INITIAL STUDY REPORT

APPENDIX F

SALMONID HABITAT MAPPING TECHNICAL MEMORANDUM

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SALMONID HABITAT MAPPING TECHNICAL MEMORANDUM

LA GRANGE HYDROELECTRIC PROJECT FERC NO. 14581

Prepared for:
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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 upstream reservoirs: Hetch Hetchy, Lake Eleanor, 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.

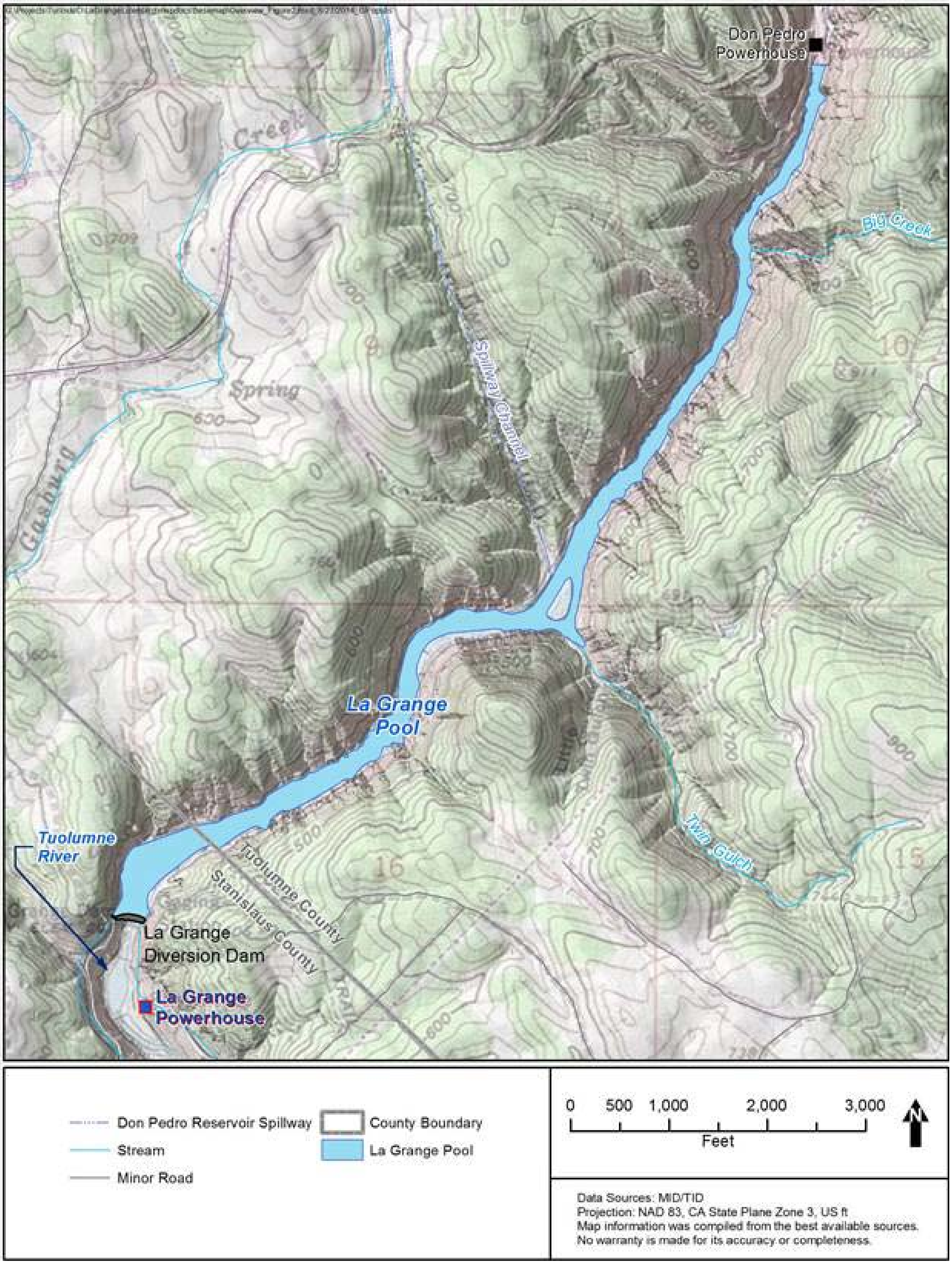

Figure 1.1-1. La Grange Hydroelectric Project location map.

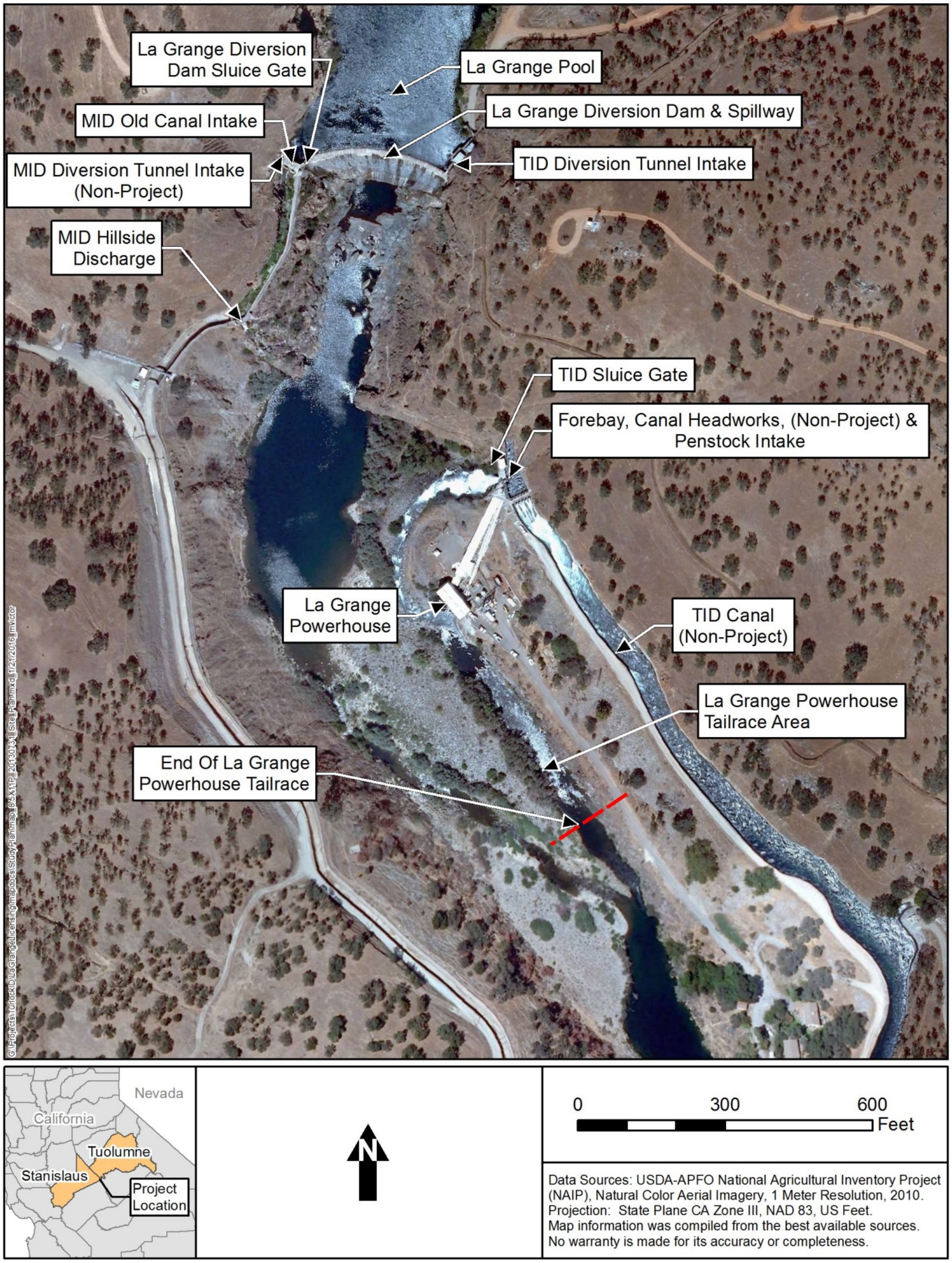

Figure 1.1-2. La Grange Hydroelectric Project site plan.

1.2 Licensing Process

On January 29, 2014, the Districts commenced the pre-filing process for the licensing of the La Grange Project by filing a Pre-Application Document (PAD) with FERC[1]. The Districts' PAD included descriptions of the Project facilities, operations, and lands as well as a summary of existing information available on Project area resources.

On September 5, 2014, the Districts filed their Proposed Study Plan (PSP) to assess Project effects on fish and aquatic resources, recreation, and cultural resources in support of their intent to license the Project. On October 6, 2014, the Districts held a PSP meeting at MID's offices in Modesto, California. Based on discussion at the PSP meeting, the Districts prepared an Updated Study Plan document that went to licensing participants (LP) for review and comment on November 21, 2014. On December 4, 2014, the National Marine Fisheries Service (NMFS), the Conservation Groups (CG), and the California Department of Fish and Wildlife (CDFW) filed comments on the PSP and/or Updated Study Plan.

On January 5, 2015, in response to comments from LPs, 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]. Comments on the RSP were received from CDFW on January 16, 2015, and from NMFS, the CGs and the City of Modesto on January 20, 2015.

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 NMFS in its July 22, 2014 comment letter. Of the eight studies requested by LPs, FERC approved only the NMFS study noted above.

Although FERC's SPD did not require the Districts to undertake the Upper Tuolumne River Basin Habitat Assessment studies contained in the RSP, the Districts are voluntarily conducting the Upper River Barriers Study and the Water Temperature Monitoring and Modeling Study. Regarding the third component of the Upper Tuolumne River Basin Habitat Assessment, the ongoing upstream habitat characterization work being completed by NMFS, the Districts anticipate the results of this work becoming available for consideration in this licensing proceeding.

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[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.

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 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 Project's powerhouse draft tubes and to determine the potential for injury or mortality from contact with the turbine runners. Per the SPD, the Districts developed a study plan in consultation with NMFS and other LPs. 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.

This technical memorandum describes the objectives, methods, and results of the Salmonid Habitat Mapping study, which is one of the four study components of the Fish Habitat and Stranding Assessment below La Grange Diversion Dam being implemented by the Districts in accordance with FERC's SPD. Documents relating to the Project licensing are publicly available on the Districts' licensing website at www.lagrange-licensing.com/.

1.3 Study Plan

FERC's Scoping Document 2 (SD2) issued on September 5, 2014 identified the potential for Project effects on anadromous fish spawning habitat downstream of the LGDD. According to the SD2, such effects might possibly result from the retention of sediment in the La Grange pool, or if changes in Project outflows alter downstream spawning habitat suitability and thereby impact spawning due to stranding or displacement of fish or redds in either the main channel, the tailrace channel, or the sluice gate channel.

FERC's SPD approved with modifications the Districts' proposed Fish Habitat and Stranding Assessment below La Grange Diversion Dam. In its SPD, FERC ordered the Districts to: (1) continue monitoring existing flow conduits where flow monitoring is already occurring, conduct two years of flow monitoring at flow conduits not currently monitored (i.e., the Modesto hillside discharge and LGDD sluice gate), develop estimates of historical flows, data permitting, for each of the five flow conduits at the Project, and, based on existing information, to the extent available, characterize the magnitude and rate of flow and stage changes when Project conduits are shut down; (2) collect topographic, depth, and habitat data downstream of, and in the vicinity of, the Project; (3) assess fish presence and the potential for stranding; and (4) in consultation with NMFS and other interested parties, develop and implement a plan for monitoring anadromous fish movement into the powerhouse draft tubes.

The Salmonid Habitat Mapping effort reported herein describes the work associated with Item (2) above. Other components related to this study directive, including topographic surveying of longitudinal channel profiles to assess water depth and potential stranding in the main channel, tailrace channel, and sluice gate channel are provided in a separate report entitled Topographic Survey Technical Memorandum (TID/MID 2016).

2.0 STUDY GOALS AND OBJECTIVES

The goal of this study is to collect information to aid in the evaluation of the potential for Project operations to affect anadromous fish habitat in the Tuolumne River in the vicinity of the LGDD and La Grange Project facilities. Specific objectives of the study include:

- Map substrate and habitat in the main channel and tailrace, delineating the presence of pools, runs, high- and low-gradient riffles, step-pools, and chutes.
- Map patches of spawning-sized gravels in the tailrace and main channel that are greater than two m^2.
- Conduct pebble counts in riffles, runs, and pool tailouts to document substrate particle size distribution in these habitats.

At the request of NMFS representatives during a May 5, 2015 telephone discussion of study implementation, data collection for this study element was expanded to provide complete gravel facies mapping of channel and bar features found within the study area and an expanded assessment of spawning gravel areas with an estimate of maximum potential spawning population sizes of Chinook salmon and *Oncorhynchus mykiss* (*O. mykiss*).

3.0 STUDY AREA

The study area included the main channel of the Tuolumne River from the base of the LGDD downstream to its confluence with the powerhouse tailrace channel near RM 51.8, the length of the tailrace channel, and the length of the TID sluice gate channel (see previous Figure 1.1-2). Gravel mapping included the large, exposed bar that separates the main channel from the tailrace channel along with associated bar features on the north side of the main channel near the confluence with the tailrace (RM 51.8).

4.0 METHODOLOGY

Habitat typing and gravel mapping were conducted on May 12, 2015. Flow measurements taken in the main channel (8.4 cfs) combined with the tailrace channel (165.5 cfs) closely reflected readings at the La Grange gage (USGS 11289650) located near RM 51.7, which recorded a discharge of 171 cfs. Methods implemented to characterize aquatic habitat and riverbed substrate in the study area are discussed below.

4.1 Habitat Typing

Habitat typing was based upon USFWS (2009) mesohabitat typing recommendations used in the *Instream Flow Incremental Methodology Study of the Lower Tuolumne River* (IFIM Study) implemented in accordance with the May 12, 2010 FERC Order (Stillwater Sciences 2013). Table 4.1-1 describes the mesohabitats used during the IFIM Study.

Table 4.1-1. Mesohabitat types used during the habitat typing surveys.

Channel form, Habitat Type	Description
Bar Complex	Submerged and emergent bars are the primary feature, sloping cross-sectional channel profile.
Flatwater	Primary channel is uniform, simple and without gravel bars or channel controls, fairly uniform depth across channel.
Pool	Primary determinant is downstream control - thalweg gets deeper going upstream from tail of pool. Fine and uniform substrate, below average water velocity, above average depth, tranquil water surface.
Glide	Primary determinants are no turbulence (surface smooth, slow and laminar) and no downstream control. Low gradient, substrate uniform across channel width and composed of small gravel and/or sand/silt, depth below average and similar across channel width (but depth not similar across channel width for Bar Complex Glide), below average water velocities, generally associated with tails of pools or heads of riffles, width of channel tends to spread out, thalweg has relatively uniform slope going downstream.
Run	Primary determinants are moderate turbulence and average depth. Moderate gradient, substrate a mix of particle sizes and composed of small cobble and gravel, with some large cobble and boulders, above average water velocities, usually slight gradient change from top to bottom, generally associated with downstream extent of riffles, thalweg has relatively uniform slope going downstream.
Riffle	Primary determinants are high gradient and turbulence. Below average depth, above average velocity, thalweg has relatively uniform slope going downstream, substrate of uniform size and composed of large gravel and/or cobble, change in gradient noticeable.

Habitat mapping was conducted by wading the channels using high resolution aerial imagery dated April 6, 2012 as a base map to record mesohabitat unit boundaries. Mesohabitat units were numbered consecutively extending from near the confluence of the main channel and tailrace channel (RM 51.8) upstream along the main channel to the LGDD, then back downstream from where the sluice gate channel enters the tailrace channel at the La Grange powerhouse to the confluence of the main channel and tailrace channel.

Field maps were then digitized into polygons corresponding to primary mesohabitats as well as any unique features present within the study area (e.g., step-pools which were not present in downstream habitats investigated as part of the IFIM Study).

4.2 Gravel Mapping

As noted in Section 2.0, data collection for this study element was expanded to include sediment-facies mapping throughout the study area. Gravel mapping activities were conducted in the field on May 17, 2015 by traversing the study area channels and gravel bars on foot using low-altitude aerial photographs of the study area to record distinct units of surface sediment mixtures on the field tiles at a scale of 1:2000 with a minimum recordable unit of approximately 100 ft^2. The facies mapping method used for this study was based on the methodology devised by Buffington and Montgomery (1999). The alluvial surface was classified according to the proportional occurrence of the five most prevalent substrate types: sand, gravel, cobble, boulder, and bedrock (see Table 4.2-1). The qualifying criterion for a substrate type to be included in a facies classification was a requirement that an individual substrate type represented $\geq$5 percent of all surface facies, or that the two sub-ordinate classes together represented $\geq$10 percent of all surface facies. Where the qualifying criterion was not met, the surface was classified according to the one or two most frequently observed substrate types, with the dominant substrate type being listed last. For example, the facies classification of "C" was applied if cobbles represented more than 95 percent of the material or "gC" if gravel represented at least 5 percent of the bed material and cobble represented the remaining bed material and no other substrate type represented more than 5 percent of the surface area.

Table 4.2-1. Particle size classes used for sediment facies mapping and pebble count measurements.

Size class	Grain size (mm)
Bedrock	>4,096
Boulder	
very coarse	2,048–4,096
coarse	1,024–2,048
medium	512–1,024
fine	256–512
Cobble	
coarse	128–256
fine	64–128
Gravel	
very coarse	32–64
coarse	16–32
medium	8–16
fine	4–8
very fine	2–4
Sand	0.0625–2

Source: Wentworth (1922).

Wolman (1954) pebble counts were conducted in selected areas using methods developed by Bunte and Abt (2001) to calibrate visual estimates of sediment facies and to chronicle the actual grain size distributions of individual facies. The intermediate (b) axis of 100 surface bed particles was measured at four locations in the study area (see Figure 4.2-1). The relative proportion of each grain-size class was calculated in the field to then guide the classification of facies units with the same visual characteristics. To provide an indication of gravel quality and suitability, an attempt was made where feasible to estimate grain size parameters (i.e., D_{84}, D_{50}, and D_{16}) for each sediment facies using methods employed in the *Spawning Gravel Study* (TID/MID 2013a) conducted as part of the Don Pedro Relicensing. Areas where grain size parameters could not be feasibly estimated included bedrock cascades and deep pools. All mapping and substrate measurements were conducted by the same field crew member to eliminate observer bias.

In the office, the sediment-facies mapping and pebble count data were compiled into an electronic database and transferred to a GIS format for graphical presentation. Sediment-facies maps with pebble-count sample locations were generated for the main channel, tailrace channel, and TID sluice gate channel. A map of the field-based polygons was produced using the April 6, 2012 aerial photography as a base map. The wetted perimeter captured in the imagery corresponds to a river discharge of approximately 320 cfs at the La Grange gage (USGS 11289650), with the majority of this flow contained within the La Grange powerhouse tailrace.

4.3 Spawning Habitat Suitability

Spawning habitat suitability was assessed using methods employed in the above-referenced *Spawning Gravel Study*. Suitable areas were delineated using binary habitat criteria for both water depth and water velocity previously developed as part of the IFIM Study (Stillwater Sciences 2013). Depth and velocity measurements were collected using a standard velocity meter (Marsh-McBirney Flo-Mate) and a top-set wading rod to delineate the areal extent of polygons hydraulically suitable for Chinook salmon and *O. mykiss* spawning over areas of suitable spawning gravel. Suitable gravel areas were determined for both Chinook salmon and *O. mykiss* based on the D_{50} size ranges of the mapped gravel areas. As described in Kondolf and Wollman (1993), a D_{50} size range between 16–78 millimeters (mm) was used to define suitable Chinook salmon spawning gravels and a D_{50} size range between 10–46 mm was used to define suitable *O. mykiss* spawning gravels.

Suitable spawning hydraulic conditions were defined as follows:

- Suitable depths ranging from 0.7–2.7 feet.
- Suitable velocity ranging from 1.0–3.1 feet per second (fps).

Based on spawning habitat suitability, the maximum spawning run size for the study area was estimated using methods described in Attachment D of the Spawning Gravel Study. This analysis uses the suitable spawning hydraulics data in combination with suitable substrate areas to derive a relationship between flow and spawning habitat area.

Areas of suitable spawning hydraulic conditions delineated over areas of suitable spawning gravels form the basis of the estimate. Suitable gravel areas were determined for both Chinook salmon and *O. mykiss* based on the D_{50} size ranges of the mapped gravel areas. As described in Kondolf and Wolman (1993), a D_{50} size range between 16–78 mm was used to define suitable

Chinook salmon spawning gravels and a D_{50} size range between 10–46 mm was used to define suitable *O. mykiss* spawning gravels. Because no suitable spawning substrates were identified in the main channel (Section 5.3), the estimate of total suitable spawning area in the reach was based on mapping of suitable substrates in the tailrace channel at a flow of 175 cfs. Beginning with the suitable spawning gravel areas digitized within the 320 cfs wetted perimeter, the following steps were applied from the *Spawning Gravel Study* (TID/MID 2013a) to estimate spawning habitat availability at any other flow "Y" in the range examined by the IFIM Study (Stillwater Sciences 2013)(100–1,000 cfs).

Step 1. Delineate in GIS the total suitable spawning gravel area in wetted riffle habitats of at 320 cfs = A_{320} ft^2

Step 2. Using PHABSIM results from the IFIM Study (Stillwater Sciences 2013) the proportion of spawning WUA at flow 'Y' cfs to spawning WUA at 320 cfs in riffle habitats is P_Y = (spawning WUA at flow 'Y')/(spawning WUA at 320 cfs)

Step 3. Total suitable spawning habitat in wetted riffle habitats at flow Y is the product of the Step 1 area and Step 2 proportions, $A_Y = P_Y \times A_{320}$ ft^2.

Using the approach described above, total suitable spawning area for Chinook salmon and *O. mykiss* will be used as a basis for estimating maximum spawning run size over a range of simulated flows by simply dividing the total spawning area available by the average redd size for each species.

Estimated maximum potential spawning population size for a specific flow was computed by dividing the total suitable spawning area (i.e., area with suitable substrate, depth, and velocity) by an estimate of the disturbed gravel area (i.e., the area of egg deposition) within completed redds for each species, and multiplying by a factor of two fish per redd. For Chinook salmon redds, an area estimate of 52 ft^2 (4.8 m^2) was calculated from detailed measurements (n=354) collected in 1988–1989 (TID/MID 1992, Appendix 6). A comparable estimate was made from Chinook salmon redd data collected in the fall of 2012 in the *Redd Mapping Study* for the Don Pedro Project Relicensing (TID/MID 2013b) using an average redd area of 43.1 ft^2 (4.0 m^2) for Chinook salmon based on redd measurements (n=286) in fall of 2012. Corresponding redd size estimates for *O. mykiss* were based on an average disturbed redd area of 3.1 ft^2 (0.3 m^2) calculated using measurements (n=36 redds) collected in spring 2013 as part of the *Redd Mapping Study*.

5.0 RESULTS

5.1 Habitat Typing

Habitat mapping results from the May 17, 2015 survey are shown in Figure 5.1-1 and summarized in Table 5.1-1. The main channel in the study area is dominated by pool habitat, including a plunge pool immediately downstream of the LGDD, a large mid-channel pool adjacent to the MID hillside discharge, and two smaller pools in the lower portion of the channel. There are a total of three small low-gradient riffles with no spawnable substrate in the lower portion of the main channel, along with one glide associated with the tailout of the large pool, and a bedrock outcrop separating the large pool from the plunge pool. The estimated average channel width downstream of the large mid-channel pool is approximately 35 feet, while the mid-channel pool width is estimated to be approximately 176 feet. Correspondingly, the aerial extent of the mid-channel pool was calculated as 134,483 ft^2, representing 74 percent of the total area comprising the main channel habitats. Depths of the habitats found in the main channel were generally described as being from 1–4 feet, with the mid-channel pool and plunge pool depths estimated as >10 feet. More precise depths of pool habitat can be derived from longitudinal channel profiles described in the Topographic Survey Technical Memorandum.

The tailrace channel includes two riffles, one of which include spawnable substrate, along with one run habitat in the lower portion of the channel (Figure 5.1-1). The upper portion of the tailrace channel includes a single pool with turbulent flow from the La Grange powerhouse discharge along with a glide associated with the tailout of this pool. Estimated average width of habitats in the tailrace channel is approximately 50 feet. The TID sluice gate channel is a high-gradient step-pool that originates at the TID canal (a non-Project feature) and empties into the pool at the upstream portion of the tailrace channel. Estimated average width of the sluice gate channel is approximately 30 feet.

Table 5.1-1. Summary of mesohabitat mapping results.

Main Channel			
Mesohabitat	**Total Number**	**Total Length (ft)**	**Percent of Channel**
Riffle	3	523	30%
Glide	1	122	7%
Pool	4	1,022	58%
Outcrop, bedrock	1	106	6%
Total	**9**	**1,773**	**100%**
Tailrace Channel			
Riffle	2	400	57%
Glide	1	49	7%
Pool	1	152	22%
Run	1	98	14%
Total	**5**	**699**	**100%**
Sluice Gate Channel			
Step-pool	1	383	100%
Total	**1**	**383**	**100%**

Figure 5.1-1. Habitat types downstream of La Grange Diversion Dam.

5.2 Gravel Mapping

Sediment–facies mapping results from the May 17, 2015 field survey are summarized in Tables 5.2-1 and 5.2-2, and shown in Figure 5.2-1. The pebble count data from the four samples collected in select facies units—PC1 in unit 2, PC2 in unit 5, PC3 in unit 6, PC4 in unit 10—are summarized in Table 5.2-3 and plotted in Figure 5.2-2. Overall, the study area was mapped predominately as gravel-boulder-Cobble (41 percent), sand-bedrock-Cobble (30 percent), and boulder-gravel-Cobble (11 percent) (see Table 5.2-2).

The sluice gate and tailrace channels, as mapped with facies units 1 through 7, are predominately cobble-bedded with varying proportions of gravel- and boulder-size substrates, along with some bedrock outcrops in the sluice gate channel. The three pebble-count samples collected here exhibited a well-graded (poorly sorted) texture, with measurable sizes varying between sand (~2 mm) and bedrock (>4,096 mm). The results also support the observation of a downstream-fining trend along the channels' total length. Substrates in the sluice gate channel (facies units 1 and 2) are the coarsest in the study area, being composed of cobbles, boulders, and bedrock with some coarse gravel. The La Grange powerhouse tailrace channel (facies units 4 through 7) is composed of cobble with varying proportions of gravel- and boulder-size substrates. A minor fraction of sand was observed in the lower-most facies unit of the tailrace channel (at sample PC3).

The thalweg of the Tuolumne River main channel, as mapped with facies units 10, 11, 13, 14, 17, 18, 20, 22, 24, and 25, is also predominately composed of cobble-sized sediments, with varying proportions of gravel- and boulder-size substrates, and some bedrock outcrops. The pebble-count sample collected along the thalweg near the confluence with the tailrace channel (in facies unit 10) exhibited a well-graded (poorly sorted) texture, with measurable sizes varying between fine gravel (~7 mm) and fine boulder (460 mm). Particle sizes did not appear to be correlated with longitudinal direction along the Tuolumne River main channel, as was observed and measured along the TID sluice gate and tailrace channels. The substrates within the large and deep pool unit downstream of LGDD, mapped as facies unit 22, appeared to be very well graded (i.e., very poorly sorted), with sizes ranging from sand (~2 mm) to bedrock (>4,096 mm).

The medial and lateral floodplain areas, as mapped with facies units 8, 12, 19, and 23, are composed of a mixture of sediment facies types similar to that present in the tailrace and main river channel.

Table 5.2-1. Summary of sediment-facies mapping results.

Sediment facies [1]		Channel / feature	Corresponding mesohabitat [2]	Area (ft^2)	Grain size fractions (mm) [3]		
Unit no.	**Type**				D_{84}	D_{50}	D_{16}
1	cobble-boulder-Bedrock (cbBr)	Sluice gate channel	Step-pool (unit 11)	8,813	N/A	N/A	N/A
2	gravel-boulder Cobble (gbC)	Sluice gate channel	Step-pool (unit 11)	8,598	320	180	90
3	gravel-cobble-Boulder (gcB)	Sluice gate levee	N/A	17,603	800	400	200
4	boulder-gravel-Cobble (bgC)	Tailrace channel	Pool (unit 12)	9,624	300	110	50
5	boulder-gravel-Cobble (bgC)	Tailrace channel	Glide, Riffle, Run (units 13, 14, 15)	14,573	200	110	50
6	boulder-gravel-Cobble (bgC)	Tailrace channel	Riffle (unit 16)	11,606	150	70	23
7	gravel-boulder-Cobble (gbC)	Tailrace channel	Riffle (unit 16)	2,039	250	150	50
8	boulder-gravel-Cobble (bgC)	River medial floodplain	N/A	2,583	150	70	25
9	unknown	River channel	Riffle and Pool (unit 1)	69,714	N/A	N/A	N/A
10	gravel-boulder-Cobble (gbC)	River channel	Riffle (units 1 and 2)	6,356	240	160	80
11	gravel-boulder-Cobble (gbC)	River channel	Riffle (unit 2)	5,932	240	170	90
12	gravel-boulder-Cobble (gbC)	River lateral floodplain	N/A	54,173	300	200	80
13	gravel-boulder-Cobble (gbC)	River channel	Riffle (unit 2)	4,061	300	150	50
14	gravel-cobble-Boulder (gcB)	River channel	Pool (unit 3)	5,337	800	500	200
15	bedrock-cobble-Boulder (brcB)	River lateral floodplain (talus slope)	N/A	8,662	N/A	N/A	N/A
16	Bedrock (Br)	River lateral floodplain (outcrop)	N/A	2,645	N/A	N/A	N/A
17	gravel-boulder-Cobble (gbC)	River channel	Riffle (unit 4)	2,628	300	200	80
18	bedrock-gravel-Cobble (brgC)	River channel	Pool (unit 5)	1,258	N/A	N/A	N/A
19	gravel-boulder-Cobble (gbC)	River medial floodplain	N/A	103,572	300	200	100
20	boulder-gravel-Cobble (bgC)	River channel	Riffle and Glide (units 6 and 7)	11,176	250	100	50

Sediment facies [1]		Channel / feature	Corresponding mesohabitat [2]	Area (ft^2)	Grain size fractions (mm) [3]		
Unit no.	Type				D_{84}	D_{50}	D_{16}
21	gravel-cobble-Boulder (gcB)	River lateral floodplain (talus slope)	N/A	6,911	800	500	200
22	sand-bedrock-Cobble (sbrC)	River channel	Pool (unit 8)	137,118	N/A	N/A	N/A
23	boulder-cobble-Gravel (bcG)	River lateral floodplain	N/A	20,822	200	50	20
24	gravel-boulder-Bedrock (gbBr)	River channel	Outcrop (unit 9)	7,919	N/A	N/A	N/A
25	Bedrock (Br)		Pool (unit 10)	6,648	N/A	N/A	N/A

[1] See Figure 5.2-1 for location of sediment facies units.
[2] See Figure 5.1-1 for location of mesohabitat units.
[3] Size fractions: D_{84} and D_{16} represent the grain sizes for which 84 percent and 16 percent of the distribution is finer, respectively; D_{50} represents the median grain size.

Table 5.2-2. Summary of sediment-facies mapping results.

Sediment facies type [1]	Area (ft^2)	Percent of mapped Area
boulder-cobble-Gravel (bcG)	20,822	5%
boulder-gravel-Cobble (bgC)	49,562	11%
bedrock-gravel-Cobble (brgC)	1,258	0%
gravel-boulder Cobble (gbC)	187,359	41%
sand-bedrock-Cobble (sbrC)	137,118	30%
gravel-cobble-Boulder (gcB)	29,851	6%
bedrock-cobble-Boulder (brcB)	8,662	2%
gravel-boulder-Bedrock (gbBr)	7,919	2%
cobble-boulder-Bedrock (cbBr)	8,813	2%
bedrock (Br)	9,293	2%

[1] List order based on smallest to largest sediment/bedrock sizes; does not include “unknown” facies type from Unit No. 9.

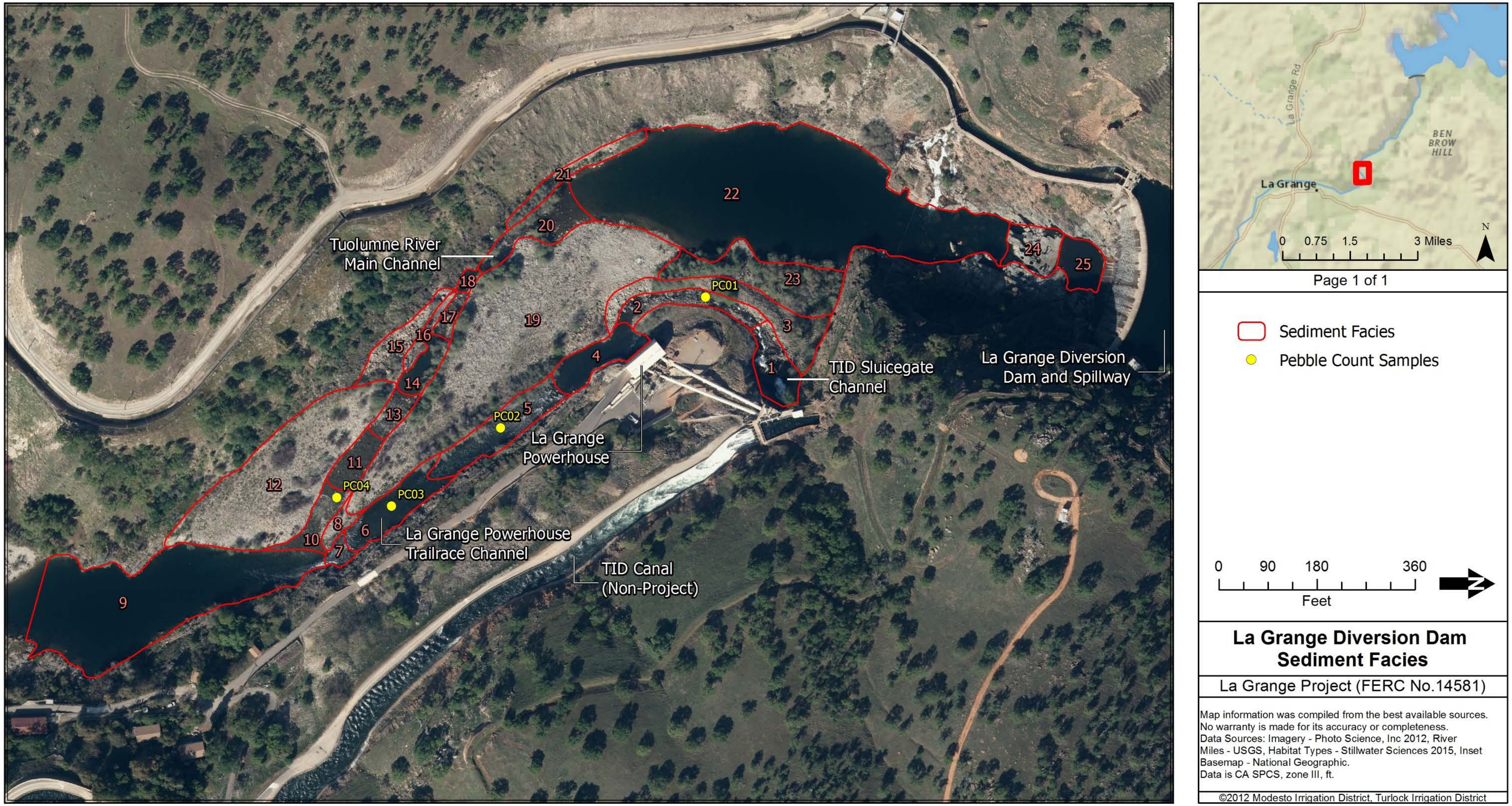

Figure 5.2-1. Sediment facies mapped downstream of La Grange Diversion Dam.

Table 5.2-3. Summary of pebble-count measurement results.

Pebble count sample [1]	Sediment facies unit no.	Grain size fractions (mm) [1]				Degree of bed sorting[2]
		D_{84}	D_{50}	D_{16}	D_G	
PC1	2	320	180	90	176	2.2
PC2	5	200	110	50	101	1.9
PC3	6	150	70	23	53	3.1
PC4	10	240	160	80	126	2.0

[1] Size fractions: D84 and D16 represent the grain sizes for which 84 percent and 16 percent of the distribution is finer, respectively; D50 represents the median grain size; DG represents the geometric mean of the distribution.

[2] Bed sorting describes the measure of non-uniformity of sediment mixtures (i.e., high values indicate well-graded [poorly sorted] conditions) and is computed as the geometric standard deviation: σG=(D84/D16)0.5 (Julien 2002).

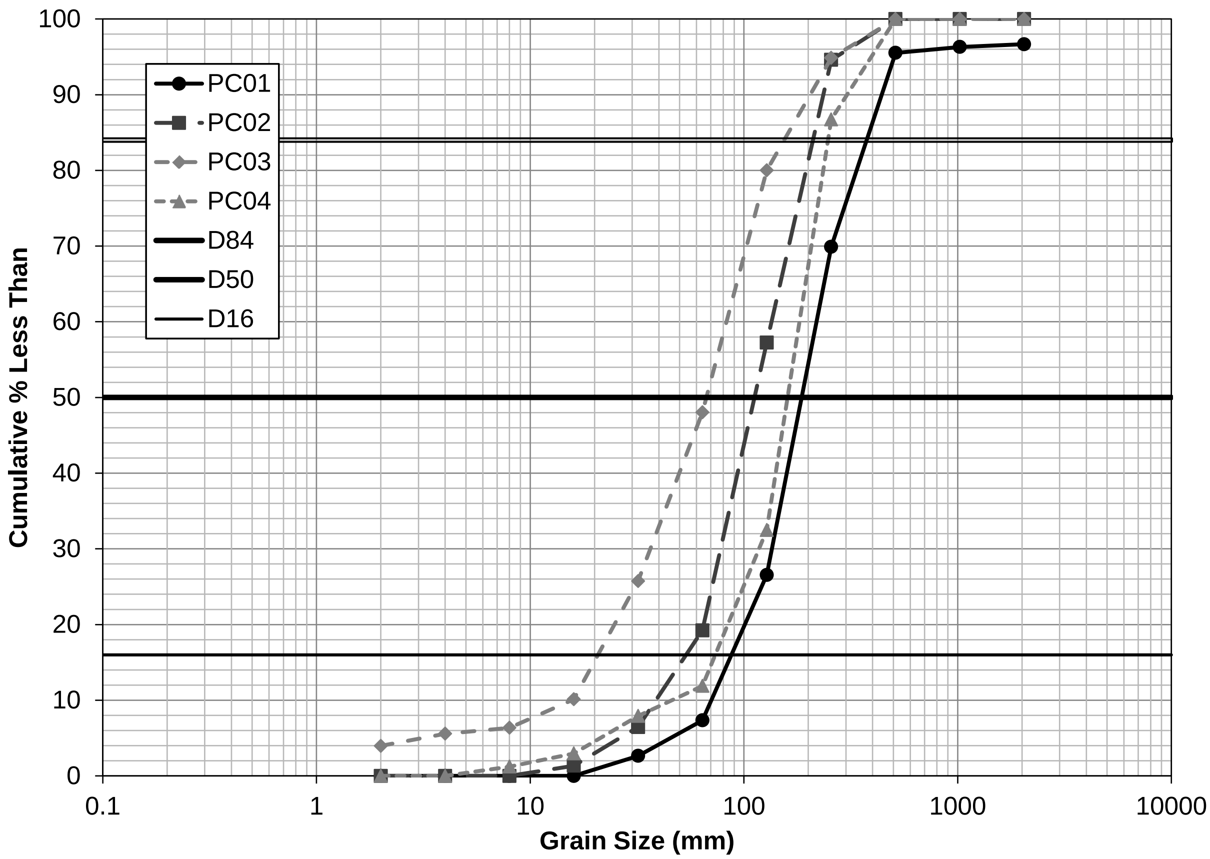

Figure 5.2-2. Particle-size distributions from the pebble-count samples collected in the study area.

5.3 Spawning Habitat Suitability

Only one of the two spawning gravel patches (facies unit 6, riffle habitat unit 16) mapped in the La Grange powerhouse tailrace channel was suitable for Chinook salmon spawning based on a pebble count D50 of 70 mm (Table 5.2-1 and Figure 5.2-1). The D_{50} of 112 mm, based on a pebble count within the other spawning gravel patch (facies unit 5, riffle habitat unit 14), exceeded the suitable range for Chinook (16–78 mm). Neither of the tailrace spawning gravel patches had suitable substrate for *O. mykiss* spawning, based on D_{50} values that exceeded the suitable range for *O. mykiss* (10–46 mm). In addition to falling outside the suitable substrate range; run habitat (unit 15) and pool habitat (unit 12) located in the La Grange powerhouse tailrace exceeded the depth criteria across the center of the channel with velocity measurements below the minimum criteria along the margins, while riffle habitat (unit 14) and glide habitat (unit 13) exceeded velocity criteria across the channel, with depths along the margin below the minimum criteria.

For Chinook salmon, the total area of suitable spawning gravel within the tailrace channel was estimated to be 13,610 ft^2. Of that area, a total of 9,014 ft^2 was estimated to meet the spawning depth and velocity criteria at approximately 175 cfs (Table 5.3-1). There was no suitable spawning gravel found in the Tuolumne River main channel or TID sluice gate channel, and no suitable spawning substrate found for *O. mykiss* at any location within the study area.

Table 5.3-1. Estimated suitable spawning area and maximum Chinook salmon population size in the tailrace channel.

FERC (1996) spawning flow requirement (cfs)	FERC (1996) Water Year type(s)	Suitable spawning area (ft^2)	Estimated maximum potential Chinook spawning population size[3]	
			1988-1989 redd size data[1]	2012 redd size data[2]
150	Critical and below through Median Dry	8,540	328	396
175	Median Below Normal	9,014	346	418
180	Intermediate Dry-Below Normal	9,086	350	422
300	Intermediate Below Normal-Above Normal through Median Wet/Maximum	8,839	340	410

[1] Based on average Tuolumne River Chinook salmon disturbed redd area of 52 ft^2 (4.8 m^2) (TID/MID 1992, Appendix 6).
[2] Based on average Tuolumne River Chinook salmon disturbed redd area of 43.1 ft^2 (4.0 m^2) from the *Redd Mapping Study* (TID/MID 2013b).
[3] Population size is a theoretical maximum based solely on spawning area divided by redd size.

The suitable spawning habitat area for Chinook salmon was extrapolated to current spawning flow requirements (October 16 – May 31) of the Don Pedro Project (FERC 1996) to estimate the maximum potential Chinook salmon spawning population sizes (Table 5.3-1). Maximum population sizes for Chinook salmon would range from approximately 328–422, dependent on redd size estimates. These maximum potential spawning population size estimates are based on the average redd size estimates from the Tuolumne River (Section 4.5) and do not take into account factors related to actual spawning site selection (i.e., non-uniform habitat selection at the site-scale) or superimposition of redds constructed by later arriving spawners upon previously constructed redds.

6.0 STUDY VARIANCES AND MODIFICATIONS

At the request of NMFS representatives during a May 5, 2015 telephone discussion of study implementation, the study was expanded to provide: (1) complete gravel facies mapping of channel and bar features found within the study area; and (2) an expanded assessment of spawning gravel areas with an estimate of maximum potential spawning population sizes of Chinook salmon and *O. mykiss*. Aside from these two additional objectives, there were no other variances or modifications to the study.

7.0 REFERENCES

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