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Hydraulic Laboratory Report HL-2011-01

COE Feasibility Level Fish Bypass Design at Marble Bluff Dam

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

April 2011

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14. ABSTRACT The objective of this study is to provide the Fish and Wildlife Service (FWS) and the U.S. Army Corps of Engineers (COE) with appraisal level quantities and cost estimates for reconstruction of the Pyramid Lake fishway at Marble Bluff Dam. Both River and Lake fishway designs are evaluated.						
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COE Feasibility Level Fish Bypass Design at Marble Bluff Dam

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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.

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Executive Summary

The objective of this study is to provide the Fish and Wildlife Service (FWS) and the U.S. Army Corps of Engineers (COE) with appraisal-level quantities so the COE can develop cost estimates for reconstruction of the Pyramid Lake fishway at Marble Bluff Dam. Pyramid Lake Fishway and Marble Bluff Dam are Reclamation facilities operated by FWS. The Corps of Engineers is supporting fish passage improvements at Marble Bluff Dam under a basin wide Truckee River restoration program.

Historically, when the water elevation in Pyramid Lake falls below 3805 feet, fish passage access up the river is blocked by a sediment delta at the river's mouth. During these periods of low lake elevations the fishway serves as the main access for fish moving upriver to spawn. However, the fishway as constructed in 1976 fails to provide effective fish passage for the endangered and threatened fish species of Pyramid Lake. Without an effective fishway, spawning during years when the lake elevation falls below 3805 is severely restricted.

The existing fish lock which passes fish from the toe of the dam to the upstream river is designed to pass large numbers of fish moving upstream during the spring spawning season. The lock has worked well in this capacity. However, the lock was not intended to provide passage throughout the entire year. Recent efforts to reestablish Lahontan cutthroat trout to the Truckee River has created the need for year-round passage at Marble Bluff Dam. Both fishways proposed in this study will expand the Marble Bluff Dam passage window from about three to twelve months.

The existing fishway contains five fish ladders. Starting at the lake, the ladders are referred to as the entrance ladder (also referred to as the terminal ladder in prior documents), intermediate ladders 1, 2 and 3 and the exit ladder. In its current condition (Dec 2010) the original fishway is operational from intermediate ladder 1 through the exit ladder. The original entrance ladder is currently buried by sand deposited during years of high water levels in Pyramid Lake. As a result, intermediate ladder 1 has been temporarily connected to Pyramid Lake with a temporary meandering rock channel fishway. The temporary entrance fishway consists of a series of pools separated with riffle drops and does not lie within the current right of way boundaries. Constructing a new fishway within the right of way of the existing fishway was requested by the FWS to achieve an effective fish pass from Pyramid Lake to the existing exit ladder that was constructed in 1998. The exit ladder would be used as a part of the new reconstructed fishway with a recommendation to include improvements to the baffle design that have occurred since the exit ladder was installed.

The COE requested that feasibility-level designs be developed that will allow fish passage to Pyramid Lake elevation 3975 feet. Unfortunately, due to the lack of current data and the time constraints to obtain such, feasibility level designs as defined by the Bureau of Reclamation were not possible. As such, this report contains what the Bureau of Reclamation considers an appraisal-level design. This is based on the definitions of appraisal and feasibility as found in the Reclamation Manual on Directives and Standards FAC 03-03:

> *"Appraisal studies (and design activities in support thereof) are conducted using existing data to make cost estimates and to determine if at least one potentially viable alternative exists, and whether or not to recommend that the project proceed to feasibility-level studies. Feasibility studies (and design activities support thereof) are detailed investigations specifically authorized by law to make cost estimates and to determine the desirability of seeking congressional authorization."*

Considering the above definition the following design approaches the feasibility level but falls short in that no current data is available regarding groundwater levels and geotechnical information. As a result, the following designs were created making assumptions based on the original fishway construction in 1976 and the limited information obtained from the 1998 construction of the new exit ladder and fish lock.

Two main concepts were developed during this study, one providing passage along the existing fishway alignment from Pyramid Lake to the exit ladder, the second providing a new alignment which will allow fish passage from directly below Marble Bluff dam to the existing exit ladder. The first design was initially investigated and developed by the BOR in November 2000 (Reclamation, 2000), the second was presented to the BOR by the COE in July 2010. For the remainder of the document the first fishway design along the existing fishway alignment will be referred to as the Lake design and the second new alignment from the river below Marble Bluff Dam will be referred to as the River design. To achieve year round passage for all lake and river flow conditions require both fishways. The Lake design is required for passage at lake elevations below 3805. When lake evaluations are above 3805 the River design is necessary because fish tend to move up the river.

The Lake design includes replacing the existing conveyance channels and fish ladders with a new fishway consisting of conveyance channels and rock riffles with trapezoidal cross sections having a 6.5-ft bottom and 6.0-ft channel depth with 1.5:1 side slopes. The rock riffles contain boulder weir drops and pools spaced 31.25 feet apart along a 0.80 percent sloped channel. New conveyance channels linking the rock riffles will have slopes of 0.025 percent.

The River design requires constructing a new fishway from the toe of Marble Bluff Dam (adjacent to the entrance of the fish lock) to the entrance of the exit ladder at a constant 0.89 percent slope. The fishway consists of a constant rock riffle having a trapezoidal cross section with a 6.5-ft bottom width, 1.5:1 side slopes and 6-ft channel depth. Boulder arrays spaced 28.0 feet apart will provide the elevation change and riffle pool design requested by the FWS.

Appraisal level drawing and construction quantities are presented for both fishways. Construction cost estimations are not included in this report. The COE will prepare these based on quantities presented herein. It is recommended that the Lake design be constructed prior to the River design to meet immediate fish passage needs during low lake elevations. Historically when Pyramid Lake drops to 3805 feet and below river passage can be blocked preventing fish passage through the River design.

Annual maintenance costs were estimated based on discussion with fishway operators. Costs are incurred from inspection, vegetation control and clearing of windblown weeds and sand deposits from both sediment traps and other areas of the channel. All linings will support small bobcat style loaders which will be used to remove windblown sand and replace missing riprap. Estimated annual maintenance costs for inspection and for cleaning the fishway are $25,000.

The remainder of this report contains a summary of the findings, assumptions and design criteria for both the Lake and River designs.

Introduction

Recently the COE has been engaged in studying fish passage on the entire Truckee River from Lake Tahoe to Pyramid Lake which includes both upstream and downstream passage of the cui-ui suckers and LCT in the lower river. Pyramid Lake Fishway and Marble Bluff Dam are Reclamation facilities operated by FWS. The Corps of Engineers is supporting fish passage improvements at Marble Bluff Dam under their basin wide Truckee River restoration program. COE investigations at Marble Bluff Dam include rebuilding the existing fishway to update the existing fish passage to current passage standards and constructing new year round fish passage from the river near the dam to the Truckee River above the dam. The objective of this study is to provide the COE Sacramento District with appraisal level designs and quantity takeoffs for the engineering basis of design for the above mentioned alternatives associated with improving fish passage at Marble Bluff Dam.

In accordance with MIPR #W62N6M02091212 and associated scope of work (SOW) the following report contains the design submittal and quantities for the work that has been completed for the appraisal level fish bypass designs at Marble Bluff Dam. This report contains a summary of the findings, assumptions and design criteria for the two before mentioned designs. The designs are referred to as the Lake and River designs, where the Lake design is a modification of the existing fishway along its original alignment and the River design is a completely new fishway from the toe of Marble Bluff Dam to the base of the existing exit ladder.

Background

The Corps of Engineers (COE) Sacramento District requested the Bureau of Reclamation (Reclamation) Technical Service Center (TSC), Denver, Colorado to conduct a appraisal design study to investigate replacing the Pyramid Lake Fishway at Marble Bluff Dam. Marble Bluff Dam is located on the Truckee River approximately 50 miles downstream of Reno, Nevada and approximately 3 miles upstream of Pyramid Lake (Figure 2). The terminal waters (no outlet) of Pyramid Lake are supplied largely by flow from the Truckee River. Both the Truckee River and Pyramid Lake contain unique habitats for the spawning and survival of endangered cui-ui lake suckers (Chasmistes cujus) and threatened Lahontan cutthroat trout (Oncorhynchus clarki) (LCT).

Historically Pyramid Lake elevations have fluctuated widely creating a unique challenge to keeping cui-ui and LCT from becoming extinct. Records dating sporadically from about 1844 indicate that the lake elevation remained relatively stable, with cyclical fluctuations of about 20 feet maximum until about 1910, when a general decline began. In the last 100 years, the lake elevation has dropped as much as 80 feet due to upstream diversions coupled with periods of drought (Figure 1). A declining lake elevation resulted in severe degradation of the Lower Truckee River and upstream passage problems for both cui-ui and LCT. Both species migrate up the Truckee River to spawn during high spring flows.

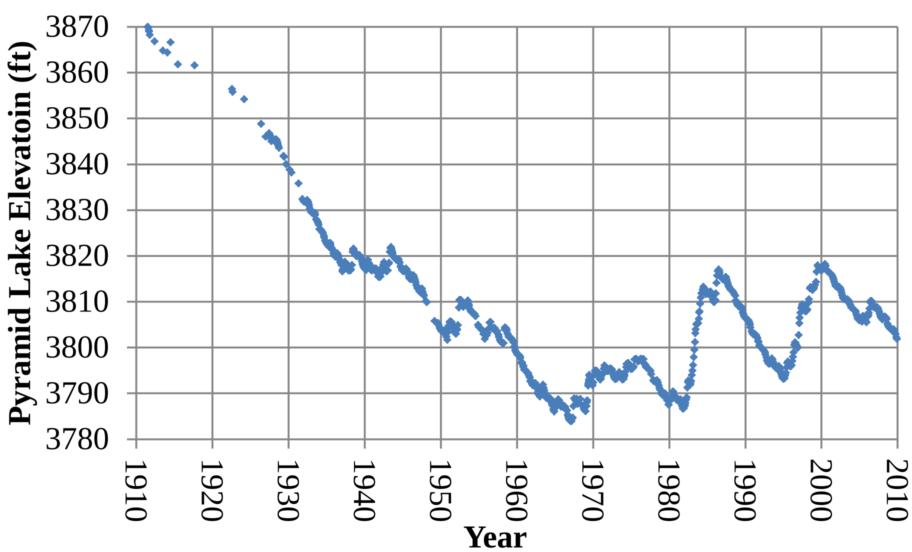

Figure 1 – Pyramid Lake elevation from 1910 to 2010

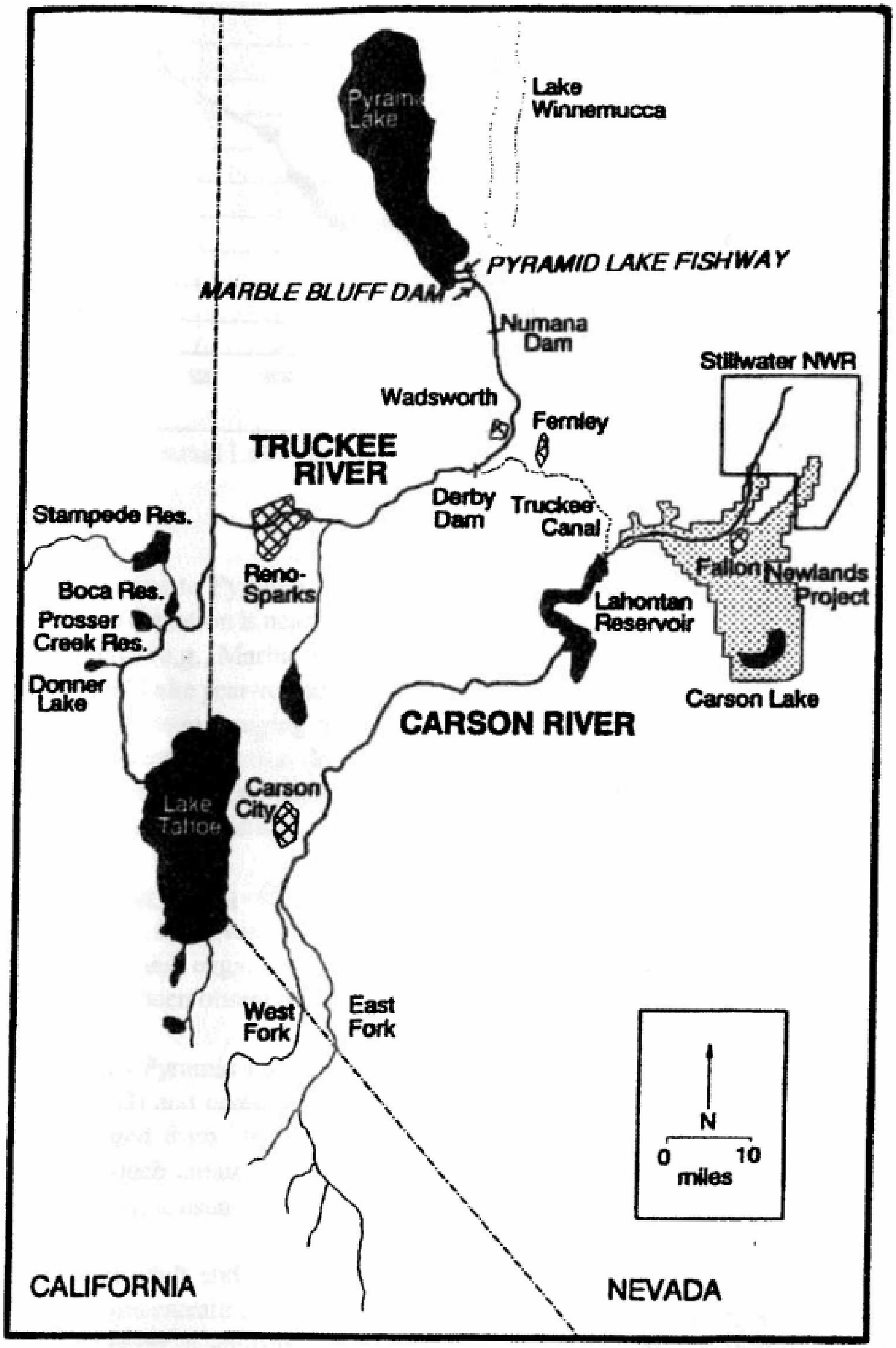

Figure 2 – Area map showing the location of Marble Buff dam

In 1992 the U.S. Fish and Wildlife Service (FWS) issued a recovery plan for the endangered cui-ui lake sucker (Service, 1995) and in 1995 a recovery plan for Lahontan cutthroat trout (LCT) (Service, 1995). These plans identify improving passage at Marble Bluff Dam as a key component to the fish's recovery. Excerpts from both Recovery Plans are reprinted herein as background on the fish, its habitat and migration to spawn.

Pyramid Lake (FWS)

Pyramid Lake is the terminus of the Truckee River. It is saline (>4.1ppt), alkaline (pH = 9.1-9.3) and categorized as oligotrophic to mesotrophic. From 1981 to 1990 the maximum depth has ranged from 365 to 390 ft. Average annual evaporative loss is approximately 440,000 acre-feet, which creates a vertical drop of 4 ft. Pyramid is a monomictic lake and may stratify as early as May; it usually remains stratified until December.

Lower Truckee River (FWS)

The lower Truckee River is a low- to moderate-gradient stream descending at a rate of approximately 7.9 ft/mile. The banks are composed of unstable sedimentary material which is vulnerable to severe erosion. The stream channel has changed significantly during this century. Lowering of Pyramid Lake and artificial straightening of the river for flood-control purposes have created a shallow, braided, and unconfined channel network, and formed a broad delta at the mouth. Marble Bluff Dam functions as a hydraulic control to reduce upstream erosion, and has also created several miles of habitat suitable for cui-ui spawning immediately upstream.

Discharge in the lower Truckee River is highly variable between seasons and years, depending, in part, on upstream storage and diversions at Derby Dam. Average annual inflow to Pyramid Lake for the period 1918-1970 was approximately 250,000 acre-feet. Runoff, a function of snowmelt, generally peaks in late spring (average of 56,000) acre-feet in May) and is lowest in late summer (average of less than 1,000 acre-feet in August).

Cui-ui Lake Sucker (FWS)

Lakesuckers (genus Chasmistes) are differentiated from other members of the family Catostomidae by thin lips, the lobes of which are separated and may lack papillae, and by a large terminal, oblique mouth. The four recognized species are residents of three distinct drainage basins: cui-ui (C. cujus) in the Truckee River basin of western Nevada (Pyramid Lake); shortnose sucker (C. brevirostris) in the Klamath River basin of Oregon and California; June sucker (C. liorus) in Utah Lake; and the recently extinct Snake River sucker (C. muriei) of the upper Snake River in Wyoming. Cui-ui is a large, robust sucker with a long, broad, and deep head. The dorsal side of its coarsely-scaled body is blackish-brown with a bluish-gray cast which fades to a creamy-white belly. Female cui-ui have been documented exceeding a length of 27.6 inch with males attaining 26.1 inch.

At the beginning of the 20th century, cui-ui inhabited Pyramid and Winnemucca Lakes. Obligate stream spawners, cui-ui congregate near the mouth of the Truckee River in spring and are reported to migrate as far as 25 miles upstream (to the vicinity of Wadsworth, Nevada) to spawn. The species was eliminated from Winnemucca Lake when it dried up in the 1930 following unrestricted diversion of water from the Truckee River and a severe drought.

Cui-ui are now restricted to Pyramid Lake and the lower Truckee River (downstream from Derby Dam). Pyramid Lake elevation is nearly 80 ft lower than at the turn of the century, and there are now structural impediments (e.g., Marble Bluff and Numana Dams) to fish passage. Adult and juvenile cui-ui inhabit Pyramid Lake year-round. Adults utilize the lower Truckee River only during the spawning season (ranging from as early as April to as late as June) and only in years in which there are sufficient attraction flow and passage above or around the delta. Most spawners utilize the 10-mile reach between Marble Bluff and Numana Dams; as the fish ladder at Numana Dam is not conducive to passage of cui-ui.

Life History and Habitat (FWS)

Cui-ui is a large, long-lived and omnivorous sucker. Pyramid Lake provides rearing habitat for larvae, juveniles, and adults. The lower Truckee River provides primary spawning habitat. Adults, eggs, and larvae may be present in the river for a maximum of several weeks. Spawning has been observed at freshwater interfaces and springs within Pyramid Lake.

For much of the year adult and juvenile cui-ui inhabit the littoral zone at depths of 60 to 100 ft. Juveniles appear to concentrate at the north and south ends of the lake. They are most active during summer and fall; however, a seasonal migration pattern has not been demonstrated.

Cui-ui Spawning (FWS)

Adult cui-ui congregate in March and April near the mouth of the river prior to migration. Spawning runs begin in April or May, depending upon timing of runoff, river access, and water temperature. There is evidence that a high volume spring runoff attracts more spawners and promotes egg ripening. Most spawners migrate less than 6 miles upstream. While most spawners spend only a few days in the river, some may remain up to 16 days. Spawning runs may continue for 4 to 8 weeks, but most fish migrate during a 1- to 2-week period.

Lahontan Cutthroat Trout (FWS)

Lahontan cutthroat trout occurred throughout the Truckee River basin. Gerstung (1986) estimated 360 miles of stream habitat and 284,000 acres of lake habitat existed before non-Indian settlement within the basin. The largest populations of LCT occurred in Pyramid Lake and Lake Tahoe, where the fish served as a major food source for local Paiute Indians and supported important commercial fisheries for several decades. Before extirpation, two distinct Pyramid Lake cutthroat trout spawning migrations existed in the Truckee River, spring run “Tommies” and fall run “redfish”. Whether more than one variety of LCT was native to Pyramid Lake and Lake Tahoe has never been determined.

Three primary threats to LCT in the Truckee River basin developed during the 19th century -- pollution, dams, and commercial marketing. Degradation of habitat commenced in the early 1860’s with logging activities. Significant quantities of sawdust and wood-chips discharged from sawmills contaminated the Truckee River until the late 1890’s. Until about 1 930, industrial and sewage waste were dumped into the Truckee River. Regulated water discharges from dams to drive logs to sawmills, supply irrigation water for agriculture, and generate power effectively disrupted spawner migrations by creating torrential floods and abruptly drying the river. Many dams served as barriers and often great numbers of spawners were harvested in pools downstream from impassable dams. Between 1873 and 1922 approximately 100,000 to 200,000 pounds of LCT were harvested annually from Pyramid Lake and the Truckee River for commercial purposes. The Lake Tahoe LCT fishery disappeared in 1939 as a result of the combined effects of overfishing, introductions of exotic species, and damage to spawning habitat caused by pollution, logging, diversions, and barriers. By 1944, the original Pyramid Lake LCT population was extinct as a result of Truckee River water diversion at Derby Dam for the Newlands Project, pollution, commercial harvest, and introductions of exotic species.

LCT Spawning (FWS)

Lake residents migrate up tributaries to spawn in riffles or tail ends of pools. Distance traveled varies with stream size and race of cutthroat trout. Populations in Pyramid and Winnemucca Lakes reportedly migrated over 100 miles up the Truckee River into Lake Tahoe.

Typical of cutthroat trout subspecies, LCT is an obligatory stream spawner. Spawning occurs from April through July, depending on stream flow, elevation, and water temperature. Females mature at 3 to 4 years of age, and males at 2 to 3 years of age. Consecutive year spawning by individuals is uncommon. King (1982) noted repeat rates of 3.2 and 1 .6 percent for LCT spawners returning in subsequent migrations 1 and 2 years later. Cowan (1982) noted post spawning mortality of 60 to 70 percent for females and 85 to 90 percent for males, and spawner repeat rates of 50 and 25 percent for surviving females and male spawners, respectively. Others observed that most repeat spawners return after 2 or more years.

History of Pyramid Lake Fish Passage

The first major effort to improve fish migration up the lower Truckee River was started by the Bureau of Indian Affairs in 1942 when the lake elevation was 3820. A diversion dam and fishway channel was started near the site of the present facilities. World War II interrupted the construction and the dam washed out during flood flows in 1950. In 1976 the Bureau of Reclamation constructed Marble Bluff Dam and fish passage facilities for the U.S. Fish and Wildlife Service. The facilities were designed to aid fish passage and stabilize the rapidly degrading river channel. The dam is a zoned, earth-fill embankment with a 150-ft-long, uncontrolled concrete ogee crest spillway, crest elevation 3854.5 (see ref. dwg. 949-D-1230 in appendix C). To the right of the spillway is a 20-ft- wide, gated sluiceway, floor elevation 3847.5. Spillway and sluiceway flows pass down a baffled apron drop to the downstream river channel. The river channel upstream of the dam is silted in to about the elevation of the sluiceway invert. During low flows there is no storage behind the dam. Prior to construction, the river channel bed elevation was about 3842. The downstream end of the baffled apron drop was constructed to elevation 3801.76 to protect the dam against channel degradation, leaving much of the baffled apron buried below the original streambed elevation. Currently the downstream river channel bed is at about elevation 3814.

In conjunction with building the dam, two different paths for fish passage from the lake to the river above the dam were constructed. Two paths were needed as river access for fish is often blocked for lake elevations below about 3805 by a large sediment delta at the junction of the river and lake. Historically, when exposed, the delta has caused the river to fan out into a shallow braided channel regime that blocks fish passage up the river. For these conditions the Pyramid Lake fishway was constructed to provide fish passage directly from the lake to upstream of Marble Bluff Dam (Figure 3).

The fishway constructed in 1976 is about 3 miles long and contains five fishway ladders. In years when the lake elevation is above 3805, fish move up the river and must be passed over the dam. For this condition, a fish trap and mechanical hoist type fish lift were constructed adjacent to the dam spillway to provide passage for fish reaching the dam. Neither of the original fish passage facilities were effective for passing cui-ui suckers. Cui-ui were incapable of passing the

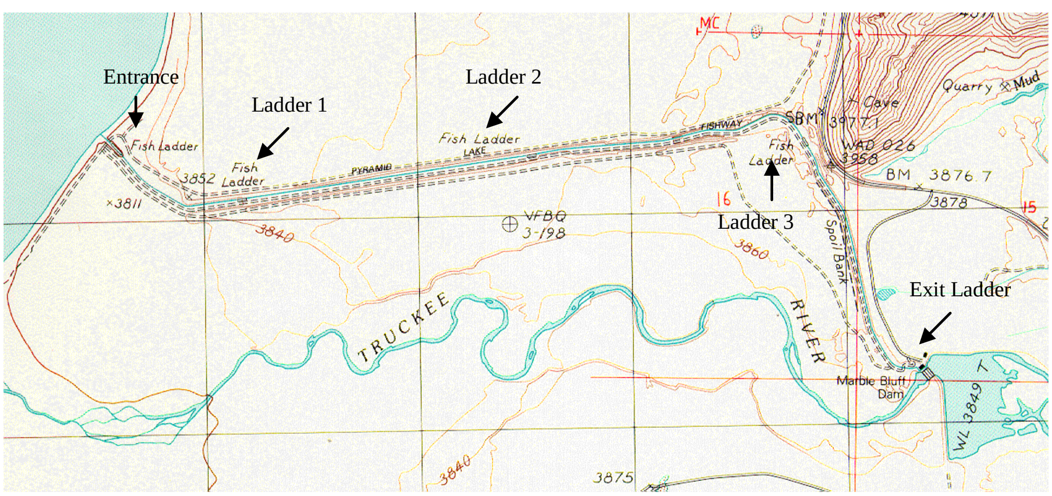

Figure 3 – Location map showing marble Bluff dam and Pyramid Lake fishway

fishway ladders as designed and their crowding behavior often resulted in fish mortality due to overcrowding in the fish trap.

Starting in 1995, (Mefford, et al., 1995), FWS and other organizations pursued a project to develop better methods for passing cui-ui suckers and LCT that move up the river to Marble Bluff Dam. The project resulted in three major structures being built. These are; replacement of the fish trap and hoist system with a hydraulic fish lock, construction of a gradient control structure in the river downstream of the dam and replacement of the exit fishway ladder with a new fish ladder designed for cui-ui. The exit fishway ladder was replaced to provide separate exit channels for the fish lock and fishway channel. The fish lock and gradient control structure have functioned well. The fishway channel including the new exit fish ladder is not considered operational as the fish ladders downstream of the exit have not been replaced.

1976 Fish Ladder Design (Reclamation, 1973)

The fishway was designed to provide fish passage for a maximum elevation gain between the lake and the river upstream of the dam of about 76 ft. The fishway contains five fish ladders linked by an earth lined trapezoidal channel. The fishway ladders are commonly referenced by location in the upstream direction of fish movement. Starting at Pyramid Lake the ladders are referred to as the fishway entrance ladder (or terminal ladder as in previous documents), ladder 1, ladder 2, ladder 3 (or intermediate ladders), and the exit ladder (Figure 3).

The ladders slope at a grade of 1 vertical to 10 horizontal (10 percent). Ladders 1, 2 and 3 are identical each providing 13 ft of elevation gain and the entrance ladder provides 31 ft of elevation change. The entrance ladder starts at elevation 3774.5 and climbs to elevation 3805.53. Ladder 1 climbs from elevation 3805.74 to 3818.74 feet, ladder 2 climbs from elevation 3819.17 to 3832.17 feet and ladder 3 climbs from elevation 3832.6 to 3845.6 feet. The exit ladder provides the final elevation gain of about 6.75 ft to the river. The fishway channel linking the ladders slopes 1 ft vertical in 10,000 ft. The channel is designed to convey 50 ft^3/s at a flow depth and velocity of 4 ft and 1 ft/sec. Reference drawings 949-D-166 and 949-D-171 in appendix C contain the original fishway ladder designs.

Ladder baffles are similar to a style used on Ice Harbor Dam on the Snake River. The baffles are a pool and combination weir and orifice design (Figure 4). Baffles were originally spaced every 10 ft, therefore providing a water surface drop across each baffle of 1 ft and a passage flow velocity of 8 ft/s. The ladder design was based on experience with salmonid passage and available studies of the cui-ui physical and behavioral attributes (Koch, 1972)(Koch, 1976)(Koch, 1973)(Ringo, et al., 1977).

During initial operation of the fishway, the ladder baffle design and head drop were found to be a poor match for cui-ui behavior and swimming strength. Cui-ui attempted to move up the ladders crowded near the fishway invert. The 8 ft/s passage velocity was found to be too high for efficient passage. In addition, the bottom oriented behavior of the cui-ui was contrary to passing over a weir that forced them high in the water column. To improve passage, FWS added weirs half way between the original baffles. This reduced the drop over each baffle to 0.5 ft and reduced the pool length between baffles to 5 ft. Velocity over the baffles was reduced to about 5 ft/s. Passage of cui-ui improved; however fish passage efficiency remains low.

Figure 4 – Current intermediate fish ladder baffles with FWS modifications

1998 Fishway Exit Ladder Replacement

In 1998 Reclamation replaced the Pyramid Lake fishway exit ladder, (see ref. dwg. 949-D-1235). The ladder was replaced as part of the fish lock construction project. One of the project objectives was to provide separate fishway and fish lock exit channels. This resulted in a new fishway exit ladder constructed to the north of the fish handling building (Figure 5). The new ladder is 8 ft wide, 6 feet deep, with baffles placed ever 8 ft of length. To improve flow conditions, the ladder gradient was reduced to 0.031-ft-vertical to 1-ft-horzontal (3.13 percent) and new dual slot chevron shaped baffles were designed specifically for cui-ui passage.

Fishway flow in the exit ladder varies with river stage at the exit of the fishway. Table 1 gives estimates of ladder hydraulics for a range of river flows. Downstream of the exit ladder a supplemental water supply and a skimming weir are used to regulate fishway channel flow to achieve a steady 50 ft^3/s flow independent of river stage. These structures are located on an extension of the fishway channel that serves the fish handling building (Figure 5 & ref. dwg. 949-D-197).

Table 1 – Pyramid Lake fishway exit ladder hydraulics

River Flow	River Elevation @ Spillway	Average WS drop per baffle	Estimated velocity through baffle slots	Depth of flow in exit ladder	Estimated exit ladder flow
(ft3/s)	(ft)	(ft)	(ft/s)	(ft)	(ft3/s)
1000	3855.90	0.22	3.0	5.10	30.6
2000	3856.75	0.25	3.2	6.00	38.4
3000	3857.5	0.28	3.4	6.75	45.9

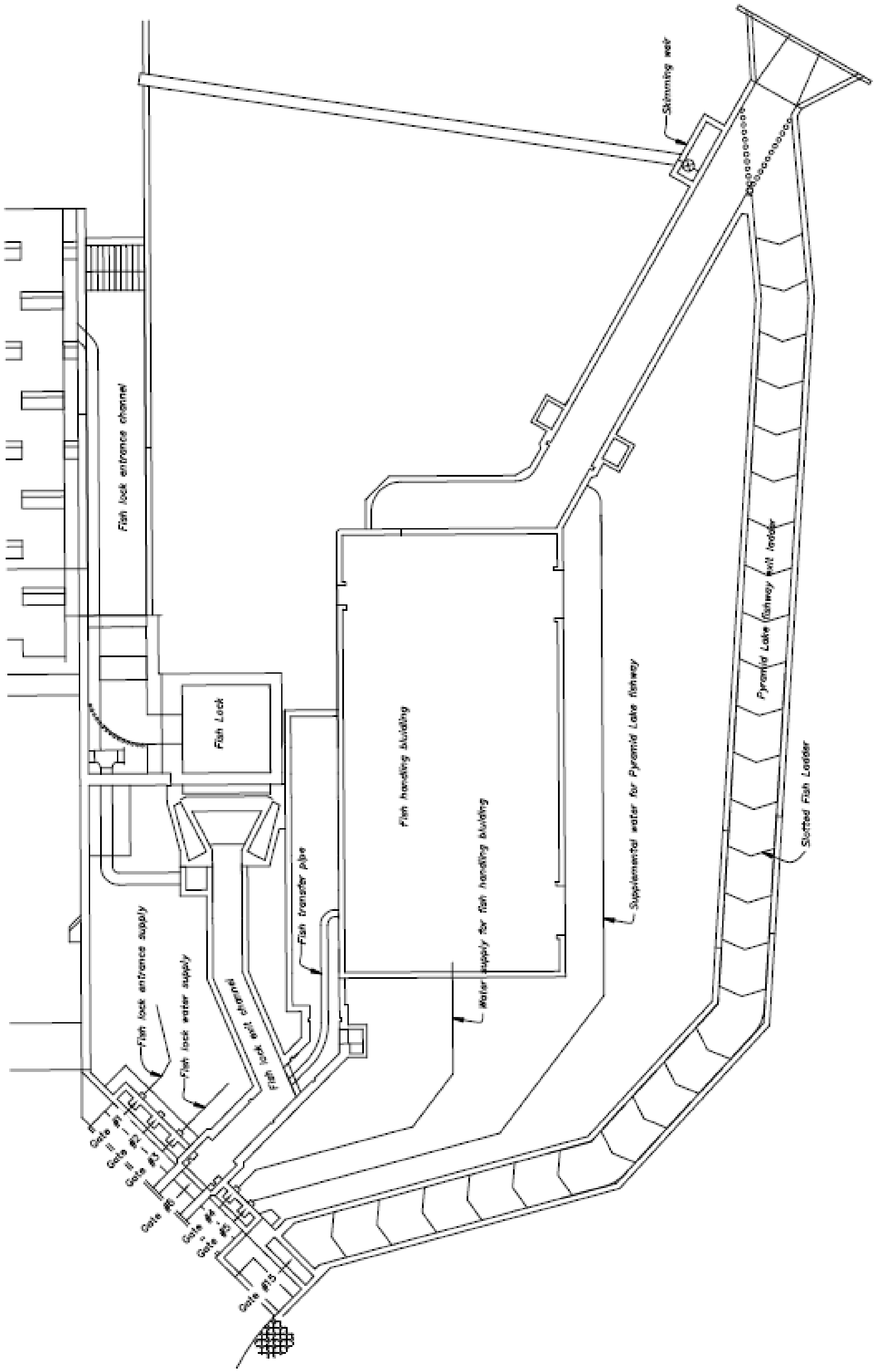

Figure 5 – Marble Bluff dam gate designation, fish lock and exit ladder

Available Data and Additional Needs

Reclamation reviewed the following information and indicated which would be beneficial to the completion of the project

- **a.** Aerial photography of the project reach at 1 meter pixel resolution (2006).
- **b.** Aerial photography of the project reach, not including entire existing fishway at 1 foot pixel resolution (2000).
- **c.** 2 ft contours of the project reach, not including entire existing fishway (2000).
- **d.** TIN of the project reach, not including entire existing fishway (2000)
- **e.** DTM of the project reach, not including entire existing fishway (2000)
- **f.** COE concept of new fish bypass design, AutoCAD drawing (2009)
- **g.** COE fish passage improvement report (2009)

Requested data were made available to Reclamation on August 10, 2010. Required data was downloaded through the COE FTP site and was combined with the data Reclamation had previously acquired internally and from Fish and Wildlife Services (FWS).

After reviewing all the compiled data Reclamation has determined that no current as-built topography is available for the existing fishway ladders and corresponding conveyance channels which extend from Pyramid Lake to the upstream exit ladder that was constructed in 1998.

As a result, it was requested through phone conversation with the COE that a current survey and or detailed topography be created and supplied to Reclamation prior the submittal of design and quantity estimates. The COE indicated that LiDAR data was being collected and that 1 ft topography will be created and made available to Reclamation after January of 2011.

Considering the lack of current topography Reclamation and COE agreed to continue working with topography that was digitized from the 1973 drawings and used to create the “Pyramid Lake Fishway Replacement Feasibility Study” published in November of 2000 by Reclamation.

The digitized topography was modified into a theoretical as built topography by using AutoCAD Civil3D and input the design specifications for the existing fishway. Creating as built topography in this manner allows Reclamation to make design and quantity estimates that approximate the current conditions. However, due to the unknown state of the current canal and fishway, quantity estimates in this report are only an estimate and should be recalculated after updated topography is created.

Several topographic surveys have been conducted of the area of the proposed River fishway. These data include; LiDAR provided by the COE and FWS, a 2 ft ground survey completed by Reclamation prior to the 1998 construction of the fish lock and new exit ladder, and a 1 ft ground survey conducted by the COE in October, 2010. To create quantity estimates for the River design the 1 ft ground survey conducted by the COE was used.

Fishway Design Criteria

Fishway riffle and conveyance channel designs were selected based on achieving flow conditions suitable for efficient cui-ui and LCT passage. Flow criteria and fishway design criteria set by FWS are listed below:

Lake Fishway Riffle Design Objectives

a. a maximum passage velocity through the boulder weirs of 4 ft/sec (based on average velocity)
b. a normal flow depth of 4.0 ft
c. a conveyance capacity of 100 ft^3/sec
d. strong downstream flow to enhance fish orientation
e. provide passage at all levels within the water column
f. mimic a natural channel with boulder weirs used to create the riffles
g. a natural looking channel with meanders should be utilized where possible

Lake Fishway Conveyance Channel Design Objectives

a. a flow of 100 ft^3/sec (normal maximum)
b. an operating depth of 4 ft (required due to the potential for pelican predation)
c. a maximum flow velocity of 2 ft/sec
d. maximize sediment transportation and provide intermediate sediment traps with velocities of 0.5-1.0 ft/sec
e. provide fish staging area prior to riffles

River Fishway Riffle Design Objectives

a. a maximum passage velocity through the bolder weirs of 4 ft/sec
b. a flow of 100 ft^3/sec (normal maximum)
c. an operating depth of 4 ft (required due to the potential for pelican predation)
d. use existing exit ladder

Fishway Design Alternatives

Historically, when the Pyramid Lake elevation falls below about 3805 feet, fish passage access up the river is partially or totally blocked by a sediment delta at the river's mouth. Without an effective fishway, cui-ui spawning during years of low lake elevation can be lost. The sediment delta has been major impediment to cui-ui spawning many times during the last fifty years. As shown in Figure 1 the lake elevation has often been below 3805 since 1950. Currently, the lake elevation is about 3800 feet and both river passage and fishway access are poor.

Lake and River passage designs have been investigated by BOR in 1995 (Mefford, et al., 1995) and 2000 (Reclamation, 2000) and recently the COE conducted a scoping study for the River design. Since about 2000, designs have focused on riffle pool fishways utilizing natural channels and rock riffles that have proven effective for sucker and trout passage on other river systems.

History and Examples of Rock Channel Fishway Design

Rock fishways are low gradient channels constructed of rock. A high boundary roughness derived from the rock is combined with features of channel topography, rock weirs or large isolated roughnesses (usually rock boulders) to create flow conditions suitable for fish passage. Rock fishways can be designed as side channels that pass around dams or as an in-stream attribute of a small dam. Rock channel fishways (also called natural bypasses, rock ramps or rock riffles) have been used for many years in the U.S., Europe and Canada for passing fish at small dams. Recently, Reclamation has constructed several rock channel fishways for passing non-salmonids. A summary of several designs follow.

Pyramid Lake Fishway, Experimental Bypass Channel

In 1996 FWS and the Nature Conservancy of Northern Nevada constructed a meandering test channel that bypassed the terminal fish ladder, (Nature Conservancy, 1995). The meandering channel was constructed to determine if a natural style riffle and pool fishway design could be used to replace the fishway ladders. The test channel was designed to test two different channel slopes. Approximately one-half of the channel length was constructed with an average channel slope of 0.0058 and the other one-half at slope of 0.0096. The channel contained a series of alternating riffle and pool sections. Pools were nearly horizontal and the riffles within the two test sections had slopes of 0.014 and 0.016, respectively. Flow in the pools was 2 to 3 ft deep and about 1 ft deep in the riffle sections. During the testing cui-ui moved steadily up the meandering fishway. Some holding and crowding of fish was observed at the downstream toe of each riffle. The tests proved cui-ui could move through riffles with 4 ft/s mean velocity for distances of at least 30 ft. The tests also demonstrated the importance of flow depth. The relatively shallow flow at the riffle pool interface where fish were holding for short periods subjected the cui-ui to heavy predation by Pelicans.

Grand Valley Irrigation Fish Pass

In 1997, Reclamation constructed an in-stream rock channel fish pass on the Grand Valley Irrigation Dam located on the Colorado River near Grand Junction, Colorado, Figure 6. The fishway provides passage over a 5 ft high run-of-river dam for many native and non-native fish found in the Colorado River. The riffle sections are designed for an average velocity of 4 ft/s at a minimum flow and depth of 50 ft^3/s and 1.5 ft, respectively. The design gradients for the fish pass are: riffle slope = 1.3 percent; thalweg slope = 0.7; and channel slope = 0.9 percent. The thalweg slope differs from the channel slope by the sinuosity of the channel. The channel is constructed of riprap laid on a filter fabric. During construction, voids in the riprap were filled with finer material to minimize interstitial flow. The sinuous pattern (meandering channel form) is used to maintain flow depths during low flows. As flow and depth increase the effect of the channel sinuosity on the flow decreases. After three years of operation under a wide range of river flows the riprap fishway channel has remained stable and has blended into the river environment.

Figure 6 – Grand Valley Irrigation rock fishway at low river flow

Figure 7 – Marble Bluff gradient restoration structure

Marble Bluff Gradient Restoration Structure

In 1998, the river bed elevation below Marble Bluff Dam was raised about 2 ft and stabilized using a rock ramp design, Figure 7. The structure was designed to prevent further channel degradation downstream of the dam and raise the minimum water surface elevation to provide fish access to the fish lock entrance channel. The structure was designed based on a 4 ft/s average velocity to ensure fish passage for cui-ui and LCT. Large boulders were added on the north half of the channel to provide additional variability in the flow field. The structure performed well in 1999. An estimated 600,000 cui-ui passed over the structure during the spawning run in 1999 with no apparent delay (personal correspondence with FWS).

Derby Dam Fishway (Truckee River Diversion Dam)

In 2000, Reclamation designed a rock ramp fishway for Derby Dam located on the Truckee River approximately 30 miles upstream of Marble Bluff Dam. The 920 ft long rock fishway is designed to pass cui-ui lake suckers and LCT (Figure 8). The fishway slopes at a constant 0.0184 ft/ft with a riprap lined channel that is trapezoidal in shape with a 4 ft wide bottom and 2:1 side slopes. The fishway contains 47 boulder weirs positioned at 20 ft intervals along the fishway (Figure 9). Each weir is formed by placing boulders about 1 ft apart in an upstream pointing chevron pattern. The boulder weirs create a hydraulic control that produces a drop in water surface of about 0.4 ft producing a maximum passage velocity of about 5.0 ft/sec. The rock fishway concept is designed to convey approximately 10 percent of the downstream river flow within the range of 250 ft^3/sec to 2,000 ft^3/sec. For downstream flows less than about 150 ft^3/sec up to 100 percent of the river flow may be passed through the fishway. The fishway was constructed in 2002.

Figure 8 – Derby Dam rock fishway close-up view

Figure 9 – Derby Dam rock fishway distant view

Proposed Fishway Designs

A rock channel fishway design similar in concept to the Derby Dam fishway is proposed for both the Lake and River designs. The two fishway designs meet all design requirements and are not intended to operate at the same time. Figure 11 (appendix B) provides an overview of both the Lake and River designs.

Lake Passage – Design

The Lake fishway design includes replacing the existing conveyance channels and fish ladders with new conveyance and rock riffle fishway sections. The fishway has a trapezoidal cross section having a 6.5-ft bottom and 6.0-ft channel depth with 1.5:1 side slopes. Boulder array style drops will provide the riffle pool design requested by the FWS. New conveyance channels and rock riffles will have slopes of 0.025 and 0.80 percent respectively. Table 2 contains a summary of each section of the lake fishway and the type of lining used in the respective section.

Table 2 – Lining types by reach for both Lake and River designs

Design and Option	Portion of Fishway		
	Conveyance Channels (Runs)	Rock Riffles	Entrance Meander
Lake Passage Design	5% compacted clay	12” Riprap & geotextile	14” Riprap & geotextile

Lake Passage – Fishway Riffles

Boulder array drop structures spaced every 31.25 ft were chosen for the fishway riffles (Figure 12 in appendix B). The boulder arrays are designed to pool water upstream to a depth of about 3.5 to 4 ft with an average drop in water surface of about 0.25 ft through the chute between boulders. An average passage velocity of about 4 ft/s would occur in the chutes. The riffles are designed to convey the full 100 ft^3/sec fishway design flow.

The rock riffles would be constructed by over excavating the channel 1.5 ft, laying down a low porosity geotextile fabric and then riprapping with well graded riprap from 2-12 inch in diameter for the intermediate riffles and 4-14 inch material for the entrance meander. Three boulders are used for each drop giving four passage routes (also referred to as chutes). Boulders will be positioned on a 60 degree angle to the channel centerline with roughly 2 ft of clear space between them (Figure 12 in appendix B). The large center boulders are about 4-4.5 feet in diameter and sit on top of the riprap bedding. The boulders to each side of center are about 3 ft in diameter. These boulders are set a minimum of 6 inches below riprap grade for stability. As rock boulders are all different shape, flow conditions will vary through each chute. Some tuning of the individual boulder arrays after initial operation is expected. The design is based on passing approximately 35 ft^3/sec between the center boulder and each side boulder (total of 70 ft^3/sec). The remaining flow will pass to the outside of the side boulders.

Lake Passage – Conveyance Channels

The fishway conveyance channels are the runs that connect each of the new rock riffles to each other and the exit ladder to create a continuous flow from Marble Bluff Dam to Pyramid Lake.

History and examples of fishway conveyance channel design

The ravine the fishway channel lies within was formed largely by erosion following the construction of a diversion dam and pilot diversion channel in 1941 by the Bureau of Indian Affairs (BIA). The fishway project then included an earth dam and spillway located at the toe of Marble Bluff. A 200-foot-wide by 18-foot-deep channel from the river to Marble Bluff was constructed with compacted earth embankments. Downstream from Marble Bluff a pilot channel was excavated and allowed to widen and deepen by erosion from diversion flows. In 1950, the BIA Diversion Dam failed. By the time the existing fishway was constructed in 1970's, the downstream portion of the diversion channel had eroded to roughly 250 feet wide and up to 40 feet deep with bottom widths ranging from 70 to 150 feet (Reclamation, 1973)**.**

In 1975 Reclamation constructed a trapezoidal shape fishway channel with a bottom width of 6 ft, 1.5:1 side slopes and a bed slope of 0.0001 ft/ft (see ref. dwg. 949-D-161). The channel was designed to provide a flow velocity of 1 ft/sec for a discharge of 50.0 ft^3/sec. Approximately 80 percent of the new fishway was constructed within the diversion channel of the 1941-42 BIE diversion project.

Conveyance channel linings

Original fishway channel lining – Material from three borrow areas (ref. dwg. 949-D-278) was tested in Reclamation's Denver laboratory for use as lining for the fishway channel (Reclamation, 1973). After the material was compacted at different densities and several chemical sealant treatments applied, the permeability of the samples was tested. Also, gradation, Atterberg limits, and Proctor compaction tests were performed. The samples from Borrow Area A and from the bank of the old existing fishway were considered to be satisfactory lining material based on the permeability tests and were classified respectively as clayey silt (ML-CL) and lean clay (CL). The testing report (Reclamation, 1973) mentions that soil-cement and concrete were considered as lining materials, but insufficient aggregates were available. Uplift and cracking of thin hard linings is also a concern at the site due to the high groundwater conditions.

Dispersive clays – The Final Construction Report (Reclamation, 1976) states that during a two-week trial operation of the fishway during October 1975, the lower two reaches eroded with undercutting as much as 8 inches. Because of this unusual erosion, two samples of the clay lining, classified as a lean clay, were tested (chemical analysis, physical erosion, and soil dispersion tests) and found to have a limited degree of dispersiveness (Reclamation, 1976).

Later, eight samples of material from the fishway lining and Marble Bluff embankment were tested using the Modified Emerson "Crumb" test, Soil Conservation Service Dispersion test, Pin Hole Test, and the Chemical Analysis of Soil Pore Fluid (Reclamation, 1979). The embankment clay was found to be dispersive except for one sample. The samples from the lining were given a dispersive rating of "intermediate" and "dispersive."

On May 18, 1977, two engineers from the Denver office inspected the soils in the vicinity of the fishway and the dam and noted that soil along the bluffs by the fishway had the appearance of dispersive clays. They noticed deep, narrow erosion patterns; a continuous channel going from a vertical hole to a horizontal hole; and jug-shaped caverns (Reclamation, 1977). Based on this site inspection, it appears likely that dispersive soils are found throughout the area.

<u>Recommended method for lining the new conveyance channel</u> – Dispersive clay soils will erode in slow-moving or even quiet water as individual colloidal clay particles go into suspension and then are carried away by the flowing water (Reclamation, 1998). Dispersive clays can be made nondispersive by adding a small percentage of hydrated lime (about 2 to 4 percent by dry mass of soil) to the clay. The following general procedures have been used by Reclamation for soil-lime construction (Reclamation, 1998).

> *<u>a. Handling and Mixing</u>. – Soil to be lime treated is pulverized in a high speed rotary mixer or with a disk harrow prior to applying lime, and the moisture content is brought to within 2 percent of optimum. Lime is uniformly spread on the pulverized soil to the specified percent lime by dry mass of soil. Lime is mixed with the soil using a rotary mixer, and additional water is added as necessary to again bring the mixture to within 2 percent of optimum. When mixing is completed, the soil-lime moisture is cured for at least 96 hours before placing and compacting. Exposed surfaces of the mixture are either lightly rolled to prevent moisture loss or the mixed material is stockpiled and the surface sealed.*
>
> *<u>b. Placing</u>. – Each section of the foundation is carefully prepared coincident with final mixing and pulverization of the lime-treated material. The soil-lime is mixed until 100 percent passes the 1 inch (25 mm) sieve and 60 percent passes the No. 4 (4.75-mm) sieve. Immediately after final mixing, the lime-treated earthfill is placed and compacted in horizontal lifts of no more than 6 inches after compaction. The material is compacted to no less than 95-percent laboratory maximum dry density, using a tamping roller followed by a pneumatic-tire roller. The top of each compacted lift is scarified or disked before the next lift. The exposed surface of the lime-treated earthfill is compacted with a pneumatic-tire roller to seal the surface, and it is sprinkled with water for 7 days.*

It is assumed that nearby borrow areas of clay that could be used for lining the fishway are dispersive. This assumption should be checked by testing potential borrow area material for dispersiveness. Based on available soils data, a 3-ft-thick lime treated clay lining is proposed for the channel. The lining material would be native clays with 5 percent lime is added; 4 percent to make the clay non-dispersive and an extra 1 percent to account for losses, uneven distribution and incomplete mixing.

Proposed conveyance channel design

Compacted lime treated clay channels will be used to connect each riffle. The lime treatment is to protect the channel from erosion and prevent the dispersive clays (native substrate) from becoming a design issue. Each run will have a cross section similar to the riffle designs having a 6.5-ft bottom width, 6-ft depth with side slopes of 1.5:1. Sediment deposition traps (located at the upstream side of each run) will have the same bottom width and side slopes but will be at an elevation of 2 ft below the conveyance run. Both sediment traps and conveyance channels should be lined with 5 percent lime treated clay to 3 ft thick (Figure 10 and Figure 13 in appendix B).

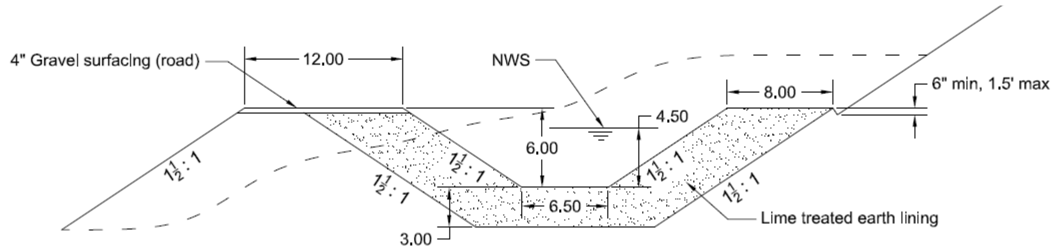

Figure 10 – Typical conveyance channel for Marble Bluff Dam fishway

Lake Passage – Fishway Location

Due to the discontinuity of the stationing between the existing construction drawings from 1973 and the 1996 re-construction drawings of the new exit ladder and fish lock, new stationing was determined starting from station 0+00.00 off the 1996 exit ladder specification drawings (Spec. No. 20-C0451) that was constructed in 1998. The centerline of the existing fishway and channel were used as a base for the new rock fishway design to reduce right of way concerns and minimize excavation costs. Table 3 provides an overview of the proposed fishway components and their stationing including a viewing area, runs, and riffle sections.

Rock riffle No. 3 – Is a step-pool riffle at a 0.8 percent slope (0.008 ft/ft). The riffle will be between stations 35+78.50 and 52+03.50 over 13 feet of elevation change (see Table 3 and Figure 14 in appendix B).

Rock riffle No. 2 – Is a step-pool riffle at a 0.8 percent slope (0.008 ft/ft). The riffle will be between stations 79+50.00 and 95+75.00 over 13 feet of elevation change (see Table 3 and Figure 15 in appendix B).

Rock riffle No. 1 – Is a step-pool riffle at a 0.8 percent slope (0.008 ft/ft). The riffle will be between stations 124+00.00 and 139+00.00 over 12 feet of elevation change (see Table 3 and Figure 16 in appendix B).

Entrance meander – Is a step-pooled riffle at a 0.8 percent slope (0.008 ft/ft), unlike ladders 1-3 the entrance riffle contains a large meander with a sinuosity (valley slope/riffle slope) of approximately 1.3 (see Table 3 and Figure 17 in appendix B). The channel sinuosity reduces the valley length required to achieve the desired fishway slope and imparts additional channel complexity that more closely emulates the natural river channel. The entrance riffle is designed to lie within the existing BOR right-of-way. The riffle extends from station 144+27.28 to 163+12.28 and will provide operation to lake elevation 3795 ft.

Table 3 – Marble Bluff fishway proposed stationing – Lake design

Description	Station (ft)	Channel Invert Elevation (ft)	Cut Invert Elevation (ft)	Grade In (ft/ft)	Grade Out (ft/ft)	Grade Change (ft/ft)
Existing U/S Channel	2+79.44'	3846.50	3844.00	--	--	--
U/S View Area	2+89.44'	3844.50	3843.50	0	0	0
D/S View Area	4+47.00'	3844.50	3843.50	0	0	0
U/S Run #4	4+57.00'	3846.00	3843.00	0	-0.00025	0.00025
D/S Run #4	35+68.50'	3845.22	3842.22	-0.00025	-0.00025	0
U/S Rock Riffle #3	35+78.50'	3845.22	3843.72	-0.00025	-0.008	0.00775
D/S Rock Riffle #3	52+03.50'	3832.22	3830.72	-0.008	0	-0.008
U/S Staging/Sed. #3	52+13.50'	3830.22	3827.22	0	0	0
D/S Staging/Sed. #3	53+93.50'	3830.22	3827.22	0	0	0
U/S Run #3	54+03.50'	3832.22	3829.22	0	-0.00025	0.00025
D/S Run #3	79+40.00'	3831.59	3828.59	-0.00025	-0.00025	0
U/S Rock Riffle #2	79+50.00'	3831.58	3830.08	-0.00025	-0.008	0.00775
D/S Rock Riffle #2	95+75.00'	3818.58	3817.08	-0.008	0	-0.008
U/S Staging/Sed. #2	95+85.00'	3816.58	3813.58	0	0	0
D/S Staging/Sed. #2	97+65.00'	3816.58	3813.58	0	0	0
U/S Run #2	97+75.00'	3818.58	3815.58	0	-0.00025	0.00025
D/S Run #2	123+90.00'	3817.93	3814.93	-0.00025	-0.00025	0
U/S Rock Riffle #1	124+00.00'	3817.93	3816.43	-0.00025	-0.008	0.00775
D/S Rock Riffle #1	139+00.00'	3805.93	3804.43	-0.008	0	-0.008
U/S Staging/Sed. #1	139+10.00'	3803.93	3800.93	0	0	0
D/S Staging/Sed. #1	140+90.00'	3803.93	3800.93	0	0	0
U/S Run #1	141+00.00'	3805.93	3802.93	0	-0.00025	0.00025
D/S Run #1	144+27.28'	3805.84	3802.84	-0.00025	-0.00025	0
U/S Ent. Meander	144+37.28'	3805.84	3804.34	-0.00025	-0.008	0.00775
D/S Ent. Meander	163+12.28'	3790.84	3789.34	-0.008	--	--

River Passage Design

The River design includes building a new fishway that travels from the toe of Marble Bluff Dam (adjacent to the entrance of the fish lock) to the entrance of the exit ladder at a constant 0.89 percent slope. The fishway will have a trapezoidal cross section with a 6.5-ft bottom width, 1.5:1 side slopes and 6-ft channel depth (Figure 19 in appendix B). Boulder array style drops will control flow velocity resulting in a series of small chutes and long pools. The River fishway will not impact operation of the existing fish lock if sufficient water is in the river to operate both facilities concurrently. Table 4 provides a summary of lining types for the River design.

Table 4 – Lining types by reach for the River design

Design and Option	Portion of Fishway	
	Conveyance Channels (Runs)	Rock Riffles
River Passage Design	None	12" Riprap & geotextile

River Passage – Fishway Riffles

The River design includes one continuous rock riffle at a slope of 0.89 percent (0.0089 ft/ft). Boulder array drop structures are spaced every 28.0 ft along the fishway channel (Figure 18 in appendix B). The boulder arrays are designed to pool water to a depth of about 3.5 to 4 ft with an average drop in water surface of about 0.25 ft across each array. An average passage velocity between the boulders of about 4 ft/s will occur at the drops. The fishway is designed to convey the full 100 ft^3/sec design flow.

The rock fishway will be constructed by over excavating the channel 1.5 ft, laying down a low porosity geotextile fabric and then riprapping with well graded riprap from 2 to 12 inch in diameter. Three boulders are used for each drop structure. Boulders will be positioned on a 60 degree angle to the channel centerline with roughly 2 ft of clear space between them (Figure 18 in appendix B). The large center boulders are about 4-4.5 feet in diameter and sit on top of the riprap bedding. The boulders to each side of center are about 3 feet in diameter. These boulders are set a minimum of 6 inches below riprap grade for stability. As rock boulders are all different shape, flow conditions will vary through each drop structure. Some tuning of the individual boulder arrays after initial operation is expected. The design is based on passing approximately 35 ft^3/sec between the center boulder and each side boulder (total of 70 ft^3/sec). The remaining flow will pass to the outside of the side boulders

River Passage – Entrance and Exit

The River fishway entrance will be a 12.5 feet wide rectangular channel set at the same starting elevation and adjacent to the fish lock entrance just below Marble Bluff Dam (Figure 19 in appendix B). Vertical concrete walls will taper with the existing topography to prevent degradation of the fishway entrance.

It is assumed that the River fishway will be constructed after the Lake design, as a result the River fishway ties into the existing exit ladder on the left side (facing downstream) of the new viewing and staging area of the Lake fishway. The transition will be constructed of a 12.5 feet wide 6 feet deep rectangular concrete channel. The concrete channel will have a 12.5 wide slide gate used to isolate the fishway when it is not in use (Figure 21 in appendix B). An additional transition section will need to be added to the Lake design which will allow isolation of each fishway. This section will be the same 12.5 feet 6 ft deep channel as in the River design and be located directly downstream of the viewing area.

River Passage – Fishway Location

Stationing for the River design starts at the upstream location where the 12.5 ft wide transition section will connect to the viewing area and continues down the fishway to the exit (Figure 20 and Figure 21 in appendix B).

Exit – Is a concrete section with 12.5 ft bottom width and 6 ft channel depth at a 0.89 percent slope (0.0089 ft/ft). The exit will connect to the proposed viewing area at approximately station 4+50 ft and will extend from station 0+00.00 to 0+50.00 over about 0.5 feet of elevation change (see Table 5 and Figure 20 in appendix B).

Rock riffle – Is a rock riffle at a 0.89 percent slope (0.0089 ft/ft). The riffle will be between stations 0+60.00 and 31+50.00 over 27.5 feet of elevation change (see Table 5 and Figure 20 in appendix B).

Entrance – Is a concrete section with 12.5 ft bottom width and 6 ft channel depth at a 0.89 percent slope (0.0089 ft/ft). The entrance will connect to the river downstream of Marble Bluff dam adjacent to the fish lock entrance between stations 31+60.00 and 32+50.00 over about 0.8 feet of elevation change (see Table 5 and Figure 20 in appendix B).

Table 5 – Marble Bluff Fishway proposed stationing – River design

Description	Station (ft)	Channel Invert Elevation (ft)	Cut Invert Elevation (ft)	Grade In (ft/ft)	Grade Out (ft/ft)	Grade Change (ft/ft)
U/S Exit Channel	0+00.00'	3844.00	3849.00	0.00	-0.0089	0.0089
D/S Exit Channel	0+50.00'	3843.56	3842.56	-0.0089	-0.0089	0.00
U/S Rock Riffle	0+60.00'	3843.47	3841.97	-0.0089	-0.0089	0.00
D/S Rock Riffle	31+50.00'	3815.97	3814.47	-0.0089	-0.0089	0.00
U/S Ent. Channel	31+60.00'	3815.88	3814.88	-0.0089	-0.0089	0.00
D/S Ent. Channel	32+50.00'	3815.08	3814.08	-0.0089	--	--

Fishway Hydraulics

Both the Lake and River designs require modifications to current water supply lines to ensure that hydraulic conditions meet design criteria. The existing fishway is designed to pass 50 ft^3/sec by the means of 2 sources: 1) fishway exit ladder (Gate #15 in Figure 5) and 2) fishway supplemental supply line (Gate #5 in Figure 5). These two sources are not adequate to provide the new design flow of 100 ft^3/sec. As a result, an additional water supply is required for both fishways. One possible source of supplemental water is the intake to the fish handling building (Gate #4 in Figure 5). This intake was originally designed to supply water to the handling building where fish were held in holding pens prior to being examined and then released to the river above the dam. This intake no longer functions in this manor at the facility.

The 2000 BOR study (Reclamation, 2000) identified using the fish handling building intake and supply line to supply additional fishway flow. The 2000 study routed the supplemental fishway flow through the handling building as open channel flow following the original 1973 design. FWS has requested that water not be allowed to pass through the building as open channel flow. Therefore, a design was prepared that pipes the flow from the intake through the building to the existing supplemental fishway supply channel west of the building. Pipe length and sizing for both the supplemental supply line and the fish handling building supply line were taken from the original 1973 specification drawings (ref. dwg. 949-D-206). These measurements were used to determine the maximum flow rate from each of the sources.

Calculations for flow rates through each supply were made for water surface elevations upstream of Marble Bluff Dam of 3854.00 and 3856.75 feet. Elevation 3854.00 is just below the dam crest elevation where the majority of river flows will be supplied to the fishway. Elevation 3856.75 is the river water surface corresponding to a river flow of around 2000 ft^3/sec, which is the maximum normal river flow according to the 1999 modified Marble Bluff Dam fish passage facilities designer operating criteria. Table 6 provides flow rates to the fishway through each of the three available sources.

Table 6 – Supply lines flows for upstream WSE 3854.00 and 3856.75 ft

River WSE (ft)	Flows (ft^3/sec)			
	Fish Handling Building (Gate #4 in Figure 5)	Supplemental Supply (Gate #5 in Figure 5)	Exit Fishway (Gate #15)	Total
3854.00	25	23	24	72
3856.75	33	30	36	99

The fish handling building supply line will require adding pipe and valves within the building to allow water to be bypassed though the building in pipe or to allow the building to operate as originally intended. A detailed site visit is necessary to determine the specifics for the piping, for quantities purpose it is assumed that 100 linear feet of 24 inch diameter steel pipe will be needed with 1 tee, 3-90 degree elbows and a valve. The pipe will need to be passed through 2-1 foot thick concrete walls.

Normal fishway operations are assumed to be between 72 and 99 cfs. For both flow rates the boulder weirs will control the flow into each fishway and maintain flow depths above 3.5 ft. Flow depths calculated for the Lake design conveyance channels are shown in Table 7. Depths are given for the expected range of channel roughness that is likely to occur during the project life. Flow depth calculations for the rock ladders are not necessary because the boulder weirs will be adjustable to maintain target depths.

Table 7 – Conveyance channel flow depths for different Mannings n values

Mannings n	Max Depth (ft) @ Flow	
	75 ft^3/sec	100 ft^3/sec
0.020	3.43	3.96
0.025	3.77	4.36

Hydraulic flushing of channel sediments

Sediment load within the fishway can result from windblown sand depositing within the fishway channel along its entire length and sediment carried into the fishway by flow diverted from the Truckee River. Ensuring that sediment can be transported through the fishway and or removed easily is an essential part of the fishway design.

Conveyance channel sediment issues

An analysis was performed to identify movement of bed sediment through the conveyance channels located between fish ladders using the 100 ft^3/sec design flow and a channel slope of 0.00025 ft/ft. The Corps of Engineers HEC-RAS model for hydraulic design of channels was used to estimate sediment concentration and stable channel dimensions for a theoretical sediment gradation (very fine to medium sand). Analysis was performed recognizing that the lime treated clay liner will be non-erodible under fishway flow conditions. Using this approach it was determined that concentrations of sand below 65 ppm will be transported through the fishway. Higher bed load concentrations will result in some deposition within the conveyance channels.

Understanding that windblown deposition combined with the entrained sediment load will often exceed the transport capacity of flow through the conveyance channels, a method to remove sediment is necessary. As a result, sediment traps (enlarged channel reaches) supporting water velocities below 1 ft/sec are included in the design at the upstream end of each run. The sediment traps will force deposition in localized areas that can be easily accessed with removal equipment. The enlarged channel reaches also are designed to serve as fish staging areas prior to each rock ladder section of the fishway.

Rock fish ladder sediment issues

The fishway rock ladders slope at 0.008 ft/ft, or about 30 times greater than the slope of the conveyance channels. The complexity of flow moving through the fishway ladders prohibits analyzing sediment movement using one dimensional stable channel models. For the current level of design, we have drawn upon experience from similar fishways operating with high sediment loads. Experience shows sediment deposition in low velocity zones within the pools between the rock weirs is expected during normal flow through the fishway. There is no evidence from similar fishways that deposition within the pools would reach levels that could significantly alter flow conditions or access for fish passage.

Reducing fishway flow to about 10 percent of design flow has been shown to be an effective method of flushing sand and silt in similar rock fishways. Reducing flow well below design levels alters the fishway flow from a deep step-pool regime to a shallow boundary flow of relatively uniform hydraulic slope capable of eroding and transporting sediment along the entire bed while maintaining the integrity of riprap lined channel.

Geology and Geotechnical Data

Regional Geology (Reclamation, 1973)

The Marble Bluff site is in a northwesterly trending structural basin formed by faulting within the western portion of the Basin and Range Province as described by Fenneman (Fenneman, 1931). Mountains in the province consist of roughly parallel ranges alternating with basins or troughs. The ranges have been uplifted along faults relative to the adjacent valley areas. Pyramid Lake, in a valley between two of these ranges, is a remnant of old Lake Lahontan which at one time covered all the nearby areas and submerged many of the mountain slopes. Bedrock exposures consisting of limestone and extrusive and intrusive igneous rocks occur primarily in the mountains. There are lake deposits of varying character in the valley areas and on the slopes of mountains. Some alluvial fans, flood-plain and delta deposits occur along the Truckee River.

1973 Pyramid Lake Fishway (Reclamation, 1973)

The fishway was largely constructed in an existing diversion channel of the earlier Marble Bluff Project which was constructed in 1942 by the Bureau of Indian Affairs. The materials encountered in the investigations along the fishway consist of sand, gravel and silt with minor quantities of clay, cobbles and boulders. Much of the fishway, particularly between Stations 45 and 135 (*1973 drawings and associated stations)*, was expected to be excavated in SP-SM, Poorly Graded Sand and Gravelly Sand. When visually classified, these materials appear to contain little or no fines but were found to contain about 10 percent fines when laboratory tested according to Earth Manual Procedure E-5. Microscopic examination and laboratory experiments conducted in the Mid-Pacific Geology Branch laboratory show that the fines occur as durable coatings and as aggregated sand-size masses which break down when vigorously mixed during standard laboratory testing procedures. Increased mixing time (up to 30 min) resulted in greater percentage of fines (up to 25 percent) with marked abrasion of the quartz grains. In the field, these materials have engineering and permeability characteristics of clean (SP) sands containing almost no fines.

Between Stations 45 and 49 (*1973 drawings and associated stations)* the fishway crosses surface deposits of gravelly sand containing cobbles and boulders up to 4 feet in size. The cobbles and boulders are probably riprap, scattered by torrential flows while the former project was in operation. Between Stations 140 and 162 (*1973 drawings and associated stations)* the fishway crosses a delta of unconsolidated sand deposited by diversion channel flows near the terminus of the channel.

Nearly all of the material encountered in the investigations was classed as "loose" or "soft" and will erode easily. The fishway prism should be cut with 1 1/2:1 or flatter slopes and will require a protective lining.

Tufa crops out right of centerline between stations 42 and 44+50 (*1973 drawings and associated stations).* The southern end of this outcrop has been deposited as a one to two-foot thick rind on gravel but the northern portion may be deposited on marble. This section of the alignment was changed after investigations were completed and consequently it was not explored. While it is anticipated that rock will not be encountered within the fishway prism as it is presently located, this possibility does exist.

A small spring and several water seeps emanating from tufa were noted right of centerline between Stations 43 and 45 (*1973 drawings and associated stations).* Surface flow from the spring was estimated to be 3 gpm (August 17, 1972); water temperature recorded at the spring was 69^0 F, about 10 degrees warmer than the temperature in test wells at Marble Bluff dam site, and the water has a notable H_2S odor. The H_2S content was not measured.

Seismicity

The seismic and geologic factors indicate that the risk of severe, and possibly damaging earthquakes, in the project vicinity is relatively high; but the nature of the project features preclude any catastrophic threat caused by failure of the structure. The design ground acceleration would be 0.25g which has a 90 percent probability of not being exceeded in a 50-year period (Survey, 2000).

Frost Heave

Frost heave is a problem in cold climates when ice lenses form and damage overlying structures due to differential movements caused by the growth of the ice lenses. The necessary conditions for frost heave are present at this site: availability of water, frost-susceptible soils, and freezing temperatures. The area has an air-freezing design index of about 750 to 1,000 degree Fahrenheit-days and a corresponding depth of frost penetration of 3 to 3.5 feet in silty sand (Reclamation, 1982).

Frost heave can be controlled or reduced by restricting the amount of water that can move upward from the groundwater table, thereby restricting the growth of ice lenses. Also, frost heave can be controlled by replacing frost-susceptible soil with free-draining material. Considering that flexible nature of the rock fish ladder and lime treated clay conveyance channels no considerations have been made regarding frost heave.

Recommended Soils Testing (Reclamation, 1990)

Borrow area – As mentioned earlier, samples of material for the lining of the fishway from proposed borrow areas should be tested for dispersiveness. Also, index properties tests (gradation and Atterberg limits) and compaction tests should be performed on representative samples.

Reclamation's standard dispersive clay tests are the following:

USBR 5400 (Determining Dispersibility of Clayey Soils by the Crumb Test Method);

USBR 5405 (Determining Dispersibility of Clayey Soils by the Double Hydrometer Method); and USBR 5410 (Determining Dispersibility of Clayey Soils by the Pinhole Test Method).

Tests on soil-lime mixtures – Laboratory tests should be performed to determine the minimum lime content, USBR 5860 (Performing Compressive Strength Testing of Compacted Soil-Lime Mix) and to determine the optimum moisture content and maximum dry unit weight, USBR 5850 (Performing Laboratory Compaction of Soil-Lime Mixtures).

Construction control – It will be necessary to control the construction by inspection and testing. Two construction control tests are recommended: USBR 7240, Performing Rapid Method of Construction Control, and USBR 5865, Performing Construction Control of Compacted Soil-Lime Mixtures.

Dewatering Plan

Hydro-geologic Setting

Pyramid Lake is located in the Basin and Range Province of western Nevada. Typical of this province are linear block mountain ranges surrounded by valleys. The desert valleys are filled with alluvial materials eroded form the surrounding mountains. Bedrock is near surface at desert edges. In the valley center, alluvial materials can be hundreds of feet deep.

Pyramid Lake is the terminus for the Truckee River. Present day lake level is around 3800 ft and could potentially rise higher. The Truckee River has incised a channel though the valleys fill alluvial material. At the upper end of the fishway, Marble Bluff dam checks up the Truckee River to an average elevation of 3855.

The fishway will be constructed within delta and terrace bank materials deposited in former glacial Lake Lahontan. This lake once extended about 200 feet above the present day level. The interbedded deposits are thought to extend tens of feet below the fishway sub grade. Typical materials range from silty sands to sandy gravels. The amount of fine (passing #200 sieve) materials overall may be around 10%.

In 1972 water level data was recorded in a number of test pits and drill holes along the fishway alignment. Based on the geologic setting and the water level data, the local groundwater table is unconfined with a gradual slope toward present day Pyramid Lake. Table 8 provides the original water data and layout according to the 1972 construction.

Table 8 – 1972 ground water level data

Ladder Location (1972 Stationing)	Elevation (ft)	1972 Ground Water Level (Sta: EL)
Ladder 3 45+50 to 47+06	3845.60 to 3832.60	36+50: 3842 43+50: 3840 (3 gpm seep) 47+20: 3827
Ladder 2 90+00 to 91+56	3832.17 to 3819.17	85+25: 3821 98+90: 3816
Ladder 1 135+00 to 136+56	3818.74 to 3805.74	120+00: 3809.5 140+00: 3799.5
Terminal Ladder 157+27 to 160+27	3805.53 to 3774.50	140+00: 3799.5 160+00: 3795.5 (Lake)

An outcrop of tufa and marble exists around Stations 40 to 45+00, just upstream of ladder 3. About three small seeps were recorded about elevation 3840. A measurable flow of 3 gpm was found in one seep. The water table in this location is probably perching about the more impermeable bedrock.

Previous Construction Water Handling Techniques

During the construction of the Pyramid Lake entrance ladder, a semicircular sheet pile cofferdam with pumped wells was used. The dam was 360 feet long and 60 feet deep. Nineteen 12-inch diameter pumped wells, 70 feet deep were drilled. Reported pump sizes were 450 gpm. Only 6 wells needed pumping to successfully keep the excavation dry. The lake was about 18 feet above the entrance to the ladder during the construction period. For the three intermediate fish ladders, a combination of sumps, buried perforated pipes, and well points were used. The success was described as “tenuous at best” (Reclamation, 1973).

Dewatering Requirements

During construction the groundwater level needs to be drawn down about 3 feet below the cut invert in all areas of the fishway conveyance channels and rock riffles. Considering that no current information is available regarding ground water surface data the existing water table from the 1973 drawings was used to determine de-watering needs. Based on the stated assumptions, Table 9 provides estimated ground water control data according to station, including the max and average drawdown for each dewatering section.

Table 9 – Estimated ground water control required for construction

Location Identifier Near:	New Stationing		Length (ft)	Max Drawdown		Average Drawdown (ft)
	Start (Upstream)	End (Downstream)		Station	(ft)	
Run 4*	2+79.44	35+78.50	3299	Unknown	Unknown	Unknown
Rock Riffle 3	51+05.93	60+32.05	926	52+13.50	2.75	1.375
Rock Riffle 2	88+48.64	100+59.59	1211	95+85.00	4.30	2.15
Ent. Meander	148+96.80	163+12.28	1415	163+12.28	10.16	5.08

*no groundwater data was available to determine dewatering needs

Groundwater Aquifer and Flow

The glacial lake materials are laterally discontinuous and tend to be on the coarser side with a low percentage of fines. An unconfined aquifer is thus assumed. The previous construction reports noted that the materials are loose and some beds have high porosity. Occasional silt and clayey beds are thin and would likely range a few tens to a few hundreds of feet in extent.

The materials are assumed to be homogeneous in the horizontal and vertical directions. The predominant material type is silty sand. Typical hydraulic conductivity values range from about 1 to 100 gallons per day per square foot for a silty sand average (Freeze, et al., 1979)(Driscoll, 1986). A vertical permeability value of about 10 and the horizontal permeability of about 100 were assumed. The concept study dewatering plan is based on an equivalent permeability of about 30 gallons per day per square foot

Water Handling and Analysis Methods

This study is based on water level data and geologic information from the 1972 studies. It is assumed that present ground water levels would be about the same as in 1972, except where the lake has risen. Present ground water levels could be different and should be identified prior to final design.

Dewatering for the entrance meander will require similar techniques as used in the 1970's for the terminal ladder. The large drawdown depths needed at the entrance meander will require using pumped wells in combination with sheet pile cutoffs and cofferdaming.

Better groundwater control is proposed for dewatering other areas of the fishway than was used in 1972. A combination of well points and sheet pile cutoffs is proposed. Sowers (Sowers, 1992) found well points work well for surface dewatering of silty sand materials typical of Marble Bluff fishway when minimal draw down is required. Where greater depth of dewatering is needed, well points used in combination with cutoff walls are recommended.

Construction dewatering techniques include placing sheet piles and well points inside the excavation zone. Water will flow horizontally toward the excavation with a vertical component under the sheet pile barrier.

Dewatering plans were made following the assumptions and calculations done in 2000 (Reclamation, 2000), adjustments were made according to the total de-watering length that was required. No additional calculations were made, as they will need to be completed by a geotechnical engineer after updated geotechnical data and groundwater data are made available. As stated in the 2000 report regarding the dewatering plan calculations:

> *"Although, well points are suitable for the type of materials at the site, the prior construction of the intermediate ladders had questionable success using just well points and sumps. For this study a combination of well points and cutoff walls are recommended. Excavations for ladders No. 2 and No. 3 will use sheet pile cutoffs and well points for evacuating water. A sheet pile embedment (D) of D = 1.5 to 2.0 H, where H is about the excavation change in water surface was used for the design. The ladder profiles show the maximum excavation would be 10 ft and the dewatering level change would be about 10 ft, therefore 30 ft sheet piles were assumed for cutoffs.*
>
> *"Well point spacing was determined by estimating the flow under the cutoff wall and the withdrawal rate of the well points for the rock or concrete ladder options at their respective grades. Flow under the sheet pile cutoffs was estimated using a 1-D flow calculation. For the calculations, an excavation depth of 10 feet and a ground water table about 5 feet below original ground surface was assumed. This flow was*

then compared to the calculated flow into an equivalent circular excavation using a modified (large well) borehole equation."

Proposed Dewatering

Lake Passage – Entrance Meander

Construction of the entrance meander will require a combination of unwatering and dewatering. A maximum draw down of 10 feet was assumed for this study. The data gathered during the prior dewatering of the entrance (terminal) ladder was used as the basis of design. For the proposed construction, thirty-foot deep sheet piles would be driven in a semicircular alignment around the channel's furthest downstream location. The thirty-foot deep sheet piles would continue up the sides of entrance meander for 250 feet on each side, where they will be reduced to fifteen-foot deep sheet piles for another 650 feet on each side of the meander. The Z factor for these piles should be about S = 14 in^3. After completing the cutoff work, low head pumps would be used to empty the area of standing water and pumped wells would be drilled. Ten wells at 10-inch diameter fitted with 150 gpm pumps would be installed. At 50 foot spacing, each well is designed to pump about 100 gallons per minute. During the 1970's terminal ladder dewatering they found six 12-inch diameter wells spaced at 60 ft were sufficient.

Lake Passage – Rock Riffles 2 and 3

Dewatering near rock riffles 2 and 3 can be found in the profile views of the design. Where specified, fifteen feet long, 1-1/2 in diameter, self jetting well points should be installed. Each well point is estimated to flow at 0.6 gallons per minute. The points should be placed about 25 ft to each side and parallel to the fishway centerline, spaced 5 feet apart. Well points would be connected to a 3" ID Schedule 80 PVC pipe header pipe connected to a vacuum pump capable of 100 gpm. The vacuum pump would discharge to another pump or a sump. Either a 2-stage pump or a second low head pump would be needed to lift the sucked ground water out of the excavation.

Previous construction reports mention there were some erosion problems when the fishway was operated. Apparently some riprap was placed to control the erosion. The zones of riprap need to be delineated.

The actual permeability value will affect how much water is pumped for evacuation. For the deep wells, if the K value is closer toward the high horizontal value of 100 instead of the assumed 30, the flow out of the pumped wells would be higher. The proposal uses 100 gpm pumps in the wells. Ten-inch diameter wells can fit a pump with a flow rate up to about 300 gpm, so the well size should be adequate for a higher K. The pumps could be easily switched out if needed. Six-inch wells were considered, however they can only fit pumps up to about 120 gpm. This was considered to small as a maximum flow rate. Soil stability tests should be conducted prior to final design to determine the drawdown required to support machinery and large riprap during construction.

River Passage

The extent dewatering is necessary for the River fishway is unknown due to the lack of groundwater and geotechnical data in the area. Assumptions were made that considerable dewatering will be required for construction at the River fishway entrance near the fish lock and along the fishway channel. Dewatering was assumed to be similar to the dewatering of the Lake passage design.

Earth Waste Areas

Borrow areas excavated during previous construction projects at Marble Bluff Dam could likely be used for earth waste disposal for the fishway project. A number of borrow areas and waste sites have been used during construction, (ref. dwg. 949-D-278). Sites on the south side of the river are not considered suitable for waste disposal. These sites are largely in areas that were inundated by water following the dam construction. These areas have typically silted in, now support good vegetation and offer poor access from the fishway channel. Two borrow areas identified as areas A and E on ref. dwg. 949-D-278 provide good access. The extent to which the areas were excavated during construction and therefore the volume of material that they could receive could not be determined in this study. Borrow area A was used again during the 1998 construction of the fish lock and fishway exit channel. It was established as a small waste/construction use site. A field site survey of area A should be conducted prior to final design to determine the suitability of the site for wasting material excavated from the fishway. Demolition of the existing concrete flumes will require disposal of the broken concrete. The concrete material will be trucked to a managed disposal site.

Fencing

The Fish and Wildlife Service installed new fence along both sides to the fishway several years ago. The fencing generally runs along the top of the bluffs either side of the fishway channel. Cattle are commonly grazed on the lands on both sides of the fishway and, in the past, have gotten through the fencing and grazed in the fishway channel for extended periods of time. The exiting fence is generally in good condition. The fence is constructed of 6 inch square woven wire with barbed wire above. The wire is strung between metal tee posts. Although the fence is generally sufficient to hold out cattle, several wire gates located along the fence are in poor condition and can easily be left open. All existing gates should be replaced with woven wire type stock gates that are spring loaded to close automatically. In the areas where posts and fencing is in poor condition new fence should be constructed.

Viewing Area

As requested by the FWS a viewing area has been incorporated into the Lake and River designs. The viewing area will be adjacent to the new concrete staging area downstream of the existing exit ladder. Several 2.5 by 2.5 foot glass viewing windows will be located on the side of the concrete section of the flume. A pedestrian viewing area (Figure 21 and Figure 22 in appendix B) will allow access to the viewing windows.

Bridge

As part of the reconstruction of the Lake design, a new bridge will need to be constructed to cross the conveyance channel near the exit ladder. The current bridge will be demolished to allow reconstruction and a new bridge will be built at station 5+00.00. The new bridge will be constructed of voided slab precast concrete bridge on spread footings. Figure 21 in appendix B provides an overview of the bridge location and access. Addition information on the bridge can be found in Figure 23 in appendix B.

Project Construction Costs

No construction costs were estimated as part of this project. The U.S. Army Corps of Engineers was provided quantity take offs to prepare cost estimates for both the Lake and River design. The quantities provided to the COE are included in Appendix A. For the latest current working estimate please contact the COE.

Operation and Maintenance

The fishway is operated by fully opening the slide gate at the head of the fishway and allowing water to pass down the exit ladder. Auxiliary water can be added downstream of the exit ladder by opening Gate #5, or through the fish bypass building by opening Gate #4 of the headworks structure (Figure 5). Flow should be added if the flow depth in the fishway channel is less than 4.0 feet. The swing bar gate at the downstream end of the exit ladder should be positioned to guide fish up the exit ladder. The rock riffle design does not have flow bypass capability. If found necessary fish will be controlled into the fishway at the lake interface with the entrance meander by the means of a bar gate structure. The bar gate could be moved each year as needed to follow changes in the lake elevation.

The fishway will require cleaning prior to each operation. Cleaning will consist of removing blown in weeds and large sediment deposits. Within the fishway weeds should be removed to prevent possible debris plugging of the baffles or boulder riffles. The ladders should not require mechanical removal of sediment. If large windblown sand deposits from within the riffles the fishway should be operated at low flows prior to the fish run to flush material to the sediment traps where it can be removed by a small bobcat type loader.   In the channel between riffles, blown in weeds should be removed by hand. Large sediment deposits should be removed by a small loader driven along the channel invert. The cleaning crew should be versed in proper cleaning techniques that protect the integrity of the channel lining. Based on FWS experience, in most years the cleaning is estimated to require two people three days to complete. If the fishway is not used or cleaned for several years, the cleaning requirements may increase.

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APPENDIX A

QUANTITY ESTIMATE WORKSHEET

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BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:	**PROJECT:**
Marble Bluff Dam - Fishway Modifications	**Washoe Project**
Existing Fishway Modifications	
Lake Design - Clay Runs and Riprap Ladders	**WOID:** / **ESTIMATE LEVEL:** **Appraisal**
	REGION: / **PRICE LEVEL:**
8140 Water Conveyance	**FILE:** E:\Projects\Marble Bluff Fish Passage\[Marble Bluff Fishway - Cost Estimation WS.xlsx]8140 LAKE OPTION

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Removal of Existing Ladders and Structures	68140				
		Assume removal, haul off and disposal of					
		Include cost of transportation and disposal					
		structures are 1'-0" thick and reinforced					
		Diffuser Box					
		Concrete		28	CY		
		Terminal Fish Ladder					
		Concrete		1,100	CY		
		Handrails		810	LF		
		24" Concrete Pipe		530	LF		
		Concrete Fish Ladder #1					
		Concrete		200	CY		
		Handrails		310	LF		
		24" Concrete Pipe		120	LF		
		Concrete Fish Ladder #2					
		Concrete		200	CY		
		Handrails		310	LF		
		24" Concrete Pipe		120	LF		
		Concrete Fish Ladder #3					
		Concrete		200	CY		
		Handrails		310	LF		
		24" Concrete Pipe		120	LF		

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Bryan Heiner	**Arthur Streifel**		
DATE PREPARED	**PEER REVIEW**	**DATE PREPARED**	**PEER REVIEW**
12/6/2010	**Dave Edwards 1-12-2011**		

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

Marble Bluff Dam - Fishway Modifications

Existing Fishway Modifications

Lake Design - Clay Runs and Riprap Ladders

8140 Water Conveyance

PROJECT: **Washoe Project**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION:

PRICE LEVEL:

FILE: E:\Projects\Marble Bluff Fish Passage\[Marble Bluff Fishway - Cost Estimation WS.xlsx]8140 LAKE OPTION

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		EXCAVATION	TOTAL:	120,430	CY		
		Common, removal and disposal (max 3 miles)					
		Transition to View Area		20	CY		
		Viewing/Staging Area		840	CY		
		Run #4		21,000	CY		
		Rock Fish Ladder #3		7,500	CY		
		Staging/Sediment #3		1,750	CY		
		Run #3		15,500	CY		
		Rock Fish Ladder #2		6,200	CY		
		Staging/Sediment #2		1,800	CY		
		Run #2		16,000	CY		
		Rock Fish Ladder #1		7,000	CY		
		Staging/Sediment #1		1,850	CY		
		Run #1		1,750	CY		
		Entrance Meander		39,000	CY		
		Bridge		220	CY		
		COMPACTED BACKFILL	TOTAL:	17,053	CY		
		Structural, hauled in from borrow (max 3 miles)					
		Viewing/Staging Area		4	CY		
		Run #4		220	CY		
		Rock Fish Ladder #3		6,500	CY		
		Staging/Sediment #3		140	CY		
		Run #3		2,000	CY		
		Rock Fish Ladder #2		3,200	CY		
		Staging/Sediment #2		12	CY		
		Run #2		1,300	CY		
		Rock Fish Ladder #1		2,500	CY		
		Staging/Sediment #1		11	CY		
		Run #1		56	CY		
		Entrance Meander		900	CY		
		Bridge		210	CY		

QUANTITIES		PRICES	
BY: Bryan Heiner	CHECKED: Arthur Streifel	BY:	CHECKED:
DATE PREPARED: 12/6/2010	PEER REVIEW: Dave Edwards 1-12-2011	DATE PREPARED:	PEER REVIEW:

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:

Marble Bluff Dam - Fishway Modifications

Existing Fishway Modifications

Lake Design - Clay Runs and Riprap Ladders

8140 Water Conveyance

PROJECT: Washoe Project

WOID:

ESTIMATE LEVEL: Appraisal

REGION:

PRICE LEVEL:

FILE: E:\Projects\Marble Bluff Fish Passage\[Marble Bluff Fishway - Cost Estimation WS.xlsx]8140 LAKE OPTION

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		CAST-IN-PLACE CONCRETE					
		Transition					
		Wall		28	CY		
		Slab		28	CY		
		Viewing/Staging Area					
		Wall		135	CY		
		Slab		180	CY		
		Stairs		35	CY		
		Bridge Curb and Footings		15	CY		
		CONCRETE REINFORCEMENT					
		rebar calculated assuming 150 lb/cy of concrete					
		Transition					
		Wall		4,200	LB		
		Slab		4,200	LB		
		Viewing/Staging Area					
		Wall		20,250	LB		
		Slab		27,000	LB		
		Stairs		5,250	LB		
		Bridge Curb and Footings		2,250	LB		
		CEMENTIOUS MATERIAL					
		cemet calculated assuming 0.282 ton/cy of concrete					
		Transition					
		Wall		8	TON		
		Slab		8	TON		
		Viewing/Staging Area					
		Wall		38	TON		
		Slab		51	TON		
		Stairs		10	TON		
		Bridge Curb and Footings		4	TON		

QUANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Bryan Heiner	Arthur Streifel		
DATE PREPARED	PEER REVIEW	DATE PREPARED	PEER REVIEW
12/6/2010	Dave Edwards 1-12-2011		

BUREAU OF RECLAMATION	ESTIMATE WORKSHEET				SHEET 4 OF 7

FEATURE:	PROJECT:
Marble Bluff Dam - Fishway Modifications	**Washoe Project**
Existing Fishway Modifications	
Lake Design - Clay Runs and Riprap Ladders	**WOID:** / **ESTIMATE LEVEL:** **Appraisal**
	REGION: / **PRICE LEVEL:**
8140 Water Conveyance	**FILE:** E:\Projects\Marble Bluff Fish Passage\[Marble Bluff Fishway - Cost Estimation WS.xlsx]8140 LAKE OPTION

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		CANAL LINING - LIME TREATED CLAY	TOTAL:	52,400	CY		
		include 5% lime treatment (by volume) and compaction					
		Run #4		17,500	CY		
		Staging/Sediment #3		1,350	CY		
		Run #3		14,000	CY		
		Staging/Sediment #2		1,350	CY		
		Run #2		15,000	CY		
		Staging/Sediment #1		1,350	CY		
		Run #1		1,850	CY		
		INTERMEDIATE LADDER LINING - RIPRAP	TOTAL:	8,400	CY		
		2-10" diam. well graded riprap (≈1.5 ton/cy)					
		Rock Fish Ladder #3		2,900	CY		
		Rock Fish Ladder #2		2,900	CY		
		Rock Fish Ladder #1		2,600	CY		
		ENTRANCE MEANDER LINING - RIPRAP	TOTAL:	3,300	CY		
		4-14" diam. well graded riprap (≈1.5 ton/cy)					
		Entrance Meander		3,300	CY		
		GEOTEXTILE FABRIC	TOTAL:	27,600	SY		
		make allowance for overlapping joints 3 feet					
		Rock Fish Ladder #3		6,800	SY		
		Rock Fish Ladder #2		6,800	SY		
		Rock Fish Ladder #1		6,200	SY		
		Entrance Meander		7,800	SY		
		GRAVEL SURFACING		2,400	CY		
		12' X 4" access road along the entire fishway					
		CHEVRON WEIRS		212	WEIRS		
		individual weirs include one 4.5' and two 3'					
		4.5' diameter boulder		212	EACH		
		3' diameter boulder		424	EACH		
		BRIDGE		1	EACH		
		span 32.5 ft span over 6 ft deep trap channel					
		HS-20 Load, on spread footings					
		Precast Concrete Voided Slap Beams		5	EACH		
		32.5' long 1.5' deep, 4.0' wide, 3 10" circ. voids					

QUANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Bryan Heiner	Arthur Streifel		
DATE PREPARED	PEER REVIEW	DATE PREPARED	PEER REVIEW
12/6/2010	Dave Edwards 1-12-2011		

FEATURE:

Marble Bluff Dam - Fishway Modifications

Existing Fishway Modifications

Lake Design - Clay Runs and Riprap Ladders

8140 Water Conveyance

PROJECT: **Washoe Project**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION:

PRICE LEVEL:

FILE: E:\Projects\Marble Bluff Fish Passage\[Marble Bluff Fishway - Cost Estimation WS.xlsx]8140 LAKE OPTION

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Handrails		500	LF		
		Along viewing area and bridge					
		Metals					
		24" diam, 1/4" thick steel pipe		100	LF		
		24" diam, 1/4" thick steel tee		1	EACH		
		24" diam, 1/4" thick steel 90 degree elbow		3	EACH		
		(supplemental supply through fish bldg)					
		Entrance meander control structure		3,000	LB		
		Viewing window frames		1,500	LB		
		Viewing Windows		2	EACH		
		2.5'X2.5'X4" thick glass, 1/4" neoprene seal					
		Mechanical					
		24" full port valve with automation		1			
		(supplemental supply through fish bldg)			EACH		
		Miscellaneous					
		24" diam 12" thick concrete bores		2			
		DEWATERING BY ROCK FISH LADDER #3					
		Includes installing vacuum well points					
		from sta: 51+05.93 to 60+32.05 @ avg. 1.38 ft drawdown					
		zone is about 926' long by 50' wide					
		Mobilization		1	LS		
		F&P well points, self jetting, 1-1/2", 15' deep		410	EACH		
		include stop cock valve and pipe and tee to header pipe					
		F&P 3" Schedule 80 header pipe		2,300	LF		
		Furnish and operate 150 gpm vacuum pump		1	LS		
		assume 2 month duration					
		Furnish and operate 150 gpm low head pump		1	LS		
		assume 2 month duration					
		Installing observation wells 1" diam, 30' deep Push		9	EACH		
		Labor onsite for monitoring		2	MONTH		

QUANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Bryan Heiner	Arthur Streifel		
DATE PREPARED	PEER REVIEW	DATE PREPARED	PEER REVIEW
12/6/2010	Dave Edwards 1-12-2011		

FEATURE:

Marble Bluff Dam - Fishway Modifications

Existing Fishway Modifications

Lake Design - Clay Runs and Riprap Ladders

8140 Water Conveyance

PROJECT: **Washoe Project**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION:

PRICE LEVEL:

FILE: E:\Projects\Marble Bluff Fish Passage\[Marble Bluff Fishway - Cost Estimation WS.xlsx]8140 LAKE OPTION

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		DEWATERING ROCK BY FISH LADDER #2					
		Includes installing vacuum well points					
		from sta: 88+48.64 to 100+59.59 @ avg. 2.15 ft drawdown					
		zone is about 1211' long by 50' wide					
		Mobilization		1	LS		
		F&P well points, self jetting, 1-1/2", 15' deep		524	EACH		
		include stop cock valve and pipe and tee to header pipe					
		F&P 3" Schedule 80 header pipe		2,900	LF		
		Furnish and operate 200 gpm vacuum pump		1	LS		
		assume 2 month duration					
		Furnish and operate 200 gpm low head pump		1	LS		
		assume 2 month duration					
		Installing observation wells 1" diam, 30' deep Push		9	EACH		
		Labor onsite for monitoring		2	MONTH		
		DEWATERING ROCK BY FISH LADDER #1					
		none					

QUANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Bryan Heiner	Arthur Streifel		
DATE PREPARED	PEER REVIEW	DATE PREPARED	PEER REVIEW
12/6/2010	Dave Edwards 1-12-2011		

ESTIMATE WORKSHEET

FEATURE:	**PROJECT:**
Marble Bluff Dam - Fishway Modifications	**Washoe Project**
Existing Fishway Modifications	
Lake Design - Clay Runs and Riprap Ladders	**WOID:** / **ESTIMATE LEVEL:** Appraisal
	REGION: / **PRICE LEVEL:**
8140 Water Conveyance	**FILE:** E:\Projects\Marble Bluff Fish Passage\[Marble Bluff Fishway - Cost Estimation WS.xlsx]8140 LAKE OPTION

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		DEWATERING BY ENTRANCE MEANDER & LAKE					
		Includes installing sheet piles and pumped well points					
		from sta: 151+07.36 to 163+12.28 @ avg. 4.33 ft drawdown					
		zone is about 1204.92' long by 60' wide					
		Mobilization		1	LS		
		F&P Sheet piling, PMA-22, salvage after use		42,000	SF		
		semicircular 250' X 30' deep					
		outside meander 250' X 30' deep both sides					
		outside meander 650' X 15' deep both sides					
		assume (25lb steel/sqft)					
		Furnish and operate 250 gpm pump for site unwatering		1	LS		
		assume 4 day duration, kept 2 weeks at site					
		Drilling 10" diam., 70 feet deep pump wells		10	EACH		
		cased with 25 foot well screen, 50' well spacing					
		Furnish and operate 150 gpm pumps in the wells		10	EACH		
		submersible, assume 2 month duration					
		Discharge pipe, 10" Schedule 80 PVC		3,000	LF		
		Furnish and operate 750 gpm low head pump		2	EACH		
		assume 2 month duration					
		Labor onsite for monitoring		2	MONTH		

QUANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Bryan Heiner	Arthur Streifel		
DATE PREPARED	PEER REVIEW	DATE PREPARED	PEER REVIEW
12/6/2010	Dave Edwards 1-12-2011		

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

SHEET 1 OR 3

FEATURE:	**PROJECT:**
Marble Bluff Dam - Fishway Modifications	**Washoe Project**
New Fishway	
River Design - Riprap Lined Fishway	**WOID:** / **ESTIMATE LEVEL:** **Appraisal**
	REGION: / **PRICE LEVEL:**
8140 Water Conveyance	**FILE:** E:\Projects\Marble Bluff Fish Passage\[Marble Bluff Fishway - Cost Estimation WS.xlsx]8140 RIVER OPTION

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		EXCAVATION	TOTAL:	51,250	CY		
		Common, removal and disposal (max 3 miles)					
		COE Option Fishway and Transitions		51,000	CY		
		Bridge		250	CY		
		COMPACTED BACKFILL	TOTAL:	2,090	CY		
		Structural, hauled in from borrow (max 3 miles)					
		COE Option Fishway and Transitions		1,850	CY		
		Bridge		240	CY		
		CAST-IN-PLACE CONCRETE					
		include cement (0.282 ton/cy) and rebar (150 lb/cy)					
		Entrance Transition					
		Wall		32	CY		
		Slab		32	CY		
		Exit Transtion					
		Wall		47	CY		
		Slab		47	CY		
		Bridge Curb and Footings		15	CY		
		CONCRETE REINFORCEMENT					
		rebar calculated assuming 150 lb/cy of concrete					
		Entrance Transition					
		Wall		4,800	LB		
		Slab		4,800	LB		
		Exit Transtion					
		Wall		7,050	LB		
		Slab		7,050	LB		
		Bridge Curb and Footings		2,250	LB		

QUANTITIES		PRICES	
BY Bryan Heiner	**CHECKED** Arthur Streifel	**BY**	**CHECKED**
DATE PREPARED 12/6/2010	**PEER REVIEW** Dave Edwards 1-12-2011	**DATE PREPARED**	**PEER REVIEW**

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

SHEET 2 OR 3

FEATURE:

Marble Bluff Dam - Fishway Modifications

New Fishway

River Design - Riprap Lined Fishway

8140 Water Conveyance

PROJECT: **Washoe Project**

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION:

PRICE LEVEL:

FILE: E:\Projects\Marble Bluff Fish Passage\[Marble Bluff Fishway - Cost Estimation WS.xlsx]8140 RIVER OPTION

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		CEMENTIOUS MATERIAL					
		cemet calculated assuming 0.282 ton/cy of concrete					
		Entrance Transition					
		Wall			TON		
		Slab			TON		
		Exit Transtion					
		Wall			TON		
		Slab			TON		
		Bridge Curb and Footings			TON		
		RIPRAP LINING		5,400	CY		
		2-10" diam. well graded riprap (≈1.5 ton/cy)					
		GRAVEL SURFACING		940	CY		
		12' X 4" access road along the entire canal					
		CHEVRON WEIRS		114	WEIRS		
		individual weirs include one 4.5' and two 3'					
		4.5' diameter boulder		114	EACH		
		3' diameter boulder		228	EACH		
		BRIDGE		1	EACH		
		span 32.5 ft span over 6 ft deep trap channel					
		HS-20 Load, on spread footings					
		Precast Concrete Voided Slap Beams		5	EACH		
		32.5' long 1.5' deep, 4.0' wide, 3 10" circ. voids					
		GEOTEXTILE FABRIC		13,000	SY		
		HANDRAILS		300	LF		
		MECHANICAL					
		12.5' wide 6' deep slide gate 9		2	EACH		
		or similar isolation type gate					
		Metals					
		Baffles 3 sets (1500lb/baffle, 500lb/guide)		6,000	LB		

QUANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Bryan Heiner	Arthur Streifel		
DATE PREPARED	PEER REVIEW	DATE PREPARED	PEER REVIEW
12/6/2010	Dave Edwards 1-12-2011		

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

SHEET 3 OR 3

FEATURE:	PROJECT:
Marble Bluff Dam - Fishway Modifications	**Washoe Project**
New Fishway	
River Design - Riprap Lined Fishway	**WOID:** | **ESTIMATE LEVEL:** **Appraisal**
	REGION: | **PRICE LEVEL:**
8140 Water Conveyance	**FILE:** E:\Projects\Marble Bluff Fish Passage\[Marble Bluff Fishway - Cost Estimation WS.xlsx]8140 RIVER OPTION

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		DEWATERING BY FISHWAY ENTRANCE (RIVER)					
		Includes installing sheet piles and pumped well points					
		from sta: 31+50.00 to 32+50					
		zone is about 100' long by 60' wide					
		Mobilization		1	LS		
		F&P Sheet piling, PMA-22, salvage after use		7,800	SF		
		linear 260' X 30' deep (25lb steel/sqft)					
		Furnish and operate 250 gpm pump for site unwatering		1	LS		
		assume 1 day duration, kept 2 weeks at site					
		Drilling 10" diam., 70 feet deep pump wells		5	EACH		
		cased with 25 foot well screen, 40' well spacing					
		Furnish and operate 100 gpm pumps in the wells		5	EACH		
		submersible, assume 2 month duration					
		Discharge pipe, 8" Schedule 80 PVC		500	LF		
		Furnish and operate 500 gpm low head pump		1	EACH		
		assume 2 month duration					
		Labor onsite for monitoring		2	MONTH		

QUANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Bryan Heiner	Arthur Streifel		
DATE PREPARED	PEER REVIEW	DATE PREPARED	PEER REVIEW
12/6/2010	Dave Edwards 1-12-2011		

APPENDIX B

DESIGN DRAWINGS

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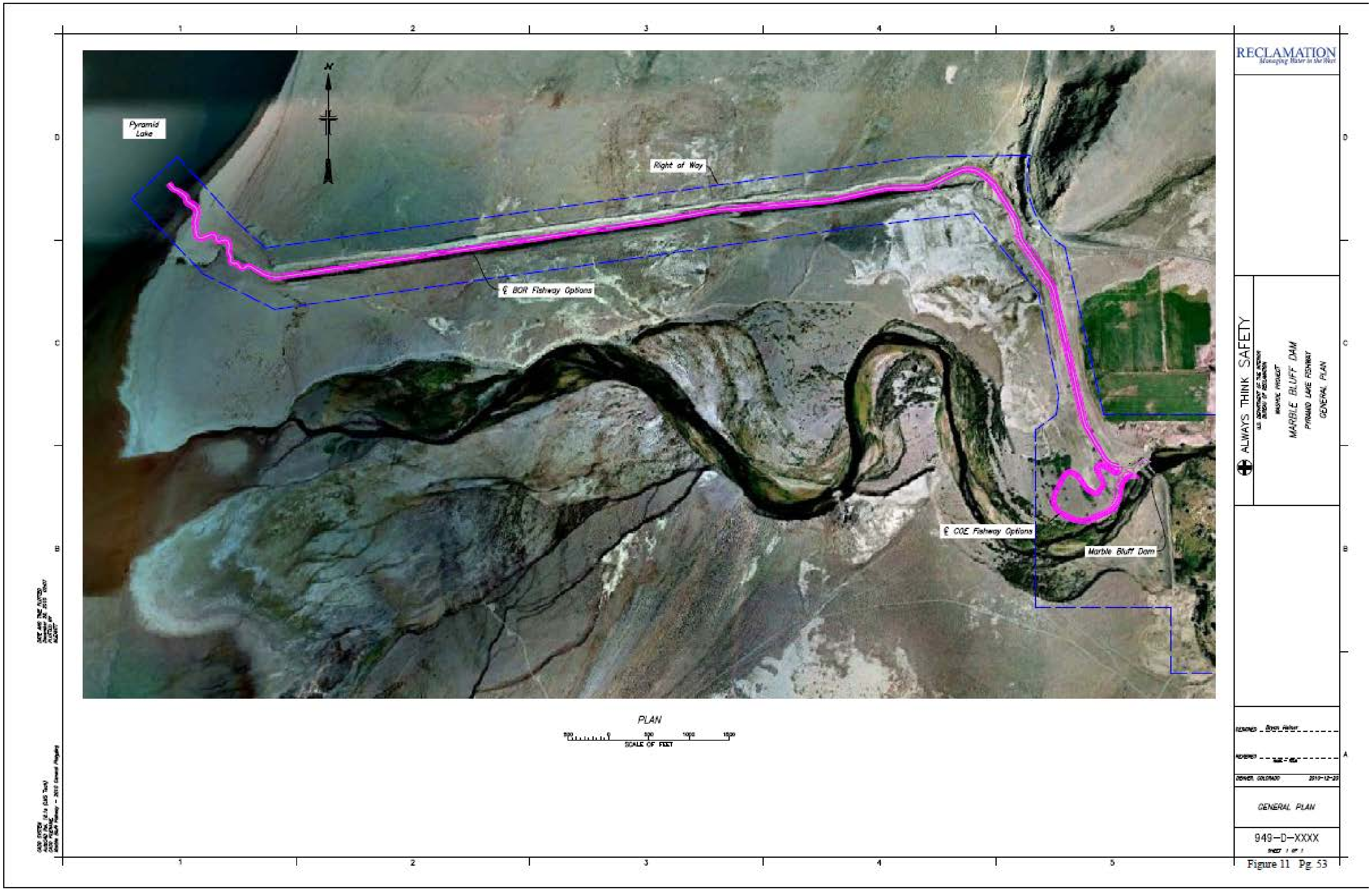

Figure 11 – General plan of Lake and River fishway designs

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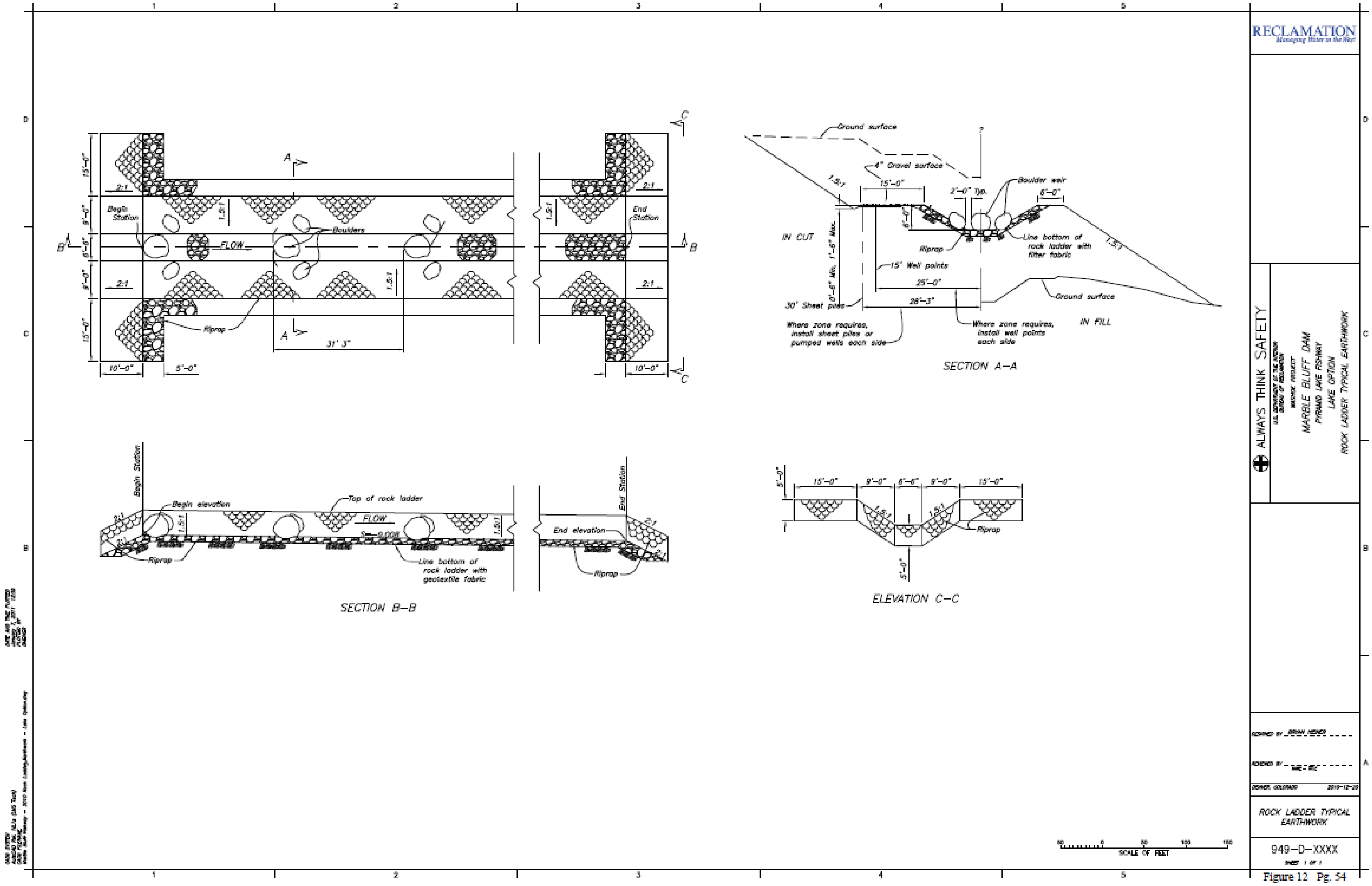

Figure 12 – Lake fishway – rock fishway typical earthwork

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FISHWAY CROSS SECTION			
Begin Station	End Station	Description	BOR Design Template
0+00	2+56.37	Existing U/S Fishway	1 (not shown)
2+56.37	2+79.44	Transition to View Area	2 (not shown)
2+79.44	4+57	Viewing Area	3
4+57	35+68.50	Run #4	4
35+68.50	52+03.50	Rock Fish Ladder #3	6
52+03.50	54+03.50	Staging/Sediment #3	5
54+03.50	79+40	Run #3	4
79+40	95+75	Rock Fish Ladder #2	6
95+75	97+75	Staging/Sediment #2	5
97+75	123+90	Run #2	4
123+90	139+00	Rock Fish Ladder #1	6
139+00	141+00	Staging/Sediment #1	5
141+00	144+27.28	Run #1	4
144+27.28	163+12.28	Entrance Meander	6

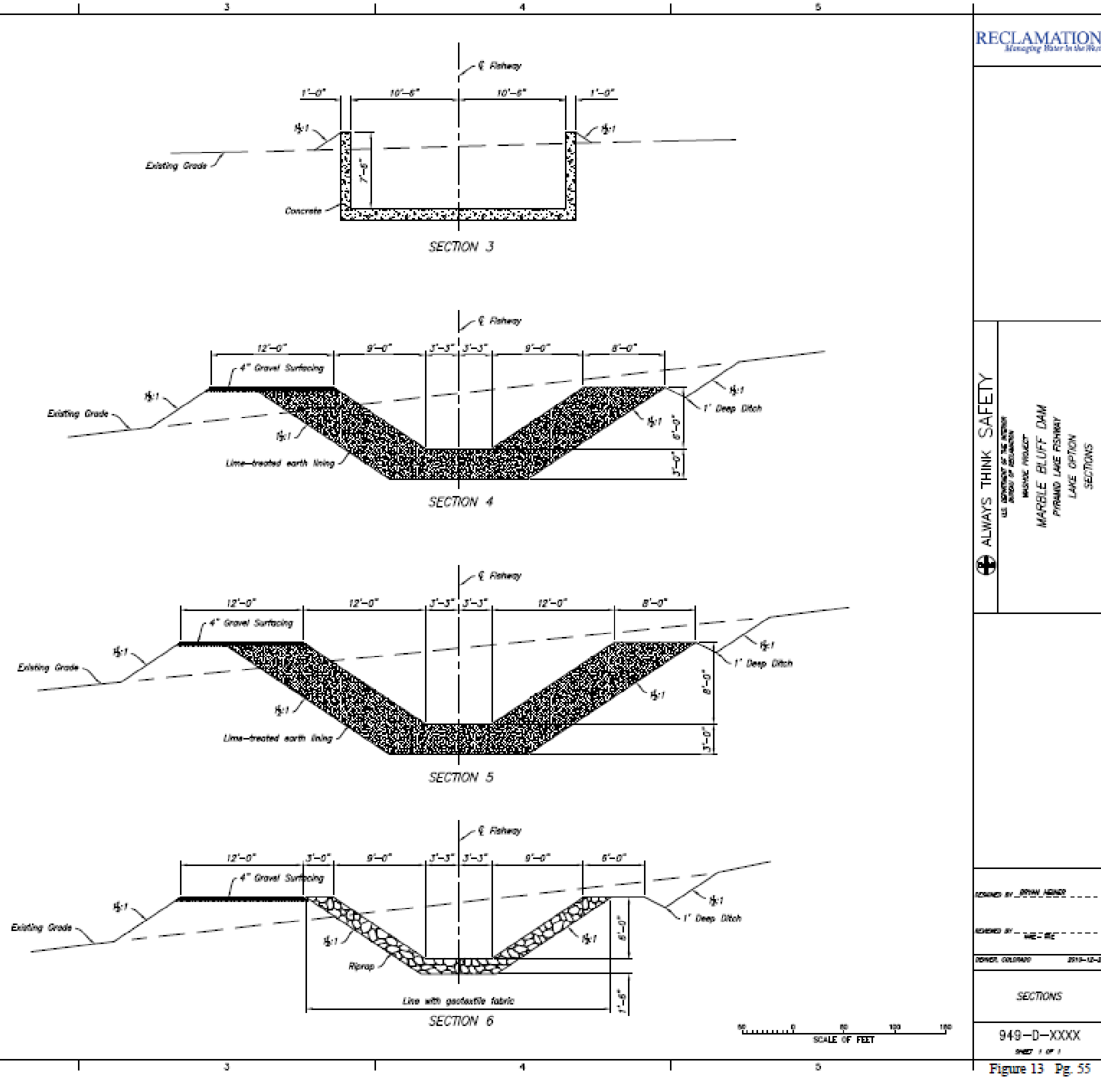

Figure 13 – Lake fishway – typical fishway sections

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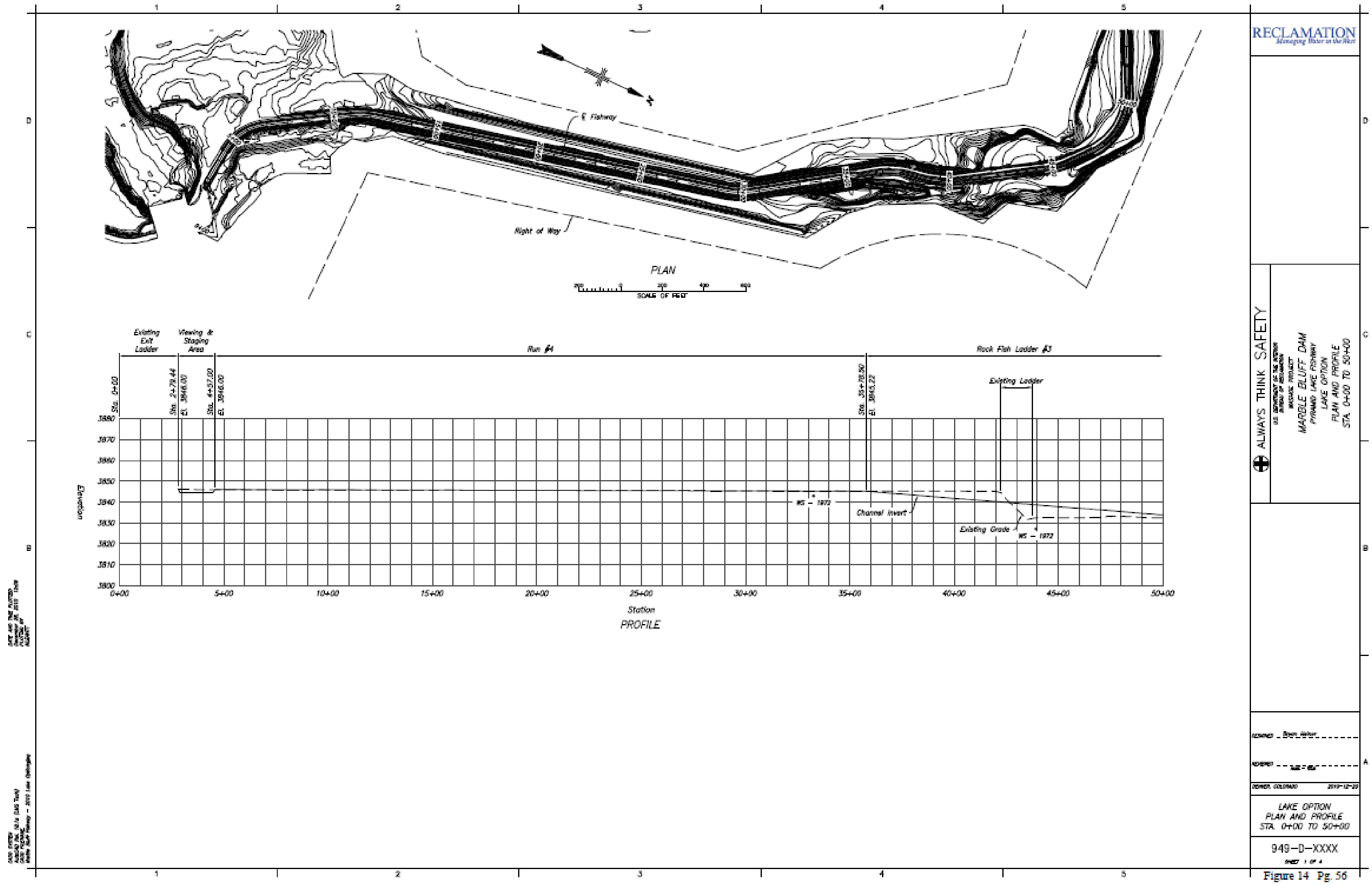

Figure 14 – Lake fishway – plan and profile – station 0+00 to 50+00

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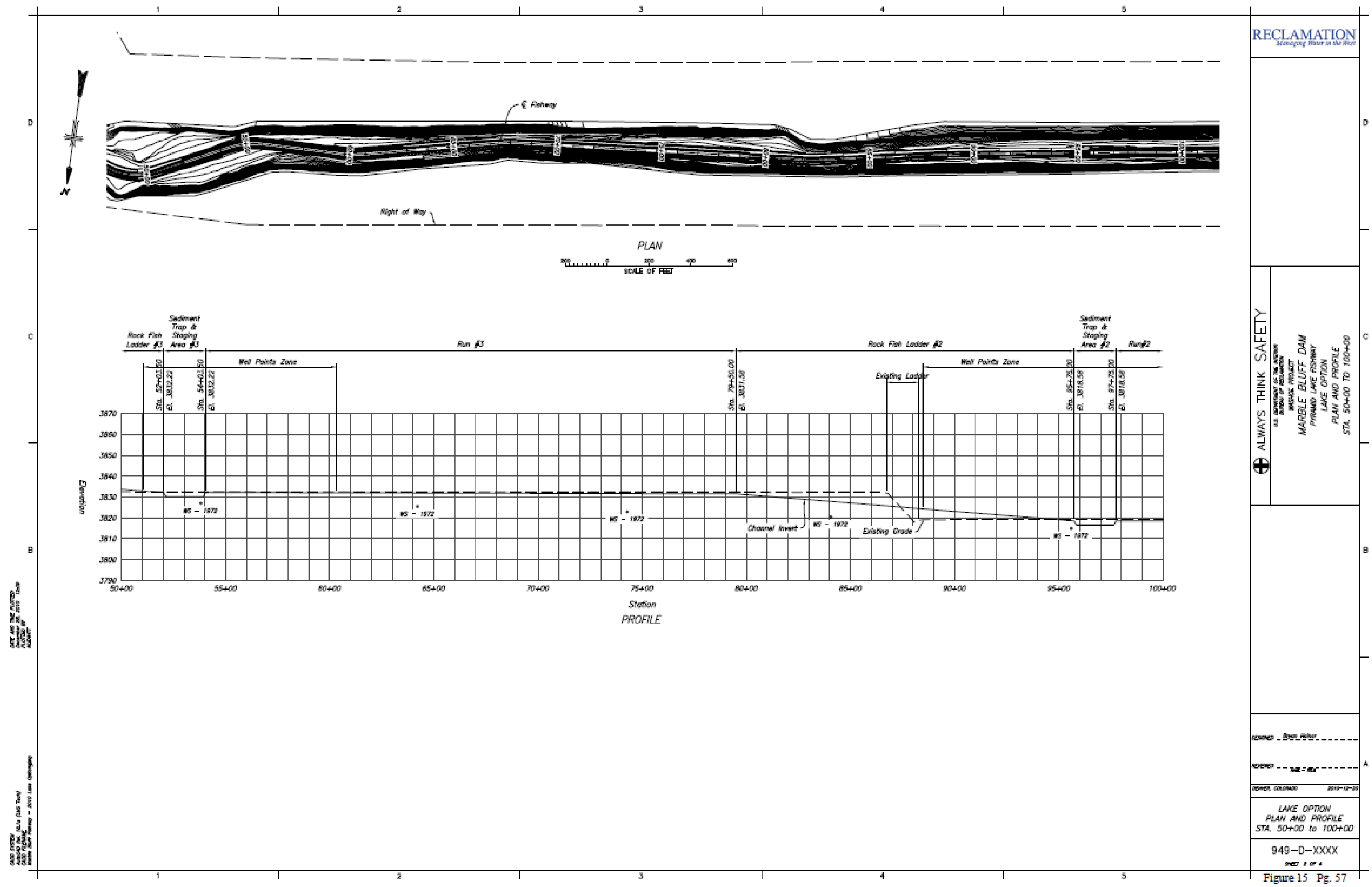


Figure 15 – Lake fishway – plan and profile – station 50+00 to 100+00

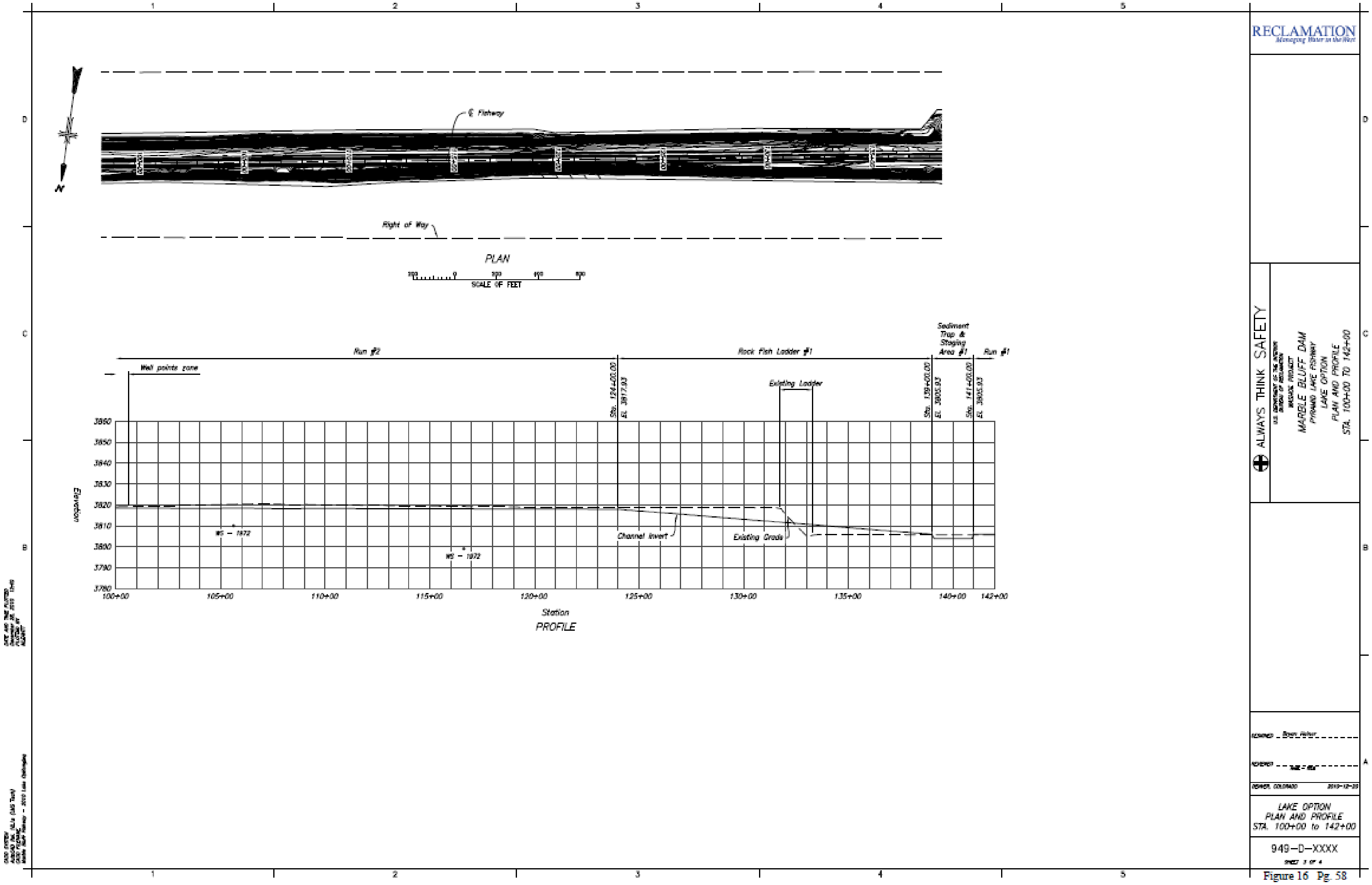


Figure 16 – Lake fishway – plan and profile – station 100+00 to 142+00

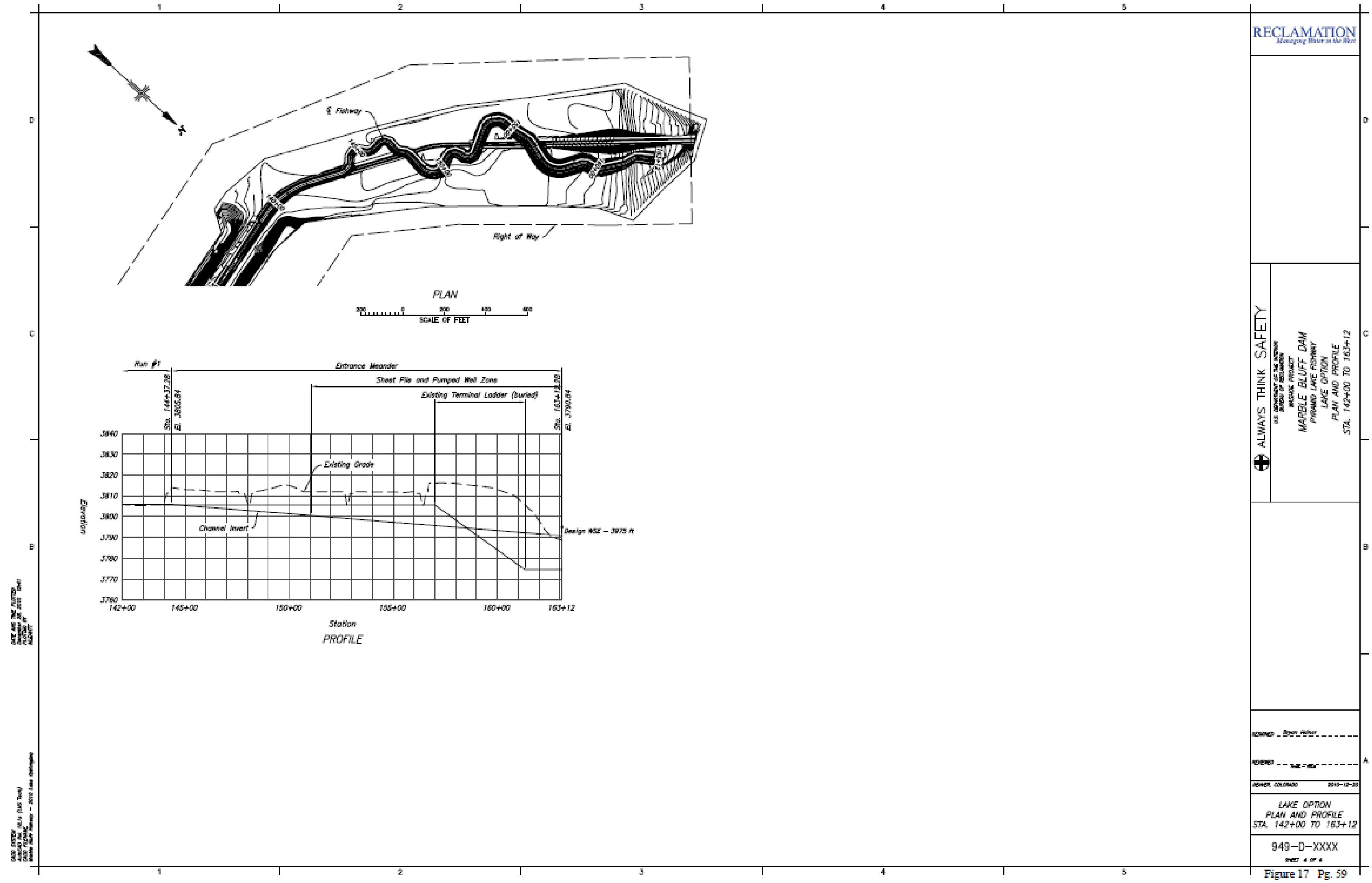


Figure 17 – Lake fishway – plan and profile – station 142+00 to 163+12

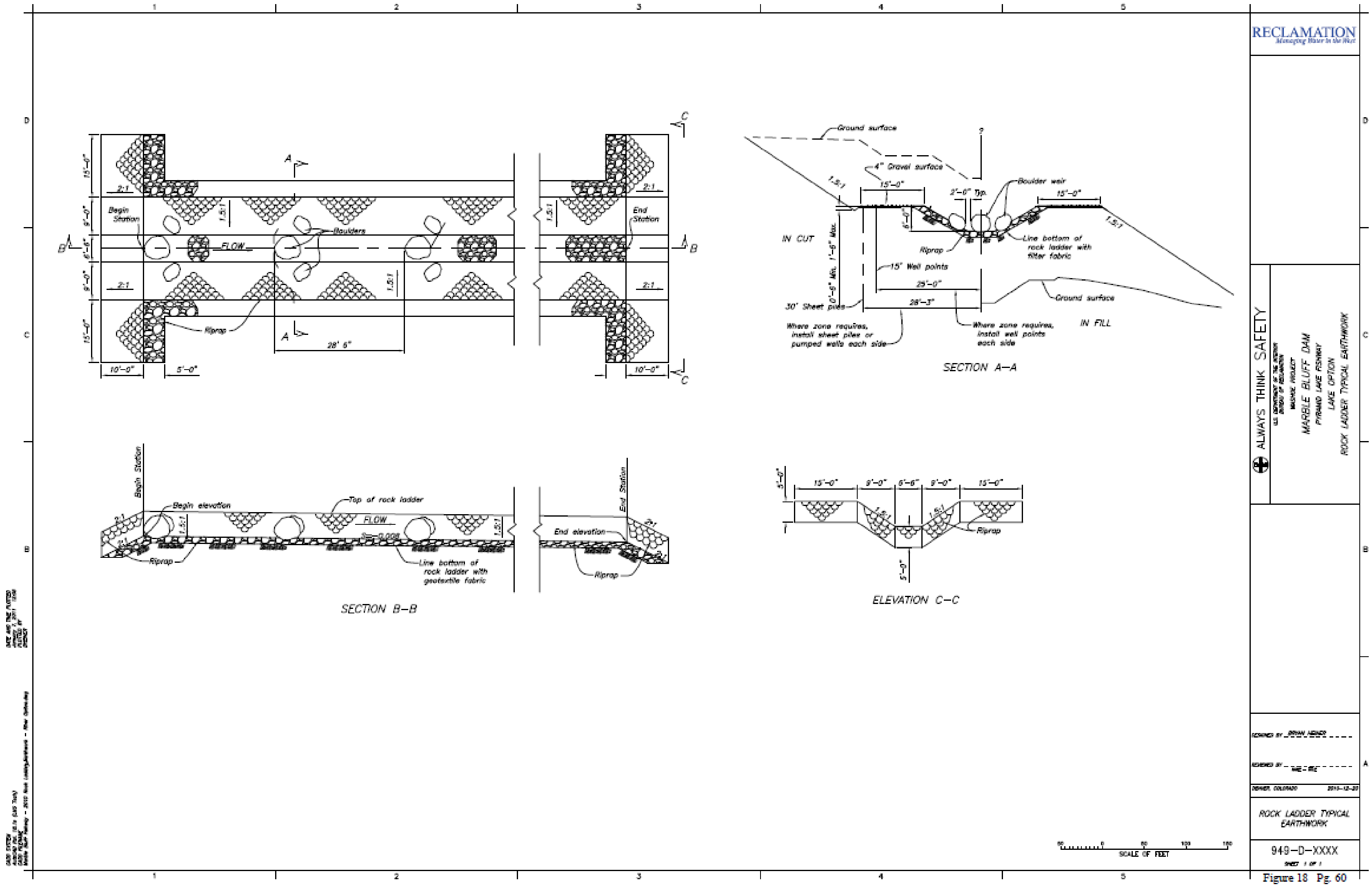
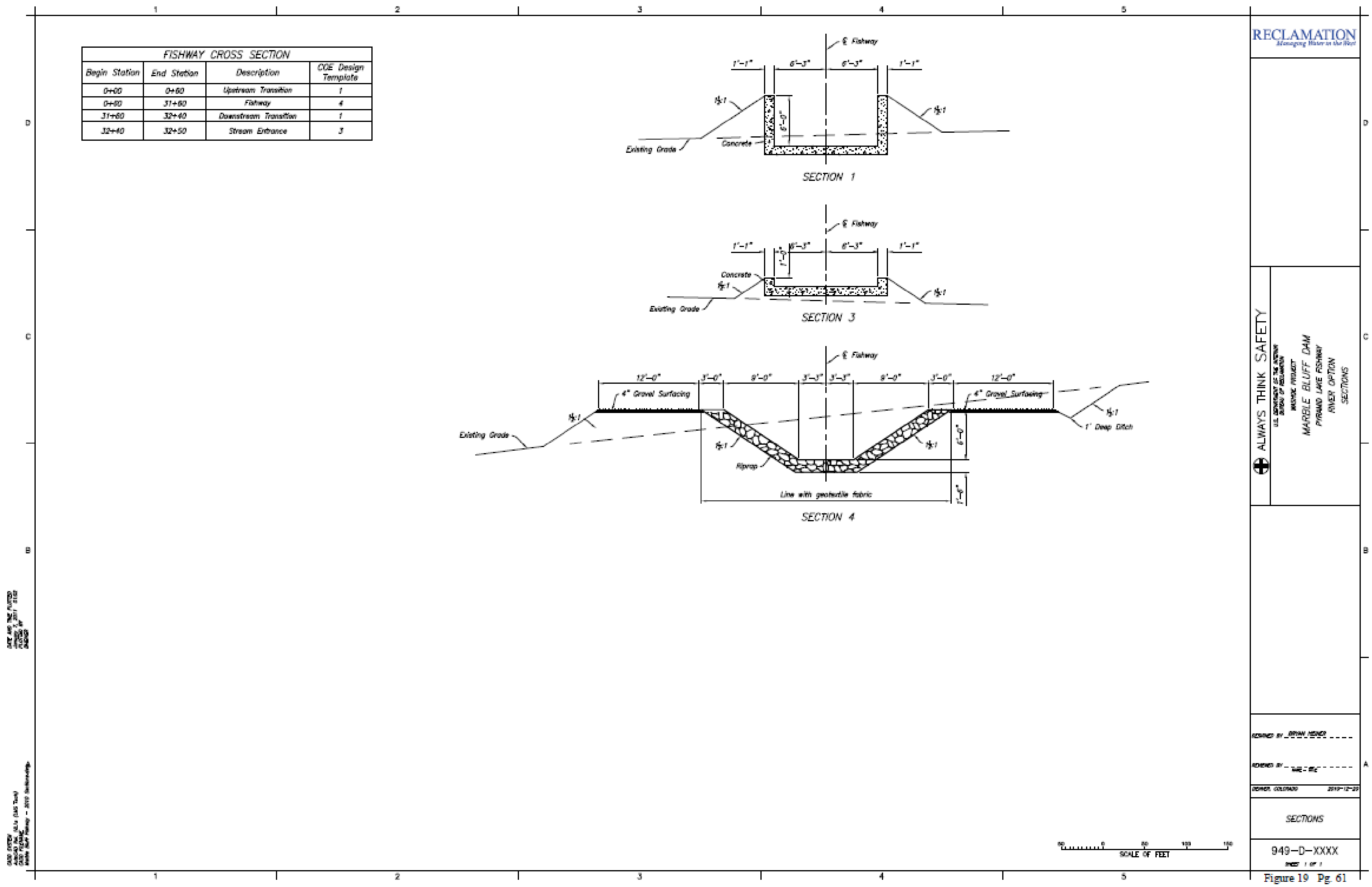


Figure 18 – River fishway – rock ladder typical earthwork



FISHWAY CROSS SECTION			
Begin Station	End Station	Description	COE Design Template
0+00	0+60	Upstream Transition	1
0+60	31+60	Fishway	4
31+60	32+40	Downstream Transition	1
32+40	32+50	Stream Entrance	3

Figure 19 – River fishway – typical fishway sections

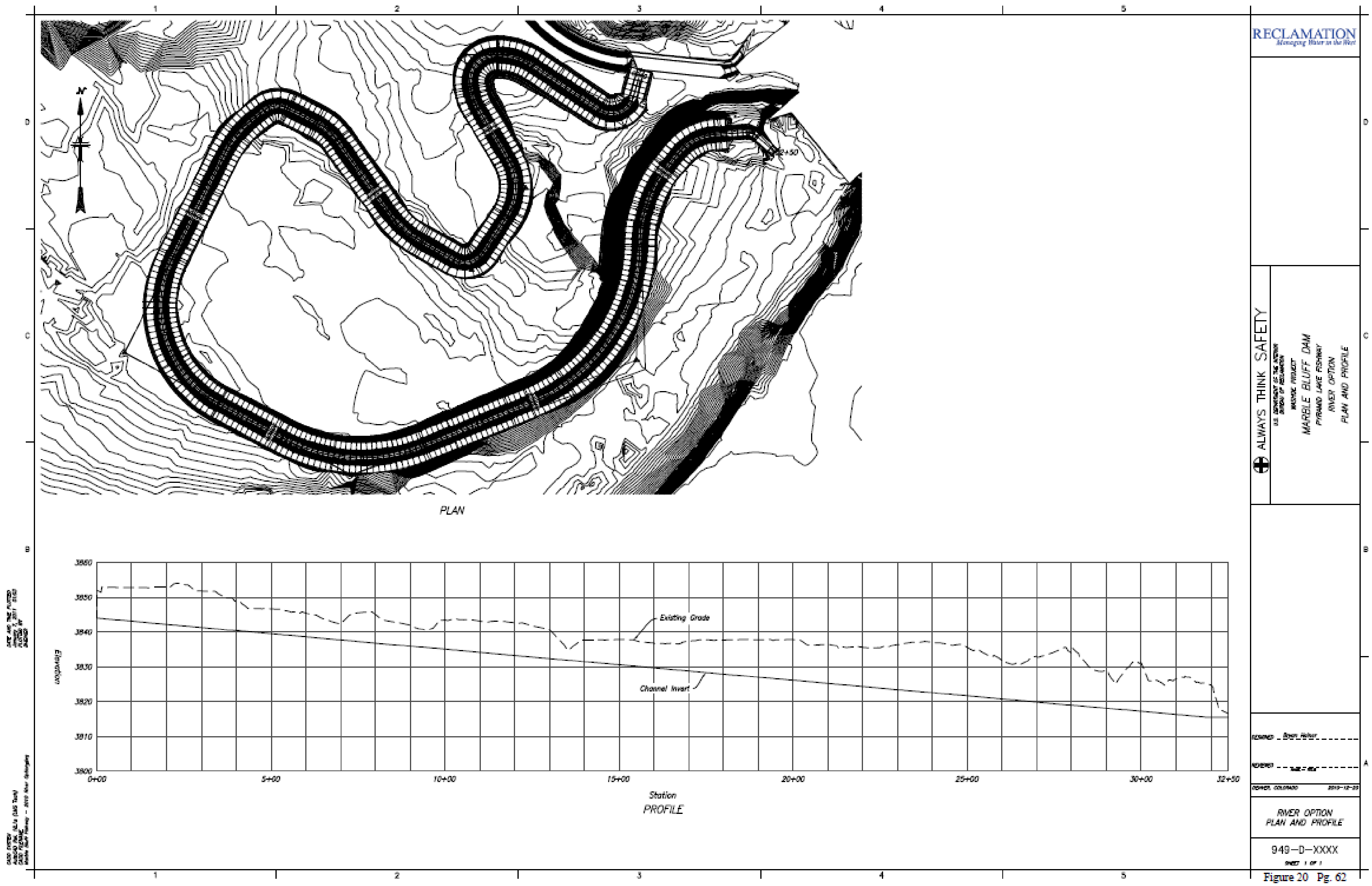


Figure 20 – River fishway – plan and profile

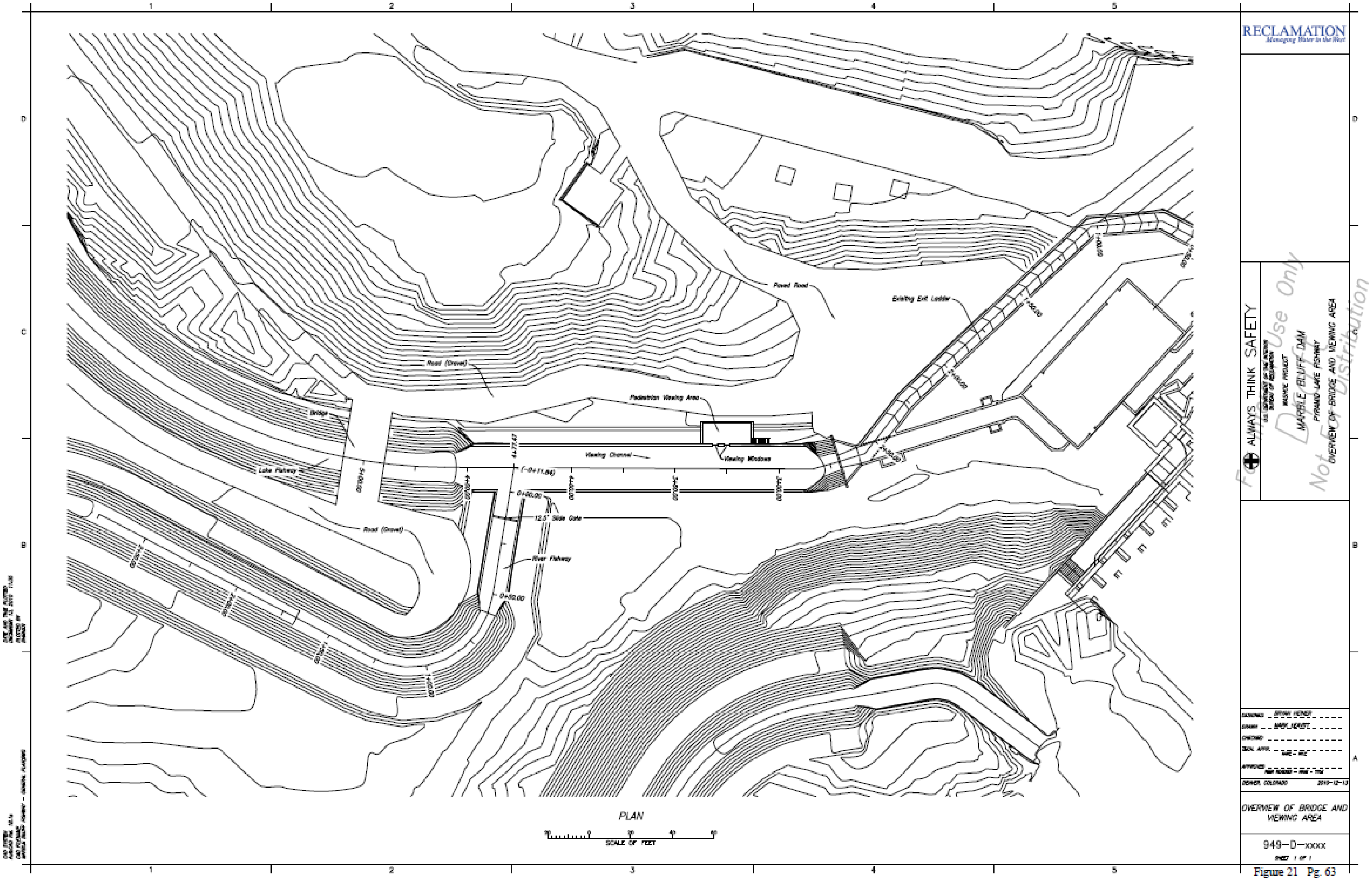


Figure 21 – Overview of viewing are, bridge and fishway connections

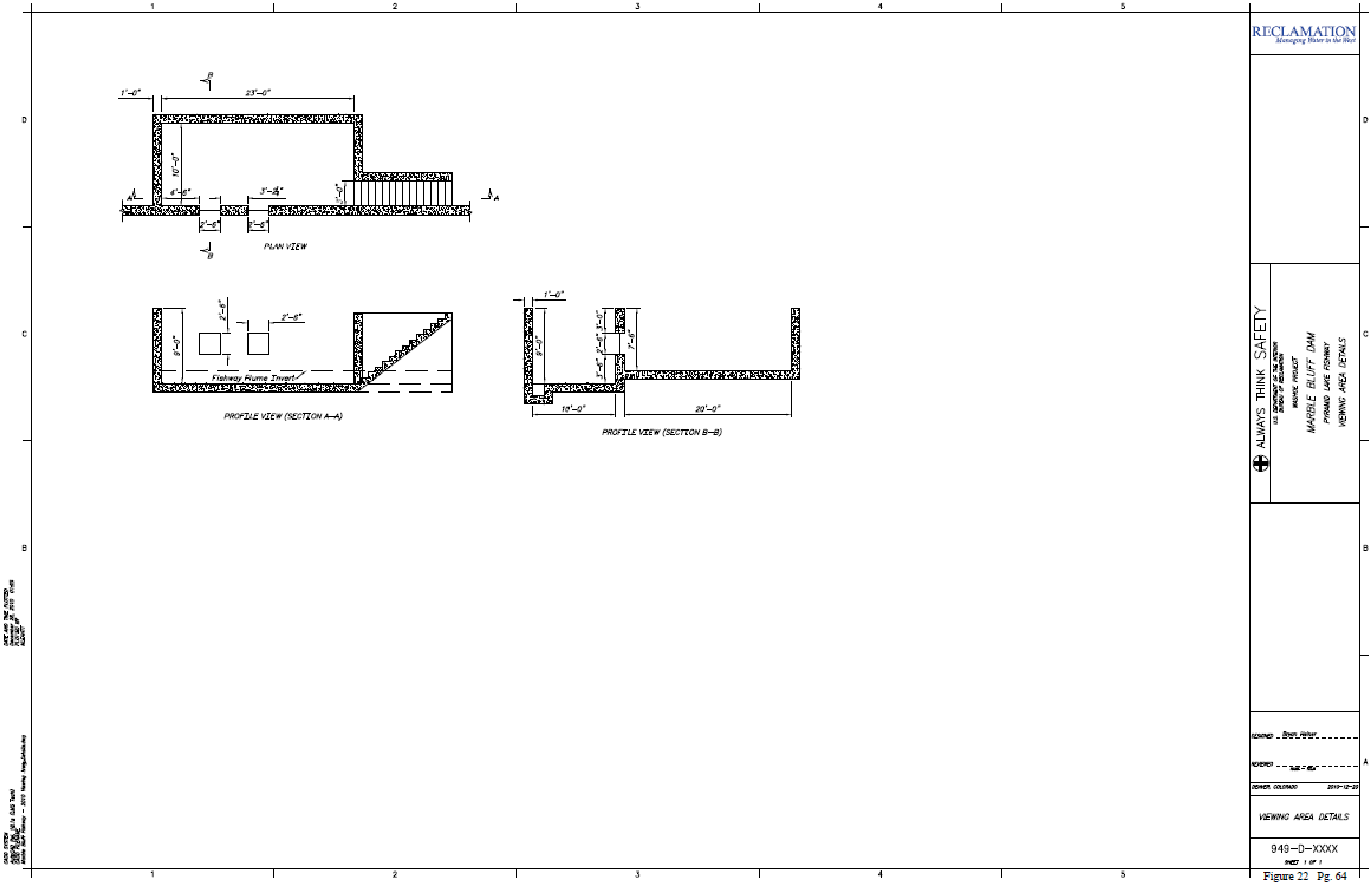


Figure 22 – Viewing area details

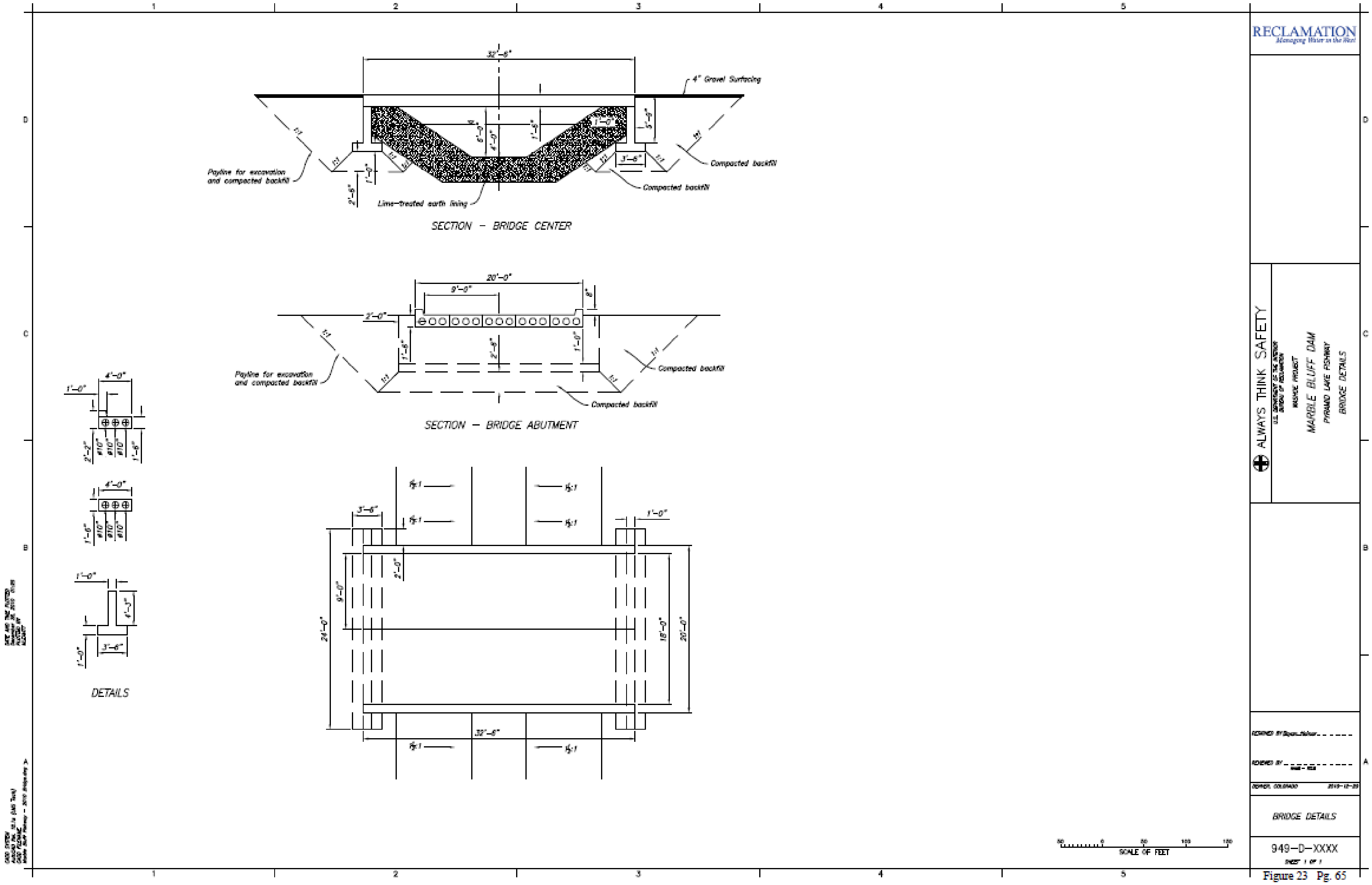


Figure 23 – Bridge details

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APPENDIX C

REFERENCE DRAWINGS

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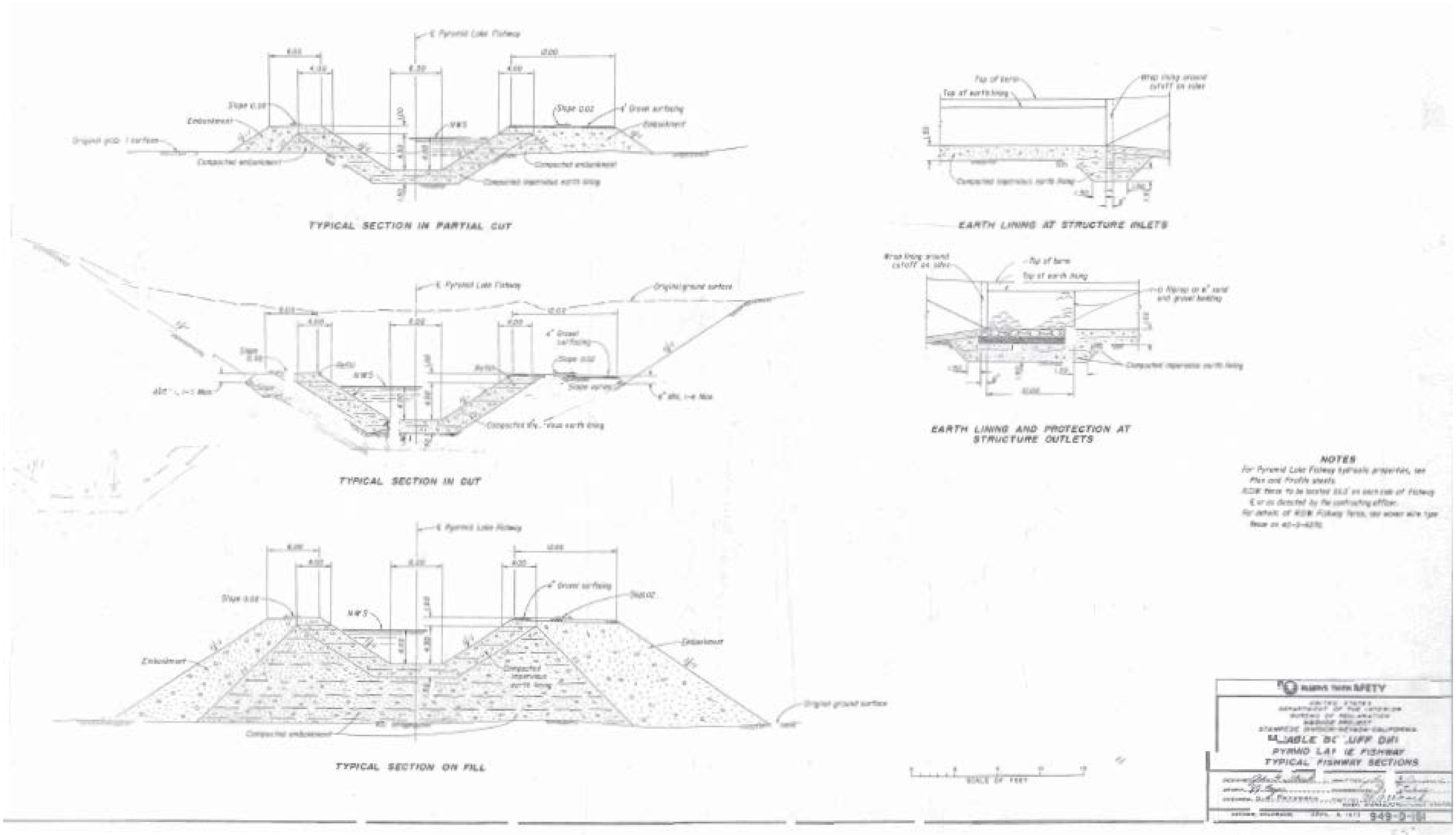

TYPICAL SECTION IN PARTIAL CUT
EARTH LINING AT STRUCTURE INLETS
TYPICAL SECTION IN CUT
EARTH LINING AND PROTECTION AT STRUCTURE OUTLETS
NOTES
TYPICAL SECTION ON FILL
TYPICAL FISHWAY SECTIONS
949-D-181

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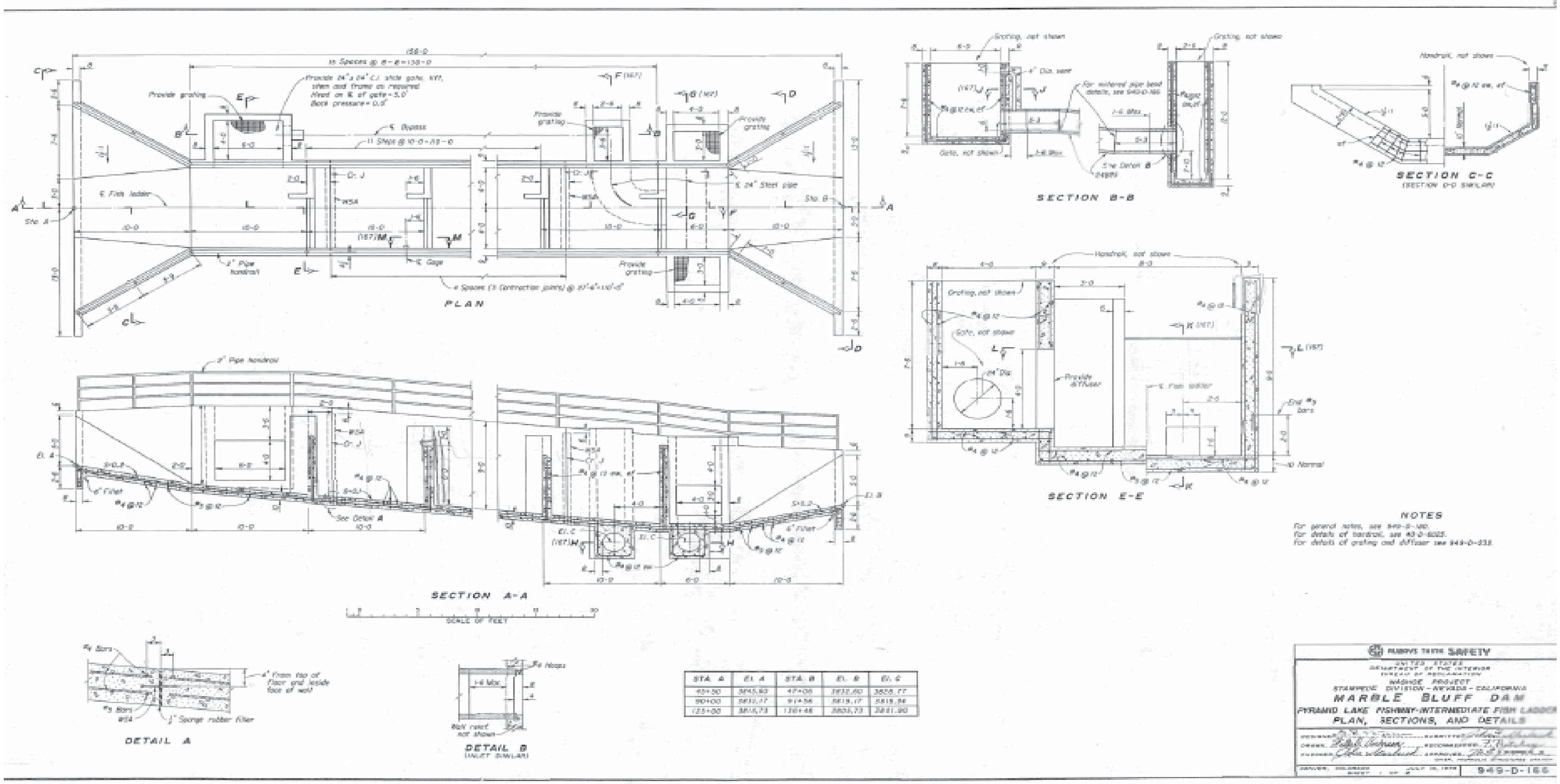

STA. A	EL. A	STA. B	EL. B	EL. C
45+50	3845.80	47+06	3832.60	3828.77
90+00	3812.17	91+56	3819.17	3819.84
125+00	3818.73	126+46	3805.73	3801.90

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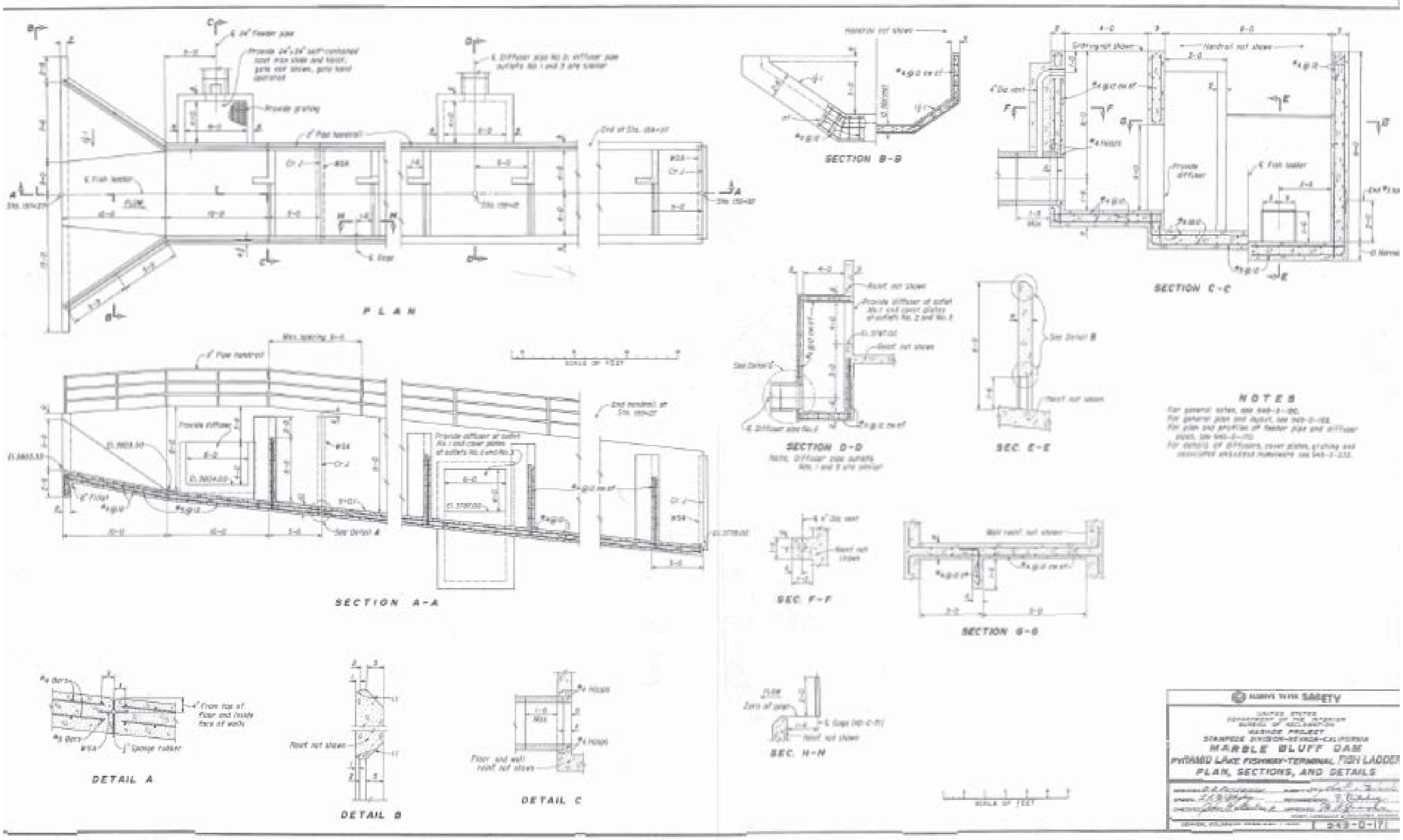
PLAN
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SEC. E-E
SEC. F-F
SECTION G-G
SEC. H-H
NOTES
DETAIL A
DETAIL B
DETAIL C
SAFETY
MARBLE BLUFF DAM
PLAN, SECTIONS, AND DETAILS

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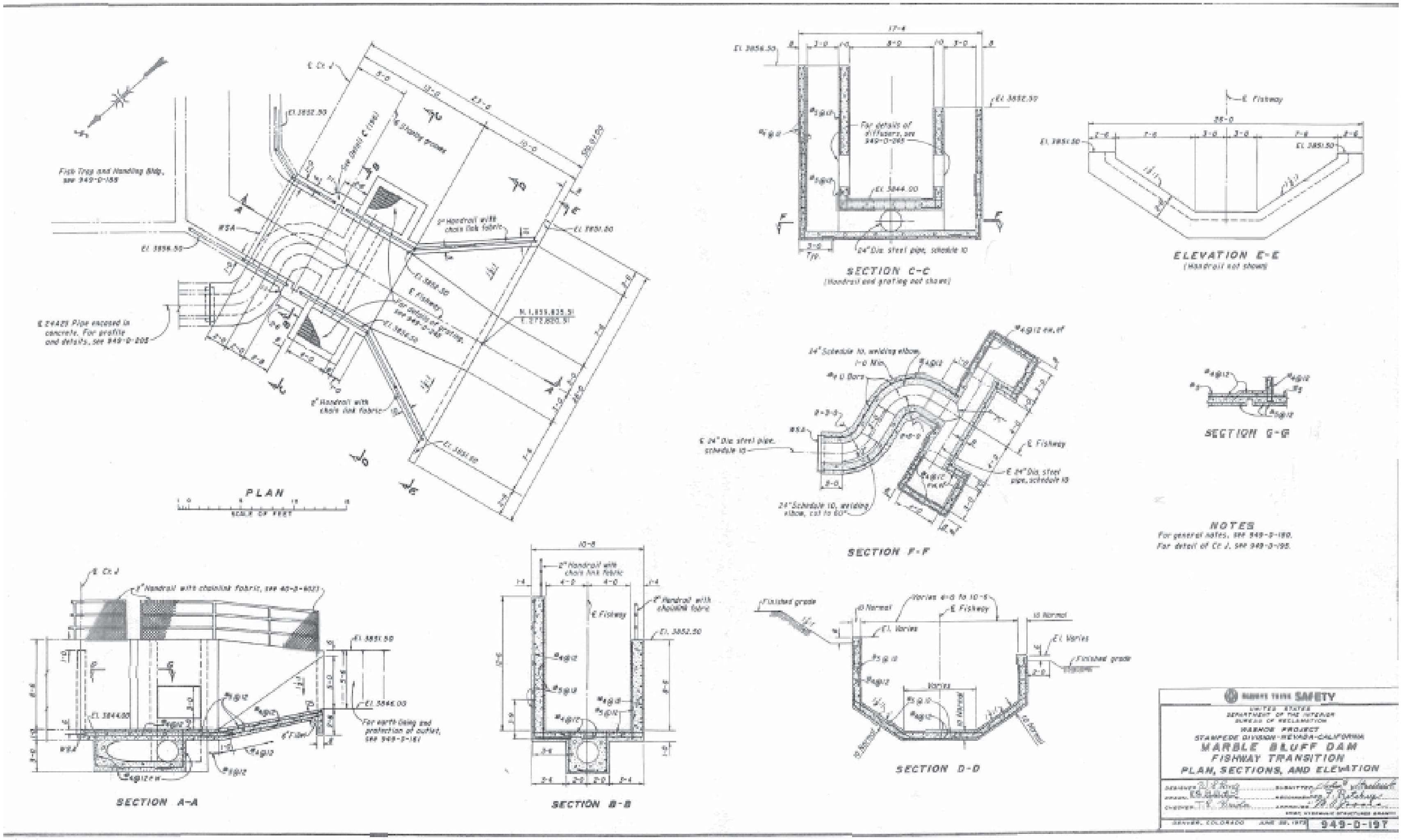
PLAN
SECTION A-A
SECTION B-B
SECTION C-C
(Handrail and grating not shown)
ELEVATION E-E
(Handrail not shown)
SECTION F-F
SECTION G-G
SECTION D-D
NOTES
For general notes, see 949-D-180.
For detail of Ct. J, see 949-D-195.
SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WASHOE PROJECT
STAMPEDE DIVISION-NEVADA-CALIFORNIA
MARBLE BLUFF DAM
FISHWAY TRANSITION
PLAN, SECTIONS, AND ELEVATION
DENVER, COLORADO
949-D-197

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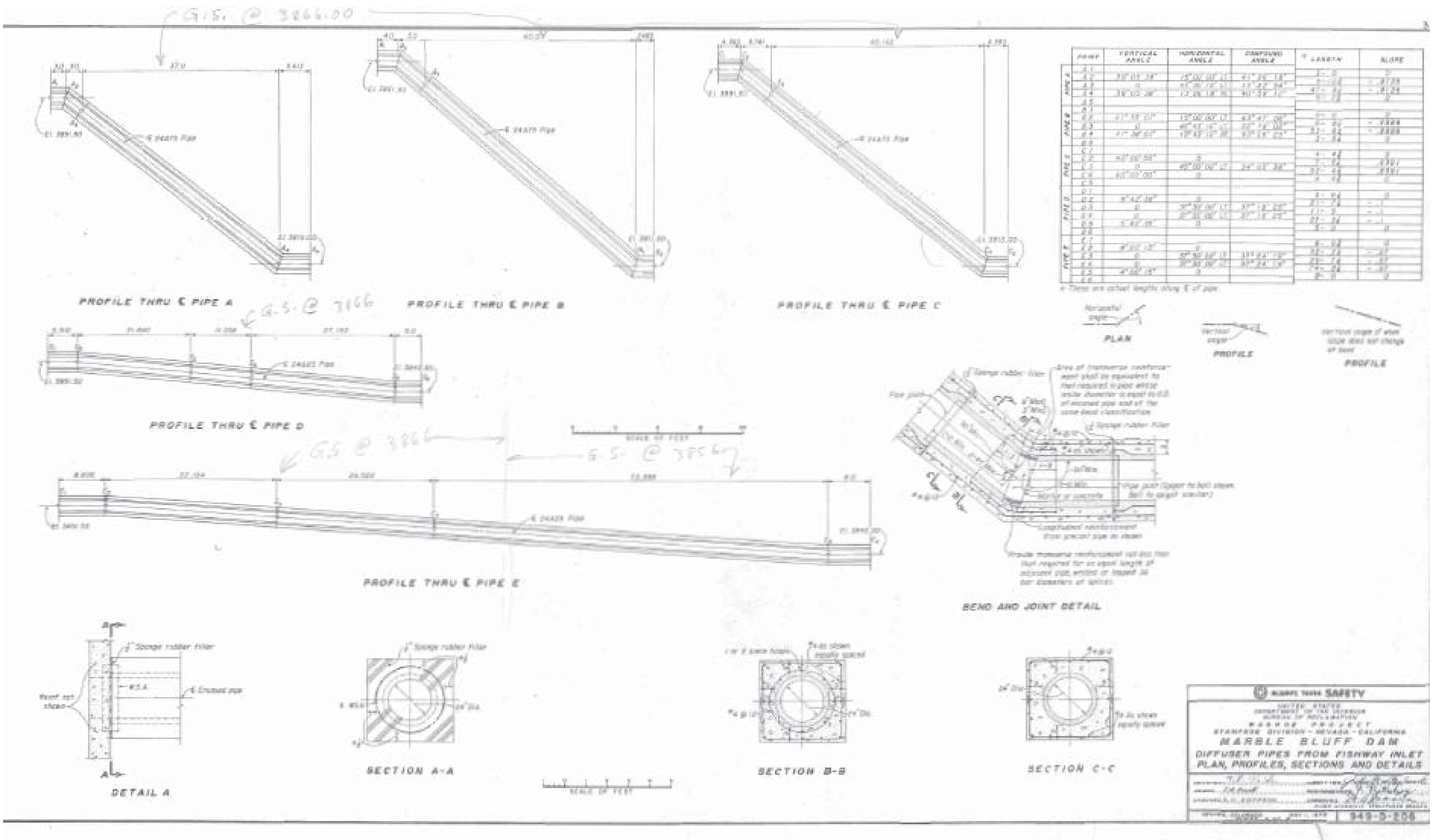
G.S. @ 3866.00
PROFILE THRU ℄ PIPE A
PROFILE THRU ℄ PIPE B
PROFILE THRU ℄ PIPE C
G.S. @ 3866
PROFILE THRU ℄ PIPE D
G.S. @ 3866
G.S. @ 3856
PROFILE THRU ℄ PIPE E
PLAN
PROFILE
PROFILE
BEND AND JOINT DETAIL
DETAIL A
SECTION A-A
SECTION B-B
SECTION C-C
SAFETY
MARBLE BLUFF DAM
DIFFUSER PIPES FROM FISHWAY INLET
PLAN, PROFILES, SECTIONS AND DETAILS

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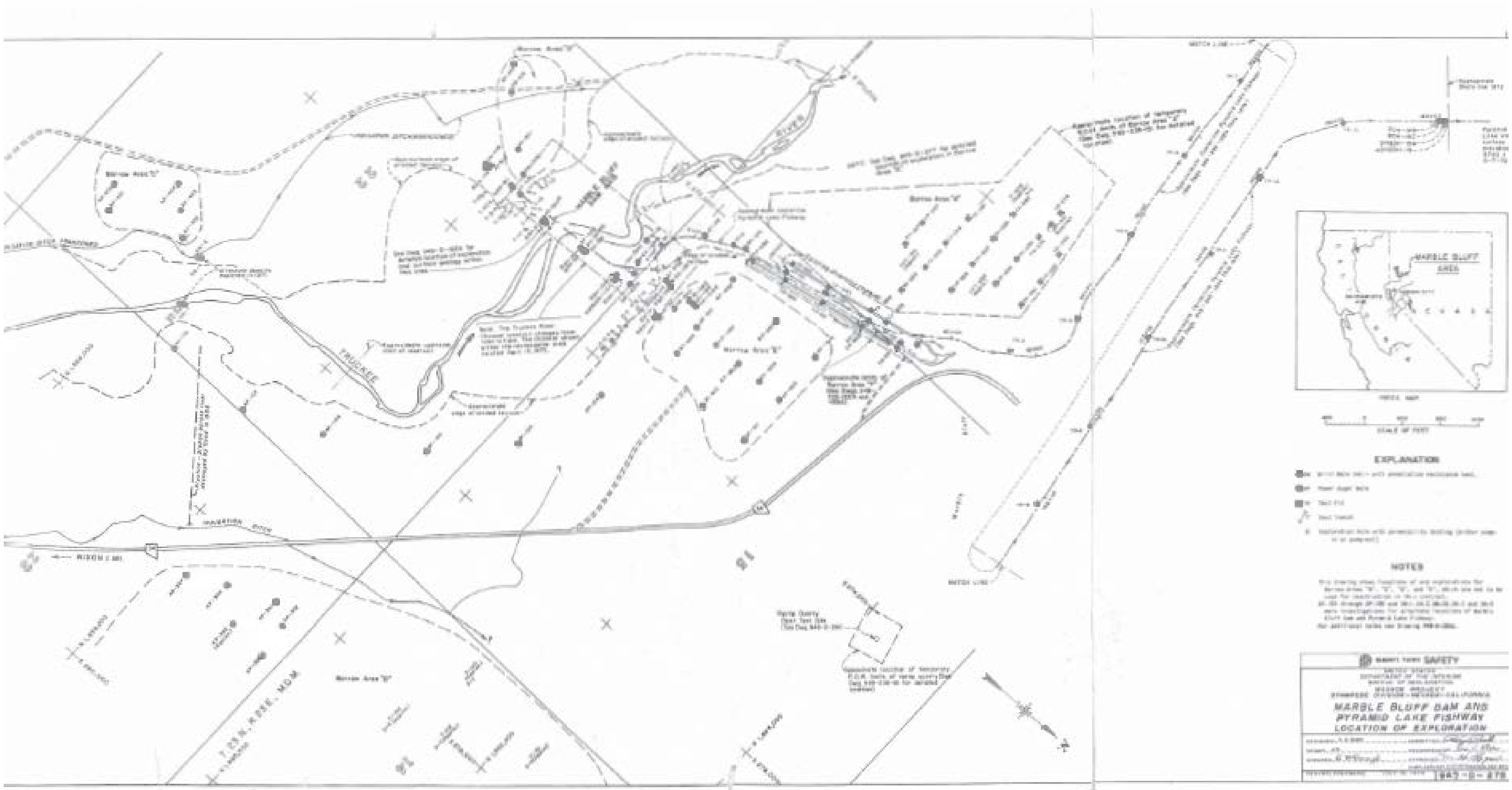

MARBLE BLUFF
AREA
EXPLANATION
NOTES
SAFETY
MARBLE BLUFF DAM AND
PYRAMID LAKE FISHWAY
LOCATION OF EXPLORATION
TRUCKEE
RIVER

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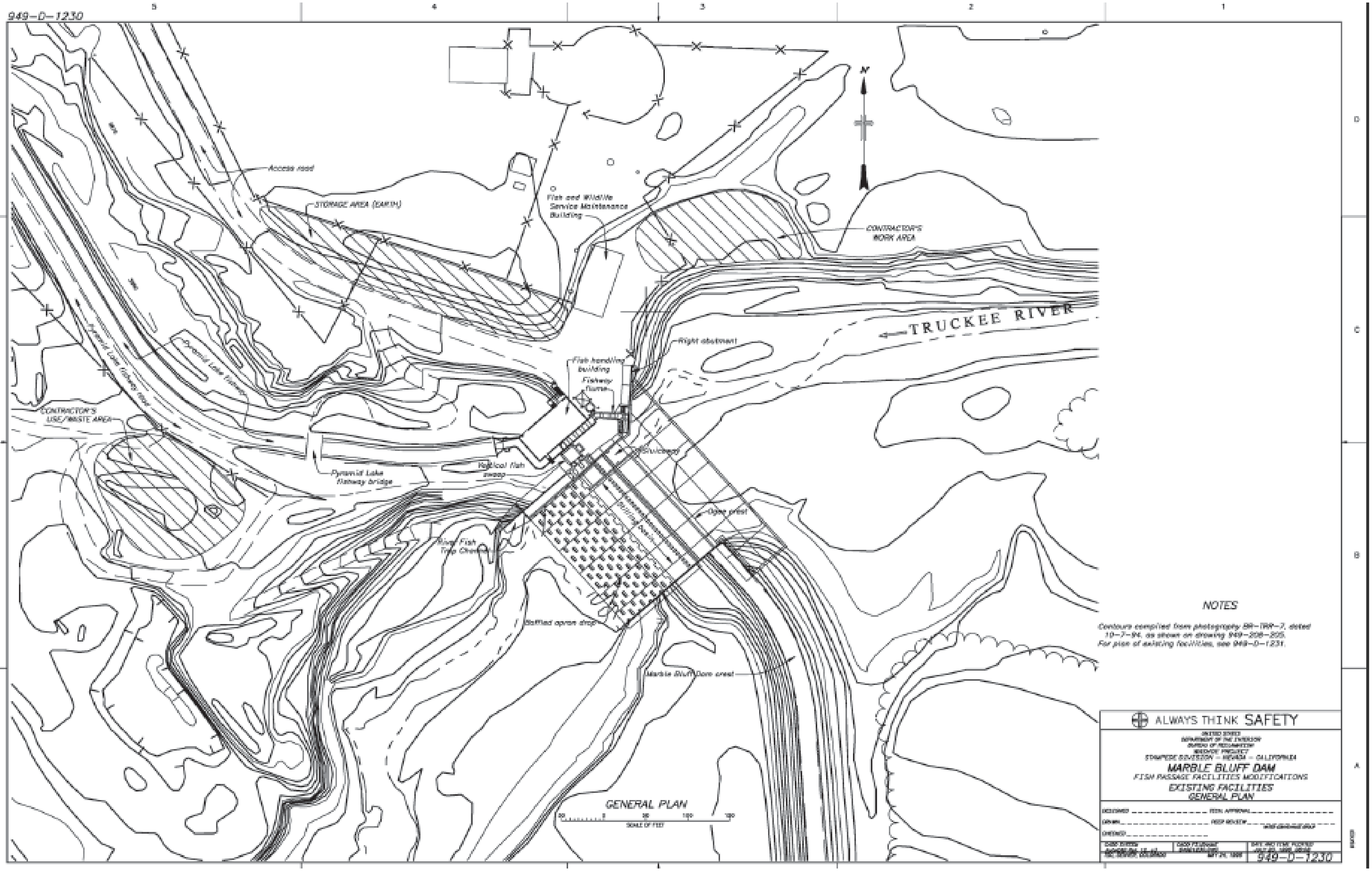
949-D-1230
Access road
STORAGE AREA (EARTH)
Fish and Wildlife
Service Maintenance
Building
CONTRACTOR'S
WORK AREA
TRUCKEE RIVER
Right abutment
Fish handling
building
Fishway
flume
CONTRACTOR'S
USE/WASTE AREA
Sluiceway
Pyramid Lake
fishway bridge
Vertical fish
sweep
Ogee crest
River Fish
Trap Channel
Baffled apron drop
Marble Bluff Dam crest
GENERAL PLAN
SCALE OF FEET
NOTES
Contours compiled from photography BR-TRR-7, dated
10-7-94, as shown on drawing 949-208-205.
For plan of existing facilities, see 949-D-1231.
ALWAYS THINK SAFETY
MARBLE BLUFF DAM
FISH PASSAGE FACILITIES MODIFICATIONS
EXISTING FACILITIES
GENERAL PLAN
949-D-1230

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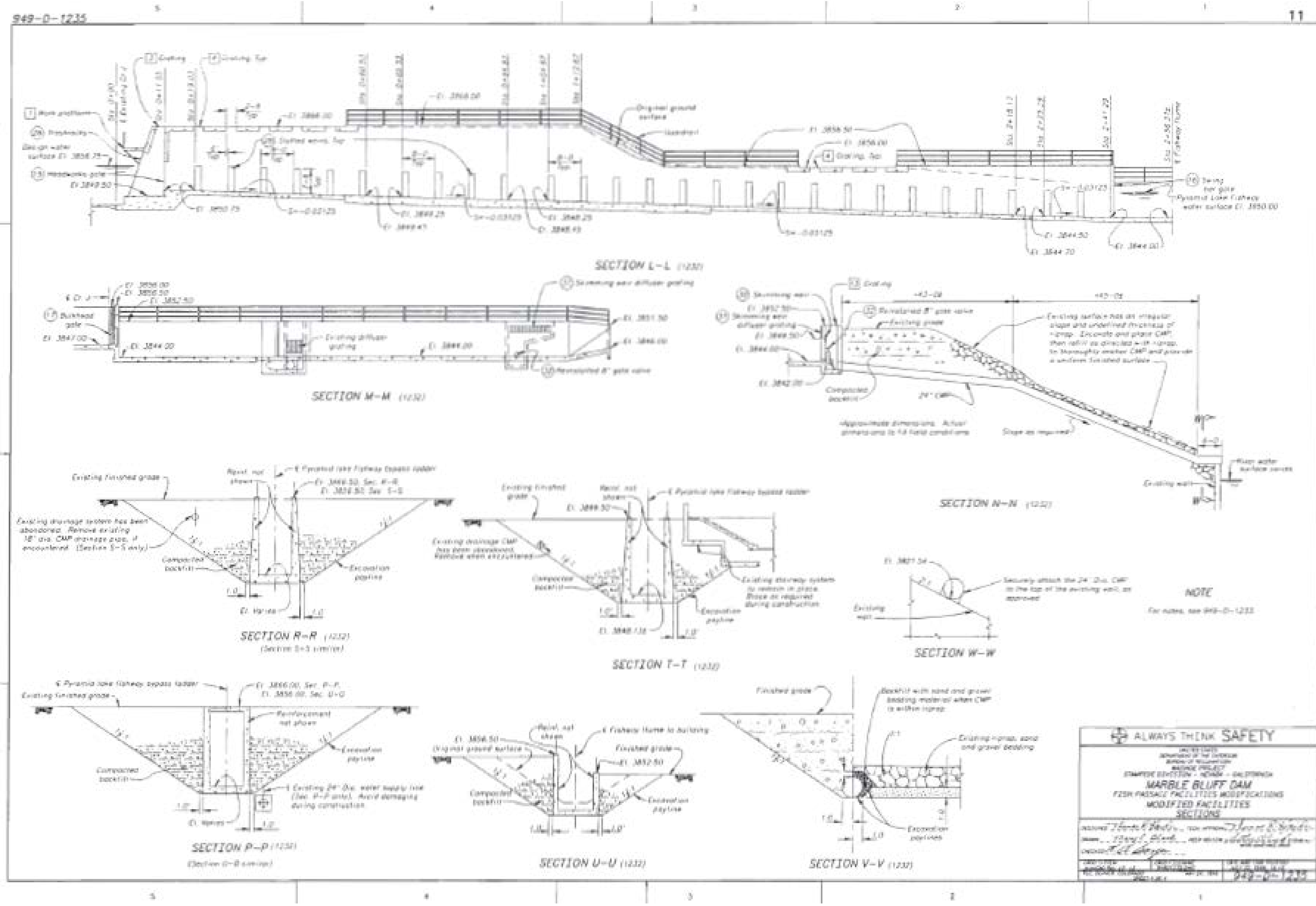
949-D-1235
SECTION L-L (1232)
SECTION M-M (1232)
SECTION N-N (1232)
SECTION R-R (1232)
SECTION T-T (1232)
SECTION W-W
SECTION P-P (1232)
SECTION U-U (1232)
SECTION V-V (1232)
NOTE
ALWAYS THINK SAFETY
MARBLE BLUFF DAM
MODIFIED FACILITIES
SECTIONS

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