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Managing Water in the West

Habitat Assessment Final Report

Shasta Dam Fish Passage Evaluation

United States Department of the Interior

Mid-Pacific Region

Bureau of Reclamation

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Bureau of Reclamation

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Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Appendix A: Framework for Assessment of Habitat Conditions to Inform Planning for a Pilot-Level Chinook Salmon Reintroduction Study

Appendix B: Reach-Specific Habitat Inventories

Appendix C: Habitat Suitability Assessments

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Abbreviations and Acronyms

%	percent
°C	degrees Celsius
°F	degrees Fahrenheit
<	less than
>	greater than
≤	less than or equal to
≥	greater than or equal to
BO	Biological Opinion
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
D_{50}	median particle size
Fq	frequency
f_T	feet
ft^2	square feet
GIS	geographic information system
GPS	geographic positioning system
IFPSC	Interagency Fish Passage Steering Committee
LWD	large woody debris
m	meters
m^2	square meter
mm	millimeter

MMWAT	monthly maximum weekly average water temperatures
NMFS	National Marine Fisheries Services
OHW	ordinary high water
PG&E	Pacific Gas and Electric Company
PHABSIM	physical habitat simulation
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RM	river mile
RPA	reasonable and prudent alternative
sDVR	spatial digital video recorder
SWFSC	Southwest Fisheries Science Center
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WUA	weighted usable area
WY	Water Years

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Disclaimer

Mention of trade names in this report is for the sole purpose of documenting the scientific methodology used for this habitat assessment and does not imply endorsement by the U.S. government.

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Chapter 1 Introduction

This habitat assessment report was prepared as part of the U.S. Department of the Interior, Bureau of Reclamation's (Reclamation) planning for a pilot-level study to evaluate the feasibility of Chinook salmon reintroduction in tributaries upstream from Shasta Lake. This is required by the reasonable and prudent alternative (RPA) specified in the National Marine Fisheries Service's 2009 Biological Opinion on Long-term Operations of the Central Valley Project and State Water Project, as amended in 2011 (NMFS BO). Evaluation of habitat conditions above dams is required by the RPA "Action V-Fish Passage Program" as a priority action during the near-term phase of implementation of the RPA. The primary objective of these habitat assessments has been further specified by the Interagency Fish Passage Steering Committee (IFPSC), formed in 2010, to quantify and characterize the location, amount, suitability, and functionality of existing and/or potential spawning and rearing habitat above dams for reintroduction of Chinook salmon listed under the Endangered Species Act.

Purpose

This report describes the findings of a habitat assessment conducted in accordance with the Shasta Dam Fish Passage Evaluation *Framework for Assessment of Habitat Conditions to Inform Planning for a Pilot-Level Chinook Salmon Reintroduction Study* (Appendix A), hereafter, referred to as the "*Habitat Assessment Framework*," designed to inform development of the Shasta Dam Fish Passage Pilot Implementation Plan. The primary purpose of this habitat assessment is to describe habitat availability and conditions relative to the requirements for the freshwater life stages of Chinook salmon being considered for reintroduction rather than quantitatively predict the potential production of Chinook salmon upstream from Shasta Dam. This approach provides sufficient information for estimating the potential number of salmon that could be supported by the existing habitat conditions for purposes of a pilot-level study. The analytical tools consist of a spatially-explicit stream classification procedure; a set of habitat suitability criteria derived from the literature; use of existing regionally relevant data and information, augmented with aerial videography and limited field verification surveys to fill data gaps; and assumptions concerning the potential distribution and use of habitat by Chinook salmon in portions of the watershed to which they have not had access for over 70 years.

This report is organized to 1) provide a brief summary of the methodology and variances to the work plan described in the *Habitat Assessment Framework* (Appendix A) that were required to implement this habitat assessment; 2) present the findings of an aquatic habitat inventory and assessment of habitat conditions relative to the freshwater life history requirements of Chinook salmon; and, 3) based on the habitat assessment, provide preliminary estimates of the potential number of Chinook salmon that could be supported by the existing habitat

conditions in the upper Sacramento and McCloud rivers above Shasta Lake. To the extent practical, existing information with relevance to aquatic habitat conditions in the McCloud and Sacramento rivers above Shasta Dam was incorporated and used in this assessment.

Chapter 2 Methods

This chapter provides a brief overview of the methods used to collect, compile, and analyze data and information on aquatic habitat conditions in stream reaches upstream of Shasta Lake on the Sacramento and McCloud rivers. These data are used to characterize and assess the suitability and spatial distribution of the habitat that would be available for different life stages of reintroduced anadromous salmonids and to calculate a preliminary estimate of the potential number of Chinook salmon the river could support. A detailed study plan and analytical framework for conducting the *Habitat Assessment Framework* (Appendix A).

Data Collection

Relevant existing information applicable to the aquatic habitat assessment for the McCloud and Sacramento rivers above Shasta Dam was obtained and cataloged as part of the *Habitat Assessment Framework* (Appendix A). To supplement the existing information on habitat conditions, geo-referenced aerial videography was collected, along with limited ground-level surveys at locations representative of the larger study area.

A helicopter flight service was contracted to obtain low-altitude, slow-flight aerial videography along mainstem river channels and portions of significant tributaries during base flow conditions. The river sections flown included the Sacramento River from Shasta Lake to Box Canyon Dam, and the McCloud River from Shasta Lake to McCloud Dam and from McCloud Lake to Lower McCloud Falls[1]. Flights were conducted at the lowest practical altitude, usually 200 to 400 feet above ground-level, where legal and safe, and at a ground-speed of 17 to 30 knots (15-25 miles per hour). A Red Hen spatial digital video recorder (sDVR) connected to a geographic positioning system (GPS) and a Sony HDR–PJ790V video camcorder (set to 720 x 576 pixel video resolution for compatibility with the sDVR) was used to simultaneously obtain aerial video images and GPS coordinates. Flight altitudes were periodically recorded to an audio channel in the video files, which were used to calibrate lineal distances measured from the video images. Video files collected with the sDVR were analyzed directly within a geographic information system (GIS) platform using specialized extension software for videographic mapping.

To the extent possible, within the level of resolution of video images, geomorphic channel units were visually assigned to channel center line features in the GIS following the Level III habitat typing convention described in the U.S. Forest

[1] Aerial videography was postponed and completed in late-November 2013 rather than in October as proposed in the *Habitat Assessment Framework* because of temporary work order suspensions resulting from the Federal Government shutdown in 2013.

Service Pacific Southwest Region Stream Condition Inventory Technical Guide (Frazier et al. 2005), which is comparable to the methodology of historic surveys of the McCloud River (McCloud Coordinated Resource Management Plan 2001) and the Sacramento River (Thomas R. Payne & Associates 1992). The only exception to this habitat classification scheme was for describing flatwater geomorphic channel units, which were classified according to the Level IV habitat typing conventions, a higher level of detail used to identify specific habitat attributes important in assessing habitat function. For each geomorphic channel unit, habitat parameters associated with channel morphology (e.g. unit lengths, channel widths and depths), substrate, and bank condition were determined. Characterization of riverbed substrates was limited in the videos to determination of only dominant and subdominant bed sediment particle classes. Unfortunately, video coverage and detail was not sufficient to confidently apply cover shelter rating values. This was because aerial videography was obtained during the fall month, after much of the in-channel and near shore vegetation, which can provide some overhead cover, had died back.

Key features associated with pools, specifically the differentiation of deep and shallow pools, pools with suitable spawning gravel on their downstream tailouts, and areal extents of potentially suitable spawning gravel patches on pool tailouts, and elsewhere, were measured from the video images and recorded in the GIS database. Approximate areas of suitable spawning gravel on pool tailouts and riffle features were measured for the river stage at the time of video collection (approximately baseflow) and at the ordinary high water (OHW) mark. The OHW mark, in this case, is thought to represent the typical stage of the study streams at flows when the winter-run Chinook salmon spawns during the spring to early-summer months. Indicators of the OHW mark consisted of a distinct demarcation of the extent of terrestrial plant establishment between the active channel and floodplain, if any, but, in no case, extended above the bankfull elevation. Gravel areas on these channel features were assumed to provide generally suitable spawning conditions in terms of gravel area, water depth and velocity, if gravel deposits were at least one square meter (m^2) in area and would be inundated to a depth of at least 0.15 meters (m) (6-inches) under the targeted river stages, which were at baseflow and the OHW mark stages. Where spawning gravel deposits, at least $1m^2$, occurred in discontinuous patches within a habitat unit, the sum total of the areas of the gravel patches and the number of contributing patches was recorded.

Ground-level surveys were performed at a number of representative sites on each study stream to verify videographic interpretations across a range of channel types and in locations where aerial videography was obscured or in specific areas of interest with unique habitat features or transitional conditions (e.g., increased sediment deposition). Each of the study streams was divided into a series of relatively homogeneous study reaches. Study reaches were individually designated based on geomorphic and physiographic characteristics along the length of each stream (Tables 2-1 and 2-2).

Up to ten representative sites in the Sacramento River between Shasta Lake and Box Canyon Dam and in the McCloud River between Shasta Lake and McCloud Dam were originally selected for ground-level surveys. Late-seasonal topographic aspect shading and flight limitations due to weather conditions impeded video quality for determining certain habitat parameters (e.g., geomorphic unit type, channel dimensions, substrate composition, and cover) despite efforts to use frame-by-frame sequences and adjusting the video display contrast during the review. This required an expansion of the number and size of ground-level survey sites to sufficiently characterize the available habitat. The expanded size and effort to survey sites and the associated impact to budget expenditures for field work limited the total number of field sites that could be completed on the McCloud River. Additionally, access restrictions on private land, which borders nearly the entire reach of the McCloud River below McCloud Dam and above McCloud Reservoir to the Lower Falls, limited field sites to “Hawkins” and “Ah-Di-Na” in the upper reach (Shasta-Trinity National Forest) and “Ladybug” in middle reach (The Nature Concervancy’s (TNC) McCloud River Preserve), and none in the lower or headwaters reaches. Access to the lower reach was granted by Westlands Water District, but exhausted budget for field effort prevented the survey completion. As a result, 11 representative sites were surveyed on the upper Sacramento River, but only three sites on the McCloud between McCloud Dam and Ladybug Creek were able to be included in the this effort (Table 2-3).

Table 2-1. Reach-Scale Delineation for the Upper Sacramento River Used for Assessment of Habitat Condition

Study Reach	Begin/End Points (proceeding downstream)	Reach Description	Rationale for Selection
Box Canyon	Box Canyon Dam to Big Canyon Creek (RM 37.0-34.0)	This reach is characterized by a deep canyon, bedrock-confined channel, with minimal floodplain development and habitat diversity. High gradient, cascade and step-pool morphology.	This reach is geomorphically and physiographically unique and differs significantly from the other surveyed stream reaches.
Mossbrae	Big Canyon Creek to Dunsmuir (RM 34.0-30.0)	This is a transitional reach between the cascade and step-pool habitat upstream of Big Canyon Creek and the plane-bed habitat common through, and downstream of, Dunsmuir. Channel opens up and habitat diversity and channel access to the floodplain increases.	Reach is unique and transitional in nature between geomorphic channel types in adjacent reaches.
Dunsmuir	Dunsmuir to Soda Creek (RM 30.0-24.5)	This reach exhibits little tributary input. Although natural channel confinement is less than upstream, man-made channel confinement occurs through much of this reach. Primarily plane-bed, with slightly higher gradients than the Canyon Reach.	Plane-bed morphology, human influences, increasing gradient and lack of significant tributary input make this reach unique.
Canyon	Soda Creek to Mears Creek (RM 24.5-15.5)	This reach includes two large contributing tributaries (Soda and Castle creeks). Channel is moderately confined. Alternating bar sequences and riffle-pool morphology begin to dominate in this reach.	Transitional reach, where riffle-pool morphology begins. Reach selected to represent the quality and extent of habitat where increasing tributary inputs begin having noticeable effect on channel development.
Shotgun	Mears Creek to North Salt Creek (RM 15.5-7.2)	Increased hydrologic and alluvial sediment inputs from increasing size of tributary watersheds; wider and deeper channel, decreasing channel confinement, larger floodplains. Regular alternating bar sequences and riffle-pool morphology common.	Reach selected because its characteristics were intermediate to those in the North Salt and Canyon Reaches. Selected in part to inform whether longitudinal gradients in habitat quality and spawner capacity exist.
North Salt	North Salt Creek to Campbell Creek (RM 7.2-0.2)	This is the lowest gradient stream reach ending at Shasta Lake and is characterized by alternating riffle/pool sequences, with alluvial bar features and floodplain development, within a modestly bedrock-confined channel.	Dominant reach characteristic is the low-gradient and wide-open channel geometry, with riffle/pool sequences. Reach has the most alluvial characteristic resulting from the “mid-river” tributary inputs.

Key:
RM = river mile

Table 2-2. Reach-Scale Delineation for the McCloud River Used for Assessment of Habitat Condition

Study Reach	Begin/End Points (proceeding downstream)	Reach Description	Rationale for Selection
Headwater	Lower Falls to McCloud Reservoir (RM 36.0-29.0)	This headwater reach extends upstream from McCloud Reservoir to Lower Falls. Channel is moderately confined. Alternating riffle-flatwater (run, glide, pocketwater) morphology dominant in this reach. Large-deep pools infrequent. Big Springs, a substantial natural spring, contributes significant flow to the McCloud River in this reach.	This reach is geographically, geomorphically and physiographically unique and differs significantly from the other surveyed stream reaches.
Upper	McCloud Dam to AhDiNa Campground (RM 23.2-19.8)	This reach is characterized by a deep canyon, bedrock-confined channel, with minimal floodplain development and habitat diversity. High gradient, cascade and step-pool morphology.	This reach is geomorphically and physiographically unique and differs significantly from the other surveyed stream reaches.
Middle	AhDiNa Campground to Squaw Valley Creek (RM 19.8-9.5)	Increased hydrologic and alluvial sediment inputs from increasing size of tributary watersheds; wider and deeper channel, decreasing channel confinement and larger floodplains in places. Generally bedrock-controlled channel. Regular alternating bar sequences and riffle-pool morphology uncommon; pocketwater dominated.	Reach selected to represent the quality and extent of habitat where increasing tributary inputs begin having noticeable effect on channel development and habitat diversity.
Lower	Squaw Valley Creek to Nawtawaket Creek (RM 9.5-0.0)	Increased hydrologic and alluvial sediment inputs from increasing size of tributary watersheds; wider and deeper channel. Bedrock-controlled channel; alternating bar sequences and riffle-pool morphology uncommon. Step-pool, pocketwater, and pool-flatwater morphology typical.	Reach selected to represent the larger, yet bedrock-dominated morphology common in the lower McCloud River. Some alluvial features, but primarily dominated by pool and pocketwater features.

Key:
RM = river mile

Table 2-3. Representative Field Sites Selected for Ground-Level Surveys to Verify Videographic Interpretations over a Range of Channel Types and in Locations Where Aerial Video Coverage was Obscured in the Sacramento and McCloud Rivers

Stream	Site Name	Survey Date	Location[a]				Selection Procedure
			Downstream Boundary		Upstream Boundary		
			Northing	Easting	Northing	Easting	
Sacramento	Cantara	1/16/2014	557873	4568242	557227	4568913	Systematically assigned
Sacramento	Mossbrae	1/09/2014	561414	4565971	560859	4566653	Systematically assigned
Sacramento	Dunsmuir 1	1/07/2014	561080	4562152	561046	4563117	Systematically assigned
Sacramento	Dunsmuir 2	1/07/2014	560933	4561395	560739	4560792	Systematically assigned
Sacramento	Canyon 3	1/06/2014	558049	4555648	558760	4555600	Random
Sacramento	Canyon 2	1/15/2014	556602	4551686	556410	4550950	Random
Sacramento	Canyon 1	1/15/2014	554216	4547352	554401	4547840	Random
Sacramento	Shotgun 2	1/08/2014	551121	4542294	550970	4542906	Random
Sacramento	Shotgun 1	1/08/2014	549763	4538773	549979	4539227	Random-adjusted
Sacramento	North Salt 1	1/13/2014	547676	4533081	547835	4534182	Random
Sacramento	North Salt 2	1/14/2014	548467	4537747	549211	4538000	Random
McCloud	Hawkins	1/28/2014	578476	4551645	578639	4552376	Systematically assigned
McCloud	AhDiNa	1/29/2014	576088	4551643	577152	4551767	Systematically assigned
McCloud	Ladybug	1/29/2014	574153	4549580	574587	4550073	Systematically assigned

Notes:
[a] Location: Universal Transverse Mercator (UTM), NAD 83, zone 10 (meters)

Representative sites were first assigned to reaches or channel segments where the aerial videography was obscured to the extent that geomorphic channel units and basic habitat parameters (e.g., substrate composition, channel widths and depths) could not be determined. Remaining sites were allocated proportionally among distinct reach types and survey starting points were selected at random (Figures 2-1 and 2-2[2]). Each representative site consisted of a length of stream channel equal to at least 20 average bankfull channel widths, up to 1,000 m, depending on local channel conditions and complexity. The minimum objective for each representative site was to include at least one full channel meander wavelength, or two riffle-pool sequences.

Field surveys included collection of data for an inventory of habitat types, identification of potential migratory impediments created by some high-gradient riffles and cascades, characterization of bed substrate composition, characterization of type and extent of cover components, assignment of pool complexity and shelter values, and estimation of the areal extent of suitable spawning gravel (see the *Habitat Assessment Framework* (Appendix A) for details on survey protocols).

[2] Only the first three survey sites from McCloud Dam downstream to Ladybug Creek on this figure were included in the habitat assessment effort, to date.

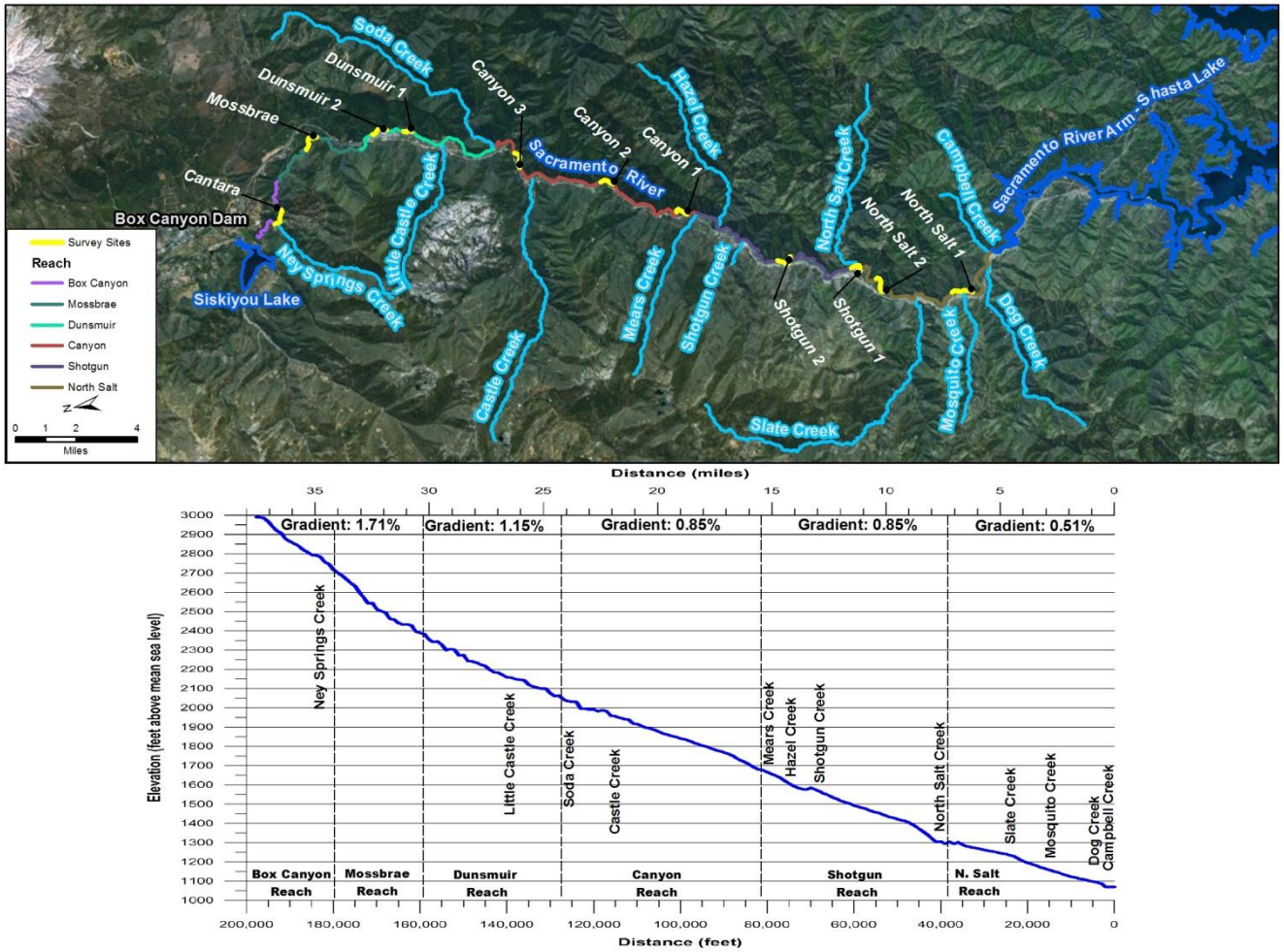
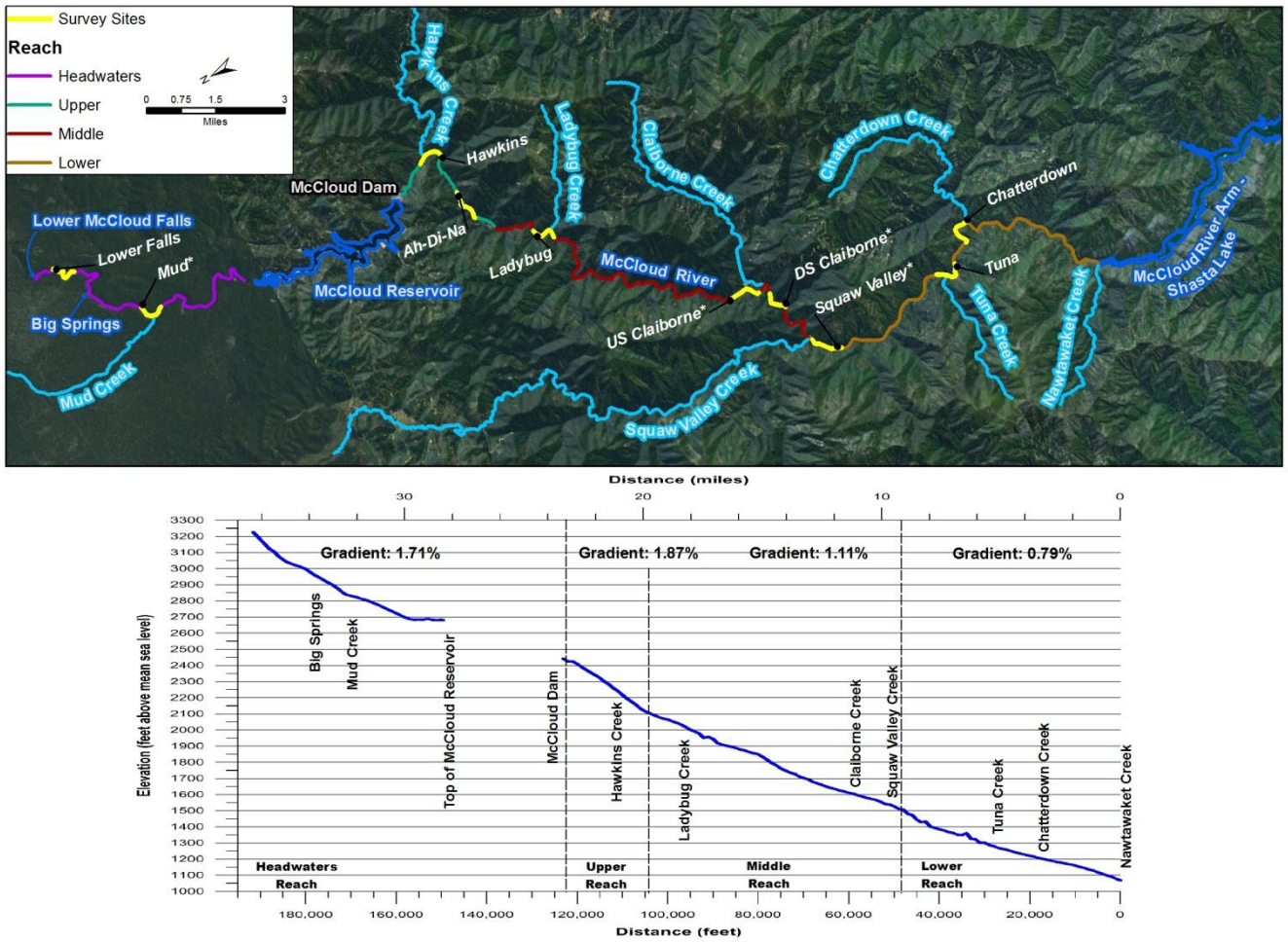


Figure 2-1. Sacramento River Channel Profile between Shasta Lake and Box Canyon Dam Illustrating Selected Study Reaches and Representative Field Sites for the Shasta Dam Fish Passage Evaluation During 2013 and 2014



McCloud River - Shasta Lake to Lower McCloud Falls

Vertical lines delimit reaches based on hydrogeomorphic characteristics.
** Signifies survey sites to which access has not been granted.*

Figure 2-2. McCloud River Channel Profile Between Shasta Lake and Lower McCloud Falls Illustrating Selected Study Reaches and Representative Field Sites for the Shasta Dam Fish Passage Evaluation During 2013 and 2014

Aquatic Habitat Inventory

A GIS was used to integrate various types of habitat condition data and other relevant information in one or more geospatial database layers that were organized on the stream reach network as the base map. Habitat attribute data obtained from aerial videography and field surveys were entered into spreadsheets, subjected to data quality assurance procedures, and organized to facilitate comparisons of data from the two methods. Data from representative survey sites were compiled and summarized as the representative habitat conditions for their respective study reaches. In comparison, data from videographic interpretation for the entire length of each study reach were used to characterize habitat conditions for the respective reaches. Aquatic habitat inventory metrics for channel morphometry; channel bed substrate, including spawning gravel areas; and cover were compiled and statistical distributions were summarized for comparison of the videographic and field survey data. Although the methods described in the *Habitat Assessment Framework* (Appendix A) called for comparing and evaluating the statistical distributions of key habitat metrics for the two methods to develop a single inventory from which to conduct the habitat assessment, the difficulties encountered in extracting measurements from the videography for all of the habitat metrics, previously described, led to discrepancies in the completeness and comparability of data sets. Consequently, habitat inventories, habitat suitability assessments, and spawner estimation are presented separately for each data collection method, along with the uncertainties associated with the findings for both methods.

In particular, limitations on channel lighting and image quality of the aerial videography prevented determination of substrate composition and the extent and type of cover at all locations throughout the study area. To adjust for this limitation, average cover and substrate metric values, by geomorphic channel unit type, computed from the representative field survey sites, were applied to each of the respective geomorphic channel units in video images, for each study reach. Additionally, for the aerial video-derived datasets, channel gradients for each study reach were determined from map-based topography. For aerial video and field survey datasets, channel entrenchment for each study reach was estimated from aerial imagery and applied to both.

Existing available hydrologic and water temperature data for the Sacramento and McCloud rivers were compiled to characterize the annual variability, seasonal, and longitudinal patterns in flow and temperature metrics. Statistical metrics computed and evaluated include monthly mean, minimum, and maximum average daily flows for continuous data records for the Sacramento River at Delta (U.S Geological Survey [USGS] Gage No. 11341500) and the McCloud River above Shasta Lake (USGS Gage No. 1136800) and at Ah-Di-Na (USGS Gage No. 11367800). Water temperature data were similarly compiled and metrics computed for the Sacramento River at Delta, McCloud River above Shasta Lake and for the McCloud at the McCloud River Preserve (TNC, unpublished data). Longitudinal warming of water temperature in the Sacramento River was evaluated by comparing the daily average water temperatures at ten stations on

the Sacramento River during Water Year 2012 (Reclamation, unpublished data). Similar trends in water temperature were evaluated for the McCloud River using the available water temperatures (daily average) reported in Pacific Gas and Electric Company (PG&E 2008) and provided in electronic format by PG&E for May through October in 2006 to 2008. Thermographs located above McCloud Reservoir, downstream of major tributary confluences (Hawkins Creek, Ladybug Creek, Claiborne Creek, Squaw Valley Creek, Chatterdown Creek), and above Shasta Lake were selected to characterize thermal patterns in the McCloud River. Monthly maximum weekly average water temperatures (MMWAT) were computed for each month between May and October using the available thermographic records, including the Sacramento River at Delta, McCloud River above Shasta Lake, and at the McCloud River Preserve for water years 2003 to 2012; each of the ten Reclamation monitoring stations on the upper Sacramento River for water year 2012; and each of the PG&E thermographs on the McCloud River for water years 2006 to 2008. The MMWAT value is the maximum 7-day moving average of daily average water temperatures for any given month. The standard deviation of the monthly maximum 7-day moving daily average water temperature is reported with the MMWATs in this report to provide an indication of the variability (or stability) of the thermal regime during the period of peak summer temperatures in the study rivers.

Habitat Suitability Assessment

Figure 2-3 depicts the scheme used to provide a preliminary assessment of habitat conditions for the reintroduction of anadromous salmonids. The assessment methodology uses forty-two habitat inventory metrics measured from aerial video interpretation and field surveys to derive a number of life stage-specific habitat suitability metrics, to which can be assigned habitat condition ratings, or scores, based on literature-derived, life stage-specific, habitat suitability criteria (Figure 2-3). The aquatic habitat inventory metrics were used to compute attribute metric values, which were assigned associated suitability ratings, using the criteria provided in the *Habitat Assessment Framework* (Appendix A), that, with minor modifications, are shown in Tables 2-4 and 2-5. Attribute metric values were computed for index sections, which were subdivisions of each study reach consisting of four sequential geomorphic channel units for both the aerial video and field survey datasets. Attribute group metric means, along with the standard errors of the means were provided as a measure of the variability of metric mean values for the index sections, and were summarized for each study reach. The term “standard error” used here is the conventional statistical term for the standard deviation of a group of mean values intended to represent a population, in this case, the habitat metrics for each study reach. Finally, in the course of this assessment, it became clear that two metrics were redundant and added no additional information or value to the habitat suitability metrics or attribute groups; namely, 1) pool complexity and shelter value, and 2) pool proximity to spawning gravel; and were omitted from further evaluation.

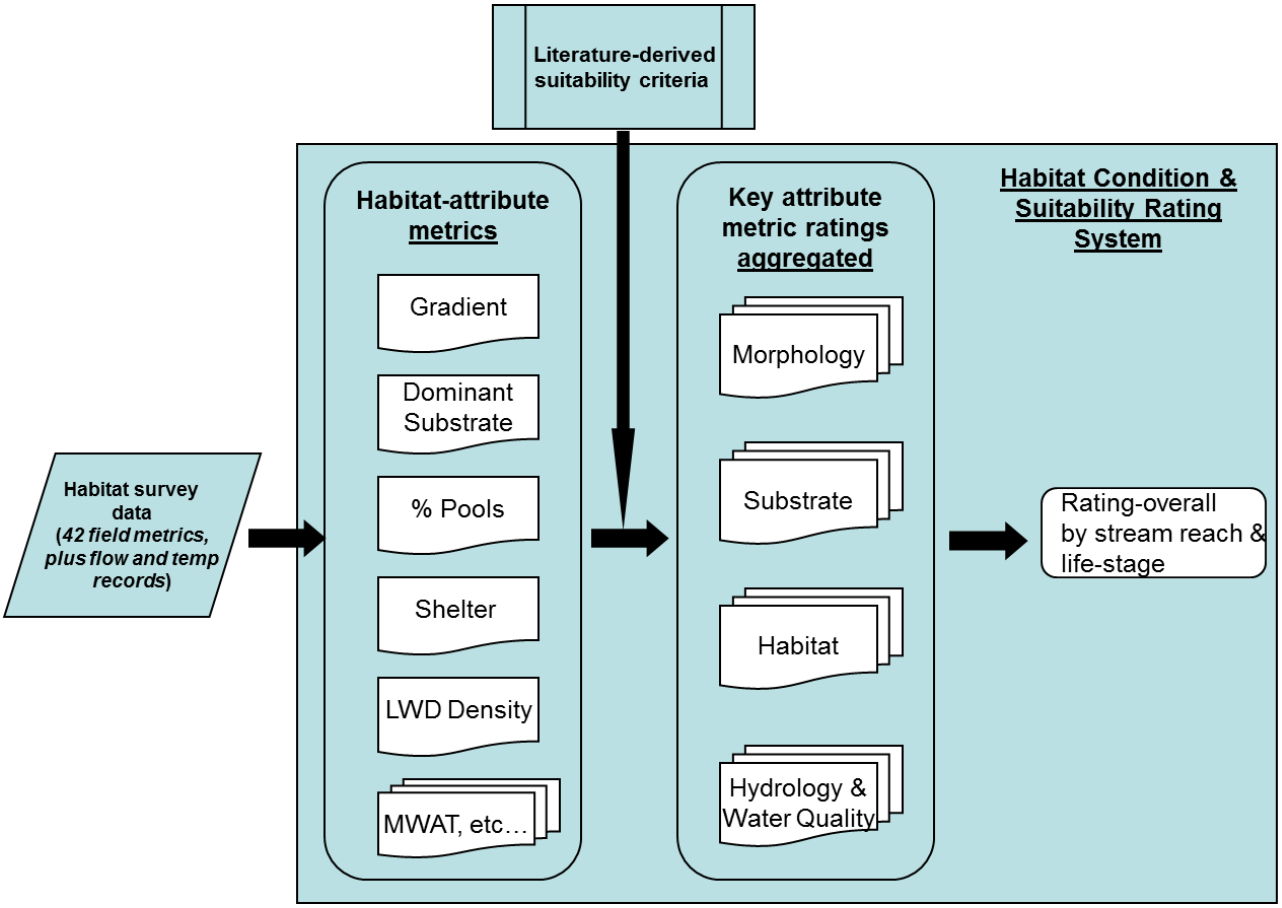


Figure 2-3. The Relationships of Habitat Inventory Metrics Measured from Aerial Videography and Ground-Level Field Surveys of Representative Sites to Habitat Attribute Metrics and Key Habitat Attribute Groups and the Habitat Suitability Rating System

Table 2-4. Literature Derived Chinook Salmon Spawning, Egg Incubation, and Emergence Criteria Selected for a Reach-Scale Spawning Habitat Condition Assessment on the Sacramento and McCloud Rivers

Attribute	Metric	Good	Fair	Poor
Channel morphometry	Channel type	pool-riffle	plane bed	step-pool, cascade
	Gradient	1-3%	3-4%	≥ 4%
	Entrenchment (flood prone width : bankfull width)	≥ 2.2	1.5-2.2	≤ 1.5
	Channel depth	0.25-3.0 m	--	< 0.25 m
Substrate (before redd construction)	subdominant bed substrate	gravel/cobble	gravel/fines	cobble/fines
	% gravel in riffles	> 30%	15-30%	< 15%
	% cobble in riffles	20-40%	10-20%; 40-70%	< 10%; > 70%
	% fines in riffles	≤ 10%	10-20%	> 20%
	Embeddedness in riffles	< 25%	25-50%	> 50%
Habitat	ratio	40-60% pools with tailouts	20-40% pools	< 20%; > 60% pools
	Pool proximity to spawning gravel	adjacent	--	--
	Pool depth	> 2.5-3 m	1.5-2.5 m	< 1.5 m
	Spawning gravel area	> 6 m^2	3-6 m^2	< 3 m^2

Note:

See Habitat Assessment Framework (Appendix A) for detailed review of the literature, bibliography, and selection of habitat criteria for reach scale habitat assessment.

Key:
% = percent
≤ = less than or equal to
≥ = greater than or equal to
< = less than
> = greater than
m = meters
m^2 = square meter
"--" = no data available

Table 2-5. Literature Derived Chinook Salmon Rearing Habitat Criteria Selected for a Reach-Scale Spawning Habitat Condition Assessment on the Sacramento and McCloud Rivers

Attribute	Metric	Good	Fair	Poor
Channel morphometry	Channel type	pool-riffle	plane bed	step-pool, cascade
	Gradient	< 1-2%	2-5%	> 5%
	Entrenchment (flood prone width : bankfull width)	≥ 2.2	1.5-2.2	≤ 1.5
	Channel depth	shallow (0.10-0.25 m) for fry; progressively deeper for parr	--	--
Substrate	Bed Substrate: dominant/subdominant	cobble/gravel	gravel/cobble	gravel/fines
	% Gravel	≥ 15%	5-15%	< 5%
	% Cobble	≥ 15%	8-15%	< 8%
	% Fines	≤ 10%	10-30%	> 30%
	% Embeddedness	≤ 25%	25-50%	> 50%
Cover	Cover type dominant/subdominant	boulder/LWD/ overhead	--	--
	Overhead cover (% of surface area)	≤ 30%	10-30%	< 5%
	% Boulder	≥ 20%	5-20%	< 5%
	LWD (Overall *Fq*/100 m)	≥ 20	10-20	< 10
	Shelter (total cover) value (0-3)	3	2	0-1
Habitat	riffle ratio	40-60% pools/glides	20-40% pools/glides	< 20%; > 60% pools
	Large, deep pool *Fq* (> 0.6 m deep, ≥ 9 m wide)	≥ 50% of pools	20-50% of pools	< 20% of pools
	Pool complexity/ Shelter value	good	fair	poor

Note:

See Habitat Assessment Framework (Appendix A) for detailed review of the literature, bibliography, and selection of habitat criteria data for reach scale habitat assessment.

Key:
% = percent
< = less than
> = greater than
≤ = less than or equal to
≥ = greater than or equal to
Fq = frequency
LWD = large woody debris
m = meters
"--" = no data available

Spawner Capacity

Procedures used for estimating the number of salmon spawners (represented as the number female salmon) for the purposes of the Shasta Dam Fish Passage Pilot Implementation were described in detail in the *Habitat Assessment Framework* (Appendix A). The selected methodology takes into account the amount of available suitable spawning habitat and the required redd and defended territory size (i.e., area required per pair of fish). The spawner capacity is a function of the area of spawning habitat available, substrate composition, number of gravel patches, and spawning territory requirements (redd space and defended space). The original spawning territory size criterion of 20 m^2, described in the *Habitat Assessment Framework* (Appendix A), was augmented by adding 5 m^2 and 10 m^2 criteria because the range of requirements for salmon redd areas and defended territory sizes in the literature is broad for Chinook salmon, and also, because on-site field conditions and incidental observations of salmonid nests tended to suggest that defended redd areas could likely be smaller than 20 m^2 in the study streams. Additionally, the consensus opinion of several experts on the Fish Passage Habitat Subcommittee was that winter-run Chinook salmon typically exhibit smaller nest sizes than fall-run Chinook salmon to which most of the literature-derived data refer. Spawner capacities for aerial video interpreted habitat metrics were computed for entire study reaches for the baseflow and OHW mark stages. Spawner capacities from field survey-derived habitat metrics were computed by simple linear expansion of the number of spawners and spawning habitat area delineated within representative sites to the full study reach (i.e., number of spawners was divided by surveyed field site length and multiplied by the study reach length). One of the limitations of the video-derived habitat assessment was our ability to differentiate between gravel- and cobble-sized bed sediments. Further, the inability to distinguish isolated spawning gravel patches and the inability to identify substrates in video images with high levels of shading and vegetative cover also affected our ability to accurately estimate suitable salmonid spawning habitat from the aerial videography.

Results

These results present the findings on habitat conditions in the upper Sacramento and McCloud rivers upstream from Shasta Lake to support the development of the Shasta Dam Fish Passage Pilot Implementation Plan. This report is organized to provide results for the Sacramento and McCloud rivers separately, describing aquatic habitat inventories, assessment of habitat suitability for freshwater life stages of Chinook salmon, and estimates of Chinook salmon spawner capacity for each stream. Detailed data on reach-specific habitat inventories and habitat suitability assessments are provided in "Reach Specific Habitat Inventories," Appendix B and "Habitat Suitability Assessment," Appendix C, respectively. A complete spatially-explicit habitat inventory database is available in electronic format.

Sacramento River

Aquatic Habitat Inventory

Aerial videography was obtained along the upper mainstem Sacramento River between Shasta Lake and Box Canyon Dam on November 23, 2013. Average daily flow on this date at the USGS Delta gage (USGS Gage No. 11341500) was 210 cubic feet per second (cfs), when releases from Box Canyon Dam were approximately 45 cfs, based on Siskiyou County records (Siskiyou Power Authority, unpublished record, http://www.co.siskiyou.ca.us /content/general-services-siskiyou-power-authority). Video quality and coverage generally decreased with distance upstream from Shasta Dam as channel widths decreased and the channel sinuosity, hillslope, topographic aspect, and vegetation cover increased (Appendix Table B-1). Overall, video coverage and quality was sufficient to allow delineation of geomorphic channel units and identification of most habitat parameters, except for those related to channel gradient, bed substrate details, and complex cover shelter ratings. In the vicinity and upstream of the town of Dunsmuir, video quality was poor because flight conditions and topographic shading affecting the ability to clearly see the river channel and reliably identify habitat units and measure key features. These sites were subsequently included in the ground-level field surveys.

Ground-level surveys were conducted at representative field sites between January 6, 2014 and January 16, 2014. Average daily flow at the Delta gage during the field survey period averaged 200 cfs, while Box Canyon Dam releases were about 45 cfs (Siskiyou Power Authority, unpublished record, http://www.co.siskiyou.ca.us /content/general-services-siskiyou-power-authority). Several salmonid redds were observed during field site surveys (Table 3-1). Following habitat surveys, California Department of Fish and Wildlife (CDFW) biologists and North State Resources, Inc. Aquatic Scientist Keith Marine collected approximately 50 developing eggs from three of these redds near Sims Road and Gibson Road on the Sacramento River, which were transferred to the

NMFS Southwest Fisheries Science Center (SWFSC) to determine if these eggs were from Chinook salmon stocked in Shasta Lake as part of the inland fisheries management program. Genotyping results indicated that the eggs were not from Chinook salmon; however, the genetic test could not distinguish to which salmonid species the eggs belonged, other than that they were, indeed, from another salmonid (Garza 2014). Other salmonid species occurring in the region that may have spawned in the late-fall and early winter include, most likely, brown trout (Salmo trutta) and, perhaps, rainbow trout (Oncorhynchus mykiss). Adfluvial populations of both species are known to migrate from Shasta Lake to spawn in the upper Sacramento River (North State Resources [NSR] 2010). The incidental observation of salmonid redds were used as corroborative evidence of the potential suitability of habitat features for spawning salmonids.

Review of existing data, aerial video and ground surveys indicate the only notable upstream fish passage impediment in the Sacramento River between Shasta Lake and Box Canyon Dam is Mears Falls, located immediately upstream of the Mears Creek confluence with the Sacramento River (RM 15.6) (Table 3-2). This feature is a three step, compound, cascade approximately 50 meters in length. The middle and downstream-most cascades are the most formidable sections for fish passage with a 30 to 40 percent gradient and each cascade is 2 to 2.5 meters in height at typical late-summer and fall flows (Figure 3-1). This feature forms an incomplete, seasonally temporary, impediment to upstream migration during such times, but would not be a complete barrier and would certainly be passable during the higher river flows of the winter through early-summer months.

Table 3-1. Observations of Salmonid Redd Observations in the Upper Sacramento and McCloud Rivers During January 2014 Fish Habitat Surveys

Stream	Date	Location[a]		# of Redds	Habitat Unit	Gravel Size Distribution	Notes
		Northing	Easting				
Sacramento	1/8/2014	551057	4542311	1	Pool-tail	D_{50}: 68 mm 44% gravel 49% cobble	Redd size was 0.9 m wide x 1.4 m long.
Sacramento	1/15/2014	554370	4547529	1	Pool-tail	D_{50}: 36 mm 10% sand 70% gravel 20% cobble	Redd size was 1.2 m wide x 1.8 long.
McCloud	1/29/2014	574441	4549588	1	Pool-tail	D_{50}: 16 mm 97% gravel 3% cobble	Redd size was 1.1 m wide x 1.7 m long. Scattered gravel patches in pool-tail. Redd appeared to be a little older. Embeddedness low, however, quite a bit of very fine silt in gravel matrix.
McCloud	1/28/2014	578686	4551662	2	Depositional bar along margin of step-pool	D_{50}: 12 mm 98% gravel 2% cobble	Redd size was 0.9 m wide x 1.3 m long. Along edge of margin deposit.
McCloud	1/28/2014	578833	4551938	1	Pocketwater	D_{50}: 13 mm 99% gravel 1% cobble	Redd size was 0.9 m wide x 1.3 m long. Scour patch of gravel within pocketwater.
McCloud	1/29/2014	576623	4551699	4	Pool-tail	D_{50}: 20 mm 98% gravel 2% cobble	Redd size was 0.9 m wide x 1.2 m long. All on large-pool tail gravel deposit. 3-older redds, one very new redd (< 2 weeks old?).

Source: National Marine Fisheries Service Southwest Fisheries Science Center

Notes:

Genotypes of eggs sampled from Redds were determined not to be Chinook salmon.

[a] Location: Universal Transverse Mercator, NAD 83, zone 10 (meters)

Key:
= number
% = percent
D_{50} = median particle size
m = meter
mm = millimeter

Table 3-2. Observations of Fish Passage Impediments in the Upper Sacramento and McCloud Rivers During January 2014 Fish Habitat Surveys

Stream	Barrier Name	Location[a]		Barrier/Impediment Characteristics		
		Northing	Easting	Class[b]	Height	Description
Sacramento	Mears Falls	554209	4546932	Complex chute	2 to 3 m at each jump	Three step, complex cascade; 50 m long
McCloud	Tuna Falls	566308	4538334	Boulder cascade	1.5 to 2 m	Simple boulder cascade; 15 m long

Notes:
[a] Location: Universal Transverse Mercator, NAD 83, zone 10 (meters)
[b] Powers and Orsborn (1985)
Key:
m = meter

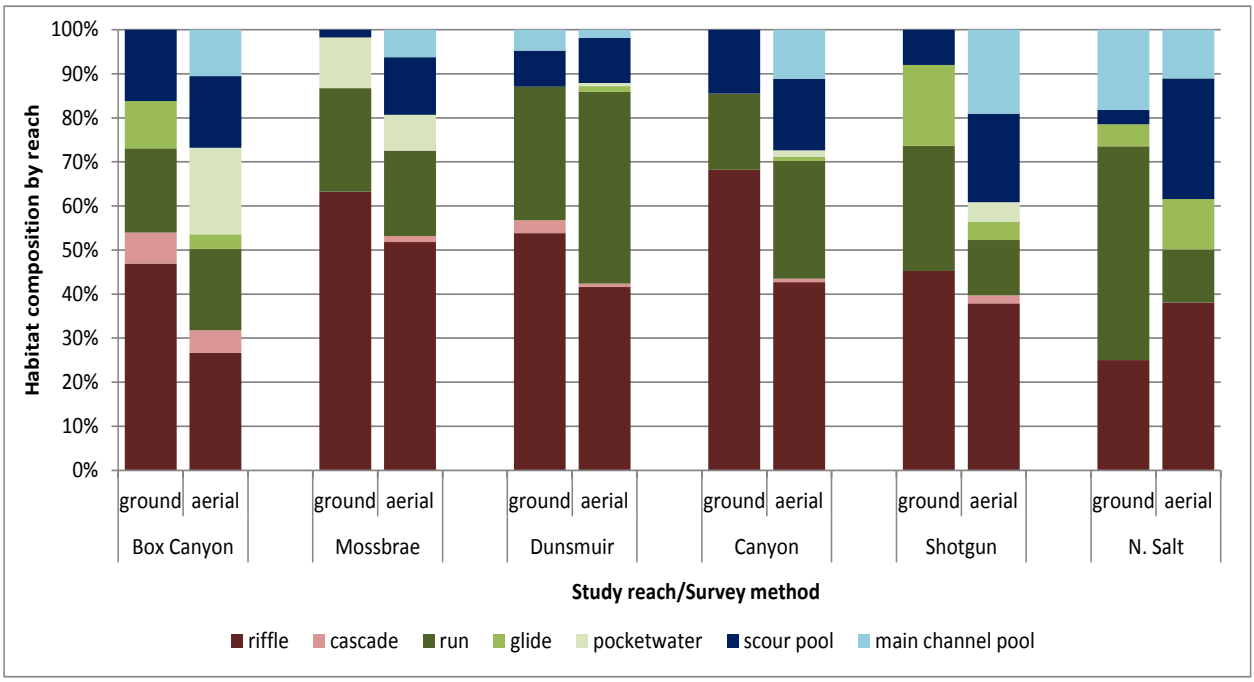
Note: Top left photo is downstream end of impediment looking upstream, top right photo is midway up impediment looking upstream and bottom photo shows upstream end of impediment looking upstream

Figure 3-1. Photographs of Mears Falls on the Sacramento River

Aquatic habitat inventory data collected by aerial videography interpretation and by representative field surveys were compiled by study reach, details of which are provided in Appendix B[3]. Ground-level (field) site surveys covered between 14 and 27 percent of the entire lengths of each study reach (Table 2-1 and Figure 2-1) and were conducted in part to augment video interpretation where video coverage was poor and certain parameters were not discernable (i.e., cover and substrate composition). Geomorphic habitat composition in the Sacramento River between Shasta Lake and Box Canyon Dam was dominated by flatwater (consisting of runs, glides, and pocket water) and pools in the two downstream-most study reaches up to Mears Creek, comprising 15.5 miles, or nearly forty-two percent, of the entire upper Sacramento River (Figure 3-2). From Mears Creek, up to Box Canyon Dam, which comprises 21.5 miles of the river, the proportion of high-gradient, riffle and cascade habitat increases as the channel morphology transitions from a bedrock-confined channel, with alluvial features, to a bedrock-confined, wholly plane-bed channel. Pool habitat becomes quite limited (less than 10 percent of the available habitat) from the Dunsmuir Reach on up to Box Canyon Dam; habitat there is dominated by bedrock-controlled riffle-run sequences consistent with the increasing channel confinement in these reaches.

Differences were expected to occur in the aquatic habitat inventories obtained using the two data collection methods. Differences most commonly resulted from the lack of detail available in the aerial videography to correctly identify or measure habitat features, and less commonly occurred as a result of chance absence or omission of habitat features at the selected field sites. Comparison of the geomorphic channel unit inventories showed that aerial video interpretation misidentified some riffles for runs and some runs for pools as was verified by ground surveys of representative sites (see Appendix B for reach-by-reach comparisons of inventories of the two methods), which resulted in higher frequencies of pools and lower frequencies of riffles relative to that estimated from representative site surveys (Figure 3-2). Flatwater habitat units were often difficult to distinguish from pools because of obscured or unclear views of channel depth and bottom features in the deep shade that occurred at many locations along the river on the dates of aerial surveys. Differences in these habitat inventory results were sufficient that it was decided to not combine, as originally proposed, but compute and present separate habitat condition assessment scores for both data collection methods.

[3] Complete database files are also available in electronic file format.

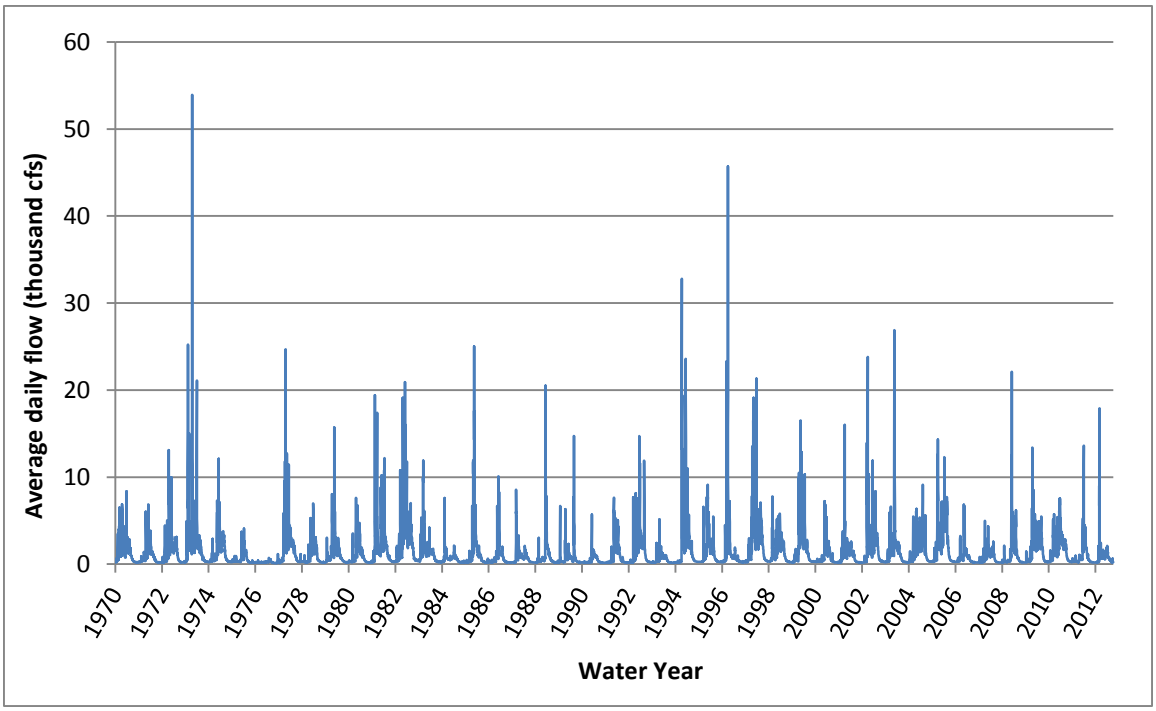


Key:
% = percent

Figure 3-2. Comparison of Geomorphic Channel Unit (riverine habitat type) Composition in the Upper Sacramento River, by Study Reach, for Aerial Videographic Interpretation (aerial) and Representative Field Site (ground) Surveys

Available stream flow and water temperature records for the Sacramento River between Box Canyon Dam and Shasta Lake are compiled and summarized in Appendix B. The compilation includes annual and seasonal hydrographs and thermographs, streamflow and temperature frequency duration curves, and annual statistics (minimum, maximum, and average metric values) for the available data. A summary and overview of streamflow and water temperature records for the upper Sacramento River study area follows.

Streamflow in the upper Sacramento River is partially regulated by releases from Box Canyon Dam; however, analysis of the daily stream flow record shows that the operation of Box Canyon Dam has not measurably changed the baseflow discharge of the upper Sacramento River (NSR 2010). Minimum instream flow releases from Box Canyon Dam are 40 cfs but are typically set to 47.5 cfs rather than 40 cfs to avoid releasing less than the minimum instream flow (Federal Energy Regulatory Commission [FERC] 2006). No contemporary or continuous stream flow records are available between Box Canyon Dam and the USGS gage at Delta, which is located less than one mile upstream of the full pool elevation of Shasta Lake. The pattern of average daily flows at the Delta gage for Water Years (WY) 1971 to 2012 is provided in Figure 3-3. The flow regime in this reach of the upper Sacramento River is generally low and relatively stable between July and



November, with considerable variation in response to precipitation and peak flows during the winter months (detailed record summaries provided in Appendix B).

Key: cfs = cubic feet per second

Figure 3-3. Average Daily Flow for the Sacramento River at Delta (USGS Gage No. 11341500) for Water Years 1971 to 2012

Continuous water temperature records were available only for the Sacramento River at the Delta gage, which are provided in Appendix B. To augment the thermographic record at the Delta gage, Reclamation installed nine thermographs along the Sacramento River between Box Canyon RM 36 and Gibson Road (RM 9) in late-2011. Table 3-3 shows the MMWAT in the Sacramento River for these nine thermographs during the spring and summer months of 2012, which was a below normal water year (California Department of Water Resources 2014). A longer time series of MMWAT for the Sacramento River at the Delta gage was compiled and is provided in Table 3-4 for WYs 2003 to 2012. During July and August, the MMWAT progressively increases from approximately 50°F (10°C) in both months at Box Canyon Dam (RM 36) to 62.0°F (16.7°C) in July and 66.0°F (18.9°C) in August at Gibson (RM 9), and then increases up to approximately 69.0°F (20.6°C) at Delta (Tables 3-3 and 3-4). The average daily water temperatures do not vary more than about ±1.0°F (±0.6°C) at any of the monitoring stations during the summer baseflow period when the MMWAT occurs (see standard deviations of MMWAT statistics in Tables 3-3 and 3-4 and Appendix B for details); so, the MMWAT statistic provides a reasonable measure of the magnitude and duration of chronic high temperature conditions within the

various river reaches. Furthermore, examination of daily maximum and minimum water temperatures shows that the typical range of daily temperature fluctuation is no greater than ±3.0°F (±1.6°C) around the average daily temperature at most of the monitoring stations (see Appendix B for technical details).

Habitat Suitability

Overall spawning life stage habitat condition scores in the upper Sacramento River computed from both aerial video- and field-derived habitat inventories indicated that spawning habitat condition in all study reaches throughout the upper Sacramento River ranges from fair-to-good (Table 3-5, Appendix B). Substrate attribute scores, which were the highest of the three spawning habitat attributes, were similar for both habitat inventory methods because several of the component substrate parameters from field surveys had to be substituted and used for the video substrate metric computations due to previously described limitations on videographic interpretations of bed substrate conditions. The lowest spawning habitat component scores were for structural habitat metrics (e.g., proportion of pool habitat, maximum pool depth, and spawning substrate area), suggesting that one of the limiting factors of overall salmon spawning habitat condition in the Sacramento River may be the frequency of large-deep pools and the amount of suitable-sized spawning gravel, especially in the river reach upstream of Dunsmuir. However, pool depths and spawning gravel areas may be more limiting under the low, baseflow conditions occurring in the late-summer and fall, when spring-run Chinook salmon spawn, but not so limiting during the higher flows of spring and early summer, when winter-run Chinook salmon spawning peaks, although the later spawning fraction of the winter-run Chinook salmon would be affected since they have been observed to spawn as late as into August (Vogel and Marine 1991; Moyle 2002).

Table 3-3. Monthly Maximum Weekly Average Temperatures for the Upper Sacramento River at Ten Monitoring Locations, with Approximate River Mile, During May to October, Water Year 2012

Month	Station Name	MMWAT (°F) ± 1 Standard Deviation[a]									
		Box Canyon (RM 36)	Cantara (RM 35)	Mossbrae Upper (RM 32)	Mossbrae Lower (RM 31)	Soda (RM 24)	Riverside (RM 23)	Conant (RM 19)	Sims (RM 15)	Gibson (RM 9)	Delta (RM 0)
May		49.4±0.3	49.8±0.2	50.6±0.4	50.5±0.4	53.1±1.0	53.5±1.1	54.7±1.4	55.5±1.6	57.0±1.6	59.1±2.0
June		49.5±0.2	51.3±0.3	51.8±0.5	51.4±0.5	55.7±0.9	56.5±1.1	58.4±1.3	59.8±1.4	62.0±1.7	64.1±1.9
July		50.8±0.1	52.4±0.0	53.5±0.1	52.5±0.1	57.3±0.7	58.4±0.2	60.8±0.2	62.7±0.2	65.7±0.3	68.8±0.3
August		51.8±0.1	52.9±0.2	53.8±0.2	52.6±0.4	57.3±0.2	58.4±0.2	61.0±0.2	62.9±0.2	66.0±0.2	69.2±0.3
September		53.6±0.2	54.1±0.2	53.0±0.1	51.5±0.1	54.6±0.2	55.2±0.1	57.0±0.2	58.4±0.2	60.8±0.2	64.0±0.5
October		56.4±0.1	55.5±0.6	53.3±0.4	51.3±0.4	53.4±0.6	53.8±0.7	55.1±0.7	56.1±0.7	58.1±0.8	60.7±0.2

Source: Reclamation, unpublished data and USGS (2013)

Note:

[a] The standard deviation shown in this table is that for the daily average temperatures comprising the MMWAT (peak 7-day moving average) for each given month.

Key:

MMWAT = Monthly Maximum Weekly Average Temperatures

RM = River Mile

Table 3-4. Monthly Maximum Weekly Average Temperatures for the Upper Sacramento River at Delta (USGS Gage No. 11341500) During May to October for Water Years 2003 to 2012

Month	Year (MMWAT [°F] ± 1 Standard Deviation)[a]									
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
May	56.3±0.7	58.8±1.0	55.1±0.2	51.7±1.0	64.6±1.1	55.7±1.5	61.3±1.0	50.3±0.7	50.5±0.8	59.1±2.0
June	63.9±0.9	68.5±0.6	62.5±1.4	63.7±0.7	68.5±0.8	68.0±1.0	67.9±1.3	58.0±0.4	57.2±0.7	64.1±1.9
July	70.5±0.5	70.5±0.3	68.4±0.4	68.3±0.6	71.4±0.6	71.0±0.4	71.7±0.4	66.6±0.3	65.8±0.6	68.8±0.3
August	70.2±1.0	70.4±0.8	68.3±0.1	67.1±0.9	69.7±0.6	70.6±0.7	71.7±1.1	66.2±0.4	65.8±0.3	69.2±0.3
September	66.1±0.5	65.5±0.4	64.0±0.4	63.1±0.6	68.4±0.5	67.1±1.3	64.8±0.2	62.6±0.3	64.0±0.6	64.0±0.5
October	61.0±2.7	59.4±3.7	56.5±1.2	56.4±2.5	55.7±1.1	59.2±2.8	61.3±2.3	59.1±2.5	59.6±2.3	60.7±0.2

Note: [a] The standard deviation shown in this table is that for the daily average temperatures comprising the MMWAT (peak7-day moving average) for each given month.

Key:

MMWAT = Monthly Maximum Weekly Average Temperatures

USGS = U.S. Geological Survey

Table 3-5. Aerial Video- and Field Survey-derived Chinook Salmon Spawning, Egg Incubation, and Emergence Life Stage Habitat Attributes Scores for the Upper Sacramento River Between Shasta Lake and Box Canyon Dam

Study Reach	Chinook Salmon Spawning, Egg Incubation, and Emergence Life Stage Criteria			
	Attribute Metric Scores (mean ± standard error)			Overall Habitat Condition Score
	Channel Morphometry	Substratea	Habitat	
Video-derived				
Box Canyon	2.0±0.00	3.0±0.00	1.4±0.15	2.1
Mossbrae	2.2±0.04	2.8±0.00	1.5±0.24	2.1
Dunsmuir	2.5±0.00	2.9±0.02	1.4±0.20	2.3
Canyon	2.6±0.02	2.9±0.02	1.6±0.14	2.4
Shotgun	2.8±0.00	2.8±0.00	2.0±0.12	2.5
North Salt	2.7±0.03	2.6±0.00	2.3±0.14	2.5
Field-derived				
Box Canyon	2.0±0.00	2.9±0.10	2.1±0.28	2.3
Mossbrae	2.3±0.00	2.8±0.00	0.8±0.44	1.9
Dunsmuir	2.5±0.00	2.8±0.12	1.9±0.29	2.4
Canyon	2.6±0.07	2.9±0.04	1.7±0.29	2.4
Shotgun	2.9±0.07	2.8±0.05	1.3±0.59	2.3
North Salt	2.9±0.07	2.6±0.08	1.8±0.55	2.4

Notes:
[a] Video-derived substrate attribute metric scores were computed with substrate composition parameter values (percent particle class composition and dominant bed substrate) derived from representative field sites.

The quality of physical spawning habitat attributes generally improved progressing downstream. Both aerial video- and field-derived spawning habitat condition scores were lowest upstream of Dunsmuir and increased downstream to Shasta Lake, with overall scores ranging from 2.3 to 2.5 (Figures 3-4 and 3-5). While the component attribute scores comprising the overall spawning habitat condition varied somewhat in these lower reaches, the overall scores indicate that suitable physical spawning habitat for anadromous salmonids occurs throughout the upper Sacramento River under suitable water temperature conditions. However, the long-term thermograph record for the Delta gage indicates that optimal water temperature conditions for winter-run Chinook salmon egg incubation [less than or equal to 56.0°F (13.5°C) daily average; USFWS (1999)]

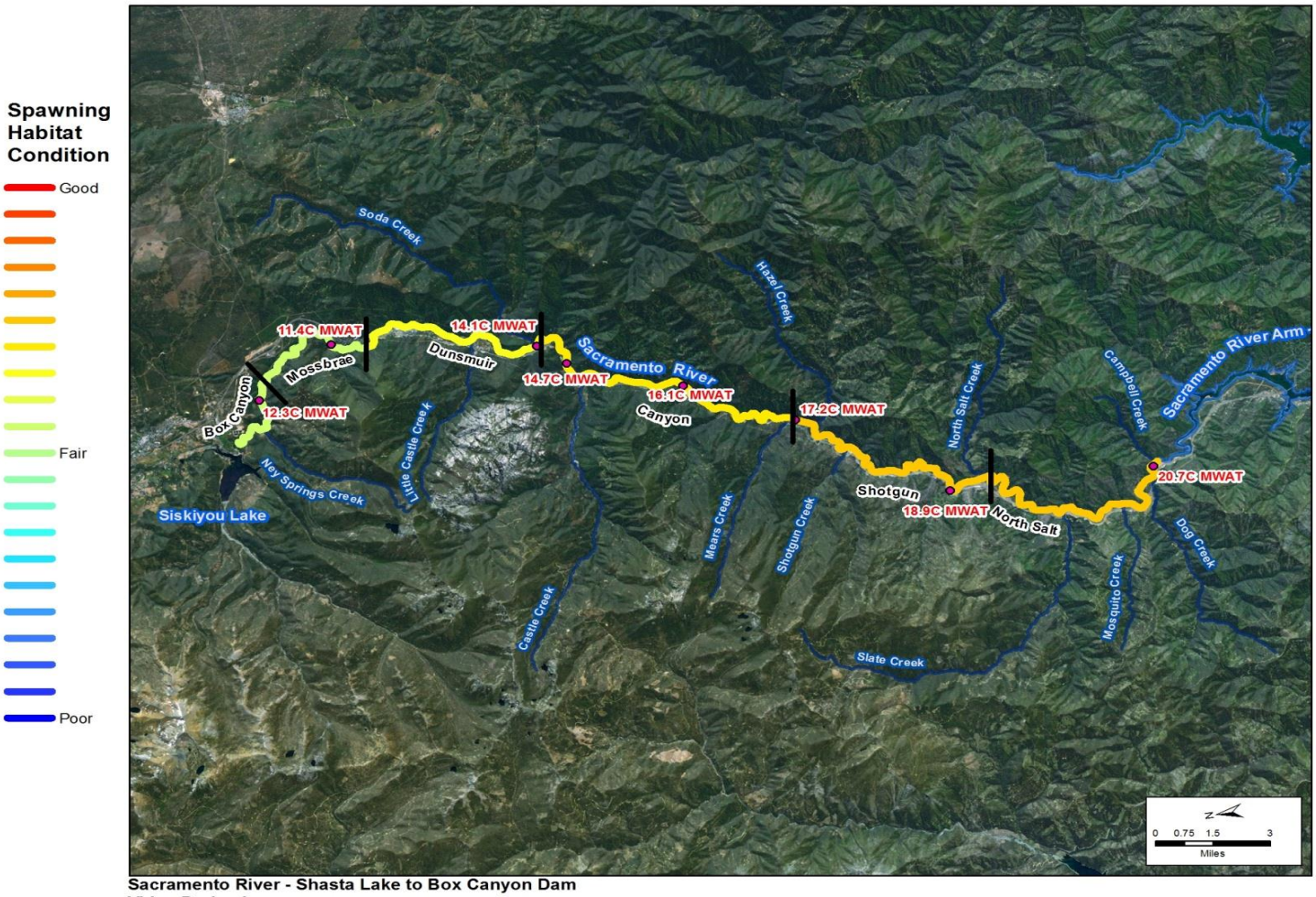
are exceeded in most years from June through August (Table 3-4)[4], which coincides with much of the winter-run Chinook salmon egg incubation season. Furthermore, based on the only available longitudinal thermograph record, WY 2012, a below normal water year, this optimal thermal threshold appears to be limiting for winter-run Chinook salmon spawning in the entire river downstream from about Soda Creek to Shasta Lake (Table 3-3). Despite large, cold, spring inflows that occur in the Mossbrae Reach (RM 30–34), water temperatures can warm and exceed the optimal spawning and incubation range for salmon by the time the river reaches Soda Creek (RM 24). In wetter water years with larger snowpack, when snow melt extends the period of runoff later into the summer, the length of river with suitable spawning temperatures may be longer by an, as yet to be determined, distance.

Similar to the pattern in Chinook salmon spawning habitat suitability, rearing habitat suitability tends to progressively improve, particularly downstream of Dunsmuir to Shasta Lake; this was more pronounced using the video-derived habitat inventory (Figures 3-6 and 3-7). Habitat attribute scores for juvenile salmon rearing conditions were fair in the upper Sacramento River from both aerial video- and field-derived habitat inventories (Table 3-6). Cover attribute scores were typically less than 2, indicating a relatively poor-to-fair cover condition; although cover condition scores were somewhat higher based on the field surveys compared to the aerial video-derived habitat inventories, especially in the reach upstream of Dunsmuir, where the video images were not sufficient to see much of the cover features (Table 3-6). Generally, the limiting Chinook salmon rearing habitat attribute component was the diversity and quality cover; however, the literature-based rearing cover criteria are highly dependent on amounts and diversity of large woody debris (LWD) for pool-formation and physical cover, which may not be as important in the large river tributaries to Shasta Lake, where bedrock controls are more important than LWD for pool formation and abundant boulders and bedrock ledges and undercuts provide similar cover functions. Rearing habitat substrate metrics and the condition of Chinook salmon rearing habitat increased longitudinally downstream along the length of the river (Table 3-6). The overall rearing habitat condition score indicates the upper Sacramento River provides fair rearing habitat conditions for Chinook salmon from at least Dunsmuir downstream to Shasta Lake, including mostly suitable thermal conditions for a majority of the river's length.

Based on the longitudinal thermographic record for 2012, MMWAT did not exceed 66°F (19°C) along most of the river (Table 3-3), except at the Delta gage, where the July and August MMWATs range from 65.0°F to 72.0°F (18.0°C to 22.0°C) (Table 3-4). Optimal growth conditions for juvenile Chinook salmon can occur up to about 66.0°F to 68.0°F (19.0°C to 20.0°C), but chronic exceedances

[4] Accounting for the typical variance in average daily temperatures and daily temperature fluctuations in the thermograph records for the study reach, optimal thermal conditions are likely to not be exceeded when MMWAT less than or equal to 55.0°F (12.7°C).

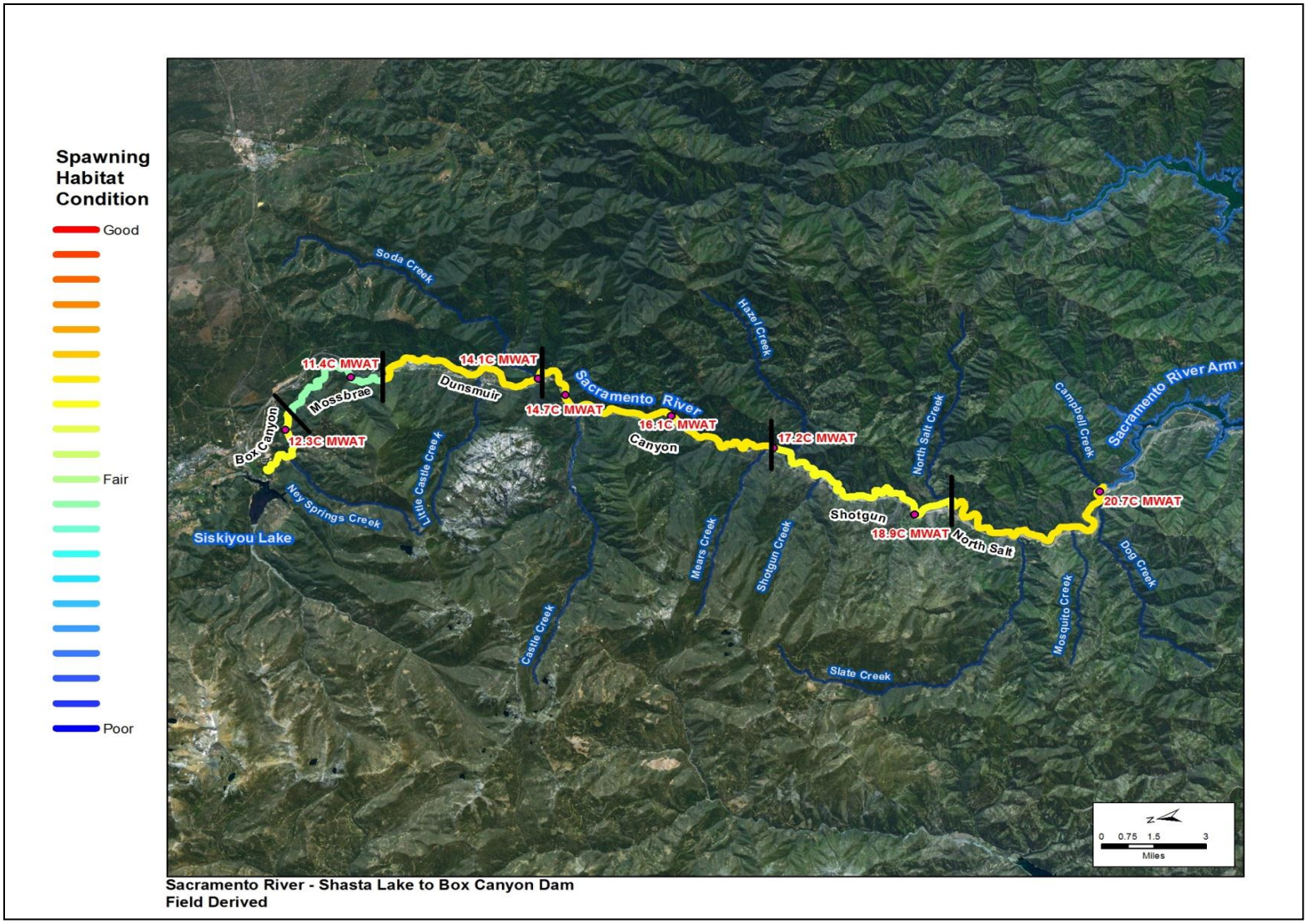
of about 63.0°F (17.0°C), especially during the smolt life stage can result in sub-lethal effects on certain physiological processes and ecological interactions, such as vulnerability to predation (McCullough 1999, Sullivan et al. 2000, Marine and Cech 2004). While it is uncertain how long juvenile winter-run Chinook salmon will rear and when they will migrate downstream, if reintroduced to tributaries above Shasta Dam, the ocean type life history pattern of the winter-run Chinook salmon population downstream of Shasta Dam suggests that they may, after emerging in the late-summer, rear only into the early fall months, prior to initiating their emigration to the lower river and estuary (Moyle 2002). Therefore, the thermal regime along much of the upper Sacramento River (upstream from Shasta Lake), except in the immediate vicinity of the Delta gage and the head of Shasta Lake, appears to be highly suitable for rearing Chinook salmon.



Sacramento River - Shasta Lake to Box Canyon Dam
Video Derived

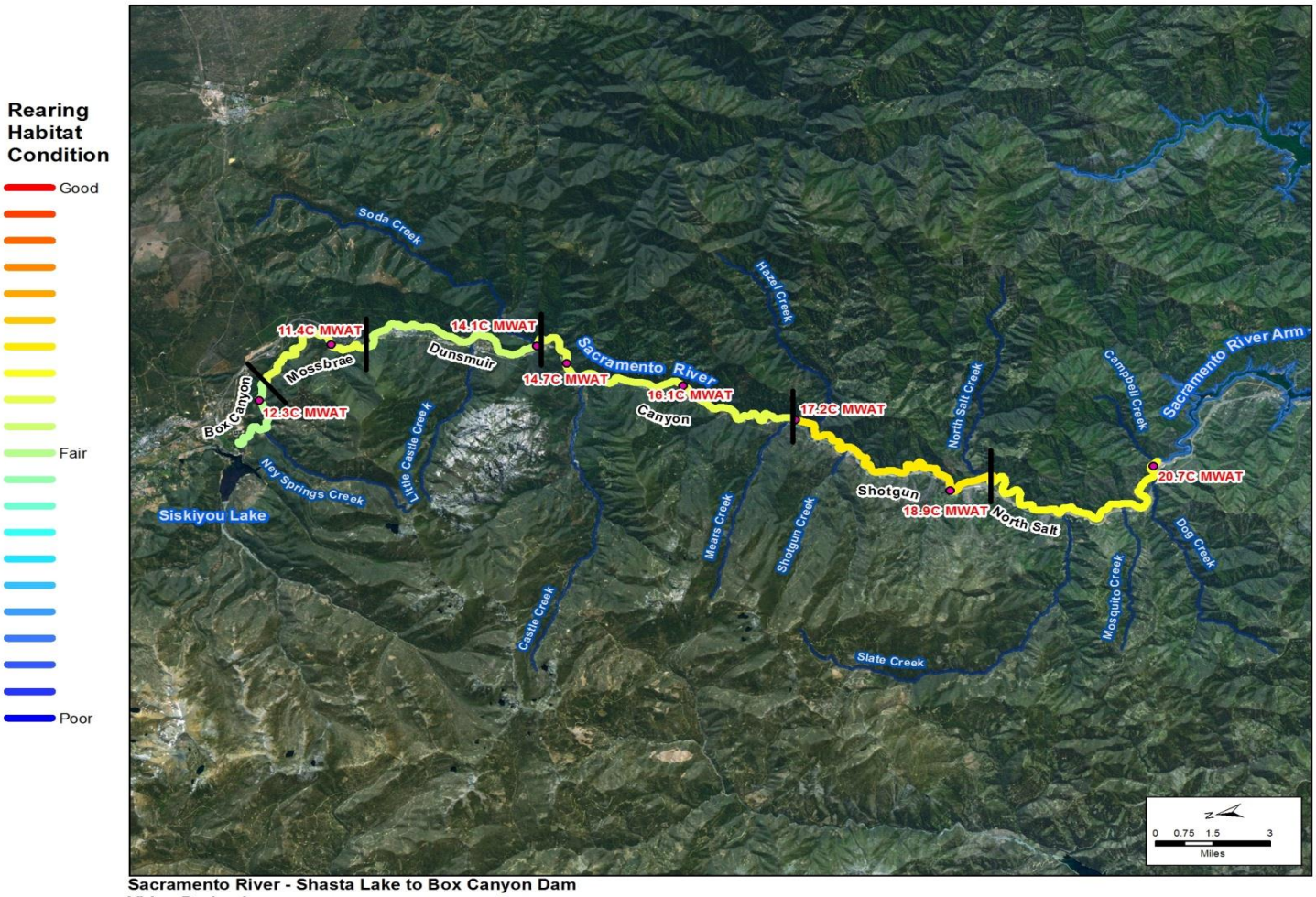
Note: Reach breaks denoted by black lines; thermograph locations and maximum weekly average temperatures for water year 2012 are indicated for each study reach.

Figure 3-4. Chinook Salmon Spawning Habitat Condition (derived from aerial video interpretation) in the Upper Sacramento River Between Shasta Lake and Box Canyon Dam



Note: Reach breaks denoted by black lines; thermograph locations and maximum weekly average temperatures for water year 2012 are indicated for each study reach.

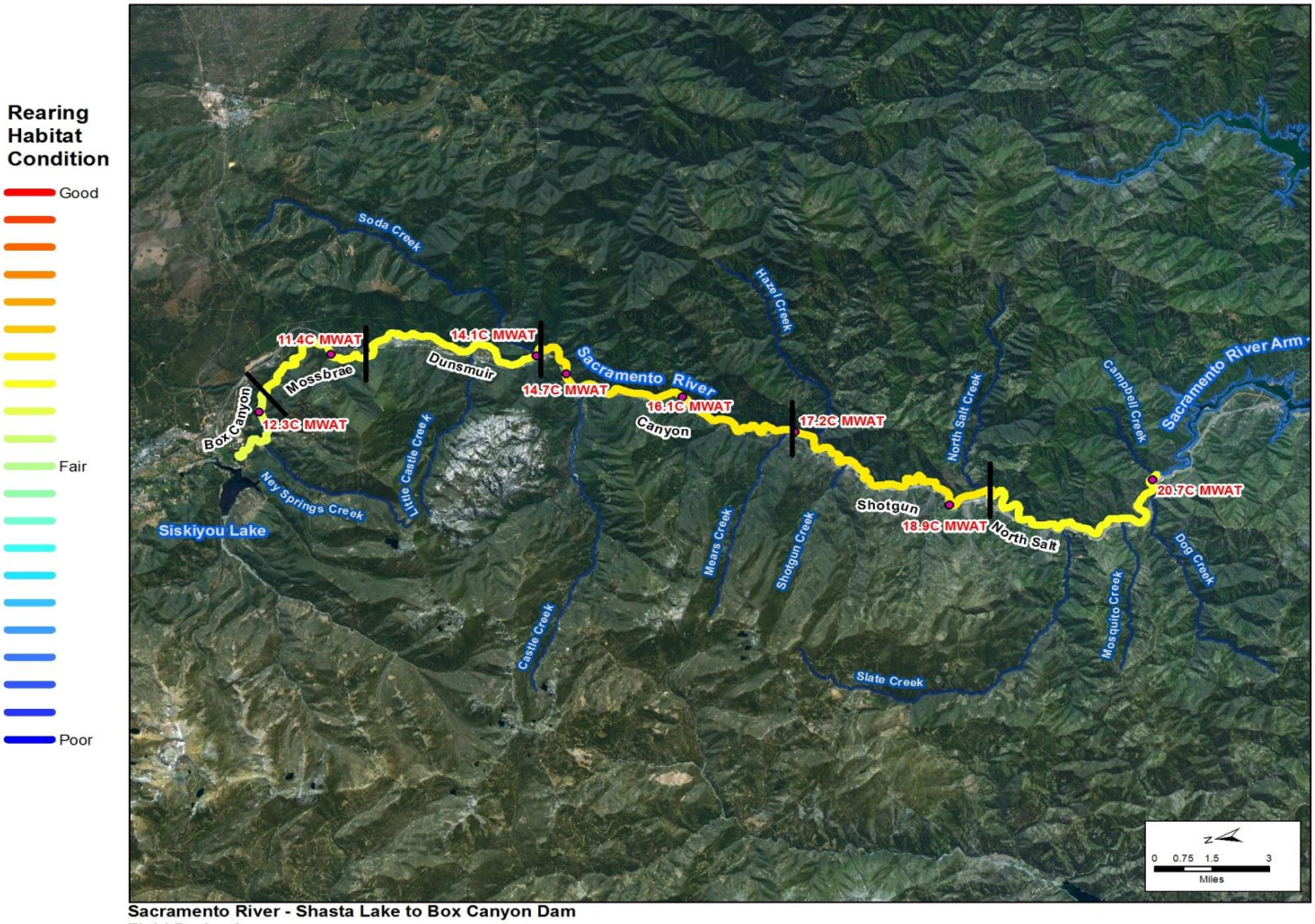
Figure 3-5. Chinook Salmon Spawning Habitat Condition (derived from field surveys) in the Upper Sacramento River Between Shasta Lake and Box Canyon Dam



Sacramento River - Shasta Lake to Box Canyon Dam
Video Derived

Note: Reach breaks denoted by black lines; thermograph locations and maximum weekly average temperatures for water year 2012 are provided for each study reach.

Figure 3-6. Chinook Salmon Rearing Habitat Condition (derived from aerial videographic interpretation) in the Upper Sacramento River Between Shasta Lake and Box Canyon Dam



Sacramento River - Shasta Lake to Box Canyon Dam
Field Derived

Note: Reach breaks denoted by black lines; thermograph locations and maximum weekly average temperatures for water year 2012 are provided for each study reach.

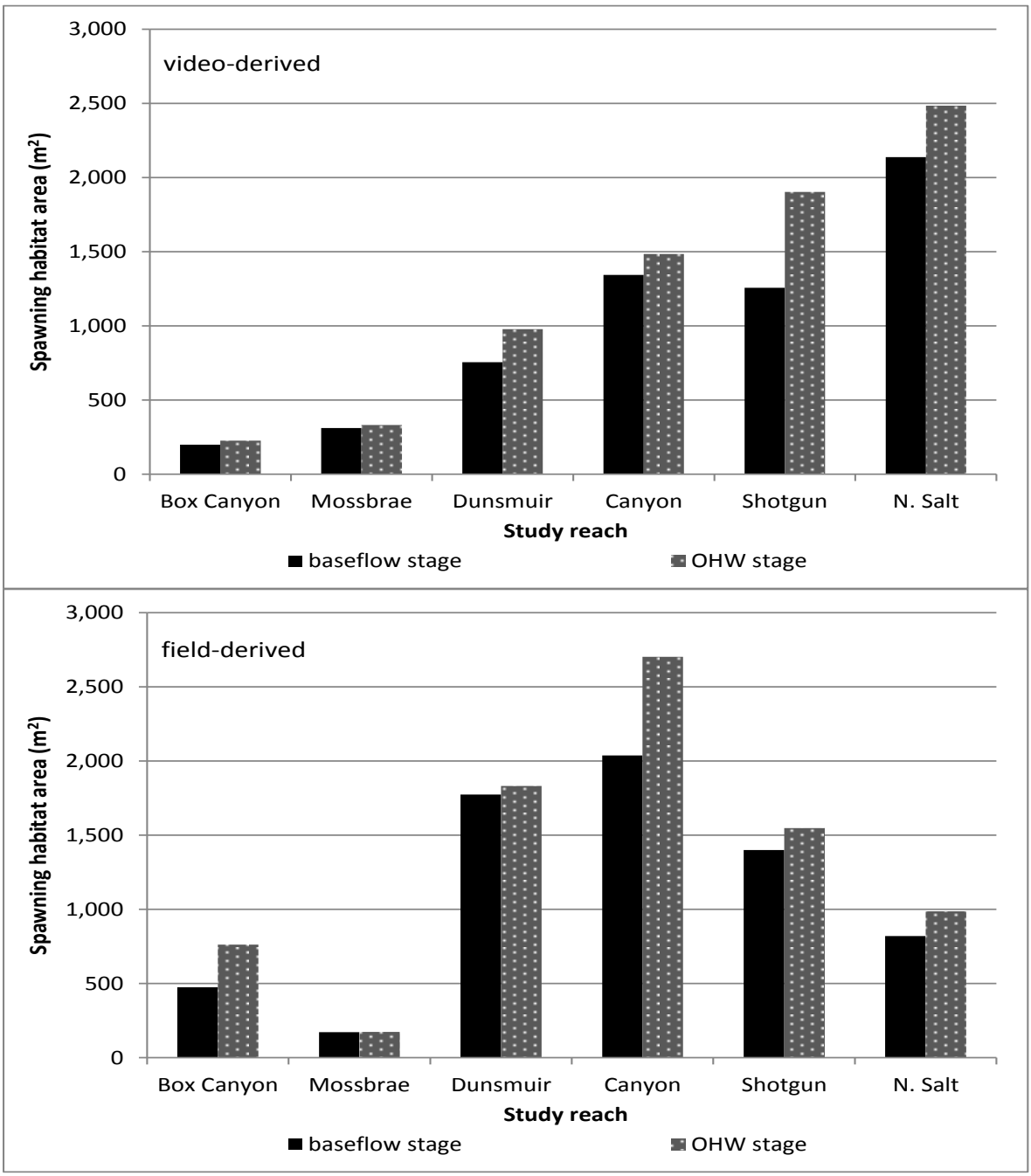
Figure 3-7. Chinook Salmon Rearing Habitat Condition (derived from field surveys) in the Upper Sacramento River Between Shasta Lake and Box Canyon Dam Table 3-6. Aerial Video- and Field Survey-derived Chinook Salmon Rearing Life Stage Habitat Attribute Scores for the Upper Sacramento River Between Shasta Lake and Box Canyon Dam

Study Reach	Chinook Salmon Rearing Life Stage Criteria				
	Attribute Metric Scores (mean ± standard error)				Overall Habitat Condition Score
	Channel Morphometry	Substratea	Covera	Habitat	
Video-derived					
Box Canyon	2.0±0.02	2.8±0.00	1.5±0.06	1.8±0.17	2.0
Mossbrae	2.2±0.04	3.0±0.00	2.0±0.00	1.7±0.18	2.2
Dunsmuir	2.5±0.00	2.8±0.00	1.6±0.03	1.5±0.16	2.1
Canyon	2.6±0.02	2.8±0.00	1.6±0.03	1.7±0.12	2.2
Shotgun	2.7±0.02	3.0±0.00	1.7±0.01	2.0±0.00	2.4
North Salt	2.7±0.02	2.8±0.00	1.6±0.05	2.0±0.00	2.3
Field-derived					
Box Canyon	2.0±0.00	2.8±0.15	1.5±0.10	2.4±0.13	2.2
Mossbrae	2.3±0.00	2.9±0.13	1.9±0.08	2.0±0.00	2.3
Dunsmuir	2.5±0.00	2.8±0.20	1.8±0.14	2.2±0.17	2.3
Canyon	2.6±0.09	2.9±0.07	1.8±0.07	2.2±0.15	2.4
Shotgun	2.8±0.00	2.9±0.10	1.8±0.10	2.1±0.13	2.4
North Salt	2.6±0.07	2.6±0.12	1.4±0.12	2.4±0.13	2.3

Notes:
a Video-derived substrate and cover attribute metric scores were computed with substrate composition (percent particle class composition and dominant bed substrate) and cover parameter values derived from representative field sites.

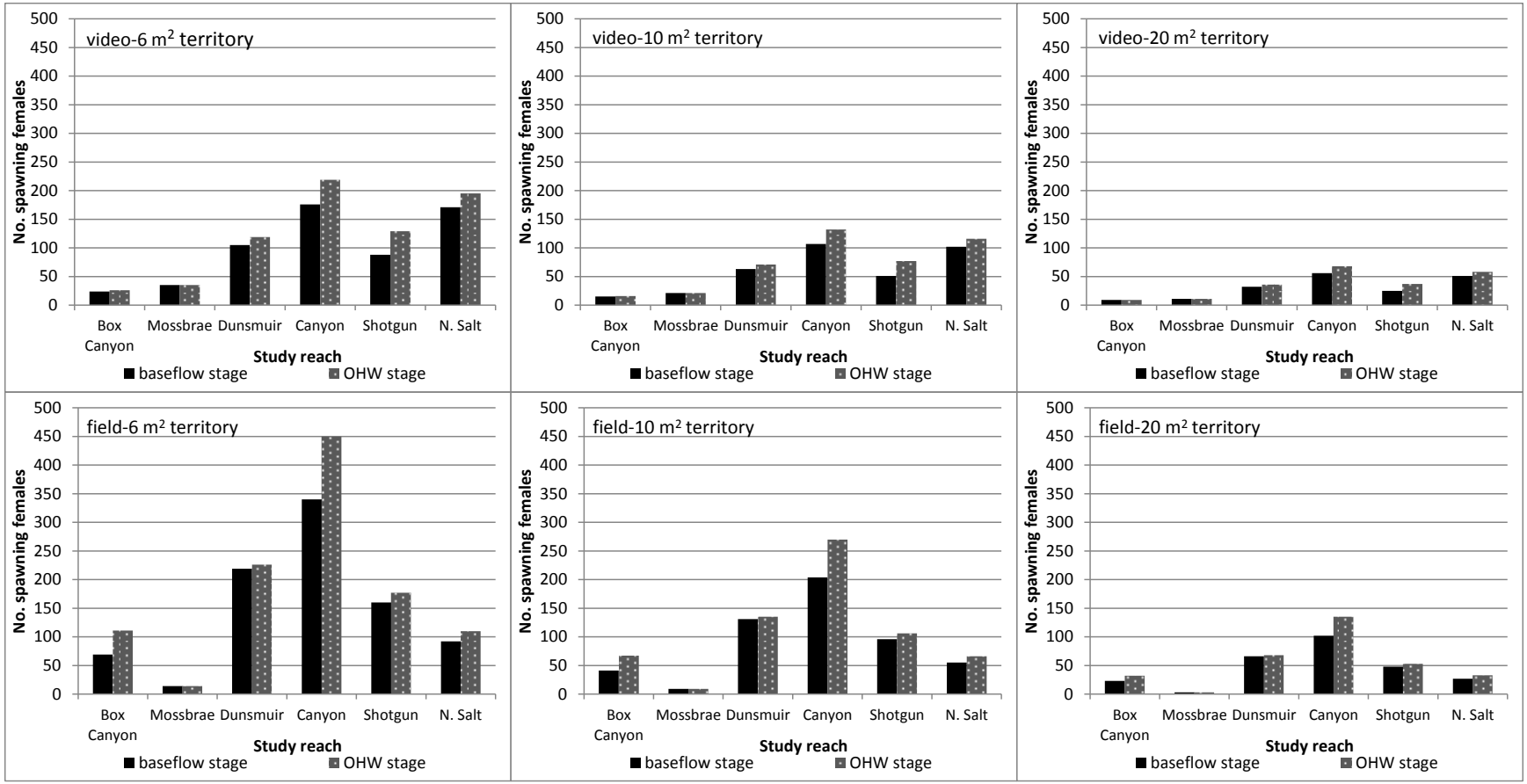
Spawner Capacity

The spatial distribution of estimated spawning habitat area (Figure 3-8) and Chinook salmon spawning capacity (number of females) (Figure 3-9) in the upper Sacramento River were lowest in the Box Canyon and Mossbrae study reaches and highest in the Canyon study reach (Table 3-7). Nearly 80 percent of the estimated Chinook salmon spawning habitat in the upper Sacramento River occurred between North Salt Creek and Dunsmuir, with nearly half of this suitable habitat occurring in the nine mile long section of the Canyon Reach. Potential Chinook salmon spawning capacity estimates using the representative field survey reach expansion were about 50 percent higher than for those computed using the aerial video-derived habitat inventory, which reflects the lower frequency of riffle habitat, and, consequently, less total spawning riffle area using the latter method. On average, spawner capacity was 16 percent greater at the OHW mark stage than at the baseflow stage (Table 3-7).



Key:
m^2 = square meter
OHW = ordinary high water

Figure 3-8. Estimated Potentially Suitable Chinook Salmon Spawning Habitat Area in the Upper Sacramento River, by Study Reach, for Video- (upper panel) and Field-derived (lower panel) Estimates at Baseflow and Ordinary High Water Mark (OHW) Stages



Key:
m^2 = square meter
OHW = ordinary high water

Figure 3-9. Estimated Chinook Salmon Spawner Capacities (number females) in the Upper Sacramento River, by Study Reach, for Aerial Video- (upper panel) and Field-derived (lower panel) Estimates at Baseflow and Ordinary High Water Mark Stages for a Range of Literature-based Spawning Area Territory Requirements from 6 Square Meters to 20 Square Meters

Table 3-7. Aerial Video- and Field Survey-derived Estimates of Potential Chinook Salmon Spawning Habitat Area and Potential Spawner Capacity, as the Number of Female Salmon, by Study Reach, in the Upper Sacramento River Between Shasta Lake and Box Canyon Dam

Study Reach	Total Spawning Habitat Area (m2)		Estimated Spawner Capacity (number females)					
			6 m2 Spawning Territory		6 m2 Spawning Territory		20 m2 Spawning Territory	
	Baseflow Stage	OHW Stage	Baseflow Stage	OHW Stage	Baseflow Stage	OHW Stage	Baseflow Stage	OHW Stage
Video-derived								
Box Canyon	199	227	24	26	15	16	9	9
Mossbrae	311	332	35	35	21	21	11	11
Dunsmuir	755	978	105	119	63	71	32	36
Canyon	1,343	1,485	176	219	107	132	56	68
Shotgun	1,257	1,904	88	129	51	77	25	37
North Salt	2,138	2,485	171	195	102	116	51	58
Total	6,004	7,412	600	723	359	434	183	219
Field-derived								
Box Canyon	474	761	69	111	41	67	23	32
Mossbrae	172	172	14	14	9	9	3	3
Dunsmuir	1,774	1,830	219	226	131	135	66	68
Canyon	2,037	2,700	340	450	204	270	102	135
Shotgun	1,400	1,547	160	177	96	106	48	53
North Salt	820	985	92	110	55	66	27	33
Total	**6,677**	**7,994**	**893**	**1,087**	**536**	**652**	**269**	**324**

Key:
m^2 = square meter
OHW = ordinary high water

McCloud River

Aquatic Habitat Inventory

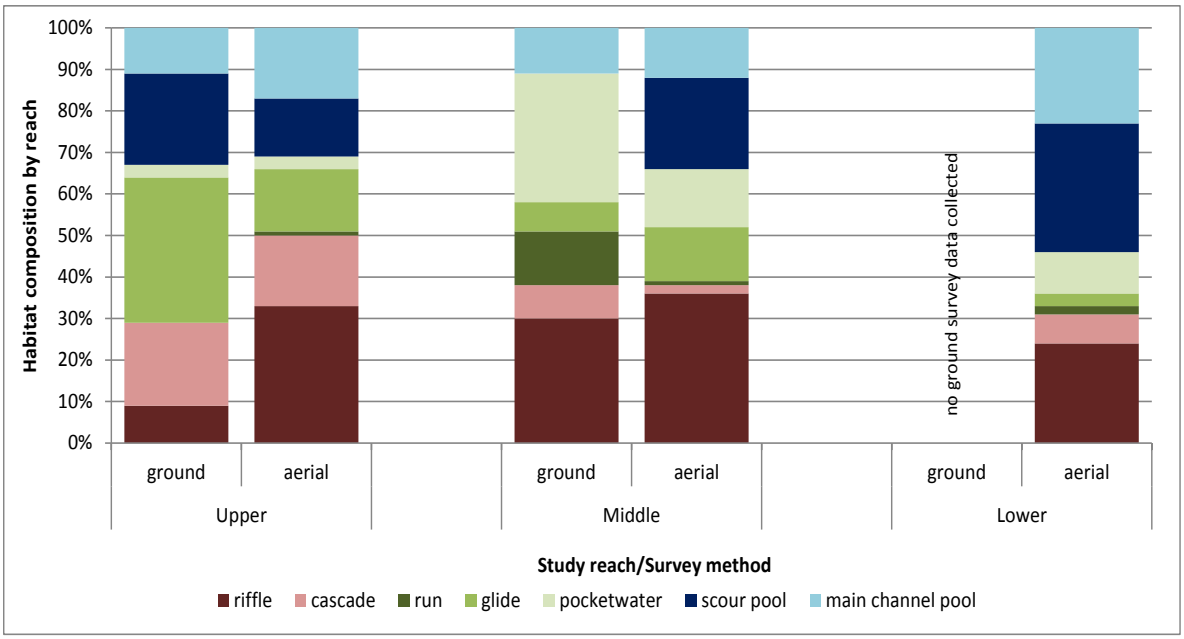
Aerial video was collected along the mainstem McCloud River between Shasta Lake and McCloud Dam and from McCloud Reservoir to Lower McCloud Falls on November 24, 2013[5]. Average daily flow in the McCloud River at the gage above Shasta Lake (USGS Gage No. 1136800) was 270 cfs, at Ah-Di-Na (USGS Gage No. 11367800) was 190 cfs, and upstream of McCloud Reservoir (USGS Gage No. 11367500) was 640 cfs. Video quality and coverage decreased with distance upstream, particularly upstream of Squaw Valley Creek, as channel widths decreased, and the channel sinuosity, hills slope, topographic aspect, and vegetation cover increased (Appendix B). With the same limitations as described for the upper Sacramento River, a geomorphic channel unit inventory and identification of a number of key habitat parameters for the McCloud River could be determined from the aerial videography.

As described in the Methods Section, ground-level field surveys were limited, by restricted access to much of the river and by budget and time limitations, to only three representative sites on the McCloud River, which were systematically assigned to the section of the river from Ladybug Creek to the McCloud Dam, where aerial video was most obscured. Field surveys were conducted between January 28 and January 29, 2014. Average daily flow in the McCloud River during the field survey period averaged 260 cfs above Shasta Lake and 190 cfs near Ah-Di-Na. During field surveys, several salmonid redds were also observed in the McCloud River and information on the locations and characteristics of these redds are summarized in Table 3-1.

Habitat inventory technical data for both aerial video and field survey methods are detailed in Appendix B. Field survey sites covered 38 percent of the channel length in the upper study reach and 7 percent of the channel length of the middle study reach (see Figure 2-2 and Table 2-2 for the location and details on these survey sites). The lower study reach habitat inventory was limited to aerial video interpretation only because, although permission to access much of this study reach on the Bollibokka Club from Westlands Water District was obtained, the timing of weather, flow, and, ultimately, budget restricted the completion of the surveys for this reach. However, the representative survey reaches that were selected for this study plan are shown in Figure 2-2 and are recommended to be surveyed to update this analysis, pending future phases of work.

[5] Aquatic habitat inventory was conducted only for the McCloud River between Shasta Lake and McCloud Dam, excluding the Headwaters Reach due to insufficient video quality and stream access.

Habitat composition in the McCloud River determined by aerial video interpretation was dominated by pools and flatwater habitats (consisting of runs, glides, and pocket water) in all three study reaches. The frequency of pool habitats tends to progressively increase downstream from McCloud Dam becoming the dominant habitat in the lower study reach (Figure 3-10). Higher gradient, fast water habitats (i.e., riffles and cascades) comprised a greater proportion of the available habitat in the upper study reach, consistent with its bedrock-controlled, cascade and step-pool, bed morphology. However, the field survey site near Hawkins Creek in the upper study reach exhibited lower proportions of these high gradient features than was measured in the aerial video interpretation and, thus, may under-represent this dominant habitat type in the study reach. Similarly, the single field survey site in the middle study reach exhibited a greater proportion of flatwater habitats, particularly, pocket water, than was measured in the aerial videography. This may be partly attributable to the relatively short length of channel that could be legally accessed for field surveys in the middle study reach but may also have been contributed by difficulties differentiating between flatwater, pools, and some riffle habitats in video imagery for the middle study reach. As a result, it is difficult to fully assess the potential error or bias that may affect the habitat inventory determined by aerial video interpretation, especially for the middle and lower study reaches.



Key:
% = percent

Figure 3-10. Comparison of Geomorphic Channel Unit (riverine habitat type) Composition in the McCloud River, by Study Reach, for Aerial Videographic Interpretation (aerial) and Representative Field Site (ground) Surveys

The frequency and extent of suitable Chinook salmon spawning habitat areas observed at the representative field sites was considerably greater than measured from the aerial videography (see Appendix B for technical data details). Deep shade and shadows, visual obstructions, and flight speed in many river sections prevented reliable identification of the aerial extent and substrate-size composition of river bed sediment deposits, particularly in deeper water and of the numerous isolated sediment deposits in the commonly occurring pocket water, runs, and riffles in the McCloud River. Therefore, confidence in the accuracy of the inventory of suitable Chinook salmon spawning habitat determined from the aerial video is low but is thought to underestimate spawning habitat based on limited comparisons with field survey sites in the upper study reach.

Figure 3-11. Photograph of Tuna Falls on the McCloud River near its Confluence with Tuna Creek

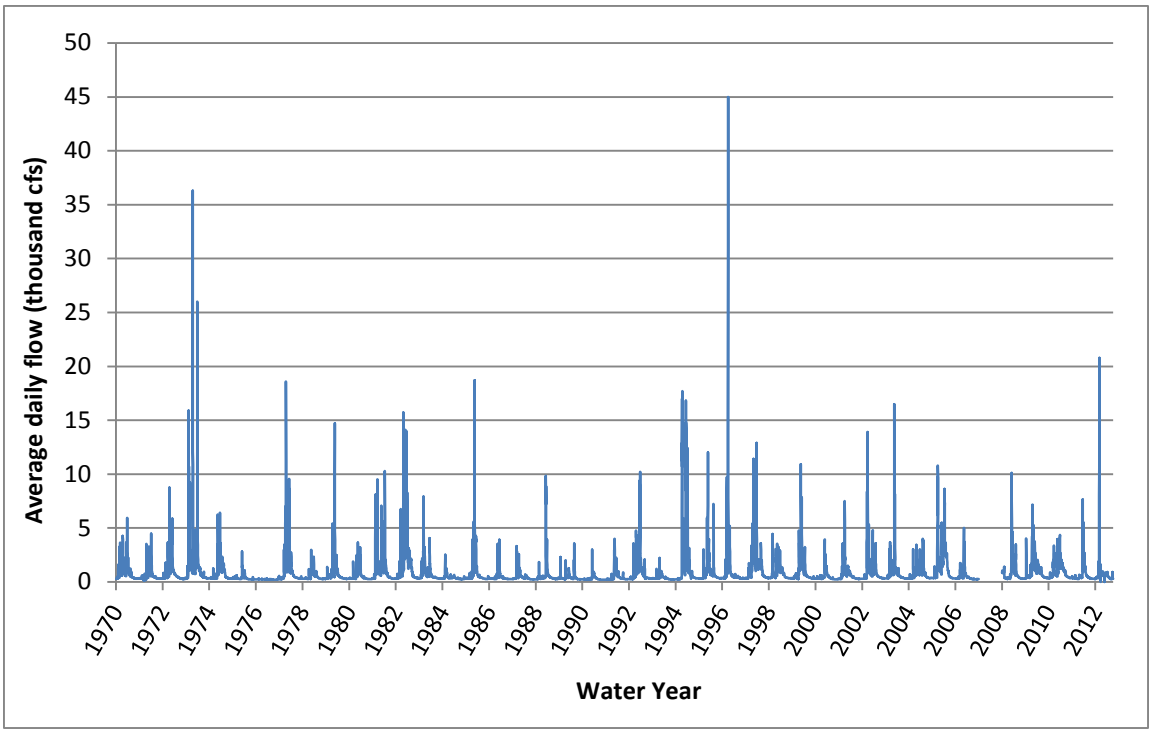
Review of existing data, aerial video, and field surveys indicates that the only potential fish passage impediment in the McCloud River between Shasta Lake and McCloud Dam is a simple cascade known as "Tuna Falls," located immediately upstream of the Tuna Creek confluence, about 2.5 miles upstream of Shasta Lake (Table 3-2 and Figure 3-11). This boulder cascade is about 15 m in length and 1.5 to 2.0 meters in height and is likely only an incomplete, seasonal impediment for some non-salmonid species, such as black bass (*Micropterus spp.*) migrating from Shasta Lake, but does not pose a significant passage barrier or impediment to salmonid fish migration. Further evidence that Tuna Falls does not impede fish migration is that rainbow and brown trout are documented to successfully make adfluvial migrations from Shasta Lake and spawn above them and throughout the lower McCloud River (Rode 1989, Rode and Dean 2004).

Long-term stream flow and water temperature records for the McCloud River are limited to the USGS gage above Shasta Lake (USGS Gage No. 11368000) and seasonal temperature records maintained by TNC at the McCloud River Preserve, which are compiled and summarized in Appendix B. Additionally, temperature monitoring and modeling information provided as part of the 2010 relicensing studies for PG&E's McCloud-Pit Project (FERC Project No. 2106), particularly for the river reach between the long-term monitoring stations, was used to augment understanding of longitudinal thermal heating under a range of

hydrological and meteorological conditions[6]. Flow in the McCloud River is partially regulated by releases from McCloud Dam and is subject to minimum instream flows stipulated under the McCloud-Pit Project (FERC Project No. 2106) operating license. Additional runoff and baseflow accretion occurs from a large watershed along the 23 miles of the McCloud River below McCloud Dam to Shasta Lake. Similar to the Sacramento River, the flow regime of the McCloud River is lowest and relatively stable during the summer and fall and exhibits more flow variability and peak flows in response to precipitation events and snowmelt runoff from the winter through the spring (Figure 3-12).

Continuous water temperature records since 2003 for the McCloud River Preserve (RM 18) and the USGS gage upstream of Shasta Lake (RM 1) are compiled and summarized in Appendix B. The MMWAT statistics for these two locations and six additional thermographs operated by PG&E during 2006–2008 are shown in Table 3-8. Similar, to the Sacramento River, these temperature records indicate that average daily water temperatures during the warmest weeks of summer are very stable at locations above McCloud Reservoir and below the reservoir to about RM 18, varying by not more than about ± 0.5°F (0.3°C), and by no more than about ±1.0-1.3 °F (0.6-0.7°C) downstream of RM 18, which, again, makes use of the MMWAT statistic appropriate for the purpose of this assessment. Based on the available record, MMWAT during the summer and early fall months (May through October) appears to remain below 55.0°F (12.7°C) from McCloud Dam downstream to a point between RM 18 (Ladybug Creek) and RM 12 (Claiborne Creek). Farther downstream, from Claiborne Creek to Shasta Lake, the MMWAT regularly exceeded 55.0°F in most years as early as May, and ranged from 60.0°F (15.5°C) at RM 9 (Squaw Valley Creek) to 65.0°F (18.3°C) at RM 1, near Shasta Lake, through July and August. The McCloud-Pit Project relicensing study's temperature monitoring for WYs 2006 to 2008 and water temperature modeling, using a variety of hydrologic and meteorological combinations for the lower McCloud River, showed that average daily water temperatures remain below about 58.0ºF (14.4ºC) from Squaw Valley Creek upstream to McCloud Dam at the typical range of baseflows occurring during the summer (Figure 3-13; see Appendix B for a summary of PG&E's temperature modeling results).

[6] Water temperature statistics for WYs 2006–2008 during summer months at several monitoring stations along the McCloud River were obtained from PG&E in Technical Memorandum 28 – Water Temperature Monitoring Program Report for 2007 (PG&E 2008), unpublished daily thermographic records for six locations, and flow temperature relationships from Technical Memorandum 38 – Lower McCloud River Water Temperature Modeling (PG&E 2009), all of which were used to inform understanding of thermal warming along the river.



Key:
cfs = cubic feet per second

Figure 3-12. Average Daily Flow in the McCloud River above Shasta Lake (USGS Gage No. 1136800) for Water Years 2003 to 2012

Table 3-8. Monthly Maximum Weekly Average Temperatures for the McCloud River at Eight Monitoring Locations, with Approximate River Mile, During May to October for Various Periods of Record, Water Years 2003 to 2012

Month	Year (MMWAT [°F] ± 1 Standard Deviation)								
	2003	2004	2005	2006	2007	2008	2009	2010	2
McCloud River Above McCloud Reservoir (RM29) (source 1)									
May	-	-	-	-	46.6±0.1	47.2±0.3	-	-	-
June	-	-	-	47.6±0.1	46.6±0.1	47.0±0.1	-	-	-
July	-	-	-	47.5±0.1	46.7±0.1	46.8±0.0	-	-	-
August	-	-	-	46.8±0.2	46.4±0.1	46.3±0.0	-	-	-
September	-	-	-	-	46.1±0.0	45.7±0.3	-	-	-
October	-	-	-	-	44.9±0.1	45.3±0.1	-	-	-
McCloud River Below Hawkins Creek (RM22) (source 1)									
May	-	-	-	-	50.0±0.2	50.8±0.5	-	-	-
June	-	-	-	-	51.6±0.3	54.2±0.5	-	-	-
July	-	-	-	52.9±0.1	52.3±0.1	51.8±0.4	-	-	-
August	-	-	-	52.3±0.3	52.3±0.1	51.2±0.1	-	-	-
September	-	-	-	50.2±0.2	51.4±0.0	50.7±0.3	-	-	-
October	-	-	-	-	47.6±0.3	50.3±0.4	-	-	-

Sources: (1) Pacific Gas and Electric Company (unpublished thermographic records); (2) The Nature Conservancy (2010); (3) USGS (2013)

Note:

a The standard deviation shown in this table is that for the daily average temperatures comprising the MMWAT (peak7-day moving average) for each given month.

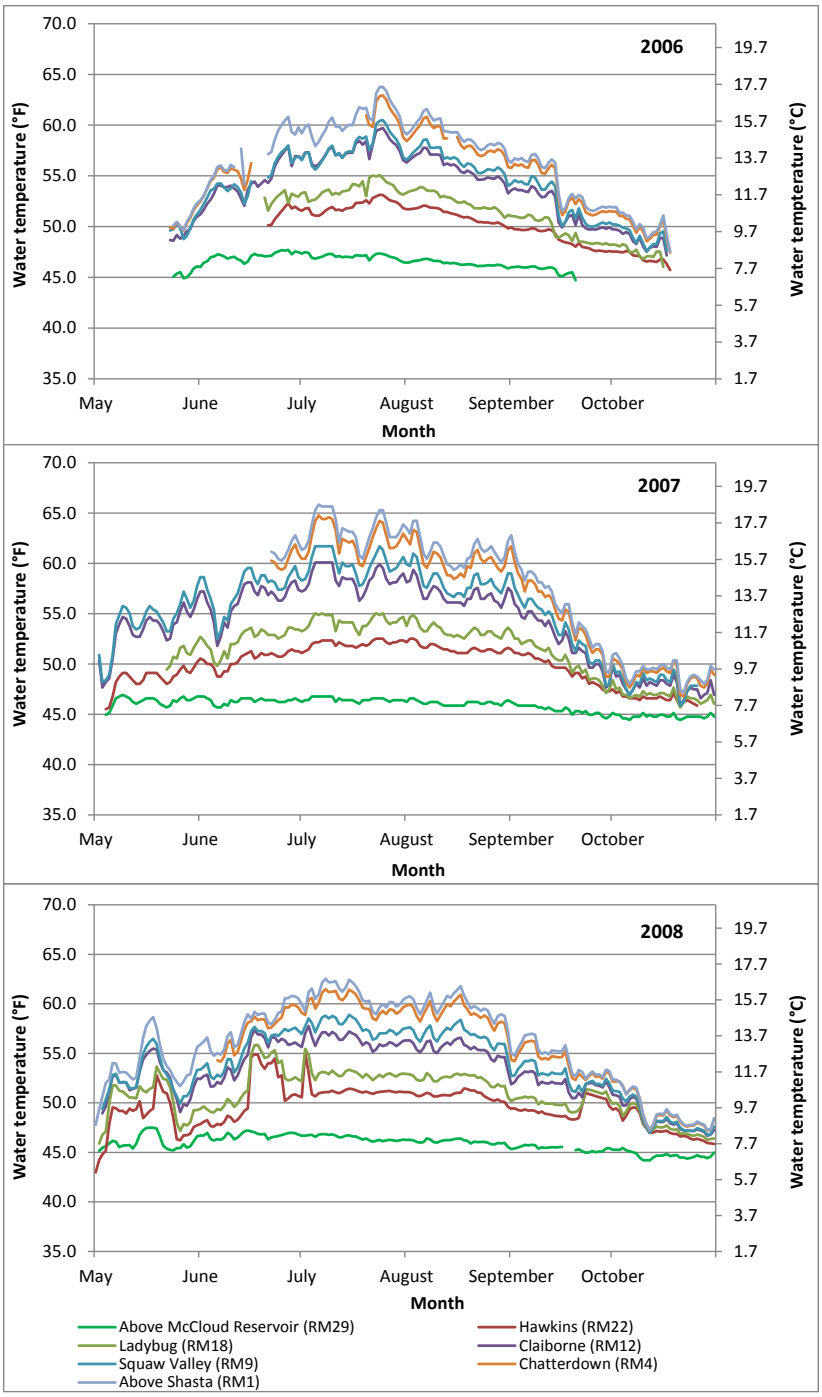
Key:

"-" no data available

°F = degrees Fahrenheit

MMWAT = Maximum Monthly Weekly Average Temperature

RM = river mile

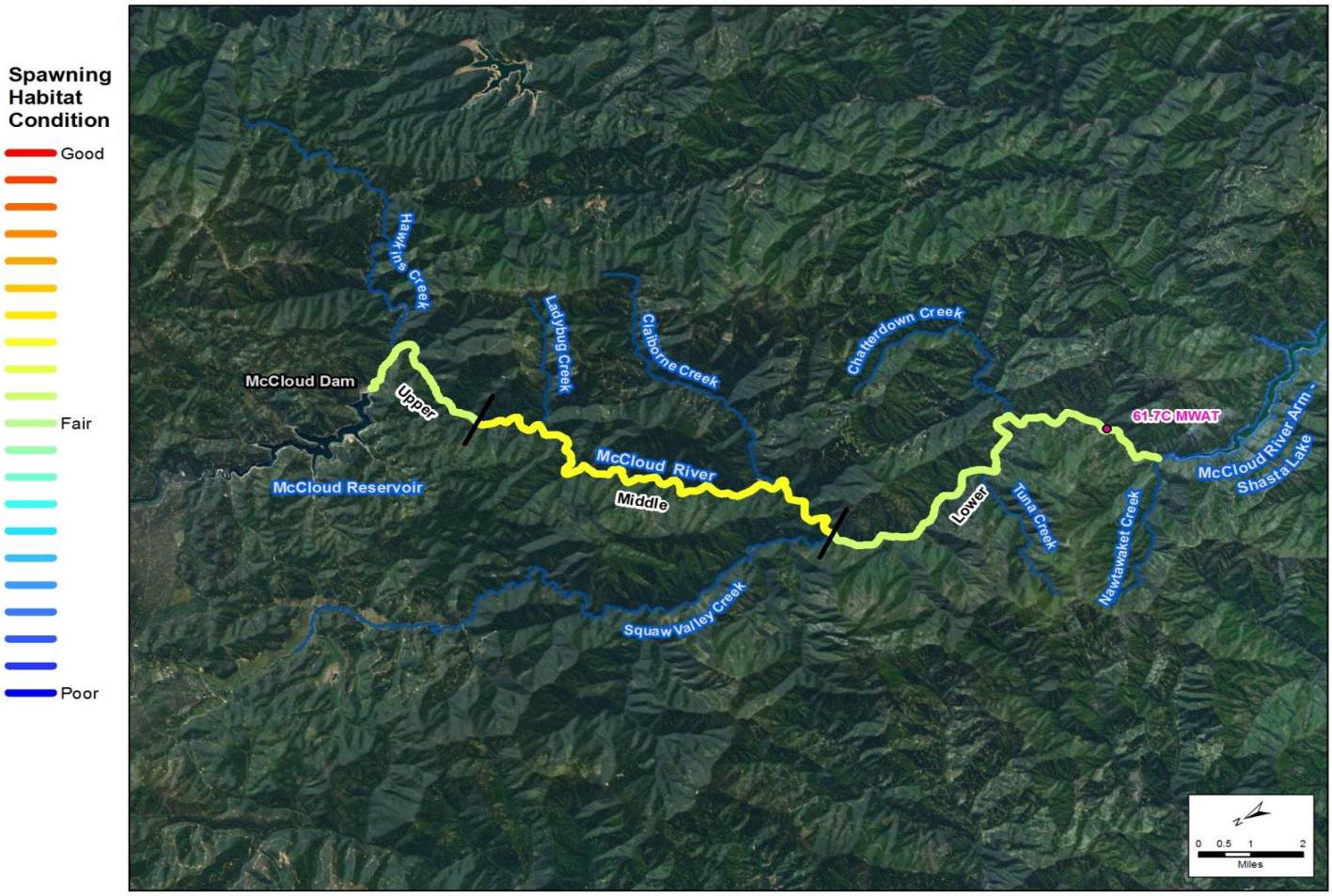


Source: PG&E (2008)
Key:
°C = degrees Celsius
°F = degrees Fahrenheit
RM = river mile

Figure 3-13. Daily Average Water Temperature between May and November During 2006 to 2008 at Seven Locations on the McCloud River from Above McCloud Reservoir to Shasta Lake

Habitat Suitability

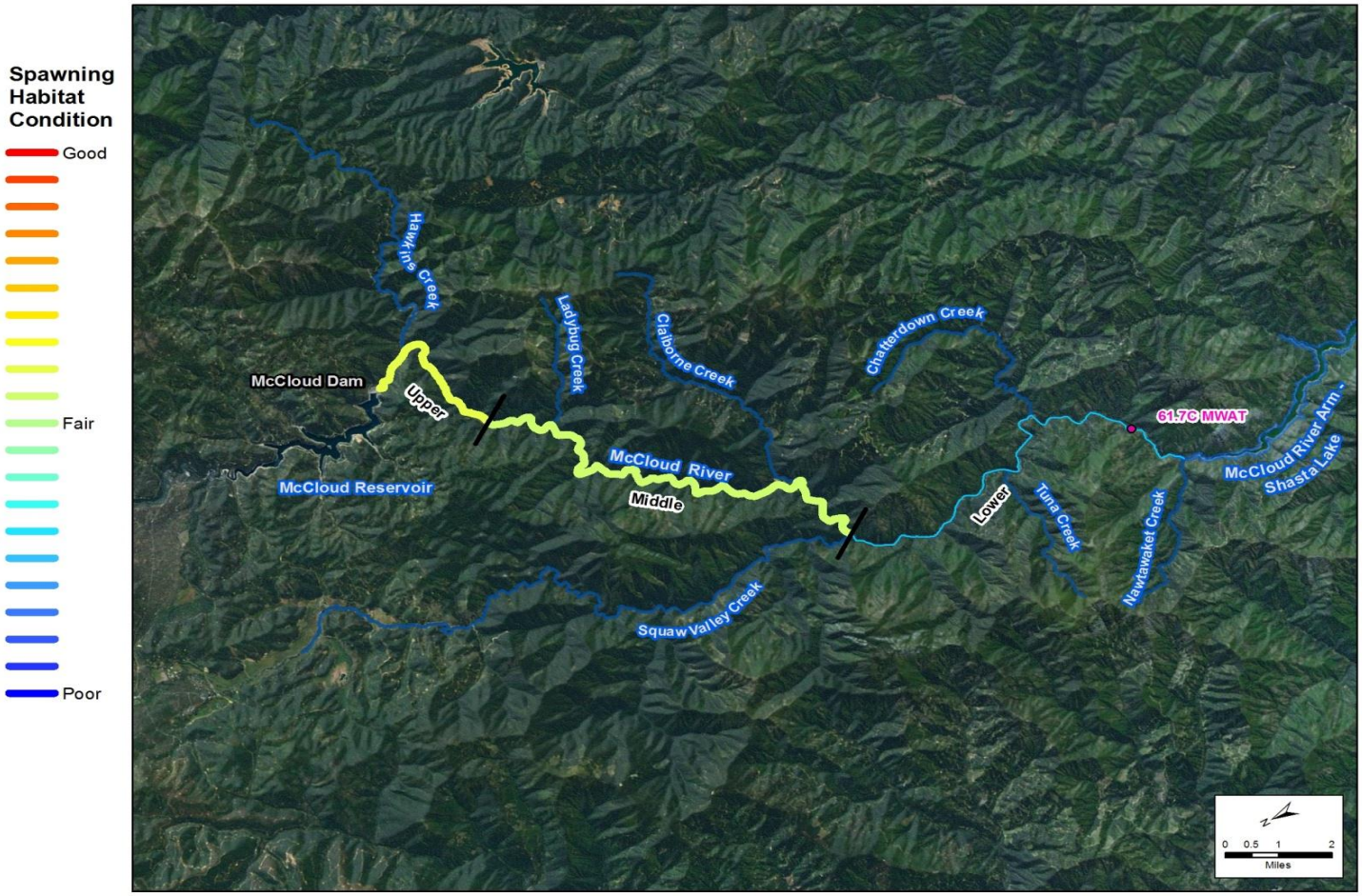
Overall spawning life stage habitat condition scores in the upper and middle study reaches of the McCloud River were fair-to-good as computed from both aerial video- and field-derived habitat inventories (Table 3-9; Figure 3-14). No spawning habitat condition scores are provided for the lower study reach because field surveys have yet to be performed to provide reliable measurements for substrate attribute metrics for use in computing habitat conditions scores for both assessment methods. Although, the spawning habitat condition score for the middle study reach, from Squaw Valley Creek to Ah-Di-Na campground, was highest for the aerial video-derived data, the potential error or bias associated with this score may be higher than for the upper study reach because field verification was limited in this reach due to restricted access. Field-derived scores indicated similar spawning habitat conditions among the two study reaches (Figure 3-15). Similar to the upper Sacramento River, the physical habitat attribute component scores were generally the limiting factors in overall magnitude of spawning habitat condition ratings, mostly a function of the relatively limited frequency of deep pools for adult holding and distribution of spawning areas in many isolated patches; however, these conditions may be of less importance for winter-run Chinook salmon than for spring-run, which are more reliant on deep pools for oversummering. Collectively, substrate attribute scores were in the upper fair-to-good range for the upper and middle study reaches (Table 3-9). Spawning habitat condition scores indicate fair-to-good physical spawning habitat occurs for Chinook salmon throughout the McCloud River between Shasta Lake and McCloud Dam under suitable water temperature conditions. However, the available long-term temperature records and PG&E's (2009) recent water temperature modeling information suggest that suitable thermal conditions (i.e., less than or equal to 56°F (13.3°C) daily average temperature) for the entire duration of winter-run Chinook salmon egg incubation season (late-April through September), under most water types, occurs upstream of RM 15, between Squaw Valley and Claiborne creeks, to McCloud Dam (Figure 3-13; see Appendix B for a summary of PG&E's temperature model results).



McCloud River - Shasta Lake to McCloud Reservoir
Video Derived

Note: Reach breaks denoted by black lines; maximum weekly average temperature at the USGS Gage No. 1136800 is provided for comparison to the Upper Sacramento River thermograph records for the same year.

Figure 3-14. Chinook Salmon Spawning Habitat Condition (derived from aerial videographic interpretation) in the McCloud River Between Shasta Lake and McCloud Dam



McCloud River - Shasta Lake to McCloud Reservoir
Field Derived

Note: Reach breaks denoted by black lines; maximum weekly average temperature at the USGS Gage No. 1136800 is provided for comparison to the upper Sacramento River thermograph records for the same year; field surveys of the lower reach have not been performed, to date

Figure 3-15. Chinook Salmon Spawning Habitat Condition (derived from field surveys) in the McCloud River Between Shasta Lake and McCloud Dam

Table 3-9. Aerial Video- and Field Survey-derived Chinook Salmon Spawning, Egg Incubation, and Emergence Life Stage Habitat Attribute Scores for the McCloud River between Shasta Lake and McCloud Dam

Study Reach	Chinook Salmon Spawning, Egg Incubation, and Emergence Life Stage Criteria			
	Attribute Scores (mean ± standard error)			Overall Habitat Condition Score
	Channel Morphometry	Substrate[a]	Habitat	
Video-derived				
Upper	2.1±0.03	2.6±0.00	1.6±0.10	2.1
Middle	2.3±0.00	2.4±0.00	2.1±0.11	2.3
Lower	2.3±0.00	-	1.9±0.09	-
Field-derived				
Upper	1.6±0.11	2.6±0.00	2.4±0.21	2.2
Middle	2.1±0.17	2.6±0.00	1.7±0.33	2.1
Lower	-	-	-	-

Note:
[a] Video-derived substrate attribute metric scores were computed with substrate composition parameter values (percent particle class composition and dominant bed substrate) derived from representative field sites.
Key:
"-" = no data available.

Chinook salmon rearing life stage habitat condition scores were fair-to-good, with little spatial variation in the upper and middle study reaches, for both aerial video- and field-derived habitat inventories (Figures 3-16 and 3-17). Cover attribute scores were the lowest rated component, which influenced the overall rearing habitat condition scores for each study reach (Table 3-10).[7] As for the upper Sacramento River, the cover attribute scores are highly dependent on the amounts and diversity of LWD for pool formation and physical cover, which are limited in the McCloud River and may not be as important in the large river tributaries because of the bedrock-controlled channel and pool forming structures. Substrate and habitat attribute scores were fair-to-good from both the aerial video- and field-derived habitat inventories (Table 3-10). Although both assessment methods relied on field-derived metrics for bed substrate composition and embeddedness, the difference between aerial video- and field-derived rearing habitat substrate attribute scores may have been a function of the combined error or bias associated with the aerial video-interpreted habitat inventory and the limited, short field site surveyed in the Middle study reach, not being fully representative of that study reach. Channel morphometry attribute scores for rearing habitat condition increased with distance downstream from McCloud Dam, a function of increasing

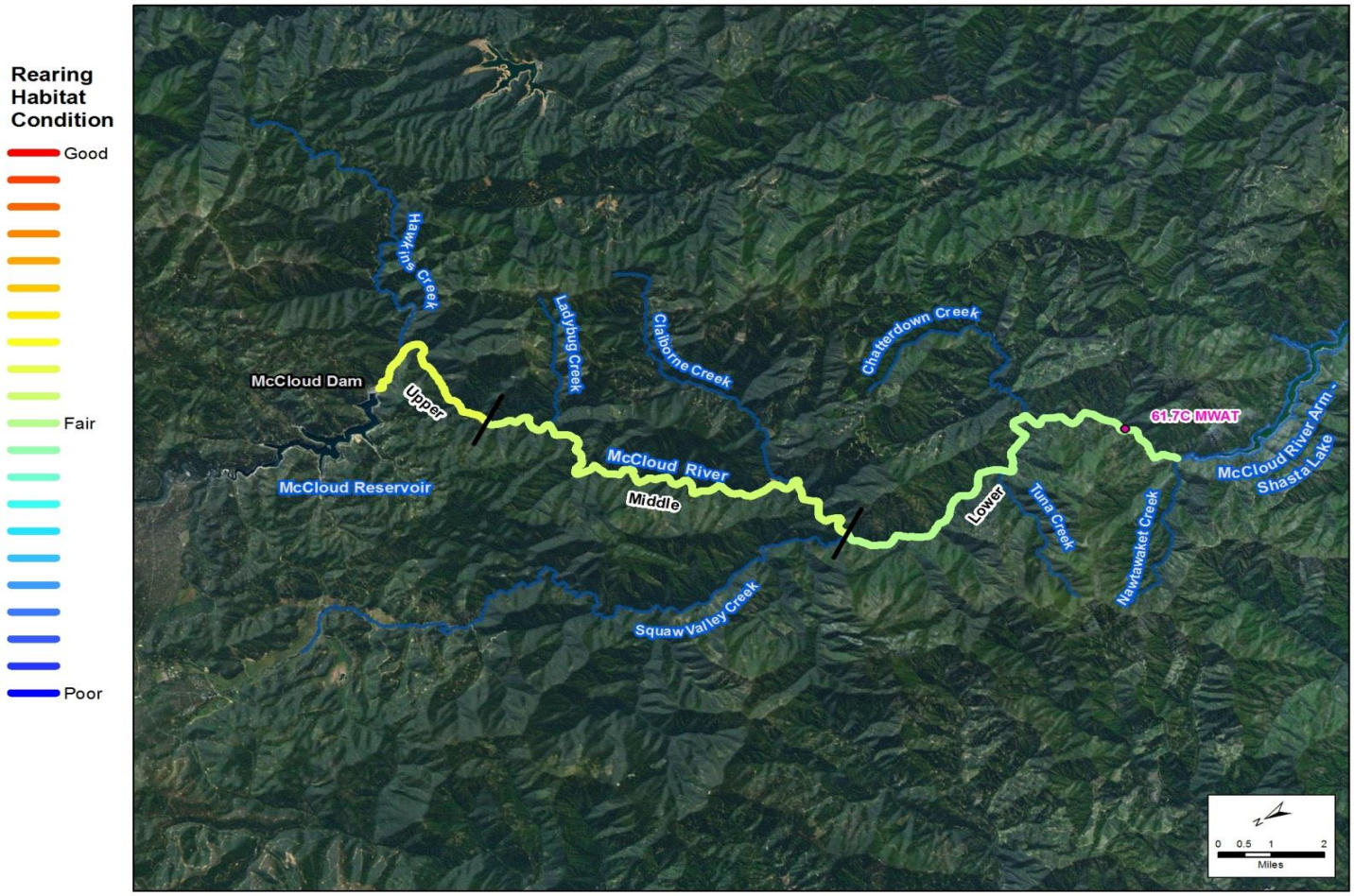
[7] Qualitative observations suggest that the December 2012 flow event caused localized scour and deposition and reduced the extent of terrestrial cover in and adjacent to the McCloud River and may have decreased overall cover ratings evaluated during 2014 in the McCloud River.

frequencies of flatwater habitats preferred by juvenile Chinook salmon (Table 3-10). Physical rearing habitat conditions, including water temperatures through the summer months, are fair-to-good for Chinook salmon in the McCloud River from McCloud Dam downstream through the middle study reach to at least Squaw Valley Creek. While the rearing habitat condition assessment of the lower study reach using aerial video interpretation will ultimately need to be verified through ground-level field surveys of representative sites, the thermal conditions throughout the summer remain within the suitable range for juvenile Chinook salmon growth and survival, not exceeding an MMWAT of 66.0°F (19.0°C), all the way downstream to Shasta Lake.

Table 3-10. Aerial Video- and Field Survey-derived Chinook Salmon Rearing Life Stage Habitat Attribute Scores for the McCloud River Between Shasta Lake and McCloud Dam

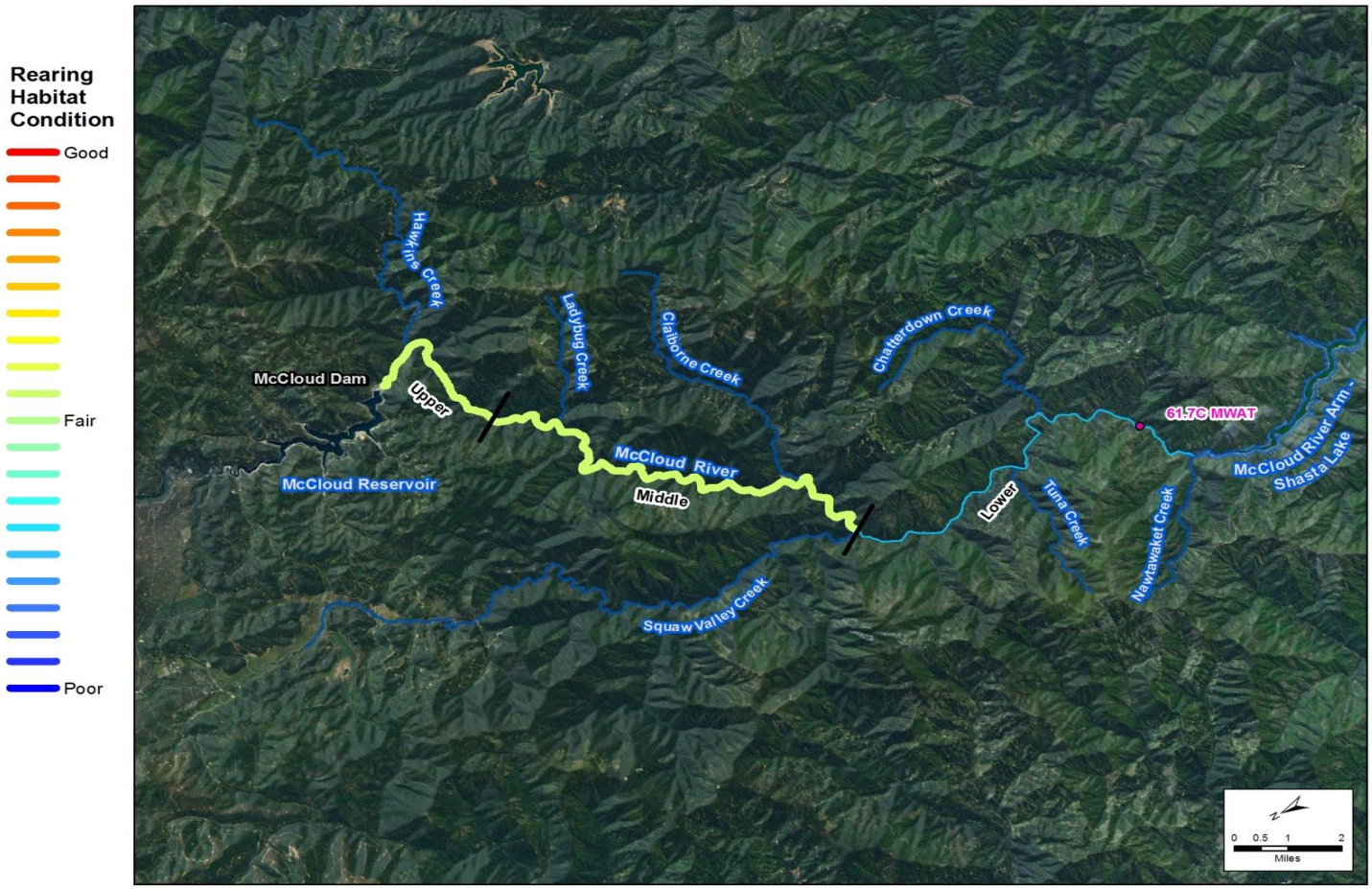
Study Reach	Chinook Salmon Rearing Life Stage Criteria Attribute Scores (mean ± standard error)				Overall Habitat Condition Score
	Channel Morphometry	Substrate	Cover[a]	Habitat[a]	
Video-derived					
Upper	2.1±0.06	2.4±0.00	1.9±0.03	2.3±0.10	2.2
Middle	2.2±0.01	2.2±0.00	1.8±0.00	2.3±0.08	2.1
Lower	2.5±0.05	-	1.0±0.00	2.4±0.09	-
Field-derived					
Upper	1.7±0.05	2.4±0.03	1.8±0.07	2.3±0.26	2.1
Middle	2.3±0.00	2.4±0.00	1.8±0.08	2.0±0.50	2.1
Lower	-	-	-	-	-

Notes:
[a] Video-derived substrate *and* cover attribute metric scores were computed with substrate composition (percent particle class composition and dominant bed substrate) and cover parameter values derived from representative field sites.
Key:
"-" = no data available.



Note: Reach breaks denoted by black lines; maximum weekly average temperature at the USGS Gage No. 1136800 is provided for comparison to the upper Sacramento River thermograph records for the same year.

Figure 3-16. Chinook Salmon Rearing Habitat Condition (derived from aerial videographic interpretation) in the McCloud River Between Shasta Lake and McCloud Dam



McCloud River - Shasta Lake to McCloud Reservoir
Field Derived

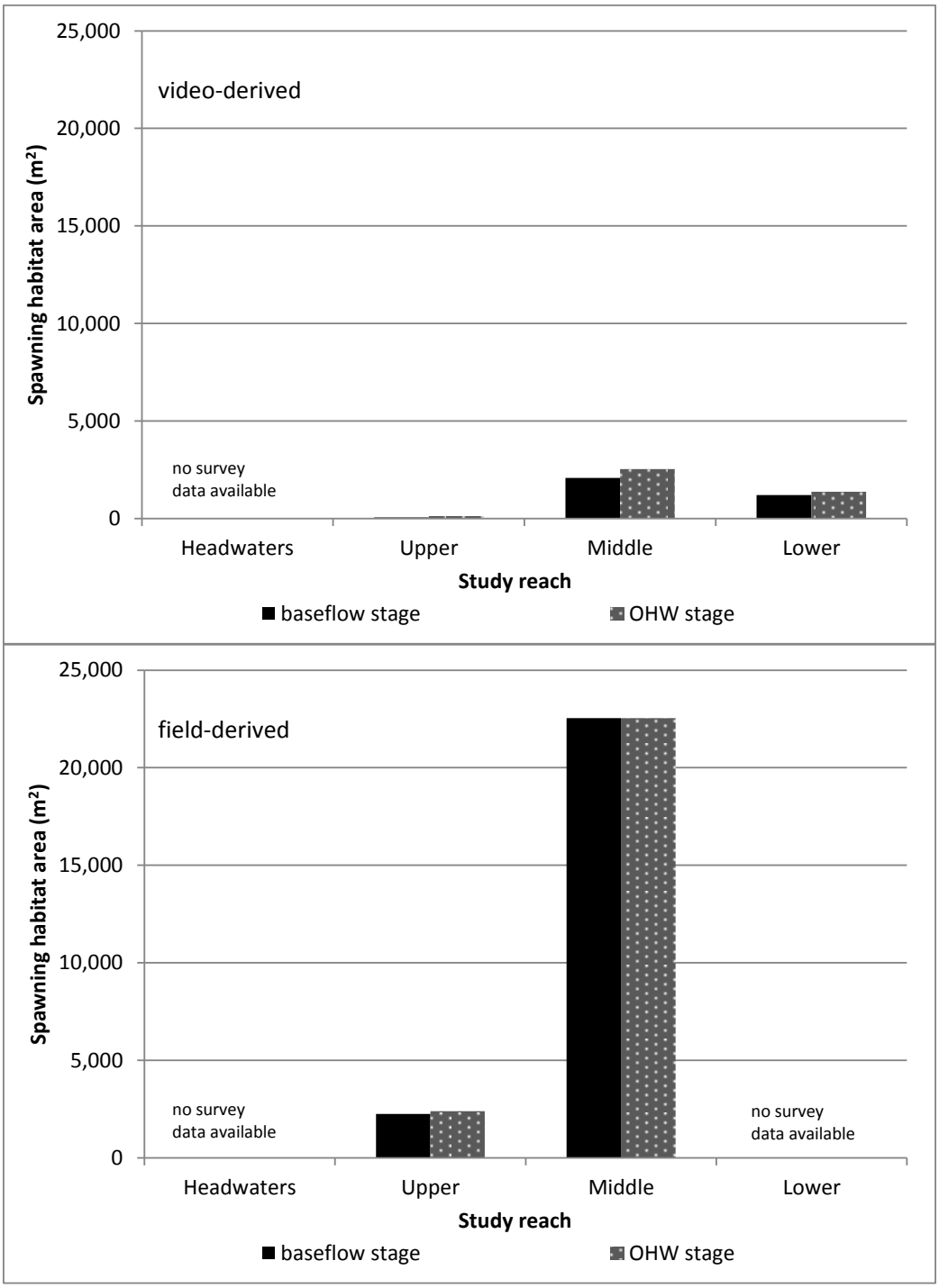
Note: Reach breaks denoted by black lines; maximum weekly average temperature at the USGS Gage No. 1136800 is provided for comparison to the upper Sacramento River thermograph records for the same year; field surveys of the lower reach have not been performed, to date.

Figure 3-17. Chinook Salmon Rearing Habitat Condition (derived from field surveys) in the McCloud River Between Shasta Lake and McCloud Dam

Spawner Capacity

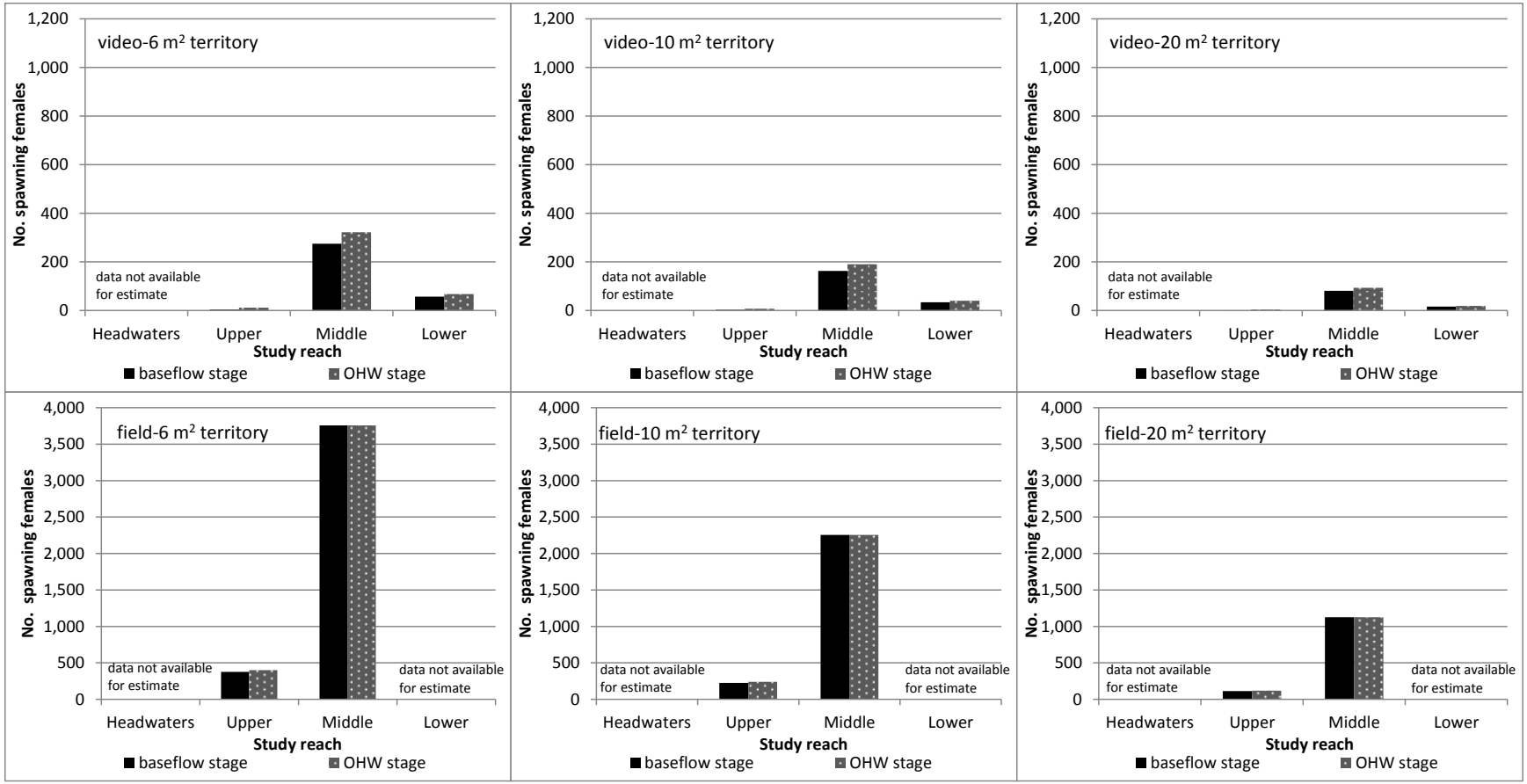
Estimates of Chinook salmon spawning habitat and spawning capacity for the McCloud River from McCloud Dam to Shasta Lake are currently reliant on use of aerial video-derived habitat inventory, with currently incomplete verification of representative field sites for all study reaches. Accordingly, the sources of error and bias associated with the aerial video interpretations previously described for the habitat inventory result in a greater level of uncertainty in these estimates for the McCloud River than for the upper Sacramento River. The spatial distribution of estimated spawning habitat area (Figure 3-18) and Chinook salmon spawning capacity (numbers of females) (Figure 3-19) in the McCloud River were lowest in the upper study reach and highest in the middle study reach (Table 3-11).[8] Based on the aerial video interpretation, 98 percent of the estimated available spawning habitat occurs in the middle and lower study reaches, with over 60 percent occurring in the middle study reach, from Squaw Valley Creek to Ah-Di-Nah campground. Field survey-derived estimates of spawning habitat area and Chinook salmon spawning capacity in the McCloud River were as much as 7 times greater than aerial video-derived estimates (Table 3-11). This discrepancy between the two habitat estimation methods is, again, likely a function of the combined error or bias associated with the aerial video-interpreted habitat inventory and the limited, short field site surveyed in the middle study reach, not being fully representative of that study reach. Additionally, due to obscuring vegetative cover and deep shadows on the McCloud River, determination of the extent of suitable spawning habitat, especially isolated sediment patches, from the aerial video was limited. The particle-size distribution of the extensive sediment deposits in isolated patches, lateral deposits and pool tails, particularly downstream of Claiborne Creek, were difficult to fully classify for the purpose of determining spawning habitat quality. Field observations in the middle and upper study reaches suggest a large volume of alluvial material was introduced and distributed during a large storm event in December 2012, which was reported to have mobilized landslides and abundant sediment runoff in the McCloud River and adjacent watersheds as a result of the Bagley Fire (Bachmann 2013). Total spawner capacity was about 19 percent greater at the OHW mark stage compared to the baseflow stage, based on the aerial video interpreted spawner estimates (Table 3-11).

[8] No estimates of spawning habitat area or spawning capacity were made for the Headwaters reach upstream of McCloud Reservoir because no access was granted to conduct ground-level field verification surveys necessary to obtain sufficient habitat inventory data required for computations.



Key:
m^2 = square meter
OHW = ordinary high water

Figure 3-18. Estimated Potentially Suitable Chinook Salmon Spawning Habitat Area in the McCloud River, by Study Reach, for Video- (upper panel) and Field-derived (lower panel) Estimates at Baseflow and Ordinary High Water Mark (OHW) Stages



Note: y-axis Scales are Different for Video- and Field-derived Estimates

Key:

m^2 = square meter

OHW = ordinary high water

Figure 3-19. Estimated Chinook Salmon Spawner Capacities (number females) in the McCloud River, by Study Reach, for Aerial Video- (upper panel) and Field-derived (lower panel) Estimates at Baseflow and Ordinary High Water Mark (OHW) Stages for a Range of Literature-based Spawning Area Territory Requirements from 6 Square Meters to 20 Square Meters

Table 3-11. Aerial Video- and Field Survey-derived Estimates of Potential Chinook Salmon Spawning Habitat Area and Potential Spawner Capacity, as the Number of Females, by Study Reach, in the McCloud River Between Shasta Lake and McCloud Dam

Study Reach	Total Spawning Habita Area (m2)		Estimated Spawner Capacity (number of females)					
			6 m2 Spawning Territory		10 m2 Spawning Territory		20 m2 Spawning Territory	
	Baseflow Stage	OHW Stage	Baseflow Stage	OHW Stage	Baseflow Stage	OHW Stage	Baseflow Stage	OHW Stage
Video-derived								
Headwater	-	-	-	-	-	-	-	-
Upper	53	143	4	12	3	7	1	4
Middle	2,088	2,547	275	322	163	190	81	93
Lower	1,208	1,389	57	68	34	40	16	19
Total	3,350	4,079	337	402	200	237	97	116
Field-derived								
Headwater	-	-	-	-	-	-	-	-
Upper	2,261	2,391	377	399	226	239	113	120
Middle	22,536	22,536	3,756	3,756	2,254	2,254	1,127	1,127
Lower	-	-	-	-	-	-	-	-
Total	**24,797**	**24,927**	**4,133**	**4,155**	**2,480**	**2,493**	**1,240**	**1,246**

Key:
"-" = no data available.
m^2 = square meter
OHW = ordinary high water

Synthesis and Conclusions

This section provides a brief synthesis and discussion of current study's findings relative to historic and other recent information on potential Chinook salmon spawning habitat in the Sacramento and McCloud rivers upstream of Shasta Lake. This section also compares and discusses the relative condition of Chinook salmon spawning and rearing habitat and spawner capacity in each of the study rivers. Finally, this section provides a list of recommended habitat assessment-related tasks and study elements for consideration in developing the Shasta Dam Fish Passage Pilot Implementation Plan.

Historical Comparisons

As part of the fish-salvage investigations prior to construction of Shasta Dam, Hanson et al. (1940) estimated the potential Chinook salmon spawning capacities of the tributaries to the Sacramento River, including the tributaries located now above the dam. The potential spawning capacity estimated by Hanson et al. (1940) for the upper Sacramento River from Delta to the Cantara Loop were higher, particularly in the Delta to Flume Creek reach, than the estimates resulting from the current habitat assessment (Table 4-1). Several important methodological differences are thought to account for these differences. The timing of habitat surveys for both the Hanson et al. (1940) and the current study were likely conducted under similar flow conditions, fall and winter baseflows, because they reported average channel widths and field verification of spawning area using direct observations of spawning fall-run Chinook salmon, which would have been from October to December; therefore, it can be assumed that flow levels and seasonal survey timing is comparable and did not account for the differences. Two other aspects of the techniques used by Hanson et al. (1940), though, likely account for differences in the spawner capacity estimates compared to the current study. The spawning territory requirement used by Hanson et al. (1940) was smaller than in the current study, 3.7 m^2 versus 6 to 20 m^2, respectively. Additionally, the historic spawner capacity estimates did not take into account a varying redd density as a function of substrate quality as did the method used in the current study. For example, 50 percent of the spawning habitat area at baseflow in the Sacramento River downstream of the Cantara Loop was considered "fair," because the streambed in otherwise suitable spawning habitat was dominated by cobble-sized particles, which was assigned a 0.5 spawning density coefficient, essentially reducing the potential spawning capacity by one half in that reach compared to not using this approach.

Table 4-1. Comparison of Historic (from Hanson, et al. 1940) Estimates of Chinook Salmon Spawner Capacity, as the Number of Female Salmon, with This Study for the Upper Sacramento River Between Shasta Lake and Box Canyon Dam

		Estimated Spawner Capacity (Number of Females)			
Reach	**Reach Length**	**Historic**	**This Studyb, c**		
	(miles)	**Hanson et al. (1940) [a]**	**6 m^2 Spawning Territory**	**10 m^2 Spawning Territory**	**20 m^2 Spawning Territory**
Delta to Flume Creek (RM 0–15)	15	1,919	252	151	75
Flume Creek to Cantara Loop (RM 15–34)	19	1,147	641	385	194
Total	34	3,066	893	536	269

Notes:

[a] Spawning capacity estimates in Hanson et al. (1940) assumed spawning area requirements as 3.7 m^2 territory for all their estimates.

[b] The spawner capacity (as number of females) reported for this study is based on extrapolations of field-derived estimates of suitable spawning habitat areas at 11 representative study sites and included redd density adjustment based on substrate quality (see Appendix A for details on methodology).

Key:
cfs = cubic feet per square meter
m^2 = square meters
RM = river mile

Estimates of spawner capacity for this study are for habitat conditions at baseflow (approx.. 200-250 cfs at the Delta gage); Hanson et al. (1940) did not specify the flow level for which estimates were made, but based on average channel widths that they reported, it is believed that their estimates reflect surveys conducted during summer baseflow conditions.

The historical, potential salmon spawning capacity for the McCloud River was reported by Hanson et al. (1940) for two reaches, from Bollibokka to Squaw Valley Creek, and from Squaw Valley Creek to Lower McCloud Falls, including the area now inundated by McCloud Reservoir. For the purpose of comparing Hanson, et al.'s spawner capacities to the current study's, spawning habitat was assumed to be spatially uniform within these reaches and then proportionally split out the estimate of spawners upstream and downstream of McCloud Dam based on relative channel lengths in these two reaches (Table 4-2; see footnote to this table for how Hanson et al. (1940) values were modified for comparison). The breakout estimate of historic spawner capacity in the Squaw Valley Creek to McCloud Dam reach, which was inclusive of the current study's middle and upper study reaches, was similar to the current study's estimate, using the 6 m^2 redd territory size (Table 4-2). In contrast, historic estimates of spawner capacity downstream of Squaw Valley Creek are considerably higher than for the current study (Table 4-2). This was primarily a result of having to use the less reliable aerial video-derived habitat assessment for this exercise in the lower study reach

because field surveys have not been conducted there, to date. As described in Chapter 3 "Results," confidence in the potential spawner capacity estimate for the lower study reach for the current study is very low.

Although, a reliable assessment of habitat condition and spawner capacity for the McCloud River above McCloud Reservoir could not be made with the available aerial videography, and field surveys were not permitted due to lack of access to private property, an estimate of the historic potential spawner capacity from the data presented by Hanson et al. (1940) was possible and is also presented in Table 4-2 for comparison (see footnote to the table for a description of derivation of this estimate). Due to the lack of field surveys in the lower and middle segments of the McCloud River, a priority for further planning studies is adequate field calibration and verification of aerial surveys to support whether the estimates in this assessment are accurate.

Table 4-2. Comparison of Historic (from Hanson et al. 1940) Estimates of Chinook Salmon Spawner Capacity, as the Number of Female Salmon, with This Study for the McCloud River Between Shasta Lake and Lower McCloud Falls

		Estimated Spawner Capacity (Number of Females)			
		Historic	This Studyc, d		
Reach	**Reach Length (miles)**	**Hanson et al. (1940) a**	**6 m2 Spawning Territory**	**10 m2 Spawning Territory**	**20 m2 Spawning Territory**
Bollibokka to Squaw Valley Creek (RM 0.0–9.5)	9.5	2,846	57	34	16
Squaw Valley Creek to McCloud Dam (RM 9.5–23.2)	13.7	4,360[b]	4,133	2,480	1,240
Wyntoon to Lower McCloud Falls RM 23.2–35.7	6.5	2,069[b]	-	-	-
Total	29.7	9,275	4,190	2,514	1,256

Notes:

[a] Spawning capacity estimates in Hanson et al. (1940) assumed spawning area requirements as 3.7 m^2 territory for all their estimates.

[b] The historic spawner capacity estimates for these reaches were interpolated from a single value, 8,339, reported by Hanson et al. (1940) for the entire reach from Squaw Valley Creek to Lower Falls, which now includes the area occupied by McCloud Dam and Reservoir. Assuming a uniform spatial distribution of spawning habitat, a simple proportional break out based on lineal river distance (8,339*(13.7/26.2)) for Squaw Creek to McCloud Dam and (8,339*(6.5/26.2)) for Wyntoon to Lower Falls was used for interpolating the potential distribution of the historic spawning capacity within the contemporary, available reaches, both downstream and upstream of the McCloud Reservoir.

[c] The spawner capacity (as number of females) reported for the current study is based on extrapolations of field-derived estimates of suitable spawning habitat areas at representative study sites in the McCloud River between Squaw Valley Creek and McCloud Dam; spawning capacity estimates for the Bollibokka to Squaw Valley Creek reach were derived from aerial video interpretation of habitat conditions and spawning areas. Includes redd density adjustment based on substrate quality (see Appendix A for details on methodology).

[d] Values represent estimates of spawner capacity at baseflow (approx. 200-300 cfs above Shasta); Hanson et al. (1940) did not specify the flow level for which estimates were made, but based on average channel widths that they reported, it's believed that their estimates reflect surveys conducted during summer baseflow conditions

Key:
m^2 = square meters
RM = river mile
"-" = no data available.

Consideration of McCloud-Pit Hydroelectric Project Relicensing Study Findings about Potential Suitable Salmon Spawning Habitat

As part of the recent PG&E's relicensing application with FERC for the McCloud-Pit Hydroelectric Project (FERC Project No. 2106), an investigation of potential habitat-flow relationships for Chinook salmon and steelhead was conducted pursuant to requests by resource agencies participating in the relicensing proceedings. PG&E conducted three tasks including: 1) develop literature-based habitat suitability criteria (HSC) for Chinook salmon and steelhead for use with the Lower McCloud River one-dimensional (1-D) physical habitat simulation (PHABSIM) models; 2) conduct additional spawning gravel surveys to update a 1-D PHABSIM model for use with substrate criteria for Chinook salmon and steelhead; and 3) conduct a 1-D PHABSIM analysis using the HSC developed for Chinook salmon and steelhead life stages to evaluate the potential flow-habitat relationships for these species in the Lower McCloud River (PG&E 2011, 2012a,b).

To allow comparison with the current study, total spawning habitat was extrapolated from weighted usable Chinook salmon spawning habitat areas measured in weighted useable area (WUA) reported in PG&E's PHABSIM modeling study over a range of flows in the McCloud River below McCloud Dam by multiplying the reach-specific WUA values (spawning area (square feet) per 1000 feet) by the reach lengths (in feet) (Table 4-3). These total estimated spawning areas, in turn, were used to estimate Chinook salmon spawner capacity for two reaches of the McCloud River, applying a range of spawning territory requirements (Table 4-4). Estimated spawner capacities derived from PG&E's PHABSIM modeling study were greater than for both the historic (Hanson et al. 1940) and the current study's estimates. However, direct comparison of the current study's estimates for the McCloud River with those derived from the PG&E WUA Chinook salmon spawning habitat curves must be made with the following cautions and caveats. Firstly, the factor that likely contributes most the differences in these spawner estimates is that spawning substrate suitability defined for the PG&E PHABSIM modeling was over a broader range of gravel sizes than used by the current study. The redd density adjustment factor, varying redd density as a function of substrate quality, used to estimate spawner capacity for the current study (see Appendix A for details on methodology), if similarly applied to the PG&E PHABSIM study would have had the effect of reducing the estimated suitable habitat area extrapolated from the WUA curves by some unknown amount. Secondly, the previously described low reliability of the aerial video-derived habitat assessment for use in estimating spawner capacity in the lower study reach impedes confidence for any comparisons with the PG&E PHABSIM derived spawner capacity estimates.

Table 4-3. Weighted Usable Chinook Salmon Spawning Habitat Areas Generated from Pacific Gas and Electric Company's PHABSIM Modeling Study and the Associated Extrapolations for Total Spawning Habitat Area in the McCloud River Below McCloud Dam over a Range of Flows

Reach	Reach Length	Chinook Salmon Spawning Weighted Usable Area (ft2/1,000ft)			Extrapolated Total Spawning Habitat Area (m2)		
	(miles)	100 cfs	200 cfs	300 cfs	100 cfs	200 cfs	300 cfs
Bollibokka to Squaw Valley Creek (RM 0.0–9.5)	9.5	5,500	6,500	6,200	36,935	43,651	41,636
Squaw Valley Creek to McCloud Dam (RM 9.5–23.2)	13.7	12,000	19,200	22,000	55,884	89,415	102,455

Source: Adapted from: PG&E (2012)
Key:
cfs = cubic feet per second flow
ft = feet
ft2 = square feet
m2 – square meters
PHABSIM = Physical Habitat Simulation
"-" = no data available

Table 4-4. Estimates of Chinook Salmon Spawner Capacity, as the Number of Female Salmon, Extrapolated from the Weighted Usable Chinook Salmon Spawning Habitat-Flow Relationship from Pacific Gas and Electric Company's PHABSIM Modeling Study for the McCloud River Below McCloud Dam over a Range of Flows

Reach	Reach Length	Estimated Spawner Capacity (Number Females)								
		6 m2 Spawning Territory			10 m2 Spawning Territory			20 m2 Spawning Territory		
	(miles)	100 cfs	200 cfs	300 cfs	100 cfs	200 cfs	300 cfs	100 cfs	200 cfs	300 cfs
Bollibokka to Squaw Valley Creek (RM 0.0–9.5)	9.5	6,156	7,275	6,939	3,694	4,365	4,164	1,847	2,183	2,082
Squaw Valley Creek to McCloud Dam (RM 9.5–23.2)	13.7	9,314	14,903	17,076	5,588	8,942	10,245	2,794	4,471	5,123
Total	35.7	15,470	22,178	24,015	9,282	13,307	14,409	4,641	6,654	7,205

Key:
"-" = no data available
cfs = cubic feet per second
m^2 = square meters
PHABSIM = Physical Habitat Simulation
RM = river mile

Comparison of Habitat Conditions for the Sacramento and McCloud Rivers

The longitudinal temperature record, to date, for the upper Sacramento River, though limited to WYs 2012 and 2013, suggests that optimal temperature conditions for winter-run Chinook salmon egg incubation (less than or equal to 56.0°F [13.3°C]) may be limited to the upper nine miles of the river below Box Canyon Dam. Similarly, based on a limited set of long-term thermographic records and PG&E's (2008) temperature modeling for the McCloud River below McCloud Dam, optimal temperatures for Chinook salmon egg incubation during the winter-run Chinook salmon spawning season through the summer months is limited to the upper 11.6 miles of the river below McCloud Dam. Overall habitat condition scores for spawning, egg incubation and emergence attributes were similar for the thermally optimal reaches of both rivers (Table 4-5). With the exception of thermal conditions, the physical habitat scores within the thermally optimal reaches were lower than those in the downstream stream reaches for both study streams. This result is primarily attributable to a lower frequency of pool habitats and less overall spawning habitat area with distance upstream in both rivers, with the exception that, in the McCloud River, regular sequences of large pools were observed during field-level surveys of the stream reach from Hawkins Creek to Ah-Di-Na.

The available thermographic record indicates that thermal conditions remain within the suitable range for juvenile Chinook salmon growth and survival throughout the summer, not exceeding an MMWAT of 66.0°F (19.0°C), for all 23 miles of the McCloud River from McCloud Dam to Shasta Lake and for 28 miles of the upper Sacramento River from Box Canyon Dam downstream to Gibson Road (RM 9) (Table 4-6). Habitat condition scores for rearing habitat within the thermally suitable reach of the upper Sacramento River were slightly greater than for the McCloud River (Table 4-6). This comparison is affected by the limitations on use of the aerial video-derived habitat assessment for the lower study reach of the McCloud, which may have affected a reduced overall rearing habitat condition score. Overall, rearing habitat conditions for juvenile Chinook salmon in both streams is rated as fair-to-good, with some limitations due to relatively low quantity and diversity of the cover composition.

Estimates of Chinook salmon spawning capacity within reaches of the Sacramento and McCloud rivers with optimal temperatures for spawning and egg incubation differed considerably despite similar lengths of each stream within optimal temperature regimes (Table 4-7). These differences were largely attributable to the differences in spatial distribution of the suitable physical spawning habitat in the two rivers. The habitat assessment found nearly 80 percent of the total potential Chinook salmon spawning habitat occurred between North Salt Creek (RM 7.2) and Dunsmuir (RM 30), although less than 10 percent of the total potential spawning habitat in the upper Sacramento River occurred within the reaches influenced by the large, cold spring inflows (in the Mossbrae Reach) upstream of Dunsmuir with temperatures suitable for winter run spawning. In contrast, a considerably larger proportion of the total potential spawning habitat estimated for the McCloud River appears to occur within a thermally optimal reach, particularly from Ah-Di-Na Campground (RM 19.8) downstream to just above Squaw Valley Creek (RM 9.5). Relying on the total potential spawning habitat estimates derived from the PG&E PHABSIM spawning habitat WUA curves because of limitations on the estimates from the current study, nearly 68 percent of the potential Chinook salmon spawning habitat of the McCloud River between McCloud Dam and Shasta Lake occurs within the thermally optimal reach.

In summary, the habitat assessment for both rivers indicated fair-to-good habitat conditions exist to support spawning and rearing life stages of Chinook salmon. Though the lowest reach of the upper Sacramento River may have some limitation on thermal suitability for rearing life stages, the overall length of both rivers within the thermally optimal range for juvenile salmon rearing is quite similar. The most significant difference in potential habitat conditions is that the Sacramento River has considerably less potentially suitable spawning habitat, within thermally optimal stream reach through the summer than is potentially available in the McCloud River. Although both rivers exhibit suitable conditions for potential salmon spawning and rearing habitat, in comparison to the McCloud River, the temperature regime of the upper Sacramento River would likely be a major factor limiting the number of winter-run Chinook salmon that could be

successfully reintroduced due to its influence on a majority of the upper Sacramento River's spawning habitat.

Table 4-5. Comparison of Habitat Attributes Scores for the Chinook Salmon Spawning and Egg Incubation Life Stage in Thermally Optimal Reaches of the Upper Sacramento River and McCloud River Study Reaches

River	Total River Length(miles)	Length within Optimal Thermal Range (miles)	Chinook Salmon Spawning, Egg Incubation, and Emergence Life Stage Criteria			
			Attribute Metric Scores (combined reach mean ± standard error)			Overall Habitat Condition Score
			Channel Morphometry	Substrate	Habitat	
Video-derived						
Sacramento	37.0	9.0	2.2±0.08	2.9±0.02	1.4±0.12	2.3
McCloud	23.2	11.6	2.2±0.10	2.5±0.08	1.8±0.15	2.2
Field-derived						
Sacramento	37.0	9.0	2.2±0.15	2.8±0.06	1.6±0.22	2.3
McCloud	23.2	11.6	1.8±0.15	2.6±0.11	2.2±0.19	2.2

Note:
Optimal water temperature conditions for Chinook salmon spawning and egg incubation were consistent with winter-run Chinook salmon egg incubation requirements considered to be less than or equal to 56.0°F (13.5°C) daily average water temperature or an Monthly Maximum Weekly Average Temperature of 55.0°F (12.8°C).

Table 4-6. Comparison of Habitat Attributes Scores for the Chinook Salmon Rearing Life Stage in Thermally Optimal Reaches of the Upper Sacramento River and McCloud River Study Reaches

River	Total River Length (miles)	Length within Optimal Thermal Rangel (miles)	Chinook Salmon Rearing Criteria				
			Attribute Metric Scores (combined reach mean ± standard error)				Overall Habitat Condition Score
			Channel Morphometry	Substrate	Cover	Habitat	
Video-derived							
Sacramento	37.0	28.0	2.4±0.04	2.9±0.02	1.7±0.03	1.7±0.09	2.3
McCloud	23.2	23.2	2.3±0.05	2.3±0.05	1.6±0.03	2.3±0.07	2.1
			Field-derived				
Sacramento	37.0	28.0	2.4±0.09	2.8±0.05	1.7±0.07	2.2±0.15	2.3
McCloud	23.2	23.2	1.9±0.13	2.4±0.11	1.8±0.10	2.2±0.20	2.1

Note:

Optimal water temperature conditions for rearing Chinook salmon were considered to be less than or equal to 66.0°F (18.9°C) Monthly Maximum Weekly Average Temperature.

Table 4-7. Comparison of Estimates of Chinook Salmon Spawner Capacity, as the Number of Female Salmon, that Occurs in Reaches of the Upper Sacramento River and McCloud River with Summer Water Temperatures Within the Optimal Range for Spawning and Egg Incubation

River	River Length (miles)	Length of Reach Thermally Optimal (miles)	Estimated Spawner Capacity (Number of Females)		
			6 m2 Spawning Territory	10 m2 Spawning Territory	20 m2 Spawning Territory
Field-derived					
Sacramento	37.0	9.0	224	134	68
McCloud	23.2	11.6	3,382	2,029	1,014

Note:

Optimal water temperature conditions for winter-run Chinook salmon egg incubation were considered to be less than or equal to 56.0°F (13.5°C) daily average water temperature or an Monthly Maximum Weekly Average Temperature of 55.0°F (12.8°C)

Key

m^2 = square meters

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Concluding Considerations

The following are recommended habitat assessment-related tasks and study elements for prioritization in developing the Pilot Reintroduction Implementation Study Plan:

- Complete field surveys of the representative sites in the lower study reach of the McCloud River on the Bollibokka Fishing Club, where permission has been granted to the project by Westlands Water District.

- Describe and integrate monitoring hypotheses, studies and metrics for evaluating adult and juvenile salmon habitat use and preferences in the Pilot Reintroduction Implementation Study Plan.

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