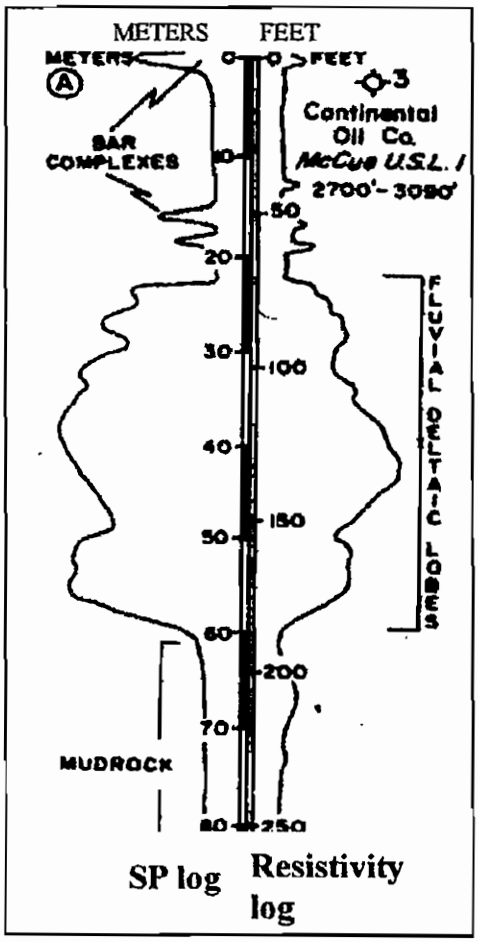


Figure 6. SP and resistivity log of lacustrine prodelta mudrock overlain by delta sand lobes, overlain by a mouth-bar complex: Ridge-Basin, California (from Link and Osborne, 1978).

1)**Funnel-shaped logs, over 20 to 100 m vertical extent**, overlain by abruptly more resistive sands, and correlative over 10's of km. These are interpreted as prodelta coarsening upward mud sequences overlain by channel sands.

2)**Funnel-shaped logs, of 5 to 20 m vertical extent**, and repeated in the section. Several to 10 or more units are repeated over intervals of 30 to 100 m. Units are rarely correlative over a few km. Sands generally medium-grained. These are interpreted as stacked mouth bars of streams entering the lake, or as beach sands.

3) **Monotonous low resistivity, and irregular medium gamma** activity, over vertical extents of 30 to 400 or more meters, interpreted as muds deposited in the open lake environment.

4) **Thin bell shaped units, less than 3 m thick**, and enclosed by thick muds, are interpreted as fining upward density-flow sands, and generally made up of fine well-sorted sand.

5) **Bell-shaped logs, with abrupt bases, 7 to 40 m in vertical extent.** Sands are typically coarse, and some have gravel at base. These are interpreted as fluvial channels, and rarely correlative over a few km.

6) **Spikey logs, with resistive units 3 to 7 m,** and low resistance units typically 3 m in vertical extent. 7 m units with abrupt bases, and high gamma. These are interpreted as alluvial fan deposits, with high-gamma rhyolite gravel with abrupt bases, and alternating silt and muddy sand layers none of which can be individually correlated.

Figure 7. Useful electric and natural gamma-ray signatures of depositional facies in Lake Idaho sediments (from Wood and others, 2000)

lobe (Figure 6). Studies by Ainsworth and others (1999), Flint and others (1988, 1989) of Miocene lake sediments in Thailand illustrate the continuity of bars and other lacustrine sands. They found mouth-bar sands to be coarsening upward (funnel-shaped logs), fine-grained sands with a sheet geometry of variable thickness. Individual sheets of mouth-bar sands, vary in thickness from 0.5 to 5 meters,and could be traced for a distances up to 5 km. Their studies of a Thailand oil field was for wells about 1 km apart accompanied by a 3D-seismic survey, a set of data far more detailed than that usually available in water resource studies.

The shapes of logs we have found useful in interpreting facies in the sedimentary section beneath Boise are summarized in Figure 7. Squires and others (1992) identified the log character of mixed alluvial-fan-and-braided-stream facies in the southeast Boise area (Figure 5).

The great value of borehole-geophysical logs is their ability to detect sand and gravel aquifers, and distinguish aquifers from low permeability mudstone, siltstone, and clay. The best log is one that measures electrical resisitivity in an open, uncased hole full of water or drilling mud (the 16 or 64-inch normal log, or induction logs). This log shows high resistivity in a fresh-water-filled clean sand or gravel aquifer, but the response is greatly reduced by low-resistivity (high-conductance, > 400 μS) groundwater in the aquifer. The single-point resistance log gives a similar response to resistivity in the sand and mudstone section and is equally useful, though not quantitative. Electrical resistivity logs have low values in silt and clay bearing sediments, thereby distinguishing them from aquifer sands and gravels. Natural gamma logs are generally useful, but their similar response in silt-clay and gravels with cobbles of high potassium content make an ambiguous interpretation of gravel or clay, unless accompanied by a resistivity or resistance log.

Background Geology and Problems

In the past, aquifers were typically named for the geologic formations in which they occurred. However, the variety of depositional environments of the lake-stream systems and the changing environments with fluctuating lake levels tells us that the sand units are complex. In previous reports on the western plain (Whitehead, 1992), the aquifer systems are associated with a set of geologic formations originally defined by Malde and Powers (1962). The stratigraphic order and characteristic lithology of the formations is a useful framework, because the changing lithology in some cases can be attributed to basin-wide geologic events or progressions of similar depositional environments across parts of the basin. However, it is unlikely that these formation units reliably relate to hydraulic connectivity of aquifers. In the areas Malde and Powers had geologically mapped, they found a general sequence of granitic rocks overlain by rhyolite, overlain by basalt, overlain by lake and stream sediments. They recognized an early set of lake and stream deposits that had been tilted, faulted and beveled off by erosion which they called the Chalk Hills Formation. Their concept of the Banbury Basalt beneath the Chalk Hills Formation is misleading, because we now know that many local basalt fields erupted during the time lake and stream sediments were accumulating in the basin (Wood and Clemens, in press). The Poison Creek Formation was originally identified on the south side of the plain as sediments dominated by one or several layers of 1-to-7-meter-thick fluvial or coarse-grained delta sand at or near the base of the lake and stream section.

These sands are discontinuous, and the Poison Creek Formation is best regarded as just a local sand facies of the Chalk Hills Formation (Wood and Clemens, in press). The basis for the top of the Chalk Hills Formation is well established as an unconformity with slight angularity on the south side of the western plain. On the south side, it is overlain by beach gravel and in places shoreline carbonate oolitic sands. On the north side of the plain, we have searched for such a straight-forward contact of a widespread angular unconformity overlain by the oolites or gravel, but have it only in one locality in the Boise foothills (discussed later in this section), and are uncertain of its occurrence in the subsurface, as discussed later in this report.

In the Boise foothills and in the subsurface are several gravel and coarse-sand occurrences indicating stream deposition or beach gravel over lake-bed muds. This can result from streams flowing out over the exposed mud surface as the lake lowers. These layers can also result from beach sand facies being spread as waves work the shoreline of a rising lake. We are looking for criteria to identify both situations, but the relationships in outcrop and on the well logs are not yet obvious to us. The gravel and coarse sand layers occur at several horizons within the mudstones, but we are still uncertain of the correlation of many of these layers.

Carbonate oolitic sands lenses occur in a 400-ft thick section of shoreline sands in the foothills which Burnham and Wood (in press) have always considered a part of their definition of the Terteling Springs Formation. The oolite bearing section varies greatly in thickness, and appears to be absent in places. The oolites were deposited as shoreline sand beaches and bars, and therefore occur only as lenses within the sediments. The oolite lithology appears to be a unique lithology associated with lake level rise (Wood and Clemens, in press; Repenning and others, 1994, p. 54). In the subsurface beneath Boise, oolite sands have been documented in the UWID'S Cassia, Taggert, and Cole water wells (locations of these wells is shown on Figure 3) at a relatively shallow depth (<300 ft), and above elevation 2500 ft.

Oolite sand also occurs in the Veterans Administration (VA) Reinjection Well, at a depth of 450-ft deep at elevation 2,300 feet. We mention this here, because the oolite layer is only 90 feet above the basalt of Aldape Heights which Clemens and Wood (1993) have dated by K-Ar as 9.4 million years old. The oolite sand occurrence here is not well understood. Because oolite in the VA well is only 90 feet above the basalt, it may be that most of the Chalk Hills sediments were eroded from this locality near the edge of the foothills, and oolite of the Terteling Springs Formation transgressed over the basalt surface. It is unlikely that the oolite in the VA well is a carbonate facies within the older Chalk Hills Formation, because nowhere else in the basin has carbonate sediment been found in the Chalk Hills Formation. The oolite layer in the VA well has probably been faulted down at least two hundred feet deeper than occurrences in the 3 UWID wells of west central Boise, suggesting a graben structure near the edge of the foothills.

We believe the sediments containing lenses of shoreline oolites to be a transgressive sequence over an unconformity at the top of the Chalk Hills Formation. An angular unconformity is mapped at the base of the oolite in Stewart Gulch (NW ¼, sec. 22, T. 4 N., R. 2 E.), but elsewhere in the foothills the contact appears to be conformable.

Overlying the oolite-bearing section in the western Boise foothill outcrops, is the "Pierce Park Sand", a 150-to-250- foot-thick layer of coarse sand. This thick sand represents a large "Gilbert-type" delta system. Where the oolite section is absent, the

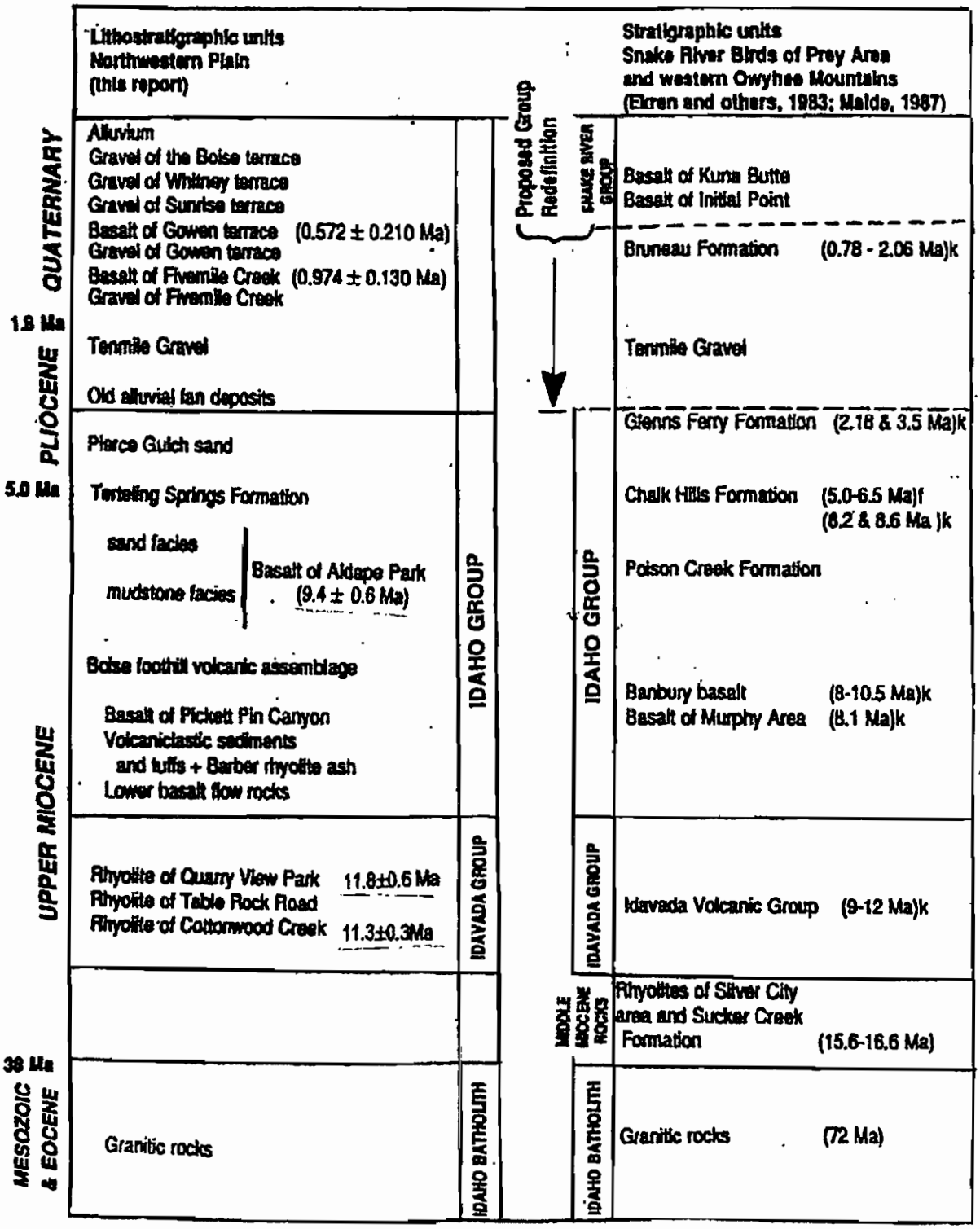


Figure 8. Stratigraphic names in the western Snake River Plain: Comparison of stratigraphic units of the Boise area (from Burnham and Wood, in press) to units mapped on the south side of the plain by other workers.

Pierce Park Sand conformably overlies mudstone. The reason the coarse sand directly overlies mudstone is because the delta prograded basinward over muds of the deep-lake deposits. The delta apparently formed as the level of Lake Idaho began lowering after it reached its spill point into Hells Canyon, probably in the early Pliocene (about 4 or 5 million years ago).

For the first time, in this study, we attempt to correlate the main features mapped in the Boise foothills with the subsurface sedimentary sequence in water wells beneath the city. We make an assumption that the oolite sequence is a singular occurrence in the stratigraphic record. We allow that gravel occurrences in the subsurface could be channel gravel, beach gravel, or river-terrace gravel, and that all gravel occurrences require a beach or a stream environment for deposition. The occurrence of an angular unconformity is not generally detectable in geophysical logs or the sequence of drill cuttings. Logs that detect dip (dip meter, resistivity borehole imager, or acoustic televiewer) have not been run in the Boise area water wells. To detect dip and angular unconformities, the configuration on high-resultion seismic reflection is also useful.

Discussion of the NE-W section from Claremont Subdivision Well to Cassia Street Well (Figure 9)

The dip of the deeper section between the Capitol Mall #2 well and the Julia Davis Well may be as much as 11° to the southwest as determined by a seismic reflection survey by Liberty (1998). The deeper sediments are a mudstone sequence more than 800 feet thick, shown on the borehole geophysical log of the Julia Davis well. Overlying the mudstone, between elevations 2,100 and 2,280 feet, is a sequence of stacked, coarse sand layers, each one 25 to 70 feet thick. Each of the upper 4 sand layers shows a coarsening-upward log signature. The log character of this sand sequence is similar to that shown in the Ridge Basin, California study by Link and Osborne (1978) as a delta-front bar complex (Figure 6). Similar beds occur near the bottom of the Ann Morrison Park well between elevation 2,000 and 2,200 foot elevation.

The overall funnel shape of the Cassia Street logs indicates a fine and medium sand delta above the silty mud at 2,100 foot elevation. These delta sands appear to correlate to sands in the Ann Morrison Park Well, but the funnel-shaped log signature is not as prominent in this well. That correlation implies an apparent dip of about 1.4° in the southwest direction between these two wells, which seems too low a dip, in view of deeper strata dipping in excess of 10 degrees in southwest direction. Another possibility is correlation of the Ann Morrison Park well sands to the deepest sands of the Cassia Street well.

Gravel occurs at the bottom of the Cassia Well at elevation 1,700 feet, but that part of the section was not geophysically logged. No other wells drilled gravel at that depth. The gravel indicates either a gravel beach deposit or a stream channel deposit. The gravel was deposited about 4 miles basinward from the basin margin indicating that the lake environment was not at this locality at the time of deposition: this locality was either a stream bed or a shoreline.

The major sand section of these wells is below an unconformity marked by an upper gravel, generally occurring in wells between elevation 2,400 and 2,550 feet (line colored pink on Figure 9). In the next paragraph we discuss evidence interpreting this

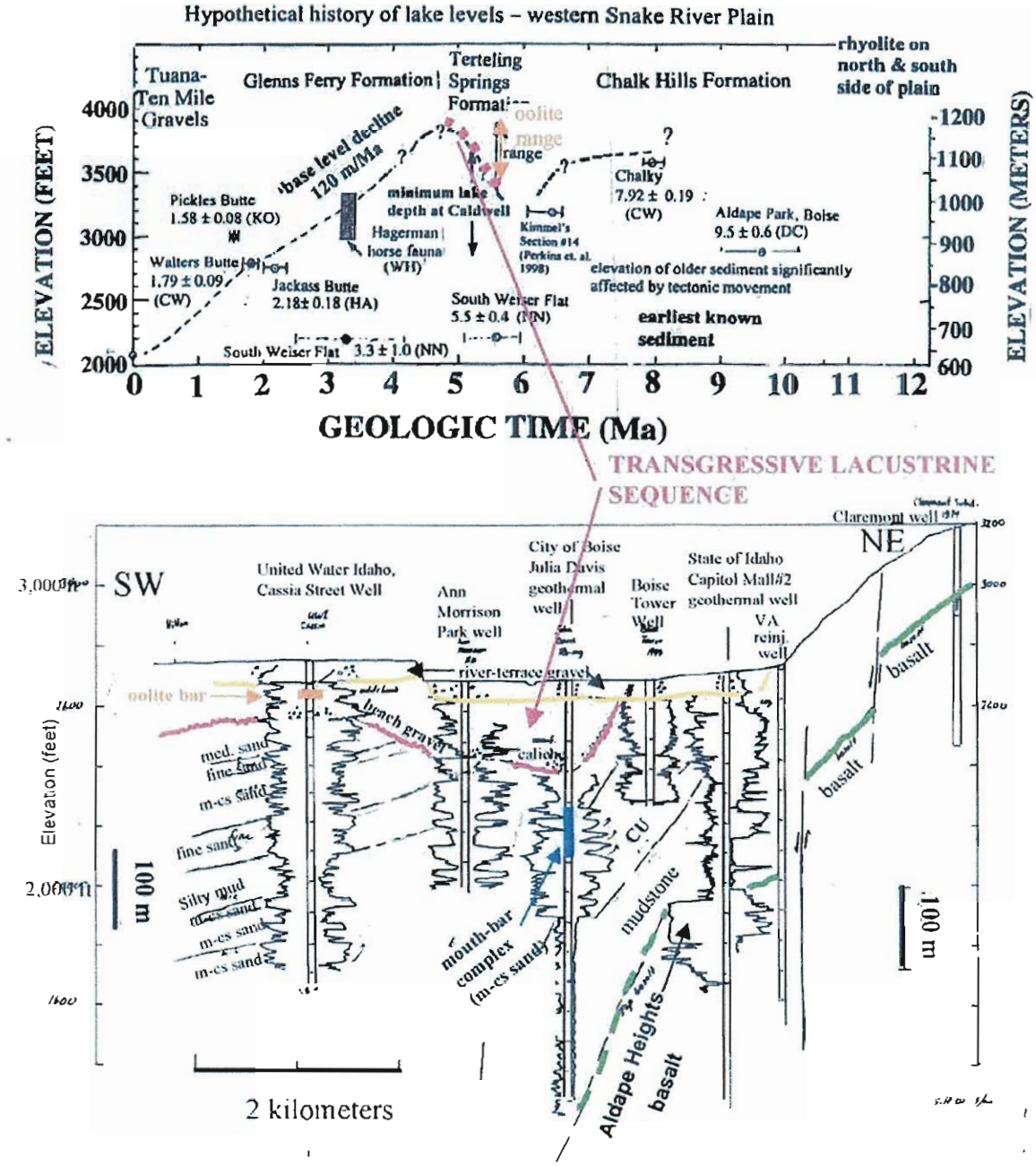


Figure 9. Correlation of strata in wells in a section from the Boise foothills (Claremont well, Boise Heights) to the Cassia Street Well. Basalt of Aldape Heights (9.5 Ma) shown in green. Mouth-bar complex of a sand delta deposited over mudstone shown in blue at the Julia Davis well. CU refers to coarsening upward sand layers, shown by small arrows. Dark pink line is an unconformity at about 2,400-ft elevation, indicated by Carbon-13 isotope analysis of caliche in the Julia Davis Well by Cavanagh (2000, p. 68-72). The unconformity surface is identified by occurrence of gravel in other wells, and is interpreted as the top of the **Chalk Hills Formation**. Sediment above the unconformity contains oolite, and is interpreted to be a part of the **Terteling Springs** Formation. Quaternary-aged terrace gravel shown in yellow. Hypothetical lake history corresponding to deposits is from Wood and Clemens (in press).

unconformity as the top of the Chalk Hills Formation. The deeper sand section in these wells on the north side of the Boise River all appear to be good aquifers down to at least 1,600 elevation; however, temperatures approaching 85°F below that level may preclude development for cold-water supply.

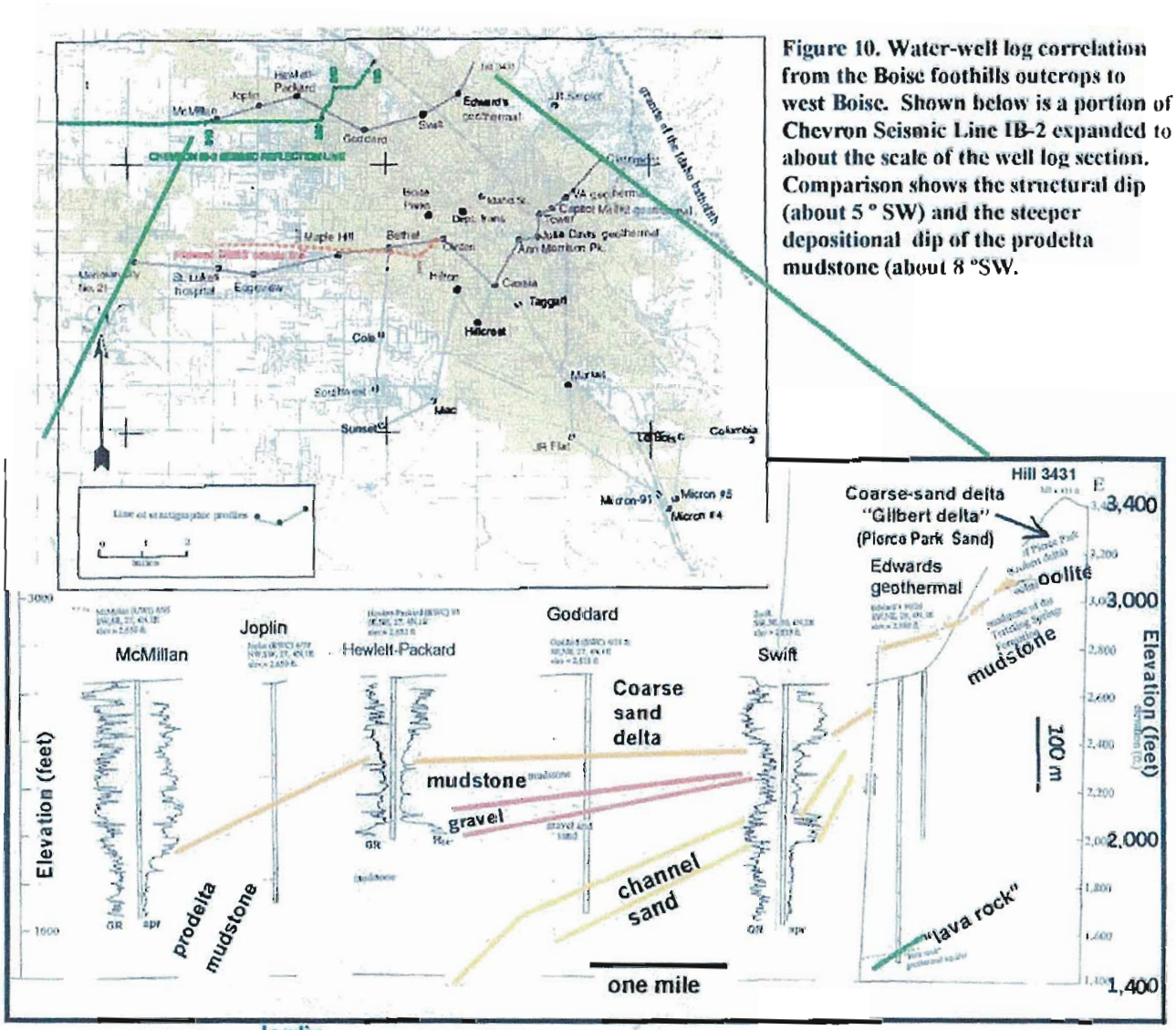
The unconformity is marked by a prominent gravel bed about 30 feet thick in the Cassia Well at elevation 2, 550 feet. This gravel correlates with gravel in the Ann Morrison Park Well and with the Julia Davis well. This gravel horizon is shown with a pink line in Figure 9. Cavanagh (2000, p. 68-72) discovered from examination of well cuttings and Carbon-13 isotopic analysis of carbonate that a soil caliche had developed in this gravel layer. This discovery shows that the lake had receded from this area at one time, and a soil formed upon a river-terrace gravel, or perhaps an abandoned beach gravel. Above this gravel, in the Cassia well, a 30-ft thick carbonate oolite sand containing gastropod fossils occurs as a coarsening upward layer at a depth of 110 feet (elevation about 2,670 ft.) These features are taken as evidence that rising lake water transgressed over this gravel and and laid down the upper 200 to 300 feet of mostly near-shore lake sediment of these wells. It is uncertain whether the erosional unconformity is in the Capitol Mall#2 well. It may warrant re-examination of the cuttings to see if it can be identified. No obvious correlative gravel is reported from that well or the recently drilled Tower well, suggesting that this gravel horizon was not deposited to the northeast, or has since been eroded by the downcutting of the Boise River Valley.

Gravel of the active floodplain of the Boise River is about 60 feet thick in the downtown Boise area of these wells, and so is the terrace gravel that mantles the Whitney Bench. The bases of both river gravels are shown in Figure 9 by a yellow line.

Although we do not have a good geochronology of the lake deposits beneath Boise, the major geologic events can be tentatively correlated with the proposed, albeit hypothetical lake history proposed by Wood and Clemens (in press). In this correlation, none of the deposits shown in the section of Figure 9 would be correlated with the Glenns Ferry Formation. The very thick sediment section beneath the transgressive sequence would be regarded as the Chalk Hills Formation. The overlying sequence would be the Terteling Springs Formation. To the north of here (Swift Well to McMillan Well) is a delta sequence that appears to correlate with the Pierce Park sand. The Pierce Park sand is believed to be correlative in time with the declining lake level and the Glenns Ferry Formation.

Discussion of E-W section from Swift Well to the McMillan Well (Figure 10)

The two Swift-well sand aquifers appear to correlate with the Hewlett-Packard well, almost straight across; however, the Chevron Seismic data shows the lower sand in Swift to have an apparent west dip of about 2°, and to lie at least 300 feet below the bottom of the Hewlett Packard well (Figure 10). Well-log character of the deeper aquifer sand in the Swift Well has an abrubt base, typical of a channel sand, and the grain size is medium-fine sand. That lower aquifer appears to correlate with the bottom sand aquifer in the Goddard well. However, information on that bottom aquifer in the Goddard well is limited to the 1968 driller's description (see Squires and others, 1992, p. 94). It is problematic that no major sand units occur in the up-faulted foothills section to the northeast, either in outcrop or in wells, that might correlate with the lower Swift well



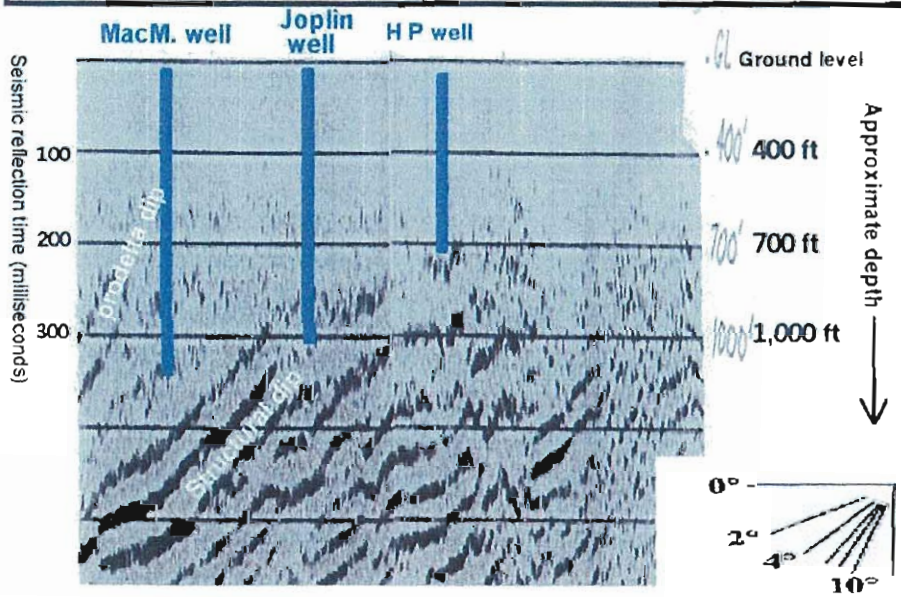


Figure 10. Water-well log correlation from the Boise foothills outcrops to west Boise. Shown below is a portion of Chevron Seismic Line IB-2 expanded to about the scale of the well log section. Comparison shows the structural dip (about 5 ° SW) and the steeper depositional dip of the prodelta mudstone (about 8 °SW.

aquifer. The nearby deep wells in the foothills (Hillside Jr. High, Quail Hollow Golf Course, and wells on the Terteling Stewart-Gulch properties) drilled mostly mudstone according to driller's logs. Possibly the section containing the lower Swift well aquifer sand has been eroded from the upthrown fault block, and for that reason it does not occur in the foothills. Alternatively the lower sand may be a channel deposit that simply was not deposited to the northeast.

One and one-half miles to the northwest of the Swift well, an 80-ft-thick coarse sand occurs in the UWID Gary Lane well below 350 feet of mudstone at a depth of 740 feet. In this well, the grain size is mostly 0.5 to 2 mm, and much coarser than the medium-fine sand reported for the lower Swift well aquifer. Otherwise, it appears to be a similar and possibly correlative sand. Three and one-half miles to the northwest of the Swift well is the Treasure Valley Hydrologic Project Monitoring Well #1 (TVHP#!) in which several medium-fine-grained sand beds occur beneath 300 feet of mudstone at a depth of 770 feet. Individual beds are 2 to 10 feet thick, and the sandy sequence is 120 feet thick (Dittus and others, 1997). Grain-size and depth are similar to the lower Swift well aquifer. The TVHP#1 well was not completed below 340 feet, so the hydraulic connection to the other two wells cannot be studied. All of these occurrences are probably along strike and indicate sand about 700 feet deep and 300 feet beneath a thick mudstone unit, suggesting they may correlate and be hydraulically connected.

Gravel occurs at about 2,100-ft elevation near the bottom of the Hewlett Packard well, but it does not occur in the Swift well. The Hewlett Packard well is situated about 6 miles basinward from the basin margin, therefore the gravel must represent a river or beach out in the basin at the time of deposition. Its absence in the foothills, requires that the gravel was not deposited there, or has been eroded from the section nearer the foothills. It is problematic that no gravel occurs in the Swift Well, but the "pink line" is projected east to show where an unconformity might occur in that well. "Red-colored" gravel is reported by the driller at a corresponding level in the Goddard well (see Squires and others, 1992, p. 94). We suspect the gravel in the Hewlett Packard well marks the top of the Chalk Hills Formation, which we represent by a pink line on the section (Figure 10). The mudstone above the gravel is tentatively correlated with the Terteling Springs Formation, deposited by the rising transgressive lake water. That mudstone, changes upward to the prodelta mud of a delta prograding basinward, discussed in the next paragraph.

In the foothills, and in all wells on the section depicted in Figure 10 is a clear signature of a delta prograding into the Basin. The delta signature on the logs the a funnel shape of side-by-side gamma and resistivity logs (Figure 4 B and D) seen in the Swift and Hewlett Packard wells above 2,350-ft elevation, and in the McMillan well above 1,900-ft elevation. The sand thickness and depth increase progressively to the west. The delta sand is coarse in the foothills, and the driller reported coarse sand in the depth interval 153 to 280 feet in the McMillan well.

Because this is the uppermost delta in the lacustrine sequence, we correlate it to the Pierce Park sand that crops out in the upper part of the foothills section west of Crane Creek. In the foothills, this unit is mostly foreset beds of coarse sand typical of the "Gilbert-type" of delta. Some foreset bed sets are 60 feet thick, and the sand unit as a whole is up to 250 feet thick in the foothills (Burnham and Wood, in press). This delta is then correlated by Wood and Clemens (in press) to the history of Lake Idaho. Since it is

the uppermost major delta in the section its deposition over mudstone, is explained as a prograding sand delta in response to the slow lowering of lake levels after Lake Idaho spilled over into Hells Canyon. In the lake history context, this uppermost delta should correspond to the upper part of the Glenns Ferry Formation of Malde and Powers (1962) and Reppening and others (1994) which crops out south and southeast of the Boise area along the Snake River

We feel fairly certain that there is a "long term" hydraulic connection in the sands of the upper delta sequence (Figure 10); however, local lenses of mudstone in that section may prevent short-term detection of well-drawdown responses. It may take months to decades for large drawdowns to propagate through this seemingly continuous section of interbedded sand and thin muds.

Other older sand deltas surely occur in the lacustrine section. For example in Figure 9, the lower sands in the upper 800 feet in the Julia Davis well are mouth-bar sands of a delta sequence over mudstone. However because this section is steeply dipping, this delta is much older than the upper 800 foot section of the McMillan well (Figure 10). In our interpretation the delta sands in the Julia Davis well are part of the much older Chalk Hills Formation.

Comments on structure

We did not re-interpret the structure along the two cross-sections; however the framework published by Squires and others (1992, their Figure 11) generally concurs with observations in this study. They show the Eagle-west Boise fault with 800 feet of offset between the Swift well and Goddard well using data available to them at that time. The 800-ft offset they show is the offset of the volcanic basement. The fault does not necessarily offset of the upper section. The aquifer section below 2000-ft elevation (about 700 ft deep) may be offset, but the Eagle-west Boise fault does not appear to significantly offset the upper delta sequence.

Squires and others (1992) also show the "foothills fault zone", just northeast of the Swift well. In our Figure 10, the base of the upper delta is shown as offset by 300 feet with respect to the foothills outcrops, however this elevation shift could also be due to tilting without significant faulting. It is likely that a major fault or fault system occurs between the Swift well and the Edwards geothermal well and that this fault offsets the deeper section. Lava rock is reported by the driller at elevation 1,500 ft in the 1926 well (Idaho Supreme Court Records, *Silkey vs. Teigs*, 1931) showing that the "volcanic basement is relatively shallow here (Figure 10). None of these geothermal wells have been logged by borehole geophysics, and we do not know whether the geothermal aquifer in this area is basalt or rhyolite.

Conclusions

In this study we have identified gravel layers, oolite beds, thick mudstone sequences, and thick delta sequences that appear to correlate with regional concepts of fluvial and lacustrine deposition as outlined by Wood and Clemens (in press). We are still uncertain how many gravel layers are in the section; however, occurrence of gravel layers out in the basin, several miles basinward from the basin margin is an indication that the lake level lowered several times and streams flowed over exposed lake beds and delivered gravel

away from the uplands. Some gravel may be beach gravel, and some may be channel or remnant terrace gravel; however, it had to be originally delivered to the site by a stream.

Our best evidence that a lake transgressed over the gravel is the occurrence of oolite sands in the shallow section of the Cassia, Taggert, and Cole wells (Figure 3 and 9). This section shown in Figure 9 also indicates that there may be topographic relief upon the tilted and eroded older section. This is also our best evidence that the sedimentary sequences shown in this profile (Figure 9) correlate to the Chalk Hills Formation and the overlying Terteling Springs Formation. We also conclude that the Pierce Park sand (correlative with the upper Glenns Ferry Formation) is absent from the section shown in Figure 9, but the Pierce Park Sand is the same sand as the upper delta sequence in the Swift, Hewlett-Packard, and McMillan wells shown in Figure 10.

Deeper sedimentary strata comprising the aquifer system have been tilted basinward (to the southwest, 2 to 11 degrees. The deeper strata are offset by faulting, but the amount of offset is known only where seismic data is available. The extent to which shallow parts of the aquifer system are faulted and tilted has not been determined, because the available petroleum-industry data was not focused on the shallow section (<600 feet) (see seismic section in Figure 10).

Eventually, the aquifer geometry can be determined accurately using high-resolution seismic reflection methods and continued diligence in obtaining borehole geophysical logs and cuttings examination of drilled water wells. We hope that this study provides a framework for future study.

Ackowledgements

The authors would like to thank United Water Idaho, Inc. for granting permission to use their well data. Roger Dittus was a great help in many aspects of this study. Terry Scanlon helped us with data from Idaho Dept. of Transportation, and City of Boise, and Micron wells. The study has benefited from discussions with Christian Petrich and Jon Hutchings of the Idaho Water Resources Research Institute and the Idaho Department of Water Resources. This study was supported by the Treasure Valley Hydrologic Project of the Idaho Department of Water Resources.

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Contribution to the Treasure Valley Hydrologic Project -1997

STRUCTURE CONTOUR MAP OF TOP OF THE MUDSTONE FACIES, Western Snake River Plain, Idaho

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August, 1997

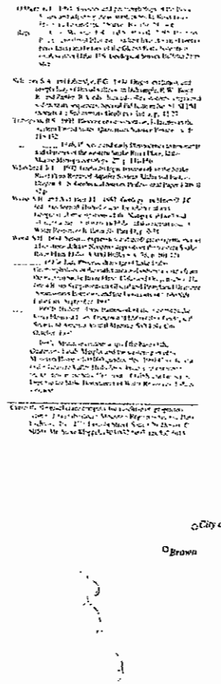
Boise Map Sheet, Idaho: Scale = 1:100,000
Elevations in feet with respect to sea level
Contour Interval = 100 feet (contours dashed where uncertain or lack of control)

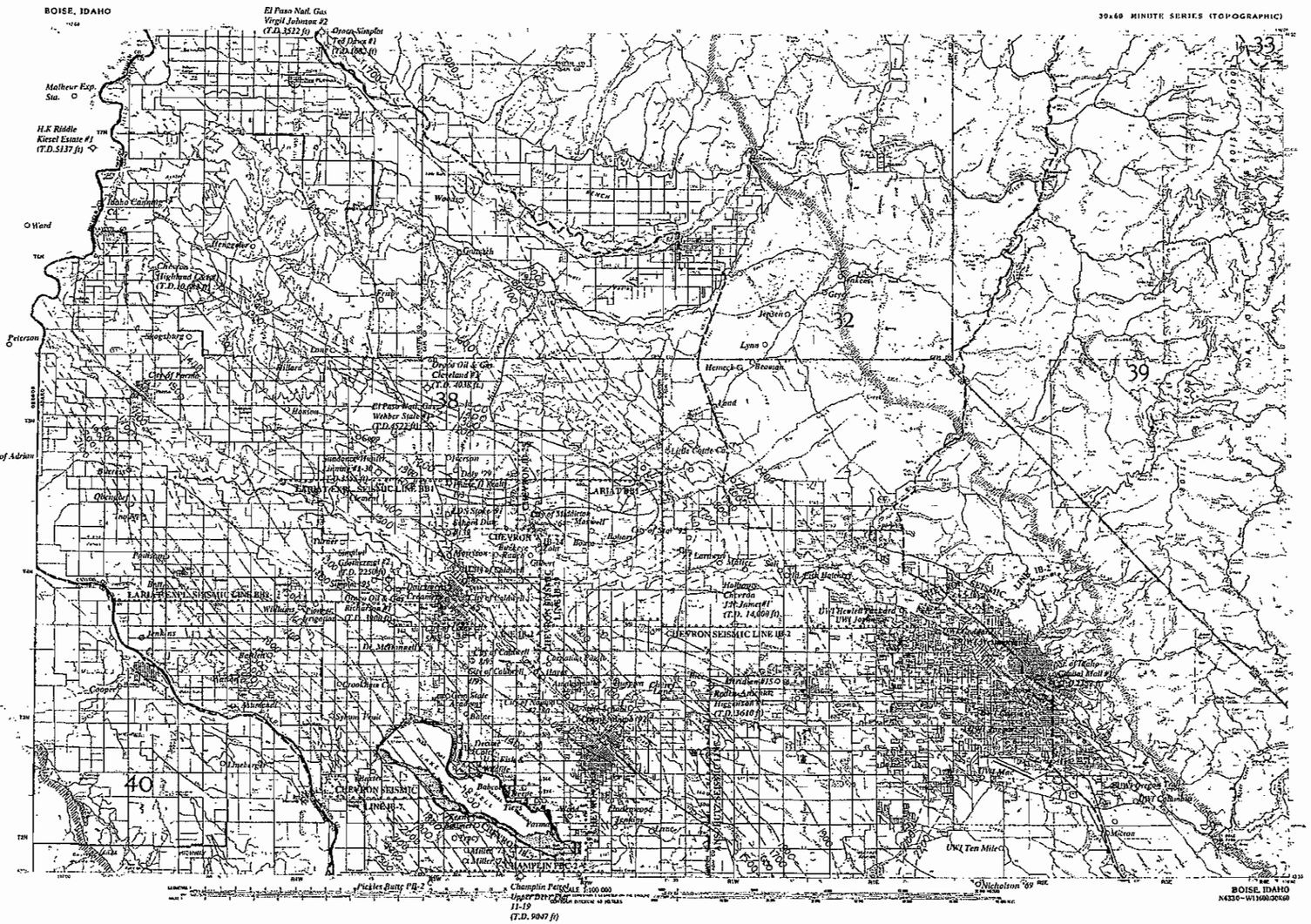
Doty '79 = deep water well used for control, giving name of owner listed on driller's log, and date of completion.

Oreco Oil and Gas Cleveland #1 (T.D. 4038 ft) = deep petroleum or geothermal exploration well, giving operator, lease name, and total depth

= edge of sedimentary basin

= approximate trace where contact is at the surface (i.e. the contact between the fluvial-deltaic section and the underlying mudstone skylights in the Snake River Canyon)




BOISE, IDAHO
30x60 MINUTE SERIES (TOPOGRAPHIC)
El Paso Natl. Gas Virgil Johnson #2 (T.D. 3522 ft)
Oreco-Simplot Ted Dixon #1 (T.D. 1980 ft)
Malheur Exp. Sta.
H.K. Riddle Kiesel Estate #1 (T.D. 5137 ft)
Idaho Canyons
Ward
Peterson
Boise
Meridian
Nampa
Caldwell
Parma
Greenleaf
Notus
Wilder
Homedale
Marsing
Oreana
Ola
Banks
Hillard
Sweetzberg
Cloverdale
Eagle
Star
Middleton
Middleton Heights
Sunset Peak
Lake Lowell
Lake Shore
Deer Flat
Lake Forest
Ridgecrest
Lake Hazel
Orchard
Gowen Field
Boise Air Terminal
Boise Municipal Golf Course
Boise Country Club
Quail Hollow Golf Course
Hillcrest Golf Course
Shadow Hills Golf Course
Warm Springs Golf Course
Table Rock
Morris Hill
Boise Front
Foothills
Dry Creek
Cottonwood Creek
Crooked River
Willow Creek
Jerry Creek
Jackson
Lynx
Hennock
Brough
Lynx Creek
Little Canyon Creek
Big Gulch
Big Willow Creek
Mores Creek
Mores Creek Summit
Idaho City
Placerville
Pioneerville
Centerville
Quartzburg
Grimes Pass
Grimes Creek
Robie Creek
Robie Creek Reservoir
Arrowrock Reservoir
Arrowrock Dam
Lucky Peak
Lucky Peak Dam
Lucky Peak Lake
Lucky Peak Reservoir
Diversion Dam
Barber Park
Barber Pool
Eckert
Gowen
Orchard
Cole
Overland
Federal Way
Gowen Field
Boise Air Terminal
Ustick
Meridian
Kuna
Swan Falls
Swan Falls Dam
Snake River
Oreana
Ola
Banks
Horseshoe Bend
Hulen Meadows
Lowman
Grandjean
Garden Valley
Crouch
Lowman
Centerville
Pioneerville
Idaho City
Plac

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Seismic Expression and Geological Significance of a Lacustrine Delta in Neogene Deposits of the Western Snake River Plain, Idaho[1]

Spencer H. Wood[2]

ABSTRACT

High-resolution seismic reflection profiles and well data from the western Snake River plain basin are used to identify a buried lacustrine delta system within Neogene Idaho Group sediments near Caldwell, Idaho. The delta system is detected, 305 m (1000 ft) deep, near the center of the basin by progradational clinoform reflections having dips of 2–5°, a slope typical of prodelta surfaces of modern lacustrine delta systems. The prodelta slope relief, corrected for compaction, indicates the delta system prograded northwestward into a lake basin 255 m (837 ft) deep. Resistivity logs in the prodelta mud and clay facies are characterized by gradual upward increase in resistivity and grain size over a thickness of about 100 m (300 ft). Lithology of the prodelta is mostly calcareous claystone, with several layers of fine sand, some of which fine upward, indicating a density-flow mechanism of transport and deposition. Delta-plain and front sediments are mostly very fine-grained, well-sorted sand separated by thin mud layers. These sediments produce several to five cycles of horizontal, high-amplitude reflections with a toplap relationship to prodelta clinoforms. The sands have an abrupt lower contact with prodelta muds and have high resistivity on logs. In this study, permeable lacustrine sands within a predominantly mud and clay section are located by using high-resolution seismic reflection data.

Identification of a delta system in the Idaho Group provides insight into the history of Pliocene "Lake Idaho." The present depth of the delta/prodelta facies contact of 305 m (1000 ft) is 445 to 575 m (1460–1900 ft) below the lake deposits on the margins. Estimated subsidence from compaction is 220 m (656 ft), and the remaining 225 to 325 m (740–1066 ft) is attributed to tectonic downwarping and faulting.

The original lake area had been reduced to one third of the original 13,000 km² (5000 mi²) by the time the delta front prograded to the Caldwell area. The original lake area may have been sufficient to evaporate most of the inflow, and the lake may have only occasionally spilled into other basins. Diminished area for evaporation later in the history of the lake, combined with reduced evaporation accompanying onset of the ice ages, may have caused the lake to rise and overtop a basin sill about 2 Ma, and subsequently deepen Hells Canyon.

INTRODUCTION

Lacustrine deposits in rift basin environments have become major petroleum exploration targets in many parts of the world (Katz, 1990). Likewise, important groundwater resources are exploration targets in lacustrine sediments. Exploration methods are needed to identify facies of permeable strata within thick sections of impermeable mud rocks characteristic of lacustrine deposits because these permeable strata may be hydrocarbon reservoirs or freshwater aquifers. Recognition of clastic depositional systems and permeable facies on seismic reflection sections in the marine environment has been advanced by the work of Mitchum et al. (1977), Sangree and Widmier (1977), and Berg (1982). This study illustrates the seismic expression and well-log character of a fine-sand delta facies within lacustrine clay and mud deposits of the Neogene western Snake River plain, and compares its geometry with lacustrine deltas studied elsewhere in the world.

With the exception of a study of the Paleocene Fort Union Formation of Wyoming by Liro and Pardus (1990) and Quaternary Lake Biwa, Japan (Ikawa,

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[1]Manuscript received, April 8, 1991; revised manuscript received, May 13, 1993; final acceptance, August 11, 1993.

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This study was made possible through the donation of seismic data to Boise State University by David Hawk. His continued help and encouragement in this study is greatly appreciated. J. K. Applegate provided information on the original acquisition and processing of the data. The author thanks Ed Squires of Boise State University, employees of J. R. Simplot Co., Vaughn Thomas Drilling Co., and COLOG, Inc. for their help in acquiring drilling, logging, and production data, and John Armentrout for a most helpful review of the manuscript. This study was partly supported by Idaho State Board of Education Grant 91-099, Center for Geophysical Investigation of the Shallow Subsurface Contribution 0024.

Table 1. Comparison of Settings of Lacustrine Deltas*

	[Delta Area] Lake Area (km^2)	River Drainage Area (km^2)	Average Annual Discharge (10^9 m^3/yr)	Annual Suspended Load (10^6 m^3/yr)	Annual Bedload (10^6 m^3/yr)	Basin Origin	Latitude
Lake Constance Rhine River (Bodensee) Switzerland	[6+] 600	6122	6.95	2.57	0.04	Würm-age glaciated basin	temperate
Pyramid Lake Truckee River Nevada, USA	[20] 428	4785	0.72 0.26**	0.1	?	tectonic, lake level lowered, eroded and rebuilt delta	temperate 40° N
Lake Laitaure Sweden	[10] 9	684	6.3	0.24	0.04	glaciated	arctic 67°N
Lake Maracaibo Catatumbo River Venezuela	[1200] 12,900	15,000	29	4.8		broad tectonic subsidence	tropical 10°N
Neogene Lake Idaho (Snake River) Idaho, USA	13,000†	180,000†	16††	11††	0.4-1.1††	tectonic, subsidence & faulting	temperate 44°N

*References: Lake Constance = Müller, 1966; Pyramid Lake = Born, 1972; Lake Laitaure = Axelsson, 1967; Lake Maracaibo = Hyne et al., 1979.

**Discharge after diversion of the Truckee River for irrigation. Much of the modern delta was built after diversion in the early 20th Century.

†Original lake area taken from distribution of Idaho Group sediments. Position of the buried delta discussed in this paper suggests the floodplain occupied about two thirds of the basin, and the lake about one third or 4300 km^2. Discharge of the modern Snake River at Weiser, Idaho, 70-year average (from Kjelstrom, 1986).

††Sediment loads measured at Lewiston, Idaho are the only available measurements (from Seitz, 1976). Bedload (>0.2mm caught in bed-load sampler) ranges from 5 to 10% of the suspended load. This reach of the river is below Hells Canyon, and the river is impounded by a series of hydroelectric dams about 100 km above here; therefore, these measurements may not be representative of sediment load in Neogene time.

1991), little has been published that relates seismic stratigraphy of lacustrine deposits to their subsurface geology. Most of the literature is concerned with outcrop-scale features (Fouch and Dean, 1982). Comparison to studies of the seismic expression of marine delta systems, particularly the paper by Berg (1982) was most useful for interpretation in the present study. The few studies of modern lacustrine deltas cited in Table 1 are helpful in understanding facies distributions in these environments, but research that incorporates shallow subsurface studies to understand the facies geometry of modern lacustrine environments is clearly needed.

REGIONAL SETTING

The western Snake River plain basin is a normal-fault–bounded intermontane basin between the northern Rocky Mountains province and the northern Basin and Range extensional province. The plain is underlain by a sequence of up to 2 km (6000 ft) of lacustrine and fluvial sediment of the Idaho Group (Wood and Anderson, 1981). The history of deposition and facies distributions within this section of strata have not been previously studied. High-resolution seismic reflection profiles combined with geophysical logs and well-site study of cuttings provide an opportunity for interpretation of the Neogene subsurface geology near Caldwell, Idaho (Figures 1, 2).

The western plain basin is a northwest-trending graben-form tectonic basin that evolved after voluminous rhyolite volcanism (16–9 Ma) on the south side of the present basin, and after voluminous Columbia River basalt volcanism (17–14 Ma) on the north side (Leeman, 1989; Wood, 1989a). Tectonic setting of the Columbia River flood basalts is reviewed by Hooper and Conrey (1989). Tectonic setting of the rhyolite systems has the appearance of a northeast-migrating continental hot spot (Armstrong et al., 1975; Rodgers et al., 1990; Pierce and Morgan, 1992). Brott et al. (1981) hypothesized that cooling of the lithosphere

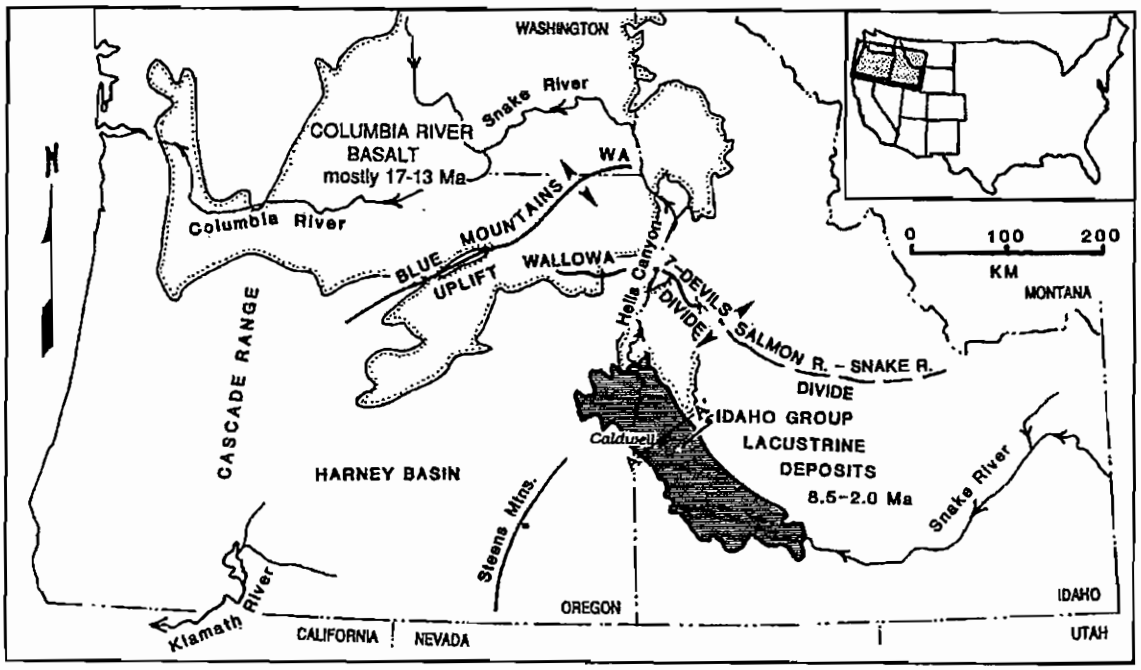

Figure 1—Index map showing distribution of Neogene Idaho Group lacustrine deposits in the western Snake River plain, location of physiographic features and drainages influencing the Neogene lakes that occupied the western plain region, and distribution of Columbia River basalt, shown by dotted line. Accumulation of Columbia River basalt in the early Neogene and subsequent broad uplift of the Blue Mountains and Wallowa–Seven Devils Mountains formed a barrier to northern drainage of the Snake River system. Outlet of the lake system may have been southwest through Harney Basin. Other workers have suggested connection to the Klamath River system of northern California. AA' is location of cross section shown in Figure 3.

after passage of the hot spot produced the downwarp structure of the eastern Snake River plain. Although the eastern and western parts of the Snake River plain form a continuous physiographic lowland, the eastern plain is a southwest-trending downwarp without major fault boundaries, whereas the northwest-trending western plain is clearly a graben form with normal fault boundaries. The fault boundaries parallel other extensional features that formed perpendicularly to the hot spot track.

Middle Miocene volcanic rocks form an acoustic basement about 2 km beneath the deepest part of the western plain basin (Figure 3). Sporadic olivine-tholeiite basalt volcanism has continued through the Neogene and Quaternary from vents of a north 70° west trending volcanic zone that traverses the western plain, and from vents on the margins (Wood, 1989b). Minor amounts of these basalts are intercalated with the sedimentary fill of the western plain. The eastern plain is largely covered with Pliocene and Quaternary basalts, which erupted from N40°W trending volcanic rift zones (Kuntz et al., 1992), with accumulations that are locally 1000 m (3280 ft) thick.

Because of its large size and graben structure the western plain basin has been called a tectonic continental rift. The western plain basin meets the definition of a tectonic rift in that it is a "long, narrow continental trough that is bounded by normal faults, a graben of regional extent" (Bates and Jackson, 1980). The structural geometry is similar to other continental rift basins described by Bosworth (1985). The buried horst block in the center (Figure 3) is interpreted to be an interbasinal ridge or an extension transfer zone (using terminologies of Rosendahl et al., 1986; Morley et al., 1990) between half-graben structures formed during early basin evolution. Areal extent of the horst is indicated by a +20 mGal gravity anomaly outlined by the dotted line in Figure 3. Structural dip of the margin fault blocks and infilling sediment toward the center of the basin suggest the lithosphere has more recently undergone extension and necking that create negative buoyancy of the basin, and broad subsidence of the center of the basin in a manner suggested by Braun and Beaumont (1989). Some components of the dip of the sediments and subsidence of the center of the basin, however, are because of com-

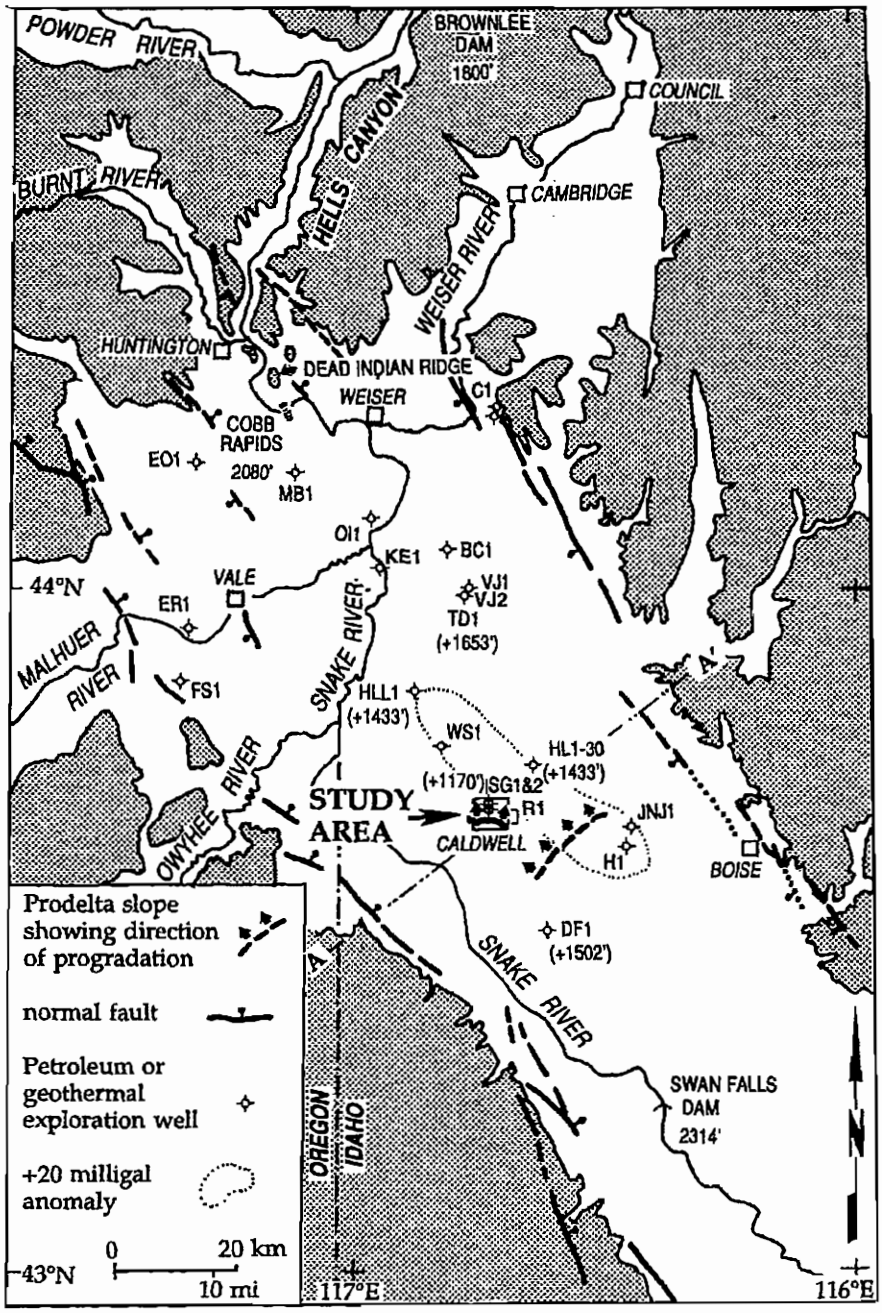

Figure 2—Map of western Snake River plain showing location of study area of Figure 5. Map shows position and progradation direction of the lacustrine delta system in the Pliocene interpreted from this study and from a previous study by Wood and Anderson (1981). Numbers in parentheses are the present elevations (in feet above sea level) of the prodelta/delta-front transition identified on well logs. Names of deep wells examined for this relationship are listed in Table 2. AA' is the line of section shown in Figure 3. Dashed line enclosing northwest-southeast–trending oval area north of Caldwell is a +20 mGal gravity-anomaly expression of the buried horst shown on the cross section of Figure 3.

paction of the thick accumulation of fine sediment in the center of the basin.

The basin contained large freshwater lakes and river systems from about 8.5 to 2.0 Ma and filled with predominantly fine siliciclastic sediment and minor intercalated pyroclastic and flow basalt layers. Numerous earlier papers summarized in Wheeler and Cook (1954) and Jenks and Bonnichsen (1989) alluded to a large Pliocene lake in the western plain, commonly referred to as Lake Idaho, but little is

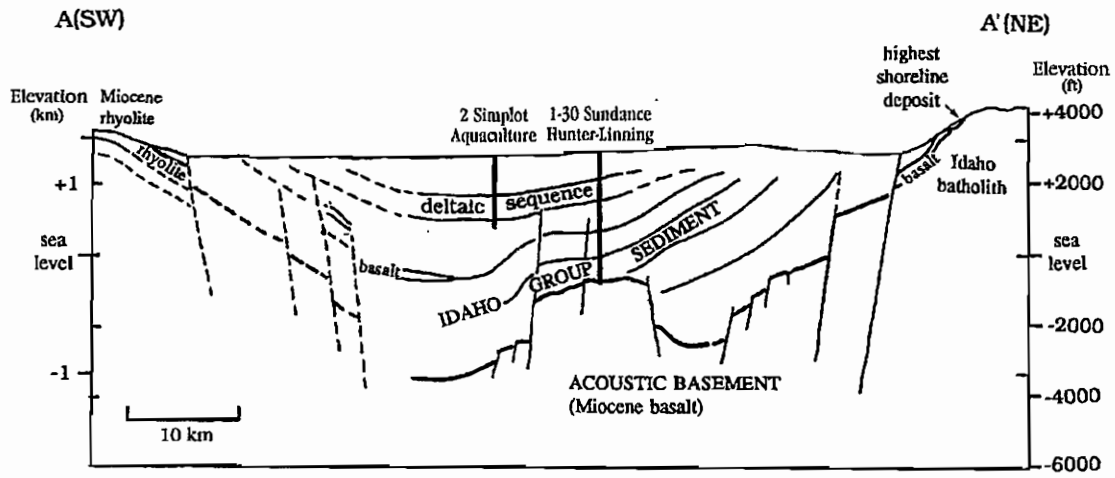

Figure 3—Structural features of the western plain in an exaggerated vertical-scale cross section showing position of the deltaic sequence discussed in this paper. Location of section is shown in Figure 2. Cross section shows that the plain has continued to subside since the progradation of delta sequence. Basis for section is seismic reflection data reported by Wood and Anderson (1981). Dashed contacts where seismic data are not available are inferred from geologic mapping.

known of the history of lake systems. Discontinuous lacustrine shoreline deposits typically occur up to about 975 m (3200 ft). Higher deposits such as 1128 m (3700 ft) in the foothills on the north side of the basin (Gallegos et al., 1987) and 1036 m (3400 ft) on the south side of the basin (Smith et al., 1982) may have been elevated by faulting. Although the oldest lake deposits in the graben are clearly downfaulted one or more kilometers from their remnants in the margin foothills, evidence for the highest lake levels remarkably occurs on both sides of the basin at similar elevations (1000 ± 130 m). These elevations suggest relatively little differential vertical movement of the basin margins since the last high-lake level. Apparently, the graben subsided by downwarping and minor normal faulting, with minor flank uplift during the late Neogene and Quaternary.

At its maximum extent, the sedimentary basin covered about 13,000 km², judging from distribution of thick, fine-grained sediments and shoreline deposits (Figure 1). The drainage basin delivering water to the lake may have been similar in size to the present upper Snake River catchment (above Weiser, Idaho), which is 175,000 km². Some have speculated that in the Neogene the lake basin drained through southeastern Oregon to the Klamath River system in northern California (Figure 1) (Wheeler and Cook, 1954; Taylor, 1960, 1985; Smith, 1975; Smith et al., 1982). Physical evidence for such an outlet through the Great Basin has not been found; the evidence is mainly paleozoological affinities of fossil mollusks and fish in lacustrine deposits of the western plain (Smith, 1981). Wheeler and Cook (1954) proposed that the downcutting of ancestral Hells Canyon through the Blue Mountains and the Wallowa–Seven Devils structural arches caused capture of the Snake River basin by the Columbia River drainage system. Surficial deposits of fluvial gravel deposited over the lake sediments mark the conversion of the basin from an aggrading lacustrine and fluvial basin to an eroding stream system (Malde, 1991; Othberg, 1992; Othberg and Sanford, 1992). This enormous diversion of Snake River basin waters caused further downcutting of Hells Canyon, now the deepest gorge in North America. The Snake River is now incising its lacustrine deposits in the western plain basin.

STRATIGRAPHY OF BASIN FILL

Stratigraphy of the basin fill has been developed from the study of dissected deposits, mostly on the southwest margin of the plain. A diagram of lithostratigraphic units published by Malde and Powers (1962) is shown in Figure 4. Much of the mud, silt, and clay in the upper 1000 m of the basin fill could be called mudrock, mudstone, siltstone, and claystone, because, in a geological sense, they are mostly soft friable rocks. In a geotechnical sense these materials fall to both sides of the definition of rock [unconfined compressive strengths above 1500 kN/m² (200 psi); in other words, materials that can-

AGE (Ma)	SERIES		GROUPS AND FORMATIONS (typical lithology)	GEOCHRONOLOGY	THICKNESS (ft)
	PLEIS-TOCENE		SNAKE RIVER GROUP & BRUNEAU FORMATION (basalt lava, river-terrace and lava-dammed-lacustrine deposits)	0.11 to 2.1 Ma (K-Ar)4, (Ar-Ar)5	0-1000
1.8 –					
	PLIOCENE	NEOGENE IDAHO GROUP	TEN MILE GRAVEL (fluvial gravel)		0-70
			GLENNS FERRY FORMATION (lacustrine & fluvial sediment, minor basalt)	1.8 & 1.9 Ma (f) 2.4 Ma (f) 3.5 Ma (K-Ar)1 3.75 Ma (fz)	3000+
5.0 –			CHALK HILLS FORMATION (lacustrine & fluvial sediment, silicic volcanic ash, minor basalt)	5.0 Ma (f) 6.5 Ma (f) 8.4 Ma (K-Ar)1	300+
	UPPER MIOCENE		POISON CREEK FORMATION (tuffaceous sediment, arkosic sand, minor basalt)		400+
			IDAVADA VOLCANIC GROUP (rhyolite flows and tuffs)	9-12 Ma (K-Ar)1&2	0-3000+
			COLUMBIA RIVER BASALT GROUP (NORTH SIDE OF PLAIN) (basalt lavas and minor sediment)	14-17.5 Ma (K-Ar)3	0-9000+
			SUCKER CREEK FORMATION & SILVER CITY RHYOLITE (SOUTH SIDE OF PLAIN) (tuffaceous lacustrine and fluvial sediment, rhyolite and basalt)	15-17 Ma (K-Ar)2	0-2300+
24.0 –					

Figure 4—Neogene stratigraphy of the western Snake River plain near Caldwell, Idaho, after Malde and Powers (1962), Wood and Anderson (1981), Middleton et al. (1985), and Kimmel (1982). f = fission track (glass) from Kimmel (1982); fz = fission track (zircons in glass) from Izett (1981); (K-Ar)1 = potassium-argon ages from Armstrong et al. (1975; 1980), (K-Ar)2 = ages from Ekren et al. (1981, 1984); (K-Ar)3 = ages from Fitzgerald (1982); (K-Ar)4 from Malde, 1987; (Ar-Ar)5 from Othberg and Stanford (1992).

not be crushed between one's fingers (e.g., Sowers, 1979, p. 3)]. The rocks or sediments generally yield good cuttings from rotary wells, but they will be referred to only by their sediment names unless indurated by cementation or calcite recrystallization to the extent that they are no longer friable. The Miocene Poison Creek Formation is defined as a clastic and volcaniclastic unit lying unconformably on the Idavada rhyolites. The formation is mostly silicic volcanic ash, fine-grained tuffaceous material in massive beds with some beds of locally cemented arkosic sand and gravel, and some basaltic pyroclastic beds. The Chalk Hills Formation is a silt and sand unit with numerous thin layers of fine silicic ash. The Pliocene-aged Glenns Ferry Formation is the thickest and most widespread of the exposed deposits. At its type locality along a 25-mi reach of the Snake River near Glenns Ferry, Malde (1972) described 660 m (2000 ft) of section of flood-plain and lacustrine facies. The fluviatile facies is described as thick, evenly layered beds of drab, very pale brownish-gray sand and some silt. Among the layers of gray and brown sand and silt are some beds of olive silt, dark-olive clay, and paper shale, which are characteristic of the flood-plain facies. The lacustrine facies is described as dominantly massive layers of tan silt that form drab monotonous outcrops having little lithologic variety but marked by faint, diffuse, gray bands arranged parallel to bedding and spaced several feet apart. Neither vertical nor lateral facies distributions of the basin fill have ever been studied on a basin-wide scale. In the Caldwell area of the present study, similar muds, silts, and sands occur to a depth of about 365 m (1200 ft), below which the section is dominantly calcareous claystone with minor sand layers to a depth of at least 670 m (2200 ft). Surprisingly, the section described by Malde (1972) contains only minor claystone and carbonate, whereas in the subsurface to the west, calcareous claystone is the dominant lithology. In the present study, seismic sections combined with examination of cuttings and geophysical logs from an area near Caldwell (Figures 5, 6, 7) give a clearer picture of depositional features than the study of outcrops has

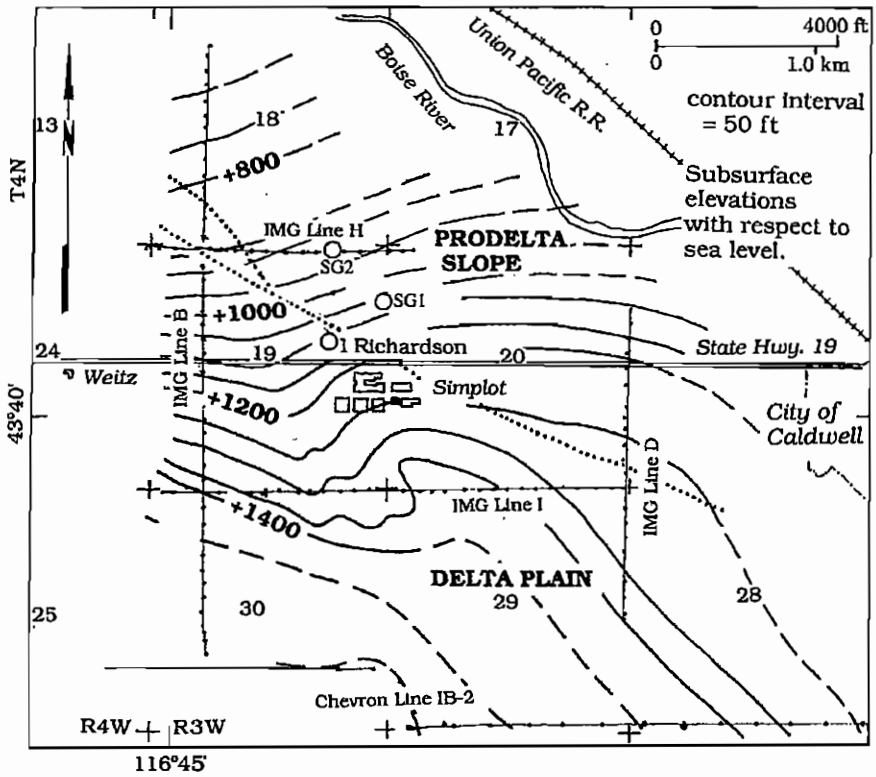

Figure 5—Location map of Caldwell study area showing structure contours of a reflecting horizon. Mapped reflector is shown on the interpreted section at about 0.5 s on IMG Line H (Figure 6b) as a heavy line within the prodelta clay facies. Configuration of the reflector is considered a depositional surface (i.e., not tectonically deformed) passing northward from the delta plain to the prodelta slope environment. Dotted line with a northwest-southeast orientation is the trace of the fault on the contoured surface. Displacement appears to be less than 17 m (50 ft) on the contoured surface. SG1 and SG2 are Simplot Aquaculture 1 and 2 Simplot Geothermal wells. IMG Lines I and D, and Chevron Line IB-2 used to construct this map, are not published in this paper. Base map is the Caldwell, Idaho quadrangle.

given. In particular, a large northwestward-prograding delta system is identified in the subsurface, about 305 m (1000 ft) deep beneath the middle of the plain near Caldwell, Idaho.

PETROLEUM AND GEOTHERMAL EXPLORATION RESULTS

A number of petroleum and geothermal exploration wells (Table 2) have drilled the Neogene lacustrine deposits and the deeper Miocene volcanic and sedimentary rock beneath the western Snake River plain (Figure 2). Earlier results are reviewed by Kirkham (1935) and Newton and Corcoran (1963), and geothermal aspects of recent drilling have been reviewed by Wood and Anderson (1981) and Blackwell (1989). Many early wells had hydrocarbon gas shows in the sandy strata. Several uncontrolled blowouts and gushers either sanded up or depleted gas in the reservoir within a few days (Kirkham, 1935). Controlled formation tests in several wells drilled since 1950 produced low flows (50–350 mcf/day), but these flows also dwindled within a few days or less (Newton and Corcoran, 1963). Sanyal et al. (1980) and GeothermEx, Inc. (1980) report significant gas on the mud log of the Ore-Ida Foods 1 Ore-Ida well from the section above 2195 m (7200 ft). Possible high-gas saturation from the interval 2106 –2137 m (6910–7010 ft) is interpreted from geophysical logs by Sanyal et al. (1980). No production has been established in the basin, and as Deacon and Benson (1971) concluded, test results thus far indicate low-volume reservoirs of gas.

Dry cuttings samples from the deepest wildcat well (Halbouty-Chevron 1 J. N. James) were studied by Geochem Laboratories, Inc. (unpublished data) for prospective source rocks. Ten sample intervals of fine sediment having the highest total organic carbon content ranging from 0.43 to 1.95% were examined. Organic matter type in the kerogen concentrate is predominantly woody material with secondary amounts of herbaceous spore pollen and tertiary inertinite, indicating the sediments are potential source rocks for gas but not for liquid hydrocarbons. Samples from 300 to 640 m (1000–2100 ft) (Pliocene Idaho Group sediments) are considered thermally immature based on the greenish light-yellow to orange-brown coloration of recognizable plant cuticle contained in the kerogen concentrate. Samples

from the interval 1170–2650 m (3840–8700 ft) (sediments from below the acoustic basement interface shown in Figure 3) are interpreted as thermally mature based on orange-brown to dark-brown coloration of recognizable plant cuticle kerogen (stage 2+ to 3 alteration). Only two wells (Halbouty-Chevron 1 J. N. James and Champlin Petroleum 1 Deer Flat) have penetrated this deeper section. Questionable solid hydrocarbon material was found in the Halbouty-Chevron 1 J. N. James well, and successful drill-stem testing could not be done on the prospective zones in the Champlin Petroleum 1 Deer Flat well.

Geothermal gradients in the western plain basin are relatively high, ranging from 30 to 40°C/km (16.5–22°F/1000 ft) (Wood and Anderson, 1981; Blackwell, 1989). Several exploratory wells were drilled for geothermal water in the 1980s (Table 2), but significant water production has been 74°C (165°F) or less. The present study is based on data from a geothermal aquaculture project.

In the study area near Caldwell, Idaho (Figure 5), Oroco Oil and Gas Co. drilled the 1 Richardson wildcat well in 1955 to a depth of 926 m (3036 ft). A production test of the lower 50-ft interval initially flowed methane at 50 mcf/day, but rapidly dwindled to a low flow (Newton and Corcoran, 1963). The well currently produces artesian geothermal 40°C (105°F) water that flows at a rate of 3.1 L/s (50 gal/min), and has a surface shut-in pressure of 0.17 MPa (24 psi). The well is presently obstructed below 769 m (2524 ft). A temperature log to that depth shows a temperature of 64°C (148°F), and flow of geothermal water entering the well through several places where the casing was broken by explosives.

To support a geothermal aquaculture operation in the same area, in 1988 the J. R. Simplot Co. completed a 342-m (1120 ft) well (G1 on Figure 5) into a fine sand aquifer, with an artesian flow of 39°C (101°F) water at a rate of 25 L/s (400 gal/min) and a shut-in well-head pressure of 0.22 MPa (32.5 psi). In 1989 a second well (G2 on Figure 5) was drilled to 686 m (2250 ft) to explore the deeper and hotter sands indicated on the original logs of the Oroco 1 Richardson well, but drilling difficulties prevented completion of the well. Examination of rotary cuttings from these wells now allows lithologies to be associated with the reflections on the seismic sections and the character of the geophysical logs.

SEISMIC STRATIGRAPHY

The emphasis of this paper is on the interpretation of a clinoform structure on seismic sections, illustrated in Figure 6, that is now buried 305 m (1000 ft) beneath the plain. The upper 0.7 s (approximately 760 m or 2500 ft) of high-resolution seismic records show three distinct seismic facies units. These units will be described in terms of seismic facies shown best in Figure 6a and then calibrated to geological data from boreholes.

The uppermost unit (unit 1) contains four high-amplitude, continuous reflections, each separated by low-amplitude or reflection-free intervals about 0.04 s (43 m or 141 ft) thick. The basal reflections of this unit are inclined northward from 0.24 to 0.31 s (about 250 to 300 m or 800 to 1000 ft). Strong reflections are continuous over 300 to 500 m (985–1640 ft), and their terminations generally overlap by 150 m (492 ft) with an adjacent, continuous, strong-amplitude cycle. Some strong reflectors show subtle low-angle onlap to the south with underlying reflections.

The next unit (unit 2) is typically four or five adjacent cycles of strong-amplitude reflections, which are continuous for about 1 km. The upper reflections overlap, climb in elevation to the south, and generally terminate to the north and east into the basal reflection-free interval of unit 1. The lower reflections of unit 2 are the upper topset segment of a complex sigmoid-oblique progradational reflection configuration (using terminology from Mitchum et al., 1977, p. 125). This unit has the highest amplitude reflections on the profile, and is about 0.05 s (50 m or 165 ft) thick.

Below unit 2 are the clinoform reflectors of the progradational reflection configuration with a 5° depositional dip to the northwest. This interval is labeled unit 3 on Figure 6a. These clinoforms have mostly oblique toplap relationships with the topset reflectors of unit 2, although some may be crudely sigmoid. The upper clinoforms segments are less than 400 m (1312 ft) long. Amplitude of the clinoform reflections in this unit (unit 3) varies from strong, where the unit is thin in the south, to very weak, where the unit thickens to the north and west. The lower segments of the clinoforms as they flatten are continuous for about 1.2 km (1 mi), and some have relatively high amplitude. The lower segments have a downlap relationship to underlying reflectors of lesser dip.

Below unit 3 are reflectors with low dips to the north, which are probably the distal ends of the progradational configurations. The reflections appear to have high amplitude and ringing of lower frequency wavelets, partly as a result of the natural loss of high-frequency content and partly as a result of the data processing parameters that emphasize resolution in the upper section.

LITHOLOGY AND LOG EXPRESSION OF SEISMIC FACIES UNITS

The Simplot Aquaculture 2 Simplot Geothermal well (G2 on Figure 5) was drilled through the stratigraphic interval of seismic facies units 1, 2, and 3.

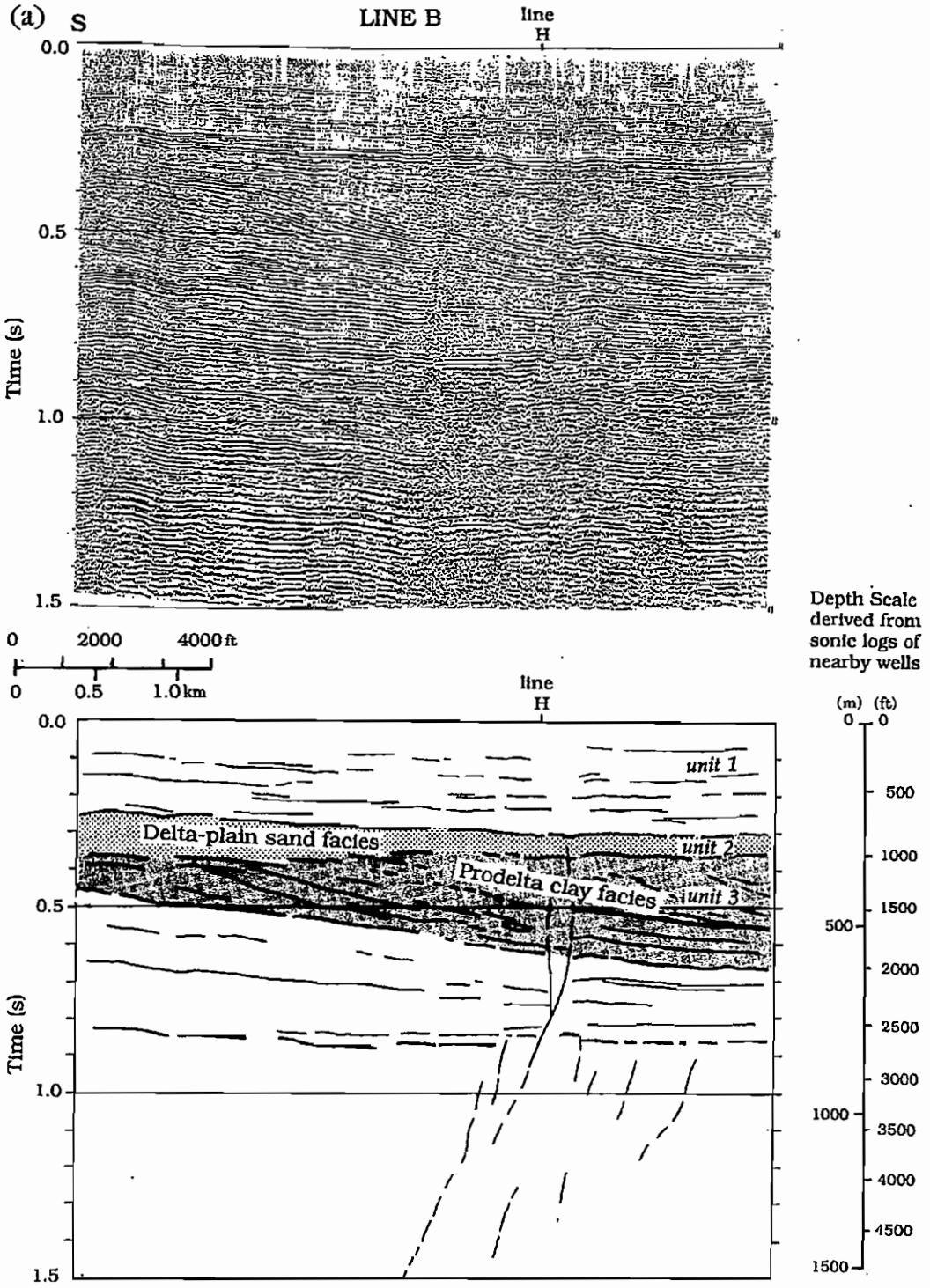

Figure 6—High-resolution seismic sections of IMG lines B and H (unmigrated). Location of lines shown in Figure 5. Datum is 762 m (2500 ft) above sea level. Elevation of ground level along lines is between 707 and 728 m (2320 and 2390 ft).

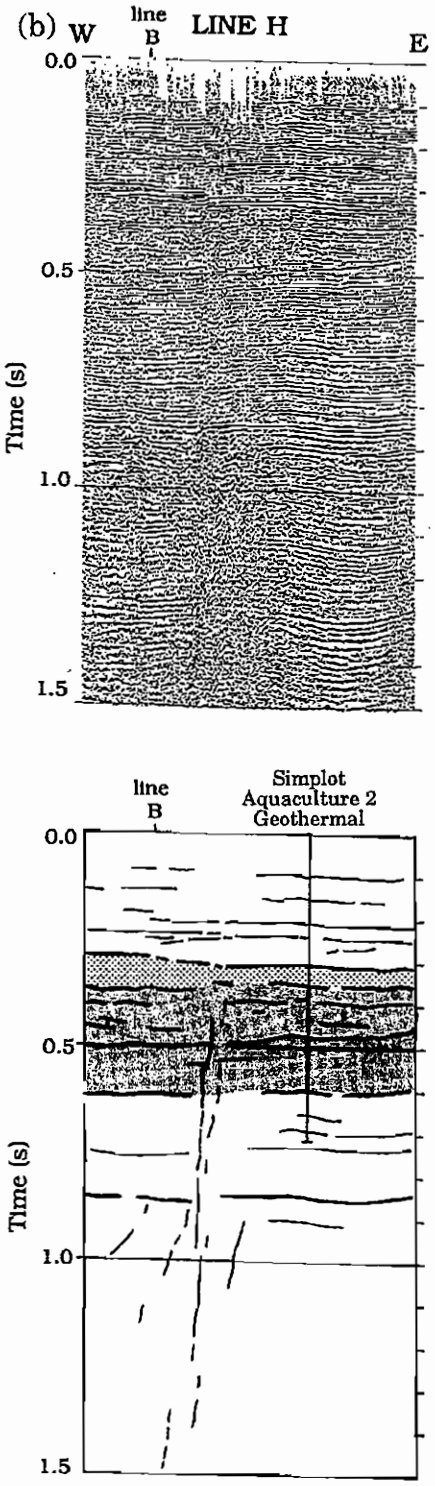

Figure 6–Continued.

The well was drilled with a truck-mounted rotary rig, using bentonite mud to control artesian flow. The mud line did not have a desander so fine sands circulated with the mud. This and other drilling problems resulted in an uneven quality of cuttings; nevertheless, sand units could be detected by a flush of sand in the cuttings. Samples were taken at 3.3 m (10 ft) intervals and washed through a stack of sieves, the finest sieve being #200 (0.074 mm). The relative amounts of sand and grain-size distribution are estimated from sieve analysis. The samples were examined and described with the use of a binocular microscope. The carbonate content of the clay and mud cuttings was estimated using criteria on Table 3, and colors were described using the Munsell system (Munsell Color, 1990). These attempts to quantify examination of cuttings of poorly consolidated sediment will prove useful in future studies comparing outcrop and other well data.

The lithology of the section can best be understood by viewing Figure 7, and will be discussed starting at the bottom of the figure. The deepest sediment from which cuttings have been recovered and examined from the study area is calcareous claystone, which dominates the lithology from 689 to 375 m (2250–1230 ft). This stratigraphic interval corresponds to unit 3 and underlying strata of the seismic profiles (Figure 6). Within this section of calcareous claystone are several fine-grained sand units about 7 m (20 ft) thick, some showing log profiles suggestive of fining-upward beds (Figure 7). Correlation of gamma and resistivity logs from 1 Richardson to 2 Simplot Geothermal wells (Figure 7) is consistent with the down-to-north depositional dip of this stratigraphic interval, as interpreted from the seismic sections.

Resistivity logs in Figure 8 show gradually upward-increasing resistivity from 457 m (1500 ft) to the top of seismic unit 3 at 366 m (1200 ft), indicating diminishing clay content and increasing silt and sand content upward in the sequence. This log character distributed over a thickness of 100 m (328 ft) is considered characteristic of distributary mouth-bar deposits of a prograding marine delta sequence by Coleman and Prior (1982) and Serra (1986). This coarsening-upward character may be too gradational to detect in cuttings, core, or outcrop of a claystone or mudstone; however, it is clearly the log signature of the transition from the prodelta facies to the delta-plain facies.

Overlying the relatively thick section of calcareous claystone is the principal sand facies, corresponding to seismic unit 2. Resistivity logs (Figure 8) show the sand is made up of several 3- to 7-m–thick beds, separated by thin clay beds about 1 m thick. Fine stratification (beds less than 20 cm), if present, cannot be resolved because the 16 in. (0.5 m) normal resistivity log cannot detect such thin beds. Cuttings and sand produced during well development are loose, very well sorted, and fine grained, having

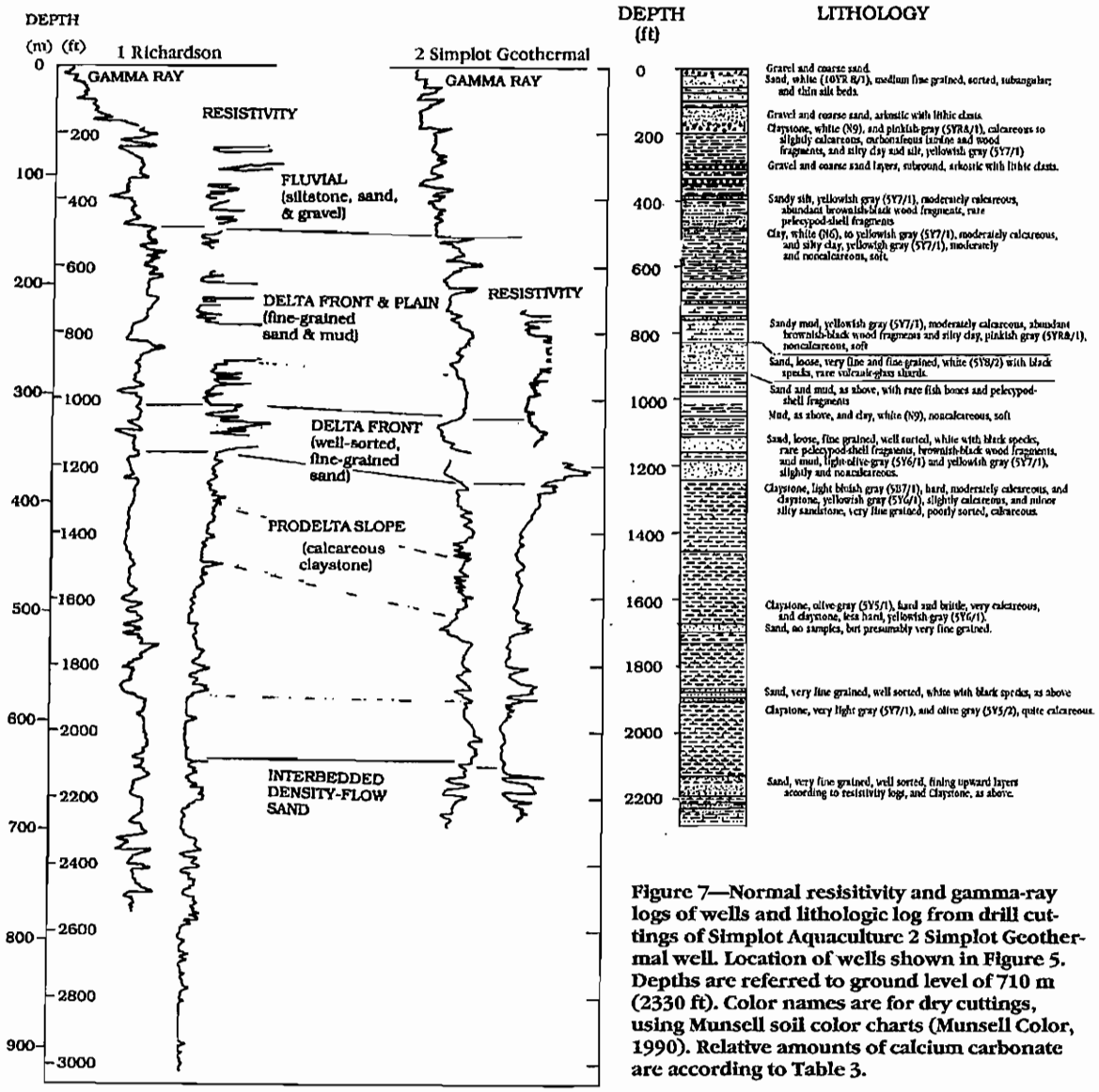

Figure 7—Normal resisitivity and gamma-ray logs of wells and lithologic log from drill cuttings of Simplot Aquaculture 2 Simplot Geothermal well. Location of wells shown in Figure 5. Depths are referred to ground level of 710 m (2330 ft). Color names are for dry cuttings, using Munsell soil color charts (Munsell Color, 1990). Relative amounts of calcium carbonate are according to Table 3.

a mean diameter of 0.1 mm ($\phi = 1$, with one standard deviation of 0.5ϕ). Log profiles are interpreted as both massive beds and beds that coarsen (become less silty) upward. The logs show that sands are separated by thin clay beds. The Simplot Aquaculture 1 Simplot Geothermal well was completed with a 6-m screened interval in this sand. Pump testing of this 6-m section indicated a hydraulic conductivity of the screened section of 12 m/day, equivalent to a permeability of 1.0 d.

Between 457 m (1200 ft) and 107 m (350 ft), the stratigraphic interval corresponding to seismic unit 1, are numerous layers of well-sorted fine sand interbedded with moderately to slightly calcareous mud. The sand beds are typically 3 to 12 m (10–40 ft) thick. Woody and carbonaceous material are abundant in silt cuttings. Above 60 m (200 ft), the mudstones are noncalcareous, and the sands are mostly medium grained with some coarse-grained sands and gravels.

Table 2. Deep Petroleum and Geothermal Exploration Wells*

Map Symbol	Operator, Well Name, Date	Location	Total Depth (ft)	Bottom Formation
EO1	Sinclair 1 Eastern Oregon Land Co. (1955)	SW, Sec. 15, T16S, R44W	4888	unknown
MB1	Oroco 1 Mcbride (1955)	SE, Sec. 19, T16S, R46E	4506	unknown
OI1	Ore-Ida Foods/DOE 1 Ore-Ida (1979)	NE, Sec. 3, T18S, R47E	10,054	Miocene(?) basalt
KE1	H. K. Riddle 1 Kiesel Estate (1955)	SW, Sec. 8, T19S, R47E	5137	unknown
ER1	Idaho-Oregon Prod.Co. 1 Elvera-Recla (1950)	Sec. 19, T19S, R44E	4611	unknown
FS1	El Paso Natural Gas 1 Federal Spurrier (1955)	NE, Sec.5, T20S, R44E	7470	unknown
C1	Phillips Petroleum Geothermal A1 Chrestesen (1980)	NW, Sec. 2, T11N, R6W	7978	granite
BC1	Oroco-Simplot 1 Betty Carpenter (1955)	Sec. 4, T8N, R5W	2775	Idaho Group
VJ1	Oroco-Simplot 1 Virgil Johnson (1955)	SE, Sec.27, T8N, R4W	4040	unknown
VJ2	El Paso Natural Gas 2 Virgil Johnson (1956)	SE, Sec. 27, T8N, R4W	3522	Idaho Group
TD1	Oroco-Simplot 1 Ted Daws (1955)	NE, Sec. 34, T8N, R4W	1682	Idaho Group
HLL1	SOCAL 1 Highland Land & Livestock (1972)	Sec. 24, T6N, R5W	10,682	Miocene basalt
WS1	El Paso Natural Gas 1 Webber State (1956)	SW, Sec. 16, T5N, R3W	4522	Idaho Group
HL1	Sundance 1-30 Hunter-Linning (1983)	SW, Sec. 30, T5N, R3W	3555	Miocene basalt
R1	Oroco 1 Richardson (1955)	NW, Sec. 19, T4N, R3W	3000	Idaho Group
SG2	Simplot Aquaculture 2 Simplot Geothermal (1989)	NW, Sec. 19, T4N, R3W	2250	Idaho Group
JNJ1	Halbouty-Chevron 1 J. N. James (1976)	SE, Sec. 27, T4N, R1W	14,000	Tertiary volcanics
H1	Roden-Anschutz 1 Higgenson (1972)	NW, Sec. 9, T3N, R1W	3610	Miocene basalt
DF1	Champlin Petroleum 11-19 Upper Deer Flat (1981)	NW, Sec. 19, T2N, R2W	9047	Miocene basalt

*Locations shown in Figure 2.

INTERPRETATION OF SEISMIC FACIES UNITS

Seismic facies unit 3 is interpreted as the prodelta clay facies of a lacustrine delta system. The 4 to 5° dip of clinoform reflectors within this stratigraphic interval is similar to the slope of modern lacustrine deltas (Figure 9). The logs through this interval show it to be relatively monotonous claystone, very gradually coarsening upward in the upper 100 m, and interrupted in the lower part by interbedded fine sand layers. The seismic section (Figure 6a) shows this unit produces few or no reflections, and is interpreted to be characteristic of the monotonous claystone. The reflections within this unit and the higher amplitude lower segments of the clinoforms are interpreted to be intercalated sand layers on the prodelta slope, and density-flow sand accumulating as downlapping layers at the base of the slope.

Seismic facies unit 2 is interpreted to be the delta-front and delta-plain sand facies. This unit is the topset interval of the progradational reflection configuration. Unit 2 contains the principal sand aquifers in this section because of the relatively thick and very well-sorted sands of the delta front.

In Mitchum et al. (1977, p. 128), seismic facies units 2 and 3 would be considered a single seismic facies unit of a prograding depositional system. The units are discussed separately in this paper because of the great difference in lithology and permeability between the sand of unit 2 and the predominant claystone of unit 3.

Seismic facies unit 1 is interpreted as the delta-plain, fluctuating-shoreline, and river flood-plain facies. The uppermost calcareous muds (about 65 m or 215 ft deep) are an indication of a lacustrine envi-

Table 3. Terminology for Carbonate Content of Well Cuttings Used in Figure 7: Response to 10% HCl, Cold*

Very calcareous: sample reacts violently, floats on top of acid and moves about the surface (90–100% $CaCO_3$).

Calcareous: sample reacts immediately but only moderately and jumps off bottom every 0.3–1 s, moves about in acid between bottom and surface (50–90% $CaCO_3$).

Moderately calcareous: Sample reacts slowly at first, but accelerates to a continuous reaction after a minute or two with some bobbing at the bottom (50–10% $CaCO_3$).

Slightly calcareous: very slow reaction, bubbles evolve one at a time, with several seconds between release of each bubble (<10% $CaCO_3$).

Noncalcareous: sample put into warm HCl to verify that no bubbles are released.

Dolomitic: pure dolomite effervesces only when crushed or abraded and put in cold 10% acid or put into warm acid; if dolomite is suspected, it can be verified by digestion in warmer or stronger acid or by staining methods.

*Modified after Exploration Logging, Inc. (1981).

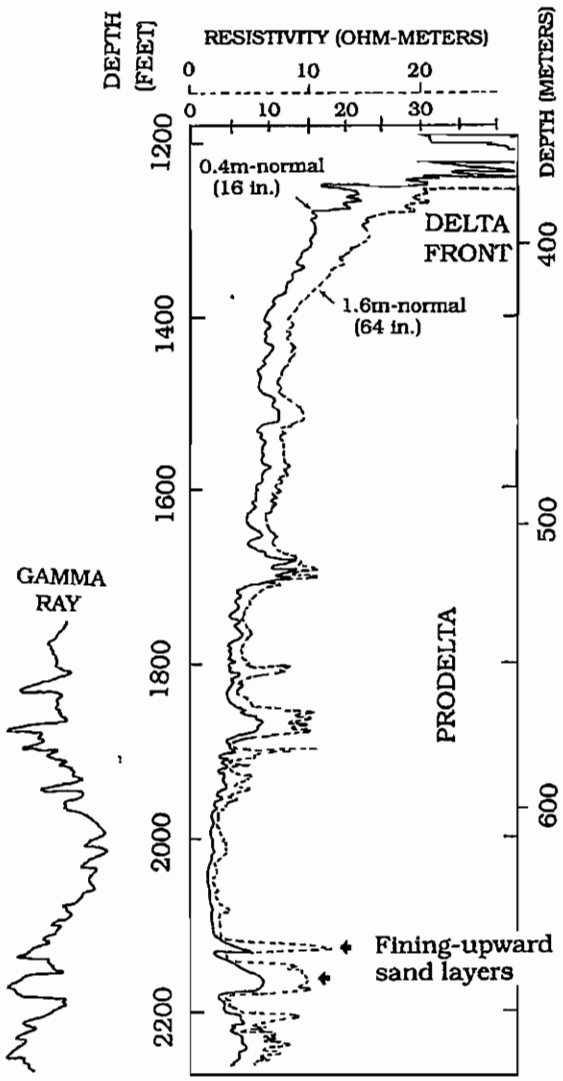

Figure 8—Detailed resistivity log of Simplot Aquaculture 2 Simplot Geothermal well showing fining-upward sand layers in the prodelta facies, the gradual upward-increasing resistivity in the prograding prodelta clays, and the abrupt contact and high resistivity of the delta-front sands.

ronment; however, interbedded gravel and coarse sand indicate fluvial systems, and lakeshore environments may have alternated during deposition of this unit. Abundant woody material in parts of this unit indicates a delta-plain environment, and muds may be interdelta bays and lagoons.

SLOPE GEOMETRY OF LACUSTRINE DELTAS AND CLINOFORM REFLECTIONS

The key to identifying the delta system is recognition of the unit with clinoform reflections as the prodelta slope. To verify that this is indeed the prodelta slope, bathymetry of modern lakes was examined. Two studies of the geometry of modern lacustrine deltas (Born, 1972; Müller, 1966) are sufficiently detailed to use as a model of the features seen on seismic sections and well logs. Profiles of modern deltas of the Truckee River in Pyramid Lake of Nevada, and of the Rhine River into Lake Constance, are shown in Figure 9. These delta bathymetric profiles are nearly identical to clinoform reflections on the seismic sections (Figure 6). Prodelta slopes of these modern lacustrine deltas are 2 to 6°. Seismic sections showing clinoforms of a prograded fluvial-dominated marine prodelta (Figure 10b) closely resemble the slope geometry of lacustrine deltas shown on Figure 9).

A point of confusion still exists among some geologists working with seismic data but using ideas of delta deposition from older literature dating back to Gilbert (1885). Large-scale morphology of bedded delta deposits is vastly more complex than Gilbert's illustration (Figure 10a) for the form of bed-load material deposited by a stream issuing into a body of still water. The illustration describes internal sedimentary structure that occurs in some sand layers at the delta front, but it is not generally applicable to all sand layers. The term "Gilbert delta" still pervades geological literature and is a common misconception for the shape of all delta deposits. The feature Gilbert described should be called "Gilbert bedding" because it is a form of stratification of one type of bed, and is not a characteristic of the delta as a whole. The distinction is appropriate here because the true- scale diagram of Gilbert bedding is nearly identical in appearance to the appearance of the prodelta beds shown on a seismic section with a 10× vertical exaggeration (Figure 10b). This apparent similarity of geometry is a matter of display scale. The foreset beds of Gilbert bedding may constitute a sand unit 2 to 30 m (7–100 ft) thick, with internal stratification dipping 8 to 33°, whereas the seismically displayed prodelta unit is in reality a mud or clay unit several hundred meters thick with internal stratification dipping only 2 to 6°.

FINE-GRAINED DELTAS AND COARSE-GRAINED DELTAS

Recent literature on alluvial deltas distinguishes between deltas that have steep delta-face slopes composed of coarse clastic material, and deltas that have gently sloping delta-face slopes composed

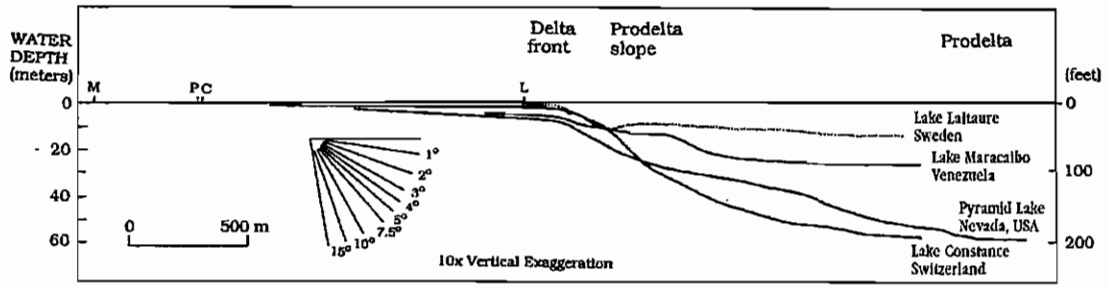

Figure 9—Profiles of modern lacustrine deltas showing the delta front and the prodelta slope. Data sources are Lake Constance (Müller, 1966); Lake Laitaure (Axelsson, 1967); Lake Maracaibo (Hyne et al., 1979); and Pyramid Lake (Born, 1972; Russell, 1885).

mostly of fine sand and mud (Nemec, 1990). In the "coarse-grained delta," gravel and coarse sand beds are deposited at the delta front; these deposits are characteristic of braid deltas and fan deltas (McPherson et al., 1987). Coarse-grained deposits do not occur in the delta-front deposits described in this paper.

The delta described in this paper is a fine-grained delta because only fine sand is deposited at the delta front. Stanley and Surdam (1978) describe a lacustrine-delta sequence of mostly fine sand and mud in the Laney Member of the Green River Formation. In this delta only medium to fine sand sediment, along with suspended silts and clays, was transported to the delta front. Presumably, this delta is the deposit of a large river system where sediment is transported over a long, low-gradient flood plain and delta plain to the lake edge, a considerable distance from the source of coarse clastic material. The sand beds are 30 m thick, with an internal stratification as described by Gilbert (Figure 10a). Therefore, the Gilbert type of internal stratification also occurs in tabular bodies of fine sand; however, examination of fine-grained delta systems in the Green River Formation on a broader scale may show that much of the sand bedding is horizontal and not angle-of-repose bedding at the delta front.

Beyond the delta front is the prodelta slope, formed mostly by the deposition of the suspended load of silt and clay, as illustrated in Figure 11. Slopes of the prodelta beds are generally a few degrees (Figure 9). The prodelta deposits, however, make up most of the volume of deposits of the fine-grained deltas, and also are the most easily identified part of the delta on seismic sections. The zone of gently inclined bedding of the lacustrine prodelta extends at least 300 m (1000 ft) horizontally, and more typically 1500 to 2000 m, (5000–6500 ft) beyond the delta front (see examples in Figure 9). The vertical drop over the slope of Gilbert foreset beds seen in outcrop is often used as an indicator of lake depth; however, the vertical drop of the low-dipping prodelta slope deposits commonly is much greater and is a better indicator of the total depth of the lake basin. As stated by Stanley and Surdam (1978), thickness of the Gilbert-type sequence is an indicator of the depth of water into which bed-load deposits prograded, but not the depth of the lake basin itself.

EVIDENCE FOR DENSITY-FLOW ORIGIN OF SAND IN THE PRODELTA DEPOSIT

Sand layers are relatively rare in the thick sequence of the prodelta calcareous claystone described in this paper; nevertheless, several high-amplitude seismic reflections do occur from the lower part of this unit (Figure 6), and indeed, the resistivity logs show layers of fine sand 3 to 7 m (10–20 ft) thick in the 2 Simplot Geothermal well at depths of 518 m (1700 ft), 579 m (1900 ft), and 640 m (2100 ft) (Figure 7). All of these sand layers have resistivities less than 15 ohm-meters, much less than resistivities of the clean-sand aquifers at 335 m (1100 ft). Although drilling problems prevented collection of good cuttings from the well, the resistivity logs show that the layers at 640 m (2100 ft) are fining upward. This kind of graded bedding with better sorted, coarser grains at the base of the bed, suggests a density-flow mechanism for dispersal of sands into layers several to 10 m (33 ft) thick on the prodelta slope. Sturm and Matter (1978) describe prodelta slope deposits in Lake Brienz, Switzerland. In the bottom sediments about 5 km (3 mi) from the delta front, they found centimeter-scale graded fine sand and silt beds, deposited annually with laminated calcareous mud, and rare thick beds (up to 1.5 m or 5 ft) of sand. Sturm and Matter attribute the annual thin sand layers to low-density turbidity currents during high discharge that travel in channels down the delta slope and spread on the flat lake floor. They attribute the thick layers to high-density turbid-

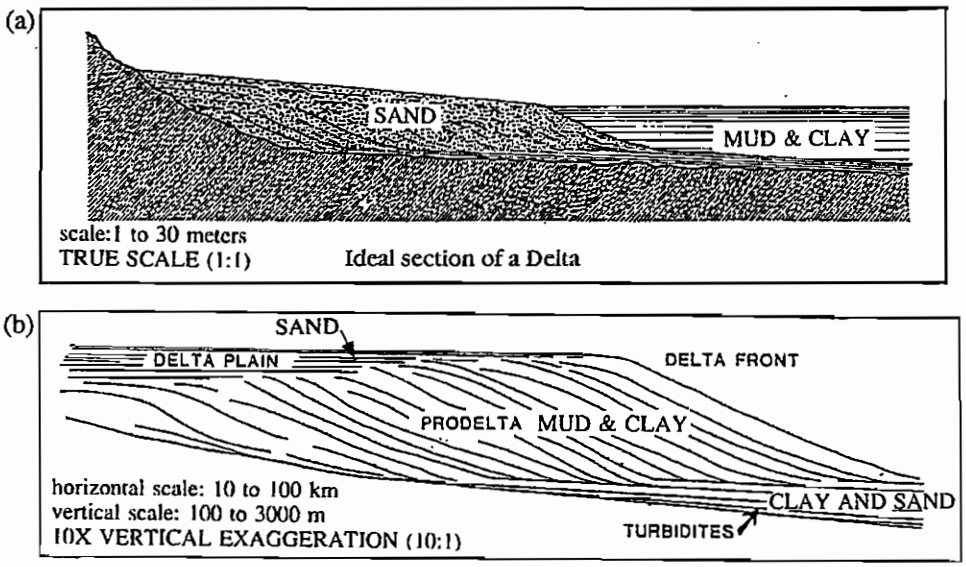

Figure 10—Illustration of the similarity in morphology of relatively small scale bedding of the Gilbert delta compared to the grand scale of Berg's (1982) model of a fluvial-dominated marine delta. (a) Misconception of delta morphology dating shown on G. K. Gilbert's (1885) true-scale illustration of a section through a delta based on observations of coarse-grained deposits of streams that issued into Pleistocene Lake Bonneville, Utah. Thickness of the foreset-bedded sand is typically 1 to 30 m. (b) Berg's (1982) generalized model of a large prograded fluvial-dominated delta from seismic sections. Horizontal scale is 10 to 100 km, and vertical scale is 100+ to 3000 m (O. R. Berg, 1991, personal communication).

ity currents of catastrophic floods that occur once or twice a century. These floods could produce a rapid accumulation of delta-front sands on angle-of-repose slopes that fail to produce turbidity flows and thick sand units beyond the delta front. Sand layers shown by the logs (Figure 7) are thicker than those described by Sturm and Matter (1978); however, they may be of similar origin.

Further evidence of the graded nature of these beds is gained from attempts to develop these layers for artesian flow of hot water. Casing was run to the top of sands at 649 m (2130 ft), and 9 m (30 ft) of well screens set across these sands, resulting in a flow of only 2.5 L/s (40 gal/min) of 40°C (141°F) water detected by downhole flowmeter and temperature logging. The test was an imperfect measure of the artesian flow from the zone because of a leak in the annular packer at 336 m (1200 ft), which allowed pressure of about 0.15 MPa (21 psi) and flow of about 9.5 L/s (150 gal/min) from the upper sands to enter the hole at this higher level. Nevertheless, it appears from the resistivity log and the flowmeter test that these deeper sand layers yield only small flows and have lower permeability relative to shallower sands. Because of their graded stratification, only the thin basal part of the sands may be clean, sorted, and have good permeability.

IMPLICATIONS FOR LAKES IN THE WESTERN SNAKE RIVER PLAIN BASIN

The delta sequence described in this paper records an episode of sediment infilling of Pliocene Lake Idaho. Relief of the prodelta slope on the seismic section (Figure 6a) is 180 m (600 ft). Decompacting this thickness of prodelta mud by an estimated 120% implies an original prodelta slope relief of about 255 m (840 ft). From this, one can conclude that the prodelta was prograding into a lake that was about 255 m (840 ft) deep, and that the delta was prograding northward. Seismic data to the east of the Caldwell study area also show a similar prograding sequence with a slope facing northwestward (Wood and Anderson, 1981); these directions of progradation are shown on Figure 2.

The following discussion attempts to reconcile the relatively low elevation of the delta system preserved in the middle of the basin with the much higher elevation lake deposits exposed around the margin of the basin, generally within 130 m (430 ft) of an elevation of 1000 m (3300 ft). The interface between the prodelta mud and the delta sand facies occurs in shallow water (about 10 m or 33 ft according to modern examples in Figure 9). Therefore, the base of the delta sands can be regarded as about

lake level at the time of deposition.

The top of the buried prodelta facies in the Caldwell area is at elevation of 405 m (1330 ft), considerably lower than the present bedrock sill at Cobb Rapids (634 m, 2080 ft), and much lower than the highest lake deposits near the present outlet, which are 850 to 975 m (2790–3200 ft) near Huntington, Oregon. The top of the prodelta is identified on the resistivity logs of four other wells generally in the center of the basin, and the elevation is shown in brackets on the map (Figure 2). These elevations range from 437 to 504 m (1433–1653 ft), up to 100 m (330 ft) higher than at Caldwell. It appears that the deltaic sequence at Caldwell has subsided about 445 to 575 m (1460–1900 ft) from the level of the highest lake deposits since it was deposited. Differential compaction and a small tectonic component may account for the higher elevation in the other wells. The amount of compaction subsidence can be estimated for a horizon that is now 405 m deep, (1330 ft) and underlain by about 853 m (2800 ft) of mudstone. Using the method of Sclater and Christie (1980) programmed for PC-computer calculation by Hsui (1986), the calculation suggests compaction subsidence at Caldwell may be about 220 m (720 ft). The remaining 225 to 325 m (740–1060 ft) can be attributed to tectonic faulting and downwarping of the center of the basin. This tectonic component agrees well with 180 to 370 m (600–1200 ft) of offset of Idaho Group sediment typically observed on the boundary normal faults on the north side of the plain (Figure 3) (Wood and Burnham, 1987). Therefore, the relatively low elevation of the delta deposits can be reconciled with the higher elevation of remnant lake deposits on the basin margins by taking into account compaction and tectonic fault displacement and downwarping.

Position of the delta in the middle of the basin (Figures 1, 2) suggests that at the time of deposition, the upper southeastern two thirds of the basin was delta plain and flood plain, and the lower northwestern third was a deep lake environment. The fact that prodelta deposits slope north and northwest (Figure 2) indicates that a major source of sediment lay to the southeast, just as the Snake River flows today.

The previous discussion provides some insight on the history of the lake and its outlet. During part of the history of the basin, the lake may have had only an ephemeral outlet; much of the inflow may have evaporated. Present inflow to the basin averages 16 $\times$ 10^9 m^3/yr. Typical annual evaporation from reservoirs in the Snake River plain region is about 1 m (3 ft), and this interior continental region evaporation may have been similar during the Pliocene. At the maximum areal extent shown in Figure 1, a surface area of 13,000 km^2 (5000 mi^2) evaporation could have exceeded 13 $\times$ 10^9 m^3/yr, an amount that nearly equals the inflow, so that in some years most or all of the inflow may have evaporated. The general lack of evaporitic facies in the Glenns Ferry Formation (Kimmel, 1982) is evidence against a closed basin environment. Although gypsum is common in the older Chalk Hills Formation, little is reported in the Glenns Ferry Formation. Deposition of oolitic sands on shorelines and assemblage of fish fossils led Swirydczuk et al. (1980) to suggest a water environment similar to that of the present Pyramid Lake, Nevada. This analogy is further supported by the abundance of calcareous claystone in the prodelta facies (Figure 7) that is similar to the prodelta clay of Pyramid Lake, which was examined by Swain and Meader (1958). Pyramid Lake waters are 5% total dissolved solids and have an alkaline pH of 9. Therefore, evaporation appears to have significantly increased alkalinity and chemical concentration in Lake Idaho over the 0.01% total dissolved solids of inflow streams. Occasional outflow prevented the water from becoming saline.

At the time of deposition of the deltaic sequence, near Caldwell, the upper two-thirds of the basin was a river flood plain and the surface area of the lake may have been reduced to one third of that shown in Figure 1, or about 4000 km^2 (1500 mi^2). As the lake area was reduced by sediment infilling, reduced evaporation must have allowed the lake level to rise in a closed basin and ultimately spill into adjacent basins.

Many workers have cited paleobiological evidence of freshwater mollusks and fish as evidence of a former course of the Snake River through eastern Oregon to the Klamath basin of California (Malde, 1991) shown in Figure 1. No physical evidence for such an outlet channel has been found, although if lakes only occasionally spilled into other closed basins, a deep canyon might not have been cut nor the fluvial sediment preserved. Details of the lake's past spill points and chemical history of its waters remain a fascinating puzzle for future research.

The lake was eventually doomed, with waning rates of tectonic subsidence in the western plain in the late Pliocene (Clemens, 1993), and as sediment displaced the lake area causing a reduced area for evaporation. The lake waters finally overtopped a spillway into the Columbia–Salmon rivers drainage near Huntington, Oregon. Timing of the capture of the waters of the Snake River drainage basin appears to be about 2 Ma (Malde, 1991; Othberg, 1992). It is tempting to correlate the final lake rise with the climatic change that heralded the northern hemisphere ice ages, which, on the basis of the marine oxygen–isotope record, Shackleton and Opdyke (1977) place at 2.5 m.y. Benson (1981) shows that 100-m (330-ft) lake-level rises in the Lake Lahontan basin were caused by paleoclimate fluctuations in the late Pleistocene. Such lake-level rises also likely occurred in the early Pleistocene and overtopped

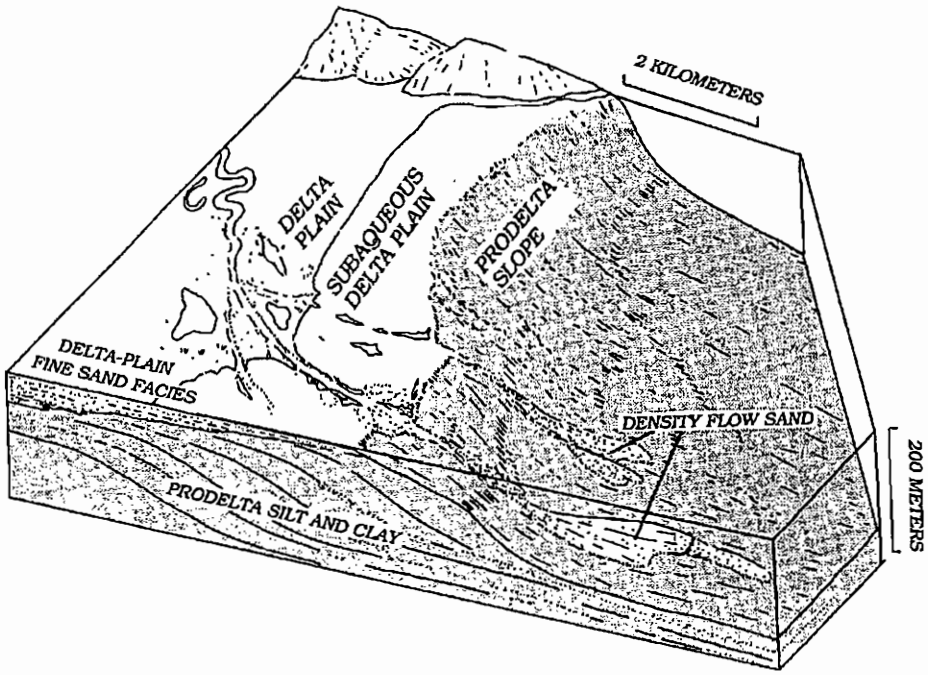

Figure 11—Drawing of a lacustrine delta environment, with a 10× exaggerated vertical scale, showing distribution of sand units within the dominantly mud and clay sequence.

the basin sill. Once the new outlet was established, the river would have eroded the sill and deepened the ancestral Hells Canyon. Present geomorphology suggests that Dead Indian Ridge near Weiser, Idaho, was the sill (Figure 2), and that the outlet has cut down about 215 m (700 ft) to the present river level of 635 m (2080 ft) at Cobb Rapids, where it descends into Hells Canyon.

CONCLUSIONS

Neogene lake sediments of the western Snake River plain provide an example of a lacustrine delta and prodelta system that can be identified in the subsurface by seismic reflection patterns. The key to recognizing the delta system is progradational clinoform reflections of the prodelta mud and clay facies detected on seismic sections oriented normal to the direction of progradation. The clinoforms have a 2 to 6° depositional dip, which is similar to the prodelta slopes of modern lakes. Upper ends of the prodelta clinoforms are overlain in a toplap relationship by strong amplitude, near-horizontal reflections from the delta-front sands. Delta-front sands are expressed by several to 5 cycles of strong amplitude reflections, each continuous for several hundred meters. The prodelta can be identified on resistivity logs as a gradually coarsening upward mud unit typically 100 m (330 ft) thick and abruptly overlain by high-resistivity sands of the delta front. The downward distal ends of the prodelta clinoforms have a downlap relationship to underlying strong amplitude reflections of density-flow sand layers. Density-flow sands 3 to 7 m (10–25 ft) thick are identified on resistivity logs of boreholes by a fining-upward character.

In the delta described here, the delta-front sands are well sorted and fine grained. The prodelta sediment is mostly calcareous mud and clay with intercalated layers of density-flow sands in the lower part.

On an exaggerated vertical-scale seismic section the prodelta reflection patterns have the appearance of the true-scale diagram of a Gilbert delta. It is a misconception that these large delta systems resemble the Gilbert delta with steeply dipping foreset beds. Foreset bedding is a relatively small-scale feature limited to internal bedding of sands, whereas the prodelta slope is less than 6° and is mostly mud and clay.

The delta system described here is the first major depositional system identified for deposits of the Idaho Group, and provides some insight into the history of Pliocene Lake Idaho. The delta facies occurs in the center of the basin and has subsided 445 to 575 m (1460–1900) with respect to sediment exposed on the basin margins. Estimated subsidence from sediment compaction is about 220 m (720 ft), leaving about 225 to 325 m (740–1060 ft) attributable to tectonic down-

warping and faulting. The prodelta slope relief, corrected for compaction, indicates a lake basin about 255 m (840 ft) deep at the time of delta deposition in the center of the basin.

Position of the delta in the northwestern part of the basin indicates that the southeastern two thirds of the original lake area of about 13,000 km² (5000 mi²) had filled by the time the delta sequence had reached Caldwell, Idaho, so that the existing lake area was about 4000 km² (1500 mi²). The large surface area of the early lake could have evaporated most of the annual inflow, suggesting the lake only occasionally spilled into other basins. As lake-surface area was reduced by sedimentation, evaporation diminished, and the lake level rose. Onset of the northern hemisphere ice ages further reduced evaporation and perhaps triggered a lake-level rise that overtopped a basin sill near Weiser, Idaho, and spilled into the Columbia–Salmon River drainage about 2 m.y. Present geomorphology near the spillway suggests the Snake River subsequently cut down the spillway about 215 m, (700 ft) and deepened Hells Canyon, now the deepest gorge in North America.

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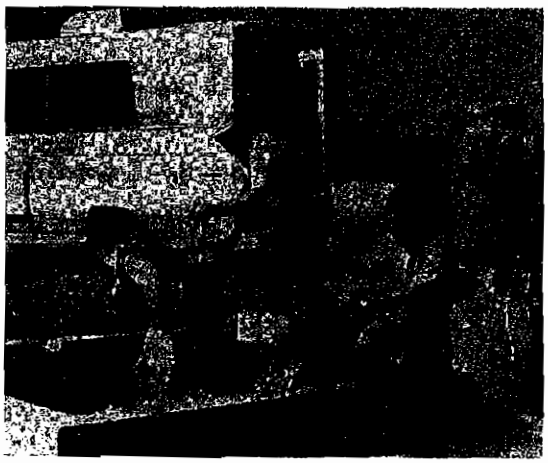
GEOTHERMAL INVESTIGATIONS IN IDAHO

Part 11

GEOLOGICAL, HYDROLOGICAL, GEOCHEMICAL AND GEOPHYSICAL INVESTIGATIONS OF THE NAMPA-CALDWELL AND ADJACENT AREAS, SOUTHWESTERN IDAHO



Well 2N-3W-27bab1, south of Lake Lowell, being sampled for chemical and isotopic constituents. Photo-Alan Mayo

IDAHO DEPARTMENT OF WATER RESOURCES
WATER INFORMATION BULLETIN NO. 30
DECEMBER 1981

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GEOTHERMAL INVESTIGATIONS IN IDAHO
PART 11

Geological, Hydrological, Geochemical and Geophysical
Investigations of the
Nampa-Caldwell and Adjacent Areas
Southwestern Idaho

John C. Mitchell
EDITOR

Work performed under U.S. Department of Energy Contract
No. DE-AS07-77ET28407
Modification No. A003
Designation DOE/ET/01834-3
Idaho Department of Water Resources
Statehouse
Boise, Idaho

December 1981

TABLE 1-1
Conversion Factors

To Convert from	To	Multiply by
	DISTANCE	
inches (in)	centimeters (cm)	2.540
feet (ft)	meters (m)	0.305
yards (yd)	meters (m)	0.914
miles (mi)	kilometers (km)	1.609
centimeters (cm)	inches (in)	0.394
meters (m)	feet (ft)	3.281
meters (m)	yards (yd)	1.094
kilometers (km)	miles (mi)	0.621
	AREA	
square miles (sq mi)	square kilometers (sq km)	2.589
sq kilometers (sq km)	square miles (sq mi)	0.386
	VOLUME — MASS	
gallons (gal)	liters (l)	3.785
ounces (oz)	grams (gm)	28.349
liters (l)	gallons (gal)	0.264
grams (gm)	ounces (oz)	0.035
	ENERGY	
British thermal units (BTU)	calories (cal)	1.996
British thermal units (BTU)	joules (j)	1054.35
calories (cal)	British thermal units (BTU)	0.004
calories (cal)	joules (j)	4.186
joules (j)	British thermal units (BTU)	0.0009
joules (j)	calories (cal)	0.239
	GRADIENTS	
degrees Fahrenheit/100 ft (°F/100 ft)	degrees Celcius/kilometers (°C/km)	1.822
degrees Celcius/kilometer (°C/km)	degrees Fahrenheit/100 ft (°F/100 ft)	0.055
	THERMAL CONDUCTIVITY	
$\frac{\text{millicalories}}{\text{centimeter/second °Celcius}}$	$\frac{\text{(mcal)}}{\text{(cm/sec °C)}} = \frac{\text{calories}}{\text{centimeter/second °Celcius}}$ $\frac{\text{(cal)}}{\text{(cm/sec °C)}}$	0.001
$\frac{\text{calories}}{\text{centimeter/second °Celcius}}$	$\frac{\text{(ucal)}}{\text{(cm/sec °C)}} = \frac{\text{millicalories}}{\text{centimeter/second °Celcius}}$ $\frac{\text{(mcal)}}{\text{(cm/sec °C)}}$	1000
	HEAT FLOW	
$\frac{\text{microcalories}}{\text{centimeter}^2\ \text{second}}$	$\frac{\text{(ucal)}}{\text{(cm}^2\ \text{sec)}} = \text{milliwatts/meter}^2\ \text{(mwatt/m}^2\text{)}$	41.871
milliwatts/meter² (mwatt/m²)	$= \frac{\text{microcalories}}{\text{centimeter}^2\ \text{second}}$ $\frac{\text{(m)}}{\text{(cm}^2\ \text{sec)}}$	.024

CHAPTER 2 - GEOLOGY

By
Spencer H. Wood[1]
and
John E. Anderson[2]

INTRODUCTION

The cities of Nampa and Caldwell lie within the western Snake River Plain. The plain is a northwest-trending physiographic lowland and contains the incised valleys of two major rivers flowing to the northwest. The Snake River rises at the far eastern end of the plain and flows nearly 700 km (435 mi) across the arcuate plain until it turns north and descends through Hells Canyon and into the Columbia. The Boise River heads in the granitic mountains north of the plain and then flows northwestward until it joins the Snake.

The plain is also a great structural basin formed by downwarping and faulting in late Cenozoic time (Figure 2-1). The amount of late Cenozoic vertical movement in the western plain is impressive. The basin-fill sediments and volcanic flows have been drilled to a depth of 4.3 km (2.7 mi), and Mabey (1976) has suggested the total basin fill may be 7 km (4.4 mi) or more.

A variety of ideas and models have recently been advanced since Armstrong and others (1975) published the K-Ar geochronology of silicic volcanics of the plain. Their study shows that the inception of silicic volcanism becomes progressively younger eastward across the plain; and that basalt volcanism persists for a long time after the inception of silicic volcanism. Brott and others (1978) show evidence for increasing values of heat flow eastward across the plain and emphasizes the significance of the increase in elevation eastward across the plain. These features of the plain are modelled by an eastward propagating thermal event which passed through the western plain 8 to 16 million years ago and is currently manifested as dormant volcanism and as the hydrothermal systems of the Yellowstone area.

The model of an eastward propagating thermal event coincident with the eastward development of the plain is reasonably consistent with available data. A similar, but diametrically opposite, pattern of silicic volcanism is recognized as having propagated westward across eastern Oregon also from the area of the western plain (MacLeod and others, 1975), but this system was not accompanied by the formation of a deep structural basin.

The present western Snake River Plain has the appearance of a northwest-trending graben 50 km (31 mi) wide. The western plain differs from the plain to the east in that the upper 700 to 1700 m (435 to 1056 ft) of basin fill is mostly sediment, whereas in the eastern plain the upper section is mostly Quaternary basalt. Although basalt volcanism has been active during the Quaternary of the western plain, it is not nearly so voluminous as in areas to the east.

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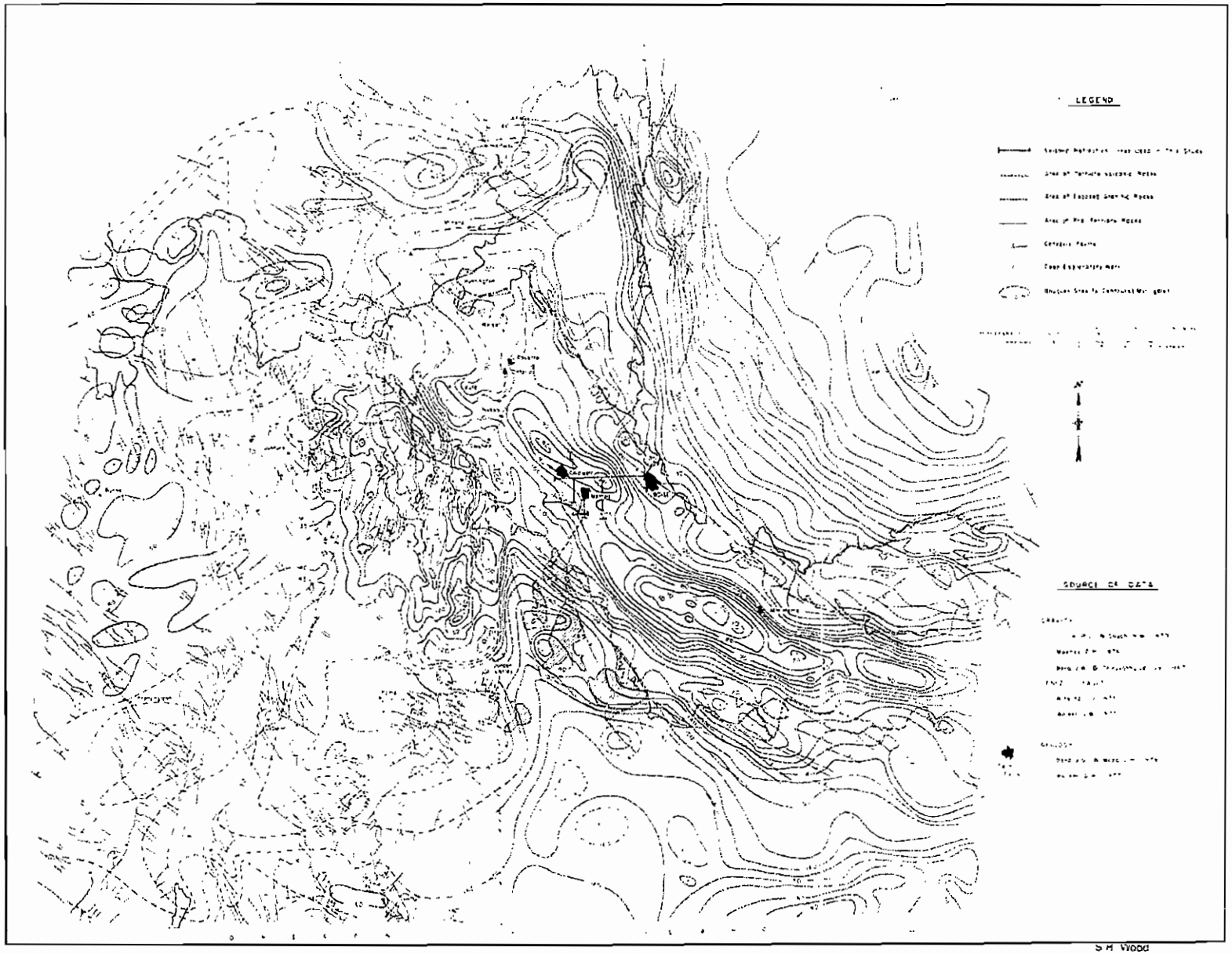


FIGURE 2-1. Map showing generalized geology, major faults, and Bouguer gravity contours in southwestern and west-central Idaho and eastern Oregon.

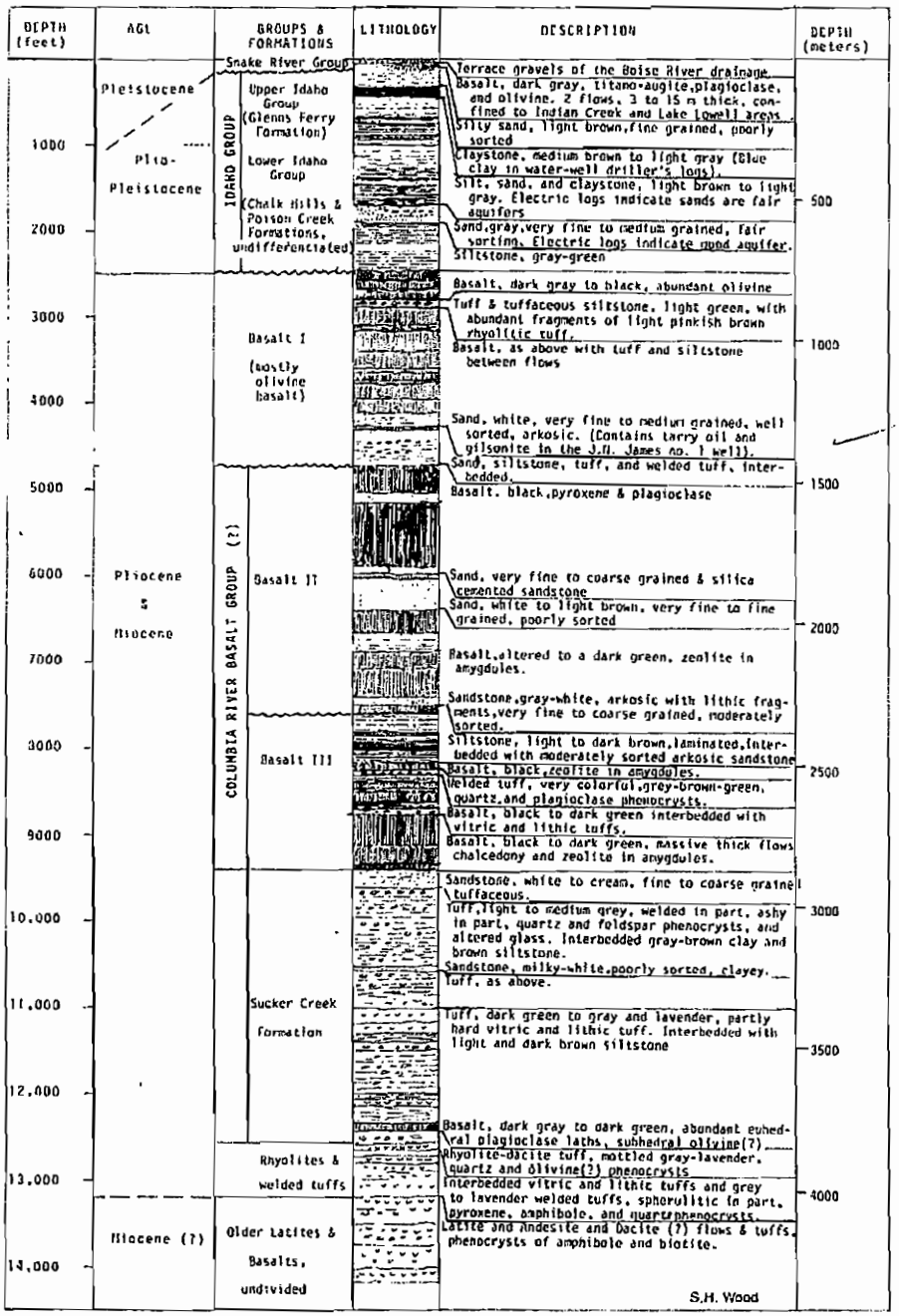
The main basis for this geological report of the Nampa-Caldwell area is a study of available well logs from deep wells in the area (fig. 2-2, and 2-3) and seismic reflection profiles (figure 2-4 and 2-5). Field mapping at a 1:24,000 scale was completed for all of the Nampa, Middleton, Caldwell and Lake Lowell quadrangles and a part of the Melba, Walters Butte and Given's Hot Springs quadrangles (figure 2-6, shown at 1:62,500 scale in pocket). Little geologic mapping had previously been done in the relatively featureless and flat part of the plain. Previous work by Lindgren and Drake (1904) and Savage (1958) did not recognize the extensive faulting of the Quaternary Gravels. Mapping utilized the limited exposures in sand and gravel pits, road cuts and river banks. Mapping of the Snake River Group basalts in the area relied heavily upon well logs filed by water-well drillers. The recent soil survey of Canyon County (Priest and others, 1972), and various terraces and topographic surfaces were also helpful in identifying the surficial deposits. In order to understand the subsurface stratigraphy a limited amount of detailed mapping was done of exposed strata on the margins of the plain.

The following section of this report discusses the stratigraphy of subsurface rocks and of the exposed surficial units. Exposures are quite limited, but localities are discussed in sufficient detail to allow examination of type sections of the mapping units. The structural geology of the Nampa-Caldwell area is discussed more fully in the geophysics chapter.

GENERAL STATEMENT

The thickness of Cenozoic volcanic and sedimentary fill in the western Snake River Plain is at least 4.3 km (2.7 mi) as demonstrated by the section penetrated by the exploratory well drilled near Meridian, Idaho (J.N. James No. 1). Basement rock was not penetrated. Because granitic rocks of the Idaho Batholith and associated metamorphic rocks occur in the mountains north and south of the plain (Taubeneck, 1971; Ekren and others, 1978a, and figure 2-1, it is commonly supposed that these rocks comprise basement beneath the plain. Although Challis volcanics have not been encountered in deep wells, it is possible that Challis volcanics and associated sediments lie deep in the subsurface, beneath the plain. Numerous, northeast-striking, porphyry dikes of intermediate to silicic composition invade the granitic rocks along the north margin of the plain. These porphyries have been dated at 40 to 42 $\pm$ 10 million years by the Lead-alpha method in the Lowman area (Jaffe and others, 1959 quoted in Armstrong, 1974) and may have been feeder dikes to Challis volcanism. The Challis volcanic sequence is at least 1,200 m (3900 ft) thick in the central Idaho Mountains and may be as thick as 3,200 m (10,500 ft) (Cater, et al., 1973). Challis-aged volcanics are also mapped in the eastern Owyhee Mountains by Ekren and others (1981) where they may be greater than 300 m (985 ft) thick.

In this report, the subsurface stratigraphy (figure 2-2) expected in the Nampa-Caldwell area is based upon the lithologic and geophysical logs of the 4.3 km deep Meridian well (J. N. James No. 1) and a limited amount of information from the Champlain Oil Company (Deer Flat No. 1) well recently drilled and abandoned south of Nampa. Interpretation of seismic reflection profiles discussed in Chapter 6 provides considerable stratigraphic information and shows that the section in the J. N. James No. 1 well may not be entirely representative of the western Snake River plain because it is drilled on a structural high with at least 700 m (2100 ft) of relief (figure 2-4). Some rock units similar to those encountered in the well are described from exposures at a number of localities on the margins of the plain by Malde and Powers (1962), Kittleman and others (1965), and Ekren and others (1981). Correlation of subsurface units to exposed sections can be made for some distinctive lithologic



The generalized stratigraphy of Cenozoic rocks beneath the Nampa-Caldwell-Meridian, Idaho, area is based upon the lithologic log of the M.T. Halbouty - Chevron, U.S.A. exploratory well near Meridian (Sec. 27, T4N, R1W), "J.N. James #1." Rock descriptions are from the cuttings log compiled by Miner (1976): it is not known if any of the volcanic rock descriptions on the log were verified by petrographic examination. Surficial rock and sediment of the Snake River Group in the uppermost 50 m (166 ft) are shown for completeness, but the Snake River Basalts do not occur at the well. Basalts within the Idaho Group do not occur at this well and are not shown, but they are encountered in the Champlain Oil Co., Deer Flat #1, 22 km (6.7 mi) to the southwest. Stratigraphic units are defined by Malde and others (1963), and Ekren and others (1976a). Stratigraphic units reported in the operator's records of this well do not exactly agree with the interpretation here. Correlation of units in this well to exposed rocks on the margin of the plain are discussed in the text.

FIGURE 2-2. Generalized stratigraphy of Cenozoic rocks from J.N. James No. 1 well near Meridian, Idaho.

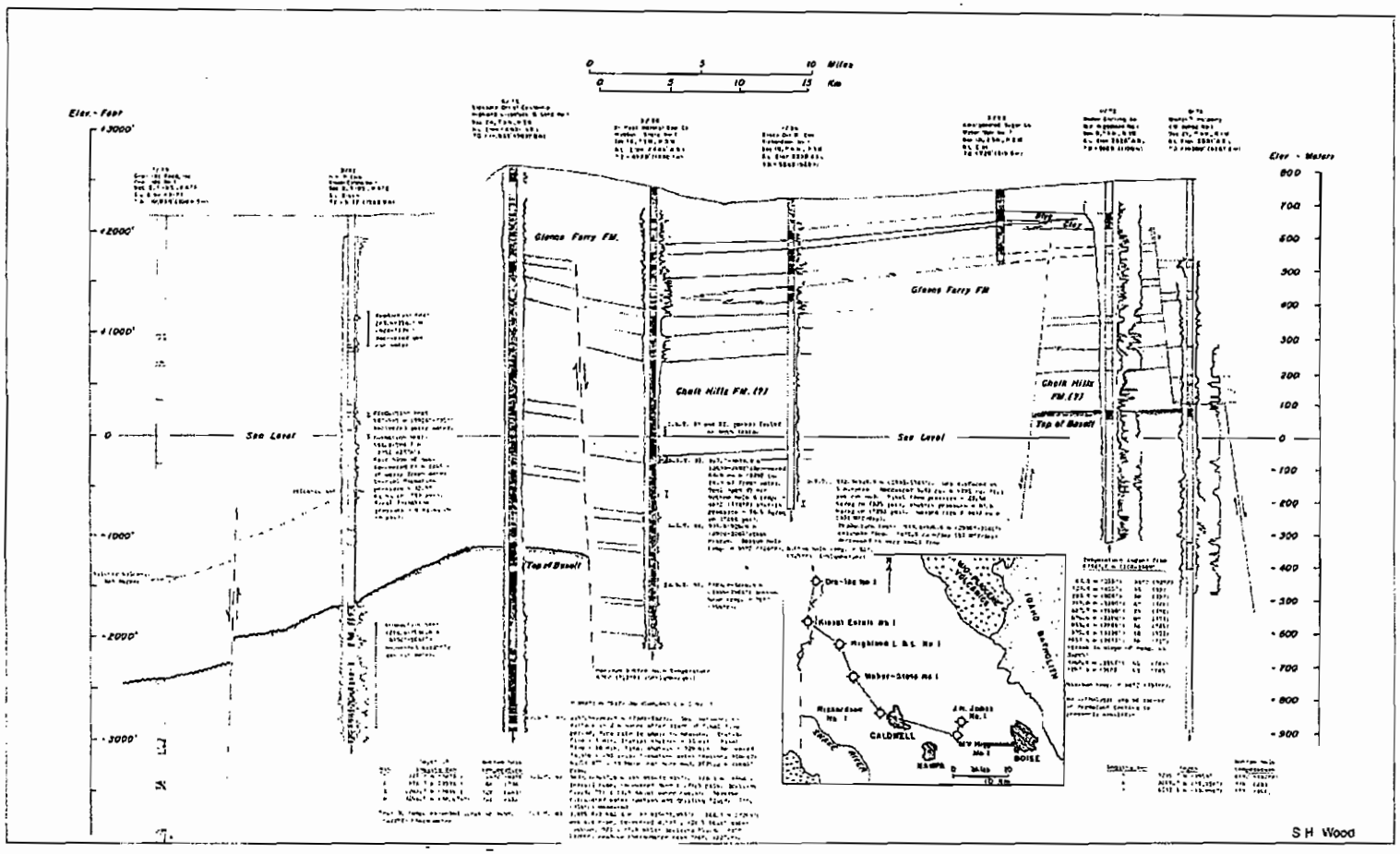
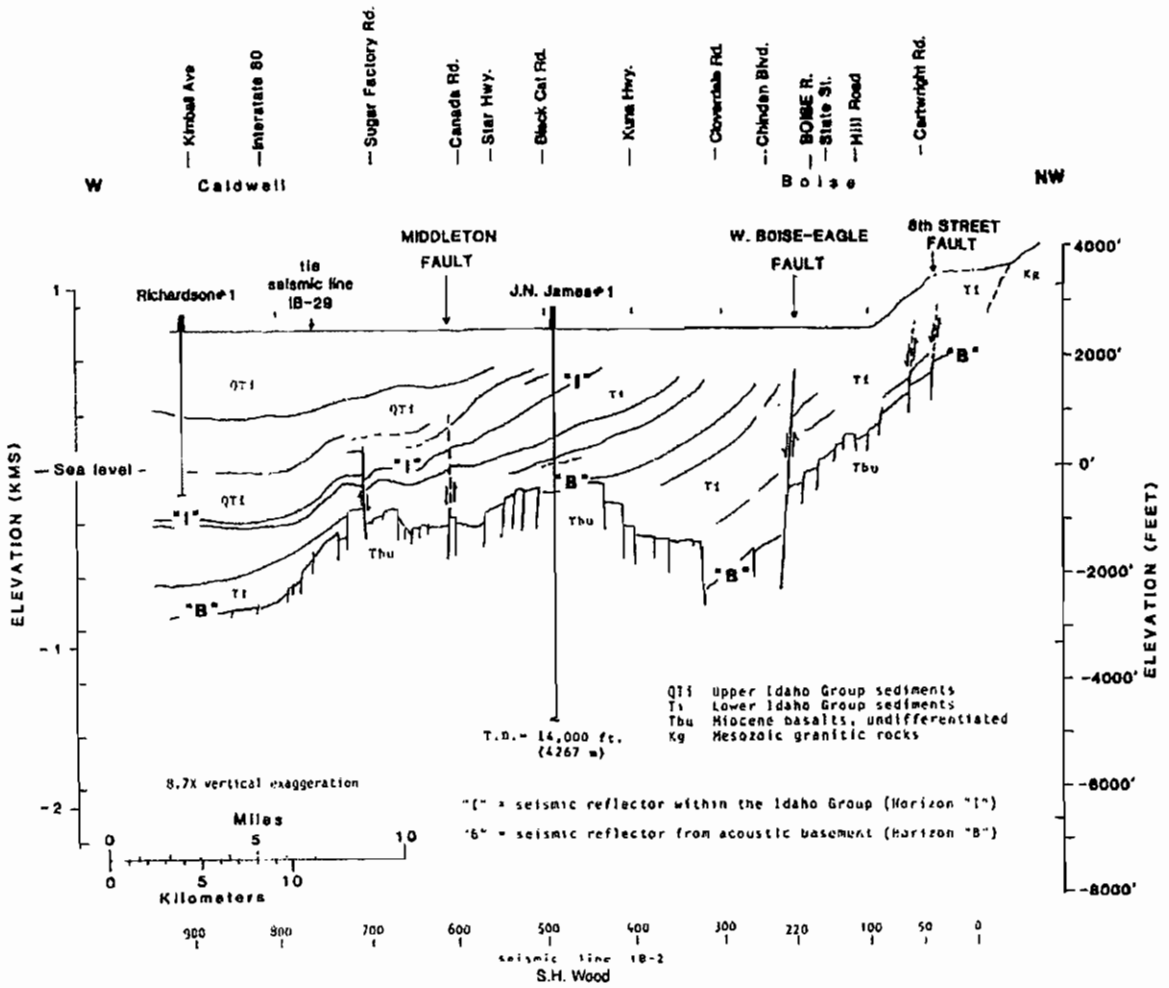
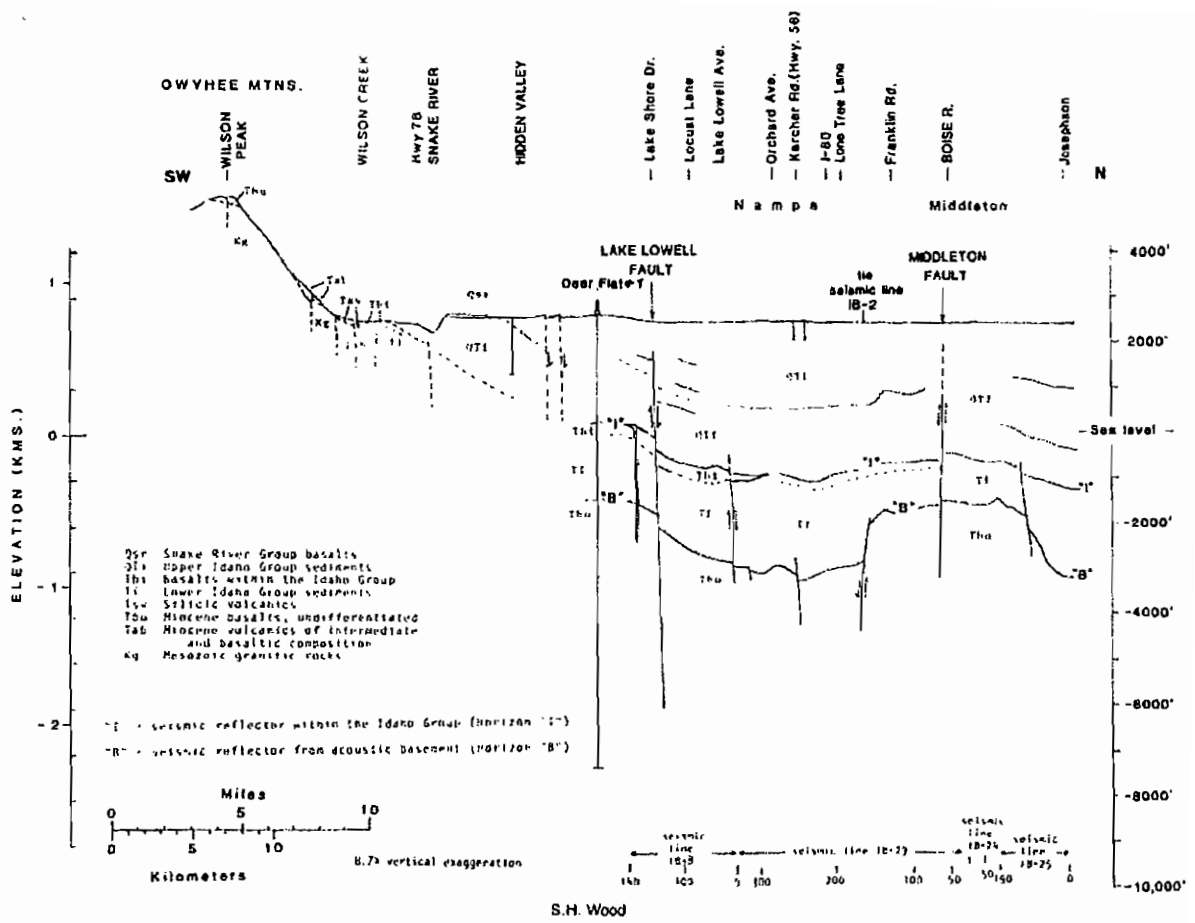


FIGURE 2-3. Stratigraphic cross section of late Cenozoic deposits, western Snake River Plain, Idaho, with electric log correlations, temperature and formation testing data



Structural cross-section prepared from seismic reflection profile IB-2. Line starts in the Boise foothills and runs down Stuart Gulch, v.p. 1-110, and then northwest along Hill Road, v.p. 110-135, along Castle Road, v.p. 135-180, across the Boise River at the Strawberry Glen Bridge, and then westward along Elm Lane to Caldwell, v.p. 260-1025. Location of section is shown on figure 2-1.

FIGURE 2-4. East-west geologic cross-section along seismic reflection line IB-2.



Structural cross-section prepared from seismic reflection profiles IB-25, IB-24, IB-29, and IB-8. Seismic line begins 5.5 mi north of Middleton and continues south along Cemetery Road to Middleton, IB-25, v.p. 1-190, and then west 1.6 km (1 mi) along Highway 44, IB-24, v.p. 75-25, and then south on Middleton Road to the edge of Lake Lowell, line IB 29, v.p. 25-134, and from the south city limits of Nampa south along Highway 45, line IB8 - v.p. 1-140. Continuation of section south to the Owyhee Mountains is based upon preliminary results from the Champlain Oil Deer Flat No. 1 well, unpublished geologic mapping by S.H. Wood, and from Ekren, McIntrye, and Bennett (1978). Location of section is shown on Figure 2-1.

FIGURE 2-5. North-south geologic cross-section along seismic-reflection lines IB-25, IB-29, and IB-8.

STRATIGRAPHY

Older Volcanics of Intermediate Composition

The J.N. James No. 1 well bottomed at 4,267 m (14,000 ft) in 240 m (800 ft) of volcanics variously described as latite, dacite(?), andesite, vitric and lithic tuffs, and minor basalt. Some of the felsic rock bears phenocrysts of amphibole and biotite. This section resembles the Miocene or older rocks described by Ekren and others (1981) in parts of the Owyhee Mountains. Volcanic rocks of intermediate composition are in the Reynolds and Salmon Creek drainages. Dikes bearing amphibole and biotite phenocrysts occur in the War Eagle Mountain area (Pansze, 1973). These rocks could also be Challis-aged volcanics mapped on the south side of the plain by Ekren and others (1981) and on the north side by Malde and others (1963).

Older Rhyolites and Welded Tuffs

The 195 m (640 ft) section from 3,828 m (12,560 ft) to 4,023 m (13,200 ft) contains a group of rhyolitic rocks described as gray-to-lavender welded tuffs that contain spherulites. Other rocks of the group are lithic and vitric tuffs. According to Hiner (1976) some of the rocks bear phenocrysts of pyroxene, amphibole and quartz. Because this unit is overlain by sediments that are considered the Sucker Creek Formation by Warner (1977), these rhyolites in the well are probably related to the Miocene "gold bearing rhyolites" of Malde and Powers (1962). A number of rhyolites underlying the Sucker Creek Formation are mapped in the Owyhee Mountains by Ekren and others (1981). In particular, the Silver City Rhyolites of Bennett and Galbraith, (1975) locally exceed 200 m in thicknesses. K-Ar dating on the Silver City Rhyolites yielded ages of 15.6 to 15.7 + 0.4 million years (Pansze, 1973).

Sucker Creek Formation

A unit of 815 m (2,760 ft) of monotonous brown claystone and siltstone with interbedded welded and non-welded ashy tuffs, and one basalt flow near the base of the unit is encountered from 2,865 m (9,400 ft) to 3,828 m (12,560 ft). Descriptions of the cuttings and the overall character of the unit, and the stratigraphic position are very similar to the type section of the Sucker Creek Formation of Kittleman and others (1965), and Ekren and others (1978a) along the Oregon-Idaho border.

Along the northern margin of the western Snake River Plain, much of the area mapped as Payette Formation by Lindgren (1898, p. 632), Kirkham (1931a or b), and Savage (1958 and 1961) may contain strata correlative with the Sucker Creek Formation; however, mapping and stratigraphic correlations necessary to establish continuity or contemporaniety of the formations has not been attempted to date. Kirkham (1931a or b) defined the Payette Formation as the silty and clayey sediments that interfinger with basalts of the Columbia River Group in the vicinity of Horseshoe Bend and Weiser. McIntyre (1976) found that much of the sediment in the Weiser area identified as Payette Formation by Kirkham (1931a, or b) was, in fact, overlying the main volcanic sequence in this region. A basaltic andesite dike cutting the Weiser area sediments yields a whole rock K-Ar age of 10 ± 0.6 million years indicating a late Miocene or older age for the sediments (McIntyre, 1976).

Age of the Sucker Creek Formation is late Miocene based upon Barstovian mammalian fossils collected near the type locality and middle Miocene based on flora of Mascall age (Kittleman, et al., 1965, p. 7). A basalt within the Sucker Creek Formation yielded a potassium-argon age of 16.7 million years (Evernden and James, 1964, p. 971). The above age assignments from the Owyhee Canyon area are consistent with four potassium-argon ages on the overlying Owyhee Basalts (Bryan, 1929) obtained by Watkins and Baksi (1974, p. 173) that ranged from 13.1 to 13.6 million years.

Basalt Section in the J.N. James No. 1 Well

Well logs indicate a 2,100 m (7,000 ft) thick section of basalt with lesser amounts of interbedded arkosic and tuffaceous sediments overlie the Sucker Creek Formation. This basalt section is entirely penetrated by J.N. James No. 1 well. Basalt is first encountered at a depth of 728 m (2,390 ft) and the basalt dominated section extends to a depth of 2,865 m (9,400 ft). Deep wells west of the study area, Highland Land and Livestock No. 1 (T.D. = 3,638 m [11,935 ft]) and Ore-Ida No. 1 (T.D. = 3,064 m [10,054 ft]) encounter a greater proportion of fine-grained sediment, much less basalt, and generally thinner basalt units (figure 2-2). Thick flows within the upper 100 to 150 m (300 to 500 ft) of this basaltic section act as the acoustic basement for seismic reflection profiling over most of the western plain.

The following breakdown of the 2,100 m (7,000 ft) section of basalt and sediments is based entirely upon the lithologic log description of Hiner (1976) and geophysical logs of the J.N. James No. 1 well where basalt is first encountered at 728 m (2,390 ft) depth.

BASALT UNIT I — The lowermost unit of interbedded sediment and basalt extends from 2,322 m (7,620 ft) to 2,865 m (9,400 ft), a thickness of 542 m (1,780 ft). The lower 189m (620 ft) is made up of at least two thick basalt flows, described as black to dark green with zeolite and calcite amygdules. These thick flows rest upon Sucker Creek Formation sediments. The upper part of this unit is mostly brown siltstone with minor arkosic sandstone interbedded with thin basalt flows. Chevron geologists considered this unit to be a part of the Sucker Creek Formation (unpublished records on file with the Idaho State Petroleum Engineer, see Hiner, 1976).

BASALT UNIT II — A 884 m (2,900 ft) thick unit of basalt, extends from 1,438 m (4,720 ft) to 2,322 m (7,620 ft). This unit consists of about 60 percent thick flows of pyroxene-plagioclase phyric basalt and about 40 percent moderately-to-poorly-sorted, fine to coarse grained, arkosic sandstone. Absence of visible olivine in the flows is inferred because it is not mentioned in the well log (Hiner, 1976). Identification of such phenocrysts in basalt on field lithologic logs must be regarded with caution for it is unlikely that the drill cuttings were viewed in thin section with a petrographic microscope.

BASALT UNIT III — The uppermost basalt unit from 728 m (2,390 ft) to 1,438 m (4,720 ft) is composed of 520 m (1,700 ft) of dark grey to black, olivine basalt with minor interbeds of arkosic white sand, welded and non-welded tuff, and siltstone and claystone. The lithologic log describes cuttings of a light-pinkish-brown rhyolite tuff from the upper part of this unit. Such a distinctive rock may serve as a marker in other wells. It is also possible that this tuff is the lone representative of the Idavada Group in this area. The lower part of the unit contains 61 m (200 ft) of well sorted sand indicating the possibility of sand aquifers within the basalt. This sand also contains a tarry-black hydrocarbon-like material (Hiner, 1976). Thick flows within this unit constitute the regional acoustic basement mapped as a reflection horizon in figure 2-7 and discussed in Chapter 6.

Basalts in Adjacent Areas

The basalt stratigraphy in this region of Idaho is complex. No correlative subsurface marker beds have thus far been established. Age of the basalts are not known, although it is likely that much of this basalt section is Miocene to early Pliocene in age, and is related to the basalts of the Columbia River Group. Recent studies of the Columbia River Group summarized in Swanson and others (1979) indicate that the Lower-to-Middle-Miocene Imnaha and the widespread Grande Rhonde Basalt Formations extend into the Weiser embayment of the Columbia River Basalt Plateau. These basalt units are down faulted to the west (Newcomb, 1970), and dip to the west and southwest beneath sediments of the lower Idaho Group. They presumably underlie a part of the western Snake River Plain. Feeder dikes of these two oldest formations of the Columbia River Group comprise the majority of dikes of the north-northwest striking Chief Joseph dike swarm of northeastern Oregon and western Idaho (Taubeneck, 1970 and Swanson and others, 1979). Most flows of the Imnaha basalt are coarse grained and plagioclase phyric. Zeolite amygdules and smectite alteration are common and widespread. Imnaha basalt flows are known only in the southeastern part of the Columbia Plateau, on both sides of the Blue Mountain-Seven Devils uplift. Maximum thickness of the Imnaha basalt is reported to be about 500 m (1600 ft) in Hells Canyon (Vallier and Hooper, 1976; and Hooper, 1981).

The Grande Ronde Basalt is now recognized as the most widespread formation of the Columbia River Group and exceeds 500 to 700 m (1640 to 2300 ft) thick on the north flank of the Blue Mountains (Swanson and Wright, 1981). Basalt flows of the Grande Ronde Formation are overwhelmingly aphyric to very sparsely phyric fine-grained tholeiitic basalts (Swanson and others, 1979). Most flows in the Grande Ronde contain rare plagioclase microphenocrysts and plagioclase-clinopyroxene clots visible in hand specimens. Olivine is generally absent as phenocrysts but is commonly present in the ground mass of all but the least magnesium flows.

K-Ar ages on the Grande Ronde Basalt range from 14 to 15.5 million years. The underlying Imnaha Basalt has not been extensively dated. Chemical and petrographic variations within these formations are discussed in Wright and others (1973 and 1979). Magnetostratigraphy of the group is summarized in Swanson and others (1979).

Geochronology and magneto-stratigraphy of the Basalts of the Owyhee Ridge in eastern most Oregon (Bryan, 1929, and Kittleman and others, 1965) are discussed by Watkins and Baksi (1974). No detectable age difference was found across the 16 flows in this area. Four K-Ar age determinations ranged from 13.1 to 13.9 million years. These ages indicate the Owyhee Basalts are a younger group of flows than the recognized Columbia River Group in the area immediately north of the Snake River Plain. The Owyhee Basalts are described as fine grained with rare phenocrysts of plagioclase in a ground mass of olivine, pyroxene and feldspar, Watkins and Baksi (1974).

Previous workers have applied local formation names of basalts to distant localities without consideration of the basalt petrography, geochemistry, or careful geologic mapping. Formation names such as the Grassy Mountain Formation (Bryan 1929, Kittleman and others, 1965), the Banbury Basalt (Stearns and others, 1938, Malde and Powers, 1962, Armstrong and others, 1975 and 1980, and Ekren and others, 1978a) have led to considerable confusion when applied regionally in the western Snake River Plain. These two formations may have correlatives within the lower Idaho Group, but neither of them are expected in the

J.N. James well section. The seismic reflection profiles across the well site show a regional, complexly-faulted, acoustic basement overlain by Idaho Group sediments with a marked unconformity (figures 2-4 and 2-5). The basalts on the structural high can be considered to be older than other basalts that are interbedded and conformable with the sedimentary section of the Idaho Group that laps upon the structural high.

Idavada Volcanic Group

To be consistent with the stratigraphic system of Malde and Powers (1962), Ekren and others (1981), and Armstrong and others (1980), the Idavada Group of silicic volcanics is discussed here. However, no obvious silicic or intermediate volcanics of the Idavada Group are noted in the upper two subunits of the basalt section with the exception of the light pinkish brown fragments of a felsic tuff in the J.N. James No. 1 well encountered between 853 and 884m (2,800 and 2,900 ft). Likewise, the only silicic volcanics noted in the lithologic log of the Highland Land and Livestock No. 1 well are described as greenish gray and light brown hard felsites between 2,659 and 2,774 m (8,720 and 9,100 ft), and black obsidian(?) at 1,650 m (5,415 ft) depth. The remainder of the volcanic units in the Highland Land and Livestock No. 1 well are described as basalt. In the Ore-Idaho Foods No. 1 well, no hard felsic rocks are described, but hard tuffs are noted in the intervals 1,692-1,700 m (5,550-5,580 ft), 2,560-2,585 m (8,400-8,480 ft) and at 2,972 to 2,978 m (9,750-9,770 ft). None of the above rock units bear a resemblance to the Idavada Group described in the north side of the Plain by Malde and Powers (1962) and Malde and others (1963). Nor do any of the above seem thick enough to be correlatives with the various rhyolites and welded tuffs mapped in the Owyhee Mountains by Ekren and others (1981).

The Idavada silicic volcanics are described by Malde and Powers (1962) as being mostly silicic latite, bearing phenocrysts of andesine, clinopyroxene, hypersthene and magnetite. They are distinguished from the older "gold-bearing" silicic rocks by their lack of hornblende or biotite. The Idavada sequence is made up of both intermediate-to-silicic ash flow and lava-flow units, that commonly have prophyritic black vitric layers and thinly flow-banded lavender and gray felsite layers. Ekren and others (1978b) have suggested that some of the widespread silicic rocks were initially emplaced as very hot ash flow sheets that remelted and remobilized as lava flows. Ekren and others (1981) also indicate that some of the silicic volcanics in the Owyhee Mountains of this group may have originated from vents in the present area of the Snake River Plain.

Ages for the Idavada Volcanic Group are published by Armstrong and others (1980). Thirteen potassium-argon dates range from 14.2 and 13.5 million years for the member units of the formation near Poison Creek to 9.6 million years for the stratigraphically youngest units.

The Idaho Group

The sedimentary deposits and local basaltic vents and lava flows that unconformably overlie the rhyolite rocks (Idavada Group) on the margins of the plain are considered by Malde and Powers (1962) to be the Idaho Group. Seven overlapping formations are discussed in their redefinition of the group. The Idaho Group in the western Snake River Plain is locally overlain by a relatively thin group of fresh, unaltered basalt flows and associated fluviatile and to a lesser extent lacustrine deposits. This latter group, containing numerous unaltered, olivine basalt lavas, is called the Snake River Group.

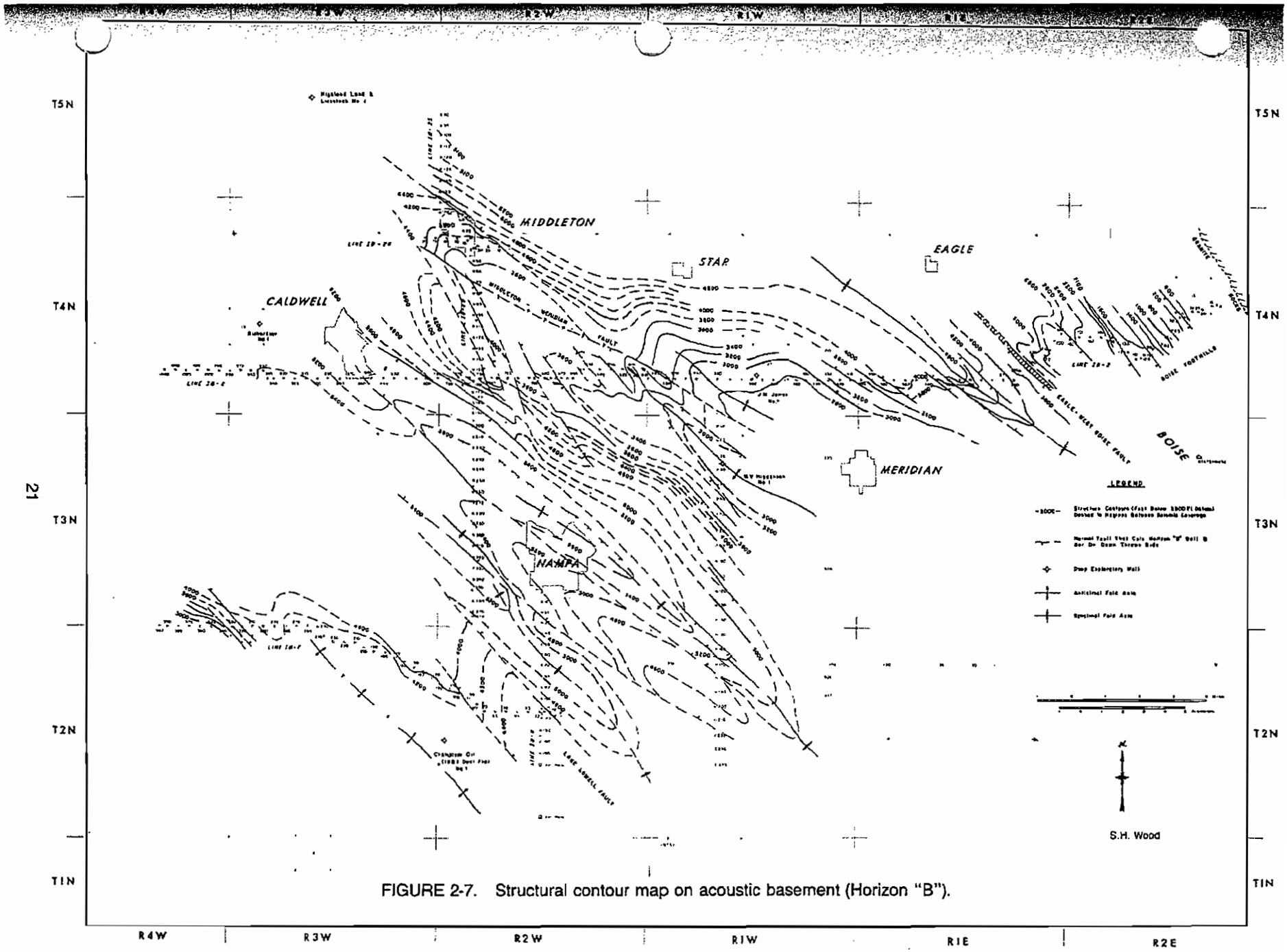


FIGURE 2-7. Structural contour map on acoustic basement (Horizon "B").

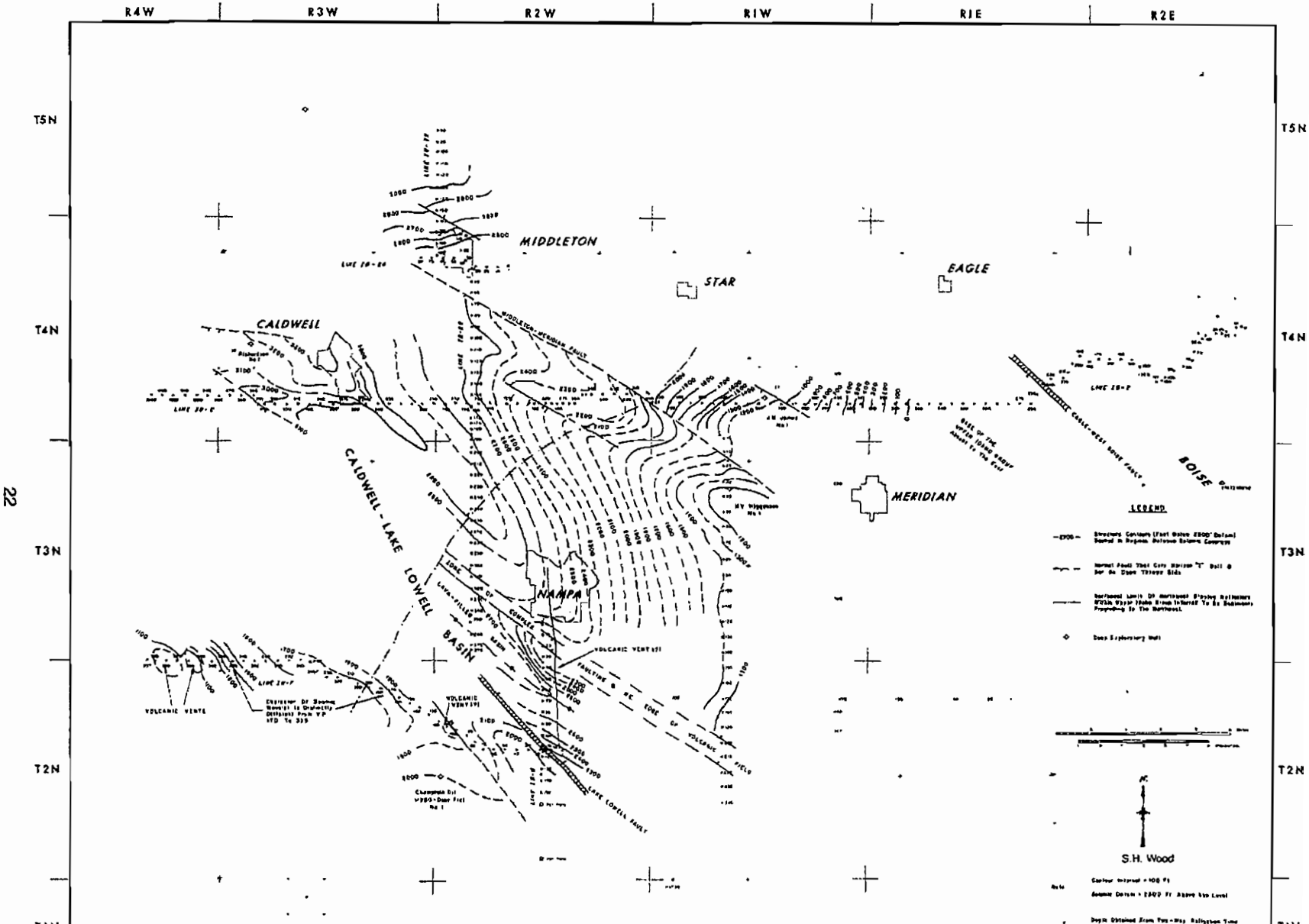


FIGURE 2-8. Structural contour map on horizon within the Idaho Group (Horizon "I").

The stratigraphic relationships within the Idaho Group beneath the western plain are complex; however, geophysical well logs (figure 2-3) and seismic reflection profiles, discussed in this study, produce a generally consistent group of subsurface units beneath the Nampa-Caldwell area. All those deposits lying between the seismically-defined "acoustic basement" and the Snake River Group are considered to be the Idaho Group in this report. Seismic reflection data shows that a maximum of 1710 m (5,600 ft) of Idaho Group sediment underlies the western part of the study area (figure 2-7). A similiar thickness is penetrated by the Ore-Ida Foods No. 1 well at Ontario (figure 2-3). The Idaho Group lies unconformably upon the faulted and eroded surface of basalts that acts as acoustic basement.

In the Nampa-Caldwell area the subsurface Idaho Group can be subdivided into a lower and an upper part. The division is made at the upper surface of a local subsurface basalt field within the group that is mapped from seismic reflection profiles south of Nampa. This surface can be traced as a seismic reflection (Horizon "I", figures 2-4 and 2-5) over most of the study area, but its lithologic character changes from a siltstone-basalt contact south of the zone of complex faulting (figure 2-8) to a sandstone-siltstone contact in the region north of Nampa. The surface rises to the east and northeast so that its depth is less than 330m (1,000 ft) beneath the Meridian area, and it may be eroded and absent from the area east and north of Meridian. The seismic horizon used to subdivide the upper and lower Idaho Group unconformably overlies the structural subsurface high of older basalts in the middle of the Plain (figure 2-5). The seismic reflection profiles also indicate that the lower Idaho Group thickens to the north and east, and that most of the exposed Idaho Group on the north margin of the Plain should be considered Lower Idaho Group. In contrast the upper Idaho Group thickens to the southwest and reaches a maximum of about 915 m (3,000 ft) beneath Caldwell.

LOWER IDAHO GROUP (including Poison Creek Formation, Banbury Basalt, and the Chalk Hills Formation) — Type localities for sediments and basaltic volcanics of the Lower Idaho Group are entirely on the south side of the Snake River Plain along the northern edge of the Owyhee Mountains. Malde and Powers (1962) defined the Poison Creek and Chalk Hills formations, but their age relationship to one another and to related basaltic volcanics is obscure (Ekren and others, 1978a). K-Ar age control within the Banbury Basalt and the Idaho Group is published by Armstrong and others (1980). The Banbury Basalt mapped by Malde and others (1963), on the north side of the Plain is dated at 9.4 $\pm$0.6 million years correcting earlier reported younger ages (Armstrong, 1980). The exposed sediments are generally described as lake and stream deposits of buff, white, brown, and grey sand, silt, clay diatomite, numerous thin beds of vitric ash and some basaltic tuffs. Well-cemented arkosic sandstones within the Poison Creek unit form dipping mesas and tilted buttresses along the north side of the Owyhee Mountains. Basalts intruding and within these beds are described as intergranular-to-ophitic textured olivine basalt, and some are mapped by Ekren and others (1978a) as the Banbury Basalt Formation.

Boise Area — Sediments similar to those of the lower Idaho Group exposed along the edges of the Owyhee Mountains on the south side of the Plain are exposed in the Boise foothills where the lower Idaho Group is a series of arkosic, deltaic and lake margin sand units and buff siltstones about 200 m (650 ft) thick (Wood and Vincent, 1980). On the north side of the Plain in the Boise foothills these sediments rest upon an irregular erosion surface of silicic volcanics of the Idavada Group, or upon weathered, eroded, plagioclase phyric basalt flows and basaltic tuffs that are similar to the Banbury Basalt Formation north of Mountain Home, described by Malde and others (1963). A flow of fine-grained olivine-

bearing basalts also occurs within the lower part of the arkosic lake margin sand units, and at places these basalts rest upon an eroded surface of a sedimentary unit of tuffaceous silt and white vitric tuffs.

Most of the Idaho Group exposed in the Boise area might be the Lower Idaho Group. Previous workers have described these sediments as the Glenns Ferry Formation of the Idaho Group (Savage, 1958, Hollenbaugh, 1973, Thomas and Dion, 1974); however cross sections of the Plain prepared from seismic reflection profiles (figure 2-4) show that these foothills units emerge to the northeast from deep beneath the Plain at dips of 7° to 10°, and they may not be a part of the Glenns Ferry Formation. The Glenns Ferry Formation, if it exists as a subsurface unit beneath Boise, must lie unconformably on the Lower Idaho Group and be less than 300 m (1,000 ft) thick. Stratigraphic details of the upper 300 m (1,000 ft) are not known, for we have no seismic reflection data for the upper section. The widespread "blue clay" encountered in water wells within the upper 180 m (600 ft) of section may be a part of the Glenns Ferry Formation, and so might the sandy coarse facies that rests upon it. It is important for geohydrologic considerations to recognize that the emerging deep units are not conformable. A geohydrologic framework for the upper 300 m (1,000 ft) of section beneath Boise is proposed by Burnham (1979) and represents the first reasonable geologic explanation of the groundwater system; however, well data is sparse and inconclusive regarding the detailed stratigraphy of the upper section.

Nampa-Caldwell Area — West of Boise, in the Meridian area, the Lower Idaho Group fills a deep basin developed by faulting and downwarping before and during the deposition (figures 2-4, 2-5). The basin is bounded to the southwest by structurally high basalt. Lower Idaho Group sediments filled and overtopped the structure and sediments were transported to the west-southwest into the Lake Lowell-Caldwell Basin. Thick sand units at 600 to 700 m (2,000 to 2,300 ft) depth, encountered in wells drilled upon the structural high probably represent a deltaic facies prograding to the west across the submerged high to the subsiding basin to the south in the Lake Lowell-Caldwell area. These sands should exist as aquifers along the top of the high and to the northeast where they emerge or are truncated by younger sediments. The contrast between the deep and shallow investigation resistivity logs (figure 2-9 and Chapter 3, indicates these sands should be good aquifers with moderate permeability. These sands have never been formation tested, nevertheless, they have resistivities and thicknesses comparable to shallower units in the Upper Idaho Group that yield good flows to wells. It is not known if, in the Lower Idaho Group, these sands persist in the subsurface south of the structural high into the Lake Lowell-Caldwell Basin. Coarse arkosic sandstone of the Lower Idaho Group outcrops along the north margin of the Owyhee Mountains south of Nampa and Caldwell (Ekren, and others, 1981). Some of these sandstones have fair permeability; however, many are also tuffaceous and silty and of low permeability. However, the source of these sands may not be the same as the sand in the subsurface for they may have been derived from sources south of the subsiding plain.

The Lower Idaho Group locally contains subsurface basaltic lava fields and several thin flows. A subsurface basaltic lava field is mapped from seismic reflection profiles in the area immediately southwest of Nampa (figure 2-5). The basalt appears to be thickest in the Lake Lowell basin. The top of the basalt surface ranges in depth from 549 m (1,800 ft) to about 823 m (2,700 ft). Within areas that were topographically low at the time of eruption seismic profiles indicate the Idaho Group Basalts may be as much as 150 m (500 ft) thick.

In the Champlain Oil Company (Deer Flat No. 1) well only a few flows 10 to 20 m (30 to 65 ft) thick are encountered at 822 m (2,040 ft) depth. Much of the basaltic material occurs as interbedded sedimentary tuffaceous silt and sand. To the west in the vicinity of Knowlton Heights, the basalt shallows to a depth of 335 m (1,100 ft) and several volcanic vents appear on the reflection profiles (figure 2-5). Subsurface occurrence of these basalts is shown on figure 2-8, and the horizon (Horizon "I") at which the basalts occur is arbitarily used in this report to subdivide the Idaho Group into an upper and lower part.

UPPER IDAHO GROUP — The Upper Idaho Group, as defined in this report, includes the sedimentary sequence above seismic Horizon "I" (figures 2-2, 2-7, and figure 2-8). During deposition of the upper Idaho Group the axis of the sedimentary basin lay beneath Lake Lowell and Caldwell. The basin axis has a northwest trend and plunges down to the northwest. The deepest part of the basin lies northwest of Caldwell beyond the area for which seismic reflection coverage was obtained (figure 2-8). Sedimentation during Upper Idaho Group time was not affected by the large subsurface structural high in the middle of the basin for it was buried by sediments.

A number of continuous seismic reflections occur within the Upper Idaho Group. These reflections are at depths of 240 to 1000 m (800 to 3,200 ft), and are apparently higher velocity siltstone and claystone. These sand units are encountered in deep wells and are well defined by their high resistivity on electrical logs shown on figure 2-9 and higher acoustic velocity on some logs. These widespread sands may represent fluvial episodes that extended out into the basin during epoisodes of regression of a lacustrine environment.

The base of the upper Idaho Group, as defined by reflector "I" in the subsurface, is probably close to the base of the Glenns Ferry Formation as mapped by Malde and others (1963) and Ekren and others (1981). In the foothills along the base of the Owyhee Mountains between Marsing and Murphy, Idaho, gray siltstone of the Glenns Ferry Formation rests unconformably on sediments and basaltic volcanics of the Chalk Hills and Poison Creek Formations. To the east, in the Bruneau area, the base of the Glenns Ferry Formation is locally marked by algal and oolitic limestone resting on beveled beds of the Chalk Hills Formation with slight angular discordance (Malde and Powers, 1962, p. 1207). Oolitic limestone near the base of the Glenns Ferry Formation has been described at numerous localities in a recently completed study by Kimmel (1979).

On the north margin of the plain in the foothills between Boise and Emmett, oolitic sand and limestone occur in the uppermost strata of a sequence of deltaic sands and siltstone that rest upon older basalt (Wood, 1981, unpublished mapping). Oolitic and algal limestone is a common shoreline facies of large saline lakes (Eardley, 1938), and it is likely that the occurrence of oolitic deposits around margins of the Snake River Plain may mark a limited stratigraphic interval within the Idaho group and show the outline of a large lake that existed during Idaho Group time. Kimmel (1979) has suggested that oolitic limestone and sandstone may locally serve as a definition for the base of the Glenns Ferry Formation. It is not known if oolitic sand occurrences on the margins of the plain are stratigraphically equivalent to the seismically defined boundary between the upper and lower Idaho Group; however, there does appear to be a coincidence between the stratigraphic occurrence of oolites on the margins, locally identified unconformities and the uppermost occurrence of local basalt fields in the strata of the Idaho Group of the western plain.

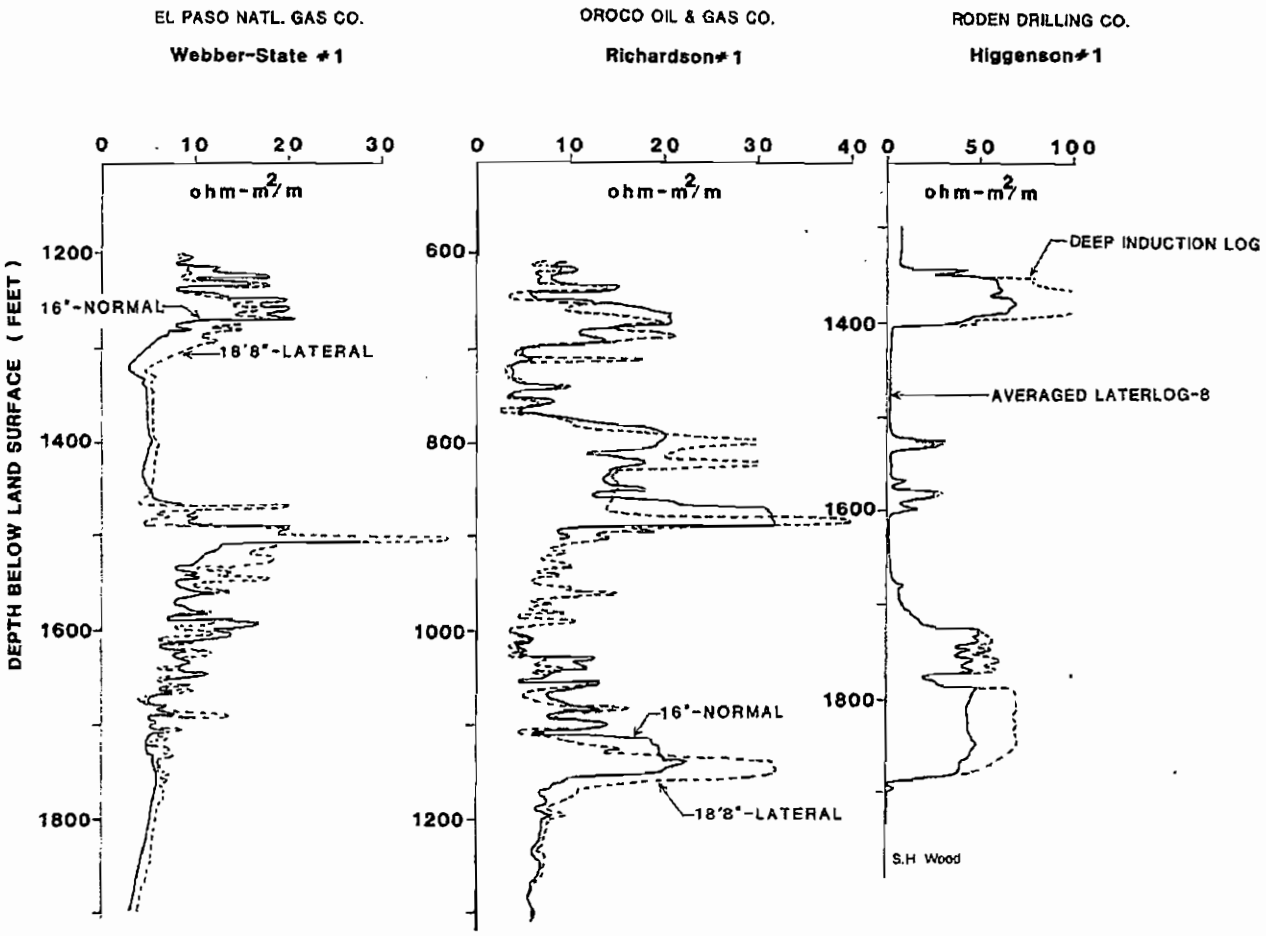


FIGURE 2-9. Resistivity log character of deep aquifer in the Nampa-Caldwell area.

Exposures of the Glenns Ferry Formation mapped along the Snake River Canyon south of Nampa and Caldwell are entirely within the upper Idaho Group (figure 2-6). Here the section consists of 100 m (300 ft) of monotonous, indistinctly-bedded, gray, lacustrine siltstone and fine sandstone. The only variation in this lithology is a 10 m ± (30 ft ±) thick layer of indurated buff-colored, tuffaceous, poorly sorted, fluvial sandstone that outcrops in Dead Horse Canyon (Sections 17, 18 and 20, T. 2N, R. 3W, figure 2-6). At this locality, and also locally along the basalt-capped white bluffs on the north side of the river, the Glenns Ferry siltstones are conformably overlain by a 20-m (65 ft) thick gravel deposit identified by clast content and stratigraphic setting as the Tuana Gravels of Malde and Powers (1962).

Fission-track ages have been determined on a number of volcanic ash members within the Idaho Group (Kimmel, 1979). Ages of ash layers within the Chalk Hills Formation range from 8.5 ± 1.2 to 7.0 ± 0.5 million years. Ash layers bracketing oolitic limestone in the basal Glenns Ferry Formation are 3.2 ± 0.4 to 2.5 ± 1.0 million years and 2.4 ± 0.2 million years. This geochronology and field evidence of an unconformity between the Chalk Hills and Glenns Ferry Formation indicate a hiatus of deposits on the margin of the Plain between about 7.0 ± 0.5 and 3.2 ± 0.4 million years.

Tuana Gravels

Well sorted pebble and cobble gravels and coarse sand are exposed along the walls of the Snake River Canyon (Deadhorse Canyon in the SW corner of the Lake Lowell Quadrangle). Stratigraphic position and clast content indicates that these gravels correlate with the Tuana Gravels of Malde and Powers (1962). These gravels contain a few clasts of orange quartzite indicating a Snake River drainage provenance and distinguishing them from the Tenmile Gravels. At this locality Tuana Gravels dip 5 to 10° north and mark an angular unconformity with the overlying, horizontal, Bruneau lake beds. Thickness of gravel is 0 to 15 m (0-50 ft).

The Bruneau Formation

The lacustrine facies and basalt of the Bruneau Formation locally lie unconformably on the north dipping Tuana Gravels and Glenns Ferry Formation in localities along the north side of the Snake River (figure 2-10). The lacustrine deposits are horizontal and contain both gray siltstone and beds of brown tuffaceous sandstone bearing palagonized basalt and scoria. A number of scoria deposits, minor basalt flows and small basalt necks of the Bruneau Formation intrude and overlie the Glenns Ferry Formation. These basalt vents stand out as small hills where the Glenns Ferry Formation has been eroded away in the cutting of the modern Snake River Valley. The Bruneau Formation is mostly confined to the present Snake River Valley area and is probably less than 50 m (160 ft) thick or non-existent in the Nampa-Caldwell area. The formation thickens to the east and is up to 240 m (800 ft) thick in the Bruneau-Grandview area (Malde, 1965). The Bruneau Formation is thought to have originated from a complex series of lava dammed lakes along the canyon of the Pleistocene Snake River (figure 2-10), but many features of its origin have yet to be explained (Malde, 1965).

Age of the Bruneau Formation is middle Pleistocene based upon a single K-Ar determination on basalt of 1.4 million years (Evernden and others, 1964). All lavas have reversed magnetic polarity and are included in the Matuyama Polarity epoch (Malde and Williams, 1975).

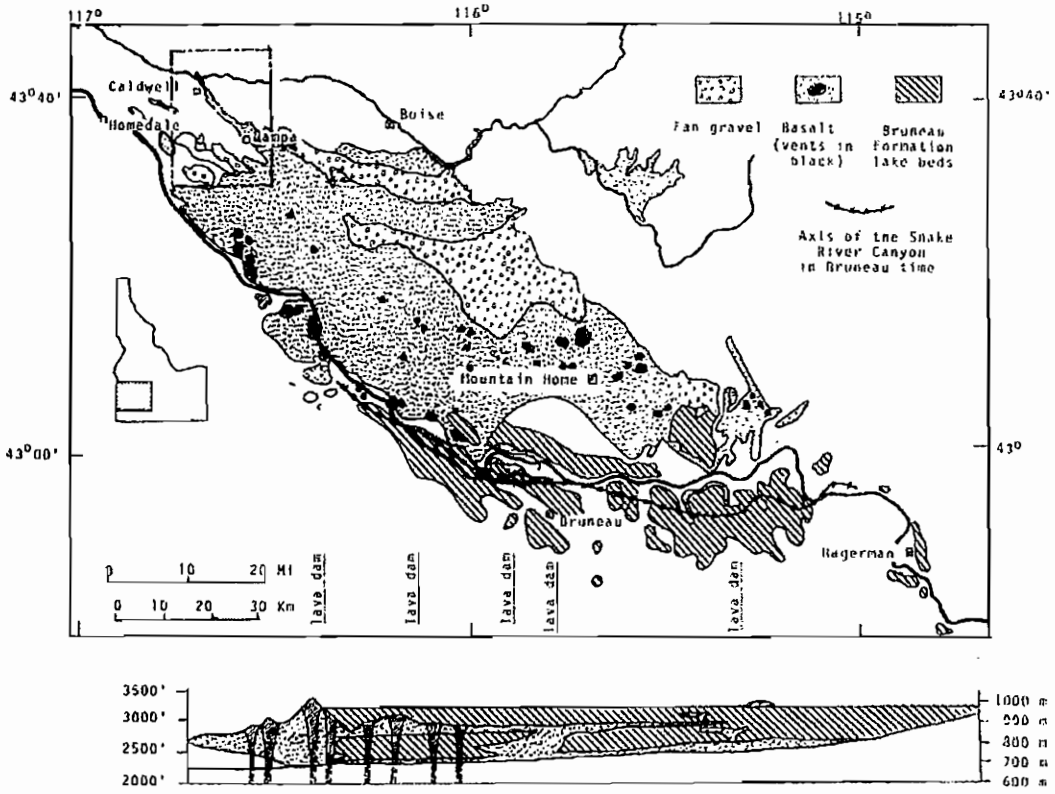


FIGURE 2-10. Occurrences of the Bruneau Formation in the western Snake River Plain. After Malde (1965a).

The Tenmile Gravels

In the Nampa-Caldwell area, the top of the upper Idaho Group is marked by a widespread fluvial gravel deposit that caps many of the hills in the area. The gravel extends eastward across the plain to the mountains east of Boise where it laps against the granitic bedrock. The gravel has a cobble assemblage of granitic rocks and felsic porphyries derived from the adjacent Idaho Batholith terrain. This gravel unit was named the Tenmile Gravels by Savage (1958) because it forms the entirety of Tenmile Ridge south of Boise where it is up to 150 m (500 ft) thick. In the Nampa-Caldwell area, the thickness rarely exceeds 15 m (50 ft). It is widely exploited as a source of gravel for construction and concrete pipe manufacturing. The geometry of the deposit and the cobble assemblage clearly mark the Boise River drainage as the source of the Tenmile Gravels. The Tenmile Gravels are distinct from the Tuana Gravels, because the Tuana Gravels bear a few orange quartzite cobbles and other metamorphics whereas the clasts of the Tenmile Gravels are almost entirely intrusive porphyries and granitic rocks. The stratigraphic relationship of the Tenmile Gravels to other Plio-Pleistocene units such as the Bruneau Formation is uncertain.

Snake River Group

SEDIMENTS OF THE DEER FLAT SURFACE — The higher upland surface both north and south of the Boise River is underlain by at least 30 m (100 ft) of unconsolidated fluvial sand and gravel. The sands are mostly coarse, arkosic and cross-bedded. The gravels are typically in beds 0.5 to 2 m (1.5 to 7 ft) thick and are composed of rounded clasts of intrusives derived from the Boise River drainage. The gravels are indistinguishable from the Tenmile Gravels. The unit is identified by its topographic position on a surface that is about 60 m (200 ft) above the present Boise River. The surface rises generally from 760 m (2,500 ft) on the west side of the map to 823 m (2,700 ft) elevation in the northeast corner of the Middleton 7 1/2 minute quadrangle (figure 2-6). A good exposure of this unit is located in a gravel pit in the SWI/4, Section 3, T. 4N, R. 4W, 3 km (1.9 mi) north of Caldwell. No extensive exposures of this unit are known south of the Boise River. The unit is best identified by the elevation of its surface and by soil development. Priest and others (1972) classify soils upon this surface in the Scism or the Power-Durham series characterized by a moderately well-cemented caliche horizon 0.5 to 1.2 m (1.5 to 4 ft) deep.

The Indian Creek Basalt flows erupted onto surfaces of the Deer Flat Sediments, and are reported in the driller's logs to be interbedded with this unit. The unit is probably middle Pleistocene in age.

INDIAN CREEK BASALT FLOWS — Basalt which outcrops in Section 13, T. 3N, R. 1W by the Nampa State School and also in the north Caldwell area along the Boise River is the same flow unit. The flow is about 0.7 km (0.5 mi) wide. This flow is named the Indian Creek Basalt, for it extends as a continuous flow from beyond the west edge of the map to Caldwell and parallels the course of Indian Creek. Subcrop of this flow has been mapped from the numerous driller's logs in the area. The flow is a gray, titano-augiteplagioclase-olivine basalt, and is typical of basalts of the Snake River Group. The gray color results from an abundance of small lath shaped plagioclase crystals.

One or more deeper flows are identified from the water-well driller's logs at depths of 15 to 30 m (50 to 100 ft). This deeper flow underlies much of the city of Nampa, but the previously discussed shallow flow lies mostly to the north of Nampa. Subcrops of both the

flow units are shown with dotted lines on figure 2-6. Both flows probably erupted onto an aggrading surface of sediment and can be considered as interbedded with the fluvial sediments of the Deer Flat Surface. Paleomagnetism of samples from three localities was measured with a field fluxgate magnetometer. Declination was consistently east-northeast, and inclination was much too shallow to clearly identify the direction of paleomagnetism as reversed or normal. The cause of this anomalous magnetization is unknown. Because of the association of the flows with the sediment of Deer Flat Surface, and the presence of an indurated caliche, the age of these basalts is probably middle Pleistocene.

The Indian Creek Basalts constitute the important unconfined, shallow groundwater system of the Nampa-Lake Lowell-Caldwell area. The basalt flow aquifers are tapped by numerous, shallow, domestic and irrigation wells. The groundwater is presently recharged mostly by seepage of imported irrigation water and canal leakage. The water level is quite stable. Because of their shallow situation and high transmissivity, the Indian Creek basalt aquifers can be easily contaminated by surface spills or leakage from buried storage tanks. The extent of these aquifers, is shown in figure 2-6. Wells situated on the hills capped by the older Tenmile Gravels do not encounter shallow aquifers and wells must be drilled deeper to tap the confined aquifers of the upper Idaho Group in order to obtain flows adequate for irrigation.

WHITNEY TERRACE DEPOSIT — Alluvium of the Whitney Terrace of the Boise River (Nace and others, 1957) consists of rounded cobble and pebble gravels, arkosic sands and minor silts. The unit is identified by the relatively flat terrace surface 10 to 20 m (30 to 65 ft) above the present Boise River floodplain. Soils developed upon the terrace gravels have a well developed profile with a brown silty clay loam "B" horizon composed of up to 0.9 m (3 ft) of calcareous nodules extending to a depth of up to 1.3 m (4 ft). These soils are assigned to the Power and Greenleaf series by Priest and others (1972). Soil profiles developed on this surface suggest a pre-Wisconsin age for the Whitney Terrace Deposits, or an age of 100,000 years or more.

QUATERNARY ALLUVIUM AND FAN DEPOSITS — Recent fluvial deposits cover the modern flood plain of the Boise River and Indian Creek. The Boise River flood plain is about 5 km wide in the map area. In the Middleton Quadrangle, ephemeral tributaries have formed small alluvial fans that extend into the Boise River flood plain.

STRUCTURE

Early Pleistocene gravels and older stratigraphic units in the Nampa-Caldwell area have been deformed by normal faulting, gentle tilting of fault blocks and broad downwarping toward the axis of the plain. Normally faulted gravels and sand layers are observed in several quarries in the area (figure 2-6) with displacements of a few decimeters to 10 m (1 to 30 ft). All mapped faults strike in a Northwest-southeast direction with dips ranging from 55° to nearly vertical. The only exception is the North Caldwell Fault exposure with an east-west strike. Linear ridges capped by the Tenmile Gravels trend northwest through the area in the vicinity adjacent to, and southwest of, Lake Lowell. The steeper sides of these asymmetric ridges are interpreted as fault-line scarps of normal faults that have apparent displacements up to 30 m (100 ft). Cross sections constructed from driller's logs (figure 3-1) show offsets up to 50 m (150 ft) of distinctive lithologic units. These offsets are interpreted as normal faults (figure 2-6). Bedding attitudes on exposure of the late Pliocene or early Pleistocene Glenns

Ferry Formation and Tuana Gravels are generally down to the northwest 3° to 10°. These attitudes are taken along the north rim of the Snake River Canyon and are consistent with dips interpreted from seismic reflection profiles (figure 2-5).

Attitudes on the Tenmile Gravel bedding are generally horizontal, but variations in elevation of the base of the gravel indicate that the gravels are faulted and slightly tilted. The elevation of gravels and direction of throw on faults is not in any consistent direction and no broader structures larger than individual fault blocks one or two km (0.6 to 1.2 mi) wide are indicated by deformation of the gravels.

Lack of the Tenmile Gravels northeast of Nampa, in the area covered by Terrace deposits and Quaternary alluvium, is attributed to erosion of the gravels by the Boise River and not to downfaulting. Very few surface faults are shown in the area on the map (figure 2-6) because the younger Boise River alluvial deposits are not faulted. Seismic reflection profiles show that a number of subsurface faults do occur in this area, and these are shown with a different symbol on figure 2-6.

The upper surface of the middle Pleistocene Snake River Basalts varies somewhat, and along the north rim of the Snake River the basalts appear to be slightly tilted, a few degrees, downward toward the basin axis of the plain to the northeast. The basalt surface is probably slightly downwarped by continued subsidence of the plain, but the flows do not appear to be broken by faulting in the map area. The larger tilted and faulted basalt buttes in the map area are probably earlier basalts of the Bruneau Formation (Pickles Butte, and the buttes in Hidden Valley); although, some of these basalts may have been mapped as the Snake River Group on figure 2-6.

The middle Pleistocene Snake River Basalts are not obviously faulted except in the vent areas. Faulting and vent fissures trend northwest across the two major basalt-shield vents shown on the map (Kuna Butte and Powers Butte). Kuna Butte differs from Powers Butte in that its north flank is made up of tilted Tenmile Gravels that were either a pre-existing fault block, or were arched by a shallow intrusion of the basalt. It is not a simple shield volcano such as Powers Butte. The northwest trend of the vent fractures suggests that the basalt erupted from deep sources along fissures opened by the same northeast-southwest oriented extentional stresses that produced the faulting in the slightly older Tenmile Gravels.

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M3 EAGLE LLC
EXHIBIT
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Test Well #1 - M3 Eagle, LLC

Water Level Monitoring - Zone #1

Monitored For M3 Eagle By: Hydro Logic Inc.