Intake Diversion Dam

Fish Protection and Passage Concept Study Report II

Lower Yellowstone Project
Yellowstone River, Montana

April 2004

U. S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Bureau of Reclamation
Technical Service Center
Denver, Colorado

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INTAKE DIVERSION DAM
FISH PROTECTION AND PASSAGE
CONCEPT STUDY REPORT II

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Errata

The following pages in the text of the subject concept report are deleted and the revised attached pages are substituted therefore:

Remove pages:	Insert pages:
i	i
ii	ii
iii	iii
1 through 29	1 through 30 *
Figure 15	Figure 15 **
	Concrete Weir Cost Estimate Sheet ***

A concrete weir option for replacing the spillway has been added.

* Revisions are on pages 2, 19, 20, and 26.
** Revised May 12, 2004.
*** New

Table of Contents

Figures

Tables

Appendix A: Water Surface Model Data

Appendix B: Construction Cost Estimate Worksheets

Appendix C: Value Engineering Study Responses

Appendix D: Hydrographs

Appendix E: FWS Preference for Inflatable Weir at Intake Diversion Dam

Appendix F: Construction Schedule

Appendix G: Experience with Obermeyer Gates

Appendix H: Operation and Maintenance

Appendix I: Drawings of Existing Dam

I-1. - Lower Yellowstone Diversion Dam, Plan and Sections (from Project Data Book)
I-2. - Lower Yellowstone - Project Montana - North Dakota - Topographic Map of Vicinity of Lower Yellowstone Dam (undated)
I-3. - Fort Bufford Project - North Dakota - Montana - Lower Yellowstone Dam - Plan and Details - July 1905
I-4. - Fort Bufford Project - North Dakota - Montana - Lower Yellowstone Dam - Plan and Details of Abutment and Dike, July 1905
I-5. - S-3510 - Lower Yellowstone Project - Montana - North Dakota - Lower Yellowstone Dam, October 14, 1911
I-6. - S-3510 - Lower Yellowstone Project - Montana - North Dakota - Lower Yellowstone Dam, October 18, 1911
I-7. - S-3722 - Lower Yellowstone Project - Montana - North Dakota - Lower Yellowstone Dam, Steel Sheet Piling Driven Between December 15, 1911 and January 20, 1912, February 21, 1912
I-8. - S-478 - Lower Yellowstone Project - Montana - North Dakota - Plan and Profile of Round Piles - Lower Yellowstone Dam - December 29, '08

Executive Summary

This concept report is an update of the concept report dated January 2000 and covers three features:

- A positive barrier screen to exclude/divert fish from the canal
- Upstream fish passage
- Replacement of the existing diversion dam spillway

Pallid sturgeon are the primary species of concern for protection. The facilities are also designed for other species, such as, shovelnose sturgeon, sauger, paddlefish, sturgeon chub, and burbot.

A Value Engineering Study (VE) was completed and a final report issued on July 29, 2002. This concept report includes the responses (Appendix C) to the proposals in the VE study.

Fish exclusion. - The 2000 concept report looked at two options for the fish exclusion: (1) fish screens and (2) louvers. This report presents the Technical Service Center (TSC) recommended option, which is the fish screens. The fish screen facility design has been updated from the 2000 concept report. The design includes: a trashrack structure, a V-configured fish screen structure, a check structure downstream from the fish screens, and a fish bypass to the river

Upstream fish passage and replacement of exiting diversion dam spillway. - For upstream fish passage, the following alternatives are discussed in this report:

1. Concrete flume with slotted baffles at the right abutment
2. Riprap channel fishway with boulder weirs at the right abutment
3. A long low gradient channel
4. Obermeyer gated spillway

The first three fish passage alternatives would operate all year round: concrete flume, riprap channel, and low gradient channel. The first two fishways are similar in that they provide continuous passage around the right abutment of the diversion dam. The long low gradient facility (approximately 3.6-miles-long) would provide fish passage over the spillway but is anticipated to be too costly to be feasible. The fourth alternative replaces the exiting diversion dam spillway with an Obermeyer gated spillway across the entire width of the river for fish passage during the non-irrigation season and high river flows. Lowering the weir gates would provide unobstructed passage across the full width of the river.

Of the first two options, the riprap channel is more natural and would be easier to maintain than the concrete flume, making it the TSC recommended fishway.

Disregarding construction cost considerations, replacement of the dam with an Obermeyer gated spillway in conjunction with the riprap channel fishway is recommended by the TSC for the most effective fish passage. The U.S. Fish and Wildlife Service (FWS) has expressed preference for this combination. Construction costs and maintenance issues are included in this report for the final decision considerations. Also, included in this report is a design and construction cost estimate for a concrete spillway. The concrete spillway would not allow upstream fish passage.

The construction cost estimates for the features are:

1. Fish screen facility - $8,100,000
2. Riprap channel fishway at right abutment - $640,000
3. Obermeyer gated spillway - $11,500,000
4. Concrete spillway - $7,200,000

Project Purpose

Intake Diversion Dam and the diversion headworks for the Lower Yellowstone Irrigation District's Main Canal are located on the Yellowstone River about 17 miles northeast of Glendive, Montana (Figure 1). The effect of the dam and unscreened diversion on the fisheries of the lower Yellowstone River has been the subject of multiple studies by state and federal resource agencies. Entrainment studies by Hiebert (2000) show significant numbers of fish are entrained with diversion flow into the canal. Fish population studies conducted by Montana Fish Wildlife and Parks (Stewart, 1986, 1988, 1990, 1991) indicate the dam is a partial barrier to many species and likely a total barrier to some species. The Intake Diversion Dam is the furthest downstream of six low head diversion dams on the lower Yellowstone River. Providing passage at the diversion dam would make approximately 160 miles of additional habitat in the Yellowstone River available to the pallid sturgeon as well as providing access to the confluences of the Powder and Tongue rivers.

The purpose of this study is to present designs for reducing fish entrainment into the canal and increasing upstream fish passage.

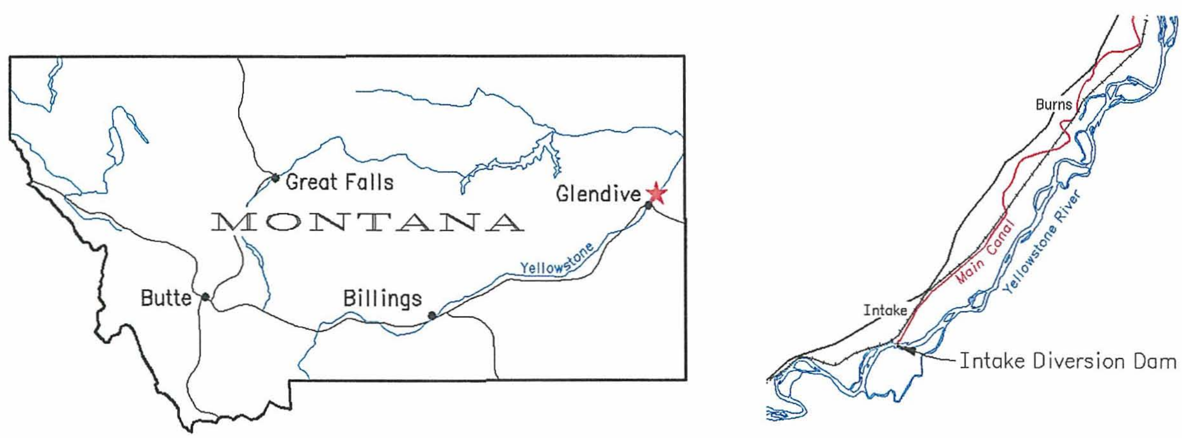

Figure 1. Location of Intake Diversion Dam, Montana.

Project Description - Lower Yellowstone Project (Reclamation Project Data, 1981)

The Reclamation Service began investigating the project in 1903. A report by a board of consulting engineers, dated April 23, 1904, served as a basis for authorization of the project. The project was authorized by the Secretary of the Interior on May 10, 1904, under the Reclamation Act of June 17, 1902. Construction of a diversion dam, canal headworks and delivery canals began on July 22, 1905, (Specifications No. 57 - Lower Yellowstone Dam - Fort Bufford Project, North Dakota and Montana). Water was available for the 1909 irrigation season.

The Lower Yellowstone Project lies in east-central Montana and western North Dakota. The project includes the Lower Yellowstone Diversion Dam, Thomas Point Pumping Plant, the Main Canal, 225 miles of laterals, and 118 miles of drains. The purpose of the project is to furnish a dependable supply of irrigation water for 52,000 acres of fertile land along the west bank of the Yellowstone River. About one-third of the project lands are in North Dakota and two-thirds in Montana.

Water is diverted from the Yellowstone River into the Main Canal by the Intake Diversion Dam (also known as the Lower Yellowstone Diversion Dam) near Intake, Montana. It is carried by gravity to the greater portion of the project lands. About 2,300 acres of benchland are irrigated by water pumped from the canal by the Thomas Point Pumping Plant.

Intake Diversion Dam (Spillway)

Intake Dam was originally constructed as a rock-filled timber crib weir about 12-feet-high and 700-feet-long (Appendix I). The original dam contained approximately 23,000 cubic yards of material. The dam raises the upstream water elevation from about two to five feet depending on river flows. Since the construction of Intake Dam, the structure has required frequent repair to maintain the needed upstream head to divert flow into the canal. Heavy ice and large flood flows work to progressively move riprap material downstream from the dam. A cableway that crosses the river along the crest of the dam is used to place riprap along the dam crest when repairs are required. Over the years, large quantities of rock have been added to the dam to replace rock displaced by the river. Riprap now extends one hundred or more feet downstream of the dam and across the width of the river channel.

Diversion Headworks and Canal

The Main Canal diverts to the west side of the Yellowstone River at Intake and extends down the valley to the confluence of the Yellowstone and Missouri Rivers. The canal is 71.6 miles long, unlined, and has an initial capacity of about 1,400 ft^3/s. The canal headworks is a concrete structure with 11 slide gates (Figure 2). There are no trashracks in front of the intake gates but there are horizontally spaced timbers (Appendix I). The canal was originally designed with a 30-feet-bottom-width and 1.5:1 side slopes. The canal is designed to convey its full capacity at a flow depth of about 10 feet and a velocity of 3.1 ft/s. The canal operates from late April through September of each year.

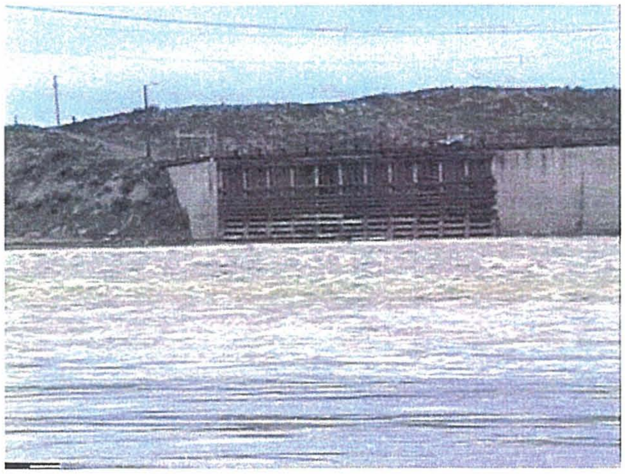

Figure 2 - View of Intake Dam and Main Canal Headworks.

Hydrology

The Monthly Average stream flows for the Yellowstone River measured at the Sidney, Montana gage (USGS #06329500 - about 90 years of record) are as follows:

Month	Flow
January -	5,742 ft^3/s
February -	6,891 ft^3/s
March -	10,990 ft^3/s
April -	10,380 ft^3/s
May -	18,400 ft^3/s
June -	39,110 ft^3/s
July -	23,210 ft^3/s
August -	8,798 ft^3/s
September -	7,201 ft^3/s
October -	8,323 ft^3/s
November -	7,371 ft^3/s
December -	5,977 ft^3/s

Note: These values do not include flow diverted at Intake or any diversions downstream between Intake and the gage at Sidney which is approximately 40 miles downstream of the dam.

Two hydrographs from the Sidney gage are shown in Appendix D: a summary hydrograph for 1953 through 2003, and a hydrograph for 1978, which was a high flow year.

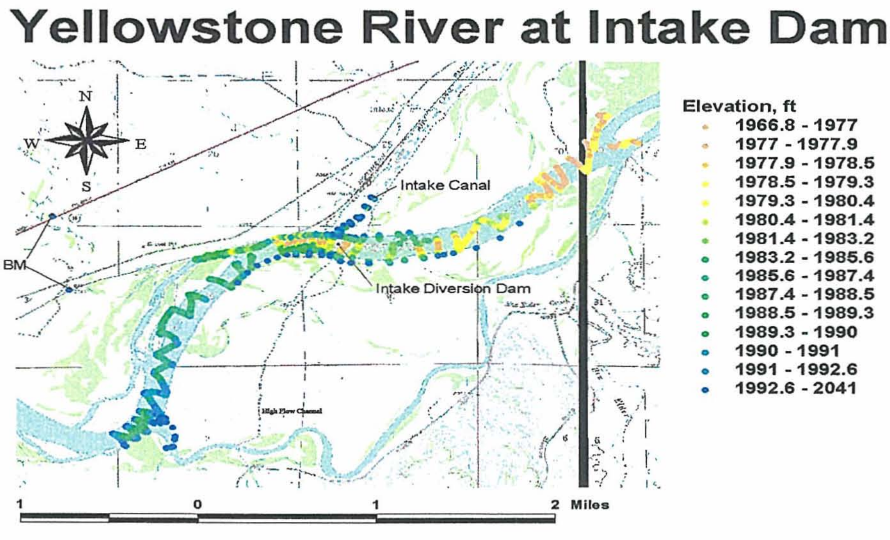

Figure 3 - Location of survey data points measured for the concept study. Ground surface elevations are denoted by the color spectrum shown in the legend. Note, the river has migrated laterally in some locations since the U.S. Geological Survey Map shown as a background was generated.

Water Surface Modeling

Model. - A water surface flow relationship for the Yellowstone River near Intake Dam was developed using the Corp of Engineers' HEC-RAS program. HEC-RAS is a one-dimensional standard step backwater simulation model. The model requires topography cross-sections along the river and canal as input. A site survey was conducted on April 18 and 19, 1999. The survey was conducted prior to the canal being watered up for the irrigation season. The survey included: measuring cross sections through the canal for a distance of about 1,600 feet downstream of the diversion headworks, surveying random river bank elevations for a distance of about 1.0 mile upstream and downstream of the diversion dam, and conducting river bathymetry measurements for a distance of about 1.5 miles upstream and downstream of the diversion dam. The land based survey data was obtained using a GPS system referenced to a benchmark located just east of Thirteen Mile Creek at the railroad crossing. River bathymetry data was obtained using a boat mounted ADCP (acoustic doppler current profiler) with a GIS link. The ADCP provided nearly continuous location, flow depth and velocity data along the path taken by the survey boat. The location of all survey data collected are shown on Figure 3. Note, bathymetry data was not collected for a distance of about 500 feet downstream of the dam crest due to shallow and turbulent flow conditions. A contour map of the river, river bank area and canal prism was generated from the survey data, Figure A1 of Appendix A. Cross section data were cut from the contour model and input into a HEC-RAS geometry file. A plan view of the river section modeled, including the location of cross-sections used in the model, is shown in Figure A2. River channel roughness used in the HEC-RAS model was adjusted by calibrating the model against the river water surface profile measured during the topographic survey. For final design, the data and computer model should be updated as required.

Model output - Flow simulations were conducted for a range of river flows with and without canal diversion. Figure 4 shows water surface profiles across the dam for each river flow modeled. For river flows above 30,000 ft^3/s, the high flow channel that bypasses the dam to the south is assumed to flow as given in Figure 5. Table A1 gives estimated water surface elevations and related hydraulic data for a range of river flows. The estimated rise in the upstream water surface elevation caused by the dam is 5.5 feet to 2.0 feet for flows of 5,000 and 80,000 ft^3/s, respectively.

The normal water surface elevation in the canal is estimated to be 1990.8 just downstream of the diversion headworks for a flow of 1,400 ft^3/s. The canal water surface elevation varies as the canal flow varies. Canal geometry data could not be obtained in the first 100 feet of the canal due to standing water in the canal at the time the field survey was conducted. Near the headworks, the canal prism has changed significantly since construction. The canal width has increased within the first bend and a large scour hole followed by a deposition berm has formed in the invert downstream of the headworks. Therefore, the downstream prism of the canal was extrapolated to the headworks for the model. The canal prism beyond 100 feet downstream of the headworks remains similar to the excavated shape with some aggredation of the canal invert and degradation of canal side slopes. The bottom width is still about the original 30 feet. It does not appear the changes in the canal profile have significantly affected the hydraulics of the canal. The original canal design flow depth of 9.8 feet appears to be reasonable.

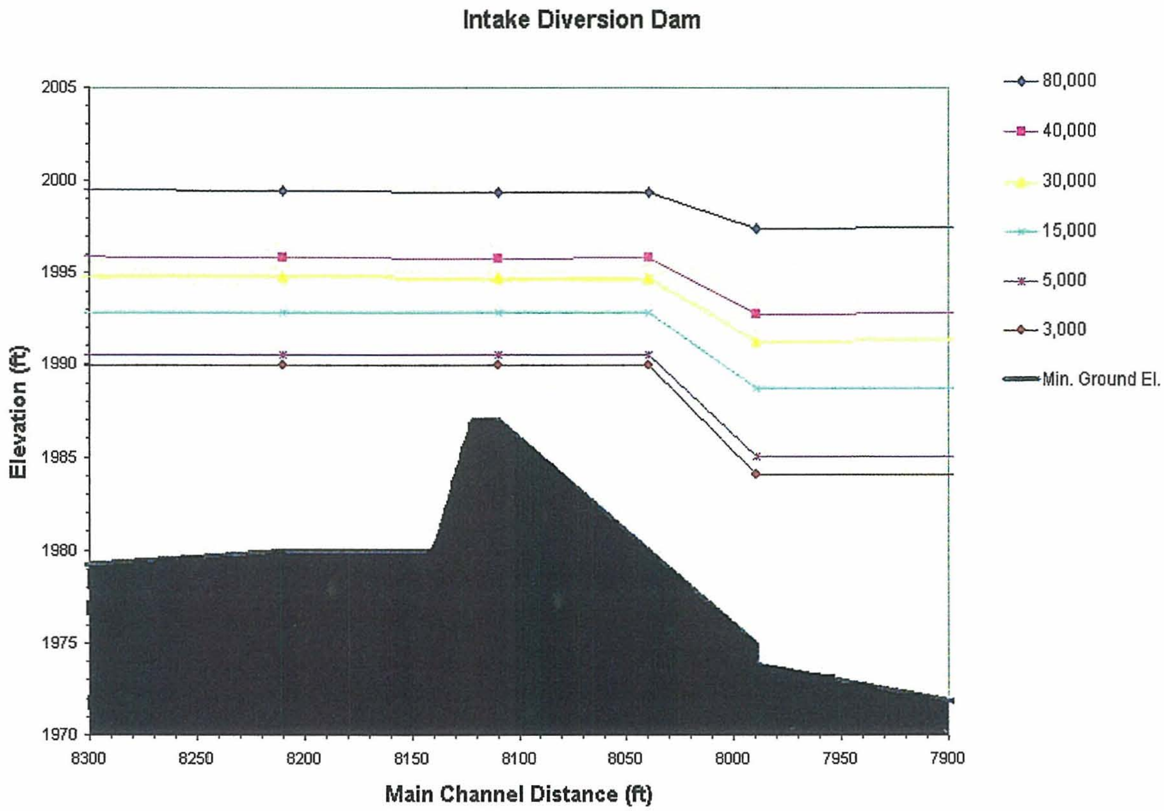

Figure 4 - Estimated water surface profiles across Intake Dam for river and canal flows (ft^3/s) of:

River flow upstream of high flow channel	Canal diversion	Flow over dam	Flow in high flow channel
81,400	1,400	73,500	6,500
41,400	1,400	38,500	1,500
31,400	1,400	29,500	500
16,400	1,400	15,000	0
5,050	50	5,000	0

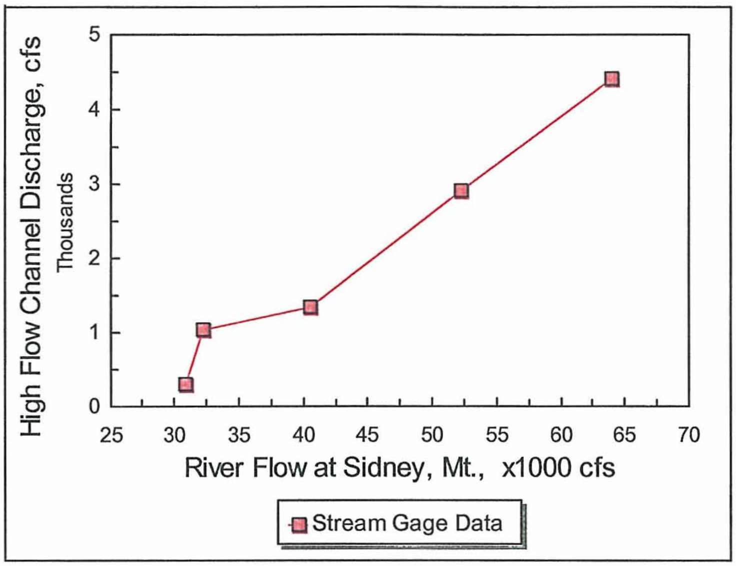

Figure 5 - Flow relationship between the river at Intake Dam and the high flow channel that bypasses the dam. (Phil Stewart MFW&P, 1997).

Fish Protection

Various methods of reducing fish entrainment are used at water diversions. These methods are generally divided into two categories, positive barriers and behavioral barriers. Positive barrier screens prevent all fish larger than fingerling size and a high percentage of fry from passing on downstream. Screens allow water to pass through while guiding fish to escape routes commonly called fish bypasses. Behavioral barriers rely on triggering an avoidance response in fish. Most behavioral barriers use artificially imposed stimulus to guide fish away from diverted flow. The most common behavioral barriers are louvers, strobe lights, sound generators and electric fields. Behavioral barriers vary widely in effectiveness and application, however no behavioral barriers are considered 100 percent effective. Louvers are a barrier (vertical bars closely spaced, Figure 6) that are designed to generate flow turbulence that fish can detect and avoid. Light, sound and electric fields are non-structural barriers. In most cases, non-structural barriers have not been proven to be effective substitutions for structural barriers. They should only be considered if structural barriers cannot be constructed due to site restrictions or cost.

A positive barrier screen and louver style barrier were reviewed in the 2000 concept report. The two concepts differ in fish protection efficiency, size of structure, debris handling, and construction costs. Both can be located downstream of the diversion headworks and contain similar fish bypasses. The louver concept would be less effective (especially for small fish) and more difficult to clean. Therefore, a positive barrier screen is the TSC recommended design.

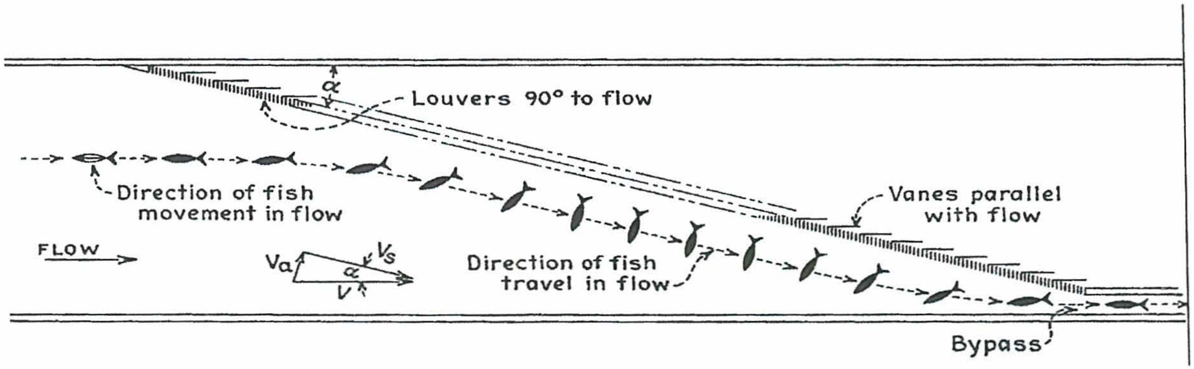

Figure 6 - Louver style fish barrier, Rhone 1955.

Barrier Location

A fish protection facility at Intake Diversion Dam could be placed on-river in front of the diversion headworks structure or off-river in the canal downstream of the headworks. Both locations have advantages and disadvantages. On-river fish barriers are generally preferred where applicable because they prevent fish from leaving the river. On the down side, on-river means the barrier must be designed to contend with large debris, ice, large changes in river stage and relatively poor access to the barrier for maintenance. An off-river location downstream of the canal headworks has the advantage of being removed from the extremes of flow and debris that occur in the river. The structure can be unwatered for maintenance and inspection each year after the irrigation season. The down side of an off-river location is the uncertainty of fish mortality or injury associated with passing through the headworks gates and the potential for increased predation by predator fish due to the concentration of fish in bypass flows. At Intake Dam, the severity of flood flows, large debris and ice jams favor an off-river fish barrier.

Selecting a location of the structure along the canal is a function of fish bypass construction and residence time of the fish in the canal. Two possible locations for the fish protection structure were considered, either locating the structure near the diversion headworks (herein referred to as the headworks site, Figure 7) or about 8.2 miles further downstream near a canal wasteway at Burns (Figure 8). Locating the structure near the headworks will require improving access along both sides of the canal and constructing a bypass pipeline for about 700 feet through a 40- to 60-feet-high bluff that parallels the river. At this location the fish screen structure is just downstream from a curve in the canal. The curve may cause nonuniform flow at the entrance to the fish screen structure. The flow condition entering the fish screen may be adjusted and improved by selecting which headworks gates are used (using downstream gates may be best). At the Burns location, the canal is constructed through an area of fill material. The canal sits above the natural topography which provides good access and offers a short fish bypass. The canal wasteway discharges into a natural slough that joins the river about 1 mile from the canal, Figure 8. The resource agencies have expressed their desire to return fish to the river as quickly as possible and minimize the need to salvage fish when the canal is shutdown each fall. Therefore, for the purpose of this concept level design the canal headworks site was chosen. If the

Burns site is pursued in the future, the fish screen designs proposed for the headworks site will also be applicable there. Only site access and the fish bypass pipeline would differ.

Improved access to the fish screen structure will be required at the headworks site. Access from the canal bridge crossing leading to the Intake recreation area is anticipated. Roads would be constructed, on either side of the canal, that slope down to the O&M bank elevation. A turn around area will also be required on both sides.

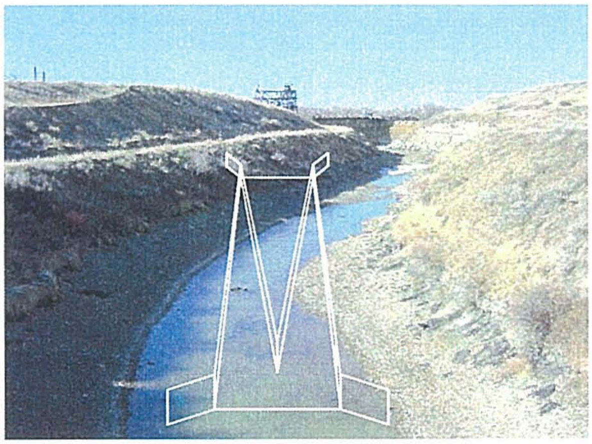

Figure 7 - View looking upstream toward the Main canal headworks. Photo was taken from the access bridge to the Intake boat launch and recreation area. Outline of the screen structure shows the approximate location.

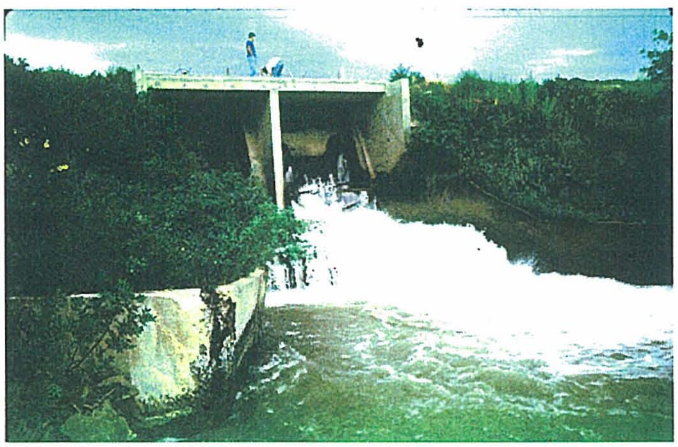

Figure 8 - View looking upstream at the Burns Wasteway flow control gates.

Flow Criteria for Positive Barrier Screens

Primary objectives and hydraulic criteria of a fish barrier must be established prior to selection of a barrier design. Typical fish protection objectives and hydraulic criteria include: fish species, size and swimming strength; barrier approach velocity (velocity measured perpendicular to the barrier face); barrier sweeping velocity (velocity measured parallel to the barrier face); and barrier design (screen opening size). Screen velocity criteria for salmon fry and fingerlings have been established by many state and federal agencies - Table 1. Criteria for other species have generally not been established. However, the criteria given in Table 1 are generally applicable to most fish species indigenous to a river environment. Consideration should be given to reducing the barrier approach velocity from the values given if very weak swimming fish are to be protected. Barrier approach velocity and barrier size are inversely related. The lower the barrier approach velocity, the larger the structure size.

A maximum exposure time of 60 seconds (National Marine Fisheries Service) is used in the Northwest where salmonids reside. There are no known criteria for non-salmonids.

Screen opening criteria are available for several types of screens. Commonly used criteria (NMFS and Washington) for fry sized salmon, which are less than 2.36 inches, are:

- Perforated plate - Screen opening shall not exceed 3/32-inches (2.38 millimeters), measured in diameter
- Profile bar - Screen openings shall not exceed 0.0689 inches (1.75 millimeters) in width
- Woven wire - Screen openings shall not exceed 3/32-inches (2.38 millimeters) measured diagonally
- The screen material shall have a minimum 27 percent open area.

Variances from the salmonid criteria can be requested for projects in the Northwest. Granting of a variance usually requires monitoring and testing of the facilities.

Table 1. Agency velocity criteria for screening salmonids.
(Sources: EPRI 1986; K. Bates, Washington Department of Fisheries, personal communication.)

Agency	Approach velocity (ft/s)[a]		Sweeping velocity[d]
	Fry[b]	Fingerlings[c]	
National Marine Fisheries Service	≤0.4	≤0.8	Greater than approach velocity
California Department of Fish and Game	≤0.33 for continuously cleaned screens: ≤0.0825 for intermittently cleaned screens	Same as fry	At least twice the approach velocity
Oregon Department of Fish and Wildlife	≤0.5	≤1.0	Approach velocity or greater
Washington Department of Fisheries	≤0.4	≤0.8	Approach velocity or greater
Alaska Department of Fish and Game	≤0.5	Same as fry	No criterion
Idaho Department of Fish and Game	≤0.5	≤0.5	Sufficient to avoid physical injury to fish
Montana Department of Fish Wildlife and Parks	≤0.5	≤1.0	No criterion

[a] Velocity component perpendicular to and approximately 3 inches in from or the screen face.
[b] Fish less than 2.36 inches (60 mm) long.
[c] Fish 2.36 inches (60 mm) or longer.
[d] Theoretical velocity vector along and parallel to the barrier face; often considered equal to the average

Positive Barrier Screen Concept

Fixed screens designed for open channel diversions are typically designed as a series of flat screen panels positioned nearly vertical or vertical. The screens are aligned at an angle to the canal flow to obtain the desired screen area and create a strong sweeping flow parallel to the screen face. A single line of screens (Figure 9) or a"V" arrangement (Figure 10) can be used. The "V" design allows the structure length to be shortened, but requires the fish bypass be placed mid-channel. The mid-channel bypass is not desirable if large debris is common as it can become wedged in the apex of the "V" and be difficult to remove. A single line screen has a fish bypass positioned at the downstream end of the screen on the channel wall.

The screen surface of a fixed screen is cleaned by moving a brush over the screen or hydraulic spraywash head behind the screen. Debris can be either raked vertically up the screen and collected on the screen deck or passed down the length of the screen to the fish bypass to be carried back to the river.

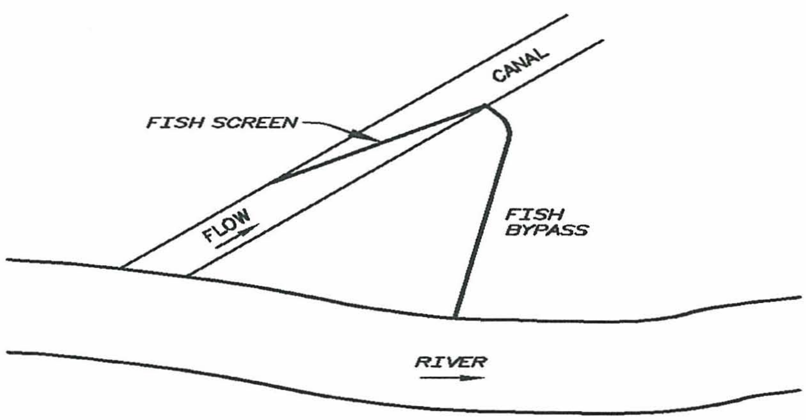

Figure 9 - Typical layout of a linear flat plate fish screen structure

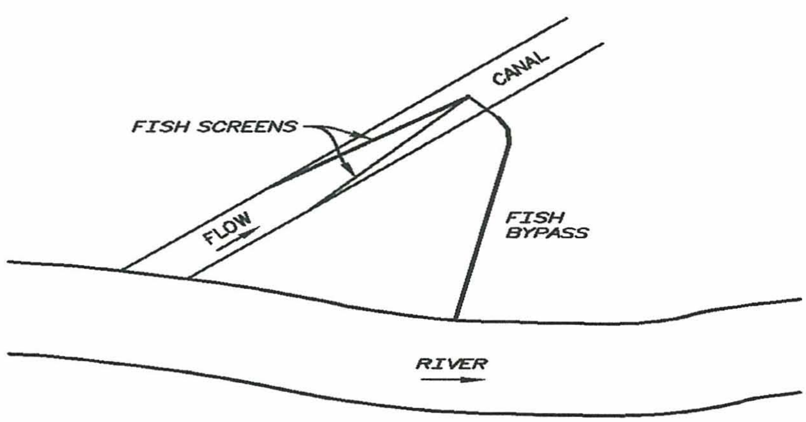

Figure 10 - Typical layout of a "V" shaped fish screen structure.

TSC Recommended Positive Barrier Screen Design

General. - A flat plate "V" screen structure is recommended as the best screen option for the Main Canal. The estimated construction cost of the fish screen structure is $8,100,000, which includes the trashrack structure, the fish screen structure, the check structure, and the fish bypass pipeline. An itemized construction cost estimate for the screen facility is given in Appendix B.

The flat "V" screen structure layout is shown in Figures 12 and 13. The design of the "V" screen structure requires the following:

- A trashrack with trashrake and conveyor at the upstream end of the fish screen structure.
- A fish screen structure. The screen structure is mounted on a 12-inch high concrete sill.
- Two cable operated sweeps to clean the fish screens. Each cable system will have two brushes.
- Adjustable baffles behind the fish screens to produce a uniform flow across the screens.
- Fish bypass pipeline back to the river.
- A fish bypass entrance designed so that a fish trap can be inserted and removed.
- Downstream check structure.
- Pressure relief panels to allow water flow and prevent structure failure in case of fish screens plugging.

Trashracks. - The trashrack structure is designed to pass a flow of 1,440 ft^3/s at a 2.5 ft/s unit velocity. A VE study proposal recommended a variable spacing on the trashbars from top to bottom, to allow for best opportunity for fish passage. The proposal was: 4-inch spacing for the upper portion of the water profile, a 12-inch spacing for the mid-section, and a 24-inch spacing for the lower 3 feet. The variable spacing will make cleaning the trashrack more difficult. A bar spacing of 8-inches is recommended and the bars should be stopped 2 feet above the structure invert. This will allow fish passage but prevent passage of large debris. An hydraulic trashrake and conveyor, for automated cleaning, will be located on the deck.

Fish screen structure. - The fish screen structure is designed to pass a flow of 1,400 ft^3/s with an approach velocity of 0.4 ft/s and a sweeping velocity greater than the approach velocity. Although approach velocities of up to 0.5 ft/s have been used, it was decided that weak swimming fish would more likely be impinged on the screens at this higher approach velocity and than debris would be difficult to remove. The sweeping velocity, at canal design flow of 1,400 ft^3/s and a depth of 10 feet, is 2.5 ft/s at the upstream end of the fish screens and 2.0 ft/s at the downstream end.

Three sill heights were considered for the fish screen structure: 6 inches, 12 inches, and 18 inches. There were three main considerations in selecting a sill height: (1) passing benthic species which tend to move along the bottom of the water column, (2) sediment deposits, and (3) construction cost. The higher sill heights would tolerate greater sediment deposition without affecting operation and allow the benthic species to pass without being exposed to the fish screens. However, a higher sill height would result in a longer and more costly screen structure. The 12-inch sill height was selected. The 12-inch sill height will allow adequate room for deposition of sediment without greatly increasing the cost of the structure. Sediment deposition is reportedly negligible in this reach of the canal and can be removed during the off-season. The total length of fish screen is estimated to be 440 feet (assumes 10 percent of the gross screen area is for structural members).

Two options for the structure configuration were considered: (1) straight line and (2) "V." With a sweeping velocity of 2 to 2.5 ft/s, fish exposure time for each configuration was estimated using a 2.25 ft/s average velocity:

Straight line configuration	"V" configuration
200 seconds	100 seconds

A 120-second screen exposure time criteria combined with a 12-inch bottom sill should be acceptable at Intake diversion. The "V" fish screen structure layout with a 120 second exposure time allows the use of one bypass. To meet the 60-second criterion would require two additional bypasses (one midway on each leg of the structure). Additional bypasses are not recommended because of:
(1) increased bypass flow which may require adding a pump back structure from the bypass pipeline to the canal, (2) significantly increased construction costs, (3) increased operating complexity of the screen cleaning system, and (4) increased maintenance efforts and costs.

The "V" configuration results in a sweeping to approach velocity ratio of approximately 9.0. Normally a sweep to approach velocity ratio between 5 and 10 is desired. The larger the ratio the easier it is to clean the screens.

Although several types of screen material are available, 1.75-mm-slot opening stainless steel wedge wire (profile bar) screen material with about a 40 percent open area is recommended. This screen material is very durable, has a high porosity, and will withstand the impact of larger debris that frequently enter the canal. Wedge wire screens have been in use for many years at other fish screening facilities and have performed very well. The screens are designed with 10-feet-wide by 10-feet-high panels so the slots can be oriented either vertically or horizontally. Eight-feet-high blocking panels will be required above the fish screen. During final design, consideration should be given to eliminating the barrier panels and making the fish screens higher and thus lowering the approach velocity during high river flows.

There are two options for mounting the fish screens: (1) guides or (2) bolting to the structure frame. An installation using guides allows easier placement and removal of the fish screens; however, bolting the screens to the structure frame reduces the construction cost. Bolting the fish screens to the structure was used for this concept study since the screens will be accessible for maintenance during the off-season. A mobile crane capable of lifting 3,000 lbs. (weight of baffle panels) at a 50-feet-reach would be required to remove and replace the screens and baffles. An alternative to using a mobile crane, would be to install a monorail on the screen structure. Concept cost estimates include four spare screen panels.

The screens and baffles are expected to cause about 0.5 foot or less of water surface drop (headloss) through the structure. The majority of the headloss in a properly cleaned screen structure occurs at the baffles. Baffles are used to adjust the flow distribution passing through the screen. An even through-screen flow distribution is important to prevent high velocity hot spots from occurring that can cause fish impingement and debris cleaning difficulties. Adjustable baffles are mounted parallel to the screen on the downstream side, see Figure 14 (Section D-D). Baffles are designed to create high resistance to the flow in areas where the approach velocity is high and low resistance in areas where velocity is low. The difference in flow resistance along the structure caused by the baffles then forces a more uniform flow distribution through the fish screen. The greater the non-uniformity of flow velocity approaching the screen structure the tighter the baffles must be closed to even out the flow and the greater the headloss. The upstream bend in the canal and unbalanced inlet gate operation are factors that can create non-uniform flow velocity upstream of the screen structure. In previous designs, the baffles have typically been 6-inch-wide to 10-inch-wide vertical steel plates with a pin mounted on each end to allow rotation. However, for this facility we would use a set of two perforated plates. One plate will be fixed on the bottom and the second plate will be adjusted vertically to control the orifice openings. The new design will be less expensive and easier to adjust.

Baffles are typically adjusted during initial startup of the facility to achieve good uniformity of approach flow to the entire screen. The baffles should only have to be adjusted during the first season of operation of the screen structure. Baffles should not require further adjustment unless operating conditions change significantly.

Fish Bypass. - The fish bypass consists of an entrance structure, a bypass pipe, and an exit structure. The fish bypass entrance is located at the downstream end of the fish screens. The entrance to the bypass pipe is a 2-feet-wide rectangular opening. The bypass then transitions to a 48-inch-diameter pipe that passes through a bluff between the canal and river for a distance of approximately 700 feet. The bypass pipe enters the river about 350 feet downstream of the dam. The fish bypass will convey 40 ft^3/s flow at a 1,400 ft^3/s irrigation diversion flow. The bypass will be designed to have the capability of having a fish trap inserted for testing the fish passage. Figure 14 (Section E-E) shows a fyke net option for trapping fish; other options can be considered.

As the river flow increases above approximately 28,000 ft^3/s, the river water level downstream from the dam, rises above the canal normal water surface. A check structure, downstream of the fish screen structure, is required to increase the canal water level so the bypass will function properly and not have reverse flow or force the operators to close the bypass gate. The fish facilities are designed to allow operation of the fish bypass for river flows up to 80,000 ft^3/s. Based on hydraulic records going back to 1953, the 80,000 ft^3/s river flow is exceeded only approximately once every 10 years and not for a very long time (1 to 6 days) during each occurrence. It is anticipated that fish can be held up for these short periods of non-bypass flow operation without significantly affecting the overall operation of the fish facility.

The water level in the canal will be controlled by the new check structure when river flows are high (above approximately 28,000 ft^3/s) and will vary with the water level in the river at lower river flows. Table 2 shows water surface elevations in the river and canal for a range of river flows. At river flows up to 80,000 ft^3/s, the water level in the canal will be checked up as high as El. 1998.4 to provide an adequate differential between the canal and the river for 40 ft^3/s to pass through the bypass.

Table 2. - River and Canal Water Surface Elevations

River flow (ft^3/s) at Sidney gage	Water surface elevation at dam		Water surface elevation in canal	
	Upstream	Downstream	Unchecked	Min. checked[3]
3,000	1990.0	1984.1	1983.5[1]	NA
5,000	1990.6	1985.1	1983.5[1]	NA
15,000	1992.8	1988.7	1990.8[2]	NA
30,000	1994.7	1991.3	1990.8[2]	1992.3
40,000	1995.8	1992.8	1990.8[2]	1993.8
80,000	1999.4	1997.4	1990.8[2]	1998.4

[1] 50 ft^3/s flow in canal

[2] 1,400 ft^3/s flow in canal

[3] Assumes 1.0 foot head differential between the bypass entrance and the river is required for bypass flow

Screen Cleaning System. - Large debris will be removed at the trashracks. Two cable operated brush systems (each with two brushes) will be used for cleaning smaller debris from the fish screens (Figure 14). The systems clean during upstream and downstream travel. Once the debris is brushed off the screens, the flow carries the debris downstream to the bypass and then the river. Periodic cleaning with the sweeps should be suitable; however, during periods of high river moss or leaf fall, continuous operation of the sweeps may be necessary. The system should be designed for both periodic (timed and water surface differential) and continuous modes of operation.

An air blower system will be included with the cable operated sweeps. The air blower system will be capable of loosening sediment near the invert of the fish screens so the sediment can be suspended in the water and carried downstream through the fish bypass and to the river.

It is anticipated that the fish screen structure will not be operated in the winter and that ice will not be a concern.

Check Structure. - The check structure contains two 15-feet-wide by 17-feet-high radial gates. During river flows of 80,000 ft^3/s, the water in the canal may be backed up to El. 1998.4, which is a canal depth of 17.6 feet. The gate opening and closing speed will have to be slow. Opening the gates quickly while there is more than a two to three feet water surface differential across the gates, could cause a large flow surge in the downstream canal section. Also at this time, the headworks gates may need to be adjusted for the desired flow.

Fish Passage Concepts

Passage must be provided for Pallid Sturgeon, a listed species. Fish passage studies conducted by White and Mefford (2002) and Kynard, Pugh, Henyey, and Parker (2002) support the use of a rock channel fishway for passing sturgeon. It is important to provide the best possible fish passage (FWS preferred option in Appendix E).

A fishway is a channel which is constructed around a barrier for the purpose of providing upstream fish passage. This report discusses the two FWS preferred fish passage options (Appendix E): (1) a riprap channel fishway which would operate all year round, and (2) an Obermeyer gated spillway which would allow fish passage during the non-irrigation season and high river flows. The riprap channel fishway is also a TSC recommended feature. The TSC recognizes the fish passage benefits of the Obermeyer gates spillway; however, construction costs and maintenance are items that will have to be considered by those who decide on whether to construct the Obermeyer gated spillway. This decision on the Obermeyer gated spillway will be made by others.

Concept level designs and construction cost estimates for the riprap channel fishway and the Obermeyer gated spillway are included in this report.

If a new spillway is not constructed, it is recommended that measures be taken to prevent fish passage on the north side of the river. Fish often hug a river bank to escape high velocity flow. At Intake Dam, the riprap downstream of the crest appears to be at a flatter slope near the north bank. This could cause two problems for fish passage. First, the existing spillway shape may create flow conditions that attract fish to the north bank of the river and away from a future fishway on the south bank. Second, fish passage along the north river bank leads the fish directly in front of the Main Canal headworks where entrainment with the canal diversion flow is likely. Canal entrainment studies by Hiebert (January, 2000) support this theory. Hiebert's study shows the downstream most gate on the canal headworks entrains the largest percentage of the fish. Two possible protective measures are (1) raising the dam on the north side and (2) removing downstream riprap.

Riprap Channel with Boulder Weirs Fishway

The riprap channel fishway design will provide fish passage for all river flows above 5,000 ft^3/s. The estimated stage discharge elevations upstream and downstream from the dam are given in Table A1. The low river condition for fish passage (5,000 ft^3/s) resulted in the maximum water surface differential across the dam of 5.5 feet.

As the river flow increases above approximately 10,000 ft^3/s, the invert boulders will become submerged and the flow will increase rapidly. The side slope boulders will not be submerged until the river flow exceeds approximately 40,000 ft^3/s.

The criteria used for design of the fishway are:

- Maximum water surface differential across the dam is 5.5 feet.
- Maximum water surface drop per boulder weir is 0.35 foot
- Maximum passage velocity through slots is 4.8 ft/s
- Minimum flow depth is 2.0 feet.
- Maximum channel slope of 2 percent

The riprap channel fishway alinement follows the south river bank. The fishway, shown in Figure 16, starts upstream from the dam crest and extends approximately 260 feet downstream along the bank. The bottom width is 8 feet and the sides are at 2 ½ horizontal to 1 vertical slope. The fishway design is similar to the recently constructed Derby Dam fishway near Reno, Nevada. Chevron-shaped boulder arrays are placed within the fishway to create hydraulic drops about every 16.5-feet along the channel. The boulder arrays are required to maintain sufficient flow depth within the fishway and also create pools, between boulder arrays, that provide resting areas for fish. The chevron shape concentrates flow toward the center of the fishway channel and produces higher flow velocity in the center of the channel than at the banks. Stability of a riprap structure is a major design concern. Each year as river flows start to increase in the spring, river ice moves some of the riprap on the existing dam downstream. Some of the riprap is probably floated out of position by surrounding ice or is moved by the force of ice jams pushing against the rock. Both mechanisms of moving the rock could effect the stability of rock placed on the fishway. Downstream riprap, in the river channel, will be removed as required to allow fish passage to the fishway entrance.

Flow through the fishway will vary with the river flow and upstream depth. A range of river and fishway flows are shown in Table 3.

Table 3. - Fishway Flow

Upstream Surface Elevation	Depth (ft)	Fishway flow (ft^3/s)	River flow (ft^3/s)
1990.3	2.0	1% 50	4,500
1991.3	3.0	1% 80	8,200
1992.3	5.0	7% 900[1]	13,000
1994.3	6.0	5% 1,300[1]	28,000

[1] Center boulders in weirs are submerged. Used Manning's equation to estimate fishway flow and assumed n=0.050

Two options were considered for protecting the riprap and boulders in the fishway from ice damage: (1) piles angled across the entrance (Corps 2002) and (2) grouting the fishway riprap. Grouting the riprap would not protect the boulder weirs and would make the riprap channel rigid and subject to undermining. Therefore, concrete piles were selected as the best option (Figure 16). The concrete piles are shown on the drawings and are included in the construction cost estimate. The concrete piles shown can withstand 3.0 feet of ice load. Design of the piles should use MDOT criteria for the lower Yellowstone River area.

The construction cost estimate for the riprap channel fishway is $640,000. An itemized construction cost estimate is given in Appendix B. The cost estimate includes: concrete piles for ice protection, sheetpile under the fish passage at the dam to prevent a washout (grouted riprap cutoff would be another option), and concrete work (undefined at this time) at the right abutment of the existing dam. Work at the right abutment of the existing dam will depend on the condition of the abutment as determined when fishway channel is excavated during construction.

Spillway Replacement

General. - The existing spillway is in poor condition. The spillway was originally a rock filled timber crib approximately 12-feet high (drawings in Appendix I). During 1911-1912, ice damaged the structure and it was rehabilitated with steel sheet piling and riprap. In 1939, rock was placed below the dam to repair the apron. The spillway was partially replaced 25 to 30 years ago. The center section has failed and the spillway is being maintained on an as needed basis by placing rock in the area. The diversion dam now resembles a long rapid. It is anticipated that the spillway will have to be replaced in the next 5 to 15 years. In addition to needing replacement due to its poor condition, it is desired to replace the spillway with a facility which would allow upstream fish passage. Other considerations for replacing the existing spillway include: (1) maintaining the present upstream water surface, (2) passing trash and debris downstream, (3) passing ice downstream, (4) operation and maintenance effort and expense, (5) boat passage, and (6) construction cost.

The FWS preferred replacement option (Appendix E) is an Obermeyer gated spillway. The pallid sturgeon pass upstream during the irrigation season and the high river flow period (Figure 11). The gates can be lowered during the non-irrigation season and when river flows are greater than 30,000 to 40,000 ft^3/s. A concrete weir design is also presented in this report; however, the concrete weir will not allow upstream fish passage and appears to be unacceptable to the FWS.

During high river flows the gates must be operated to provide a differential head to drive the fish screen bypass flow. The maximum differential head that allows upstream river fish passage over the spillway is approximately 1.0 foot, which would require a swimming burst speed of 8 ft/s. The 1.0-foot differential head across the dam will be sufficient to allow a reduced fish bypass flow of 30 ft^3/s instead of 40 ft^3/s.

The head differential can be created by one of the following options:

1. Fully opening a sufficient number of gates (Corps 2002) next to the headworks
2. Raising all the gates partially
3. A combination of items 1 and 2 above.

Another option to allow upstream fish passage would be drop the gates periodically to allow fish passage during the upstream migration. With this mode of operation fish would hold temporarily in the canal and the river.

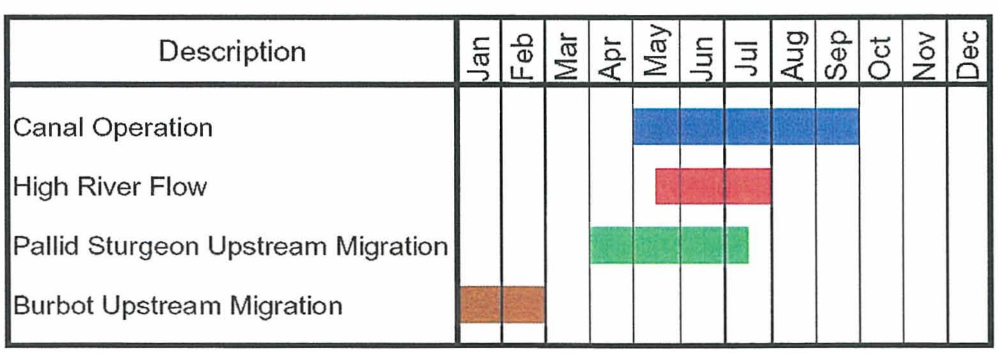

Figure 11. - Timing of canal operation, high river flows, and upstream fish migration

Concrete weir. - A concrete weir would: (1) reduce the maintenance cost associated with the existing dam, (2) have less maintenance costs than an Obermeyer gated spillway, and (3) have a lower construction cost than the Obermeyer gated spillway. The estimated construction cost of the concrete spillway is $7,200,000.

Obermeyer gated spillway. - The Obermeyer gated spillway would consist of: (1) a concrete foundation slab, (2) a series of approximately 16-feet-long steel plates hinged at the bottom (across the width of the river), (3) a series of approximately 16-feet long air bladders (44 total) set behind the steel plates and which would control the position of the steel plates, (4) tie down straps on the back, (5) air compressor, and (6) air piping connections and check valves. A section through the Obermeyer gated spillway is shown on Figure 15. The spillway requires: (1) a downstream concrete apron in the area of turbulence due to an hydraulic jump, and (2) downstream riprap to prevent scour from undermining the structure. A survey of the upstream and downstream areas will be done for final design. At that time, the apron elevations should be reviewed and revised as necessary. Riprap will be removed from the downstream river channel to improve fish passage.

It is anticipated that piping would be divided into groups. The gates could be raised and lowered in groups by adjusting air in the bladders, and isolated in groups. Also, it is anticipated that each gate bladder will have a check valve in case of leakage in other bladders. The air bladders, plates and hinges, tie down straps, and much of the air piping would be located in the river where access for inspection and maintenance would be difficult.

The Obermeyer gated spillway has the advantage of being able to lower the gates to pass trash, sediment, fish (going upstream), and ice in the winter. The biggest drawbacks of the Obermeyer gates are: (1) potential damage due to ice or debris passing over the gates, (2) vandalism, (3) accessibility to the gates at low river flows (approximately 8,500 ft^3/s or less) for inspection and maintenance, and (4) the overall operation and maintenance costs of the gate system.

Telephone conversations (Appendix G, Wagner) with the manufacturer (Obermeyer) indicate the gate panels should be strong enough to pass any ice flow over the top. The major ice flows can occur from early March through mid-April. This is before the canal operating season begins and the gates would be in the down position. If the gates are up and a particularly heavy ice flow gets hung up, the bag would compress and allow the ice chunk to pass over, and than the bag would re-expand. For ice adhering to the gate panel, anchor bolts are sized for the additional shear, and the hinge flap is designed for the tension (calculations are based on the ice thickness). The hinge and bolts can also be designed to withstand impact from a large block of ice when the gates are in a down position.

For the Obermeyer gates, it is important to select materials with as long a life as possible. We assumed stainless steel for the face plate in the construction cost estimate. Durability of the air bladder was also considered. A Kevlar reinforced bladder added $600,000 above the cost of an unreinforced bladder to the cost of the gates. The Kevlar reinforced bladder would better withstand gunshots. Other materials can be considered during final design.

To fix or replace an air bladder or other gate parts would require cofferdaming and dewatering the area so work can be done in the dry. To facilitate repair or replacement, use of a spare gate may be helpful. We have added a spare gate to the construction cost estimate. It is anticipated that the repair work would be done in the non-irrigation season when river flows are low and the gates are down. The flow at this time may be as high as 8,000 to 9,000 ft^3/s with the water surface at approximately El. 1991.5 upstream and 1986.5 downstream. A barge and/or the overhead cable and/or divers would probably be required for removing, replacing, or repairing the gates in place. The river water velocity will be approximately 1.0 to 2.0 ft/s during the maintenance work. Two options were considered to allow unwatered access to a spillway gate:

(1) Using stoplogs upstream and downstream of the gate and placing sand bags across the gates. Removable vertical steel beams could be placed in blockouts in the concrete and then the stoplogs could be placed between the vertical steel beams.

(2) A four-sided aluminum box that could be lowered around the gate and then the area within the box unwatered. The box would be approximately 9-feet-high, 16-feet-long, and 16-feet-wide. The box would be high enough to be placed during river flows of up to 8,500 ft^3/s. The metal weir plates would be made with 1-foot-wide removable edges on each side, which are bolted to the main weir plate (14-feet-long). The edges would be removed by divers before the metal box is lowered and replaced after the work is completed. The metal box is estimated to weigh approximately 5,000 lbs.

The gates can also be designed to be held open by metal struts in an emergency.

The gate manufacturer (Obermeyer) (teleconference notes with Pete Hoffman 2/19/04) has informed us that the expected life of the bladders and gates is 50 years. Obermeyer offers a 5-year warranty and has reportedly had no failures due to deterioration in 15 years.

The construction cost estimate for the Obermeyer gated spillway is $11,500,000 (includes Kevlar reinforced bladder). In addition to the initial construction cost, we estimated the life cycle cost for the Obermeyer gates for a 100-year period. It was assumed that the stainless steel plates would last 50 years and the air bladders would last 33 years. The present worth of the replacement cost is approximately $960,000. The itemized construction cost estimate is given in Appendix B.

Electrical

Power at the site currently powers the lights only. It is anticipated that a new power line will be required if the facilities are constructed.

Geology

General. - The Intake Diversion Dam, hereafter referred to as Intake Dam, is situated along the northeast flank of the Cedar Creek Anticline, a major structural feature in southeastern Montana. Cretaceous strata, exposed along the axis of this northwest-southeast trending (northwest plunging) anticline, dip gently to the northeast and are overlain by Paleocene sedimentary strata of the Fort Union Formation in the Intake area. Here, the Yellowstone River has incised an approximately 2-mile-wide channel into the surrounding upland.

The Fort Union Formation constitutes bedrock in the area and consists of an alternating sequence of clay shales, siltstones, sandstones, lignitic shales and lignite. Because of the terrestrial-type deposition, the beds interfinger and grade both laterally and vertically. The stratigraphic section varies from location to location and correlation between points is unpredictable. Permeability of the various strata varies greatly due to the varying degree of compaction and cementation. The high erodibility of Fort Union material on steep, unprotected slopes gives rise to badland type topography along the walls of the Yellowstone River valley.

Weathered bedrock is soft and has soil properties. Unweathered bedrock materials have both rock- and soil-like characteristics. Exceptions are lenticular bodies of moderately cemented, moderately hard sandstone locally present within the Fort Union. Also, thicker lignite beds have burned back from their outcrops and overlying shales have been baked and fused to form moderately hard material locally referred to as clinker. These vary in both thickness and lateral extent. Beds of variable thickness of lignitic shale to lignite occur throughout the Fort Union Formation.

Several terrace levels, cut into the Fort Union Formation and overlain with gravel, are recognized along the valley. These range in age from Pleistocene to Holocene (recent) and occur from 14 to as high as 420 feet above the present river level. The younger terraces which range from 14 to 90 feet above the river underlie most of the Intake Dam area. The gravel terrace occurring in the floodplain is generally blanketed with fine-grained soils.

Fish Screen and Bypass Structures. - The fish screen structure, located within the Main Canal, will be founded on bedrock of the Fort Union Formation. The fish bypass, extending from the downstream end of the screen to the Yellowstone River downstream of the Intake Dam, a distance of approximately 700 feet, will be excavated in bedrock of the Fort Union Formation. Overburden is up to about 55 feet thick above the bypass invert.

Surficial deposits consisting of alluvial, colluvial, eolian and terrace deposits of Quaternary age generally mantle the bedrock and occur along the upper portion of the canal prism. Surficial deposits consisting of material excavated from the canal and placed in waste banks is present on both sides of the canal. Also, fill material has been placed along the river bank downstream of the Intake Dam to provide slope protection. Depending on the direction of the bypass alignment, the slope protection material may be encountered at the bypass outlet. Surficial deposits will have no significant design or construction considerations for the fish screen and, depending on designs and construction methods, no to minor considerations for the fish bypass.

Shales, siltstones, uncemented sandstones, lignitic shales and lignite of the Fort Union Formation generally are rippable with modern equipment and excavated by common methods. Cemented sandstones and concretions within the Fort Union can not be ripped and, if encountered, may require drilling and blasting to remove from excavations. It should be anticipated bedrock will bulk about 27 percent if excavated and dumped. It will probably bulk 10 to 15 percent after being excavated and compacted.

The siltstones, uncemented sandstones, lignitic shale and lignite are all quite erodible. However, the shales and cemented sandstones will retard (but not eliminate) erosion.

There is a potential of encountering methane gas within the lignitic shales and lignite beds.

Stability of bedrock materials within the fish barrier and bypass excavations is not expected to be a significant problem. Shallow excavations in bedrock will be stable on 1/2:1 slopes. Permanent excavations should be laid back on 1:1 slopes.

Bedrock materials below the weathered zone (upper 5 to 10 feet) likely will have sufficient bearing capacity to support the fish barrier and bypass pipeline. However, lignitic shales and lignite are fractured, soft, low in density and readily air slake. If these materials are encountered within the excavations, they should be overexcavated and replaced with compacted backfill to preclude problems with deformation. Also, shales exposed within the excavations will likely air slake rapidly and freshly exposed surfaces should be protected before being covered with concrete or compacted backfill.

Groundwater is believed to be tributary to the Yellowstone River with the water table occurring at or above the river. Perched groundwater may occur in surficial deposits just above the bedrock contact and also in sandstone units and fractured lignite beds within the bedrock.

The shales and siltstones are generally impervious. The sandstones are semipervious and will weep water. The lignite beds are fractured, low in density and semipervious to pervious. Lignite beds encountered within the screen or bypass excavations should be expected to pass water rapidly.

Fishway. - The proposed fishway is situated on the right abutment of the Intake Dam. The dam across the center section and right abutment is founded on Quaternary alluvial deposits. Alluvial deposits are shown to extend across the floodplain (Torrey and Kohout, 1956) and mapped by McKenna, et al (1994) to vary between 20 and 50 feet thick in the vicinity of the Intake Dam. However, a small, isolated exposure of bedrock of the Fort Union Formation appears to outcrop locally along the right (south) bank of the river downstream of the dam.

Preconstruction drill hole information indicate alluvial deposits within the area of the present river channel consist of sand and gravel. Although not noted on the logs, cobble-size material is also present within the coarse-grained materials. These coarse-grained soils are continuous across the floodplain but, outside the river channel, including the right abutment, are overlain with fine-grained soils (silts and clays).

Fill material was placed on the right abutment to divert river flows around and support the right abutment concrete wall. These materials consist of a varying percentage of boulders and cobbles in a matrix of fine- and coarse-grained soils. The dimensions and configuration of the fill material is uncertain but maximum thickness is believed to be about 20 feet adjacent to the right abutment concrete wall based on design drawings.

It appears fishway excavation will be in fill material and, along a portion of the alignment, alluvial deposits composed of both fine- and coarse-grained soils. The fill material may contain boulders up to 3 feet maximum size. Drill hole data suggest the bedrock surface occurs at approximate elevation 1960 feet along the fishway and bedrock is not expected to be encountered. However, if bedrock is present within the fishway excavation, design and construction considerations of geologic conditions of bedrock materials discussed for the fish screen and bypass are applicable for the fishway.

The coarse-grained alluvial deposits are rounded and consist of sand, gravel, and cobbles, up to about 6-inch-maximum size with lesser amounts of cohesive and cohesionless fines. These materials are stable on 2-1/2:1 slopes.

The fine-grained alluvial deposits and fill material are stable on 2:1 slopes if seepage is not occurring. If seepage occurs in these materials, remedial measures may be required to prevent internal erosion and slope instability including flattening the cut slopes.

Groundwater on the right abutment is anticipated to approximate the river water surface. Seepage through coarse-grained materials into the fishway excavation are expected to be significant and some type of dewatering system may be necessary during construction.

Low Gradient Fishway Channel. - The proposed low gradient fishway channel, extending in a southwesterly direction from the toe of the Intake Dam to the main channel of the Yellowstone River, would be a 3.6-mile-long channel with about a 0.04 percent slope. The channel, if this option is selected, would be excavated in Quaternary alluvial deposits. These deposits generally consist of fine-grained soils overlying coarse-grained soils. Both soil types would be encountered within the channel excavation. Refer to fishway (above) for description of alluvial deposits along the channel. Bedrock of the Fort Union Formation could potentially be encountered. If encountered, however, the occurrence of bedrock along the alignment would be localized.

Construction Materials. -

Pervious. - Pervious material can be readily obtained from terrace deposits within 1 to 2 miles of the proposed structures.

Impervious. - Several sources may provide impervious materials. These include colluvial (slopewash) and alluvial deposits found along the valley walls and floor. Another source of impervious material is the weathered shales of the Fort Union Formation. The colluvial and alluvial deposits have not been investigated but likely consist of low plasticity, silty clays and clayey sands or nonplastic, silty sands. Weathered shale (upper 5 to 10 feet) can be used for impervious fill; however, it may be difficult to work because of high plasticity, moisture controls and/or fragments that will not easily break down and compact. Impervious material likely can be obtained within 1 or 2 miles of any of the proposed structures.

Concrete Aggregate. - Reclamation has previously conducted tests on concrete aggregate from 7 sources along the Yellowstone River in the vicinity of Savage and Glendive, Montana, about 15 and 20 miles straight-line distance from the Intake Dam. Material from these sources, though some marginal, was suitable for use in concrete provided the proper gradations are obtained and low-alkali cement is used.

It is assumed concrete aggregate can also be obtained from terrace deposits within several miles of the proposed sites. These deposits are similar to approved sources of concrete aggregate upstream and downstream of the Intake Dam. However, suitability tests would have to be conducted on samples collected from these proposed sources.

Riprap. - The Lower Yellowstone Irrigation District is currently obtaining rock from a source situated about 2 miles from the Intake Dam. The source is located in the SW ¼ of Section 31, Township 18 North, Range 57 East on privately-owned land. Rock from this source has been used extensively in the past to replace rockfill along the dam due to ice gouging and flood flows dislodging and transporting the rock downstream. Past performance of existing riprapped areas suggest this rock is durable and does not readily break down. The quantity of rock remaining at this source is not known.

Another possible option for riprap is to utilize moderately cemented sandstones occurring intermittently in the Tertiary and Cretaceous deposits in the area. This rock has been used locally for stream protection; however, it will break down after a number of wet-dry, freeze-thaw cycles. In most instances, it is not a desirable rock for riprap. Six sources of sandstone of this quality were identified in the early 1950's. These sources are located from about 20 to 50 miles from the proposed structures. Two of the sources were found suitable for use as riprap. The results of testing of the other four sources is not known. Also, since these sources have been quarried for stream protection in the past, it is not known how much rock material remains in each of the six sources.

An additional source for riprap is the area around Dickinson, North Dakota, located a considerable distance from the Intake Dam. This source consists of a highly cemented, lenticular deposits of siliceous siltstone capping isolated knobs north and south of Dickinson, North Dakota. This material is extremely hard and durable. It has been used to face Dickinson and Heart Butte Dams. Truck and/or rail haul to the proposed sites would be about 150 miles.

Construction Considerations

The site plan for the fish screen structure, riprap channel fishway, and spillway is shown on Figure 12. There are several assumptions made about construction of these facilities:

1. Unless a temporary bypass is constructed, the construction of the fish screen structure will occur during the non-irrigation season which varies depending on the weather. The construction window for the fish screen structure in the canal may begin from mid-September to mid-October. The construction window may end sometime between mid-April and mid-May. It is anticipated that the fish screens will require two to three construction seasons. In the first season the concrete will be placed, and in the second and third seasons some concrete may still have to be placed and the metal work will be installed. During final design, consideration should be given to using coarse gravel and riprap instead of the concrete lining. This may allow completion in two instead of three construction seasons and be less expensive.
2. The riprap fishway can be constructed in two to four months.
3. The spillway can be constructed in two years. This assumes that the contractor will work during the low flow periods in the river. One half of the spillway would be constructed each year.
4. The contractor may work in the river during any time of the year. Flow to the canal will have to be maintained during the irrigation season.
5. The wood and steel sheet piling cutoffs for the existing spillway are not required but may be incorporated in the final design.
6. The bypass pipe will be installed in a casing which will be installed by pipe jacking (micro tunneling).

7. The cofferdams in the river can be constructed of embankment with membrane and riprap cover. The cofferdams and dewatering will be contractor-designed items.
8. Purchase of additional right-of-way will not be required.
9. Waste and borrow areas are within one to two miles.
10. Use existing riprap source within 2 miles.
11. Access for constructing the fish passage is through Glendive. Contractor may construct a temporary embankment over the high flow channel with 12- to 18-inch corrugated metal pipe culverts.
12. Monitoring should be done to ensure nesting bald eagles or interior least terns would not be disturbed.

Construction Cost Estimates

The construction cost estimate worksheets are shown in Appendix B. The estimates include 10 percent for unlisted items and 20 percent for contingencies. The estimated construction costs are as follows:

1. Fish screen structure - $8,100,000
2. Riprap channel fishway with boulder weirs - $640,000
3. Obermeyer gated spillway - $11,500,000
   a. The cost of the Obermeyer spillway gates were estimated based on using stainless steel plates, and Kevlar reinforced bladders. These materials were used due to the poor accessibility of the site. Both should give a long service life.
   b. The present worth of the life cycle costs over a 100-year period for the Obermeyer gates is approximately $960,000 (not included in construction cost estimate).
   c. The concept design assumes that a spread footing type foundation will be adequate. If the geologic exploration indicates that there are compressible materials in the foundation, the structure may require piles for support. The piles would cost approximately $300,000.
4. Concrete weir - $7,200,000

Design Data Requirements/Studies Required Prior to Starting Final Design

1. Surveys
    a. River bathymetry downstream from the dam past the campground and upstream past the headworks and at the fishway
    b. additional survey to the south of the fishway
2. Geologic Investigations
    a. Headworks site
    b. Burns site if needed
    c. Fish passage and spillway
    d. Construction materials investigations
    e. Sheet pile driving
    f. Dewatering requirements
    g. Fish screen structure site
3. Water quality
4. Waste areas
5. Borrow areas
6. Contractor use areas
7. Environmental:
    a. Contractor use of water
    b. In-river work period
    c. Dewatering and cofferdaming requirements
        1. Material requirements
        2. Treatment requirements for discharge water
8. Overhead powerline clearance
9. Condition of existing spillway, especially the left and right abutments (evaluate by TSC engineer)
10. Operation of existing canal and headworks gates
11. Condition of existing overhead cable, requirements for maintenance, and requirements for repairs or replacement. The overhead cable is reportedly in good condition.
12. Source of riprap. The site the district uses near the dam or another site.
13. Drawings of existing dam.

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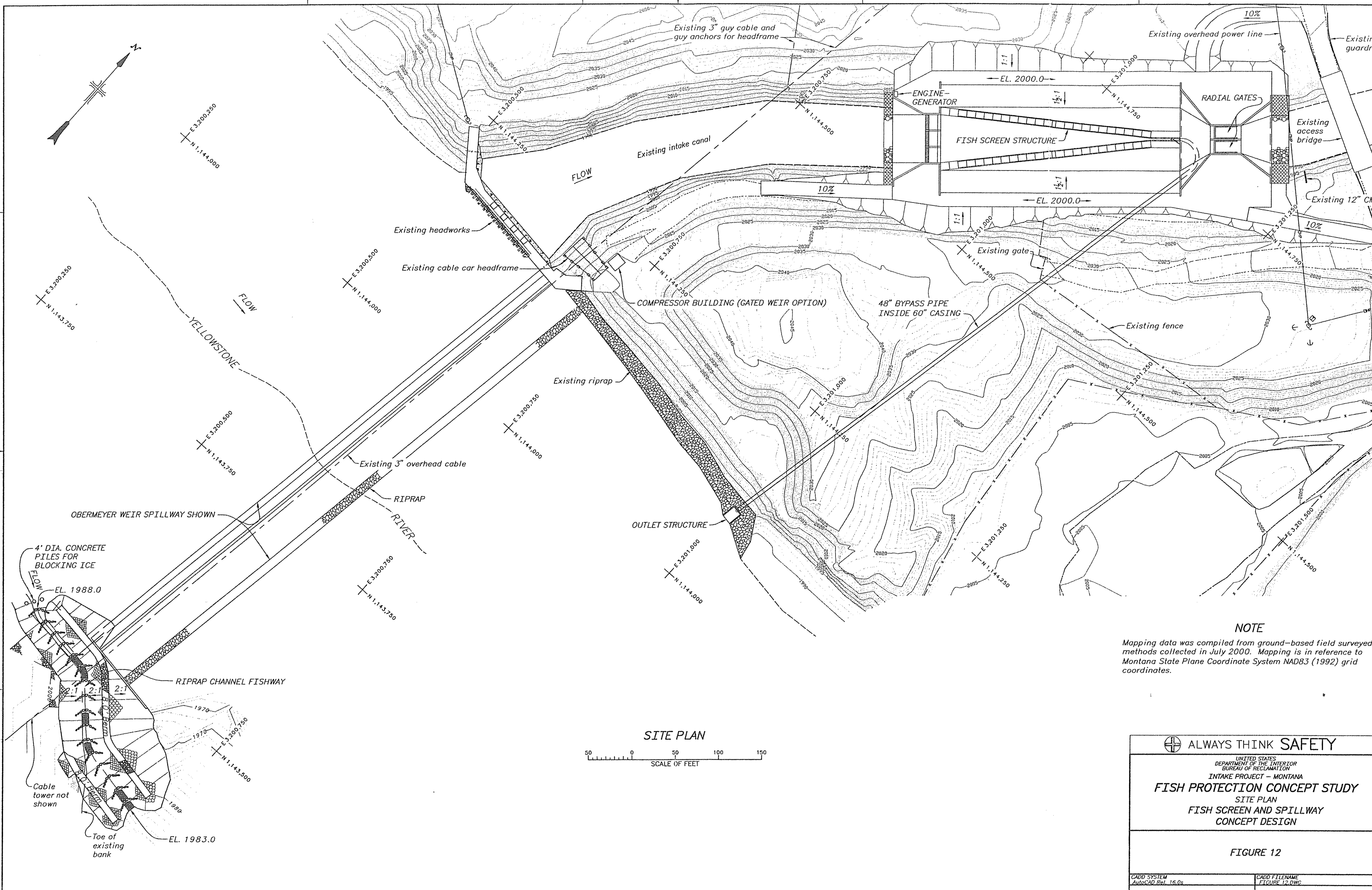

NOTE

Mapping data was compiled from ground–based field surveyed methods collected in July 2000. Mapping is in reference to Montana State Plane Coordinate System NAD83 (1992) grid coordinates.

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INTAKE PROJECT – MONTANA

FISH PROTECTION CONCEPT STUDY

SITE PLAN
FISH SCREEN AND SPILLWAY
CONCEPT DESIGN

FIGURE 12

CADD SYSTEM	CADD FILENAME
AutoCAD Rel. 16.0s	FIGURE 12.DWG

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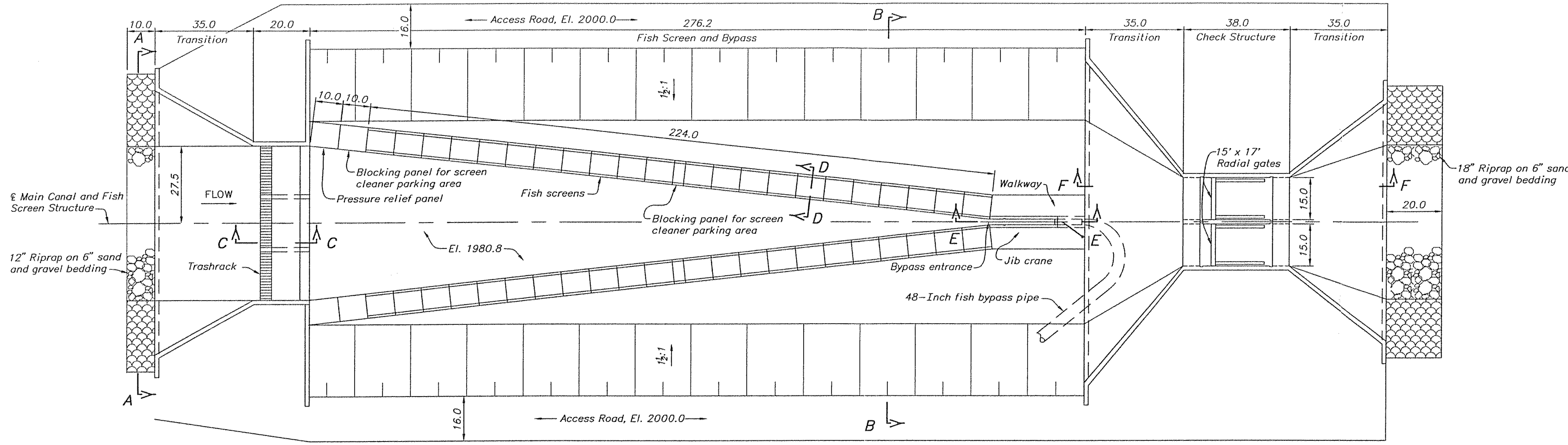

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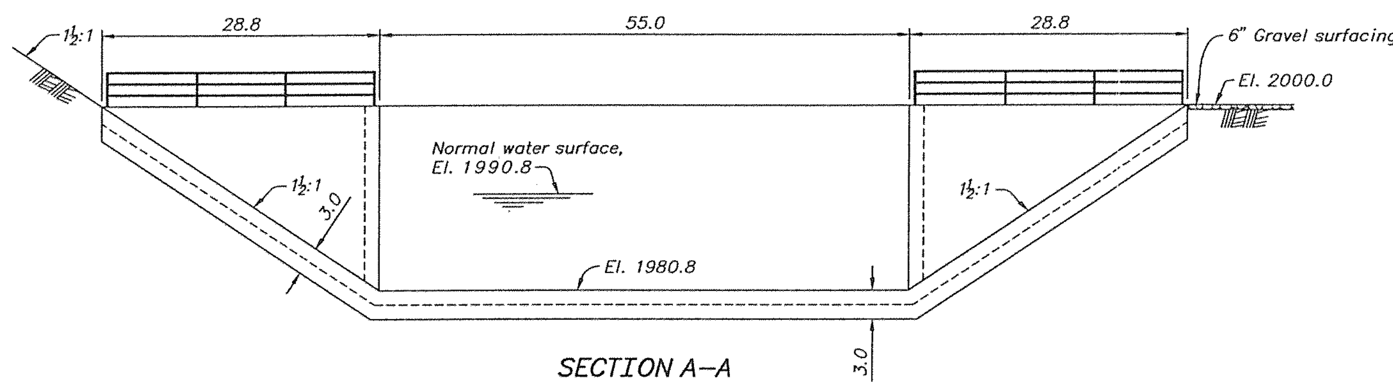

SECTION A–A

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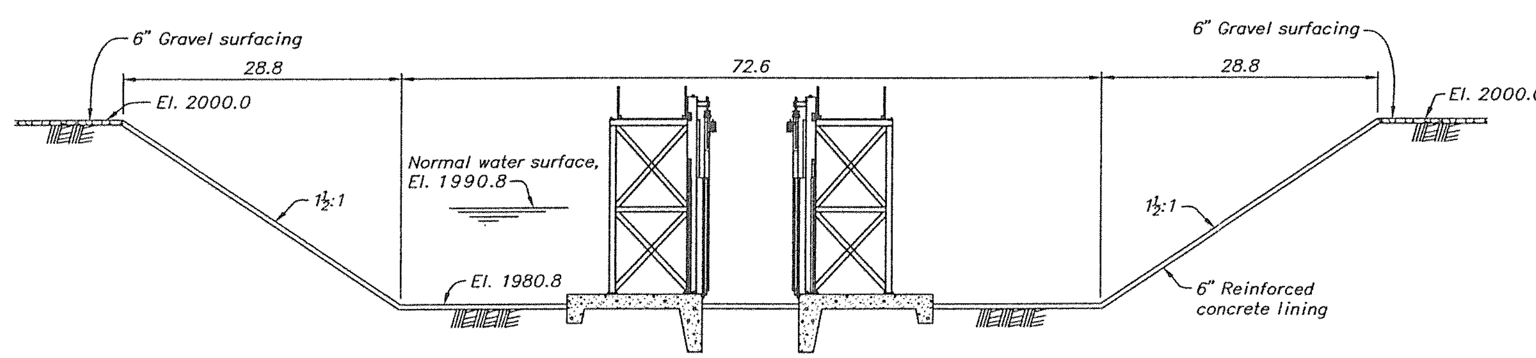

SECTION B–B

10 0 10 20 30
SCALE OF FEET

NOTES

1. Design flow = 1400 cfs.
2. Fish screen length of 224' is based on 0.4 ft/s approach velocity and 9.0' water depth at screen, assumes 10% of fish screen is structural members, and includes 4' for one brush parking area.

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FISH PROTECTION CONCEPT STUDY

FISH SCREEN
FISH SCREEN STRUCTURE
CONCEPT DESIGN

FIGURE 13

CADD SYSTEM	CADD FILENAME
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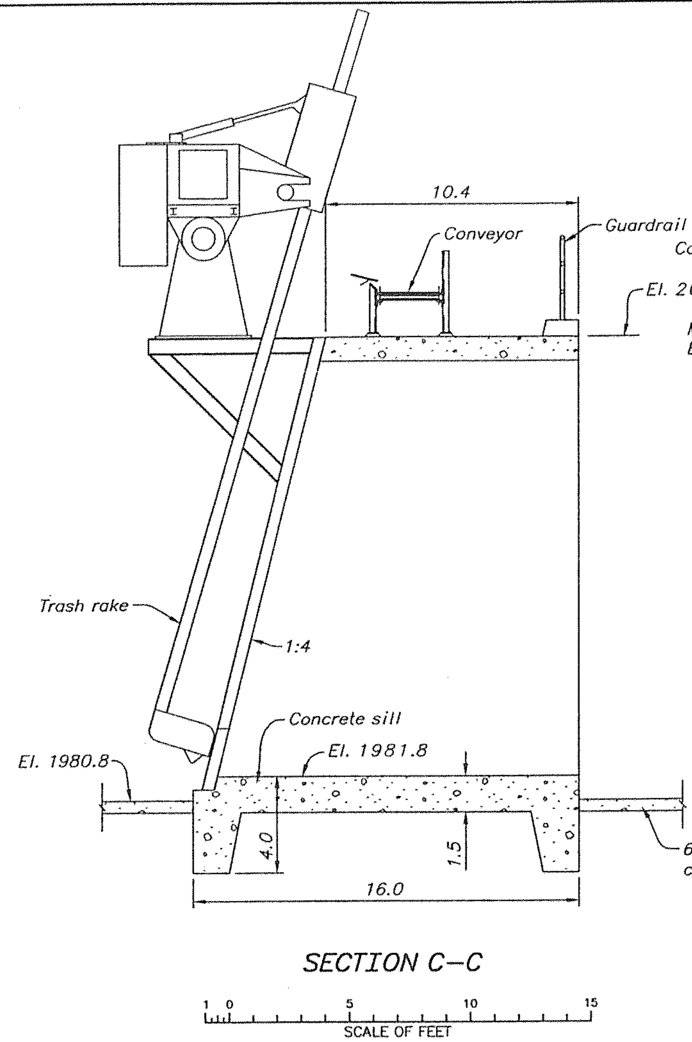
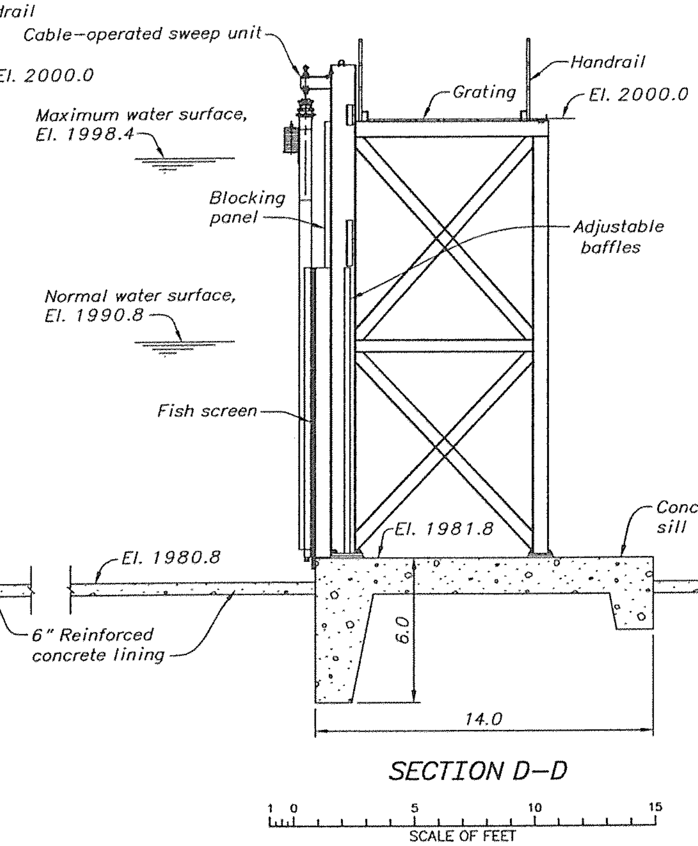


SECTION C–C



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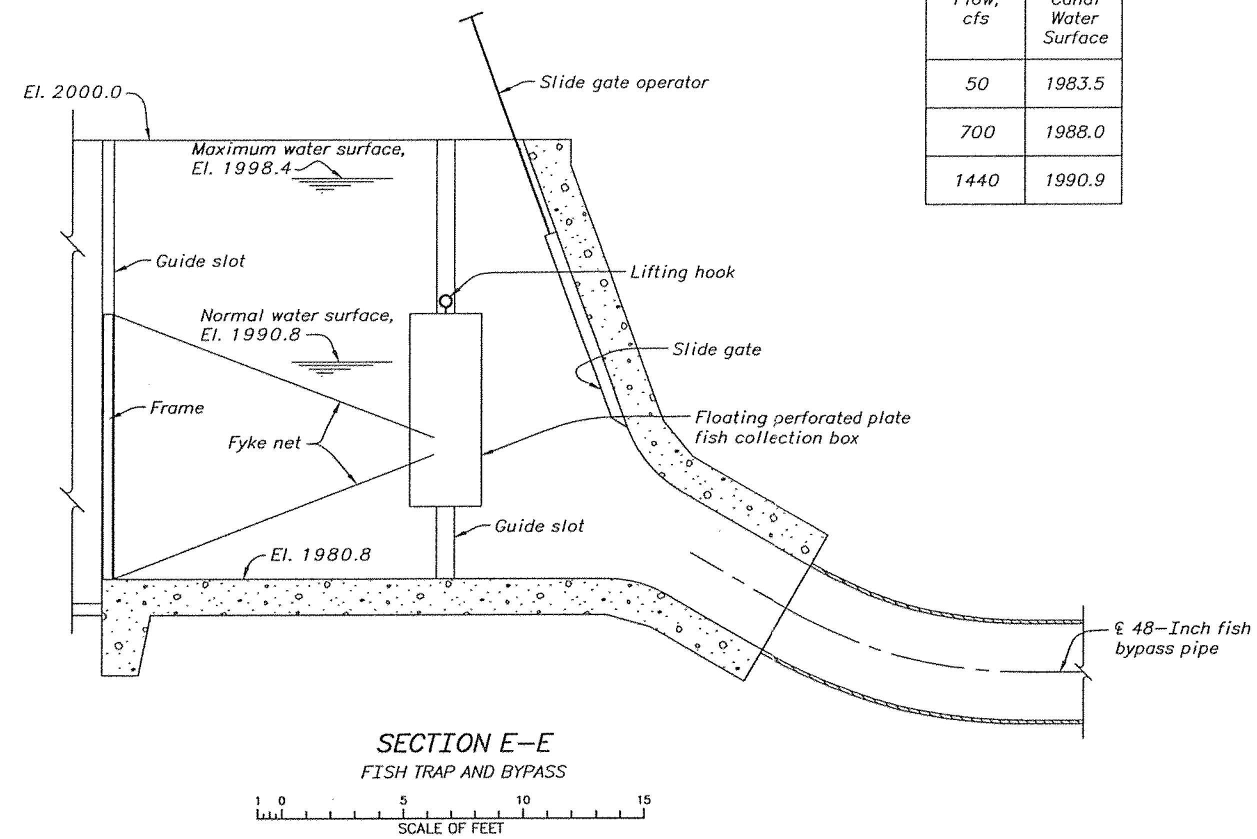
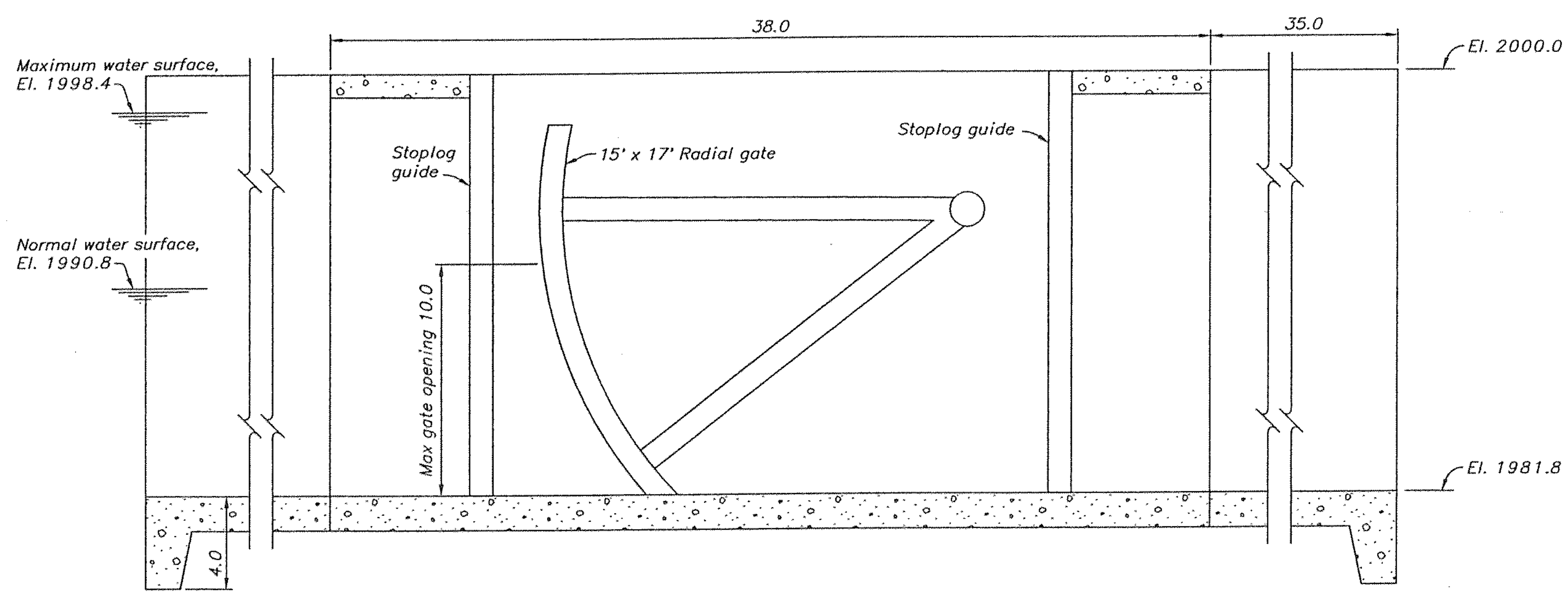


SECTION E–E

FISH TRAP AND BYPASS

Flow, cfs	Canal Water Surface
50	1983.5
700	1988.0
1440	1990.9



SECTION F–F

HYDRAULIC PROPERTIES

Screen Flow, cfs	Approach Velocity, Va, ft/s	Req. Net Area, sf	Req. Gross Area, sf	Depth, ft	Total Length, ft	Bypass flow, cfs	Bypass Pipe V, ft/s	Sweeping Velocity, ft/s	Exposure time, s
700	0.29	2,455 [1]	2,728 [1]	6.2	440	40	3.2	1.9–2.8 [2]	105 [4]
1400	0.4	3,500	3,850	9	440	40	3.2	2.0–2.5 [3]	110 [4]

[1] Screen area exposed to flow
[2] 1.9 ft/s at upstream end and 2.8 ft/s at bypass
[3] 2.5 ft/s at upstream end and 2.0 ft/s at bypass
[4] Used average sweeping velocity

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FISH PROTECTION CONCEPT STUDY

FISH SCREEN
FISH SCREEN STRUCTURE – SECTIONS
CONCEPT DESIGN

FIGURE 14

CADD SYSTEM	CADD FILENAME
AutoCAD Rel. 16.0s	FIGURE 14.DWG

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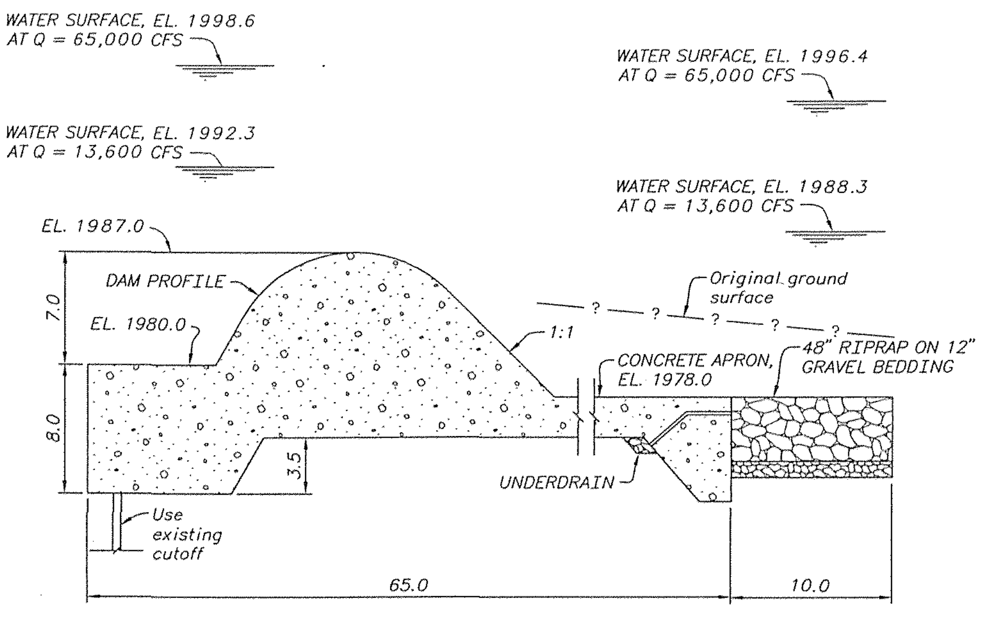
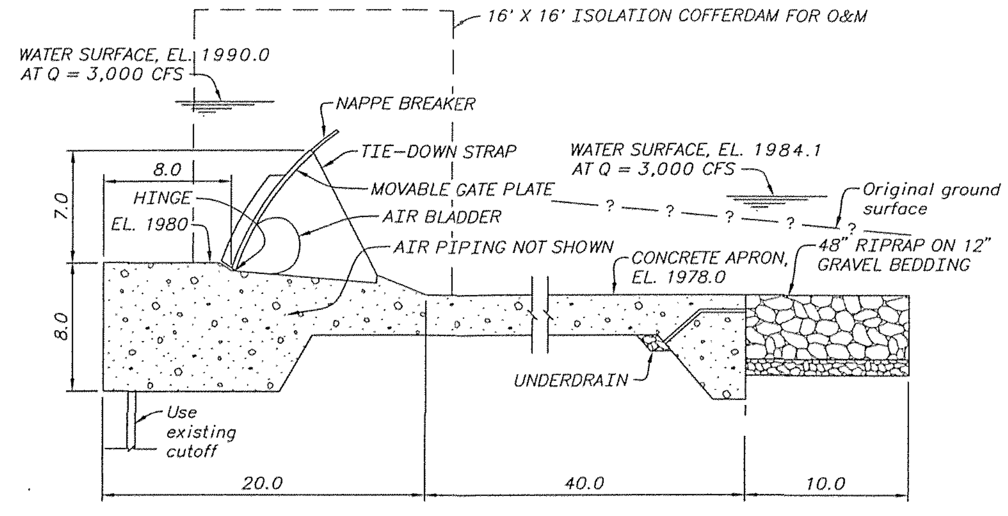
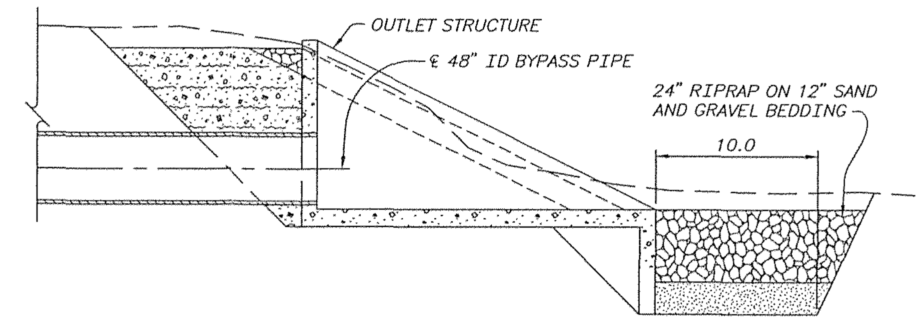


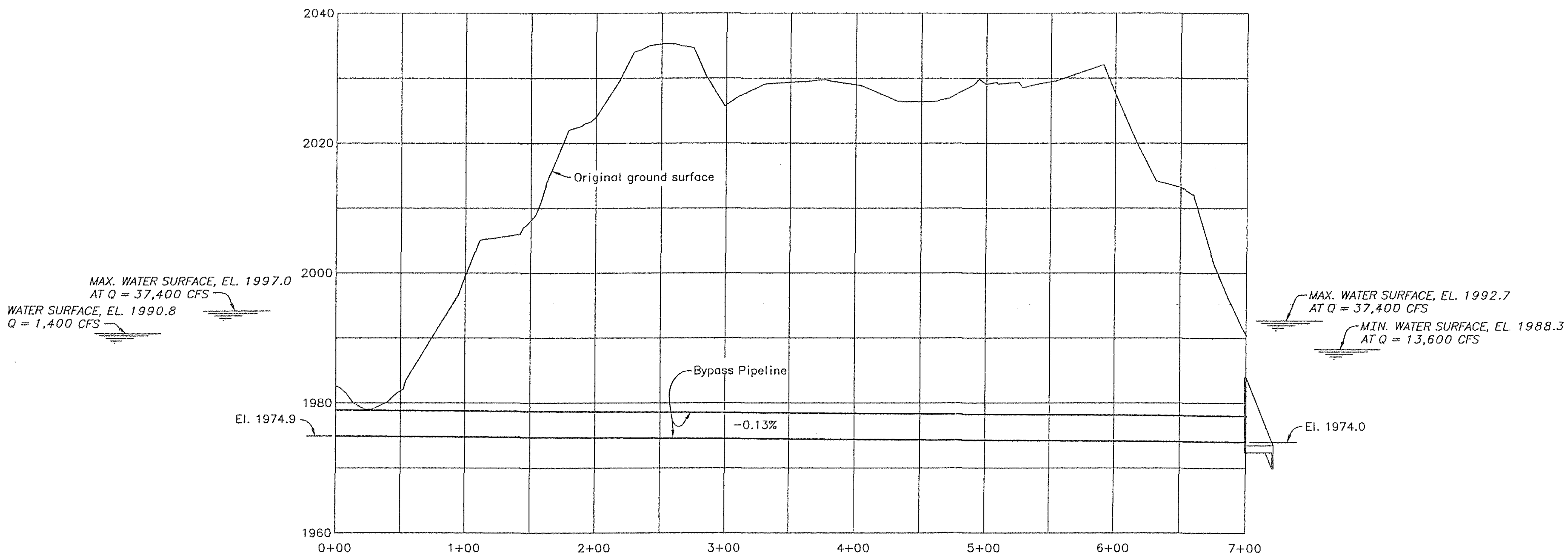
CONCRETE WEIR OPTION



GATED SPILLWAY WEIR



SECTION THRU FISH BYPASS OUTLET STRUCTURE



PROFILE THROUGH BYPASS PIPELINE

NOTES

1. Elevation of fish bypass structure will verified by final survey.
2. Maximum size rock in 48" riprap layer will be approx. 24".

REV NO	DATE	DESCRIPTION
1	2004–05	Add Concrete Weir Option

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FISH PROTECTION CONCEPT STUDY

SPILLWAY WEIR OPTIONS AND FISH BYPASS

CONCEPT DESIGN

FIGURE 15

CADD SYSTEM AutoCAD Rel. 16.0s | CADD FILENAME FIGURE 15.DWG

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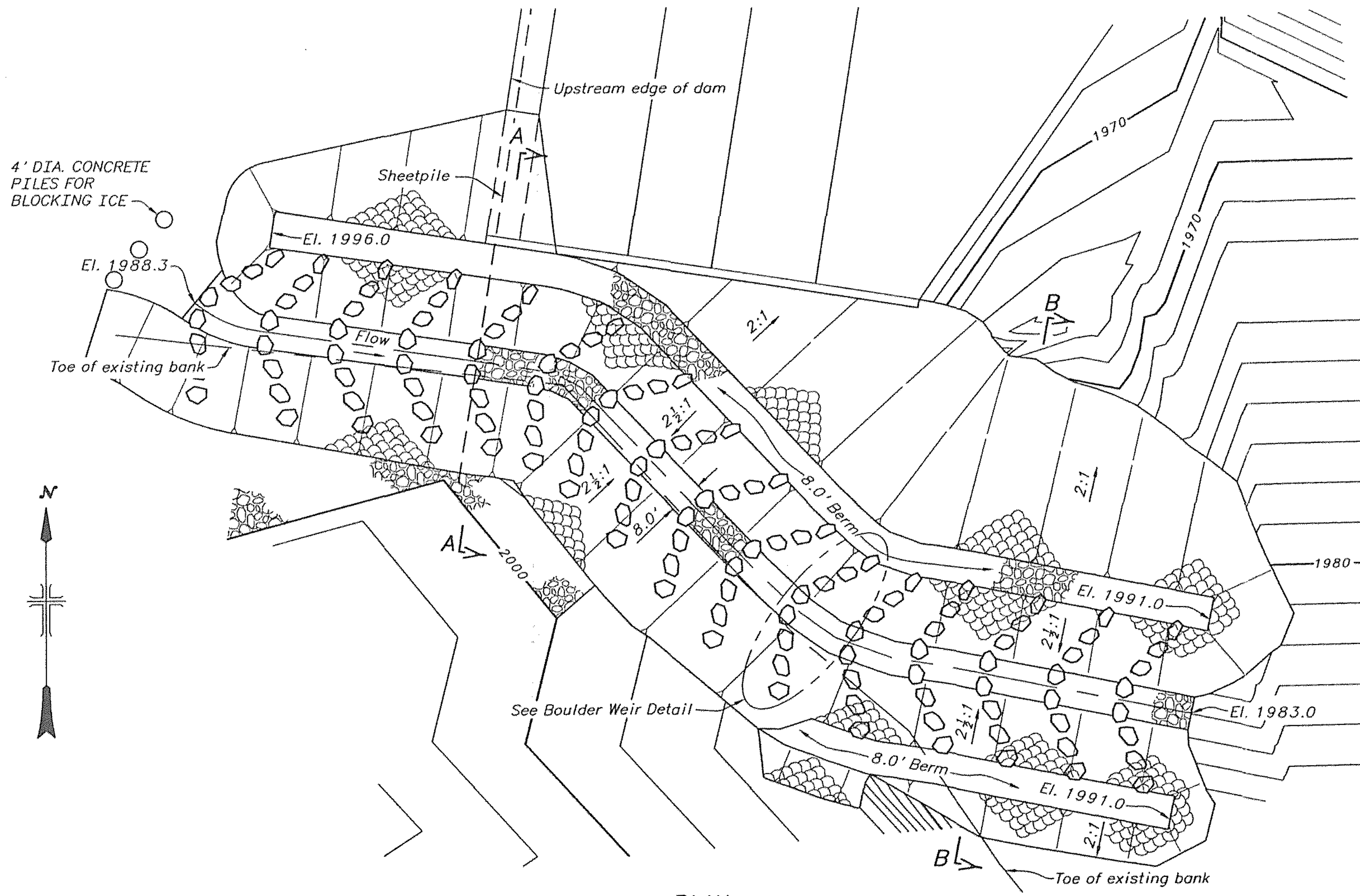

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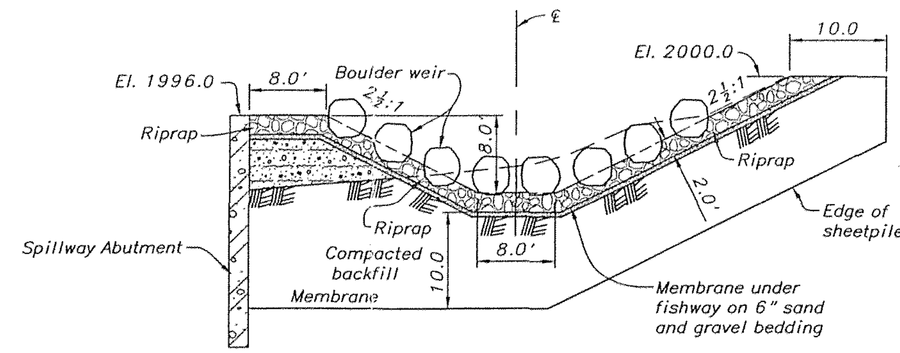
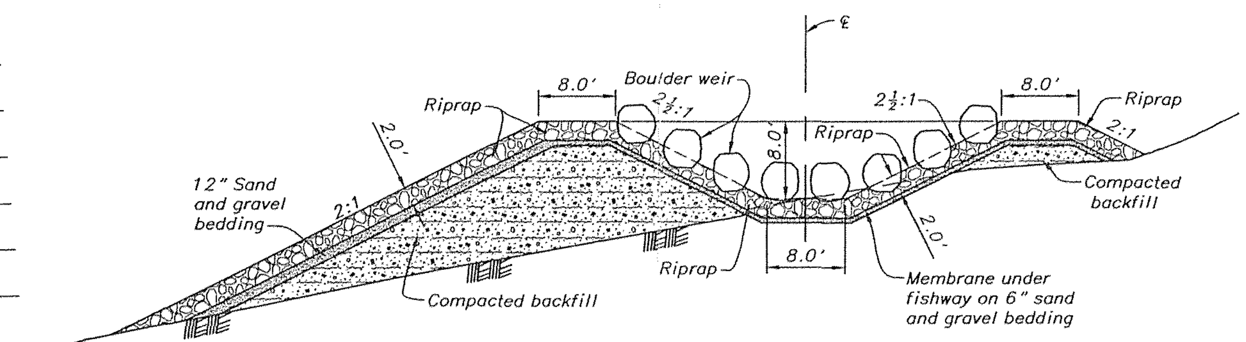
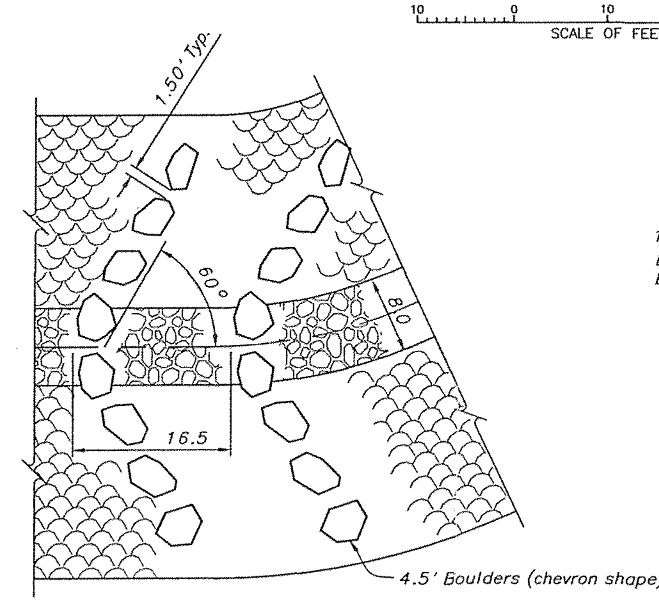


SECTION A—A



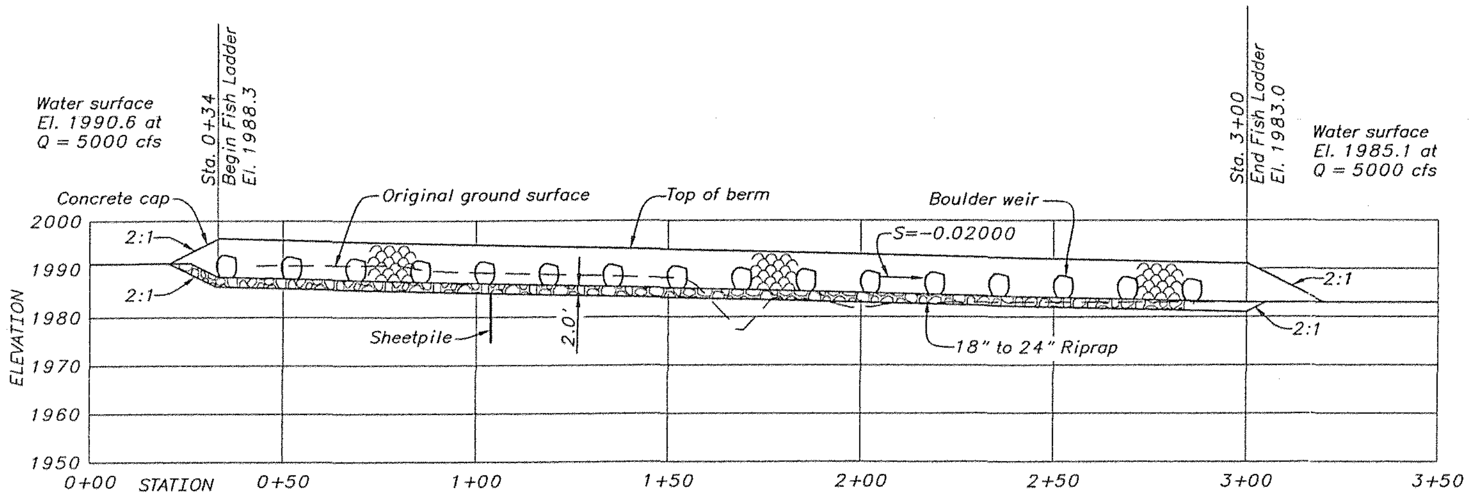
SECTION B—B



BOULDER WEIR DETAIL

NOTES

1. Boulders on invert are placed on surface of riprap. Boulders on side slopes are embedded in riprap up to $\frac{1}{3}$ the boulder size.



PROFILE

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FISH PROTECTION CONCEPT STUDY

FISH PASSAGE
RIPRAP CHANNEL FISHWAY
CONCEPT DESIGN

FIGURE 16

CADD SYSTEM AutoCAD Rel. 16.0s	CADD FILENAME FIGURE 16.DWG

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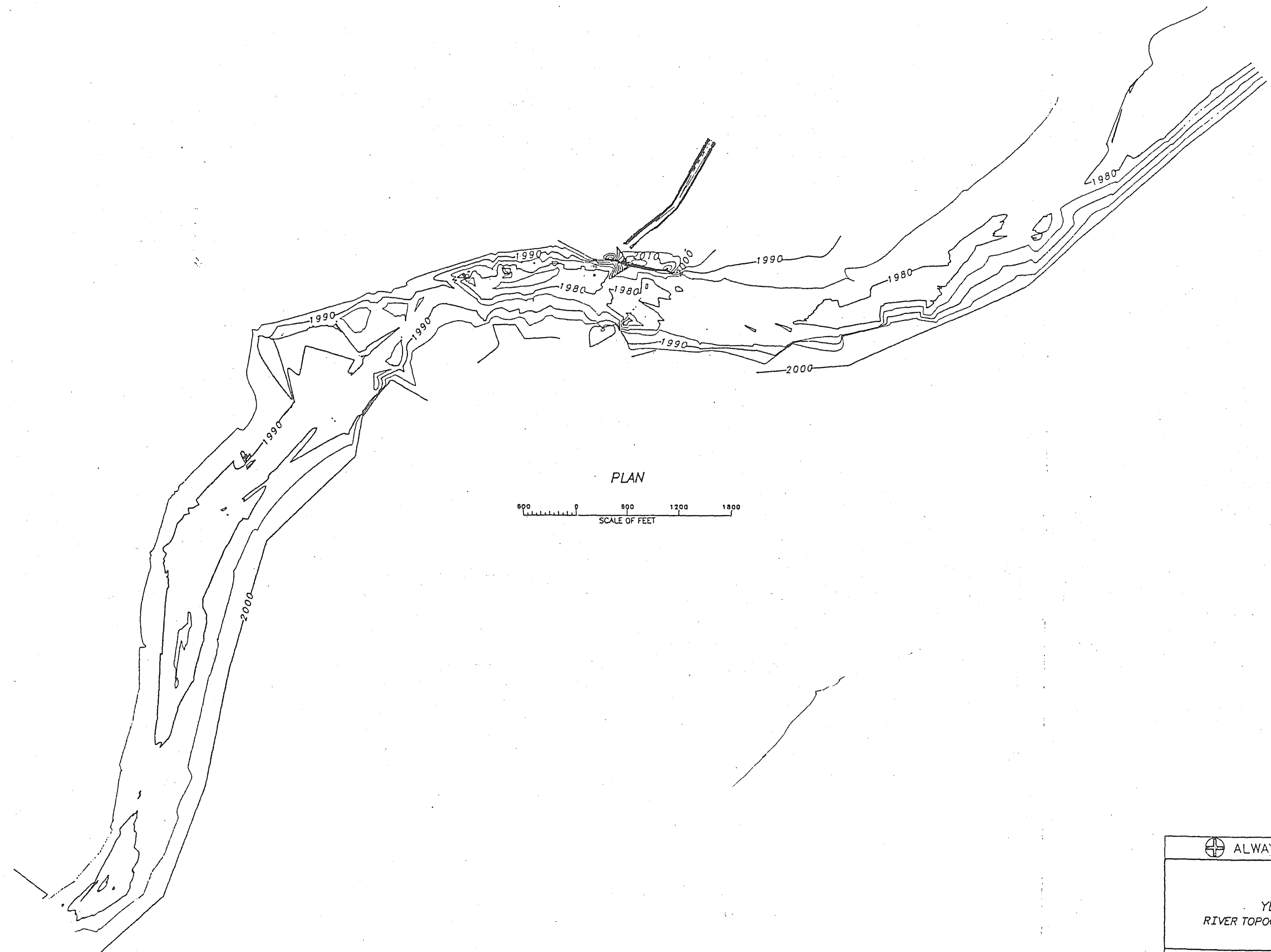
Appendix A
Water Surface Model Data

Table A1. - Flows shown in column four (profile) are for the river at Sidney gage, the high flow channel, and the canal respectively.



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YELLOWSTONE
RIVER TOPOGRAPHY NEAR INTAKE DAM

FIGURE A1

CADD SYSTEM	CADD FILENAME	DATE AND TIME PLOTTED
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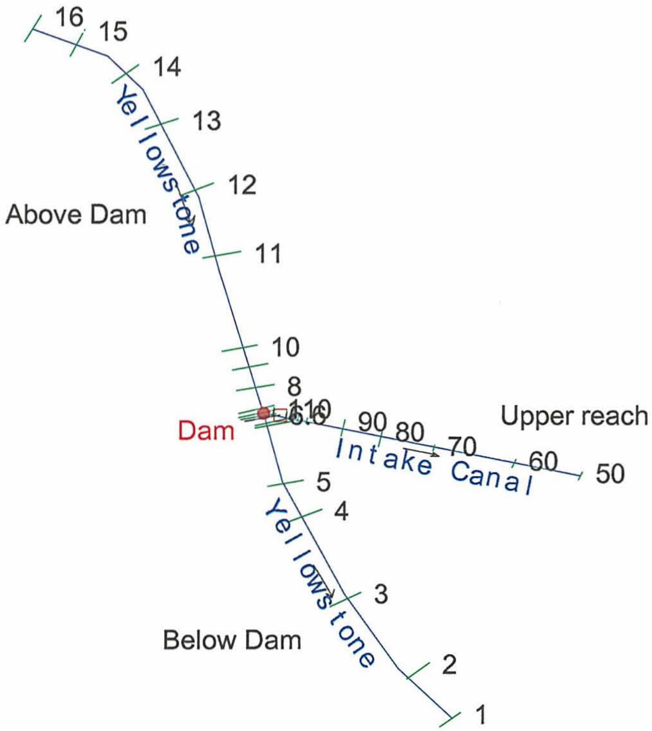


River Reach Station	Distance (ft)
Above Dam 16	906.4
Above Dam 15	1179.8
Above Dam 14	1368.7
Above Dam 13	1700.1
Above Dam 12	190.0
Above Dam 11	2230.5
Above Dam 10	484.9
Above Dam 9	515.7
Above Dam 8	496.9
Above Dam 7	100.0
Above Dam 6.75	70.0
Below Dam 6.6	50.0
Below Dam 6.5	135.0
Below Dam 6.25	93.3
Below Dam 6	1368.0
Below Dam 5	907.7
Below Dam 4	2108.2
Below Dam 3	2243.4
Below Dam 2	1269.0
Below Dam 1	

Figure A2 - Hec-Ras geometry plan showing cross-section locations within the reach of the Yellowstone River modeled

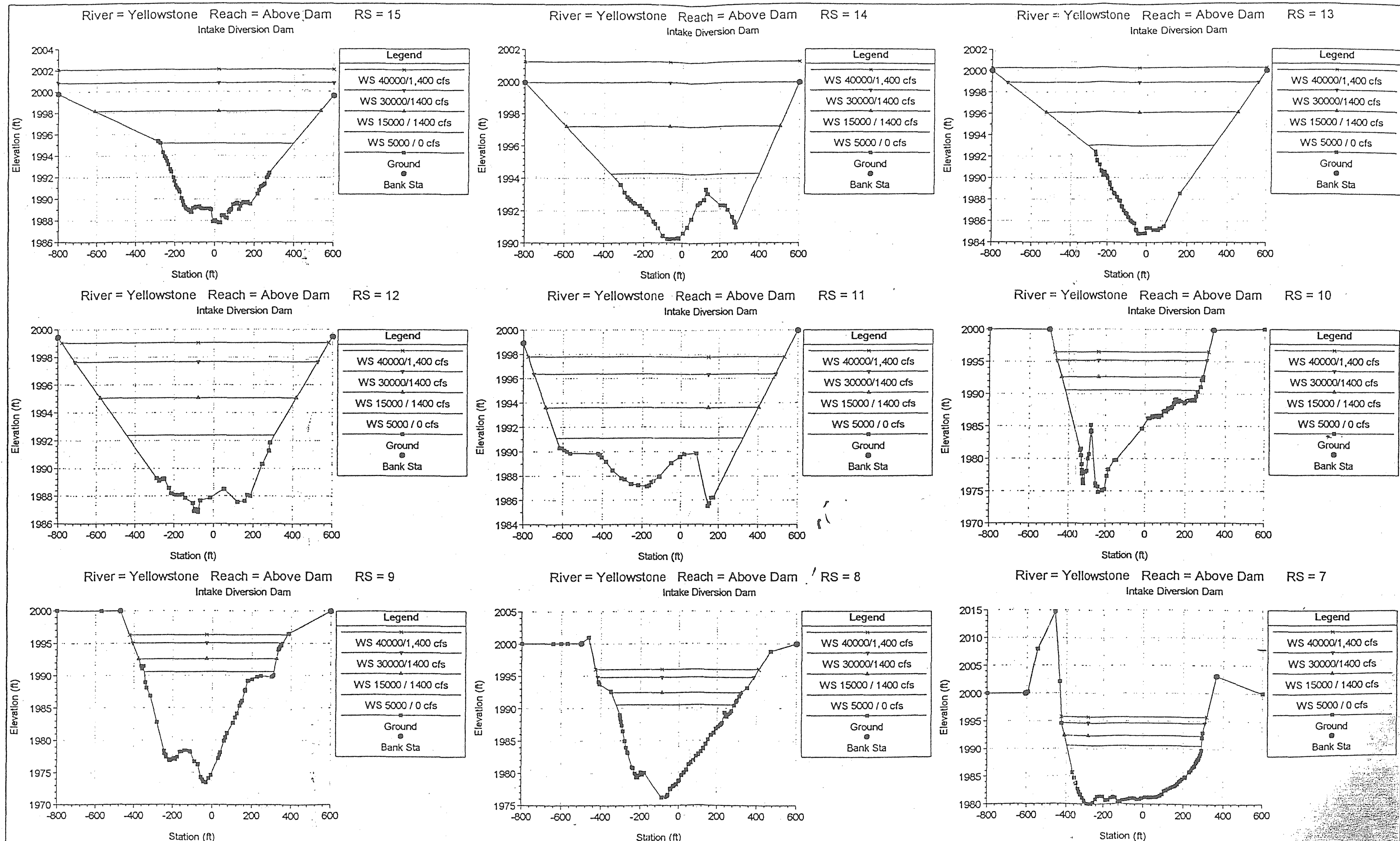


Figure A3 - Hec-Ras model output of Yellowstone River cross-sections upstream of Intake Dam.

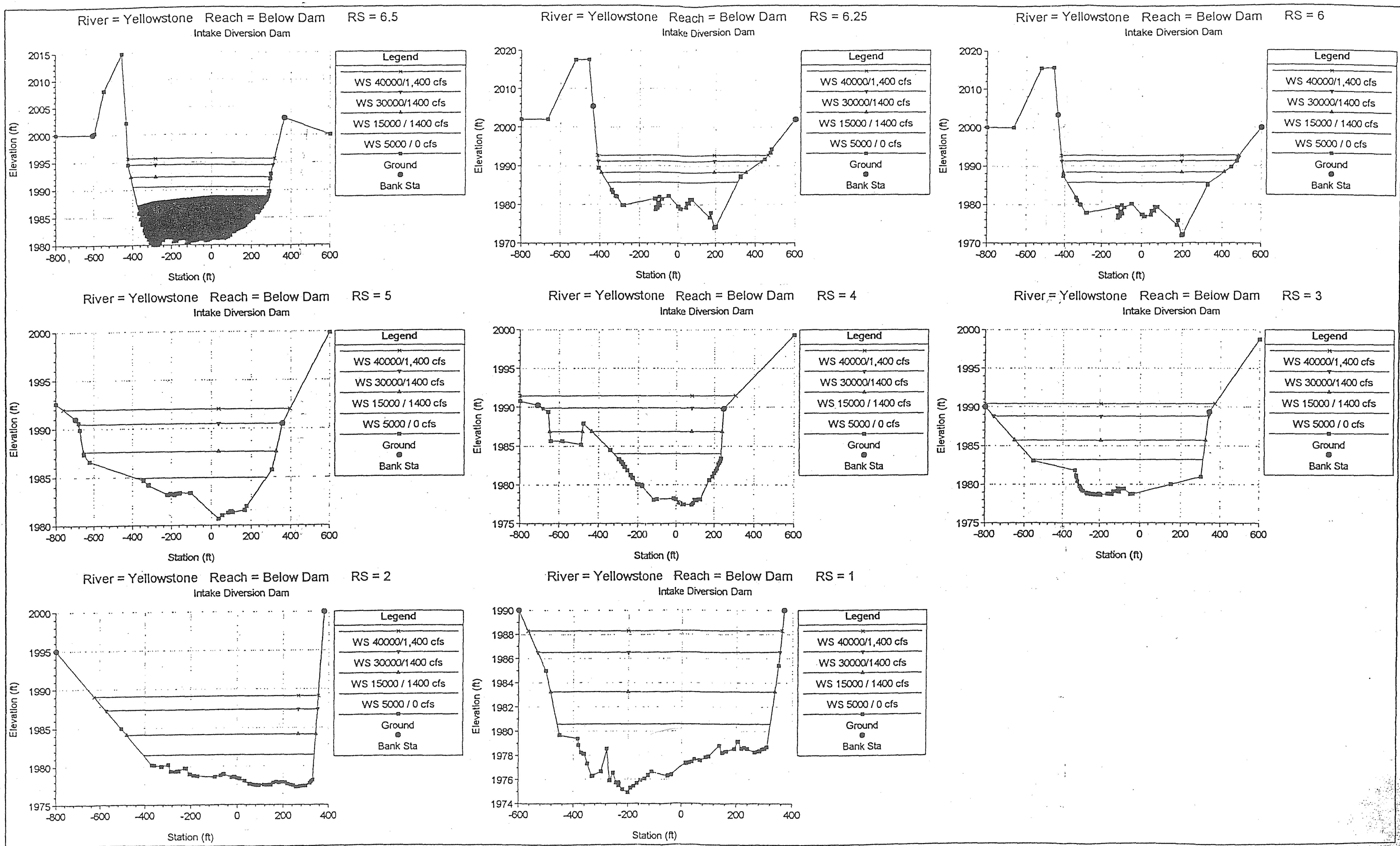


Figure A4 - Hec-Ras model output of Yellowstone River cross-sections downstream of Intake Dam.

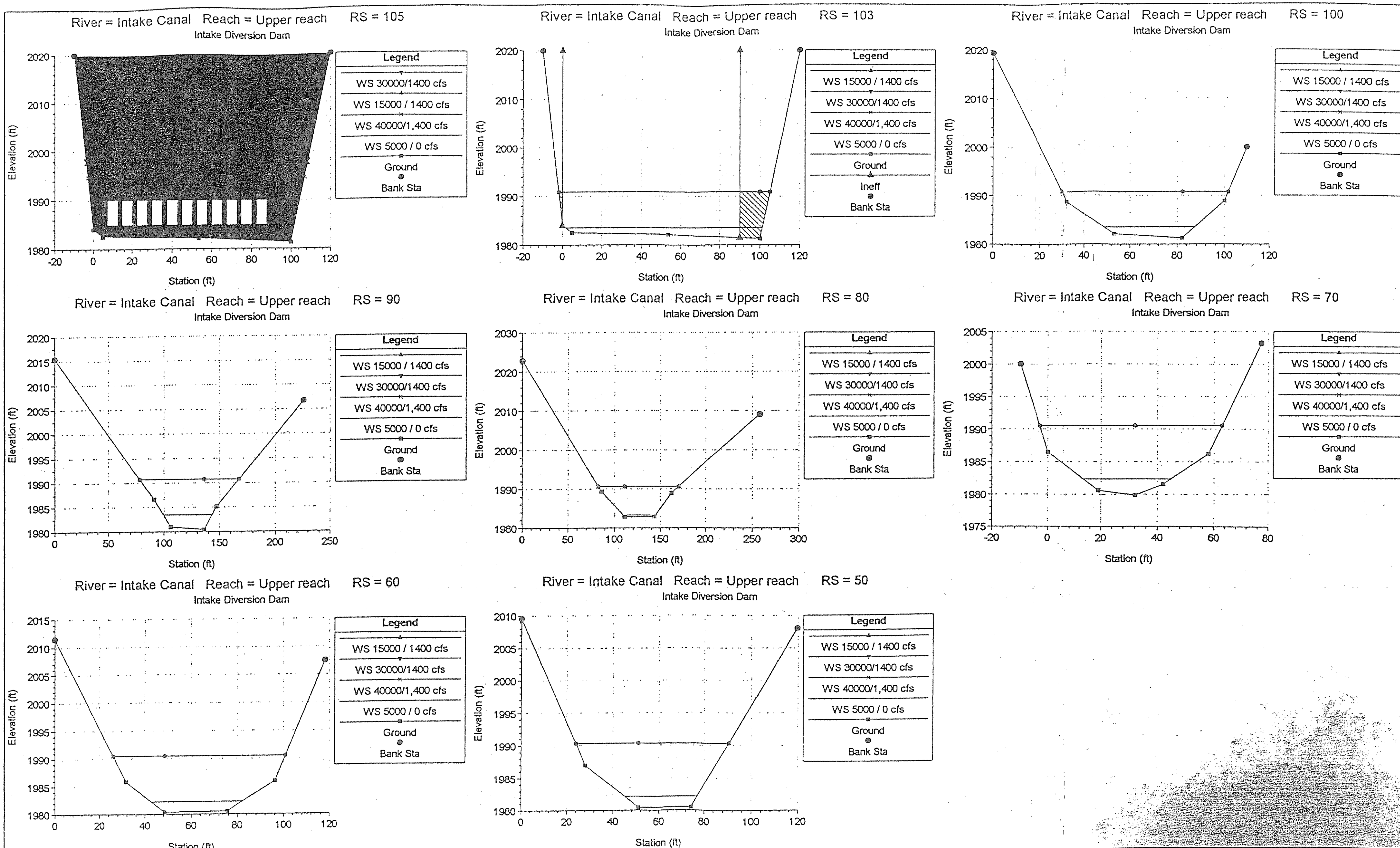


Figure A5 - Hec-Ras model output of Main Canal cross-sections downstream of canal headworks.

Table A1 - HEC-RAS Water Surface Profile Output

River	Reach	River Sta	Profile	Total Flow (ft^3/s)	W.S. Elev (ft)	Vel Chnl (ft/sec)
Yellowstone	Above Dam	16	3000/0/50	3050	1994.28	3.80
Yellowstone	Above Dam	16	5000/0/50	5050	1995.34	4.04
Yellowstone	Above Dam	16	15000/0/1400	16400	1999.14	4.59
Yellowstone	Above Dam	16	30000/500/1400	30900	2001.59	5.19
Yellowstone	Above Dam	16	40000/1500/1400	39900	2002.72	5.47
Yellowstone	Above Dam	16	80000/6500/1400	74900	2006.33	6.29
Yellowstone	Above Dam	15	3000/0/50	3050	1993.89	1.40
Yellowstone	Above Dam	15	5000/0/50	5050	1994.85	1.82
Yellowstone	Above Dam	15	15000/0/1400	16400	1998.42	2.74
Yellowstone	Above Dam	15	30000/500/1400	30900	2000.98	3.28
Yellowstone	Above Dam	15	40000/1500/1400	39900	2002.15	3.60
Yellowstone	Above Dam	15	80000/6500/1400	74900	2005.82	4.62
Yellowstone	Above Dam	14	3000/0/50	3050	1992.45	5.93
Yellowstone	Above Dam	14	5000/0/50	5050	1993.75	3.82
Yellowstone	Above Dam	14	15000/0/1400	16400	1997.40	3.53
Yellowstone	Above Dam	14	30000/500/1400	30900	2000.07	3.85
Yellowstone	Above Dam	14	40000/1500/1400	39900	2001.31	4.09
Yellowstone	Above Dam	14	80000/6500/1400	74900	2005.04	5.00
Yellowstone	Above Dam	13	3000/0/50	3050	1991.90	1.36
Yellowstone	Above Dam	13	5000/0/50	5050	1992.91	1.78
Yellowstone	Above Dam	13	15000/0/1400	16400	1996.37	2.89
Yellowstone	Above Dam	13	30000/500/1400	30900	1999.04	3.53
Yellowstone	Above Dam	13	40000/1500/1400	39900	2000.35	3.79
Yellowstone	Above Dam	13	80000/6500/1400	74900	2004.21	4.70
Yellowstone	Above Dam	12	3000/0/50	3050	1991.42	1.63
Yellowstone	Above Dam	12	5000/0/50	5050	1992.23	2.07
Yellowstone	Above Dam	12	15000/0/1400	16400	1995.22	3.25
Yellowstone	Above Dam	12	30000/500/1400	30900	1997.75	3.91
Yellowstone	Above Dam	12	40000/1500/1400	39900	1999.07	4.14
Yellowstone	Above Dam	12	80000/6500/1400	74900	2003.14	4.89
Yellowstone	Above Dam	11	3000/0/50	3050	1990.15	2.15
Yellowstone	Above Dam	11	5000/0/50	5050	1990.91	2.38
Yellowstone	Above Dam	11	15000/0/1400	16400	1993.93	3.14
Yellowstone	Above Dam	11	30000/500/1400	30900	1996.50	3.75
Yellowstone	Above Dam	11	40000/1500/1400	39900	1997.88	3.99
Yellowstone	Above Dam	11	80000/6500/1400	74900	2002.20	4.69
Yellowstone	Above Dam	10	3000/0/50	3050	1990.00	0.71
Yellowstone	Above Dam	10	5000/0/50	5050	1990.60	1.08
Yellowstone	Above Dam	10	15000/0/1400	16400	1993.08	2.55
Yellowstone	Above Dam	10	30000/500/1400	30900	1995.27	3.82
Yellowstone	Above Dam	10	40000/1500/1400	39900	1996.52	4.41
Yellowstone	Above Dam	10	80000/6500/1400	74900	2000.60	6.03

River	Reach	River Sta	Profile	Total Flow (ft^3/s)	W.S. Elev (ft)	Vel Chnl (ft/sec)
Yellowstone	Above Dam	9	3000/0/50	3050	1989.99	0.57
Yellowstone	Above Dam	9	5000/0/50	5050	1990.59	0.88
Yellowstone	Above Dam	9	15000/0/1400	16400	1993.01	2.21
Yellowstone	Above Dam	9	30000/500/1400	30900	1995.14	3.44
Yellowstone	Above Dam	9	40000/1500/1400	39900	1996.35	4.02
Yellowstone	Above Dam	9	80000/6500/1400	74900	2000.35	5.45
Yellowstone	Above Dam	8	3000/0/50	3050	1989.98	0.65
Yellowstone	Above Dam	8	5000/0/50	5050	1990.57	1.00
Yellowstone	Above Dam	8	15000/0/1400	16400	1992.90	2.49
Yellowstone	Above Dam	8	30000/500/1400	30900	1994.91	3.81
Yellowstone	Above Dam	8	40000/1500/1400	39900	1996.06	4.40
Yellowstone	Above Dam	8	80000/6500/1400	74900	1999.86	5.98
Yellowstone	Above Dam	7	3000/0/50	3050	1989.98	0.59
Yellowstone	Above Dam	7	5000/0/50	5050	1990.55	0.91
Yellowstone	Above Dam	7	15000/0/1400	16400	1992.82	2.30
Yellowstone	Above Dam	7	30000/500/1400	30900	1994.74	3.63
Yellowstone	Above Dam	7	40000/1500/1400	39900	1995.84	4.28
Yellowstone	Above Dam	7	80000/6500/1400	74900	1999.44	6.22
Yellowstone	Above Dam	6.75	3000/0/50	3050	1989.97	0.59
Yellowstone	Above Dam	6.75	5000/0/50	5050	1990.55	0.91
Yellowstone	Above Dam	6.75	15000/0/1400	16400	1992.81	2.31
Yellowstone	Above Dam	6.75	30000/500/1400	30900	1994.70	3.64
Yellowstone	Above Dam	6.75	40000/1500/1400	39900	1995.80	4.29
Yellowstone	Above Dam	6.75	80000/6500/1400	74900	1999.37	6.25
Yellowstone	Above Dam	6.6	3000/0/50	3050	1989.97	0.59
Yellowstone	Above Dam	6.6	5000/0/50	5050	1990.55	0.91
Yellowstone	Above Dam	6.6	15000/0/1400	16400	1992.81	2.31
Yellowstone	Above Dam	6.6	30000/500/1400	29500	1994.71	3.47
Yellowstone	Above Dam	6.6	40000/1500/1400	38500	1995.81	4.14
Yellowstone	Above Dam	6.6	80000/6500/1400	73500	1999.39	6.13
Yellowstone	Above Dam	6.5	Inline Structure - Existing Dam			
Yellowstone	Below Dam	6.25	3000/0/50	3050	1984.08	1.17
Yellowstone	Below Dam	6.25	5000/0/50	5050	1985.08	1.55
Yellowstone	Below Dam	6.25	15000/0/1400	16400	1988.70	2.82
Yellowstone	Below Dam	6.25	30000/500/1400	29500	1991.29	3.73
Yellowstone	Below Dam	6.25	40000/1500/1400	38500	1992.77	4.20
Yellowstone	Below Dam	6.25	80000/6500/1400	73500	1997.39	5.49
Yellowstone	Below Dam	6	3000/0/50	3050	1984.08	0.77
Yellowstone	Below Dam	6	5000/0/50	5050	1985.08	1.08
Yellowstone	Below Dam	6	15000/0/1400	16400	1988.71	2.20
Yellowstone	Below Dam	6	30000/500/1400	29500	1991.32	3.04
Yellowstone	Below Dam	6	40000/1500/1400	38500	1992.79	3.49
Yellowstone	Below Dam	6	80000/6500/1400	73500	1997.44	4.77

River	Reach	River Sta.	Profile	Total Flow (ft^3/s)	W.S. Elev (ft)	Vel Chnl (ft/sec)
Yellowstone	Below Dam	5	3000/0/50	3050	1983.28	6.18
Yellowstone	Below Dam	5	5000/0/50	5050	1984.55	4.35
Yellowstone	Below Dam	5	15000/0/1400	16400	1988.09	3.92
Yellowstone	Below Dam	5	30000/500/1400	29500	1990.62	4.37
Yellowstone	Below Dam	5	40000/1500/1400	38500	1992.09	4.63
Yellowstone	Below Dam	5	80000/6500/1400	73500	1996.77	5.39
Yellowstone	Below Dam	4	3000/0/50	3050	1982.92	1.62
Yellowstone	Below Dam	4	5000/0/50	5050	1983.98	2.06
Yellowstone	Below Dam	4	15000/0/1400	16400	1987.35	3.38
Yellowstone	Below Dam	4	30000/500/1400	29500	1989.99	4.08
Yellowstone	Below Dam	4	40000/1500/1400	38500	1991.52	4.42
Yellowstone	Below Dam	4	80000/6500/1400	73500	1996.31	5.34
Yellowstone	Below Dam	3	3000/0/50	3050	1982.15	1.80
Yellowstone	Below Dam	3	5000/0/50	5050	1983.05	2.10
Yellowstone	Below Dam	3	15000/0/1400	16400	1986.05	3.17
Yellowstone	Below Dam	3	30000/500/1400	29500	1988.85	3.64
Yellowstone	Below Dam	3	40000/1500/1400	38500	1990.48	3.87
Yellowstone	Below Dam	3	80000/6500/1400	73500	1995.51	4.64
Yellowstone	Below Dam	2	3000/0/50	3050	1980.64	2.00
Yellowstone	Below Dam	2	5000/0/50	5050	1981.47	2.37
Yellowstone	Below Dam	2	15000/0/1400	16400	1984.44	3.66
Yellowstone	Below Dam	2	30000/500/1400	29500	1987.54	4.09
Yellowstone	Below Dam	2	40000/1500/1400	38500	1989.27	4.34
Yellowstone	Below Dam	2	80000/6500/1400	73500	1994.48	5.09
Yellowstone	Below Dam	1	3000/0/50	3000	1979.78	1.68
Yellowstone	Below Dam	1	5000/0/50	5000	1980.63	2.05
Yellowstone	Below Dam	1	15000/0/1400	15000	1983.60	3.11
Yellowstone	Below Dam	1	30000/500/1400	30000	1986.79	3.97
Yellowstone	Below Dam	1	40000/1500/1400	40000	1988.53	4.38
Yellowstone	Below Dam	1	80000/6500/1400	80000	1993.68	5.67
Intake Canal	Upper reach	110	3000/0/50	50	1990.00	0.06
Intake Canal	Upper reach	110	5000/0/50	50	1990.57	0.06
Intake Canal	Upper reach	110	15000/0/1400	1400	1992.86	1.25
Intake Canal	Upper reach	110	30000/500/1400	1400	1994.89	1.04
Intake Canal	Upper reach	110	40000/1500/1400	1400	1996.08	0.95
Intake Canal	Upper reach	110	80000/6500/1400	1400	1999.96	0.73
Intake Canal	Upper reach	107	3000/0/50	50	1990.00	0.06
Intake Canal	Upper reach	107	5000/0/50	50	1990.57	0.06
Intake Canal	Upper reach	107	15000/0/1400	1400	1992.86	1.25
Intake Canal	Upper reach	107	30000/500/1400	1400	1994.89	1.04
Intake Canal	Upper reach	107	40000/1500/1400	1400	1996.08	0.95
Intake Canal	Upper reach	107	80000/6500/1400	1400	1999.96	0.73
Intake Canal	Upper reach	105	Inline Structure - Canal Headworks			

River	Reach	River Sta	Profile	Total Flow (ft^3/s)	W.S. Elev (ft)	Vel Chnl (ft/sec)
Intake Canal	Upper reach	103	3000/0/50	50	1983.53	0.41
Intake Canal	Upper reach	103	5000/0/50	50	1983.53	0.41
Intake Canal	Upper reach	103	15000/0/1400	1400	1990.87	1.79
Intake Canal	Upper reach	103	30000/500/1400	1400	1990.87	1.79
Intake Canal	Upper reach	103	40000/1500/1400	1400	1990.88	1.79
Intake Canal	Upper reach	103	80000/6500/1400	1400	1990.87	1.79
Intake Canal	Upper reach	100	3000/0/50	50	1983.52	0.82
Intake Canal	Upper reach	100	5000/0/50	50	1983.52	0.82
Intake Canal	Upper reach	100	15000/0/1400	1400	1990.78	2.91
Intake Canal	Upper reach	100	30000/500/1400	1400	1990.78	2.91
Intake Canal	Upper reach	100	40000/1500/1400	1400	1990.78	2.91
Intake Canal	Upper reach	100	80000/6500/1400	1400	1990.78	2.91
Intake Canal	Upper reach	90	3000/0/50	50	1983.51	0.48
Intake Canal	Upper reach	90	5000/0/50	50	1983.51	0.48
Intake Canal	Upper reach	90	15000/0/1400	1400	1990.75	2.43
Intake Canal	Upper reach	90	30000/500/1400	1400	1990.75	2.43
Intake Canal	Upper reach	90	40000/1500/1400	1400	1990.75	2.43
Intake Canal	Upper reach	90	80000/6500/1400	1400	1990.75	2.43
Intake Canal	Upper reach	80	3000/0/50	50	1983.27	3.58
Intake Canal	Upper reach	80	5000/0/50	50	1983.27	3.58
Intake Canal	Upper reach	80	15000/0/1400	1400	1990.63	3.03
Intake Canal	Upper reach	80	30000/500/1400	1400	1990.63	3.03
Intake Canal	Upper reach	80	40000/1500/1400	1400	1990.64	3.03
Intake Canal	Upper reach	80	80000/6500/1400	1400	1990.63	3.03
Intake Canal	Upper reach	70	3000/0/50	50	1982.33	1.01
Intake Canal	Upper reach	70	5000/0/50	50	1982.33	1.01
Intake Canal	Upper reach	70	15000/0/1400	1400	1990.54	2.87
Intake Canal	Upper reach	70	30000/500/1400	1400	1990.54	2.87
Intake Canal	Upper reach	70	40000/1500/1400	1400	1990.55	2.86
Intake Canal	Upper reach	70	80000/6500/1400	1400	1990.54	2.87
Intake Canal	Upper reach	60	3000/0/50	50	1982.24	0.84
Intake Canal	Upper reach	60	5000/0/50	50	1982.24	0.84
Intake Canal	Upper reach	60	15000/0/1400	1400	1990.47	2.47
Intake Canal	Upper reach	60	30000/500/1400	1400	1990.47	2.47
Intake Canal	Upper reach	60	40000/1500/1400	1400	1990.47	2.47
Intake Canal	Upper reach	60	80000/6500/1400	1400	1990.47	2.47
Intake Canal	Upper reach	50	3000/0/50	50	1982.15	1.08
Intake Canal	Upper reach	50	5000/0/50	50	1982.15	1.08
Intake Canal	Upper reach	50	15000/0/1400	1400	1990.33	3.00
Intake Canal	Upper reach	50	30000/500/1400	1400	1990.33	3.00
Intake Canal	Upper reach	50	40000/1500/1400	1400	1990.33	3.00
Intake Canal	Upper reach	50	80000/6500/1400	1400	1990.33	3.00

Appendix B
Construction Cost Estimate Worksheets

CODE: D-8140

ESTIMATE WORKSHEET

SHEET 1 of 1

FEATURE:	PROJECT
INTAKE DIVERSION DAM FISH PASSAGE filename: C:\Artichoker\cost curves\[Steel Pipe.xls]Sheet1	LOWER YELLOWSTONE
	PRICE LEVEL: Feasibility — WOID: 6B552
	UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	10% incr						
	+35	**Fish passage**					
	+35	Excavation		790	CY	$12.00	12,800 $9,480
		Compacted backfill		3,400	CY	$17.00	$57,800
	x20	Riprap (2-mile haul, drill, blast, process, place)		1,800	CY	$30.00	64,800 $54,000
	+25	Boulders		160	CY	$65.00	13000 $10,400
	+20	Riprap bedding		380	CY	$45.00	20,520 $17,100
	+20	Geotextile		3,000	SY	$3.50	12,600 $10,500
		Concrete abut wall (ass.50 x 15 x 2)		60	CY	$500.00	$30,000
		Sheet Pile (sat 70 ft long x 10 ft deep)		15	ton	$2,000.00	$30,000
		Reinforcing Steel		6,000	lb	$1.00	$6,000
		Cofferdam					
		Embankment (place and remove)		4,500	CY	$23.00	$103,500
		Riprap (2-mile haul, drill, blast, process, place, remove)		400	CY	$40.00	$16,000
		40-mil pvc membrane		1000	SY	$9.00	$9,000
		Dewatering using sump pumps (2 months)		2	mo	$13,000.00	$26,000
		Upstream Piles					
		Alt #1 (good for 1.5 ft thick ice)					
		Upstream H-piles (HP14X117) 7-30 FT length, drive 20 ft					
		(not used in the total cost, roughly $40,000 LS)					
		Alt #2 (Use this alt. for the estimate. Good for 3' ice)					
		Concrete pier (48-inch dia.)					
	+30%	Concrete *(includes augering hole, 50" steel casing)*		42	CY	$950.00	51,870 $39,900
		Reinforcing Steel		42,000	lb	$1.00	54,600 $42,000
							508490
							25425
		Mobilization		(+/-)	5%		$23,000
		Subtotal					~~$484,680~~ 533915
		Unlisted Items		(+/-)	10%		~~$45,320~~ 53391
		Contract Cost					~~$530,000~~ 587300
		Contingencies		(+/-)	20%		~~$110,000~~ 117,000
		Field Cost					~~$640,000~~ ~~704,751~~ 705,000

QUANTITIES		PRICES	
BY: a. glickman	APPROVED	BY: T. Artichoker	CHECKED
DATE PREPARED: nov. 21, 2003	DATE	DATE: 3/16/2004	PEER REVIEWER: D. Donaldson — DD 3/16/04

CODE: D-8140

ESTIMATE WORKSHEET

FEATURE: INTAKE DIVERSION DAM FISH SCREEN STRUCTURE FACILITY	PROJECT: LOWER YELLOWSTONE RIVER
filename: C:\Artichoker\cost curves\[Steel Pipe.xls]Sheet1	PRICE LEVEL: Feasibility — WOID: 6B552
	UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Civil Work					
		Structural concrete		2,000	CY	$500.00	$1,000,000
		Reinforced concrete lining		780	CY	$500.00	$390,000
		Reinforcement		330,000	lb	$1.00	$330,000
		Miscellaneous metal (handrail)		5,400	lb	$5.50	$29,700
		Earthwork (15% of above)		1	LS	$262,000.00	$262,000
		Riprap (2-mile haul, drill, blast, process, place)		250	CY	$30.00	$7,500
		Sand and gravel bedding for riprap		120	CY	$50.00	$6,000
		48-inch bypass pipeline (HDPE)		650	LF	$125.00	$81,250
		60-inch steel casing pipe - jacked		550	LF	$550.00	$302,500
		Grout between casing and carrier pipe		52	CY	$740.00	$38,480
		4" Gravel road surfacing.		330	CY	$35.00	$11,550
		Mechanical Work					
		15'x17' Radial gates		2	ea	$125,000	$250,000
		Fish Screen Structure		1	LS	$3,000,000	$3,000,000
		Air Cleaning System		1	LS	$115,000	$115,000
		Mobilization			(+/-)	5%	$290,000
		Subtotal					**$6,113,980**
		Unlisted Items			(+/-)	10%	$586,020
		Contract Cost					**$6,700,000**
		Contingencies			(+/-)	20%	$1,400,000
		Field Cost					**$8,100,000**

QUANTITIES		PRICES	
BY: a. glickman	APPROVED	BY: T. Artichoker	CHECKED: [signature]
DATE PREPARED: nov. 21, 2003	DATE	DATE: 3/16/2004	PEER REVIEWER: D. Donaldson — DCD 3/16/04

CODE:D-8170

ESTIMATE WORKSHEET

SHEET 1 OF 2

FEATURE: 19-Mar-04

"Vee" CONF. FISH SCREEN STRUCTURE
Deck raised to El. 2000
MECHANICAL
Option with 1.0 ft sill height

PROJECT:
INTAKE PROJECT

DIVISION:

FILE:
C:\ARTICHOKER\APPRAISAL-FEASIBILITY ESTIMATES\YELLOWSTONE INTAKE DIVER

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Fish screens, 10'W x 10' H, 44 + 4 spares, steel	D8410	48,000	lbs SS	$13.00	$624,000
		& stainless steel (approx. 2000 lbs/panel)		48,000	lbs steel	$5.00	$240,000
	2	Adj. perforated plate baffles, 10'W x 10'H, 44 panels	D8410	88,000	lbs steel	$4.00	$352,000
		steel, (approx. 2000 lbs/panel)					
	3	Two screen cleaners (sweeps), cable-operated drive	D8410	280	lbs SS	$25.00	$7,000
		systems, sheaves, 2 brush arm units/side, travel rails		16,400	lbs steel	$4.50	$73,800
		Two systems: each with 2 hp motor and reducer		600	lbs	$12.00	$7,200
	4	Screen support structure, bracing, blocking panels	D8410	150,000	lbs steel	$4.00	$600,000
	5	Steel transition to bypass	D8420	8,000	lbs steel	$5.00	$40,000
		2'W x 6'H to 48" dia. pipe					
	6	Isolation, 2' W x 6' H steel slide gate at bypass	D8420	1,500	lbs	$5.00	$7,500
	7	Water level measuring equipment	D8410	4	LS	$11,000.00	$44,000
	8	Stoplog guides at bypass entrance	D8410	600	lbs steel	$6.00	$3,600
	9	a. Engine-generator set (100 kW)	D8410	1	LS	$70,000.00	$70,000
		b. Diesel, 250-gallon fuel tank (convault type)		8,000	lbs	$4.00	$32,000
	10	Trashracks, steel	D8410	30,000	lbs steel	$5.00	$150,000
	11	Hydraulic trash rake, rail and supports	D8410	1	LS	$120,000.00	$120,000
		single boom, 18' lift, 60 feet travel length (6,000 lbs)					
	12	Conveyor or transporter, 65 foot length	D8410	6,500	lbs	$4.50	$29,250
	13	Safety walkway - 3' wide, galv. steel	D8140	14,000	lbs steel	$5.50	$77,000
	14	Aluminum guardrails as manufactured by	D8140	1,100	lin-ft	$75.00	$82,500
		Hollaender Manufacturing Co.					

QUANTITIES		PRICES	
BY R. Christensen	CHECKED	BY T. Artichoker	CHECKED
DATE PREPARED 11/20/03 and 2/24/04	APPROVED	DATE 03/19/2004	PRICE LEVEL

CODE:D-8170

ESTIMATE WORKSHEET

FEATURE: 19-Mar-04

"Vee" CONF. FISH SCREEN STRUCTURE
Deck raised to El. 2000
MECHANICAL - continued
Option with 1.0 ft sill height

PROJECT: INTAKE PROJECT

DIVISION:

FILE: C:\ARTICHOKER\APPRAISAL-FEASIBILITY ESTIMATES\YELLOWSTONE INTAKE DIVERSION\VEEOPT

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	15	Pressure relief panels, 10'W x 18'H, 2 panels	D8410	10,800	lbs steel	$4.00	$43,200
		steel (approx. 5400 lbs/panel)					
		Two hoist and sheave systems (1500 lbs/system)		3,000	lbs	$12.00	$36,000
	16	Barrier panels, 10' W x 8' H, 44 panels		88,000	lbs	$4.00	$352,000
		steel (approx. 2000 lbs/panel)					
				SUBTOTAL			$2,991,050

QUANTITIES		PRICES	
BY R. Christensen	CHECKED	BY T. Artichoker	CHECKED
DATE PREPARED 12/3/03 and 2/24/04	APPROVED	DATE 03/19/2004	PRICE LEVEL

CODE: D-8140

ESTIMATE WORKSHEET

SHEET 1 of 1

FEATURE:

INTAKE DIVERSION DAM
SPILLWAY - OBERMEYER TYPE GATE

filename: C:\Artichoker\Appraisal-Feasibility Estimates\Yellowstone Intake Diversion\[Revised Fish Passage Intake diversion.xls]spillway-oberm

PROJECT: LOWER YELLOWSTONE

PRICE LEVEL: Feasibility

WOID: 6B552

UNIT:

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Remove existing weir		23,000	CY	$6.00	$138,000
		Gravel/earth cofferdam					
		Cofferdam (place and remove material)		20,000	CY	$38.00	$760,000
		Riprap (2-mile haul, drill, blast, process, place, remove)		1,000	CY	$60.00	$60,000
		40-mil PVC		2,000	SY	$18.00	$36,000
		(All items above are assumed to be used twice.					
		Cofferdam will be constructed 1/2 river at a time)					
		Dewatering: 35 well points@15 ft depth (4 months)		1	LS	$250,000.00	$250,000
		Obermeyer type weir					
		Concrete		6,850	CY	$390.00	$2,671,500
		Reinforcement		410,000	lb	$1.10	$451,000
		Riprap (2-mile haul, drill, blast, process, place)		1,100	CY	$30.00	$33,000
		Bedding for riprap		260	CY	$45.00	$11,700
		Remove rock from river channel		15,000	CY	$10.00	$150,000
		Standard Obermeyer design for 7-foot high		700	LF	$3,900.00	$2,730,000
		bladder gates. Differential head at Max W.S.					
		is 4 foot of head. Differential head at Min W.S.					
		5.5 foot of head. Assume stainless steel faceplate.					
		Include in system, 16-foot long bags, air-compressor,					
		air-treatment equipment, operating controls, one					
		supply/exhaust pipe, wallplates for a complete					
		package. Separate installation costs by Contractor.					
		Pete Hoffman > Quote $2,100,000					
		Install 700 feet of bladder gates and piping, compressor		700	LF	$150.00	$105,000
		and control equipment.					
		Aluminum Cofferdam for dewatering during repairs		5,000	lb	$10.00	$50,000
		(16x13x9)					
		Compressor building (for Obermeyer weir)	D8120	1	LS	$30,000.00	$30,000
		13' x 15' in plan, 9' height, constructed of precast c					
		Spare Obermeyer Gate (bladders and faceplates)		1	ea	$62,500.00	$62,500
		Kevlar Reinforcing for bladders (add-on)		1	LS	$600,000.00	$600,000
		(one each for the gate and spare)					
		Mobilization			(+/-)	5%	$410,000
		Subtotal					**$8,548,700**
		Unlisted Items			(+/-)	10%	$851,300
		Contract Cost					**$9,400,000**
		Contingencies			(+/-)	20%	$2,100,000
		Field Cost					**$11,500,000**

QUANTITIES		PRICES	
BY: A. Glickman	APPROVED	BY: T. Artichoker	CHECKED
DATE PREPARED: 21-Nov-2003	DATE	DATE: 4/9/2004	PEER REVIEWER: D. Donaldson (signed) 4/9/04

CODE: D-8140

ESTIMATE WORKSHEET

SHEET 1 of 1

FEATURE:	PROJECT	
INTAKE DIVERSION DAM SPILLWAY - OBERMEYER GATE Life cycle Cost for Bladder/Faceplate Replacement filename: C:\Artichoker\Appraisal-Feasibility Estimates\Yellowstone Intake Diversion\[Revised Fish Passage Intake diversion.xls]spillway-oberm	LOWER YELLOWSTONE	
	PRICE LEVEL Feasibility	WOID 6B552
	UNIT	

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Assumptions:					
		Life cycle is 100 years					
		Bladders lasts 33 years, thus two replacements					
		(assume kevlar reinforced bladders)					
		Faceplates last 50 years, thus one repalcement					
		10% Unlisted Items are included in replacement					
		Real discount rate of 3.5% is used for all outyears					
		(per OMB circular A-94)					
		$PW = F(1+.035)^{-33} =$ 0.3213 (33 yr)					
		$PW = F(1+.035)^{-50} =$ 0.1791 (50 yr)					
		$PW = F(1+.035)^{-66} =$ 0.1033 (66 yr)					
		Where:					
		PW = Present Worth					
		F = Future Worth					
		0.035 = Real Discount Rate					
		Year 33 Obermeyer bladder replacement		1	LS	$1,650,000	
		Unlisted Items		(+/-)	10%	$165,000	
		Present Worth					**$583,237**
		Year 50 Obermeyer faceplate replacement		1	LS	$950,000	
		Unlisted Items		(+/-)	10%	$95,000	
		Present Worth					**$187,111**
		Year 66 Obermeyer bladder replacement		1	LS	$1,650,000	
		Unlisted Items		(+/-)	10%	$165,000	
		Present Worth					**$187,419**
		TOTAL PRESENT WORTH*					**$957,767**
		*The life cycle cost represents the present value of replacing the bladders and faceplates only.					

QUANTITIES		PRICES	
BY A. Glickman	APPROVED	BY T. Artichoker	CHECKED
DATE PREPARED 21-Nov-2003	DATE	DATE 4/9/2004	PEER REVIEWER D. Donaldson DCD 4/9/04

CODE: D-8140

ESTIMATE WORKSHEET

FEATURE:

INTAKE DIVERSION DAM
SPILLWAY - CONCRETE WEIR

filename: C:\Artichoker\cost curves\[Steel Pipe.xls]Sheet1

PROJECT: LOWER YELLOWSTONE

PRICE LEVEL: Feasibility

WOID: 6B552

UNIT:

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Remove existing weir		23,000	CY	$6.00	$138,000
		Gravel/earth cofferdam					
		Cofferdam (place and remove material)		20,000	CY	$38.00	$760,000
		Riprap (2-mile haul, drill, blast, process, place, remove)		1,000	CY	$40.00	$40,000
		40-mil PVC		2,000	SY	$9.00	$18,000
		Dewatering: 35 well points@15 ft depth (4 months)		1	LS	$250,000.00	$250,000
		(All items above are assumed to be used twice.					
		Cofferdam will be constructed 1/2 river at a time)					
		Concrete weir					
		Concrete		9,000	CY	$390.00	$3,510,000
		Reinforcement		460,000	lb	$1.00	$460,000
		Riprap (2-mile haul, drill, blast, process, place)		520	CY	$30.00	$15,600
		Bedding for riprap		260	CY	$45.00	$11,700
		Mobilization			(+/-)	5%	$260,000
		Subtotal					**$5,463,300**
		Unlisted Items			(+/-)	10%	$536,700
		Contract Cost					**$6,000,000**
		Contingencies			(+/-)	20%	$1,200,000
		Field Cost					**$7,200,000**

QUANTITIES		PRICES	
BY a. glickman	APPROVED	BY T. Artichoker	CHECKED
DATE PREPARED 21-Nov-2003	DATE	DATE 3/16/2004	PEER REVIEWER D. Donaldson DCD 3/16/04

Appendix C
Value Engineering Study Responses

PRELIMINARY ACCOUNTABILITY REPORT
VE STUDY
INTAKE DIVERSION – FISH PROTECTION AND PASSAGE

The Value Engineering Study was performed in July 2002. The following are our responses and dispositions to study comments. Our responses are reflected in Concept Report No. II.

VE Proposal No. 1. – Replace the dam with a collapsible gate and fish passage channel. Existing data suggest the rock that has been deposited on the dam crest through maintenance and has washed downstream which has contributed to the impediment of passage of fish, such as pallid sturgeon. The estimated cost change is an increase of $360,000.

Response. – This proposal is still being evaluated. This proposal is one of three options considered: (1) continue to maintain existing dam, (2) replace existing dam with a concrete weir, (3) replace existing dam with adjustable overtopping gate (all the way across). The adjustable overtopping gate is desirable for the concerns mentioned above. However, reliability and access to the proposed gates are the significant concerns. These gates have been maintenance intensive at some sites. Access to any gate would be restricted to a low flow period when the water depth is approximately 2 to 7 feet.

VE Proposal No. 2. – Increase height of concrete sill under screens to 18 inches from 6 inches. This would increase the sediment storage capacity but also reduce the exposure of bottom swimming fish to the screens. The estimated cost increase is $150,000.

Response. – This proposal is partially accepted. The preferred option in Concept Report No. II will have a 1-foot sill. Each 6-inch increase in sill height results in an approximate 20 feet increase in screen length and resulting increase in construction cost.

The difference in performance of the proposed 18-inch sill is not expected to be significantly better than a 1-foot sill for fish passage. The 18-inch sill would allow some additional area for sediment deposits; however, we anticipate the canal will be dewatered every winter for maintenance.

VE Proposal No. 3. – Build a fish trapping facility into the bypass area of the fish screen. The trap would be submerged in the bypassed flow for brief intervals to collect live fish for monitoring and research. The estimated additional cost for this is $82,000.

Response. – This proposal is accepted. The proposed fish trapping facility will be incorporated into the final design. The bypass in the concept drawings is sized to allow insertion of a fyke net; however, other options may be considered for trapping.

VE Proposal No. 4. – Install a trashrack in front of the fish screen. The trashrack would have variable bar spacing to allow for the greatest opportunity for fish passage. The portion of the rack in the upper half of the water profile would consist of bars set vertically with 4-inch spacing, the mid-section of the water profile would have a spacing of about 12 inches, and the lower 3-feet portions would have a spacing of approximately 24- to 48-inches. A hydraulic trash rake and conveyor would be included to provide a mechanical means of removing the debris for collection and removal. The estimated additional cost for this proposal is $380,000.

Response. – This proposal is accepted except for the bar spacing. The proposed trashrack, trashrake, and conveyor will be incorporated into the final design. The proposed bar spacing has been revised. The Concept Report No. II recommends using 8 inch bar spacing and leaving a 2-feet gap between the bottom of the trashrack and the structure invert. The bottom gap is for passage of large fish.

VE Proposal No. 5. – Reduce concrete in the fish screen structure. Eliminate the concrete floor and wall downstream of the fish screens. The left side of the transition at the lower end of the structure would be relocated to just downstream from the upper end of the fish screen. The concrete floor of the canal would be reduced to only that needed for a foundation for the screen structure. Estimated savings is $590,000.

Response. – This proposal is accepted. The structural concrete channel that was shown about the fish screen structure was eliminated. Two options were considered for lining the channel about the fish screen structure: (1) coarse gravel, and (2) reinforced concrete lining. The reinforced concrete lining will provide a good surface for O&M personnel and was selected in the Concept Report No. II. Also, the 1.5:1 side slopes are steep for coarse gravel on a canal this size.

VE Proposal No. 6. – Use light, durable polyethylene material for flat plate screens instead of stainless steel. Estimated savings is $740,000.

Response. – This proposal is not accepted. Screens constructed of polyethylene material with the opening size required are currently being used as part of a traveling water screen but have not yet been used for stationary fish screens. The polyethylene screens would provide an open screen area of 32 percent compared to approximately 45 percent for stainless steel wedge wire screens. Polyethylene screens would also require considerably more framework and backing to make polyethylene screens stable during normal flows and during use of the screen sweeps. We anticipate that accepting the proposal would involve some risk and incur more maintenance costs. Instead, the Concept Study No. II reduces screen cost by having a steel support frame for a stainless steel screen in lieu of an all stainless steel support frame.

VE Proposal No. 7. – Reduce screen structure wall thickness. This proposal would reduce the thickness of concrete walls from 1.5 feet to 1 foot. Freeze-thaw problems would be avoided by adding a 1.5-feet thick section of drain rock backed by filter fabric. Estimated savings are $50,000.

Response. – This proposal is not accepted. The structural design of the walls is a final design item. Adding a drain behind the walls does not always reduce the estimated loading on a wall since the dependability of a drain is often questioned and not relied upon. Also, there will at times be a differential head across the fish screens and a drain would allow a short path for seepage behind the structure. Also, since the wall lengths have been greatly shortened (VE Proposal No. 5) the cost savings will be minimal, if at all, since the drain would be adding to the complexity of construction.

VE Proposal No. 8. – Replace baffles with perforated plates. The plates would be epoxy coated steel plates. Two perforated plates would be used behind each screen panel. One plate would be fixed while the other perforated plate would be on a screw movement system, which would allow the perforated plate to slide up or down, thus changing the porosity. Estimated savings are $725,000.

Response. – This proposal is accepted. The perforated plate option is less expensive and allows easier adjustments.

We note that the original 2000 Concept Report estimate cost of the baffles was $540,000, which is less than the estimated savings.

VE Proposal No. 9. – Install a three-brush cleaning system in place of a single brush system. With the length of the screen, a multiple brush system will clean the screens more successfully than one brush. The three-brush system is designed for brushing whereas the single brush system included in the base design is designed for raking. Estimated savings are $365,000.

Response. – This proposal is not accepted. Concept Report No. II recommends a "V" shaped screen structure with a sweep system on each side. Each sweep system will have two brushes.

VE Proposal No. 10. – Replace dam with pumps using an intake gallery, pump, battery, and manifold. Remove dam and headworks entirely. Estimated additional cost is $10,800,000.

Response. – This proposal is not accepted. The additional construction cost is too high and the anticipated additional operation and maintenance costs and effort are too high. Pump intakes would still have to be screened and we do not have a feasible backup system if the power failed.

The Following Are From The Disposition Of Ideas Section Of The VE Study Report:

Idea. – Lengthen screen to better protect smaller fish (lower the approach velocity from 0.5 ft/s to 0.3 ft/s).

Response. - This idea is partially accepted. The design approach velocity for the fish screens in the 2000 Concept Study was 0.5 ft/s. The high approach velocity may also increase debris impingement on the screens. Two approaches can be used to reduce debris impingement on the fish screens: (1) the angle of the screens to the flow (approximately 6:1 sweeping to approach velocity ratio in the 2000 Concept Report) can be reduced to a 10:1 sweeping to approach velocity ratio, or (2) the approach velocity can be reduced. With the recommended "V" configuration in the Concept Report No. II, the sweeping to approach velocity ratio is approximately 6.8:1.

The approach velocity has been reduced to 0.4 ft/s, as recommended by National Marine Fisheries Service, Northwest Region.

Idea. – Add non-positive avoidance measures in front of the screen, e.g., light, electric fields, etc.

Response. – This idea is not accepted. These non-positive measures have been tested and are not proven effective as fish screens.

Idea. – Add trashrack in front of headgates.

Response. – This idea is not accepted. A trashrack will be added upstream from the fish screens (VE proposal No. 4). Adding the trashrack at the upstream side of the headworks would minimize the handling of trash since the trash would be mostly pushed downstream but the trashrack would be exposed to damage from winter ice and debris.

Idea. – Use manmade riprap for boulder in the fish passage.

Response. – We are not sure what was intended by the term "manmade riprap." The preferred material would most likely be reinforced concrete. If riprap is available and feasible, it is preferred.

Idea. – Use sheet piling to support screen structure.

Response. – This idea is not accepted. We anticipate that a slab on grade foundation will be satisfactory and less expensive unless geologic investigation has some surprises.

Idea. – Add more rock to south side of dam to lengthen gradient.

Response. – This idea is accepted but modified. The relatively high river channel on the north downstream side of the dam allows better upstream fish passage on the north side than on the south side. This is undesirable since the headworks are on the north side and upstream migrating fish could become entrained in the canal. There are two other options for addressing this concern:

If the existing dam remains, raise the north side of the dam to encourage fish to pass on the south side.

If the existing dam is replaced, the downstream channel will be regraded.

Idea. – Improve passage through natural bypass channel as a secondary bypass channel.

Response. – This idea is not accepted. The bypass channel comes into the river 0.5 miles below the dam so fish would swim upstream past the bypass channel to the dam. The proposed fishway would be better at low river flows.

Idea. – Put an electrical field below the intake in addition to the fish screen.

Response. – This idea is not accepted. We assume this means the location of the electrical field would be at the headworks gates. This would be a great expense for minimal gain. Electrical fields are only partially effective and are not accepted by many fishery agencies.

Idea. – Move the bypass pipe to near the bridge.

Response. - Not sure what this means.

Idea. – Move the whole screen structure to near the bridge.

Response. – This idea is accepted. The fish screen structure has been moved near the bridge to avoid the effects of the bend in the canal. The best possible approach conditions are obtained by providing as much distance as possible between the bend and the fish screen structure. We still will have to consider an uneven approach velocity operation of the headworks gates.

Idea. – Salvage rock from the dam maintenance (recover rock in the river).

Response. This idea will be evaluated during final design. We may allow this as an option in the specifications as long as the rock meets the size and quality requirements.

Idea. – Move the diversion dam and canal inlet downstream in the canal with the new regulating structure behind the screen.

Response. – Not sure what this means.

Idea. – Place fish pumps in the canal and pump fish back to the river.

Response. – This idea is not accepted. The fish pumps would save money on the bypass pipe (may be able to install pipe by open excavation instead of pipe jacking) but the fish pump and motor would add to the construction cost and operation and maintenance costs would be greater. Also, the use of fish pumps in a bypass system is not currently accepted technology.

Idea. – Place soil cement in the bottom of the fish passage. Color it brown for aesthetics.

Response. – This idea is not accepted. It is not anticipated that soil cement would be as durable as riprap.

Idea. – Extend the bypass pipe 150 feet into the river from the north bank and swing the outlet downstream.

Response. – This idea is not accepted. This would require additional pipe and cofferdam and would be more expensive. The outlet would end up in the river and may then be subject to damage that would go unnoticed and be difficult to repair.

Idea. – Develop a cost share agreement from a recovery program on the Main Stem Missouri.

Response. – This idea is being developed.

Idea. – Lower the gradient in the passage to 1.5 percent.

Response. – This idea is partially accepted. The slope has been flattened from 2.5 percent to 2.0 percent.

Idea. – Rebuild dam and incorporate fishway on the south side.

Response. – A fishway will be incorporated at the south dam abutment. Concept Study No. II presents three options for the dam. The preferred option is still being evaluated.

The preferred option for constructing the fish passage is on the south side of the dam and is independent of the three dam options.

Idea. – Use an air blowout system.

Response. – This idea is accepted. An air system added to the screen sweep cleaning system is included in the Concept Study No. II. The air blower system will be used to keep sediment deposits moving downstream.

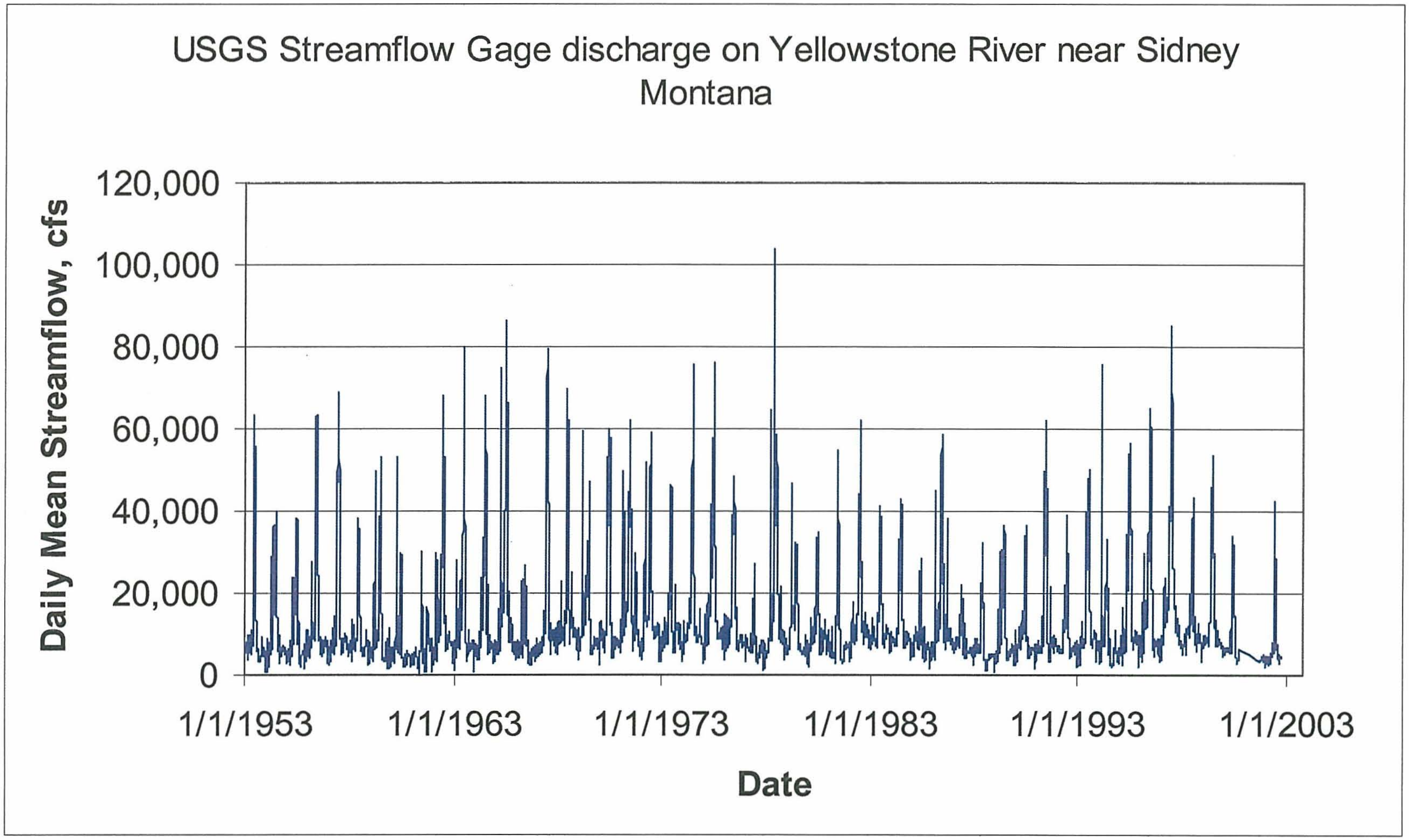
Idea. – Install removable safety panels.

Response. – This idea is accepted. The recommended fish screen structure in Concept Study No. II includes a 10-feet-wide pressure relief panel.

Idea. – Increase the bypass entrance width and pipe diameter to accommodate the large size of fish (paddlefish) found in the river.

Response. – This idea is not accepted. The bypass entrance width should be adequate at 2.0 feet. However, the pipe diameter was increased to 48-inches to reduce headloss.

Appendix D
Hydrographs


USGS Streamflow Gage discharge on Yellowstone River near Sidney Montana
Daily Mean Streamflow, cfs
120,000
100,000
80,000
60,000
40,000
20,000
0
1/1/1953
1/1/1963
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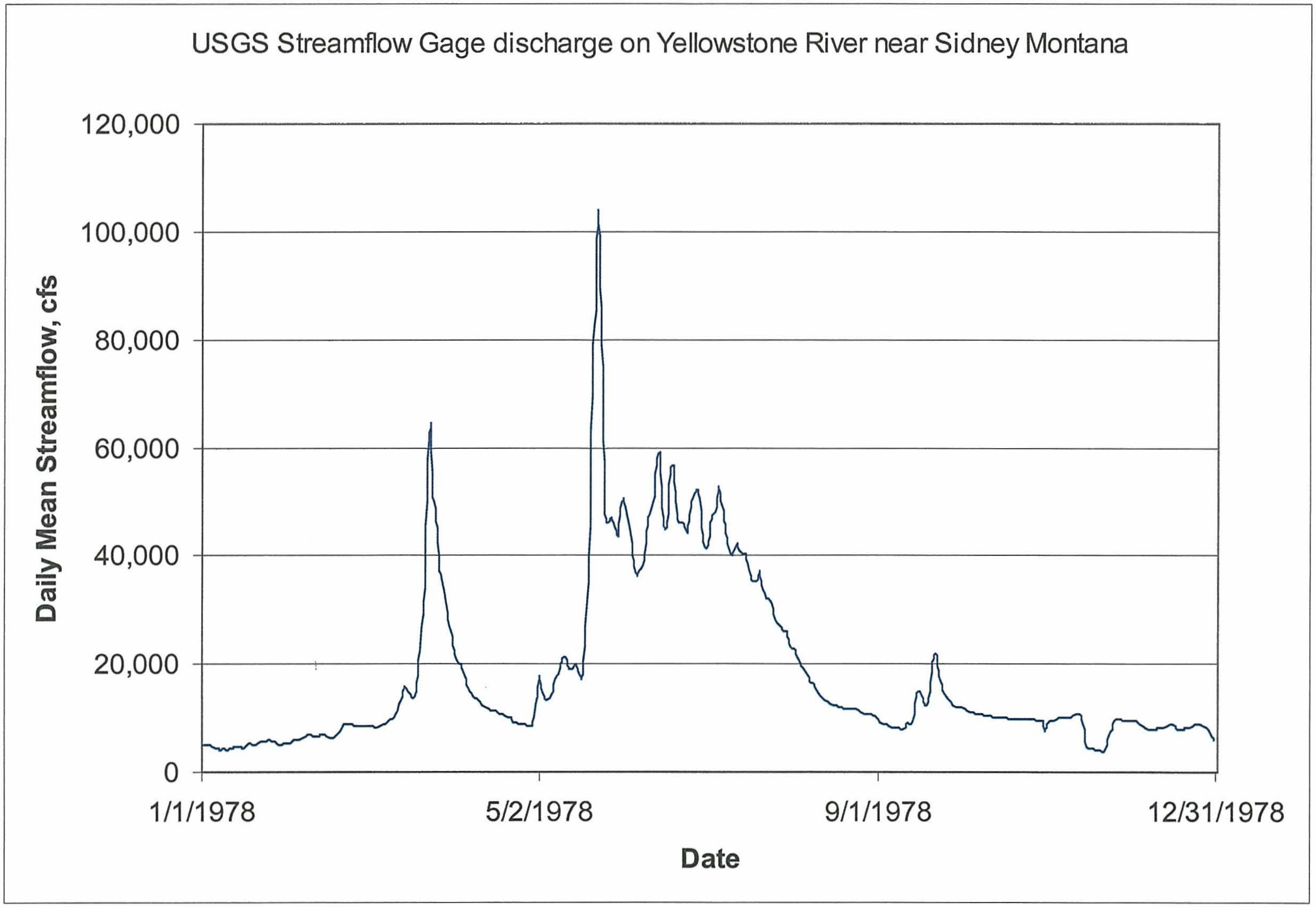
1/1/1983
1/1/1993
1/1/2003
Date


USGS Streamflow Gage discharge on Yellowstone River near Sidney Montana
120,000
100,000
80,000
60,000
40,000
20,000
0
Daily Mean Streamflow, cfs
1/1/1978
5/2/1978
9/1/1978
12/31/1978
Date

Appendix E
FWS Preference for Inflatable Weir at Intake Diversion Dam

U.S. Fish and Wildlife Service (Service) Reasons for Preference for Inflatable Weirs Alternative for Fish Passage at Intake Diversion Dam

The Service feels that replacement of the existing diversion dam with inflatable weirs, if properly designed and in conjunction with a rock fishway, would provide the best opportunity for upstream migrating sturgeon passage. Sturgeon are adapted to large, turbid, free-flowing rivers and typically avoid areas of turbulence (Forbes and Richardson 1905, Kallemeyn 1983, and Gilbraith et al 1988).

White and Mefford (2002), using shovelnose sturgeon as a surrogate species, showed that Yellowstone River sturgeon were able to negotiate horizontal and vertical eddies in a test flume, but this turbulence tended to cause delays and decrease passage success. This study also tested sturgeon in prototype fishways and found that of fishway options, the rock fishway provided the best alternative for passage (as compared to vertical slot and duel slot fishways). However, this fishway design still requires some turbulence to buffer velocities in order to provide a passable channel, and there is some concern that this turbulence may affect sturgeon passage success. It is not known whether a fishway alone will provide adequate passage for sturgeon.

If inflatable weirs could be designed so that, when deflated, it would be as if there was no dam there at all, there would be no impediment to fish passage. During high flow conditions when sturgeon are typically migrating, the weirs could be operated in the down position for natural passage (U.S. Army COE 2002). There is also considerable turbulence in the channel below the dam due to ongoing maintenance that the Service feels will be detrimental to fish passage; replacement of the dam would result in removal of this passage impediment as well.

Kapuscinski (2003) estimates that only 178 wild pallid sturgeon live in this reach of the river (Recovery Priority Management Area 2) and predicts their extirpation by 2017 if declines are not reversed. The Service is directed by the ESA to make decisions based on the best available science, and to err on the side of the species if science is lacking. The Service feels that there is no science available proving a rock fishway will provide passage for sturgeon, and the turbulence required to buffer flows may hamper passage. Given this direction and the dire situation of the pallid, they are requesting replacement of the dam with weirs that can be deflated to provide natural, run of the river fish passage during high flow conditions for the best possible opportunity for sturgeon to pass upstream of Intake to access historical spawning habitat.

Literature Cited

Forbes, S.A. and R.E. Richardson, 1905. On a new shovelnose sturgeon from the Mississippi River. Bulletin of the Illinois State Laboratory of Natural History, 7:37-44.

Gilbraith, D.M., M.J. Schwalbach, and C.R. Berry, 1988. Preliminary report on the status of the pallid sturgeon, Scaphirhyncus albus, a candidate endangered species. Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings SD.

Kallemeyn, L.W., 1983. Status of the pallid sturgeon (Scaphirhyncus albus). Fisheries. 8(1):3-9.

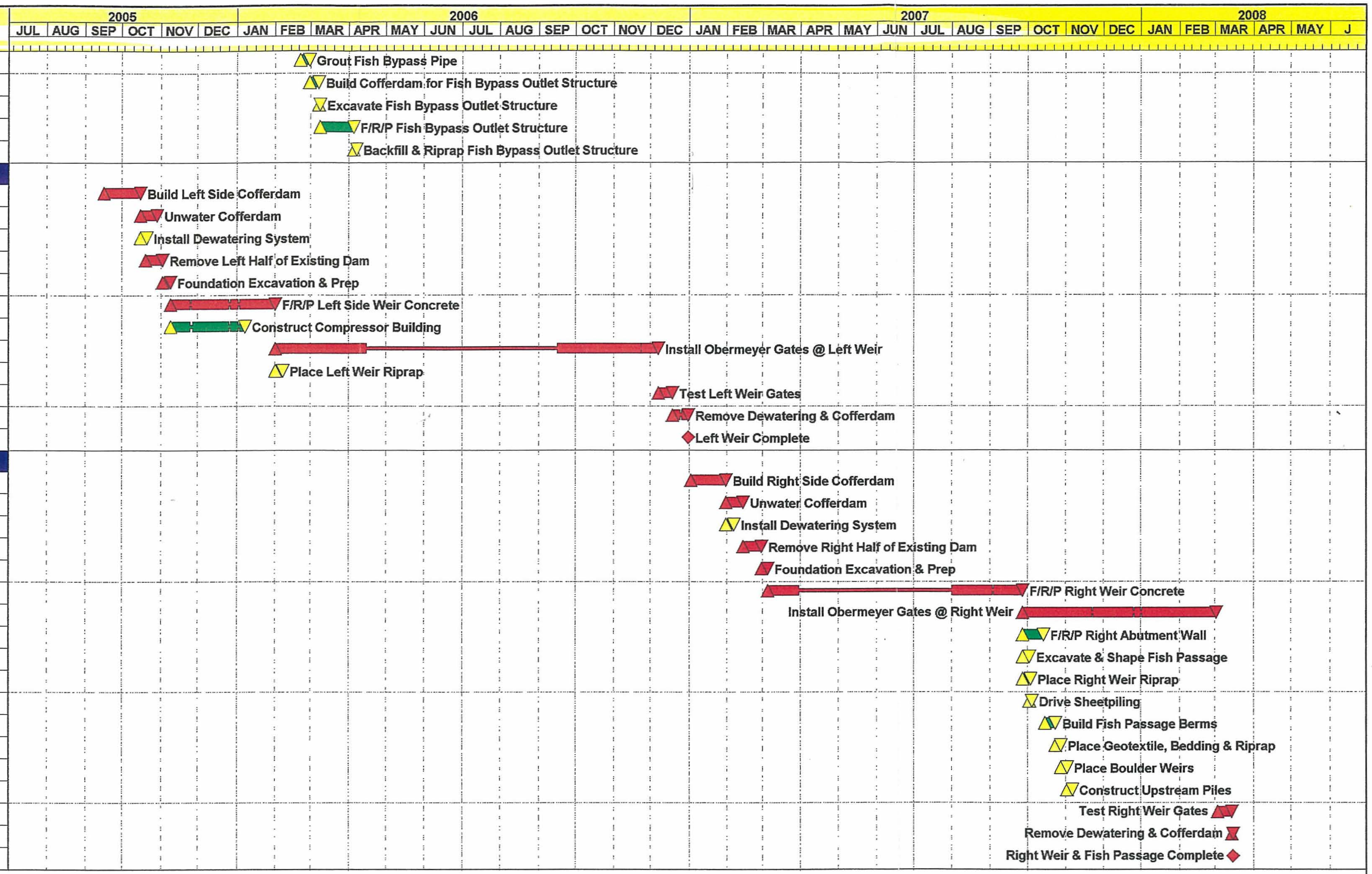
Kapuscinski, K., 2003. Status of wild pallid sturgeon in Montana. Abstract from presentation at American Fishery Society Annual Meeting, Montana Chapter, Great Falls MT.

U.S. Army Corps of Engineers, 2002. Lower Yellowstone River Intake Dam Fish Passage Alternatives Analysis. Omaha District, Omaha, NE.

White, Dr. Robert B. and B. Mefford, 2002. Assessment of behavior and swimming ability of Yellowstone River sturgeon for design of fish passage devices. Montana State University, Montana Cooperative Fishery Research Unit, Bozeman MT and Bureau of Reclamation, Water Resources Research Laboratory, Denver CO.

Appendix F
Construction Schedules

Activity ID	Activity Description	Orig Dur	Cal ID	Total Float	Early Start	Early Finish
190	Grout Fish Bypass Pipe	5	1	492	21FEB06	27FEB06
FS192	Build Cofferdam for Fish Bypass Outlet Structure	5	1	492	28FEB06	06MAR06
195	Excavate Fish Bypass Outlet Structure	1	1	492	07MAR06	07MAR06
200	F/R/P Fish Bypass Outlet Structure	20	1	492	08MAR06	04APR06
FS205	Backfill & Riprap Fish Bypass Outlet Structure	2	1	492	05APR06	06APR06
t Weir Structure						
/005	Build Left Side Cofferdam	25	3	0	16SEP05	14OCT05
LW015	Unwater Cofferdam	12	3	0	15OCT05	28OCT05
/010	Install Dewatering System	5	3	10	15OCT05	20OCT05
/020	Remove Left Half of Existing Dam	12	3	0	19OCT05	01NOV05
LW025	Foundation Excavation & Prep	5	3	0	02NOV05	07NOV05
LW030	F/R/P Left Side Weir Concrete	70	3	0	08NOV05	31JAN06
/050	Construct Compressor Building	40	1	233	08NOV05	06JAN06
LW040	Install Obermeyer Gates @ Left Weir	132	3	0	01FEB06	06DEC06
LW035	Place Left Weir Riprap	5	3	137	01FEB06	06FEB06
/055	Test Left Weir Gates	10	3	0	07DEC06	18DEC06
/060	Remove Dewatering & Cofferdam	10	3	0	19DEC06	30DEC06
LW065	Left Weir Complete	0	3	0		30DEC06
ht Weir Structure & Fish Passage						
/005	Build Right Side Cofferdam	25	4	0	02JAN07	30JAN07
RW015	Unwater Cofferdam	12	4	0	31JAN07	13FEB07
/010	Install Dewatering System	5	4	19	31JAN07	05FEB07
/020	Remove Right Half of Existing Dam	12	4	0	14FEB07	27FEB07
RW025	Foundation Excavation & Prep	5	4	0	28FEB07	05MAR07
RW030	F/R/P Right Weir Concrete	70	4	0	06MAR07	26SEP07
/040	Install Obermeyer Gates @ Right Weir	132	4	0	27SEP07	01MAR08
RW060	F/R/P Right Abutment Wall	15	4	108	27SEP07	13OCT07
FP005	Excavate & Shape Fish Passage	4	4	117	27SEP07	01OCT07
/035	Place Right Weir Riprap	5	4	137	27SEP07	02OCT07
008	Drive Sheetpiling	2	4	117	02OCT07	03OCT07
FP010	Build Fish Passage Berms	7	4	108	15OCT07	22OCT07
015	Place Geotextile, Bedding & Riprap	4	4	108	23OCT07	26OCT07
020	Place Boulder Weirs	5	4	108	27OCT07	01NOV07
FP025	Construct Upstream Piles	3	4	108	02NOV07	05NOV07
/055	Test Right Weir Gates	10	4	0	03MAR08	13MAR08
/065	Remove Dewatering & Cofferdam	1	4	0	14MAR08	14MAR08
RW070	Right Weir & Fish Passage Complete	0	4	0		14MAR08



Date	01JUN05	Early Bar
h Date	14MAR08	Progress Bar
Date	01JUN05	Critical Activity
un Date	22APR04 15:05	

INTK

Bureau of Reclamation

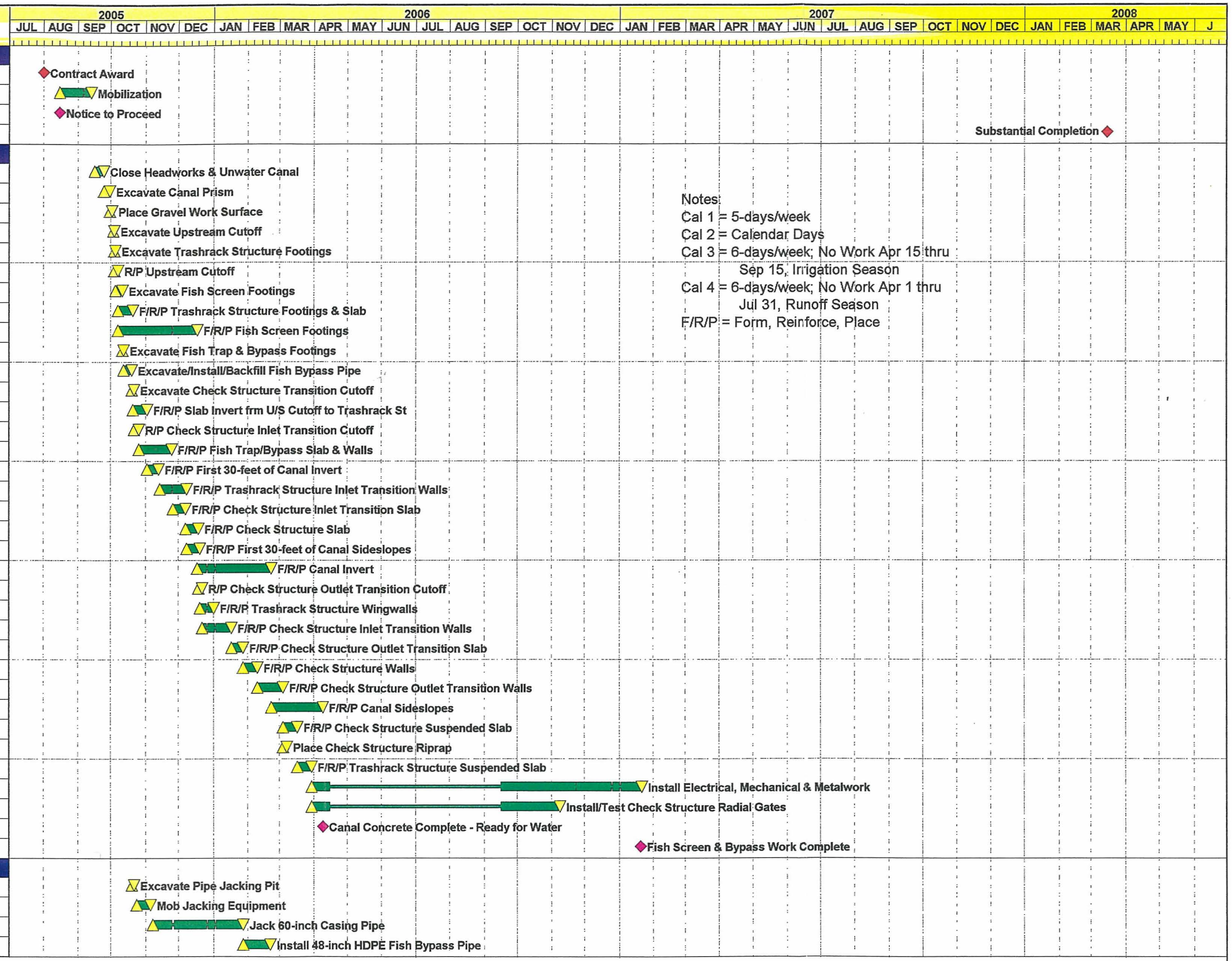
Intake Diversion Dam

Lt Weir then Rt Weir

Sheet 2 of 2

Date	Revision	Checked	Approved

Activity ID	Activity Description	Orig Dur	Cal ID	Total Float	Early Start	Early Finish
ministrative						
AWD	Contract Award	0	2	0	01AUG05*	
005	Mobilization	20	1	3	15AUG05	12SEP05
TP	Notice to Proceed	0	2	3	15AUG05*	
COMP	Substantial Completion	0	2	0		14MAR08
h Screen Structure						
005	Close Headworks & Unwater Canal	7	3	223	16SEP05	23SEP05
FS010	Excavate Canal Prism	5	3	223	24SEP05	29SEP05
FS015	Place Gravel Work Surface	2	3	223	30SEP05	01OCT05
020	Excavate Upstream Cutoff	1	3	223	03OCT05	03OCT05
S025	Excavate Trashrack Structure Footings	1	3	223	04OCT05	04OCT05
FS030	R/P Upstream Cutoff	3	3	286	04OCT05	06OCT05
035	Excavate Fish Screen Footings	5	3	223	05OCT05	10OCT05
040	F/R/P Trashrack Structure Footings & Slab	12	3	286	07OCT05	20OCT05
FS050	F/R/P Fish Screen Footings	60	3	334	07OCT05	16DEC05
045	Excavate Fish Trap & Bypass Footings	1	3	223	11OCT05	11OCT05
055	Excavate/Install/Backfill Fish Bypass Pipe	7	3	223	12OCT05	19OCT05
FS060	Excavate Check Structure Transition Cutoff	2	3	223	20OCT05	21OCT05
070	F/R/P Slab Invert frm U/S Cutoff to Trashrack St	10	3	286	21OCT05	01NOV05
065	R/P Check Structure Inlet Transition Cutoff	3	3	223	22OCT05	25OCT05
FS095	F/R/P Fish Trap/Bypass Slab & Walls	25	3	223	26OCT05	23NOV05
075	F/R/P First 30-feet of Canal Invert	10	3	286	02NOV05	12NOV05
080	F/R/P Trashrack Structure Inlet Transition Walls	20	3	286	14NOV05	07DEC05
FS100	F/R/P Check Structure Inlet Transition Slab	10	3	223	25NOV05	06DEC05
FS105	F/R/P Check Structure Slab	10	3	223	07DEC05	17DEC05
085	F/R/P First 30-feet of Canal Sideslopes	10	3	286	08DEC05	19DEC05
S160	F/R/P Canal Invert	55	3	334	17DEC05	21FEB06
FS110	R/P Check Structure Outlet Transition Cutoff	3	3	223	19DEC05	21DEC05
090	F/R/P Trashrack Structure Wingwalls	10	3	286	20DEC05	31DEC05
115	F/R/P Check Structure Inlet Transition Walls	20	3	223	22DEC05	16JAN06
FS120	F/R/P Check Structure Outlet Transition Slab	10	3	223	17JAN06	27JAN06
125	F/R/P Check Structure Walls	10	3	223	28JAN06	08FEB06
130	F/R/P Check Structure Outlet Transition Walls	20	3	223	09FEB06	03MAR06
FS165	F/R/P Canal Sideslopes	40	3	334	22FEB06	08APR06
135	F/R/P Check Structure Suspended Slab	11	3	223	04MAR06	16MAR06
145	Place Check Structure Riprap	2	3	363	04MAR06	06MAR06
FS150	F/R/P Trashrack Structure Suspended Slab	11	3	223	17MAR06	29MAR06
155	Install Electrical, Mechanical & Metalwork	120	3	223	30MAR06	20JAN07
140	Install/Test Check Structure Radial Gates	60	3	283	30MAR06	08NOV06
S210	Canal Concrete Complete - Ready for Water	0	2	706		08APR06
S215	Fish Screen & Bypass Work Complete	0	1	293		19JAN07
h Bypass						
S170	Excavate Pipe Jacking Pit	2	1	492	20OCT05	21OCT05
S175	Mob Jacking Equipment	10	1	492	24OCT05	04NOV05
180	Jack 60-inch Casing Pipe	55	1	492	07NOV05	26JAN06
185	Install 48-inch HDPE Fish Bypass Pipe	17	1	492	27JAN06	20FEB06



Notes:
Cal 1 = 5-days/week
Cal 2 = Calendar Days
Cal 3 = 6-days/week; No Work Apr 15 thru Sep 15, Irrigation Season
Cal 4 = 6-days/week; No Work Apr 1 thru Jul 31, Runoff Season
F/R/P = Form, Reinforce, Place

Date	01JUN05
h Date	14MAR08
Date	01JUN05
un Date	22APR04 15:18

Early Bar
Progress Bar
Critical Activity

INTK

Sheet 1 of 2

Bureau of Reclamation

Intake Diversion Dam

Lt Weir then Rt Weir

Date	Revision	Checked	Approved

Appendix G
Experience with Obermeyer Gates

Previous Reclamation Experience with Obermeyer Type Gates:

1. The Boise Office has reported (email correspondence with Eugene Humbles dated March 25, 2003) that Obermeyer gates can be maintenance intensive due to maintaining the bladder pressure and required effort to continuously tighten the bolts (*would think this could be handled in design*). At Lemhi L-6 and L-7/7A a computer controlled Obermeyer system was used in a variable crest dam and pool weir ladder arrangement. The computer control system has not worked properly *(would think this could be handled?)*, so the system has been operated in a manual mode. Also, there have been problems with bladder leakage.

2. Fishway entrance at Marble Bluff Dam. Obermeyer Gate in fish intake channel – ten-feet-wide (Email from Bob Macdougal, Reno dated June 12, 2003). Basically he and the operators are happy with the operation, and estimate the gates have logged at least 5,000 cycles.

   - The operation is basically up or down, but the gates have been used with only six inches of flow over the top to count fish. For intermediate operation, a computer will be needed to control position.

   - It is hard to get more than 5% accuracy in setting gate elevation.

   - The gates do not go up smoothly due to side seal friction. As air pressure is increased, the gates have a tendency to pop up. Closing the gates down is hard to control unless computer operated. It takes about 10 minutes for the gates to start going down from time air pressure is released, but they go down smoothly due to orientation of side seal.

   - A custom position indicator with a linear transducer was designed and installed to measure gate position.

   - The position indicator supplied by Obermeyer was considered to be marginal. It has a flex electrical cable in the water, which they did not think would last long.

   - If the gate is operated with water overtopping it, the gate position will change with the depth over the weir due to changes in pressure in the bladder.

   - The air dryer supplied by Obermeyer was greatly undersized. This would allow water to enter the bladder and make lowering the gate all the way impossible.

- The regulator supplied by obermeyer had a plastic housing, which cracked a few times. They have replaced the plastic housing.

- The gates have a fish-friendly trailing shield. If sediment deposits on the downstream side of the shield when the gate is up, the sediment will prevent the weir from being lowered. The fish lift is used to flush out the sediment. They fill the fish lift part way and then open the fish lift gate. The shield is perforated so if sediment is in the overtopping flow, the sediment could drop out underneath the shield and then again will prevent the shield from being lowered.

Obermeyer Gates in Cold Weather Conditions
(Installed within the last 1 to 3 years) - Jason Wagner 3/01/04

Contacted Rob Eckman from Obermeyer Hydro on 2/23/04 (970-568-9844)

Ice Loading Conditions:

While Gate is up: If ice comes in contact with gate, it can cause the gate to partially lower due to the load of ice. This in turn would create a larger contact area between the gate and bladder, until equilibrium is reached. Some ice may flow over top of gate while partially lowered.

While Gate is down: One concern is ice adhering to the gate panel. To account for this, the anchor bolts are sized for representative shear, and the hinge flap is designed for the tension. These calculations are all dependent on the thickness of the ice. A second concern is floating ice coming in contact with part of the lowered gate.

In addition to answering these questions, additional references were provided of others who have recently used Obermeyer gates in similar conditions. These are listed below.

Reliant Energy – 5 sites in New York, Contacted Jeff Bernard (315-413-2746)

These are still very new structures, only two of them have been through a winter. They are operationally different than our design. The design is a 3-feet- high, 600-feet-long gate structure on the Black River. They are used for hydropower generation, and the gates remain up except during floods to pass trash and ice. They are happy with the gates so far, the main problem is that there is some leakage in the seals between the gates, and in the winter this creates ice downstream of the gates, making the gates difficult to close at times. The only other problem mentioned was wave action over the top of the gates.

John Fetcher – Smith Ditch (Photos attached) (970-879-2424)

This is a single Obermeyer gate used as diversion dam to raise the water level in a tributary of the Yampa River to irrigation turnouts. The operation of the gate is similar to our design, in the winter the gates are down. There has not been any problem with ice flowing over top of the lowered gates.

Sinnissippi Dam – Central Illinois, Contacted Randy Bell (815-625-2538)

There are four 96-feet-long, 10-feet-high gates and three 48-feet-long, 10-feet-high gates used as part of a modification to the existing Sinnissippi Dam. Since the gates have been installed, there has not been a real cold winter. Randy said that he had been out to the site recently and measured 9" of ice. The operation is that the gates are up in the winter, and allow for a very small flow to overtop the gates to retard formation of ice. There are also channels in the piers filled with glycol that can be connected to a heater to heat the piers to prevent ice. There haven't been any problems related to ice since the retrofit.

Appendix H
Operation and Maintenance

OPERATION AND MAINTENANCE

Fish Screen Facilities

Debris removal. –

1. Trashracks – An automated trash rake will be provided for cleaning. A conveyor is provided to transport the trash to the side of the operating deck. Operators will have three options for operating the trash rake: (1) local pushbutton, (2) based on a maximum differential head across the trashracks, and (3) at adjustable timed intervals. Trash deposited by the conveyor will have to be removed.
2. Fish Screen Cleaners – Each side of the fish screen structure will have a sweep cleaner system (each with two brushes). Operators will have three options for operating the sweeps: (1) local pushbutton, (2) based on a maximum differential head across the fish screen structure, and (3) at adjustable timed intervals. The cleaners will loosen debris from the fish screens. The debris will then be carried downstream, through the fish bypass, by the flow.
3. Debris not removed by the automatic cleaning systems will have to be removed manually.

Flow control. – Flow into the canal can be controlled by either the headworks gates or the new radial gates. Flow through the fish bypass will be controlled by the slide gate at the entrance of the bypass pipe. The design flow for the fish bypass is 40 ft^3/s.

Water Level Control. – It is anticipated that normal depth at the fish screen structure for a flow of 1,400 ft^3/s is approximately 10.0 feet. For flows below 1,400 ft^3/s, the water surface will be lower. It is not anticipated that the water level will drop low enough to cause the approach velocity through the fish screens to exceed the maximum allowable. If it does, the radial gates can be lowered to check up the water surface. Otherwise, the radial gates will normally be in the up position above the water surface except during high river flows.

When river flows are above approximately 28,000 ft^3/s, the river water level will approach canal water level and decrease the flow through the fish bypass. To maintain the design flow through the fish bypass, the water level must be checked up with the radial gates. The water level in the canal should always be 1.0 foot or greater than the water level in the river downstream from the diversion dam. Water level gages will have to be placed upstream and downstream of the fish screen.

Maintenance. – Items to maintain will include:

1. Automated trash rake and electric motor
2. Fish screen cleaners and electric motors
3. Radial gates and electric motors
4. Fish bypass slide gate and electric motor
5. It is anticipated metal work will require touch up painting every two to five years and complete painting approximately every 10 years.
6. Riprap which is displaced will have to be replaced
7. The concrete structures should not require maintenance
8. Area lighting

9. Backup electric generator
10. Electrical equipment

Obermeyer Gated Spillway

Operation. - The Obermeyer Gates will be up during the irrigation season, except during upstream migration of pallid sturgeon, and down during the non-irrigation season or high river flows to allow fish passage. While the gates are up, the air compressor will go on as required to maintain the gate position. It is anticipated the gates will be either all the way up or all the way down. Water level gages will have to be placed upstream and downstream of the spillway.

Maintenance. – Items which require maintenance will include:

1. The air bladders for the gates
2. The gates - made of stainless steel
3. The air piping and associated valves
4. The air compressor
5. Electrical equipment
6. We anticipate providing one extra gate which can be used to replace a gate which malfunctions
7. We anticipate designing the gates so that a metal box cofferdam can be lowered over the gate to provide for unwatering the area and working on the gate. Working on a gate in the river will require use of the overhead cable and potentially a barge and divers.

Winterizing would require draining the air dryer and filters of residual water and perhaps blowing condensed water out the air supply/exhaust line.

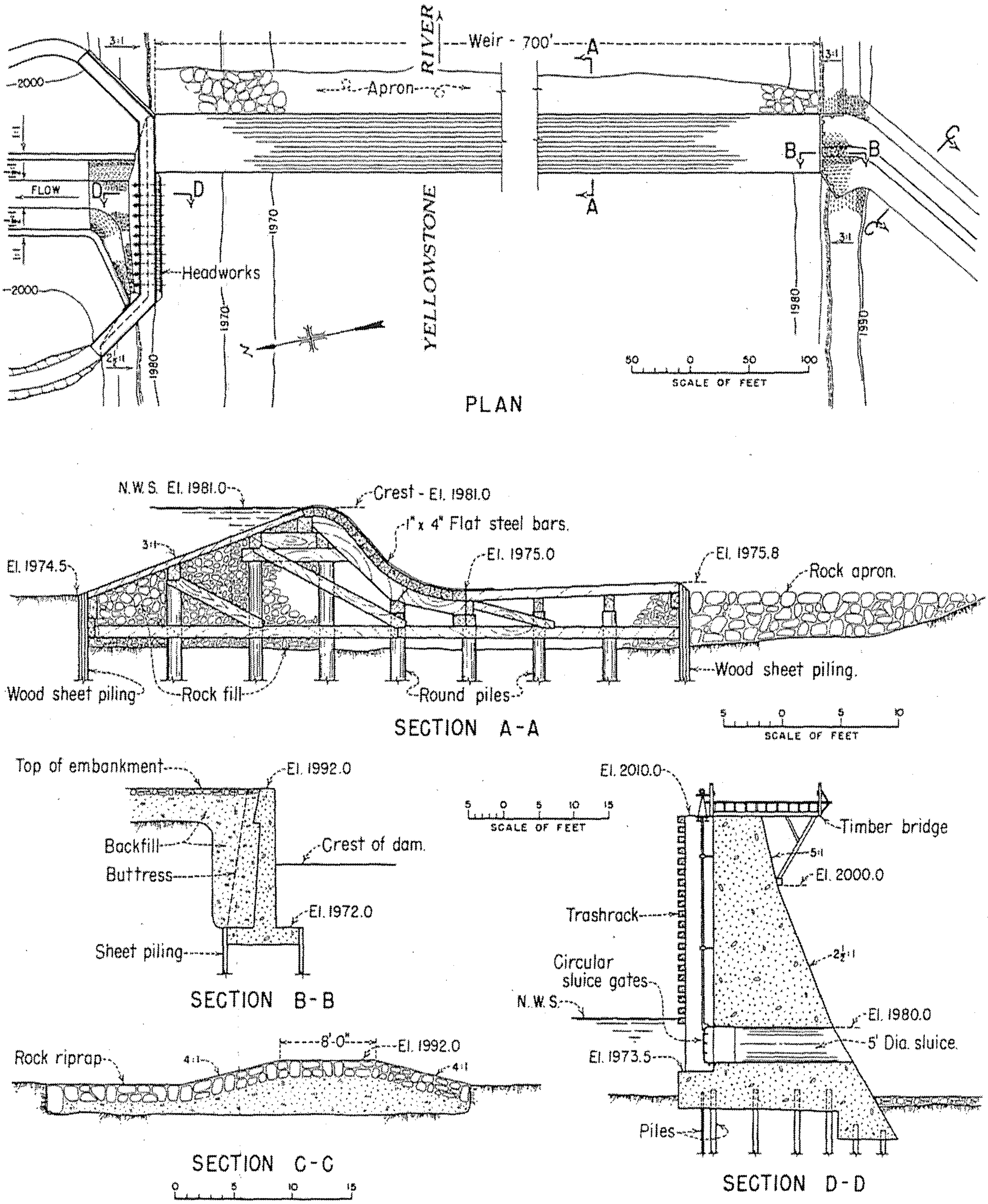
Riprap Channel Fishway

Operation. – Once the boulder weirs are set after construction, the setting should allow fish passage for flow 5,000 ft^3/s and higher. If a boulder is somehow moved it will have to be reset to provide the maximum 0.35 feet drop per boulder weir.

Maintenance. – Replace riprap and boulders as required. Replace or repair the upstream concrete piles for ice blocking as required.

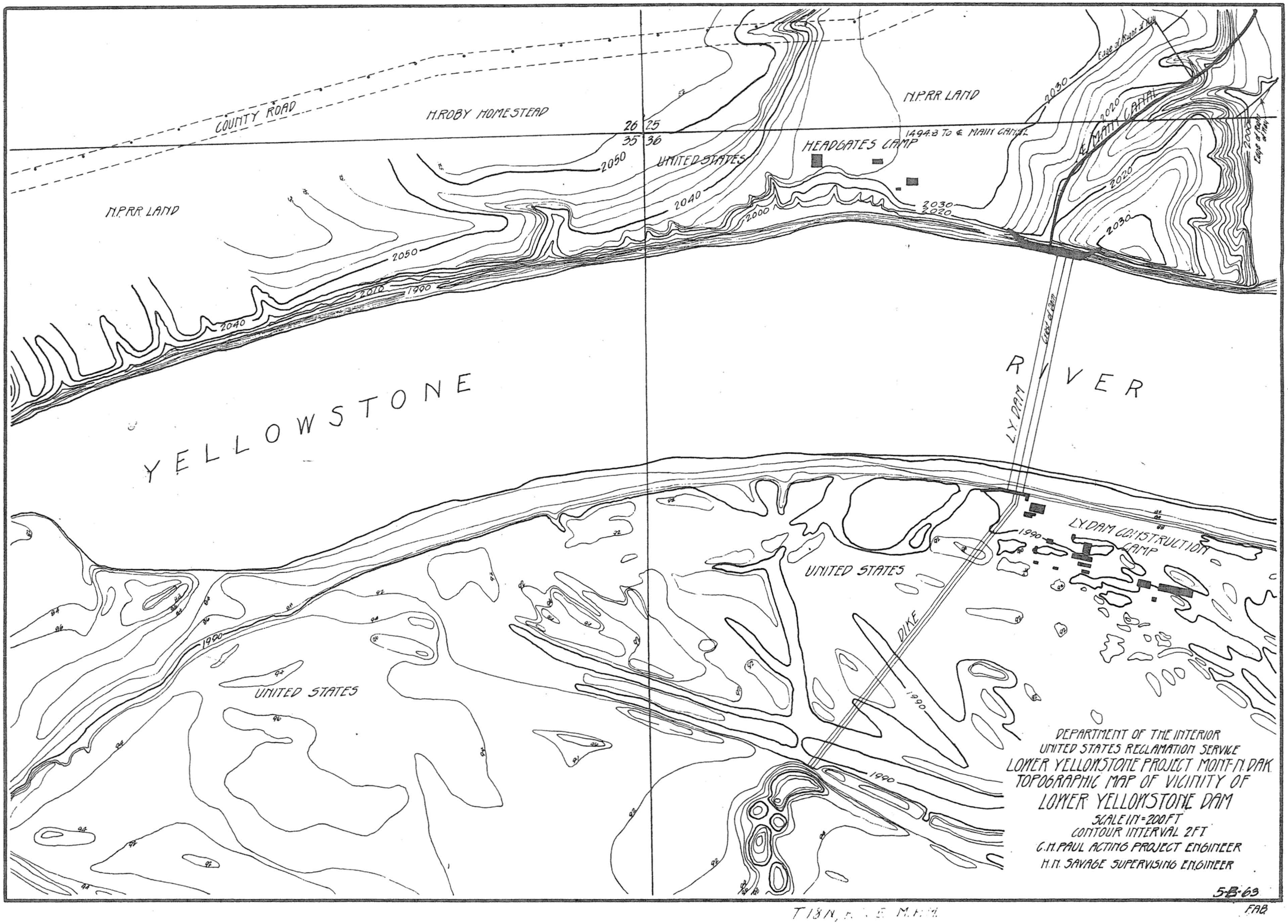
Appendix I
Drawings of Existing Dam

Figure I-1



Lower Yellowstone Diversion Dam, Plan and Sections

Figure I-2

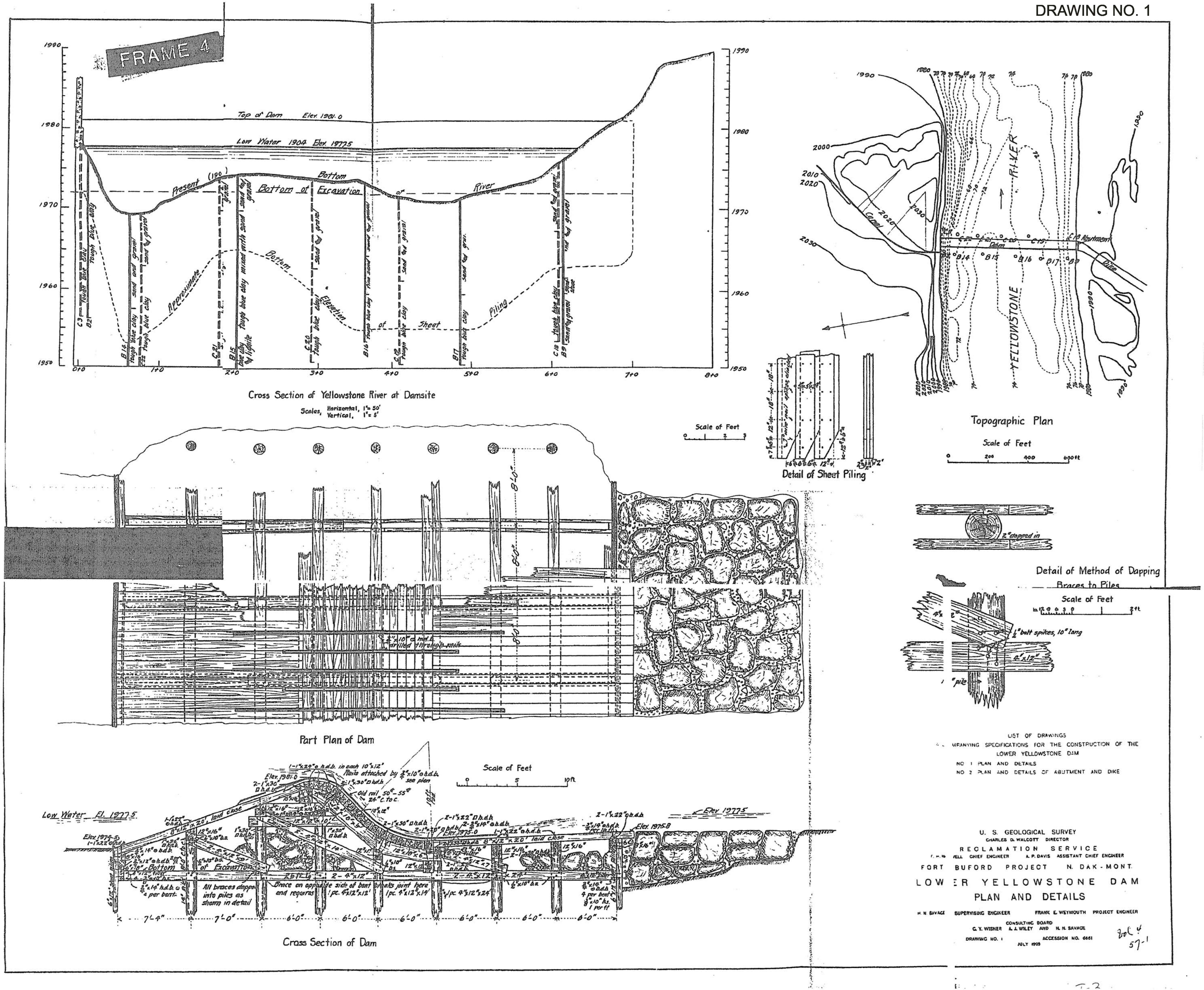


FAB

1S-1312

Figure I-3

DRAWING NO. 1



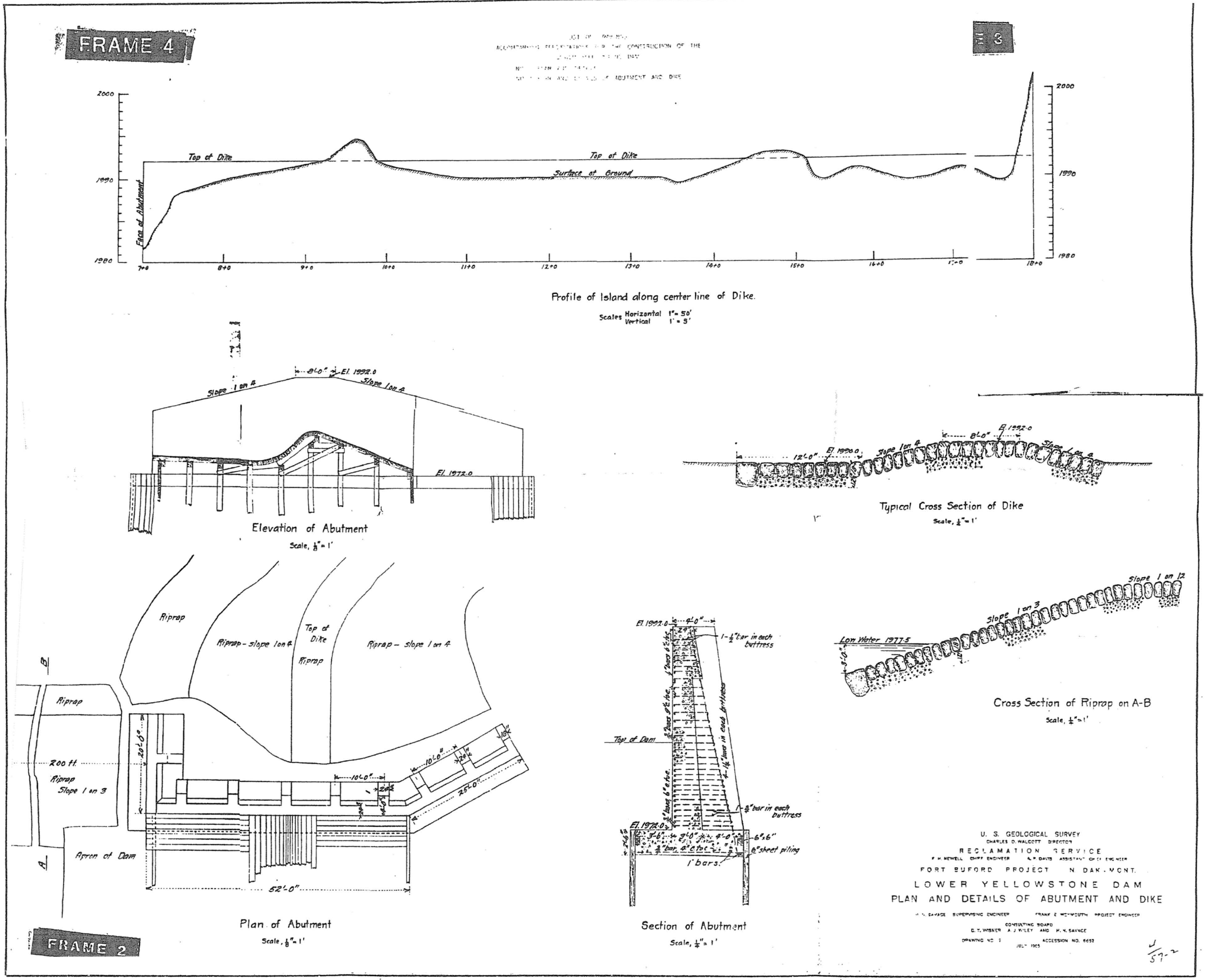
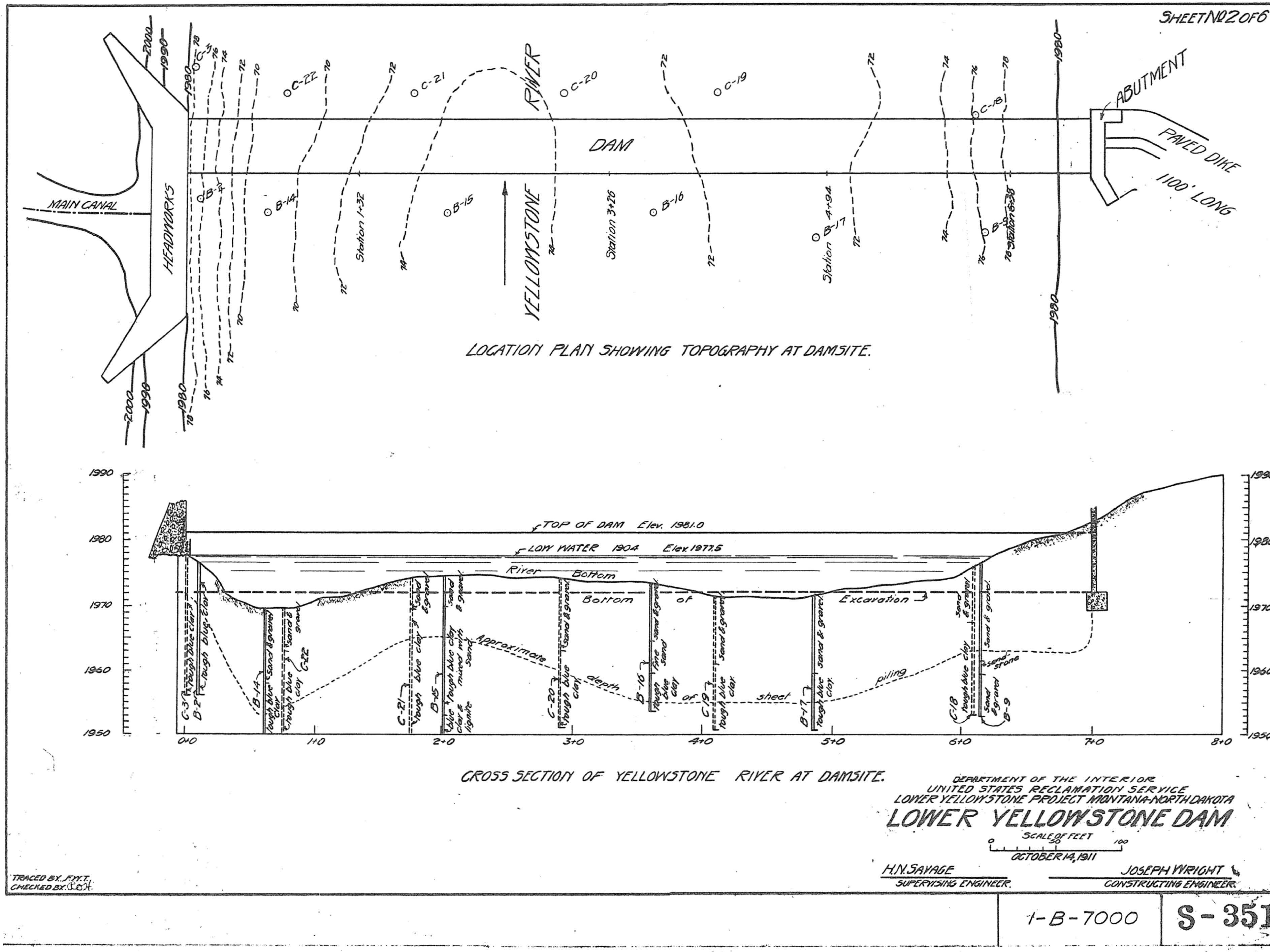
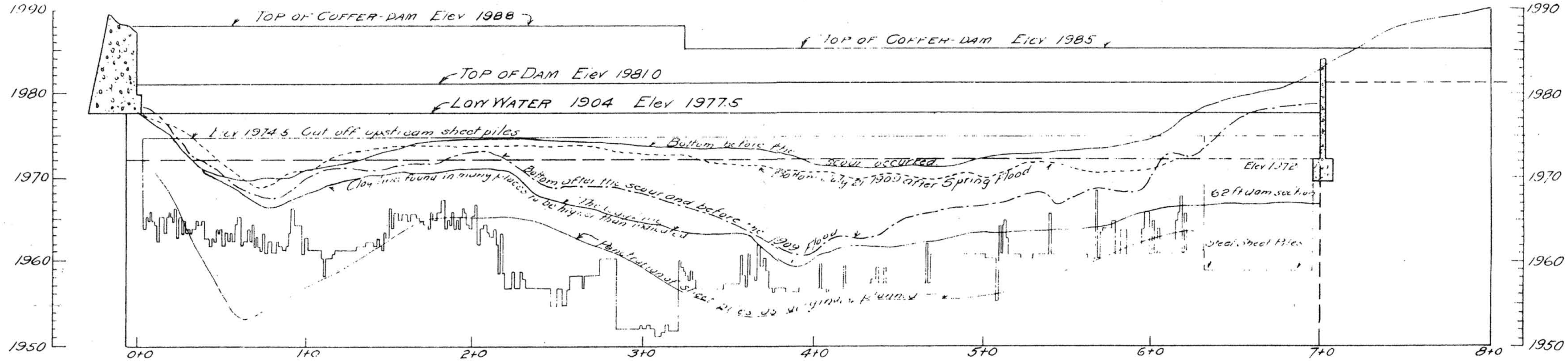

FRAME 4
3
ACCOMPANYING SPECIFICATIONS FOR THE CONSTRUCTION OF THE
ABUTMENT AND DIKE
2000
1990
1980
Top of Dike
Top of Dike
Surface of Ground
Face of Abutment
7+0
8+0
9+0
10+0
11+0
12+0
13+0
14+0
15+0
16+0
18+0
Profile of Island along center line of Dike.
Scales Horizontal 1" = 50' Vertical 1" = 5'
8'-0"
El. 1992.0
Slope 1 on 4
Slope 1 on 4
El. 1972.0
Elevation of Abutment
Scale, 1/8" = 1'
12'-0"
El. 1990.0
Slope 1 on 4
8'-0"
El. 1992.0
Slope 1 on 4
Typical Cross Section of Dike
Scale, 1/4" = 1'
Riprap
Riprap - slope 1 on 4
Top of Dike
Riprap
Riprap - slope 1 on 4
Riprap
200 ft.
Riprap
Slope 1 on 3
Apron of Dam
20'-0"
10'-0"
10'-0"
25'-0"
52'-0"
B
A
Plan of Abutment
Scale, 1/8" = 1'
El. 1992.0
4'-0"
1-1/2" bar in each buttress
Top of Dam
1-1/2" bar in each buttress
El. 1972.0
3'-6"
4'-0"
4'-0"
6"x6"
6" sheet piling
1" bars.
Section of Abutment
Scale, 1/4" = 1'
Slope 1 on 12
Slope 1 on 3
Low Water 1977.5
Cross Section of Riprap on A-B
Scale, 1/4" = 1'
U. S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT DIRECTOR
RECLAMATION SERVICE
F. H. NEWELL CHIEF ENGINEER A. P. DAVIS ASSISTANT CHIEF ENGINEER
FORT BUFORD PROJECT N. DAK.-MONT.
LOWER YELLOWSTONE DAM
PLAN AND DETAILS OF ABUTMENT AND DIKE
SUPERVISING ENGINEER FRANK E. WEYMOUTH PROJECT ENGINEER
CONSULTING BOARD
G. Y. WISNER A. J. WILEY AND H. N. SAVAGE
ACCESSION NO. 6652
57-2
FRAME 2

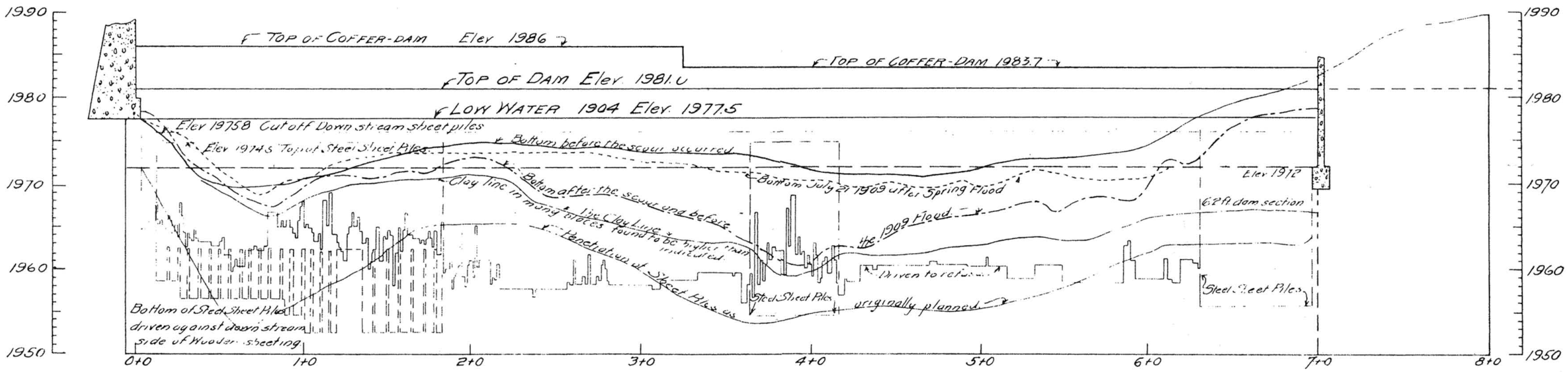
Figure I-5


SHEET No. 2 OF 6
ABUTMENT
PAVED DIKE
1100' LONG
MAIN CANAL
HEADWORKS
DAM
YELLOWSTONE RIVER
C-22
C-21
C-20
C-19
C-18
B-14
B-15
B-16
B-17
B-9
Station 1+32
Station 3+26
Station 4+94
Station 6+38
LOCATION PLAN SHOWING TOPOGRAPHY AT DAMSITE.
TOP OF DAM Elev. 1981.0
LOW WATER 1904 Elev. 1977.5
River Bottom
Bottom of Excavation
Approximate depth of sheet piling
CROSS SECTION OF YELLOWSTONE RIVER AT DAMSITE.
DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
LOWER YELLOWSTONE PROJECT MONTANA-NORTH DAKOTA
LOWER YELLOWSTONE DAM
SCALE OF FEET
OCTOBER 14, 1911
H.N. SAVAGE
SUPERVISING ENGINEER.
JOSEPH WRIGHT
CONSTRUCTING ENGINEER.
TRACED BY F.W.T.
1-B-7000
S-3510

SHEET NO 5 OF 6



UP STREAM LINE OF SHEET PILING



DOWN STREAM LINE OF SHEET PILING

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
LOWER YELLOWSTONE PROJECT MONTANA-NORTH DAKOTA

LOWER YELLOWSTONE DAM

SCALE OF FEET 50 0 50 100

OCTOBER 18, 1911.

Drawn by C.L.B & R.M.B
Traced by R.M.B
Checked by D.H.C.

H.N. SAVAGE
SUPERVISING ENGINEER

JOSEPH WRIGHT
CONSTRUCTING ENGINEER

1-B-7006 | S-3510

Figure I-7

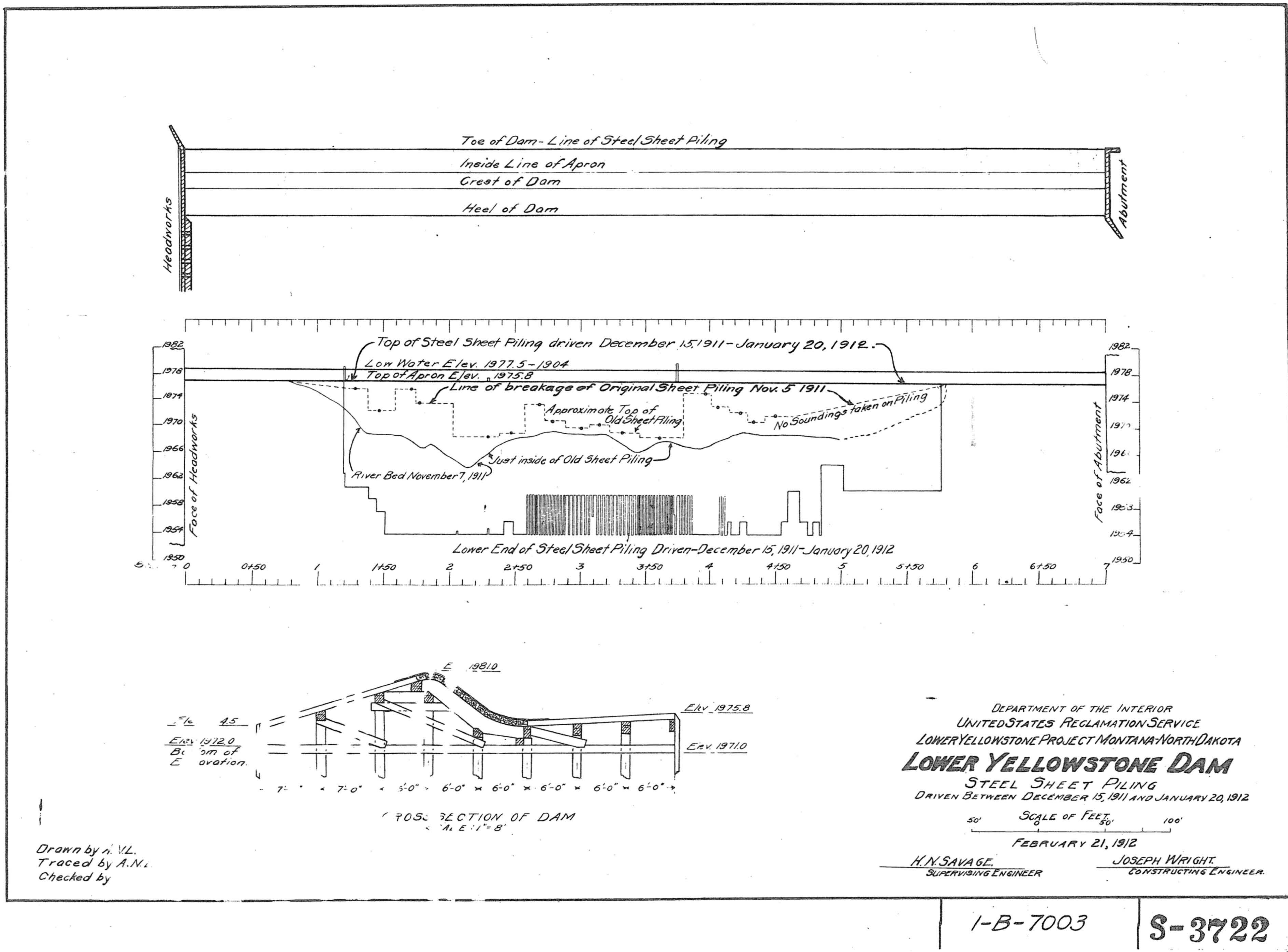
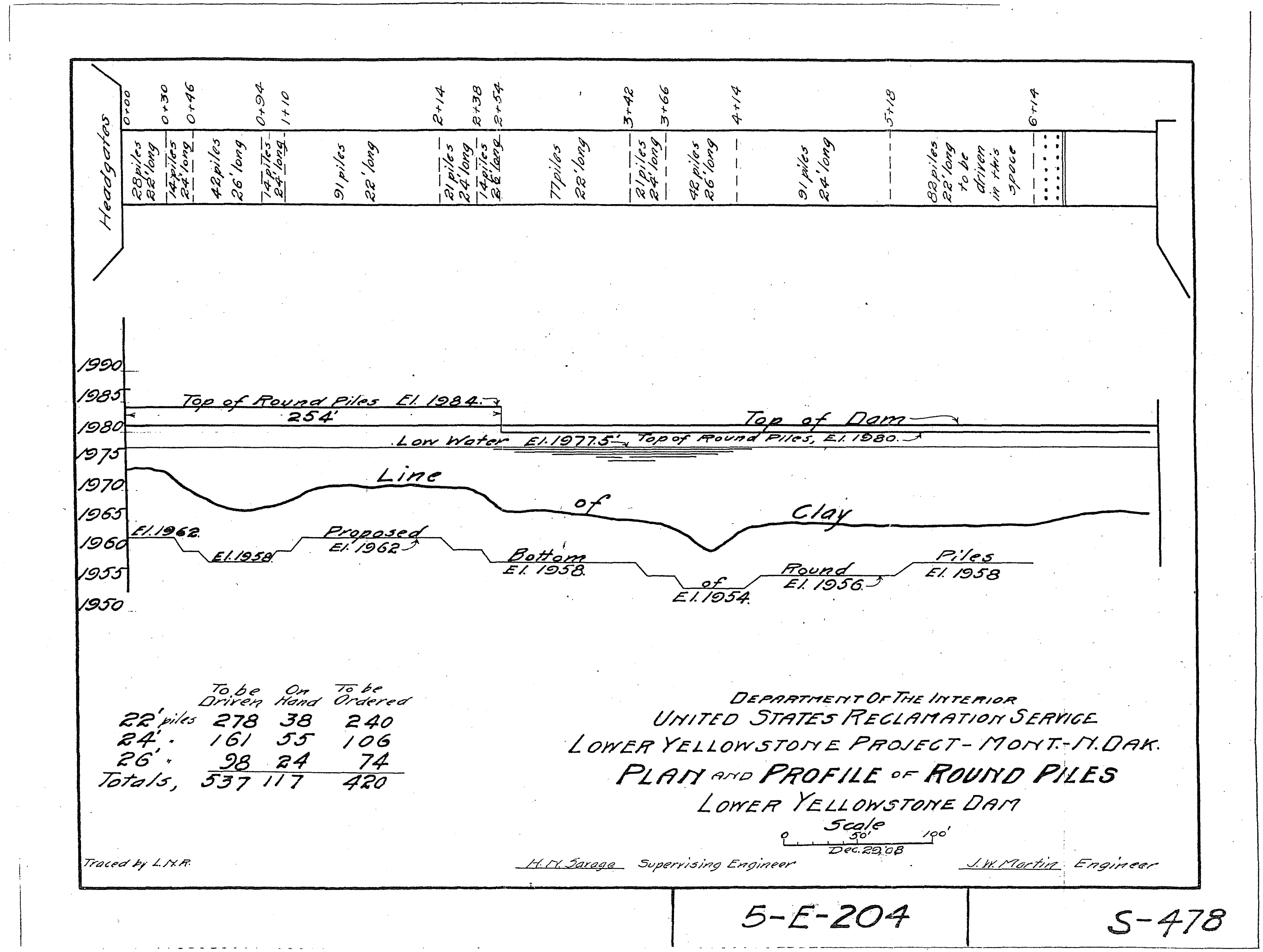

Toe of Dam - Line of Steel Sheet Piling
Inside Line of Apron
Crest of Dam
Heel of Dam
Headworks
Abutment
Top of Steel Sheet Piling driven December 15, 1911 - January 20, 1912.
Low Water Elev. 1977.5 - 1904
Top of Apron Elev. 1975.8
Line of breakage of Original Sheet Piling Nov. 5 1911
Approximate Top of Old Sheet Piling
No Soundings taken on Piling
Just inside of Old Sheet Piling
River Bed November 7, 1911
Face of Headworks
Face of Abutment
Lower End of Steel Sheet Piling Driven - December 15, 1911 - January 20, 1912
Elev. 1975.8
Elev. 1971.0
Cross Section of Dam
Scale: 1" = 8'
DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
LOWER YELLOWSTONE PROJECT MONTANA-NORTH DAKOTA
LOWER YELLOWSTONE DAM
STEEL SHEET PILING
DRIVEN BETWEEN DECEMBER 15, 1911 AND JANUARY 20, 1912
SCALE OF FEET
FEBRUARY 21, 1912
H. N. SAVAGE.
SUPERVISING ENGINEER
JOSEPH WRIGHT.
CONSTRUCTING ENGINEER.
Checked by
1-B-7003
S-3722

Figure I-8


Headgates
0+00
0+30
0+46
0+94
1+10
2+14
2+38
2+54
3+42
3+66
4+14
5+18
6+14
28 piles 22' long
14 piles 24' long
42 piles 26' long
14 piles 24' long
91 piles 22' long
21 piles 24' long
14 piles 26' long
77 piles 22' long
21 piles 24' long
42 piles 26' long
91 piles 24' long
82 piles 22' long to be driven in this space
1990
1985
1980
1975
1970
1965
1960
1955
1950
Top of Round Piles El. 1984.
254'
Top of Dam
Low Water El. 1977.5'
Top of Round Piles, El. 1980.
Line of Clay
El. 1962.
El. 1958
Proposed El. 1962
Bottom El. 1958.
of El. 1954.
Round El. 1956.
Piles El. 1958
To be Driven
On Hand
To be Ordered
22' piles 278 38 240
24' " 161 55 106
26' " 98 24 74
Totals, 537 117 420
Department Of The Interior
United States Reclamation Service
Lower Yellowstone Project - Mont.-N. Dak.
Plan and Profile of Round Piles
Lower Yellowstone Dam
Scale
0 50' 100'
Dec. 29, 08
Traced by L.N.R.
H. N. Savage Supervising Engineer
J. W. Martin Engineer
5-E-204
S-478