UPPER TUOLUMNE RIVER BASIN FISH MIGRATION BARRIERS STUDY STUDY REPORT

LA GRANGE HYDROELECTRIC PROJECT FERC NO. 14581

Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

Prepared by:
HDR, Inc.

February 2017

TABLE OF CONTENTS

List of Figures

List of Tables

List of Attachments

List of Acronyms and Abbreviations

ac-ft .....acre-foot
BLM.....Bureau of Land Management
BOR .....Bureau of Reclamation
CCSF.....City and County of San Francisco
CDFG.....California Department of Fish and Game, now CDFW
CDFW.....California Department of Fish and Wildlife
cfs.....cubic feet per second
CG .....Conservation Groups
Districts.....Turlock Irrigation District and Modesto Irrigation District
FERC.....Federal Energy Regulatory Commission
FLA .....Final License Application
FPA .....Federal Power Act
GIS .....geographic information system
ILP.....Integrated Licensing Process
ISR .....Initial Study Report
LGDD .....La Grange Diversion Dam
LPs .....licensing participants
M&I.....municipal and industrial
MID.....Modesto Irrigation District
NMFS.....National Marine Fisheries Service
NPS .....National Park Service
O&M .....operation and maintenance
PAD.....Pre-Application Document
PSP.....Proposed Study Plan
QA/QC .....quality assurance/quality control
RM .....river mile
RSP .....Revised Study Plan
SD2 .....Scoping Document 2
SPD .....Study Plan Determination
TAF .....thousand acre-feet
TID.....Turlock Irrigation District
TM.....technical memorandum
USFWS .....United States Fish and Wildlife Service
USGS .....United States Geological Survey
USR.....Updated Study Report

1.0 INTRODUCTION

1.1 Background

The Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) own the La Grange Diversion Dam (LGDD) located on the Tuolumne River in Stanislaus County, California (Figures 1.1-1 and 1.1-2). LGDD is 131 feet high and is located at river mile (RM) 52.2 at the exit of a narrow canyon, the walls of which contain the pool formed by the diversion dam. Under normal river flows, the pool formed by the diversion dam extends for approximately one mile upstream. When not in spill mode, the water level upstream of the diversion dam is between elevation 294 feet and 296 feet approximately 90 percent of the time. Within this 2-foot range, the pool storage is estimated to be less than 100 acre-feet of water.

The drainage area of the Tuolumne River upstream of LGDD is approximately 1,550 square miles. Tuolumne River flows upstream of LGDD are regulated by four reservoirs: Hetch Hetchy, Lake Eleanor, Lake Lloyd (known as Cherry Lake), and Don Pedro. The Don Pedro Hydroelectric Project (Federal Energy Regulatory Commission [the Commission or FERC] No. 2299) is owned jointly by the Districts, and the other three dams are owned by the City and County of San Francisco (CCSF). Inflow to the La Grange pool is the sum of releases from the Don Pedro Project, located 2.3 miles upstream, and very minor contributions from two small intermittent streams downstream of Don Pedro Dam.

LGDD was constructed from 1891 to 1893 displacing Wheaton Dam, which was built by other parties in the early 1870s. LGDD raised the level of the Tuolumne River to permit the diversion and delivery of water by gravity to irrigation systems owned by TID and MID. The Districts' irrigation systems currently provide water to over 200,000 acres of prime Central Valley farmland and drinking water to the City of Modesto. Built in 1924, the La Grange hydroelectric plant is located approximately 0.2 miles downstream of LGDD on the east (left) bank of the Tuolumne River and is owned and operated by TID. The powerhouse has a capacity of slightly less than five megawatts. The La Grange Hydroelectric Project (La Grange Project or Project; FERC No. 14581) operates in a run-of-river mode. The LGDD provides no flood control benefits, and there are no recreation facilities associated with the Project or the La Grange pool.

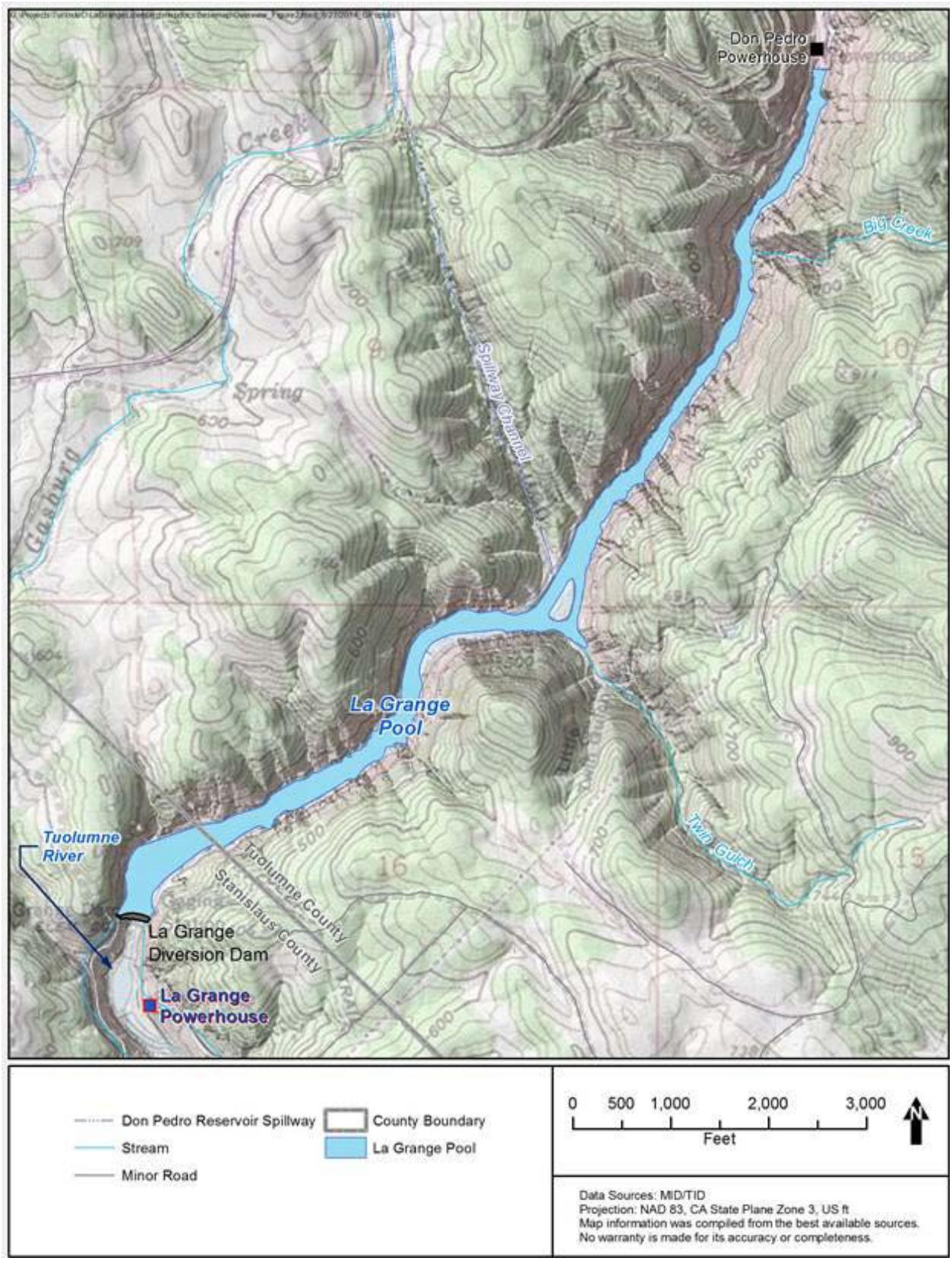


Figure 1.1-1. La Grange Hydroelectric Project location map.

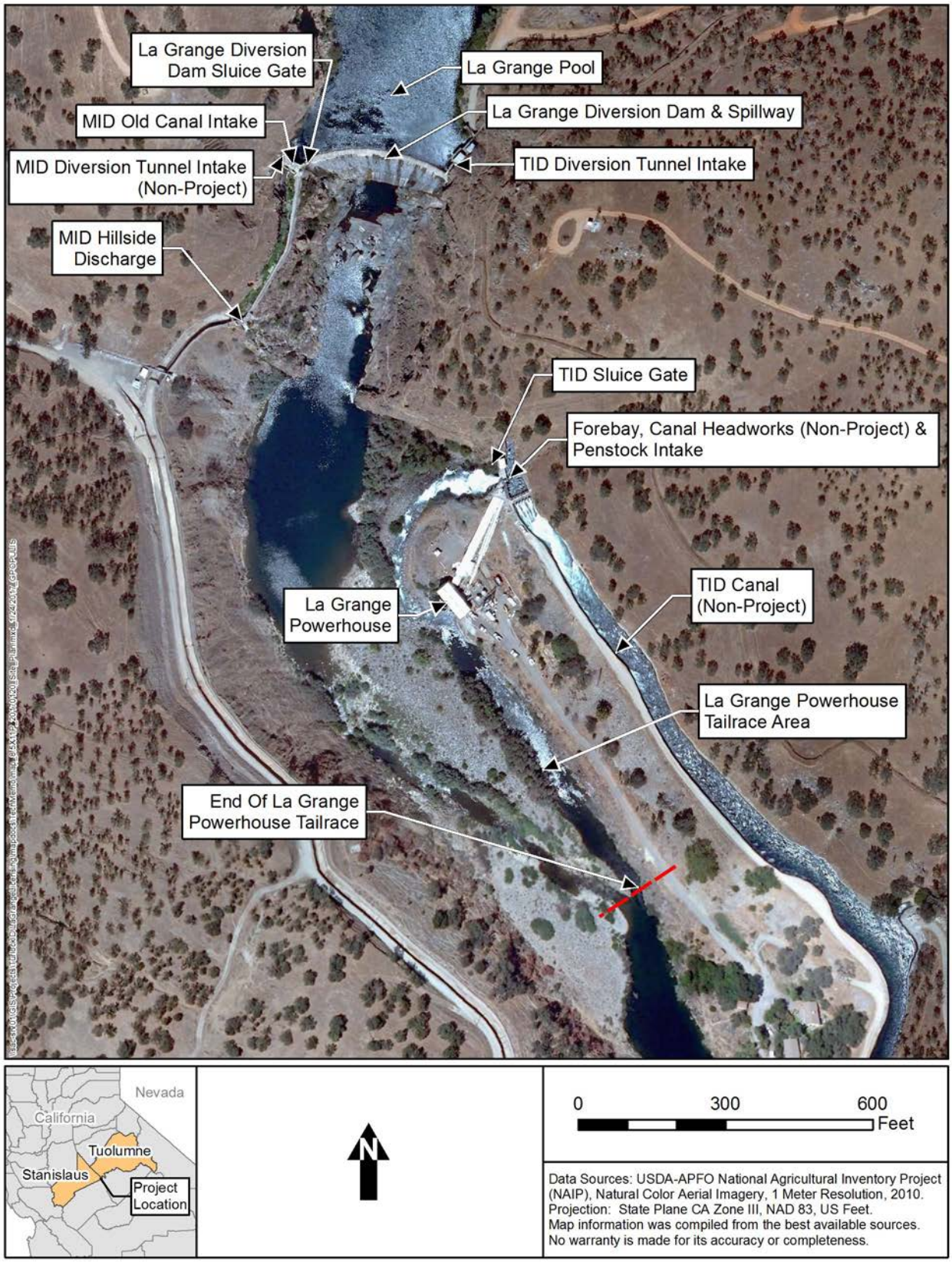


Figure 1.1-2. La Grange Hydroelectric Project site plan.

1.2 Licensing Process

In 2014, the Districts commenced the pre-filing process for the licensing of the La Grange Project by filing a Pre-Application Document with FERC[1]. On September 5, 2014, the Districts filed their Proposed Study Plan to assess Project effects on fish and aquatic resources, recreation, and cultural resources in support of their intent to license the Project. On January 5, 2015, in response to comments from licensing participants, the Districts filed their Revised Study Plan (RSP) containing three study plans: (1) Cultural Resources Study Plan; (2) Recreation Access and Safety Assessment Study Plan; and (3) Fish Passage Assessment Study Plan[2].

On February 2, 2015, FERC issued the Study Plan Determination (SPD), approving or approving with modifications six studies (Table 1.2-1). Of those six studies, five had been proposed by the Districts in the RSP. The Districts note that although FERC's SPD identified the Fish Passage Barrier Assessment, Fish Passage Facilities Alternatives Assessment, and Fish Habitat and Stranding Assessment below La Grange Diversion Dam as three separate studies, all three assessments are elements of the larger Fish Passage Assessment as described in the RSP. The sixth study approved by FERC, Effects of the Project and Related Activities on the Losses of Marine-Derived Nutrients in the Tuolumne River, was requested by the National Marine Fisheries Service (NMFS) in its July 22, 2014 comment letter.

Table 1.2-1. Studies approved or approved with modifications in FERC's Study Plan Determination.

No.	Study	Approved by FERC in SPD without Modifications	Approved by FERC in SPD with Modifications
1	Recreation Access and Safety Assessment		X
2	Cultural Resources Study		X
3	Fish Passage Barrier Assessment		X[1]
4	Fish Passage Facilities Alternatives Assessment		X
5	Fish Habitat and Stranding Assessment below La Grange Dam		X
6	Effects of the Project and Related Activities on the Losses of Marine-Derived Nutrients in the Tuolumne River	X[2]	

[1] Page A-1 of Appendix A of FERC's SPD states that FERC approved with modifications the Fish Passage Barrier Assessment. However, the Districts found no modifications to this study plan in the SPD and page B-7 of the SPD states that "no modifications to the study plan are recommended."

[2] FERC directed the Districts to conduct the study plan as proposed by NMFS.

In the SPD, FERC recommended that, as part of the Fish Passage Facilities Alternatives Assessment, the Districts evaluate the technical and biological feasibility of the movement of anadromous salmonids through La Grange and Don Pedro project reservoirs if the results from

[1] On December 19, 2012, Commission staff issued an order finding that the La Grange Hydroelectric Project is required to be licensed under Section 23(b)(1) of the Federal Power Act. Turlock Irrigation District and Modesto Irrigation District, 141 FERC ¶ 62,211 (2012), aff'd Turlock Irrigation District and Modesto Irrigation District, 144 FERC ¶ 61,051 (2013). On May 15, 2015, the U.S. Court of Appeals for the District of Columbia Circuit denied the Districts' appeal and affirmed the Commission's finding that the La Grange Hydroelectric Project requires licensing. Turlock Irrigation District, et al., v. FERC, et al., No. 13-1250 (D.C. Cir. May 15, 2015).

[2] The Fish Passage Assessment Study Plan contained a number of individual, but related, study elements.

Phase 1 of that study indicate that the most feasible concept for fish passage would involve fish passage through Don Pedro Reservoir or La Grange pool. On September 16, 2016, the Districts filed the final study plan with FERC. On November 17, 2016, the Districts filed a letter with FERC after consulting with fish management agencies (i.e., NMFS and the California Department of Fish and Wildlife [CDFW]) regarding the availability of test fish and a determination that no fish would be available to support conducting this study in 2017. On January 12, 2017, the Districts filed a letter with FERC stating that with FERC's approval, they intend to conduct the study in 2018 if the results from the Fish Passage Facilities Alternatives Assessment indicate that upstream or downstream fish passage at La Grange and Don Pedro projects would require anadromous fish transit through one or both reservoirs.

In addition to the six studies noted in Table 1.2-1, the SPD required the Districts to develop a plan to monitor anadromous fish movement in the vicinity of the Project's powerhouse draft tubes to determine the potential for injury or mortality from contact with the turbine runners. The Districts filed the Investigation of Fish Attraction to La Grange Powerhouse Draft Tubes study plan with FERC on June 11, 2015, and on August 12, 2015, FERC approved the study plan as filed.

On February 2, 2016, the Districts filed the Initial Study Report (ISR) for the La Grange Project. The Districts held an ISR meeting on February 25, 2016, and on March 3, 2016, filed a meeting summary. Comments on the meeting summary and requests for new studies and study modifications were to be submitted to FERC by Monday, April 4. One new study request was submitted; NMFS requested a new study entitled Effects of La Grange Hydroelectric Project Under Changing Climate (Climate Change Study). On May 2, 2016, the Districts filed with FERC a response to comments received from licensing participants and proposed modifications to the Fish Passage Facilities Alternatives Assessment and the La Grange Project Fish Barrier Assessment. On May 27, 2016, FERC filed a determination on requests for study modifications and new study. The May 27, 2016 determination approved the Districts' proposed modifications and did not approve the NMFS Climate Change Study.

This report describes the objectives, methods, and results of the Upper Tuolumne River Basin Fish Migration Barriers Study (herein referred to as the Upper River Barriers Study), which is one of nine studies being implemented voluntarily by the Districts (see Section 1.3 for more information). Documents relating to the Project licensing are publicly available on the Districts' licensing website at www.lagrange-licensing.com/.

1.3 Voluntary Studies

As part of the Fish Passage Facilities Alternatives Assessment, in September 2015, the Districts provided to licensing participants Technical Memorandum No. 1, which identified a number of information gaps critical to informing the biological and associated engineering basis of conceptual design. To address these critical information gaps, in November 2015 licensing participants formed a Plenary Group and adopted a plan to implement the Upper Tuolumne River Fish Reintroduction Assessment Framework (Framework) intended to develop the information needed to undertake and complete the Fish Passage Facilities Alternatives Assessment and to assess the overall feasibility of reintroducing anadromous salmonids into the upper Tuolumne

River (TID/MID 2016a). In support of the Framework, licensing participants agreed on the need for site-specific studies to inform decisions regarding fish reintroduction and fish passage and, in January 2016, formed a Technical Committee to take the lead on assessing site-specific information needs and study plan development.

The Districts are implementing a number of voluntary studies in support of the licensing proceeding and in support of the Fish Passage Facilities Alternatives Assessment (Table 1.3-1). Although FERC's SPD did not require the Districts to undertake the Upper Tuolumne River Basin Habitat Assessment studies proposed in the RSP, in 2015 the Districts voluntarily began implementing both the Upper Tuolumne River Basin Fish Migration Barriers Study and the Upper Tuolumne River Basin Water Temperature Monitoring and Modeling Study.

Figure 1.3-1. Studies being conducted voluntarily by the Districts.

No.	Study
1	Upper Tuolumne River Basin Fish Migration Barriers Study
2	Upper Tuolumne River Basin Water Temperature Monitoring and Modeling Study
3	Upper Tuolumne River Chinook Salmon and Steelhead Spawning Gravel Mapping Study
4	Upper Tuolumne River Habitat Mapping Assessment
5	Upper Tuolumne River Macroinvertebrate Assessment
6	Upper Tuolumne River Instream Flow Study
7	Hatchery and Stocking Practices Review
8	Socioeconomic Scoping Study
9	Regulatory Context for Potential Anadromous Salmonid Reintroduction into the Upper Tuolumne River Basin

Based on Technical Committee feedback provided on a preliminary list of studies, the Districts drafted study plans for seven additional voluntary studies: (1) Upper Tuolumne River Chinook Salmon and Steelhead Spawning Gravel Mapping Study; (2) Upper Tuolumne River Habitat Mapping Assessment; (3) Upper Tuolumne River Macroinvertebrate Assessment; (4) Upper Tuolumne River Instream Flow Study; (5) Hatchery and Stocking Practices Review; (6) Socioeconomic Scoping Study; and (7) Regulatory Context for Potential Anadromous Salmonid Reintroduction into the Upper Tuolumne River Basin. The study plans were refined through a collaborative process with the Technical Committee and final study plans were posted to the La Grange Project licensing website in July 2016. In the summer of 2016, the Districts began implementing these seven additional studies and continued the second year of implementation on the two voluntary studies that began in 2015 (i.e., Upper Tuolumne River Basin Fish Migration Barriers Study and Upper Tuolumne River Basin Water Temperature Monitoring and Modeling Study).

On May 2, 2016, the Districts filed a proposal with FERC to revise the remaining portion of the pre-filing licensing schedule to allow more time for both the Districts to complete ongoing FERC-approved studies and voluntary studies and for NMFS to complete its Upper Tuolumne River Habitat and Carrying Capacity Study and its study of Tuolumne River *O. mykiss* genetics. On May 27, 2016, FERC filed a determination on requests for study modifications and new study, approving the revised schedule as proposed.

1.4 Description of the Upper Tuolumne River Basin

The upper Tuolumne River originates from tributary streams located on Mount Lyell and Mount Dana in the Sierra Nevada. These tributaries join at Tuolumne Meadows (elevation 8,600 feet), and from this point the upper Tuolumne River descends rapidly through a deep canyon in wilderness areas of Yosemite National Park to Hetch Hetchy Reservoir (at an elevation of about 3,500 feet). Six miles below O'Shaughnessy Dam, which impounds Hetch Hetchy Reservoir, the Tuolumne River leaves Yosemite National Park and enters the Stanislaus National Forest. Except for a short reach at Early Intake Reservoir, the river flows unimpeded through a deep canyon for approximately 40 miles, from O'Shaughnessy Dam to the upstream end of Don Pedro Reservoir (Figure 1.4-1).

The mainstem Tuolumne River is joined by several tributaries–including (from upstream to downstream) Cherry Creek, the South Fork/Middle Fork Tuolumne River, the Clavey River, and the North Fork of the Tuolumne River–before entering the Don Pedro Project Boundary at approximately RM 80.8[3]. There are two dams in the Cherry Creek basin: Cherry Dam, which impounds Cherry Lake, located on Cherry Creek about 12 miles above its confluence with the Tuolumne River and Eleanor Dam, which impounds Lake Eleanor, located about 3.5 miles upstream of its confluence with Cherry Creek (SFPUC 2008).

1.4.1 Geomorphology of the Upper Tuolumne River Basin

The upper Tuolumne River and its tributaries flow through steep, narrow valleys that confine the river channel. In most areas the channels have high gradients, and habitat consists mostly of bedrock chutes, boulder cascades, and pools (SFPUC 2008). From the Poopenaut Valley to Early Intake, channel morphology is diverse, ranging from low-gradient, sand-bedded areas and wetland meadows to steep, bedrock-confined reaches. Although hydraulic conditions in the upper Tuolumne River are controlled primarily by channel width constrictions or expansions and resistant bedrock outcrops, there are smaller geomorphic controls that give rise to a complex morphology, which provide a variety of aquatic and riparian habitats (McBain and Trush 2004).

From Early Intake to the confluence with the South Fork of the Tuolumne River, the channel is deeply incised with steep side slopes. Channel gradient in this reach is as high as four percent, and habitat consists mostly of pools separated by steep cascades, although alluvial bars and side-channels occur in places where the valley widens or bedrock controls reduce channel gradient. From the South Fork to the Clavey River, the channel consists of boulder cascades separated by pools. Downstream of the Clavey River, gradient decreases, and the channel becomes semi-alluvial. There are three major waterfalls on the upper mainstem Tuolumne River: Clavey Falls (RM 91), Lumsden Falls (RM 98.25), and Preston Falls (RM 110).

[3] At its normal maximum water surface elevation of 830 feet, Don Pedro Reservoir extends upstream to about RM 79.5.

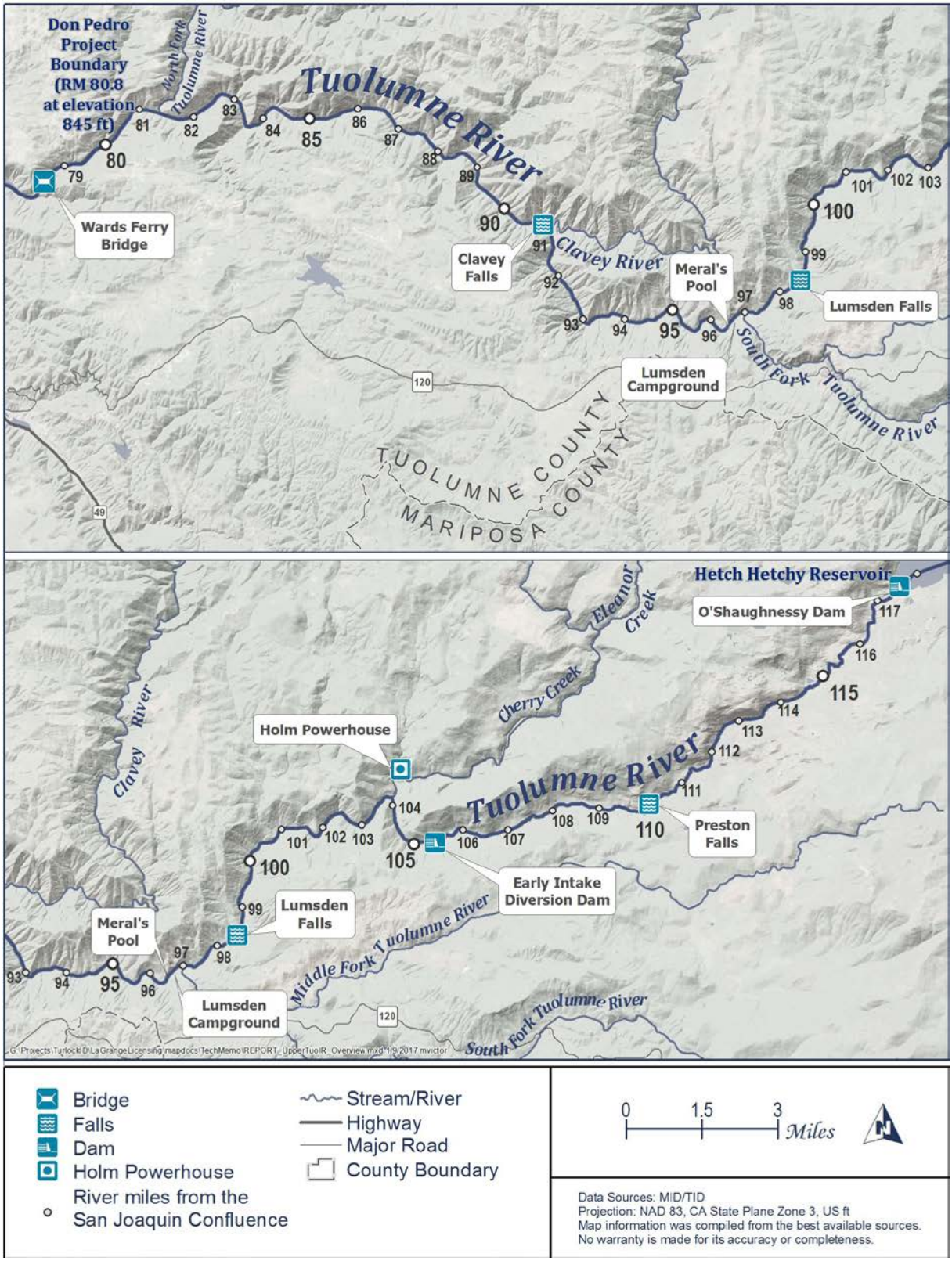


Figure 1.4-1. **The Tuolumne River basin upstream of Don Pedro Project. The top map depicts the river from Wards Ferry Bridge to RM 101, and the bottom map depicts the river from RM 94 to RM 118.**

Cherry Creek is a steep stream (≈ five percent gradient) confined within a narrow bedrock canyon (SFPUC 2008). Its bed consists mainly of boulders and bedrock, although much sand is stored in pools. Immediately downstream of Cherry Dam there are low gradient gravel-bedded sections interspersed with steep, bedrock chutes. In the upper reaches of Cherry Creek, riparian and upland vegetation have encroached onto formerly active alluvial bars due to flow regulation. For most of its length, Eleanor Creek, a tributary to Cherry Creek, flows through a bedrock canyon, with a steep channel (≈ six percent gradient) made up of a series of pools and waterfalls (SFPUC 2008).

The Clavey River is the longest unregulated river in the Sierra Nevada (McBain & Trush 2004). Research suggests that in the Clavey River (1) frequent small floods scour and deposit sand at pools and bars, (2) moderate-sized floods (every 12 to 17 years) move gravel and cobbles, reshape side channels, and may move large woody debris, and (3) large floods (every 70 to 100 years) erode large bars, remove and create side channels, and move large boulders over short distances (SFPUC 2008). Based on existing information, it is unclear to what extent channel-forming events in the other tributaries mirror those in the Clavey River.

1.4.2 Hydrology of the Upper Tuolumne River Basin

The Tuolumne River upstream of Don Pedro Dam has a watershed area of about 1,533 square miles. Above 5,000 feet, the flow regimes of the Tuolumne River and its tributaries are snowmelt-dominated. Smaller streams in this elevation range may have extremely low summer flows, although groundwater and interflow may provide small amounts of water in late summer. About 75 percent of the natural runoff above 5,000 feet occurs between April and July, with 20 percent or less occurring from December through March, and as little as 5 percent occurring from August through November (ACOE 1972). In the middle elevations, from 3,000 to 5,000 feet, more precipitation occurs as rainfall, and there can be multiple rain-on-snow events each year. Much of the runoff in these elevations occurs from December through March during winter rains, with most of the remaining runoff occurring from April through July (ACOE 1972).

In 1918, CCSF completed Lake Eleanor, a reservoir on Eleanor Creek, a tributary to Cherry Creek, which is in turn a tributary to the Tuolumne River (SFPUC 2008). Hetch Hetchy Reservoir was built on the mainstem Tuolumne River in 1923 and expanded in 1938. CCSF completed Cherry Lake (also known as Lake Lloyd) on Cherry Creek in 1955 (SFPUC 2008).

The San Francisco Public Utilities Commission (SFPUC) diverts water from Hetch Hetchy Reservoir and conveys it to the San Francisco Bay Area via the Hetch Hetchy water conveyance system, which consists of a series of facilities that extend to Crystal Springs Reservoir in San Mateo County (SFPUC 2008). Water from Hetch Hetchy Reservoir is delivered through the Canyon Power Tunnel to Kirkwood Powerhouse above Early Intake. Water exiting the powerhouse is returned either to the Tuolumne River or discharged into the Mountain Tunnel, which conveys water to Priest Reservoir and Moccasin Powerhouse. Water released from Moccasin Powerhouse is returned to the Tuolumne River via Moccasin Reservoir and Moccasin Creek or routed to the Foothill Tunnel for delivery to the Bay Area. Priest and Moccasin reservoirs are small waterbodies used to control flow into Moccasin Powerhouse and regulate discharge to Moccasin Creek, respectively (SFPUC 2008).

The SFPUC uses most of the water in Cherry Lake to generate hydroelectric power at Holm Powerhouse (SFPUC 2008). Water released from Holm Powerhouse returns to Cherry Creek and is used to satisfy the Districts' water rights (SFPUC 2008). Water impounded in Lake Eleanor is conveyed to Cherry Lake and subsequently to Holm Powerhouse. The SFPUC diverts an average of 244,000 acre-feet per year (218 million gallons per day) from the Tuolumne River at Hetch Hetchy Reservoir to supply water to about 2.4 million people in Tuolumne, Alameda, Santa Clara, San Mateo, and San Francisco counties (SFPUC 2008). Water diverted by the SFPUC for water supply represents about 32.6 percent of the average annual unimpaired runoff at Hetch Hetchy Reservoir, which is estimated to be 749,607 acre-feet (SFPUC 2008).

There are four locations of streamflow measurement (i.e., U.S. Geological Survey [USGS] stream gages) in the Tuolumne River basin upstream of Don Pedro Reservoir: (1) Tuolumne River below Early Intake near Mather, (2) Cherry Creek below Holm Powerhouse, (3) South Fork Tuolumne River near Oakland Recreation Camp, and (4) Middle Tuolumne River at Oakland Recreation Camp. The sum of flow measurements from these four gages accounts for the majority of flow in the Tuolumne River watershed. Based on USGS gage measurements, the annual unimpaired flow of the Tuolumne River just upstream of Don Pedro Reservoir has averaged about 1.97 million acre-feet since 1975. The maximum annual unimpaired runoff since 1975 was 4.6 million acre-feet (Water Year [WY] 1983), and the minimum was 0.38 million acre-feet (WY 1977). A substantial portion of the difference between historical and current unimpaired flows to Don Pedro Reservoir is accounted for by out-of-basin diversions by the SFPUC to provide water to residential, commercial, and industrial users in the Bay Area.

The hydrogeologic units underlying the Tuolumne River from Hetch Hetchy Reservoir to Don Pedro Reservoir exhibit low permeability (SFPUC 2008), and as a result there are no large groundwater bodies along this reach of the river. Significant groundwater storage in the basin occurs in the permeable terrain downstream of Don Pedro Reservoir, i.e., the San Joaquin Valley Groundwater Basin, which underlies the foothills and valley floor.

1.4.2.1 Within-day Flow Variability in the Upper Tuolumne River

Daily flows in the Tuolumne River upstream of Don Pedro Reservoir can vary greatly, as illustrated by data summarized in Tables 1.4-1, 1.4-2, and 1.4-3, which characterize how flows may vary within a single day in the Tuolumne River downstream of the Clavey River confluence during Critical, Below Normal, and Above Normal water years[4].

Table 1.4-1. Within-day flow fluctuation (cfs) in Critical water years, by month, in the Tuolumne River below Clavey River confluence.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	0	0	7	19	9	6	2	2	1	0	0	0
Percentile (5^{th})	1	1	39	55	28	38	397	286	49	3	1	4
Median	135	218	223	517	620	794	798	688	377	184	134	157

[4] California Department of Water Resources CDEC Historical Water Year Hydrologic Classification Indices.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Percentile (95th)	721	736	783	1,033	1,021	1,209	1,142	1,071	805	478	582	746
Maximum	5,142	1,549	1,110	2,122	1,058	1,285	1,209	1,366	1,109	1,074	1,211	3,822

Table 1.4-2. Within-day flow fluctuation (cfs) in Below Normal water years, by month, in the Tuolumne River below Clavey River confluence.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	0	3	8	8	7	2	5	3	1	0	1	0
Percentile (5th)	4	110	34	55	23	18	48	10	2	3	14	11
Median	337	451	545	513	354	651	984	818	269	223	260	283
Percentile (95th)	1,245	756	964	950	1,163	1,293	1,021	1,016	619	638	826	796
Maximum	6,105	906	2,064	2,410	6,101	2,576	1,249	1,066	1,032	1,207	2,009	1,998

Table 1.4-3. Within-day flow fluctuation (cfs) in Above Normal water years, by month, in the Tuolumne River below Clavey River confluence.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	0	14	9	14	8	35	7	2	1	0	0	0
Percentile (5th)	35	36	36	45	74	129	63	50	6	2	1	2
Median	319	331	196	218	420	684	816	923	411	180	136	231
Percentile (95th)	1,162	1,243	1,364	1,002	2,562	2,341	1,599	1,152	977	688	828	1,320
Maximum	14,307	5,571	12,910	5,774	20,390	5,789	6,934	1,365	1,160	4,095	1,975	23,764

1.4.2.2 Flow Releases to Support Fisheries and Whitewater Boating

Minimum flow releases from Hetch Hetchy Reservoir, which were developed to support rainbow (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) throughout their life histories, vary according to water-year type. Releases in normal, dry, and critically dry years total at least 59,235; 50,019; and 35,215 acre-feet, respectively (SFPUC 2008). SFPUC must release an additional 64 cfs into the river below Hetch Hetchy Reservoir when the diversion through Canyon Tunnel (which flows from Hetch Hetchy Reservoir to Kirkwood Powerhouse) exceeds 920 cfs. Once minimum flow releases are made at O'Shaughnessy Dam, they cannot be diverted at Early Intake, but instead must remain in the Tuolumne River where they are supplemented by tributary flows and occasional releases at Kirkwood Powerhouse to the Tuolumne River.

The minimum required stream flow below Cherry Lake is 5 cfs from October through June and 15.5 cfs from July through September (RMC and McBain & Trush 2007, Revised 2016). In years when no pumping takes place between Lake Eleanor and Cherry Lake, the required minimum flow downstream of Lake Eleanor is 5 cfs from October through June and 15.5 cfs from July through September (RMC and McBain & Trush 2007, Revised 2016). In years when pumping does occur the minimum required stream flow is 5 cfs from November through February, 10 cfs from March 1 through April 14, 20 cfs from April 15 through September 15, and 10 cfs from September 16 through September 30 (RMC and McBain & Trush 2007, Revised 2016). There are no specific minimum flow releases required for October in years when pumping occurs, but the SFPUC operational practice in pumping years has been to continue the

September 16-30 release of 10 cfs through October 31 (RMC and McBain & Trush 2007, Revised 2016). These minimum flows were established based on the life-history requirements of trout, and take into consideration the effects of seasonal water temperatures on habitat suitability.

Flows in the Tuolumne River downstream of its confluence with Cherry Creek are also regulated during summer to provide flows for whitewater rafting (SFPUC 2008). SFPUC releases pulses of water from Cherry Lake via Holm Powerhouse to support whitewater recreation on most summer days (SFPUC 2008).

1.4.3 Water Quality in the Upper Tuolumne River Basin

The Tuolumne River watershed upstream of Hetch Hetchy Reservoir lies entirely within the less developed parts of Yosemite National Park, and as a result water quality in Hetch Hetchy Reservoir is excellent. Nitrogen and phosphorus concentrations are typically near or below detection limits, and dissolved oxygen concentrations are usually at or near saturation (SFPUC 2008).

Water quality in the Tuolumne River between O'Shaughnessy Dam and Don Pedro Reservoir is very good, but nutrient concentrations increase slightly with distance downstream. The Districts conducted a study during the summer of 2012 to characterize water quality in the Tuolumne River just upstream of Don Pedro Reservoir (TID/MID 2013). This sampling confirmed that water in the river just upstream of Don Pedro Reservoir was clear, DO was near saturation, alkalinity was low (<16 mg/L), pH was near neutral, fecal coliform bacteria were below detection limits, nitrogen and phosphorous occurred at concentrations generally less than 1 mg/L, and algae blooms were absent.

Maximum summer (June through July) water temperatures in the Tuolumne River between Hetch Hetchy and Don Pedro reservoirs at times can exceed 23°C (TID/MID 2016b). The Districts developed a Tuolumne River Flow and Water Temperature Model, Without Dams Assessment (Jayasundara et al. 2014) to simulate water temperatures in the Tuolumne River without the effects of the Hetch Hetchy (including Cherry Lake and Eleanor Lake), Don Pedro, and La Grange projects. Comparison of the seven-day average of daily maximum (7DADM) temperatures under with- and without-dams conditions indicates that summer/fall maximum water temperatures in the upper Tuolumne River would be substantially higher, up to 7°C, in the absence of the Hetch Hetchy impoundments than they are under existing conditions, particularly at RM 98 (Figures 1.4-2 and 1.4-3). During of the remainder of the year, 7DADM temperatures are similar to or slightly higher, up to 2°C, with the dams in place (Figures 1.4-2 and 1.4-3). As noted in the figure captions, plots for RM 98 and RM 88 compare simulated without-dams temperatures to empirically derived with-dams temperatures. The without-dams simulation also reveals that 7DADM water temperatures in the Tuolumne River mainstem, in the absence of impoundments, would approach thermal equilibrium well upstream of the current location of the Don Pedro Project.

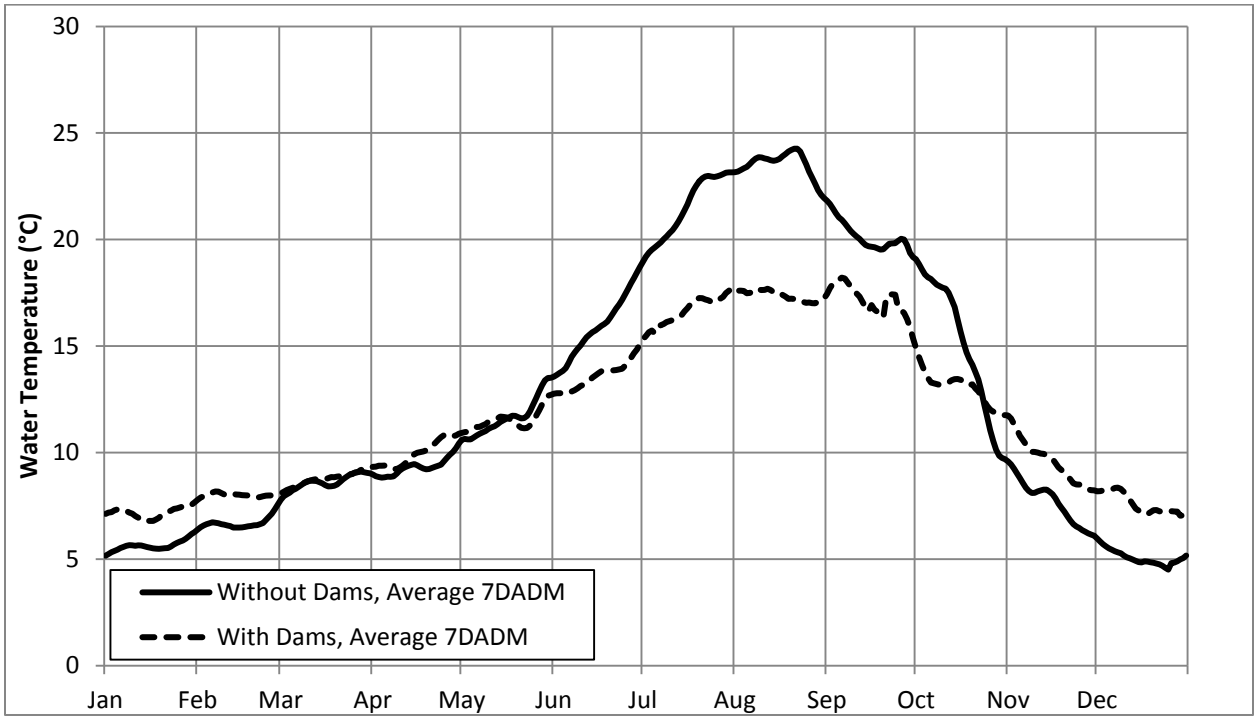


Figure 1.4-2. **Comparison of 7DADM water temperatures under with- and without-dams conditions in the Tuolumne River below the South Fork Tuolumne River (≈RM 98). Without-dams temperatures are simulated based on the period 1970 - 2012 (Jayasundara et al. 2014), and with-dams temperatures are based on data collected by temperature loggers from 2005 - 2012.**

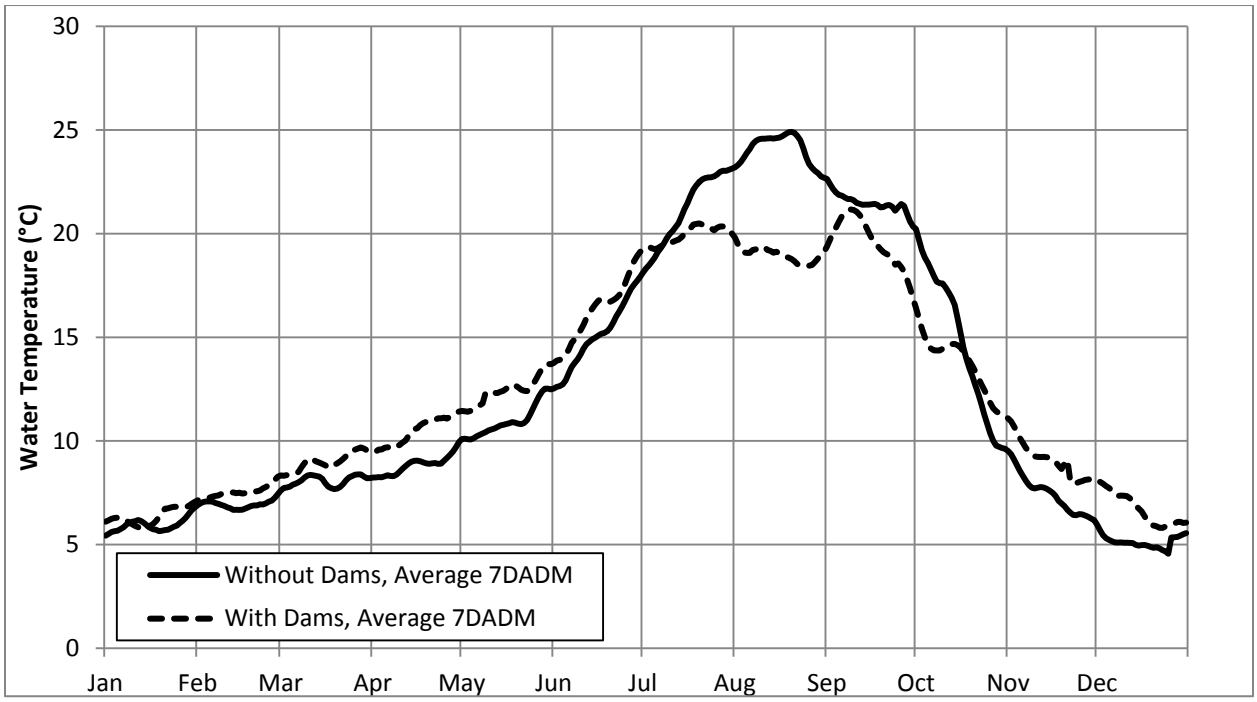


Figure 1.4-3. **Comparison of 7DADM water temperatures under with- and without-dams conditions in the Tuolumne River below Indian Creek (≈RM 88). Without-dams temperatures are simulated based on the period 1970 - 2012 (Jayasundara et al. 2014), and with-dams temperatures are based on data collected by temperature loggers from 2009 – 2012.**

1.4.4 Existing Fish Species in the Upper Tuolumne River Basin

The fish assemblage in the upper Tuolumne River and its tributaries consists mainly of rainbow trout, brown trout, Sacramento sucker (*Catostomus occidentalis*), Sacramento pikeminnow (*Ptychocheilus grandis*), California roach (*Hesperoleucus symmetricus*), and hardhead (*Mylopharodon conocephalus*) (SFPUC 2008).

During 2009, CDFW conducted a Heritage and Wild Trout Program Phase 1 assessment of the upper Tuolumne River near the USFS Lumsden Campground. During the survey, the following salmonid species were identified in an approximately 1,500-foot survey reach: coastal rainbow trout (*O. mykiss irideus*), Chinook salmon (*O. tshawytscha*), kokanee (*O. nerka*), and brown trout (Weaver and Mehalick 2009). Some of the coastal rainbow and brown trout exceeded 18 inches (457 mm) in length, and estimated average rainbow trout and brown trout densities were 1,122 and 128 fish per mile, respectively (Weaver and Mehalick 2009). Farther upstream, fish species observed during a 2014 survey in the Tuolumne River between Early Intake and Hetch Hetchy Dam included rainbow trout, brown trout, riffle sculpin (*Cottus gulosus*), California roach, and Sacramento sucker (Stillwater Sciences 2016). According to Weaver and Mehalick (2009), however, no trout species are native to the Tuolumne River upstream of Preston Falls, so "the NPS [National Park Service] does not support Wild Trout designation in this portion of the river [i.e., above the falls]."

Although some brook trout (*Salvelinus fontinalis*) reportedly still occur in headwater areas, they are not considered self-sustaining in the mainstem Tuolumne River (De Carion et al. 2010). Because of its relatively low spring flows and high spring and summer temperatures, the North Fork Tuolumne River supports smallmouth bass (*Micropterus dolomieu*) (De Carion et al. 2010). Brook trout, kokanee, brown trout, and smallmouth bass are nonnative to the basin, and brown trout and smallmouth bass can be highly piscivorous. Other non-native fish species that have been documented in the upper Tuolumne River basin include golden shiner (*Notemigonus crysoleucas*) and green sunfish (*Lepomis cyanellus*) in Cherry Lake (SFPUC 2008).

Field observations made from October 20, 1987 to June 14, 1990 confirmed that self-sustaining rainbow and brown trout populations exist in the upper Tuolumne River basin (SFPUC 2008). There is also anecdotal evidence that kokanee and adfluvial Chinook salmon from the Don Pedro Reservoir spawn in the upper basin (SFPUC 2008, Bacher 2013, Perales et al. 2015). Juvenile Chinook were observed in the upper Tuolumne River in May 2012 moving downstream to Don Pedro Reservoir (Perales et al. 2015).

CDFW stocks rainbow trout throughout the upper Tuolumne River watershed (CDFW 2016). CDFW has released, or continues to release, kokanee, brook trout, rainbow trout, coho salmon, Chinook salmon, brown trout, Eagle Lake trout, and largemouth bass (*Micropterus salmoides*) in Don Pedro Reservoir. Largemouth bass are also stocked in Don Pedro Reservoir by the Don Pedro Recreation Agency. Kokanee and adfluvial Chinook reproducing in the upper Tuolumne River (see preceding paragraph) are the product of CDFW stocking programs conducted in Don Pedro Reservoir (Perales et al. 2015). The planted Chinook are "surplus" juveniles from Iron Gate Hatchery, located on the Klamath River, outside the Central Valley (Perales et al. 2015).

1.4.5 Fish Habitat in the Upper Tuolumne River Basin

Twelve habitat types have been identified in the Tuolumne River reach between O'Shaughnessy Dam and Early Intake: deep pools, shallow pools, pocket waters, cascades, cascades/deep pools, cascades/pocket waters, chutes, riffles, runs, glides, side channels, and backwaters (SFPUC 2008).

Water temperatures may at times affect trout in the upper basin. Maximum summer (June–July) water temperatures in the Tuolumne River between Hetch Hetchy and Don Pedro reservoirs can exceed 23°C, which could adversely affect rainbow and brown trout (SFPUC 2008). Winter water temperatures are typically low and might limit the successful egg incubation and emergence of brown trout (SFPUC 2008).

SFPUC makes minimum releases from Hetch Hetchy Reservoir, Cherry Lake, and Lake Eleanor to support resident fisheries (see Section 1.4.2). However, flows in the Tuolumne River downstream of its confluence with Cherry Creek are also regulated during summer to provide flows for whitewater rafting (SFPUC 2008). SFPUC releases pulses of water from Cherry Lake via Holm Powerhouse to support rafting for several hours on most summer days (SFPUC 2008). The resulting flow fluctuations in the upper Tuolumne River (see Section 1.4.2) influence resident trout habitat and may result in the stranding of trout, other fish species, and macroinvertebrates.

1.4.6 Species of Interest for Upper Tuolumne River Studies

There are three anadromous salmonid species/runs of interest that pertain to upper Tuolumne River Basin studies, i.e., those that can be considered potential candidates for reintroduction into the upper Tuolumne River Basin: Central Valley (CV) Spring-Run and Fall-Run Chinook Salmon (*O. tshawytscha*) and California Central Valley (CCV) Steelhead (anadromous *O. mykiss*). The federal Endangered Species Act (ESA) listing status is described below for each species/run.

1.4.6.1 Central Valley Spring-Run Chinook Salmon

The Central Valley spring-run Chinook salmon ESU was originally listed as a threatened species in 1999 (64 FR 50394). After the development of the NMFS hatchery listing policy, the status of the ESU was re-evaluated, and a final determination was made that reaffirmed the threatened species status for the ESU (70 FR 37204) (NMFS 2016a). NMFS proposed critical habitat for Central Valley spring-run Chinook salmon on December 10, 2004 (69 FR 71880) and published a final rule designating critical habitat for the ESU on September 2, 2005 (70 FR 52488) (NMFS 2016). There is no CV spring-run Chinook salmon critical habitat in the Tuolumne River watershed.

1.4.6.2 California Central Valley Steelhead

NMFS listed the CCV steelhead as a threatened species on March 19, 1998 (63 FR 13347), and on September 8, 2000, pursuant to a July 10, 2000 rule issued by NMFS under Section 4(d) of

the ESA (16 USC § 1533(d)), statutory take restrictions that apply to listed species began to apply, with certain limitations, to CCV steelhead (65 FR 42422) (NMFS 2016b). On January 5, 2006, NMFS reaffirmed the threatened status of CCV steelhead and decided to apply the joint U.S. Fish and Wildlife Service-National Marine Fisheries Service DPS policy (61 FR 4722). NMFS proposed critical habitat for CCV steelhead on February 5, 1999 (64 FR 5740) in compliance with Section 4(a)(3)(A) of the ESA. In the Tuolumne River, critical habitat for CCV steelhead extends from the confluence with the San Joaquin River upstream to La Grange Diversion Dam.

1.4.6.3 Central Valley Fall-Run Chinook Salmon

Because of concerns over population size and hatchery influence, the Central Valley fall/late fall-run Chinook salmon ESU is considered a Species of Concern under the ESA.

2.0 STUDY GOALS AND OBJECTIVES

The goal of this study is to assess barriers to the upstream migration of adult spring-run Chinook salmon and steelhead in the upper Tuolumne River basin from the head of the Don Pedro Reservoir to Early Intake. Study objectives include:

- compile results from any relevant prior studies and conduct field surveys to identify barriers (both total and partial) to upstream anadromous salmonid migration in the mainstem Tuolumne River upstream of the Don Pedro Project Boundary and tributaries, including the North, Middle, and South forks of the Tuolumne River, Cherry Creek, and the Clavey River; and
- characterize and document the physical structure of each barrier under base flow and high flow (i.e., spring runoff) conditions.

3.0 STUDY AREA

The study area includes the following mainstem and tributary stream reaches of the Tuolumne River watershed (Figure 3.0-1):

- **Tuolumne River** – From approximate upstream limit of the Don Pedro Project at approximately RM 81 (below the North Fork confluence) upstream to Early Intake RM 105.4).
- **North Fork Tuolumne River** – From the confluence with the Tuolumne River upstream to the first total fish passage barrier.
- **South Fork/Middle Fork Tuolumne River** – From the confluence with the Tuolumne River upstream to the first total fish passage barrier.
- **Clavey River** – From the confluence with the Tuolumne River upstream to the first total fish passage barrier. Note that Reed Creek (a tributary to the Clavey River) may be included depending upon the presence/absence of a total fish passage barrier downstream of its confluence with the Clavey River.
- **Cherry Creek/Eleanor Creek** – From the confluence with the Tuolumne River upstream to the first total fish passage barrier.

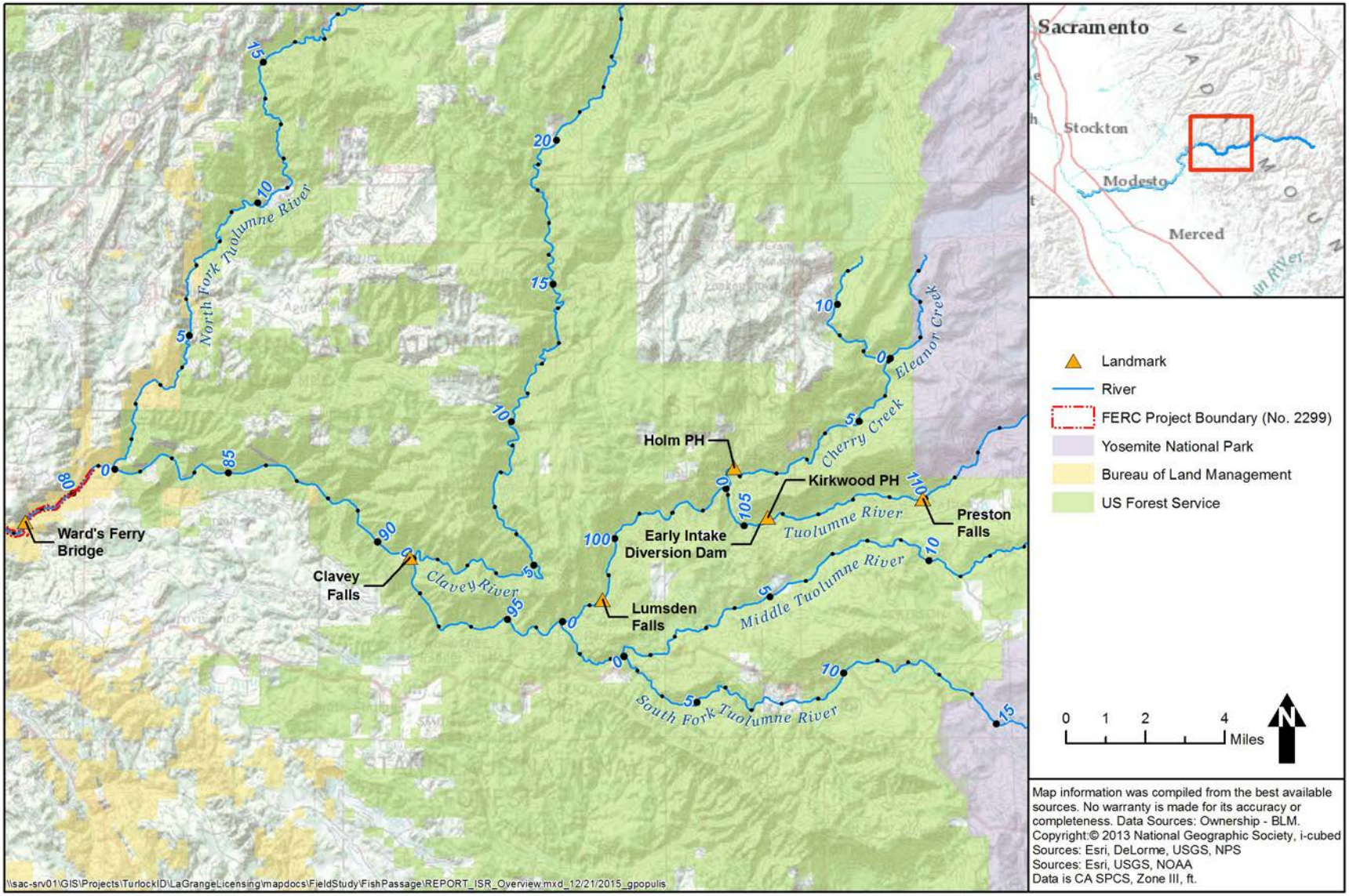


Figure 3.0-1. Overview map presenting the study area with notable rivers, tributaries and features.

4.0 METHODOLOGY

The Upper River Barriers Study included both desktop exercises and measurements in the field. Desktop exercises utilized topographic mapping software, aerial photographs, available hydrologic data, and other existing information to identify initial accounts of physical features that may potentially be barriers to the upstream migration of spring-run Chinook salmon and steelhead. Field investigations included visual observation and the collection of physical data to confirm site characteristics and draw conclusions regarding the ability of migrating anadromous fish to pass physical features that may potentially be barriers.

Features identified within the study area through desktop or field exercises which may or may not be impediments to fish passage are classified in the report as follows:

- **Potential Barrier** – A feature identified by the study team that may exhibit conditions which create an impediment to upstream fish passage of adult spring-run Chinook or steelhead on a partial or temporal basis but where conclusions have not yet been developed to establish the duration, range of flows, or conditions when or if the feature is passable.
- **Partial Barrier** – A feature which has been evaluated by the study team and conclusions have been developed which establish a feature as passible on a partial or temporal basis. The term "partial" generally extends to barriers that are impassible by one or more species or life stages of fish species being evaluated. The term "temporal" generally refers to barriers that are impassable intermittently on a seasonal basis or when a certain range of flow, debris, or sediment conditions exist. For the purposes of this study, the term "Partial" combines both interpretations.
- **Total Barrier** – A feature which has been evaluated by the study team and found to be not passable by adult spring-run Chinook or steelhead throughout the range of flows when migration is anticipated.
- **Passable Feature** – A feature which has been evaluated by the study team and found to be passable by adult spring-run Chinook or steelhead throughout the range of flows when migration is anticipated.

The presence and/or absence of barriers to upstream passage and findings regarding the ability of fish to pass identified features employed a phased approach as described below.

- A list of potential barriers to upstream passage was initially developed based upon the information gathered by desktop methods described in Section 4.1;
- As described in Section 4.2, field surveys were performed to gather physical data at each feature and to characterize major elements which influence fish passage;
- A screening level barrier assessment was performed using the data from activities described in Section 4.1 and the field surveys described in Section 4.2;
- Each feature identified was classified as one of the following: (1) a "total barrier" to fish passage; (2) a "passable feature"; (3) a "potential barrier"; or a "partial barrier" to fish

passage. The initial classification was based upon screening criteria summarized in Section 4.3;

- Potential barriers requiring additional field surveys and further evaluation to improve the certainty of final classifications were identified and recommendations for additional data collection were made.

In summary, the determination of fish passage and ultimate classification for each physical feature identified in this study was performed using the process outlined in Figure 4.0-1. Activities performed in 2015 and 2016 focused on collection of data, performing the first field surveys, and conducting a screening level assessment of features identified in the field. Additional activities were performed in 2016 to further evaluate any feature that remained a potential barrier after the first round of initial classifications.

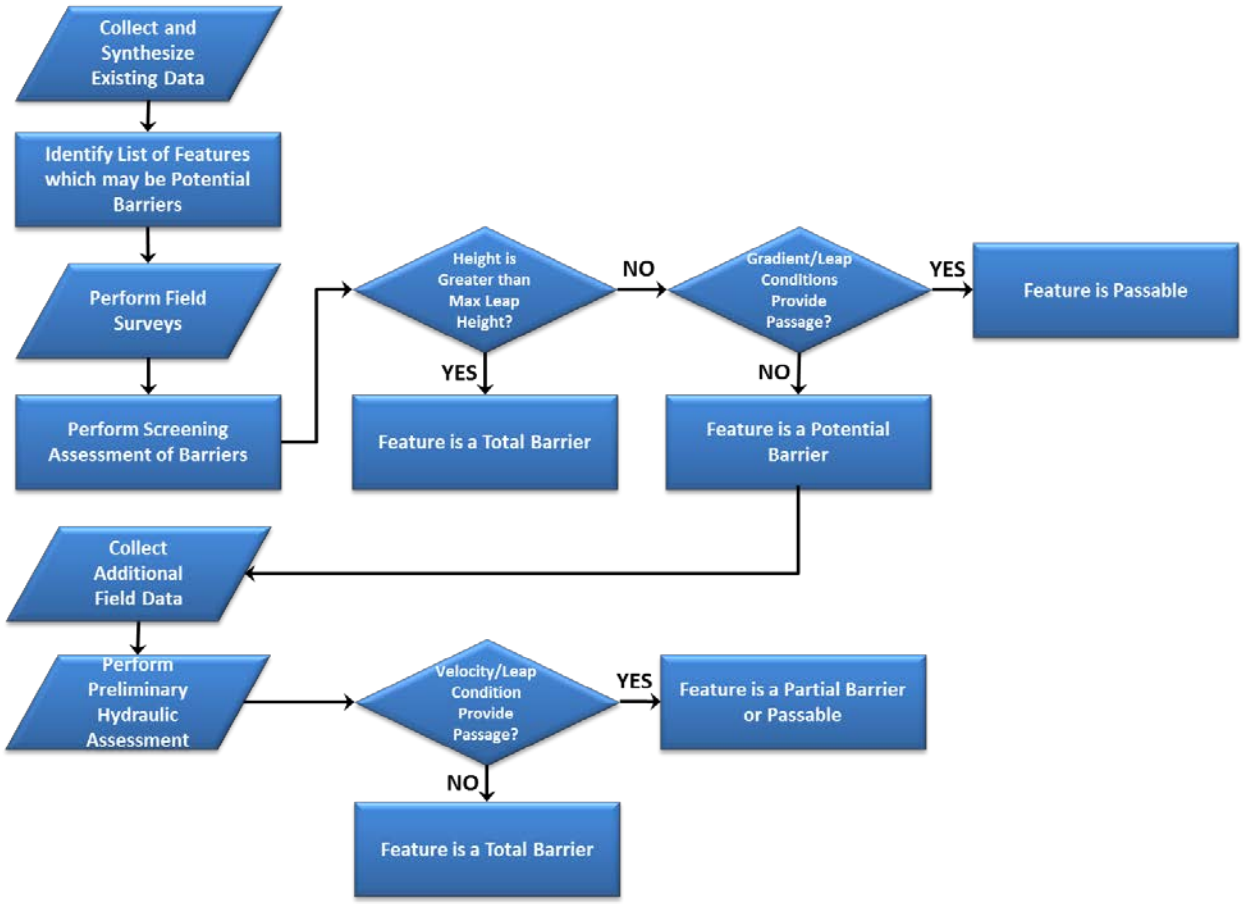


Figure 4.0-1. Process flow chart summarizing barrier study methodology.

4.1 Obtain and Review Existing Information

Existing data pertinent to the existence and classification of potential impediments to migration of anadromous salmonids within the study area were compiled and reviewed. Completion of this task included background research into multiple sources of data including habitat studies, recreational documentation (such as recreational boating maps and photos), ethnographic data,

videos and photographs, newspaper records, historical accounts, and available geographic information system (GIS) data characterizing conditions in the upper Tuolumne River basin. This task also included requesting data from the Districts, federal and state agencies, and other entities that have performed work in the study area.

Data from the upper Tuolumne River LiDAR and hyperspectral remote sensing-based habitat evaluation being conducted by NMFS was not available for use in this study. Review and incorporation of any relevant information from the NMFS study would occur upon this information becoming available.

4.2 Perform Field Surveys

Field surveys were performed during the 2015 and 2016 field seasons to gather information for this study. A summary of survey dates, subject river reaches, and activities performed is provided in Table 4.2-1. The types of data and information gathered during the field surveys are presented in the following paragraphs. The results of each survey are discussed by river or tributary in Section 5. A photograph log containing images of each feature surveyed and an account of the data collected is provided in Attachment A.

Table 4.2-1. Summary of field surveys performed during the 2015 and 2016 field seasons.

River or Tributary	RM or Feature		Activities Performed
Mainstem Tuolumne River	80 to 97	August 2-4, 2015	Survey performed via watercraft
	97 to 103	Sept 14, 2016	Survey performed on foot
	103 to 104.3	October 27, 2015	Survey performed on foot
	Lumsden Falls	August 5-6, 2015	Survey performed on foot
	Lumsden Falls	May 11, 2016	High flow survey performed on foot
	Lumsden Falls	Sept 14, 2016	Survey performed on foot
North Fork	0 to 1.69	July 15, 2016	Survey performed on foot
South Fork	0 to 1.9	August 5, 2015	Survey performed on foot
Clavey River	0 to 2.05	August 3, 2015	Survey performed on foot
Cherry Creek	1.0 to 1.95	October 26, 2015	Survey performed on foot
	0 to 1.0	October 27, 2015	Survey performed on foot
	1.7 to 1.95	May 11, 2016	High flow survey performed on foot

Watercraft was used primarily to transport personnel and equipment to the Clavey River and the North Fork Tuolumne River confluence with the mainstem Tuolumne River so that surveys could be conducted on foot in those tributaries. Qualitative observations of potential fish passage barriers were made while traveling along the mainstem Tuolumne River from the put-in at Meral's Pool to the take-out at Wards Ferry Bridge but in general it was not necessary to make additional stops while traveling along the mainstem to conduct barrier assessments. One stop was made at Clavey Falls to collect data and to conduct barrier surveys in the Clavey River.

Field surveys performed on foot were performed over very difficult terrain. Progress was slow and arduous even at low flow conditions. Challenges along the Clavey River, South Fork, and North Fork tributaries of the Tuolumne River included frequent deep and shallow water crossings, bouldering, climbing, steep descents, and navigating through high levels of topographic diversity. In many cases, water portage through deep pools was required to avoid technical climbing requirements or traversing steep confined bedrock walls. Travel rates,

excluding time required for surveying, were as slow as two or three hours per mile in higher gradient areas. Given the difficult conditions, limited field gear was carried and in many cases abbreviated surveys were conducted given the constraint of safety protocols and requirements. The following information was recorded at each identified feature during the field surveys:

- GPS coordinate points;
- effective height of each barrier either measured in the field or through approximation of scaled features in photographs;
- gradient/slope of the barrier (when applicable) measured with range finder and hand level;
- notes describing leap conditions and presence of obstacles (e.g. overhanging ledges, shallow bedrock, dewatering, distance, boulder complex, etc.);
- an assessment and documentation of adjacent channel features that might be inundated at higher flows;
- photograph of the barrier from one or more relevant photo-points; and
- periodically flow and velocity measurements describing tributary flow and landing conditions at the feature crest.

The above list deviates slightly from the original elements defined in the original RSP. Three measurements were not consistently recorded: (1) maximum and average depth of plunge pools at the base of barriers; (2) water velocity measurements at the apex of the barrier; and (3) maximum and average depth of the landing zone on the upstream side of the barrier. These elements were not consistently recorded due to site-specific safety considerations, equipment requirements, time constraints, and the ability to measure using alternative desktop methods. Depth of the plunge pool below each barrier was difficult to evaluate on a quantitative basis for all sites and therefore the summary of results presented herein are based on field notes, photographs, and aerial photos available for each site. As conditions allowed, water velocities, depths, and landing conditions above the feature crest were sampled to characterize some features.

Existing information collected during activities summarized in Section 4.1 and field data collected as part of the field surveys in Section 4.2 were synthesized and a screening level fish passage assessment was performed to classify each selected feature as one of the following: (1) a total barrier to fish passage; (2) a passable feature; or (3) a potential barrier to fish passage. Barrier classifications were performed using the methods and criteria detailed in Section 4.3 below.

4.3 Barrier Classification and Rationale

The analysis and classification of barriers was performed by comparing fish swimming and leaping capabilities against the physical characteristics of each potential barrier identified and evaluated in the field. Swimming capabilities for spring-run Chinook salmon and steelhead were calculated using mathematical relationships outlined in Bell (1973), Power and Orsborn (1985), and Hunter and Mayor (1986). Calculated “sustained,” “prolonged,” and “burst” swim speeds

and durations were used to assess those situations where steep gradients create high velocity, turbulent conditions through chutes or cascades. The calculated burst speed for each fish species was also used to calculate the leaping capability using the mathematical relationships presented in Power and Orsborn (1985). Resulting calculations provided a series of leap angles, leap spans, and leap heights for specific size classes of adult fish. The combination of calculated swimming and leaping capabilities was used to identify whether or not a hydraulic feature (high velocity or leap condition) is passable.

The velocity and minimum leap conditions that a fish may experience can vary seasonally and are dependent upon the hydraulic regime occurring at the time a fish attempts to ascend a feature. The data gathered in the tributaries to the Tuolumne River during the first field survey represented low-flow conditions; therefore, the first field survey focused on the identification of features exhibiting no opportunities for passage or those that would be classified as total barriers. Based upon the initial findings, collection of additional and more detailed information is recommended for a selected number of features to occur during a second field visit for those barriers that remain classified as potential barriers to fish passage.

Data and analysis presented by Bell (1973), Power and Orsborn (1985), and Hunter and Mayor (1986) speak generally of "Chinook" salmon or "steelhead" without clearly distinguishing between fall-run or spring-run. The swimming and leaping performance for either run can vary. Variations in ability are associated with the degree of maturation at the time of river entry, fish length, migration distance, the temperature and flow characteristics of the spawning site, and their actual time of spawning. The swimming and leaping capabilities developed for this study are therefore intended to characterize a representative population of spring-run Chinook and winter-run steelhead that are candidates for reintroduction into the upper Tuolumne River watershed according to NMFS' Recovery Plan (NMFS 2014). It is recognized that fall-run Chinook may also be considered for reintroduction in the upper Tuolumne River by NMFS and although not specifically mentioned, results presented in this document for spring-run can be extended to include fall-run Chinook as well.

4.3.1 Classification of Total Barriers

Features are classified as a total barrier if a feature exhibits a measured effective barrier height that is greater than the calculated maximum leap height of a spring-run Chinook salmon or steelhead. The maximum leap height is estimated for this study using the burst speed resulting from swimming capability data presented in Bell (1973) and Hunter and Mayor (1986) and the leap height relationships outlined in Powers and Orsborn (1985). Results from these calculations provided estimated leap heights and leap spans over a range of trajectory angles for spring-run Chinook and steelhead. The classification for total barriers used the maximum estimated leap height calculated for a trajectory of 85 degrees.

This study used a maturity coefficient, Cfc, of 0.75 to represent a fish in good condition (i.e., in the river a short time with spawning colors apparent, but still migrating upstream). The Cfc of 0.75 was applied to represent the expected general condition of spring-run Chinook salmon and steelhead by the time they have traveled upstream to the study area. Given that upstream migration requires travel over a significant distance (fish originate from the Bay-Delta and

migrate up the San Joaquin River), this Cfc value is expected to be conservative and result in a higher swimming and leaping capability than fish that may reach the upper Tuolumne River. The maximum leaping capability calculated for steelhead in good condition is provided in Figure 4.3-1. The maximum leaping capability calculated for spring-run Chinook salmon in good condition is provided in Figure 4.3-2.

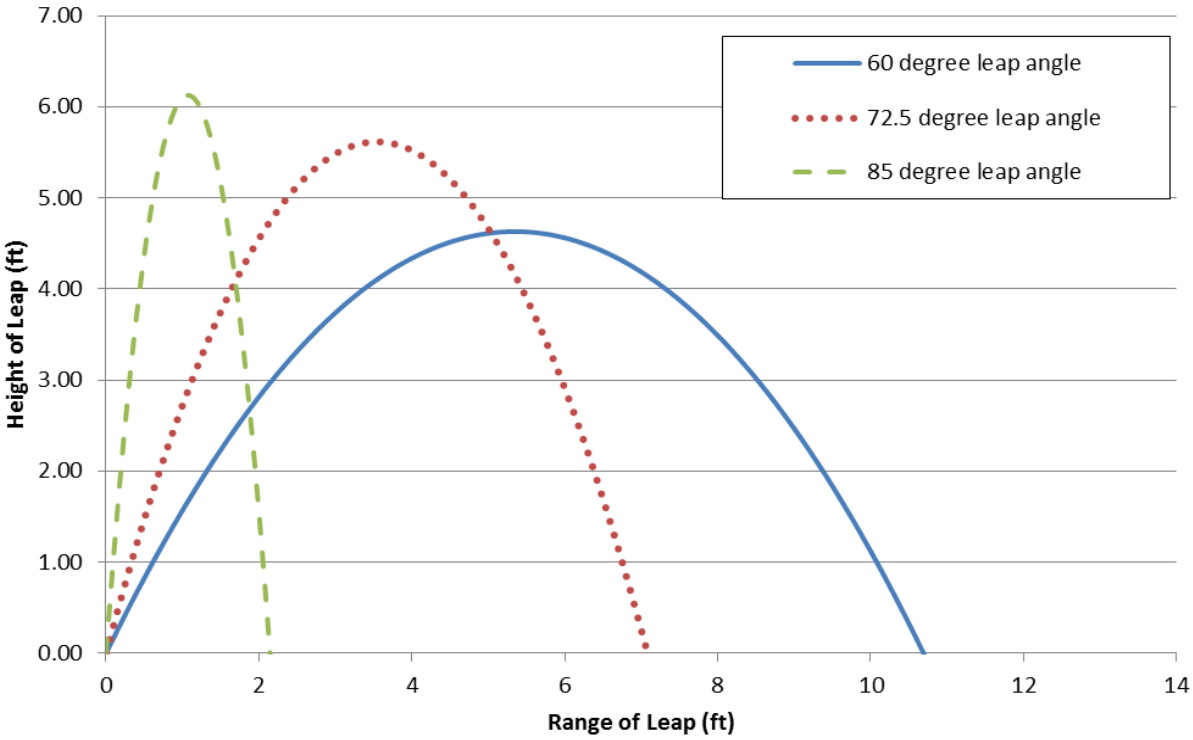


Figure 4.3-1. Maximum leaping capability calculated for steelhead in good condition, Cfc=0.75.

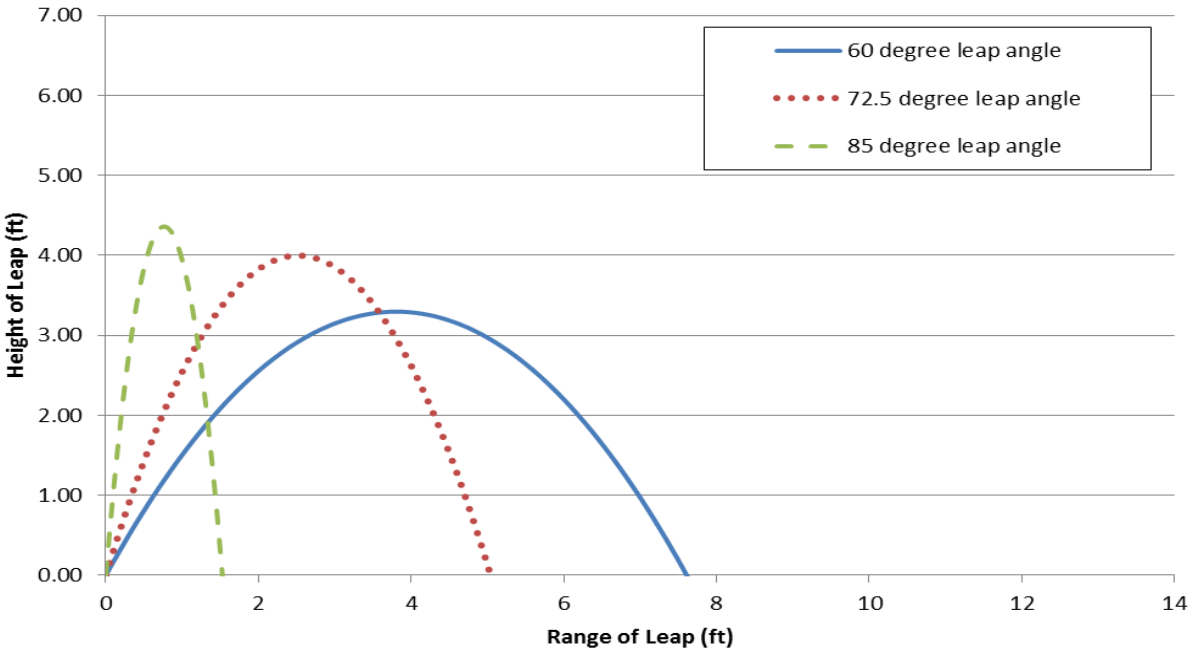


Figure 4.3-2. Maximum leaping capability calculated for spring-run Chinook salmon in good condition, Cfc=0.75.

The calculated maximum leap heights resulting from an 85 degree leap angle and a Cfc of 0.75 are estimated to be 6.12 feet for adult steelhead and 4.36 feet for adult spring-run Chinook salmon. Therefore, a feature with a measured effective height greater than 4.36 or 6.12 feet is classified as a total barrier, with respect to each individual species. One exception to this conclusion is if upon inspection it appeared that the effective leap height in question would be influenced by higher flow regimes or alternative pathways. One such example could occur when the cross-sectional geometry of the tailwater control is narrower than the crest height or landing area then such a feature may exhibit lower hydraulic differential conditions at higher flows, which may have implications upon feature classification. Features where multiple pathways appeared to be hydraulically connected at higher flows were also identified. If the study team determined that passable conditions could exist at different flow regimes, such features were classified as potential barriers and identified for further evaluation. Otherwise, the feature was documented as a total barrier and a recommendation for no further evaluation was made for that site.

4.3.2 Classification of Passable Features

A feature was classified as a passable feature if the feature exhibits a measured effective barrier height, potential leap span, and pool depth that fall within the calculated leaping capabilities estimated using the Powers and Orsborn (1985) methodology or if the average gradient of a feature meets the general requirements outlined in the U.S. Forest Service Handbook 2090.21 Adult Salmonid Migration Blockage (USFS 2001).

In this scenario, a number of leap trajectories, leap spans, and resulting leap heights were considered and compared to the barrier heights and leap spans measured in the field. If the

measured field condition for a unique feature exhibits values lower than any combination of estimated leap trajectory, leap span, and leap height capability for each species, the feature was classified as passable for that individual species. If an apparent velocity impediment met the general gradient and length requirements outlined in USFS (2001), then the feature was classified as passable. Figure 4.3-1 and Figure 4.3-2 illustrate several potential leaping trajectory, span, and height combinations for adult steelhead and spring-run Chinook salmon in good condition. These values are summarized in Table 4.3-1. General criteria for average gradient and pool depth requirements as described by USFS (2001) are summarized in Table 4.3-2.

Table 4.3-1. Summary of leaping trajectory, span, and height capabilities for spring-run Chinook salmon and steelhead.

Species	Angle of Trajectory (degrees)	Height of Leap (ft)	Range of Leap (ft)
Steelhead	60.0	4.63	5.35
	72.5	5.62	3.55
	85.0	6.12	1.05
Spring-run Chinook Salmon	60.0	3.30	3.80
	72.5	4.00	2.50
	85.0	4.36	0.75

Table 4.3-2. Minimum pool depth and gradient criteria adapted from USFS (2001).

Metric	Criterion
Pool depth: A blockage may be presumed if pool depth is less than the values to the right.	1.25 x jump height, except that there is no minimum pool depth for falls: (a) <4 feet in the case of steelhead; and (b) <2 feet in the case of spring-run Chinook salmon
Steep Channel: A blockage may be presumed if channel steepness is greater than the following without resting places for fish.	>225 feet @ 12% gradient >100 feet @ 16% gradient >50 feet @ 20% gradient

Likewise with the classification of total barriers, if the measured conditions appear to exhibit values lower than any combination of estimated leap trajectory, leap span, flow velocity, and leap height capability for each species but the study team determined that conditions could exist at different flow regimes which were impassible, such features were classified as potential barriers and identified for further evaluation.

4.3.3 Classification of Potential Barriers

River hydraulics have a significant influence on upstream fish passage; the ability of a fish to pass a barrier is variable and can change seasonally. Higher seasonal flow events may increase plunge pool depths and reduce barrier heights when a certain species or portion of a fish population are present and actively migrating upstream. Run timing varies between spring-run Chinook salmon and steelhead. Spring-run Chinook salmon generally enter streams from the ocean coinciding with high flow events and generally hold for an extended period before spawning which may expose them to low flow periods with higher water temperatures. Steelhead enter streams from the ocean coinciding with higher spring flows, move high in the watershed, hold, and spawn during elevated flows (Moyle 2002). The extent to which either

species would ascend upstream in the study area during elevated flows is an unknown factor that makes it difficult to determine at what flow a species would likely encounter a potential barrier[5].

Features classified as potential barriers that were identified by the study team exhibited conditions which create an impediment to upstream fish passage of adult spring-run Chinook or steelhead on a temporal or intermittent basis but additional data collection or observations are required to develop final conclusions whether the feature is a total barrier, partial barrier, or passable feature.

Specifically, features were classified as a potential barrier, rather than total barrier or passable feature, if one of the following conditions occurred:

- the identified feature exhibited measured effective barrier heights, horizontal leap distances, or flow velocities greater then the maximum leaping or swimming capability of spring-run Chinook or steelhead but conditions which may facilitate passage at some range of migration flows were identified by the study team (e.g., alternative pathway or decreasing hydraulic differential with increasing flows); or
- the identified feature exhibited measured effective barrier heights, horizontal leap distances, or flow velocities less than the maximum leaping or swimming capability of spring-run Chinook or steelhead but possessed low pool depths, obstructions at the leaping or landing zones, or high levels of turbulence which may inhibit passage at some range of migration flows were apparent.

4.3.4 Feature Descriptions

Narratives describing findings of field observations for each feature were prepared using relative classifications of water depth (for both leaping and swimming), turbulence and flow velocity. For instance, high or low flow velocity is used in relation to fish swimming capabilities rather than in reference to high flow, low-frequency events. These terms are frequently referenced in the results section (Section 5.0) in qualitative terms such as shallow, moderate, deep, low and high. Although definitive measurements were not taken for all features during the first round of field surveys, these terms are used to refer to specific, quantitative ranges of conditions that influence the ability of adult salmonids to ascend each feature based upon the visual observations made in the field. The range of values and terms used in each narrative are assigned as shown in Tables 4.3-3 through 4.3-6.

[5] Evaluation of partial barriers will include the identification of anticipated migration timing and potential flows experienced during migration in the Tuolumne River mainstem and tributaries. Flow periods and quantities should also account for the travel time needed for spring-run Chinook or steelhead to complete their upstream migration to the upper Tuolumne River basin. Because there are no spring-run Chinook or steelhead populations in the Tuolumne River, life stage periodicities are currently unknown and can only be inferred from other regional data sources. Additional input and collaboration with fisheries agencies has been requested on this subject. At the time of report development, there have been no responses by licensing participants on this issue.

Table 4.3-3. Water depth criteria for leaping.

Descriptor	Depth (feet)	Description
Shallow	< 2	Leaping potentially impaired by inadequate water depth.
Moderate	2 - 5	Sufficient water depth for shorter leaps (less than 1.25 times the pool depth) but impaired leaping for barriers greater than 1.25 times the pool depth (adapted from USFS 2001)
Deep	> 5	Likely no impediment to leaping features within leaping capability

Table 4.3-4. Water depth criteria for swimming.

Descriptor	Depth (feet)	Description
Shallow	< 1	Swimming impaired or delayed by inadequate water depth.
Deep	> 1	Water depth sufficient for swimming.

Table 4.3-5. Turbulence criteria.

Descriptor	Energy Dissipation Factor ($ft\text{-}lb/ft^3/sec$)	Description
Low	< 2	Laminar flow, little energy loss, few eddies or gyres. Conditions generally do not impede passage.
Moderate	2 - 6	Turbulent flow with some eddies, gyres, air entrainment, and energy loss. Conditions may impede swimming ability and cause some loss of locomotion.
High	> 6	Very turbulent flow with eddies, gyres, air entrainment and high energy loss. Air entrainment begins to limit fish locomotion capability. Conditions are difficult to navigate and likely impede swimming ability.

Table 4.3-6. Flow velocity criteria.

Descriptor	Swimming Speed[1]			Duration	Description
	Swimming Mode	Steelhead (ft/s)	Chinook Salmon (ft/s)		
Low	Sustained	0 - 4.6	0 - 3.4	> 200 min	Low water velocities where sustained swimming speeds can be maintained for long durations of time.
Moderate	Prolonged	4.6 - 13.7	3.4 - 10.8	15 sec to 200 min	Moderate water velocities where speed and/or duration are compromised; fish may be able to sustain prolonged swimming speeds for some duration, or swim at burst speeds for short durations.
High	Burst	13.7 - 26.5	10.8 - 22.4	Less than 15 sec	High water velocities where prolonged and burst swimming speed capabilities may be exceeded even for short durations of time.

[1] Powers and Orsborn 1985.

5.0 RESULTS

The following section summarizes the study results obtained in the 2015 and 2016 field seasons. Activities performed during this time period included a desktop review of existing information and field surveys on the mainstem Tuolumne River from the upper extent of the Don Pedro Project (approximately RM 81) to Early Intake (RM 105.3), Clavey River, and the South Fork Tuolumne River.

5.1 Review of Existing Information

A review of existing information regarding fish passage barriers in the upper Tuolumne River basin discovered five primary sources that were available prior to performance of field surveys. Features which may potentially be barriers to fish passage identified in the literature are presented in Table 5.1-1 and discussed further in the paragraphs below.

Table 5.1-1. Fish passage barriers in the upper Tuolumne River basin, based on a review of existing information.

River/Tributary	Barrier Location	Description	Sources
Mainstem Tuolumne River	RM 90.0	Clavey Falls	Yoshiyama et al. 2001
	RM 97.3	Lumsden Falls	Tim Hutchins (personal communication, October, 13, 2015)
	RM 105.3	Early Intake	Visual observation August 2015
	RM 108.5	Preston Falls	Buckmaster et al. 2009, Yoshiyama et al. 2001
North Fork Tuolumne River	RM 1.0	12-foot waterfall	Buckmaster et al. 2009, Yoshiyama et al. 2001
South Fork Tuolumne River	No specific location given	Presumably not used by salmon – steep section at the mouth	Yoshiyama et al. 2001
	No specific location given	25-30 feet waterfall in the lower South Fork	Stanley and Holbek 1984
Clavey River	RM 0.2 - 0.7	Large magnitude falls (no size estimate given)	EA Engineering 1990
	RM 0.25	Barrier falls	Buckmaster et al. 2009, Yoshiyama et al. 2001
	RM 9 - 10	Large magnitude falls (no size estimate given)	EA Engineering 1990

Information presented in existing literature suggests that the mainstem Tuolumne River has at least two and possibly three natural barriers to fish passage. The first is Preston Falls located approximately four miles upstream of Early Intake (Yoshiyama et al. 2001, Buckmaster et al. 2009). The falls are approximately 15 feet high and present a complete barrier to fish migration (Yoshiyama et al. 2001, Buckmaster et al. 2009). Additionally, Yoshiyama et al. (2001) identified several waterfalls just below the current Hetch Hetchy Reservoir that stop all fish that might have ascended to that point. Yoshiyama et al. (2001) also hypothesized that Clavey Falls (located on the mainstem Tuolumne River immediately downstream of the Clavey River confluence) could be a migration barrier at certain flows.

The North Fork Tuolumne River has one known potential barrier to fish passage. The feature is located approximately one mile upstream of the confluence with the mainstem Tuolumne River. Both Buckmaster et al. (2009) and Yoshiyama et al. (2001) identified this feature as a waterfall with a height approaching 12 feet.

According to Yoshiyama et al. (2001), the South Fork Tuolumne River has presumably never been used by salmon; Yoshiyama et al. (2001) hypothesized that the steep section near the mouth of the South Fork Tuolumne River likely obstructed salmon from moving further upstream. Additionally, Stanley and Holbek (1984) report that there is a 25 to 30 foot waterfall in the lower reach. However, the exact location of this falls was not provided.

The Clavey River has four barriers that were identified during the existing information review. EA Engineering (1990) found several large magnitude falls within the first mile of the confluence with the mainstem Tuolumne River. Buckmaster et al. (2009) and Yoshiyama et al. (2001) both identified river mile 0.25 as having a barrier to fish migration. EA Engineering (1990) also identified several large magnitude falls from RMs 9 through 10, and cascades and steep streambed at the mouth of Hunter Creek.

5.2 Results of 2015 and 2016 Field Investigations

The following Section summarizes data obtained during the 2015 and 2016 field investigations, discussion and interpretation of results, and barrier classifications for each feature. Barrier classification followed the methods outlined in Section 4.0.

5.2.1 Mainstem Tuolumne River

Field surveys were performed on the mainstem Tuolumne River via raft on August 2 - 4, 2015 and observed by land on August 5 and 6, 2015 and September 14, 2016. Additional field surveys and observations were made specifically at Lumsden Falls on May 11 and September 14, 2016. Results from all field investigation identified two potential barriers to fish passage: Clavey Falls (RM 90) and Lumsden Falls (RM 97.3). The primary characteristics of each feature are presented in Table 5.2-1 and Table 5.2-2. Each feature was initially observed at two flow conditions based upon releases from upstream hydropower facilities owned and operated by CCSF. Flows at Lumsden and Clavey Falls ranged from 400 to 600 cubic feet per second (cfs) during the evening to the morning and flows up to 1,200 cfs were observed during mid-day. Additional observations were made at Lumsden Falls at flows of up to 8,600 cfs. A map summarizing the location of each feature is presented as Figure 5.2-1 (see page 5-4). A narrative description of each identified feature is provided in the following paragraphs. Images and a data record of each feature are provided as Photos A-1 through A-12 in Attachment A.

Table 5.2-1. Summary of potential barriers identified on the mainstem Tuolumne River during field surveys.

Feature	River Mile	Description	Initial Classification
Clavey Falls	90	Cascade and steps	Passable
Lumsden Falls	97.3	Cascade	Potential Barrier

Table 5.2-2. Physical characteristics of potential barriers identified on the mainstem Tuolumne River during field surveys.

Feature	Total Height (ft)	Max Leap (ft)	Obstructed Launch or Landing	Leaping Depth	Swimming Depth	Turbulence	Velocity	Alternate Pathway Present?
Clavey Falls	12	3	Unobstructed	Moderate	Deep	Moderate	Moderate	Yes
Lumsden Falls	18	3-5	Unobstructed	Moderate	Deep	High	High	Potential

5.2.1.1 Clavey Falls

Clavey Falls comprises a cascade sequence and several steps at RM 90 on the mainstem Tuolumne River. The downstream step is a constriction formed by a bedrock wall on river left and a large boulder (approximately 10 feet diameter) in the middle of the river (Attachment A, Photo A-1). The main flow comprises a relatively smooth tongue on river left, with an approximately three-foot vertical drop. Both the launch and landing zones are deep and long (approximately 50 and 80 feet, respectively) with moderate velocity and turbulence. During observed on-peak flows, flow to the river right of the large boulder provides an alternative path, dropping approximately three vertical feet over a boulder-formed step. The launching pool has moderate depth and turbulence. The landing pool has moderate depth and low velocity. During observed flow conditions as low as 400 cfs, this pathway became too shallow to facilitate fish passage.

Upstream of the lower drop, there are several boulder-formed steps (each less than approximately two vertical feet; Attachment A, Photo A-2). The steps occur within runs with moderate velocity and turbulence and without clear launching or landing pools. During higher on-peak flows, flow to the river right provides an alternative path with a lower gradient and low velocity; however, this pathway may be dewatered or too shallow for fish passage during lower flows.

Further upstream, the cascade sequence extends for approximately 70 feet, with an approximate vertical rise of 6 feet (Attachment A, Photos A-3 through A-5). The cascade sequence occurs within a series of boulders ranging from approximately two to five feet in diameter, with multiple drops and pathways; the flow has high turbulence through this area, particularly at higher (recreational) flows. Steps within the cascade range from approximately one to three feet in height, with high velocity, high turbulence, moderate depth launching and landing zones. During low flow conditions there is an alternate, lower gradient, moderate velocity and turbulence pathway on the river left, with one clear step (approximately one to two feet in height) with high turbulence and velocity launching and landing zones of moderate depths.

Information collected during the field survey suggests that this feature is passable at a wide range of flow conditions. The feature is likely a barrier at very low flows but generally exhibits conditions sufficient for passage throughout the range of flows observed. This feature is classified as passable given that multiple pathways exist which exhibit unobstructed leap heights within the leaping capabilities for both spring-run Chinook and steelhead calculated in Section 4.3.

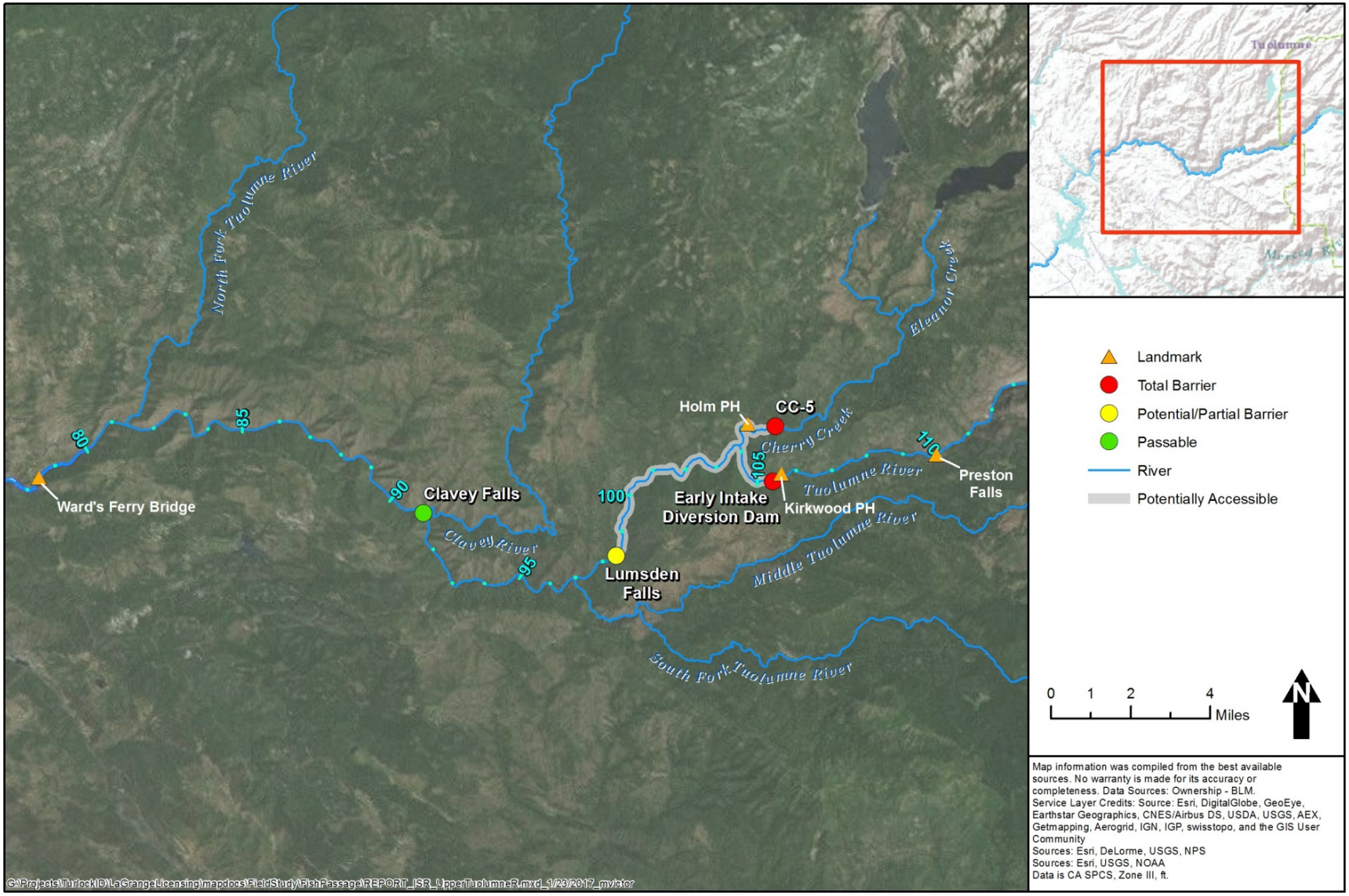


Figure 5.2-1. Summary of passage features and classification on the upper Tuolumne River.

5.2.1.2 Lumsden Falls

Lumsden Falls is a cascade feature located at RM 97.3 on the mainstem Tuolumne River (Attachment A, Photos A-6 through A-12). The flow takes multiple paths through a high gradient series of boulder cascades confined by bedrock on river right. Boulders range in diameter from approximately 5 to 10 feet. The main drop of the cascade is approximately 18 vertical feet over a distance of approximately 100 feet (18 percent average gradient). A large, deep pool occurs at the bottom of the falls but has moderate turbulence, particularly at the presumed launching zone at the base of the falls. Leaps with heights on the order of three to five feet taken in intermediate steps up the falls would have high turbulence and high velocity launching and landing zones of moderate depth. A boulder field forms the crest of the falls and also has high turbulence and velocity. Multiple pathways of flow occur throughout the falls, but a bedrock wall on river right confines flow to the main channel, eliminating side channel development and therefore alternate fish passage pathways on river right. A large boulder field (with boulder diameters ranging from 5 to 20 feet diameter) resides on the river left floodplain could potentially provide alternative navigational pathways at high flow events.

Lumsden Falls was visited on four separate occasions over the course of the 2015 and 2016 study period. Observed river flows ranged from lower flow conditions (~420 cfs) to higher flow conditions resulting from upstream reservoir releases (~8,600 cfs). Photo documentation from these visits provide insight into the general hydraulic characteristics of this feature and highlighted the uncertainty about opportunities for fish passage. During the September 2015 field survey, Lumsden Falls was observed at low flow conditions of approximately 423 cfs (see Figure 5.2-2). The confining bedrock on river right (left side of photo) and the large boulders on river left were exposed. High turbulence existed from the crest of the cascade to well into the launching zone downstream. Exposed boulders throughout the cascade created leap conditions that appeared navigable from a leap-height perspective but high levels of turbulence created very challenging leap and swimming conditions. Low velocity areas that could provide resting, staging, or launching areas near shear zones or behind boulders were not present for the length of the feature. Alternate flow paths around the boulder field on river left were not observed at this flow condition.

As flow increases at Lumsden Falls, hydraulic conditions and therefore conclusions relative to fish passage are similar to the 423 cfs observations. Figures 5.2-3 and 5.2-4 depict the feature at 1,226 cfs, as observed during the August 2015 site visit. High turbulence continues to dominate the entire length of the feature. The launching pool at the downstream extent is deeper, but areas of low turbulence are still minimal and the zone of high turbulence and velocity extends further downstream into the launching pool than at lower observed flows. Figure 5.2-4 depicts high turbulence at the base of the feature and suggests that the nearest area of lower turbulence to support leap attempts is well downstream of the most downstream step. Similar to lower flows, low velocity areas that could provide resting, staging, or launching areas near shear zones or behind boulders were not present for the length of the feature. Alternate flow paths on river left are still not available for fish to circumnavigate the feature at this flow.

Figure 5.2-2. Lumsden Falls at 423 cfs in Sept 2016.

Figure 5.2-3. Lumsden Falls at 1,226 cfs in Aug 2015.

Figure 5.2-4. Closer view of Lumsden Falls turbulence at initial leap position, 1,226 cfs.

Figure 5.2-5. Lumsden Falls at 8,600 cfs in May 2016.

Lumsden Falls was also visited in May 2016 during a period of high release flows (~8,600 cfs) from Hetch Hetchy Dam upstream. This flow event provided additional insight into the hydraulic behavior of this feature. High flows inundated the boulder field on river left that were exposed during lower flows and water surfaces were substantially higher at the downstream tailwater pool of the feature as seen in Figure 5.2-5. The majority of the primary flow path exhibited turbulence and velocity that was extremely high and well above the swimming capability of spring-run Chinook and steelhead. Two alternate flow paths became apparent around the periphery of the boulder field on river left similar to the one shown in Figure 5.2-6. The secondary flow paths along the left bank did exhibit leap heights, depths, and velocities that were within the capability of spring-run Chinook and steelhead. However, given the velocity and turbulence in the main river, it is unknown whether fish could navigate to the base of the secondary flow paths and navigate upstream along the periphery of the primary falls.

Figure 5.2-6. Inundated boulder field on river left, Lumsden Falls at 8,600 cfs in May 2016.

Information collected during the field surveys suggests that this feature is a potential barrier to fish passage based upon the definitions presented in Section 4.3.3. The primary impediments to fish passage include: high leap height, high velocity, high turbulence, high gradient, and high velocity launching and landing zones. Although individual leap heights within the feature itself appear to be within the range achievable by spring-run Chinook and steelhead, step pools exhibit high turbulence and velocity with shallow or moderate step pool depths. No single passable pathway is readily apparent in the middle of the feature at the flows observed. The feature is likely a barrier to fish passage at a majority of flow conditions. Given the overall hydraulic complexity and potential formation of alternative flow paths during a narrow range of high flows, there may be intermittent periods when spring-run Chinook and steelhead could navigate around the periphery of this feature. Given that there are potential pathways where passage could occur, it is concluded that this feature is a partial barrier.

5.2.2 North Fork Tuolumne River

A field survey of the North Fork Tuolumne River was performed on July 17, 2016. One total barrier and numerous potential barriers were identified within two miles of the confluence with the Tuolumne River. During this field survey, up to 9 individual features were documented. Features are more sporadic and separated by longer reaches of river pools and glides as the gradient decreases near the confluence with the mainstem Tuolumne River. The primary characteristics of each feature are presented in Table 5.2-3 and Table 5.2-4. A map summarizing the location of each feature is presented as Figure 5.2-7. Narrative descriptions of each feature identified in the field are provided in the following paragraphs. Images and a data record of each feature are provided as Photos A-51 through A-62 in Attachment A. The river flow on the day of the field survey was measured to be 2.8 cfs.

Table 5.2-3. Summary of potential barriers identified on the North Fork Tuolumne River during field surveys.

Feature	River Mile	Description	Classification
NT-1	0.52	Bedrock chute and step	Potential Barrier
NT-2	0.55	Boulder field	Passable
NT-3	0.57	Split flow bedrock falls	Potential Barrier
NT-4	0.72	Split flow bedrock falls	Potential Barrier
NT-5	1.28	Bedrock falls	Potential Barrier
NT-6	1.54	Step pool falls	Potential Barrier
NT-7	1.60	Boulder field	Potential Barrier
NT-8	1.65	Boulder field	Potential Barrier
NT-9	1.69	Bedrock and boulder step falls	Total Barrier

Table 5.2-4. Physical characteristics of potential barriers identified on the North Fork Tuolumne River during field surveys.

Feature	Total Height (ft)	Max Leap (ft)	Obstructed Launch and/or Landing	Leaping Depth	Swimming Depth	Turbulence	Velocity	Alternate Pathway Present?
NT-1	5	2	Unobstructed	Deep	Shallow	Moderate	Moderate	No
NT-2	Unknown	N/A	Unobstructed	Shallow	Deep	Low	Low	No
NT-3	4	4	Obstructed	Moderate	Deep	Moderate	Moderate	Yes
NT-4	6	3.5	Obstructed	Deep	Deep	Moderate	Moderate	Yes
NT-5	4-5	4-5	Unobstructed	Deep	Shallow	Low	Moderate	No
NT-6	5	3	Unobstructed	Moderate	Shallow	Low	Low	Yes
NT-7	Unknown	4-5ft	Obstructed	Shallow	Deep	Moderate	Moderate	Yes
NT-8	Unknown	N/A	Obstructed	Shallow	Deep	Moderate	Moderate	Yes
NT-9	10	10	Obstructed	Deep	Deep	Moderate	Moderate	No

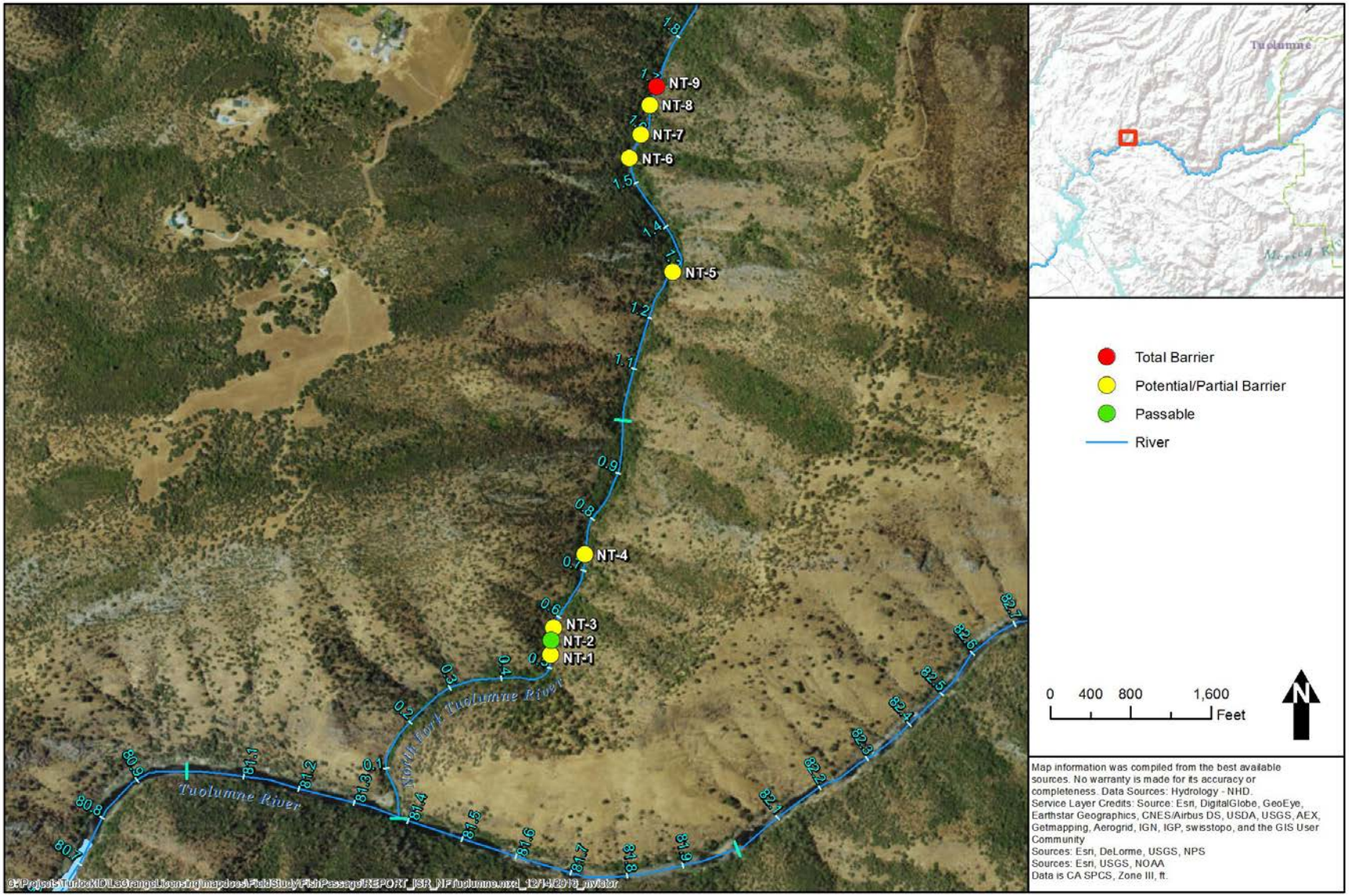


Figure 5.2-7. Summary of passage features and classification on North Fork Tuolumne River.

5.2.2.1 Feature NT-1

Feature NT-1 is a bedrock chute that ends with a step to the tailwater pool and is located at RM 0.52 on the North Fork Tuolumne River (Attachment A, Photo A-51 and Photo A-52). The chute forms in a channel between exposed bedrock on both sides of the valley and has a total vertical height of approximately five feet at the observed flow condition with measured gradient of 13 percent. The chute ends with a drop of approximately 2 vertical feet. The launching pool is long with deep depth and low turbulence and velocity. However, the horizontal length of the chute, about 23 feet, would force leaping fish to land mid-chute which possesses shallow water with moderate velocity and turbulence. The bedrock outcrops confine the river on both the right and left banks, therefore eliminating the development of side channels and alternative fish passage pathways.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The leap height appears to be ascendible for both spring-run Chinook and steelhead at low flow conditions. The horizontal component to the leap precludes passage by leap alone and requires that fish burst through the remainder of the chute. The primary impediments to fish passage include: shallow depths and high velocities within the chute. The feature is likely a barrier at medium to high flows.

5.2.2.2 Feature NT-2

Feature NT-2 is a short boulder field feature located at RM 0.55 on the North Fork Tuolumne River (Attachment A, Photo A-53). The boulder field extends for over 70 feet and spans the width of the valley floor with continuous, interlocking large boulders (approximately 3 to 6 feet in diameter). Flow through this reach weaves under, around, over and between boulders throughout the length of the feature with intermittent pools. Multiple pathways for flow exist throughout the boulder field and it is likely passable throughout the range of flows when fish may potentially be present and attempting to migrate upstream.

Information collected during the field survey suggests that this feature is likely passable.

5.2.2.3 Feature NT-3

Feature NT-3 is a split flow, step pool falls formed over bedrock located at RM 0.57 on the North Fork Tuolumne River (Attachment A, Photo A-54). The flow splits around a medial island, forming stepped falls on both the river right and river left sides of the channel. The river left channel is confined between a bedrock wall on the river left bank and bedrock outcropping on the right. The total vertical rise is approximately 4 feet over a series of steps with little separation. The bottommost launching pool is long (over 50 feet) with moderate depth and low velocity and turbulence, but no true intermediate launching and landing pools exist The short pool configuration suggests that the flow regime will transition to a streaming flow scenario making this channel more of a chute feature as flows increase. The river right channel forms between bedrock outcroppings and has a total vertical rise of approximately 4 feet. The launching zone is unobstructed, and fall crests narrower than the width at the base of both falls provides for an obstructed landing. The two channels described represent the two alternative pathways present for fish passage, although the majority of flow is present in the river right channel.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Although the effective heights of these features are less than the leaping capability of spring-run Chinook and steelhead, hydraulic conditions at higher flows may be more complex creating velocity and turbulence conditions that may inhibit passage. The primary impediments to fish passage include: shallow, turbulent and obstructed landing zones. The feature possesses multiple pathways that may provide sufficient conditions for passage at various ranges of the hydrograph. The feature is likely to be a barrier at high flows but exhibits features which create conditions sufficient for passage at low and medium flows.

5.2.2.4 Feature NT-4

Feature NT-4 is a split flow, step pool falls formed over bedrock located at RM 0.72 on the North Fork Tuolumne River (Attachment A, Photo A-55). The flow splits around a medial island, forming stepped falls on both the river right and river left sides of the channel. The river right channel forms between a bedrock outcropping and large boulder (6-10 feet) on the left and exposed bedrock on the right. The total vertical rise is approximately six feet over a series of two steps with a short run between drops of 3.5 feet and 2.5 feet. The bottommost launching pool is long (over 80 feet) with deep depth and low velocity and turbulence. The intermediate landing/launching pool in the river right channel appears to have shallow depth and moderate velocities. The intermediate landing pool is narrow and is partial obstructed by protruding rock at the periphery. The river left channel is confined between a bedrock wall on the river left bank and bedrock outcropping on the right. The two channels described represent the two alternative pathways present for fish passage, although the majority of flow is present in the river right channel.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Although the effective heights of these features are less than the leaping capability of spring-run Chinook and steelhead, hydraulic conditions at higher flows may be more complex creating velocity and turbulence conditions that may inhibit passage. The primary impediments to fish passage include: shallow, turbulent and obstructed landing zones. The feature possesses multiple pathways that may provide sufficient conditions for passage at various ranges of the hydrograph. The feature is likely to be a barrier at high flows but exhibits features which create conditions sufficient for passage at low and medium flows.

5.2.2.5 Feature NT-5

Feature NT-5 is a bedrock falls located at RM 1.28 on the North Fork Tuolumne River (Attachment A, Photo A-56). The falls forms in a channel between a bedrock outcropping on both sides of the valley and has a total vertical height of approximately four to five feet at low flow conditions. The launching pool is long with deep depth and low turbulence and velocity. However, the landing pool is formed by an eroded depression in the bedrock itself and limits the landing depth. During low flows, the landing pool has low velocities and turbulence. Additionally, the falls itself is set back at an angle and would therefore require a moderate horizontal leap at least as long as the falls are high, to clear the crest of the falls. The bedrock

outcrops confine the river on both the right and left banks and there does not appear to be an opportunity for a separate, alternate pathway to form during higher flows.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The leap height appears to exceed the leaping capability of spring-run Chinook at low flow conditions but may be ascendable by steelhead. The horizontal jump requirement as well as the tailwater control hydraulics could be evaluated further to define the range of flows potentially passable by both species. The primary impediments to fish passage include: high leap height and shallow landing area. During higher flows, the feature may begin to function as a chute, depending on tailwater conditions, and during such a condition, passage may rely less on leaping and more on burst swimming. The feature is likely a barrier at moderate flows and exhibits features which create conditions sufficient for passage at low and high flows.

5.2.2.6 Feature NT-6

Feature NT-6 is a step pool falls located at RM 1.54 on the North Fork Tuolumne River (Attachment A, Photo A-57). The falls form between larger boulders (diameter approximately 6 to 15 feet) on both sides. The total vertical drop is approximately 5.5 feet, split between two main drops of 2 feet and 3.5 feet. The downstream drop consists of two, 1-foot steps, while the upstream fall consist of a single drop over an exposed bedrock outcropping. The launching pool is long (over 20 feet, approximately) and unobstructed with moderate depth and low velocity and turbulence. An intermediate pool between drops appears to have shallow depth at the observed flow level, with low velocity and turbulence. An alternative pathway for fish passage may occur through the boulders on river left during higher flow conditions. However, more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The leap height appears to be within the leaping capability of both spring-run Chinook and steelhead at low flow conditions. The horizontal jump requirement as well as the tailwater control hydraulics could be evaluated further to define the range of flows potentially passable by both species. The primary impediments to fish passage include: shallow intermediate pool and complex initial leaping feature. The initial leap may turn into a swim through feature during moderate flows, but the same increase in flows may likely increase the velocity and turbulence of the intermediate pool which would impede leaping conditions for the upstream fall. Due to the shape and position of the two large boulders confining flows over the lower falls, high flows may backwater the upstream fall and provide adequate depth for landing and swimming beyond the intermediate pool. Tailwater conditions of the initial launching pool would need to be investigated to determine if the vertical leap over the initial step during high flows, between the large boulders, is not beyond the capability of both species. The feature is likely a barrier at low flows and exhibits features which create conditions sufficient for passage at high flows.

5.2.2.7 Feature NT-7

Feature NT-7 is a boulder field located at RM 1.6 on the North Fork Tuolumne River (Attachment A, Photo A-58 to Photo A-59). The boulder field extends for over 200 feet and

spans the width of the valley floor with continuous, interlocking large boulders (approximately 5 to 20 feet in diameter). Flow through this reach weaves under, around, over and between boulders throughout the length of the feature with intermittent pools. At one intermediate pool within the boulder field, flow falls over a series of interlocking boulders with total vertical relief of approximately 4 to 5 feet. The launching pool is shallow and obstructed, and the landing zone is also obstructed by boulders. An alternate path exists at this intermediate feature along river left that might provide passage under certain flow conditions. Multiple pathways for flow exist throughout the boulder field, but many are unsuitable for fish passage due to obstruction by large boulders, leap barriers, or hydraulic pathways flowing directly under boulders with inadequate clearance.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The primary impediments to fish passage include: high leap height and shallow/obstructed launching and landing conditions. Medium flows may provide sufficient depth downstream of the intermediate leap feature to improve passage potential. The feature is likely a barrier at high and low flow conditions.

5.2.2.8 Feature NT-8

Feature NT-8 is a boulder field located at RM 1.65 on the North Fork Tuolumne River (Attachment A, Photo A-60 to Photo A-61). The boulder field extends for over 150 feet and spans the width of the valley floor with continuous, interlocking large boulders (approximately 5 to 40 feet in diameter). Flow through this reach weaves under, around, over and between boulders throughout the length of the feature with intermittent pools. Multiple pathways for flow exist throughout the boulder field, but many are unsuitable for fish passage due to obstruction by large boulders, or hydraulic pathways flowing directly under boulders with inadequate clearance.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The primary impediments to fish passage include shallow depths, leaping and landing obstructions and inadequate clearance around and under large boulders at low flows with high velocity and turbulence conditions at high flows. The feature is likely a potential barrier at high and low flow conditions.

5.2.2.9 Feature NT-9

Feature NT-9 is a boulder and bedrock falls located at RM 1.69 on the North Fork Tuolumne River (Attachment A, Photo A-61). The bedrock ledge extends the full width of the channel, and is further obstructed by large (10-15 feet in diameter) boulders wedged along the crest and against the rock walls of the canyon. The river flows through a single gap between these large boulders onto an outcropping of bedrock, and finally into the downstream pool. The feature consists of two distinct drops, with an intermediate landing of shallow depth and high turbulence. The falls have a total vertical drop of approximately 10 feet at the flow conditions observed. However, the hydraulic depth in the notch created at the feature crest will increase at a higher rate than the tailwater pool as flows increase and therefore, the leap height is anticipated to increase up to 14 feet as the notch fills. Flow plunges into a deep, large pool (approximately 50 feet long). The bedrock canyon walls confines the river on both the river right and river left, therefore eliminating the development of alternative fish passage pathways.

Information collected during the field survey suggests that this feature is a total barrier to fish passage as defined in Section 4.3.1. The effective height of this feature exceeds the leaping capability of spring-run Chinook and steelhead at all flows and there are no opportunities to alternative pathways at any range of flows. The primary impediment to fish passage is barrier height.

5.2.3 South Fork Tuolumne River

A field survey of the South Fork Tuolumne River was performed on August 5, 2015. One total barrier and numerous potential barriers were identified within two miles of the confluence with the Tuolumne River. During this field survey, up to 17 individual features were documented. Features occurring within 0.5 miles of the total barrier identified during this study are closely interlinked with one another and represent a series or complex of rock features with no apparent separation from one to the next. Features are more sporadic and separated by longer reaches of river pools and glides as the gradient decreases near the confluence with the mainstem Tuolumne River. The primary characteristics of each feature are presented in Table 5.2-5 and Table 5.2-6. A map summarizing the location of each feature is presented as Figure 5.2-8. Narrative descriptions of each feature identified in the field are provided in the following paragraphs. Images and a data record of each feature are provided as Photos A-26 through A-44 in Attachment A. Flows on the day of the field survey measured five cfs.

Table 5.2-5. Summary of potential barriers identified on the South Fork Tuolumne River during field surveys.

Feature	River Mile	Description	Classification
ST-1	0.45	Split flow bedrock falls	Potential Barrier
ST-2	0.5	Step pool falls	Potential Barrier
ST-3	0.63	Split flow step pool falls	Potential Barrier
ST-4	0.67	Falls between boulders	Potential Barrier
ST-5	0.9	Split flow step pool falls	Potential Barrier
ST-6	0.95	Bedrock falls	Potential Barrier
ST-7	1.05	Bedrock falls	Potential Barrier
ST-8	1.15	Bedrock and boulder falls	Potential Barrier
ST-9	1.2	Bedrock and boulder step falls	Potential Barrier
ST-10	1.35	Boulder falls	Potential Barrier
ST-11	1.53	Split flow step falls	Potential Barrier
ST-12	1.57	Cascade	Potential Barrier
ST-13	1.6	Step pool falls	Potential Barrier
ST-14	1.62	Step pool falls	Potential Barrier
ST-15	1.65	Split flow step pool falls	Potential Barrier
ST-16	1.8	Bedrock falls	Potential Barrier
ST-17	1.85	Cascade	Potential Barrier
ST-18	1.9	Bedrock falls	Total Barrier

Table 5.2-6. Physical characteristics of potential barriers identified on the South Fork Tuolumne River during field surveys.

Feature	Total Height (ft)	Max Leap (ft)	Obstructed Launch and/or Landing	Leaping Depth	Swimming Depth	Turbulence	Velocity	Alternate Pathway Present?
ST-1	5-7	3-5	Unobstructed	Shallow	Deep	Moderate	Moderate	Yes
ST-2	3-4	3-4	Unobstructed	Shallow	Deep	Low	Low	Yes

Feature	Total Height (ft)	Max Leap (ft)	Obstructed Launch and/or Landing	Leaping Depth	Swimming Depth	Turbulence	Velocity	Alternate Pathway Present?
ST-3	4-5	4-5	Obstructed	Shallow	Deep	Low	Low	Yes
ST-4	6	6	Obstructed	Shallow	Shallow	Low	Low	Yes
ST-5	3.5	3.5	Obstructed	Moderate	Deep	Low	Low	Yes
ST-6	11	4	Unobstructed	Shallow	Deep	Moderate	Moderate	Yes
ST-7	5	5	Unobstructed	Moderate	Deep	Low	Low	No
ST-8	6	6	Obstructed	Moderate	Deep	Low	Low	Yes
ST-9	16	3	Unobstructed	Shallow	Deep	Moderate	Moderate	Yes
ST-10	3-5	3-5	Obstructed	Shallow	Shallow	Moderate	Low	Yes
ST-11	3-5	3	Obstructed	Shallow	Shallow	Moderate	Moderate	Yes
ST-12	10	4	Obstructed	Shallow	Deep	Moderate	Moderate	No
ST-13	6-8	4-6	Obstructed	Deep	Deep	Low	Low	No
ST-14	14	6	Obstructed	Shallow	Deep	Moderate	Moderate	Yes
ST-15	3-4	1	Obstructed	Shallow	Deep	Moderate	Moderate	Yes
ST-16	5-6	5-6	Obstructed	Deep	Deep	Moderate	Moderate	No
ST-17	7	4	Obstructed	Shallow	Shallow	Moderate	Moderate	Yes
ST-18	32	32	Unobstructed	Deep	Deep	Low	Low	No

5.2.3.1 Feature ST-1

Feature ST-1 is a split flow falls over a bedrock outcrop located at RM 0.45 on the South Fork Tuolumne River (Attachment A, Photos A-26 and A-27). The flow is split roughly evenly, with river right flow down a continuously high velocity, high turbulence, high gradient chute, and river left flow down a bedrock-formed step-pool sequence. The total drop of the features is approximately five to seven vertical feet. The step-pool sequence contains two steps: a lower step that is at approximately three to five feet high, and an upper step that is approximately two feet high. The launching pool for the step is shallow with moderate turbulence but is unobstructed. The landing and launching pool in the middle of the step is set back somewhat from the drop and is shallow with moderate turbulence; the upper landing pool is also shallow, set back from the edge and has moderate turbulence and velocity. The two channels described represent the two alternative pathways present for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions provided in Section 4.3.3. The primary impediments to fish passage include: high leap height, high velocity, high gradient, and shallow and turbulent launching and landing zones. Although leap heights may be within the limits capable by spring-run Chinook and steelhead there is no defined launching pool and the chute identified along river right is not accessible until higher flows are present. The feature is likely a barrier at low flows and exhibits features which would create conditions sufficient for passage at high flows.

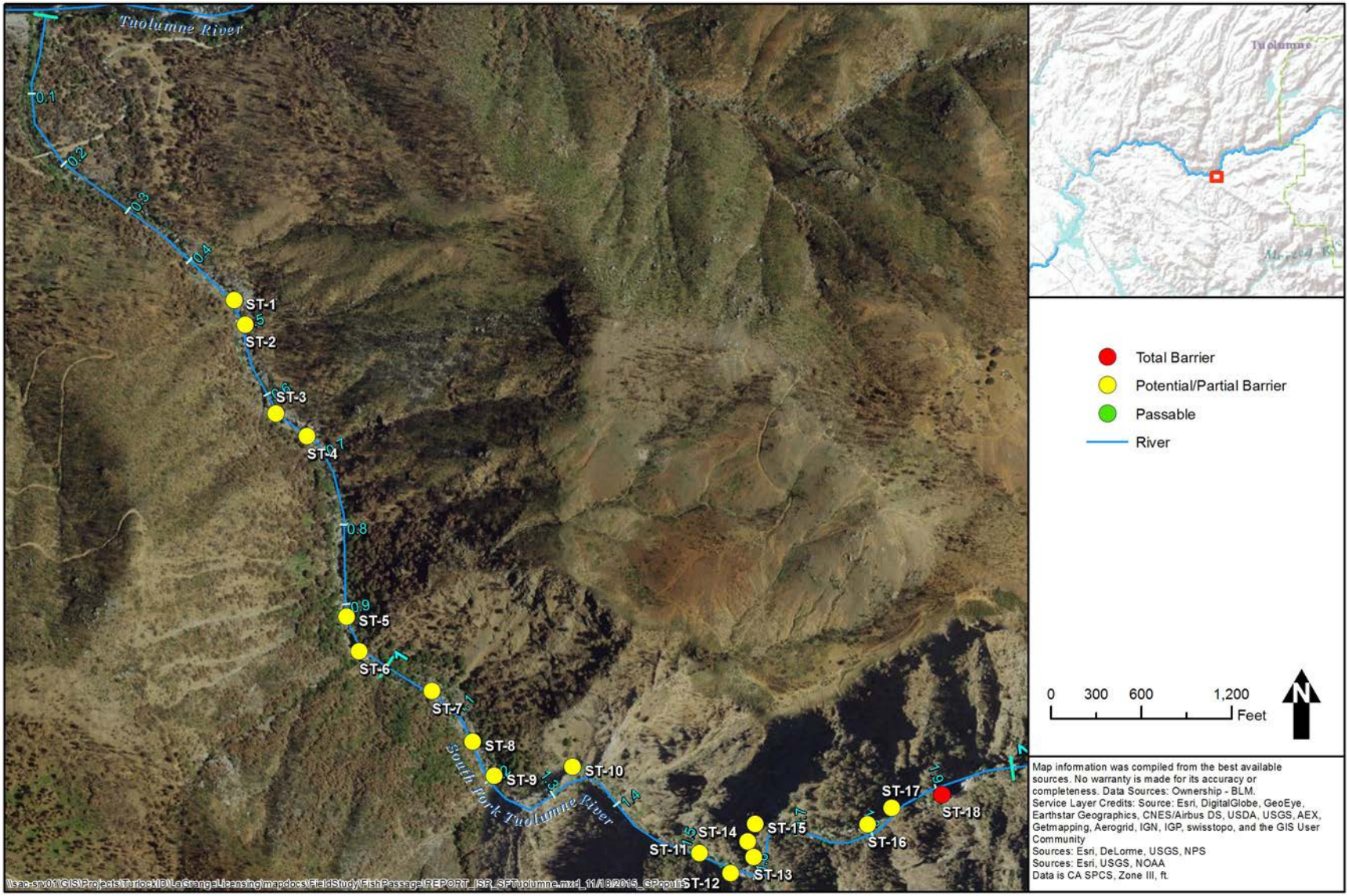


Figure 5.2-8. Summary of passage features and classification on the South Fork Tuolumne River.

5.2.3.2 Feature ST-2

Feature ST-2 is a step pool falls located at RM 0.5 on the South Fork Tuolumne River (Attachment A, Photo A-28). The falls forms between a bedrock outcrop on river left and a series of boulders (approximately two to four feet in diameter) on river right. The vertical height of the falls is approximately three to four feet. The launching and landing pools are small and shallow (approximately three feet long) but with low velocity and turbulence. During higher flow conditions, there is likely flow to the river right of the falls over a series of boulders but more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions provided in Section 4.3.3. The primary impediment to fish passage is shallow launching and landing pool depth, which is an impediment to both spring-run Chinook and steelhead. However, the feature may exhibit better leaping conditions and alternative pathways along river right at higher flows. The feature is likely a barrier at low flows and exhibits features which would create conditions sufficient for passage at high flows.

5.2.3.3 Feature ST-3

Feature ST-3 is a split flow step pool falls located at RM 0.63 on the South Fork Tuolumne River (Attachment A, Photo A-29). The falls forms over and between several boulders, ranging in diameter from two to five feet and has two distinct channels split by a boulder during the low flow conditions observed during the field survey. The vertical height of the falls is approximately four to five feet. The launching and landing pools are each about 15 feet long but are shallow and obstructed by boulders at or near the water surface. Flow may occur over and through the boulders on river left during higher flow conditions but more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions provided in Section 4.3.3. Although the leap requirements are less than or equal to the leaping capabilities of spring-run Chinook and steelhead, the primary impediment to fish passage is low pool depth with the presence of obstructions. More favorable leaping conditions and alternative pathways may be exhibited along river right at higher flows. The feature is likely a barrier at low flows and exhibits features which would create conditions sufficient for passage at high flows.

5.2.3.4 Feature ST-4

Feature ST-4 is a falls located at RM 0.67 on the South Fork Tuolumne River (Attachment A, Photo A-30). The falls forms between several large boulders (diameter approximately 10 to 12 feet). The vertical height of the falls is approximately six feet. The launching pool is obstructed by a boulder (approximately four feet in diameter) and shallow. The landing pool has low velocity and is unobstructed. Flow may occur over and through the boulders on river right

during higher flow conditions but more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions provided in Section 4.3.3. Although leap requirements exceed spring-run Chinook leaping capabilities and do not exceed steelhead leaping capabilities, the primary impediment to fish passage include a shallow and obstructed launching pool. Passage may only be possible at this feature when the larger boulders are hydraulically flanked on the right side which may offer passable conditions for both species at higher flows. The feature is likely a barrier at low flows and exhibits features which would create conditions sufficient for passage at high flows.

5.2.3.5 Feature ST-5

Feature ST-5 is a split flow step pool falls located at RM 0.9 on the South Fork Tuolumne River (Attachment A, Photo A-31). The falls forms between several large boulders (diameter approximately 4 to 12 feet). The primary flow is at the center of the channel and drops approximately 3.5 feet. The launching and landing pools for this feature are long (at least 20 feet) and are unobstructed with low velocity, low turbulence, and moderate depth. There is a smaller portion of flow over several smaller boulders (diameter approximately two feet) on the river right. The launching pool for the river right pathway is the same as for the main pathway. However, the launching pool and overall trajectory for the river right pathway is obstructed by protruding boulders at the conditions observed with horizontal leap requirements exceeding spring-run Chinook and steelhead capability.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions provided in Section 4.3.3. The primary impediments to fish passage include: high leap height and obstructed launching and landing pool. The feature is likely a barrier at low flows and exhibits features which would create conditions sufficient for passage at high flows.

5.2.3.6 Feature ST-6

Feature ST-6 is a bedrock falls located at RM 0.95 on the South Fork Tuolumne River (Attachment A, Photo A-32). The falls forms in a channel between bedrock outcropping on both sides of the valley and comprises three smaller steps. The lowest step is approximately four feet high with flow splitting around a boulder, and with moderate turbulence and velocity and shallow depth in the launching and landing pools. The middle step is approximately three feet high, with a moderate turbulence and velocity in the launching pool but a low velocity and turbulence in the landing pool. The uppermost step is approximately 4 feet high with long, low velocity and turbulence launching pools. However, the landing pools are partially obstructed on the river right side of the falls by shallow water depths over bedrock. During high flow conditions, water appears to flow over the bedrock to the river right of the falls features. Although more information is necessary to evaluate this alternative, it appears that flow may be

shallow with high velocity over this feature. As flows increase, it appears that the low flow channel may be washed out and the streaming flow over the feature may become more dominant.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Although the feature appears to exhibit hydraulic conditions that meet swimming and leaping capabilities of spring-run Chinook and steelhead at lower flows, visual evidence suggests that the feature may transition to a high velocity chute type feature at higher flows. The primary impediments to fish passage include: high leap height and potentially high velocities during periods when higher flows exist. The feature is likely a barrier at high flows and exhibits features which create conditions sufficient for passage at low flows.

5.2.3.7 Feature ST-7

Feature ST-7 is a bedrock falls located at RM 1.05 on the South Fork Tuolumne River (Attachment A, Photo A-33). The falls forms in a channel between bedrock outcropping on both sides of the valley and has a total vertical height of approximately five feet at low flow conditions. The launching and landing pools are long with moderate depth and low turbulence and velocity. However, the falls itself is set back at an angle and would therefore require a substantial horizontal leap component to clear the crest of the falls. The bedrock outcrops confine the river on both the right and left banks, therefore eliminating the development of side channels and alternative fish passage pathways.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The leap height appears to exceed the leaping capability of spring-run Chinook at low flow conditions but may be ascendable by steelhead. The horizontal jump requirement as well as the tailwater control hydraulics could be evaluated further to define the range of flows potentially passable by both species. The primary impediments to fish passage include: high leap height and shallow depths within the falls. The feature is likely a barrier at moderate flows and exhibits features which create conditions sufficient for passage at low or high flows.

5.2.3.8 Feature ST-8

Feature ST-8 is a falls located at RM 1.15 on the South Fork Tuolumne River (Attachment A, Photo A-34). The falls form between a bedrock wall on the river left side and larger boulders (diameter approximately 6 to 15 feet) on river right. The total vertical drop is approximately 6 feet. The launching pool is long (over 20 feet, approximately) and unobstructed with moderate depth and low velocity and turbulence but the falls splits over and around several large rocks and exhibits an overhanging leap condition as well as obstructing the landing pool. An alternative pathway for fish passage may occur through the boulders on river right during higher flow conditions. However, more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The leap height appears to exceed the leaping capability

of spring-run Chinook at low flow conditions but may be ascendable by steelhead. The horizontal jump requirement as well as the tailwater control hydraulics could be evaluated further to define the range of flows potentially passable by both species. The overhanging crest and formation of hydraulic nappe creates a difficult leaping condition. The primary impediments to fish passage include: high leap height and obstructed landing zone. The feature is likely a barrier at low flows and exhibits features which create conditions sufficient for passage at high flows.

5.2.3.9 Feature ST-9

Feature ST-9 is a bedrock and boulder step pool falls located at RM 1.2 on the South Fork Tuolumne River (Attachment A, Photo A-35). The feature forms between a bedrock wall on the river left and a series of boulders (diameters ranging from approximately three to eight feet) on river right. The falls have a total vertical rise of approximately 16 feet over about 50 horizontal feet (gradient of approximately 32 percent) and comprise a series a smaller steps (approximately two to three feet high) separated by runs with moderate turbulence and velocity. The most downstream launching pool is approximately 20 feet long, narrow, with moderate depth, velocity and turbulence at low flows. Intermediate launching and landing pools are also have moderate turbulence and velocity with shallow depths at low flows. Alternative pathways for fish passage may occur through the boulders at river right during higher flow conditions. However, more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage. The high gradient exceeds the gradient criteria expressed in Table 4.3-2 of 20 percent for 50 feet at the observed low flow conditions but the presence of steps and potential for alternative pathways at higher flows may provide conditions sufficient for passage by spring-run Chinook and steelhead during some portion of the hydrograph. The primary impediments to fish passage include: high gradient, moderate velocity and turbulence in shallow launching and landing zones. The feature is likely a barrier at low and high flows but may exhibit conditions sufficient for passage at more moderate flows. Alternative pathways may be present at these moderate flows that could provide additional opportunities for passage.

5.2.3.10 Feature ST-10

Feature ST-10 is a split falls located at RM 1.35 on the South Fork Tuolumne River (Attachment A, Photo A-36). The falls is split around boulders (approximately one to three feet in diameter) and vegetation and has a total vertical height of approximately three to five feet at low flow conditions. The launching and landing zones of the primary flow path are moderately turbulent, narrow, and shallow, and the falls itself is set back at an angle and would therefore require a substantial horizontal component to successfully leap past the hydraulic crest. Additionally, this setback combined with shallow water depth at the top of the falls comprises an obstruction to the landing zone. Aerial photographs indicate that an alternative fish passage pathway may occur on the river left side through boulders during higher flow conditions. However, more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Although the leap heights appear to be less than the leaping capabilities of spring-run Chinook and steelhead, insufficient leaping conditions create and impediment to passage at the observed low flow conditions. Further hydraulic assessment of this site would be necessary to determine if hydraulic conditions are sufficient for passage at various ranges of the hydrograph. The primary impediments to fish passage include: high leap height, horizontal leap distance, shallow and turbulent launching and landing zones, and obstructed landing zone. The feature is likely a barrier at low flows and exhibits features which create conditions sufficient for passage at high flows.

5.2.3.11 Feature ST-11

Feature ST-11 is a split flow step falls located at RM 1.53 on the South Fork Tuolumne River (Attachment A, Photo A-37). The flow splits around a medial island, forming step pool falls on both the river right and river left sides of the channel. The river left channel in confined between a bedrock wall on the river left bank and boulders (diameter approximately two to four feet) on the right. The total vertical rise is approximately three to five feet over a series of steps separated by short runs. The bottommost launching pool is long (over 50 feet) with moderate depth and low velocity and turbulence, but the intermediate launching and landing pools are short (approximately less than 5 feet long) with shallow depth and moderate velocity and turbulence. The short pool configuration suggests that the flow regime will transition to a streaming flow scenario making this channel more of a chute feature as flows increase. The river right channel forms between several boulders (diameter approximately three to five feet) and has a total vertical rise of approximately three to five feet. The launching zone is obstructed by boulders, and the landing zone condition is unknown. The two channels described represent the two alternative pathways present for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Although the effective heights of these features are less than the leaping capability of spring-run Chinook and steelhead, hydraulic conditions at higher flows may be more complex creating velocity and turbulence conditions that my inhibit passage. The primary impediments to fish passage include: shallow, turbulent and obstructed launching and landing zones. The feature possesses multiple pathways that may provide sufficient conditions for passage at various ranges of the hydrograph. The feature is likely to be a barrier at moderate flows but exhibits features which create conditions sufficient for passage at low flows and high flows.

5.2.3.12 Feature ST-12

Feature ST-12 is a complex of three cascades closely co-located near RM 1.57 on the South Fork Tuolumne River (Attachment A, Photo A-38 which shows the middle series of steps). The series of cascades forms between bedrock walls on the river right and river left and large boulders in the channel center (diameters ranging from three to six feet). In each of the three sub-units flow spills over and around boulders for approximately 10 to 15 vertical feet each. With an approximate rise of 35 to 45 feet over a distance of 150 feet, the overall gradient of this complex

is estimated to be 23 to 30 percent. Each major step identified in the three cascades appeared to have a vertical leaping component of three to four feet at the observed flow condition. In most cases, the launching and landing areas are short with moderate velocity and turbulence, and shallow depth. The bedrock outcrops confine the river on both the right and left banks, which appears to eliminate the development of side channels or additional pathways with the exception of the very top of the feature. The short pool configuration suggests that the flow regime will transition to a streaming flow scenario making this channel more of a turbulent chute feature as flows increase.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Although the leap heights appear to meet the leaping capabilities of spring-run Chinook and steelhead at the observed flow conditions, short turbulent pools and the lack of alternative pathways may create an impediment to upstream passage at higher flows. The primary impediments to fish passage include: short turbulent and obstructed launching and landing zones. The feature is likely a barrier at high flows and exhibits features which create conditions sufficient for passage at low flows.

5.2.3.13 Feature ST-13 and ST-14

Features ST-13 and ST-14 represent a complex of step pool falls located at RM 1.6 on the South Fork Tuolumne River. ST-13 represents the most downstream step pool feature (Attachment A, Photo A-39) which leads to Feature ST-14, comprising a longer complex of step pools (Attachment A, Photo A-40). The falls at ST-13 flow over and between a series of large boulders (diameters approximately 6 to 15 feet) and into a large, deep pool (approximately 50 feet long) with low turbulence and velocity. The vertical rise at the falls is approximately six to eight feet, and the launching pool is obstructed by boulders. The landing pool is also set back somewhat from the edge of the falls creating a long horizontal leap component. The bedrock outcrops on both the left and right valley walls confine the river on both sides, therefore eliminating the development of side channels or alternative pathways.

Throughout Feature ST-14, the river flows over, around and through a series of boulders (ranging in diameter from two to eight feet) via multiple pathways and forms multiple steps and small pools. There are four distinct drops for a total 14 feet vertical drop. The most downstream drop is about 6 vertical feet with moderately turbulent flow over multiple protruding boulders which may obstruct leap paths. There is also a flow pathway to the river right of this feature with two shorter, steeper rises but shallow depth. At the top of the most downstream drop is a pool (approximately 10 feet long, depth unknown), followed by a short boulder-formed step (approximately 2 vertical feet), another pool (approximately 6 feet long), and another short boulder-formed step (approximately 2 vertical feet). The most upstream step is approximately four vertical feet with split flow and both the launching and landing pools are partially obstructed by protruding boulders. The bedrock outcrops on both the left and right valley walls (visible in aerial photography) confine the river on both sides, therefore eliminating the development of additional alternative fish passage pathways.

The combined height of ST-13 and ST-14 is approximately 22 feet over a length of 115 feet which corresponds to a gradient of 19 percent.

Information collected during the field survey suggests that the ST-13 and ST-14 complex is a potential barrier to fish passage as defined in Section 4.3.3. Leap heights, obstructed landing and launching areas, and the overall horizontal leap requirement appear to exceed the leaping capability of spring-run Chinook and steelhead at the observed low flow condition. The primary impediments to fish passage include: high leap height, long horizontal leap component, and obstructed launching and landing zones. ST-13 and ST-14 are likely barriers to fish passage at low flows and exhibit features which create conditions sufficient for passage at high flows.

5.2.3.14 Feature ST-15

Feature ST-15 is a split flow step pool falls located at RM 1.65 on the South Fork Tuolumne River (Attachment A, Photo A-41). The river flows over, around and through a series of boulders (diameters ranging from one to eight feet) in a channel confined by bedrock walls on both the left and right sides of the valley. The primary flow channel on the river left side comprises a low angle falls with a series of short, successive steps (one vertical foot) for an overall vertical rise of approximately three to four feet. Two smaller channels occur at river center and river right. The river right channel is similar to the river left channel, with a low angle falls comprising multiple small steps. The center channel is a steeper step falls. The bottom launching pool for each of the three pathways has low velocity and turbulence and shallow depth but intermediate landing and launching pools for the river right and river left channels are shallow with moderate turbulence and velocity. At higher flows, both channels on river right may transition into a streaming flow regime exhibiting high velocities and high levels of turbulence. The channel observed at river left may convey a smaller majority of flow and leaping conditions may improve as the tailwater control is backwatered. Bedrock outcrops on both the left and right valley walls confine the river on both sides, therefore eliminating the development of additional alternative fish passage pathways than the three observed at low flow.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Leaping conditions on a portion of the feature may improve while velocities and turbulence may impede fish passage on other portions of the feature as flows increase. The primary impediments to fish passage include: high gradient, high velocity, and obstructed launching and landing zones which impede passage of both spring-run Chinook and steelhead. The feature is likely a barrier at low flows and exhibits features which create conditions sufficient for passage at high flows.

5.2.3.15 Feature ST-16

Feature ST-16 is a bedrock chute located at RM 1.8 on the South Fork Tuolumne River (Attachment A, Photo A-42). The chute is formed in a narrow channel (approximately six feet wide) inset within a narrow canyon (approximately 30 feet wide). The total vertical rise is approximately 5 to 6 feet over a distance of approximately 40 feet (gradient 15 percent). The tailwater pool is deep and long (approximately 55 feet) but narrow with moderate turbulence and velocity at the approach to the first step. The entrance to the chute at low flow includes a series of short steps set back at an angle that would require a substantial horizontal leap component to clear the first crest. The bedrock canyon walls confine the river on both the right and left banks,

therefore eliminating the development of potential side channels or alternative fish passage pathways. The narrow feature is likely overwhelmed easily and exhibits high velocities and high levels of turbulence as river flows increase.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Although the leaping ability of spring-run Chinook and steelhead may facilitate passage at lower flows, it is apparent that the feature may exhibit much different hydraulic characteristics at higher flows which may impede passage. The primary impediments to fish passage include: high leap height, long horizontal leap distance, high velocity and obstructed launching and landing conditions. The feature is likely a barrier at high flows and exhibits features which create conditions sufficient for passage at low flows.

5.2.3.16 Feature ST-17

Feature ST-17 is a cascade located at RM 1.85 on the South Fork Tuolumne River (Attachment A, Photo A-43). The river flows via multiple pathways over, around and through boulders (diameters ranging from two to six feet) creating small pocket pools and flowing over multiple steps. The downstream most step is approximately four vertical feet with flow tumbling over multiple protruding boulders. The launching and landing pools are shallow and small (approximately three feet in length, depth unknown) with moderate turbulence and velocity. Both the launch and landing are partially obstructed by boulders. The upstream step is approximately three vertical feet with flow tumbling over multiple protruding boulders. The launch pool is the same as the landing pool for the first step. Intermediate pools are turbulent, shallow and small, and the upper landing zone condition is unknown. Alternate pathways for fish passage exist within the cascade features but would need to be observed at different flow levels to asses their viability for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Spring-run Chinook and steelhead possess leaping capabilities that are greater than the effective heights measured at this feature, however, shallow, small launching pools and obstructed leap paths may impede passage during some portion of the hydrograph. The primary impediments to fish passage include: shallow, small, and obstructed launching and landing conditions. The feature is likely a barrier throughout a portion of the anticipated hydrograph but further hydraulic assessment would be required to determine the limits of passage.

5.2.3.17 Feature ST-18

Feature ST-18 is a bedrock falls located at RM 1.9 on the South Fork Tuolumne River (Attachment A, Photo A-44). The bedrock ledge extends the full width of the channel and river flows down the bedrock face. The falls have a total vertical drop of approximately 32 feet. Flow plunges into a deep, large pool (approximately 100 feet long). The bedrock canyon walls confines the river on both the river right and river left, therefore eliminating the development of alternative fish passage pathways.

Information collected during the field survey suggests that this feature is a total barrier to fish passage as defined in Section 4.3.1. The effective height of this feature exceeds the leaping capability of spring-run Chinook and steelhead at all flows and there are no opportunities to alternative pathways at any range of flows. The primary impediment to fish passage is barrier height.

5.2.4 Clavey River

A field survey of the Clavey River was performed on August 3, 2015. One total barrier and two potential barriers were identified within two miles of the confluence with the Tuolumne River. The primary characteristics of each feature are presented in Table 5.2-7 and Table 5.2-8. A map summarizing the location of each feature is presented as Figure 5.2-9. Narrative descriptions of each identified feature are provided below. Images and a data record of each feature are provided as Photos A-13 through A-25 of Attachment A. Flow measurements taken near the mouth of the Clavey River indicate that observations occurred at a river flow near 4 cfs.

Table 5.2-7. Summary of potential barriers identified on the Clavey River during field surveys.

Feature	River Mile	Description	Classification
CR-1	0.2	Split flow bedrock falls	Potential Barrier
CR-2	1.15	Split flow falls with chute	Potential Barrier
CR-3	2.05	Boulder field	Total Barrier

Table 5.2-8. Physical characteristics of potential barriers identified on the Clavey River during field surveys.

Feature	Total Height (ft)	Max Leap (ft)	Obstructed Launch and/or Landing	Leaping Depth	Swimming Depth	Turbulence	Velocity	Alternative Pathway Present?
CR-1	12	5	Obstructed	Shallow	Shallow	Low	Low	Yes
CR-2	8	6	Obstructed	Shallow	Shallow	Moderate	Moderate	Yes
CR-3	7-13	7-13	Obstructed	Shallow	Shallow - Deep	Low	Low	No

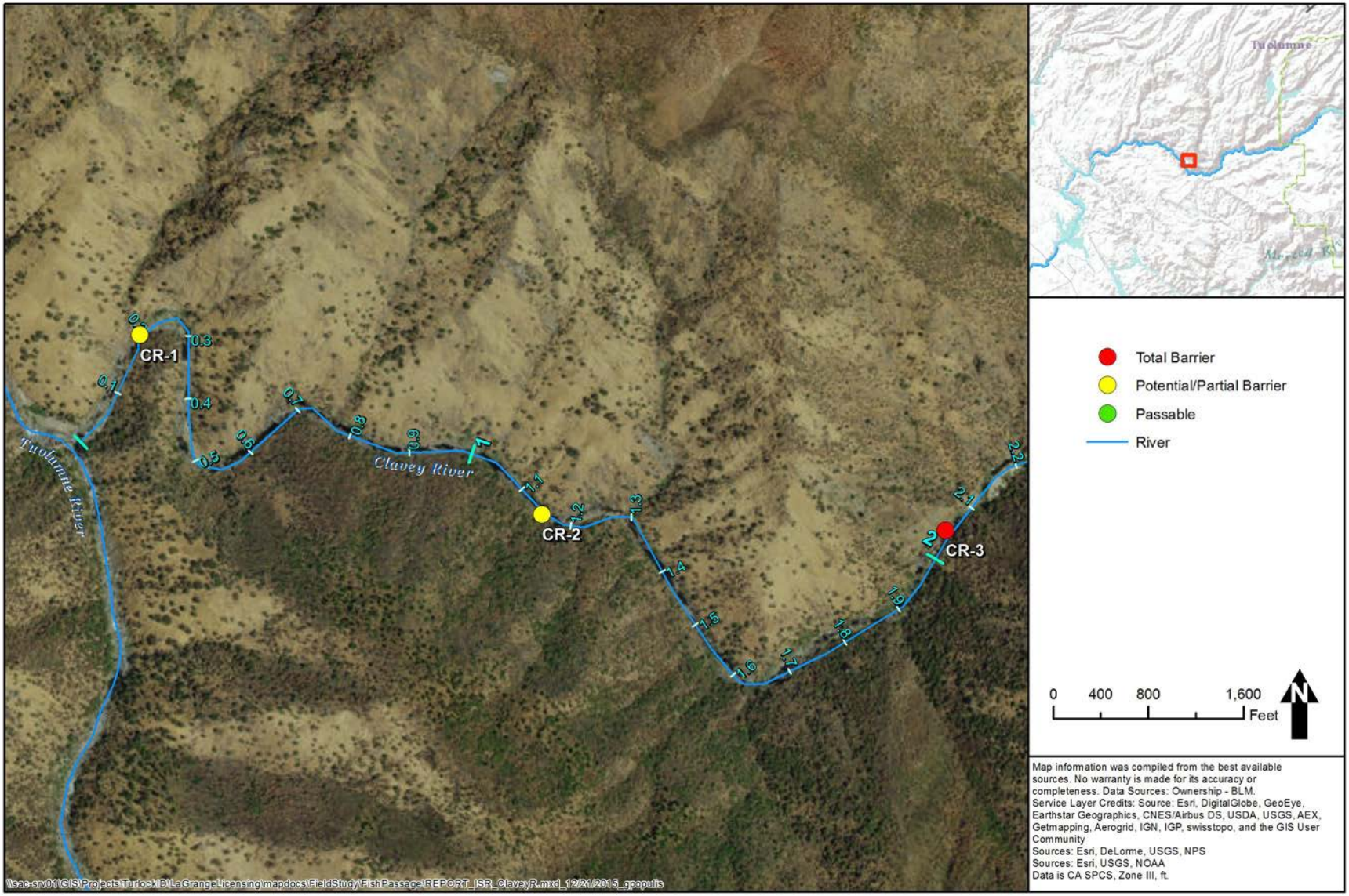


Figure 5.2-9. Summary of passage features and classification on the Clavey River.

5.2.4.1 Feature CR-1

Feature CR-1 is a split flow bedrock falls feature located at RM 0.2 on the Clavey River (Attachment A, Photos A-13 and A-14). During low flow conditions, flow occurs in two discrete channels down the face of a bedrock outcrop, with relatively more flow in the river right channel. The overall vertical drop is approximately 12 feet. The launching pools are shallow and partially obstructed by protruding rock at the base of both channels. The landing pools at the top of the falls are also shallow and set back from the maximum vertical relief. Neither channel has prominent intermediate launching/landing pools, although the river right channel has two shallow, sub-horizontal features located approximately one third and two-thirds of the way up the falls. The river left channel has two small, shallow, sub-horizontal features located near the top of the falls. A bedrock outcrop confines the river on the left banks, therefore eliminating the development of side channel. River right is less confined and a step pool side channel appears to be prominent which ties back to a pool further upstream. Passage at higher flows may be possible along this potential side channel.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions provided in Section 4.3.3. The primary impediments to fish passage include: high leap height and shallow and obstructed launching and landing conditions. Although the required leap heights are greater than the capability of spring-run Chinook and steelhead, passage may be achievable through a side channel along the right bank during higher flows. The feature is likely a barrier at low flows and exhibits features which create conditions sufficient for passage at high flows.

5.2.4.2 Feature CR-2

Feature CR-2 is a split flow feature over large boulders and bedrock located at RM 1.15 on the Clavey River (Attachment A, Photos A-15 through A-18). During low flow conditions, the primary flow is on the river left down a bedrock chute. The overall vertical relief of the chute is approximately eight feet. After a small step (approximately one foot) from the launching pool, the lower portion of the chute comprises a high gradient but continuous chute feature, while the upper portion of the feature is a small falls (approximately three feet high) with high velocity launching and landing zones. In addition to the main flow feature active at low flows, two small channels also flow over boulders in the river center and to the river right. The vertical relief associated with the river right and center channels is approximately six feet. For the center and right to center channels, the launching pool is shallow and obstructed by boulders at the observed flow condition. Adequate launching zones are present approximately six to eight feet horizontally from the landing crest. The crest and landing zone is set back from the edge and thus obstructed. The river right channel flows over protruding rocks, which would require a more horizontal component for a leaping fish to clear. The launching pool has low velocity, but the landing zone is also set back from the edge and thus obstructed. Feature CR-2 is constrained by bedrock outcrops on both sides of the valley, but presence of a large boulder and rock accumulations along the right bank create a potential alternative pathway which may be hydraulically connected at slightly higher flows. If and when wetted, this alternative pathway may provide decreased leaping opportunities on the order of three to four feet.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The primary impediments to fish passage include: high leap height, high velocity, and shallow and obstructed launching and landing conditions. The leaping opportunities at low flow conditions exceed the leaping capabilities of spring-run Chinook and steelhead; however, the presence of potential alternative pathways may provide passage at higher flow events. Further, tailwater control features downstream of the leaping pool potentially constrain hydraulics and thus higher flow conditions may backwater this feature and reduce overall leaping requirements. The feature is likely a barrier at low flows and exhibits features which create conditions sufficient for passage at high flows.

5.2.4.3 Feature CR-3

Feature CR-3 is a long boulder field feature located at RM 2.05 on the Clavey River (Attachment A, Photos A-19 through A-25). The boulder field extends for over 400 feet and spans the width of the valley floor with continuous, interlocking large boulders (approximately 5 to 40 feet in diameter). Flow through this reach weaves under, around, over and between boulders throughout the length of the feature with intermittent pools. At the crest of the boulder field, flow falls over a series of interlocking boulders with total vertical relief of approximately 7 to 13 feet. The launching pool is shallow and obstructed, and the landing zone is also obstructed by boulders. Multiple pathways for flow exist throughout the boulder field, but many are unsuitable for fish passage due to obstruction by large boulders, leap barriers, or hydraulic pathways flowing directly under boulders with inadequate clearance. No alternate pathways for flow or passage were observed at the boulder field or at the crest barrier. The boulder field appears to be remnants of a dip-slope bedrock landslide. The slide appears to be recent from a geological perspective and appears in aerial photography dated back to 1993.

Information collected during the field survey suggests that this feature is a total barrier to fish passage. Leaping or swimming opportunities meeting the maximum capabilities of spring-run Chinook or steelhead presented in Section 4.3.1 are not apparent. The primary impediments to fish passage include: high leap height, complete channel obstructions, and shallow and obstructed launching and landing conditions. The feature is therefore a barrier at high and low flow conditions.

5.2.5 Cherry/Eleanor Creeks

Field surveys for the Cherry/Eleanor Creek watershed were completed in October 2015 and May 2016. The primary characteristics of each feature are presented in Table 5.2-9 and Table 5.2-10. A map summarizing the location of each feature is presented as Figure 5.2-10 (see page 5-31). Narrative descriptions of each identified feature are provided below. Images and a data record of each feature are provided as Photos A-45 through A-50 of Attachment A.

Table 5.2-9. Summary of potential barriers identified on Cherry Creek during field surveys.

Feature	River Mile	Description	Classification
CC-1	0.76	Bedrock and Boulder Step Pool Falls	Potential Barrier
CC-2	0.87	Bedrock and Boulder Step Pool Falls	Potential Barrier

Feature	River Mile	Description	Classification
CC-3	1.45	Bedrock Falls	Potential Barrier
CC-4	1.50	Bedrock Falls	Potential Barrier
CC-5	1.62	Bedrock Falls	Total Barrier

Table 5.2-10. Physical characteristics of potential barriers identified on Cherry Creek during field surveys.

Feature	Total Height (ft)	Max Leap (ft)	Obstructed Launch and/or Landing	Leaping Depth	Swimming Depth	Turbulence	Velocity	Alternative Pathway Present?
CC-1	5	3	Unobstructed	Moderate	Shallow	Moderate	Moderate	Yes
CC-2	8	5	Obstructed	Shallow	Shallow	Low	Low	No
CC-3	7	7	Unobstructed	Unknown	Shallow	Moderate	High	No
CC-4	6	6	Obstructed	Moderate	Shallow	Low	Low	Yes
CC-5	17	17	Unobstructed	Deep	Deep	Low	Low	No

5.2.5.1 Feature CC-1

Feature CC-1 is a bedrock and boulder step pool falls located at RM 0.76 on Cherry Creek (Attachment A, Photo A-45). The feature forms between a series of boulders (diameters ranging from approximately three to eight feet) on river left and a bedrock wall on the river right. The falls have a total vertical rise of approximately 5 feet over about 60 horizontal feet (gradient of approximately 32 percent) and comprise a series a smaller steps (approximately 2 to 3 feet high) separated by runs with moderate turbulence and velocity. The most downstream launching pool is approximately 200 feet long, wide, with moderate depth, and low velocity and turbulence at low flows. Intermediate launching and landing pools also have moderate turbulence and velocity with shallow depths at low flows. Alternative pathways for fish passage may occur through the boulders at river left during higher flow conditions. However, more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage. The gradient does not exceed the gradient criteria expressed in Table 4.3-2. The primary impediments to fish passage include: moderate velocity and turbulence through reaches of shallow swimming depth. The feature is likely a barrier at low flows, but may exhibit conditions sufficient for passage at moderate flows. Alternative pathways may be present at these moderate to high flows that could provide additional opportunities for passage.

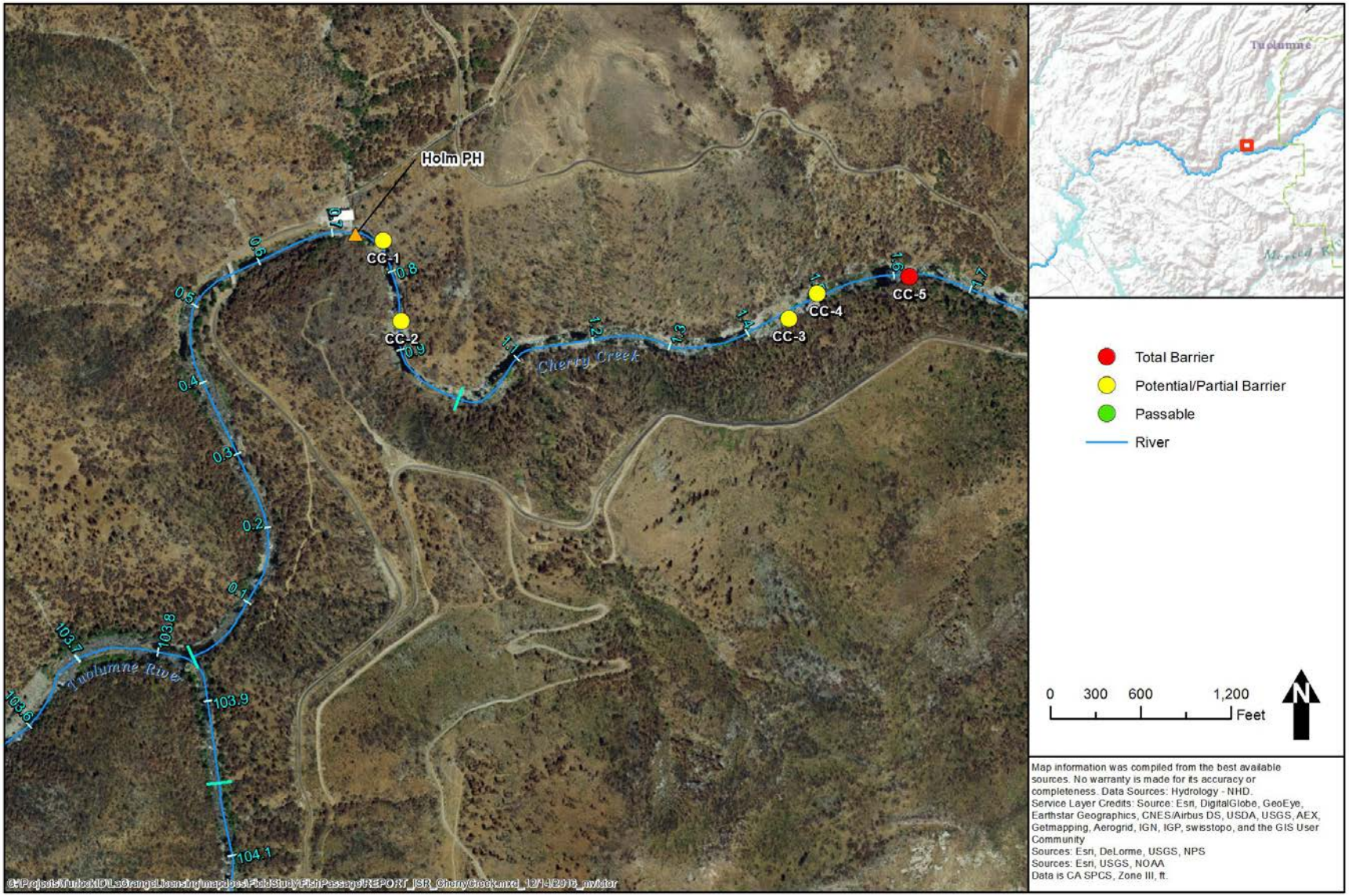


Figure 5.2-10. Summary of passage features and classification on Cherry Creek.

5.2.5.2 Feature CC-2

Feature CC-2 is a bedrock and boulder step pool falls located at RM 0.87 on Cherry Creek (Attachment A, Photo A-46). The falls form between a bedrock wall on the river left side and larger boulders (diameter approximately 6 to 15 feet) on river right. The river flows via multiple pathways over, around and through boulders (diameters ranging from two to six feet) creating small pocket pools and flowing over multiple steps. The most downstream step is approximately five vertical feet with flow cascading over multiple protruding boulders. The launching and landing pools are shallow and small (approximately three feet in length, depth unknown) with low velocity and turbulence. Both the launch and landing areas are partially obstructed by boulders. The upstream step is approximately three vertical feet with flow cascading over multiple protruding boulders. The total vertical drop is approximately 8 feet. A bedrock outcrop confines the river on the left banks, therefore eliminating the development of a side channel. During higher flows, however, given the shape of the bedrock, the step pool nature may begin to exhibit chute like properties, possibly reducing leap heights. However, more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The obstructed leaping pool and shallow depths make for less than ideal leap conditions. The leap height appears to exceed the leaping capability of spring-run Chinook at low flow conditions but may be ascendable by steelhead. The overhanging crest and formation of a hydraulic nappe creates a difficult leaping condition. The primary impediments to fish passage include: shallow and obstructed leap pool, high leap height and an obstructed landing zone. The feature is likely a barrier at low flows and exhibits features which may create conditions sufficient for passage at high flows.

5.2.5.3 Feature CC-3

Feature CC-3 is a sloping bedrock chute located at RM 1.45 on Cherry Creek (Attachment A, Photo A-47). The chute forms in a channel between bedrock outcrops on river left and large boulders on river right. The feature is formed by a uniform, convex shaped outcropping of bedrock that provides for uniform distribution of shallow laminar flow across the face. Velocities are high, with shallow depth and moderate turbulence. The vertical drop is approximately 7 feet, but the horizontal length is over 20 feet (average gradient of 35 percent). The launching pool appears sufficiently large, with unknown depths and low velocity and turbulence. The exposed bedrock on river left and the large boulders on river right appear to preclude any alternate fish passage pathway being formed. During higher flows, it is expected that flows will become more turbulent and have high velocities over this feature. Due to the wide nature of the feature, it's possible that the tailwater control will cause sufficient rise in the downstream water surface to reduce the feature height.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The primary impediments to fish passage include: high leap height, high velocity, and shallow depths. The leap height and shallow depth appears to

exceed the leaping and swimming capability of spring-run Chinook and steelhead at low flow conditions. The gradient and overall length of the feature does not exceed the gradient criteria expressed in Table 4.3-2 which suggests that fish may be able to burst upstream when sufficient depths are present. The overall hydraulics of this feature could be evaluated further to define the range of flows potentially passable by both species. The feature is likely a barrier at low and moderate flows and exhibits features which may create conditions sufficient for passage at high flows.

5.2.5.4 Feature CC-4

Feature CC-4 is a bedrock falls located at RM 1.50 on Cherry Creek (Attachment A, Photo A-48 and Photo A-49). The falls forms in a channel between bedrock outcropping on both sides of the valley and has a total vertical height of approximately six feet at low flow conditions. The launching pool is long with moderate depth and low turbulence and velocity. However, the landing pool is obstructed by a large boulder resting against the rock sill and forces flows to split and increase in velocity before the crest of the fall. Additionally, the falls itself is set back at an angle and would therefore require a substantial horizontal leap component to clear the crest of the falls. The bedrock outcrops confine the river on both the right and left banks, however, alternate pathways for passage may be formed during higher flows across other sections of the bedrock outcropping that serves as a sill (to the far left bank looking downstream as shown in Attachment A, Photo A-49).

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The leap height appears to exceed the leaping capability of spring-run Chinook at low flow conditions but may be ascendable by steelhead. The horizontal jump requirement as well as the tailwater control hydraulics could be evaluated further to define the range of flows potentially passable by both species. The primary impediments to fish passage include: high leap height and obstructed landing area. The feature is likely a barrier at low and moderate flows and exhibits features which may create conditions sufficient for passage at high flows.

5.2.5.5 Feature CC-5

Feature CC-5 is a bedrock falls located at RM 1.62 on Cherry Creek (Attachment A, Photo A-50). A high bedrock ledge extends the full width of the channel and is confined by steep bedrock walls on both edges. The crest is cross-sloped toward the middle creating a large shallow vee which focusses flow to the center of the feature. Water passing over the falls drops a single vertical distance of 17 feet at the low flow conditions observed during the initial field visit. Flow plunges into a large, deep pool below the falls which is approximately 200 feet in length. The pool tailwater control is as wide as or wider than the falls crest. The bedrock canyon walls confines the river on both the river right and river left, therefore eliminating the development of alternative fish passage pathways. Given the vee-shaped crest and wide tailwater control, the hydraulic differential is anticipated to remain similar to or potentially increase as streamflows increase.

Information collected during the field survey suggests that this feature is a total barrier to fish passage as defined in Section 4.3.1. The effective height of this feature exceeds the leaping capability of spring-run Chinook and steelhead at all flows and there are no apparent opportunities for alternative pathways. The primary impediment to fish passage is barrier height.

6.0 DISCUSSION AND FINDINGS

The work conducted in 2015 and 2016 included a review of existing data, collection of field data, and analysis of all the resulting available data. Field surveys performed on foot were performed in very difficult terrain and required a high level of effort. For each of the studied tributaries (Clavey River, South Fork Tuolumne River, North Fork Tuolumne River, and Cherry Creek), the 2015 and 2016 work identified features generally consolidated together in the lower reaches of each tributary and a total barrier existing within two miles of the confluence of each tributary with the mainstem Tuolumne River. A summary of the features identified during the 2015 and 2016 work is provided in Table 6.0-1. As presented in the results Section of this document, two potential barriers and one total barrier were identified on the Clavey River, 17 potential barriers and one total barrier were identified on the South Fork Tuolumne River, 7 potential barriers and one total barrier were identified on North Fork Tuolumne River, and 4 potential barriers and one total barrier were identified on Cherry Creek.

As described in the results discussion for each feature, potential barriers exhibited one of the following conditions:

(1) The identified feature exhibited conditions which exceeded the maximum leaping or swimming capability of spring-run Chinook or steelhead but conditions which may facilitate passage at some range of migration flows were apparent; or

(2) The identified feature exhibited conditions which were less than the maximum leaping or swimming capability of spring-run Chinook or steelhead but possessed elements which may inhibit passage at some range of migration flows.

For many of the features identified as potential barriers, it is noted in the results that hydraulic conditions sufficient for passage of spring-run Chinook and steelhead may exist at various ranges of higher or lower streamflows not observed by the study team. These observations indicate that the lower reaches of Clavey River, the South Fork Tuolumne River, the North Fork Tuolumne River, and Cherry Creek are likely accessible by anadromous salmonids on a temporal or intermittent basis.

Given the limited additional length of stream reach potentially available to anadromous fish below the identified total barrier, and the high level of effort required to quantitatively determine the range of passable conditions at each potential barrier, features initially classified as potential barriers in surveyed tributary reaches were given a final classification as partial barriers without further discretization of passable ranges of flow. Features with a final classification of either passable or total barrier would require no further study. As such, the identified potential barriers of this study are concluded to be partial barriers as defined in Section 4.0 of this document.

Table 6.0-1. Summary of features identified within the upper Tuolumne River watershed which are impediments to anadromous fish passage.

Feature	River Mile	Current Classification
Mainstem Tuolumne River		
Clavey Falls	90.0	Passable
Lumsden Falls	97.3	Partial Barrier

Feature	River Mile	Current Classification
Early Intake	104.3	Total Barrier
North Fork Tuolumne River		
NT-1	0.52	Partial Barrier
NT-2	0.55	Passable
NT-3	0.57	Partial Barrier
NT-4	0.72	Partial Barrier
NT-5	1.28	Partial Barrier
NT-6	1.54	Partial Barrier
NT-7	1.60	Partial Barrier
NT-8	1.65	Partial Barrier
NT-9	1.69	Total Barrier
Clavey River		
CR-1	0.20	Partial Barrier
CR-2	1.15	Partial Barrier
CR-3	2.05	Total Barrier
South Fork Tuolumne River		
ST-1	0.45	Partial Barrier
ST-2	0.50	Partial Barrier
ST-3	0.63	Partial Barrier
ST-4	0.67	Partial Barrier
ST-5	0.90	Partial Barrier
ST-6	0.95	Partial Barrier
ST-7	1.05	Partial Barrier
ST-8	1.15	Partial Barrier
ST-9	1.20	Partial Barrier
ST-10	1.35	Partial Barrier
ST-11	1.53	Partial Barrier
ST-12	1.57	Partial Barrier
ST-13	1.60	Partial Barrier
ST-14	1.62	Partial Barrier
ST-15	1.65	Partial Barrier
ST-16	1.80	Partial Barrier
ST-17	1.85	Partial Barrier
ST-18	1.90	Total Barrier
Cherry Creek		
CC-1	0.76	Partial Barrier
CC-2	0.87	Partial Barrier
CC-3	1.45	Partial Barrier
CC-4	1.50	Partial Barrier
CC-5	1.62	Total Barrier

Conclusions resulting from the information gathered as part of this study are summarized on a reach-by-reach basis in Table 6.0-2. A map illustrating the corresponding river reaches which are accessible by anadromous salmonids is provided in Figure 6.0-1. Conclusions suggest that the mainstem Tuolumne River is accessible by anadromous fish to Lumsden Falls at RM 97.3 and may potentially be accessible from Lumsden Falls to the Early Intake at RM 104.3. The lower mile and a half of the North Fork Tuolumne River is also potentially accessible during adequate flow conditions while the reach upstream of RM 1.69 is not accessible. The lower two miles of the Clavey River are potentially accessible during adequate flow conditions while the Clavey River upstream of RM 2.05 is not accessible by anadromous fish. The lower two miles of the South Fork Tuolumne River are also potentially accessible during adequate flow

conditions while the reach upstream of RM 1.9 is not accessible. The Middle Fork Tuolumne River originates upstream of RM 1.9 of the South Fork and therefore is also not accessible by anadromous fish. The lower mile and a half of Cherry Creek are also potentially accessible during adequate flow conditions, while the reach upstream of RM 1.62 is not accessible.

Table 6.0-2. Summary of upper Tuolumne River reaches accessible by anadromous salmonids.

River/Tributary	River Mile	Current Classification
Mainstem Tuolumne River	Don Pedro Reservoir to 97.3	Accessible
	97.3 to 104.3	Potentially Accessible
	104.3 and upstream	Not Accessible
North Fork Tuolumne River	0 to 0.52	Accessible
	0.52 to 1.69	Potentially Accessible
	1.69 and upstream	Not Accessible
Clavey River	0 to 0.2	Accessible
	0.2 to 2.05	Potentially Accessible
	2.05 and upstream	Not Accessible
South Fork Tuolumne River	0 to 0.45	Accessible
	0.45 to 1.9	Potentially Accessible
	1.9 and upstream	Not Accessible
Middle Fork Tuolumne River	All	Not Accessible
Cherry Creek	0 to 1.62	Potentially Accessible
	1.62 and upstream	Not Accessible

Lumsden Falls exhibits complex hydraulic characteristics at all observed flow conditions. Lumsden Falls possesses velocities, turbulence, air entrainment, and jump heights that are likely to significantly impede the upstream migration of adult Chinook salmon and steelhead populations throughout a wide range of flows experienced in that reach of the mainstem Tuolumne. There are potentially intermittent windows of opportunity where the strongest of fish could achieve passage. However, the timing of the appropriate hydraulic event that supports passage conditions would need to overlap with the timing of fish presence – thus reducing the probability of passage and likely causing attrition of portions of the population over time. Over periods of years or decades, the intermittent alignment of passable conditions and migratory fish presence at this feature is likely to act as a filter – where passage is likely only possible by the strongest portion of the population.

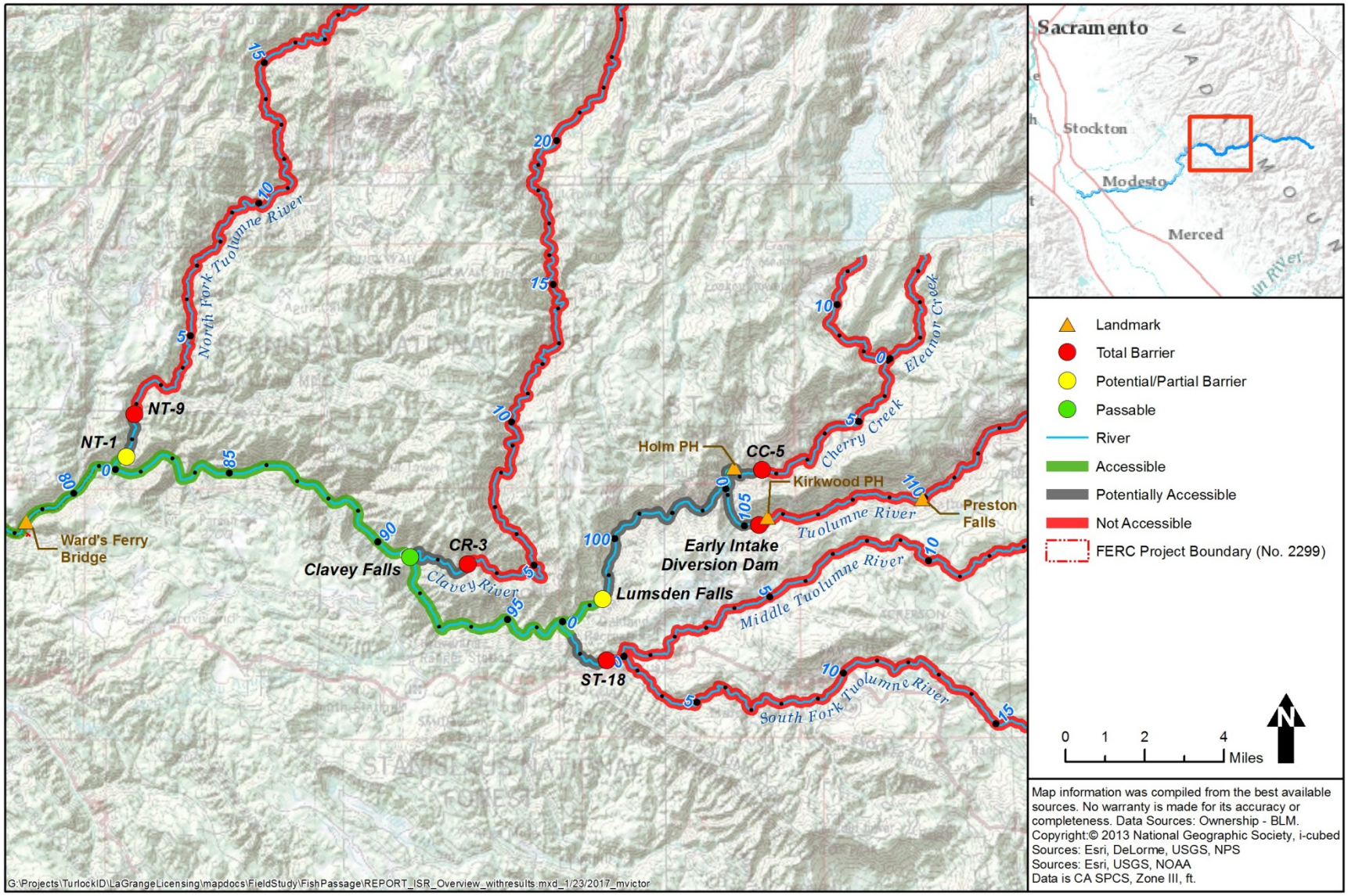


Figure 6.0-1. Overall conclusions and summary of river reaches accessible to anadromous fish based upon field surveys.

7.0 REFERENCES

63 FR 13347. National Marine Fisheries Service. Final Rule: Endangered and Threatened Species: Threatened Status for Two ESUs of Steelhead in Washington, Oregon, and California. Federal Register 63: 13347-13371. March 19, 1998.

64 FR 50394. National Marine Fisheries Service. Final Rule: Endangered and Threatened Species: Threatened Status for Two Chinook Salmon Evolutionarily Significant Units (ESUs) in California. Federal Register 64: 50394-50415. September 16, 1999.

64 FR 5740. National Marine Fisheries Service. Proposed Rule: Designated Critical Habitat: Proposed Critical Habitat for Nine Evolutionarily Significant Units of Steelhead in Washington, Oregon, Idaho, and California. Federal Register 64: 5740-5754. February 5, 1999.

65 FR 42422. National Marine Fisheries Service. Final Rule: Endangered and Threatened Species; Final Rule Governing Take of 14 Threatened Salmon and Steelhead Evolutionarily Significant Units (ESUs).

69 FR 71880. National Marine Fisheries Service. Proposed Rule: Endangered and Threatened Species; Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon (Oncorhynchus tshawytscha) and Steelhead (O. mykiss) in California. Federal Register 69: 71880-72017. December 10, 2004.

70 FR 37204. National Marine Fisheries Service. Final Policy: Policy on the Consideration of Hatchery-Origin Fish in Endangered Species Act Listing Determinations for Pacific Salmon and Steelhead. Federal Register 70: 37204-37216.

70 FR 52488. National Marine Fisheries Service. Final rule: Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California. Federal Register 70: 52488-52627. September 2, 2005.

Bacher, D. 2013. Triple Fishing Fun and Lake Don Pedro. The Fish Sniffer 32(14):6-7.

Bell, M.C. 1973. Fisheries Handbook of Engineering Requirements and Biological Criteria. Fisheries Engineering Research Program. U.S. Army Engineering Division. North Pacific Corps of Engineers. Portland, OR.

Buckmaster, Nicholas, A. Clause, T. Hatch, H. Jackson, A. Stephenson. 2009. Effects of unregulated tributaries on a regulated mainstem (Tuolumne River). University of California, Davis, Center for Watershed Sciences.

California Department of Fish and Wildlife (CDFW). 2016a. Fish Planting Schedule. Available at < https://nrm.dfg.ca.gov/fishplants/> Accessed August 25, 2016.

De Carion, D., G. Epke, P. Hilton, D. Holmberg, C. Stouthamer and M. Young. 2010. Natural History Guide to the Tuolumne River. University of California, Davis.

EA Engineering. 1990. Exhibit E (Report 3) of the Clavey River Project Administrative Draft FERC License Application.

Holbek, Lars and Chuck Stanley. 1984. A Guide to the Best Whitewater in the State of California. Sacramento: Friends of the River Books.

Hunter, Larry A. and Mayor, Lesley. 1986. Analysis of Fish Swimming Performance Data, Volume I.

Jayasundara, N. C., M. L. Deas, E. Sogutlugil, E. Miao, E. Limanto, A. Bale, and S. K. Tanaka. 2014. Tuolumne River flow and temperature model: without project assessment. Prepared by Watercourse Engineering, Inc., Davis, CA.

McBain, S. and W. Trush. 2004. Attributes of Bedrock Sierra Nevada River Ecosystems. USDA Forest Service, Stream Notes, Stream Systems Technology Center, Ft. Collins, CO, January.

Moyle, P.B. 2002. Inland Fisheries of California, 2nd Ed. University of California Press. Davis, CA.

National Marine Fisheries Service (NMFS). 2014. Recovery Plan for the Evolutionary Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and The Distinct Population Segment of California Central Steelhead. July 2014.

_____. 2016a. Central Valley Recovery Domain 5-Year Review: Summary and Evaluation Central Valley Spring-run Chinook Salmon Evolutionarily Significant Unit. Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232 and Central Valley Office, 650 Capitol Mall, Suite 5-100, Sacramento, CA 95814-4706.

_____. 2016b. Central Valley Recovery Domain 5-Year Review: Summary and Evaluation California Central Valley Steelhead Distinct Population Segment. Prepared by N. Alston, M. Rea, S. Rumsey, and B. Ellrott. Central Valley Office, 650 Capitol Mall, Suite 5-100, Sacramento, CA 95814-4706.

Perales, K. Martin. 2015. What Lies Behind the Dam? In Some Cases, Self-Sustaining Salmon. California Water Blog. Available at https://californiawaterblog.com/2016/02/14/5714/. Accessed August 25, 2016.

Powers, P.D. and J.F. Orsborn. 1985. Analysis of Barriers to Upstream Migration: An Investigation of the Physical and Biological Conditions Affecting Fish Passage Success at Culverts and Waterfalls. BPA Report No. DOE/BP-36523-1.

RMC Water and Environment and McBain & Trush, Inc. 2007. Upper Tuolumne River: Description of River Ecosystem and Recommended Monitoring Actions. Prepared for the San Francisco Public Utilities Commission. April 2007 (revised January 2016).

San Francisco Public Utilities Commission (SFPUC). 2008. Final Program Environmental Impact Report, Volume 3 of 8, for the San Francisco Public Utilities Commission's Water System Improvement Program, Water Supply and System Operations, Chapter 5 Setting and Impacts. San Francisco Planning Department File No. 2005.0159E, State Clearinghouse No. 2005092026.

Stillwater Sciences. 2016. Upper Tuolumne River Ecosystems Program, Hetch Hetchy Reach Fisheries Monitoring, Revised Sampling Approach and 2014 Results. Prepared for San Francisco Public Utilities Commission. Prepared by Stillwater Sciences in coordination with McBain Associates, Arcata, California.

Turlock Irrigation District and Modesto Irrigation District (TID/MID). 2013. Water Quality Assessment Study Report (W&AR-01). Prepared by HDR Engineering, Inc. December 2013.

_____. 2016a. Fish Passage Facilities Alternatives Assessment Progress Report. Prepared by HDR, Inc. Appendix to La Grange Hydroelectric Project Initial Study Report. February 2016.

_____. 2016b. Upper Tuolumne River Basin Water Temperature Monitoring and Modeling Progress Report. Prepared by Watercourse Engineering, Inc. Appendix to La Grange Hydroelectric Project Initial Study Report. February 2016.

U.S. Army Corps of Engineers (ACOE). 1972. Don Pedro Lake, Tuolumne River, California: Reservoir Regulation for Flood Control. Department of the Army, Sacramento, California.

U.S. Forest Service (USFS). 2001. Aquatic habitat management handbook. Chapter 20 – Fish and Aquatic Stream Habitat Survey, Forest Service Handbook 2090.21.

Weaver, J. and S. Mehalick. 2009. Tuolumne River 2009 Summary Report. Heritage and Wild Trout Program, CDFG.

Yoshiyama, Ronald M., E. Gerstung, F. Fisher, P. Moyle. 2001. Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California. Contributions to the Biology of Central Valley Salmonids. Fish Bulletin 179: Volume 1.

UPPER TUOLUMNE RIVER BASIN
FISH MIGRATION BARRIERS STUDY
STUDY REPORT

ATTACHMENT A

PHOTOGRAPH LOG AND SUMMARY OF COLLECTED DATA

	**Photo A-1** **Waterbody:** Mainstem Tuolumne River **Feature:** Clavey Falls **River Mile:** 90 **Date:** 8/4/2015 **Time:** 10:54 **Image Name:** IMG_20150804_105404_-832109627.jpg **Coordinates:** 37.86466659, -120.11769261 **Total Vertical Height:** 3 feet **Description:** Recreational flows, looking upstream at constriction step. **Barrier:** Passable
	**Photo A-2** **Waterbody:** Mainstem Tuolumne River **Feature:** Clavey Falls **River Mile:** 90 **Date:** 8/4/2015 **Time:** 10:54 **Image Name:** IMG_20150804_105459_1342125081.jpg **Coordinates:** 37.86467865, -120.11781715 **Total Vertical Height:** 2-3 feet **Description:** Recreational flows, looking upstream at boulder steps. **Barrier:** Passable
	**Photo A-3** **Waterbody:** Mainstem Tuolumne River **Feature:** Clavey Falls **River Mile:** 90 **Date:** 8/4/2015 **Time:** 09:46 **Image Name:** IMG_20150804_094635_2064884884.jpg **Coordinates:** 37.86431125, -120.1178997 **Total Vertical Height:** 6 feet **Description:** Low flows, looking upstream at cascade. **Barrier:** Passable

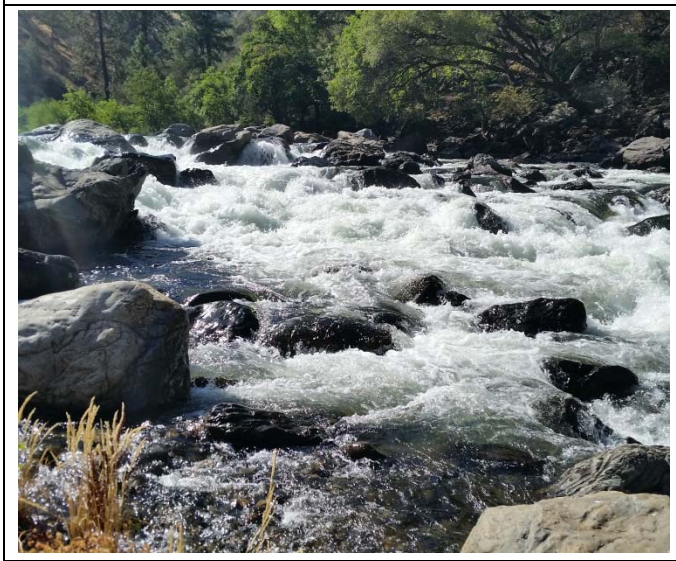
	**Photo A-4** **Waterbody:** Mainstem Tuolumne River **Feature:** Clavey Falls **River Mile:** 90 **Date:** 8/4/2015 **Time:** 10:57 **Image Name:** IMG_20150804_105707_1230910478.jpg **Coordinates:** 37.86418216, -120.11777968 **Total Vertical Height:** 6 feet **Description:** Recreational flows, looking upstream at cascade. **Barrier:** Passable
	**Photo A-5** **Waterbody:** Mainstem Tuolumne River **Feature:** Clavey Falls **River Mile:** 90 **Date:** 8/4/2015 **Time:** 09:47 **Image Name:** IMG_20150804_094733_1267904529.jpg **Coordinates:** 37.86417511, -120.11785951 **Total Vertical Height:** 6 feet **Description:** Low flows, looking upstream close up at cascade. **Barrier:** Passable
	**Photo A-6** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/5/2015 **Time:** 09:59 **Image Name:** IMG_20150805_095948_1451836945.jpg **Coordinates:** 37.84819453, -120.02996637 **Total Vertical Height:** 18 feet **Description:** Low flows, overview looking upstream at cascade. **Barrier:** Potential

	**Photo A-7** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/6/2015 **Time:** 11:20 **Image Name:** IMG_20150806_112005_1245804360.jpg **Coordinates:** 37.84821225, -120.02995430 **Total Vertical Height:** 18 feet **Description:** Recreational flows, overview looking upstream at cascade. **Barrier:** Potential
	**Photo A-8** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/5/2015 **Time:** 10:21 **Image Name:** IMG_20150805_102121_-648207368.jpg **Coordinates:** 37.84589793, -120.04109135 **Total Vertical Height:** 18 feet **Description:** Low flows, looking upstream at cascade. **Barrier:** Potential
	**Photo A-9** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/6/2015 **Time:** 11:32 **Image Name:** IMG_20150806_113246_706160864.jpg **Coordinates:** 37.84830553, -120.02972330 **Total Vertical Height:** 18 feet **Description:** Recreational flows, looking upstream at cascade. **Barrier:** Potential

	**Photo A-10** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/5/2015 **Time:** 10:25 **Image Name:** IMG_20150805_102537_1451836945.jpg **Coordinates:** 37.84842667, -120.02952527 **Total Vertical Height:** 18 feet **Description:** Low flows, looking upstream from mid-falls. **Barrier:** Potential
	**Photo A-11** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/6/2015 **Time:** 11:46 **Image Name:** IMG_20150806_114406_-428109626.jpg **Coordinates:** 37.84853852, -120.02931625 **Total Vertical Height:** 18 feet **Description:** Recreational flows, looking upstream from mid-falls. **Barrier:** Potential
	**Photo A-12** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/6/2015 **Time:** 11:47 **Image Name:** IMG_20150806_114742_2071543936.jpg **Coordinates:** 37.84843521, -120.02914996 **Total Vertical Height:** 18 feet **Description:** Recreational flows, looking upstream at falls crest. **Barrier:** Potential

	**Photo A-13** **Waterbody:** Clavey River **Feature:** CR-1 **River Mile:** 0.2 **Date:** 8/3/2015 **Time:** 17:38 **Image Name:** IMG_20150803_173808_789570304.jpg **Coordinates:** 37.86620440, -120.11463213 **Total Vertical Height:** 12 feet **Description:** Looking upstream at split flow bedrock falls. **Barrier:** Partial
	**Photo A-14** **Waterbody:** Clavey River **Feature:** CR-1 **River Mile:** 0.2 **Date:** 8/3/2015 **Time:** 17:39 **Image Name:** IMG_20150803_173949_-865758468.jpg **Coordinates:** 37.86618723, -120.11466690 **Total Vertical Height:** 12 feet **Description:** Looking downstream at tail water control pool. **Barrier:** Partial
	**Photo A-15** **Waterbody:** Clavey River **Feature:** CR-2 **River Mile:** 1.15 **Date:** 8/3/2015 **Time:** 16:24 **Image Name:** IMG_20150803_162424_502621589.jpg **Coordinates:** 37.86219766, -120.10301435 **Total Vertical Height:** 8 feet **Description:** Looking upstream at split flow feature. **Barrier:** Partial

	**Photo A-16** **Waterbody:** Clavey River **Feature:** CR-2 **River Mile:** 1.15 **Date:** 8/3/2015 **Time:** 16:05 **Image Name:** IMG_20150803_160556_1431754020.jpg **Coordinates:** 37.86201539, -120.10293057 **Total Vertical Height:** 8 feet **Description:** Looking upstream at river left flow feature over bedrock chute. **Barrier:** Partial
	**Photo A-17** **Waterbody:** Clavey River **Feature:** CR-2 **River Mile:** 1.15 **Date:** 8/3/2015 **Time:** 16:08 **Image Name:** IMG_20150803_160818_1515502728.jpg **Coordinates:** 37.86202495, -120.10295292 **Total Vertical Height:** 8 feet **Description:** Looking upstream at river right flow features over boulders. **Barrier:** Partial
	**Photo A-18** **Waterbody:** Clavey River **Feature:** CR-2 **River Mile:** 1.15 **Date:** 8/3/2015 **Time:** 16:00 **Image Name:** IMG_20150803_160000_1021997947.jpg **Coordinates:** 37.86205223, -120.10296322 **Total Vertical Height:** 8 feet **Description:** Looking upstream at feature crest. **Barrier:** Partial

	**Photo A-19** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 13:40 **Image Name:** IMG_20150803_134054_1556097379.jpg **Coordinates:** 37.86087502, -120.09213326 **Total Vertical Height:** not applicable **Description:** Looking upstream at 400 feet long boulder field. **Barrier:** Total
	**Photo A-20** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 13:28 **Image Name:** IMG_20150803_132843_1574218901.jpg **Coordinates:** 37.86150460, -120.09135843 **Total Vertical Height:** not applicable **Description:** Looking upstream at flow under boulder with inadequate clearance for fish passage. **Barrier:** Total

	**Photo A-21** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 13:15 **Image Name:** IMG_20150803_131516_139401152.jpg **Coordinates:** 37.86138223, -120.09151098 **Total Vertical Height:** not applicable **Description:** Looking upstream at flow through boulder field. **Barrier:** Total
	**Photo A-22** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 13:04 **Image Name:** IMG_20150803_130436_2021697091.jpg **Coordinates:** 37.86150460, -120.09135843 **Total Vertical Height:** not applicable **Description:** Looking downstream at flow through boulder field. **Barrier:** Total
	**Photo A-23** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 12:54 **Image Name:** IMG_20150803_125441_1710042233.jpg **Coordinates:** 37.86157972, -120.09111681 **Total Vertical Height:** not applicable **Description:** Looking uphill at hill slope slide area feeding into boulder field. **Barrier:** Total

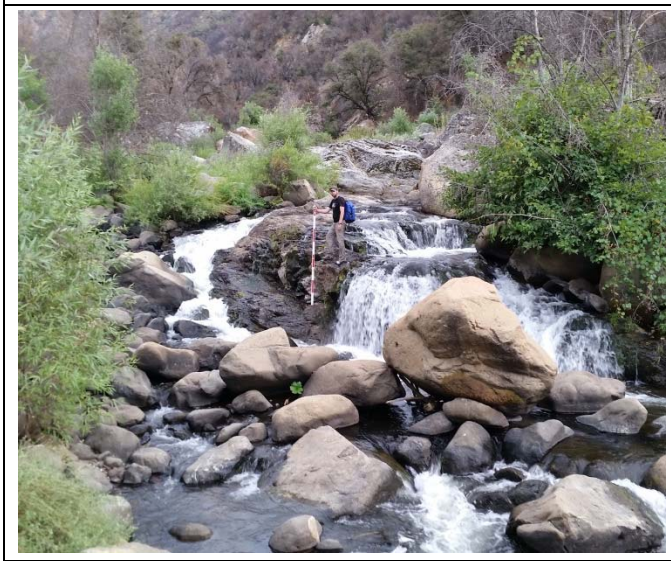
	**Photo A-24** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 12:42 **Image Name:** IMG_20150803_124235_1273056850.jpg **Coordinates:** 37.86148716, -120.09138184 **Total Vertical Height:** 7-10 feet **Description:** Looking upstream at crest of boulder field. **Barrier:** Total
	**Photo A-25** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 12:50 **Image Name:** IMG_20150803_125009_144389114.jpg **Coordinates:** 37.86160869, -120.09119522 **Total Vertical Height:** 7-10 feet **Description:** Looking upstream at crest of boulder field. **Barrier:** Total
	**Photo A-26** **Waterbody:** South Fork Tuolumne River **Feature:** ST-1 **River Mile:** 0.45 **Date:** 8/5/2015 **Time:** 19:13 **Image Name:** IMG_20150805_191358_-159393085.jpg **Coordinates:** 37.83525797, -120.04364120 **Total Vertical Height:** 5-7 feet **Description:** Looking upstream at split flow falls over bedrock. **Barrier:** Partial

	**Photo A-27** **Waterbody:** South Fork Tuolumne River **Feature:** ST-1 **River Mile:** 0.45 **Date:** 8/5/2015 **Time:** 19:16 **Image Name:** IMG_20150805_191631_90572858.jpg **Coordinates:** 37.83530969, -120.04354825 **Total Vertical Height:** 5-7 feet **Description:** Looking upstream at river right falls over bedrock. **Barrier:** Partial
	**Photo A-28** **Waterbody:** South Fork Tuolumne River **Feature:** ST-2 **River Mile:** 0.5 **Date:** 8/5/2015 **Time:** 19:06 **Image Name:** IMG_20150805_190643_2052653629.jpg **Coordinates:** 37.83469790, -120.04358405 **Total Vertical Height:** 3-4 feet **Description:** Looking upstream at step pool falls. **Barrier:** Partial
	**Photo A-29** **Waterbody:** South Fork Tuolumne River **Feature:** ST-3 **River Mile:** 0.63 **Date:** 8/5/2015 **Time:** 18:50 **Image Name:** IMG_20150805_185040_68629034.jpg **Coordinates:** 37.83317976, -120.04269041 **Total Vertical Height:** 4-5 feet **Description:** Looking upstream at split flow step pool falls. **Barrier:** Partial

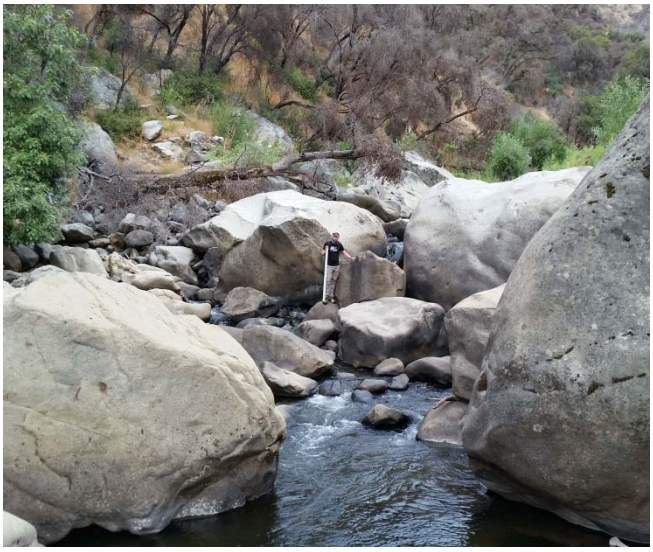
	**Photo A-30** **Waterbody:** South Fork Tuolumne River **Feature:** ST-4 **River Mile:** 0.67 **Date:** 8/5/2015 **Time:** 18:44 **Image Name:** IMG_20150805_184426_1120698503.jpg **Coordinates:** 37.83276546, -120.04197991 **Total Vertical Height:** 6 feet **Description:** Looking upstream at falls between boulders. **Barrier:** Partial
	**Photo A-31** **Waterbody:** South Fork Tuolumne River **Feature:** ST-5 **River Mile:** 0.9 **Date:** 8/5/2015 **Time:** 18:24 **Image Name:** IMG_20150805_182414_1616201536.jpg **Coordinates:** 37.82947237, -120.04108911 **Total Vertical Height:** 3.5 feet **Description:** Looking upstream at split flow step pool falls. **Barrier:** Partial
	**Photo A-32** **Waterbody:** South Fork Tuolumne River **Feature:** ST-6 **River Mile:** 0.95 **Date:** 8/5/2015 **Time:** 18:17 **Image Name:** IMG_20150805_181720_1605778994.jpg **Coordinates:** 37.82883430, -120.04079654 **Total Vertical Height:** 11 feet **Description:** Looking upstream at bedrock falls. **Barrier:** Partial

	**Photo A-33** **Waterbody:** South Fork Tuolumne River **Feature:** ST-7 **River Mile:** 1.05 **Date:** 8/5/2015 **Time:** 18:08 **Image Name:** IMG_20150805_180841_2002098336.jpg **Coordinates:** 37.82810769, -120.03913301 **Total Vertical Height:** 5 feet **Description:** Looking upstream at bedrock falls. **Barrier:** Partial
	**Photo A-34** **Waterbody:** South Fork Tuolumne River **Feature:** ST-8 **River Mile:** 1.15 **Date:** 8/5/2015 **Time:** 17:57 **Image Name:** IMG_20150805_175753_1094997848.jpg **Coordinates:** 37.82718331, -120.03820443 **Total Vertical Height:** 6 feet **Description:** Looking upstream at falls between bedrock and boulders. **Barrier:** Partial
	**Photo A-35** **Waterbody:** South Fork Tuolumne River **Feature:** ST-9 **River Mile:** 1.2 **Date:** 8/5/2015 **Time:** 17:50 **Image Name:** IMG_20150805_175027_481678163.jpg **Coordinates:** 37.82655809, -120.03770691 **Total Vertical Height:** 16 feet **Description:** Looking upstream at bedrock step falls. **Barrier:** Partial

	**Photo A-36** **Waterbody:** South Fork Tuolumne River **Feature:** ST-10 **River Mile:** 1.35 **Date:** 8/5/2015 **Time:** 17:37 **Image Name:** IMG_20150805_173718_2036909888.jpg **Coordinates:** 37.82671097, -120.03590602 **Total Vertical Height:** 3-5 feet **Description:** Looking upstream at falls between boulders. **Barrier:** Partial
	**Photo A-37** **Waterbody:** South Fork Tuolumne River **Feature:** ST-11 **River Mile:** 1.53 **Date:** 8/5/2015 **Time:** 17:15 **Image Name:** IMG_20150805_171534_1269685908.jpg **Coordinates:** 37.82512415, -120.03300482 **Total Vertical Height:** 3-5 feet **Description:** Looking upstream at split flow step falls. **Barrier:** Partial

	**Photo A-38** **Waterbody:** South Fork Tuolumne River **Feature:** ST-12 **River Mile:** 1.57 **Date:** 8/5/2015 **Time:** 17:06 **Image Name:** IMG_20150805_170644_1217473234.jpg **Coordinates:** 37.82475480, -120.03229264 **Total Vertical Height:** 10 feet **Description:** Looking upstream at cascade. **Barrier:** Partial
	**Photo A-39** **Waterbody:** South Fork Tuolumne River **Feature:** ST-13 **River Mile:** 1.6 **Date:** 8/5/2015 **Time:** 16:59 **Image Name:** IMG_20150805_165914_1249065127.jpg **Coordinates:** 37.82504767, -120.03175838 **Total Vertical Height:** 6-8 feet **Description:** Looking upstream at step pool falls. **Barrier:** Partial

	**Photo A-40** **Waterbody:** South Fork Tuolumne River **Feature:** ST-14 **River Mile:** 1.62 **Date:** 8/5/2015 **Time:** 16:54 **Image Name:** IMG_20150805_165427_526436975.jpg **Coordinates:** 37.82533042, -120.03189472 **Total Vertical Height:** 14 feet **Description:** Looking upstream at step pool falls. **Barrier:** Partial
	**Photo A-41** **Waterbody:** South Fork Tuolumne River **Feature:** ST-15 **River Mile:** 1.65 **Date:** 8/5/2015 **Time:** 16:48 **Image Name:** IMG_20150805_164822_208747719.jpg **Coordinates:** 37.82565017, -120.03171151 **Total Vertical Height:** 3-4 feet **Description:** Looking upstream at split flow step pool falls. **Barrier:** Partial
	**Photo A-42** **Waterbody:** South Fork Tuolumne River **Feature:** ST-16 **River Mile:** 1.8 **Date:** 8/5/2015 **Time:** 16:29 **Image Name:** IMG_20150805_162930_1651167043.jpg **Coordinates:** 37.82563017, -120.02913378 **Total Vertical Height:** 5-6 feet **Description:** Looking upstream at bedrock falls. **Barrier:** Partial

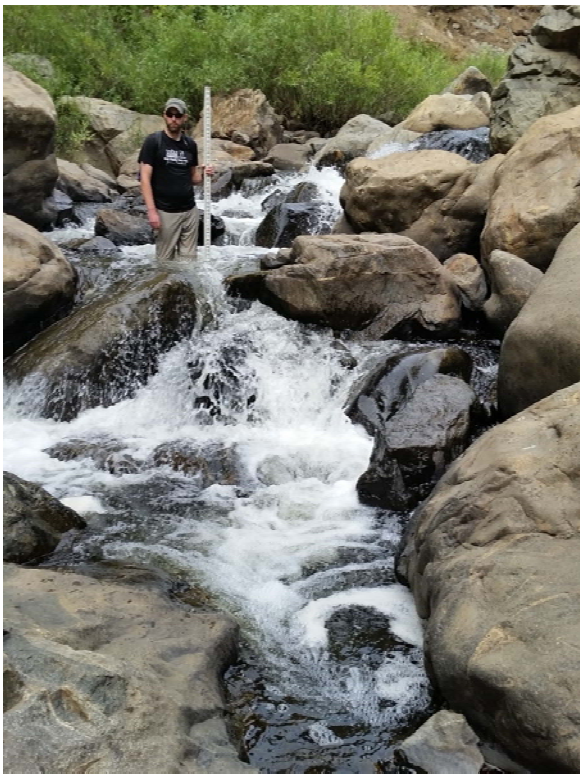
	**Photo A-43** **Waterbody:** South Fork Tuolumne River **Feature:** ST-17 **River Mile:** 1.85 **Date:** 8/5/2015 **Time:** 16:22 **Image Name:** IMG_20150805_162219_1883865277.jpg **Coordinates:** 37.82593146, -120.02857645 **Total Vertical Height:** 7 feet **Description:** Looking upstream at cascade. **Barrier:** Partial
	**Photo A-44** **Waterbody:** South Fork Tuolumne River **Feature:** ST-18 **River Mile:** 1.9 **Date:** 8/5/2015 **Time:** 16:22 **Image Name:** IMGP0109.jpg **Coordinates:** 37.82616354, -120.02741986 **Total Vertical Height:** 32 feet **Description:** Looking upstream at bedrock falls. **Barrier:** Total

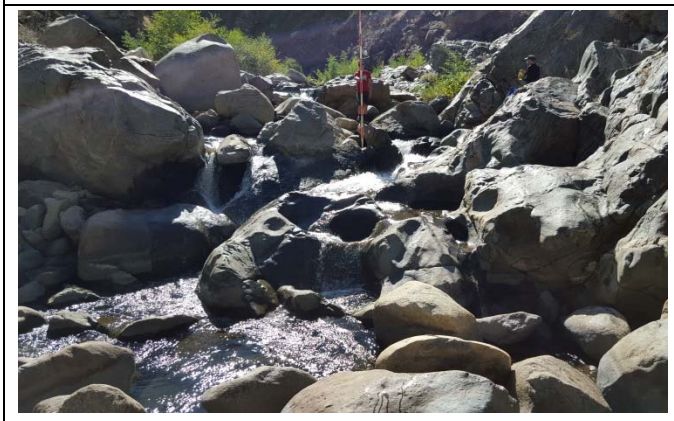
	**Photo A-45** **Waterbody:** Cherry Creek **Feature:** CC-1 **River Mile:** 0.76 **Date:** 10/26/2015 **Time:** 12:59 **Image Name:** IMG_20151026_125924_1871653236.jpg **Coordinates:** 37.8962499, -119.9679786 **Total Vertical Height:** 5 feet **Description:** Looking upstream of Holm Powerhouse at bedrock step pool falls **Barrier:** Potential
	**Photo A-46** **Waterbody:** Cherry Creek **Feature:** CC-2 **River Mile:** 0.87 **Date:** 10/26/2015 **Time:** 12:30 **Image Name:** IMG_20151026_123035_-851055533.jpg **Coordinates:** 37.8947168, - 119.9672991 **Total Vertical Height:** 8feet Description: Looking upstream at bedrock and boulder step pool falls. **Barrier:** Potential
	**Photo A-47** **Waterbody:** Cherry Creek **Feature:** CC-3 **River Mile:** 1.45 **Date:** 10/26/2015 **Time:** 11:18 **Image Name:** IMG_20151026_111804_-391179401.jpg **Coordinates:** 37.8945612, -119.9584881 **Total Vertical Height:** 7feet **Description:** Overview of bedrock falls from right bank. **Barrier:** Potential

	**Photo A-48** **Waterbody:** Cherry Creek **Feature:** CC-4 **River Mile:** 1.50 **Date:** 10/26/2015 **Time:** 11:10 **Image Name:** IMG_20151026_111025_1189265632.jpg **Coordinates:** 37.8950546, -119.9579556 **Total Vertical Height:** 6 feet **Description:** Looking upstream at bedrock falls and leap pool. **Barrier:** Potential
	**Photo A-49** **Waterbody:** Cherry Creek **Feature:** CC-4 **River Mile:** 1.50 **Date:** 10/26/2015 **Time:** 11:01 **Image Name:** IMG_20151026_110154_-36629795.jpg **Coordinates:** 37.8950626, -119.9577084 **Total Vertical Height:** 6 feet **Description:** Looking downstream at tailwater control; leap obstruction to the left. **Barrier:** Potential
	**Photo A-50** **Waterbody:** Cherry Creek **Feature:** CC-5 **River Mile:** 1.62 **Date:** 10/26/2015 **Time:** 10:42 **Image Name:** IMG_20151026_104247_-26553618.jpg **Coordinates:** 37.8955601, -119.9563437 **Total Vertical Height:** 17 feet **Description:** Looking upstream at bedrock falls **Barrier:** Total

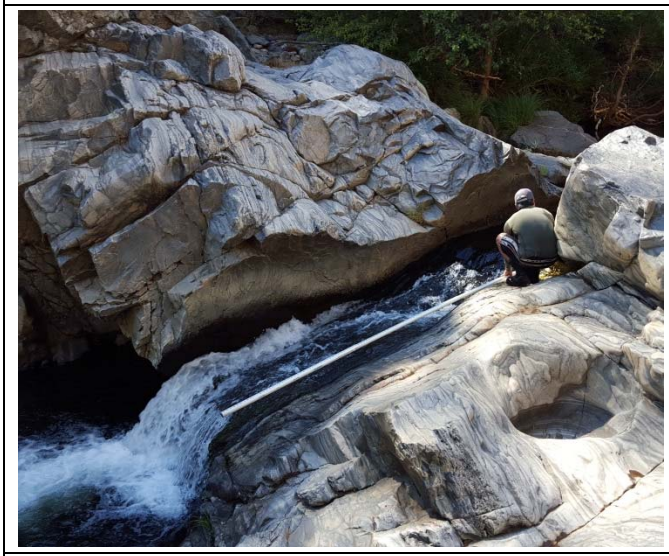
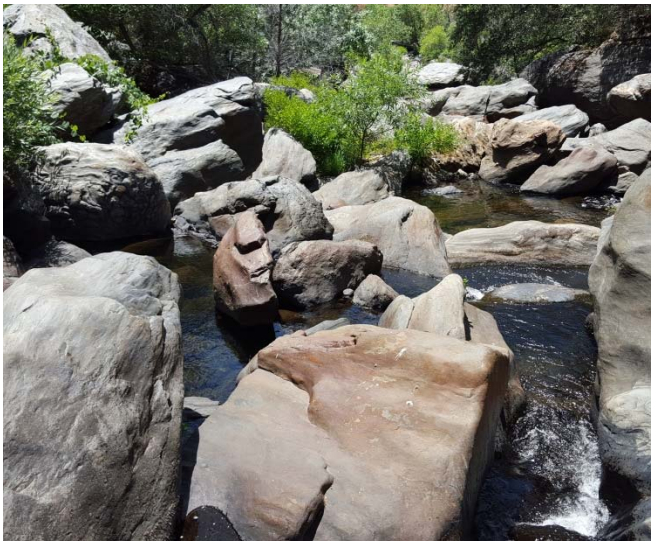
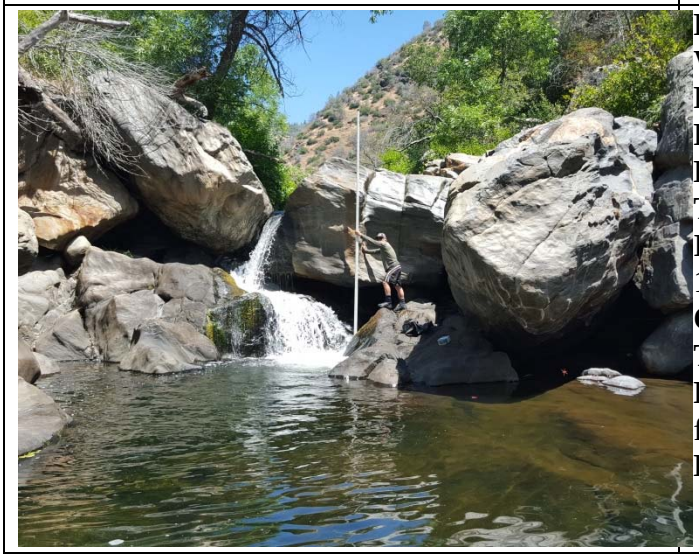
	**Photo A-51** **Waterbody:** North Fork Tuolumne River **Feature:** NT-1 **River Mile:** 0.52 **Date:** 7/15/2016 **Time:** 16:36 **Image Name:**IMG_20160715_163633_ -1637339064.jpg **Coordinates:** 37.9008948, -120.2484138 **Total Vertical Height:** 5 feet **Description:** Looking upstream at bedrock chute **Barrier:** Potential
	**Photo A-52** **Waterbody:** North Fork Tuolumne River **Feature:** NT-1 **River Mile:** 0.52 **Date:** 7/15/2016 **Time:** 16:30 **Image Name:**IMG_20160715_162920_ -1047313509.jpg **Coordinates:** 37.9011379, -120.2485955 **Total Vertical Height:** 5 feet **Description:** Bedrock chute from left bank **Barrier:** Potential
	**Photo A-53** **Waterbody:** North Fork Tuolumne River **Feature:** NT-2 **River Mile:** 0.55 **Date:** 7/15/2016 **Time:** 16:24 **Image Name:**IMG_20160715_162410_ 1166953418.jpg **Coordinates:** 37.9014107, -120.2482831 **Total Vertical Height:** N/A Description: Looking upstream at short boulder field **Barrier:** Passable

	**Photo A-54** **Waterbody:** North Fork Tuolumne River **Feature:** NT-3 **River Mile:** 0.57 **Date:** 7/15/2016 **Time:** 16:12 **Image Name:**IMG_20160715_161158_202957753.jpg **Coordinates:** 37.9017276, -120.2482568 **Total Vertical Height:** 4 feet **Description:** Looking upstream at bedrock falls **Barrier:** Potential
	**Photo A-55** **Waterbody:** North Fork Tuolumne River **Feature:** NT-4 **River Mile:** 0.72 **Date:** 7/15/2016 **Time:** 15:44 **Image Name:**IMG_20160715_154445_1491411188.jpg **Coordinates:** 37.9036612, -120.2472935 **Total Vertical Height:** 6 feet **Description:** Looking upstream at bedrock falls **Barrier:** Potential
	**Photo A-56** **Waterbody:** North Fork Tuolumne River **Feature:** NT-5 **River Mile:** 1.28 **Date:** 7/15/2016 **Time:** 14:18 **Image Name:**IMG_20160715_141835_1216811287.jpg **Coordinates:** 37.9115373, -120.2443782 **Total Vertical Height:** 4-5 feet **Description:** Looking upstream at bedrock falls **Barrier:** Potential

	**Photo A-57** **Waterbody:** North Fork Tuolumne River **Feature:** NT-6 **River Mile:** 1.54 **Date:** 7/15/2016 **Time:** 13:45 **Image Name:**IMG_20160715_134501_ -1940720911.jpg **Coordinates:** 37.9146038, -120.245619 **Total Vertical Height:** 5 feet **Description:** Looking upstream at step pool falls **Barrier:** Potential
	**Photo A-58** **Waterbody: North Fork Tuolumne River** **Feature:** NT-7 **River Mile:** 1.60 **Date:** 7/15/2016 **Time:** 13:24 **Image Name:** IMG_20160715_132439_ 1750772831.jpg **Coordinates:** 37.9151397, -120.2453156 **Total Vertical Height:** N/A **Description:** Looking upstream at downstream extent of boulder field **Barrier:** Potential
	**Photo A-59** **Waterbody: North Fork Tuolumne River** **Feature:** NT-7 **River Mile:** 1.60 **Date:** 7/15/2016 **Time:** 13:18 **Image Name:** IMG_20160715_131812_ 1436285870.jpg **Coordinates:** 37.9159268, -120.245061 **Total Vertical Height:** 5ft **Description:** Looking upstream at leap feature at intermediate pool **Barrier:** Potential

	**Photo A-60** **Waterbody:** North Fork Tuolumne River **Feature:** NT-8 **River Mile:** 1.65 **Date:** 7/15/2016 **Time:** 13:14 **Image Name:** IMG_20160715_ 131401_1236056317.jpg **Coordinates:** 37.915501, -120.2449928 **Total Vertical Height:** N/A **Description:** Looking upstream at downstream extent of boulder field **Barrier:** Passable
	**Photo A-61** **Waterbody:** North Fork Tuolumne River **Feature:** NT-8 **River Mile:** 1.65 **Date:** 7/15/2016 **Time:** 13:03 **Image Name:** IMG_20160715_ 130252_48155320.jpg **Coordinates:** 37.9161552, -120.2449428 **Total Vertical Height:** N/A **Description:** Looking upstream at flow through boulder field **Barrier:** Passable
	**Photo A-62** **Waterbody:** North Fork Tuolumne River **Feature:** NT-9 **River Mile:** 1.69 **Date:** 7/15/2016 **Time:** 12:32 **Image Name:** IMG_20160715_ 123204_1836932897.jpg **Coordinates:** 37.9165518, -120.2446404 **Total Vertical Height:** 10 feet **Description:** Looking upstream at bedrock falls **Barrier:** Total Barrier