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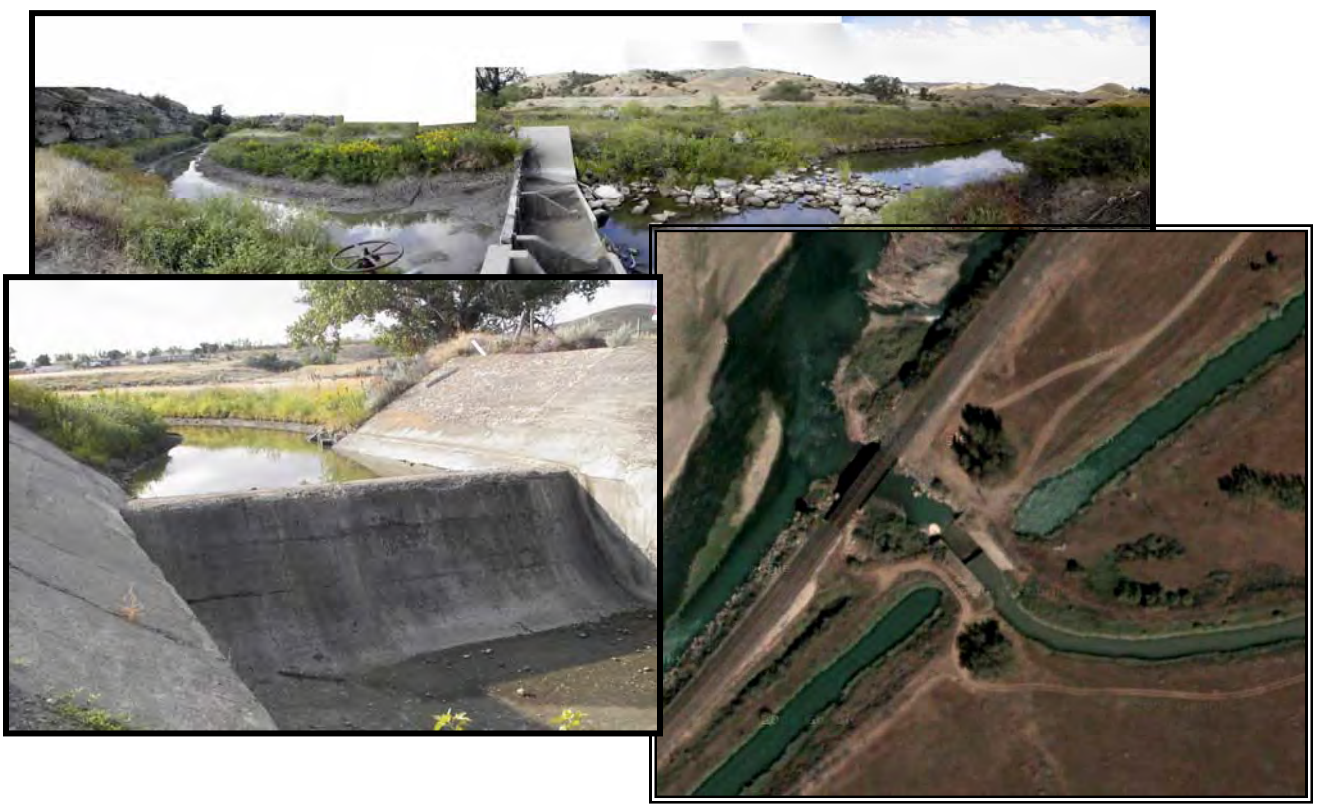
WRRL-PAP Report 0962

Lower Pryor Creek Fish Passage Assessment Study



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Lower Pryor Creek
Fish Passage Assessment Study

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Bureau of Reclamation
Technical Service Center
Water Resources Research Laboratory
Denver, Colorado

May 2007

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Acknowledgments

This report is part of Memorandum of Understanding no. 06AG602167 between the Custer and Yellowstone County Conservation Districts and Reclamation. The Conservation Districts are primary sponsor of the assessment study and have provided both financial and technical assistance. Brent Esplin from the Montana Area Office provided assistance in coordinating the study and funding. Rudy Campbell of the Water Resources Research Laboratory assisted with preparing site drawings.

Hydraulic Laboratory Reports

This report is produced by the Bureau of Reclamation's Water Resources Research Laboratory. (Mail Code 86-68560), PO Box 25007, Denver, Colorado 80225-0007. At the time of publication, this report was also made available online at **http://www.usbr.gov/pmts/hydraulics_lab/pubs/PAP/PAP-0962.pdf**

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PRYOR CREEK FISH PASSAGE ASSESSMENT STUDY

INTRODUCTION

Pryor Creek is a tributary to the Yellowstone River near the town of Huntley, Montana. The Creek drains about 600 sq. miles of lands to the south of the Yellowstone River, (Figure 1). For nearly 100 years, fish passage up Pryor Creek has been blocked by man-made structures. This study looks at fish passage opportunities for two structures located near the mouth of Pryor Creek.

In the early 1900's, the Huntley Canal was constructed to carry water from the Yellowstone River to farms along the valley. The canal crosses nearly perpendicular to Pryor Creek just upstream of the confluence with the Yellowstone River. The canal crosses the creek through a large box culvert (Figure 2). The culvert was designed as a drop structure in the creek with the canal passing at grade. The creek drops approximately 10 ft across the culvert. The drop has blocked upstream fish passage from the Yellowstone River into Pryor Creek since construction. (See photograph reference sheet, p 36)

Several miles upstream a second barrier to upstream fish passage occurs at the Siewert Irrigation Diversion Dam. The weir style diversion dam is about 4.0 ft high (Figure 3). The height of the weir crest can be raised an additional 8 inches using weir boards placed on the weir crest. Irrigation water is diverted into a ditch on the right abutment. A 4-ft-wide sluice is located in the dam near the right abutment. The sluice is used to move sediment downstream away from the irrigation intake. The sluice is opened by removing weir boards. (See photograph reference sheet, p 37)

STUDY OBJECTIVES

This study is designed to provide a preliminary assessment of fish passage opportunities for the structures discussed. There are many alternatives for passage that are not presented herein due to limited site and hydrologic data and information on structure operation. The passage options presented are intended to foster an understanding of the opportunities for passage. Options that would impact structure function or require significant modifications to the existing structures are only mentioned and not developed.

PRYOR CREEK

Pryor Creek is characterized by large variations in flow throughout the year and is subject to periods of no flow in the lower reach. Within the last 100 years, several US Geological Service (USGS) flow measurement stations have been operated at different locations on Pryor Creek. However, little historic data is available in the lower reach where the structures are located. The nearest active station is USGS gage 6216900 entitled "Pryor Creek nr Huntley MT". The gage is located several miles upstream of the Siewert Diversion near where Pryor Creek road crosses Pryor Creek. No attempt was made in this study to identify other diversions or inflows between the USGS gage and the Siewert Diversion. Therefore, flows at the structures may vary significantly from the USGS flow data. For the objectives of this study, the upstream flow data is used as a reference to characterize the range and seasonality of flow for evaluating fish passage alternatives.

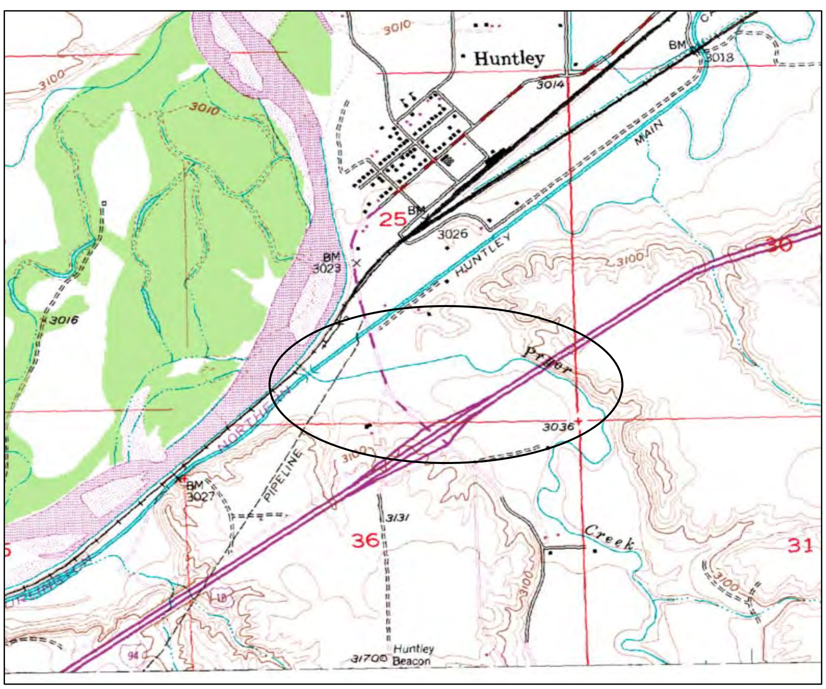

Figure 1 - Location map of Pryor Creek, Montana

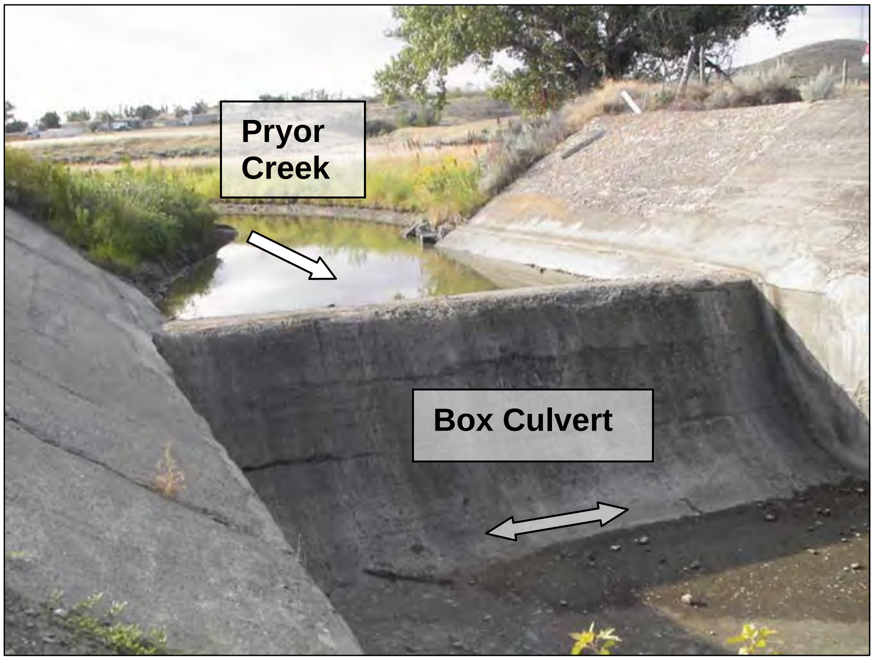

Figure 2 - View of Huntley Canal crossing at Pryor Creek

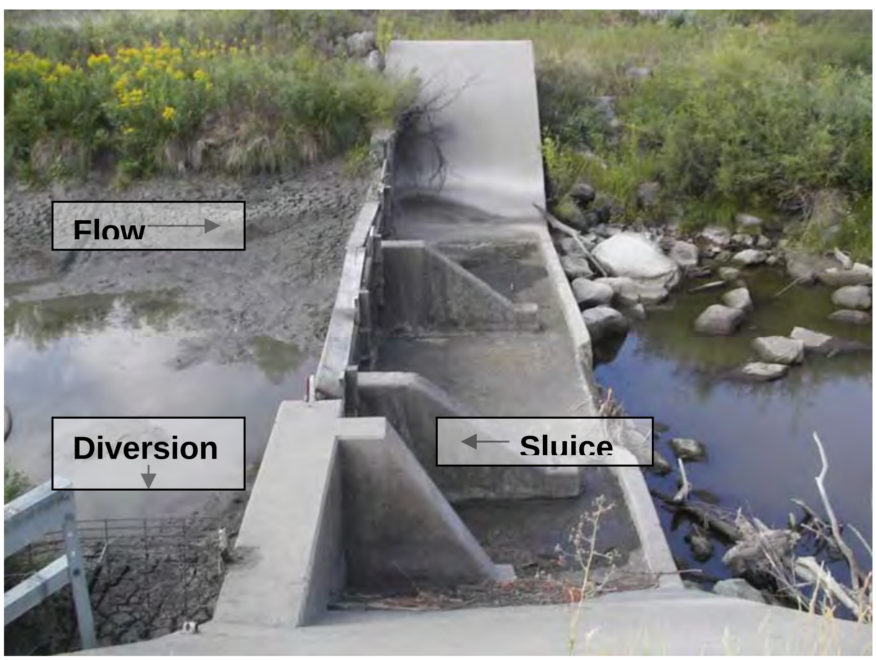

Figure 3 - View of Siewert Diversion Dam on Pryor Creek

HYDROLOGY

To arrive at anticipated flow conditions that the fish passage facilities must operate under, flow exceedance analyses were performed using gage data from USGS Gage Station 6216900 with data collected from the years 1978 to 2000. Average monthly data is presented in Figure 4. In spring and early summer Pryor Creek averages about 100 ft^3/s. Flows declines to about 20 ft^3/s in late summer and then rise to about 50 ft^3/s during winter months. A flow exceedance curve based on average daily flow for the entire year is shown in Figure 5. The exceedance curve shows historical creek flow is greater than 110 ft^3/s 10 percent of the time, greater than 47 ft^3/s 50 percent of the time and greater than 16 ft^3/s 90 percent of the time. The peak average daily flow recorded during the 22 year period of record was 2000 ft^3/s with 44 days of flows greater than 500 ft^3/s.

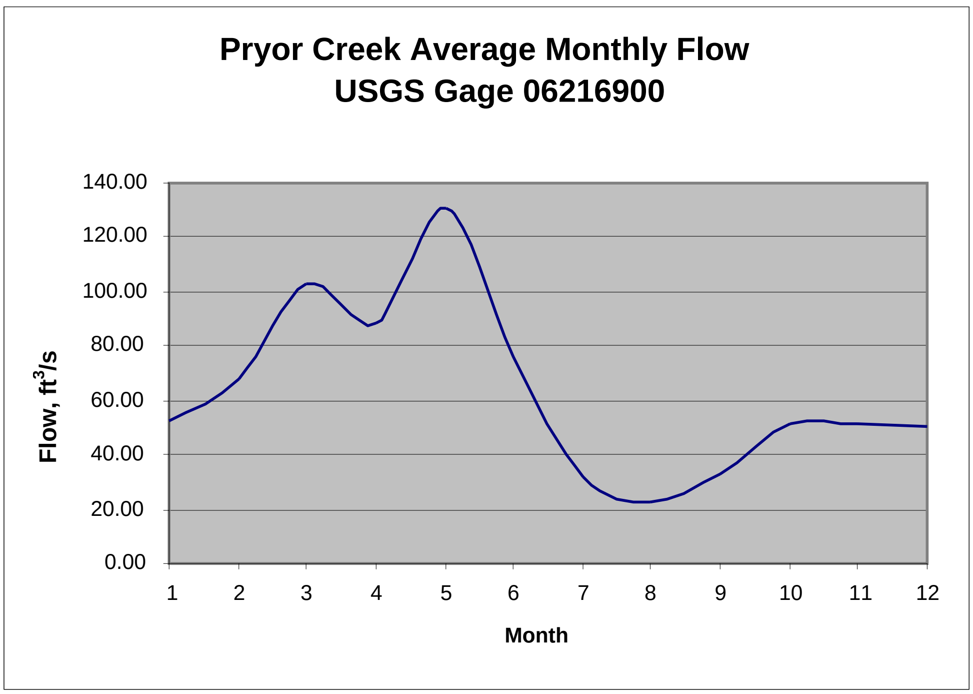

Figure 4 - Average monthly flow in the lower reach of Pryor Creek

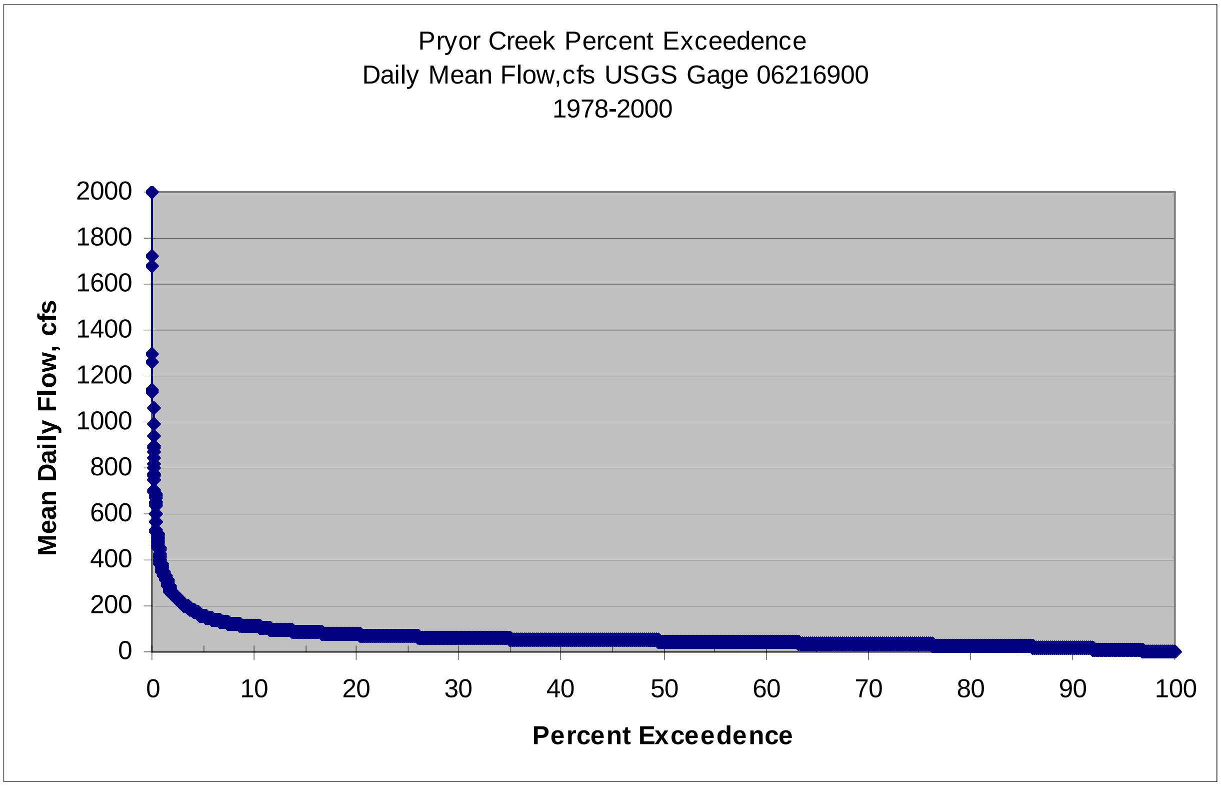

Figure 5 – Mean daily flow exceedance in lower Pryor Creek

FISH SPECIES

The Yellowstone River supports a diverse community of native and non-native fish species. A good representation of the fish community in the Yellowstone River near the confluence of Pryor Creek is documented in a study of entrainment losses to the Huntley Canal conducted by Reclamation in 2003. Table 1 lists the species that were collected during the study. It is likely, many of these species would utilize Pryor Creek for habitat, foraging or spawning if accessible.

Table 1. List of fishes collected at Huntley Diversion, Montana (2003)

Common name	Scientific name	Family	Native
Goldeye	Hiodon alosoides	Hiodontidae	x
Western Silvery Minnow	Hybognathus argyritis	Cyprinidae	x
Brassy Minnow	Hybognathus hankinsonidae	Cyprinidae	x
Fathead Minnow	Pimephales promelas	Cyprinidae	x
Longnose Dace	Rhinichthys cataractae	Cyprinidae	x
Common Carp	Cyprinus carpio	Cyprinidae	
Flathead Chub	Platygobio gracilis	Cyprinidae	x
Emerald Shiner	Notropis atherinoides	Cyprinidae	x
Mountain Sucker	Catostomus platyrhynchus	Catostomidae	x
Longnose Sucker	Catostomus catostomus	Catostomidae	x
White Sucker	Catostomus commersoni	Catostomidae	x
Shorthead Redhorse	Moxostoma macrolepidotum	Catostomidae	x
River Carpsucker	Carpiodes carpio	Catostomidae	x
Channel Catfish	Ictalurus punctatus	Ictaluridae	x
Stonecat	Noturus flavus	Ictaluridae	x
Yellow Bullhead	Ictalurus natalis	Ictaluridae	
Bluegill	Lepomis macrochirus	Centrarchidae	
Pumpkinseed	Lepomis gibbosus	Centrarchidae	
Largemouth Bass	Micropterus salmoides	Centrarchidae	
Smallmouth Bass	Micropterus dolomieui	Centrarchidae	
Crappie	Pomoxis spp.	Centrarchidae	
Green Sunfish	Lepomis cyanellus	Centrarchidae	
Brown Trout	Salmo trutta	Salmonidae	
Rainbow Trout	Oncorhyncus mykiss	Salmonidae	
Mountain Whitefish	Prosopium williamsoni	Salmonidae	x
Burbot	Lota lota	Gadidae	x
Brook Stickleback	Culaea inconstans	Gasterosteidae	x
Walleye	Stizostedion vitreum	Percidae	

SWIMMING ABILITY OF LOCAL FISH SPECIES

Swimming ability of some Yellowstone River fish species are given in Table 2. Sustained swimming speed is generally defined as the maximum sustained swimming speed for durations of several minutes. Burst speed is typically defined as short term, <15 sec duration, maximum attainable swimming speed. Fishways are generally designed to provide passage in which fish use a combination of sustained and burst swimming modes.

Table 2 - **Swimming performance estimates for several species found in the Yellowstone River near Huntley, Montana.**

Fish Species	Maturity	Sustained Swimming Speed, ft/s	Burst Speed ft/s
Brown Trout	adult	7	12
Shovelnose Sturgeon	adult	1.8	5.4*
Longnose Sucker	adult	4	8
Sauger	adult	1.5	4.5*
Goldeye	adult	2.2	6.6*
Mountain sucker	adult	5	8
White sucker	adult	2	4
Burbot	adult	1.5	4
Whitefish	adult	5	10
Walleye	adult	4	10*
Chub	adult	2.5	5*

* Burst speeds are estimated

FISHWAY OPTIONS

Two fishway options were developed to the assessment level and are presented herein for each structure. Two in-channel fish passage alternatives are presented for the Huntley canal crossing. These are a Denil Fishway and a rock ramp with boulder drops. Two bypass fishway alternatives are presented for the Siewert Diversion Dam. These are a riprap lined bypass channel with boulder weirs and a fishway flume with vertical slot style baffles. Several examples of similar fishways that have been successfully used for passage of non-salmonids are presented as background.

ROCK FISHWAYS

Rock fishways are either constructed channels that bypass a portion of the river flow around a dam or an in-river rock ramp that provides a low gradient path over a dam. Rock fishways are often chosen because they provide good opportunity for multi-specie passage due to the variability of flow conditions across the channel. Rock fishways may be designed as simple prismatic channels of constant bed slope or include features such as meanders, pools and riffles or boulder weirs. As in a natural stream, fishway flow velocity is controlled by stream gradient, bed roughness, channel hydraulic radius, and large scale flow obstructions. These parameters are related in the well known Manning's Formula for uniform flow in an open channel as:

$$V = \frac{1.49}{n}[R^{\frac{2}{3}}S^{\frac{1}{2}}] \qquad (1)$$

where: V = average flow velocity, ft/s
n = Manning's coefficient of roughness
R = channel hydraulic radius, ft (ratio of water area to wetted perimeter)
S = slope of the energy grade line

The Manning's coefficient of roughness is a semi-empirical coefficient. Cowan (1956) further describes the coefficient as:

$$n = (n_0 + n_1 + n_2 + n_3 + n_4)m_5 \qquad (2)$$

where: n_0 is a function of bed material,

n_1 is a function of channel cross section irregularity,

n_2 is a function of variation in channel cross section,

n_3 is a function of degree of large scale obstructions,

n_4 is a function of aquatic vegetation within the channel and

m_5 is a function of degree of channel meander.

Values for computing *n* in equation *2* can be found in Chow (1959). For a rock lined fishway, Manning's *n* typically is in the range of 0.035 to 0.05.

Equation 1 defines channel flow velocity as a function of channel geometry, bed roughness and slope. For a straight prismatic channel of constant bed roughness and slope, flow velocity varies as a function of the hydraulic radius (area / wetted perimeter) to the ⅔ power. Therefore, a wide shallow channel will convey flow at a lower average velocity than a square shaped channel of similar wetted cross section. Velocity is also a function of the energy slope to the ½ power. Energy slope and channel slope are similar for flow at normal depth. Rock fishway channel slopes typically range from less than 1 percent to 3 percent slope.

Fishway flow velocity can also be varied by adding attributes that create gradually or rapidly varied flow conditions (pools, riffles and drops). In varied flow, depth and velocity vary along the channel length. Examples of attributes that create varied flow in rock fishways are changes in channel slope, bottom depressions or flow obstructions, like boulders. Recent examples of rock fishway designs on Reclamation projects are listed in Table 3.

Table 3 - **Rock fishways designed for non-salmonid passage.**

Type	Fishway	Elevation Gain, ft	Fishway Slope, %	Status
Rock Ramp or Channel	Marble Bluff Dam, Truckee River near Nixon, Nv.	1.5	0.3	Constructed in 1998
Rock Channel with Pool and Riffle	Pyramid Lake Fishway, Experimental Bypass Channel	12	0.58/1.4 0.96/1.6 (pool/riffle)	Constructed in 1996
Rock Channel with Pool and Riffle	Grand Valley Irrigation Company Diversion Dam, Colorado River Grand Junction, Co.	5	0.9/1.3	Constructed in 1997
Rock Channel with Boulder Weirs	Huntley Diversion Dam, Yellowstone River, Billings, Montana	8	1.8/3.9	Constructed in 1999
Rock Channel with Boulder Weirs	Derby Diversion Dam, Truckee River, Reno, Nevada	17	1.8	Constructed in 2003
Rock Channel with Boulder Weirs	PNM Diversion Dam, San Juan River, Farmington, New Mexico	12	1.6	Constructed in 2004

Rock Fishway Examples

Huntley Diversion Dam Fishway - In 1999, the Huntley Irrigation District constructed a rock channel fishway with boulder weirs on the left abutment of Huntley Diversion Dam. The fishway was designed to pass salmonids and many warm water fish species. The fishway, Figure 6, is a riprapped trapezoidal channel designed at a 1.8 percent grade with boulder arrays spaced every 20 ft. The fishway was constructed in the fall of 1999. The fishway has not provided effective passage for some non-salmonids due to a break in grade during construction. The downstream third of the channel was constructed at a grade several times design. The difference in flow velocity in the upstream channel constructed at grade and the downstream channel is shown in Figure 6.

Figure 6 - View looking upstream at Huntley fishway fishway exit. **View looking downstream at fishway entrance.**

Derby Diversion Dam Fishway - A rock channel and boulder weir fishway was constructed at Derby Diversion Dam located on the Truckee River downstream of Reno, Nevada (Figure 7). The fishway is designed to pass cui-ui lake suckers and Lahontan cutthroat trout which are migratory spawners and resident fish species. The fishway is about 900 ft long at a slope of 1.8 percent. Boulder weirs are spaced 20 ft apart to create upstream pools will chute flow between boulders. The fishway has a trapezoid shape with a 4 ft wide bottom and 2:1 side slopes.

Figure 7 - Photographs of Derby Diversion Dam rock channel and boulder weir fishway.

VERTICAL SLOT FISHWAYS

A vertical slot fishway uses a series of baffles with vertical slots in each baffle. The baffles are designed to create backwater pools between baffles and higher velocity flow through the baffle slots. The vertical slots allow passage at nearly all depths within the water column and can operate over a relatively large range of flows and river stage. Vertical slot fishways are typically constructed at 3 to 5 percent grade for non-salmonids and 10 percent grade for salmonids.

Vertical Slot Fishway Example

Redlands Diversion Dam Fishway - Redlands Fishway is located adjacent to Redlands Diversion Dam on the Gunnison River near Grand Junction, Colorado. The fishway was constructed to assist in the recovery of Colorado pikeminnow (Ptychocheilus lucius) and razorback suckers (Xyrauchen texanus) native to the Colorado River system. The fishway was designed on a 3.75 percent grade with vertical slot and orifice baffles spaced every 6 ft, (Figure 8). The total elevation difference across the ladder is about 10 ft. The ladder has been operating since 1996. A fish trap is operated at the top of the fishway to monitor fish passage and control upstream passage of some non-native species. Trap results from 1996 through 1998 show between 7,000 and 11,500 native fish including bluehead suckers (Catostomus discobolus), flannel mouth suckers (Catostomus latipinnis), roundtail chub (Gila robusta) and Colorado pikeminnow passed through the fishway each year (Burdick, 2001). The predominant fish species passing through the fishway have been bluehead and flannel mouth suckers.

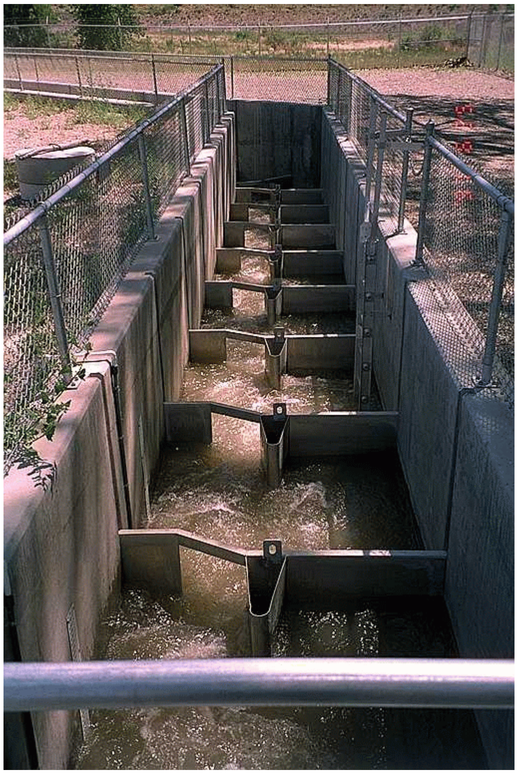

Figure 8 – Redlands Diversion Dam Fishway

DENIL FISHWAYS

Denil fishways use closely spaced baffles to create strong turbulence and rapid energy dissipation to control flow velocity (Figure 9). At a given depth, flow velocity is nearly constant along the chute while varying sharply with depth. Lowest velocities occur near the chute invert. The Denil design requires fish pass by swimming the length of the chute in a single burst. For long ladders, intermediate resting areas are used. Denil fishways are typically set at slopes of 10 to 15 percent.

Examples of Denil Fishways

<u>Fairford and Cowan Lake Fishways</u> Prototype studies of two Denil ladders on the Fairford River, Manitoba and Cowan Lake, Saskatchewan (Katopodis et al.,1991) found the ladders provided effective passage for sauger, walleys, white suckers, and other resident fish spieces. The Denil ladders at Fairford and Cowan slope at 12% with run lengths of between 15 and 30 ft (Figure 9). The ladders have a total elevation drop of about 7 ft. At Fairford, velocities in the weir chutes varied from about 4.5 ft/s at 0.6 depth to about 2.3 ft/s at 0.2 depth. Slightly higher velocities were measured at Cowan. The velocities are above reported sustained swimming velocities of many species using the ladders. However, velocities were below burst swimming speeds. Weak swimmers were assumed to pass up the Denil ladders by following the lowest velocity zone at about one-third depth. Nearly all documented fish using the ladders were adults. Katapodis's study did not compare ladder usage to downstream fish populations. Therefore, the study results do not clearly show the overall effectiveness of the ladders. A previous Canadian study by Schwalme and Mackay (1985), of two Denil ladders and a vertical slot ladder found similar results to Katopodis's. The Schwalme and Mackay study also found juveniles and weaker swimmers appeared to prefer the vertical slot ladder.

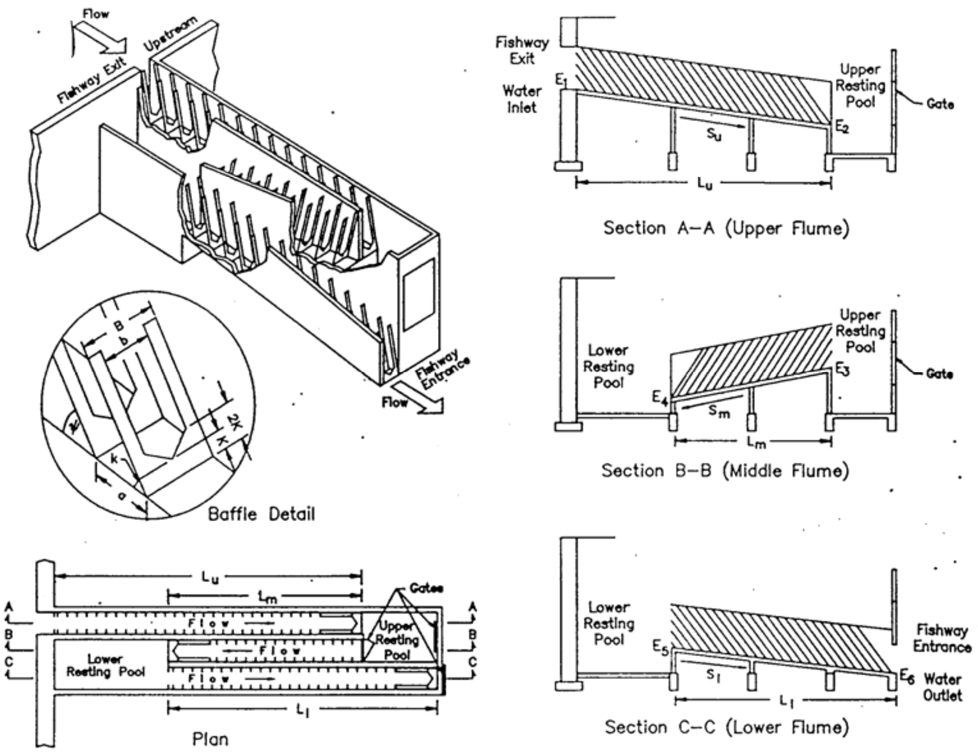

Figure 9 - Drawing of Denil fishway for Fairford River, Katapodis.

PRYOR CREEK AT HUNTLEY CANAL CROSSING FISH PASSAGE OPTIONS

A limited survey of the major site features was conducted for this study. Plan and sections showing the site are given in Figure 10. Two in-channel fish passage alternatives are presented for the Huntley Canal crossing. Fishway structures constructed in-channel were selected as they minimize modifications to the existing drop structure. The fish passage options presented are a Denil fishway and a rock ramp with boulder drops. Other options that could be considered but are not presented in detail herein are; replacing the drop structure with an inverted siphon that passes the canal under the stream or constructing a technical fishway (concrete flume with baffles) in the downstream channel bank. Replacement of the existing box culvert with an inverted siphon would remove the fish barrier. However, several issues need to be investigated and resolved before this option could be implemented. The primary issue is the Huntley Project Irrigation District diverts water from Pryor Creek into the Huntley Canal to supplement the primary diversion from the Yellowstone River. The diversion is made by gravity from Pryor Creek into the canal immediately upstream of the existing stream crossing. Replacing the box culvert and associated drop would impact the ability to gravity divert flow. Reclamation, along with the Huntley Project Irrigation District, filed a water right claim in the general stream adjudication process for the diversion. Another issue relates to potential impacts to the operation of the canal. An inverted siphon would introduce additional head loss into the canal system that may negatively impact operation of the canal. Additional data will be required to assess the potential impact to canal operations.

Removal of the existing box culvert has the potential to impact the gradient of Pryor Creek as it exists today. It is likely that some grade control measures would be required to prevent head cutting on Pryor Creek. Additional study related to assessing the impacts to the gradient of the channel would be required and are not included in this assessment. Estimated costs of replacing the box culvert with an inverted siphon are not included in this assessment, but may be completed as part of additional work related to this project.

Denil Fishway Option

Denil fishways are used extensively in the eastern United States. Although they are used primarily for strong-swimming fish, studies have shown they can also pass many non-salmonid species. The advantages of Denil fishways are; they can be used at slopes approaching 15 percent, they typically have a small cross section, require smaller flows than other fishways and can be constructed from metal, concrete or treated wood. The disadvantages are they are susceptible to debris fouling and they may not be effective at passing smaller-bodied fish due to the high level of flow turbulence that is generated by the baffles. A conceptual layout of a Denil fishway constructed along the left bank of the Huntley Canal crossing is shown in Figure 11. The fishway shown has two runs sloping at 8 degrees (14 percent) linked by a horizontal section that provides a rest area. Rock is shown placed adjacent to the fishway entrance. The rock forms an upstream sloping ramp that acts as a velocity barrier, preventing further upstream fish movement. The crest of the drop structure would be saw cut to a level surface where the fishway flume passes over the crest. Assuming a fish capable of swimming at a burst speed of 4 ft/s and a minimum fishway velocity of 2 ft/s, the fish would have to maintain the burst for about 12 seconds to pass through a 25 ft long run. The Denil fishway sections would be prefabricated off-site then installed and anchored to vertical supports on-site. The construction cost of the Denil fishway constructed from metal or treated wood, is estimated to be in the range of $25,000 to $40,000. In the judgment of the author, the Denil fishway shown would provide passage of larger-bodied adults. Passage could be improved through the Denil fishway by reducing the flume slope closer to 10 percent and reducing the length of the runs to around 15 feet. Constructing a longer Denil fishway would likely require part of the fishway be constructed in the bank of the drop structure. A layout for a multiple-run Denil fishway would be similar to that shown in Figure 9. Construction cost of a multiple-run fishway would likely be two to three times the cost of the linear design presented.

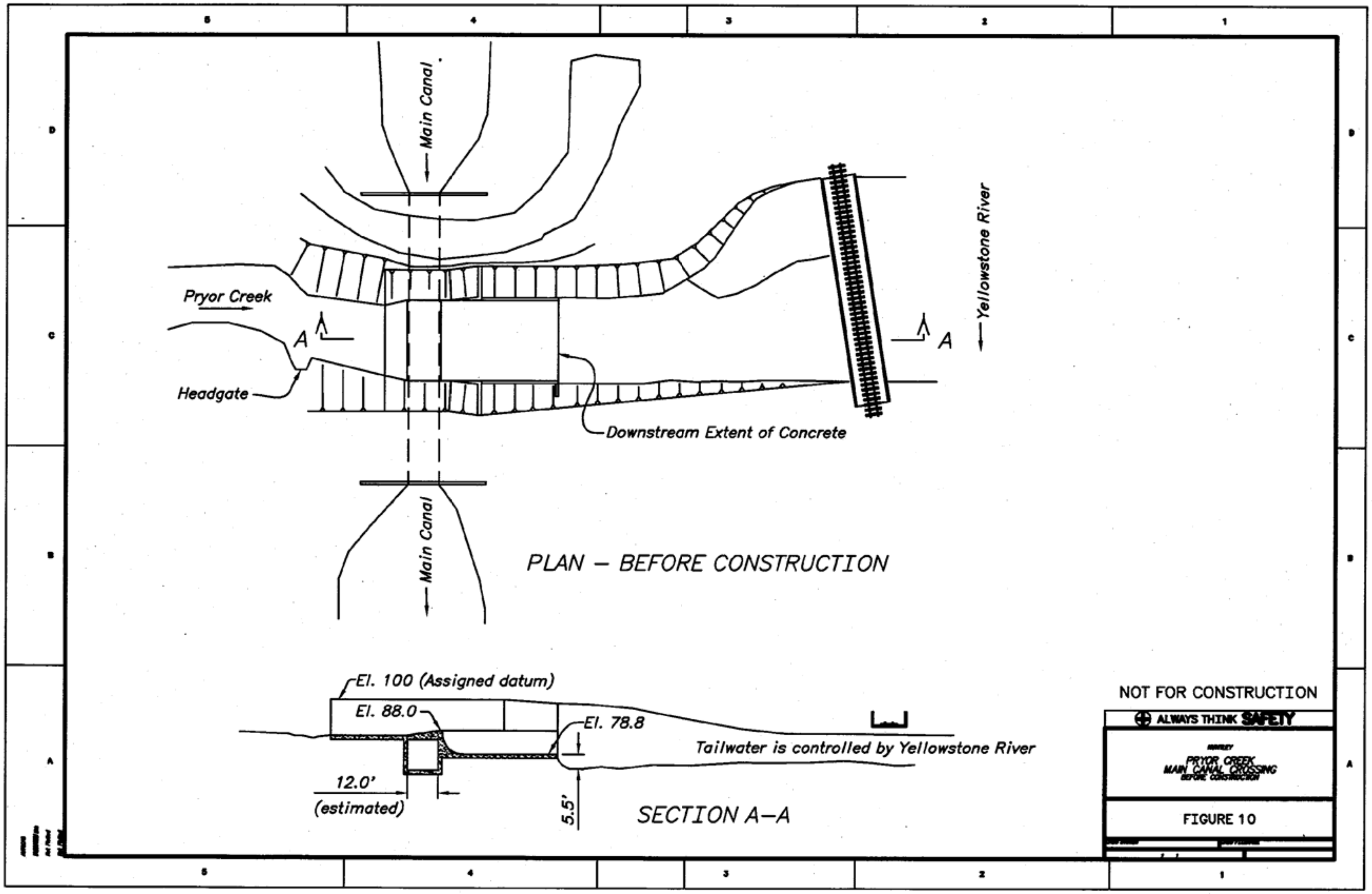

Figure 10 – Plan and sections for Huntley Canal crossing at Pryor Creek

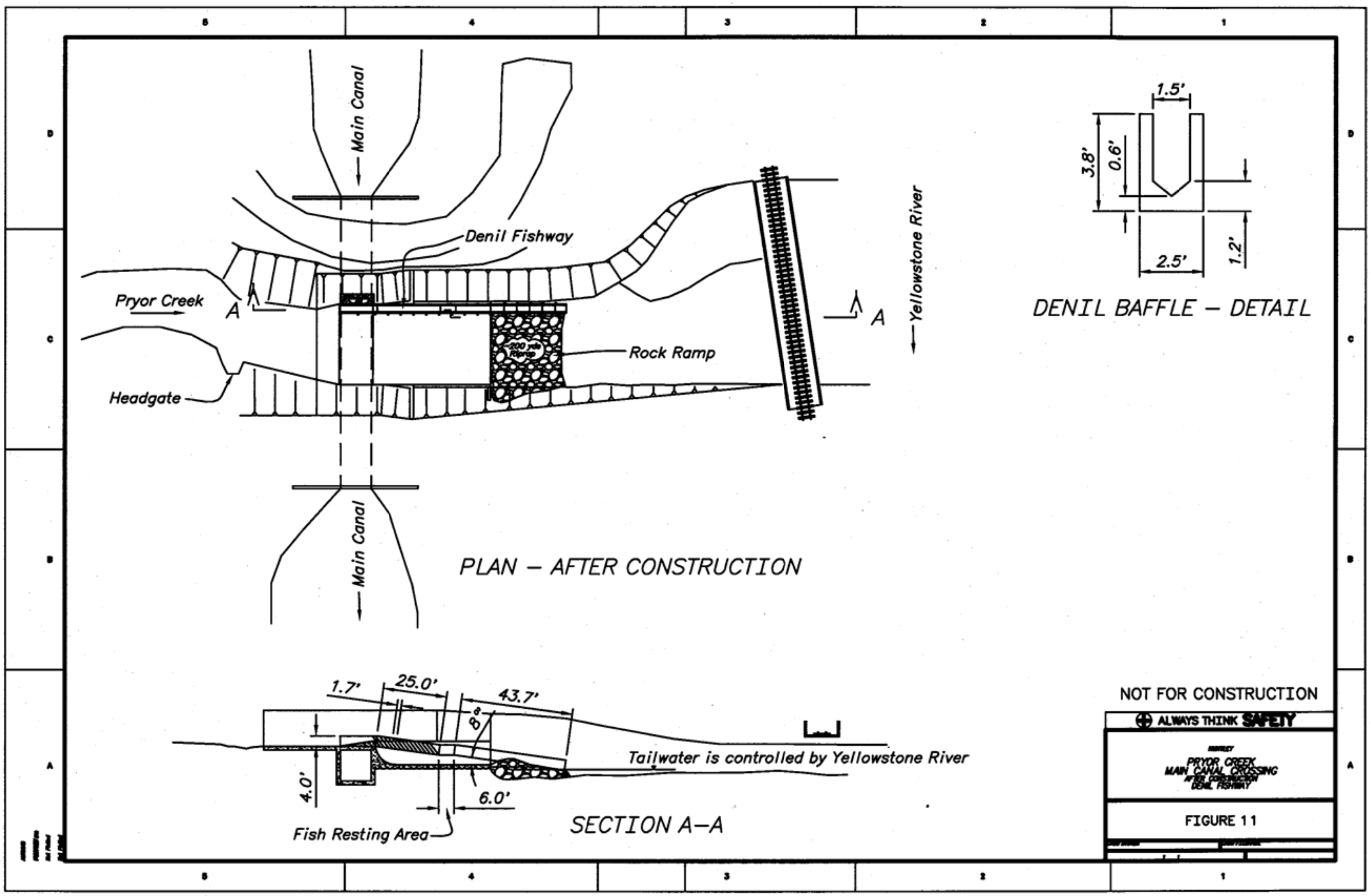

Figure 11- Plan and sections of a Denil Fishway option, Huntley Canal crossing at Pryor Creek

Rock Ramp with Boulder Drops Fishway Option

A rock ramp with boulder drop fishway emulates a steep natural riffle. These types of fishways use a series of boulder drops constructed in the channel on the downstream side of the passage barrier. The boulder drops are arched upstream for structure stability and to obtain a laterally-variable flow across the boulder drops. The arch shape concentrates flow and velocity toward the center of the channel. Less flow and lower flow velocity occurs near the channel banks. An example of a rock ramp and boulder drop design for Kidder Dam Rapids on the Red River is shown in Figure 12. An example of this type of fishpass constructed downstream of the Huntley Canal crossing is presented in Figure 13. The existing drop would be converted to ten drops of approximately 1 ft each. The advantages of a rock ramp are; they allow passage over the full channel width for strong swimmers, provide lower velocity passage near both banks for weaker swimmers, and the rock lined channel and boulders provide greater flow variability for fish to search and choose preferred flow conditions for passage. The occurrence of high flows in Pryor Creek would require the structure be constructed using boulders on the order of 3 to 5 ft diameter bedded in well graded two-ft-minus riprap material. Construction of the rock ramp would require about 1000 cubic yards of riprap and 250 boulders. Note, estimates of material quantities and costs are presented based on assessment-level data. The size of the downstream scour hole and the quality of the existing stream bed are not documented. Construction of similar types of rock ramps generally cost from $50 to $120 a cubic yard for riprap and $80 to $150 a boulder. Material haul distance is a major influence on cost. Construction of the rock ramp presented using an average of the above costs would be $ 115,000.

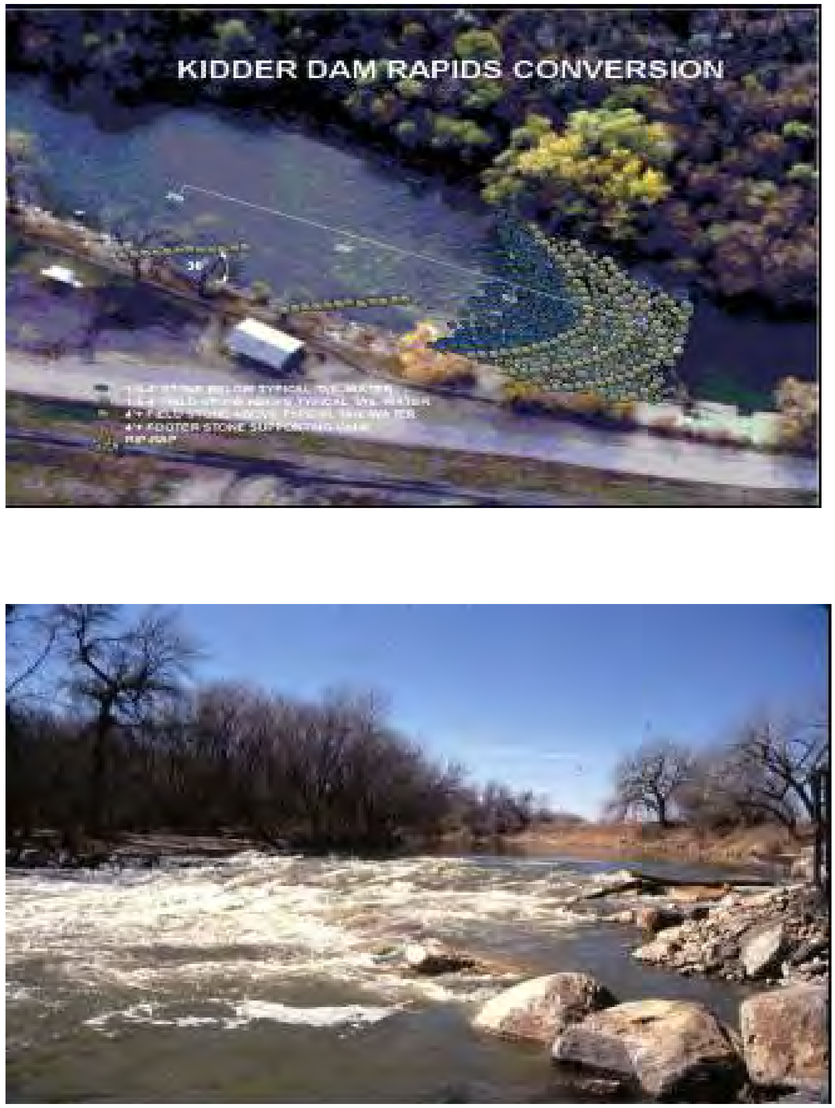

Figure 12 – Kidder Dam Rapids on the Red River of the North, L. Aadlund (American Rivers)

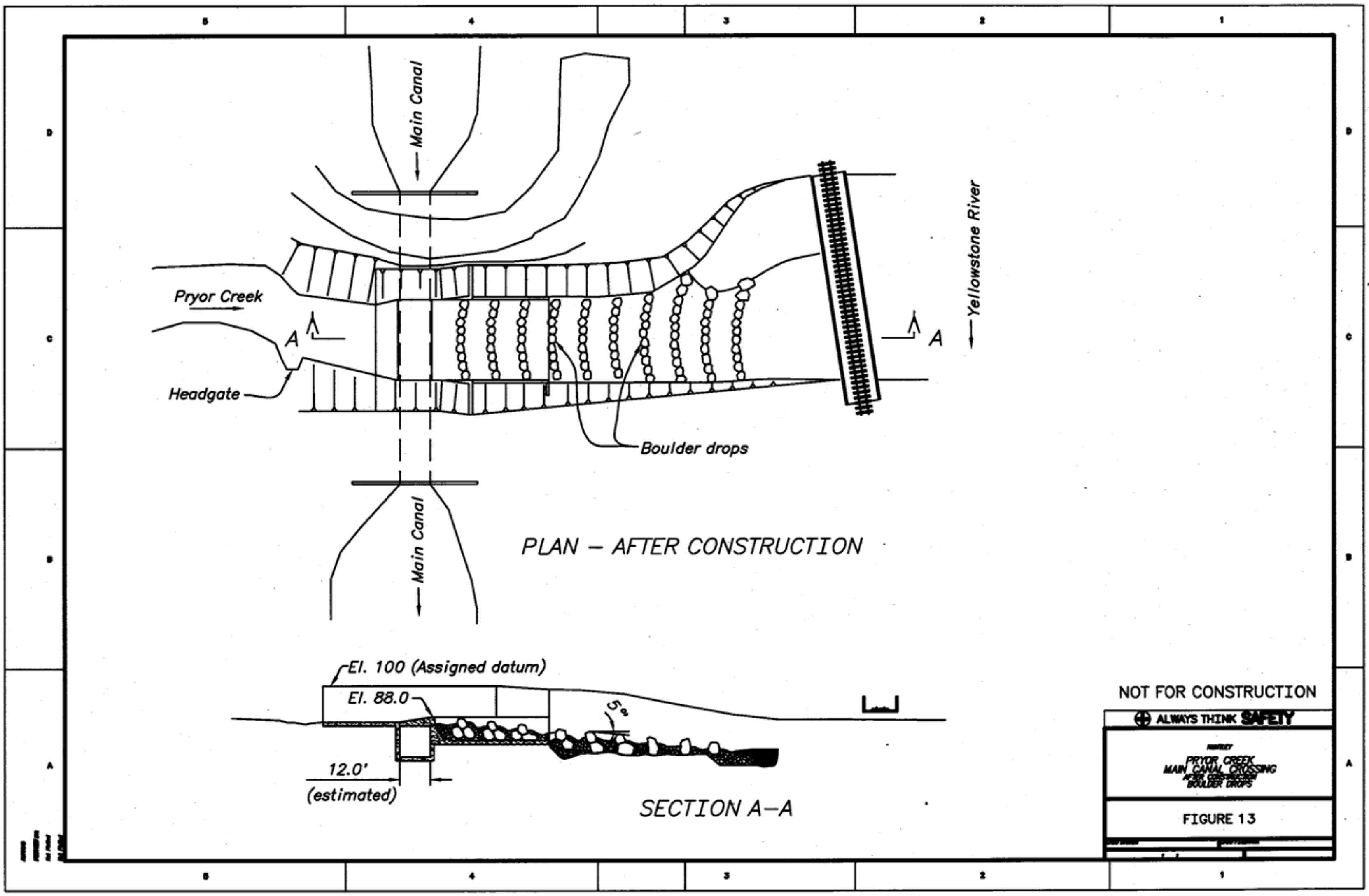

Figure 13 – Plan and sections of a rock ramp with boulder drops fishway option, Huntley Canal crossing on Pryor Creek

SIEWERT DIVERSION DAM AT PRYOR CREEK

Plan and sections for the Siewert Diversion Dam are given in Figure 14. Two fish passage bypass channel alternatives are presented for Siewert Diversion Dam. Bypass fishway structures were selected for this site due to low flow requirements of a bypass fishway, the relatively low bank heights at the site and the close proximity of an upstream bend in the stream. It should be noted, this assessment report was prepared without information on diversion water allocations, detailed site survey or tailwater versus flow data. These data would be required before final selection and design of a preferred fish pass alternative could be initiated. Discussions with the diverter are needed to evaluate if and under what conditions a bypass fishway would be closed to ensure water delivery to the diversion.

Fish passage options similar to those presented for the Huntley Canal crossing could also be applied at the site. Ideally, an in-channel rock ramp would be constructed at a grade of 5 percent or less with drops of 0.5 ft or less. The rock ramp would be about 100 ft long by 50 ft wide. The weir-board-sluice located near the right abutment would be replaced by a gate and downstream pipe that passes through the rock ramp.

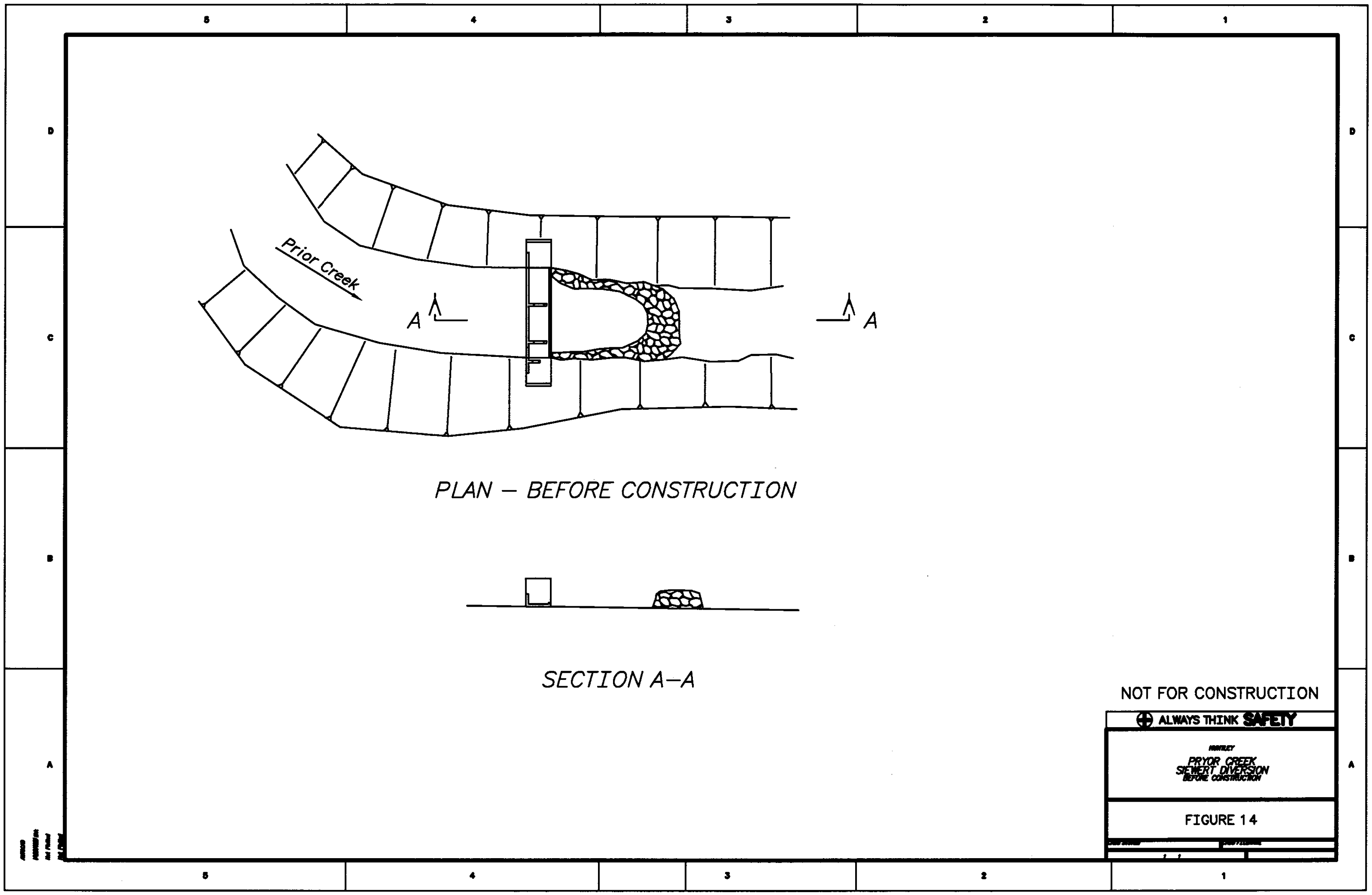

Figure 14 – Plan and sections of Siewert Diversion Dam on Pryor Creek

Rock Channel with Boulder Weirs Option

A rock channel fishway bypassing the diversion on the left abutment is shown on Figure 15. The minimum bypass channel would be about 130 ft long and contain a minimum of 10 boulder weirs spaced at about 14 ft intervals along the fishway. The fishway length and number of boulder weirs could increase if needed to facilitate site conditions. As shown, each boulder drop would provide a water surface drop across the weirs of 0.4 ft. The fishway would slope at a constant 3 percent along its length. The upstream fishway exit would be set about 0.5 ft below the diversion weir crest and the downstream fishway entrance would be set 0.5 ft below the no-flow tailwater level. A stream water surface elevation at the weir crest would result in the fishway bypassing about 5 ft^3/s flow. The fishway would bypass approximately15 ft^3/s during a stream flow of approximately 130 ft^3/s. If required, a gate structure can be constructed at the upstream fishway exit to shut off fishway flow during periods of low stream flow to protect diversion water rights. A small rock ramp would be constructed downstream of the diversion structure to maintain sufficient tailwater on the fishway entrance during low stream flows. The rock ramp would be constructed approximately in the present location of a scour deposit downstream of the diversion, (Figure 13). A rock fishway with boulder weirs without an upstream gate is estimated to cost in the range of $25,000 to $40,000. Including an upstream gate with concrete entrance structure would approximately double the fishway cost.

Vertical Slot Fishway Option

A vertical slot style fishway constructed around the left abutment of the diversion is shown on Figure 16. The fishway would consist of a 75-ft-long by 6-ft-wide concrete flume constructed on a seven percent slope around the left abutment. The flume would contain 11 vertical slot style baffles, each providing a maximum of 0.5 ft of water surface drop. The baffles would be positioned on 6 ft centers along the length of the fishway. Fishway flow would be about 2.1 ft^3/s at a minimum operating depth of 0.5 ft. In the normal operating range of 1 ft to 3 ft deep, the fishway would pass 4.2 ft^3/s and 12.5 ft^3/s, respectively. These fishway flow depths would correspond to stream flows of about 50 ft^3/s and 500 ft^3/s, respectively. The fishway exit would set 0.5 ft below the weir crest and the fishway entrance would set about 2 ft below the downstream concrete apron. A coarse trashrack would be placed at the upstream exit to prevent large debris from entering the fishway. A gate or stoplogs could be provided at the fishway exit to shut off fishway flow. The construction cost of the vertical slot fishway shown with upstream stoplogs and wood baffles is estimated to cost in the range of $35,000 to $50,000.

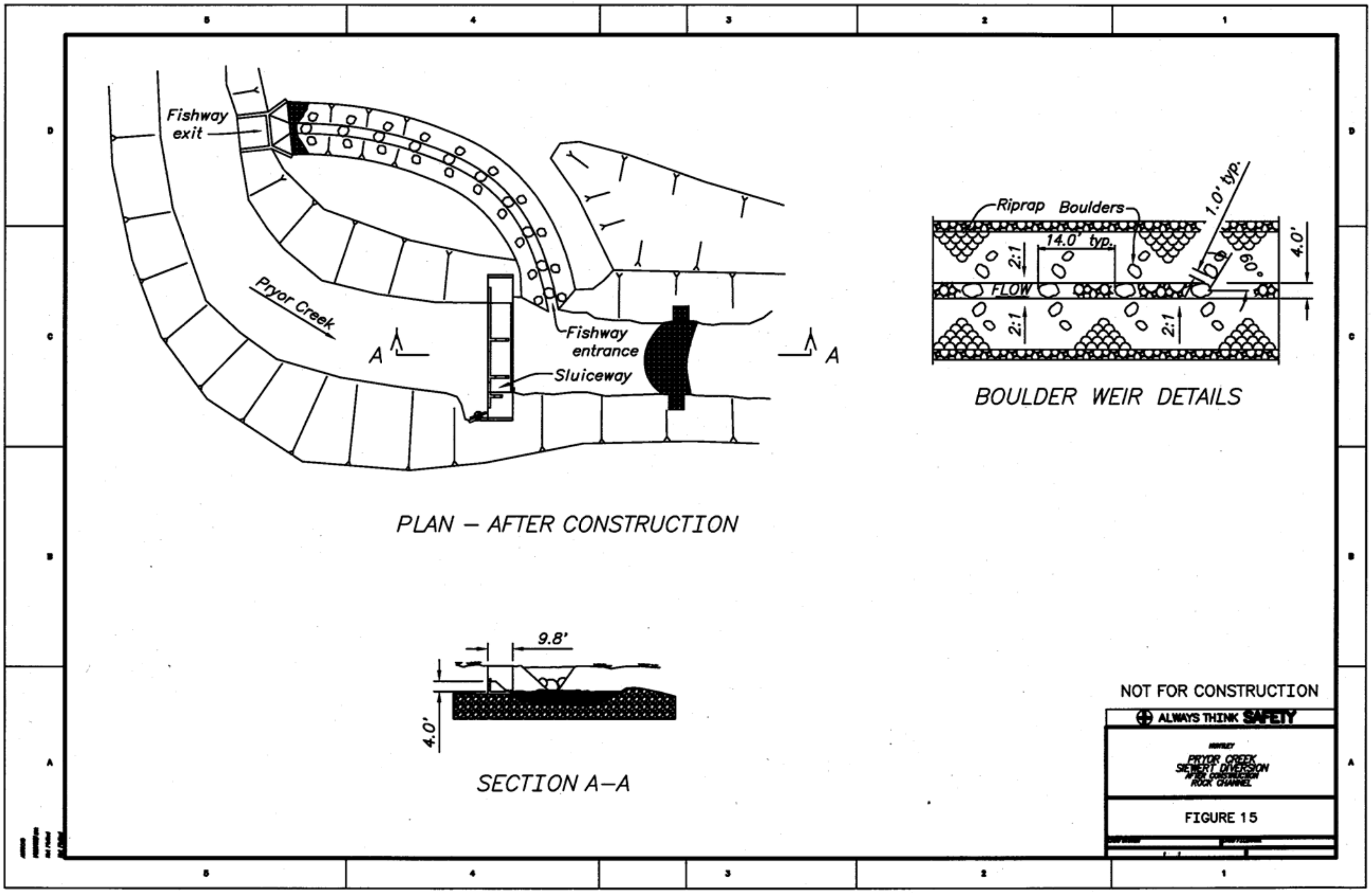

Figure 15 – Plan and Sections of a rock with boulder weirs fishway option, Siewert Diversion Dam on Pryor Creek

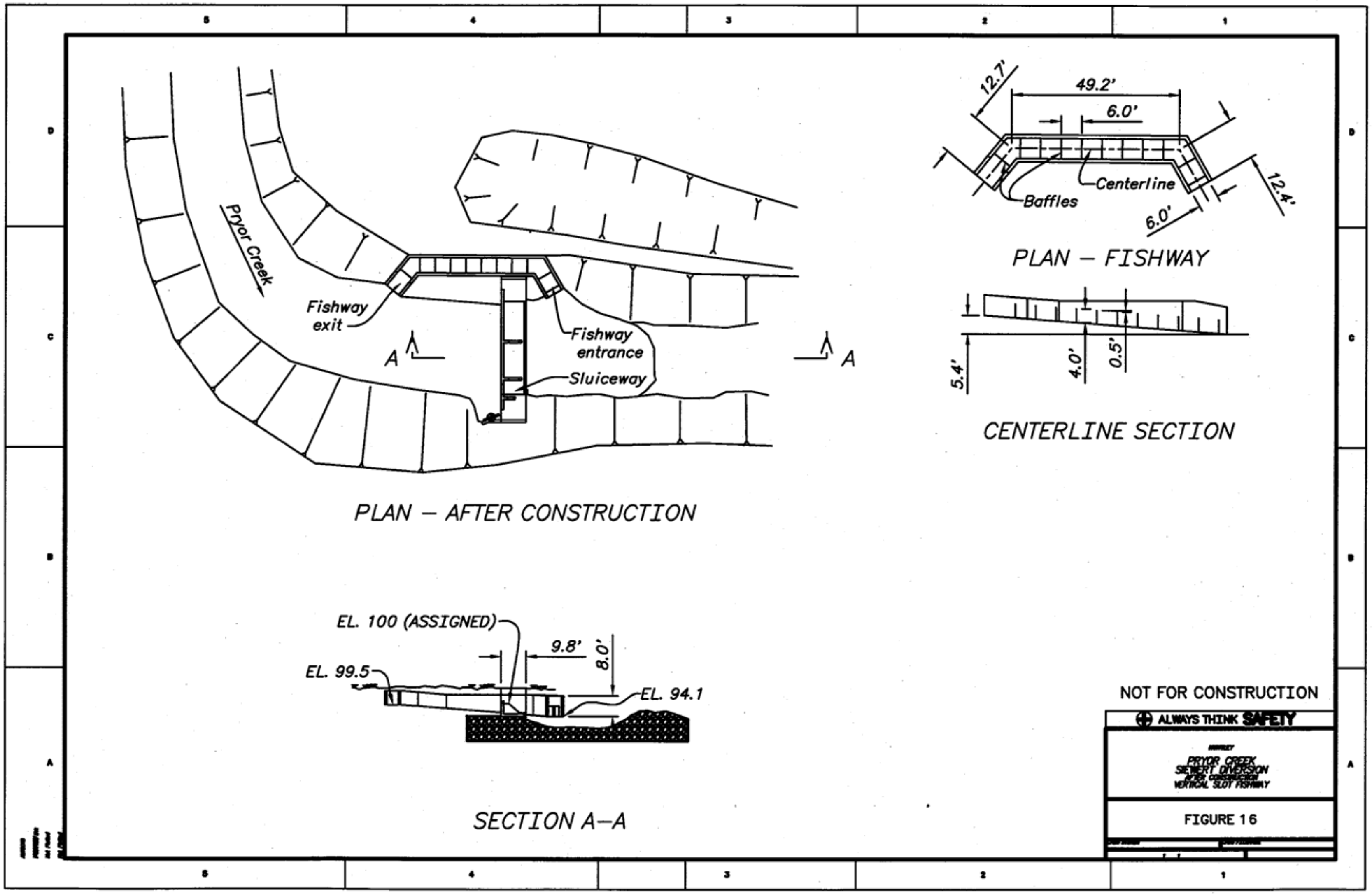

Figure 16 – Plan and sections of a vertical slot fishway option, Siewert Diversion Dam on Pryor Creek

SUMMARY

Huntley Canal Crossing Barrier

The Huntley Canal Crossing presents several challenges to fish passage. The structure height coupled with a site confined by the canal on both sides and the railroad and Yellowstone River downstream limit the opportunities for low gradient passage that is desirable to pass the full community of aquatic species. Passage effectiveness and project cost are generally directly related. Accepting poor passage of many juvenile and weaker swimming species may be required in favor of providing passage for stronger swimming fish based on budget. Structure costs given herein are based on estimated structure quantities and typical costs encountered at other facilities. All fishway types discussed are ranked in Table 5 to give a relative comparison of cost to performance for the Huntley Canal crossing barrier.

Table 4 – Relative Performance versus Cost Ranking of Fishway Options for Huntley Canal Crossing.

Fishway Type	Passage Efficiency	Relative Cost Ranking	Maintenance Requirements
Replace Drop with Inverted Siphon	Best	High	Low (Some increase in canal maintenance may occur)
Vertical Slot Fishway at < 5 Percent Slope	Good	Medium to High	Medium (Removal of debris from the fishway following large flood flows would likely be required)
Rock Ramp with Boulder Drops	Good to fair (1 ft drops may limit passage of juvenile and weaker swimming species)	Medium (Cost will depend largely on haul distance for large riprap and boulders)	Low (Assumes design provides sufficient protection against scour at the downstream toe)
Denil Fishway	Fair to poor (passage performance for species found in the Yellowstone river is largely unknown)	Low	Medium to High (Debris plugging and structure exposure during flood flows are concerns)

Siewert Diversion Dam Barrier

There are many fish passage options that could be implemented at the Siewert Diversion Dam. The bypass channels options presented and in-channel methods similar to those discussed for the Huntley Canal crossing could provide effective passage. The options presented represent the minimum recommended structure size (maximum drop and fishway slope) that could be expected to provide good to fair adult passage for many of the species listed in Table 5. Fish passage performances of similar fishways in the west clearly demonstrate the passage benefit of lower fishway slopes and small drop heights for passage of sub-adult and weak swimming species. For broader passage of sub-adult and weaker swimming species, I recommend designing fishways using a maximum passage velocity for a short duration of about 4.5 ft/s corresponding to an equivalent drop in water surface of 0.3 ft across a baffle or weir.

Table 5 - Relative Performance versus Cost Ranking of Fishway Options for Siewert Diversion Dam.

Fishway Type	Passage Efficiency	Relative Cost Ranking	Maintenance Requirements
Rock Channel Fishway with Boulder Weirs	Good (Better passage for all life stages and species could be obtained by lengthening the fishway and reducing the slope to about 2 percent)	Medium – Low (Cost will depend on requirements for an isolation gate and the haul distance for riprap)	Low
Vertical Slot Fishway at 7 Percent Slope	Good – Fair (Lengthening the fishway and reducing the fishway slope to about 4 percent would increase passage performance)	Medium - High (Cost of constructing the concrete flume will vary depending on site soil and ground water conditions.)	Medium (Removal of debris from the fishway following large flood flows would likely be required)
In-Channel Rock Ramp with Boulder Drops	Good to Fair (Passage would be expected to be good if the overall slope is less than three percent and drops are less than 0.5 ft.)	Medium - High (Cost will depend largely on haul distance for large riprap and boulders)	Low (Assumes design provides sufficient protection against scour at the downstream toe)
Denil Fishway	Fair to Poor (Fair passage for smaller fish could be achieved by using short run lengths (< 15 ft and slopes of 10 percent or less)	Low	Medium to High (Debris plugging and structure exposure during flood flows are concerns)

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6. U.S. Army Corps of Engineers, *“Fisheries Handbook.* “ Pacific Northwest Division, 1991.

Photograph Reference of Huntley Canal Crossing at Pryor Creek


Looking Upstream


Looking Downstream

Looking Up Canal across the Drop

Looking Down the Canal

Photograph Reference of Siewert Diversion Dam on Pryor Creek


Looking Across the Diversion Dam


Looking Upstream at Dam

Looking Upstream from Dam


Looking Downstream from Dam