Michael Love & Associates
Hydrologic Solutions
PO Box 4477 • Arcata, CA 95518 • (707) 476-8938

June 1, 2006

SENT VIA EMAIL

Sandra Guldman
Friends of Corte Madera
Creek Watershed
Box 415
Larkspur, CA 94977

Subject: Fish ladder concept alternative for Saunders Crossing on San Anselmo Creek

Dear Sandra,

We have completed development of a fish ladder concept design as a fish passage alternative for the Saunders Avenue road crossing on San Anselmo Creek. The following briefly describes the design alternative. It is meant to be considered along with non-fish ladder type design alternatives developed by Stetson Engineers.

Please contact us if you have any questions or comments.

Michael Love
Project Hydrologist
mlove@h2odesigns.com

Antonio Llanos, P.E.
Project Engineer
llanos@h2odesigns.com

CC: Matt Smeltzer, Joe DeMaggio, James Reilly

Enclosed: Concept Design Report and Fish Ladder Drawings
Location of sewer lines in plan and profile

Preliminary fish ladder concept design for Saunders Crossing on San Anselmo Creek

1.0 BACKGROUND

San Anselmo Creek is a major tributary to Corte Madera Creek, which drains into San Francisco Bay in Marin County. San Anselmo Creek supports populations of anadromous steelhead trout, which are listed as threatened under the Federal Endangered Species Act.

Saunders Avenue crosses San Anselmo Creek within the town of San Anselmo. The crossing is in a residential neighborhood and consists of a concrete bridge on concrete abutments and concrete pilings. A large apron spans the abutments and serves as a grade control structure. The apron was likely constructed in multiple phases during the lifetime of the bridge to protect its structural integrity as the downstream channel incised. Across the upstream end of the apron is a concrete weir that encases a sewer line. About 12 feet upstream of the end of the apron is an additional sewer line encased in concrete. The rough concrete encasement is exposed at the surface of the streambed.

The apron maintains a drop of over 4 feet. In the 1980’s an Alaskan Steeppass fish ladder was installed and a low-flow channel was constructed to provide for steelhead passage (Figure 1). However, the Steeppass is poorly suited for providing adult passage at typical migration flows. At migration flows the hydraulic capacity of the Steeppass is overwhelmed, and there is inadequate attraction flow for fish to find the outlet. At lower flows there is inadequate depth in the low-flow channel for adult steelhead to swim through. Additionally, an Alaskan Steeppass does not provide passage for juvenile salmonids and is highly susceptible to plugging by debris.

A recent fish passage assessment of road-stream crossings in Marin County identified the Saunders Avenue site as a high priority for treatment (Taylor, 2003). The Friends of Corte Madera Creek Watershed received grant funding to develop design alternatives for improving fish passage at the site. Michael Love and Associates was tasked with developing a fish ladder alternative for the project. Nature-like and natural-grade alternatives are to be developed by Stetson Engineers. Stetson Engineers are also to prepare cost estimates for each alternative and are responsible for final engineering and design once a preferred alternative is selected.

2.0 FISH PASSAGE OBJECTIVES AND SITE CONSTRAINTS

The developed alternative is intended to improve passage conditions for adult steelhead, resident rainbow trout, and juvenile salmonids.

Figure 1 –The existing crossing at Saunders Avenue has been extensively modified and (a) the grade is maintained with various concrete structures. An Alaskan Steeppass fish ladder and low-flow channel (b) provides marginal adult steelhead passage conditions.

2.1 Site Constraints

A primary site constraint is the two sewer lines that cross the channel upstream of the existing bridge. Based on sewer line drawings (attached) provided by the Marin County Sanitary District No. 1, the downstream most sewer line was assumed to be abandoned and capped, and could be removed. The second, more upstream sewer line is encased in concrete that is exposed in the channel (Figure 2). It was assumed that this line would remain undisturbed at its current elevation and alignment. A fish ladder to improve passage conditions at the site will require providing passage over this exposed sewer line.

In addition to the goal of providing fish passage, is the need to avoid reducing the hydraulic capacity of the channel. The channel currently does not accommodate flood flows and the adjacent properties are within the 100-year floodplain as mapped by FEMA.

Another site constraint was to avoid a structure that encroached on the existing bridge abutments. For structural reasons, Stetson's engineer, Joe DeMaggio, recommended that the fish ladder be set back a minimum of 5 feet from both bridge abutments.

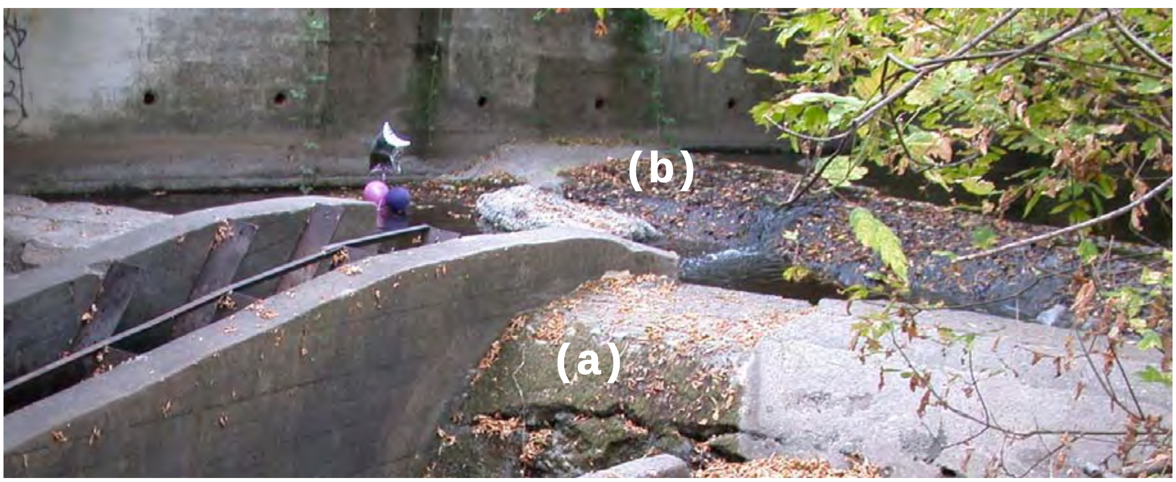


Figure 2 – Looking upstream at existing fish ladder exit. Two sewer pipes cross the channel encased in concrete (a) at the weir across the apron, and (b) approximately 12 feet upstream of the apron.

3.0 PREFERRED FISH LADDER TYPES

After exploring various types of fish ladders, a pool and weir fish ladder was selected as the most appropriate for the site. Pool and weir fish ladders provide suitable passage conditions for salmon and steelhead by taking advantage of their leaping abilities. This type of fishway consists of a series of pools formed by weirs placed across the channel. The weirs form a series of drops that fish leap or swim over, while the pools dissipate energy from the plunging water and provide needed resting areas for the fish.

Accommodating the inlet and outlet alignment of the existing bridge and apron requires the ladder to have a turn of approximately 50 degrees. When compared to other fish ladders, such as a pool and chute ladder, pool and weir ladders are most effective at turning the flow of water without creating undesirable hydraulics. Bates (2001) provides a detailed description of pool and weir ladders along with design procedures.

4.0 FISH PASSAGE DESIGN CRITERIA

The developed alternative is intended to improve passage conditions for both adult and juvenile salmonids. Both the California Department of Fish and Game (DFG) and NOAA Fisheries (formerly NMFS) have guidelines for adult and juvenile salmonid passage at road-stream crossings (CDFG, 2002; NMFS, 2001). The guidelines were written jointly and are intended to be functionally equivalent. The guidelines recognize that for retrofit of an existing crossing, meeting the hydraulic design criteria should be “a goal for improvement and not the required design threshold”.

4.1 Fish Passage Flows

The low and high fish passage design flows define the range of flows that passage should be provided. Both NOAA Fisheries and DFG have recommended fish passage design flow criteria that are based on exceedance flows (Table 1). The low and high fish passage flows for juvenile salmonids, resident trout, and adult steelhead are estimated from exceedance flows for the site. Since San Anselmo Creek is not gaged, exceedance flows from two nearby stream gaging stations were utilized:

USGS Station No.:	11460100	11460000
Station Name:	Arroyo Corte Madera D Pres A Mill Valley	Corte Madera C A Ross
Drainage Area:	4.68 mi^2	18.1 mi^2
Years in Operation:	1965 -1986	1951 - 1993

The two streams have very similar flow characteristics and their drainage areas bracket the 9.1 mi^2 drainage area of San Anselmo Creek at Saunders Ave. Exceedance flows for the two streams were scaled by drainage area to develop a flow duration curve for the project site (Figure 3). From the flow duration curve, design flows were obtained (Table 1).

Table 1 – Estimated fish passage design flow for San Anselmo Creek at Saunders Ave., based on DFG (2002) and NOAA Fisheries (NMFS 2001) criteria.

Drainage Area = 9.1mi^2				
	Low Passage Flow		***High Passage Flow***	
Species and Lifestage	**Criteria**	**Flow**	**Criteria**	**Flow**
Juvenile Salmonids	Greater of 95% Exceedance Flow of 1 cfs	1 cfs	10% Exceedance Flow	28.3 cfs
Adult Rainbow Trout	Greater of 90% Exceedance Flow of 2 cfs	2 cfs	5% Exceedance Flow	65.1 cfs
Adult Steelhead	Greater of 50% Exceedance Flow of 3 cfs	3 cfs	1% Exceedance Flow	252.8 cfs

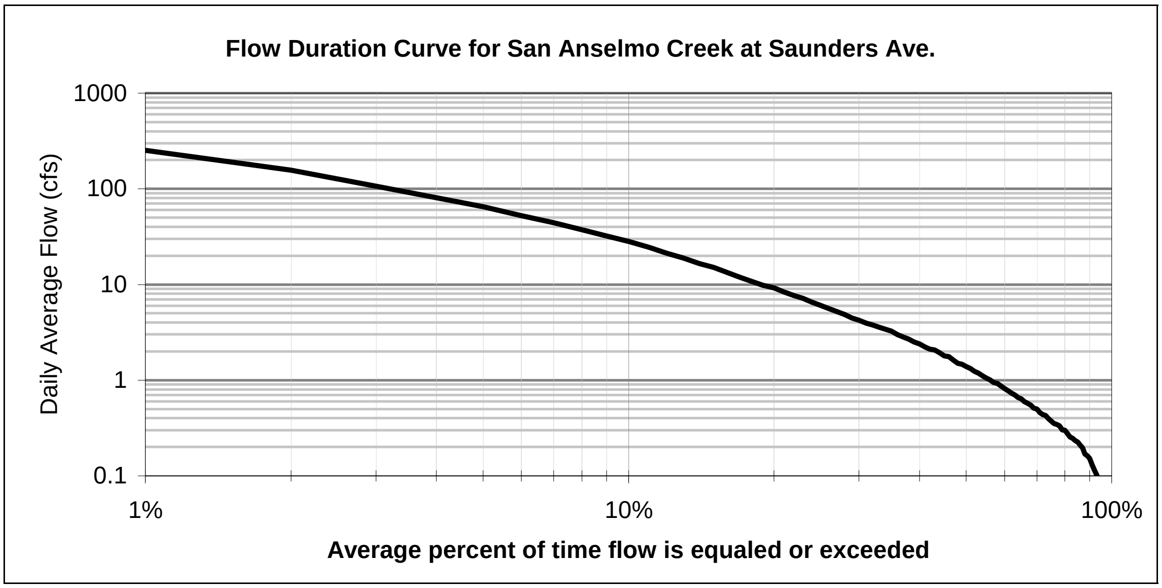


Figure 3 – Annual flow duration curve for Saunders Avenue project site based on exceedance flows from two nearby gaged streams, scaled by drainage area.

4.2 Hydraulic Design Criteria

For hydraulic design of fish ladders, the DFG and NMFS guidelines have the following applicable criteria:

Maximum drop between weirs
Juvenile Salmonids: 6 inches
Adult Steelhead: 12 inches

Additional criteria are provided by Bates (2001) for design of pool and weir fish ladders are listed below:

Minimum Pool Depth:	2.0 feet
Maximum EDF[1] Adult Rainbow Trout: Adult Steelhead:	 3.0 ft-lbs/s/ft^3 4.0 ft-lbs/s/ft^3
Minimum attraction flow:[2]	25%

[1] Energy Dissipation Factor (EDF) is a measure of the amount of turbulence produced in the pool below each weir.
[2] Attraction flow is the percent of total streamflow contained within the fish ladder.

5.0 DEVELOPMENT OF FISH LADDER DESIGN

5.1 Hydraulic Modeling of Fish Ladder

A spreadsheet model was developed for analyzing fish passage hydraulics at various flows for different pool and weir fish ladder configurations. The hydraulics were calculated using standard equations and coefficients for sharp crested V-shaped weirs (King, 1939). For portions of the weir that were partially submerged, the flow was adjusted using a submergence ratio (Villemonte, 1947).

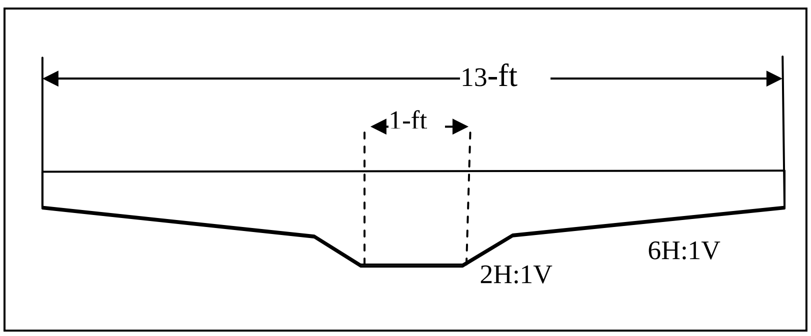


Figure 4 – Cross section of weir shape for Saunders Ave. Pool and Weir Fish Ladder.

5.2 Developed Fish Ladder Design

The design for the fish ladder alternative consists of a curved 86 feet long by 13 feet wide (inside width) pool and weir fish ladder with of 6 inch drops between each weir (see attached schematic drawings). There are a total of 13 weirs, each spaced 7 feet apart producing an overall fish ladder slope varying from 7% to 8%. The entrance of the ladder extends 8.2 feet into the existing scour pool below the apron and the ladder exit is placed slightly skewed to the upstream end of the apron.

The proposed fish ladder is gently curved to (1) improve hydraulic conditions in the ladder, (2) match alignment with the upstream and downstream channel and (3) avoid encroaching on the bridge abutments and existing concrete retaining wall under the crossing. The current design places the fish ladder 4 to 5 feet from all bridge abutments.

The preferred weir shape consists of a compound shape with a 1 foot wide by 0.75 feet deep low-flow notch combined with tapered weir crests sloping at 6H:1V (Figure 4). The weir shape is designed to provide good hydraulic conditions for passage of both adult and juvenile salmonids at both summer low-flows and during winter high-flows. It will provide desirable plunging flow conditions along the edge of the weirs and create an area of quiet water along the margins of the pools.

Bypass weirs are placed at the top of the existing apron on both sides of the ladder. They are designed to concentrate low-flows into the ladder. At higher streamflows the flow is split, with a portion of it going over the spillway and the remaining portion flowing through the ladder. The spillway was designed to allow 25% of the total flow down the fish ladder during the operational range of flows. To allow for adjustment and to fine-tune fish passage conditions the ladder can be equipped with adjustable "flashboards" placed in slots along the spillway. Flashboards could be lowered to increase bypass flow and improve adult passage at higher flows or raised to increase the attraction flow and improve ladder entrance conditions. If vandalism is a concern, the flashboards can be constructed of rigid material, such as square steel tubing, and locked in place with tamper proof fasteners.

The upper most weir and spillways are placed to minimize reduction in the cross sectional area of the channel while providing a minimal amount of water depth over the concrete encasing the upstream sewer line. By design, the low-flow notch is filled at 4 cfs, providing approximately 0.5 feet of water over the upstream concrete. At 1 cfs the upstream most weir in the fish ladder will maintain about 0.2 feet of water over the concrete. Since the concrete is rough and irregularly shaped, small fish should have no problems swimming pass it.

Figure 5 – Upstream sewer line encased in concrete. The fish ladder and bypass weirs are designed to backwater the exposed concrete to facilitate juvenile passage at low flows.

5.3 Hydraulic Performance

The fish ladder was modeled as a traditional pool and weir ladder. Table 2 provides a summary of fish passage conditions for this alternative.

The design meets juvenile fish passage criteria by maintaining maximum drops of 6 inches between weirs. The recommended minimum fish passage corridor of two feet per side is reached at the 8% exceedance flow of 37 cfs. Above this flow juvenile salmonids are likely to have difficulty ascending the ladder, and conditions will be less than optimal for adult salmonids. The maximum recommended turbulence level for adult steelhead (EDF = 4.0 ft-lb/s/ft^2) occurs at the 2.5% exceedance flow of 131 cfs, which is less than the recommended 1% exceedance flow, but is a dramatic improvement in fish passage compared to existing conditions.

Table 2 - Predicted hydraulic conditions for Saunders Ave. – Pool and Weir Fish Ladder with 6 inch Drops.

Weir Parameter	Fish Passage Corridor of 2 feet	Maximum Turbulence (EDF) Resident Rainbow Trout	Maximum Turbulence (EDF) Adult Steelhead
Streamflow (Exceedance Flow)	37 cfs (8%)	100 cfs (3%)	129 cfs (2.5%)
Proportion of Flow in Ladder	36%	25%	25%
Depth over Weirs	1.2 ft	1.7 ft	1.9 ft
Length of Dry Weir per Side[1]	2.0 ft	0	0
Energy Dissipation Factor (EDF)	1.4-lb/s/ft^3	3.0 ft-lb/s/ft^3	4.0 ft-lb/s/ft^3

[1] Weir becomes fully wetted (no dry weir) at a depth over weir of 1.5 ft.

5.4 Fish Ladder Entrance Conditions

The entrance of the fishway is the most downstream end of the structure and requires an additional hydraulic analysis. Having appropriate entrance conditions is critical to maintaining proper fish passage performance. The water level at the entrance of the fish ladder is controlled by the downstream channel shape and slope. Since the water depth over the weirs increases more rapidly than the depth in the downstream channel, this has the potential to create an excessive drop over the lowest weir.

To analyze this transition and determine the drop over the lowest weir at the design flows, a stage-discharge rating curve was developed to predict water levels in the downstream scour pool and at the fish ladder entrance. Uniform flow conditions were assumed and flows were estimated using a Manning's roughness coefficient of 0.040 for the channel bed and banks and a channel slope of 0.0042 ft/ft.

At all fish passage flows the water level at the entrance is sufficient to maintain a drop of less than 6 inches over the lowest weir. Water surface profiles for the fish ladder at the juvenile high passage flow of 28 cfs and the upper adult steelhead operational flow of 129 cfs are shown in the attached schematic drawings.

6.0 CONCLUSIONS

While the proposed pool and weir fishway with V-notch weirs does not meet all of the DFG and NOAA Fisheries design criteria for passage of adult salmon and steelhead, it represents a vast improvement to the existing condition. The proposed design utilizes the minimum accepted dimensions to meet the physical site constraints and criteria, resulting in a cost-effective design alternative.

Additionally, the proposed concrete pool and weir fishway provides a stable entrance and grade control at the upstream end, addressing concerns about headcutting. However, since this alternative involves leaving the upper most sewer line intact, the design does not increase the capacity of the upstream channel.

Concrete is a common and familiar construction material, and the V-shaped weir is a simple design to form and build. If selected as a preferred alternative, a structural engineer will need to be consulted for the design of cutting and joining the existing concrete apron to the new fishway.

7.0 REFERENCES

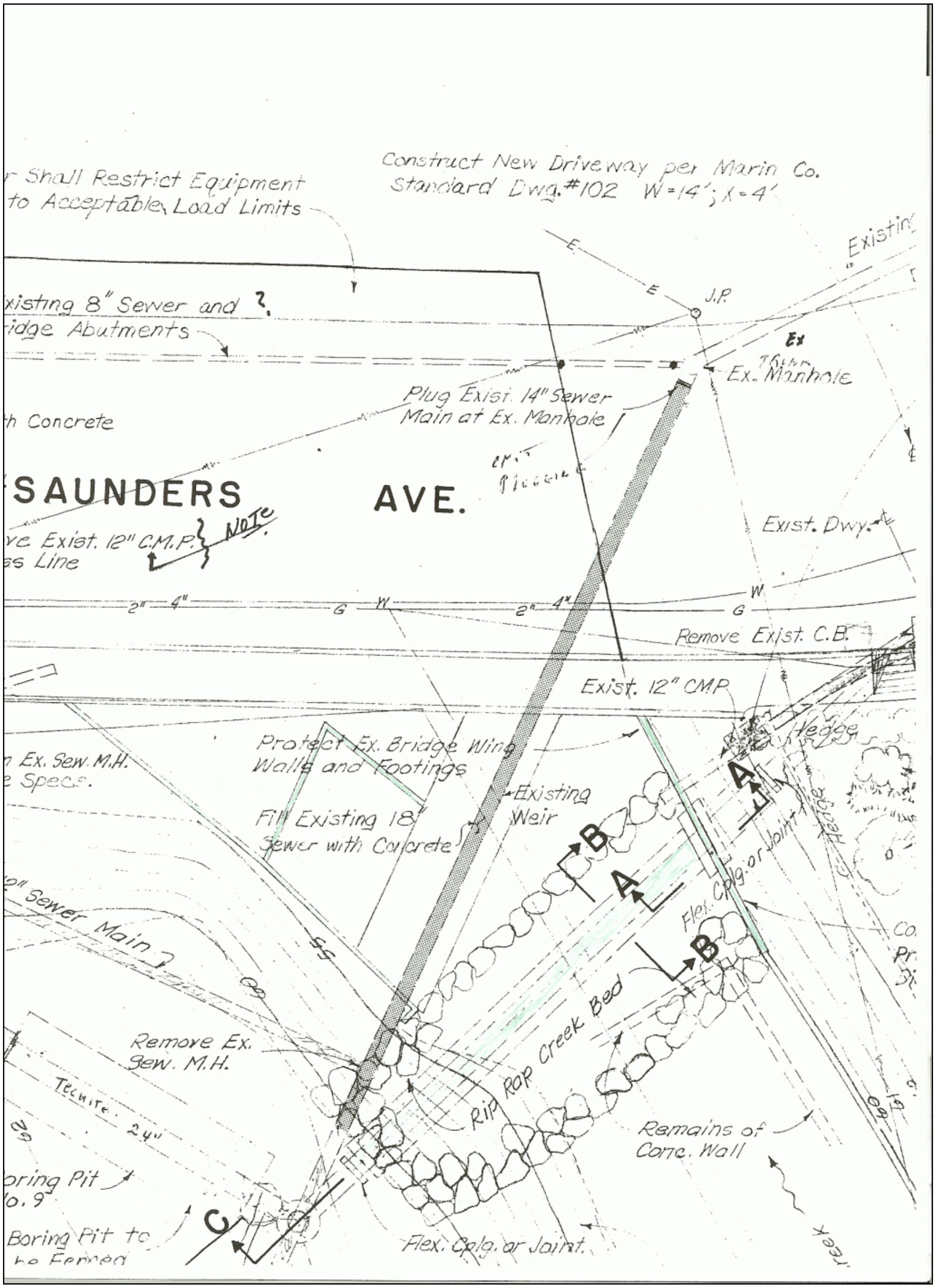
Bates, K. 2001. *Fishway Design Guidelines for Pacific Salmon*. Working paper 1.6 9/2001 Washington Department of Fish and Wildlife.

California Department of Fish and Game (CDFG). 2002. *Culvert criteria for fish passage*. 17 pages.

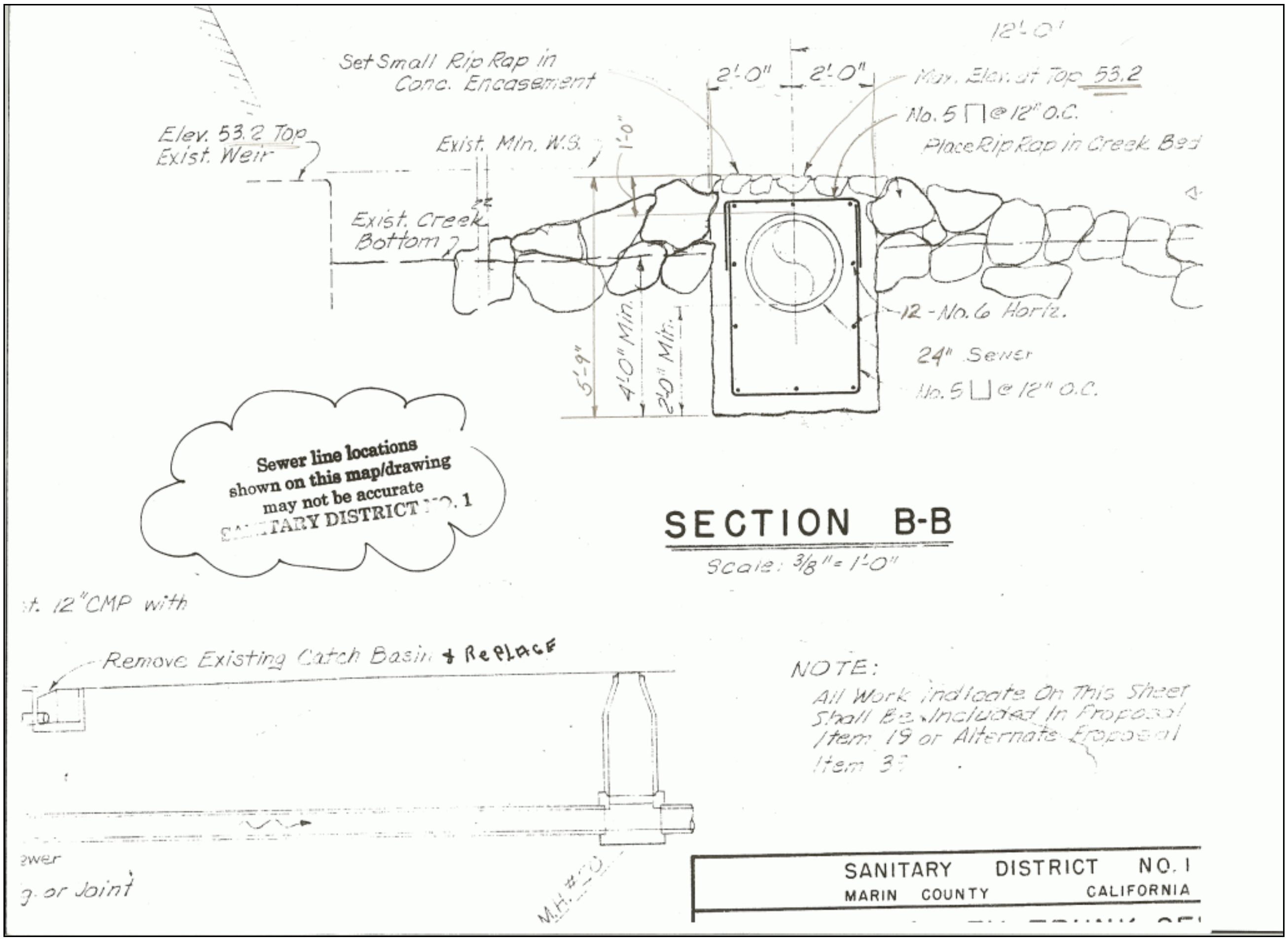
King, H.W. 1939. *Handbook of Hydraulics*, Third Edition, McGraw Hill Book Company

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

Taylor, Ross. 2003. Marin County Stream Crossing Inventory and Fish Passage Evaluation: Final Report. Prepared for the County of Marin, Dept. of Public Works.



Attachment 1 – Location of upstream sewer crossings. Drawing provided By Stetson Engineers



Attachment 2 – Profile of encased sewer crossings. Drawing provided By Stetson Engineers

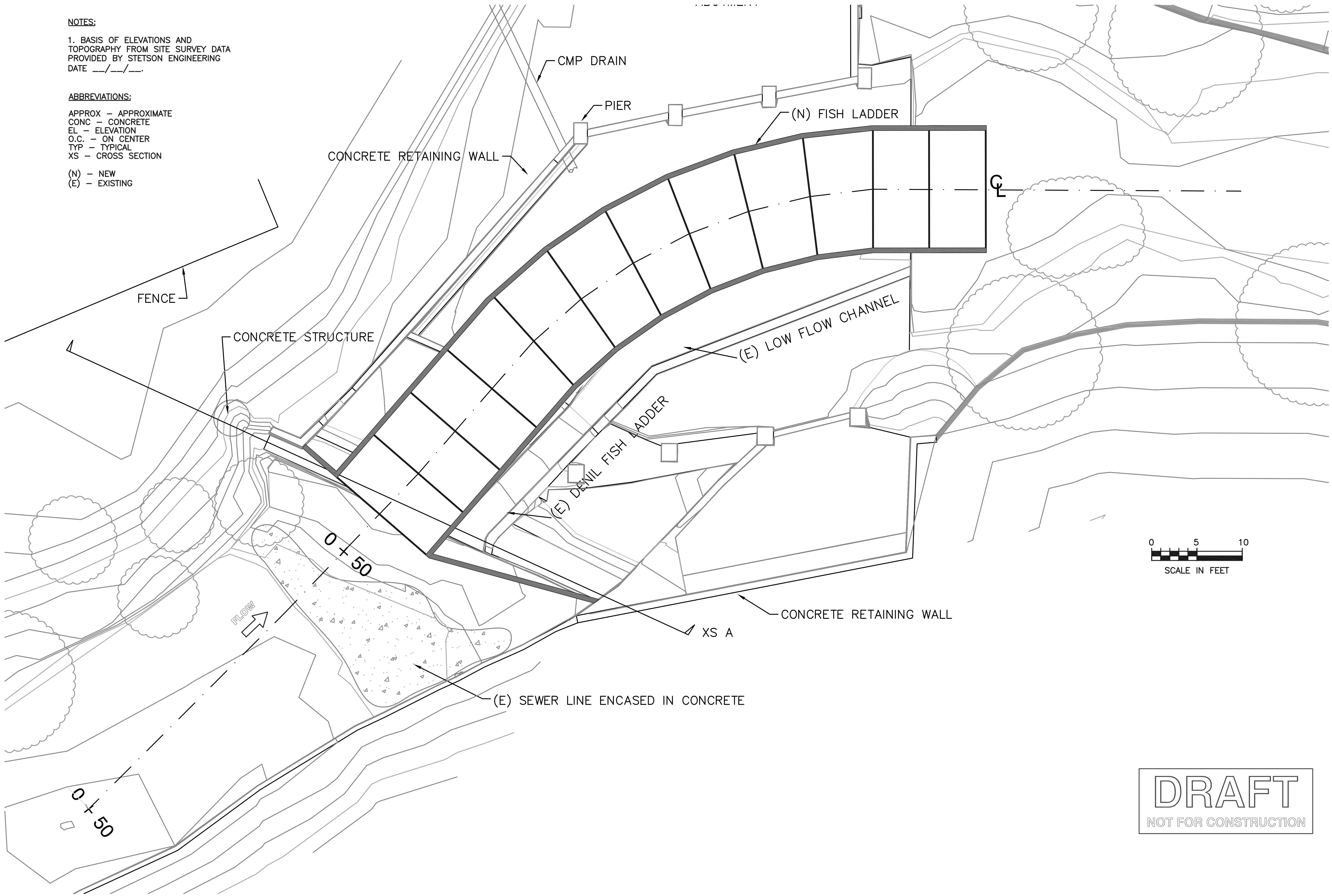
NOTES:

1. BASIS OF ELEVATIONS AND TOPOGRAPHY FROM SITE SURVEY DATA PROVIDED BY STETSON ENGINEERING DATE __/__/__.

ABBREVIATIONS:

APPROX – APPROXIMATE
CONC – CONCRETE
EL – ELEVATION
O.C. – ON CENTER
TYP – TYPICAL
XS – CROSS SECTION

(N) – NEW
(E) – EXISTING



DRAFT
NOT FOR CONSTRUCTION

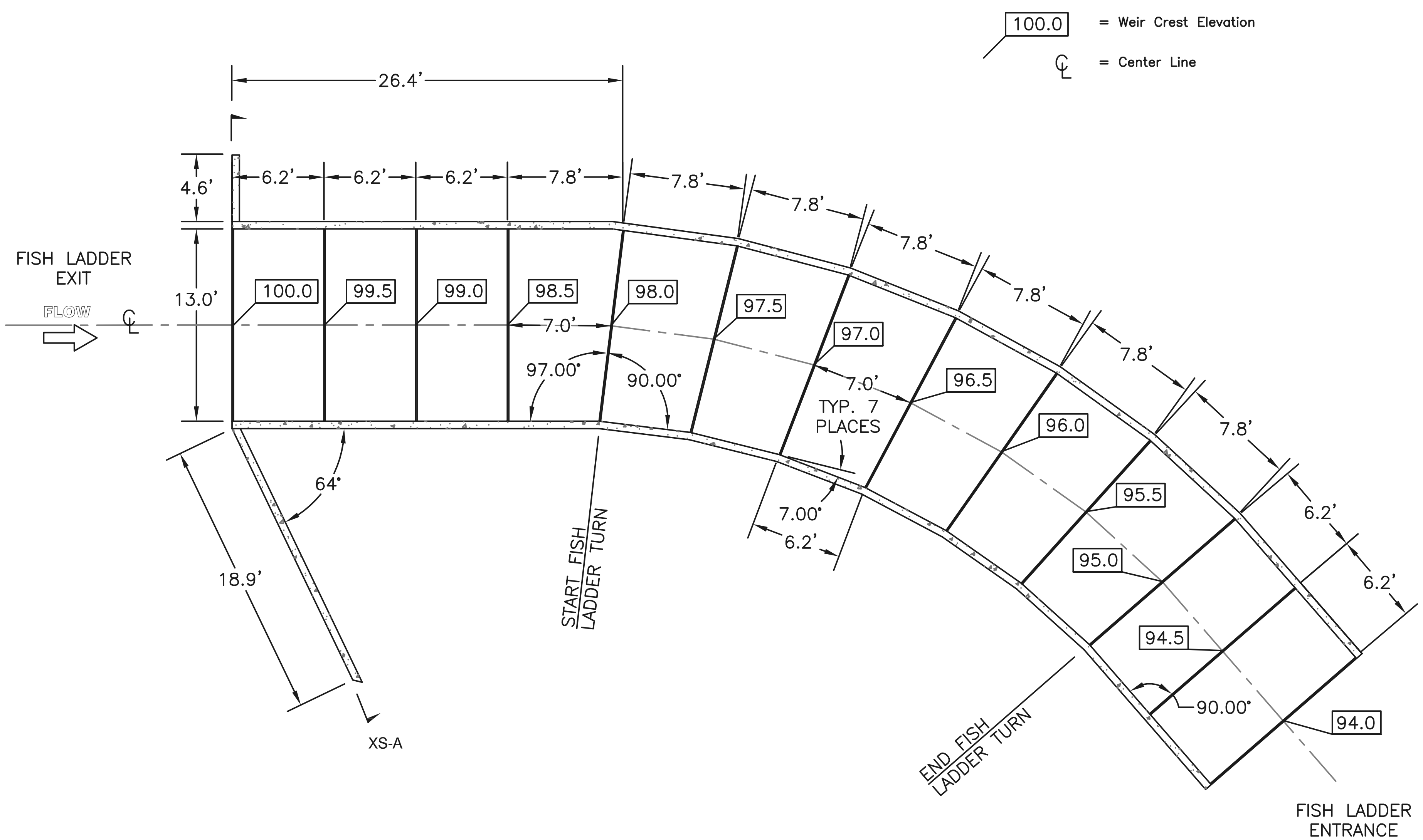
Saunders Ave. Crossing Fish Passage Project
FRIENDS OF CORTE MADERA CREEK WATERSHED

DESIGN: ML/AL DRAWN: AL
JOB: Pastori Saunders 5/21/06

Sheet 4 of 4

Conceptual Layout
Pool and Weir Fish Ladder
(San Anselmo Creek)

Michael Love & Associates
Hydrologic Solutions
PO Box 4477 • Arcata, CA 95518 • (707) 476-8938



PLAN

Scale: 1"=10'

ABBREVIATIONS:

APPROX – APPROXIMATE
CONC – CONCRETE
EL – ELEVATION
O.C. – ON CENTER
TYP – TYPICAL
XS – CROSS SECTION

(N) – NEW
(E) – EXISTING

0 5 10
SCALE IN FEET

NOTES:

1. DROP HEIGHTS FOR WEIR CRESTS IS 0.5'.

2. ALL CONCRETE TO BE CUT AND BLENDED TO NEW WORK AS DIRECTED BY A STRUCTURAL ENGINEER.

3. NEW CONCRETE TO BE REINFORCED AS DIRECTED BY STRUCTURAL ENGINEER.

4. MATERIAL FOR WEIR CONSTRUCTION TO BE DETERMINED. WEIR THICKNESS NOT TO EXCEED 0.5'.

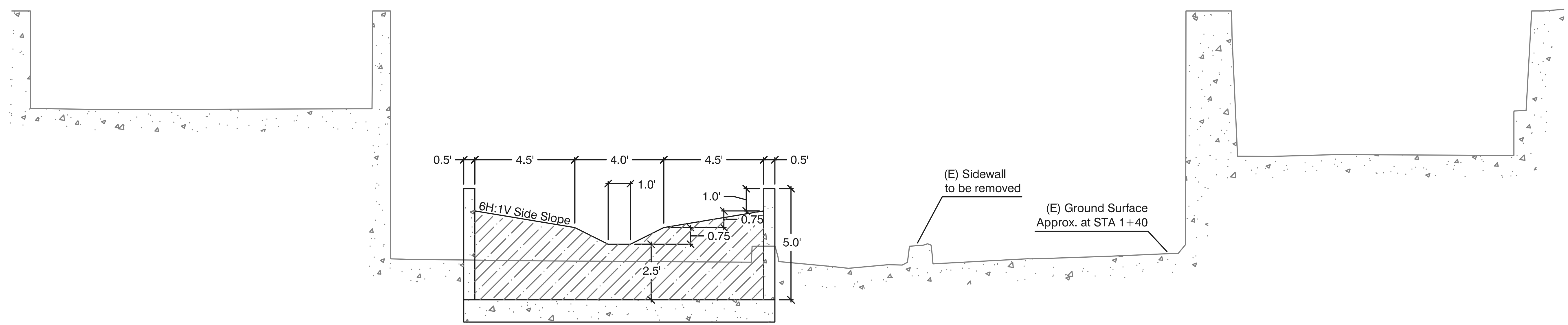
5. IF WEIRS ARE MADE OF CONCRETE, 2" STAINLESS STEEL ANGLE IRON TO BE PLACED FLUSH WITH TOP AND UPSTREAM EDGE OF ALL WEIRS

Saunders Ave. Crossing Fish Passage Project
FRIENDS OF CORTE MADERA CREEK WATERSHED

DESIGN: ML/AL DRAWN: AL
JOB: Pastori Saunders 5/21/06

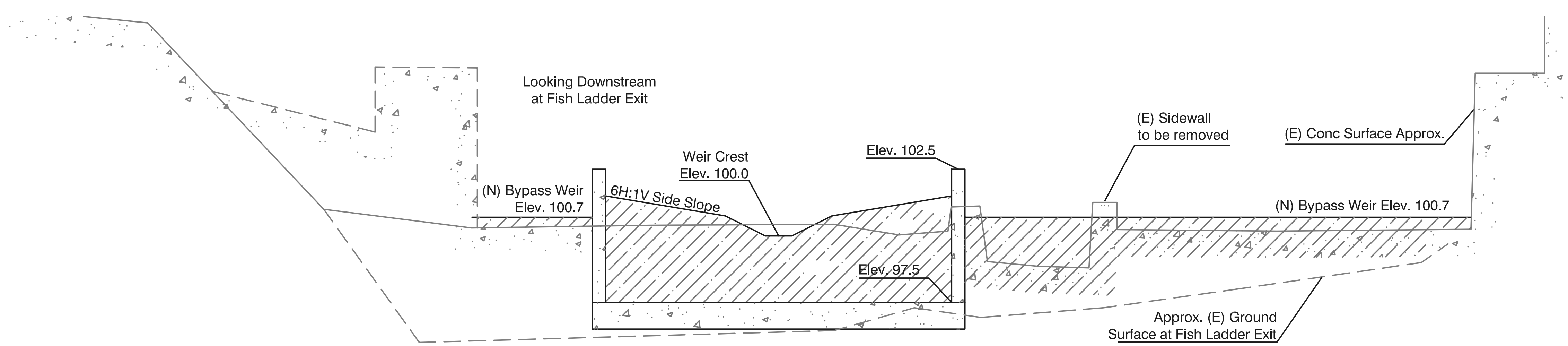
Details
Pool and Weir Fish Ladder
(San Anselmo Creek)

Michael Love & Associates
Hydrologic Solutions
PO Box 4477 • Arcata, CA 95518 • (707) 476-8938



Typical Weir Section

Looking Downstream
Scale: 1"=5'



Section A

Looking Downstream
Scale: 1"=5'

0 5
SCALE IN FEET

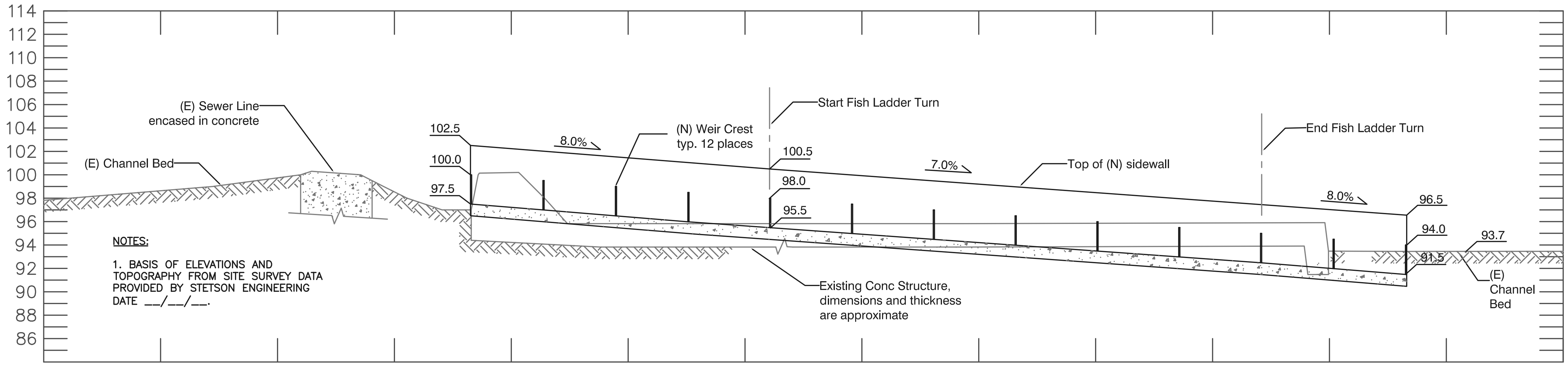
DRAFT
NOT FOR CONSTRUCTION

Saunders Ave. Crossing Fish Passage Project
FRIENDS OF CORTE MADERA CREEK WATERSHED

DESIGN: ML/AL DRAWN: AL
JOB: Pastori Saunders 5/21/06

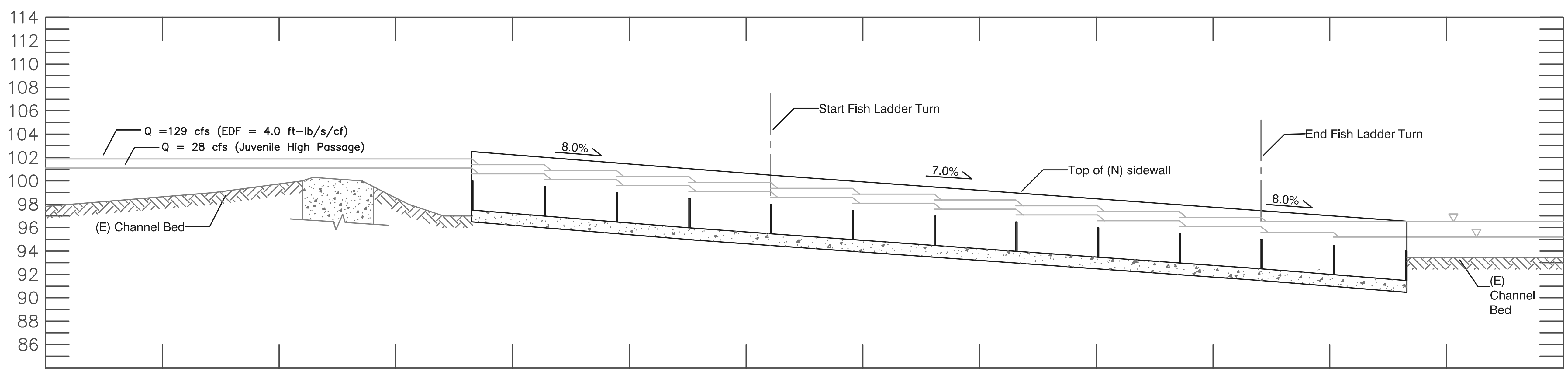
Cross Sections
Pool and Weir Fish Ladder
(San Anselmo Creek)

Michael Love & Associates
Hydrologic Solutions
PO Box 4477 • Arcata, CA 95518 • (707) 476-8938



PROFILE (N) CENTERLINE

Scale: 1"=10'



WATER SURFACE PROFILE

Scale: 1"=10'

DRAFT
NOT FOR CONSTRUCTION

Saunders Ave. Crossing Fish Passage Project
FRIENDS OF CORTE MADERA CREEK WATERSHED

DESIGN: ML/AL DRAWN: AL
JOB: Pastori Saunders 5/21/06

Sheet 3 of 4

Profile
Pool and Weir Fish Ladder
(San Anselmo Creek)

Michael Love & Associates
Hydrologic Solutions
PO Box 4477 • Arcata, CA 95518 • (707) 476-8938