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FISH PASSAGE ALTERNATIVES
DEVELOPED FOR
AUBURN RAVINE'S
NID GAGING SITE
&
HEMPHILL DAM SITE

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Purpose

The purpose of this Technical Memorandum is to describe the result from our alternatives development and feasibility level analysis for improving fish passage at two sites on Auburn Ravine operated by the Nevada Irrigation District (NID): (1) the gaging station near State Route 65 and (2) the Hemphill Diversion Dam. The information provided is intended to assist the advisory group in selecting a preferred alternative for each site. Once selected, engineering designs will be completed and a basis of design report will be prepared.

Background

Auburn Ravine is a tributary to the Sacramento River. The watershed drains the lower foothills of the Sierra and its headwaters are located near the City of Auburn at an elevation of approximately 1,600 feet. Auburn Ravine emerges from the Sierra foothills as it flows through the Town of Lincoln. Downstream of Lincoln the channel becomes highly altered as it flows through channelized section within agricultural lands dominated by rice fields.

Auburn Ravine supports runs of Chinook salmon and steelhead trout. However, two migration barriers on Auburn Ravine have been identified as limiting the population:

1. A drop at the outlet of a concrete Parshall flume at the NID Gaging Station, located 1,250 feet downstream of State Route 65 in the City of Lincoln, and

2. The Hemphill Diversion Dam, located at the northwest corner of the Turkey Creek Golf Club, approximately 1.5 miles upstream of State Route 193.

Both facilities are operated by the Nevada Irrigation District (NID).

The County of Placer has employed the services of Winzler & Kelly (project engineers), Michael Love & Associates (fish passage engineers) and McBain & Trush (riparian vegetation and fisheries consultants) to design fish passage improvements for salmonids at the NID Gaging Station and Hemphill Dam sites.

A project advisory group was composed of numerous stakeholders, which included staff from the County of Placer, the City of Lincoln, NID, and the California Department of Fish and Game (CDFG). Members of the design team met with the advisory group for a design review meeting on November 20, 2008 to review and provide comment on the conceptual alternatives. Comments and suggestions received were then incorporated into the final alternatives presented in this Technical Memorandum.

Project activities included conducting a phone interview with the operations manager for the NID facilities to clarify current operational procedures and indentify potential project constraints. A topographic survey of both sites was conducted in 2008. Existing vegetation at both sites was mapped in 2007 and fish habitat was mapped in 2008. Findings from the vegetation and fish habitat mapping will be provided in a separate report and will be used for evaluating potential project impacts.

Hydrology

The Auburn Ravine watershed has a Mediterranean climate with low-elevation rain dominated hydrology. Over 85% of precipitation occurs between November and April. Based on observations and historic streamflow records from other similar streams within the region, flows in Auburn Ravine respond rapidly to rainfall events, with the hydrograph both rising and falling abruptly. Historically, flows within Auburn Ravine would have been extremely low to nonexistent during the dry season (May through October).

Flow augmentation has dramatically changed the flow characteristics of Auburn Ravine during the dry season. Auburn Ravine currently serves as a conveyance channel for irrigation water obtained from an inter-basin transfer. The augmented flow is delivered to Auburn Ravine at the Wise Power House, operated by Pacific Gas and Electric and located approximately one mile west of Auburn. Referred to as the "irrigation season", flow augmentation generally begins between April 15th and May 1st, and ends by October 15th. NID measures flow during the irrigation season at the NID Gaging Station near State Route 65. They provided the design team with daily flow records for the irrigation season for 1974 to 2007. Mean monthly flows range from 37 cfs in September to 116 cfs in July (Table 1). To our knowledge, there has been no year-round gaging of streamflows in Auburn Ravine.

Table 1. Mean flow in Auburn Ravine at the NID Gaging Station during periods of flow augmentation.

Month	Mean Flow
May	89 cfs
June	80 cfs
July	116 cfs
August	93 cfs
September	37 cfs

Fisheries Overview

Auburn Ravine has significant anadromous fish resources, which include fall-run and late fall-run Chinook salmon and steelhead trout. Gravel bedded stream reaches suitable for spawning for salmonids exists upstream from City of Lincoln. Surveys of potential salmonid spawning habitat within streams in Western Placer County found that Auburn Ravine contains more potential spawning habitat than all other surveyed stream reaches combined (Jones & Stokes, 2004).

The historic low summer flows would have dramatically limited the amount of habitat available for summer rearing of steelhead/rainbow trout. The increased flow and cool water temperatures associated with flow augmentation has dramatically increased the quantity and quality of summer rearing and foraging habitat for salmonids. Fish sampling by CDFG in 2004 and 2005 found various size classes of steelhead/rainbow trout at all sites sampled between State Route 65 in Lincoln and the Wise Power House. Population densities of various size classes of steelhead/rainbow trout were reported to be relatively high within sampled reaches upstream of State Route 65, with relative steelhead/rainbow trout abundance ranging from 337 to 7,985 individuals per river mile. Other native fish species sampled upstream of State Route 65 included Sacramento pikeminnow, Sacramento sucker, lamprey, and speckled dace.

NID Gaging Station

Located directly downstream of State Route 65 in the City of Lincoln, the NID Gaging Station is a Parshall flume type structure owned and maintained by NID to monitor flow in Auburn Ravine during the irrigation season. The structure consists of a flat channel-spanning concrete section that forms a broad flume with vertical sides. A level ogee shaped curb, approximately 0.8 feet tall, spans the outlet of the fume. This curb provides adequate depth for fish to swim across the concrete section at all flows. The flume and curb section is 25 ft wide, with flaring sidewalls and apron at the inlet and outlet. The entire length of the flume, measured from the ends of the aprons, is 28.5 feet.

Figure 1. A riprap ramp leading up to the NID flow gaging station, which consists of a 25-foot wide concrete Parshall flume. At low flows (a) water depths are too shallow for fish passage. At higher flows (b) water velocities and turbulence can become excessive for passage of adult and juvenile salmonids.

We understand the NID Gauging Station was built in 1981. Since then, the channel bed downstream of the flume has incised approximately 6 feet. To protect the structure from erosion and undermining, large rock has been placed immediately downstream of the flume. This forms an over-steepened riprap ramp that produces shallow depths during lower flows and turbulent conditions with high velocities at higher flows (Figure 1). As a result, upstream passage is partially blocked for adult anadromous salmonids, and may be completely blocked for juvenile salmonids and adult resident trout.

Hemphill Diversion Dam

The Nevada Irrigation District operates a water diversion facility that includes the Hemphill Dam. We understand the Hemphill Canal was built by NID in 1935 and a wooden diversion structure was constructed in Auburn Ravine to divert flows into the canal. In 1969, the existing concrete head works of the Hemphill Canal were built and the existing concrete diversion dam was built in 1981. The typical maximum diversion rate is approximately 20 cfs.

The current concrete diversion dam is located within a low gradient pool-riffle reach of Auburn Ravine. The dam crest is 64 feet wide and 11 feet long, with 6 feet tall concrete abutments. The concrete dam crest is approximately 8 feet above the downstream channel. The face of the dam and channel banks extending 30 feet downstream of the crest have been armored with a mixture of rock and concrete slurry to control scour (Figure 2). Large rock has been placed along the toe of the slurry mixture. On the banks downstream of the concrete slurry, there is rock slope protection (RSP). During the irrigation season, flashboards are added to the top of the dam. The total height of the flashboards is 3.0 feet. The resulting headwater elevation provides sufficient depth at the headgate to obtain the desired diversion rate. The flashboards are generally in-place between April 15 and October 15.

Figure 2. Hemphill Dam at beginning of irrigation season, with 3-foot tall flashboards installed.

During the high winter flows, the flashboards are not in-place and it may be possible for a few adult steelhead to migrate over the dam. Once the flashboards are in-place, the dam is a total barrier adult steelhead. In addition, adult resident trout and juvenile salmonids are blocked at all flows.

Upstream of the dam is a broad active floodplain along the north side of the channel and a smaller floodplain along the south bank. The channel becomes more incised downstream of the dam and it is uncertain if high flows can access the flood plain. Overbank flows upstream of the dam in 2005/2006 return to the channel along the right (north) bank, causing extensive bank erosion. As a result, NID armored approximately 50 feet of the right bank downstream of the dam with 1- to 2-ton riprap.

Previous Fish Passage Study

A conceptual fish passage design report was developed for the NID Gaging Station and the Hemphill Dam (The Mines Group, 2005). The report provided two alternative approaches in addressing fish passage at the NID Gaging Station site. The first approach involved the removal of the structure and the second involved rock-filled gabions to construct a pool and weir fish ladder. Removal of the structure is not recommended because of the headcutting and severe upstream channel incision that would likely result. For the Hemphill Dam the report recommends rock-filled gabions pool and weir fish ladder along the face of the dam apron.

Comments made by CDFG indicated that other alternatives, such as a channel-spanning re-grade using boulder weirs, or similar rock type structures, be explored for the NID Gaging Station and Hemphill Dam sites before an alternative is selected for design.

Project Goals and Objectives

This project is part of a larger effort aimed at enhancing both anadromous and resident salmonid populations within Auburn Ravine. Specific project objectives are:

- Provide upstream passage at the NID Gaging Station and Hemphill Dam for adult anadromous Chinook salmon and steelhead trout during the migration period (October 15 – April 15).

- Provide adult resident and juvenile salmonids upstream passage at the NID gaging station and Hemphill Dam during the non-irrigation season (October 15 – April 15).

- Maintain the ability of the NID gaging station to accurately measure discharge within the flow range occurring during the irrigation season.

- Maintain NID's ability to divert water into the Hemphill Canal at current rates.

- Evaluate fish passage alternatives at the NID gaging station and Hemphill Dam that use rock and other natural materials to control channel grade ("nature-like fishways"), rather than focusing solely on traditional types of fishways.

Several other potential objectives, that have not been agreed upon nor required, may include:

- Providing upstream passage for adult resident trout during the irrigation season (April 15 – October 15).

- Providing upstream passage for juvenile salmonids during the irrigation season (April 15 – October 15).

- Providing safe downstream passage for kelts at the Hemphill Dam during irrigation season (April 15 – October 15).

FEMA Peak Flow Hydrology and Hydraulic Models

According to the 1998 FEMA FIRM, the NID Gaging Station is located in a reach of channel designated as a Floodway in Zone AE (Base Flood Elevation of 147 feet) and the Hemphill Dam is located in a reach of channel designated as Zone A (Base Flood Elevation not established). The FEMA Flood Insurance Study (FIS) is currently being revised and base flood elevations are expected to be established at the Hemphill Dam site. Additionally, the base flood elevation will likely change at the NID Gaging Station based on changes in watershed hydrology and recent grading of the floodplain within the project reach. According to Placer County Flood Control and Water Conservation District, the drainage area for the NID Gaging Station and the Hemphill Dam reaches are 32.20 square miles and 31.63 square miles, respectively. The FIS recommended revised 100-year peak flow rate for full buildout conditions is 12,109 cfs at the NID Gaging Station and 12,151 cfs at the Hemphill Dam. We did not receive an explanation to why the upper site has a higher predicted peak flow.

We requested a copy of the current FEMA FIS and associated hydraulic model from both the City of Lincoln and the County of Placer, but neither had the files available. Additionally, we were informed that the new hydraulic model as part of the FIS revision cannot be made available for this project until it is completed and accepted by FEMA which may not occur until after this project is designed.

Fish Passage Criteria

Fish passage alternatives developed for the two sites on Auburn Ravine are limited to use of the "hydraulic design approach." Under the hydraulic design approach, a fish passage facility is designed to provide passage for specific age/size classes of a fish species at all flows from the low to high fish passage design flow. Passage is provided by producing hydraulic conditions within the swimming and leaping capabilities of the target fish.

Target Species and Lifestages

For the NID Gaging Station and Hemphill Dam, the target species for upstream passage are Chinook salmon and rainbow/steelhead trout. Because juvenile Chinook salmon begin migrating downstream towards the ocean shortly after emerging from the gravels, only the adult lifestage of Chinook salmon requires upstream passage. For rainbow trout, upstream passage should be provided for juveniles and adults, including both the adult resident (rainbow trout) and adult anadromous (steelhead) life histories of the species. To assist in establishing design criteria and evaluating fish passage conditions, four "design fish" were selected:

- **Yearling Trout (*0+Year Trout*)**
  - Approximate Size Range: 60 to 100 mm (2.3 to 3.9 inches)

- **Trout Age 1 Size Class (*1+Year Trout*)**
  - Approximate Size Range: 150 to 240 mm (5.9 to 9.4 inches)

- **Trout Age 2 Size Class (*2+Year Trout*)**
  - Approximate Size Range: 250 to 310 mm (9.8 to 12 inches)

- **Adult Anadromous Steelhead Trout and Chinook Salmon**

Hydraulic Criteria

California Department of Fish and Game (CDFG, 2003) and National Marine Fisheries Service (NMFS, 2002) provide guidance in selecting water velocity, water depth, pool depth, and hydraulic drop design criteria for juvenile salmonids (*0+Year Trout*), adult resident trout (*2+Year Trout*), and adult anadromous salmonids (*Salmon and Steelhead*) (Table 2). For *1+Year Trout*, criteria were selected based on values in published literature combined with professional judgment. Turbulence within a pool can also create a barrier to fish passage, and is evaluated for pool and weir style fishways using the Energy Dissipation Factor (EDF).

Table 2. Fish passage criteria applied to both project sites.

	Salmonid Lifestage			
Fish Passage Criteria	**0+Year Trout**	**1+Year Trout**	**2+Year Trout**	**Adult Anadromous**
Max. Water Surface Drop[a]	0.5 ft	0.5 ft	0.66 ft	1.0 ft
Min. Water Depth[a]	0.5 ft	0.5 ft	0.66 ft	1.0 ft
Max. Water Velocity for distances less than 60 ft[a]	1 ft/s	3 ft/s[b]	4 ft/s	6 ft/s
Max. EDF for Pools (turbulence)[c]	Not Available	Not Available	3 ft-lb/s/ft^3	4 ft-lb/s/ft^3
Min. Depth in Pools[c]	2.0 ft			
Min. Attraction Flow (%Total Flow in Fishway)	Not Available	Not Available	10%	10%

[a] Based on CDFG (2003) and NOAA (2002) design guidelines, except where noted.
[b] Based on swimming abilities for 6 inch rainbow trout (Tsukamoto, 1975)
[c] Based on Bell (1991)

Fish passage facilities that do not span the entire channel and/or convey the entire streamflow must be designed so fish can find the fishway entrance with little difficulty or delay. This requires establishing good fish attraction, which includes placing the entrance near the barrier and creating hydraulic conditions that attract the fish to the entrance. Hydraulic features that improve attraction include creating a flow jet at the entrance that penetrates the tailwater pool and conveying at least 10% of the total streamflow through the fishway entrance.

Fish Passage Design Flows

Fish passage facilities designed using the hydraulic design approach require a low and high passage design flow for each target fish. This defines the range of flows that suitable fish passage conditions should be provided, including water depths, velocities and drop heights. CDFG (2003) and NMFS (2002) provide guidance in selecting fish passage design flows for projects involving road-stream crossings that can be applied to other projects using the hydraulic design approach. Design flows are defined based on exceedance probabilities obtained from an annual flow duration curve (FDC) constructed using daily average flows (Table **3**). For the low passage design flow, an alternative minimum flow is provided. The guidelines do not include design flow recommendations for *1+year trout.*

Table 3. Fish passage design flows, as prescribed by CDFG (2003) and NMFS (2002).

Salmonid Life Stage	Fish Passage Design Flow	
	Low	**High**
Adult Anadromous	50% Annual Exceedance Flow or 3 cfs (lesser of the two)	1% Annual Exceedance Flow
Adult Resident Trout (*2+ year trout*)	10% Annual Exceedance Flow or 2 cfs (lesser of the two)	5% Annual Exceedance Flow
Juvenile Salmonids (*1+ year trout*)	5% Annual Exceedance Flow or 1 cfs (lesser of the two)	10% Annual Exceedance Flow

Defining fish passage design flows for Auburn Ravine is made more complex due to the flow augmentation. Because flows are gaged only during the irrigation season, a synthetic FDC was constructed for Auburn Ravine to predict exceedance flows for the non-irrigation season (October 15 – April 15), which is when adult anadromous salmonids and resident trout typically migrate to spawn. Three streams with suitable streamflow records and similar watershed characteristics as Auburn Ravine were used for development of the FDC:

- Cosgrove Creek near Valley Springs, CA
  (USGS Station No. 11309000, Drainage Area = 20.6 mi^2, Operated 1929-1962)

- Murray Creek near San Andreas, CA
  (USGS Station No. 11308500, Drainage Area = 23.6 mi^2, Operated 1950-1959)

- Calaveritas Creek near San Andreas, CA
  (USGS Station No. 11306500, Drainage Area = 53.3 mi^2, Operated 1950-1966)

Other streams closer in proximity were evaluated but considered ill-suited due to the extent of urbanization within the watershed and the degree of upstream impoundments and diversions.

The synthetic FCD was constructed by developing FDC's for each gaged stream using only flows during the defined migration season of October 15 to April 15. Exceedance flows from each gaging station were then scaled to the drainage area of Auburn Ravine and averaged. A flow duration curve was also constructed for the irrigation season (April 15 to October 15) using the 31 years of daily record flows from the NID gaging station. Finally, an annual FDC was constructed by combining the two (Figure 3).

The combined FDC was used to determine fish passage design flows for the NID Gaging Station (Table 4). Velocities in the Parshall flume exceed the 1 ft/s velocity criteria for *0+ Trout* at slightly more than 25 cfs. One of the project objectives is to preserve the ability to use the flume for measuring flows. Decreasing velocities in the flume would compromise its measurement accuracy. Therefore, the high passage design flow for the *0+ Trout* was set at 25 cfs. This is equivalent to the 20% exceedance flow for the period October 15 – April 15, and would be equal to the 10% annual exceedance flow if Auburn Ravine flows were not augmented during the irrigation season.

For Hemphill Dam, not all developed alternatives assume passage is required when the flashboards are installed. Therefore, two sets of fish passage design flows were developed for Hemphill Dam: (1) with the flashboards removed (Table 5) and (2) with flashboards installed (Table 6).

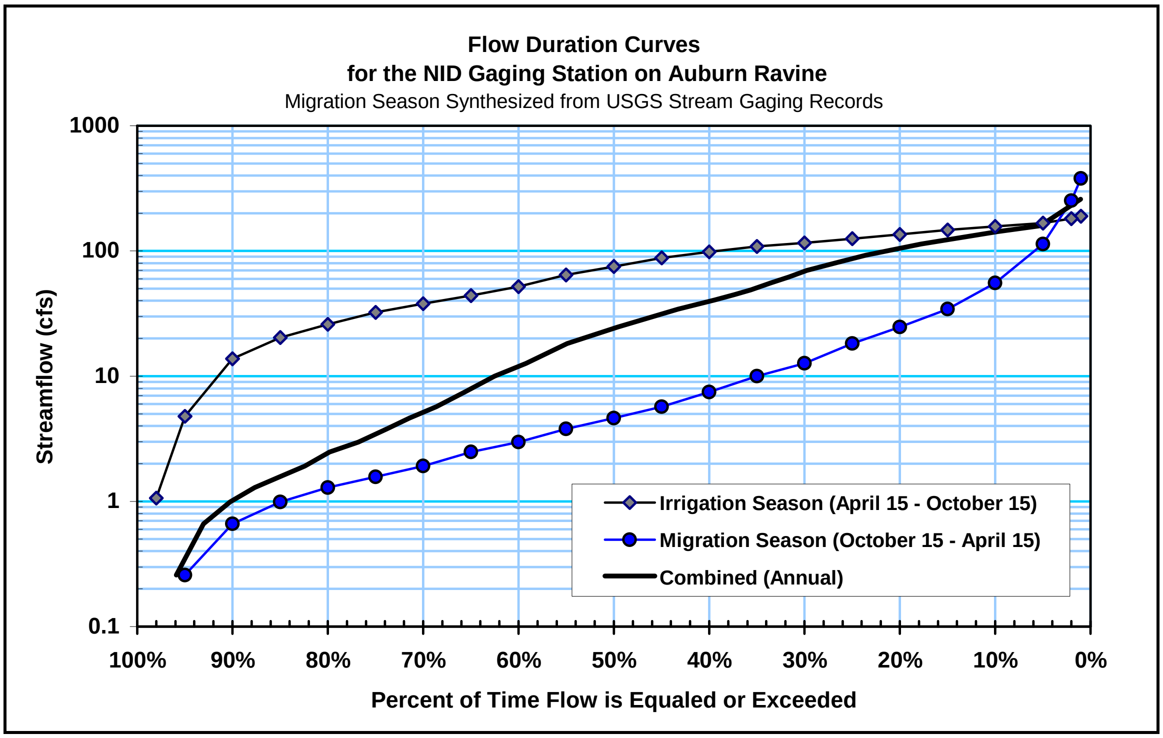


Figure 3. NID Gaging Station Flow duration curves for the irrigation season, adult anadromous salmonid migration season, and the entire year.

Table 4. Proposed fish passage design flows for NID Gaging Station.

Salmonid Life Stage	Fish Passage Design Flow		Description of High Passage Design Flow
	Low[1]	High	
Adult Anadromous	3 cfs	259 cfs	1% Annual Exceedance Flow

2+ Year Trout	2 cfs	159 cfs	5% Annual Exceedance Flow
1+ Year Trout	2 cfs	143 cfs	10% Annual Exceedance Flow
0+ Year Trout	1 cfs	25 cfs[2]	20% Exceedance Flow Oct 15– Apr. 15

[1] The CDFG and NMFS alternative minimum flows.
[2] High fish passage design flow limited by velocities in Parshall flume.

Table 5. Proposed fish passage design flows for the Hemphill Dam during periods when no flashboards are installed.

Salmonid Life Stage	Fish Passage Design Flow		Description of High Passage Design Flow
	Low[1]	**High**	
Adult Anadromous	3 cfs	254 cfs	1% Annual Exceedance Flow
2+ Year Trout	2 cfs	156 cfs	5% Annual Exceedance Flow
1+ Year Trout	2 cfs	140 cfs	10% Annual Exceedance Flow
0+ Year Trout	2 cfs	24 cfs	20% Exceedance Flow Oct 15– Apr. 15

[1] The CDFG and NMFS alternative minimum flows.

Table 6. Proposed fish passage design flows for the Hemphill Dam during periods when flashboards are installed (if passage is required).

Salmonid Life Stage	Fish Passage Design Flow		Description of High Passage Design Flow
	Low[1]	**High**	
Adult Anadromous	3 cfs	156 cfs	10% Exceedance Flow from Apr. 15 to Oct. 15
2+ Year Trout	2 cfs	156 cfs	10% Exceedance Flow from Apr. 15 to Oct. 15
1+ Year Trout	2 cfs	140 cfs	20% Exceedance Flow from Apr. 15 to Oct. 1
0+ Year Trout	1 cfs	24 cfs	80% Exceedance Flow from Apr. 15 to Oct. 1

[1] The CDFG and NMFS alternative minimum flows.

Developed Alternatives for the NID Gaging Station

Several design approaches were considered for addressing fish passage at the NID Gaging Station. Based on comments provided by CDFG in regards to the previous fish passage conceptual design report (The Mines Group, 2005), developed alternatives for the NID Gaging Station focused on use of a channel-spanning roughened channel or boulder weirs to regrade the downstream channel. A primary design constraint was to maintain NID's ability to use the flume for gaging streamflows. This requires providing adequate fish passage into the existing flume without backwatering the flume.

NID provided their current stage-discharge rating table for the flume. Based on this, existing hydraulic conditions within the flume are suitable for fish passage, especially adults, over a wide range of flows (Table 7). This is largely due to the presence of the 0.8 feet high ogee shaped curb spanning the outlet of the flume. Depth in the flume may be between 0.8 feet and 1.0 feet at flows less than 7.2 cfs, which is slightly less than the minimum depth required (1 foot) for adult anadromous salmon and steelhead.

Table 7. Existing water depth and velocities within the Parshall flume at the NID Gaging Station

Discharge (cfs)	Depth in Flume (ft)	Velocity in Flume (ft/s)	Note
0	0.8	0	Depth at No Flow Due to Curb Height
7.2	1.0	0.3	Minimum Depth Criteria for Adult Anadromous Salmon and Steelhead
31	1.3	1.0	Maximum Velocity Criteria for *0+ Trout*
168	2.2	3.0	Maximum Velocity Criteria for *1+ Trout*
276	2.8	4.0	Maximum Velocity Criteria for *2+ Trou*t
593	3.9	6.0	Maximum Velocity Criteria for Adult Anadromous Salmon and Steelhead

Two potentially feasible alternatives were developed and evaluated. Both consist of a roughened channel constructed of rock chutes and armored pools. The primary difference between them is the overall slope of the roughened channel and the downstream ending location.

Alternative 1 – Steeper Roughened Channel with Chutes & Pools

Alternative 1 consists of a roughened channel with rock chutes and pools. The conceptual designs are illustrated in Figure 4 through Figure 7. The overall slope and length of the roughened channel is 4% for 180 feet. Chutes have a slope of 8% and the drop across the chute range between 1 and 2 feet. The drop across the pools is zero feet. The chutes and pools are designed to mimic the morphology of steep natural channels. The bed and banks are constructed from a matrix of large rock mixed with smaller material to control porosity. The larger material is sized to remain stable up the 100-year flood.

The existing curb on the outlet of flume will be notched. The crest of the chute downstream of the flume will be positioned approximately 0.7 feet lower than the crest of the existing curb to minimize or avoid backwater influence on the flume. This chute will have a horizontal crest to minimize increases in water depth with increasing flows. A pool will be placed between the flume and chute to dissipate energy and provide resting habitat for fish before they swim through the flume. The stage-discharge rating curve for the flume will likely need to be updated following construction.

Channel-spanning sheetpile or cast in place concrete weirs are recommended in four locations for this alternative. One sheetpile would be located at the crest of the upstream-most chute and would be placed at grade with a concrete cap to provide a stable and consistent cross section below the flume. The tops of the remaining three sheetpiles are placed below the roughened channel bed (not visible). These provide increased stability for the roughened channel bed and banks and function as cut-off walls to minimize subsurface flow during low-flows. The geotechnical investigation, to occur during the next phase of the project, will assist in determining the suitability of the soils for use of sheetpile.

The existing banks are unstable and will be laid back to allow for replanting above the banklines of the roughened channel. The entrance (downstream end) of the roughened channel is placed upstream of a currently unstable section of channel, which includes active bank failures and channel widening in response to channel incision. During final design, tying into and stabilizing the existing banks at the downstream transition will need to ne addressed.

Preliminary analysis indicates this alternative satisfies fish passage criteria for all life stages at the indicated design flows.

Alternative 2 – Steeper Roughened Channel with Chutes & Pools

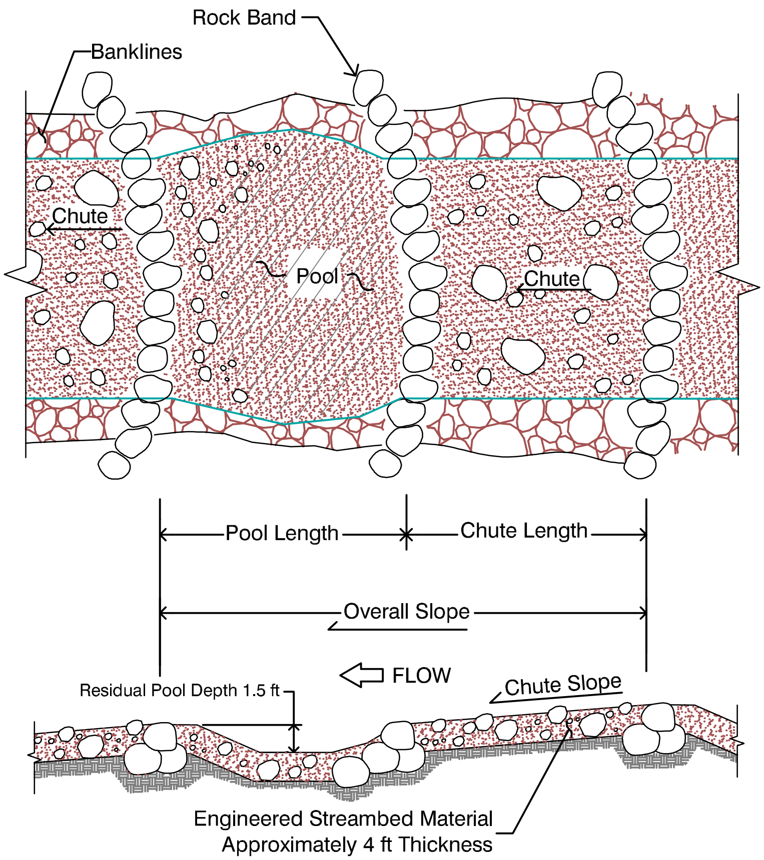
Alternative 2 is a roughened channel with chutes and pools, with design and stabilization measures similar to Alternative 1. The conceptual designs are illustrated in Figure 4 and Figure 8. For this alternative, the overall slope is reduced to 3%, causing it to extend 230 feet downstream of the flume. The alternative extends farther downstream than Alternative 1, locating the downstream end in an unstable reach with widening and unstable banks. Chutes slope at 6% and drops across the chutes are between 1 and 2 feet. The existing curb will be notched. To minimize or avoid backwatering the flume, the upstream-most chute will have a horizontal crest positioned approximately 0.7 feet lower than the crest of the existing curb in the flume.

Due to the lower overall channel slope, sheetpile may not be required for maintaining stability of the material in the chutes. However, this may provide less ability to control low-flow permeability.

Preliminary analysis indicates this alternative satisfies fish passage criteria for all life stages at the indicated design flows.

Outstanding Issue for NID Gaging Station Site

The final feasibility determination will rely on determining the discharge in the channel during the 100-year flow. This will determine if the stable rock size is reasonable at the 100-year flow is feasible. Determination of the amount of flow in the channel versus flow conveyed across the floodplain will require obtaining the most current HEC-RAS hydraulic model of the project reach. There is considerable uncertainty in the amount of flow conveyed in the channel immediately downstream of the NID Gaging Station due to the size and elevation of the upstream floodplain, and the presence of a constructed overbank flood channel south of the main channel. Based on the calculated capacity of the Parshall flume, upstream flow begins to go out of bank at approximately 1,000 cfs.



CHUTE-POOL ROUGHENED CHANNEL PLAN AND PROFILE
NOT TO SCALE

Alternative 1: Chute-Pool Sequence
Overall Slope 4%, Chute Slope 8%

Drop Across Chute	1 ft	2 ft
Chute Length	12.5 ft	25 ft
Pool Length	12.5 ft	25 ft

Alternative 2: Chute-Pool Sequence
Overall Slope 3%, Chute Slope 6%

Drop Across Chute	1 ft	2 ft
Chute Length	16.5 ft	33 ft
Pool Length	16.5 ft	33 ft

FIGURE 4 - NID GAGE SITE ALTERNATIVES 1 & 2
CHUTE - POOL CHANNEL DETAIL

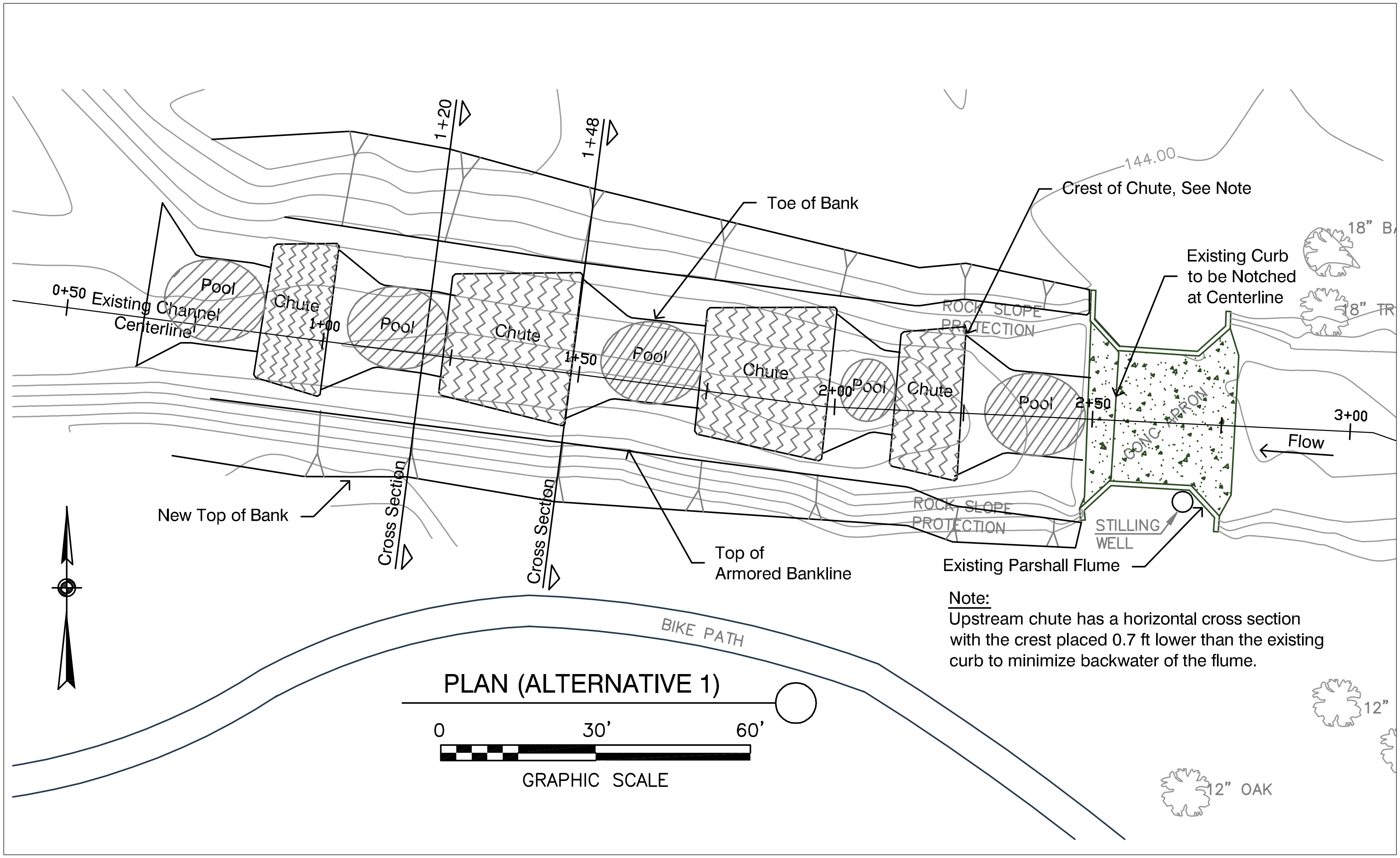


FIGURE 5 - NID GAGE SITE ALTERNATIVE 1
4% CHUTE - POOL CHANNEL, PLAN VIEW

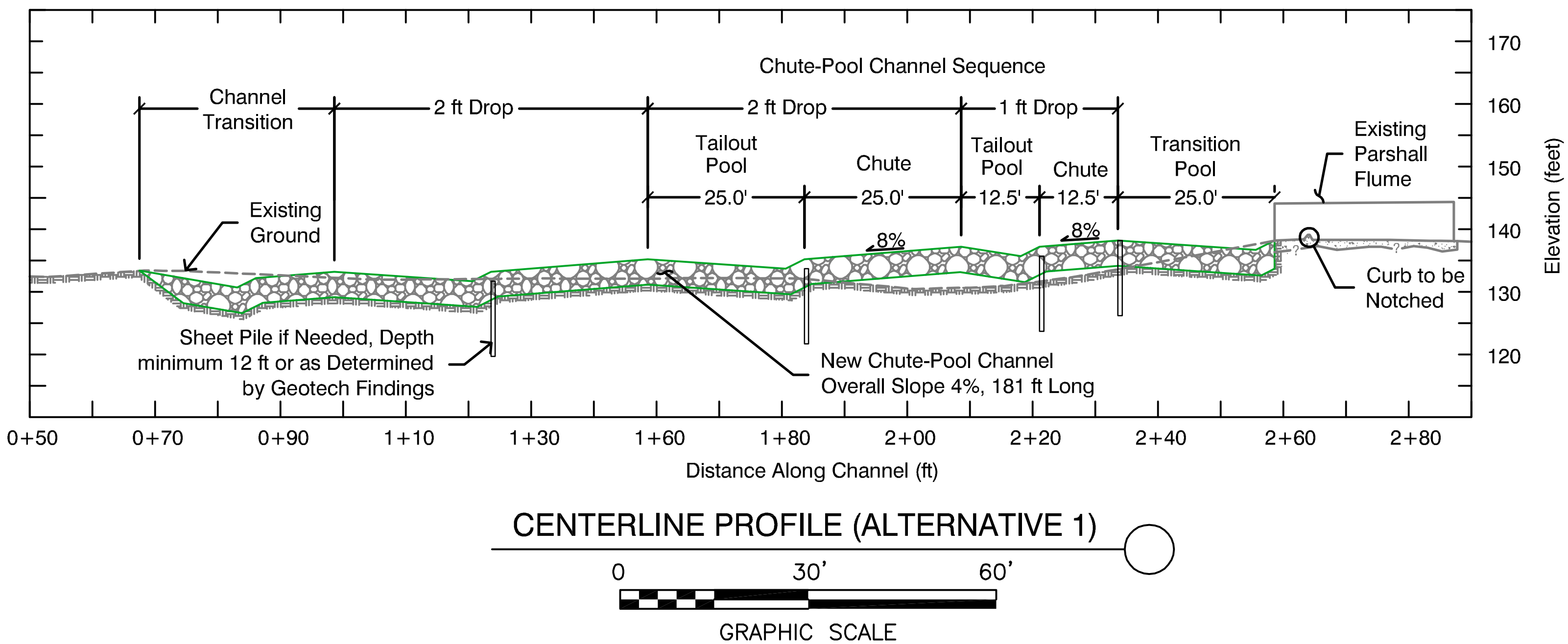
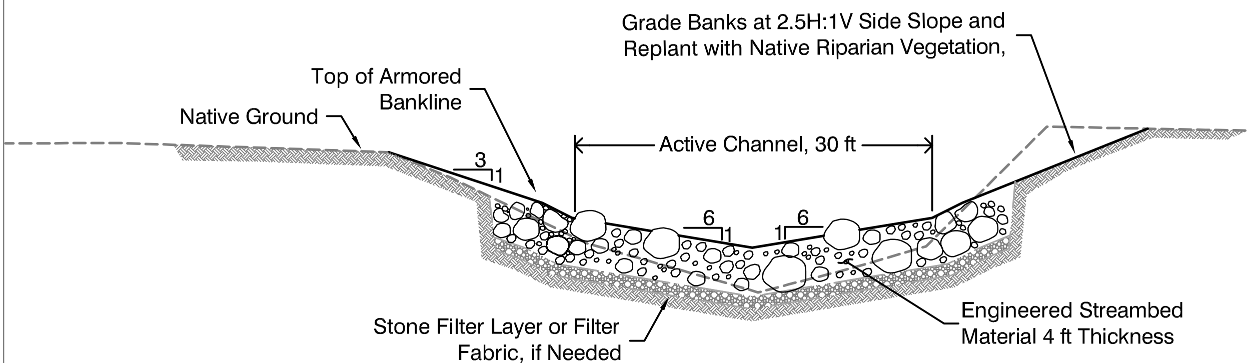
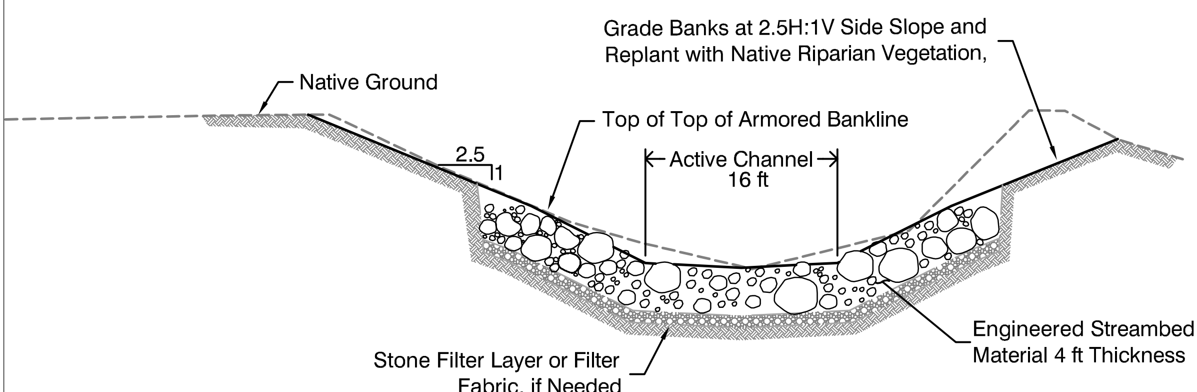


FIGURE 6 - NID GAGE SITE ALTERNATIVE 1
4% CHUTE - POOL CHANNEL, PROFILE VIEW



CHUTE CROSS SECTION
STA 1+48 (ALTERNATIVE 1)
NOT TO SCALE



POOL CROSS SECTION
STA 1+20 (ALTERNATIVE 1)
NOT TO SCALE

FIGURE 7 - NID GAGE SITE ALTERNATIVE 1
4% CHUTE - POOL CHANNEL CROSS SECTIONS

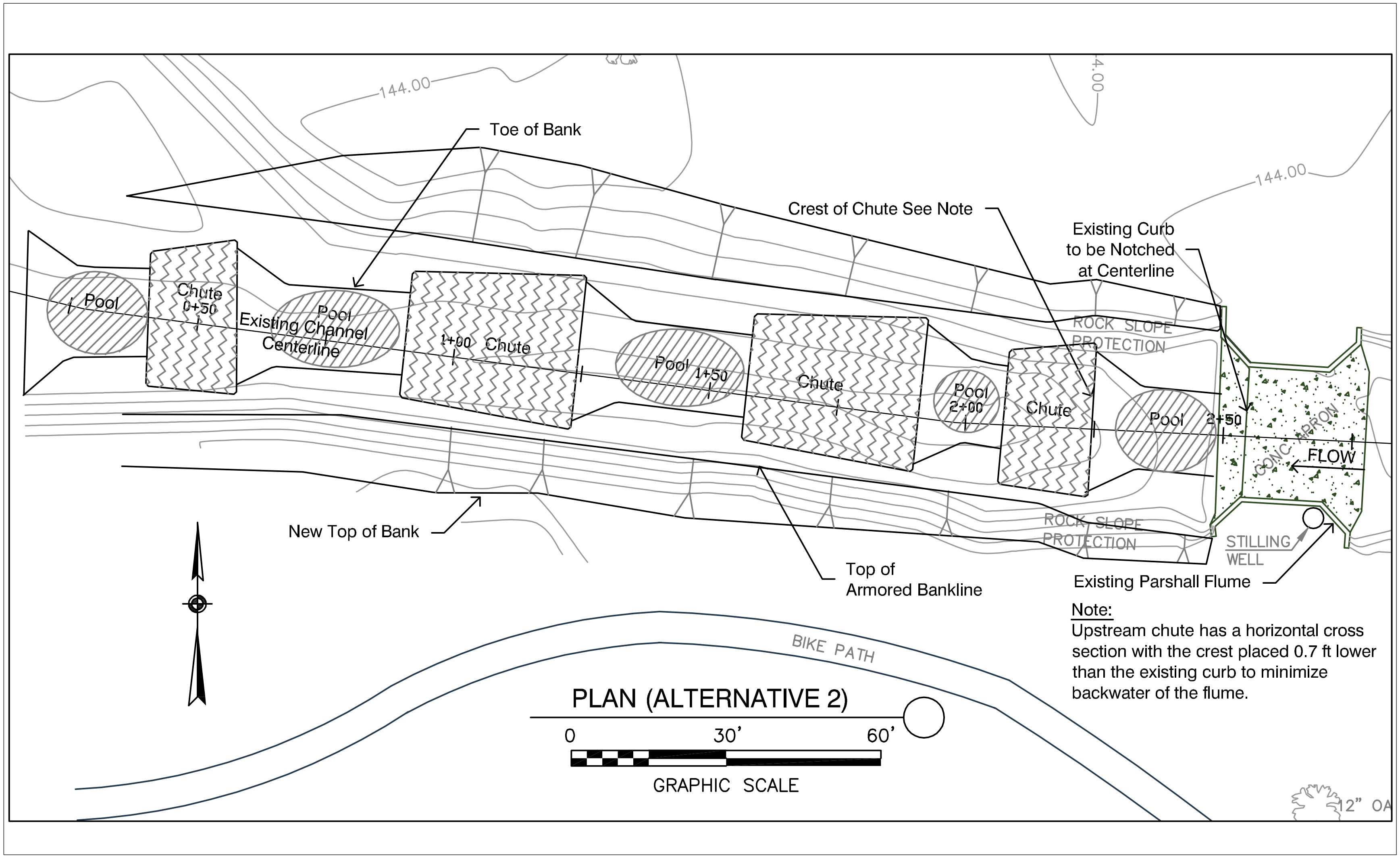


FIGURE 8 - NID GAGE SITE ALTERNATIVE 2
3% CHUTE - POOL CHANNEL, PLAN VIEW

Developed Alternatives for the Hemphill Dam

Several design approaches were considered for addressing fish passage at the Hemphill Diversion Dam. All alternatives preserve the ability of NID to install flashboards during the irrigation season. Alternatives are divided into two scenarios: (1) passage provided only during the non-irrigation season when flashboards are removed and (2) year-round passage provided using two fishway exits. The two exits accommodate the range of water surface elevations associated with and without flashboards in-place.

Based on comments provided by CDFG in regards to the previous fish passage conceptual design report (The Mines Group, 2005), one "nature-like" fishway alternative was developed for each of the two scenarios. However, use of a channel spanning roughened channel or boulder weirs was considered infeasible given the width of the dam crest (64 feet) and downstream channel bed (55 feet to 75 feet) combined with the height of the dam (8 feet, plus 3 feet tall flashboards during irrigation season). Channel spanning approaches at this site require importing an extremely large volume of rock material, and addressing challenging and potentially high-risk geotechnical issues concerning stability, permeability. Additionally, channel-spanning approaches fail to accommodate passage over the dam when the flashboards are installed. For these reasons, developed alternatives focused on partial-spanning and bypass channel approaches instead of channel spanning approaches.

Alternative 1 – Two-Stage Bypass Channel for Year-Round Passage

A nature-like bypass channel constructed along the north or south bank may be configured with two fishway exits to provide year-round fish passage with and without dam flashboards (Figure 9). This developed alternative places the bypass channel along the north bank to minimize loss of mature riparian trees and avoid having to relocate the diversion headworks. However, the same approach could be applied to the south bank. The south side may be preferable because it is less susceptible to bank erosion and deposition, and is all or nearly all, on NID's property.

The fish entrance to the bypass channel is located at the base of the dam. The channel is positioned to create a jet that would penetrate the existing scour pool to improve fish attraction. Immediately upstream of the entrance, the bypass channel crosses under the existing parking area through a 10-foot wide by 80-foot long culvert. The culvert serves a secondary function, limiting the amount of flow conveyed in the channel during overbank flooding by creating a backwater that extends to the exit of the bypass channel. Upstream of the culvert, the two-stage bypass channel uses a chute-and-pool roughened channel design to maintain an overall 3% grade. The chutes and pools are built with a matrix of large rock mixed with smaller material, which is sized to remain stable up the 100-year flood.

The Lower Stage of the bypass channel is 300 feet long (190 feet of roughened channel) and leads to a raceway and exit suitable for the headwater associated with winter operations (no flashboards on dam). The raceway has a gate that regulates flow into the fishway during winter operations and provides auxiliary flow to the bypass channel for fish attraction during summer operations (flashboards installed). With a channel width of approximately 15 feet, the first stage channel conveys at least 10% of the total stream flow at the highest fish passage design flow of 254 cfs. The slope of the channel banks is suitable for vegetation. The top width of the excavated channel could be as wide as 60 feet near the dam, decreasing in the upstream direction.

The second, Upper Stage of the bypass channel provides fish passage during summer operations, when the water surface upstream of the dam is 3 to 4 feet higher than during winter operations. From the confluence with the lower bypass channel, the upper bypass channel is 100 feet long, has a channel width of approximately 10 feet and uses chutes and pools to control the 3% channel grade. A flow control gate is located at the fish exit to control the amount of flow in the channel. The gate is closed during winter operations and this section of channel is dry. Auxiliary flow entering from the lower exit gate provides adequate attraction flows at the bypass channel entrance.

This alternative extends onto the neighboring property and impacts a limited area of mature riparian vegetation. The project survey does not extend onto the neighboring properties, so some assumptions were made regarding the elevation of the existing ground. Perusing this alternative will require additional topographic, vegetation, and geomorphic survey and characterization.

Preliminary analysis indicates this alternative satisfies fish passage criteria for all life stages at the indicated design flows.

Alternative 2 – Partial-Width Roughened Channel

Alternative 2 consists of a partial width roughened channel 170 feet in length and approximately 15 feet wide, which cuts through the existing dam abutment along the north bank (Figures 10 and 11). The channel bed consists of chutes and pools constructed at an overall slope of 3.5%. The 6% chutes have 2 feet of drop, with 24-foot long pools below each chute to dissipate energy and provide holding habitat. The chutes and pools are built with a matrix of large rock mixed with smaller material, which is sized to remain stable up the 100-year flood.

The entrance is 60 feet downstream from the end of the dam apron, and the exit is about 60 feet upstream of the dam crest, close to the property line. The walls along the sides of the channel are vertical, or nearly vertical, and constructed of either concrete or sheetpile. Rather than a vertical wall, rock placed at a 45-degree slope could be used in some locations along the north side of the roughened channel. Bed retention sills would span the top and bottom of each chute to provide additional stability and control subsurface flow. To provide flow control (manipulate rate of flow over dam vs. in the roughened channel), a 10-foot long section the dam crest would be lowered and guides installed for stoplogs.

This roughened channel alternative only provides passage when the flashboards on the dam crest are not in place. A gate is located across the roughened channel near the dam crest to shut off flow when flashboards are installed for the irrigation season. A grate could be placed over the top of the roughened channel at the dam crest for ease of operations and maintenance of the existing flashboards.

For this alternative, rock placed in the channel is vulnerable to erosion forces associated with overbank flood flows returning to the channel at this location. This is evidenced by previous bank erosion at this location. The existing conditions hydraulic model (HEC-RAS) is needed to evaluate flood conditions and determine feasibility. If this alternative is selected, moving the structure to the south bank should be considered because of the high erosion potential along the north bank associated with the return of overbank flood flows.

Preliminary analysis indicates this alternative satisfies fish passage criteria for all life stages at the indicated design flows.

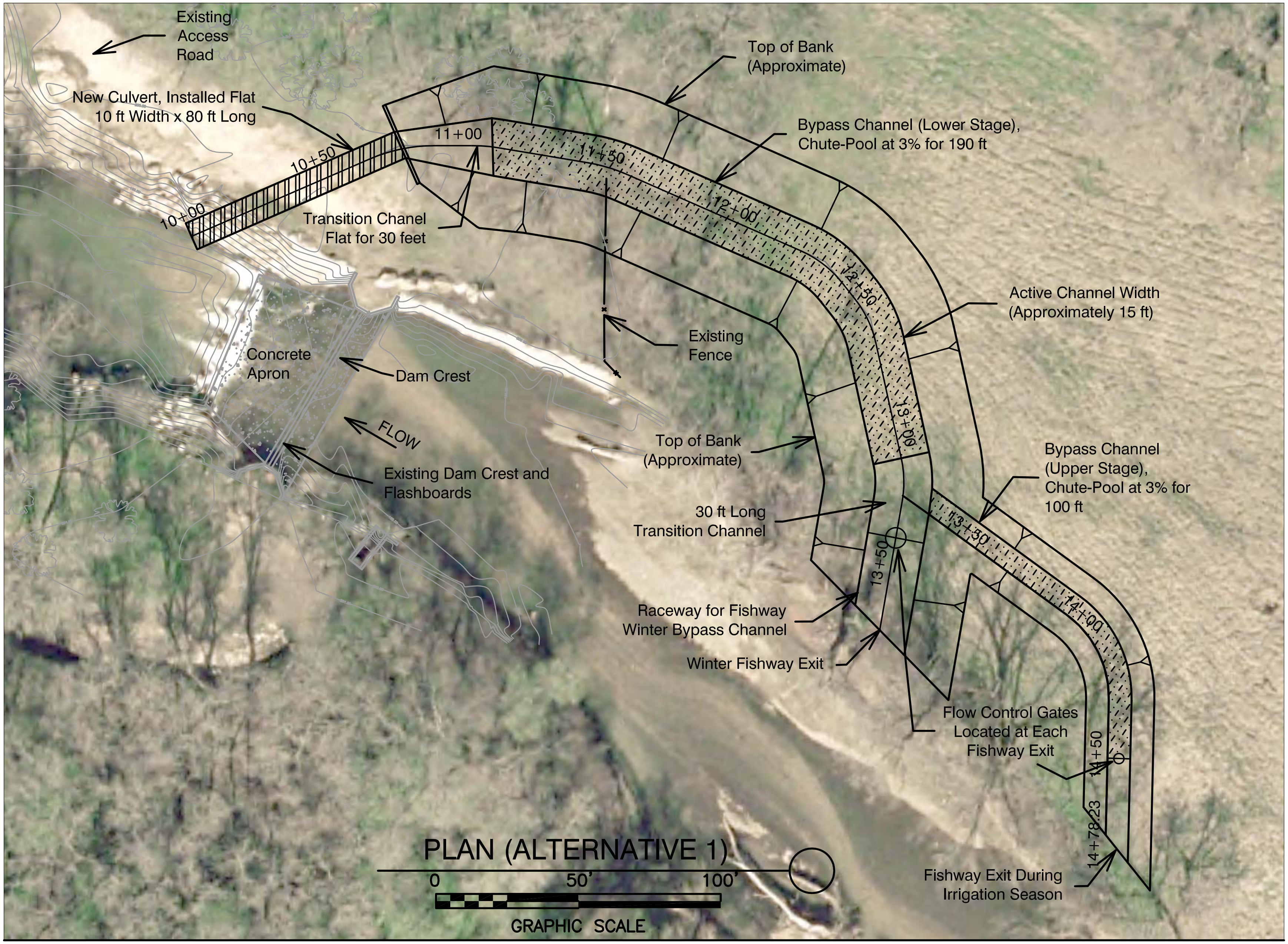


FIGURE 9 - HEMPHILL DAM SITE, ALTERNATIVE 1
TWO-STAGE BY-PASS CHANNEL LAYOUT, PLAN VIEW

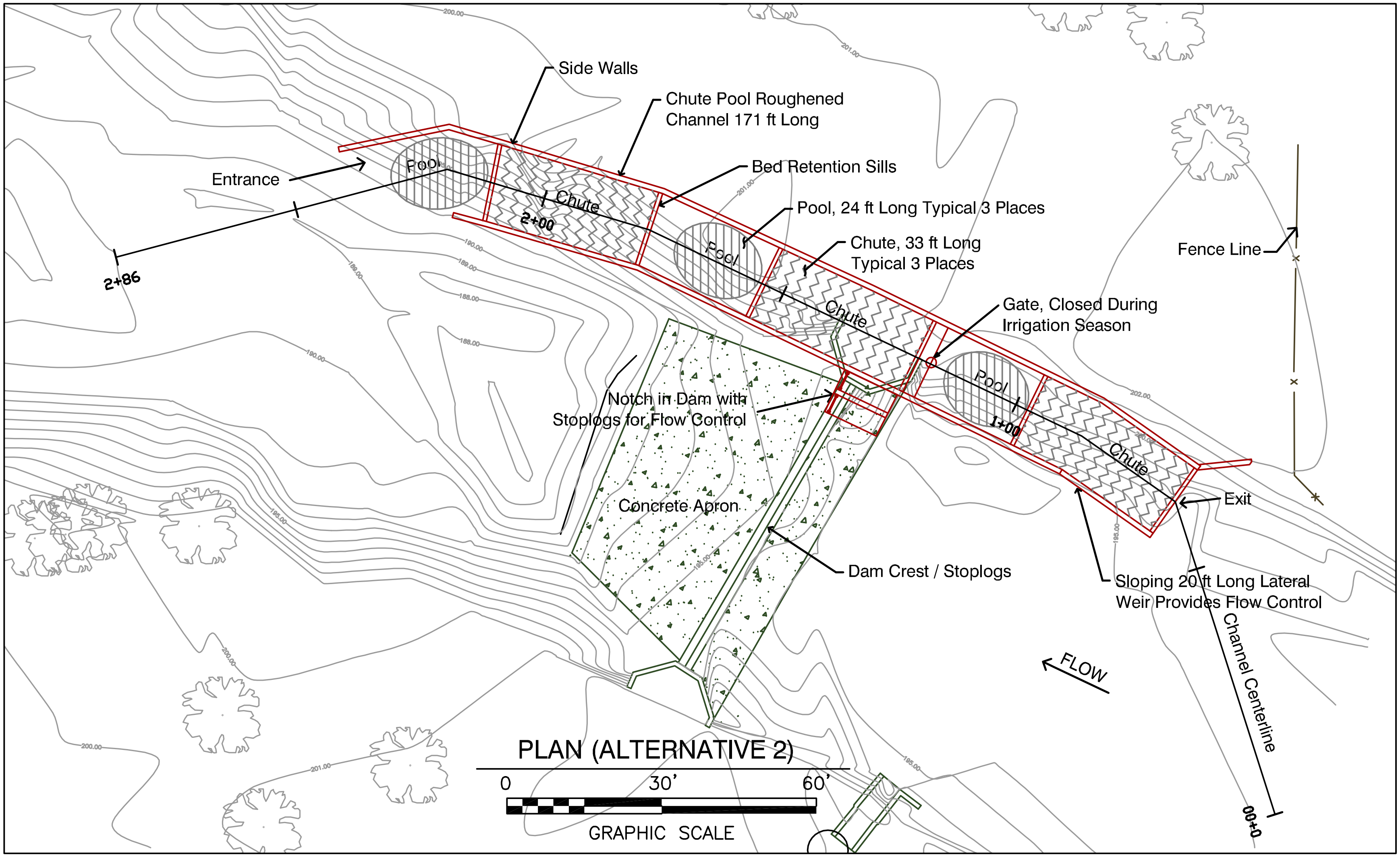


FIGURE 10 - HEMPHILL DAM SITE ALTERNATIVE 2
PARTIAL WIDTH CHUTE-POOL ROUGHENED CHANNEL FISHWAY, PLAN VIEW

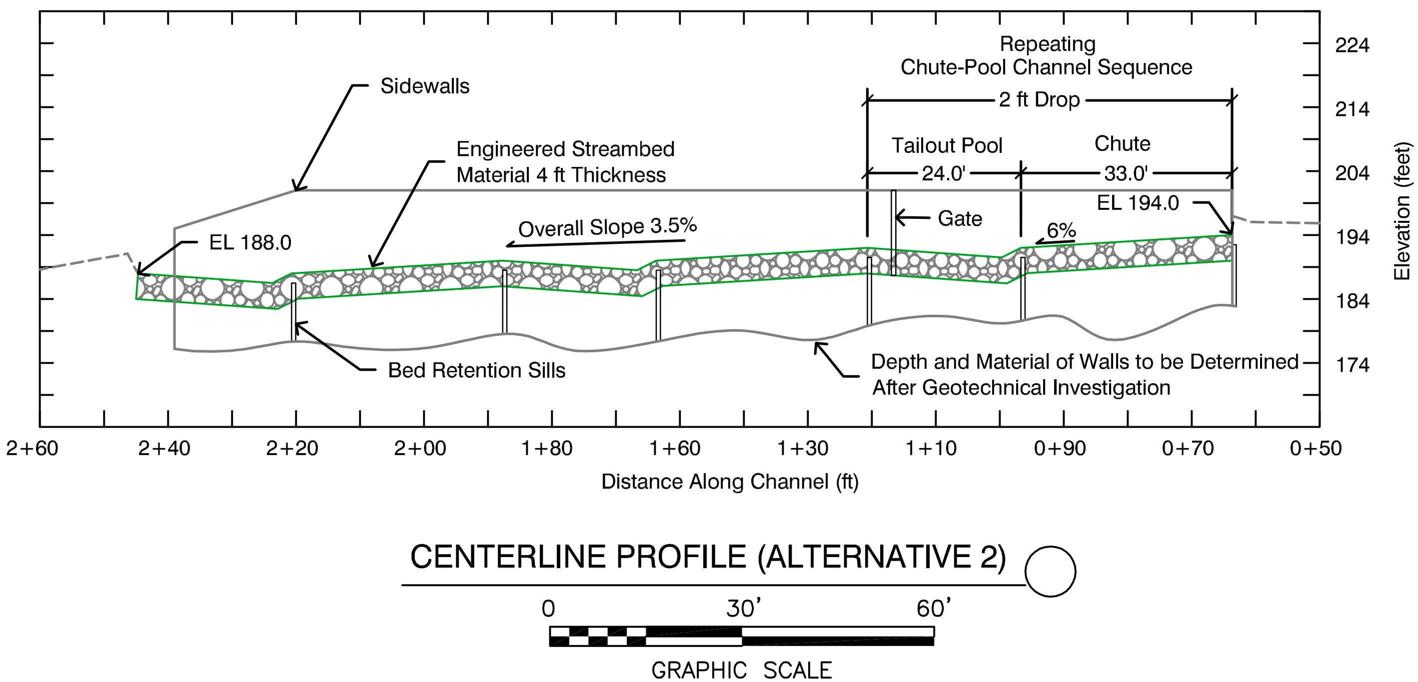


FIGURE 11 - HEMPHILL DAM SITE ALTERNATIVE 2
PARTIAL WIDTH CHUTE-POOL ROUGHENED CHANNEL FISHWAY, PROFILE

Alternative 3 – Single Stage Pool-and-Chute Fish Ladder

A pool-and-chute fish ladder built across the dam apron along the south bank can provide fish passage during winter operations (no flashboards on dam) (Figure 12 and Figure 13). Placement of the ladder along the south bank was selected due to the high erosion potential along the north bank associated with the return of overbank flood flows. The pool-and-chute ladder is 55 feet long and 10 feet wide and has 13 weirs constructed of concrete. Weirs are spaced 4.5 feet apart and the drop over each weir is 6 inches. The entrance weir is 25 feet downstream of the dam apron. Upstream of the exit weir is a removable gate, potentially constructed of removable H-beams and stoplogs. This gate would be installed when the flashboards are installed at the beginning of the irrigation season, shutting off flow to the ladder.

The ladder is designed to satisfy fish passage criteria while conveying 28 cfs within the ladder. To provide flow control, a 10-foot long section the dam crest would be lowered and guides installed for stoplogs. The logs would be set to maintain at least 10% of the total streamflow in the ladder up to the high fish passage design flow. This would allow the fish ladder to operate up to a streamflow of 280 cfs.

Pool-and-chute ladders provide good fish attraction because of the high velocity jet produced down the center of the ladder that fish can sense far from the entrance. Pool-and-chute ladders operate over a wider range of flows than a pool-and-weir ladder and are less susceptible to clogging with debris than a vertical slot fish ladder.

Alternative 4 – Two Stage Fish Ladder for Year-Round Passage

In addition to the pool-and-chute fish ladder developed in Alterative 3, a secondary ladder is included in this alternative (Figure 14 and Figure 15) to provide passage during the irrigation season. The second stage is a pool and weir ladder with a width of 4 feet and overall length of 36 feet. Weirs are formed with stoplogs, and the drop over each weir is limited to 6 inches. The exit weir height may need to be adjusted periodically as flows ramp up and down at the beginning and ending of the irrigation season. By adjusting the stoplogs, the ladder can accommodate a headwater range in the forebay of about 1.5 feet. This ladder can convey up to 5 cfs before becoming excessively turbulent in the pools between the weirs.

A short raceway leads from the exit of the lower ladder to the entrance weir of the upper ladder. A gate, potentially constructed with removable H-beams and stoplogs, is placed across the lower exit during the irrigation season. A gate in the dam abutment can then be opened to supply up to 10 cfs auxiliary water into the lower pool-and-chute ladder to provide sufficient attraction flow during the irrigation season. During winter operations, the auxiliary flow gate will be closed and the lower exit will be opened. The exit of the upper ladder will be closed using stoplogs, and the stoplog weir within the upper ladder will be removed to avoid stranding and sediment accumulation during winter flood flow.

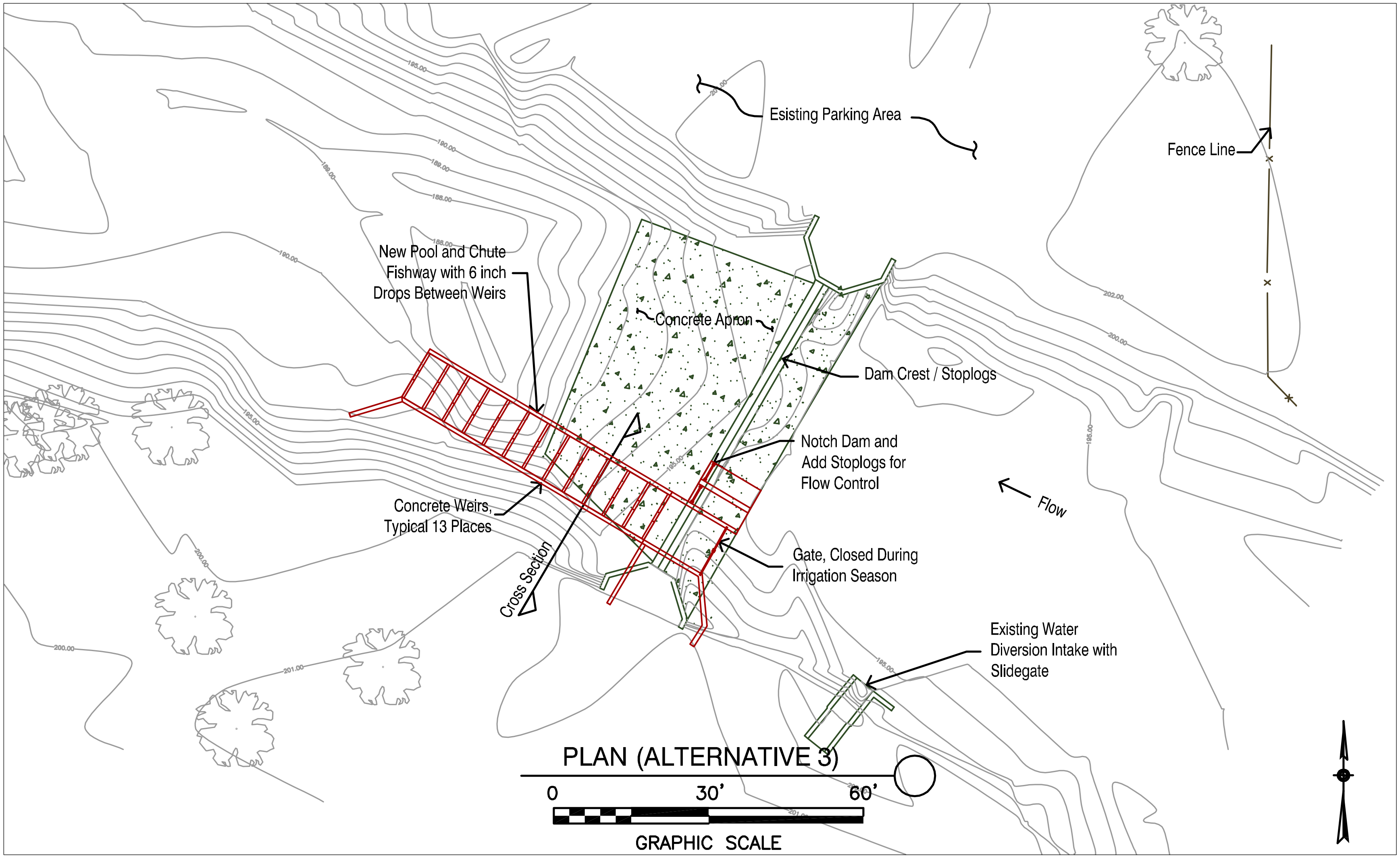


FIGURE 12- HEMPHILL DAM SITE ALTERNATIVE 3
SINGLE STAGE POOL & CHUTE FISH LADDER, PLAN VIEW

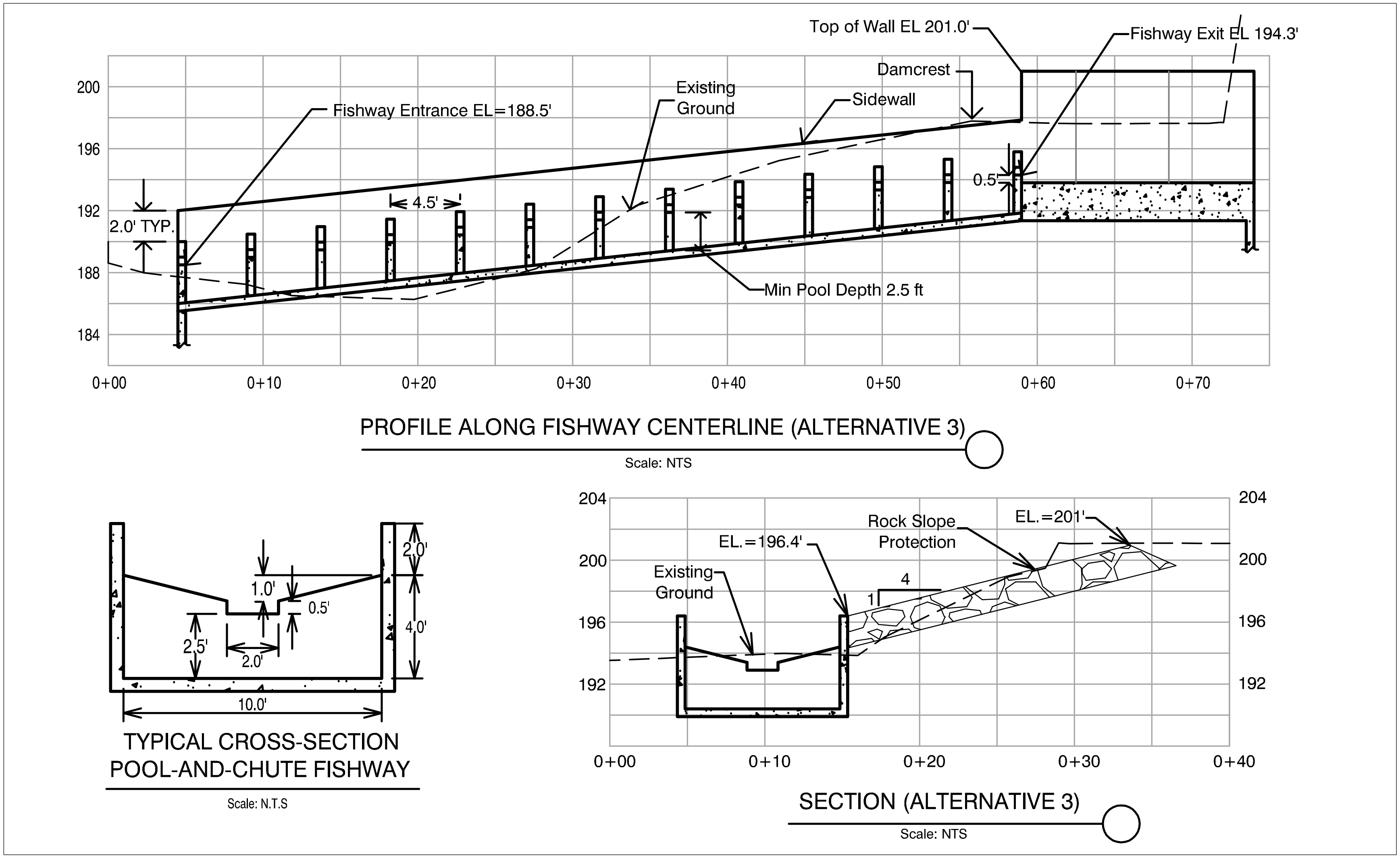


FIGURE 13 - HEMPHILL DAM SITE ALTERNATIVE 3
SINGLE STAGE POOL & CHUTE FISH LADDER, PROFILE & CROSS SECTIONS

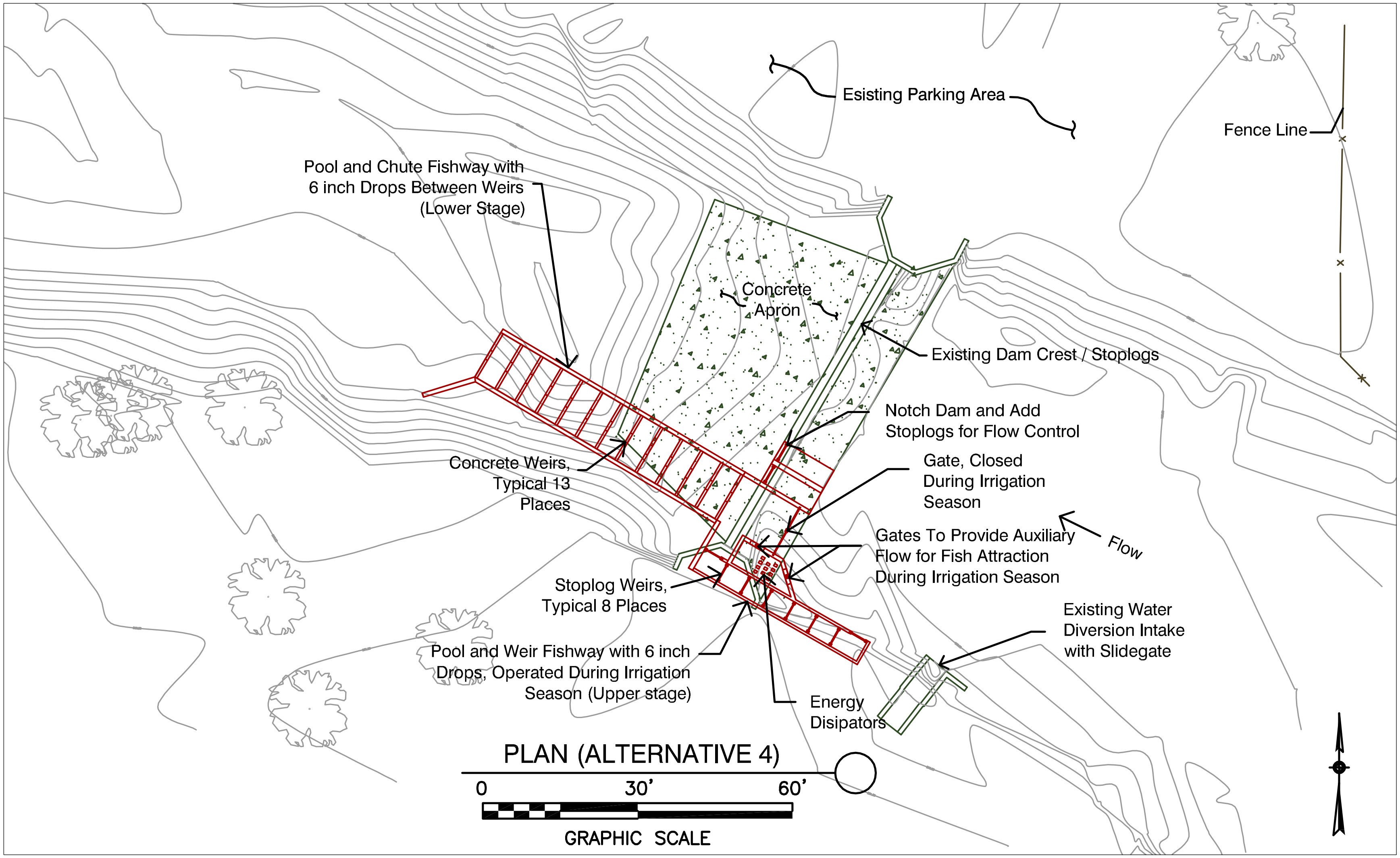


FIGURE 14 - HEMPHILL DAM SITE ALTERNATIVE 4
TWO STAGE FISH LADDER, PLAN VIEW

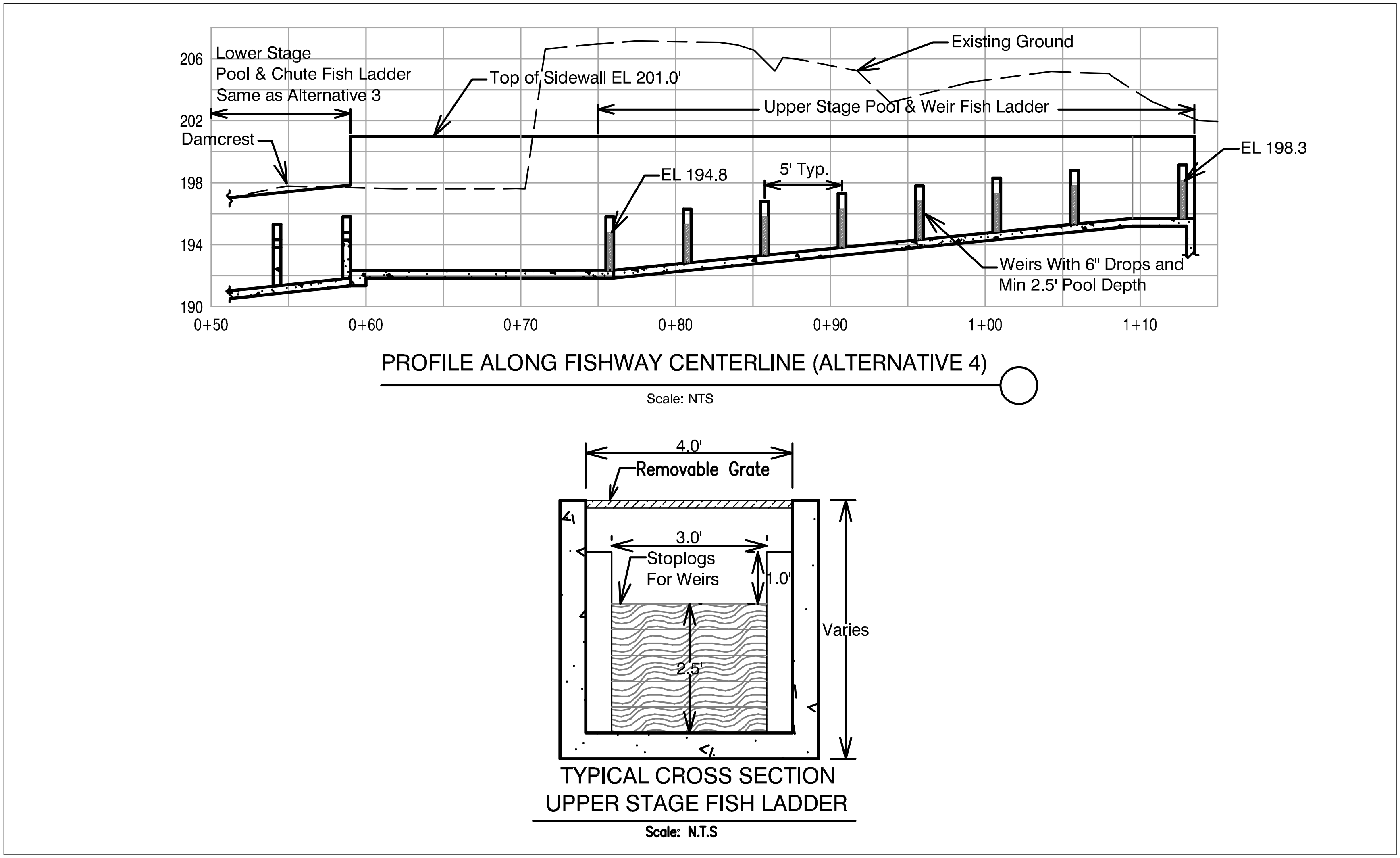


FIGURE 15 - HEMPHILL DAM SITE ALTERNATIVE 4
TWO STAGE FISH LADDER,
UPPER STAGE PROFILE & CROSS SECTION

Outstanding Issue for Hemphill Dam Site

Before an alternative can be selected for the Hemphill Dam, it needs to be determined if fish passage must be provided during the irrigation season. Feasibility of Alternatives 1 and 2 is also dependent on the size of rock required to maintain a stable roughened channel bed at the 100-year design flow. To determine this it requires obtaining the current FEMA HEC-RAS files or other data to determine the amount of flow in the channel and on floodplain during 100-year food, and to determine the project's impact on water surface elevations.

If the Advisory Group wishes to pursue Alternative 1, additional topographic survey and vegetation mapping will be required on the adjacent property.

Discussion and Recommendations

NID Gaging Station

Based on our analysis of the developed alternatives, we recommend pusuing Alternative 1 for the NID Gaging Station. The sheetpile (or other structural) cutoff walls will help ensure suitable fish passage conditions during periods of low flow by controlling subsurface flow. The proposed concrete capped sheetpile downstream of the flume will help maintain a stable and consistent cross section suitable for maintaining a stable stage-discharge rating table for the flume. The steeper (4%) slope of the roughened channel avoids placing the downstream end of the roughened channel in an area of unstable and eroding channel banks. The use of chutes instead of weirs allow for passage of both salmonids as well as other native weaker swimming fish species that may not be able to leap.

Hemphill Dam

Selection of a preferred alternative for the Hemphill Dam site requires determining if year-round fish passage must be provided. Assuming year round passage is necessary, both Alternatives 1 and 4 can meet fish passage criteria. Alternative 1 could provide the most reliable fish passage for all salmonid life stages and other native fishes over the widest range of flows given the hydraulic diversity associated with it. However, it requires extending the project onto adjacent property. It will result in the loss of several large trees, which would likely need to be mitigated. It will also involve excavation and off-site disposal of a large amount of soil. There are also some risks of erosion and sedimentation at the bypass channel exits, given historic bank erosion and bar along the north bank. During the Advisory Group meeting in November 2008, the group discussed moving the bypass channel to the south bank, which was believed to be more stable and less prone to overbank flooding. That may be a more preferable location, except that it requires removal of several more mature riparian trees. Another consideration is that during the irrigation season Alternative 1 can only operate over approximately one foot of variation in the headwater elevation. This has the potential of interfering with current NID diversion rates during low flow periods. If the requirements and constraints associated with Alternative 1 are considered too great, then Alternative 4 appears to best alternative to satisfy project objectives.

Alternative 4 is a two-stage ladder with an exit for the non-irrigation season and another for the irrigation seasons. The use of stop log weirs that can be adjusted during the irrigation season would allow NID to operate the upper pool-and-weir ladder over a wide range of headwater elevations. This type of alternative is considered a proven and reliable way of providing passage for adult anadromous and resident salmonids. Juvenile passage requirements for pool-and-chute ladders are not understood as well. Pool-and-weir ladders can also have issues with debris and sediment clogging if not properly sited.

Next Steps

Once a preferred alternative is selected for the NID Gaging Station and Hemphill Dam site, a geotechnical investigation will be conducted to determine foundation and cut-off wall requirements and evaluate slope stability. Additionally, the current FEMA HEC-RAS files or other data is required to determine the amount of flow in the channel and on floodplain during 100-year food, and to determine the project's impact on water surface elevations. Following completion of these tasks, the engineering design drawings will be completed to the 30% level and a basis of design report will be prepared. At this point, the Advisory Group will be provided the 30% plans and design report for review and comment before proceeding with final designs.

References

CDFG (2003). Part IX: Fish passage evaluation at stream crossings. *California Salmonid Stream Habitat Restoration Manual.* California Department of Fish and Game.

Jones & Stoke. 2004. Salmonid Spawning Habitat Surveys for Placer County Streams. March 24, 2004. 75 pages.

NMFS. 2001. Guidelines for salmonid passage at stream crossings. National Marine Fisheries Service SW Region. 14 pages.

The Mines Group. 2005. Auburn Ravine gaging station site selection and fish passage modifications conceptual design report. Prepared for Placer County Planning Department. 46 pages.