TECHNICAL MEMORANDUM

ASSESSMENT OF FISH MIGRATION AT RIFFLES IN SUNOL VALLEY QUARRY REACH OF ALAMEDA CREEK

Prepared for

San Francisco Public Utilities Commission

February 2010

URS HDR

TABLE OF CONTENTS

Figures

Tables

List of Acronyms

BART	Bay Area Rapid Transit
CDFG	California Department of Fish and Game
cfs	cubic feet per second
CP	subject riffles surveyed in 2004
fps	feet per second
HDR|SWRI	HDR Engineering, Inc.|Surface Water Resources, Inc.
I-680	Interstate 680
NMFS	National Marine Fisheries Service
PG&E	Pacific Gas and Electric Company
SFPUC	San Francisco Public Utilities Commission
SVQR	Sunol Valley quarry reach (of Alameda Creek)
TAC	Technical Advisory Committee
URS	URS Corporation
USGS	U.S. Geological Survey
WSE	water surface elevation
XS	subject riffles surveyed in 2006

1 INTRODUCTION

1.1 BACKGROUND INFORMATION

The San Francisco Public Utilities Commission (SFPUC) has been working with other stakeholders since the late 1980s to restore steelhead (*Oncorhynchus mykiss*) to the Alameda Creek Watershed (TAC, 1989). In conjunction with other fisheries enhancement actions, the SFPUC removed Niles and Sunol dams from Alameda Creek in September 2006 and is completing a Habitat Conservation Plan that includes steelhead as a covered species (SFPUC, 2009). The SFPUC is also a member of the Alameda Creek Fisheries Restoration Workgroup, which is working to restore steelhead to the Alameda Creek Watershed. The Alameda Creek Fisheries Restoration Workgroup is composed of a broad range of stakeholders, including representatives from the National Marine Fisheries Service (NMFS) and the California Department of Fish and Game (CDFG).

Steelhead entry into the Alameda Creek Watershed from the ocean via San Francisco Bay is currently blocked by various water development and other projects in lower Alameda Creek (TAC, 1989; ETJV and ESA-Orion Joint Venture, 2008; McBain & Trush, 2008). Efforts are underway to modify existing impediments and facilitate passage of steelhead at the BART weir and other known barriers to migration.

The SFPUC owns land in the Upper Alameda Creek Sub-Watershed, where SFPUC water supply operations are located, in addition to land used by quarry and other operations under lease from the SFPUC. This study is one of several "snapshot" field studies examining the conditions in the reach of Alameda Creek that covers the Sunol Valley quarry area.

1.2 PURPOSE

The purpose of this memorandum is to present information from a completed 2006 field survey of critical riffles[1] and related hydraulic conditions that may have influence on future steelhead in the reach of Alameda Creek in the Sunol Valley quarry area, and to present analysis of both the riffles surveyed in 2006 as well as riffles surveyed by Entrix in 2004. The purpose of this investigation was to identify critical riffles; ten riffles were analyzed, and are referred to as the subject riffles. The findings from this work, combined with similar surveys of the area, are anticipated to provide useful information to steelhead restorations efforts, including ongoing SFPUC, Pacific Gas and Electric (PG&E), and other actions throughout the reach.

1.3 SCOPE

The scope of work for this effort included three steps: (1) reviewing previous flow studies and related data for the Sunol Valley quarry reach (SVQR), (2) completing an additional field survey of critical riffles and estimate flows to support the successful movement of future adult and juvenile steelhead through the subject riffles, and (3) summarizing findings from steps (1) and (2) in this technical memorandum.

[1] Critical riffles are defined as stream channel segments with the highest probability of hindering salmonid passage. Critical riffles are characterized by relatively high width-to-depth ratios that can potentially impede salmonid migration through insufficient water depths or result in losses in habitat connectivity if they become dewatered.

1.4 ORGANIZATION OF TECHNICAL MEMORANDUM

The organization of this memorandum is as follows:

- Section 1 provides background information and introduces the purpose and scope of the investigation.
- Section 2 describes the setting, and defines the study area.
- Section 3 presents the methods used in this investigation.
- Section 4 presents the results of the investigation.
- Section 5 presents a discussion of the results, including limitations.
- Section 6 presents the conclusion of the investigation.
- Section 7 lists the preparers of this technical memorandum.
- Section 8 presents the reference materials used to prepare this technical memorandum.

2 SETTING

The approximately 440,000-acre Alameda Creek Watershed is the largest tributary to the South San Francisco Bay Estuary. It drains the interior hills and valleys east of San Francisco Bay, including the northwestern slopes of the Diablo Range and the Livermore-Amador and Sunol valleys, before cutting through the East Bay hills via Niles Canyon and flowing across its largely developed alluvial fan and floodplain. Unlike California watersheds that originate high in the Sierra Nevada Mountains, Alameda Creek Watershed does not accumulate snowpack in winter, so most of its tributaries are intermittent or ephemeral. The watershed has been modified extensively for purposes of flood control and water supply, and contains three major reservoirs (Calaveras, San Antonio and Del Valle).

This section describes the reach of Alameda Creek that flows through the Sunol Valley (Section 2.1), which includes the study area for this investigation, identified as the SVQR (Section 2.2). Aside from the study described in this memorandum, a number of other studies and actions are ongoing on Alameda Creek in the Sunol Valley, some of which are described in Section 2.3.

2.1 ALAMEDA CREEK IN THE SUNOL VALLEY

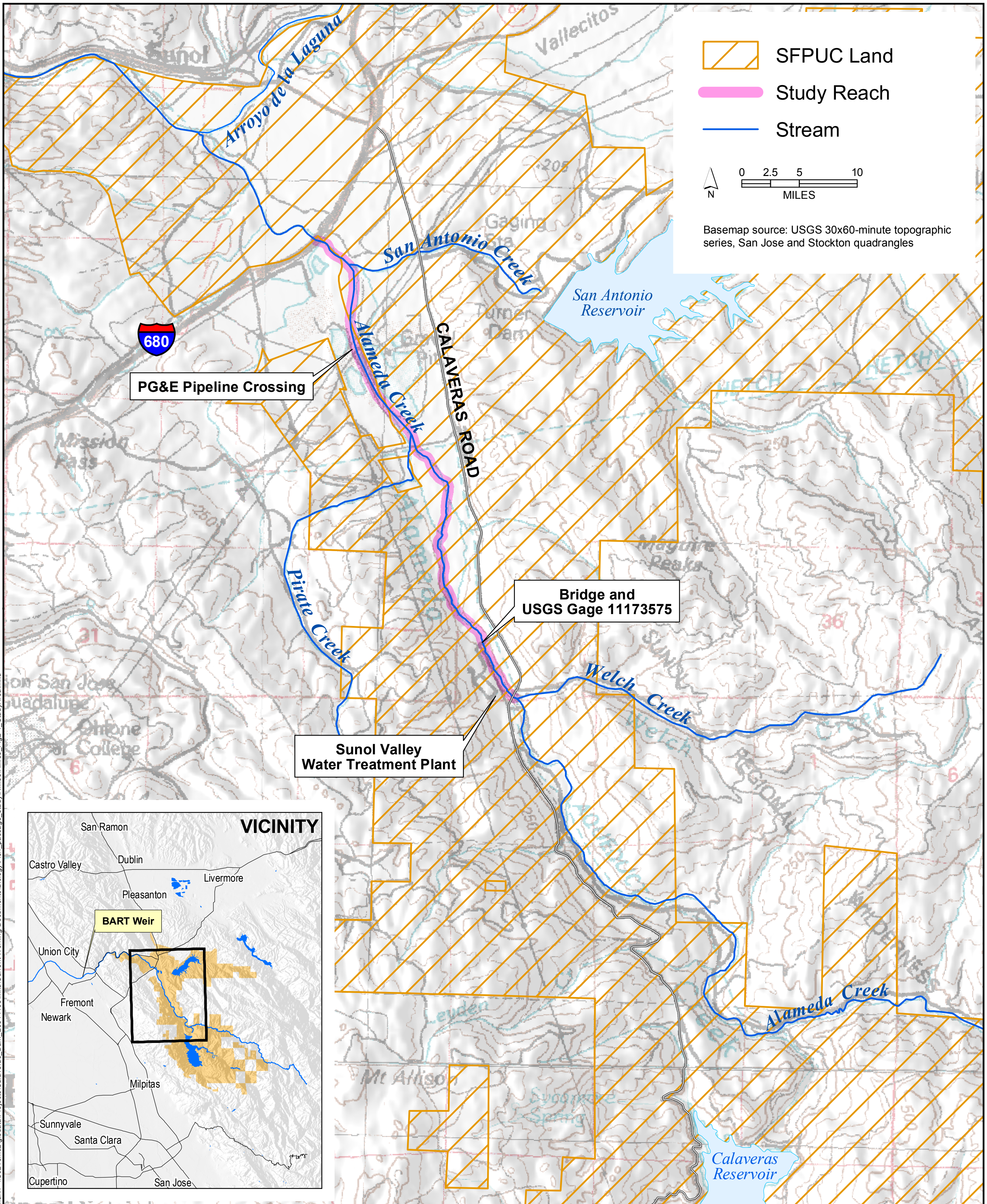
Alameda Creek Watershed is composed of three sub-watersheds as summarized in Table 2-1. The Sunol Valley is located in the Upper Alameda Creek Sub-Watershed, in the Mid-Alameda Creek Basin. Therefore, Alameda Creek in the Sunol Valley receives flow from the Mid-Alameda, Upper Alameda, Arroyo Hondo, and Calaveras Creek Basins.

Table 2-1
Approximate Acreage Within the Alameda Creek Watershed, its Three Sub-Watersheds, and the Five Basins in the Upper Alameda Creek Sub-Watershed

Watershed	Sub-Watershed	Basin	Acreage
Alameda Creek			440,000
	Arroyo de la Laguna		270,000
	Upper Alameda Creek		130,000
		Arroyo Hondo	51,000
		Upper Alameda Creek	26,000
		San Antonio	25,000
		Mid-Alameda Creek	15,000
		Calaveras	13,000
	Lower Alameda Creek		40,000

Note: Acreages reported for watersheds in this technical memorandum are based on CalWater data, accessed in January 2009 at http://cain.ice.ucdavis.edu/calwater/caldata.html.

Through the broad, alluvial Sunol Valley, Alameda Creek is characterized by a low gradient channel. Channel cross-sections are generally wide and shallow with bank full widths ranging from 35 to 140 feet and depths ranging from 1.5 to 2.5 feet. The channel substrate is primarily cobble and gravel, and the stream is braided at some locations. Riparian vegetation is sparse and consists of low willow scrub, with a widely dispersed stand of mature sycamore trees in the upper portion of the valley. Reservoirs and dams, gravel quarry operations, bridge abutments, and other engineered features have contributed to significant changes to the physical location, channel morphology and hydrology of Alameda Creek in the Sunol Valley.



Study Area and Vicinity

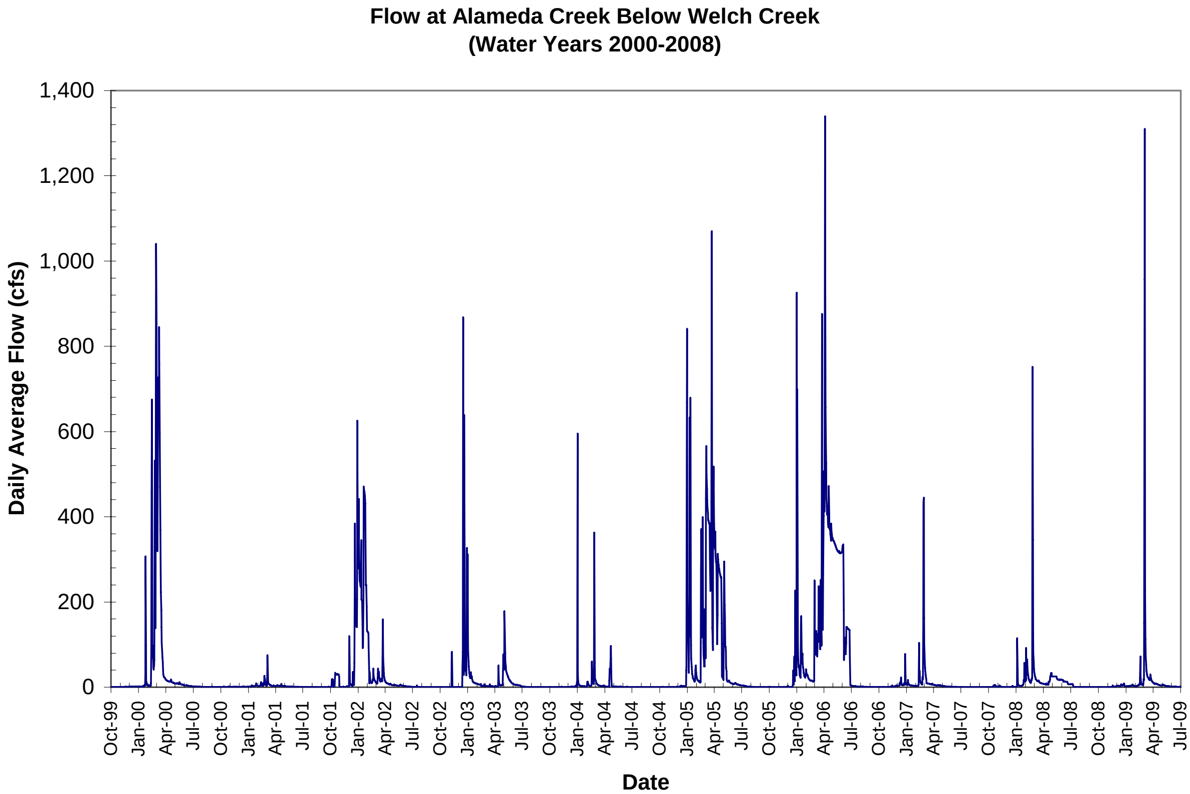
Assessment of Fish Migration at Riffles in Sunol Valley Quarry Reach of Alameda Creek

February 2010

Figure 2-1

URS Corp - Oakland CA - C.Raumann \\S021emc2\gisdata\Projects\Calaveras_Dam_26814408\Mxd\Current Working Documents\Biology\Fish_passage_study\Riffles\Riffles_Fig2-1_StudyArea.mxd

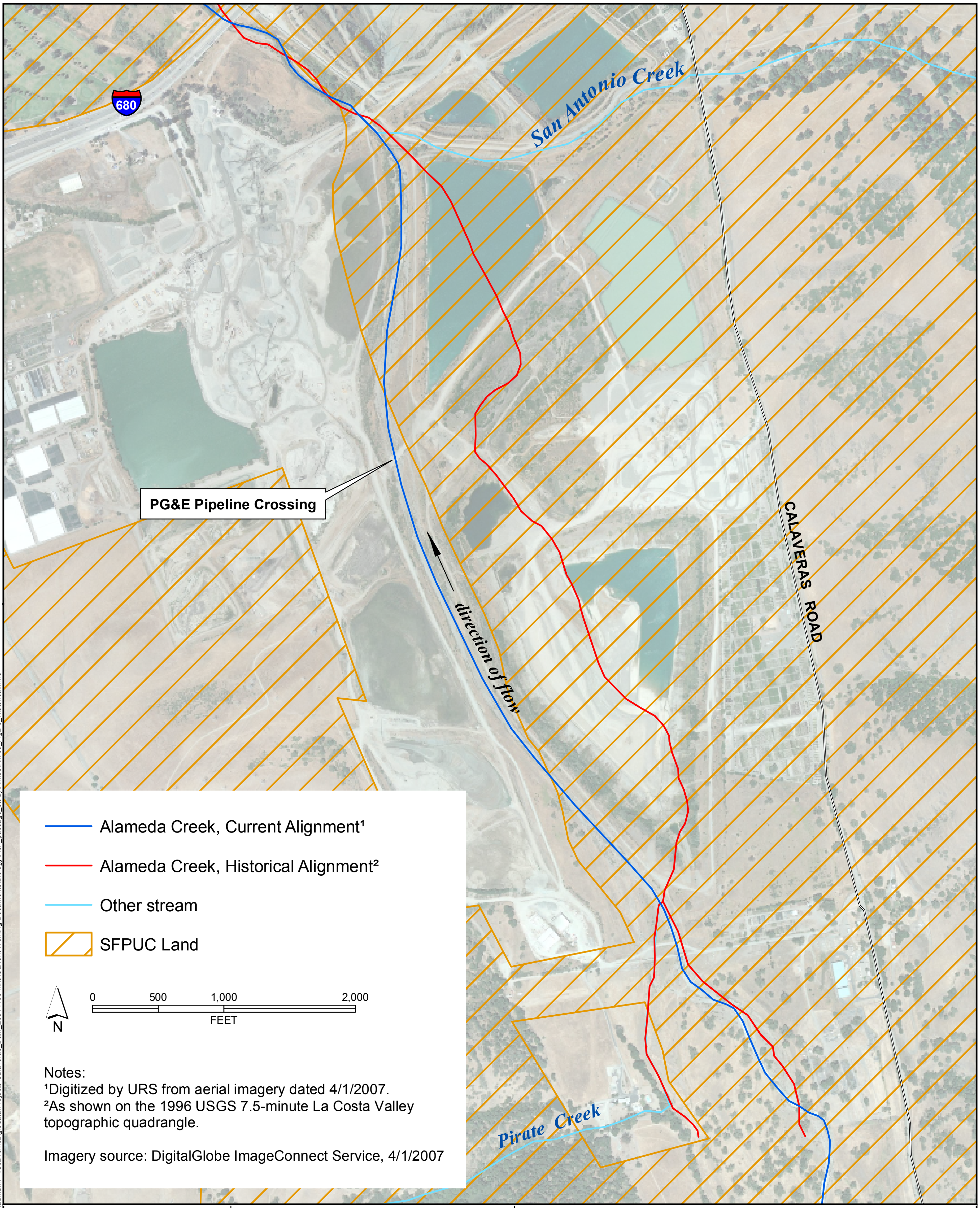
Stream flow through the Sunol Valley is influenced by operation of Calaveras Reservoir (approximately 3.7 miles upstream), the Alameda Creek Diversion Dam (approximately 5.5 miles upstream), and San Antonio Reservoir (approximately 1.5 miles up San Antonio Creek), and is variable (USGS, 2008). During the period of record (October 1999-present) for the U.S. Geological Survey (USGS) gage on Alameda Creek below Welch Creek (Gage 11173575, Figure 2-1), the flow rate has ranged from no flow during periods of 2002, 2004, 2007, and 2008, up to 5,750 cubic feet per second (cfs) on December 16, 2002. Daily average flow over the period of record is shown in Figure 2-2.



Source: USGS Gage 11173575, Alameda Creek Below Welch Creek

Figure 2-2 Flow at Alameda Creek below Welch Creek (Water Years 2000 to 2008)

Quarry facilities operating in the Sunol Valley since the 1960s also influence stream flow. In the 1970s, the segment of Alameda Creek in the vicinity of the quarries was moved to its current location and placed in a trapezoidal engineered channel (Figure 2-3). Quarry activities conducted on SFPUC property under lease by third parties are located on what is now the right bank of Alameda Creek (looking downstream), and privately owned quarry operations are located on the left bank. The operation bounded by Alameda Creek to the east and San Antonio Creek to the north does not yet have a perimeter cutoff wall to prevent seepage into the active mining pit, which is located in the former creek channel. The mining pit tends to capture a portion of the shallow underflow present in the upper 50 feet of alluvial deposits in the stream channel, infiltration which presumably results in a reduction of flow downstream under some hydrological conditions. Water is also pumped from the quarries into Alameda Creek. Planned quarry operator actions to improve hydrological conditions in this reach are discussed in Section 2.3.



Current and Historical Alignment of Alameda Creek

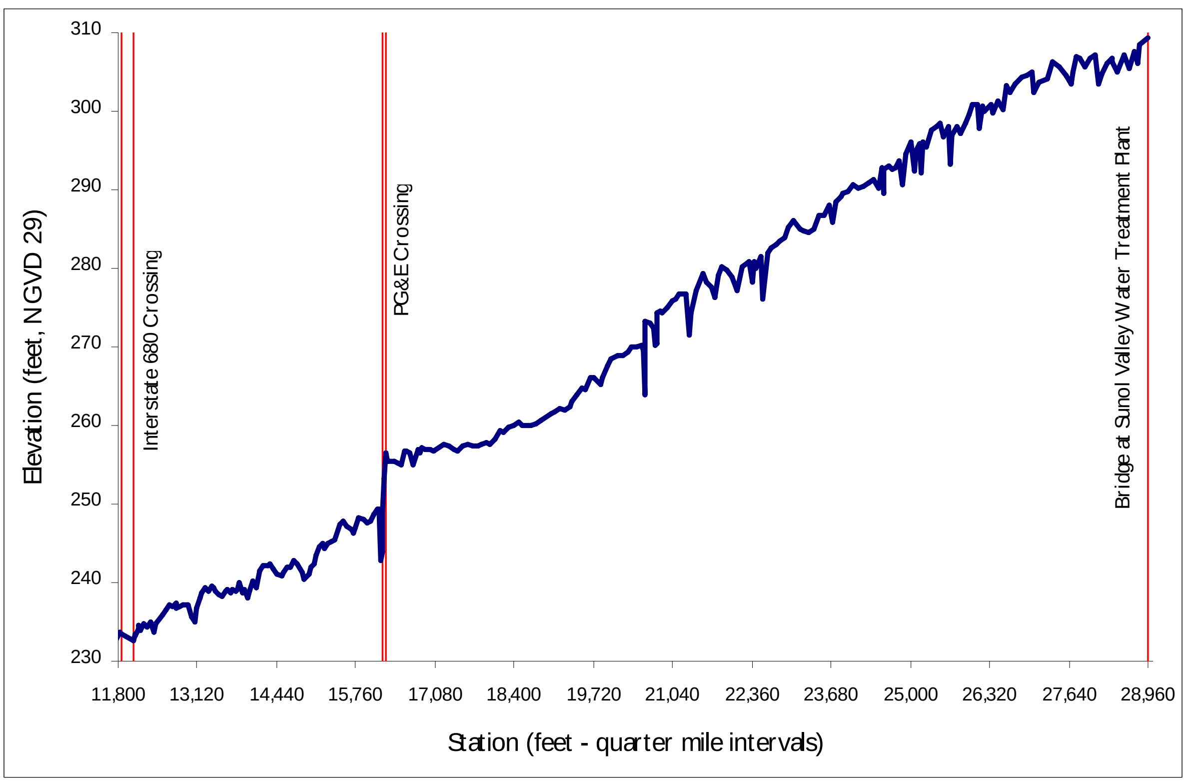
Assessment of Fish Migration at Riffles in Sunol Valley Quarry Reach of Alameda Creek

February 2010

Figure 2-3

A study of historical documentation, intended to provide better understanding of habitat and flow conditions in this area, is underway (Section 2.3), but preliminary findings suggest that even prior to reservoir construction and quarry mining activities, Alameda Creek flows through portions of the Sunol Valley were intermittent (Grossinger, pers. comm., 2009). The 1906 Livermore (known then as Pleasanton) USGS 15 minute quadrangle topographic map illustrates the historically discontinuous nature of surface flows through the Sunol Valley. It shows the creek spreading into multiple channels approximately 0.75 mile downstream of the Sunol Valley Water Treatment Plant, then becoming intermittent, and becoming perennial again near the confluence with Arroyo de la Laguna (Figure 2-1). This is consistent with historic aerial photos, historic tree surveys, remnant standing trees, and other sources that suggest there were steep gradients and variation in riparian and aquatic habitat within the full length of Sunol Valley, ranging from perennial stream with riparian forest cover to mostly unvegetated, xeric, braided channel reaches. The changes in hydrology appear to follow predictable geologic gradients, where the stream shifts from perennial to intermittent as it hits deep, coarse, valley alluvium.

Another important feature that influences stream flow and habitat conditions in the Sunol Valley is a PG&E gas pipeline crossing Alameda Creek that has been protected with a large grade control structure, or concrete apron drop structure, creating a barrier to upstream fish migration (Figures 2-1 and 5-1). The concrete apron drop structure was constructed in 1997 by PG&E to protect a 36-inch natural gas pipeline under the creek. The grade control structure at the pipeline crossing affects the condition of the stream channel upstream, by controlling the vertical gradient above the concrete apron (Figure 2-4). The upcoming removal of this drop structure is discussed in Section 2.3.



Note: Developed using data from ESA (2008).

Figure 2-4 Elevation Profile of Alameda Creek in the Sunol Valley

2.2 STUDY AREA

The study reach for this investigation includes the SVQR and begins immediately upstream of where Calaveras Road crosses Alameda Creek near the Sunol Valley Water Treatment Plant. The study reach ends where Interstate 680 (I-680) crosses Alameda Creek near the town of Sunol (Figure 2-1). The reach is approximately 3.5 miles long, and begins approximately 8.6 miles upstream of the BART weir (Figure 2-1, inset box).

Although present within the study area for this investigation, the grade control structure protecting the PG&E gas pipeline that crosses Alameda Creek in the SVQR was not investigated as a potential critical riffle because PG&E plans to remove this feature as early as 2010 (Section 2.3).

2.3 ONGOING STUDIES AND ACTIONS

In parallel to the work completed in this investigation, other studies and actions are ongoing, some of which were informed by the preliminary data provided by this assessment and similar studies. This section summarizes information on relevant studies and activities in the Sunol Valley which may affect habitat conditions and riffle passability for steelhead.

MODIFICATIONS THROUGH SFPUC-LEASED QUARRY OPERATIONS

Ongoing quarry operations on SFPUC property in the SVQR underwent environmental review and permitting, and are consistent with applicable SFPUC plans for the area (EDAW, 1998 and 2001). In coordination with those plans, as well as Alameda Creek Fisheries Restoration Workgroup studies (discussed below), PG&E fieldwork and plans (discussed below), and completed SFPUC flow studies in the SVQR (Trihey and Associates, 2003; Entrix, 2004), the SFPUC issued a request for proposals in December 2005 to re-operate the aggregate and sand quarry located to the east of Alameda Creek in the SVQR. The terms of the request for proposals included requirements to improve hydrologic/hydrogeologic and habitat conditions in the SVQR. That request for proposals process initiated quarry re-operation plans that include actions to improve environmental conditions (Oliver de Silva, Inc., 2008), including (1) installation of a bentonite cutoff wall on the right bank of Alameda Creek and possibly the left bank of San Antonio Creek to minimize seepage of creek water into the quarry pit; and (2) establishment of riparian vegetation on Alameda and San Antonio Creeks in the vicinity of the quarry.

REMOVAL OF PG&E PIPELINE CONCRETE APRON DROP STRUCTURE

Since 1999, PG&E (a member of the Alameda Creek Fisheries Restoration Workgroup), other Workgroup members, and resource agencies have been studying options for modifying the concrete apron drop structure over the pipeline crossing in Alameda Creek (Figures 2-1 and 5-1) in order to make it passable to future migrating steelhead. PG&E has proposed to retrench and lower the pipeline and remove applicable portions of the apron and concrete foundation (Ross-Leach, pers. comm., 2009). Construction may begin as soon as 2010.

SFPUC FILTER GALLERY PROJECT

SFPUC is completing initial planning documents for the Upper Alameda Creek Filter Gallery Project. The project is anticipated to consist of facilities in the Sunol Valley quarry reach for the recapture of water released from Calaveras Dam and bypassed at the Alameda Creek Diversion Dam for fisheries habitat enhancement in Alameda Creek. Preliminary design for the project includes an in-stream infiltration gallery.

PREPARATION OF SFPUC SUNOL VALLEY RESTORATION PLAN

Using data from completed and ongoing habitat, flow, and related studies, SFPUC and the lessee to re-operate the quarry adjacent to the SVQR will prepare a Sunol Valley Restoration Plan. Actions under the plan will include enhancement of relevant habitat conditions, and assessment of any needed modifications to hydraulic conditions in SVQR.

ALAMEDA CREEK FISHERIES RESTORATION WORKGROUP STUDIES

The Alameda Creek Fisheries Restoration Workgroup has conducted studies below the SVQR in Niles Canyon (e.g., a temperature study in 2008), and is currently studying habitat conditions above SVQR. Preliminary planning for field work in late 2010 and 2011 may include work in Sunol Valley.

ANALYSIS OF ALAMEDA CREEK HISTORICAL ECOLOGY

Working in conjunction with SFPUC and Alameda County, the San Francisco Estuary Institute and others are analyzing historical information on the Arroyo de la Laguna and Upper Alameda Creek subwatersheds (including SVQR) to assess watershed conditions prior to significant Euro-American modification. This work is intended to serve as a basis for understanding subsequent changes in watershed structure and function, and for identifying potential options for future environmental management. Specific topics addressed in the project will include historical extent, type, and character of riparian habitat of different kinds, seasonal and perennial wetland habitats, extent of perennial and intermittent stream reaches, changes in channel plan form alignment, changes in reach functions and uses, changes in channel cross-section, and other related characteristics of the fluvial, riparian, and wetland systems.

3 METHODS

Consistent with the study scope (Section 1.3), riffles present within the study reach were identified and evaluated in order to obtain a better understanding of how existing hydraulic conditions met a series of recognized criteria for the passage of steelhead. Passage criteria used in this study included criteria for adult migration identified by Thompson (1972), and a passage criterion for juvenile migration identified by NMFS (2001) (Section 3.2). This study drew both on riffle transect data collected specifically for the purposes of this current investigation (2006 surveys, Section 3.1.2), and on data collected during prior investigations (2004 surveys, Section 3.1.1). In both cases, transects were surveyed at subject riffles believed to be impediments to passage during low flow conditions. The analysis presented in this memorandum used the 2004 and 2006 transect data and identified hydraulic conditions where depth met the specific passage criteria. Riffles surveyed by Entrix in 2004 were not resurveyed in 2006. No surveys were conducted since 2006. Stage-versus-discharge relationships (also known as “rating curves”) were developed from the transect data to estimate flows expected to facilitate steelhead passage at the subject riffles for juvenile and adult life stages. The methods are described further in this section.

3.1 RIFFLE TRANSECT SURVEYS

This section describes the methods used to identify and survey subject riffles in the study area (Section 2.2). Some of the riffles evaluated for steelhead passage were identified and surveyed by Entrix in 2004 (Entrix, 2004) and the others were identified and surveyed by HDR|SWRI in 2006. Consistent with field studies that are conducted at distance from an established survey benchmark, stage was measured relative to an independent datum established in the field at each individual riffle.

Some of the cross section data collected previously by various groups in the study area were not analyzed in this study. Cross sections surveyed in 2001 are presented in a document titled “Sunol Valley Surface Flow Study Fall 2001” prepared by Trihey and Associates (2003), but are not analyzed in this memorandum. Also, the cross-sections surveyed by Entrix in 2004 (Section 3.1.1) and analyzed in this memorandum were surveyed by Entrix again at mostly higher flows in 2005. Results from the 2005 surveys are summarized in the document titled “Alameda Creek Streamflow Study” prepared by Entrix (2006) for Kennedy/Jenks Consultants. The 2001 and 2005 data were not used in this study because:

a. Channel conditions are expected to change over time so that the 2001 data are not expected to be as relevant as the more recent data analyzed in this memorandum.

b. The 2005 re-surveys of the Entrix 2004 cross sections were conducted primarily at flows much greater than those necessary to create conditions for passage at the subject riffles; these data were not included in this analysis because they were not expected to improve the accuracy of the relevant segments of the rating curves.

The 2004 and 2006 survey data were selected for analysis because they were relevant to current conditions and passage flows in the study area.

3.1.1 ENTRIX 2004 SURVEYS

In 2004, Entrix surveyed riffles on Alameda Creek within the Sunol Valley. Water depth and velocity measurements were collected at eight channel cross sections, six of which were identified as potential impediments to juvenile salmonid migration (see Table 3-1). Additional details regarding the Entrix 2004 data collection can be found in the document titled “Alameda Creek Juvenile Steelhead Downstream Migration Flow Requirements Evaluation, Phase 1: Field Survey Results” prepared by Entrix (2004) for URS. Those six previously surveyed channel cross sections identified as potential impediments to salmonid migration lie within the study area defined in this memorandum, were analyzed in this study, and are reported on further in this memorandum (Section 4.2). This analysis, conducted by URS and HDR in 2009, was based on preliminary depth, velocity, and flow data received by URS from Entrix (Taylor, pers. comm., 2006). Data collected by Entrix in 2004 and analyzed by URS and HDR in this study are summarized in Table 3-1.

Table 3-1
Summary of Flow Data Used to Develop Stage versus Discharge Relationships at Riffles Surveyed in 2004

Riffle	Discharge[a] (cfs)[b]	Stage[c] (feet)
CP7	0.0	96.70
	13.4	97.45
	22.8	97.72
	77.4	98.27
CP6	0.0	97.20
	10.9	98.20
	20.2	98.37
	77.7	98.75
CP5	0.0	96.19
	18.7	96.94
	75.7	97.19
CP4-2	0.0	95.63
	12.3	96.23
	21.2	96.34
	72.5	96.53
CP4-1	0.0	95.14
	21.3	95.99
	71.5	96.29
CP3	0.0	94.42
	12.3	95.26
	20.8	95.40
	71.9	95.87

Source: Entrix (2004) and Taylor, pers. comm. (2006).

Notes:

[a] Discharge values were calculated from the average of field measurements taken at cross sections located at each riffle and at upstream and downstream locations. Flow calculations for upstream and downstream locations were verified where data were available.

[b] cfs = cubic feet per second

[c] Consistent with field studies conducted at distance from a survey benchmark, stage was measured relative to an independent datum established in the field at each riffle, Stage data is not comparable among riffles.

3.1.2 HDR|SWRI 2006 SURVEYS

Additional observations and field data collection for subject riffles in the SVQR were conducted by HDR|SWRI on July 11, 2006. Fieldwork from this survey is reported in this memorandum. The field data collection team consisted of David Olson and Samantha Hadden, with assistance from Marsha Grefsrud of CDFG. Prior to the data collection, on May 25, 2006, URS and HDR conducted a site visit with a group of agency personnel including CDFG, SFPUC, U.S. Environmental Protection Agency, and U.S. Fish and Wildlife Service. Agency personnel were also invited to participate in the field data collection.

The purpose of the 2006 data collection was to characterize potential fish passage opportunities for future steelhead during seasonal low flows (i.e., seasonal baseflow conditions) that could occur during the anticipated steelhead adult immigration and juvenile emigration periods. Daily average flow recorded at the USGS gaging station on Alameda Creek below Welch Creek (USGS Gage 11173575, Figure 2-1) during the data collection was 2.7 cfs. The 2006 surveys were not conducted during a time period when steelhead are expected to migrate because large water releases to draw down Calaveras Reservoir's water surface elevation (as required by State of California, Division of Safety of Dams) during the 2006 water year prevented flows in the study reach from subsiding to target levels until July (Figure 2-2).

The field team walked the study area to identify riffles that appeared to be potentially limiting to steelhead migration, based on the channel shape and width-to-depth ratio. Representative riffles identified as a potentially limiting for steelhead migration were surveyed by establishing a transect and measuring water depth and velocity (Global Flow Probe™) across the channel's width. Surveys were conducted using standard surveying methods and instruments, including a survey level (20X Econo Line Level™) and stadia rod. The location of each cross section was recorded with a global positioning system unit (Garmin V™). Riffles surveyed by Entrix in 2004 were not resurveyed.

3.2 RIFFLE PASSAGE CRITERIA

Specific depth criteria were selected from various literatures so that minimum flow requirements could be estimated. Each criterion represented the minimum threshold expected to facilitate steelhead passage over the subject riffles. Depth criteria were selected and minimum flows were estimated for three steelhead life stages:

- adult immigration;
- juvenile emigration;
- post-spawn adult emigration.

Table 3-2 summarizes the anticipated period of migration for three specific steelhead life stages in Alameda Creek. The time periods presented in the table are based upon literature review, survey data collected in the Upper Alameda Creek Sub-Watershed, and personal communications with individuals familiar with the Alameda Creek Watershed. Migration is anticipated to occur during these annual time periods, but is ultimately dependent upon the hydrology and corresponding hydraulic conditions that occur within a given year.

Table 3-2
Steelhead Passage Element Timing

Passage Element	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Adult Immigration[a]			■	■	■	■	■					
Juvenile Emigration[b]						■	■	■	■			
Post-Spawn Adult Emigration[c]				■	■	■	■	■	■			

Sources:
[a] Gunther et al. (2000); Moyle (2002).
[b] Gunther et al. (2000); SFPUC (2004); Bjorkstedt et al. (2005); Brian Sak, pers. comm. (2009).
[c] Gunther et al. (2000).

Adult steelhead immigration in the Alameda Creek Watershed is expected to occur from December through April, with the majority of immigration occurring between December and March (Gunther et al., 2000). The ability of adult steelhead to pass through the subject riffles was evaluated using passage criteria developed by Thompson (1972). Adult steelhead are expected to be able to migrate through stream habitats with water depths greater than 0.6 foot over 25 percent of the wetted channel width, 10 percent of which must be contiguous, and have mean water velocities of less than 8 feet per second (fps). The Thompson criterion for steelhead migration at riffles was selected because it is a conservative and protective standard for riffle passage criteria.

Although most steelhead die after spawning, a significant number do not. As much as 20 to 30 percent of an annual steelhead run may be composed of repeat spawners (Shapovalov, 1953; Shapovalov and Taft, 1954). Steelhead that survive spawning typically emigrate to the ocean before returning to spawn again. Therefore, an additional consideration for adult passage is the surviving steelhead spawner downstream migration period, which is reported to be mostly completed prior to the end of May, but may continue through June in some years (Gunther et al., 2000). The Thompson (1972) riffle passage criteria are not specific to upstream or downstream migration, and are assumed to be conservative for estimating flows necessary for adult steelhead emigration.

Juvenile steelhead emigration naturally occurs simultaneously with the smoltification process when physiological changes occur that adapt the juvenile fish to life in the ocean. In the Alameda Creek Watershed, emigrating steelhead smolts are expected to migrate downstream between March and June, with older fish (ages 2 and 3 years) generally migrating earlier (March and April) and younger fish (age 1 year) migrating later (May and June) (Gunther et al., 2000). Passage criteria for juvenile steelhead primarily depend on the connectivity of stream habitats. Water depths equal to or greater than 0.5 foot are reported to provide sufficient physical passage for juvenile salmonids[2] (NMFS, 2001).

3.3 DATA ANALYSIS

3.3.1 DEVELOPMENT OF RATING CURVES

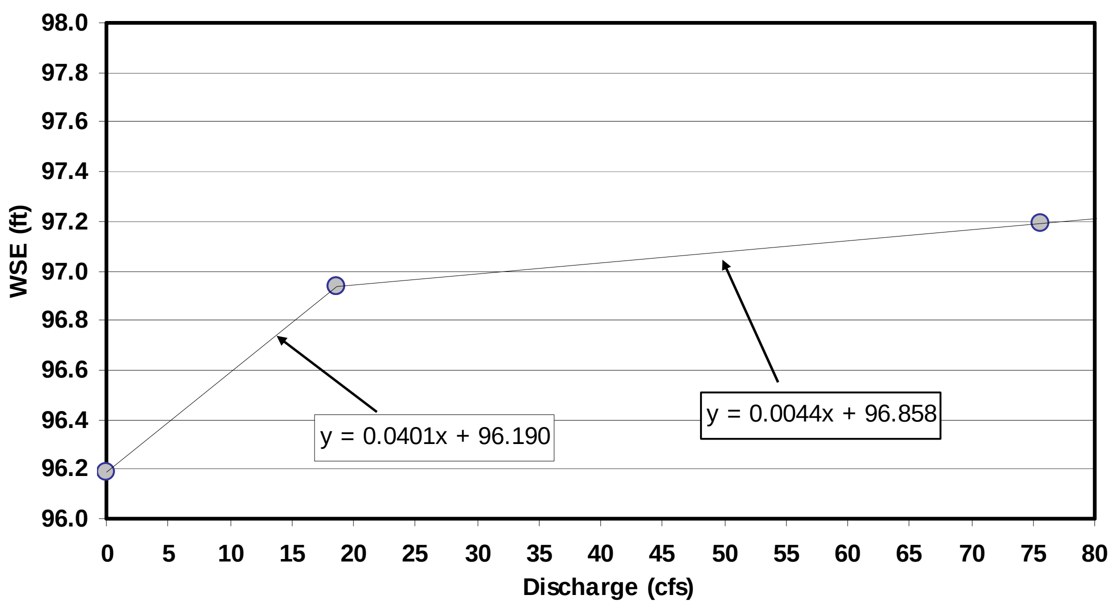
Rating curves (stage-versus-discharge relationships) were developed for each subject riffle using depth and velocity measurements collected in the field (Section 3.1). Flows were then calculated from the field measurements. The rating curves were based on the combined flow calculation and water surface elevation during representative flow events for each subject riffle location. Minimum channel elevations were assumed to correspond to a surface flow of 0 cfs.

[2] CDFG depth criterion for juvenile salmonid passage through culverts/at other stream crossings is 0.3 foot (CDFG, 2003), but the more conservative NMFS criterion is used in the analysis presented here.

Rating curves developed for transects surveyed in 2004 were based on up to three flow conditions, when flow releases from Calaveras Dam were 21 cfs, 41 cfs, and 100 cfs, respectively (Entrix, 2004), with the intent of bracketing flows meeting the minimum criteria for passage (Table 3-1). Rating curves developed for transects surveyed in 2006 were based on one flow condition (data presented in Section 4, Results) and the assumed no-flow condition. While the intent of the 2006 surveys was to bracket flows meeting criteria for passage, reservoir drawdown and subsequent abrupt cessation of flows during the 2006 water year limited opportunities to collect additional relevant measurements during the period of field work.

Flow and water surface elevation data were plotted on the *x* and *y* axes of graphs, and linear trend lines were developed to represent the relationships between points. For riffles surveyed in 2004, flow calculations were based on data provided by Entrix from subject riffles and from upstream and downstream locations during the two higher flow conditions (Calaveras Dam releases of 41 cfs and 100 cfs). Pressure transducers were used to establish temporary gages at the upstream and downstream locations, while flow at the riffles themselves was calculated from depth and velocity measurements collected along the riffle cross sections (Entrix, 2004). These flows were averaged prior to development of the rating curves. For the lower flow condition (Calaveras Dam releases of 21 cfs), flows were calculated from data measured at upstream and downstream sites only. For riffles surveyed in 2006, flows were calculated from depth and velocity measurements collected at subject riffles alone. Where only one measurement was collected at relatively low flow, the trend line was extrapolated from the assumed no-flow condition through the field-measured data point to estimate flow that would meet passage criteria.

Figure 3-1 shows an example stage-versus-discharge relationship, similar to those developed for the subject riffles. Linear trend lines with their respective mathematical formula are shown in black with the data points taken from Table 3-1 shown as gray circles. After development, each rating curve was used to estimate the minimum flows required to meet specific depth criteria for juvenile and adult passage.



Note: The stage shown in this figure and all other rating curves in this memorandum were measured relative to an independent datum established in the field at each individual riffle, and are not comparable among riffles.

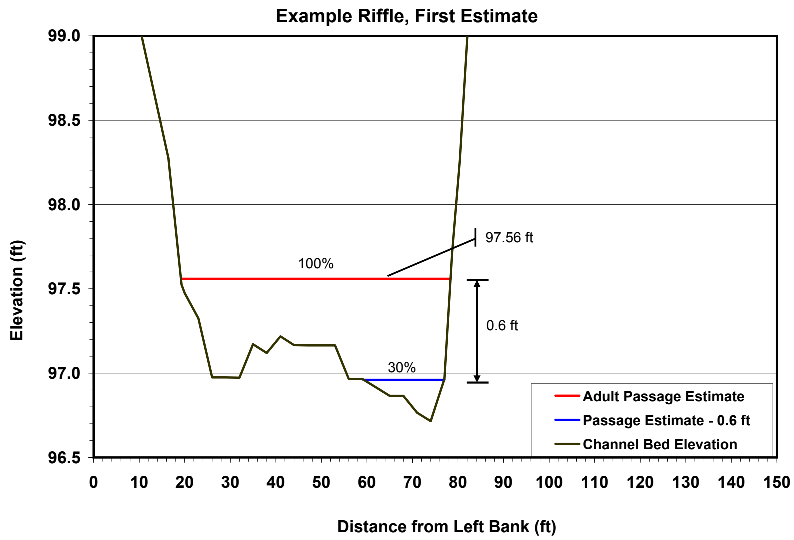
Figure 3-1 Example Stage versus Discharge (Rating Curve) Relationship Developed from Available Flow Measurements

3.3.2 ESTIMATION OF PASSAGE FLOW

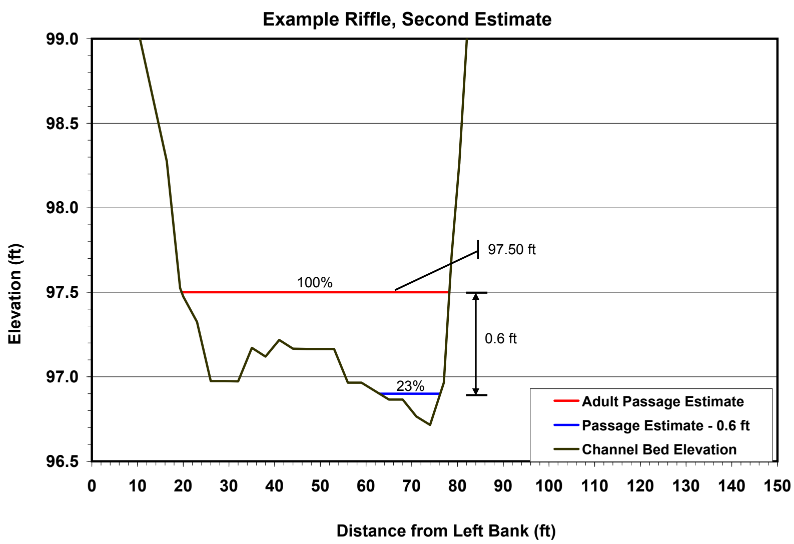
Using the criteria described in Section 3.2, the subject riffle cross sections were evaluated to estimate the minimum water surface elevation (WSE) that would be sufficient to provide passage for adult (immigration and emigration) and juvenile (emigration) steelhead migration. The WSE that met these criteria (passage WSE) was calculated separately for adult and juvenile migration at each riffle.

Juvenile passage WSE was calculated from the channel bed to provide a minimum water depth of no less than 0.5 foot, while adult passage WSE estimates were calculated using an iterative process. An initial value for the adult passage WSE was estimated based on channel bed geometry. The channel width was calculated at both the estimated passage WSE elevation and at an elevation 0.6 foot below the estimate (Figure 3-2, part a). The lower channel width was divided by the width at the estimated passage WSE, to calculate the percentage of the total wetted channel width that would be greater than or equal to 0.6 foot deep at that WSE. This percentage was then compared to the Thompson (1972) criteria. If the lower channel width was not 25 percent of the wetted channel width, the passage WSE estimate was revised and evaluated again (Figure 3-2, part b). Calculations were repeated for WSE estimates with increments up to one-hundredth of a foot (0.01 foot), until the 25 percent criterion was achieved (Figure 3-2, part c). Finally, a check was performed to ensure that at least 10 percent of the channel portion meeting the 0.6-foot depth criterion was contiguous.

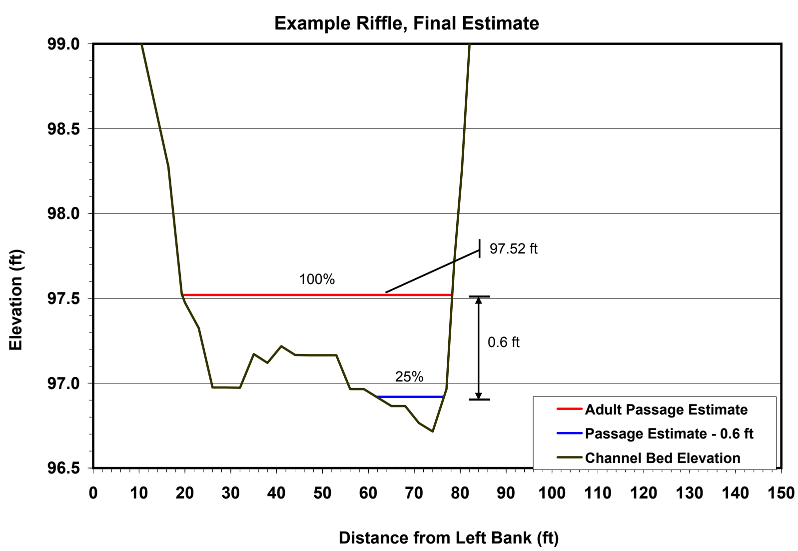
(a)



(b)



(c)



Example of an Estimate of Adult Passage Water Surface Elevation

Assessment of Fish Migration at Riffles in Sunol Valley Quarry Reach of Alameda Creek

February 2010

Figure 3-2

Minimum flows to achieve the passage WSE were estimated from the rating curves described in Section 3.3.1 using a combination of linear interpolation and linear extrapolation. Interpolation was used in the analysis of the riffles surveyed in 2004, where the channel was surveyed during multiple flow conditions and the observed flows encompass or surpass the flows which would meet the criteria for passage. The interpolation was based on the straight line function connecting two known values on the rating curve for that cross section (WSE plotted against flow), which was then used to calculate the flow value corresponding to the passage WSE. It was assumed that the WSE would be equivalent to the channel invert when flow was equal to 0, and that point was included in the rating curve and used in the interpolation in cases where the passage WSE was below any observed in the field. Figure 3-3 provides an example of how each passage flow was calculated from the estimated passage WSE using the rating curves for each riffle. The trend line is shown as a thin black line where the red and blue dashed lines show how linear interpolation was used to calculate the resulting minimum flow estimate.

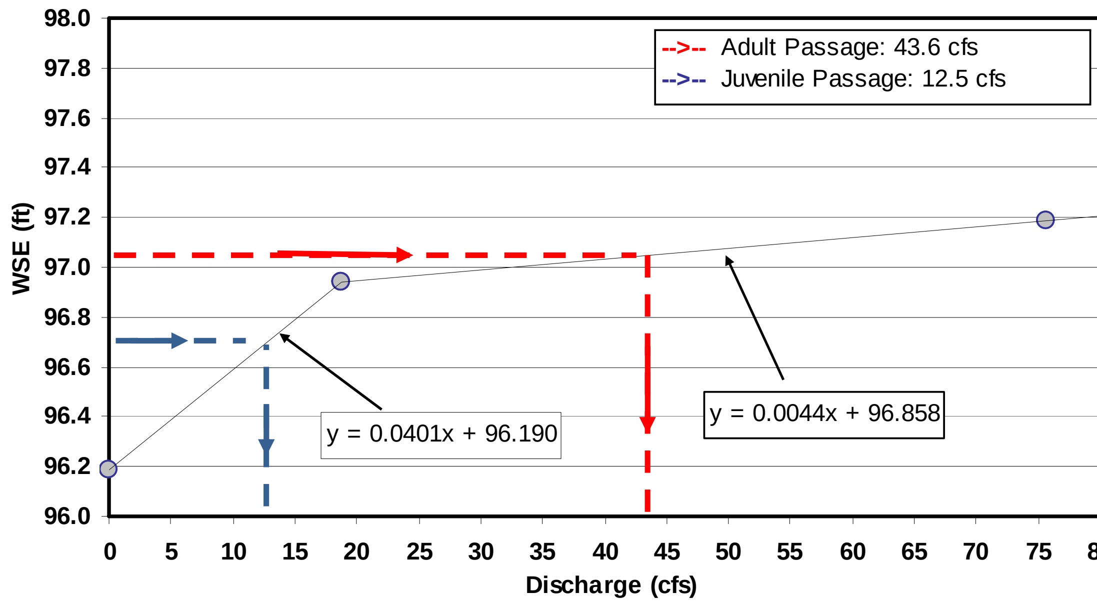


Figure 3-3 Minimum Flow Calculations for Adult and Juvenile Passage at a Hypothetical Riffle Location

For the riffles surveyed in 2006, the single field observation was typically made at flows less than those that would meet the passage criteria. Linear interpolation was not possible in those cases, so passage flows were estimated based on linear extrapolation of a function relating the observed flow and WSE to the assumed condition of a WSE equivalent to the channel invert when flow was equal to 0.

Due to limitations on precision of the cross section measurements and flow estimates as well as the interpolation and extrapolation methods used, all estimated passage flows were reported as the next whole integer in terms of cubic feet per second (for example, 1.1 cfs was reported as 2 cfs). Rounding up the analysis results was appropriate given the limitations of the data.

Based on this analysis, the subject riffles with width-to-depth ratios most sensitive to decreases in stream discharge were identified. The subject riffles with the highest flow requirements to meet the passage criteria for adult and juvenile migration were identified as the critical riffles in this memorandum.

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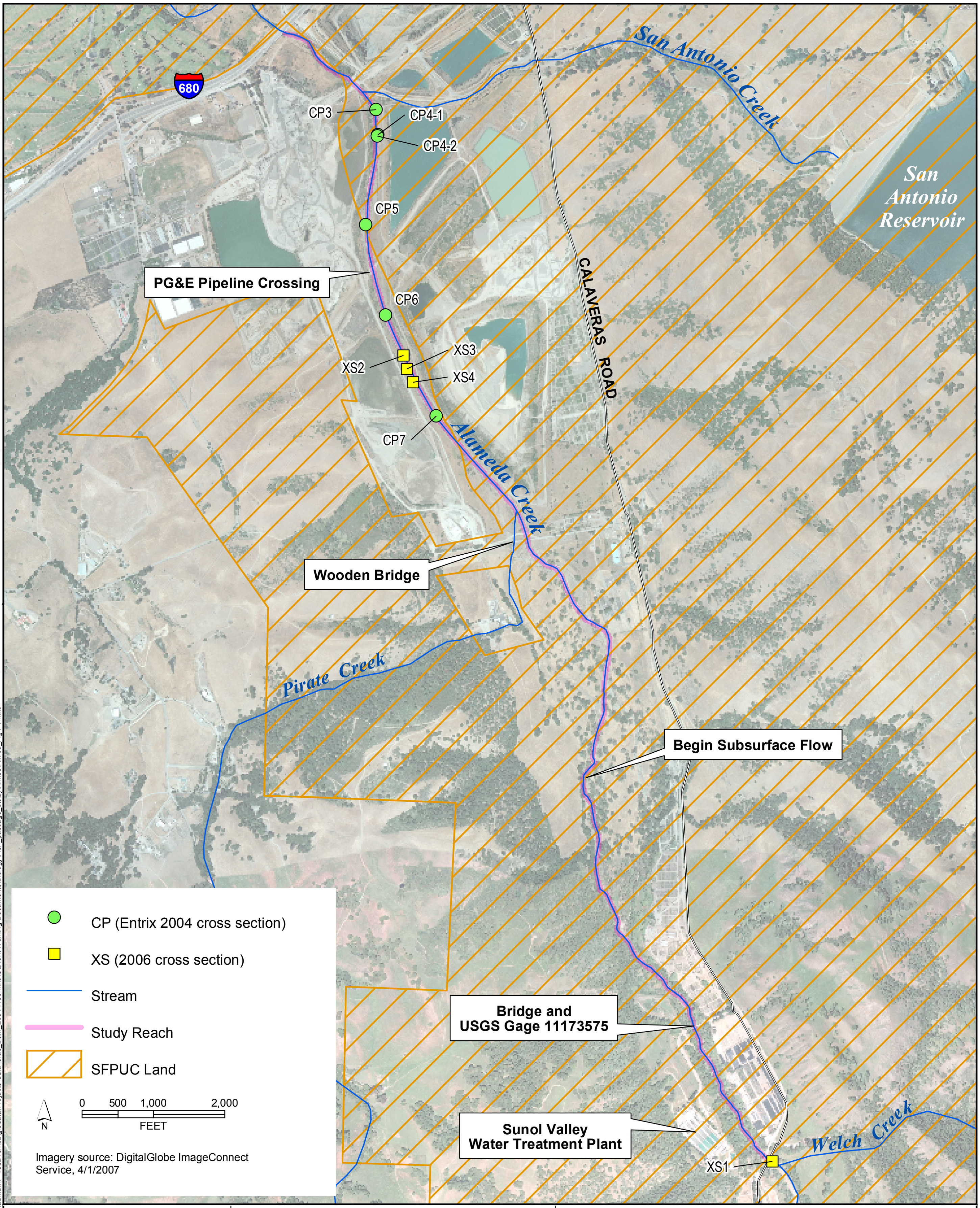


Approximate Cross Section Locations

Assessment of Fish Migration at Riffles in Sunol Valley Quarry Reach of Alameda Creek

February 2010

Figure 4-1

4 RESULTS

Four riffles with potential to limit future steelhead migration were surveyed in 2006 (referred to here as riffles XS1 through XS4). None of the riffles surveyed in 2004 (referred to here as CP3 through CP7) were re-surveyed in 2006. This section provides an overview of the 2006 survey observations, and presents the results and estimated passage flows from the analysis of the 2004 and 2006 subject riffles for both adult and juvenile steelhead.

4.1 2006 SURVEY OBSERVATIONS

Daily average flow recorded on July 11, 2006 at the USGS gage downstream of Welch Creek (11173575) was 2.7 cfs (Figure 4-1). The survey began at the upstream extent of the study area, directly above where Calaveras Road crosses Alameda Creek. A short, high-gradient, and relatively unconfined section of channel above that crossing was identified as a potential migration-limiting riffle (Figure 4-2) (and surveyed, as described in Section 4.2). About 300 feet downstream of the Calaveras Road crossing, another shallow riffle was identified, and it was noted that flow sufficient to make the riffle above the crossing passable would also make the riffle below the crossing passable. Therefore, the downstream riffle was not surveyed.

Figure 4-2 Riffle just Upstream of where Calaveras Road Crosses Alameda Creek (XS1)

Farther downstream, the channel became more confined. Between riffle XS1 and the area of subsurface flow shown on Figure 4-1, the study reach was characterized by a mostly confined channel with minor flow accretion and substrates composed primarily of small cobbles, sand, and silt. Few locations were identified as potential migration-limiting riffles, with two exceptions. One exception was a broad section of flat channel underneath the bridge near the Sunol Valley Water Treatment Plant (Figure 4-3). The field team noted that flows greater than those observed would be necessary to make this riffle passable. At a second location approximately 0.5 mile downstream of the bridge (Figure 4-4), it was noted that the channel was approximately twice the width of previously noted riffles, and the maximum water depth at the observed flow was less than 0.1 foot. These riffles may warrant further study.

Figure 4-3 Riffle at the Bridge over Alameda Creek near the Sunol Valley Water Treatment Plant

Figure 4-4 Riffle Approximately 0.5 mile Downstream of the Bridge Near the Sunol Valley Water Treatment Plant

At the downstream end of this relatively confined reach, approximately 1 mile downstream of riffle XS1 (Figure 4-1), flow disappeared beneath the surface of the stream bed (Figure 4-5). Downstream from where flow went subsurface, the stream channel was less confined as it cut through the alluvial fan on the Sunol Valley floor, and was characterized by interbedded gravel, sand, silt, and clay beds. Within the dry section of the creek, two concrete grade control structures with potential to limit fish migration at low flows were noted, both in the vicinity of a wooden bridge over Alameda Creek (Figure 4-6). In both cases, when the creek is flowing the pools abutting these structures are expected to fill with water. Shallow flow across the top of the structures may be more limiting to fish migration than the drop on the downstream side of the structures.

Figure 4-5 Subsurface Flow Location on Alameda Creek

Concrete Structures With Potential to Limit Migration at Low Flows

Assessment of Fish Migration at Riffles in Sunol Valley Quarry Reach of Alameda Creek

February 2010 Figure 4-6

Farther downstream, the channel remained dry to a point upstream of riffle XS4, where it was re-watered by discharge from one of the quarry ponds. The rate of discharge was not measured, but based on visual interpretation was estimated to be approximately 1 to 3 cfs. Downstream of the quarry discharge, adjacent to the quarry operations and upstream of the PG&E pipeline concrete apron, three riffles with the potential to limit migration were observed. The channel cross-section profiles of riffles XS4, XS3, and XS2 were surveyed. The locations of the riffle transects surveyed are illustrated on Figure 4-1. The typical channel conditions in this reach are shown on Figure 4-7.

Figure 4-7 Typical Channel Geomorphology in the Vicinity of Riffles XS4, XS3, and XS2

4.2 STEELHEAD MIGRATION FLOWS

In this section the criteria described in Section 3.2 are applied to the 10 subject riffles (those surveyed in 2004 by Entrix and by HDR|SWRI in 2006) to estimate the minimum flow expected to allow for adult and juvenile steelhead passage. Riffles were assumed to be passable for adult steelhead when depths greater than 0.6 foot occur over 25 percent of the wetted channel width, 10 percent of which must be contiguous (Thompson, 1972). The mean water velocity criterion of flows less than 8 fps (Section 3.2) is not likely to be a limiting factor at flows approximating the minimum depth criteria, given the very low-gradient reaches in the study area and the fact that even during the highest flows that Entrix (2004) measured (i.e., 74 cfs), water velocities did not exceed 8 fps. Therefore, the velocity criterion was not relevant to this analysis of minimum passage flows.

Table 4-1 lists the subject riffles in the order of upstream to downstream, and corresponding estimated minimum passage flows. A summary of field data collected during the 2006 surveys used in the rating curves from which the estimates were developed is presented in Table 4-2 (see Section 3.3.1 for presentation of data collected by Entrix [2004] used to develop rating curves for CP riffle cross sections). This section presents riffle cross-section data and analyses from the upstream study boundary sequentially to the downstream study boundary, expanding on the results summarized in Table 4-1.

Table 4-1
Estimated Minimum Flows to Support Steelhead Migration

Riffle	Estimated Flow for Adult Passage (cfs)	Estimated Flow for Juvenile Passage (cfs)
XS1	3	2
CP7	16	9
XS4	9	7
XS3	8	6
XS2	1	1
CP6	9	6
CP5	44	13
CP4-2	41	11
CP4-1	23	13
CP3	11	8

Notes:

These flow estimates assume no physical change in SVQR; see Section 2.3 for planned actions.

Estimates have been rounded to the next greatest whole number (see Section 3.3.2).

Table 4-2
Summary of Flow Data Used to Develop Stage versus Discharge Relationships at Subject Riffles Surveyed in 2006

Riffle	Discharge (cfs)	Stage[1] (feet)
XS1	0	96.89
	2.1	97.83
XS4	0	99.56
	2.6	99.77
XS3	0	99.62
	3.9	99.97
XS2	0	98.81
	0.8	99.68

[1]Stage was measured relative to an independent datum established at each individual riffle, and is not comparable among riffles.

4.2.1 RIFFLE XS1

The riffle identified as XS1 is located at the upstream extent of the study area, near where Calaveras Road crosses Alameda Creek (Figure 4-1). This location was identified as a potential migration-limiting riffle by HDR|SWRI field surveys. Based on the 2006 cross-sectional survey and the criteria described in Section 3.2, the minimum passage WSE for steelhead at riffle XS1 was estimated at 98.06 feet for adults and 97.39 feet for juveniles (Figure 4-8). Using the rating curve developed from the field data (Table 4-2), minimum flows to achieve the passage WSEs were estimated to be approximately 3 cfs and 2 cfs (rounded up to the next integer, as described in Section 3.3.2) for adult and juvenile steelhead, respectively (Figure 4-9).

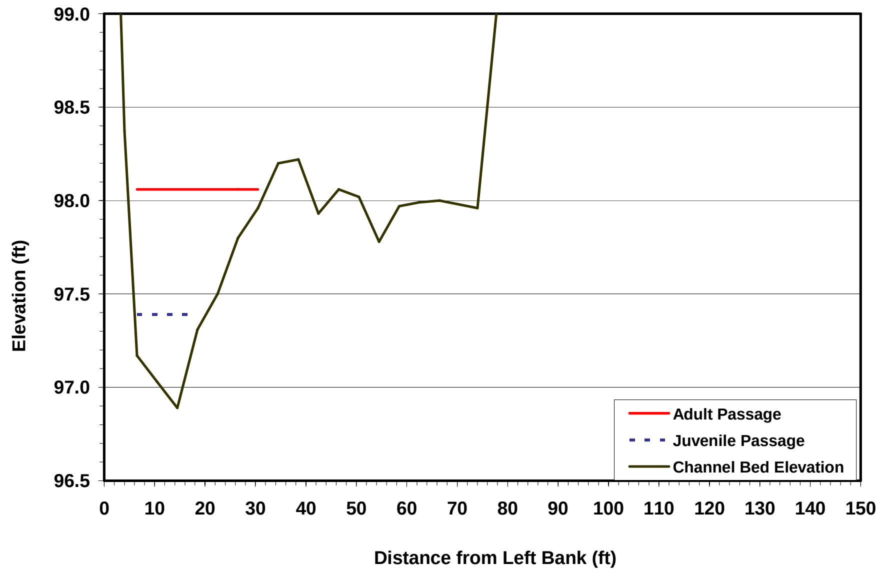


Figure 4-8 Passage Water Surface Elevations at Riffle XS1

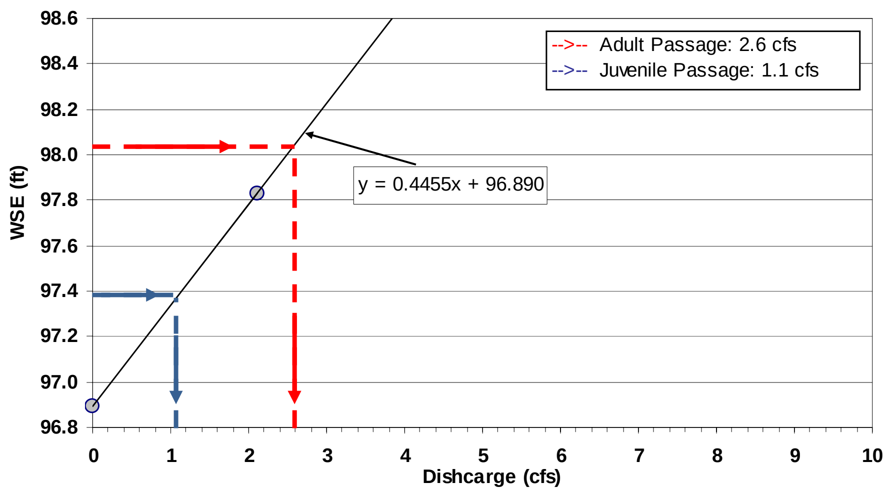
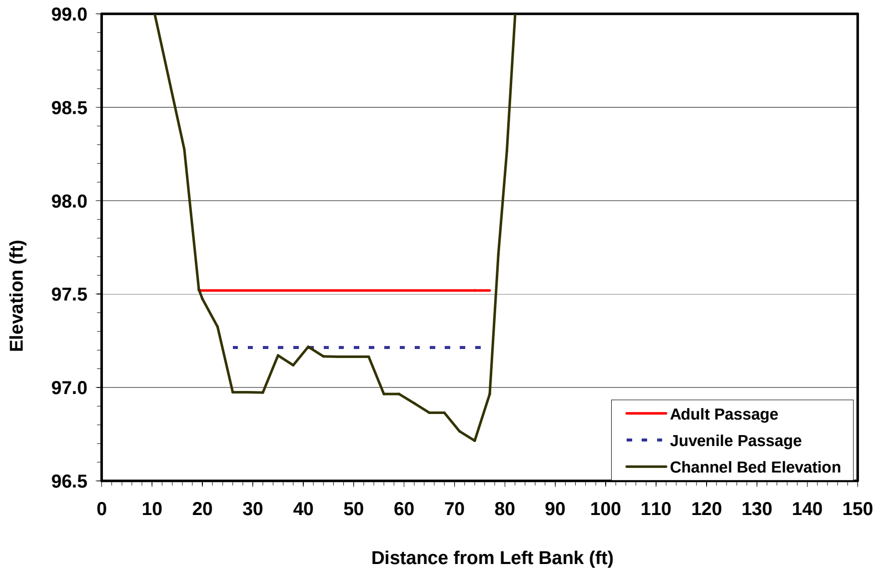


Figure 4-9 Stage-Discharge Relationship for Riffle XS1

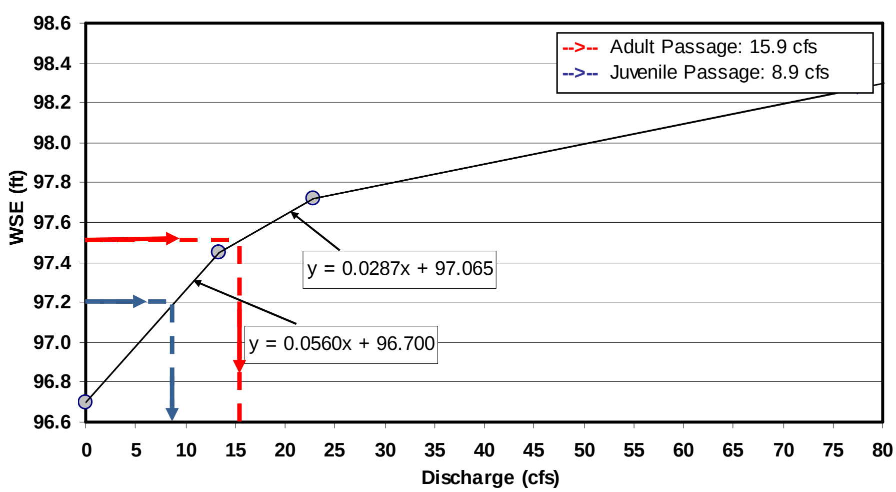
4.2.2 RIFFLE CP7

Riffle CP7 is approximately 2.2 miles downstream of riffle XS1 and approximately 0.4 mile upstream of the PG&E crossing (Figure 4-1). Based on the Entrix (2004) cross-sectional survey and the criteria described in Section 3.2, the minimum passage WSE for steelhead at riffle CP7 was estimated at 97.52 feet for adults and 97.20 feet for juveniles (Figure 4-10). Using the rating curve developed from the Entrix data (Table 3-1), the minimum flow to achieve the passage WSE was estimated to be approximately 16 cfs and 9 cfs for adult and juvenile steelhead, respectively (Figure 4-11).



Note: Channel bed elevation data source is Entrix (2004) and Taylor, pers. comm. (2006).

Figure 4-10 Passage Water Surface Elevations at Riffle CP7



Note: Stage-discharge data source is Entrix (2004) and Taylor, pers. comm. (2006).

Figure 4-11 Stage-Discharge Relationship for Riffle CP7

4.2.3 RIFFLE XS4

Riffle XS4 is approximately 600 feet downstream of riffle CP7 and approximately 1,700 feet upstream of the PG&E crossing (Figure 4-1). Based on the 2006 cross-sectional survey and the criteria described in Section 3.2, the minimum passage WSE for steelhead at riffle XS4 was estimated at 100.21 feet for adults and 100.06 feet for juveniles (Figure 4-12). Using the rating curve developed from the field data (Table 4-2), the minimum flow to achieve the passage WSEs was estimated to be approximately 9 cfs and 7 cfs for adult and juvenile steelhead, respectively (Figure 4-13).

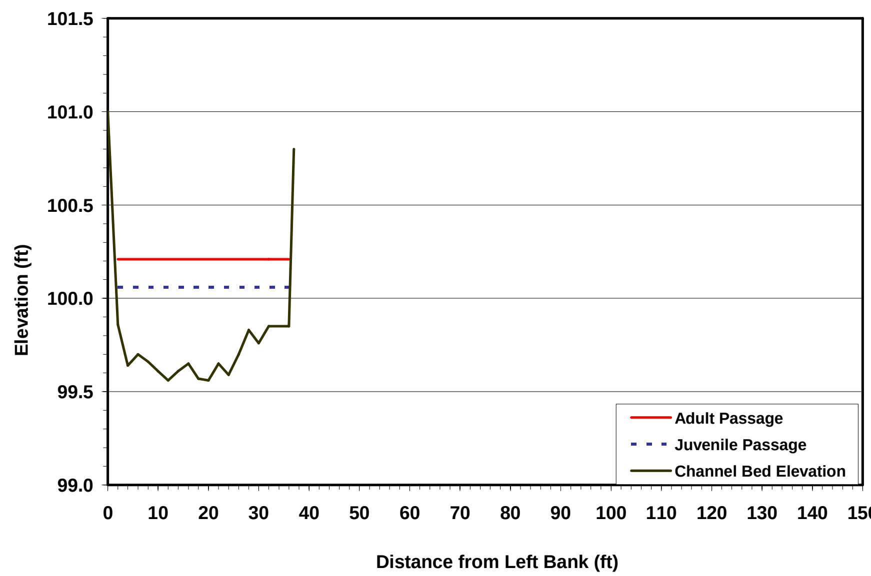


Figure 4-12 Passage Water Surface Elevations at Riffle XS4

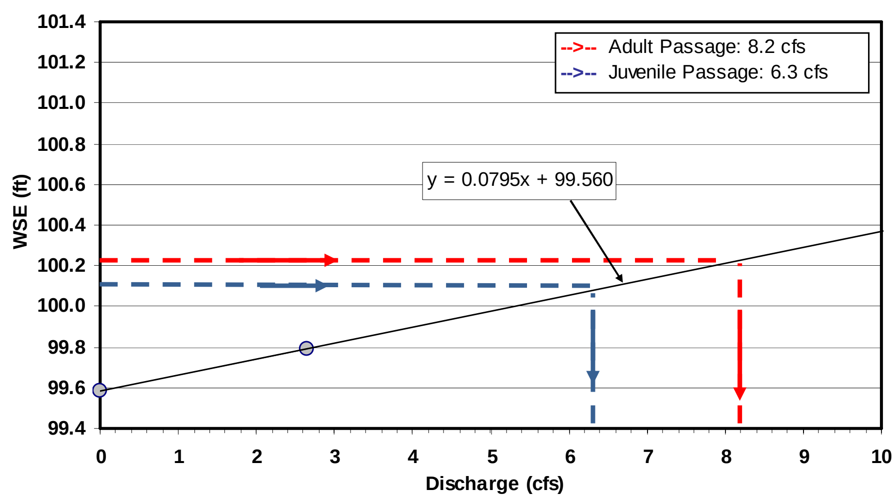


Figure 4-13 Stage-Discharge Relationship for Riffle XS4

4.2.4 RIFFLE XS3

Riffle XS3 is approximately 200 feet downstream of riffle XS4 and approximately 1,500 feet upstream of the PG&E Crossing (Figure 4-1). Based on the 2006 cross-sectional survey and the criteria described in Section 3.2, the minimum passage WSE for steelhead at riffle XS3 was estimated at 100.27 feet for adults and 100.12 feet for juveniles (Figure 4-14). Using the rating curve developed from the field data (Table 4-2), the minimum flow to achieve the passage WSE was estimated to be approximately 8 cfs and 6 cfs for adult and juvenile steelhead, respectively (Figure 4-15).

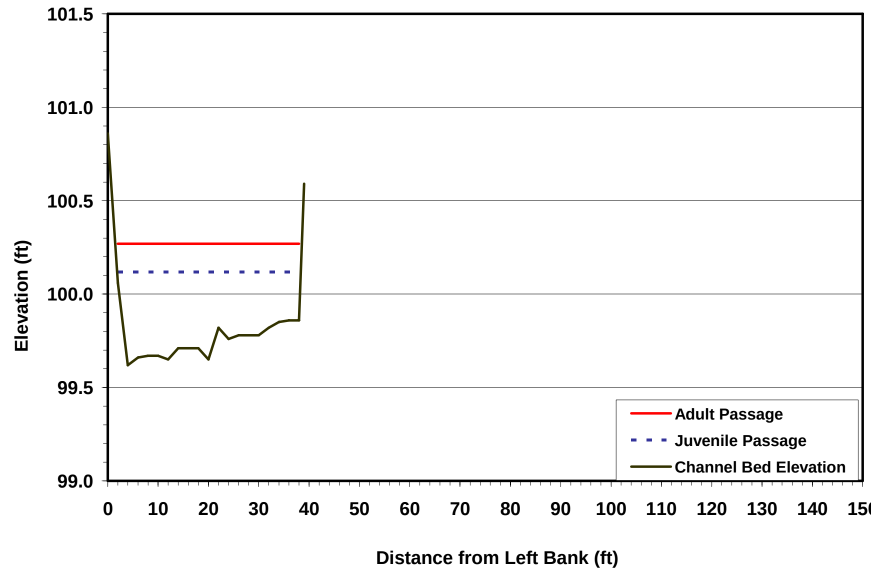


Figure 4-14 Passage Water Surface Elevations at Riffle XS3

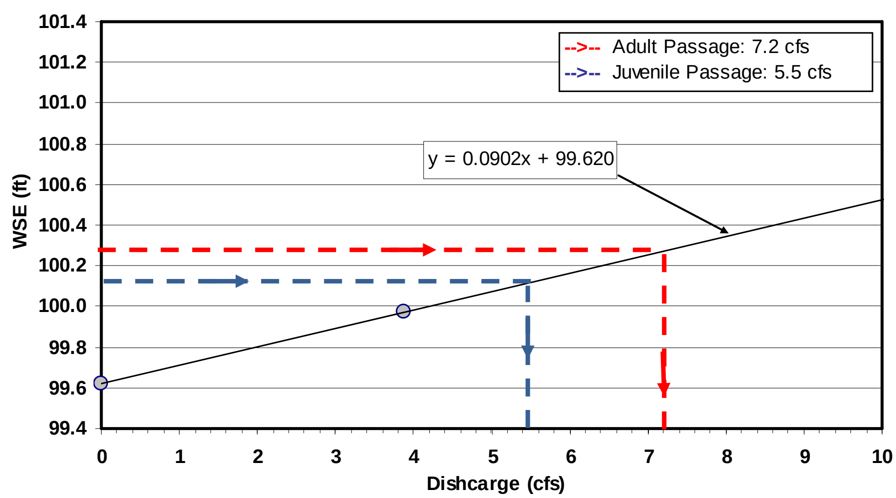


Figure 4-15 Stage Discharge Relationship for Riffle XS3

4.2.5 RIFFLE XS2

Riffle XS2 is approximately 200 feet downstream of riffle XS3 and approximately 1,300 feet upstream of the PG&E crossing (Figure 4-1). Based on the 2006 cross-sectional survey and the criteria described in Section 3.2, the minimum passage WSE for steelhead at riffle XS2 was estimated at 99.55 feet for adults and 99.31 feet for juveniles (Figure 4-16). Using the rating curve developed from the field data (Table 4-2), the minimum flow to achieve the passage WSE was estimated to be approximately 1 cfs for both adult and juvenile steelhead (Figure 4-17), and the riffle would have been passable at the time of the field survey.

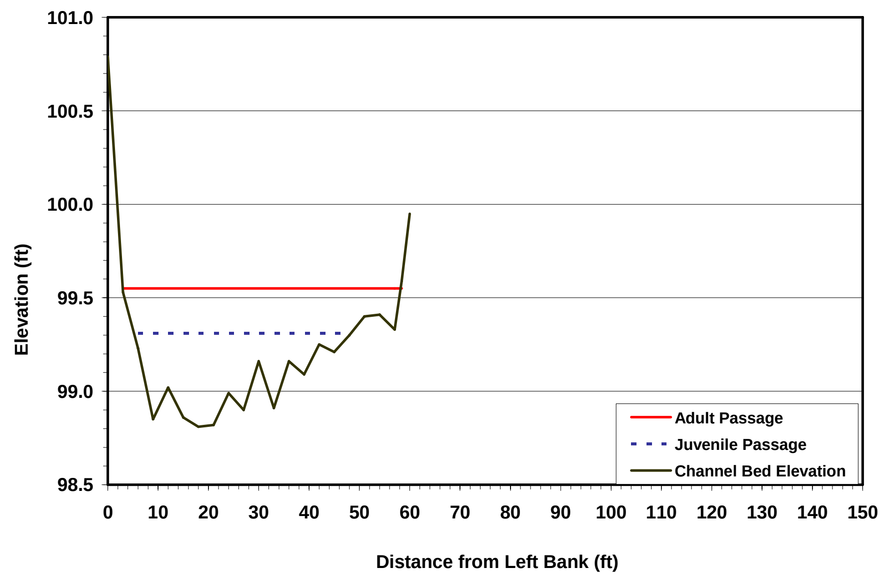


Figure 4-16 Passage Water Surface Elevations at Riffle XS2

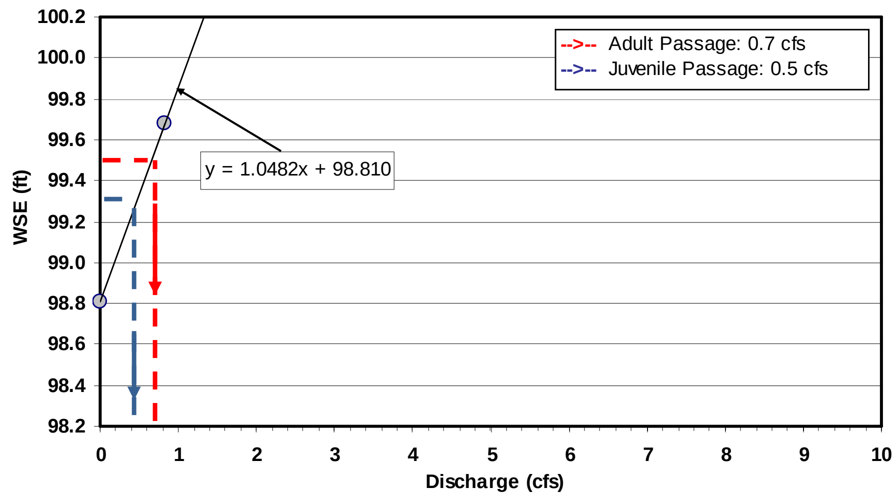
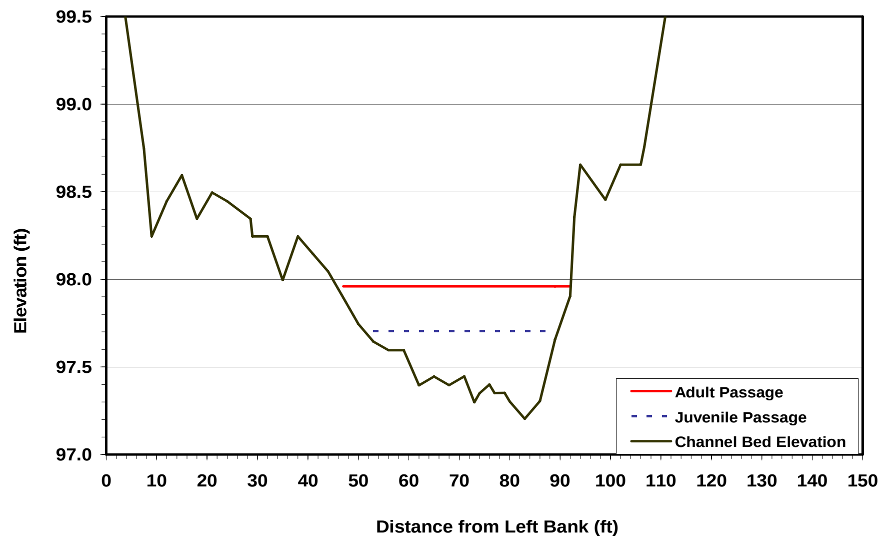


Figure 4-17 Stage Discharge Relationship for Riffle XS2

The accuracy of the flow calculation, or instantaneous discharge for riffle XS2 may be reduced relative to other cross sections, due to extremely low water velocities at this site during the survey. Additionally, since the velocities were so low and the water depth of the cross section was proportionally high compared to other subject riffles, this stream channel segment may be more appropriately described as a run than as a riffle. As such, the water depth and therefore the passability of this channel segment may depend more on groundwater or local hydraulics than on flows. As long as the localized conditions creating this run are persistent, then this location is expected to affect steelhead migration less than other subject riffles.

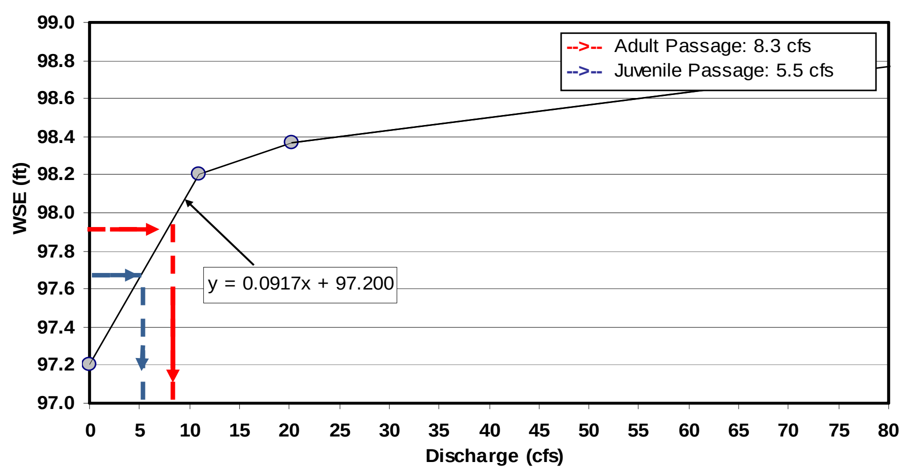
4.2.6 RIFFLE CP6

Riffle CP6 is located approximately 600 feet downstream of riffle XS2 and 700 feet upstream of the PG&E crossing (Figure 4-1). Based on the Entrix (2004) cross-sectional survey and the criteria described in Section 3.2, the minimum passage WSE for steelhead at riffle CP6 was estimated at 97.96 feet for adults and 97.70 feet for juveniles (Figure 4-18). Using the rating curve developed from the Entrix data (Table 3-1), the minimum flow to achieve the passage WSE was estimated to be approximately 9 cfs and 6 cfs for adult and juvenile steelhead, respectively (Figure 4-19).



Note: Channel bed elevation data source is Entrix (2004) and Taylor, pers. comm. (2006).

Figure 4-18 Passage Water Surface Elevations at Riffle CP6



Note: Stage-discharge data source is Entrix (2004) and Taylor, pers. comm. (2006).

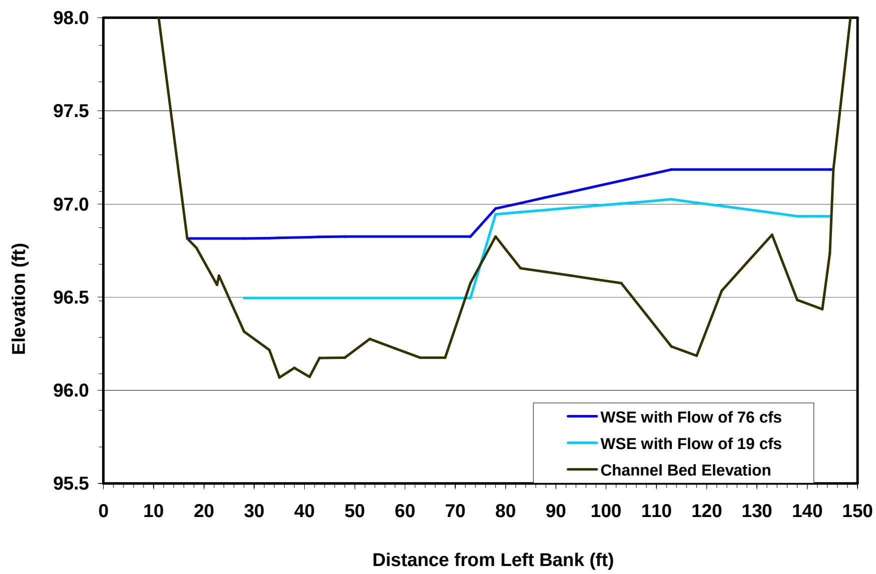
Figure 4-19 Stage-Discharge Relationship for Riffle CP6

4.2.7 RIFFLE CP5

Riffle CP5 is approximately 1,300 feet downstream of riffle CP6 and approximately 3,300 feet upstream of I-680 (Figure 4-1). The left and right sides of the channel were distinguished by a lateral change in bed elevation and presence of a shallow, potentially transitory, medial bar at approximately 80 feet from the left bank (see Section 5). The water surface elevation measurements collected (Entrix, 2004) indicate that the left side of the channel was hydraulically separated from the right side of the channel at the lowest flow measured (9 cfs).

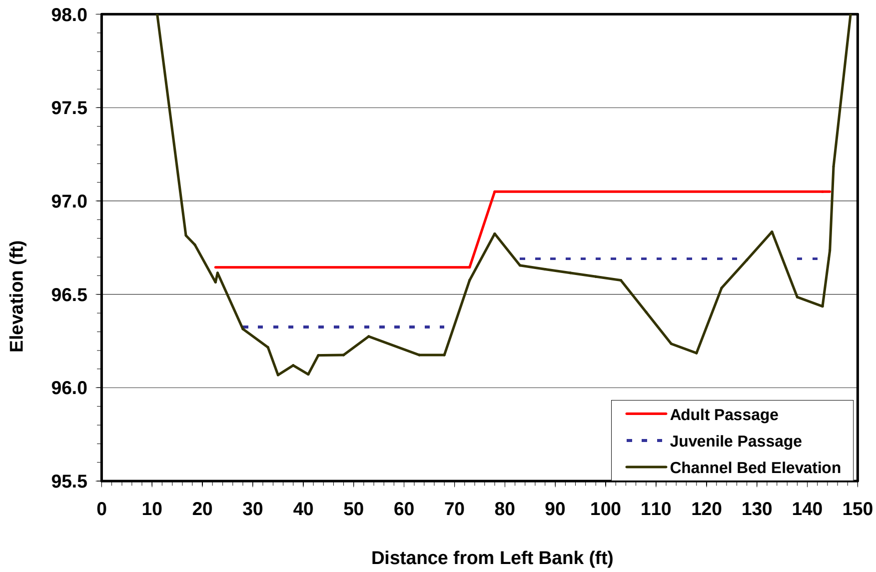
Though difficult to visualize when viewing the channel bed geometry at a single cross section, surface flow preferentially filled the right side of the channel to a greater depth before filling the left side (Figure 4-20). Therefore, at lower flows, passage criteria are expected to be met in the right channel before the left. Based on these observations, and the assumption that steelhead would migrate through whichever of the two channels met passage criteria first, regardless of conditions in the other, the right channel was used to estimate the minimum WSE necessary to facilitate fish passage.

Based on the criteria described in Section 3.2, the minimum passage WSE for steelhead in the right channel at riffle CP5 was estimated at 97.1 feet for adults and approximately 96.7 feet for juveniles (Figure 4-21). As evidenced by the Entrix survey data, limited hydraulic connectivity between the right and left channels at CP5 resulted in the two sides of the channel responding differently to changes in flow (Figure 4-20). Using the right-side rating curve developed from the Entrix data, minimum flow to achieve the passage WSE in the right channel was estimated to be approximately 44 cfs and 13 cfs for adult and juvenile steelhead, respectively (Figure 4-22).



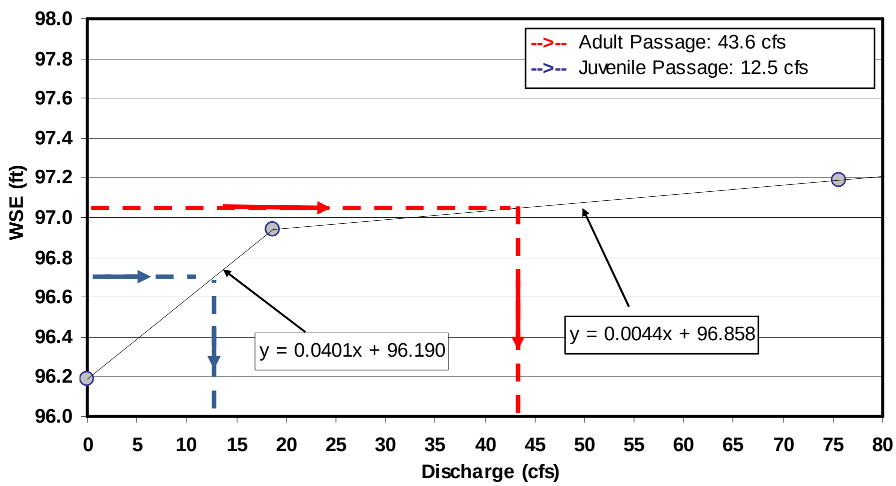
Note: Data source is Entrix (2004) and Taylor, pers. comm. (2006).

Figure 4-20 Observed Water Surface Elevations at Riffle CP5



Note: Channel bed elevation data source is Entrix (2004) and Taylor, pers. comm. (2006). Passage calculations are based on right channel, consistent with flow hydraulics at riffle.

Figure 4-21 Passage Water Surface Elevations at Riffle CP5

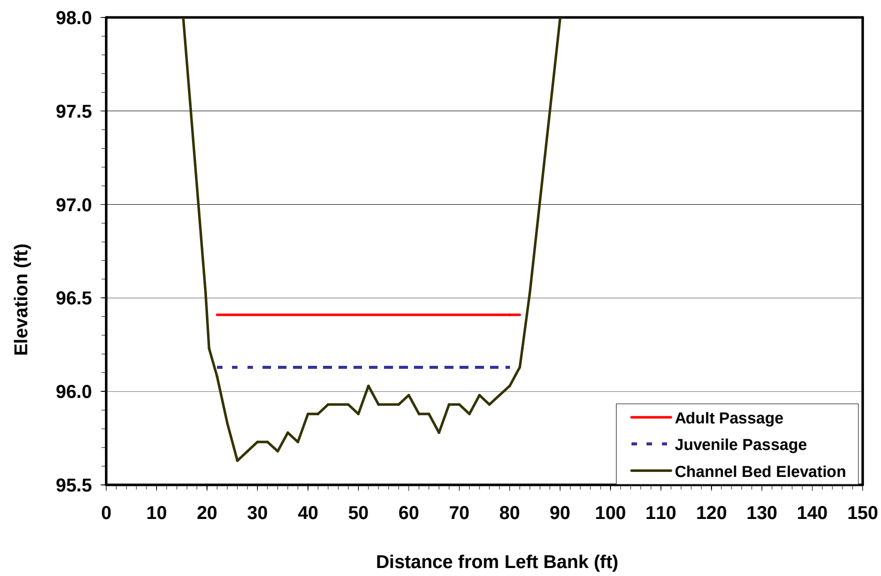


Note: Stage-discharge data source is Entrix (2004) and Taylor, pers. comm. (2006).

Figure 4-22 Stage-Discharge Relationship for the Right Side of Riffle CP5

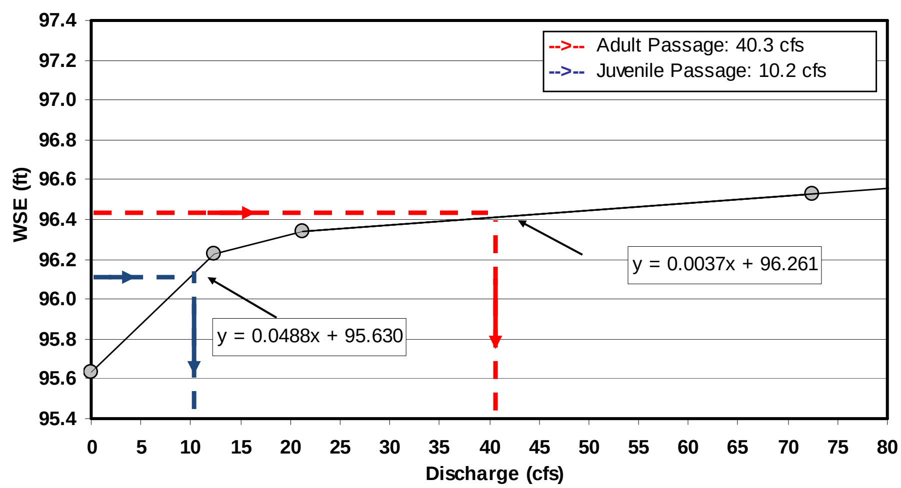
4.2.8 RIFFLE CP4-2

Riffle CP4-2 is approximately 1,200 feet downstream of riffle CP5 and approximately 2,100 feet upstream of I-680. Based on the Entrix (2004) cross-sectional survey and the criteria described in Section 3.2, the minimum passage WSE for steelhead at riffle CP4-2 was estimated at 96.41 feet for adults and 96.13 feet for juveniles (Figure 4-23). Using the rating curve developed from the Entrix data (Table 3-1), minimum flow to achieve the passage WSE was estimated to be approximately 41 cfs and 11 cfs for adult and juvenile steelhead, respectively (Figure 4-24).



Note: Channel bed elevation data source is Entrix (2004) and Taylor, pers. comm. (2006).

Figure 4-23 Passage Water Surface Elevations at Riffle CP4-2

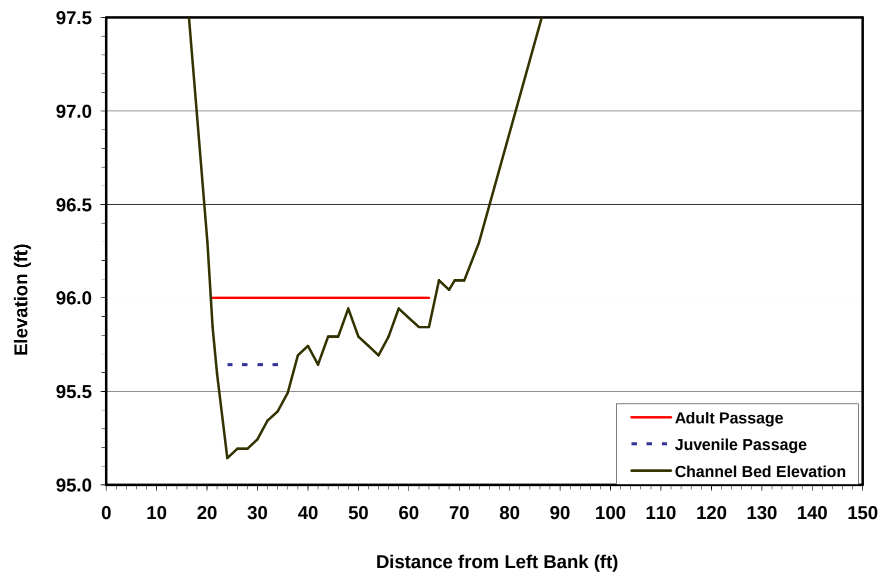


Note: Stage-discharge data source is Entrix (2004) and Taylor, pers. comm. (2006).

Figure 4-24 Stage-Discharge Relationship for Riffle CP4-2

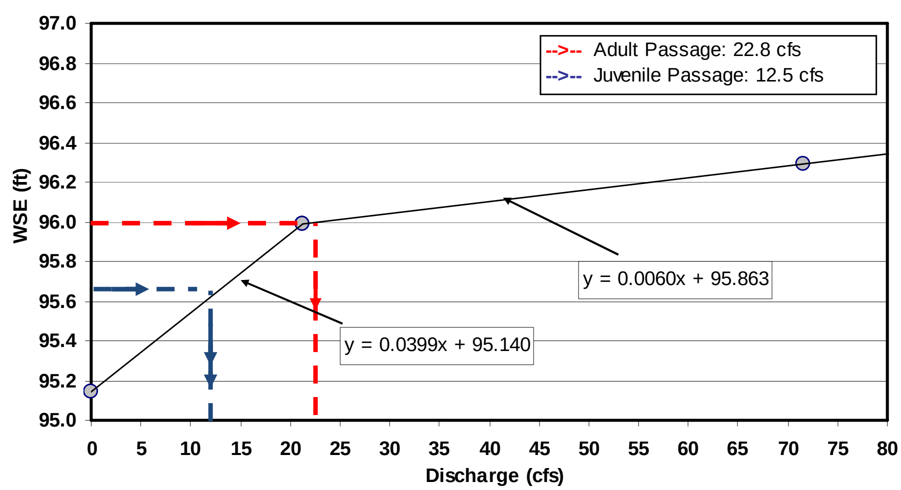
4.2.9 RIFFLE CP4-1

Riffle CP4-1 is approximately 20 feet downstream of riffle CP4-2 and approximately 2,100 feet upstream of I-680. Based on the Entrix (2004) cross-sectional survey and the criteria described in Section 3.2, the minimum passage WSE for steelhead at riffle CP4-1 was estimated at 96.00 feet for adults and 95.64 feet for juveniles (Figure 4-25). Using the rating curve developed from the Entrix data (Table 3-1), minimum flow to achieve the passage WSE was estimated to be approximately 23 cfs and 13 cfs for adult and juvenile steelhead, respectively (Figure 4-26).



Note: Channel bed elevation data source is Entrix (2004) and Taylor, pers. comm. (2006).

Figure 4-25 Passage Water Surface Elevations at Riffle CP4-1

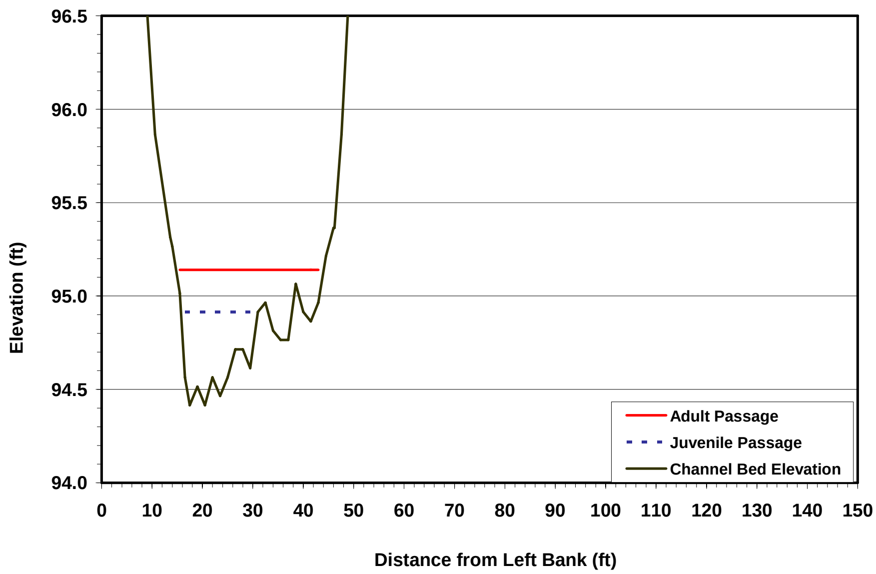


Note: Stage-discharge data source is Entrix (2004) and Taylor, pers. comm. (2006).

Figure 4-26 Stage-Discharge Relationship for Riffle CP4-1

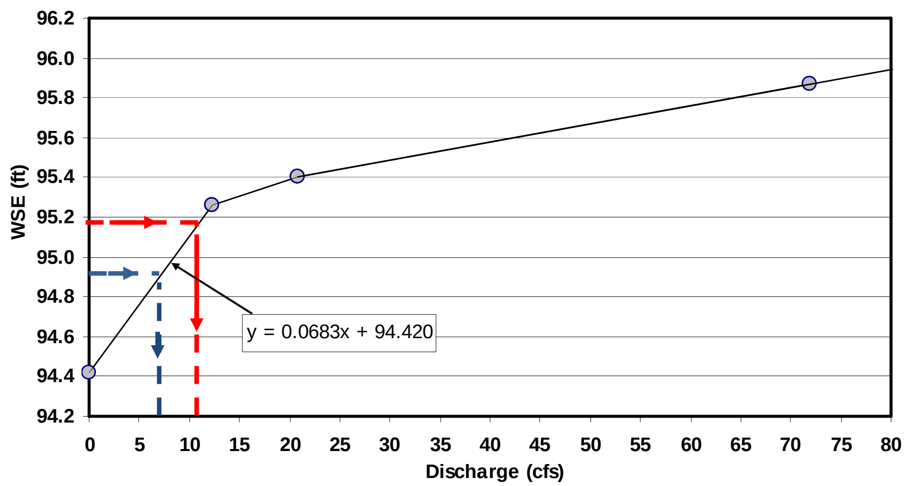
4.2.10 RIFFLE CP3

Riffle CP3, the most downstream of the sites reported on in this memorandum, is approximately 300 feet downstream of riffle CP4-1 and approximately 1,700 feet upstream of I-680. Based on the Entrix (2004) cross-sectional survey and the criteria described in Section 3.2, the minimum passage WSE for steelhead at riffle CP3 was estimated at approximately 95.14 feet for adults and 94.92 feet for juveniles (Figure 4-27). Using the rating curve developed from the Entrix data (Table 3-1), minimum flow to achieve the passage WSE was estimated to be approximately 11 cfs and 8 cfs for adult and juvenile steelhead, respectively (Figure 4-28).



Note: Channel bed elevation data source is Entrix (2004) and Taylor, pers. comm. (2006).

Figure 4-27 Passage Water Surface Elevations at Riffle CP3



Note: Stage-discharge data source is Entrix (2004) and Taylor, pers. comm. (2006).

Figure 4-28 Stage-Discharge Relationship for Riffle CP3

5 DISCUSSION

The information in this section includes a discussion of study findings, limitations, and presents the results in context with other studies and actions in SVQR.

Ten subject riffles were evaluated in Alameda Creek. Three riffles between the PG&E pipeline crossing and the confluence with San Antonio Creek (riffles CP5, CP4-2, and CP4-1 [Figure 4-1]) were found to be the most potentially limiting to future migrating steelhead (Section 4.2). These riffles had the highest passage flow estimates for both adult and juvenile migration (Table 4-1). Adult passage flow estimates at these three riffles ranged from 23 to 44 cfs, and juvenile passage flows at the same riffles ranged from 11 to 13 cfs. These values estimate instantaneous flow to provide physical passage at the subject riffles.

The highest estimated passage flow for adult migration was 44 cfs, at riffle CP5 (Section 4.2.7). Due to complex channel geometry, however, the riffle CP5 estimate may be less precise than estimated passage flows for the other CP riffles. Riffle CP5 is located in a braided channel segment with split flow between two channels, and it has the largest total cross-sectional area of all the subject riffles. The medial bar that split flow at CP5 and contributed to the high passage flow estimates at this riffle was likely a transitory feature, as the channel substrate in the study reach consists primarily of sand, gravel, and cobbles, and is expected to redistribute itself during high flows. The riffle was surveyed either at its hydraulic control point along the riffle crest, or just downstream. For these reasons, and due to the complex channel geometry, the passage flow predictions for that site are uncertain.

The second highest adult passage flow estimate was 41 cfs, at riffle CP4-2 (Section 4.2.8, Table 4-1). Although much greater than the third highest estimate, which was 23 cfs at riffle CP4-1, the relationship between riffles CP4-2 and CP4-1, as well as the relationship between stage and discharge at these two cross sections, warrants further discussion. Riffles CP4-2 and CP4-1 are approximately 20 feet apart, closer than any other subject riffles (Figure 4-1). Both surveyed cross sections were considered by the 2004 field team to be at the same riffle, but two cross sections were surveyed due to the complexity of the site (Entrix, 2004). Although the passage flow estimate for riffle CP4-2 (41 cfs) was approximately 1.8 times greater than that for riffle CP4-1 (23 cfs), the relationship between stage and discharge at the two cross sections were actually found to be quite similar.

Due to the relatively flat slope of rating curves for both cross sections at WSEs relevant to adult passage (Section 4.2, Figure 4-24 and Figure 4-26), small changes in WSE corresponded to large changes in discharge. For example, if the passage WSE at riffle CP4-2 had been 96.34 feet instead of 96.41 feet, a difference of only 0.07 foot, the passage flow estimate would be reduced from 41 cfs to 22 cfs, nearly equal to the passage flow estimate for riffle CP4-1. Similarly, if the passage WSE for riffle CP4-1 had been 96.10 feet instead of 96.00 feet, a difference of only 0.10 foot, the passage flow estimate would have been increased 17 cfs to 40 cfs, nearly equal to the passage flow estimate for riffle CP4-2. Notably, these differences in elevation (0.07 to 0.10 foot) are similar in magnitude to the margin of error that may be expected to occur during field survey data collection.

This example illustrates that riffles CP4-2 and CP4-1 were hydraulically similar, despite an 18 cfs difference in estimated passage flows, as would be expected for cross sections separated by only 20 feet. It also illustrates the sensitivity of the reported passage flows to passage WSEs. Small changes in the depth criteria used to estimate passage WSEs could result in large changes in passage flow estimates.

Given these observations, the results of this investigation should be interpreted cautiously. The highest passage flow estimates come from riffles with complex channel geometry, as may be expected for critical riffles. The complexity of the channel at these sites, in conjunction with the sensitivity of the passage flow estimates to the accuracy of the field measurements and assumptions underlying the passage criteria, suggest that small variations in the analytical methods employed could result in large differences in the resulting passage flow estimates. The most critical of the subject riffles analyzed in this memorandum may require flows on the order of 23 to 44 cfs for adult steelhead migration, and 11 to 13 cfs for juveniles. These flow estimates should not be considered absolute, but rather as an initial order-of-magnitude estimate that provides an indication of instream flows to facilitate migratory passage for steelhead through the Sunol Valley. Finally, these passage flow estimates should be considered in the context of their specific limitations (Section 5.1), and should be interpreted in the context of groundwater recharge, flow accretion, and planned modifications in the Sunol Valley reach of Alameda Creek (Section 5.2).

5.1 STUDY LIMITATIONS

5.1.1 IDENTIFICATION OF CONTROLLING RIFFLE

It is possible that neither the 2004 or 2006 field survey identified the absolute critical riffle, or the riffle with the greatest potential to limit steelhead migration in the study area. The 2004 riffle sites were initially targeted for field evaluation based on visual observation at a time when nearly the entire study area identified in this memorandum was dry (Entrix, 2004; Snider, pers. comm., 2009). Calaveras Dam releases studied in 2004 were of short duration, and site selection occurred prior to the releases so that all of the survey data could be collected before flows subsided. It is uncertain whether the site most limiting to steelhead migration would have been accurately identified based on a visual assessment without water in the creek. As noted in Section 4.1, a portion of the stream channel was also dry during the 2006 field survey, and thus identification of critical riffles in the dry portion of the channel could not be made. From the 2006 survey it is clear that the dry portion of the channel requires more than approximately 3 cfs to become wetted, but it is unknown whether flows to provide passage through all portions of that channel segment are higher or lower than at the most limiting of the subject riffles described in this memorandum. Additionally, the entire 2006 subject riffle selection and surveys occurred during one day in the field. For these reasons, the subject and critical riffles identified in this memorandum should be considered representative riffles of the reach. In order to more clearly refine the identification of critical riffles in this area, particularly in light of planned modifications to the reach (Section 5.2.2), it would be beneficial to conduct an additional survey of riffles in the study area.

5.1.2 LIMITATIONS OF PASSAGE FLOW ESTIMATES

Linear extrapolation of the stage versus discharge relationships for the “XS” riffles (2006 survey) to predict conditions at flows greater than any observed is less likely to provide accurate estimates than the linear interpolation used at CP riffles, where multiple stage versus discharge measurements were made. The slope of rating curves of the nature presented in this report tend to be steepest at low flows (e.g., Figure 4-19). Since field measurements at XS riffles were all at measured flows less than 4 cfs, extrapolation of those relationships to flows meeting passage criteria likely underestimated actual passage flows for some XS riffles. Additionally, in all cases (XS and CP riffles) where predicted passage flows are below the range of observed flows the modeled relationship may not accurately represent the relationship between the wetted channel area and flow. These limitations affect the passage flow estimates, particularly the XS riffle estimates. Also, the passage flows are instantaneous flow estimates at the subject riffles; the values do not incorporate water temperature requirements or address temporal parameters associated with the time it would take steelhead to migrate through the study reach.

5.2 RESULTS IN CONTEXT OF RECHARGE, ACCRETION, AND MODIFICATION

5.2.1 PASSAGE FLOW ESTIMATES IN CONTEXT OF FLOW LOSSES AND ACCRETION

The passage flows estimated in this memorandum are based on instantaneous discharge calculations at or near the subject riffles and do not predict what upstream flows would be necessary to achieve passage flows at those locations. Surface water monitoring in Alameda Creek has demonstrated that a substantial reduction in surface flow can occur between the Sunol Valley Water Treatment Plant and I-680 (Figure 4-1) (Trihey and Associates, 2003; Entrix, 2006). For example, in a field study of surface flows conducted in October 2001, 5.5 cfs of 29 cfs released from Calaveras Dam was measured in Alameda Creek above the confluence with Arroyo de la Laguna, which is just downstream of the study area examined in this memorandum. Surface flow losses to and gains from groundwater depend on local groundwater and surface flow dynamics, including factors such as surface flow volumes and transient flow accretions; seasonal and climatic variation in precipitation; and variation in position of the groundwater table. During storm events that occur during the steelhead migration period, the study reach could experience net gains or losses. Similarly, quarry operations may increase surface flow losses to groundwater at times, while at other times water is pumped from the quarries into Alameda Creek. Over the long term, quarry and water diversion operations have likely drawn down the local water table, but planned installation of cutoff walls (Section 2.3) and releases from Calaveras Reservoir will assist recharge. Any future effort to refine passable flows for steelhead migration through the study reach could also consider the effect of groundwater recharge or flow losses combined with tributary accretions. SFPUC and Alameda County Water District are developing hydrology models for Alameda Creek that include consideration of flow and temperature. When complete, these models may facilitate evaluation of overall flow dynamics, as well as provide analysis of flow and temperature relationships.

5.2.2 PASSAGE FLOW ESTIMATES IN CONTEXT OF PLANNED MODIFICATIONS

While this study contributes to a growing body of information on flows to provide passage for future migrating steelhead, the locations of riffles that potentially limit steelhead migration are expected to change as the stream channel is modified by flows. These locations have likely shifted since the 2004 and 2006 surveys were conducted. Additionally, several planned projects will modify the study reach as described in Section 2.3.

The PG&E pipeline concrete apron drop structure (Figure 5-1), which controls the gradient in much of the study reach (Figure 2-4), results in a loss of approximately 8 to 10 feet in stream bed elevation that would otherwise be distributed through the riffles located upstream of the PG&E crossing, potentially including riffles CP6, CP7, and XS2 through XS4 (Figure 4-1). The reduced gradient increases the stream channel width and decreases its depth, altering the number, location, and nature of the riffles and thus increasing the flows required to achieve passable conditions for future steelhead migration. When the pipeline crossing is altered and the current 8-to-10-foot stream bed drop is distributed across the entire reach, as would occur naturally, the location and nature of the riffles are expected to change. With a steeper gradient the stream channel may become more defined. These changes are expected to result in riffles that are passable at flows lower than the estimates provided in this memorandum.

Figure 5-1 PG&E Pipeline Concrete Apron Drop Structure

In addition to removal of the PG&E drop structure, plans to hydraulically isolate Alameda Creek from gravel quarries in the Sunol Valley with slurry walls (Section 2.3), and associated riparian restoration, will also alter conditions in the study reach. Implementation of the slurry wall project could substantially alter the surface-to-groundwater relationships of the reach and is expected to reduce the surface water flow losses. This is expected to improve passage conditions at riffles in the study reach, including at riffles CP3 through CP5 (Figure 4-1), which may be less affected by modifications associated with removal of the PG&E concrete apron. The Upper Alameda Creek Filter Gallery Project, though not fully defined at this time (Section 2.3), would also be anticipated to influence channel and flow conditions at riffles CP3, CP4-1, and CP4-2.

These projects, which are expected to be implemented in the near future, will have a dramatic effect on the condition of the Alameda Creek channel through the study reach. While the modifications are expected to improve conditions for fish migration, and will likely reduce the minimum flow required for steelhead passage through the reach, it is impossible to quantify the potential effect of these projects on passage flow estimates presented in this memorandum. The reach may be so different after the projects have been implemented that the riffles studied in this memorandum will no longer exist. Therefore, it will likely be necessary to conduct additional surveys and analysis following removal of the PG&E drop structure and installation of the slurry cut off walls in the study area.

6 CONCLUSION

Estimates of instream passage flows for adult and juvenile steelhead at 10 representative riffles on Alameda Creek between the Welch Creek confluence and I-680 ranged from 1 to 44 cfs for adults and 1 to 13 cfs for juveniles (Table 4-1). These estimates were based on criteria proposed by Thompson (1972) and NMFS (2001). The riffles found to be the most potentially limiting to future migrating steelhead (CP5, CP4-2, and CP4-1) are between the PG&E pipeline crossing and the confluence with San Antonio Creek, in the downstream portion of the study reach (Figure 4-1), with passage flow estimates ranging from 23 to 44 cfs for adults and 11 to 13 cfs for juveniles. A portion of the study reach upstream of the PG&E pipeline crossing may also limit steelhead migration. This portion of the reach was dry when the field surveys supporting this study were conducted and therefore flows to provide passage through that reach were not estimated in this study.

Of the two study groups of riffles evaluated in this investigation, the CP riffle migration flow estimates are expected to be more accurate than the XS riffle estimates, because they are based on measurements taken at up to three flow conditions. The XS riffle estimates are based on field measurements taken during only one flow condition, when calculated instantaneous discharges were less than 4 cfs, and may therefore underestimate minimum passage flows (Section 5). The riffle estimates provide an indication of the magnitude of minimum instream flows that would provide passage at the studied riffle locations.

The passage flow estimates presented in this memorandum include limitations. As described in Section 5, limitations in the estimates include the quantity of data used in their development, sensitivity to a margin of error that could reasonably be expected to occur in the field, and sensitivity to small differences in the parameters used to evaluate passability. Also, the estimates provided are instream flow estimates, based on instantaneous discharges calculated from measurements collected at or near the subject riffles.

Survey data supporting the flow estimates presented in this memorandum were collected in 2004 and 2006. While the exact configuration and even location of riffles in the study area will change over time, changes that have occurred since the surveys were conducted are not likely great enough to affect the relevance (representativeness) of the data. However, major modifications to Alameda Creek in the study area are expected to occur in the near future (Section 2.3); the modifications are primarily to improve conditions for fish migration (Section 5.2.2). Once those changes have occurred, updated analysis may be necessary to evaluate minimum flows for steelhead migration at riffles in Alameda Creek in the quarry reach of Sunol Valley.

7 REPORT PREPARATION

7.1 LIST OF PREPARERS

This technical memorandum was prepared with the participation of professional scientists and engineers from URS, HDR|SWRI, HDR|FishPro's Fishery Design Center, and SFPUC.

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