ONCORHYNCHUS MYKISS
HABITAT SURVEY
STUDY REPORT
DON PEDRO PROJECT
FERC NO. 2299



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MID
Modesto Irrigation District

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

Prepared by:
Stillwater Sciences

January 2013

Oncorhynchus mykiss Habitat Survey Study
Study Report

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List of Acronyms

ac................................acres
ACEC.........................Area of Critical Environmental Concern
AF ....acre-feet
ACOE.........................U.S. Army Corps of Engineers
ADA...........................Americans with Disabilities Act
ALJ.............................Administrative Law Judge
APE............................Area of Potential Effect
ARMR........................Archaeological Resource Management Report
BA..............................Biological Assessment
BDCP ....Bay-Delta Conservation Plan
BLM...........................U.S. Department of the Interior, Bureau of Land Management
BLM-S ....Bureau of Land Management – Sensitive Species
BMI............................Benthic macroinvertebrates
BMP ....Best Management Practices
BO..............................Biological Opinion
CalEPPC ....California Exotic Pest Plant Council
CalSPA.......................California Sports Fisherman Association
CAS............................California Academy of Sciences
CCC............................Criterion Continuous Concentrations
CCIC ....Central California Information Center
CCSF..........................City and County of San Francisco
CCVHJV....................California Central Valley Habitat Joint Venture
CD..............................Compact Disc
CDBW........................California Department of Boating and Waterways
CDEC.........................California Data Exchange Center
CDFA.........................California Department of Food and Agriculture
CDFG.........................California Department of Fish and Game (as of January 2013, Department of Fish and Wildlife)
CDMG........................California Division of Mines and Geology
CDOF.........................California Department of Finance
CDPH.........................California Department of Public Health

CDPR.........................California Department of Parks and Recreation
CDSOD......................California Division of Safety of Dams
CDWR........................California Department of Water Resources
CE ....California Endangered Species
CEII............................Critical Energy Infrastructure Information
CEQA.........................California Environmental Quality Act
CESA ....California Endangered Species Act
CFR............................Code of Federal Regulations
cfs...............................cubic feet per second
CGS............................California Geological Survey
CMAP ....California Monitoring and Assessment Program
CMC...........................Criterion Maximum Concentrations
CNDDB......................California Natural Diversity Database
CNPS..........................California Native Plant Society
CORP ....California Outdoor Recreation Plan
CPUE ....Catch Per Unit Effort
CRAM........................California Rapid Assessment Method
CRLF..........................California Red-Legged Frog
CRRF ....California Rivers Restoration Fund
CSAS..........................Central Sierra Audubon Society
CSBP..........................California Stream Bioassessment Procedure
CT ....California Threatened Species
CTR............................California Toxics Rule
CTS ....California Tiger Salamander
CVRWQCB ....Central Valley Regional Water Quality Control Board
CWA ....Clean Water Act
CWHR........................California Wildlife Habitat Relationship
Districts......................Turlock Irrigation District and Modesto Irrigation District
DLA ....Draft License Application
DPRA.........................Don Pedro Recreation Agency
DPS ....Distinct Population Segment
EA ....Environmental Assessment
EC ....Electrical Conductivity

EFH............................Essential Fish Habitat
EIR.............................Environmental Impact Report
EIS..............................Environmental Impact Statement
EPA............................U.S. Environmental Protection Agency
ESA............................Federal Endangered Species Act
ESRCD.......................East Stanislaus Resource Conservation District
ESU............................Evolutionary Significant Unit
EWUA........................Effective Weighted Useable Area
FERC..........................Federal Energy Regulatory Commission
FFS.............................Foothills Fault System
FL...............................Fork length
FMU...........................Fire Management Unit
FOT............................Friends of the Tuolumne
FPC............................Federal Power Commission
ft/mi............................feet per mile
ft/s..............................feet per second
FWCA........................Fish and Wildlife Coordination Act
FYLF..........................Foothill Yellow-Legged Frog
g..................................grams
GIS.............................Geographic Information System
GLO...........................General Land Office
GPS............................Global Positioning System
HCP............................Habitat Conservation Plan
HHWP........................Hetch Hetchy Water and Power
HORB........................Head of Old River Barrier
HPMP.........................Historic Properties Management Plan
ILP..............................Integrated Licensing Process
ISR.............................Initial Study Report
ITA.............................Indian Trust Assets
kV...............................kilovolt
LWD..........................large woody debris
m................................meters
M&I............................Municipal and Industrial

MCL............................Maximum Contaminant Level
mg/kg ....milligrams/kilogram
mg/L...........................milligrams per liter
mgd ....million gallons per day
mi ....miles
mi^2 ....square miles
MID............................Modesto Irrigation District
MOU ....Memorandum of Understanding
MSCS.........................Multi-Species Conservation Strategy
msl..............................mean sea level
MVA ....Megavolt Ampere
MW ....megawatt
MWh ....megawatt hour
mya.............................million years ago
NAE ....National Academy of Engineering
NAHC ....Native American Heritage Commission
NAS............................National Academy of Sciences
NAVD 88...................North American Vertical Datum of 1988
NAWQA ....National Water Quality Assessment
NCCP.........................Natural Community Conservation Plan
NEPA ....National Environmental Policy Act
ng/g ....nanograms per gram
NGOs ....Non-Governmental Organizations
NHI ....Natural Heritage Institute
NHPA.........................National Historic Preservation Act
NISC ....National Invasive Species Council
NMFS.........................National Marine Fisheries Service
NOAA ....National Oceanic and Atmospheric Administration
NOI ....Notice of Intent
NPS ............................U.S. Department of the Interior, National Park Service
NRCS ....National Resource Conservation Service
NRHP.........................National Register of Historic Places
NRI.............................Nationwide Rivers Inventory

NTU ....Nephelometric Turbidity Unit
NWI.............................National Wetland Inventory
NWIS ....National Water Information System
NWR ....National Wildlife Refuge
NGVD 29 ....National Geodetic Vertical Datum of 1929
O&M ....operation and maintenance
OEHHA.......................Office of Environmental Health Hazard Assessment
ORV ....Outstanding Remarkable Value
PAD.............................Pre-Application Document
PDO.............................Pacific Decadal Oscillation
PEIR ....Program Environmental Impact Report
PGA.............................Peak Ground Acceleration
PHG.............................Public Health Goal
PM&E ....Protection, Mitigation and Enhancement
PMF.............................Probable Maximum Flood
POAOR ....Public Opinions and Attitudes in Outdoor Recreation
ppb...............................parts per billion
ppm ....parts per million
PSP ....Proposed Study Plan
QA ....Quality Assurance
QC ....Quality Control
RA ....Recreation Area
RBP ....Rapid Bioassessment Protocol
Reclamation ................U.S. Department of the Interior, Bureau of Reclamation
RM ....River Mile
RMP ....Resource Management Plan
RP................................Relicensing Participant
RSP ....Revised Study Plan
RST ....Rotary Screw Trap
RWF ....Resource-Specific Work Groups
RWG ....Resource Work Group
RWQCB......................Regional Water Quality Control Board
SC................................State candidate for listing under CESA

SCD............................State candidate for delisting under CESA

SCE............................State candidate for listing as endangered under CESA

SCT............................State candidate for listing as threatened under CESA

SD1............................Scoping Document 1

SD2............................Scoping Document 2

SE...............................State Endangered Species under the CESA

SFP.............................State Fully Protected Species under CESA

SFPUC.......................San Francisco Public Utilities Commission

SHPO.........................State Historic Preservation Office

SJRA..........................San Joaquin River Agreement

SJRGA.......................San Joaquin River Group Authority

SJTA..........................San Joaquin River Tributaries Authority

SPD............................Study Plan Determination

SRA............................State Recreation Area

SRMA........................Special Recreation Management Area or Sierra Resource Management Area (as per use)

SRMP.........................Sierra Resource Management Plan

SRP............................Special Run Pools

SSC............................State species of special concern

ST...............................California Threatened Species under the CESA

STORET....................Storage and Retrieval

SWAMP.....................Surface Water Ambient Monitoring Program

SWE...........................Snow-Water Equivalent

SWRCB......................State Water Resources Control Board

TAC............................Technical Advisory Committee

TAF............................thousand acre-feet

TCP............................Traditional Cultural Properties

TDS............................Total Dissolved Solids

TID.............................Turlock Irrigation District

TMDL........................Total Maximum Daily Load

TOC............................Total Organic Carbon

TRT............................Tuolumne River Trust

TRTAC......................Tuolumne River Technical Advisory Committee

UC..............................University of California
USDA.........................U.S. Department of Agriculture
USDOC......................U.S. Department of Commerce
USDOI .......................U.S. Department of the Interior
USFS..........................U.S. Department of Agriculture, Forest Service
USFWS ......................U.S. Department of the Interior, Fish and Wildlife Service
USGS .........................U.S. Department of the Interior, Geological Survey
USR............................Updated Study Report
UTM...........................Universal Transverse Mercator
VAMP........................Vernalis Adaptive Management Plan
VELB.........................Valley Elderberry Longhorn Beetle
VRM ....Visual Resource Management
WPT...........................Western Pond Turtle
WSA...........................Wilderness Study Area
WSIP..........................Water System Improvement Program
WWTP ....Wastewater Treatment Plant
WY.............................water year
µS/cm ....microSeimens per centimeter

1.0 INTRODUCTION

1.1 General Description of the Don Pedro Project

Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) are the co-licensees of the 168-megawatt (MW) Don Pedro Project (Project) located on the Tuolumne River in western Tuolumne County in the Central Valley region of California. The Don Pedro Dam is located at river mile (RM) 54.8 and the Don Pedro Reservoir formed by the dam extends 24-miles upstream at the normal maximum water surface elevation of 830 ft above mean sea level (msl; NGVD 29). At elevation 830 ft, the reservoir stores over 2,000,000 acre-feet (AF) of water and has a surface area slightly less than 13,000 acres (ac). The watershed above Don Pedro Dam is approximately 1,533 square miles (mi^2).

Both TID and MID are local public agencies authorized under the laws of the State of California to provide water supply for irrigation and municipal and industrial (M&I) uses and to provide retail electric service. The Project serves many purposes including providing water storage for the beneficial use of irrigation of over 200,000 ac of prime Central Valley farmland and for the use of M&I customers in the City of Modesto (population 210,000). Consistent with the requirements of the Raker Act passed by Congress in 1913 and agreements between the Districts and City and County of San Francisco (CCSF), the Project reservoir also includes a "water bank" of up to 570,000 AF of storage. CCSF may use the water bank to more efficiently manage the water supply from its Hetch Hetchy water system while meeting the senior water rights of the Districts. CCSF's "water bank" within Don Pedro Reservoir provides significant benefits for its 2.6 million customers in the San Francisco Bay Area.

The Project also provides storage for flood management purposes in the Tuolumne and San Joaquin rivers in coordination with the U.S. Army Corps of Engineers (ACOE). Other important uses supported by the Project are recreation, protection of the anadromous fisheries in the lower Tuolumne River, and hydropower generation.

The Project Boundary extends from approximately one mile downstream of the dam to approximately RM 79 upstream of the dam. Upstream of the dam, the Project Boundary runs generally along the 855 ft contour interval which corresponds to the top of the Don Pedro Dam. The Project Boundary encompasses approximately 18,370 ac with 78 percent of the lands owned jointly by the Districts and the remaining 22 percent (approximately 4,000 ac) is owned by the United States and managed as a part of the U.S. Bureau of Land Management (BLM) Sierra Resource Management Area.

The primary Project facilities include the 580-foot-high Don Pedro Dam and Reservoir completed in 1971; a four-unit powerhouse situated at the base of the dam; related facilities including the Project spillway, outlet works, and switchyard; four dikes (Gasburg Creek Dike and Dikes A, B, and C); and three developed recreational facilities (Fleming Meadows, Blue Oaks, and Moccasin Point Recreation Areas). The location of the Project and its primary facilities is shown in Figure 1.1-1.

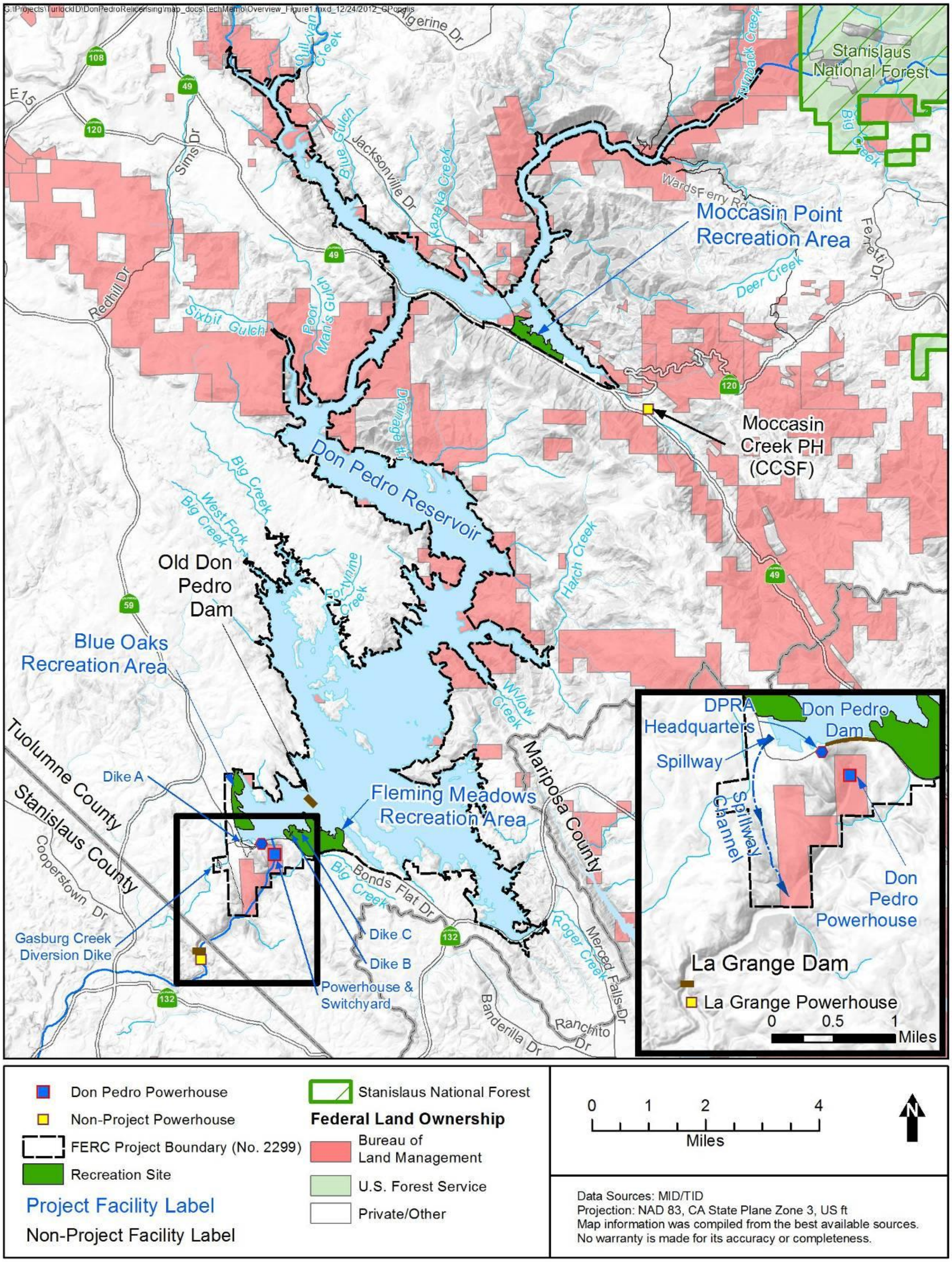

Figure 1.1-1. Don Pedro Project location.

1.2 Relicensing Process

The current FERC license for the Project expires on April 30, 2016, and the Districts will apply for a new license no later than April 30, 2014. The Districts began the relicensing process by filing a Notice of Intent and Pre-Application Document (PAD) with FERC on February 10, 2011, following the regulations governing the Integrated Licensing Process (ILP). The Districts' PAD included descriptions of the Project facilities, operations, license requirements, and Project lands as well as a summary of the extensive existing information available on Project area resources. The PAD also included ten draft study plans describing a subset of the Districts' proposed relicensing studies. The Districts then convened a series of Resource Work Group meetings, engaging agencies and other relicensing participants in a collaborative study plan development process culminating in the Districts' Proposed Study Plan (PSP) and Revised Study Plan (RSP) filings to FERC on July 25, 2011 and November 22, 2011, respectively.

On December 22, 2011, FERC issued its Study Plan Determination (SPD) for the Project, approving, or approving with modifications, 34 studies proposed in the RSP that addressed Cultural and Historical Resources, Recreational Resources, Terrestrial Resources, and Water and Aquatic Resources. In addition, as required by the SPD, the Districts filed three new study plans (W&AR-18, W&AR-19, and W&AR-20) on February 28, 2012 and one modified study plan (W&AR-12) on April 6, 2012. Prior to filing these plans with FERC, the Districts consulted with relicensing participants on drafts of the plans. FERC approved or approved with modifications these four studies on July 25, 2012.

Following the SPD, a total of seven studies (and associated study elements) that were either not adopted in the SPD, or were adopted with modifications, formed the basis of Study Dispute proceedings. In accordance with the ILP, FERC convened a Dispute Resolution Panel on April 17, 2012 and the Panel issued its findings on May 4, 2012. On May 24, 2012, the Director of FERC issued his Formal Study Dispute Determination, with additional clarifications related to the Formal Study Dispute Determination issued on August 17, 2012.

This study report describes the objectives, methods, and results of the *Oncorhynchus mykiss* Habitat Survey Study (W&AR-12) as implemented by the Districts in accordance with FERC's SPD and subsequent study modifications and clarifications. Documents relating to the Project relicensing are publicly available on the Districts' relicensing website at www.donpedro-relicensing.com.

1.3 Study Plan

FERC's *Scoping Document 2* anticipated that the continued operation and maintenance (O&M) of the Project may contribute to cumulative effects on salmonid fish habitat in the Tuolumne River downstream of La Grange Dam. More specifically, FERC listed potential effects of Project-related changes in the recruitment and movement of large woody debris (LWD) on aquatic resources and their habitat as one of the scoping issues that needed to be addressed.

To address these concerns, the Districts filed the *O. mykiss* Habitat Study Plan in the RSP filing.

The study plan proposed to conduct: 1) an inventory of instream habitat types and physical habitat characteristics, and 2) a detailed LWD inventory downstream of La Grange Dam. In addition, as recommended by FERC Staff in the December 22, 2011 SPD, an evaluation of the frequency and volume of LWD trapped and removed from Don Pedro reservoir on an annual basis was proposed. The Districts provided a revised study plan to agencies for comment, and submitted the revised study plan per SPD on April 9, 2012.

FERC's SPD of July 25, 2012 approved with modifications the revised *O. mykiss* Habitat Study Plan. In this SPD, FERC ordered that the Districts produce an estimate of the average annual volume and frequency of LWD removed from Don Pedro Reservoir using quantitative and anecdotal historical data, including appropriate aerial photography analysis methods such as those described by NMFS in its April 24, 2012 comment letter. FERC also required two annual quantitative surveys of LWD in Don Pedro Reservoir to be conducted upon the cessation of seasonal high flow events. FERC also ordered the development of a basic LWD budget that compares the average annual volume and frequency of LWD removed at Don Pedro Reservoir with the average annual volume and frequency of LWD stored in the lower Tuolumne River.

2.0 STUDY GOALS AND OBJECTIVES

The primary goal of this study is to provide information on habitat distribution, abundance, and quality in the lower Tuolumne River with a focus on *O. mykiss* habitat related to LWD. An inventory of LWD and associated habitat quality, availability, and use by salmonids will inform the evaluation of in-river factors that may cumulatively affect the juvenile *O. mykiss* life stage**.** In addition, this study provides an estimate of the quantities of LWD entering Don Pedro Reservoir on an annual basis, based on the quantity of LWD removed from the reservoir for boater safety concerns. Finally, the study provides a basic LWD budget that compares the average annual volume and frequency of LWD removed from Don Pedro Reservoir with the average annual volume and frequency of LWD stored in the lower Tuolumne River.

3.0 STUDY AREA

The instream habitat assessment was conducted in the *O. mykiss* spawning and rearing reach of the lower Tuolumne River that extends from La Grange to Roberts Ferry Bridge (approximately RM 52–39). The LWD survey area extended from RM 52 downstream to RM 24. In addition, Don Pedro Reservoir was included in the study area for purpose of estimating LWD recruitment to the system.

4.0 METHODOLOGY

Salmonid habitat quality and quantity, including characterization of habitat limitations and relative salmonid production potential, is routinely assessed through surveys of instream habitat composition and structure, such as those described by CDFG (2010). Results of such surveys can help identify land use and other related effects on habitat quality, and thus the relative potential for habitat to support an anadromous fish population. Surveys such as those described here can also help identify opportunities to restore or enhance habitat conditions and production for salmonid populations and other aquatic resources.

Large woody debris plays an important role in habitat-forming events within low-order streams. Where LWD dimensions are large relative to the channel width, LWD readily collects within channel forming areas of velocity gradation, encouraging localized sediment deposition and scour (McBroom 2010). In higher order streams, such as the lower Tuolumne River, the role of LWD in habitat formation decreases with the stream width; however, LWD becomes more ecologically significant in high order streams where it may provide the majority of stable, firm substrate that supports substantial invertebrate productivity (McBroom 2010).

The study consisted of two separate components: (1) an inventory of instream habitat types and physical habitat characteristics, and (2) an appraisal of the distribution, abundance, and function of LWD in the lower Tuolumne River. The instream habitat inventory was conducted between June 12 and 14, 2012 in the salmonid spawning and rearing reach of the lower Tuolumne River from La Grange to Roberts Ferry Bridge (approximately RM 52–39). The LWD inventory was conducted from June 12-15 of 2012. The first three days of the LWD inventory were conducted in conjunction with the instream habitat typing effort. A separate field investigation of LWD removed from Don Pedro Reservoir was conducted on March 15, 2012.

The first component relied on available aerial photography and habitat mapping, and a reconnaissance-level survey of the lower Tuolumne River, between RM 52 and RM 39.5. This study component utilized existing broad-scale habitat mapping conducted by Stillwater Sciences (2008) to identify sampling areas where *O. mykiss* occur, then implemented the CDFG Level III habitat typing methodology (CDFG 2010) to further characterize and evaluate these areas. The Level III CDFG (2010) protocol differentiates six habitat types: main channel pool, scour pool, backwater pool, riffle, cascade, and flatwater. The Level III methodology allowed for a further collapsing down to the CDFG Level II pool, riffle, and flatwater habitat types.

The second study component, a LWD inventory, consisted of utilizing the wood piece size categories as described in Montgomery (2008) to conduct a detailed survey of large wood between RM 52 and RM 24. This information was used to assess the influence of LWD on *O. mykiss* habitat quality and quantity. In addition, as requested by the National Marine Fisheries Service (NMFS) and recommended by FERC staff in the December 22, 2011 Study Determination (FERC 2011), the frequency and volume of LWD trapped and removed from Don Pedro reservoir on an annual basis was evaluated. As stated in FERC's SPD of July 25, 2012, the objective of this study element was to develop a basic LWD budget that compared the average annual volume and frequency of LWD removed at Don Pedro reservoir with the average annual volume and frequency of LWD stored in the lower Tuolumne River.

4.1 Site Selection, Field Data Collection, and Analysis

4.1.1 Study Site Selection

The study reach extended from RM 51.8 to RM 24 of the lower Tuolumne River. The study reach was divided into sub-reaches in which habitat typing and/or a LWD inventory was conducted. Ortho-rectified digital aerial photographs of the study reach taken in May 2012 were used as basemaps for the study effort, and to assist in sampling unit selection and identification of access points. The aerial photographs were also used during the field effort to delineate habitat types and LWD locations as described in Section 4.1.2.

Habitat typing was limited to six sampling units within a sub-reach between RM 51.8 and RM 39.5 (Figure 4.1-1). Existing habitat mapping studies conducted by Stillwater Sciences (2008) and McBain & Trush (2004) along with an *O. mykiss* population study (Stillwater Sciences 2010) were reviewed to aid in sampling unit selection. The habitat typing sub-reach was selected because it is the portion of the river that experiences the greatest amount of *O. mykiss* spawning and rearing activity.

Habitat typing sampling units were selected by reviewing the *O. mykiss* underwater observation counts and the associated habitat units in Stillwater Sciences (2011). Each sampling unit contained a series of habitat types that were occupied by *O. mykiss* as recorded in Stillwater Sciences (2011). As recommended in CDFG (2010), sampling units selected for detailed habitat measurements encompassed 10–20 percent of the study reach. In addition, FERC (2011) recommended that the sampling unit length be at least 20 bankfull channel width long in accordance with commonly accepted scientific protocol noted by NMFS. Therefore, six habitat typing sampling units were selected that were (1) known to experience *O. mykiss* use, (2) at least 20 bankfull channel widths long, and (3) encompassed between 10 and 20 percent of the habitat typing sub-reach. The lengths of each of the six habitat type sampling units ranged from 1,450 to 4,528 ft long. The total length of the lower Tuolumne River surveyed was 16,906 ft (3.2 mi). This equated to approximately 26 percent of the habitat typing sub-reach.

The LWD inventory was conducted within 10 sampling units throughout the entire study reach (Figure 4.1-1). Sampling unit selection for inventorying LWD was conducted in two ways. The first was to co-locate LWD inventory sites on the six sampling units selected for the *O. mykiss* habitat typing effort. In addition, four other LWD sampling units were selected in the RM 39.5–24 sub-reach downstream of the *O. mykiss* habitat typing reach. In the absence of existing LWD distribution data, the four other sample units were selected to be evenly distributed along the length of the RM 39.5–24 sub-reach and be within a few miles of publicly accessible put-in and take-out river recreation locations.

The lengths of each of the 10 sampling units ranged from 1,450 to 4,528 ft long. The total length for the combined sampling units was 28,417 ft (5.38 miles) or 19 percent of the study reach's total length. This complied with the study plan requirement that 7–10 sampling units would be selected that encompassed 10–20 percent of the study reach.

Don Pedro Reservoir study sites were selected by identifying the locations along the reservoir where the Don Pedro Recreation Agency (DPRA) conducts an annual program to remove floating LWD to provide for safe navigational conditions for recreational boaters. Since the vast majority of the LWD that enters the reservoir comes from the upper Tuolumne River, the wood removal locations are typically concentrated in the Tuolumne River Arm of the reservoir in the vicinity of Ward’s Ferry Bridge, Deer Creek, and Rough and Ready Creek. The DPRA also collects individual pieces of wood and constructs burn piles at other scattered locations around the reservoir on an as-needed basis. LWD inventory data were collected at all LWD collection sites.

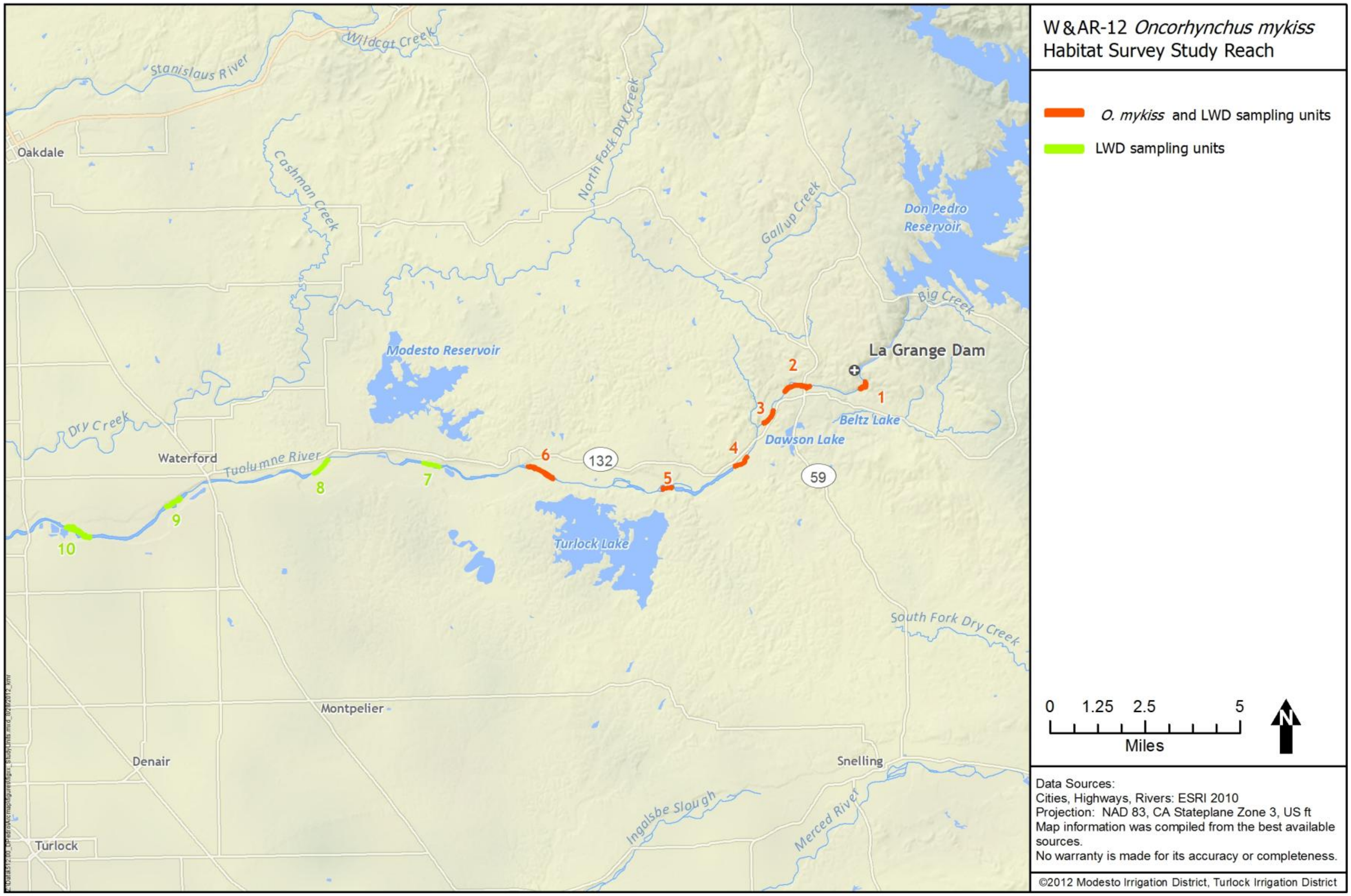

Figure 4.1-1. Habitat and LWD survey reach on the lower Tuolumne River between RM 51.8 and RM 24.

4.1.2 Field Data Collection

4.1.2.1 Instream Habitat Typing

The field survey was conducted from June 12 to 14, 2012.

The habitat typing field effort was conducted by a team of two biologists who surveyed the river via kayak. The team used maps and aerial photographs to identify the individual sampling units to be surveyed. A suite of measurements were made in each habitat type (Table 4.1-1). These measurements represent the required data collection for Level III CDFG habitat typing. Data were recorded on standardized datasheets to ensure all data were collected in a consistent manner.

Upstream and downstream boundaries for each habitat type were delineated on an aerial photograph. Each habitat type was assigned an identification number that was recorded on both the datasheet and aerial photograph. Field measurements were made with standard field equipment: a handheld thermometer was used to collect water temperature data, a digital depth finder was used to measure water depth, and a spherical densitometer measured percent overhead canopy cover. Each team was also equipped with a handheld GPS and camera. Given the large size of some of the habitat units, the length and width dimensions of individual habitat types were derived by GIS as necessary.

Table 4.1-1. List of data collected as part of the Level III CDFG habitat mapping.

Gathered Data	Description
Form Number	Sequential numbering
Date	Date of survey
Stream Name	As identified on USGS (U.S. Geological Survey) quadrangle
Legal	Township, Range, and Section
Surveyors	Names of surveyors
Latitude/Longitude	Degrees, Minutes, Seconds from a handheld GPS
Quadrant	7.5 USGS quadrangle where survey occurred
Reach	Reach name or river mile range
Habitat Unit Number	The habitat unit identification number that the bankfull width was measured
Time	Recorded for each new data sheet start time
Water Temperature	Recorded to nearest degree Celsius
Air Temperature	Recorded to nearest degree Celsius
Flow Measurement	Available from USGS monitoring stations
Mean Length	Measurement in meters of habitat unit
Mean Width	Measurement in meters of habitat unit
Mean Depth	Measurement in meters of habitat unit
Maximum Depth	Measurement in meters of habitat unit
Depth Pool Tail Crest	Maximum thalweg depth at pool tail crest in meters
Pool Tail Embeddedness	Percentage in 25% interval ranges
Pool Tail Substrate	Dominant substrate: silt, sand, gravel, small cobble, large cobble, boulder, bedrock
Large Woody Debris Count	Detailed inventory criteria are listed below
Shelter Value	Assigned categorical value: no shelter, minimal shelter (small debris, bubble curtain etc.), significant shelter (large woody debris, root wads, vegetative cover, etc.)
Percent Unit Covered	Percent of the unit occupied

Gathered Data	Description
Substrate Composition	Composed of dominant and subdominant substrate: silt, sand, gravel, small cobble, large cobble, boulder, bedrock
Percent Exposed Substrate	Percent of substrate above water
Percent Total Canopy	Percent of canopy covering the stream
Percent Hardwood Trees	Percent of canopy composed of hardwood trees
Percent Coniferous Trees	Percent of canopy composed of coniferous trees
Right and Left Bank Composition	Identify dominant substrate: sand/silt, cobble, boulder, bedrock
Right and Left Bank Dominant Vegetation	Identify dominant vegetation: grass, brush, hardwood trees, coniferous trees, no vegetation
Right and Left Bank Percent Vegetation	Percent of vegetation covering the bank
Comments	Additional notes as needed

4.1.2.2 Instream LWD Inventory

Two teams, each composed of two biologists, conducted the instream LWD inventory. Each team was assigned to survey a specific side of the river. The instream LWD distribution survey utilized the Montgomery (2008) wood size classes as follows. Within each LWD sample site, GPS locations and characteristics of each piece of LWD greater than 3 ft long within the active channel were tallied on datasheets and binned within six length classes (3–6.5 ft, 6.5–13 ft, 13–26 ft, 26–52 ft, 52–105 ft, and >105 ft) and four diameter classes (4-8 in, 8–16 in, 16–31 in, and 31–63 in). In some cases, a single location may have contained multiple pieces of LWD, which was then recorded as a single GPS location and identified on the datasheet. These data were entered in a Microsoft Excel ® spreadsheet from which summary tables were developed.

For the purposes of this study, a key piece of LWD was defined as a piece that was either longer than 1/2 times the bankfull width or of sufficient size and/or deposited in a manner that it alters channel morphology and aquatic habitat (e.g., trapping sediment or altering flow patterns).

Detailed measurements were taken for key pieces of LWD. In addition to recording the GPS locations for mapping on ortho-rectified aerial photographs, data that were collected on key LWD pieces included:

- Piece location, mapped on aerial photos/GPS documentation
- Piece length
- Piece diameter
- Piece orientation to bank
- Position relative to channel
- Rootwad presence
- Tree type (hardwood or evergreen)
- Association with any log jams
- If part of a log jam, the jam size (estimated dimensions/number of pieces)

- Source of wood (imported/riparian/unknown)
- Channel dynamic function (pool formation, sediment storage, or logjam)
- Habitat function (complex cover or velocity refuge)

4.1.2.3 Reservoir LWD Assessment

The assessment of LWD trapped on an annual basis in Don Pedro Reservoir was conducted using three techniques: (1) review of DPRA air quality permitting records, (2) aerial photograph analysis, and (3) in-field measurements of beached wood rafts and burn piles of wood collected from removal activities.

As stated above, the DPRA conducts an annual program to remove floating LWD at various locations in Don Pedro Reservoir in order to minimize boating hazards. Following high spring flows, the DPRA constructs log booms to enclose floating rafts of woody debris and tow the material to preferred beach locations. Cables attached to the boom are connected to anchored winches that compact and pull the wood rafts as close to shore as possible. As the year progresses, receding reservoir water surface elevation allows the wood raft to beach itself and eventually dry out for burning. In addition, individual pieces of LWD wood that have been washed or windblown into shallow locations also become beached. The DPRA then gathers the individual pieces of LWD into piles.

The DPRA disposes of these dried out wood rafts and piles by burning, which requires an air quality permit from the Air Resources Control Board. As part of the permit application process, the DPRA is required to conduct a field investigation to estimate the gross volume of wood in the rafts and piles that they plan on burning each year. These estimates are then reported to the Air Resources Control Board. It must be noted that some years (i.e., wet) result in a significant amount of wood being deposited into the reservoir while others (dry) experience little or no wood deposition. The DPRA supplied raft and burn pile data for the 2009, 2010, and 2011 seasons, and an oblique photograph of the single small 2012 wood raft from which an inventory of LWD was conducted and volume calculations were generated.

Stillwater Sciences collected burn pile data during the spring of 2012, which included dimensions and piece size characteristics. The LWD data were recorded on the same field form as was used for the instream wood inventory. The burn piles inventoried during this effort were left over from the 2011 LWD collection and burning season. The lack of high flows during water year 2012 resulted in very little LWD deposition; therefore, no burn piles were constructed.

4.1.3 Data Processing and Analyses

4.1.3.1 Instream Habitat Typing

All habitat typing data sheets were reviewed by the lead biologist following that day’s survey. Following completion of the field effort, all habitat typing data were again reviewed for quality control. The data were entered into a Microsoft Access® data base for analysis; each entry was error-checked. Data were summarized in tables depicting overall habitat characteristics and conditions within the study reach. Tabular data summaries included:

- Level II riffle, flatwater, and pool habitat types;
- Level III habitat types;
- Level III habitat types with side channel units;
- Level III pool types and characteristics;
- average percent shelter by habitat type;
- dominant substrates by habitat type;
- sub-dominant substrates by habitat type;
- canopy, streambank, and vegetative characteristics by habitat type; and
- summary of measured fish habitat elements.

4.1.3.2 Instream LWD Inventory

All LWD data sheets were reviewed by the lead fisheries biologist following that day's survey. Following completion of the field effort, all of the LWD datasheets were given to the data entry specialist who conducted another round of quality control and consulted with the lead fisheries biologist to resolve any questions. The data were then entered into Microsoft Excel® database for analysis.

The volume of wood within the sample areas was calculated by taking the mean diameter (e.g., 4–8 in = 6 in) and length (e.g., 6.5–13 ft = 9.75 ft) for each size class and solving the equation for volume of a cylinder:

$$V = (\pi r^2)\ L$$

Where:

V = wood volume,
π = pi,
r = piece radius, and
L = piece length.

The total number of pieces and size class volumes within the 10 sample units were then expanded to represent the entire study reach between RM 51.8 and 24. This was accomplished by multiplying the number of pieces and size class volumes by 5.17 (i.e., 27.8 mi study reach length/5.38 mi sample area length).

Data collected during the in-river LWD distribution survey were then summarized relative to size class, reach, habitat association, density, complexity, and volume.

4.1.3.3 Reservoir LWD

LWD trapped and removed from Don Pedro Reservoir during 2009, 2010, 2011, and 2012 by the DPRA was quantified, and an annual average loading estimate was developed. For the purposes of this study, the annual debris accumulation data collected by the DPRA was assumed to represent the amount of LWD that was transported to and deposited in Don Pedro Reservoir during the previous winter and spring high flows. The area and/or length, width, and depth data for the 2009–2011 debris rafts were estimated by the DPRA after the material was beached and drying. These dimensions were multiplied together to develop a gross estimate of wood volume.

During the course of the analysis, it appeared that some of the DPRA debris raft area estimates may have been of too coarse. For example, in 2009 and 2010, the raft areas were reported as "approximately half an acre" or "approximately one-quarter acre." Therefore, Stillwater Sciences reviewed Google Earth® aerial photographs for 2009–2011 to develop more accurate area estimates. A planform polygon was delineated that encompassed each wood raft, and the areas were calculated using GIS. The preliminary raft area estimates from DPRA were adjusted based on the GIS results. The existing DPRA raft depth measurements were utilized for the revised volume calculation. In addition, the lack of pore space (space between individual pieces of LWD) data for the preliminary DPRA volume estimates required an adjustment to "condense" the pile. Therefore, after reviewing debris raft photographs (Figure 4.1-2), a pore space correction factor of 0.8 (i.e., 20 percent pore volume) was applied to the debris raft volumes to adjust for this overestimate.

Water year 2012 was considered a dry year, which experienced relatively small peak flows. The small peak flows transported a very small amount of LWD into Don Pedro Reservoir, and consequently, only a single boom was deployed to corral the few floating pieces of LWD observed in the spring (David Jigour, Lake Operations Division Manager, DPRA, pers. comm., August 2012). The volume of LWD collected during the 2012 disposal effort was calculated by estimating the length and diameters of individual logs observed on the oblique photograph of the accumulation that was taken by the DPRA (Figure 4.1-3).

Figure 4.1-2. Burning debris raft in November 2011. Photograph taken by DPRA.

Figure 4.1-3. Oblique photograph of 2012 Don Pedro Reservoir LWD accumulation. Each orange boom is 10 ft long and 1 ft in diameter. Photograph taken by DPRA.

The burn pile data supplied by the DPRA included number of piles, diameters, and heights. The burn piles were generally cone-shaped (Figure 4.1-4). Therefore, a cone formula [$V = 1/3(\pi r^2)(h)$] was applied to estimate wood volume in the piles. A review of Figure 4.1-4 showed that a substantial portion (>20 percent) of each burn pile's volume was empty pore space. Therefore, a conservative correction factor of 0.8 (i.e., 20 percent pore space) was applied to the burn pile volumes to account for the pore spaces. The annual total volumes of the DPRA burn piles was used in conjunction with the raft information to generate the yearly estimates of LWD volume trapped in the Don Pedro Reservoir.

Figure 4.1-4. Don Pedro Reservoir cone-shaped burn piles left over from 2011. Photograph taken in March 2012 by Stillwater Sciences.

On March 15, 2012, Stillwater Sciences conducted a survey of burn piles and scattered LWD remaining from the 2011 DPRA wood collection season. The survey included gathering burn pile dimension data and tallying individual pieces of wood into the same size classes utilized for the instream LWD survey. Some of the pieces of LWD in burn piles were cut from single logs to facilitate easier handling by the DPRA crew. In those instances, the Stillwater Sciences surveyor measured the individual cut pieces to ascertain the original size of the log. That original log, not the individual pieces, was then entered into the tally.

The intent of this survey was to collect data on LWD piece sizes in the burn piles and raft remnants. These data were used to determine the piece size distribution of the gathered debris. The data collected from these burn piles were not used to help generate the 2011 total LWD volume trapped in the reservoir because these piles were included in the 2011 DPRA data.

The adjusted DPRA raft and burn pile estimates for 2009–2011, Stillwater Sciences data collected for 2011, and individual log tally determined from the 2012 DPRA oblique photograph were entered into a Microsoft Excel® spreadsheet from which wood volumes and size class distribution tables were developed.

5.0 RESULTS

5.1 Habitat Typing

Flow in the Tuolumne River during the habitat typing effort ranged from 200 to 240 cfs at the USGS Tuolumne River at Modesto gage (#11290000). Water temperature during this effort ranged from 15.5°C (60°F) at 1145 on June 12, 2012 to 23.5°C (74.3°F) at 1500 on June 13, 2012.

The total length of the lower Tuolumne River surveyed was 16,906 ft, which included 1,098 ft of side channel. The six sampling units ranged in length from 1,450 to 4,528 ft. This equated to approximately 26 percent of the RM 51.8–39.5 *O. mykiss* occupancy reach. A total of 33 individual habitat units were identified and measured in the six habitat type sample units (Attachment A). Four of the six Level III habitat types were present in the study reach; cascades and backwater pools did not occur.

The relative percentages of Level II riffle, flatwater, and pool habitat types are summarized in Table 5.1-1.

Table 5.1-1. Level II habitat types surveyed in the lower Tuolumne River between RM 51.8 and RM 39.5.

Level II Habitat Types	Number of Units	Percent by Occurrence	Sum of Length (ft)	Percent by Total Length
Riffle	10	30	2,384	14
Flatwater	15	45	10,342	61
Pool	8	24	4,180	25
Total	**33**	**100**	**16,906**	**100**

Note: Total percentages may not equal the sum of values reported in the column above due to rounding to nearest whole number.

Level III habitat data, which includes a breakout of pool types, for the entire reach length are summarized in Table 5.1-2. A further breakdown of the Level III habitat types that includes individual side channel units is presented in Table 5.1-3.

Table 5.1-2. Level III habitat types surveyed in the lower Tuolumne River between RM 51.8 and RM 39.5.

Level III Habitat Types	Number of Units	Percent by Occurrence	Sum of Length (ft)	Percent by Total Length
Riffle	10	30	2,384	15
Flatwater	15	45	10,342	61
Main channel pool	5	15	2,845	17
Scour pool	3	9	1,335	8
Total	**33**	**100**	**16,906**	**100**

Note: Total percentages may not equal the sum of values reported in the column above due to rounding to nearest whole number.

Table 5.1-3. Level III habitat types with side channel (SC) units surveyed in the lower Tuolumne River between RM 51.8 and RM 39.5.

Level III Habitat Types with Side Channel Units	Number of Units	Percent by Occurrence	Sum of Length (ft)	Percent by Total Length
Riffle	10	30	2,384	15
Flatwater	12	36	9,244	55
Main channel pool	5	15	2,845	17
Scour pool	3	9	1,335	8
SC flatwater	3	9	1,098	6
Total	**33**	**100**	**16,906**	**100**

Note: Total percentages may not equal the sum of values reported in the column above due to rounding to nearest whole number.

Five main channel pools and three scour pools were identified during the survey (Table 5.1-4). The maximum depths for pools ranged from 6.2 to 36.2 ft and had an average depth of 15.6 ft. Residual pool depths (maximum depth minus depth of pool tail crest) varied from 5.4 to 35.0 ft, and averaged 14.6 ft.

The depth of cobble embeddedness was estimated at pool tail-outs. The lower the embeddedness score, the higher the quality of spawning substrates. Of the pool tail-outs measured, 87 percent had an embeddedness value of 1 (i.e., <25 percent embeddedness), and 13 percent had an embeddedness value of 2 (25–50 percent). The pool length-weighted embeddedness value for the study reach was 1.1 (Table 5.1-4), which indicated that spawning habitat quality was relatively high in most of the survey reach.

A shelter rating was calculated for each habitat type within the survey using a scale of 0–300, where higher ratings reflect a greater abundance and diversity of cover types. A shelter rating of 80 or greater is desirable. Riffles, flatwater, main channel pools, and scour pools had shelter ratings of 10, 31, 49, and 40, respectively (Table 5.1-5). Pool cover types were dominated by boulders (riprap), small woody debris, bubble curtains, and aquatic vegetation.

Table 5.1-4. Level III pool types and characteristics for those units surveyed in the lower Tuolumne River between RM 51.8 and RM 39.5.

Pool Type	Residual Depth Range (ft)	Number of Units	Percent Occurrence	Total Length (ft)	Percent of Total Pool Length	Average Maximum Depth (ft)	Average Residual Depth (ft)	Average Embeddedness
Main channel pool	5.4–31	5	63	2,845	68	14.5	13.5	1.0
Scour pool	6.9–35	3	38	1,335	32	17.5	16.4	1.3
Reach Total	5.4–35	**8**	**100**	**4,180**	**100**	**15.6**	**14.6**	**1.1**

Note: Subtotals may not equal the sum of values reported due to rounding to nearest whole number.

Table 5.1-5. Average shelter values and composition for Level III habitat types surveyed in the lower Tuolumne River between RM 51.8 and RM 39.5.

Level III Habitat Type	Number of Units	Average Shelter Value	Average Shelter Rating	Average Shelter Composition (%)								
				Undercut	SWD	LWD	Rootwad	Terr. Veg.	Aquatic Veg.	Bubble Curtain	Boulder	Bedrock
Riffle	10	0.5	10	0	3	0	67	0	0	27	0	3
Flatwater	15	1.7	31	0	17	3	31	25	8	10	7	0
Main channel pool	5	2.0	49	0	32	4	12	6	0	0	24	22
Scour pool	3	2.0	40	0	18	0	0	0	25	27	27	3

Large and small cobbles were the dominant substrates observed within the survey reach (Table 5.1-6). The primary subdominant substrates were small cobbles followed by gravel (Table 5.1-7).

Table 5.1-6. Dominant substrates by habitat type surveyed in the lower Tuolumne River between RM 51.8 and RM 39.5.

Level III Habitat Type	Substrate	Percent of Substrate within Habitat Type	Percent of Substrate by Total Reach Length
Riffle	Gravel	40	6
	Small cobble	60	8
Flatwater	Gravel	17	11
	Small cobble	45	27
	Large cobble	34	21
	Boulders	0	0
	Bedrock	4	2
Main channel pool	Large cobble	65	11
	Boulders	22	4
	Bedrock	13	2
Scour pool	Large cobble	41	3
	Boulders	59	5

* Substrate size classes: Sand (<0.08 in), gravel (0.08-2.5 in), small cobble (>2.5-5 in), large cobble (>5-10 in), and boulder (>10 in).

Table 5.1-7. Subdominant substrate by habitat type surveyed in the lower Tuolumne River between RM 51.8 and RM 39.5.

Level III Habitat Type	Substrate[1]	Percent of Substrate within Habitat Type	Percent of Substrate by Total Reach Length
Riffle	Gravel	52	7
	Small cobble	40	6
	Large cobble	8	1
Flatwater	Sand	17	10
	Gravel	18	11
	Small cobble	55	34
	Large cobble	10	6
Main channel pool	Sand	31	5
	Gravel	13	2
	Small cobble	34	6
	Bedrock	22	4
Scour pool	Sand	27	2
	Small cobble	14	1
	Bedrock	59	5

[1] Substrate size classes: Sand (<0.08 in), gravel (0.08-2.5 in), small cobble (>2.5-5 in), large cobble (>5-10 in), and boulder (>10 in).

Because the lower Tuolumne River has an active channel width of up to 229 ft within the survey reach, the average percent of canopy cover is limited at 10 percent (generally shading only the stream margins), and is overwhelmingly dominated by deciduous trees (Table 5.1-8). The right and left banks of the low-flow channel have similar vegetation characteristics, with deciduous trees dominating the upper canopy. Vegetated coverage averaged 66 percent on the left bank and 70 percent on the right bank.

Table 5.1-8. Canopy cover and bank vegetation coverage by habitat type surveyed in the lower Tuolumne River between RM 51.8 and RM 39.5.

Habitat Type	Number of Units	Average Percent Canopy Cover	Canopy composition (%)		Average Percent of Left Bank Vegetated	Average Percent of Right Bank Vegetated
			Deciduous	Evergreen		
Riffle	10	3	100	0	56	69
Flatwater	15	16	100	0	73	75
Main channel pool	5	8	100	0	73	56
Scour pool	3	3	100	0	48	75
Overall	**33**	**10**	**--**	**--**	**66**	**70**

The Level III habitat type attributes, discussed above are summarized in Table 5.1-9. Overall, the wetted portion of the Tuolumne River along this reach had an average width of 114 ft. The average lengths for the riffles, flatwater, main channel pools, and scour pools were 238, 770, 569, and 445 ft, respectively. Side channels made up 6 percent of the entire reach length.

Table 5.1-9. Summary of fish habitat attributes surveyed in the lower Tuolumne River between RM 51.8 and RM 39.5.

Habitat Type	Number of Units	Total Habitat Length (ft)	Percent of Total Length	Average Length (ft)	Average Width (ft)	Average Depth (ft)	Average Maximum Depth (ft)	Average Depth Pool Crest (ft)	Average Residual Pool Depth (ft)	Average Area (ft²)	Average Percent Instream Cover	Average Percent Canopy
Riffle	10	2,384	14	238	112	0.7	1.3	--	--	26,725	4	3
Flatwater	12	9,244	55	770	130	2.3	4.4	--	--	99,822	13	8
Main channel pool	5	2,845	17	569	128	7.2	14.5	0.9	13.5	72,604	23	8
Scour pool	3	1,335	8	445	102	7.7	17.5	1.2	16.4	45,538	20	3
Side channel flatwater	3	1,098	6	366	49	1.5	2.9	--	--	18,056	25	50
Overall	**33**	**16,906**	**100**	**512**	**114**	**3**	**6.0**	**--**	**--**	**61,179**	**14**	**10**

5.2 In-river Large Woody Debris

The Tuolumne River flows during the June 12-15, 2012 LWD inventory effort ranged from 200 to 240 cfs at the USGS Tuolumne River at Modesto gage (# 11290000). The lengths of the 10 LWD sample units ranged from 1,450 to 4,528 ft for a total inventory length of 28,416 ft, or 19 percent of the RM 51.8–24 study reach (Attachment A).

A total of 200 individual pieces of LWD were inventoried during the survey effort, five of which were key pieces. The number of LWD pieces in each of the diameter and length classes are presented in Figures 5.2-1 and 5.2-2. The combined (diameter by length) size class data are presented in Table 5.2-1 and Figure 5.2-3. No LWD in the 31–63 in diameter class or 52–105 ft and >105 ft length classes was observed.

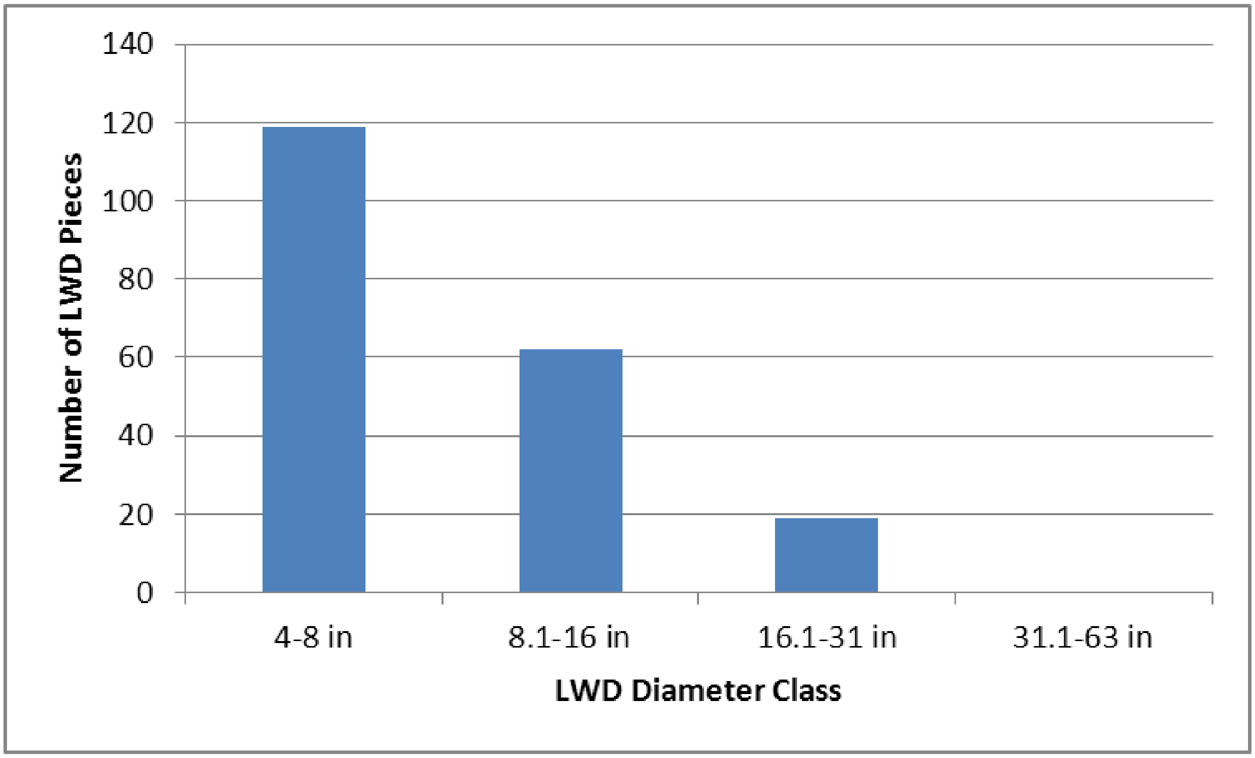

Figure 5.2-1. Number of LWD pieces in the sample units, by diameter class, at the LWD survey sites in the lower Tuolumne River between RM 51.8 and RM 24.

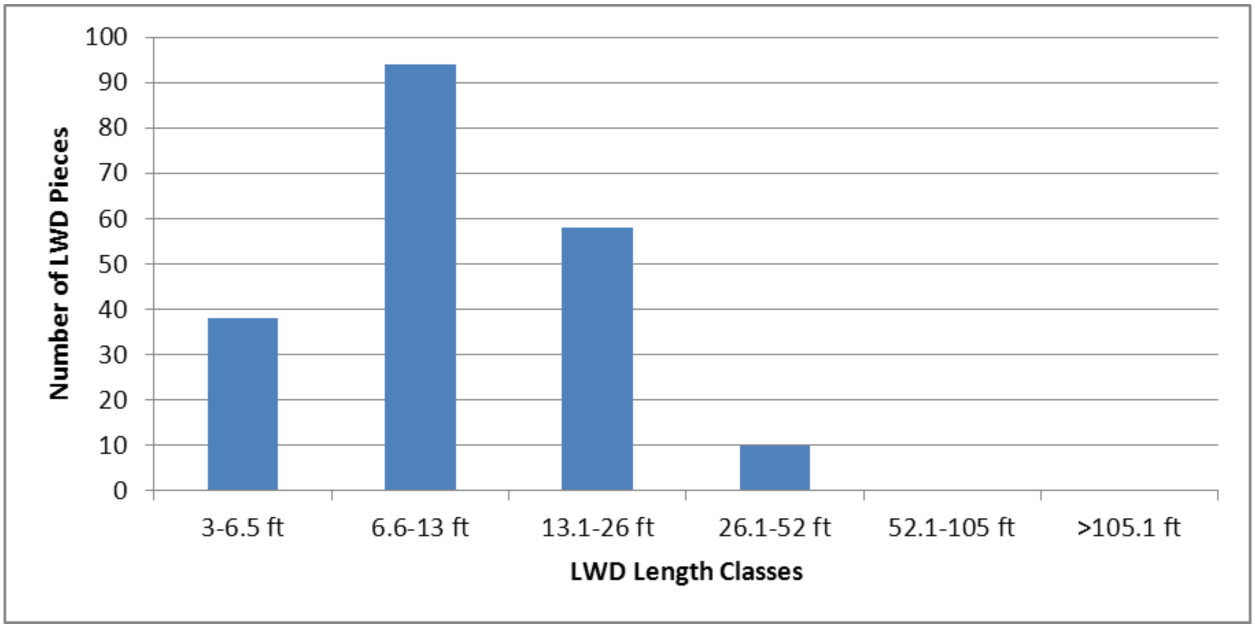

Figure 5.2-2. Number of LWD pieces in the sample units, by length class, at the LWD survey sites in the lower Tuolumne River between RM 51.8 and RM 24.

Table 5.2-1. Number, mean piece volume, and total volume per combined size class at the LWD survey sites in the lower Tuolumne River between RM 51.8 and RM 24.

Diameter Class (in)	Length Class (ft)	Number	Mean Piece Volume (ft³)	Size Class Volume (ft³)
4–8	3–6.5	30	0.9	27
	6.6–13	62	1.9	119
	13.1–26	26	3.8	99
	26.1–52	1	7.7	7
8.1–16	3–6.5	8	3.8	30
	6.6–13	28	7.8	217
	13.1–26	21	15.5	325
	26.1–52	5	30.9	154
16.1–31	3–6.5	0	14.4	0
	6.6–13	4	29.6	118
	13.1–26	11	59.1	650
	26.1–52	4	118.1	472
Total	**--**	**200**	**--**	**2,218**

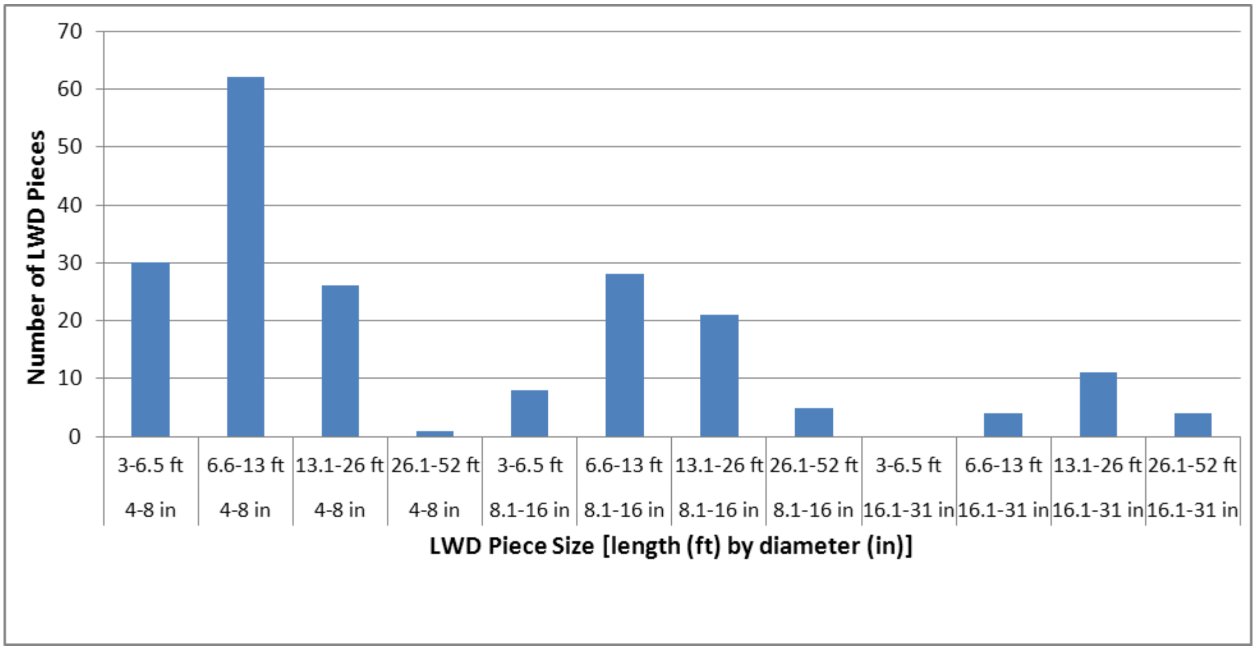

Figure 5.2-3. Number of LWD pieces in the sample units, by combined size classes, at the LWD survey sites in the lower Tuolumne River between RM 51.8 and RM 24.

The mean piece volume for each of the combined size classes ranged from 0.9 to 118 ft³ (Table 5.2-1). The total volume of LWD for each of the combined size classes ranged from 0 to 650 ft³ (Table 5.2-1). The total volume of LWD recorded during the survey was 2,218 ft³.

The majority of the LWD observed during the survey was completely or partially out of the wetted channel, deposited by previous high flows, and provided minimal habitat value for *O. mykiss*. Approximately 62 pieces (31 percent) of the LWD observed were in 12 accumulations of two to eight pieces. At least seven of these accumulations were made up of between five and eight pieces of wood. One of the accumulations was a cluster of four key pieces. The relatively small size of the wood in the accumulations limited their influence on habitat forming processes.

The extrapolated volume of LWD in the entire RM 51.8–24 study reach is 11,702 ft³ (1,053 total pieces), based on sampling 19 percent of the reach and assuming representativeness of the sampled units (Table 5.2-2).

Table 5.2-2. Number of pieces and total volume per LWD size class extrapolated to the entire RM 51.8–24 study reach of the lower Tuolumne River.

Diameter Class (in)	Length Class (ft)	Number	Size Class Volume (ft³)
4-8	3–6.5	158	147
	6.6–13	326	628
	13.1–26	137	525
	26.1–52	5	40
8.1-16	3–6.5	42	158
	6.6–13	147	1,144
	13.1–26	111	1,711
	26.1–52	26	814

Diameter Class (in)	Length Class (ft)	Number	Size Class Volume (ft³)
16.1-31	3–6.5	0	0
	6.6–13	21	624
	13.1–26	58	3,424
	26.1–52	21	2,487
Total	**--**	**1,053**	**11,702**

Only five key pieces of LWD were recorded within the 10 sampling units, and of these, four were in a single location. All of the key pieces were deciduous trees that fell into the river channel though bank erosion. The key piece diameters ranged from 12 to 20 in and were between 30 and 50 ft long. The individual piece volumes ranged from 23.6 to 109 ft³ and totaled 262 ft³. All had rootwads attached, appeared to be stable in the channel, and served as velocity and instream habitat cover. Extrapolation of the number of key pieces of LWD from the sampling units to the entire study reach yields 26 pieces with a total volume of 1,379 ft³.

There did not appear to be any pattern to the distribution of LWD between the sample units. The LWD appeared to be randomly distributed, although twice as many pieces were observed in sample unit 2 than in any of the other units (Figure 5.2-4).

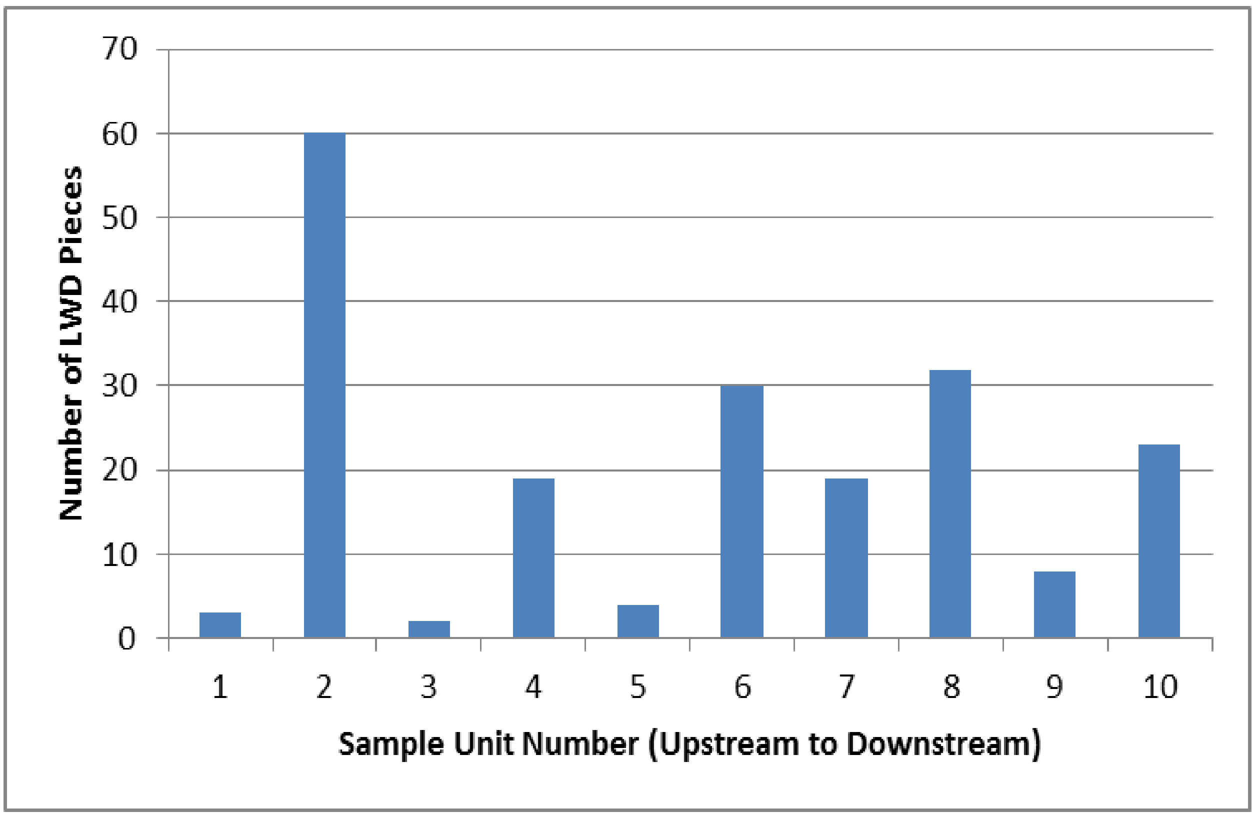

Figure 5.2-4. Number of LWD pieces in each sample unit in an upstream to downstream direction at the LWD survey sites in the lower Tuolumne River between RM 51.8 and RM 24.

5.3 Reservoir LWD

Reservoir LWD loading was generated from aerial photographic interpretation of dried up wood rafts (Figure 5.3-1) and DPRA and Stillwater Sciences data on burn pile dimensions and wood size class inventory as described in Section 4.1.3.3.

5.3.1 Don Pedro Reservoir Wood Volume Estimates

5.3.1.1 2009 Don Pedro Reservoir LWD Volume Estimates

In 2009, the DPRA collected area and/or diameter and height measurements on two dried up wood rafts and 37 burn piles. The DPRA estimated that the two dried up rafts covered a half-acre each and had a depth of 5 feet. A strict summation of the DPRA wood raft dimensions equaled an estimated preliminary volume of 217,800 ft^3.

The burn pile dimensions ranged from 10 to 20 ft in diameter and 6 to 8 ft high. The total preliminary volume for the burn piles was estimated to be 18,876 ft^3. The preliminary estimated total volume of wood accumulated in the rafts and burn piles by the DPRA in 2009, using only the recorded dimensions, was 236,676 ft^3.

Given the rough nature of the 2009 DPRA wood raft area estimates, Stillwater Sciences conducted a review of the 2009 aerial photographs on Google Earth® to develop more accurate area estimates. The aerial photograph review showed that the two rafts were 10,574 and 5,601 ft^2 in size. Using the 5 ft depth reported by the DPRA, this resulted in gross wood raft volumes equaling 81,775 ft^3. After applying a pore space correction factor of 0.8 (i.e., 20 percent pore space) as described previously, the revised volume estimate for rafted wood captured during 2009 in Don Pedro Reservoir was approximately 65,420 ft^3.

As stated above, the DPRA reported burn pile dimensions that resulted in a total volume of 18,876 ft^3. After applying a pore space correction factor of 0.8, the revised burn pile volume estimate is 15,101 ft^3. Thus, the revised 2009 wood volume captured in Don Pedro Reservoir (rafts and burn piles) was 80,521 ft^3.

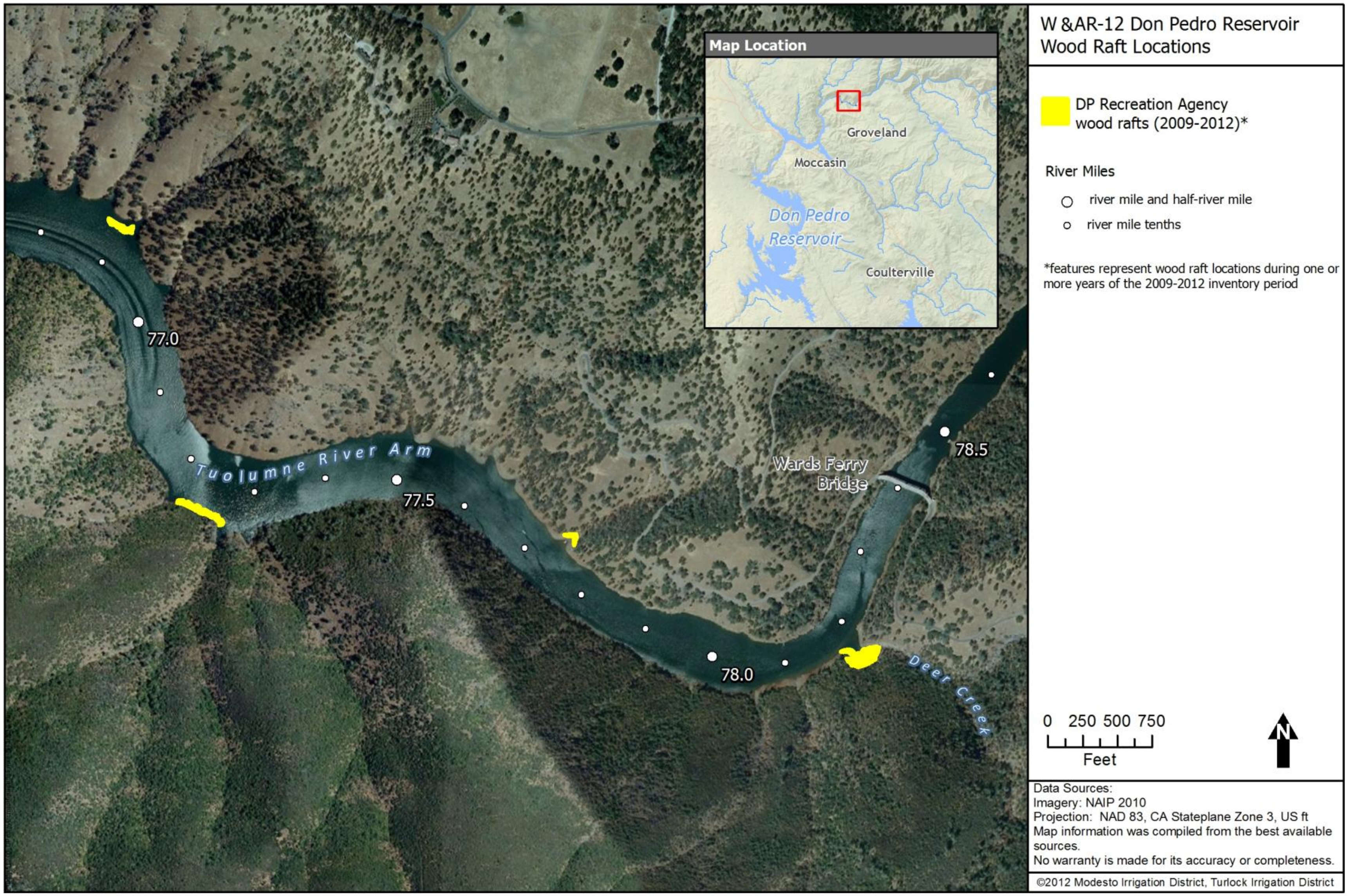

Figure 5.3-1. 2009-2012 Don Pedro Reservoir wood raft locations.

5.3.1.2 2010 Don Pedro Reservoir LWD Volume Estimates

In 2010, the DPRA collected area and/or diameter and height measurements on one dried up wood debris raft and 30 burn piles. The DPRA estimated that the dried up raft covered a quarter-acre and had an average depth of 2–3 ft. The burn pile dimensions ranged from 8 to 15 ft in diameter and from 6 to 8 ft in height. A strict summation of the DPRA accumulation dimensions equaled an estimated preliminary volume of 39,893 ft^3 of woody debris collected for disposal, of which the raft accounted for 32,670 ft^3 and the piles totaled 7,223 ft^3.

A review of the 2010 aerial photographs on Google Earth® showed a raft area of 7,346 ft^2. Using the GIS-derived area, DPRA's average depth of 3 feet, and a pore space factor of 0.8, a revised raft volume of 14,692 ft^3 was estimated. A revised estimate of the burn pile volume was developed by multiplying the initial 7,223 ft^3 by the 0.8 pore space correction factor. The revised burn pile volume estimate was 5,788 ft^3. Therefore, the revised total volume estimate for wood captured in Don Pedro Reservoir (rafts and burn piles) in 2010 was 20,470 ft^3.

5.3.1.3 2011 Don Pedro Reservoir LWD Volume Estimates

In 2011, the DPRA collected area and/or diameter and height measurements on two dried up wood debris rafts and 70 burn piles. The DPRA estimated that the 2 dried up rafts covered areas of 2,000 and 16,000 ft^2, and averaged 3 feet deep. The burn pile dimensions ranged from 5 to 20 ft in diameter and from 3 to 6 ft in height. A strict summation of the DPRA accumulation dimensions equaled an estimated preliminary volume of 67,778 ft^3 of woody debris collected for disposal, of which the rafts accounted for 54,000 ft^3 and the piles totaled 13,778 ft^3.

A review of the 2011 aerial photographs on Google Earth® showed that the areas of the 2 wood rafts were 4,789 and 10,565 ft^2. Using the revised areas, an average depth of 3 feet, and a pore space factor of 0.8 generated a revised wood raft volume estimate of 36,850 ft^3. A third wood raft was identified during the aerial photograph review. This raft had an area of approximately 1,920 ft^2, which when multiplied by 3 feet for average depth, and 0.8 pore correction factor gives a volume of 4,608 ft^3. A revised estimate of the burn pile volume was developed by multiplying the initial 13,778 ft^3 by the 0.8 pore space correction factor. The revised burn pile volume estimate was 11,022 ft^3. Therefore, the total revised volume estimate for wood captured in Don Pedro Reservoir (rafts and burn piles) was 52,480 ft^3.

5.3.1.4 2012 Don Pedro Reservoir LWD Volume Estimates

Water Year 2012 was considered a dry year, which resulted in relatively small peak flows. The small peak flows transported a limited amount of LWD into Don Pedro Reservoir, and consequently, only a single boom was deployed to corral a small LWD raft (David Jigour, Lake Operations Division Manager, DPRA, pers. comm., August 2012). No burn piles were constructed due to the lack of LWD deposited on reservoir side slopes. The volume of LWD collected during the 2012 disposal effort was calculated by estimating the length and diameters of individual logs present on the oblique photograph taken by the DPRA. The total volume of LWD captured in the Don Pedro Reservoir for 2012 was approximately 17 ft^3.

5.3.1.5 Average Annual Don Pedro Reservoir LWD Volume Estimate

The revised 2009–2012 average annual wood volume estimate captured in Don Pedro Reservoir is 38,375 ft^3 (Table 5.3-1).

Table 5.3-1. Preliminary, revised, and average annual LWD volume estimated for woody debris captured in Don Pedro Reservoir.

Year	Preliminary Wood Raft Volumes (ft^3)[1]	Preliminary Burn Pile Volumes (ft^3)[1]	Revised Wood Raft Volumes (ft^3)	Revised Burn Pile Volumes (ft^3)
2009	217,800	18,876	65,420	15,101
2010	32,670	7,223	14,692	5,788
2011	54,000	13,778	41,458	11,022
2012	0	0	17	0
Average	76,118	9,969	30,397	7,978
Average Annual	**86,087**		**38,375**	

[1] From uncorrected DPRA data

5.3.2 Don Pedro Reservoir LWD Piece Size and Volume

A total of 305 individual pieces of LWD left over from the 2011 DPRA wood collection season were inventoried during the 2012 reservoir survey effort. Many of the largest pieces of inventoried LWD were remnants of logs that were cabled together to construct the booms that collect floating wood. Of the 305 pieces, most were less than 8 inches in diameter and 13 ft long (Figures 5.3-2 and 5.3-3). The combined (diameter by length) size class data are shown in Table 5.3-2. No LWD in the 31–63 in diameter class or 52–105 ft and >105 ft length classes were observed.

The mean piece volume for each of the combined size classes ranged from 0.9 to 118 ft^3 (Table 5.3-2). The total volume of LWD for each of the combined size classes ranged from 7 to 2,126 ft^3 (Table 5.3-2). The total volume of LWD recorded during the reservoir log inventory was 5,295 ft^3. The individual piece and combined size class volumes from the leftover burn piles were not included in the 2011annual volume estimate (Table 5.3-1) because that would have been a double counting of the DPRA data.

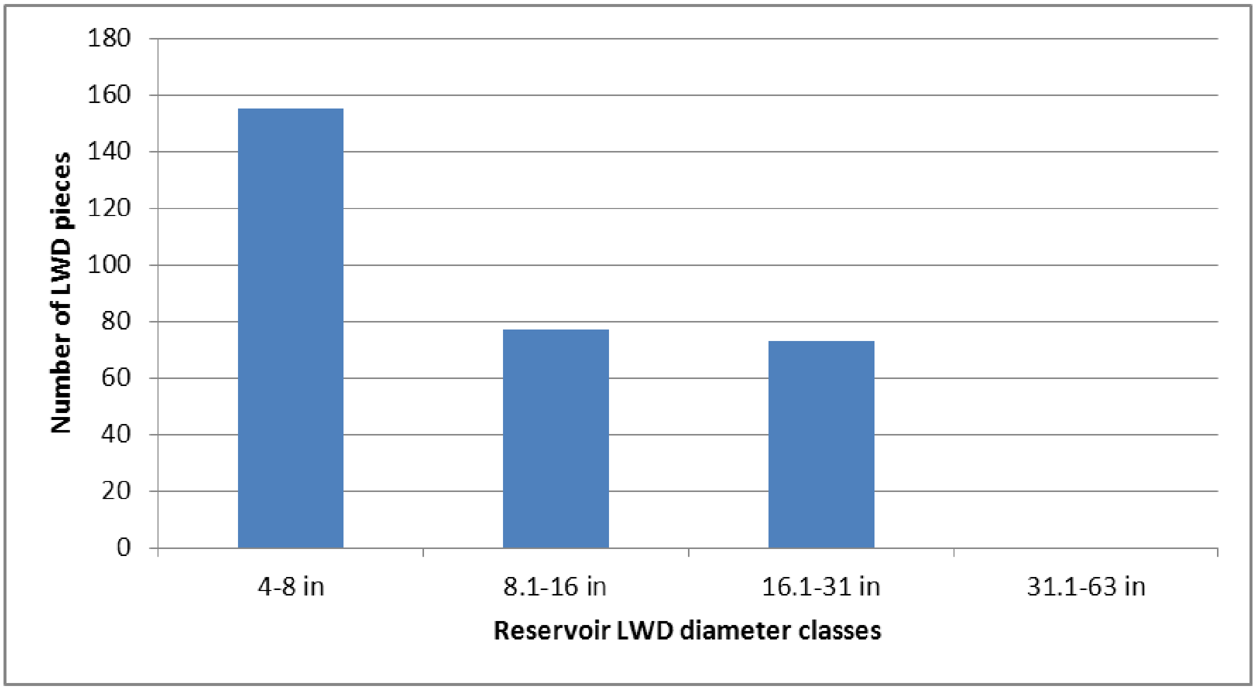

Figure 5.3-2. Number of Don Pedro Reservoir LWD pieces by diameter class in 2011 burn piles.

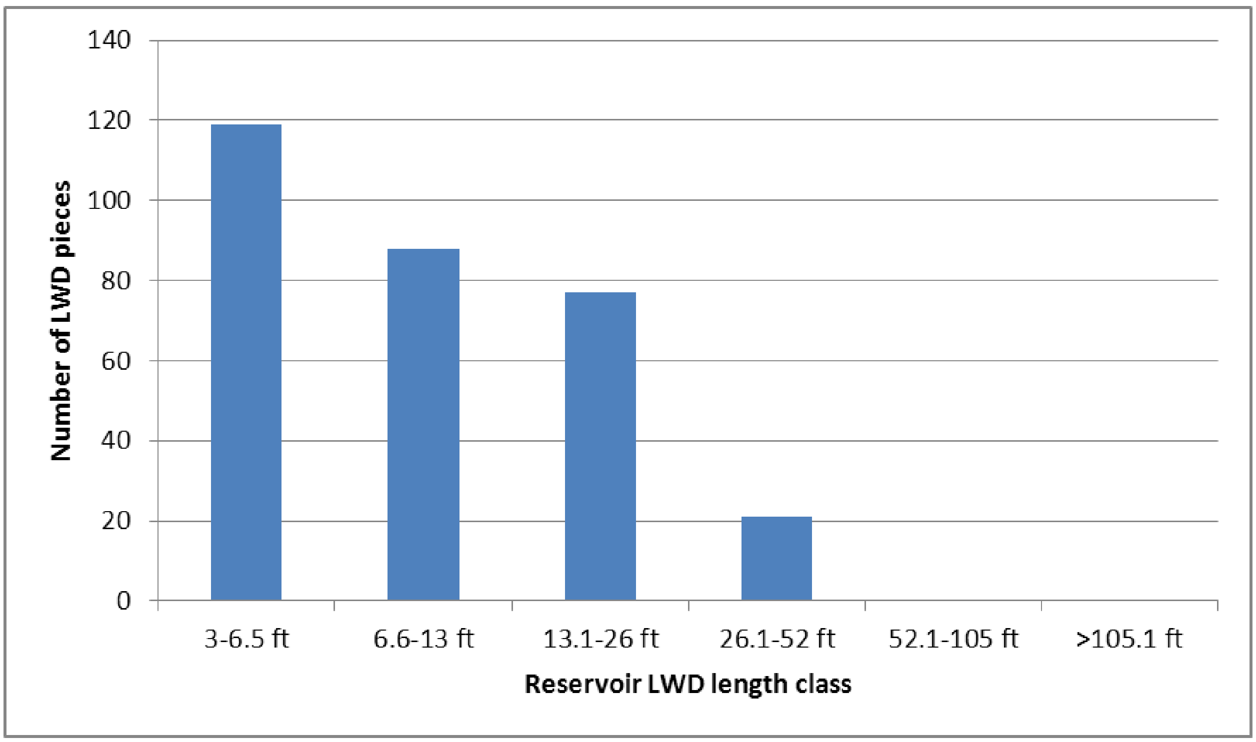

Figure 5.3-3. Number of Don Pedro Reservoir LWD pieces by length class in 2011 burn piles.

Table 5.3-2. Number, mean piece volume, and total volume per reservoir LWD size class of 2011 burn piles, remnant log booms, and individual pieces.

Diameter (in)	Length (ft)	Number	Piece Percentage of Total	Mean Piece Volume (ft³)	Size Class Volume (ft³)
4–8	3–6.5	84	27.5	0.9	78
4–8	6.6–13	42	13.8	1.9	80
4–8	13.1–26	28	9.2	3.8	107
4–8	26.1–52	1	0.3	7.7	7
8.1–16	3–6.5	23	7.5	3.8	86
8.1–16	6.6–13	27	8.9	7.8	209
8.1–16	13.1–26	25	8.2	15.5	387
8.1–16	26.1–52	2	0.7	30.9	61
16.1–31	3–6.5	12	3.9	14.4	172
16.1–31	6.6–13	19	6.2	29.6	563
16.1–31	13.1–26	24	7.9	59.1	1419
16.1–31	26.1–52	18	5.9	118.1	2,126
Total	**--**	**305**	**100**	**--**	**5,295**

5.4 Basic LWD Budget

The July 25, 2012 FERC study plan determination recommended "*that the Districts produce an estimate of the average annual volume and frequency of LWD removed from Don Pedro reservoir using quantitative and anecdotal historical data, including appropriate aerial photography analysis methods, such as those described by NMFS in its April 24, 2012 comment letter, as well as two annual quantitative surveys of LWD in Don Pedro reservoir to be conducted upon the cessation of seasonal high flow events. Also consistent with our study plan determination, we recommend the development of a basic LWD budget that compares the average annual volume and frequency of LWD removed at Don Pedro reservoir with the average annual volume and frequency of LWD stored in the lower Tuolumne River*."

As reported in Section 5.2 and based on a single year's inventory, the estimated volume of LWD within the RM 51.8–24 study reach is approximately 11,702 ft³ (Table 5.2-2). Extrapolation of the study reach's estimated LWD volume to the entire RM 51.8–0 reach of the lower Tuolumne River would equal about 25,257 ft³ of wood. As reported in Section 5.3.1.5, the 2009–2012 average annual wood volume captured in Don Pedro Reservoir is 38,375 ft³ (Table 5.3-1).

The LWD size frequency distribution between the lower Tuolumne River and Don Pedro Reservoir shows some differences. The percentage of LWD in the smaller (4–16 inch diameter) size classes is somewhat higher in the lower Tuolumne River than in Don Pedro Reservoir (Table 5.4-1 and Figure 5.4-1). This may be due to some of the Don Pedro Reservoir LWD survey areas being previously burned, which removed the small pieces and left the larger logs relatively intact, thus skewing the size frequency toward larger wood.

The percentage of LWD pieces in the largest 16.1–31 in diameter size class, some of which were conifers, in Don Pedro Reservoir is double that observed downstream of La Grange Dam (Table 5.4-1 and Figure 5.4-1). This disparity may be due to the lack of large conifer LWD recruitment to the lower river from interception by Don Pedro Reservoir and the local (i.e. downstream of La Grange Dam) recruitment that is primarily smaller hardwood trees.

Table 5.4-1. LWD size class percentages for the lower Tuolumne River and Don Pedro Reservoir.

Diameter (in)	Length (ft)	Instream Count	Percentage of Instream Total	Reservoir Count	Percentage of Reservoir Total
4–8	3.0–6.5	30	15.0	84	27.5
	6.6–13.0	62	31.0	42	13.8
	13.1–26.0	26	13.0	28	9.2
	26.1–52.0	1	0.5	1	0.3
8.1–16	3.0–6.5	8	4.0	23	7.5
	6.6–13.0	28	14.0	27	8.9
	13.1–26.0	21	10.5	25	8.2
	26.1–52.0	5	2.5	2	0.7
16.1–31	3.0–6.5	0	0.0	12	3.9
	6.6–13.0	4	2.0	19	6.2
	13.1–26.0	11	5.5	24	7.9
	26.1–52.0	4	2.0	18	5.9
Total	--	**200**	**100**	**305**	**100**

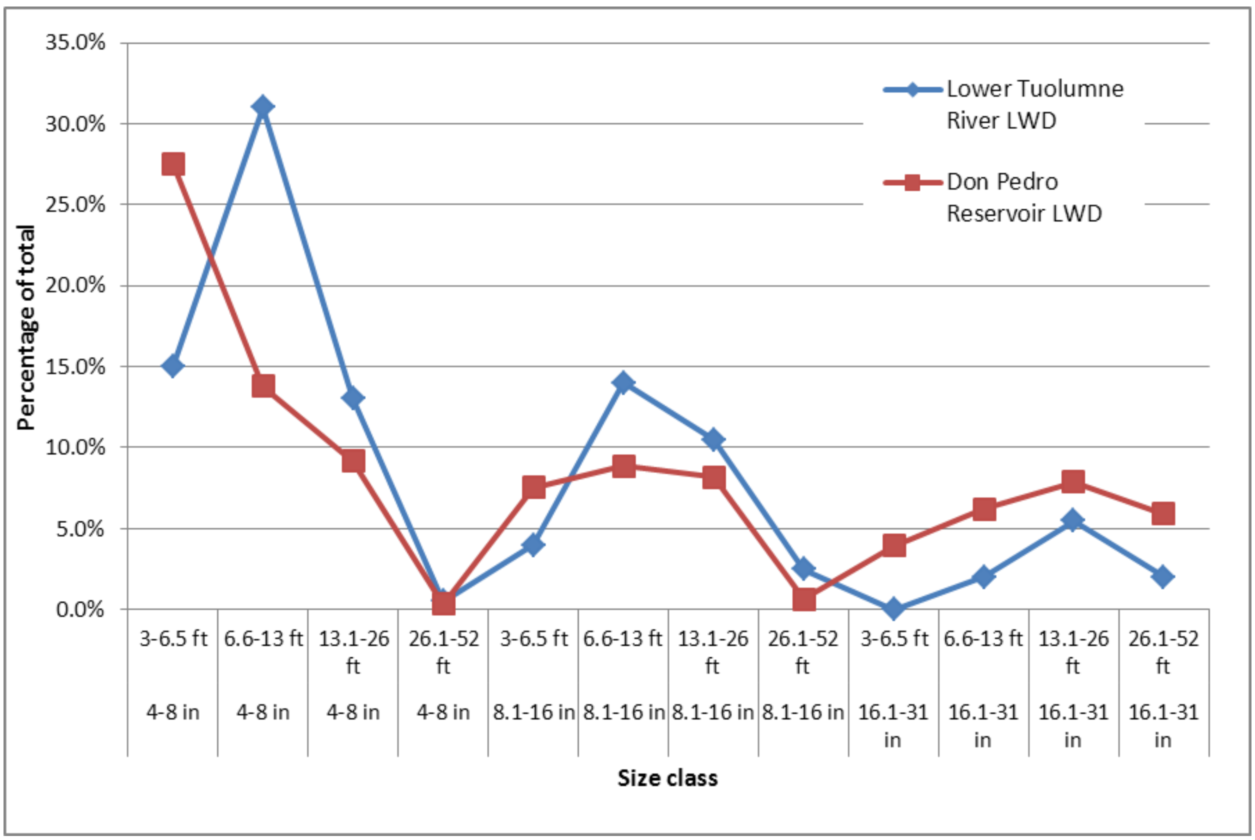

Figure 5.4-1. Comparison of LWD size classes in the lower Tuolumne River and Don Pedro Reservoir.

Due to the location of the Tuolumne River Arm and collection method, it is likely that nearly all of the individual pieces of LWD corralled in rafts by the DPRA in Don Pedro Reservoir were transported from upstream. It is reasonable to assume that, given the piece sizes, a significant portion of this wood would flush through the lower river during high flows if it had the opportunity to move through Don Pedro and La Grange reservoirs and continue into the lower Tuolumne River. However, an undetermined amount of LWD would deposit as single pieces, add to existing wood accumulations, or initiate small jams.

There are no data available to determine the persistence of LWD in the lower Tuolumne River prior to flushing out of the system. However, it is likely that peak flow retention in Don Pedro Reservoir and flow regulation downstream of La Grange Dam results in a greater persistence times for individual pieces of LWD in the lower Tuolumne River than if the system were unregulated. Longer persistence times in the lower Tuolumne River would be due to the dams' ability to lower occurrence and/or magnitude of flow spikes that would mobilize LWD.

6.0 DISCUSSION AND FINDINGS

6.1 Instream Habitat Comparison

The W&AR-12 Study Plan stated that "*The quantity, quality, and use of the lower Tuolumne River by O. mykiss will be discussed in the context of other anadromous salmonid streams. The comparison will identify the occurrence and role of LWD and other habitat attributes in the lower Tuolumne River, and provide a basis for assessing the potential implications on O. mykiss abundance. Comparisons with other Central Valley streams and similar stream systems outside the Central Valley will be made to place LWD function in the lower Tuolumne River in context with other streams of similar stream order, recruitment potential, and sources*." Therefore, the following discussion includes a comparison of the Tuolumne River to another Central Valley stream, as well as a general examination of the role LWD and other habitat attributes (substrate, stream gradient, and channel confinement) have on *O. mykiss* abundance in the lower Tuolumne River.

6.1.1 Comparison of Tuolumne River to Central Valley Streams

The lack of instream habitat typing and LWD inventories for other large, low elevation Central Valley rivers that are relatively similar to the Tuolumne River precludes broad comparative analysis of such information. The Merced River does, however, have some habitat typing and LWD data that was used as a comparison to the lower Tuolumne River reach surveyed for this study.

The Merced River is the next basin to the south of, and is slightly smaller than, the Tuolumne River. The Merced River has a drainage area of 1,726 mi^2 as compared to 1,960 mi^2 for the Tuolumne River. Similar to the Tuolumne River, the Merced River is tributary to the San Joaquin River and extends from the Central Valley floor to the foothills, and into the Southern Sierra Nevada Mountains where it reaches an elevation of 7,919 ft. The Tuolumne River headwaters are at 8,583 ft of elevation. In addition, the lower Merced River is regulated primarily by the New Exchequer Dam (RM 62.5 and 867 ft elevation), but has other dams farther downstream. These include McSwain Dam (RM 56), Merced Falls Dam (RM 55), and Crocker-Huffman Dam (RM 52).

The lower Merced River (RM 0–51.3) was habitat typed via helicopter videography in 2006 by Stillwater Sciences (2008). The reaches described in this report that most closely match the Tuolumne River instream habitat inventory reach are the upper Merced Gravel Mining Reach (RM 39–44.7), Dredger Tailings Reach (RM 44.7–51.3), and Merced Falls Reach (RM 51.3–54.3). Approximately 1.25 miles of the RM 51.3–54.3 Merced Falls Reach (not including the impoundment pool) were included in the analysis because this reach flows through the foothills and may have a slightly higher gradient similar to the first few miles downstream of La Grange Dam. In the Merced River study reaches, riffles comprised 22 percent of the total length, while flatwater and pools made up 41 percent and 37 percent, respectively. The Merced River habitat type lengths were substantially different than the 14 percent, 61 percent, and 25 percent riffle, flatwater, and pool percentages, respectively, found on the lower Tuolumne River.

Similar to the lower Tuolumne River, the lower Merced River has limited LWD. The Stillwater Sciences (2008) study tallied pieces of LWD that were equal to or greater than 0.6 ft in diameter and 3 ft long. A review of the raw unpublished Stillwater Sciences (2008) LWD data showed that the Merced River Gravel Mining, Dredger Tailings, and Merced Falls reaches between RM 39–54.3 contained only 108 pieces of LWD. By contrast, there were a total of 118 LWD pieces in the 16,905 linear ft of the six W&AR-12 habitat typing sample units, which when expanded to the RM 39.5-51.8 study reach, would equal an estimated 453 pieces. This is over four times the amount of LWD within the RM 39-54.3 Merced River reach. Given the difference in LWD loading between the two rivers, it is reasonable to conclude that wood provides a greater degree of habitat function in the Tuolumne River than in the Merced River.

A total of eight *O. mykiss* individuals were observed in the Merced River Dredger Tailings and Merced Falls reaches (Stillwater Sciences 2008). The three Dredger Tailings *O. mykiss* showed no signs of smolting and appeared to be resident fish that had washed over the dam from the Merced Falls Reach (Stillwater Sciences 2008). The five *O. mykiss* within the Merced Falls reach were resident since the downstream Crocker-Huffman Dam does not have the ability to pass fish. By comparison, in 2010, the lower Tuolumne River had an estimated juvenile and adult *O. mykiss* population of 2,405 and 2,139, respectively (Stillwater Sciences 2011). Even though LWD provides habitat for *O. mykiss*, there are no data available for the Tuolumne or Merced rivers that specifically address the role of LWD on this species' abundance.

6.1.2 Role of LWD

In higher order streams, such as the lower Tuolumne River, the role of LWD in habitat formation decreases with increasing channel width. The lower Tuolumne River between RM 51.8 and 26 has channel widths averaging 119 ft. Where LWD dimensions are large relative to the channel width, LWD readily collects within the channel, forming areas of velocity gradation, encouraging localized sediment deposition and scour (McBroom 2010). However, pieces shorter than bankfull width and with a diameter less than bankfull depth are more likely to be transported out of a reach by streamflow (Bilby 1984, Braudrick et al. 1997). Shorter pieces move more easily than longer pieces, as they encounter fewer instream obstructions and have less contact with bank regions, leaving fewer opportunities for pieces to deposit and accumulate (Bilby 1984). Wood that does collect on bars or islands is frequently out of contact with the low-flow channel and may have a limited effect on channel morphology (Keller and Swanson 1979). This is consistent with the W&AR-12 surveyors' observations that LWD had limited effect on channel morphology within the RM 51.8-24 study reach.

Nearly all of the individual pieces of LWD that are collected by the DPRA in the Tuolumne River Arm of Don Pedro Reservoir were transported from upstream. There are no data available to determine how much of the LWD trapped within Don Pedro Reservoir would deposit and persist in the lower Tuolumne River in the absence of the reservoirs. Of the 505 pieces of LWD tallied during this study's instream and reservoir wood inventories, no piece was longer than 52 ft (Tables 5.2-1 and 5.3-2). It is reasonable to assume that, given the piece sizes, a majority of this wood would flush through the lower river during high flows if it was not trapped by Don Pedro Reservoir. However, an undetermined amount of LWD may deposit as single pieces, add to existing wood accumulations, or initiate small jams.

Stillwater Sciences (2011) reported that *O. mykiss* in the lower Tuolumne River were observed primarily in riffle and run body/tail habitats where higher percentages of cobble were reported relative to other substrates associated with those habitat types. Adult fish habitat use was concentrated at upstream sampling units (above RM 45.0), and primarily occurred at transitional run head and pool head habitats. Juvenile fish habitat use showed a similar distribution from upstream to downstream and occurred primarily at riffle habitat types, along with transitional run head and pool head habitat types.

Of the 121 locations within the W&AR-12 study reach where LWD was recorded, 24 (20 percent) were located within or adjacent to riffles (7), run heads (6), or pool heads (11) typically frequented by *O. mykiss*. The rest (80 percent) of the LWD was located within or adjacent to run or pool locations that are typically not preferred habitat for juvenile or adult *O. mykiss*. Approximately 68 percent of the pieces of LWD were equal to or shorter than 13 ft long. Approximately 31 percent of the LWD was in accumulations of between 2 and 8 pieces; the rest were individual pieces. Since the majority of the LWD in the sampling units was either partially or wholly out of the channel and of small size it does not provide significant amounts of cover for *O. mykiss* to utilize, which in turn minimizes its contribution toward protection from avian and aquatic predators. In addition, the relatively low amount of complex LWD in the study reach provides limited high flow cover for *O. mykiss*. Therefore, due to the generally small size, location, and lack of complexity, the majority of the LWD in the study reach is unlikely to provide significant cover and habitat value for *O. mykiss*.

6.1.3 Role of Other Habitat Attributes

6.1.3.1 Non-LWD Instream Shelter

The quantity and quality of instream habitat plays a role in *O. mykiss* abundance in the lower Tuolumne River. Juvenile *O. mykiss* generally prefer riffles, riffle-run transitions, and riffle-pool transition habitats that provided diverse velocity conditions. These *O. mykiss* preferences for fast water and pool/run transition locations were observed in the lower Tuolumne River (Stillwater Sciences 2011). Riffles make up about one-third of the habitat types in the study reach and the transitions between riffles and pools and flatwaters are relatively common. This indicates that, from that basis alone, there is abundant *O. mykiss* habitat in the lower Tuolumne River between RM 51.8 and 39.5. However, as reported in Section 5.1, the amount of instream shelter in the form of boulders, aquatic vegetation, small woody debris, and terrestrial vegetation is very low. Riffles, flatwater, main channel pools, and scour pools had shelter ratings of 10, 31, 49, and 40, respectively (Table 5.1-5).

The amount of instream cover does not necessarily increase proportionately with stream size. For example, a 100-ft wide river with 10 ft of overhanging submerged willow vegetation would have 10 percent of its surface area covered. A smaller 20-ft wide stream with the same submerged vegetation would have 50 percent coverage. Also, the muted peak flows associated with the Project likely results in a greater amount of nearshore overhanging vegetative cover and small woody debris accumulations than if natural peak flows were allowed to periodically scour the low flow channel margins. Therefore, the low level of non-LWD instream cover is likely a function of channel size. The persistence and continued development of overhanging terrestrial vegetation and small woody debris accumulations may be related to flow regime, which would be a beneficial cumulative effect of the Project.

The riffle/pool/flatwater transition locations are interspersed with long (300 to 1,500 ft) flatwater and pool bodies with little cover that support introduced bass species and native pikeminnows, which prey on juvenile salmonids. Pikeminnows, which inhabit pools up to La Grange Dam, are especially efficient predators and are capable of foraging in faster riffle and run habitats at night (Harvey and Nakamoto 1999). Therefore, the implications of relatively low instream shelter is that exposure of *O. mykiss* to predatory pressures would increase, which in turn could affect abundance. However, as stated in the *Salmonid Population Information Integration and Synthesis Report* (W&AR-05), although predation by piscivorous fish species has been identified as a factor potentially limiting the survival and production of juvenile Chinook salmon, no data exist documenting avian or piscine predation of juvenile *O. mykiss*.

6.1.3.2 Substrate

Small and large cobbles and boulders are the dominant substrate elements in 71 percent of the study reach (Table 5.1-6). Although features such as large woody debris jams may provide some value as winter refuge, interstitial spaces in cobble or boulder substrate are the key attribute defining winter habitat suitability for juvenile *O. mykiss* (Hartman 1965, Chapman and Bjornn 1969, Meyer and Griffith 1997). Initial observations from experiments conducted by Redwood Sciences Laboratory and Stillwater Sciences in artificial stream channels indicate that juvenile *O. mykiss* respond to high flows by seeking cover deep within cobble and boulder substrate (Redwood Sciences Laboratory and Stillwater Sciences, unpublished data). Winter hiding behavior of juveniles reduces their metabolism and food requirements and reduces their exposure to predation (Bustard and Narver 1975).

The density of fish that cobble and boulder substrate can support during the winter declines when fine sediments fill the interstitial spaces of the substrate. Reductions in the use of interstitial space by age 0+ steelhead resulting from fine sediment infiltration were observed by Bjornn et al. (1977). Results of preliminary experiments by Redwood Sciences Laboratory and Stillwater Sciences in an artificial stream channel show the effect of coarse substrate embeddedness on the use of interstitial space by age 0+ juvenile steelhead during high (i.e., winter) flows. At flow velocities of 3–4 ft/s, a density of 0.65 fish/ft^2 was observed when cobbles were unembedded (Redwood Sciences Laboratory and Stillwater Sciences, unpublished data). When cobbles were at least 30 percent embedded in sand and finer particles, a lack of sufficient interstitial space precluded use of coarse substrates for refuge by juvenile steelhead.

The Spawning Gravel Report (W&AR-04) reported that the average annual total sediment yields to Don Pedro Reservoir, calculated over the 1923–2011 period, is approximately 373,966 tons yr^{-1} of which approximately 90 percent is or particles that are less than 2 mm in size. The W&AR-4 study also concluded that total volume of discrete fine bed material (<2mm in size) deposits in the reach from La Grange Dam (RM 52.1) to Roberts Ferry Bridge (RM 39.6) decreased by 44 percent from 2001 to 2012. In addition, fine bed material storage in the low flow channel diminished 36 percent from approximately 67,229 yd^3 in 2001 to approximately 42,770 yd^3 in 2012. The Gasburg Creek Fine Sediment Reduction Project, initiated in 2007, has reduced fine sediment deliver to the Tuolumne River from that tributary. Average annual total sediment yields to Don Pedro Reservoir, calculated over the 1923–2011 period, is approximately 373,966 tons yr^{1} of which approximately 90 percent is or particles that are less than 2 mm in size (W&AR-04). This information suggests that the reductions in fine sediment supply due to trapping in Don Pedro Reservoir and lower river storage may result in less embeddedness of cobble and boulder substrates that would be used by *O. mykiss* for high flow winter habitat, thus improving overwinter survival for this species.

7.0 STUDY VARIANCES AND MODIFICATIONS

The objectives of this study were to provide:

- information on habitat distribution, abundance, and quality in the lower Tuolumne River with a focus on *O. mykiss* habitat related to LWD,
- an evaluation in-river factors that may affect the juvenile *O. mykiss* life stage,
- an estimate of the quantities of LWD removed from Don Pedro Reservoir, and
- a comparison of the average annual volume and frequency of LWD removed at Don Pedro Reservoir with the average annual volume and frequency of LWD stored in the lower Tuolumne River.

These objectives have been met with the exception of development of the “average annual” volume and frequency of LWD in the lower Tuolumne River. The study collected data to develop the volume and frequency of LWD in the lower Tuolumne River for a single year (2012). Given the fact that LWD in the lower Tuolumne River is derived only from local riparian sources and not transported from the upper watershed, significant year-to-year changes are unlikely in the absence of a major flood event, and the addition of a second year of data in the same study reach would provide marginal benefit, therefore no additional studies on LWD are recommended.

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