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



Prepared for:
Turlock Irrigation District – Turlock, California
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Oncorhynchus mykiss Habitat Survey
Amended 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 Background

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 has a 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). The Project is designated by the Federal Energy Regulatory Commission (FERC) as project no. 2299.

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. The “water bank” within Don Pedro Reservoir provides significant benefits for CCSF’s 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 aquatic resources in the lower Tuolumne River, and hydropower generation.

The Project Boundary extends from RM 53.2, which is one mile below the Don Pedro powerhouse, upstream to RM 80.8 at an elevation corresponding to the 845 ft contour (31 FPC 510 [1964]). 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) 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.

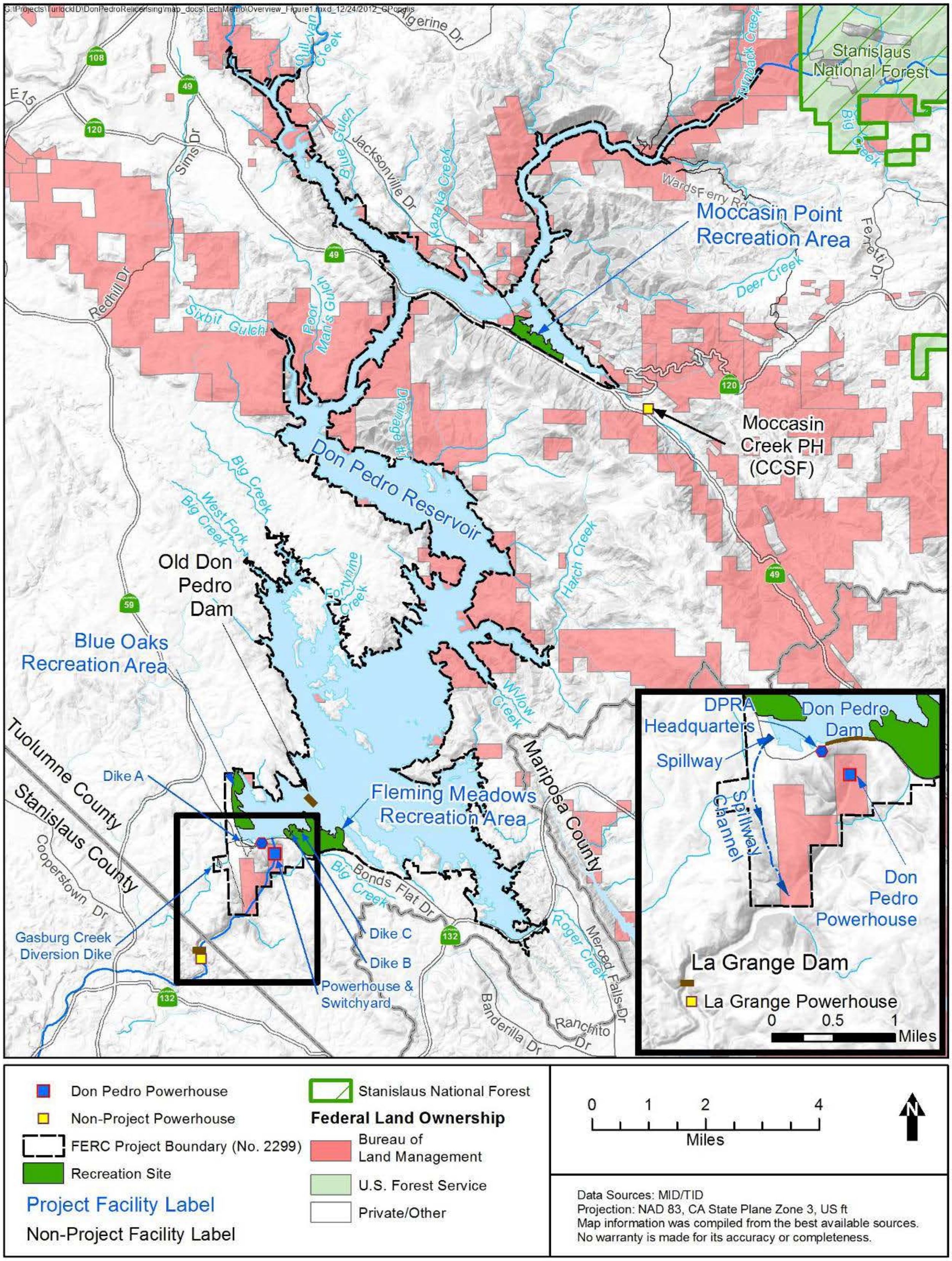

Figure 1.1-1. Don Pedro Project location.

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 (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 Survey 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 Survey 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.

The Districts filed the Initial Study Report (ISR) for the Don Pedro Project on January 17, 2013, which included the Don Pedro W&AR-12: *O. Mykiss* Habitat Survey Study Report. The National Marine Fisheries Service (NMFS), United States Fish and Wildlife Service (USFWS), and a coalition of conservation groups requested that the Districts perform additional analysis and data collection in support of the study goals. On May 21, 2013, FERC issued the Determination on Requests for Study Modifications and New Studies (May 2013 Determination), which recommended that the Districts address several information requests made by the relicensing participants.

This report has been updated to address the May 2013 Determination. FERC recommended that the Districts conduct a second year of LWD survey in 2013 and that the Districts should utilize additional data from LWD surveys conducted from 2005 to 2009. The Districts conducted both the second survey in 2013 and include analysis of available data from 2005 to 2009. This revised study report expands the census of available large wood information to include information from 2005 to 2013; the report explains available data and the aerial imagery analysis methodology used to estimate the large wood volumes in the Don Pedro Reservoir. This updated report also includes additional information regarding comparisons of LWD in other Central Valley streams.

On April 29, 2014, FERC issued its Determination on Requests for Study Modifications for the Don Pedro Hydroelectric Project. In the Determination, FERC required that the Districts perform an additional LWD survey under flows higher than the 2012 survey, as soon as conditions permit. This additional survey was completed in 2016 (Attachment A). The completion of this additional survey did not result in any changes to this study report; an updated results summary table that includes the 2016 survey data is included in Attachment A.

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 Plan Determination (SPD) (FERC 2011), the frequency and volume of LWD trapped and removed from Don Pedro reservoir on an annual basis was evaluated. 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 base maps 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, using the CDFG (2010) protocol, 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 and 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.

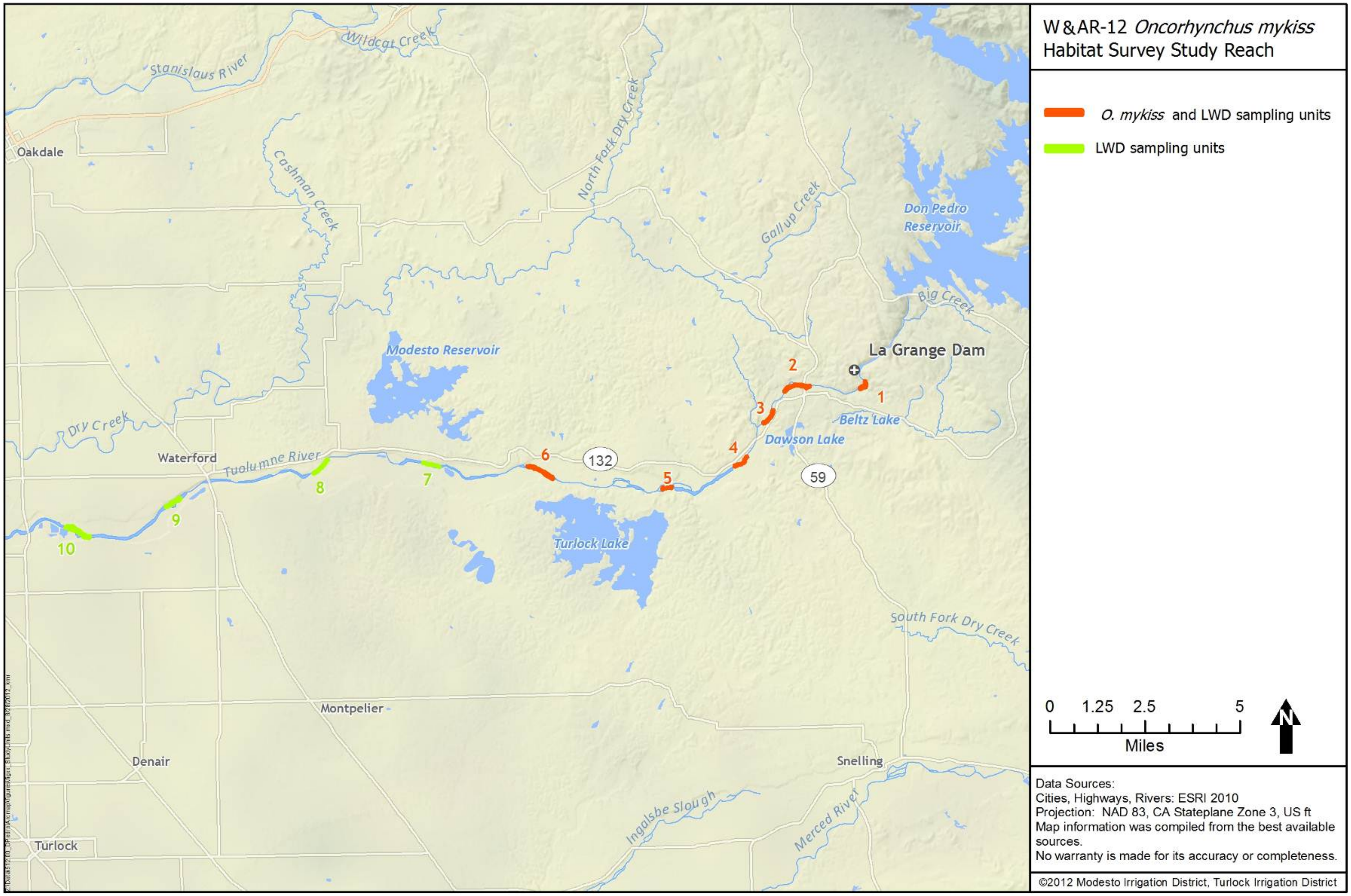

Figure 4.1-1. Habitat and LWD survey reach on the lower Tuolumne River between RM 51.8 and RM 24.

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 was 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: 0 (none), 1 (low), 2 (medium), or 3 (high) according to complexity of the shelter.
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. 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/or burn pile data for the 2005, 2006, 2009, 2010, and 2011seasons, and an oblique photograph of the single small 2012 wood raft from which an inventory of LWD was conducted and volume calculations were generated. Low flows during the springs of 2007, 2008, and 2013 resulted in little or no LWD being transported into the reservoir and no wood rafts were collected (David Jigour, Lake Operations Division Manager, DPRA, pers. comm., August 2013).

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 years 2007, 2008, 2012, and 2013 resulted in *very little* LWD deposition; therefore, no burn piles were constructed. In addition, no burn piles were constructed during 2005 and 2006; all the burnable debris was contained in the wood rafts (David Jigour, Lake Operations Division Manager, DPRA, pers. comm., August 2013). Table 4.1-2 summarizes the data collection methods used between 2005 and 2013, with additional details for each provided in Section 4.1.3.

Table 4.1-2. Summary of data collection methods for reservoir LWD from 2005-2013.

Year	Wood Raft Constructed by DPRA	Burn Pile Constructed by DPRA	Raft Area Estimate Supplied by DPRA[1]	Burn Pile or Raft Area Estimate Revised Using Aerial Imagery[2]
2005	Yes	No	Yes	Yes
2006	Yes	No	Yes	Yes
2007	No	No	Yes	No
2008	No	No	Yes	No
2009	Yes	Yes	Yes	Yes
2010	Yes	Yes	Yes	Yes
2011	Yes	Yes	Yes	Yes[3]
2012	Yes	No	No	No[4]
2013	No	No	Yes	No

[1] DPRA provided wood raft and/or burn pile area estimates for all years except 2012. For 2007, 2008, and 2013, LWD estimates were 0 ft^3.
[2] Aerial photographs were available for 2005, 2006, and 2009, 2010 and 2011; no Google Earth® aerial photographs were available for 2007, 2008, 2012, and 2013.
[3] Stillwater Sciences performed a survey in 2012 of 2011 wood raft remnants and burn piles in order to determine the LWD piece size distribution in Don Pedro Reservoir.
[4] Individual logs were tallied using oblique photograph.

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, as necessary, on an annual basis between 2005 and 2013 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 were 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 annual debris rafts were estimated by the DPRA after the material was beached. These dimensions were multiplied together to develop gross initial estimates 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 2005, 2006, 2009, 2010, and 2011 to develop more accurate area estimates. No Google Earth® photographs were available for 2007, 2008, 2012 or 2013. A planform polygon was delineated that encompassed each wood raft, and the areas were calculated using GIS. The initial 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% pore volume) was applied to the debris raft volumes to adjust for this overestimate.

Water years 2007, 2008, 2012, and 2013 were considered dry years, which experienced relatively small peak flows. No LWD was transported into Don Pedro Reservoir in 2007, 2008, or 2013; therefore, the LWD volumes for those years were zero. During 2012, 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. Note the abundance of small debris in the raft. 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 2009, 2010, and 2011 burn pile data supplied by the DPRA included number of piles, diameters, and heights. No burn piles were gathered from 2005 to 2008, 2012, and 2013 (David Jigour, Lake Operations Division Manager, DPRA, pers. comm., August 2013). 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%) of each burn pile's volume was empty pore space. Therefore, a conservative correction factor of 0.8 (i.e., 20% 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 2005–2011, 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 B). 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% embeddedness), and 13 percent had an embeddedness value of 2 (25–50%). 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 by multiplying assigned shelter value with the total percent of the habitat type covered, as per the CDFG (2010) method. For example, a shelter value of 2 multiplied by 20 percent coverage would equal a rating of 40. The shelter rating is then ranked 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[1]	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

[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).

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

[2] 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 B).

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 is 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. In-river LWD datasheets are provided in Attachment C.

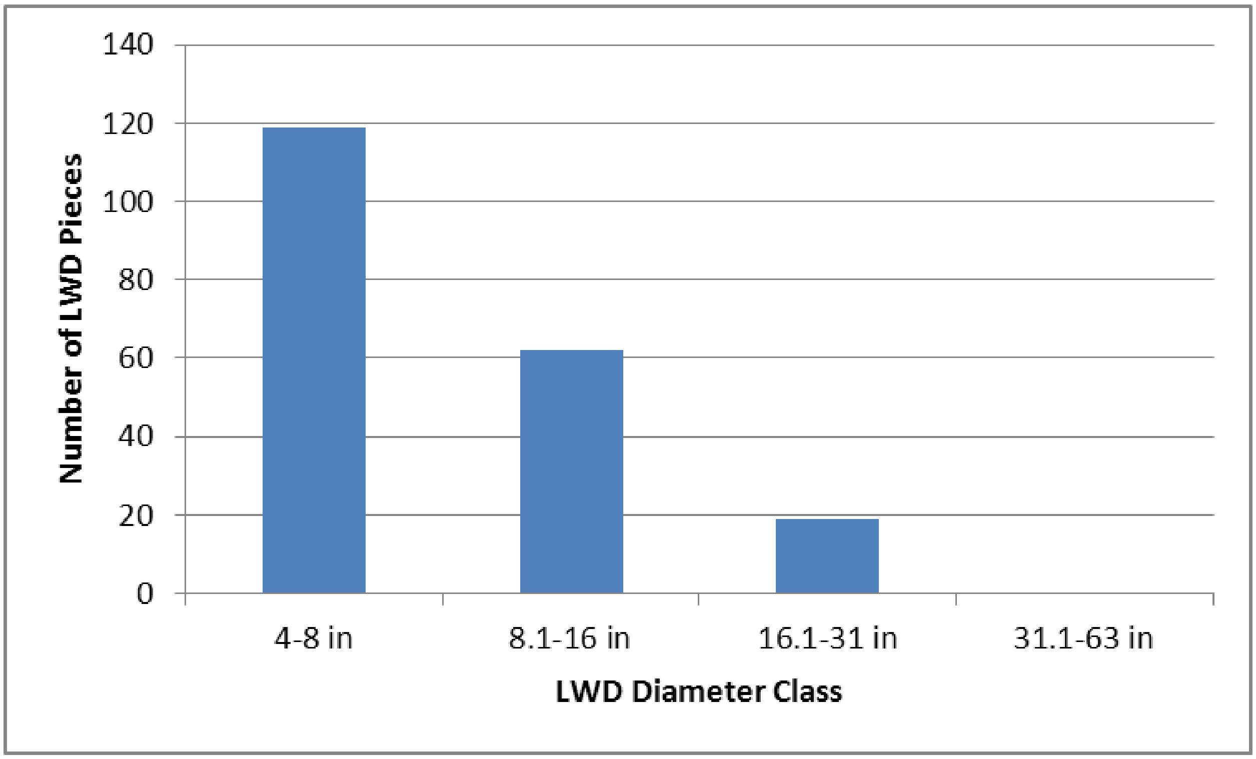

Figure 5.2-1. Number of LWD pieces in the sample units, by diameter class, at the LWD survey sites in the lower Tuolumne River between RM 51.8 and RM 24.

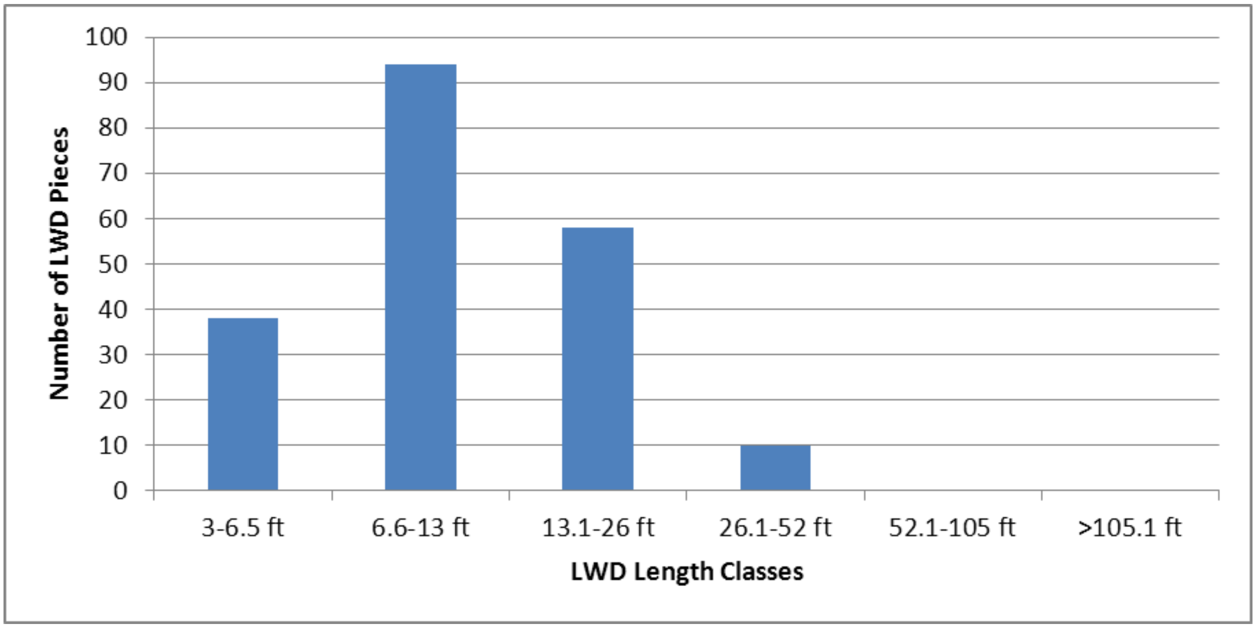

Figure 5.2-2. Number of LWD pieces in the sample units, by length class, at the LWD survey sites in the lower Tuolumne River between RM 51.8 and RM 24.

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 (ft^3)	Size Class Volume (ft^3)
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**

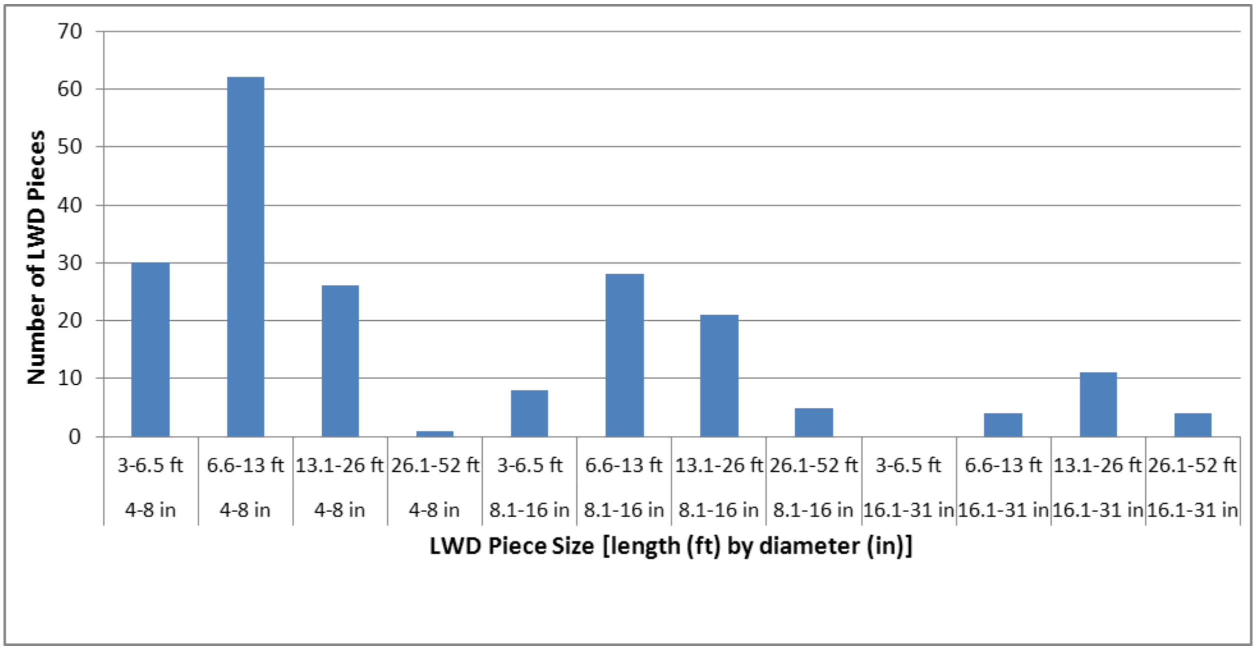

Figure 5.2-3. Number of LWD pieces in the sample units, by combined size classes, at the LWD survey sites in the lower Tuolumne River between RM 51.8 and RM 24.

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%) 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 ft^3 and totaled 262 ft^3. 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 ft^3.

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).

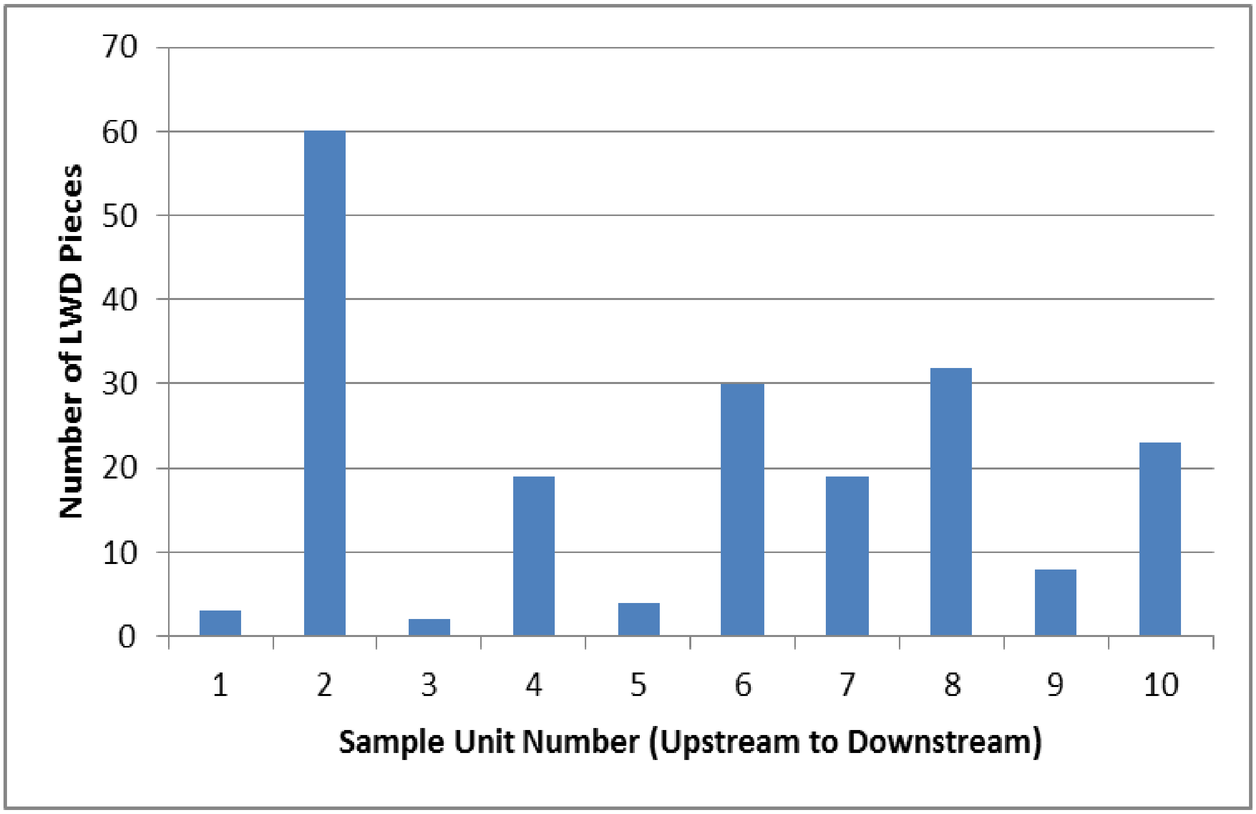

Figure 5.2-4. Number of LWD pieces in each sample unit in an upstream to downstream direction at the LWD survey sites in the lower Tuolumne River between RM 51.8 and RM 24.

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. Due to low spring flows, no LWD was collected by the DPRA in 2007, 2008, and 2013, therefore the volume assigned for these years is 0 ft^3. Available aerial photographs for 2005, 2006, and 2009, 2010 and 2011 are located in Attachment D. No Google Earth® aerial photographs were available for 2007, 2008, 2012, and 2013. A list of Google Earth® kmz file links for the above aerial photographs is located on the public Don Pedro Relicensing website at http://www.donpedro-relicensing.com/default.htm.

5.3.1 Don Pedro Reservoir Wood Volume Estimates

5.3.1.1 2005 Don Pedro Reservoir LWD Volume Estimates

In 2005, the DPRA estimated length, width, and depths of three dried up wood rafts and no burn piles. The DPRA estimated that the three dried up rafts were between 300–500 ft long, 50–60 ft wide, and 3–5 ft deep. A strict summation of the DPRA wood raft dimensions equaled an estimated initial volume of 225,000 ft^3 (Table 5.3-1).

Given the rough nature of the 2005 DPRA wood raft area estimates, Stillwater Sciences conducted a review of the 2005 aerial photographs on Google Earth® to develop more accurate area estimates. A review of the 2005 aerial photographs on Google Earth® showed four rafts with areas ranging from 2,600 to 24,882 ft^2, and totaling 54,876 ft^2. Using the GIS-derived area, DPRA's average individual raft depth of 4 ft, and a pore space factor of 0.8 (i.e., 20% pore space), a revised raft volume of 175,603 ft^3 was estimated.

5.3.1.2 2006 Don Pedro Reservoir LWD Volume Estimates

In 2006, a very wet year, the DPRA estimated length, width, and depths of four dried up wood rafts and no burn piles. The DPRA estimated that the four dried up rafts were between 100–1,000 ft long, 40–200 ft wide, and 3–4 ft deep. A strict summation of the DPRA wood raft dimensions equaled an estimated initial volume of 952,000 ft^3 (Table 5.3-1).

Given the rough nature of the 2006 DPRA wood raft area estimates, Stillwater Sciences conducted a review of the 2006 aerial photographs on Google Earth® to develop more accurate area estimates. A review of the 2006 aerial photographs on Google Earth® showed five rafts with areas ranging from 4,658 to 49,418 ft^2, and totaling 109,910 ft^2. Using the GIS-derived area, DPRA's average individual raft depth of 3.5 ft, and a pore space factor of 0.8, a revised raft volume of 307,748 ft^3 was estimated.

5.3.1.3 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 initial volume of 217,800 ft^3 (Table 5.3-1).

The burn pile dimensions ranged from 10 to 20 ft in diameter and 6 to 8 ft high. The total initial volume for the burn piles was estimated to be 18,876 ft^3. The initial 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, 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.

5.3.1.4 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 initial 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.

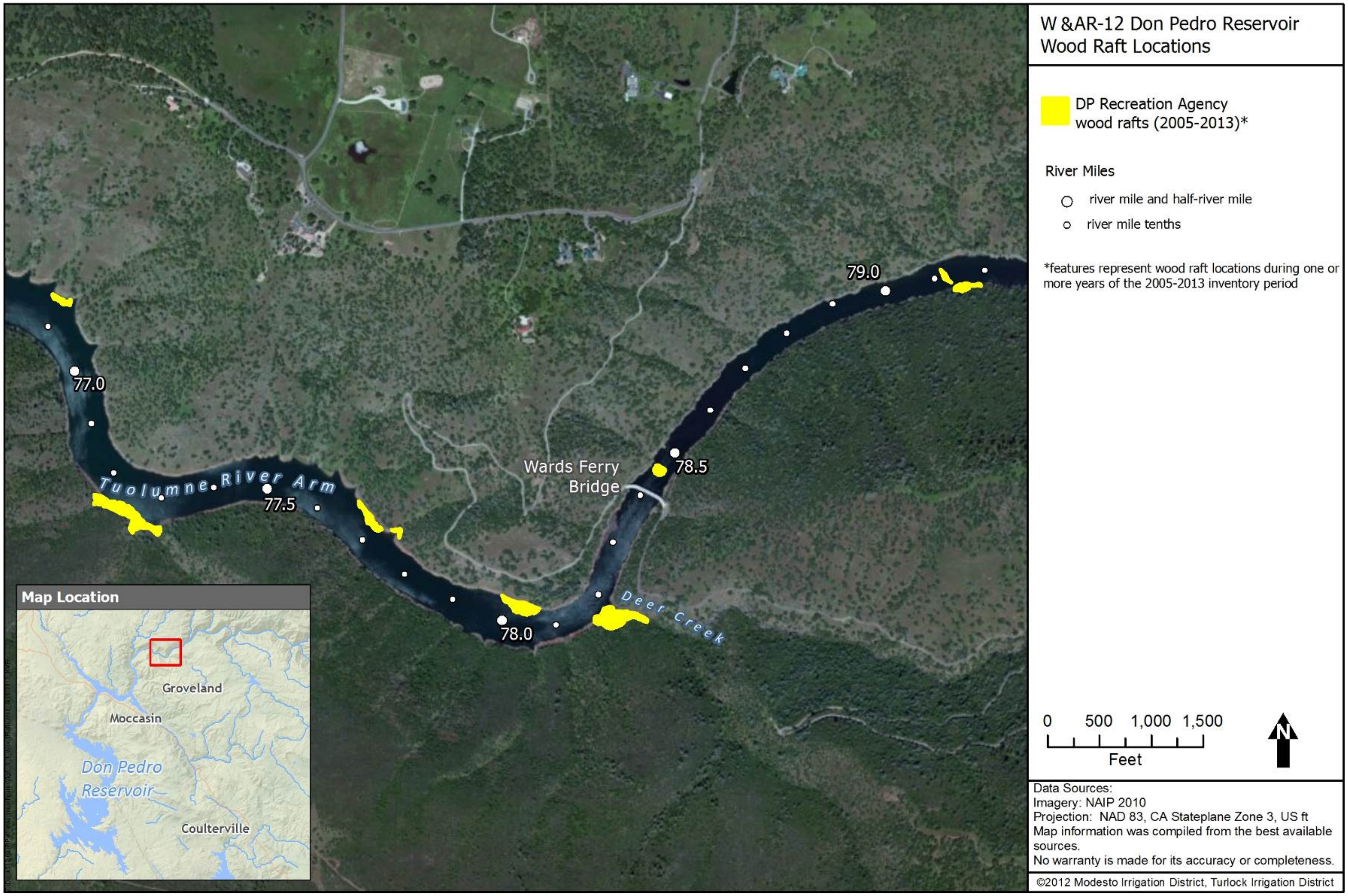

Figure 5.3-1. 2005-2013 Don Pedro Reservoir wood raft locations.

5.3.1.5 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 two 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 initial 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 two 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.

5.3.1.6 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.

5.3.1.7 Average Annual Don Pedro Reservoir LWD Volume Estimate

The revised 2005–2013 average annual LWD volume estimate captured in Don Pedro Reservoir is 70,761 ft^3 (Table 5.3-1). This is considered a conservative estimate since a large percentage of the wood pieces in the rafts and burn piles are smaller than the minimum LWD size criteria as can be seen in Figures 4.1-2 and 4.1-4.

It is apparent that the volume of LWD delivered to Don Pedro Reservoir is correlated to the flow magnitude in the spring and the amount of time instream wood has an opportunity to accumulate on river banks between high runoff events. In general, the higher the peak flow during the spring snowmelt, the more wood is mobilized from higher up the banks of the river and delivered to the reservoir. Figure 5.3-2 shows the maximum average daily flow exceedance curve for inflow into Don Pedro Reservoir from the Tuolumne River for the 1994 to 2013 period of record (DWR 2013). LWD delivery to Don Pedro Reservoir ceases once the maximum average daily flow drops below 6,000 cfs (Table 5.3.1 and Figure 5.3-2).

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

Year	Maximum Daily Mean Flow (cfs)	Initial Wood Raft Volumes (ft³)[a]	Initial Burn Pile Volumes (ft³)[a]	Revised Wood Raft Volumes (ft³)	Revised Burn Pile Volumes (ft³)
2005	17,426	225,000	0	175,603	0
2006	31,325	952,000	0	307,748	0
2007	4,699	0	0	0	0
2008	5,922	0	0	0	0
2009	12,847	217,800	18,876	65,420	15,101
2010	11,888	32,670	7,223	14,692	5,788
2011	22,275	54,000	13,778	41,458	11,022
2012	6,179	0	0	17	0
2013	3,386	0	0	0	0
Average	--	164,608	4,431	67,215	3,546
Average Annual	**--**	**169,039**		**70,761**	

[a] From uncorrected DPRA data.

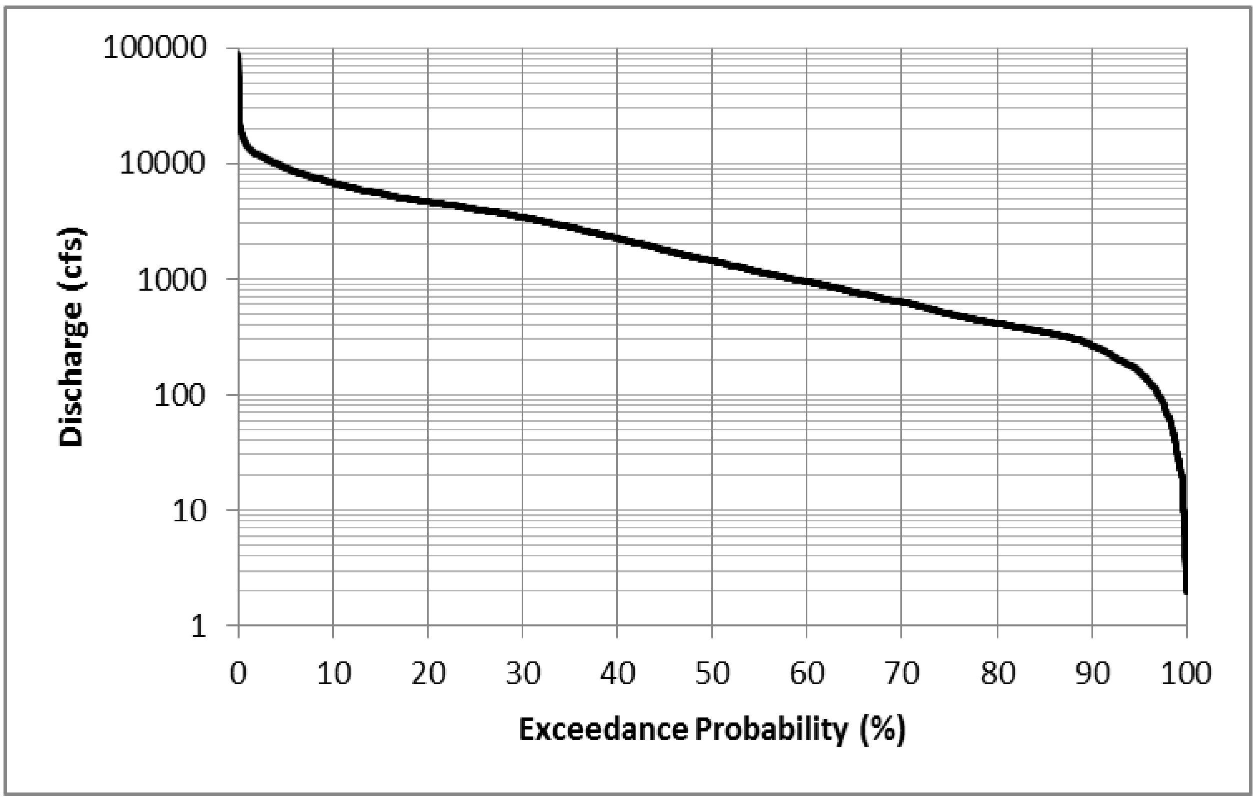

Figure 5.3-2. Flow exceedance probability for inflow to Don Pedro Reservoir (DWR 2013).

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 5.3-3 and 5.3-4). 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.

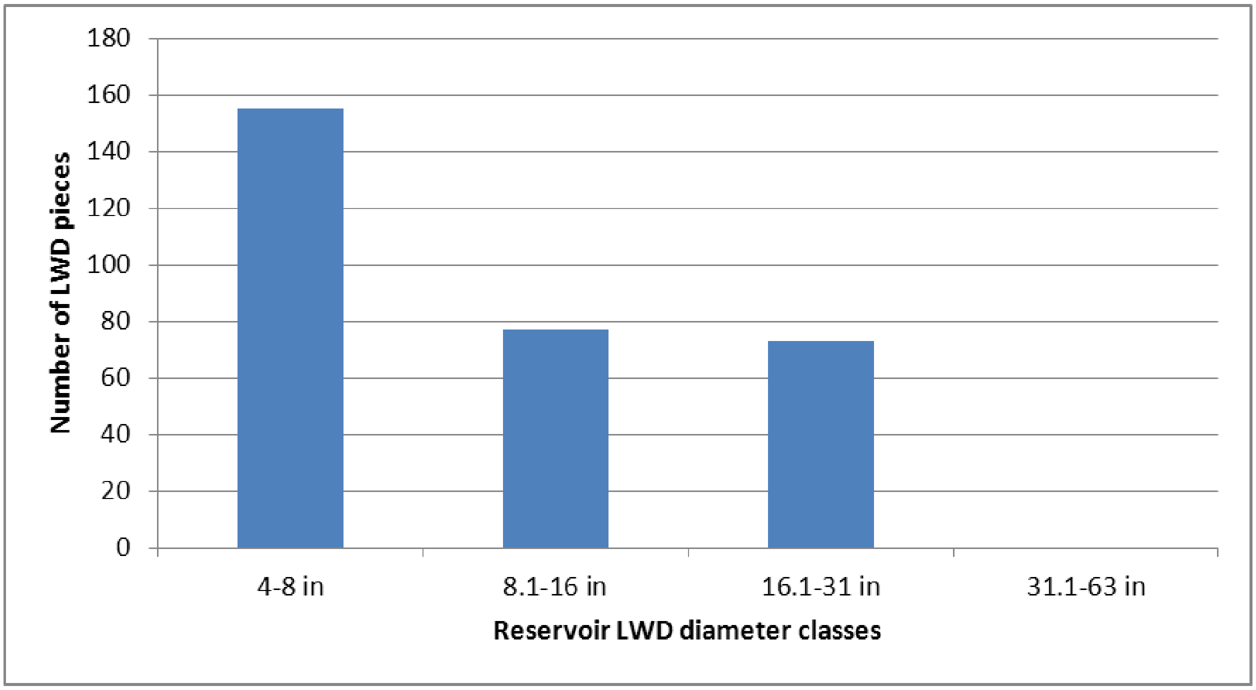

Figure 5.3-3. Number of Don Pedro Reservoir LWD pieces by diameter class in 2011 burn piles.

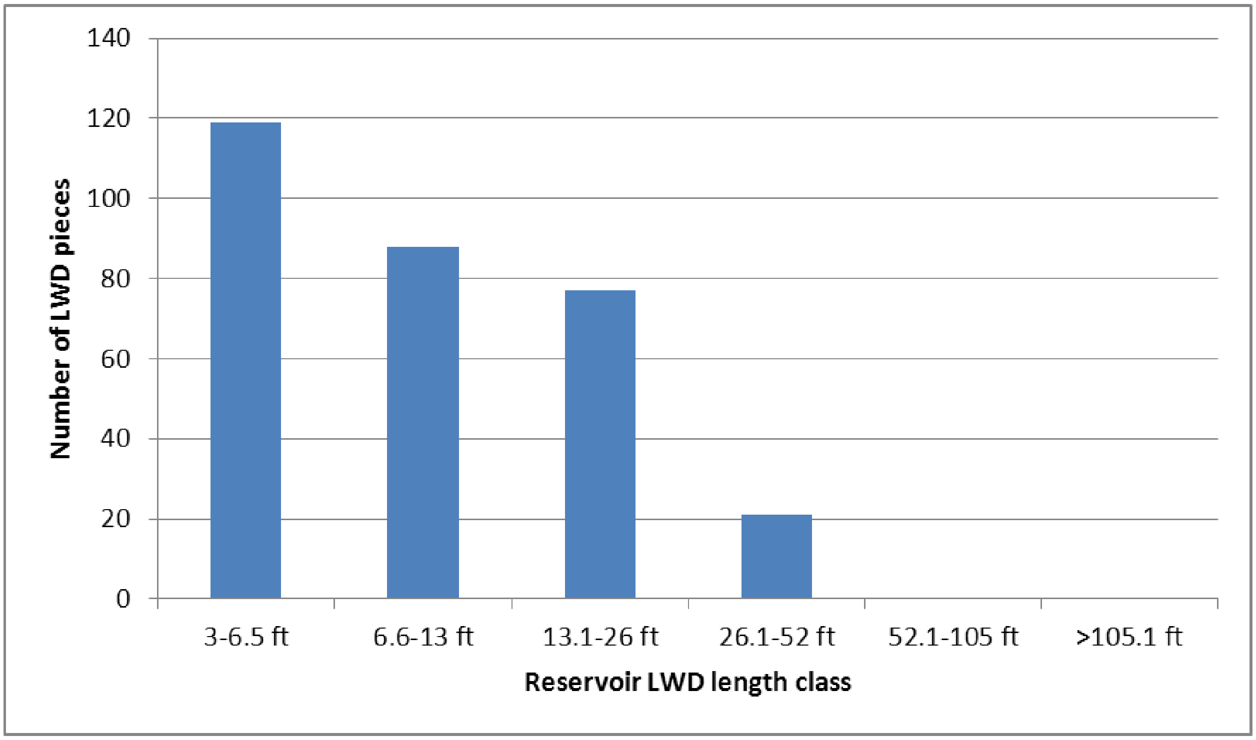

Figure 5.3-4. Number of Don Pedro Reservoir LWD pieces by length class in 2011 burn piles.

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 ft^3 (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 ft^3 of wood. As reported in Section 5.3.1.5, the 2005–2013 average annual wood volume captured in Don Pedro Reservoir is 70,761 ft^3 (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**

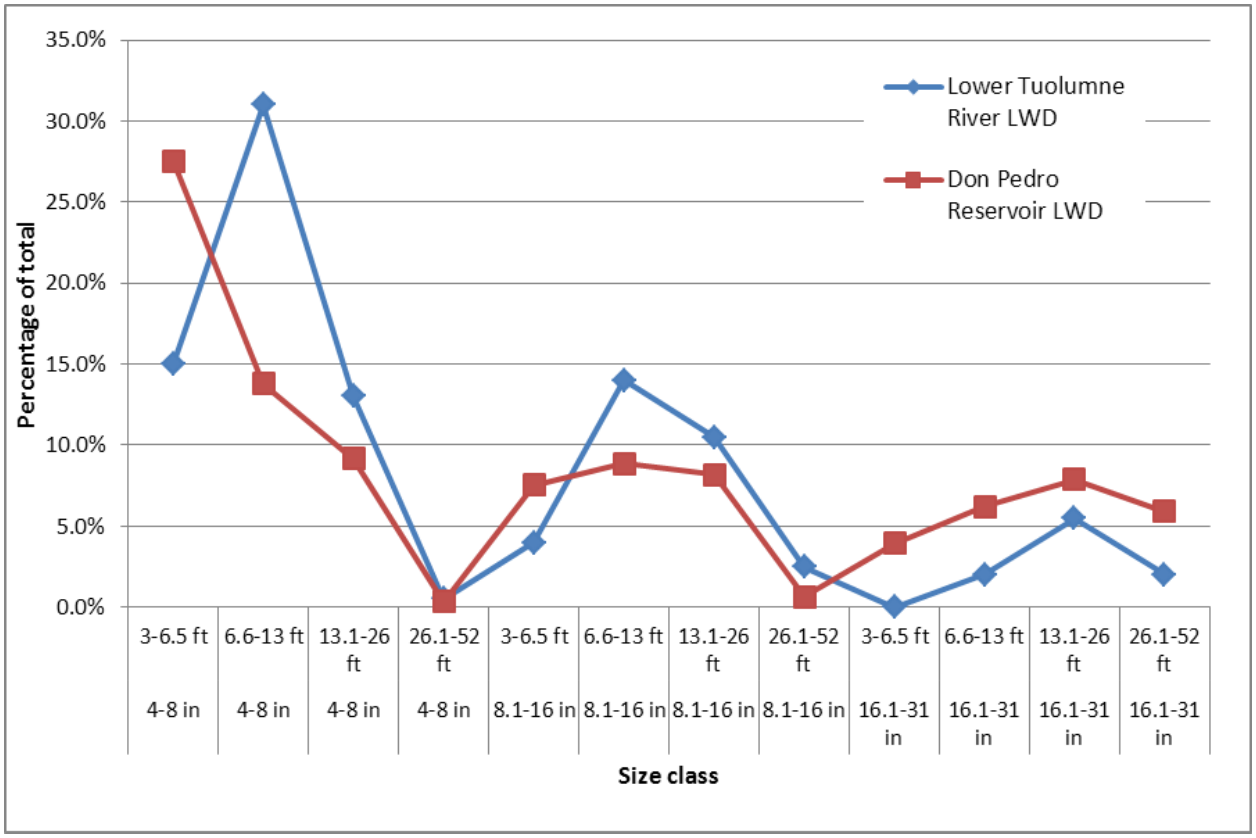

Figure 5.4-1. Comparison of LWD size classes in the lower Tuolumne River and Don Pedro Reservoir.

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

As stated in the May 2013 Determination, the goal of this study element was to assess the quantity, quality, and use of the lower Tuolumne River by *O. mykiss* as compared to other salmonid streams, and to specifically identify the occurrence and role of LWD and other habitat attributes in the lower Tuolumne River compared with other Central Valley streams and streams outside of the Central Valley of similar size and LWD characteristics.

The May 2013 Determination recommended that, in addition to the Merced River comparison, the Districts perform at least one additional comparative analysis utilizing the Yakima River, a stream outside the Central Valley, and at least one additional comparative analysis utilizing the Mokelumne River, a stream within the Central Valley. There is a general scarcity of instream habitat typing and LWD inventories for other low elevation Central Valley rivers that are relatively similar to the Tuolumne River. Information was available for the Merced and Mokelumne rivers, which are compared below to the lower Tuolumne River reach surveyed for this study. However, an extensive search to acquire LWD information for the Yakima River was unsuccessful, as explained below.

6.1.1.1 Merced River

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 mi² as compared to 1,960 mi² 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.

6.1.1.2 Mokelumne River

An instream habitat type and LWD inventory was conducted by Senter and Pasternack (2010) as part of a Chinook salmon spawning and large wood study on a 4.8-mile reach of the Mokelumne River located just downstream of Camanche Dam. The study found that riffles comprised approximately 15 percent of the total study reach length, while flatwater and pools made up 46 percent and 39 percent, respectively (Table 6.1-1). The Mokelumne River habitat type percentages were substantially different than the 14 percent, 61 percent, and 25 percent riffle, flatwater, and pool percentages, respectively, found on the lower Tuolumne River (Table 6.1-1). The reasons for the differences in habitat type percentages is unknown, but could be related to differences between the two rivers in drainage area, channel confinement and bed characteristics, slope, flow, and other factors.

The Mokelumne River LWD inventory recorded 527 pieces of LWD that were greater than 3 ft in length and 4 inches in diameter (Senter and Pasternack 2010). This corresponds to 110 pieces of LWD per mile of river (Table 6.1-1). The average piece length and diameter was 23 ± 13 ft and 9 ± 5 inches (Senter and Pasternack 2010), respectively, with maximum length 89 ft and diameter 61 inches. Senter and Pasternack (2010) estimated a total volume of 18,268 ft^3 for the 527 total LWD pieces in their study reach.

The W&AR-12 study surveyed a total of 5.4 miles of the lower Tuolumne River downstream of La Grange Dam and found fewer and smaller LWD pieces than Senter and Pasternack (2010) recorded on the Mokelumne River (Table 6.1-1). The Tuolumne River LWD piece volume range was significantly less than that found on the Mokelumne River. However, it should be noted that Senter and Pasternack (2010) included the trunk, all limbs, and branches of a tree when calculating the volume of LWD. The W&AR-12 study calculated only that portion of LWD that initially met the inventory criteria, not additional limbs or branches, which makes for a more conservative (smaller) volume. Even with this consideration, it is likely that the Mokelumne River LWD piece size volumes were likely greater than those found on the lower Tuolumne River. This observation is consistent with the fact that the study area for the Mokelumne River is generally narrower than the Tuolumne River, with little in-channel mining influence or dredge tailings on the banks, leading to a denser canopy and more streamside woody riparian vegetation that can be recruited into the river.

Table 6.1-1. LWD and habitat type characteristics of the Mokelumne and Tuolumne rivers.

River	Number of LWD Pieces	Pieces Per Mile	Piece Volume Range (ft^3)	Total Survey Volume (ft^3)	Percentage of Riffles	Percentage of Flatwaters	Percentage of Pools
Mokelumne	527	110	0.7-954	18,268	15	46	39
Tuolumne	200	37	0.9-118.1	2,218	14	61	25

6.1.1.3 Yakima River

A significant amount of effort was expended in an attempt to acquire LWD data for the Yakima River. This effort included an extensive search of on-line publications and websites, as well as contacting the NMFS and USFWS participants in the Don Pedro relicensing. No quantitative LWD data for the Yakima River was found during the search. In addition, no information was found regarding instream pool, riffle, or flatwater percentages. However, general descriptors (abundant to non-existent) for LWD resources were available in the Yakima Basin Watershed Assessment (EES 2001).

The Yakima River originates at the outlet of Lake Keechelus near the crest of the Cascade Mountains in southeastern Washington and flows 214 miles in a generally southeasterly direction to its confluence with the Columbia River (EES 2001). With its tributaries, the Yakima River drains approximately 6,150 square miles (4 million acres). Within Yakima County, the Yakima River flows through three valleys: Selah Valley, Moxee Valley, and Yakima Valley. Water development in the basin began in the 1800s and today the basin is a complex system of storage reservoirs, mainstem dams and smaller diversions, hydropower facilities and over 3,200 km (2,000 miles) of conveyance canals (EES 2001).

The watershed assessment segmented the mainstem Yakima River into six reaches in which a number of physical characteristics were described. The watershed assessment described LWD loads in the six reaches as ranging from "abundant" in the conifer-dominated forested reach just below Lake Keechelus to "non-existent, rare, or deficient" in all of the other reaches downstream of the lake (EES 2001).

6.1.2 Role of LWD

Instream wood influences stream morphology and channel form (Bilby and Ward 1989, Spence et al. 1996), creating structural heterogeneity and thus fish habitat via pools, back eddies, side channels, alcoves, and increased channel sinuosity (Bisson et al. 1987, Spence et al. 1996). In addition to contributing to geomorphic processes, instream LWD also provides a variety of fish habitat functions including, but not limited to, cover to facilitate summer and winter rearing for juvenile salmonids, protection from predators, partitioning redd territories for spawning salmonids, and production of food resources (Everest and Chapman 1972; Bilby 1984; Bjornn and Reiser 1991; Booth and Fox 2004).

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). Compared to smaller streams, Bilby and Bisson (1998) observed that wood has less effect on channel form in larger streams. 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%) were located within or adjacent to riffles (7), run heads (6), or pool heads (11) typically frequented by *O. mykiss*. The rest (80%) 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-04 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. 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 of LWD in the lower Tuolumne River are recommended.

The May 2013 Determination recommended that, in addition to the Merced River comparison, the Districts perform at least one additional comparative analysis of LWD utilizing data from the Yakima River. A significant amount of effort was expended in an attempt to acquire LWD data for the Yakima River. This effort included an extensive search of on-line publications and websites as well as contacting the NMFS and USFWS representatives participating in the relicensing process. No quantitative LWD data for the Yakima River was found during the search, and therefore, no quantitative comparison with the lower Tuolumne River was conducted.

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STUDY REPORT W&AR-12
ONCORHYNCHUS MYKISS HABITAT SURVEY

ATTACHMENT A

2016 LARGE WOODY DEBRIS INVENTORY

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1.0 INTRODUCTION

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 current Federal Energy Regulatory Commission (FERC) license for the Project expires on April 30, 2016, and the Districts applied for a new license on 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). On December 22, 2011, FERC issued its Study Plan Determination (SPD) for the Project. In the 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 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.

In compliance with the FERC SPD, the Districts developed an *Oncorhynchus mykiss* habitat study (TID/MID 2013) that assessed instream habitat for rainbow trout and developed a basic large woody debris (LWD) budget. The study included several years of LWD data collected by the Don Pedro Recreation Agency (DPRA) and one focused inventory performed by the Districts. In its determination for study modifications following the Updated Study Report (April 29, 2014), FERC required the Districts to conduct a second focused survey of LWD in Don Pedro Reservoir during the dry season following the first winter when the Tuolumne River flows exceeded a peak of 6,000 cubic feet per second (cfs) at the Wards Ferry Bridge (USGS gage 11285500). Flows exceeded that level[1] on March 6, 2016 when discharge peaked at 20,500 cfs (USGS 2016). Therefore, a LWD inventory was conducted on November 2, 2016 to augment the previous dataset and analysis contained in TID/MID (2013). The 2016 LWD inventory followed the same survey protocol contained in TID/MID (2013).

The purpose of this addendum to TID/MID (2013) is to report the results of the 2016 LWD inventory, add to the existing dataset, and revise the LWD budget.

[1] Provisional USGS gaging data that was queried during the spring of 2015 indicated a peak flow of less than 6,000 cfs. However, gaging data that were corrected at a later date indicated a flow of 6,900 cfs.

2.0 METHODS

Please see TID/MID (2013) for a detailed description of the LWD inventory and analysis methods.

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 tows the material to preferred beach locations. As the reservoir water levels drop, the rafts become beached and dry out. The DPRA also collects individual pieces of wood and constructs burn piles at those same locations. 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 estimates the dimensions of the rafts and piles that they plan on burning each year. This information is also supplied to the Districts to assist in the wood budget determination.

A focused 2016 LWD inventory was conducted by the Districts on November 2, 2016. As described in the TID/MID (2013) methods section, Don Pedro Reservoir study sites were selected by identifying the locations along the reservoir shoreline where the DPRA beached the floating wood rafts and constructed burn piles. The Districts used measuring tapes and GPS-registered aerial photographs to collect dimensional data for each wood accumulation. The aerial photographs were then “stitched” together into a composite photo using GIS to develop precise estimates of wood accumulation area. The average height of each raft and pile, collected during the inventory, was then multiplied by the LWD accumulation area to develop wood volume estimates.

A second study component, an individual LWD piece inventory, was conducted on November 2, 2016 and consisted of inventorying 522 individual pieces of wood (in rafts, burn piles, or scattered on the ground) that corresponded to the size categories described in Montgomery (2008). Those data were then entered into Microsoft Excel® spreadsheet from which wood volume estimates, size class distribution tables, and figures were developed.

3.0 RESULTS

3.1 Raft and Burn Pile Volume Estimates

In 2016, the DPRA estimated the dimensions of three dried up wood rafts and eight burn piles (DPRA 2016). These dimensions yielded a gross area estimate of 36,000 square feet (ft^2) and a depth of 4 feet (ft). A strict calculation of the DPRA wood raft dimensions yielded a volume of 144,000 cubic feet (ft^3). The DPRA estimated that the eight cone-shaped burn piles were each 15 ft in diameter and 5 ft high. The total volume for the burn piles was estimated to be 2,356 ft^3. Therefore, the estimated total gross volume of wood accumulated in the rafts and burn piles, using only the DPRA-recorded dimensions, was 146,356 ft^3. This estimate was of sufficient accuracy for the purposes of DPRA's air quality permit application.

For the purposes of the Project's relicensing analysis, a more accurate accounting of LWD within the Don Pedro Reservoir was necessary. Therefore, the Districts conducted a more intensive LWD survey of the wood collection areas in 2016 (Figure 3.1-1), at which time GPS-registered aerial photographs of each raft were taken to develop more precise area estimates. The results of the 2016 survey were then compared to those reported in TID/MID (2013) and used to estimate the average annual volume of LWD being transported down the Tuolumne River and delivered to the Don Pedro Reservoir (Table 3.1-1).

The survey showed that four rafts were present (Figure 3.1-2 and Figure 3.1-3), which had a total area of 35,527 ft^2. Using the 1–3 ft average depths recorded during the survey, the total volume of the rafts was estimated to be 92,631 ft^3. After applying a pore space correction factor of 0.8 (i.e., 20 percent pore space) as described in TID/MID (2013), the revised volume estimate for rafted wood captured during 2016 in Don Pedro Reservoir was approximately 74,105 ft^3.

A total of 10 burn piles were inventoried during the LWD survey (Figure 3.1-4). These 10 piles had a gross volume of 4,554 ft^3. After applying a pore space correction factor of 0.8, the revised burn pile volume estimate was 3,643 ft^3. Thus, the revised 2016 wood volume (rafts and burn piles) captured in Don Pedro Reservoir was 77,748 ft^3.

It should be noted that the estimated volumes of LWD in the rafts and burn piles are very conservative. A review of Figure 3.1-4 showed that a significant number of pieces of wood in the piles and rafts were smaller than the minimum size (4 inches in diameter and 3 ft in length) necessary to be considered LWD. However, these small pieces were still considered in the total LWD volume calculation.

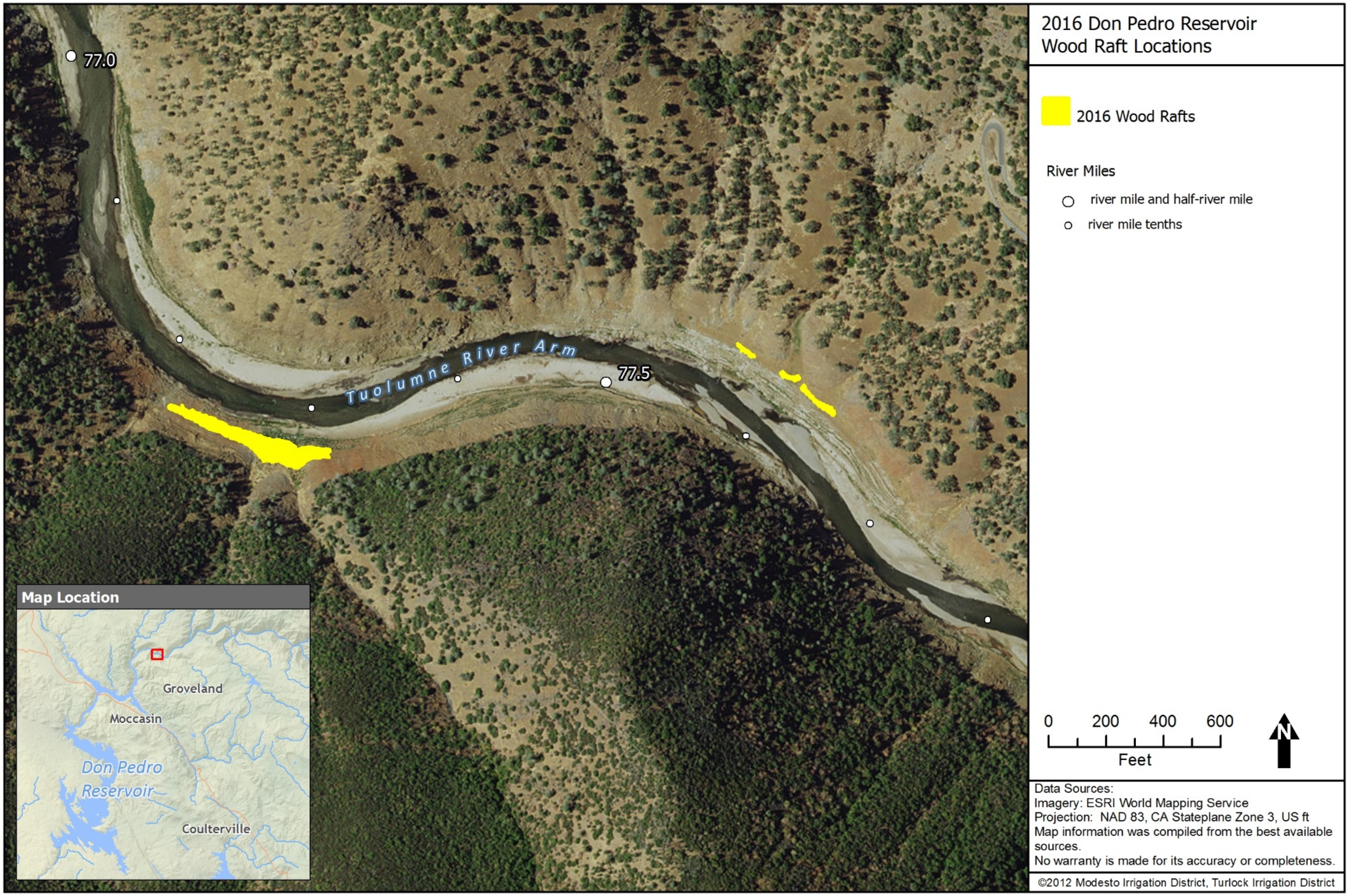

Figure 3.1-1. Locations of 2016 LWD rafts in the Tuolumne River Arm of Don Pedro Reservoir.

Figure 3.1-2. **Three beached LWD rafts and associated burn piles.**

Figure 3.1-3. **Beached 750-ft long LWD raft. Note brown vegetative growth within the raft.**

Figure 3.1-4. **Burn pile (see center of Figure 3.1-2). Note large amount of small wood with the blue phone on log used for scale.**

Table 3.1-1. **DPRA-generated, revised, and average annual LWD volume estimated for woody debris captured in Don Pedro Reservoir.**

Year	Maximum daily mean flow (cfs)	DPRA wood raft volumes (ft^3)[1]	DPRA burn pile volumes (ft^3)[1]	Revised wood raft volumes (ft^3)	Revised burn pile volumes (ft^3)
2005	17,426	225,000	0	175,603	0
2006	31,325	952,000	0	307,748	0
2007	4,699	0	0	0	0
2008	5,922	0	0	0	0
2009	12,847	217,800	18,876	65,420	15,101
2010	11,888	32,670	7,223	14,692	5,788
2011	22,275	54,000	13,778	41,458	11,022
2012	6,179	0	0	17	0
2013	3,386	0	0	0	0
2014	2,900	0	0	0	0
2015	6,900[3]	0	0	0	0
2016	20,500	144,000	2,356	74,105[2]	3,643[2]
Average by type		135,456	3,519	56,587	2,963
Total Average Annual		**138,975**		**59,550**	

[1] From uncorrected DPRA length, width, and depth estimates.
[2] Data collected during survey on 2 November 2016.
[3] Corrected data; provisional gaging data during the spring of 2015 indicated a peak flow of less than 6,000 cfs.

3.2 Individual LWD Piece Size and Volume Estimates

As stated above, the Districts inventoried individual pieces of wood to develop an understanding of the piece size distribution being delivered to the reservoir by the Tuolumne River. A total of 522 individual pieces of LWD were inventoried during the 2016 reservoir survey effort. A significant portion of the inventoried LWD consisted of partially burned remnants that had washed into the upper river following the Rim Fire (DPRA 2016). In addition, the inventory results included an unknown number of previously waterlogged pieces of wood from the reservoir that had dried out during four years of drought (DPRA 2016). Although these pieces were transported into Don Pedro Reservoir prior to 2016, they were included in the totals to provide a conservative estimate of wood transported during the winter and spring of 2016. The combined (diameter by length) size class data are shown in Table 3.2-1. Of the 522 pieces, most were less than 8 inches in diameter and 13 ft long (Table 3.2-1). No LWD in the 52.1–105 ft and >105 ft length classes were observed.

The mean piece volume for each of the combined size classes ranged from 0.9 to 236.1 ft^3 (Table 3.2-1). The total volume of LWD for each of the combined size classes ranged from 61 to 944 ft^3 (Table 3.2-1). The total volume of LWD recorded during the reservoir inventory was 4,325 ft^3. The individual piece and combined size class volumes from the burn piles were not included in the 2016 raft and burn pile volume estimates (Table 3.1-1) because that would have been double counting the survey data.

Table 3.2-1. Number, mean piece volume, and total volume per reservoir LWD size class of 2016 burn piles, remnant log booms, and individual pieces.

Diameter (in)	Length (ft)	Number	Piece Percentage of Total	Mean Piece Volume (ft^3)	Size Class Volume (ft^3)
4–8	3–6.5	148	28.4%	0.9	138
4–8	6.6–13	89	17.0%	1.9	171
4–8	13.1–26	20	3.8%	3.8	76
4–8	26.1–52	0	0.0%	7.7	0
8.1–16	3–6.5	104	19.9%	3.8	391
8.1–16	6.6–13	63	12.1%	7.8	488
8.1–16	13.1–26	25	4.8%	15.5	387
8.1–16	26.1–52	2	0.4%	30.9	61
16.1–31	3–6.5	30	5.7%	14.4	431
16.1–31	6.6–13	24	4.6%	29.6	711
16.1–31	13.1–26	10	1.9%	59.1	591
16.1–31	26.1–52	0	0.0%	0	0
31.1–63	3–6.5	3	0.6%	57.4	172
31.1–63	6.6–13	2	0.4%	118.4	355
31.1–63	13.1–26	2	0.4%	236.1	944
31.1–63	26.1–52	0	0.0%	0	0
Total	**--**	**522**	**100%**	**--**	**4,325**

4.0 DISCUSSION

There was very little LWD transported down the Tuolumne River into Don Pedro Reservoir during 2012–2015 period. This was due to very low spring runoff conditions resulting from the drought that reduced the Sierra snowpack. The low flows also resulted in a dramatic decrease in water levels in Don Pedro Reservoir, which exposed and dried out many pieces of previously submerged and waterlogged pieces of LWD. The increase in reservoir water levels during the winter and spring of 2016 refloated much of this exposed LWD, an unknown number of which were subsequently captured by the DPRA along with the wood that was transported from upstream reaches of the Tuolumne River.

The transport of LWD in the Tuolumne River and delivery to Don Pedro Reservoir is episodic and correlated with winter snowpack and subsequent spring runoff (Table 3.1-1). Little wood is transported in low-flow years. This wood then accumulates along the river's banks as the result of a variety of delivery mechanisms (normal tree fall, shallow or deep seated landslides, bank erosion, fire, etc.). This accumulated material is then carried downstream during the next year that experiences high winter/spring flows, which reduces the amount of LWD in storage along the river's banks.

Similar to what was reported in TID/MID (2013), the LWD size distribution recorded during the 2016 inventory is heavily weighted toward the smaller diameter and length size classes (Figure 3.2-1). Of the 522 pieces of LWD inventoried, only seven were in the greater than the 31-inch diameter size class.

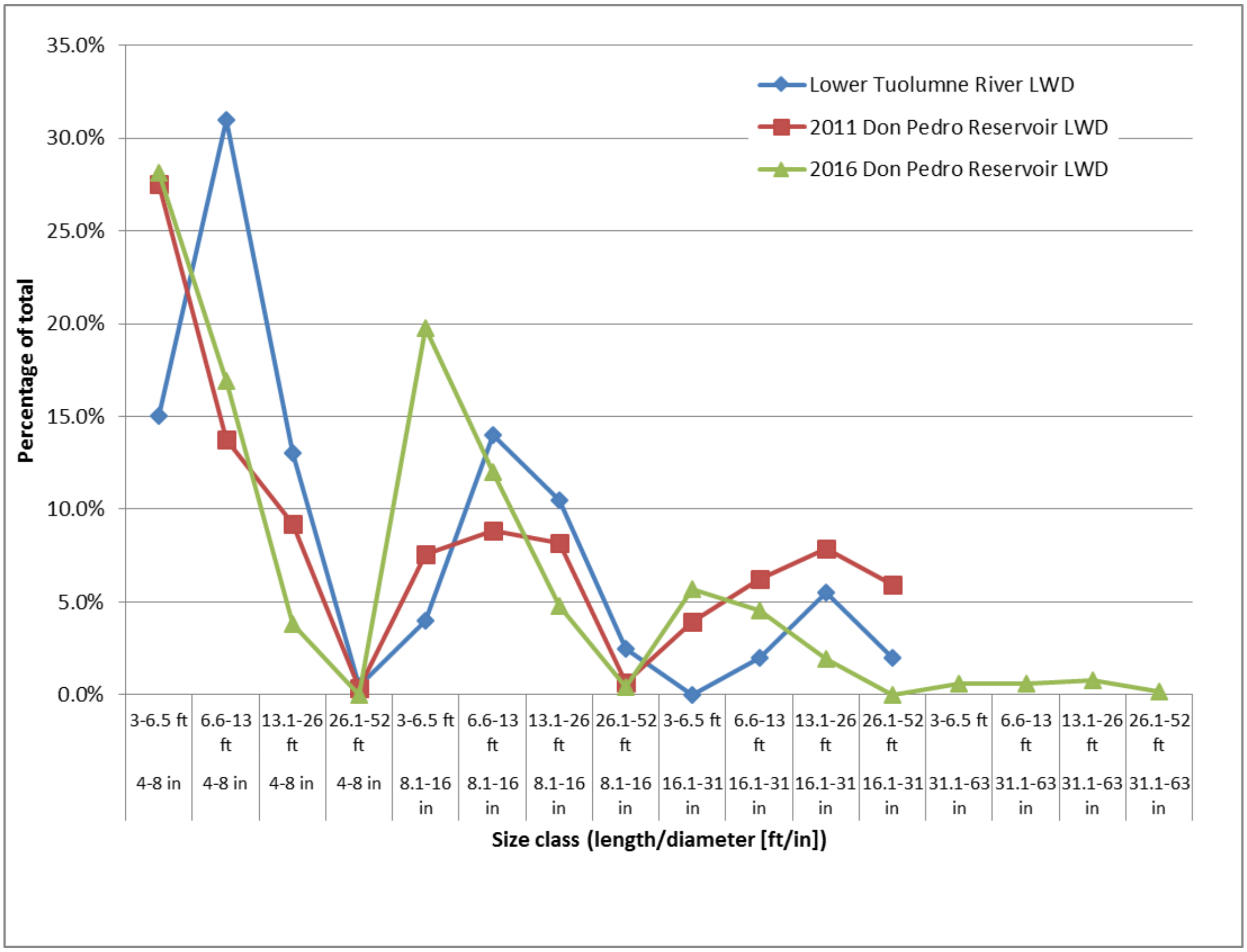

Figure 3.2-1. Comparison of LWD size classes in the lower Tuolumne River (2012) and Don Pedro Reservoir (2011 and 2016).

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STUDY REPORT W&AR-12
ONCORHYNCHUS MYKISS HABITAT SURVEY

ATTACHMENT B

INSTREAM HABITAT SAMPLING UNITS

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W&AR-12 *Oncorhynchus mykiss* Habitat Survey
Sampling Unit 1

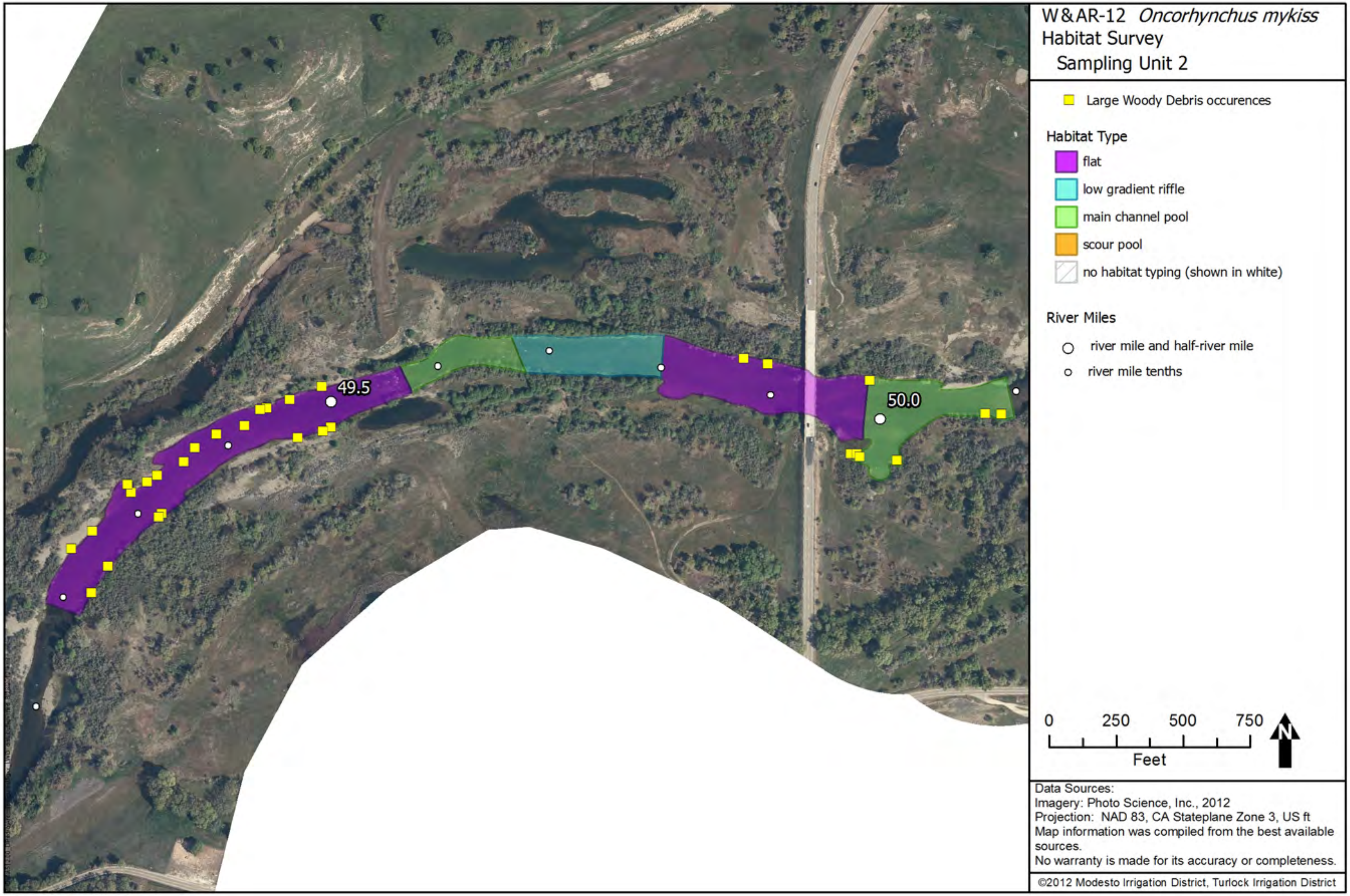
Large Woody Debris occurences

Habitat Type
- flat
- low gradient riffle
- main channel pool
- scour pool
- no habitat typing (shown in white)

River Miles
- river mile and half-river mile
- river mile tenths

0 250 500 750
Feet
N

Data Sources:
Imagery: Photo Science, Inc., 2012
Projection: NAD 83, CA Stateplane Zone 3, US ft
Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.



W&AR-12 *Oncorhynchus mykiss*
Habitat Survey
Sampling Unit 2
Large Woody Debris occurences
Habitat Type
flat
low gradient riffle
main channel pool
scour pool
no habitat typing (shown in white)
River Miles
river mile and half-river mile
river mile tenths
49.5
50.0
0
250
500
750
Feet
N
Data Sources:
Imagery: Photo Science, Inc., 2012
Projection: NAD 83, CA Stateplane Zone 3, US ft
Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.
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W&AR-12 *Oncorhynchus mykiss*
Habitat Survey
Sampling Unit 3

Large Woody Debris occurences

Habitat Type
- flat
- low gradient riffle
- main channel pool
- scour pool
- no habitat typing (shown in white)

River Miles
- river mile and half-river mile
- river mile tenths

0 250 500 750
Feet
N

Data Sources:
Imagery: Photo Science, Inc., 2012
Projection: NAD 83, CA Stateplane Zone 3, US ft
Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.

W&AR-12 *Oncorhynchus mykiss* Habitat Survey
Sampling Unit 4

Large Woody Debris occurences

Habitat Type
- flat
- low gradient riffle
- main channel pool
- scour pool
- no habitat typing (shown in white)

River Miles
- river mile and half-river mile
- river mile tenths

0 250 500 750
Feet

N

Data Sources:
Imagery: Photo Science, Inc., 2012
Projection: NAD 83, CA Stateplane Zone 3, US ft
Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.

W&AR-12 *Oncorhynchus mykiss*
Habitat Survey
Sampling Unit 5

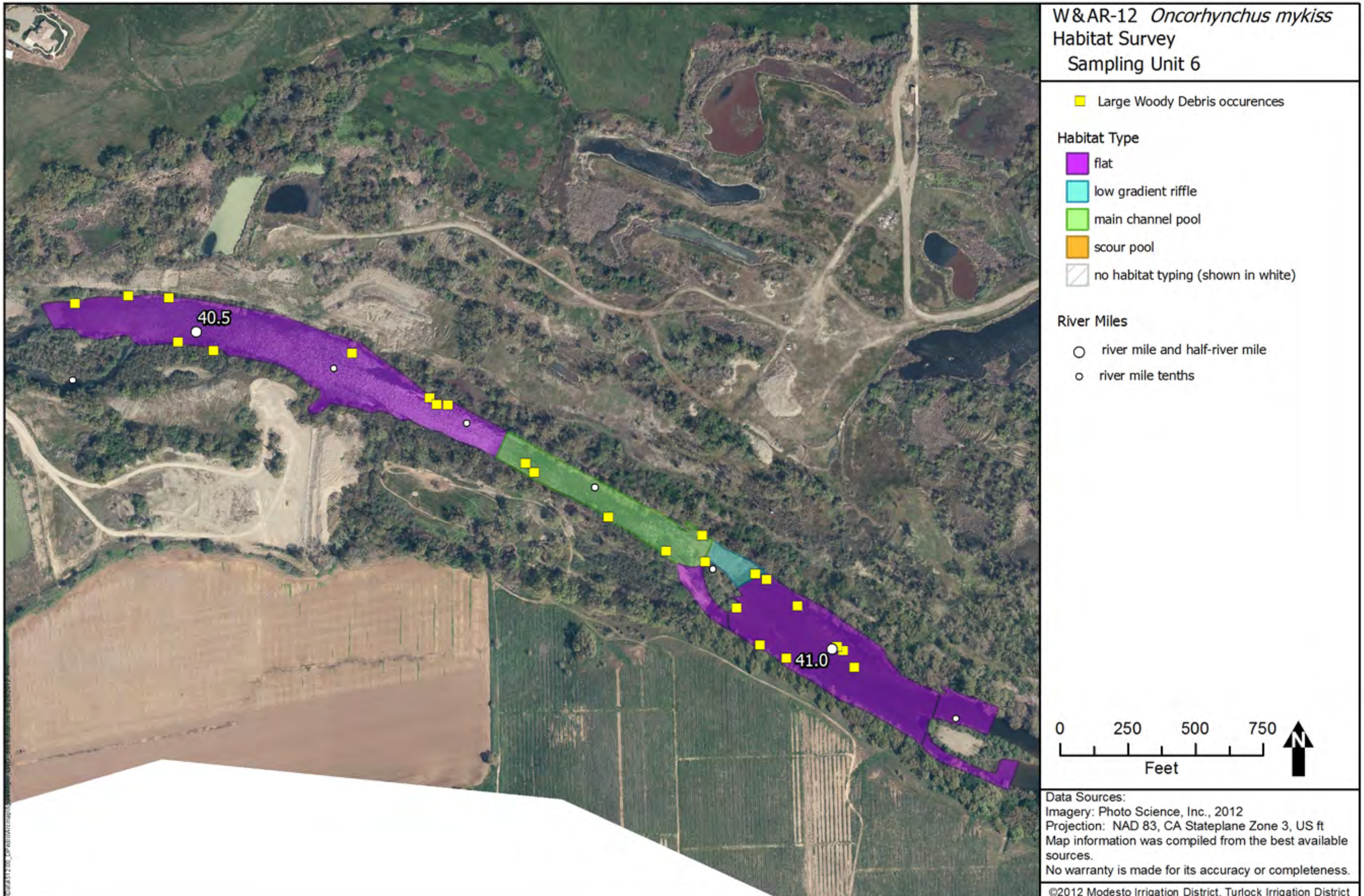
Large Woody Debris occurences

Habitat Type
- flat
- low gradient riffle
- main channel pool
- scour pool
- no habitat typing (shown in white)

River Miles
- river mile and half-river mile
- river mile tenths

0 250 500 750
Feet
N

Data Sources:
Imagery: Photo Science, Inc., 2012
Projection: NAD 83, CA Stateplane Zone 3, US ft
Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.



W&AR-12 *Oncorhynchus mykiss*
Habitat Survey
Sampling Unit 6
Large Woody Debris occurences
Habitat Type
flat
low gradient riffle
main channel pool
scour pool
no habitat typing (shown in white)
River Miles
river mile and half-river mile
river mile tenths
40.5
41.0
0
250
500
750
Feet
N
Data Sources:
Imagery: Photo Science, Inc., 2012
Projection: NAD 83, CA Stateplane Zone 3, US ft
Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.
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W&AR-12 *Oncorhynchus mykiss* Habitat Survey
Sampling Unit 7

Large Woody Debris occurences

Habitat Type
- flat
- low gradient riffle
- main channel pool
- scour pool
- no habitat typing (shown in white)

River Miles
- river mile and half-river mile
- river mile tenths

0 250 500 750
Feet
N

Data Sources:
Imagery: Photo Science, Inc., 2012
Projection: NAD 83, CA Stateplane Zone 3, US ft
Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.

W&AR-12 *Oncorhynchus mykiss* Habitat Survey
Sampling Unit 8

Large Woody Debris occurences

Habitat Type
- flat
- low gradient riffle
- main channel pool
- scour pool
- no habitat typing (shown in white)

River Miles
- river mile and half-river mile
- river mile tenths

0 250 500 750
Feet
N

Data Sources:
Imagery: Photo Science, Inc., 2012
Projection: NAD 83, CA Stateplane Zone 3, US ft
Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.

W&AR-12 *Oncorhynchus mykiss* Habitat Survey
Sampling Unit 9

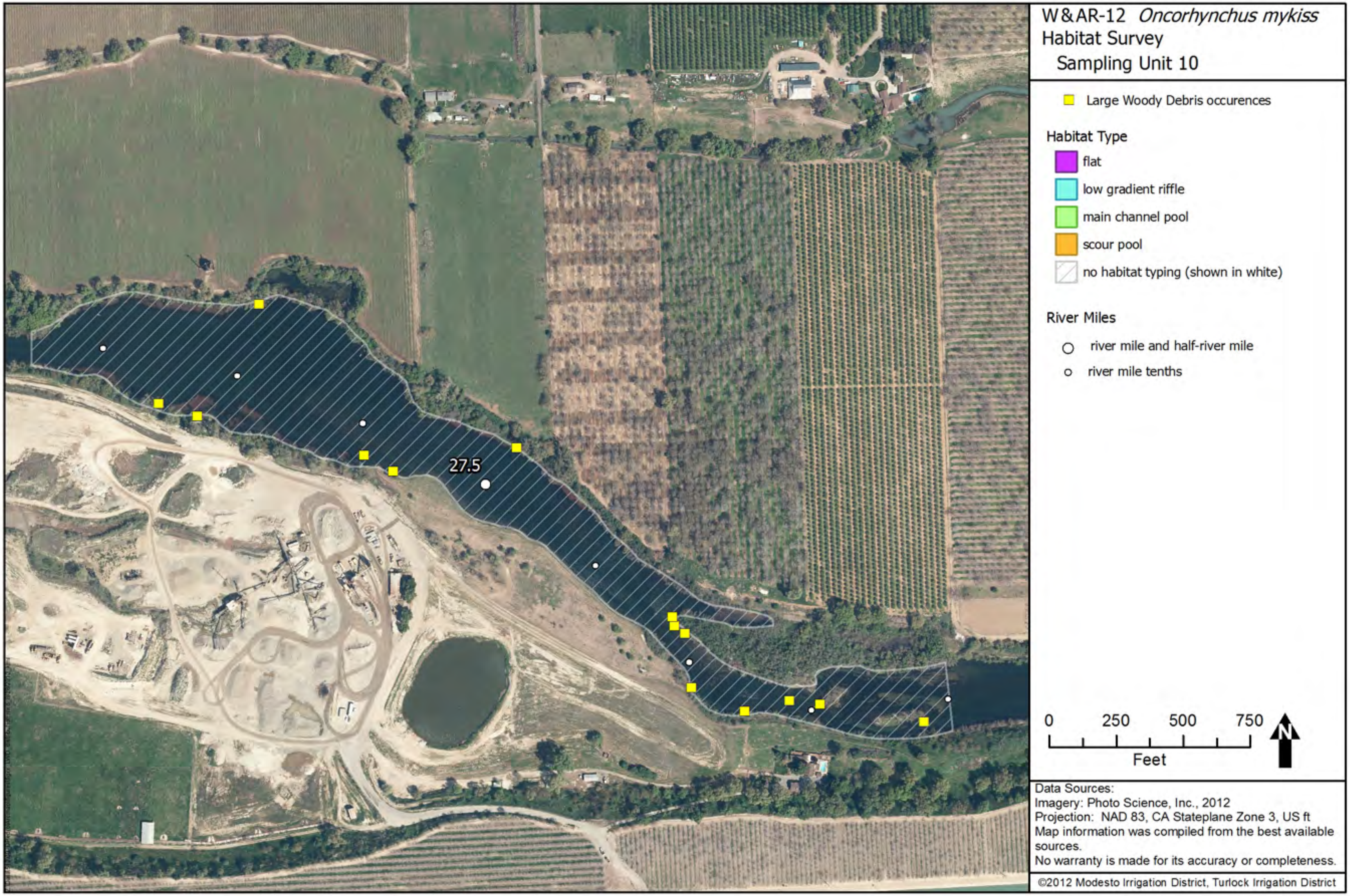
Large Woody Debris occurences

Habitat Type
- flat
- low gradient riffle
- main channel pool
- scour pool
- no habitat typing (shown in white)

River Miles
- river mile and half-river mile
- river mile tenths

0 250 500 750
Feet
N

Data Sources:
Imagery: Photo Science, Inc., 2012
Projection: NAD 83, CA Stateplane Zone 3, US ft
Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.


W&AR-12 *Oncorhynchus mykiss*
Habitat Survey
Sampling Unit 10
Large Woody Debris occurences
Habitat Type
flat
low gradient riffle
main channel pool
scour pool
no habitat typing (shown in white)
River Miles
river mile and half-river mile
river mile tenths
27.5
0 250 500 750
Feet
N
Data Sources:
Imagery: Photo Science, Inc., 2012
Projection: NAD 83, CA Stateplane Zone 3, US ft
Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.
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STUDY REPORT W&AR-12
ONCORHYNCHUS MYKISS HABITAT SURVEY

ATTACHMENT C

INSTREAM HABITAT TYPE AND LWD DATASHEETS

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HABITAT INVENTORY DATA FORM

Form # 1 of 6

Date 6/12/12 Stream Name Tuolumne R T __ R __ S __

Surveyors DPH, KL Lat. 37.6681 Lon. 120.4428

Quad. Reach 1 Channel Type ____ Reach # 1 Flow ____

Time ____ Water Temp ____ Air Temp ____ Page Length 2226 Total Length ____

****

Habitat Unit Number	1	2	3	4	5	6	7			
Habitat Unit Type	4	3	5	1	5	1				
Side Channel Type							3			
Mean Length	631	44	787	68	183	51	462			
Mean Width	122	44	106	34	45	27	25			
Mean Depth	13	1	15	1.0	5.0	0.8	1.8			
Maximum Depth	32	2	36.2	2.0	8.0	1.2	4.0			
Depth Pool Tail Crest	1.0		3.2		0.8					
Pool Tail Embeddedness	1		1		1					
Pool Tail Substrate	3		3		3					
SHELTER RATING										
Shelter Value	2	1	2	3	3	0	2			
%Unit Covered	50	30	20	30	20		25			
% undercut bank										
% swd (d<12")			10	10	10		20			
% lwd (d>12")										
% root mass										
% terr. vegetation										
% aqua. vegetation										
% bubble curtain				80	40		80			
% boulders (d>10")	40	100	80		20					
% bedrock ledges	60		10	10	10					

SUBSTRATE COMPOSITION (Select the two most dominant compositions)

A) Silt/Clay										
B) Sand (<0.08")										
C) Gravel (0.08-2.5")				2		1	2			
D) Sm. Cobble (2.5-5")				1	2	2	1			
E) Lg. Cobble (5-10")		2			1					
F) Boulder (>10")	1	1	1							
G) Bedrock	2		2							
% Exposed Substrate										
PERCENT TOTAL CANOPY	5	0	0	0	5	0	30			
% Broadleaf Trees	100				100		100			
% Coniferous Trees										

BANK COMPOSITION & VEGETATION (See bank and vegetation composition types below

Rt. Bank Composition	2	2	3	3	3	3	3			
Rt. Bank Dominant Veg.	6	5	5	6	6	5	7			
% Rt. Bank Vegetated	20	10	60	50	80	90	90			
Lt. Bank Composition	1	1	1	1	1	3	3			
Lt. Bank Dominant Veg	7	5	5	6	7	6	7			
% Lt. Bank Vegetated	2	10	40	40	20	15	90			

BANK COMPOSITION TYPE
1) Bedrock
2) Boulder
3) Cobble/Gravel
4) Silt/Clay/Sand

VEGETATION TYPES
5) Grass
6) Brush
7) Deciduous Trees
8) Coniferous Trees
9) No Vegetation

**********************COMMENTS**********************

start unit

O.M. read

P = 1601' - 73%
Rf = 119 - 5.3%
Run = 506 - 23%
2,226

HABITAT INVENTORY DATA FORM

Date 6/12/17 Stream Name Tuolumne T___ R___ S___
Surveyors OPH/KJ Lat. 37.6665 Lon. 120.4689
~~Quad.~~ Reach #2 TID O. mykiss/LWD Channel Type____ Reach # 2 Flow____
Time______ Water Temp______ Air Temp______ Page Length 3901 Total Length______

****

Habitat Unit Number	8	9	10	11	12					
Habitat Unit Type	4	3	1	4	3					
Side Channel Type										
Mean Length	538	782	544	442	1595					
Mean Width	142	160	142	89	117					
Mean Depth	5.0	2.0	0.6	9.0	4.5					
Maximum Depth	9.9	4.5	0.8	16.0	8.0					
Depth Pool Tail Crest	0.5			1.6						
Pool Tail Embeddedness	1			1						
Pool Tail Substrate	3			3						
SHELTER RATING										
Shelter Value	1	2	0	2	2					
%Unit Covered	5	10		20	15					
% undercut bank										
% swd (d<12")	100	50		20	60					
% lwd (d>12")										
% root mass										
% terr. vegetation		50								
% aqua. vegetation										
% bubble curtain					40					
% boulders (d>10")				80						
% bedrock ledges										

SUBSTRATE COMPOSITION (Select the two most dominant compositions)

A) Silt/Clay										
B) Sand (<0.08")										
C) Gravel (0.08-2.5")		2	1							
D) Sm. Cobble (2.5-5")	2	1	2	2	2					
E) Lg. Cobble (5-10")	1			1	1					
F) Boulder (>10")										
G) Bedrock										
% Exposed Substrate										
PERCENT TOTAL CANOPY	5	5	0	5	5					
% Broadleaf Trees	100	100		100	100					
% Coniferous Trees										

BANK COMPOSITION & VEGETATION (See bank and vegetation composition types below

Rt. Bank Composition	4	4	3	3	3					
Rt. Bank Dominant Veg.	7	7	7	6	5					
% Rt. Bank Vegetated	95	90	90	45	50					
Lt. Bank Composition	4	3	3	3	3					
Lt. Bank Dominant Veg	7	5	7	6	7					
% Lt. Bank Vegetated	95	80	90	80	50					

BANK COMPOSITION TYPE
1) Bedrock
2) Boulder
3) Cobble/Gravel
4) Silt/Clay/Sand

VEGETATION TYPES
5) Grass
6) Brush
7) Deciduous Trees
8) Coniferous Trees
9) No Vegetation

upstream of N.L.G. bridge

**********************COMMENTS*******************

P = 980' – 25%
R.f = 544' – 14%
R ~ 2377' – 61%
3901'

HABITAT INVENTORY DATA FORM

Form # 3 of 6

Date 6/12/12 Stream Name Tuolumne T___ R___ S___
Surveyors DPH/KJ Lat. 37.6578 Lon. 120.4869
~~Quad~~ Reach #3 TID O.M / LWD Channel Type___ Reach # 3 Flow___
Time 1145 Water Temp 15.5°C Air Temp ___ Page Length 2436 Total Length___

****

Habitat Unit Number	13	14	15	16	~~17~~					
Habitat Unit Type	1	3	1	3	~~1~~					
Side Channel Type										
Mean Length	360	655	253	1168						
Mean Width	87	123	146	112						
Mean Depth	0.4	1.0	0.8	3.0						
Maximum Depth	1.0	2.2	1.5	4.9						
Depth Pool Tail Crest										
Pool Tail Embeddedness										
Pool Tail Substrate										
SHELTER RATING										
Shelter Value	1	1	1	1						
%Unit Covered	5	5	5	5						
% undercut bank										
% swd (d<12")										
% lwd (d>12")										
% root mass	100	100	100	100						
% terr. vegetation										
% aqua. vegetation										
% bubble curtain										
% boulders (d>10")										
% bedrock ledges										

SUBSTRATE COMPOSITION (Select the two most dominant compositions)

A) Silt/Clay										
B) Sand (<0.08")										
C) Gravel (0.08-2.5")	1		2							
D) Sm. Cobble (2.5-5")	2	1	1	2						
E) Lg. Cobble (5-10")		2		1						
F) Boulder (>10")										
G) Bedrock										
% Exposed Substrate										
PERCENT TOTAL CANOPY	5	5	10	5						
% Broadleaf Trees	100	100	100	100						
% Coniferous Trees										

BANK COMPOSITION & VEGETATION (See bank and vegetation composition types below

Rt. Bank Composition	3	3	4	3						
Rt. Bank Dominant Veg.	7	7	7	7						
% Rt. Bank Vegetated	60	30	90	75						
Lt. Bank Composition	3	3	3	3						
Lt. Bank Dominant Veg	7	7	7	7						
% Lt. Bank Vegetated	80	75	90	80						

BANK COMPOSITION TYPE
1) Bedrock
2) Boulder
3) Cobble/Gravel
4) Silt/Clay/Sand

VEGETATION TYPES
5) Grass
6) Brush
7) Deciduous Trees
8) Coniferous Trees
9) No Vegetation

***********************COMMENTS*******************

P - 0 - 0%
Rif - 613' 25%
R - 1823 - 75%
2436

HABITAT INVENTORY DATA FORM

Form # 4 of 6

Date 6/12/12 Stream Name Tuolumne R T___ R___ S___

Surveyors DPH/KG Lat. 37.6402 Lon. 120.5001

~~Quad~~. Reach# 4 - TID O.m/LWD Channel Type___ Reach # 4 Flow___

Time___ Water Temp___ Air Temp___ Page Length 2364 Total Length___

****

Habitat Unit Number	17	18	19	20	21	22	23	24	~~25~~	
Habitat Unit Type	1	3	1	4	3	1	3	1		
Side Channel Type										
Mean Length	211	310	231	360	337	254	432	229		
Mean Width	82	77	81	75	84	82	93	109		
Mean Depth	0.6	1.0	1.0	4.0	2.0	0.5	2.0	0.6		
Maximum Depth	2.0	2.0	1.8	6.2	3.5	0.8	3.6	1.0		
Depth Pool Tail Crest				0.8						
Pool Tail Embeddedness				1						
Pool Tail Substrate				3						
SHELTER RATING	0	1	0	2	3	0	1	0		
Shelter Value		5		20	20		15			
%Unit Covered										
% undercut bank										
% swd (d<12")					50					
% lwd (d>12")										
% root mass		100		50	25		100			
% terr. vegetation					25					
% aqua. vegetation										
% bubble curtain										
% boulders (d>10")										
% bedrock ledges				50						

SUBSTRATE COMPOSITION (Select the two most dominant compositions)

A) Silt/Clay										
B) Sand (<0.08")										
C) Gravel (0.08-2.5")	2	1	2	2		2	1	2		
D) Sm. Cobble (2.5-5")	1	2	1		1	1	2	1		
E) Lg. Cobble (5-10")					2					
F) Boulder (>10")										
G) Bedrock				1						
% Exposed Substrate										
PERCENT TOTAL CANOPY	0	5	0	15	10	5	15	0		
% Broadleaf Trees		100		100	100	100	100			
% Coniferous Trees										

BANK COMPOSITION & VEGETATION (See bank and vegetation composition types below

Rt. Bank Composition	3	3	3	3	3	3	4			
Rt. Bank Dominant Veg.	6	6	9	6	7	7	7			
% Rt. Bank Vegetated	70	30	0	20	90	60	90			
Lt. Bank Composition	3	4	3	3	3	3	4	3		
Lt. Bank Dominant Veg	7	7	6	7	7	7	7	5		
% Lt. Bank Vegetated	20	60	40	80	90	80	90	30		

BANK COMPOSITION TYPE

1) Bedrock
2) Boulder
3) Cobble/Gravel
4) Silt/Clay/Sand

VEGETATION TYPES

5) Grass
6) Brush
7) Deciduous Trees
8) Coniferous Trees
9) No Vegetation

**********************COMMENTS*******************

P - 360' 15%
Rif - 925' - 39%
Run - 1079 - 46%
2364

HABITAT INVENTORY DATA FORM

Form # 5 of 6

Date 6/12/12 Stream Name Tuolumne R T___ R___ S___

Surveyors DPH/KJ Lat. 37.6294 Lon. 120.5365

~~Quad~~. Reach # 5 TID 0.mi/LWD Channel Type____ Reach # 5 Flow____

Time 3:30pm Water Temp 21°C Air Temp ________ Page Length 1450 Total Length____

****

Habitat Unit Number	25	26	27							
Habitat Unit Type	5	3	1							
Side Channel Type										
Mean Length	365	1085	~~219~~							
Mean Width	63	55	7							
Mean Depth	3.0	1.6								
Maximum Depth	84	48								
Depth Pool Tail Crest	1.5									
Pool Tail Embeddedness	2									
Pool Tail Substrate	3									
SHELTER RATING										
Shelter Value	2	3								
%Unit Covered	15	30								
% undercut bank										
% swd (d<12")	25	40								
% lwd (d>12")										
% root mass										
% terr. vegetation		40								
% aqua. vegetation	75									
% bubble curtain		20								
% boulders (d>10")										
% bedrock ledges										

SUBSTRATE COMPOSITION (Select the two most dominant compositions)

A) Silt/Clay										
B) Sand (<0.08")	2									
C) Gravel (0.08-2.5")										
D) Sm. Cobble (2.5-5")		2								
E) Lg. Cobble (5-10")	1	1								
F) Boulder (>10")										
G) Bedrock										
% Exposed Substrate										
PERCENT TOTAL CANOPY	5	25								
% Broadleaf Trees	100	100								
% Coniferous Trees										

BANK COMPOSITION & VEGETATION (See bank and vegetation composition types below

Rt. Bank Composition	3	3								
Rt. Bank Dominant Veg.	7	7								
% Rt. Bank Vegetated	85	85								
Lt. Bank Composition	3	4								
Lt. Bank Dominant Veg	7	5								
% Lt. Bank Vegetated	85	20								

BANK COMPOSITION TYPE
1) Bedrock
2) Boulder
3) Cobble/Gravel
4) Silt/Clay/Sand

VEGETATION TYPES
5) Grass
6) Brush
7) Deciduous Trees
8) Coniferous Trees
9) No Vegetation

**********************COMMENTS******************

HABITAT INVENTORY DATA FORM

Form # 6 of 6

Date 6/13/12 Stream Name Tuolumne R. T___ R___ S___

Surveyors DPH/KJ Lat. 37.6339 Lon. 120.5937

~~Quad~~. Reach # 6 TID O.m/LWD Channel Type____ Reach # 6 Flow____

Time 0900 Water Temp 20°C Air Temp ________ Page Length 4529 Total Length 16,906

****

Habitat Unit Number	27	28	29	30	31	32	33	34		
Habitat Unit Type	3		3	1		4	3			
Side Channel Type		3			3					
Mean Length	219	374	844	183	262	874	1773			
Mean Width	72	37	185	32	38	59	139			
Mean Depth	1.0	1.8	3.0	0.5		5.2	6.0			
Maximum Depth	1.7	2.7	3.8	1.0		8.3	11.8			
Depth Pool Tail Crest						0.8				
Pool Tail Embeddedness						1				
Pool Tail Substrate						3				
SHELTER RATING	0	2	3	0	1	3	2			
Shelter Value		30	10		20	20	15			
%Unit Covered										
% undercut bank										
% swd (d<12")		10	10			40	35			
% lwd (d>12")						20	5			
% root mass						10				
% terr. vegetation		90	40		100	30	60			
% aqua. vegetation			50							
% bubble curtain										
% boulders (d>10")										
% bedrock ledges										

SUBSTRATE COMPOSITION (Select the two most dominant compositions)

A) Silt/Clay										
B) Sand (<0.08")						2	2			
C) Gravel (0.08-2.5")	2				1					
D) Sm. Cobble (2.5-5")	1	2	2	1	2		1			
E) Lg. Cobble (5-10")			1	2		1				
F) Boulder (>10")										
G) Bedrock		1								
% Exposed Substrate										
PERCENT TOTAL CANOPY	5	30	5	5	90	10	5			
% Broadleaf Trees	100	100	100	100	100	100	100			
% Coniferous Trees										

BANK COMPOSITION & VEGETATION (See bank and vegetation composition types below

Rt. Bank Composition	4	4	4	3	3	4	4			
Rt. Bank Dominant Veg.	7	6	7	7	7	7	7			
% Rt. Bank Vegetated	100	100	100	90	100	100	85			
Lt. Bank Composition	4	4	4	3	3	4	4			
Lt. Bank Dominant Veg	6	7	7	7	7	7	7			
% Lt. Bank Vegetated	95	80	80	90	100	100	95			

BANK COMPOSITION TYPE

1) Bedrock
2) Boulder
3) Cobble/Gravel
4) Silt/Clay/Sand

VEGETATION TYPES

5) Grass
6) Brush
7) Deciduous Trees
8) Coniferous Trees
9) No Vegetation

***********************COMMENTS******************

23.5°C @ 1500

Tuolumne River LWD

PROJECT CODE: 5212 **TASK CODE:** 0200

Study Reach Page 1 of 1

Study Reach Number: 1 **O. mykiss Habitat Reach Number :** 1 **Crew Initials:** JN/MR

Date: 6 / 12 / 12

Top of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6681°, 120.4428°

Bottom of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6651°, 120.4451°

Mark location of all tally LWD on aerial photographs (waypoint #s) wood 22-24

Tally as "R" if rootwad attached

Diameter Class	Length Class					
	3–6.5 ft (1–2 m)	6.6–13 ft (2–4 m)	13.1–26 ft (4–8 m)	26.1–52 ft (8–16 m)	52.1–105 ft (16–32 m)	>105.1 ft (>32 m)
4-8 in (0.1–0.2 m)		|	|			
8.1–16 in (0.21–0.4 m)		|				
16.1–31 in (0.41–0.8 m)						
31.1–63 in (0.8–1.6 m)						

Comments:

Tuolumne River LWD

PROJECT CODE: 512.12 **TASK CODE:** 0200

Study Reach Page 1 of 1

Study Reach Number: 2 **O. mykiss Habitat Reach Number :** 2 **Crew Initials:** JN/MR/KJ

Date: 6 / 12 / 12

Top of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6665°, 120.4689°

Bottom of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6645°, 120.4813°

30 wpts
65 pcs

TR 1 – TR 15

Mark location of all tally LWD on aerial photographs (Waypoint #s) 25 - 39

Tally as "R" if rootwad attached

Diameter Class	Length Class					
	3–6.5 ft (1–2 m)	6.6–13 ft (2–4 m)	13.1–26 ft (4–8 m)	26.1–52 ft (8–16 m)	52.1–105 ft (16–32 m)	>105.1 ft (>32 m)
4-8 in (0.1–0.2 m)	12	18	16			
8.1–16 in (0.21–0.4 m)	3	4	6			
16.1–31 in (0.41–0.8 m)			1			
31.1–63 in (0.8–1.6 m)						

Comments: TR1 - grey

Multiple pieces of LWD in 1 location TR-12

Tuolumne River LWD

PROJECT CODE: 512.12 **TASK CODE:** 0200

Study Reach Page 1 of 1

Study Reach Number: 3 **O. mykiss Habitat Reach Number :** 3 **Crew Initials:** JN/MR

Date: 6 / 12 / 12

Top of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6578°, 120.4869°

Bottom of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6529°, 120.4919°

2pcs

Mark location of all tally LWD on aerial photographs (Waypoint #'s) 40 – 41

Tally as "R" if rootwad attached

Diameter Class	Length Class					
	3–6.5 ft (1–2 m)	6.6–13 ft (2–4 m)	13.1–26 ft (4–8 m)	26.1–52 ft (8–16 m)	52.1–105 ft (16–32 m)	>105.1 ft (>32 m)
4-8 in (0.1–0.2 m)		|				
8.1–16 in (0.21–0.4 m)			|			
16.1–31 in (0.41–0.8 m)						
31.1–63 in (0.8–1.6 m)						

Comments:

Tuolumne River LWD

PROJECT CODE: 512.12 **TASK CODE:** 0200

Study Reach Page 1 of 1

Study Reach Number: 4 **O. mykiss Habitat Reach Number :** 4 **Crew Initials:** JN/KJ/MR

Date: 6 / 12 / 12

Top of Reach GPS Location: Lat/Longs or ~~UTM~~ 37.6402, 120.5001°

Bottom of Reach GPS Location: Lat/Longs or ~~UTM~~ 37.6366, 120.5060°

18 pcs

Mark location of all tally LWD on aerial photographs (waypoint #s) 42-58 TR 16-17

Tally as "R" if rootwad attached

Diameter Class	Length Class					
	3–6.5 ft (1–2 m)	6.6–13 ft (2–4 m)	13.1–26 ft (4–8 m)	26.1–52 ft (8–16 m)	52.1–105 ft (16–32 m)	>105.1 ft (>32 m)
4-8 in (0.1–0.2 m)	|||| 4	~~||||~~ | 6	|			
8.1–16 in (0.21–0.4 m)	R || 3		|	|		
16.1–31 in (0.41–0.8 m)			||	| 2		
31.1–63 in (0.8–1.6 m)						

Comments:

Tuolumne River LWD

PROJECT CODE: 5/2.12 **TASK CODE:** 0200

Study Reach Page 1 of 1

Study Reach Number: 5 **O. mykiss Habitat Reach Number :** #5 **Crew Initials:** JN/MR

Date: 6 / 12 / 12

Top of Reach GPS Location: Lat/Longs or ~~UTM~~ 37.6294°, 120.5365°

Bottom of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6285, 120.5408°

Mark location of all tally LWD on aerial photographs (waypoint #s) 54-58

Tally as "R" if rootwad attached

Diameter Class	Length Class					
	3–6.5 ft (1–2 m)	6.6–13 ft (2–4 m)	13.1–26 ft (4–8 m)	26.1–52 ft (8–16 m)	52.1–105 ft (16–32 m)	>105.1 ft (>32 m)
4-8 in (0.1–0.2 m)		||| 3				
8.1–16 in (0.21–0.4 m)		|				
16.1–31 in (0.41–0.8 m)						
31.1–63 in (0.8–1.6 m)						

Comments:

Tuolumne River LWD

PROJECT CODE: 51212 **TASK CODE:** 0200

Study Reach Page 1 of 1

Study Reach Number: 6 **O. mykiss Habitat Reach Number :** 6 **Crew Initials:** JN/MR/KJ

Date: 6 / 13 / 12

Top of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6339°, 120.5937°

Bottom of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6387°, 120.6057°

Mark location of all tally LWD on aerial photographs
Tally as "R" if rootwad attached

Waypoint # 59-79
TR 18-20

Diameter Class	Length Class					
	3–6.5 ft (1–2 m)	6.6–13 ft (2–4 m)	13.1–26 ft (4–8 m)	26.1–52 ft (8–16 m)	52.1–105 ft (16–32 m)	>105.1 ft (>32 m)
4-8 in (0.1–0.2 m)	IIII 4	~~IIII~~ II 7	~~IIII~~ II 7			
8.1–16 in (0.21–0.4 m)		~~IIII~~ I 6	II 2			
16.1–31 in (0.41–0.8 m)			II 2	II 2		
31.1–63 in (0.8–1.6 m)						

Comments: 62: 3 pieces disregard wpt. 79
TR18: 5 pieces
68: 2 pieces
71: 3 pieces

LWD KEY PIECE DATA **Study reach number** 6 **Date:** 6-13 **Page** 1 **of** 1

Perform within each study reach. **Criteria for Determining Key Pieces:** >1/2 times the bankfull width, or of sufficient size and/or are deposited in a manner that alters channel morphology and aquatic habitat (e.g., trapping sediment or altering flow patterns). **Map each key piece on the applicable aerial photograph with appropriate identifying number.**

O. mykiss Habitat Reach Number (if applicable) N/A

KEY PIECE ATTRIBUTE	KEY PIECE NUMBER 1	2	3	4	5	6	7	8	9	10	11	12
O. mykiss habitat type number (if applicable)	33											
Diameter (in)	20											
Length (ft)	50											
rootwad attached (√)	√											
LOCATION IN BANKFULL CHANNEL AREA												
< 25% of piece length in bankfull channel (√)												
25-50% of piece length in bankfull channel (√)												
50-75% of piece length in bankfull channel (√)												
75-100% of piece length in bankfull channel (√)	√											
ORIENTATION												
P = perpendicular; D = angled downstream; U = angled upstream; L= parallel or near parallel to channel	D											
FUNCTION IN CHANNEL												
located in bankfull channel, but not influencing channel morphology and not associated with pool habitat (√)												
associated with, but not creating pool habitat (√)												
associated with LWD jam (3 or more key pieces) (√)												
jam dimensions (LxWxH)												
# pieces in jam												
piece is acting as sediment storage site (√)												
piece appears to be stable in stream channel* (√)	√											
HABITAT FUNCTION												
acting as velocity refuge in low flow channel (√)	√											
acting as velocity refuge outside low flow channel (√)												
acting as complex instream cover (has attached rootwad or intact branches) (√)	√											
D =dammed pool; P = plunge pool; L =lateral scour pool; B=backwater pool												
ADDITIONAL INFORMATION (OPTIONAL)												
decay class (1 = sound, limbs present; 2 = bark loose or absent, limbs absent, surface slightly rotted; 3 = surface extensively rotted, center solid or rotted)	1											
tree species (C = conifer, D = deciduous, U = unknown)	D											
input source (I=imported, R=riparian, U=upstream, B=bank erosion, Unk= unknown)	B											
Way Point #	75											

*Rootwad present, piece stabilized at more than one point by banks or channel obstructions, end anchored by streambed or bank burial, pegged by standing trees, spanning

Tuolumne River LWD

PROJECT CODE: 5/2/2 **TASK CODE:** 0200
Study Reach Page 1 of 1

Study Reach Number: 7 **O. mykiss Habitat Reach Number :** – **Crew Initials:** JN/MR/KS/DH

Date: 6 / 13 / 12

Top of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6395°, 120.6480°

Bottom of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6410°, 120.6557°

Mark location of all tally LWD on aerial photographs Waypoints 80 – 88

Tally as "R" if rootwad attached

Diameter Class	Length Class 3–6.5 ft (1–2 m)	6.6–13 ft (2–4 m)	13.1–26 ft (4–8 m)	26.1–52 ft (8–16 m)	52.1–105 ft (16–32 m)	>105.1 ft (>32 m)
4-8 in (0.1–0.2 m)	‖ 2	~~||||~~	6				
8.1–16 in (0.21–0.4 m)		~~||||~~ ||| 8	‖ 2			
16.1–31 in (0.41–0.8 m)				R		
31.1–63 in (0.8–1.6 m)						

Comments: 86: 3 pieces
88: 7 pieces

Tuolumne River LWD

PROJECT CODE: 51212 **TASK CODE:** 0200

Study Reach Page 1 of 1

Study Reach Number: 8 **O. mykiss Habitat Reach Number :** — **Crew Initials:** JN/MR/KJ/DI

Date: 6 / 13 / 12

Top of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6431°, 120.7012°

Bottom of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6381°, 120.7082°

Mark location of all tally LWD on aerial photographs Waypoints 89 – 103

Tally as "R" if rootwad attached

Diameter Class	Length Class					
	3–6.5 ft (1–2 m)	**6.6–13 ft (2–4 m)**	**13.1–26 ft (4–8 m)**	**26.1–52 ft (8–16 m)**	**52.1–105 ft (16–32 m)**	**>105.1 ft (>32 m)**
4-8 in (0.1–0.2 m)	~~IIII~~ III 8	~~IIII~~ ~~IIII~~ III 13				
8.1–16 in (0.21–0.4 m)	I	II 2	II 2	III 3		
16.1–31 in (0.41–0.8 m)			I R 2	I		
31.1–63 in (0.8–1.6 m)						

Comments: 92: 7 pieces

103: 7 pieces

~~107: 7 pieces~~

107 – 4 pcs – key – 7 total

LWD KEY PIECE DATA **Study reach number** 8 **Date:** 6-13-12 **Page** 1 **of** 1

Perform within each study reach. **Criteria for Determining Key Pieces:** >1/2 times the bankfull width, or of sufficient size and/or are deposited in a manner that alters channel morphology and aquatic habitat (e.g., trapping sediment or altering flow patterns). **Map each key piece on the applicable aerial photograph with appropriate identifying number.**

O. mykiss Habitat Reach Number (if applicable) NA

KEY PIECE ATTRIBUTE	KEY PIECE NUMBER											
	1	2	3	4	5	6	7	8	9	10	11	12
O. mykiss habitat type number (if applicable)	N/A	N/A	N/A	N/A								
Diameter (in)	12	20	14	14								
Length (ft)	30	30	30	30								
rootwad attached (√)	√	√	√	√								
LOCATION IN BANKFULL CHANNEL AREA												
< 25% of piece length in bankfull channel (√)												
25-50% of piece length in bankfull channel (√)												
50-75% of piece length in bankfull channel (√)												
75-100% of piece length in bankfull channel (√)	√	√	√	√								
ORIENTATION												
P = perpendicular; D = angled downstream; U = angled upstream; L= parallel or near parallel to channel	P	P	D	D								
FUNCTION IN CHANNEL												
located in bankfull channel, but not influencing channel morphology and not associated with pool habitat (√)	√	√	√	√								
associated with, but not creating pool habitat (√)												
associated with LWD jam (3 or more key pieces) (√)												
jam dimensions (LxWxH)												
# pieces in jam												
piece is acting as sediment storage site (√)												
piece appears to be stable in stream channel* (√)												
HABITAT FUNCTION												
acting as velocity refuge in low flow channel (√)	√	√	√	√								
acting as velocity refuge outside low flow channel (√)												
acting as complex instream cover (has attached rootwad or intact branches) (√)	√	√	√	√								
D =dammed pool; P = plunge pool; L =lateral scour pool; B=backwater pool												
ADDITIONAL INFORMATION (OPTIONAL)												
decay class (1 = sound, limbs present; 2 = bark loose or absent, limbs absent, surface slightly rotted; 3 = surface extensively rotted, center solid or rotted)	1	1	1	1								
tree species (C = conifer, D = deciduous, U = unknown)	D	D	D	D								
input source (I=imported, R=riparian, U=upstream, B=bank erosion, Unk= unknown)	B	B	B	B								
Waypoint #	107	107	107	107								

*Rootwad present, piece stabilized at more than one point by banks or channel obstructions, end anchored by streambed or bank burial, pegged by standing trees, spanning

Tuolumne River LWD PROJECT CODE: S1712 TASK CODE: 0200

Study Reach Page 1 of 1

Study Reach Number: 9 O. mykiss Habitat Reach Number : — Crew Initials: JN/MR/KJ

Date: 6 / 14 / 12

Top of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6299°, 120.7724°

Bottom of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6266°, 120.7794°

Mark location of all tally LWD on aerial photographs Waypoint TR 21 104

Tally as "R" if rootwad attached

Diameter Class	Length Class					
	3–6.5 ft (1–2 m)	6.6–13 ft (2–4 m)	13.1–26 ft (4–8 m)	26.1–52 ft (8–16 m)	52.1–105 ft (16–32 m)	>105.1 ft (>32 m)
4-8 in (0.1–0.2 m)		III	I			
8.1–16 in (0.21–0.4 m)	I	II	I			
16.1–31 in (0.41–0.8 m)						
31.1–63 in (0.8–1.6 m)						

Comments: 106 → 4 pieces

Tuolumne River LWD PROJECT CODE: 5212 TASK CODE: 0200
Study Reach Page 1 of 1

Study Reach Number: 10 O. mykiss Habitat Reach Number: — Crew Initials: JN/MR/KJ

Date: 6/14/12

Top of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6158°, 120.8159°

Bottom of Reach GPS Location: Lat/Longs ~~or UTM~~ 37.6196°, 120.8277°

Mark location of all tally LWD on aerial photographs 108

Tally as "R" if rootwad attached TR 22

Diameter Class	Length Class					
	3–6.5 ft (1–2 m)	6.6–13 ft (2–4 m)	13.1–26 ft (4–8 m)	26.1–52 ft (8–16 m)	52.1–105 ft (16–32 m)	>105.1 ft (>32 m)
4-8 in (0.1–0.2 m)		||||		|		
8.1–16 in (0.21–0.4 m)		||||	~~||||~~ |	|		
16.1–31 in (0.41–0.8 m)		||||	|||			
31.1–63 in (0.8–1.6 m)						

Comments: ||| → 8 pieces

STUDY REPORT W&AR-12
ONCORHYNCHUS MYKISS HABITAT SURVEY

ATTACHMENT D

TUOLUMNE RIVER ARM AERIAL PHOTOGRAPHS

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A list of Google Earth® kmz file links for the attached aerial photographs is located on the public Don Pedro Relicensing website at http://www.donpedro-relicensing.com/default.htm.

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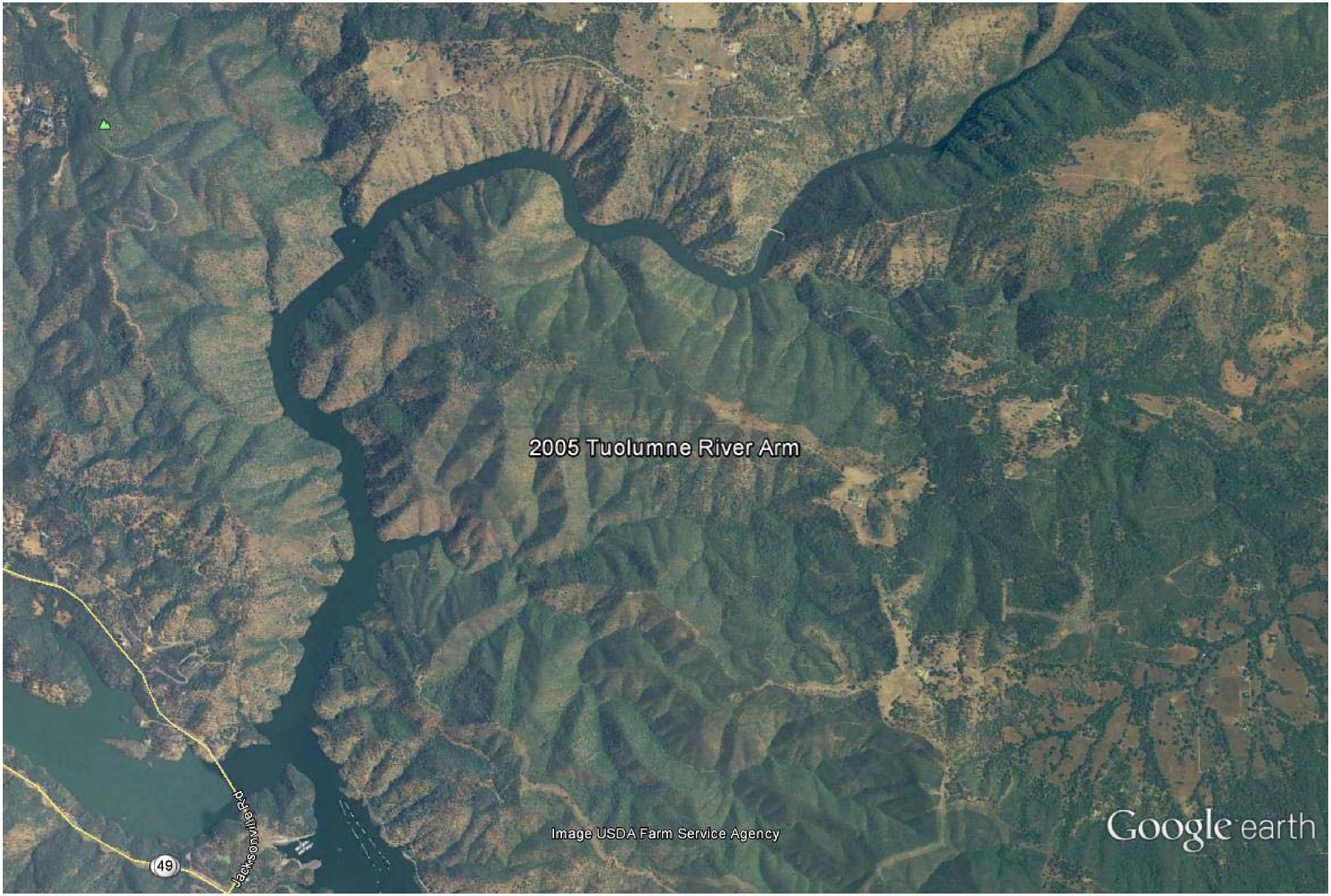


2005 Tuolumne River Arm
Image USDA Farm Service Agency
Google earth
Jacksonville Rd
49

Google earth
miles
3
km
6

Google earth

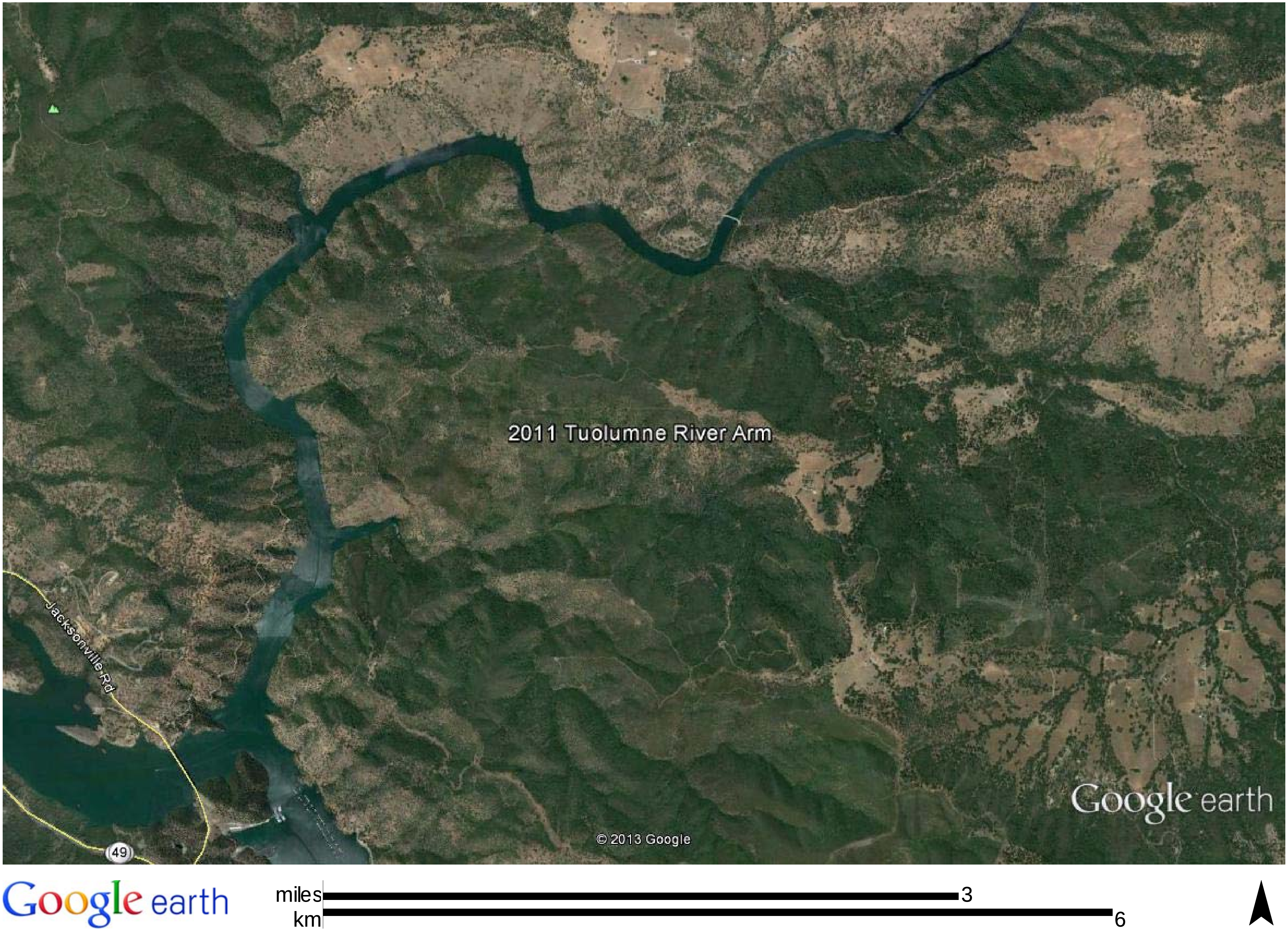
miles 3
km 6

Google earth

miles 3

km 6

2010 Tuolumne River Arm
Image USDA Farm Service Agency
Google earth
Jacksonville Rd
49
Google earth
miles
3
km
6


2011 Tuolumne River Arm
Jacksonville Rd
49
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miles 3
km 6