RECLAMATION

Managing Water in the West

Hydraulic Laboratory Technical Memorandum PAP-1083

Santa Margarita River O'Neill Diversion Dam Roughened Channel Fishway

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

January 2014

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Introduction

Background

The O'Neill Diversion Dam is located on the Santa Margarita River in southern California within the boundaries of the United States Marine Corps Base Camp Pendleton (Camp Pendleton). The diversion is 10.5 miles upstream from where the Santa Margarita River enters the Pacific Ocean (Figure 1). The existing diversion structure consists of a 280-ft-long sheet pile weir constructed in 1982 (Figure 2). Up to 100 cubic feet per second (cfs) is diverted through the headgate into O'Neill Ditch (Figure 3). The ditch delivers water to either Lake O'Neill or five groundwater recharge ponds for storage (Figure 4). During diversion operations, it is estimated that approximately 3 cfs in leakage and seepage passes downstream through the diversion weir. When flows exceed the sheet pile weir elevation, higher flows pass downstream.

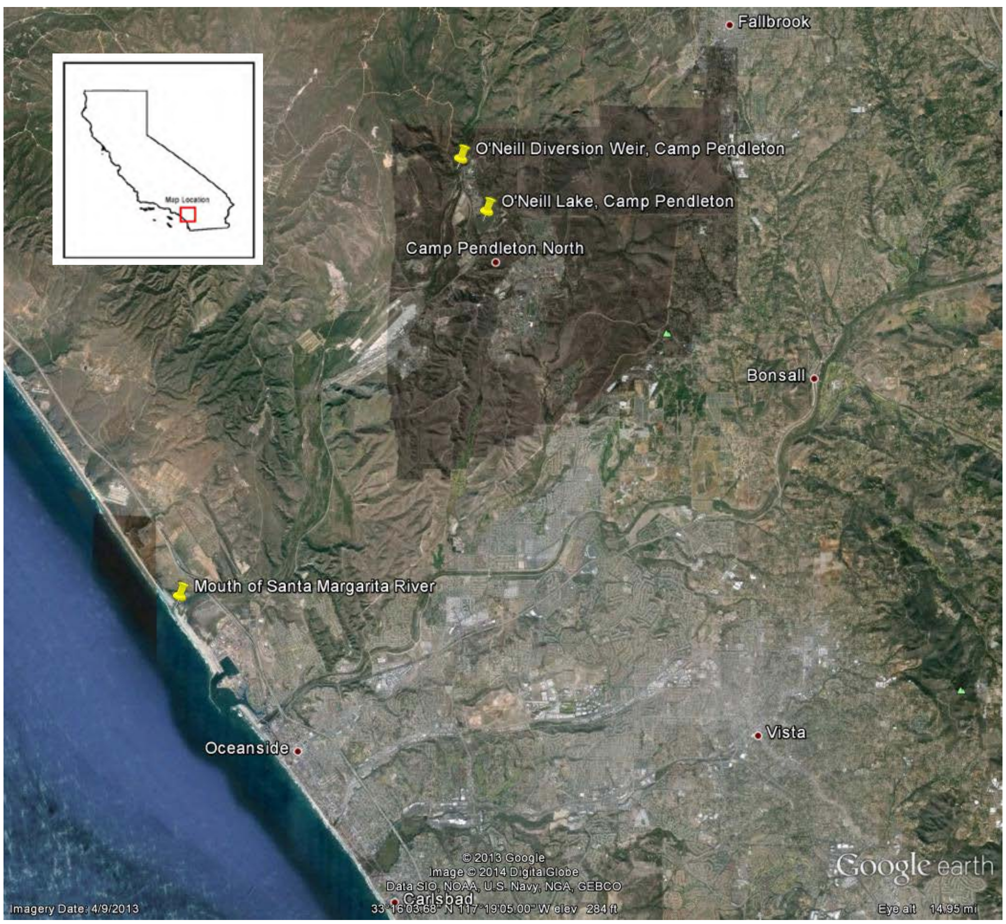

Figure 1. Location map showing Santa Margarita River and O'Neill Diversion at Camp Pendleton (Google Earth^{TM}, 2014).

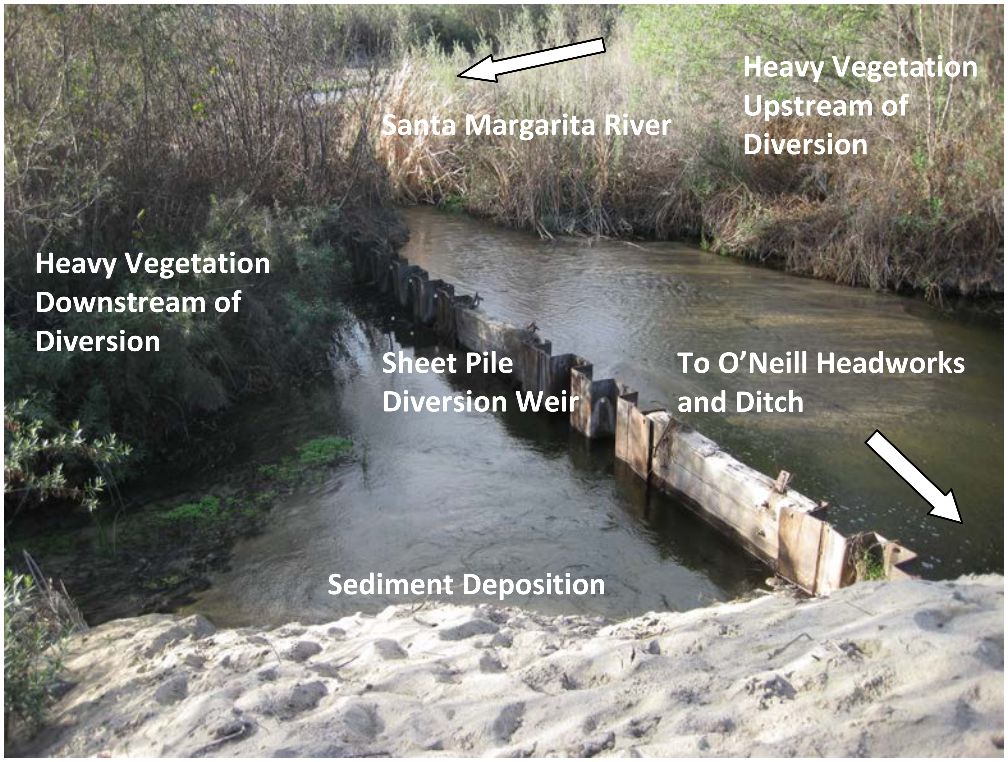

Figure 2. East side of existing sheet pile weir near the diversion intake. Note vegetation and sediment deposition near weir.

Figure 3. O'Neill ditch headworks on east bank of Santa Margarita River.

Figure 4. Map of project features (Google Earth™, 2014).

As part of the Santa Margarita Conjunctive Use Project, there is a proposal to modify the existing diversion structure to increase the diversion capacity and to reduce sedimentation issues in the river channel and diversion canal. The existing sheet pile diversion would be replaced with a new inflatable dam spanning the full width of the river (Figure 5). The inflatable dam would allow a diversion of up to 200 cfs while fully inflated and would be deflated during large runoff events to allow sediment accumulated behind the weir and in front of the diversion headgate to pass downstream. A small vertical sluice gate has been proposed to manage sediment immediately adjacent to the diversion head gate. Modifications to the headgate and intake structures are also proposed, along with possible installation of a fish screen in the diversion ditch with a fish return to the Santa Margarita River downstream of the dam.

Figure 5. Example of inflatable dam with inflatable air bladders and gate panels controlling upstream water level (from Obermeyer Hydro, Inc., www.obermeyerhydro.com).

Based on historical accounts, recent findings, and site conditions, it is assumed that federally listed endangered Southern California Steelhead (*Oncorhynchus mykiss*) may sporadically occur in the Santa Margarita River watershed. In its current configuration, upstream migrating adult steelhead would need to jump over O'Neill diversion weir to spawn in the upper watershed. Although there is little pool below the structure, the weir may be passable at higher flows when the difference between the upstream and downstream water surface elevations is reduced at the weir crest.

Under proposed modifications, an inflatable dam would be installed with a weir crest situated at 118.7 ft which is1 ft higher than the existing sheet pile weir crest of 117.7 ft. Steelhead should be able to pass over the dam when gates are deflated during large storm events. During intermediate flows, however, there is a need for fish passage at the dam. Stetson Engineers found 166 cfs to be the minimum fish passage flow with 1 ft of water depth based on analysis of 3 critical sites from a longitudinal survey and site assessment (Stetson Engineers, 2012). Fish passage should be designed to accommodate passage at 166 cfs and above with a flow depth of 1 ft. When flows are below 166 cfs, steelhead may not be able to migrate upstream to the diversion dam.

The purpose of this project is to design appraisal-level fish passage at O'Neill Diversion Dam. Several alternatives were considered before recommending a passage system. A design description, appraisal-level design drawings, and an appraisal-level cost estimate of the chosen design are provided in this report.

Fish Passage Criteria

Flow conditions in the fishway should encourage upstream passage of adult steelhead. Adult fish passage criteria and guidelines for salmonids are published by the National Marine Fisheries Service (NMFS, 2001 and 2008) and California Department of Fish and Wildlife (CDFW), formerly referred to as California Department of Fish and Game (CDFG, 2003 and 2009).

In general, fish passage criteria for adult salmonids can be summarized:

- Maximum hydraulic drop must be 1 ft or less (NMFS, 2008 for fish ladders).

- Minimum flow depth should be at least 1 ft over the fishway crest (NMFS, 2008 for fishway overflow weirs).

- Average chute design velocity should be less than 5 ft/s (NMFS, 2008 for Denil and Steep pass fishways). For culverts, the maximum design velocity should be 5 ft/s for a 60- to 100-ft-long culvert (NMFS, 2001).

NMFS (2008) states that fish passage will be impeded when weirs, aprons, hydraulic jumps or other hydraulic features produce flows depths of less than 10 inches or flow velocity greater than 12 ft/s for over 90% of the stream channel cross section. Several researchers have reported swimming speeds and recommended velocities for upstream passage of adult steelhead trout. Bjornn and Reiser (1991) suggest a maximum passage velocity of 8 ft/s, but state that steelhead are capable of sustained swim speeds up to 13.7 ft/s and darting speeds above 20 ft/s. Bell (1991) reports similar velocity ranges for sustained and darting swimming speeds. Thompson, 1972 (reported in Barnhart, 1986) reported upstream migration of steelhead is not impaired at depths greater than 0.6 ft, however, deeper depths are recommended for passage. Based on criteria and studies in literature, fish passage at O'Neill diversion was designed for average velocities of around 5 ft/s at the design flow and around 10 ft/s at the highest expected flows with a minimum flow depth of 1 ft.

There are many different types of upstream fish passage for adult salmonids. Specific criteria for newer types of fishway designs are not yet published, but NMFS (2008) recommends that roughened channels only be used when:

- Channel slope is less than 6%.
- Total length of passage is less than 150 feet.
- An appropriate mix of bed materials (from fines to boulder sized material) are used such that flow depths of at least 1 ft can be maintained for upstream adult salmonid passage.
- Sub-surface flow is minimized by filling voids between larger materials with finer-sized material.

Fishway Design

Available Design Information

Limited baseline information was available for design of the fishway structure. Floods in the Santa Margarita River are typically of short duration with rapid rise and fall of flow. Due to flashy flood conditions, low average flows, and high sediment loads, topography near O'Neill diversion changes significantly over time. Figures 6-11 from Google Earth™ demonstrate how the active channel changes with the amount and location of sediment deposits and vegetation.

Figure 6. Aerial satellite image 6/9/2003 (Google Earth™).

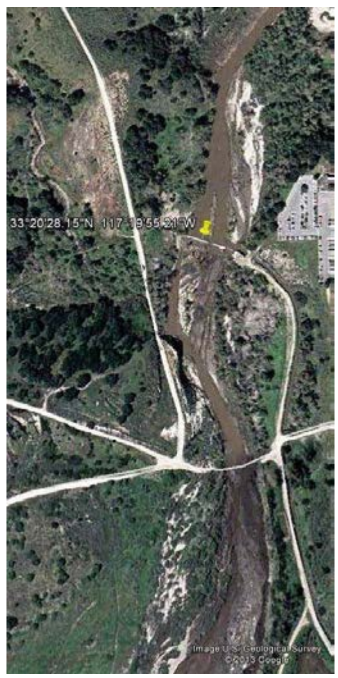

Figure 7. Aerial satellite image 12/30/2003 (Google Earth™).

Figure 8. Aerial satellite image 10/10/2005 (Google Earth™).

Figure 9. Aerial satellite image 1/3/2006 (Google Earth™).

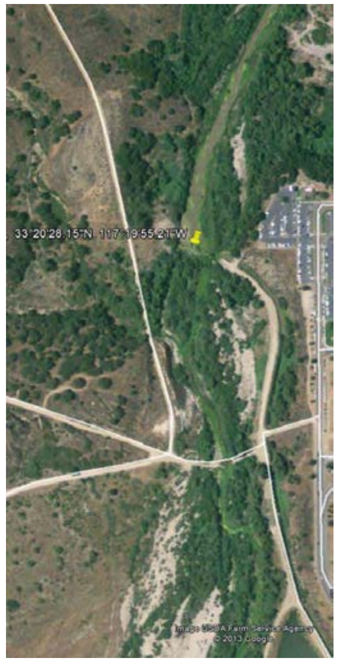

Figure 10. Aerial satellite image 6/5/2009 (Google Earth™).

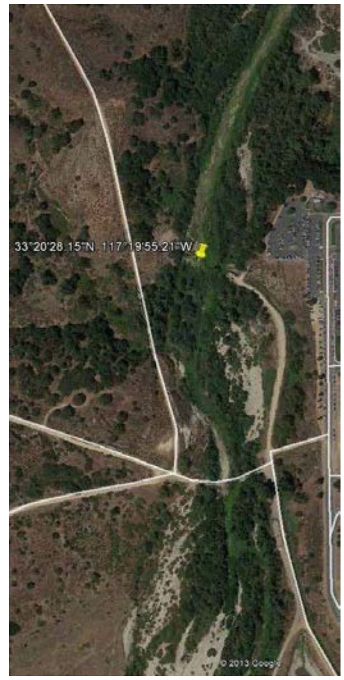

Figure 11. Aerial satellite image 8/23/2010 (Google Earth™).

A site visit to O'Neill diversion in January 2009 showed that the downstream river channel was choked with sand and contained significant debris piles composed largely of dislodged brush from a flood event in December 2008 (Frizell and Mefford, 2009). West Consultants (2000) characterized the bed material near the diversion as 93 percent sands with little material larger than medium gravel. More discussion of channel characteristics, sediment characteristics, and sediment transport and deposition issues at O'Neill diversion under current and proposed modifications can be found in Bountry, 2004. Since topography changes frequently, new survey data was collected by Stetson Engineers on May 7-8, 2012 and January 16-17, 2013 near O'Neill diversion weir. Elevations are shown in NAVD 88 datum based on nearby local benchmark PC 14. Survey boundaries are shown in Figure 12. Survey data places the top of the existing weir at elevation 117.7 ft, which is different than previously reported elevations. Elevations reported in the 2013 survey were used for design of the fishway structure in this report.

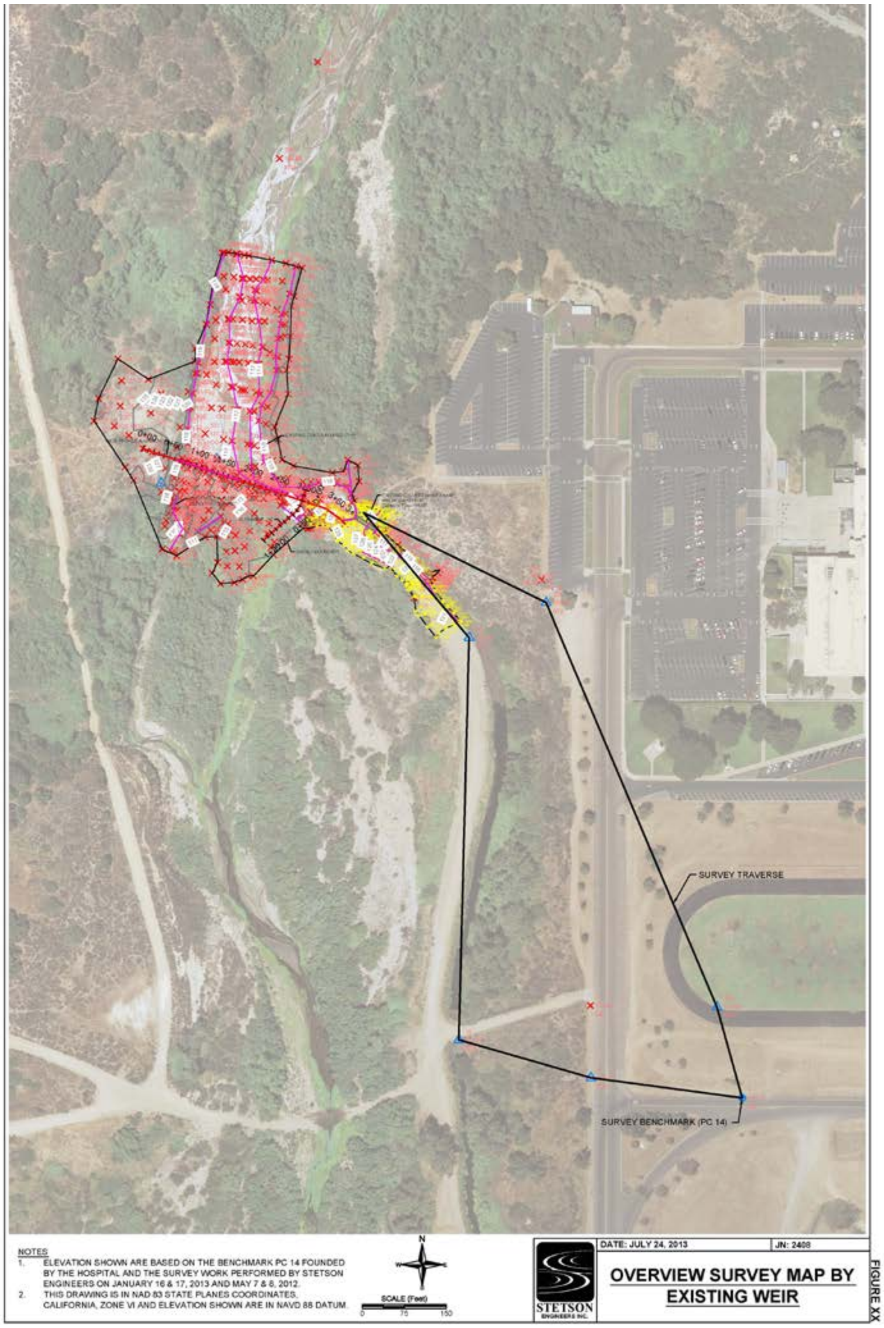

Figure 12. Boundaries from 2012-2013 Stetson Engineers topographic survey.

Tailwater data was not available directly below the weir. The closest stage reading was 2.3 miles downstream of the O'Neill diversion at USGS gage 11046000 (Santa Margarita R at Ysidora CA). Previous one-dimensional hydraulic modeling using HEC-RAS was not used because it was not based on the most recent topography in the vicinity of O'Neill diversion.

It is expected that 150 cfs will be diverted into O'Neill ditch before flows are released for fish passage. The fishway will then be operated to about 150 cfs before the O'Neill ditch increases diversion up to 200 cfs. Once full diversion has been reached, all remaining flow will pass downstream through the fishway, sluiceway, or over the inflatable dam. During flood flows, water will not be diverted because of concerns about sediment entrainment in the ditch. Proposed operations for the increased diversion are described below (from Cardno Entrix, 2013):

Table 1. Proposed facility operation at O'Neill diversion.

River Flow (cfs)	Diversion Flow (cfs)	Bypass Flow* (cfs)	Fishway Flow (cfs)
0-3	0	0-3	0
4-153	1-150	3	0
154-303	150	3	0-150
304-353	151-200	3	150
354-3,700	200	3	>150
>3,700	0	>3,700	>150

* Bypass flow occurs through sediment sluiceway when water surface is below elevation 118.7 ft. Above elevation 118.7 ft, bypass flow passes through the sluiceway and over inflatable dam.

Design Challenges

There are several challenges to designing a fishway at O'Neill diversion weir.

- Changing topography due to flashy flood conditions and high sediment loads will affect fishway entrance and exit conditions.

- Braided river conditions due to sediment deposits and vegetation downstream of the diversion weir may prevent access to fishway entrance.

- Sediment delta will likely form at the fishway entrance.

- Low flows and sediment deposition may prevent water from impounding the full area upstream of the diversion weir, limiting access to the fishway exit.

- Uncertainty on fishway submergence under higher flows due to unknown tailwater conditions.

- High concentrations of sand-size bedload and large volumes of woody debris are expected to pass through the fishway.

Alternatives Considered

A discussion of potential fish passage options and preferred alternatives can be found in Cardno Entrix (2012) and Frizell and Mefford (2009). Using guidance from these documents, a limited number of fish passage options were considered at O'Neill diversion for this evaluation.

Technical Fishway

A technical fishway employs engineered features such as baffles and weirs to control flow velocity such that average velocities fall within the swimming capability of the target fish species. Types of technical fishways include vertical slot, Denil, and Alaskan Steep pass. Technical fishways can be designed at steeper slopes than natural fishways, so the overall length of the fishway is minimized. At O'Neill diversion, the primary disadvantage of a technical fishway is that sediment may accumulate within the fishway and debris may clog baffling elements during higher flows.

Figure 13. Example of technical fishway with steel baffles at Government Highline Diversion Dam, Colorado River, CO.

Hardened Channel Fishway

Hardened channels attempt to simulate natural channels; however, engineered roughness elements are used in place of natural materials. Concrete or shotcrete is used for the channel invert, so these channels can be built to higher slopes than roughened channels with shorter overall lengths. Hardened ramps support higher velocities and limit damage during high stream flows. At O'Neill diversion, a hardened channel would be acceptable. There is some concern, however, that engineered roughness elements may collect debris and sediment.

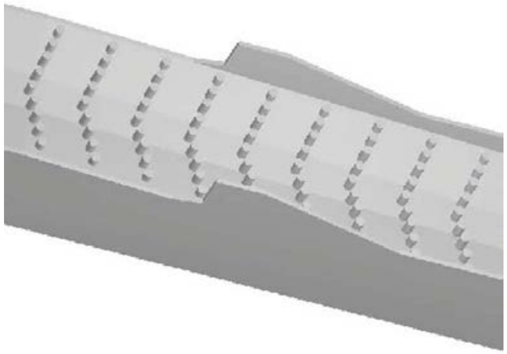

Figure 14. Numerical modeling section of trapezoidal fishway channel with concrete cylindrical baffles (Mefford, 2011).

Roughened Channel Fishway

Roughened channel fishways attempt to simulate natural channels. Roughened channels are constructed of natural materials such as rocks and boulders. Bed roughness, intermittent large scale roughness, channel shape, and slope are used to control flow velocity. Larger boulders are placed at strategic locations along the fishway to create pools with low flow and low turbulence. Boulders can be placed along channel edges to minimize sediment and debris entrainment during design flows, but provide low flow resting areas during higher flows.

This type of fishway is designed at a lower slope, so the fishway entrance may be located far downstream of the dam. Roughened channels will not move during design flows if the channel slope and rock material are carefully selected, but will likely sustain damage during peak stream flows. Roughened fishways can typically pass sediment and debris more effectively than technical fishways and can be designed to provide passage for a range of swimming capabilities.

At O’Neill diversion, a roughened channel fishway was selected for further development due to high expected sediment and debris loads. Compared to baffles in a hardened ramp, a roughened channel with boulders spaced at the channel edges will allow unobstructed flow through the fishway for all but the highest flow rates.

Figure 15. Example of a roughened channel fishway
at Derby Diversion Dam, Truckee River, NV.

Right Bank Roughened Channel Fishway

Several locations were considered for a roughened channel fishway. Serious consideration was given to a roughened channel fishway along the right bank. There are many advantages to this design, but uncertainties about sedimentation upstream of the dam ultimately made this option less desirable than a fishway along the left bank. Figures 6-11 show how the active channel changes over time on the right bank.

Advantages

- Deeper channel downstream of dam based on current topographic survey
- Ability to move fishway entrance closer to axis of dam for easier attraction of upstream migrants

Disadvantages

- Unclear if sand bar will form at fishway exit, thereby preventing flow down the fishway at the design flow
- Upstream components of fishway effectively become part of the dam structure
- Poor access for maintenance and observations
- Little benefit to downstream migrants

Left Bank Roughened Channel Fishway

A roughened channel located on the left bank was selected for further development. Figures 6-11 show how the active channel changes over time on the left bank.

Advantages

- Fishway exit should remain cleared of sediment because the adjacent diversion entrance will be dredged if necessary to control sediment deposition. Therefore, flow down the fishway is expected for all water surface elevations exceeding the fishway invert.

- Good access for operations, maintenance, and observations
- Beneficial location for use by downstream migrants

Disadvantages

- Entrance to fishway may be far downstream of dam, so adults that pass the fishway may have difficulty finding the entrance. When the fishway is the only attraction flow, this may not be a concern. When water passes over the inflatable dam, attraction flow to the fishway is less defined.
- Possible impingement of adult steelhead on diversion trashrack upstream of the fishway
- Possible entrainment of weaker swimmers or juveniles using the fishway into O’Neill ditch

Left Bank Roughened Channel Fishway with an Inflatable Gate and Plunge Pool (proposed by Cardno Entrix, 2013)

A roughened channel fishway design was recommended by Cardno Entrix (2013). This design includes a short section of inflatable dam for gate control at the fishway exit, a plunge pool, and a 2% roughened channel ramp (Figures 16-17). The top of the gate at the fishway would be set to the same elevation (118.7 ft) as the rest of the inflatable dam. The fishway gate can be lowered by 1 ft to 117.7 ft to allow flow over the gate and into the fishway channel. Steelhead may be able to jump over the gate during passage flows by using the plunge pool. During flood flows, the dam can be completely deflated to pass water, sediment, and debris downstream through the fishway.

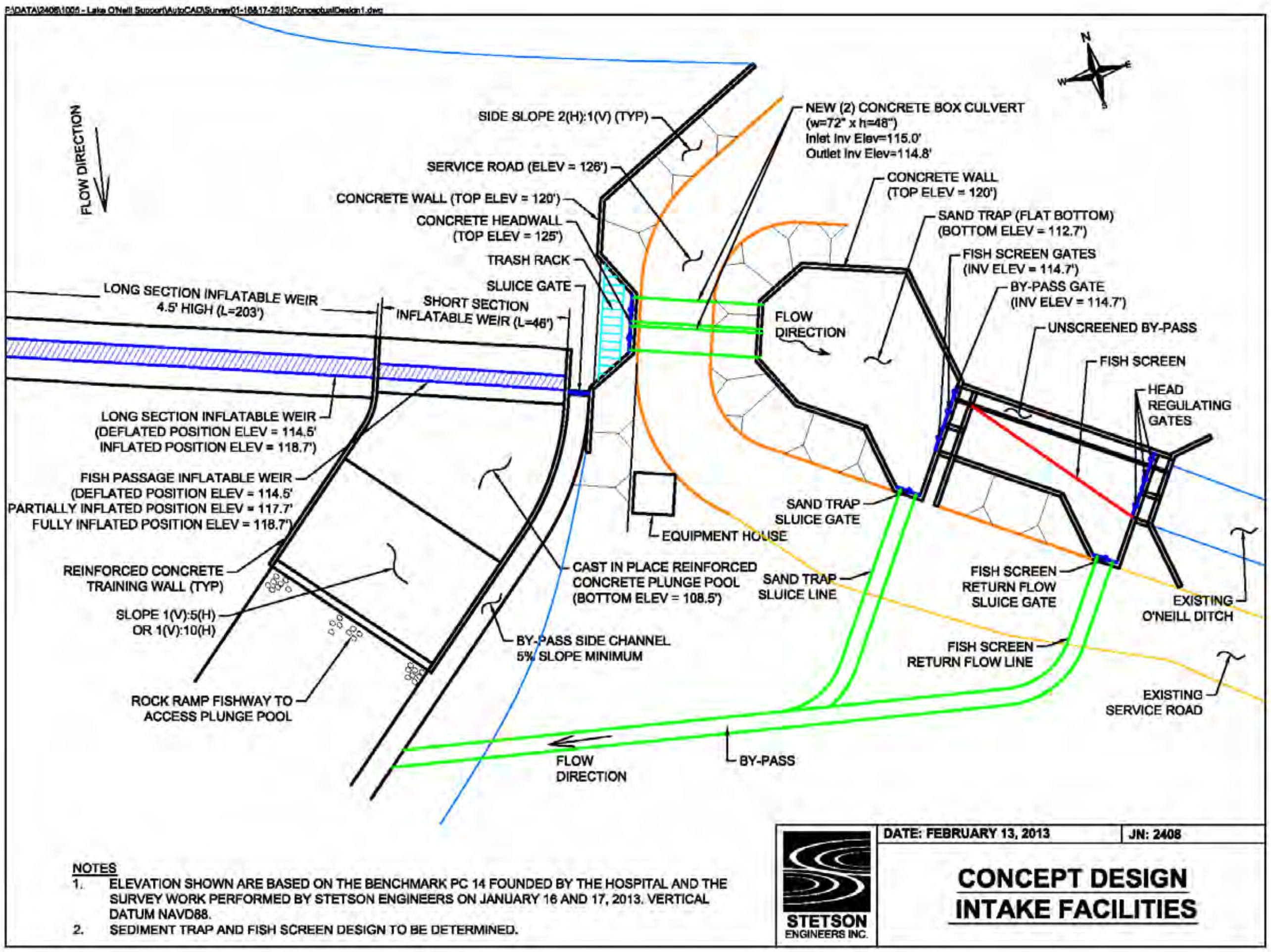

Figure 16. Plan view drawing of proposed Cardno Entrix (2013) roughened channel fishway. The concept includes a gated exit at the access of the dam, a plunge pool, and a 2% roughened channel ramp.

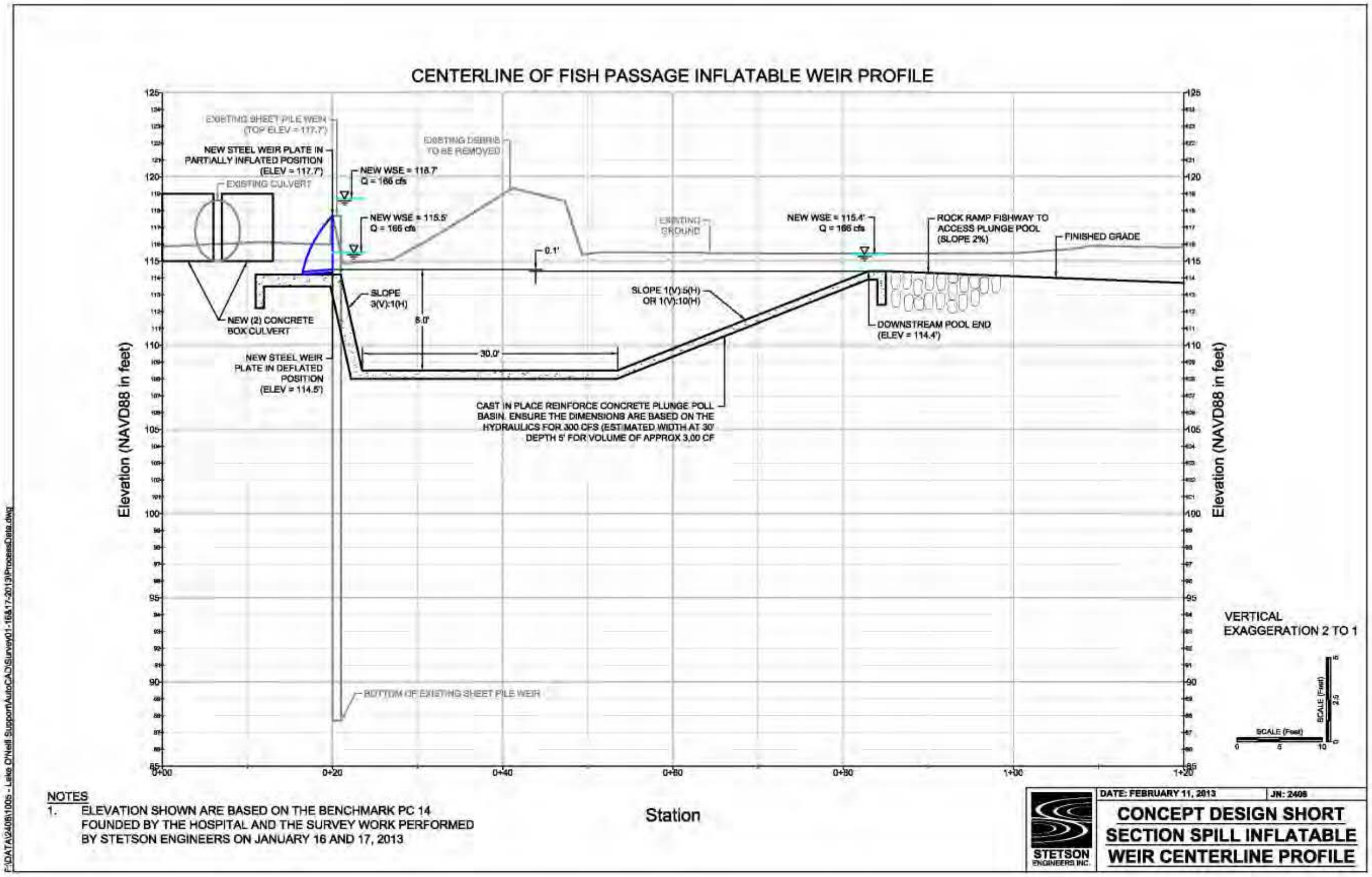

Figure 17. Sectional drawing of proposed Cardno Entrix (2013) roughened channel fishway. The concept includes a gated exit at the access of the dam, a plunge pool, and a 2% roughened channel ramp.

Advantages

- Fishway exit should be cleared of sediment because the adjacent diversion entrance will be dredged if necessary to control sediment deposition. Therefore, flow down the fishway is expected for all water surface elevations exceeding the fishway invert.
- Passes sediment and debris better than a technical fishway
- Good access for operations, maintenance, and observations
- Beneficial location for downstream migrants

Disadvantages

- Jump from plunge pool over inflatable gate will be greater than 1 ft limit specified in criteria
- Plunge pool design extends the overall length of the fishway, so the entrance to the fishway is far downstream of the dam. Adults that pass the fishway may have difficulty finding the entrance.
- Plunge pool may fill in with sediment during the design flow
- Gated exit (inflatable dam) increases operations and maintenance of fishway

Recommendations

- Cutting a V-notch into the right side of the plunge pool may allow adult steelhead to jump into the fishway plunge pool from the river channel. This would provide attraction flow for adult steelhead that passed the fishway entrance and were held up at the dam face.

Reclamation Proposed Alternative Design: Roughened Channel Fishway on Left Bank

Assumptions

1.) Assume channel upstream of diversion entrance will be maintained by dredging if necessary to maintain diversion flows. This will ensure that there is flow into the fishway for all stream flows.
2.) Heavy levels of fine sediment exist in the river. It is assumed that a sediment bar will not block access to the fishway exit or entrance and dredging will be employed if necessary.
3.) New inflatable dam will be installed at the same time as the fishway.
4.) The fishway exit invert will be fixed at 117.7 ft. Once the forebay water surface elevation reaches 118.7 ft, water will pass over the inflatable dam as well as flowing down the fishway. This will reduce the effect of attraction flow at the fishway entrance.
5.) Choke material will not be added to the fishway design because it is assumed that sediment will fill in the rock material after the first spill.

6.) Based on feedback from Camp Pendleton, it was determined that a gated fishway should not be used in order to minimize operation and maintenance. A gated fishway increases maintenance of mechanical parts and requires operators to change gate settings under differing flows.
7.) Accept movement of rockfill during large flood events.
8.) Since tailwater data was not available directly below the weir, hydraulic equations for weir flow and open channel flow were used for hydraulic calculations at the diversion.
9.) Existing topography from 2012-2013 Stetson Engineers survey was used for design elevations. Once the new dam and fishway are operating, the channel topography will change due to new operations and sediment sluicing capabilities.

Design Features

Layout of the roughened channel fishway along the left bank of the Santa Margarita River is based on drawings of the existing diversion and headgate and the 2012-2013 topography from Stetson Engineers. The fishway was designed under the assumption that the proposed inflatable dam, sluiceway, and modifications to the diversion headworks will be completed at the same time. Alignment of the fishway generally follows the preliminary alignment for the proposed fishway concept design in Cardno Entrix, 2013. A 40-ft radius aligns the fishway with topography on the left side of the river such that the sediment sluiceway and the diversion trashrack and entrance are situated to the left of the fishway exit. Final alignment may shift based on the final design of the adjacent sluiceway and diversion trashrack. Drawings for the roughened channel fishway at O'Neill diversion are shown in Figures 18-19.

The exit of the roughened channel fishway proposed in this study is at the axis of the dam. The exit could not be extended farther upstream without restricting flow to the diversion entrance. It was decided that the fishway should not be gated due to concerns raised by Camp Pendleton over increased operations and maintenance requirements.

The fishway exit invert is fixed at 117.7 ft which is 1 ft lower than the proposed inflatable dam elevation. The dam will have an inflated elevation of 118.7 ft and a deflated elevation of 114.5 ft with a concrete slab foundation at elevation 114.2 ft. If the fishway invert were set to 118.7 ft, the fishway would not flow before water spills over the dam. If the invert were set to 114.5 ft, the exit would need to be gated to allow for full diversion capacity. A fishway elevation of 117.7 ft allows O’Neill ditch to divert 150 cfs before water spills into the fishway (Cardno Entrix, 2013).

The fishway is designed to pass the minimum steelhead passage flow of 166 cfs with a flow depth of 1 ft. When the flow depth exceeds 1 ft in the fishway, the inflatable dam will begin to overtop. During the 10 year flood (average daily flow rate of 3,700 cfs with instantaneous peak flood discharge of 15,700 cfs), the inflatable dam will be lowered to pass sediment and debris. It may be possible for adult steelhead to jump directly over the dam before gates are lowered depending on the hydraulic drop across the structure, but this was not assumed in the design.

The fishway is a trapezoidal channel with 25 ft bottom width, 2:1 sideslopes, and 38 ft overall width (to pass the 10 year event). A 6-inch-deep V-shaped low-flow channel at the channel bottom is included to allow some water depth in the fishway thalweg for flows less than 166 cfs.

There is a reinforced concrete transition section with two 1-ft-thick concrete headwalls at the fishway exit. The headworks section transitions geometry from a rectangular exit at the dam to a trapezoidal section 15 ft downstream of dam axis. Concrete in this transition zone will have a roughened finish surface.

To estimate water velocity in the fishway, Manning's equation was used.

$$V = (1.49/n)\ R^{2/3}\ S^{1/2}$$

where V = average flow velocity (ft/s), n = Manning's coefficient of roughness, R = hydraulic radius (ft, ratio of flow area to wetted perimeter), and S = channel slope. Manning's coefficient was estimated by using Abt et al. (1988):

$$n = 0.0456\ (D_{50}\ S)^{0.159}$$

where D_{50} = mean sediment diameter (in) and S = channel slope. Manning's n coefficient with a D_{50} of 12 inches and slope of 2% equals 0.036. Three-ft-diameter boulders are placed approximately every 15 ft along the fishway (discussed below). Because of this additional roughness feature, a Manning's n coefficient of 0.040 is assumed for the design.

The fishway is placed at a 2% slope to maintain velocities within an acceptable range. At the design discharge of 166 cfs, average velocities are calculated to be 5.6 ft/s. At the maximum discharge of 3,700 cfs before the dam gates are lowered, approximately 1,200 cfs will pass down the fishway. Average velocities are calculated to be 11.5 ft/s at the 10 year flood event. Slopes greater than 2% produced unacceptably high fishway velocities. With the fishway extending to local grade at a 2% slope, the total fishway length is 90 ft.

Since the fishway entrance is located 90 ft downstream of the dam, adults that pass the fishway may have difficulty finding the entrance. When the fishway is 100% of the attraction flow, this should not be a concern. When water also passes over the inflatable dam, attraction flow from the fishway is less defined. At a flow depth of 2 ft in the fishway (119.7 ft) with flow passing over the top of the dam, approximately 40% of the flow passes through the fishway. At a flow depth of 3 ft in the fishway (120.7 ft) with flow passing over the dam, approximately 33% of the flow passes through the fishway.

The required riprap size is calculated from Abt and Johnson, 1991 for angular stone on a bed slope from 1 to 20%.

$D_{50} = 0.436\ S^{0.43}\ q^{0.56}$

where D_{50} = characteristic rock diameter (ft), S = channel slope, and q = maximum unit discharge (cfs/ft). For a channel slope of 2% and a maximum unit discharge of 3,700 cfs per fishway width of 38 ft, the recommended D_{50} is 1.05 ft. One-ft-diameter rockfill is chosen for the fishway (D_{50}=1 ft and D_{100}=1.5-2.0 ft).

The required depth of riprap was determined from guidance in literature. American Society of Civil Engineers (1975) recommends 1.5 D_{50}. Abt et al. found a layer thickness of D_{100} or 1.5 D_{50} is sufficient for $D_{50} > 6$ in. U.S. Army Corps of Engineers (USACE, 1991) recommends the layer should be at least D_{100} or 1.5 D_{50}, whichever is greater. The selected total depth of riprap for the fishway is 2 ft. Rockfill should be well-graded, angular rock to maximize interlocking of stones. Rip rap unit weight of 150-175 lb/ft^3 shall be used (USACE, 1991). The construction contractor must place rock deliberately to ensure that rocks are interlocked and proper channel dimensions are achieved.

Three-ft-diameter boulders (D_{50}) will be installed as isolated roughness elements. Since boulders in the center of the channel are likely to collect debris and sediment, boulders are placed on the sideslopes to minimize debris and sediment collection at lower flows. These boulders can be used as resting zones for steelhead during higher passage flows. Boulders are spaced evenly in 6 rows from Sta. 0+17 to 0+88 (approximately every 15 ft), starting 2 ft downstream of the concrete transition. Four boulders will be installed at each cross section: 2 at the break on slope for the trapezoidal sideslopes and 2 halfway up the sideslope (Figure 12, Typical Boulder Section).

Riprap protection with a geosynthetic lining is included at the downstream toe of the fishway to minimize erosion. USACE (1991) recommends channel end protection using twice the layer thickness placed over filter material for a distance of at least 3 layer thicknesses (detailed in Figure 12).

There will be an unknown level of backwater at the toe of the fishway. A tapered right wall toward entrance of fishway was considered to allow steelhead to pass over the sheet pile wall from the river channel if the fishway is backwatered. Because tapered walls would require a change in trapezoidal geometry near the fishway entrance in this design, the concept was not pursued.

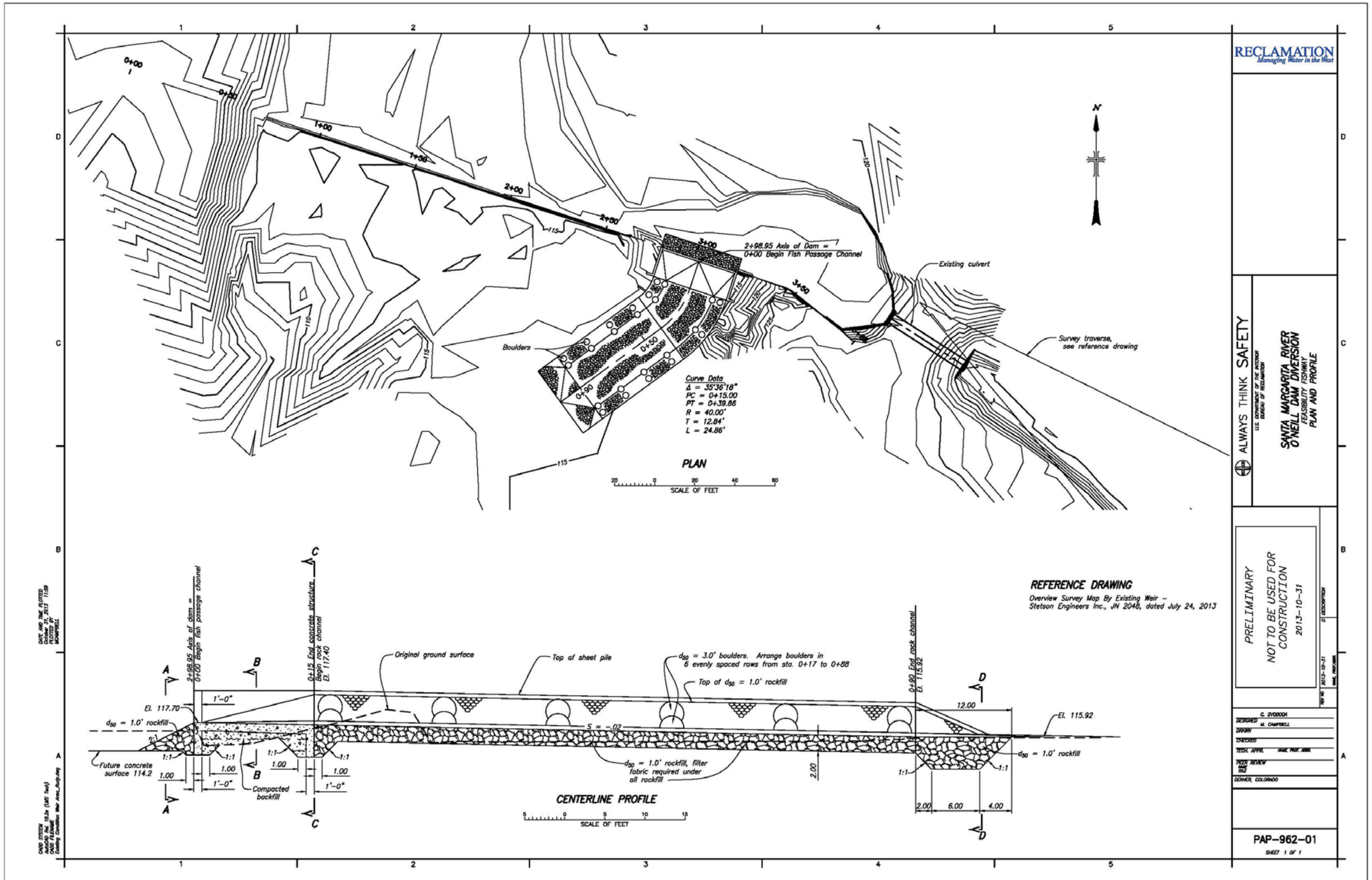

Figure 18. Appraisel-level plan and profiles drawings of a roughened channel fishway at O'Neill Diversion.

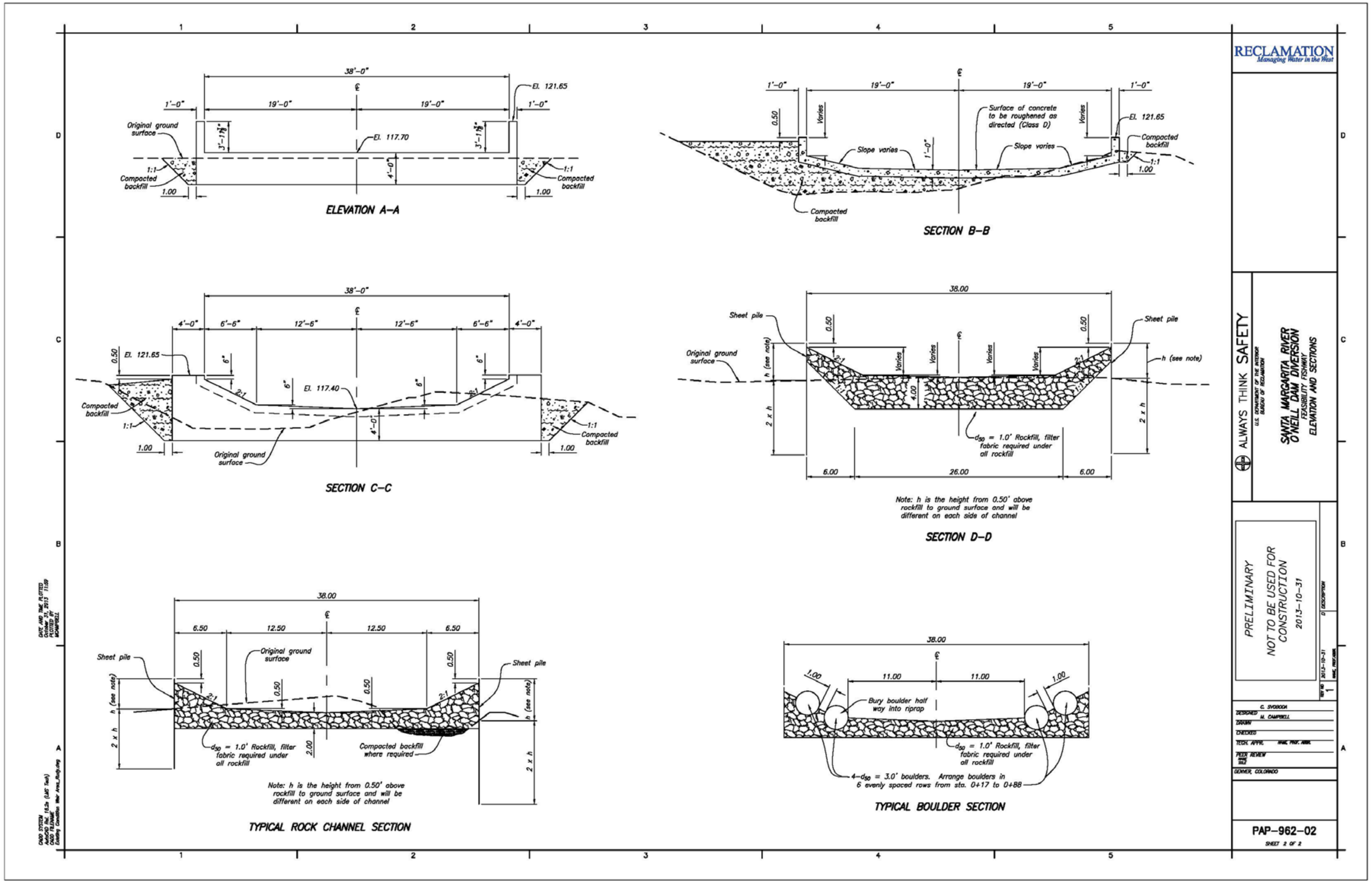

Figure 19. Appraisal-level elevation and sectional drawings of a roughened channel fishway at O'Neill Dam Diversion.

Reclamation Proposed Alternative Cost Estimate: Roughened Channel Fishway on Left Bank

Assumptions

1.) River diversion, cofferdam, and dewatering/unwatering will be part of inflatable dam installation.
2.) Assume existing access roads can be used. Any necessary road modifications will be part of inflatable dam installation.
3.) Topography from 2012-2013 Stetson Engineers survey was used for cut-and-fill estimates.
4.) Assume sheet pile must be 2/3 buried.
5.) Assume that river sediment load will fill in between rocks after first spill, so no choke material was added to fishway design.

Discussion of Cost

The local area will be cleared, grubbed, and excavated. Backfill will be placed and compacted and a geosynthetic liner will be installed above the compacted backfill. The fishway will be constrained by 0.4-inch-thick sheet pile walls along the channel sides for a total length of 150 ft. Depth of sheet pile is approximately 15.5 ft on average based on topographic estimates (10 ft 3 in driven into ground and 5 ft 3 in above ground). Sheet pile extends 6 inches above the top of the trapezoidal channel. The construction contractor will be required to cut sheet piles along a diagonal to obtain a smooth top surface.

The appraisal-level cost estimate includes clearing, grubbing, excavation, backfill and compacted backfill, reinforced concrete, rock and boulder placement, filter fabric, and sheet pile. River diversion, cofferdam, dewatering, and/or unwatering costs are not included in the estimate. Total appraisal-level cost of $460,000 includes mobilization, contracting, and construction contingencies. Non-contract costs are not included. Estimating sheets are shown in Appendix A.

References

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APPENDIX A

Appraisal-Level Cost Estimate Sheets

BUREAU OF RECLAMATION **ESTIMATE WORKSHEET** SHEET 1 OF 2

FEATURE: **O'NEILL DAM DIVERSION - FISHWAY DESIGN** **Roughened Channel Fishway Alternative**	**PROJECT: SANTA MARGARITA RIVER, CA**
	WOID: A066F **ESTIMATE LEVEL: APPRAISAL**
	REGION: LC **UNIT PRICE LEVEL:** Oct-13
	FILE: P:\Appraisal\EST Worksheets\[Estimate Worksheet_Santa Margarita Fishway_final.xlsx]Template Sheet 1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	Clearing and Grubbing		455	SY	$2.00	$910.00
	2	Excavation		275	CY	$120.00	$33,000.00
	3	Backfill		110	CY	$50.00	$5,500.00
	4	Compacted backfill		110	CY	$50.00	$5,500.00
	5	Furnish, form, place reinforced concrete		40	CY	$1,250.00	$50,000.00
	6	Furnish and place reinforcement (150#/CY)		6,000	LB	$2.00	$12,000.00
	7	Furnish and handle cement (0.282T/CY)		12	TON	$200.00	$2,400.00
	8	Riprap (D_{50} = 12")		350	CY	$150.00	$52,500.00
	9	Fishway boulders (D_{50} = 3')		24	EA	$500.00	$12,000.00
	10	Filter fabric		390	SY	$12.00	$4,680.00
	11	Furnish and drive 0.4 inch thick sheet pile (15.5 ' deep)		2,325	SF	$50.00	$116,250.00
		(total length = 150 ft, approx. 10 ft 3 in driven					
		into ground with 5 ft 2 in above gnd)					
		Estimate does not include any cofferdams or dewatering					
		as that will be part of the dam work (per design Team Lead)					
		SUBTOTAL THIS SHEET					**$294,740.00**

QUANTITIES		**PRICES**	
BY Rudy Campbell	**CHECKED** Connie Svoboda	**BY** LK PEDERSON	**CHECKED** [signature] 12/16/13
DATE PREPARED 11/7/2013	**PEER REVIEW / DATE** Connie Svoboda 11/7/2013	**DATE PREPARED** 12/09/13	**PEER REVIEW / DATE** [initials] 12/10/13

BUREAU OF RECLAMATION **ESTIMATE WORKSHEET** SHEET 2 of 2

FEATURE: **O'NEILL DAM DIVERSION - FISHWAY DESIGN** **Roughened Channel Fishway Alternative**	**PROJECT: SANTA MARGARITA RIVER, CA**
	WOID: A066F — **ESTIMATE LEVEL: APPRAISAL**
	REGION: LC — **UNIT PRICE LEVEL:** Oct-13
	FILE: P:\Appraisal\EST Worksheets\[Estimate Worksheet_Santa Margarita Fishway_final.xlsx]Template Sheet 1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal (from previous sheets)					$294,740.00
		Estimate does not include any cofferdams or dewatering					**$294,740.00**
		as Mobilization	5%	+/-			$14,500.00
		Subtotal with Mobilization					**$309,240.00**
		Contract Cost Allowances (Sum of):	20%	+/-			$60,760.00
		Design Contingencies, 15 % (+/-)					
		APS, 5 % (+/-). Type of procurement: Request for Proposal					
		CONTRACT COST					**$370,000.00**
		Construction Contingencies	25%	+/-			$90,000.00
		FIELD COST (Unit Price Level Oct 2013)					**$460,000.00**
		Non-Contract Costs		**To be determined by the appropriate responsible office**			
		CONSTRUCTION COST		**To be determined by the appropriate responsible office**			
		Ref.: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03.					

QUANTITIES		**PRICES**	
BY Rudy Campbell	**CHECKED** Connie Svoboda	**BY** LK PEDERSON	**CHECKED** [signature] 12/16/13
DATE PREPARED 11/7/2013	**PEER REVIEW / DATE** Connie Svoboda 11/7/2013	**DATE PREPARED** 12/09/13	**PEER REVIEW / DATE** MA 12/16/13