RECLAMATION

Managing Water in the West

Intake Diversion Dam

Preliminary Power Demand and Consumption for a Pumping Plant Alternative

Lower Yellowstone Project – Montana – North Dakota

U.S. Department of the Interior
Bureau of Reclamation

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BUREAU OF RECLAMATION

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Region: Great Plains Region, Montana Area Office

Project: Lower Yellowstone Intake Diversion

Feature: Intake Diversion Headworks

Subject: Preliminary Power Demand and Consumption for a Pumping Plant Alternative

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Table of Contents

Background

Reclamation is developing alternatives to address the fish passage and entrainment protection issues at the Intake Diversion Dam for the Lower Yellowstone Irrigation Project (Reference 1, 2, and 3). The irrigation project diverts up to1,400 ft^3/s annually from the Yellowstone River from mid-April through September to meet irrigation demands. As presently configured, the Diversion dam serves as a barrier to upstream migration of pallid sturgeon and other native fish in the lower reaches of the Yellowstone River and does not contain entrainment protection.

This initial assessment study looks at a pumping plant to meet the irrigation diversion demands of the irrigation project from the Yellowstone River. The pumping plant alternative would be designed to provide both upstream fish passage and entrainment protection of pallid sturgeon and other native fish. Although there are some positive aspects of such an alternative, it is recognized that a potential long-term reoccurring increase in operation and maintenance costs over existing conditions could be a significant negative impact to the Lower Yellowstone Project beneficiaries, who would likely bear the increased operation and maintenance costs. This initial study will make some assumptions associated with the pumping plant location and select potential pumps and motors that are commercially available. The power consumption demand will then be provided as base data to be incorporated into an operation and maintenance life cycle cost evaluation. If warranted, additional evaluation of the pumping plant concept would proceed to an Appraisal Design level to evaluate this alternative compared to other alternatives that address the passage and entrainment protection concerns at the intake.

Study Assumptions

Locations of the pumping plant along the river will affect the pumping power required. If the pumping plant is located further upstream, the pumping head would be minimized. If the plant is located further downstream, a higher pumping head would be required. For this study, the pumping plant location is assumed to be 1,000 feet downstream of the existing diversion dam. This is an arbitrary location with some consideration given to utilizing the existing park in minimizing earthwork for the plant yard and access.

Preliminary river hydraulic modeling was provided by the U.S. Army Corps of Engineers (COE) Omaha District as shown in Figure 1. This design data information was utilized to extrapolate the water surface elevations at the different flow stages. The elevation datum used for modeling is NAVD 88.

From Reference 1, 90 years of river hydrology were compiled and their monthly averages are as shown in Table 1 below. These monthly average stream flows are measured at the Sidney, Montana gage USGS #06329500 for the Yellowstone River. Note that the data does not include the diversion flow at the existing facility.

Table 1 - Yellowstone River average monthly flows during irrigation season.

Month	Monthly Average Flow, ft^3/s
April	10,380
May	18,400
June	39,110
July	23,210
August	8,798
September	7,201

Since there are no existing staff gauge records or logged water surface elevation data for the canal immediately downstream of the headworks, canal water surface elevations, which would be needed to provide flow and check conditions for delivery at turnouts, were obtained from topography survey information conducted in July, 2000. This survey was collected and compiled by DJ&A, P.C. Consulting and Engineering based out of Missoula, Montana. The vertical datum used was NAVD 88 which corresponds to the COE river hydraulic modeling. The month of July follows the peak river stage in June and perhaps represents the peak irrigation diversion and water surface elevation needed for system delivery in the canal. The canal water surface elevation used is 1989.5 feet.

Study Results

With the above assumptions, the study results for the required hydraulic head for pumping is shown in Figure 2. The Total Dynamic Head (TDH) includes the static lift, static height, and the friction head loss in feet. Because of the trashrack, fish screen, and exit loss, additional pumping would be required to overcome these frictional losses as tabulated in the Figure 2. They are included in the TDH column.

Examples of commercial pumps available at these TDH are Johnston Pump Model 60PO or Patterson Pump Model 72AF. There would be eight pumps rated at approximately 175 ft^3/s each for a total flow of 1,400 ft^3/s. The pump curve data can be referenced in Figure 3.

The total energy consumption for an average annual irrigation season starting at the beginning of April to the end of September is approximately 7,000 megawatt-hours. The peak energy consumption during the irrigation season would be 1,400 megawatt-hours during the month of September where river flow stage is at the lowest during the irrigation season. The horsepower rating of the motors required to operate within these head ranges would be 350 horsepower per unit. The energy required for the irrigation season per month can be referenced in Figure 2. Pump operation assumes that all pumps will be operated continuously during the irrigation season (Apr-Sep). Incremental stage operation of the pumps to water up the canal was not considered in this study.

For pumping efficiency and long term durable performance of the subject pumps, the head range would need to be between approximately 7.9 feet to 12.4 feet TDH. No commercial pumps are readily available for the lower TDH. In Figure 2, the column for water surface head shows a positive pump head during high river flow stages. This creates a potential problem for these pumps so artificial head is assumed and added into the fiction losses. This is a conservative assumption yielding a higher energy usage for a pumping plant located immediately downstream of the diversion dam.

Another study result that precipitated from this evaluation is the minimal submergence available on river fish screens during the low-flow periods with the diversion dam removed and natural stream bed gradient restored. This low flow occurs during the spring and fall diversion months and showed only approximately three to four feet of river depth. Therefore, a pumping plant alternative layout with fish screens would need to address the shallow river depth.

Conclusions

The previous value planning study looked at a preliminary pumping plant alternative (Reference 4). This study is the initial step in identifying the need to evaluate this alternative in an Appraisal Design level so that it would be comparable to other alternative studies.

Operation and maintenance of a pumping plant and its associated equipment are the potential drawbacks of such an alternative. To identify if there is merit to pursue this alternative into an Appraisal Design, basic life cycle costs associated with the operation and maintenance would first be evaluated. This study provides the power consumption data to be used for the life cycle cost evaluation.

With the above assumptions, the total average annual energy required by such a pumping plant would be 7,000 megawatt-hours. The peak energy demand occurs in September at 1,400 megawatt-hours. The pump motors would need to be 350 horsepower each for the eight pump units. Operation of the pumping plant was assumed to be from the beginning of April to the end of September where all pumps are assumed to be turned on and off with no flows lower than the required 1,400 ft^3/s.

This study also identified a potential concern for the in-river fish screen submergence requirement if the diversion dam is removed and river bed is restored to the natural gradient. This shallow depth can be overcome with fish screen concepts that are not in the river as shown in Figure 4. This concept layout was developed for another Bureau of Reclamation project with similar river submergence depths during low river flows. Future conceptual layouts at this site would resemble something similar. The concept consists of a sunken invert fish screen structure housing a “V” fish screen configuration with a fish bypass pipe system returning flow back to the river. The Yellowstone River at this location has a fairly shallow river bed gradient. Because there is not enough gradient, this type of fish bypass system would require fish-friendly pumps to drive the system. Although Reclamation has had experience with fish pumps at other projects, the acceptance of their use needs to be determined for this project.

References

1. Christensen, R., Glickman, A., Leavitt, M., Mefford, B., April 2004. Intake Diversion Dam Yellowstone River, Montana – Fish Protection and Passage Concept Study Report II, Bureau of Reclamation, Technical Services Center, Denver, Co.
2. US Bureau of Reclamation, Technical Service Center, Denver, Co., September 2007. Intake Diversion Dam, Preliminary Trashrack Concept Design for Intake Headworks, Lower Yellowstone Project – Montana-North Dakota.
3. US Army Corps of Engineers, Omaha District, February 2008. Lower Yellowstone Project Fish Screening and Sediment Sluicing Preliminary Design Report, Final Report.
4. US Bureau of Reclamation, Montana Area Office, Billings, MT, August 2005. Final Report, Lower Yellowstone Fish Passage Alternatives Value Planning Study.

Appendix

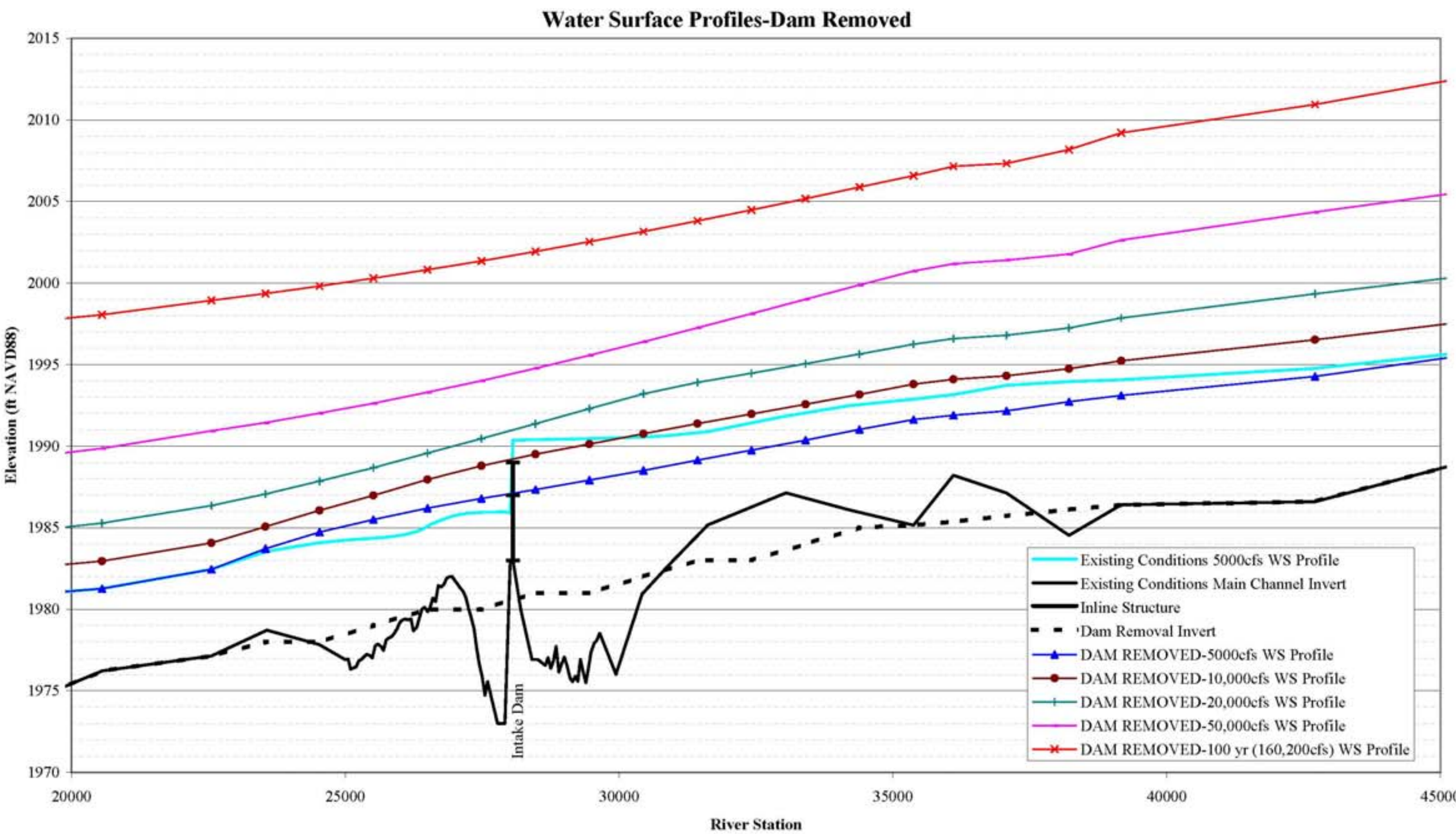

Figure 1 Yellowstone River water surface profile as provided by COE.

Lower Yellowstone River - Intake Diversion
Low Head Pumping Plant Alternative
Pumping Head

By: Chou Cha
Date: 10/14/2008

Irrigation Month	River Flow (cfs)	River Water Surface El. (ft)	Canal Water Surface El. (ft)		Water Surface Head (ft)	Trashrack Loss (ft)	Fishscreen Loss (ft)	Exit Loss (ft)	Total Head (ft)	Pump Unit Piping/Valves + Disch Pipe Friction Pipe Friction Head (ft)	Ave Unit TDH (ft)
April	10,380	1987.50	1989.5		2.00	0.5	0.25	0.25	3.00	8.60	11.60
May	18,400	1990.00	1989.5		-0.50	0.5	0.25	0.25	0.50	9.50	10.00
June	39,110	1992.50	1989.5		-3.00	0.5	0.25	0.25	-2.00	9.90	7.90
July	23,210	1990.50	1989.5		-1.00	0.5	0.25	0.25	0.00	9.30	9.30
August	8,798	1988.00	1989.5		1.50	0.5	0.25	0.25	2.50	9.60	12.10
September	7,201	1987.00	1989.5		2.50	0.5	0.25	0.25	3.50	8.90	12.40

Note:
Data is for river station at 270+00 based on COE's river stationing.
River water surface profile is based on dam removal and hydraulic modeling by the U.S. C.O.E. (Curtis Miller).
River flows were obtained from compiled hydrology data published in Reclamation "Intake Diversion Dam Fish Protection and Passage Concept Study Report II" date April 2004 for over 90 years of data.

Averge Monthly Diversion Pumping Plant Energy Usage

By: Bob Zelenka (86-68420) **Date: 10/22/08** (Revised)

Irrigation Month	Required Capacity Delivered (cfs)	Avg. Total Head (ft)	Pump Unit Piping/Valve Headloss (ft)	Add'l. Disch. Pipe Friction Headloss (ft)	Avg. Pump Unit TDH (ft)	Avg. Pump Unit Capacity (gpm)	Avg. Pump Unit Eff. (%)	Avg. Pump Unit Brake HP (hp)	Avg. Rt.-Angle Drive Eff. (%)	(Prem. Eff.) Motor Unit Eff. (%)	Avg. Motor Unit Power (hp)	PP Total Motor Input Power (kW)	Percent of Time Pumping (%)	Total Energy Required for Pumping (kW-hr)
April (30)	1400	3.00	3.14	5.46	11.60	85,500	85.0	294.7	96.0	95.0	323.1	1927.4	91.9	1,274,840
May (31)	1400	0.50	3.43	6.07	10.00	91,000	87.0	264.1	96.0	95.0	289.6	1727.8	86.3	1,073,735
June (30)	1400	-2.00	3.80	6.10	7.90	97,500	84.0	231.6	96.0	94.9	254.2	1516.3	80.6	879,471
July (31)	1400	0.00	3.55	5.75	9.30	93,500	86.3	254.4	96.0	95.0	279.0	1664.4	84.0	1,006,674
August (31)	1400	2.50	3.05	6.55	12.10	84,000	83.5	307.4	96.0	95.0	337.0	2010.7	93.5	1,353,678
September (30)	1400	3.50	3.00	5.90	12.40	82,500	83.0	311.2	96.0	95.0	341.3	2035.9	95.2	1,395,597

Avg. Annual Energy Usage: **6,983,996 kW-hr/yr**

Assume: Commercial Rate @ 45 mills/kW-hr: $0.045

Annual Energy Cost: **$314,280 per year**

Assumptions:
1. Rated Q calculated for 8 equal-size units operating to pump 1400 cfs total flow 24 hours/day each month during pumping season.
2. Piping/Valve Headloss estimated based on 54" diam unit pipe/valves and an undetermined diam manifold/discharge pipe.
3. Avg. Pump Capacity determined from performance curve selected for rated Q w/ 5% wear factor and pump operating at maximum required TDH.
4. Right-angle gear drive having a 3.5:1 gear ratio used to drive 257 rpm vertical pump with a 900 rpm horizontal motor.
5. Avg. Motor Eff. determined from pump brake HP as % of Full Load for a "Premium Efficiency", 350 hp, 900 rpm, TEFC horizontal motor.

Figure 2 Hydraulic head with power, and energy usage.

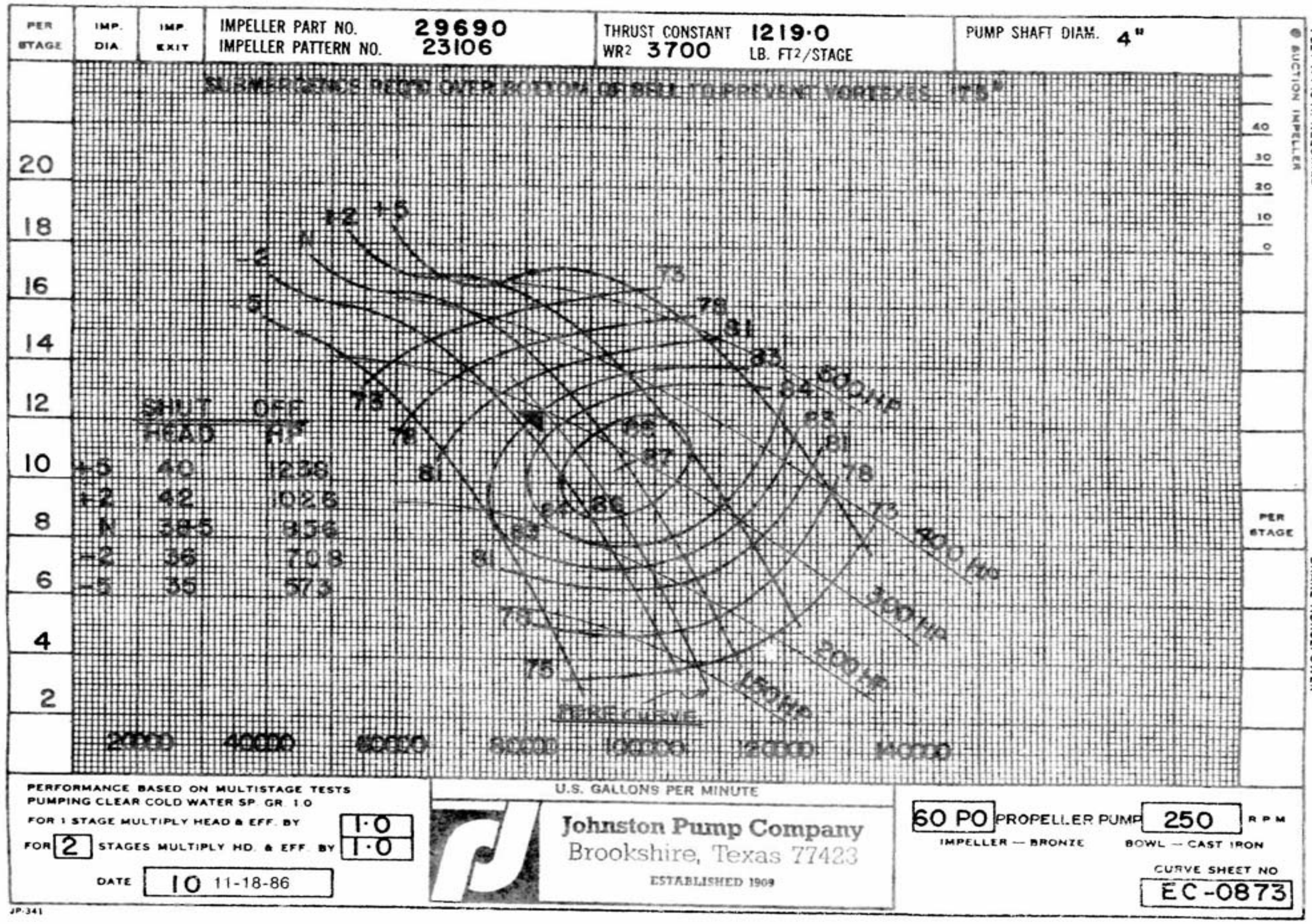

Figure 3 Pump discharge curve example.

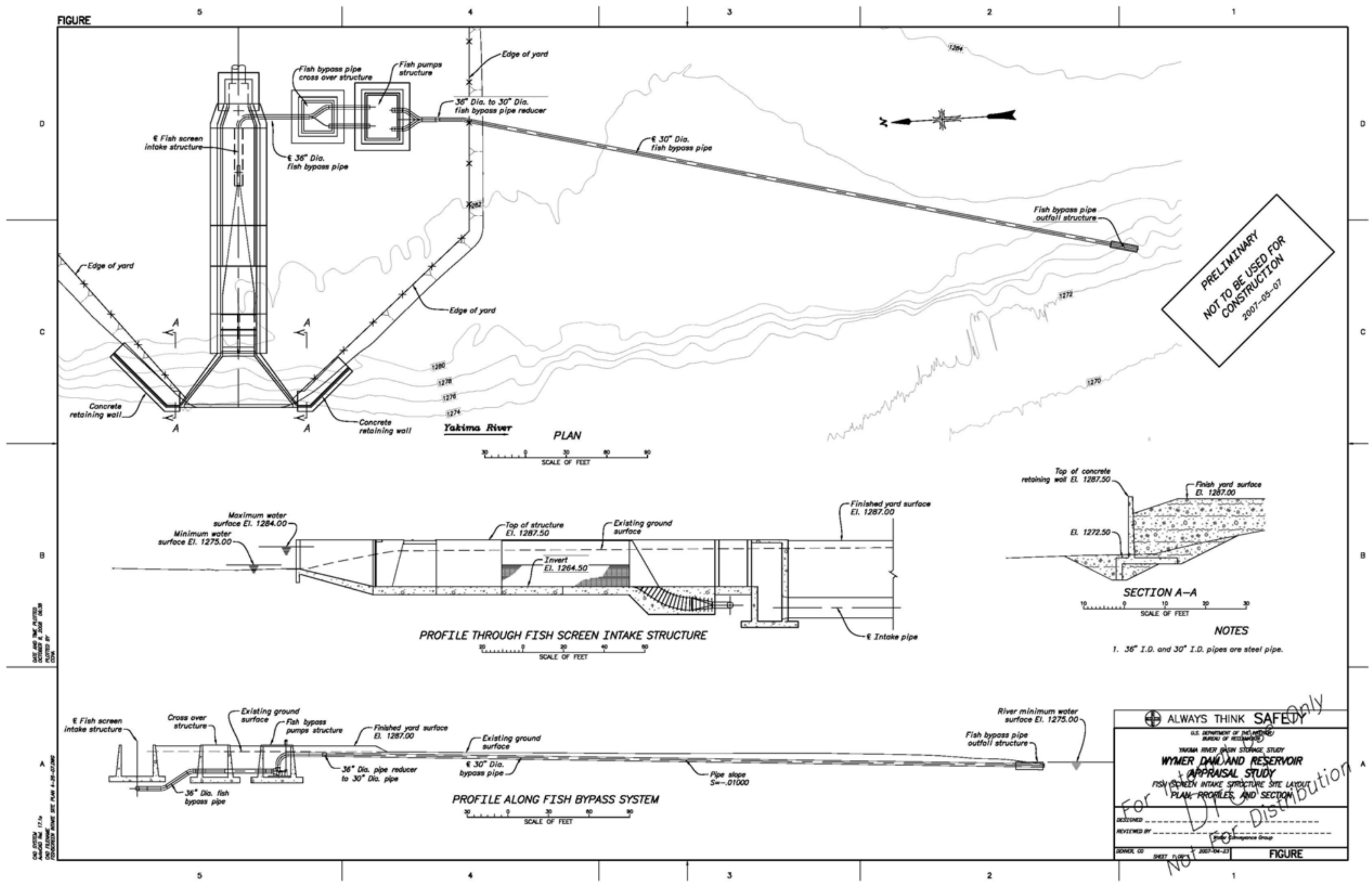

Figure 4 Potential fish screen intake concept.