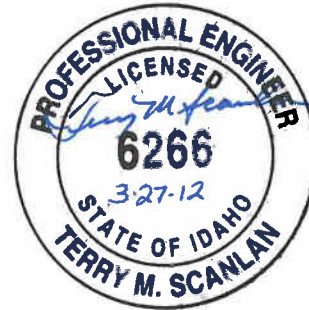


MEMORANDUM

DATE: March 27, 2012
TO: Mike Lawrence
FROM: Terry Scanlan, P.E.
CC: Mike Creamer, Scott King
RE: Black Mesa Historical Pumping Capacity Estimate



This memo finalizes my analysis concerning historical pumping capacity of the pump and pipeline system that served lands that are currently farmed by Black Mesa Farms in Elmore County, Idaho.

Question: As of May 20, 1971 (the mandatory application/permit date for surface water appropriations), could the Cottonwood Mutual Canal Company pump station have produced 103.82 cfs to provide 0.02 cfs/ac for a service area of 5191 acres?

Answer: Yes, it is my opinion that the pump system and piping could have delivered 103.82 cfs to a 5191-acre service area during peak demand periods. System pressure at 103.82 cfs would have been lower than optimum in some areas, but still adequate to operate impact sprinklers.

Analysis: There are no known measurements of the maximum capacity of the Cottonwood pumping system. The best information available to me is the data contained in the field examiner's report. For purposes of this analysis, the following is noted in bold, followed by my comments.

1. **The examiner reported a "design" capacity of 40,500 gpm (90.24 cfs).** "Design" capacity is not maximum capacity. At lower discharge pressure, the pumps will produce a higher rate. Thus, the design pumping rate may be the most efficient pumping rate for normal or design conditions and discharge pressures, but a higher rate is feasible and expected during peak water demand periods.
2. **The date of the field examination is not legible on the report, but appears to be sometime in 1967. Proof statements were made in 1965.** It is obvious that the system was expanded in pumping capacity between the time of proof statements and the field exam, as the examiner found more pumps with more total horsepower than listed in the proof statements. It is possible (and perhaps likely) that the pumping system capacity was further expanded between the 1967 field exam and the 1971 mandatory application/permit date for surface water appropriations.

3. **The river pumps consisted of nine (9) 600-hp vertical turbines.** These pumps lifted water from the Snake River (elevation 2550 via Google Earth) to the relift pumps (at an elevation of approximately 2886 feet via GoogleEarth). Static lift from the Snake River to the relift site is about 335 feet (rather than 150 feet reported by the Examiner).
4. **The relift pumps consisted of nine (9) 400-hp pumps.** Static lift from the relift pumps to the project site was an additional 215 feet. The relift pump notes suggest that one or all of the relift pumps are Peerless pumps rated to produce 4300 gpm at 330 feet head. To achieve such results without motor overload, the pump efficiency at the rated point would need to be 89%. This efficiency is very high, but not unreasonable for high-horsepower pumps.

On the day of the field exam, it appears that the relift pumps were operating near the design head with 140 psi (323 feet) discharge pressure.

5. **The sprinkler boosters consisted of 15 pumps of various sizes totaling 1440 horsepower.** A variety of sizes and configurations were noted.
6. **Pipeline diameters beyond the first gate to the sprinkler boosters are not adequately described in the report.** As a result, analysis of head loss in the distribution system beyond the first gate is not possible. However, the site is relatively flat and it is likely that the system was designed to provide similar pressures to each booster pump site. Approximately 1 foot head loss per 300 feet is typical for a 5 to 7 fps pipe velocity in the 18 to 42 inch diameter range. Straight line distance from the first booster pump gate to the last booster pump gate is 3 miles (15,700 feet), resulting in a distribution mainline head loss of 52 feet (23 psi) at 1 foot per 300 feet.
7. **The 44-inch diameter steel pipeline from the river to the project site could deliver 103.82 cfs with reasonable losses.** The pipeline from the River to the first gate was 44-inch diameter steel. No interior diameter is given. Assuming average wall thickness of 0.375-inches, the inside diameter would be 43.25 inches. An analysis of the capacity of 44-inch pipeline is provided in Exhibit A. Using a C factor of 120 (smooth pipe, but rougher than new steel pipe), the headloss in the estimated 5400 foot distance from the Snake River to the first sprinkler sub-mainline gate is 38 feet at the 103.82 cfs pumping rate. (Note that the headloss is not particularly sensitive to assumed C factor. Using a C factor of 130 (new steel pipe) decreases the head loss at 103.82 cfs by 5 feet per mile, while a C factor of 110 (riveted steel pipe) raises the head loss by 7 feet.)
8. **Maximum pump capacities are not reported by the field examiner.** The field examiner's report does not provide pump curves, pump models, or adequate piping descriptions. As a result, the report cannot be used to directly calculate maximum system capacity.

9. **There is adequate pump horsepower available to deliver 103.82 cfs to the booster pumps.** Although the examiner's report does not indicate the pumping system capacity to deliver 103.82 cfs, it does not preclude the ability to do so. A pump system with a design capacity of 90.24 cfs will produce 103.82 cfs, but at a lower discharge pressure. For example, the nine relift pumps, assuming that each are rated to produce 4300 gpm at 330 feet head, would produce a total of 38,700 gpm (86.2 cfs) at 330 feet head. The same nine pumps would each need to each produce 5178 gpm (11.5 cfs) to deliver 103.82 cfs. A typical 4300 gpm pump will produce 5178 gpm, but at lower discharge pressure. Examples are provided below.

- o Exhibit B is an example vertical turbine pump (16HH) curve from the Peerless Pump catalog. This pump with 6 stages would be rated to produce 4300 gpm at 330 feet TDH with 86% efficiency and 416 hp requirement. The same pump will produce 5178 gpm at 236 feet TDH with 80% efficiency and 384 hp.
- o Exhibit C is a second example vertical turbine pump curve (18HXB) from the Peerless Pump catalog. This pump with 3 stages would be rated to produce 4300 gpm at 330 feet TDH with 81.5% efficiency and 440 hp requirement. The same pump will produce 5178 gpm at 300 feet TDH with 85% efficiency and 460 hp. Using this same curve for the River pumps (in an equivalent 4.5 stage configuration) results in a combined capacity for the river and relift pumps of 103.82 cfs at 750 feet TDH. Although these pumps would run at the 15% service factor, the total load does not exceed the rated capacity of the motors.

The pumps in Exhibit B could be trimmed to provide an average of 5178 gpm at 260 feet per pump for the 400 hp units and 389 feet for the 600 hp units, and produce the 103.82 cfs at 649 feet TDH. This head would result in 34 psi delivery pressure to the first booster pump diversion, and would not exceed the full load capacity of the motors.

10. **There is adequate booster pump horsepower available to deliver 103.82 cfs to the sprinklers.** The field examiners report describes 15 booster pumps with a combined total of 1440 hp. Assuming a typical booster pump efficiency of 80%, these pump motors would provide an average pressure increase of 42.5 psi. At 75% efficiency, the booster pumps would provide an average pressure increase of 40 psi. At 75% efficiency and using a service factor load of 10%, the booster pumps provide a pressure increase of 44 psi.

- The booster pump notes show a 100-hp pump at submain No. 2 that produces 2100 gpm at 150' (65 psi). To achieve such results without motor overload, the pump efficiency at the rated point would need to be 79.5%.
- For several pumps, the examiner lists horsepower and capacity (in gpm). Assuming an average 80 percent efficiency (or alternatively, 72 percent efficiency and 10% motor overload), these pumps provide design boosts of between 46 psi and 65 psi.

- Under high demand conditions, these boosters could certainly provide an average boost of more than 40 psi at higher flow rates. At maximum demands, the various pumps likely produce boosts ranging from 25 psi to 55 psi. It is likely that the higher pressure pumps will be located further west, where mainline pressures might be lowest.
- Assuming that the mainline pressures under peak demands range from 34 psi near the east side of the project (closer to the River) to 7 psi at the west side of the project (at the furthest booster), booster pump discharges (i.e., mainline pressure plus boost) might average 63 psi. Such pressures are adequate, although not optimal in terms of delivery rate and coverage, for sprinkler systems using hand lines and impact sprinklers.

11. There is adequate total pump horsepower available to deliver 103.82 cfs to the sprinklers. The following is assumed, measured, or calculated in Exhibit A.

1. The static lift from the river to the furthest booster pump is 543 feet.
2. Headloss from the river to the first booster turnout is calculated to be 38 feet.
3. Headloss from the first booster turnout (i.e., east side of farm) to the furthest booster turnout (i.e., west side of farm) is estimated to be 52 feet.
4. Suction pressure at the furthest booster is 7 psi.
5. Suction pressure at the nearest booster gate is 34 psi.
6. Average booster discharge pressure is 63 psi.
7. Average total dynamic head (TDH) from river to sprinklers is 747 feet.
8. At 85% pump efficiency for the river and relift pumps, and 80% average pump efficiency for the booster pumps, the overall average pump efficiency is 84.3%.
9. At 84.3% pump efficiency, the total brake horsepower requirement to produce 103.82 cfs at 747 feet TDH is 10,429 horsepower. The field exam documented nominal horsepower available is 10,440 hp at full load (i.e., 100%) and 12,006 hp at a 15% service factor load (i.e., 115%).

Therefore, there is adequate horsepower to deliver 103.82 cfs without, on average, operating in the service factor range of the pump motors.

Black Mesa Farms Pumping Calculations - Exhibit A
 (User input values are in bold text; plain text values are calculated)

straight line distance from River to first gate	4900 feet
pipeline length river to first gate (straight line +10%)	5390 feet
straight line distance from River to last booster	20750 feet

flow rate to first gate (calculated using Hazen-Williams Eq.)	103.82 cfs
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elevation at River	2550 feet
elevation at first gate/booster	3083 feet
elevation at last (high point) booster	3093 feet
total lift River to high point (last) booster	543 feet
head loss to first gate	37.9 feet
head loss first gate to high point booster (assumed)	22.5 psi
head loss first gate to high point booster (assumed)	52.0 feet
suction pressure at high point booster (assumed)	7 psi
suction pressure at high point booster (assumed)	16 feet
suction pressure at first gate/booster	34 psi
suction pressure at first gate/booster	78 feet
total lift to boosters	649 feet

average river and relift pump efficiency	85%
total pump horsepower required (river and relift pumps)	8985 hp
pump horsepower available (river and relift pumps)	9000 hp
pump horsepower used (river and relift)	100%

average boost (i.e., pressure added by boosters)	42.5 psi
last booster discharge pressure	50 psi
first booster discharge pressure	76 psi
average booster discharge pressure	63 psi
total lift with booster pressure	747 ft
average pump efficiency (river, relift, boosters)	84.3%
total pump horsepower required	10429 hp
available pump horsepower (river, relift, and booster pumps)	10440 hp
pump horsepower used	99.9%

$V = 1.318 \cdot C \cdot R^{0.63} \cdot s^{0.54}$		Hazen-Williams Equation	
$s = h/L$			
$R = r/4$			
L =	5400 feet	Length of pipeline	
r =	43.25 inches	inside diameter of pipeline	
R =	0.901 feet	hydraulic radius of pipeline	
C =	120	new steel pipe coefficient of roughness for pipeline	
A =	10.20 sq ft	cross-sectional area of pipeline	
h =	37.9 feet	friction loss in pipeline	
s =	0.0070 ft/ft	friction loss as slope	
V =	10.18 ft/sec	velocity	
Q =	103.82 cfs	flow	
Q =	46598 gpm	flow	

	hp	Pump Efficiency
River Turbines - 9 @ 600 hp	5400	85%
Relift pumps - 9 @ 400 hp	3600	85%
Sprinkler Boosters	1440	80%
Total Horsepower	10440	84.3%
15% service factor hp	12006	

Exhibit B

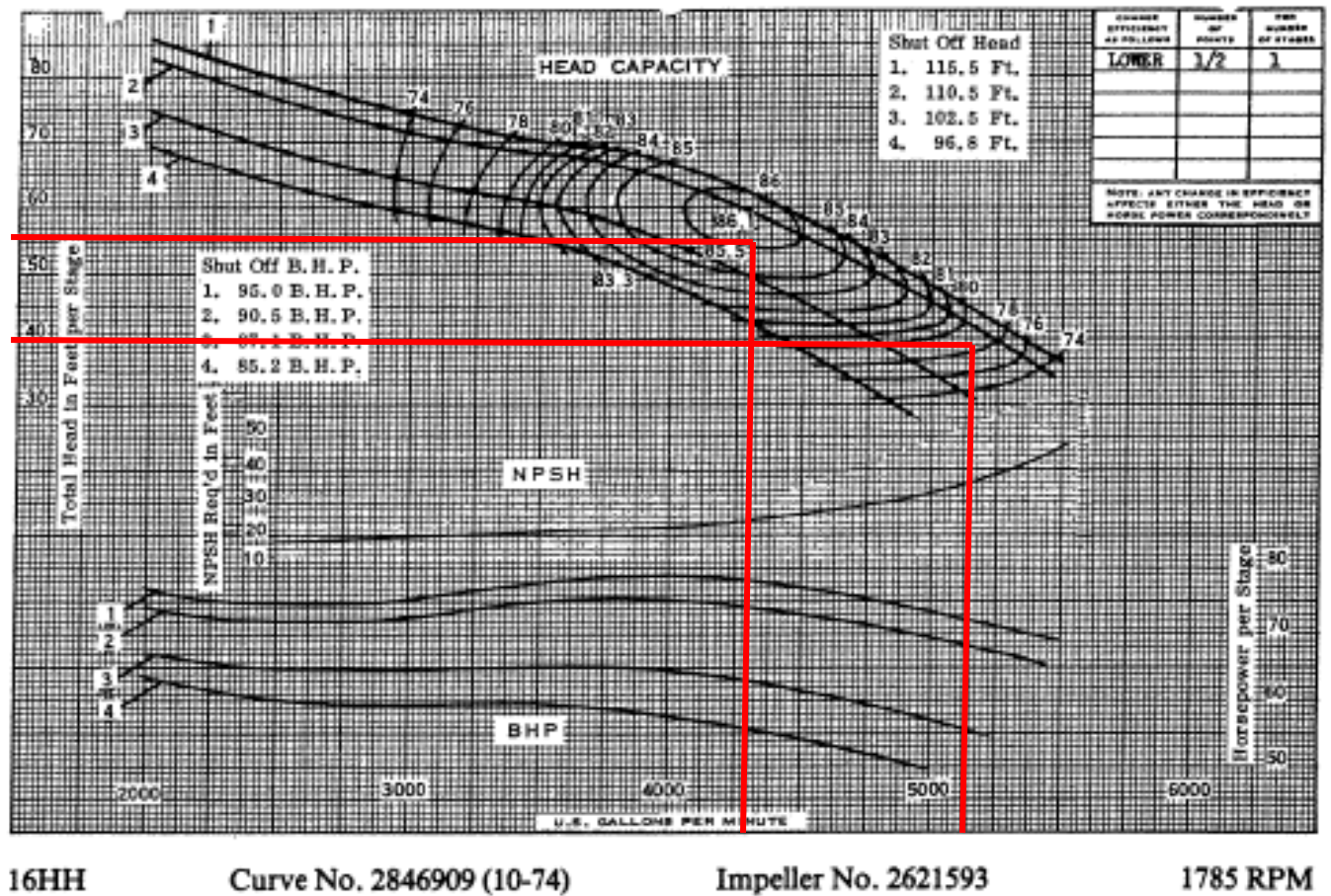


Exhibit C

