



February 10, 2014

RMEA Project 14-0010

Board of Directors
Samaria Water and Irrigation Company
c/o David Reel
5176 South 4400 West
Malad, Idaho 83252

Re: Field observation of springs

Dear Directors:

The water rights for Samaria Water and Irrigation Company (District) derive from Illum Spring, a cold-water spring west of Malad, Idaho, and from Warm Springs, located a few miles south of Illum Spring. The District is concerned over declining discharges from the springs and the potential impact of irrigation wells in the area.

On January 28, 2014, I met with Mr. Lynn Wright and Dr. Mark Ipsen to look at the springs and talk about the District's concerns. This letter describes my observations and gives an initial response to several questions:

- 1) What are the options and opportunities for cleaning the springs? Will this increase flow? What methods should be used?
- 2) Do the Russian Olive trees surrounding Warm Springs intercept a significant amount of water?
- 3) Does damming the outlet of Warm Springs retard the flow?
- 4) What are the likely effects of wells upon the springs?
- 5) What is the process to make a water call? What kind of data are needed for a call? What are the expected costs?
- 6) What are water tests that might give insight into waters that have common sources?
- 7) What are the options for measuring the discharge of Warm Springs?
- 8) How should the Flow Probe be used that was purchased by the District?

Summary of Observations

Warm Springs

When we looked at Warm Springs, salt stains on the vegetation surrounding the springs indicated that the water levels at times have been persistent at a water level about ten inches higher than we observed. There were boards on the ground near the outlet culvert but at that time the flow was not dammed. Using a velocity head rod, I made

reconnaissance flow estimates of the flow entering the main part of the pond from the north gravel bank, and of flow at the outlet culvert from the pond. The flow from the gravel bank was 162 Idaho miners' inches plus or minus 50 inches. Photo 7756 in Appendix 1 shows the flow from the gravel bank and the measurement location. The flow exiting the pond was 273 miners' inches plus or minus 30 inches. This was measured at the outlet of the culvert shown in photo 7740. Later in the day, we reviewed Mr. Wright's notes from measurements with the District's Flow Probe device and from the 12 inch Parshall Flume that brings cold water from Illum Spring. Table 1 summarizes flows from Warm Springs, after subtracting the cold water measured in through the Parshall Flume. The calculations assume that the channel shown in Photo 7746 is six feet wide.

Table 1
Discharges from Warm Springs

Date	Flow from Springs (Idaho Miners' Inches)	Comment
Historical	300 - 350 inches	From water rights and notes in water right files
8/18/2013	6 inches	Measured by Wright. Assumes concrete channel is six feet wide. Cold inflow subtracted.
8/26/2013	33 inches	"
9/1/2103	Zero flow	Wright notes springs were dry
9/9/2013	8 inches	Wright notes springs were dry; eight inches is the difference between the Parshall Flume (150 inches) and Flow Probe measurements, and is within the precision of the Flow Probe.
9/17/2013	70 inches	Measured by Wright, net of cold water inflow.
12/4/2013	280 inches	Measured by Wright. No cold water inflow.
1/28/2014	273 inches	Measured by Contor. No cold water inflow.

I measured water depth and temperature at a number of locations using a pressure-transducer device with a data logger, with Global Positioning System (GPS) readings to identify location. Figure 1 (attached) shows the GPS locations for temperature readings and other observations, and Table 2 shows the depths and temperatures recorded. A dike that appears to be man-made separates the north part of the springs from the

body of the Warm Springs area. This north area is called the "Goddard Right" in this letter and in the figures and tables.

South of the springs are two irrigation wells in close proximity to the canal. One was discharging water apparently under artesian head as shown in photo 7748. Table 2 includes a temperature measurement from this well discharge.

Table 2
Depths and Temperatures
Recorded at Warm Springs
January 28, 2014

Waypoint (See Figure 1)	Depth (ft)	Temperature (°F)	Comment
3	N/A	79.3	Flowing Well
7	0.14	74.7	Goddard Right
9	0.35	75.6	Goddard Right
11	0.19	76.3	Main Springs
12	1.53	77.4	Main Springs
14	2.34	72.9	Main Springs
15	1.29	70.7	Main Springs
17	0.86	72.5	Main Springs

I attempted to bore into the bottom material at several locations, as noted by the GPS waypoints in Figure 1. The Goddard Right area of the springs was gravely with some coarse-grained sand, and very few fine-grained materials within the few inches that I was able to bore by hand (Photo 7756). The north end of the main body of springs, including the gravel bank where significant water emerged, was similarly underlain by gravel and coarse sand. Progressing south into deeper and slower-moving water, the sand and coarse gravel were overlain by what appeared visually to be silty material. Intermittent sand boils and gas bubbles indicated inflow through this material as well. Wading through this material it was apparent that it was very light weight and loose material. My feet would sink in this material nearly knee deep, yet it offered little impediment to movement. I took three samples of this material as indicated by GPS waypoints in Figure 1. I also took water samples from the Goddard Right side of the dike and the main body side of the dike. Basic water chemistry results reported in Table 4 in the Illum Spring section below.

Illum Spring

Photos 7766 and 7769 show Illum Spring. I deployed the pressure transducer in the outlet stream below the Parshall Flume and at locations within the spring, as shown in Figure 2 (attached). Table 3 gives the depths and temperatures recorded.

Table 3
Depths and Temperatures
Recorded at Illum Spring
January 28, 2014

Waypoint (See Figure 2)	Depth (ft)	Temperature (°F)	Comment
18	0.1	61.9	Parshall Flume
19	0.9	60.1	
20	3.5	60.3	
21	3.6	60.8	
22	4.0	61.2	

At Illum Spring I did not observe the light, loose silty material that was seen at Warm Springs. Near the edges of the Illum Spring pool the bottom materials were heavy and fine textured. Where sand boils and lack of vegetation indicated upwelling of water, the bottom felt under the hand auger to be firm gravel and coarse sand, but the water was too deep to successfully bring a sample to the surface to handle. Some water was emerging from a gravel bank on the west side of the spring.

Dr. Ipsen and Mr. Wright both told me that Illum Spring does not exhibit nearly as much flow variability as Warm Springs. I measured a stage of 0.54 feet in the three-foot Parshall Flume at the outlet of the spring. I did not check the level of the flume, but if it is level, this corresponds to a flow of 228 inches. Dr. Ipsen reported a reading of 0.58 feet in the spring of 2013, 0.50 in July and 0.52 in August. These correspond to flows of 255, 202 and 215 inches, if the flume is set level. The water rights from the spring total 1,100 inches but it appears that this may include the right to access springtime runoff in the Malad River as well as discharge from Illum Spring. In a cursory search of the water right files I did find reference to a historical measurement of just under 500 inches for the spring itself.

I also took a water sample at Illum Spring. Table 4 summarizes results of the water-quality results from Rocky Mountain Environmental Associates, Inc. (RMEA) instruments. pH is related to acidity of the water, while electrical conductivity is related to hardness and salinity. The pH instrument did not properly calibrate and so those readings should be viewed as relative readings and not as indications of the actual pH. Samples were refrigerated to the same temperature prior to testing, so no temperature bias should exist between samples. The pH values are in a typical range for western irrigation water. For context of electrical conductivity, the Snake River at Nyssa, Oregon had electrical conductivity values ranging from 350 to 550 uS/cm between 2008 and 2010 (the only period of record identified). Typical irrigation guidelines are that water with electrical conductivity below 700 uS/cm may be used without restriction, and that water with conductivity over 3,000 uS/cm generally is unusable for irrigation.

Table 4
pH and Electrical Conductivity
of Springs

Sample	pH	Electrical Conductivity
Goddart Right side of Warm Springs	7.88	2,350 uS/cm
Main (south) side of Warm Springs	7.87	2,170 uS/cm
Illum Spring	8.01	589 uS/cm

Samples of Bottom Material

The silty material at Warm Springs appeared to be brown when viewed through the water, but the retrieved samples were green colored (Photo 7792). These samples drained in a coffee filter in a matter of minutes. The Illum Spring sample from the edge of the pond seemed to be clayey silt or silty clay by a ribboning and feel-test estimate, but I am not an experienced soil scientist. This sample yielded less than half a teaspoon of water in several hours of drainage in a coffee filter.

The samples were air dried and crushed to thumb-size or smaller particles. The Illum Spring sample, including voids, occupied approximately 180 to 185 milliliters of volume and weighed 220 grams. The Warm Springs sample was almost twice the volume at 325 milliliters, and weighed only 204 grams, though it was still somewhat damp to the touch. Photos 7805 and 7807 show the samples as weighed.

Literature Search and Consultation

Following the field observations, I made a cursory review of water right files for both the Distric water rights and wells to the west of the springs. I obtained two geologic maps and a hydrogeology report done by IDWR for a well permit application. I consulted with a colleague who specializes in well design and aquifer testing, and a colleague in IDWR's well-drilling program.

Discussion

Spring Configuration

Warm Springs. Warm Springs lie on or very near a mapped subterranean fault on the west side of the Malad valley. The elevated temperatures and salinity/hardness of Warm Springs definitely indicate a deep flow path and strongly suggest that this spring is controlled by geologic faulting bringing water to the surface.

Both Mr. Wright and Dr. Ipsen report apparent correlation between flows in Warm Springs and pumping of wells to the west. The well logs that were identified all indicated that the water in the wells was "cold."

Illum Spring. Illum Spring is also on or near the fault, and the fact that it is an isolated large spring suggests that it also may be fault controlled. The temperature data from Illum Spring show a greater temperature at the Parshall flume on the outlet, than in the pool itself. The volume of flow was large relative to surface area of the channel, so it is unlikely that solar heating explains this difference. Air temperature was below the water temperature, so atmospheric heating is also discounted. This probably means that an additional, warmer inflow occurs somewhere near the edge of the pool or in the short channel between the pool and the flume.

Cleaning of Springs (Question 1)

It is important to understand the physical mechanism of the spring in making decisions regarding cleaning of the springs. Especially if the spring is fed by lateral flow over an impermeable layer, a hazard exists of damaging the impermeable layer and allowing the water to seep away from the bottom of the spring. Both springs exhibit lateral inflow through gravels. Warm Spring certainly has a deep circulation path, and Illum Spring may also. Nevertheless, for both springs it is possible that water is brought to the surface by a fault or faults, but then moves laterally to the point of emergence over the top of a layer of low permeability. Hence, great care must be taken in cleaning to avoid excavating too deeply.

The light weight of the material from Warm Springs suggests that it is mostly algae or other biological material, perhaps with a component of mineral precipitate from the spring water. Its rapid drainage in the coffee filter suggests that it is likely not an impediment to flow. The greater weight, fine texture and slow drainage of the material from the side of the Illum Spring pool suggest that if that material were to extensively cover the discharge point, it could impede flow. However, in both cases it is likely that a greater controlling factor is the resisting head of water above the spring outlets. In the case of Warm Springs, almost half the water appears to enter below the water level. Most of the water in Illum Spring appears to boil up in the bottom of the pool, though there is some lateral inflow on the west.

Springs are generally low-head features and therefore are usually very sensitive to increased head or back pressure on the spring. The apparent correlation between flow in Warm Springs and pumping of wells west of the springs was noted above. A quick check of some well logs indicates that the static water level in the wells is only slightly higher in elevation than the pool elevation at Warm Springs. This also suggests that Warm Springs is a low-head feature and therefore would be sensitive to back pressure or water head over the points of emersion that are below the water line.

Based on these factors, I recommend:

- 1) It is not likely that the silt or algae in Warm Springs is a significant impediment to flow. However, removing this material by pumping and delivering it to the canal likely would not damage the spring as long as the solid bottom materials were not disturbed. If the material does impede flow, this activity may both improve spring flows and reduce losses in the canal. However, given the rapid drainage and light weight of the material, I would not expect significant improvement.
- 2) Cleaning and maintenance of the outlet channels will reduce head over the springs and improve flow. Because of the possibility of breaking through a supporting impermeable layer, care should be taken to not excavate too deeply, especially on the outlet channel of Illum Spring. Cleaning should focus especially on removal of vegetation and removal of soil that has fallen into the channel from the sides.
- 3) There may be some opportunity to improve the flow in Illum Spring by cleaning, if the heavier, finer grained material is covering subsurface emergence points. This could perhaps be done from the bank with an excavator, but great care would need to be taken to not excavate any point of the pond deeper than the active sand boils. Use of a slurry pump combined with hand digging would likely be safer, but more time consuming and labor intensive.

Effect of Russian Olives Surrounding Warm Springs (Question 2)

Evapotranspiration of water by vegetation is generally limited by the available solar energy to evaporate water. A rough estimate for the Malad area is a maximum of 3/8 inch of water depth of evaporation per day, during the heat of the summer. Because trees are higher than the surrounding area, in addition to solar radiation upon the trees, they are subject to heating from warm air moving laterally at heights above the surrounding vegetation.

A quick mapping of the Russian Olives surrounding the springs indicates about 1.6 acres of tree canopy. Some of this shades the surface of the springs and reduces evaporation. Setting this aside and assuming that with wind effects the evapotranspiration of the trees may be as much as one inch (0.084 feet) per day, the maximum consumption by the trees is approximately 0.13 acre feet per day, equivalent to about 3.4 miners' inches of steady flow.

Effect of Check Boards at Warm Springs (Question 3)

As discussed above, there is general expectation that springs are low-head features, and there is not significant elevation difference between Warm Springs and the static head in wells to the west. Nearly half the inflow to Warm Springs enters below the water level. Based on these factors, it is my professional opinion that backing up water at Warm Springs by placing check boards at the outlet culvert is likely to significantly impede flow from the springs. This could be checked by measuring outflow from the

springs with the boards in place, and without them. Flow comparisons would need to be made after the pond water level stabilized. The pond covers approximately 1.6 acres. A flow of 50 miners' inches will deliver about two acre feet every 24 hours, so if the boards were pulled, draining the pond could sustain a 50-inch increase in flow for almost a full day, regardless of any change in inflow due to reduced head.

The best time to perform such an experiment would be when irrigation wells are not operating, to avoid confounding influences.

Effect Of Wells Upon the Springs (Question 4)

The reports that Warm Springs are sensitive to pumping in the western wells, while Illum Spring is not, are puzzling and counter to expectations. The warmer, saltier spring would be expected to have a longer flow path and more distant source, while the cooler spring would be expected to be more sensitive to local influence. There are geologic configurations that can explain both situations. These are presented below as possibilities but full investigation of the mechanisms governing the springs could be quite an extensive effort.

I visited with Dr. John Tracy of Idaho Water Resources Research Institute (IWRRI), associated with University of Idaho. There is a USGS funding source for small hydrologic studies, which can fund up to \$15,000 of a \$30,000 study with matching funds from another organization. The next call for proposals is expected in December 2014. This may be an opportunity to gain understanding of the behavior and influences on both springs. RMEA would be glad to perform these investigations, but the state subsidy of IWRRI billing rates and the opportunity for matching funding may be a very good opportunity for the District.

Warm Springs. The reported correlation between pumping the west wells and changes in flow at Warm Springs is a strong indication that those wells affect the springs. The highly variable flows recorded in Table 1, as well as the reported responsiveness to the pumping of cold-water wells to the west, are very puzzling. A deep flow path generally implies an expectation of very small seasonal variations in discharge. It also implies an expectation of muted and delayed response to pumping from shallower, cold-water aquifers. There are at least four possible explanations for these unusual observations:

- 1) Warm Springs flow is highly sensitive to changes in head, and the changes in flow result from changes in the placement of boards in the culvert and/or back pressure from the cold water injection from the canal.
- 2) The apparent variability is an artifact of flow measurement, due to problems with the Flow Probe device.
- 3) Warm Springs is responding to changes in diversion rate from the nearby flowing artesian wells, which also tap a warm-water source.
- 4) Through a very unusual geologic configuration, the deep warm-water source is highly responsive to changes in head of an overlying cold-water aquifer that supplies the springs.

The existence of flowing wells near Warm Springs and further south indicate a confined aquifer beneath the Malad Valley. It is by no means certain, but it is possible that the flowing wells south and west of Samaria are reducing head in the aquifer sufficiently to affect Warm Springs. It is generally expected that wells would most strongly affect the nearest springs, and this would indicate that the southern flowing wells most strongly affect Samaria Lake west of Samaria. However, it is possible that the confined aquifer works like a single pressure vessel, with the flow to Samaria Lake representing a low-elevation but high-restriction tap, and Warm Spring representing a high-elevation, low-restriction tap. In this case, Warm Spring could conceptually be especially sensitive to reductions in head caused by flowing wells anywhere in the system.

Illum Spring. Illum Spring's colder temperature and lower electrical conductivity indicate shorter residence time and a shallower flow path than Warm Springs. Its lack of responsiveness to pumping in the western wells indicates that it is not strongly connected to the aquifer that serves them. The stable discharge rates over the summer of 2013 suggest that it is supplied by a fairly large recharge area. Its flow may be dominated by higher-elevation recharge in the surrounding hills and on the farmlands to the north.

These factors indicate that Illum Spring is not likely to be too strongly influenced by either the wells west of the springs or the southern flowing artesian wells.

Water Call Opportunities (Question 5)

In visiting with IDWR, I learned that it is very difficult to proceed with a water call outside an organized Water District, and that IDWR will only form a Water District where the water rights have been adjudicated. This has not been done in the Malad Valley. It would be a long and costly political process to commence an adjudication, and long and costly to complete. Once completed, an aquifer call would also be long and costly.

Another option is to petition the State for creation of a Groundwater Management Area or Critical Groundwater Area. These designations would impose limitations on future groundwater development and may also provide some regulation of diversions from existing wells.

The IDWR representative was very interested in the possibility of regulating the flowing wells to the south. In his opinion, discharges far exceed the stockwater uses for which the wells are authorized. He described the possible use of "packers," which are seals installed in the well bore, set six to eight feet below land surface, with a control valve operated by a t-handle. These would allow the wells to be shut off in the wintertime or otherwise when not in use, preserving aquifer head. A Groundwater Management Area

or Critical Groundwater Area may allow regulation to impose these solutions. Obviously this would create cost and inconvenience for the users of the flowing wells.

Another administrative possibility might be the conversion of the District's water rights to wells, preserving the original priority dates. The details of such an effort are beyond the scope of this letter, but RMEA's water right experts would be available to discuss options with the District.

The effort to create some kind of administrative district could be pursued by board members. IDWR would likely be willing to assist. The costs to the District are unknown.

Water Tests (Question 6)

A basic "common ions" water test would be very useful in identifying whether the flowing wells near Warm Springs are from a similar water source as the springs. This test costs \$64 per sample. For an additional \$30, fluoride, nitrate and nitrite can be added to provide additional information. Nitrate and nitrite are "short hold time" tests, which complicates handling and shipping of samples.

As with the cold water in the western wells, it is possible for a well to have a water-supply effect on a spring even if the water chemistry is different. If the springs and nearby flowing wells were shown to have similar water-chemistry signatures it would be strong evidence of likely water-supply effects, but different water-chemistry signatures would not necessarily mean there would not be a water-supply effect.

Measurement Options For Warm Springs (Question 7)

The following options are available to measure the discharge of Warm Springs:

- 1) Rated section between the outlet culvert and the junction box where cold water from Illum Spring is blended into the canal.
- 2) Rated section in the concrete channel exiting the junction box.
- 3) Periodic measurements with the Flow Probe or other flow measurement device.
- 4) Submerged orifice in the concrete channel.
- 5) Ramped flume in the concrete channel.
- 6) Parshall flume.

A "rated section" is a section of channel where the flow depth is controlled by the geometry and friction of the channel. Rated sections are not accurate where there are backwater effects. The appearance of the location and some of the District's data from the Flow Probe indicate that a rated section is not recommended in either possible location.

I was not comfortable with the roughness and apparent friction in the District's Flow Probe when I attempted to spin-test the impeller. An associate has had trouble with a similar instrument, so I hesitate to recommend the option of continuing to use the Flow Probe. Data from the flow probe will always be subject to challenge based on the condition of the instrument and the experience of the operator. RMEA can also make recommendations for purchase of a more reliable current meter, at a cost of \$2500 or greater.

A submerged orifice could be added to the concrete channel according to the sketch in Figure 3 (attached) and the description in Appendix 3. This is a very accurate measurement method that is not affected by backwater. It requires little head to operate and would not offer too much back pressure on the springs. It is read by taking the difference between the upstream and downstream water levels across the orifice. It can be read with installed pressure transducers, but it does require two transducers. This doubles the cost and adds a small amount of imprecision if the transducers are not identically calibrated.

Ramped flumes are raised sills in an open channel, constructed with a particular design geometry. They are also called broad-crested weirs. A ramped flume could be constructed in the channel. Its advantage over a submerged orifice is that it would require only a single pressure transducer, if automatic recording were desired. The ramped flume is not immune from backwater effects, however.

The two devices currently used by the District are Parshall flumes. A Parshall flume is not recommended for this location because of the possibility of backwater effects.

It appeared that there was some free fall off the downstream end of the exit channel from the junction box. In the interest of reducing back pressure and maximizing flow from Warm Springs, the District may wish to reconsider rebuilding the exit channel with the floor about six inches lower than the current configuration. Alternately, a new measuring box could be built downstream of the current box, at lower elevation. Either would allow a submerged orifice to operate without further affecting the spring, but would likely subject a ramped flume to unacceptable backwater effects.

How Should the Flow Probe Be Used (Question 7)

Attached are the manufacturer's instructions for using the Flow Probe. RMEA would be available to do side-by-side comparison measurements with its current meter, as a check on the Flow Probe accuracy. It may also be possible to send the Flow Probe back to its manufacturer for maintenance and a calibration check.

Summary

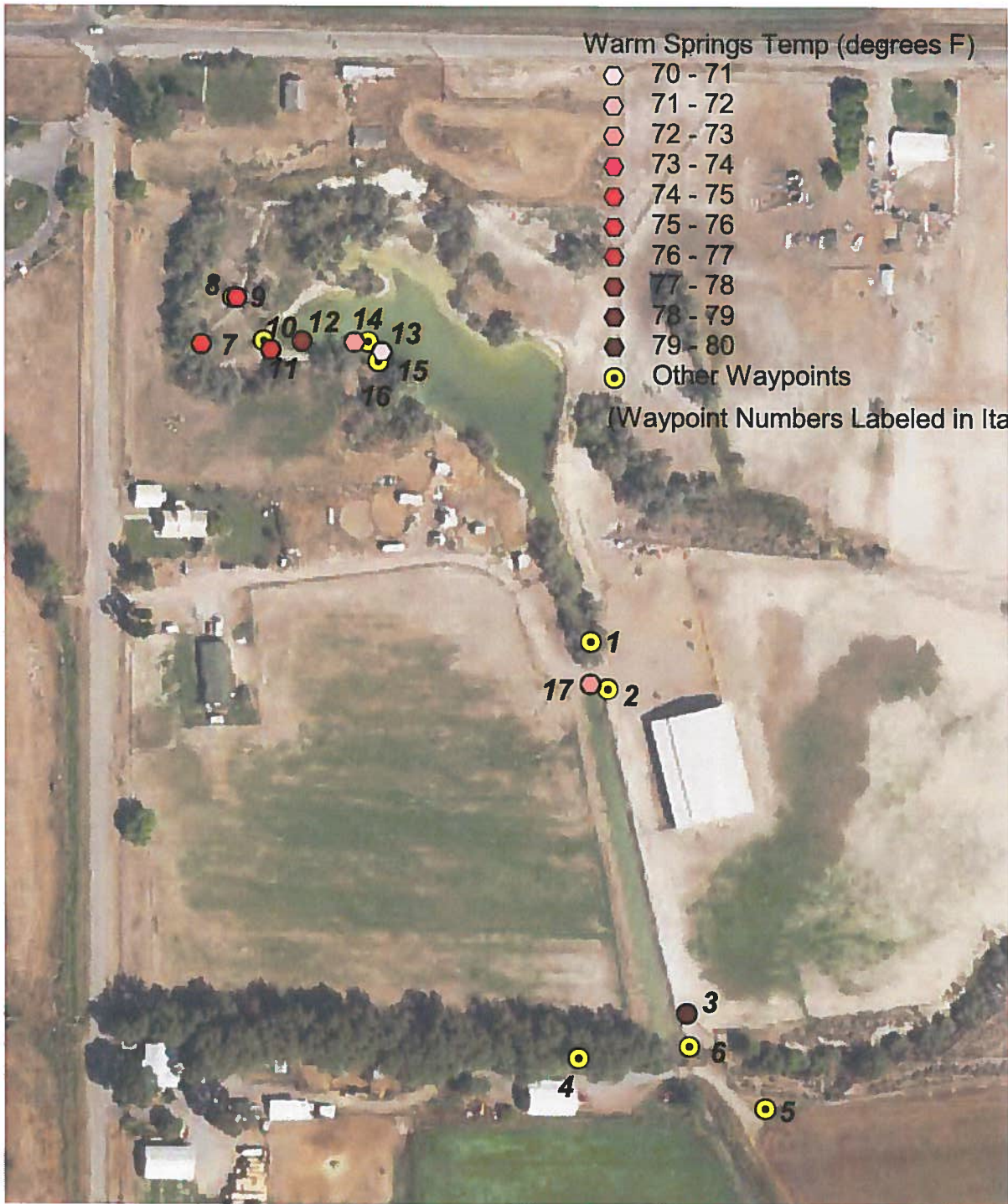
- 1) The best opportunity for cleaning the springs is to remove vegetation from outlet channels, along with soil that has fallen from channel sides. Great caution is urged against digging too deeply or aggressively in the spring bottoms. Little gain is expected from removing the silt-like material from Warm Springs.
- 2) The Russian Olive trees surrounding Warm Springs likely consume a few miners' inches of water at most.
- 3) Damming the outlet of Warm Springs is very likely to retard the flow.
- 4) The data are puzzling, but from the reported observations, it is very likely that the western wells affect Warm Springs. It is also possible that the southern flowing wells also affect it. Illum Spring may be less influenced by the wells. More precise determination would require significant investigation. The District may want to work with Idaho Water Resources Research Institute to study the interaction between the springs and the wells.
- 5) A water call is not an available option at this time, due to lack of a water district and lack of decreed water rights. A Groundwater Management Area or Critical Groundwater Area may offer some administrative relief. Costs of pursuing this effort are not estimated at this time.
- 6) Common-ion tests cost \$64 per sample and can provide some information on waters from similar sources.
- 7) The discharge from Warm Springs can be measured with an installed submerged orifice or perhaps a ramped flume. The current program of measuring with the Flow Probe could be continued but there are concerns both with the accuracy of the instrument and the defensibility of measurements obtained.
- 8) The attached manual describes use of the Flow Probe.

It has been a pleasure to assist with these questions. Please contact me if there are further questions, or if there is more we can do to be of assistance.

Sincerely,

Bryce A. Contor

Attachments:	Figure 1	Map of Warm Springs
	Figure 2	Map of Illum Spring
	Figure 3	Sketch of Submerged Orifice
	Appendix 1	Photographs
	Appendix 2	Waypoint List
	Appendix 3	Description and Rating of Submerged Orifice



Warm Springs Temp (degrees F)

- 70 - 71
- 71 - 72
- 72 - 73
- 73 - 74
- 74 - 75
- 75 - 76
- 76 - 77
- 77 - 78
- 78 - 79
- 79 - 80
- Other Waypoints

(Waypoint Numbers Labeled in Italics)

100 0 100 200 Feet

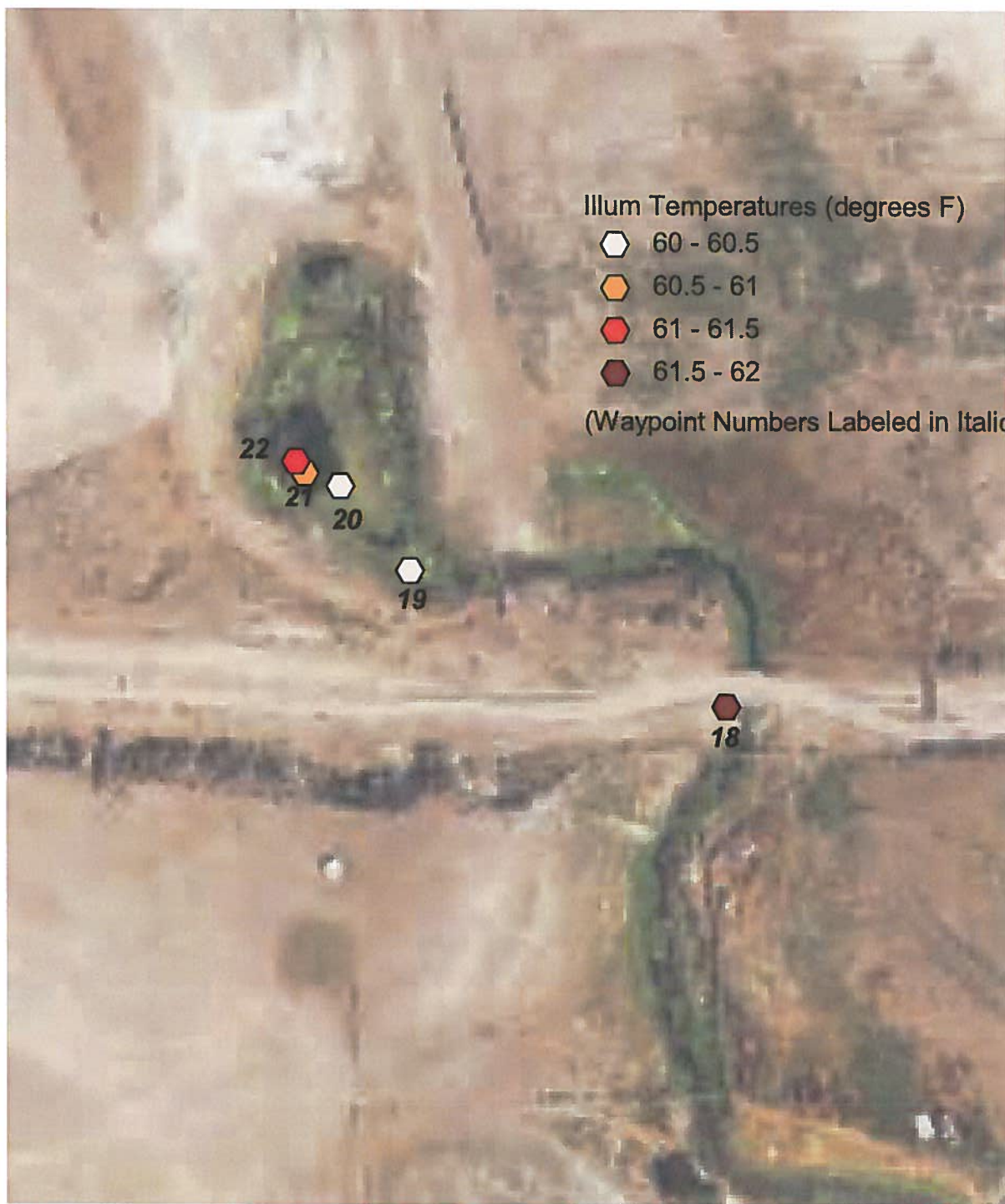


Rocky Mountain
ENVIRONMENTAL
ASSOCIATES, INC.

482 Constitution Way, Idaho Falls, ID 83402
208-524-2353

Figure 1 - Warm Springs Waypoints

Project 14-0010



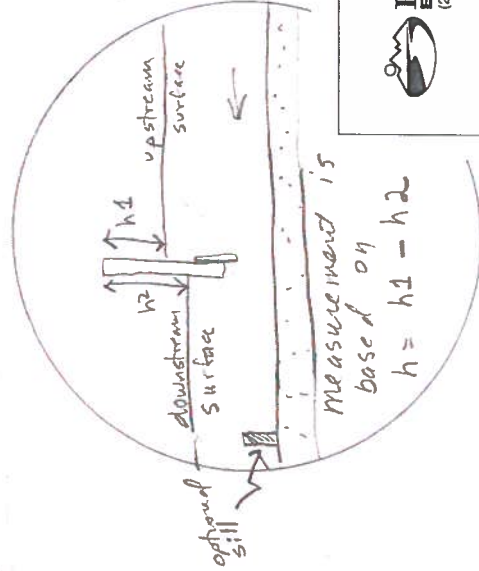
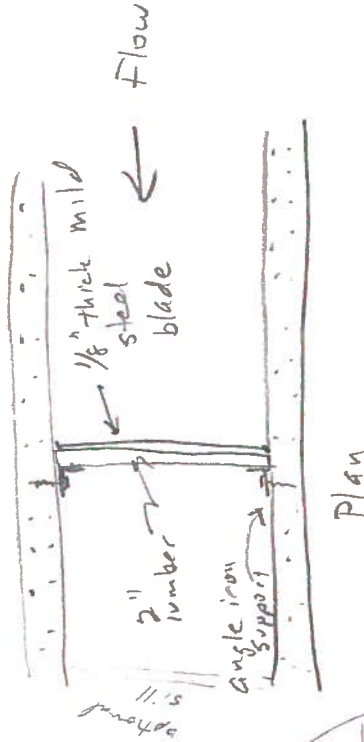
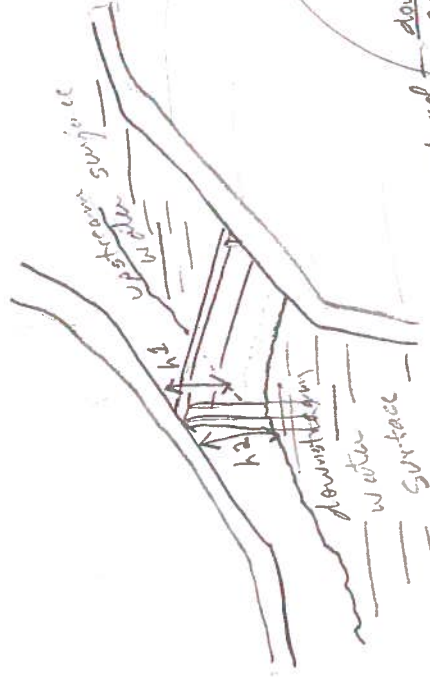
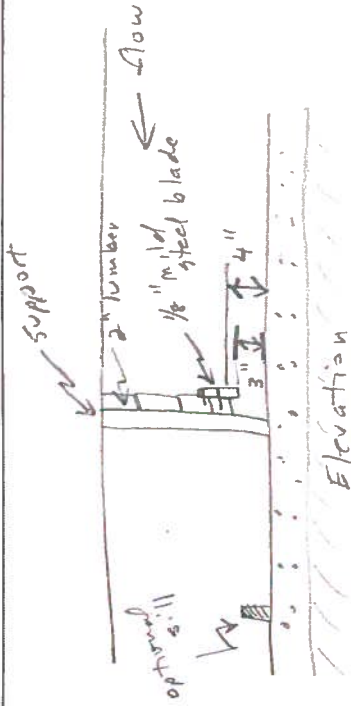
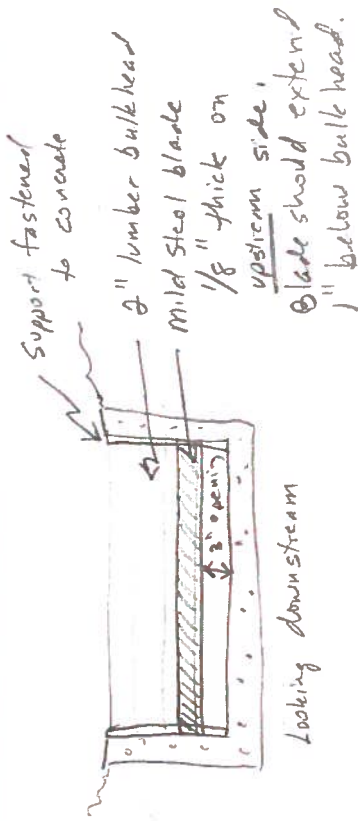
100 0 100 200 Feet



482 Constitution Way, Idaho Falls, ID 83402
208-524-2353

Figure 2 - Illum Spring Waypoints

Project 14-0010



Use USBOR tables for "Submerged Orifice - bottom and sides, suppressed" area = 1.5 square feet

Not to Scale - For illustration only

Figure 3 - Submerged Orifice Sketch



ROCKY MOUNTAIN
ENVIRONMENTAL ASSOCIATES, INC.
(208) 524-2353 FAX 524-1795

JOB 14-0010

SHEET NO. 1 OF 1

CALCULATED BY B. Conner

DATE 7 Feb 14

CHECKED BY

DATE

SCALE

Appendix 1 – Photographs



Photo 7739. Outlet culvert from Warm Springs. Note plywood boards. Note the fine silty-appearing material in channel center.



Photo 7740. Exit point of outlet culvert. Velocity-head rod measurements were made at this point.



Photo 7756. Gravel and coarse sand from Goddard Right side of Warm Springs.



Photo 7759. Outflow from gravel bank on northwest side of the main Warm Springs. Reconnaissance flow measurement was conducted in the foreground.



Photo 7746. Concrete outlet channel from junction box.

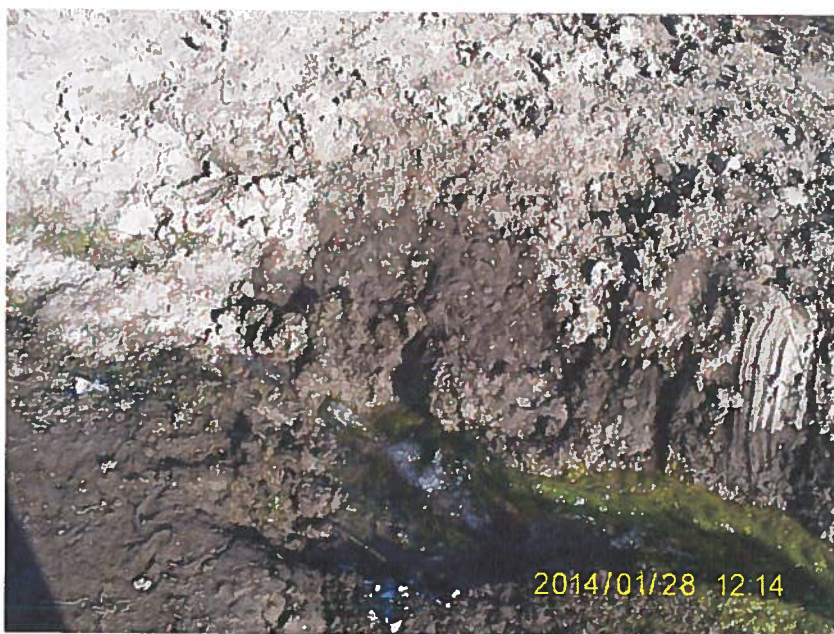


Photo 7748. Discharge from flowing artesian well.



Photo 7766. Illum Spring.



Photo 7769. Three foot Parshall flume on the outlet of Illum Spring.



Photo 7792. Warm Springs sediment sample draining in a coffee filter.



Photo 7804. Illum Spring sediment sample prepared for weighing.



Photo 7807. Warm Spring sediment sample prepared for weighing.

Appendix 2 – List of GPS Waypoints

Waypoint 1	Photo of outlet culvert, inlet side
Waypoint 2	Photo of outlet culvert, outlet side
Waypoint 3	Flowing artesian well (Quentin Jenkins), IDWR tag No. D0048572, transducer deployed in outlet stream
Waypoint 4	Parshall Flume (12") on inlet ditch from upper canal (Illum Spring water)
Waypoint 5	Seth Seamons well, IDWR tag No. D0049298
Waypoint 6	Junction box (mixing pool)
Waypoint 7	Transducer deployed in Goddard Right inflow
Waypoint 8	(accidental waypoint)
Waypoint 9	Transducer deployed on Goddard Right side
Waypoint 10	Start of reconnaissance flow measurement with velocity head rod
Waypoint 11	Transducer deployed on main springs side
Waypoint 12	Sand boils noted, transducer deployed
Waypoint 13	Silty material nearly to knees, water estimated over 3' deep
Waypoint 14	Sand boils, transducer deployed
Waypoint 15	Transducer deployed
Waypoint 16	Sample of algae/precipitate material
Waypoint 17	Transducer deployed in outlet flow
Waypoint 18	Transducer deployed at outlet flume from Illum Spring
Waypoint 19	Transducer deployed
Waypoint 20	Transducer deployed, bottom material feels smooth/silty and not sticky
Waypoint 21	Transducer deployed
Waypoint 22	Transducer deployed at location of large sand boils

Appendix 3 – Submerged Orifice Details

The device sketched in Figure 3 is a submerged orifice. As sketched with the blade three inches off the bottom, and assuming a width of six feet, it has an opening of 1.5 square feet. With the blade two inches off the bottom its opening area would be 1.0 square feet. When constructing the orifice, it will be important to measure the actual width of opening, considering the effect of any supports or brackets that may be installed, and adjust the blade height to have exactly 1.0 or 1.5 square feet of opening. The smaller opening will be more accurate at low flows and the larger opening will offer less back pressure on the springs.

The ratings provided below assume that the downstream water surface is above the top lip of the opening. At very low flows, it may be necessary to put a sill, rocks, or cinder blocks in the outlet channel to raise the downstream water level so that this condition is met.

The submerged orifice has the advantages of being immune to inaccuracy caused by backwater effects from downstream. Field observations and the relationships between velocity and depth in Mr. Wright's field notes from 2013 suggest that backwater effects are prevalent at the proposed location. Submerged orifices also have low head loss relative to other devices. This is desirable in order to reduce back pressure, which may impede flow on the springs. The primary disadvantage of the submerged orifice is that it can be difficult to observe when it is partly blocked with weeds or debris, because the opening is below the water line. If the opening is partly blocked, the submerged orifice will indicate more flow than actually is passing the device.

The sketch in Figure 3 shows construction of an orifice with "suppressed contractions" on the bottom and sides. This means that the side and bottom openings are flush (or nearly so) against the bottom and side surfaces of the channel. This configuration allows the orifice to be self cleaning of silt and sediment, and reduces the required upstream water depth as much as possible. US Bureau of Reclamation¹ provides an adjustment for standard ratings, to be used with suppressed contractions. The ratings below incorporate this adjustment for both 1.0 and 1.5 square feet of opening. The orifice loses accuracy when the upstream depth above the opening is less than the vertical dimension of the opening itself. This can also be addressed by a sill or other downstream obstruction, when flows are low.

Rating tables are for "h" measured as the elevation difference between upstream and downstream.

¹ US Bureau of Reclamation. 1967. Water Measurement Manual (1975 reprint) p. 93

Table 1
Rating for 1.5 Square Foot Submerged Orifice
Side and bottom suppressed contractions,
Downstream water surface above the top lip of the orifice opening.

h – inches & eighths		h – ft	Q – cfs	Q – Idaho Inches
0	0	0.000	0.00	0
0	1	0.010	0.81	40
0	2	0.021	1.14	57
0	3	0.031	1.40	70
0	4	0.042	1.62	81
0	5	0.052	1.81	90
0	6	0.063	1.98	99
0	7	0.073	2.14	107
1	0	0.083	2.29	114
1	1	0.094	2.42	121
1	2	0.104	2.55	128
1	3	0.115	2.68	134
1	4	0.125	2.80	140
1	5	0.135	2.91	146
1	6	0.146	3.02	151
1	7	0.156	3.13	156
2	0	0.167	3.23	162
2	1	0.177	3.33	167
2	2	0.188	3.43	171
2	3	0.198	3.52	176
2	4	0.208	3.61	181
2	5	0.219	3.70	185
2	6	0.229	3.79	189
2	7	0.240	3.87	194
3	0	0.250	3.96	198
3	1	0.260	4.04	202
3	2	0.271	4.12	206
3	3	0.281	4.20	210
3	4	0.292	4.27	214
3	5	0.302	4.35	218
3	6	0.313	4.42	221
3	7	0.323	4.50	225
4	0	0.333	4.57	229
4	1	0.344	4.64	232
4	2	0.354	4.71	236
4	3	0.365	4.78	239
4	4	0.375	4.85	242
4	5	0.385	4.91	246

h – inches & eighths		h – ft	Q – cfs	Q – Idaho Inches
4	6	0.396	4.98	249
4	7	0.406	5.05	252
5	0	0.417	5.11	255
5	1	0.427	5.17	259
5	2	0.438	5.24	262
5	3	0.448	5.30	265
5	4	0.458	5.36	268
5	5	0.469	5.42	271
5	6	0.479	5.48	274
5	7	0.490	5.54	277
6	0	0.500	5.60	280
6	1	0.510	5.66	283
6	2	0.521	5.71	286
6	3	0.531	5.77	288
6	4	0.542	5.83	291
6	5	0.552	5.88	294
6	6	0.563	5.94	297
6	7	0.573	5.99	300
7	0	0.583	6.05	302

Table 1
Rating for 1.0 Square Foot Submerged Orifice
Side and bottom suppressed contractions,
Downstream water surface above the top lip of the orifice opening.

h – inches & eighths		h – ft	Q – cfs	Q – Idaho Inches
0	0	0.000	0.00	0
0	1	0.010	0.54	27
0	2	0.021	0.76	38
0	3	0.031	0.93	47
0	4	0.042	1.08	54
0	5	0.052	1.20	60
0	6	0.063	1.32	66
0	7	0.073	1.42	71
1	0	0.083	1.52	76
1	1	0.094	1.62	81
1	2	0.104	1.70	85
1	3	0.115	1.79	89
1	4	0.125	1.87	93
1	5	0.135	1.94	97
1	6	0.146	2.02	101
1	7	0.156	2.09	104
2	0	0.167	2.15	108
2	1	0.177	2.22	111
2	2	0.188	2.28	114
2	3	0.198	2.35	117
2	4	0.208	2.41	120
2	5	0.219	2.47	123
2	6	0.229	2.52	126
2	7	0.240	2.58	129
3	0	0.250	2.64	132
3	1	0.260	2.69	135
3	2	0.271	2.74	137
3	3	0.281	2.80	140
3	4	0.292	2.85	142
3	5	0.302	2.90	145
3	6	0.313	2.95	147
3	7	0.323	3.00	150
4	0	0.333	3.04	152
4	1	0.344	3.09	155
4	2	0.354	3.14	157
4	3	0.365	3.18	159
4	4	0.375	3.23	161
4	5	0.385	3.27	164
4	6	0.396	3.32	166

h – inches & eighths		h – ft	Q – cfs	Q – Idaho Inches
4	7	0.406	3.36	168
5	0	0.417	3.40	170
5	1	0.427	3.45	172
5	2	0.438	3.49	174
5	3	0.448	3.53	176
5	4	0.458	3.57	178
5	5	0.469	3.61	180
5	6	0.479	3.65	182
5	7	0.490	3.69	184
6	0	0.500	3.73	186
6	1	0.510	3.77	188
6	2	0.521	3.80	190
6	3	0.531	3.84	192
6	4	0.542	3.88	194
6	5	0.552	3.92	196
6	6	0.563	3.95	198
6	7	0.573	3.99	200
7	0	0.583	4.03	201