SCOTT RIVER FISH PASSAGE AND LONGITUDINAL HABITAT CONNECTIVITY

1.0 Study Goals and Objectives

The goals of this study are to 1) identify potential structural and hydraulic barriers to anadromous fish passage in the Scott River, and 2) identify streamflows that support passage of anadromous fish of multiple life stages at these potential barriers. The specific objectives of the study include:

1) Review existing information and conduct field surveys to identify potential fish passage barriers.
2) Classify potential fish migration barriers and select study sites (critical passage sites) for application of fish passage and habitat connectivity assessment methods.
3) Identify the appropriate data and methods for evaluating fish passage success as a function of high and/or low flow at the study sites.
4) Using physical and hydraulic data, apply appropriate fish passage methods and criteria (e.g., minimum passage depths, maximum water velocities) to evaluate potential fish passage success. (Longitudinal habitat connectivity as affected by high water temperatures or dry channels will be addressed by temperature modeling and hydrologic study plans, respectively.)
5) Identify protective flow regimes for passage of target species and lifestages, and apply hydrologic data to evaluate the frequency and duration of suitable passage flows under existing, unimpaired, and alternative flow scenarios to recover and/or enhance populations and restore watershed function.

2.0 Review Existing Information

The purpose of this task is to review and update available information on known or potential fish passage barriers in the Scott River watershed to guide identification of key sites where additional information is needed to evaluate fish passage needs and identify actions to improve passage and connectivity of critical migration, spawning, and rearing areas. During the initial phase of study plan development, specific study reaches were identified where fish passage is a primary resource issue. Sources for relevant information on the location, status, and recommended or proposed actions at specific passage barriers within these reaches were also identified as part of this effort. A key source for updated information on fish passage barriers in these reaches is the CalFish Fish Passage Assessment Database (CalFish 2014). This database contains a GIS-based catalog of available fish passage information that can be queried using a number of search criteria, and includes the location, type, and status of known or potential barriers; passage assessment protocols; survey team and date; ownership information; and relevant citations. Additional information on hydrologic connectivity could be identified from available aerial or satellite photo sources (e.g. Google Earth) or previous investigations (Watershed Sciences 2004). Recent analyses on declining flow trends at the Ft. Jones stream gage during September (Asarian 2014) should also be considered in the passage and connectivity assessment.

This task includes: 1) reviewing and updating information on all known or potential fish passage barriers within the study reaches identified below; 2) reviewing current information on the key species and life stages of concern in these reaches; 3) interviewing biologists and other technical specialists, stakeholders, and local experts currently engaged in monitoring, evaluation, planning, and implementation of fish passage and habitat restoration actions in the Scott River watershed; and 4) identifying major gaps in information on specific barriers or barrier types within the study reaches (e.g., critical riffles).

This task also includes telephone and email correspondence with the management team to review the results and agree on major data gaps and the specific study reaches or sites where field surveys will be conducted.

3.0 Study Areas

The Scott River watershed is about 812 square miles at the confluence, and about 650 square miles at the USGS streamflow measurement station (gage) at Fort Jones. During project scoping, the Scott River was segmented into study reaches using criteria such as hydrology, length, geomorphology, and others (Normandeau Associates 2013; Figures 1 and 2). The proposed study reaches where fish passage and hydrologic connectivity have been identified as concerns are listed in Tables 1 through 3 (see Scott River Potential Studies Matrix http://www.normandeau.com/scottshasta/project_materials.asp).

Table 1. Reaches of the Scott River and tributaries where critical riffles are to be identified.

REACH DESCRIPTION	Reference(s)	Studies Status
Mainstem Scott River Studies	CDFW (2014)	Needed
Tributary Studies	CDFW (2014)	Needed

Table 2. Reaches of the Scott River and tributaries where barriers are to be identified.

REACH DESCRIPTION	Reference(s)	Studies Status
Lower Tailings to SF/EF Confluence (7)	CDFG 1974, 2009; RMFJ 2007; SRWC 2006	Partial
East Fork (Lower) (EF1)	NMFS 2012; SRWC 2006	Needed
East Fork (Upper) (EF2)	NMFS 2012; SRWC 2006	Partial
Etna Creek (Lower) (ET1)	NMFS 2012; SRWC 2006	Partial
Etna Creek (Upper) (ET2)	NMFS 2012; SRWC 2006	Partial
French Creek (Lower) (FR1)	NMFS 2012; SRWC 2006	Partial
French Creek (Upper) (FR2)	NMFS 2012; SRWC 2006	Partial
Kidder (Middle) (KD1)	NMFS 2012; SRWC 2006	Partial
Kidder/Patterson (Lower) (KP1)	NMFS 2012; SRWC 2006	Needed
Mill Creek (Lower) (ML1)	NMFS 2012; SRWC 2006	Partial
Moffett Creek (Lower) (MT1)	NMFS 2012; SRWC 2006	Partial
Patterson (Lower) (PT1)	NMFS 2012; SRWC 2006	Needed
South Fork (SF)	NMFS 2012; SRWC 2006	Partial
Shackleford Creek (Middle) (SH1)	NMFS 2012; SRWC 2006	Partial
Shackleford Creek (Upper) (SH2)	CDFW 2013	Needed

Shackleford/Mill Creek (Lower) (SM1)	NMFS 2012; SRWC 2006	Partial
Big Mill Creek	NCRWQCB 2015	Needed
Kangaroo Creek	NCRWQCB 2015	Needed
Rail Creek	NCRWQCB 2015	Needed
Boulder Creek	NCRWQCB 2015	Needed
Fox Creek	NCRWQCB 2015	Needed
Tompkins Creek	Pace 2015	Needed
Little Mill Creek	Pace 2015	Needed
Middle Creek	Pace 2015	Needed
Sniktaw Creek	Pace 2015	Needed
Clark Creek	Pace 2015	Needed
Miners Creek	Pace 2015	Needed
Grouse Creek	Pace 2015	Needed

Table 3. Scott River tributaries where tributary connectivity (within-tributary and to mainstem Scott River) needs to be evaluated.

REACH DESCRIPTION	Reference(s)	Studies Status
East Fork (Lower)	Mount et al. 2003	Needed
Etna Creek (Lower)	CFS 2010; SRWC 2006; Yokel 2006	Needed
French Creek (Lower)	CFS 2010; SRWC 2006; Yokel 2006; Quigley et al. 2001	Needed
Kidder (Middle)	CFS 2010; SRWC 2006	Needed
Mill Creek (Lower)	CFS 2010	Needed
Patterson (Lower)	CFS 2010; SRWC 2006; Yokel 2013	Partial
Sugar Creek/Wildcat Creek	CFS 2010; SRWC 2006	Needed
South Fork	CFS 2010; SRWC 2006	Needed
Shackleford Creek (Middle)	Watershed Sciences 2004; CFS 2010; SRWC 2006; Bowman 2009	Needed
Shackleford/Mill Creek (Lower)	CFS 2010	Needed

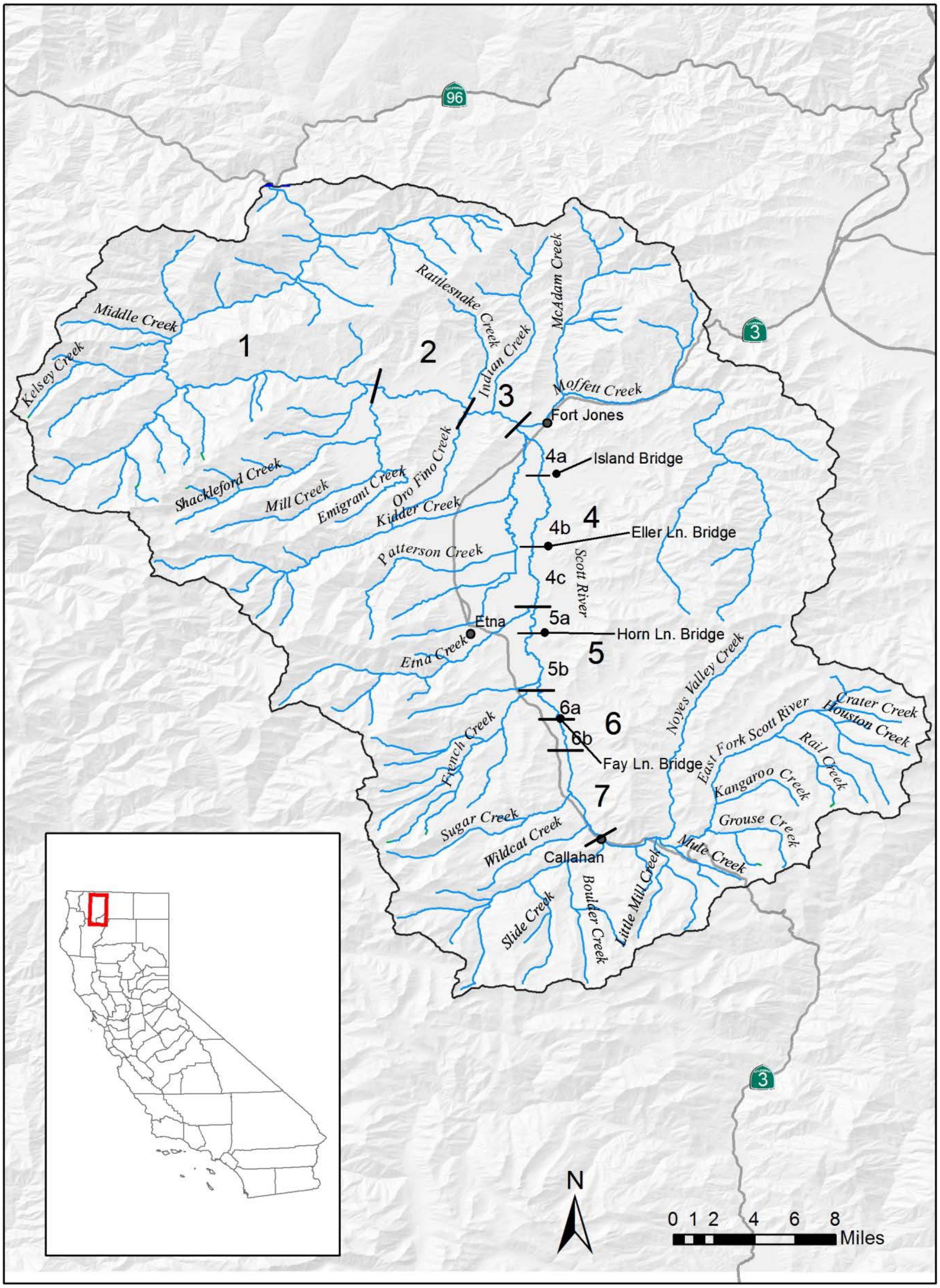

Figure 1. Scott River Mainstem Reaches.

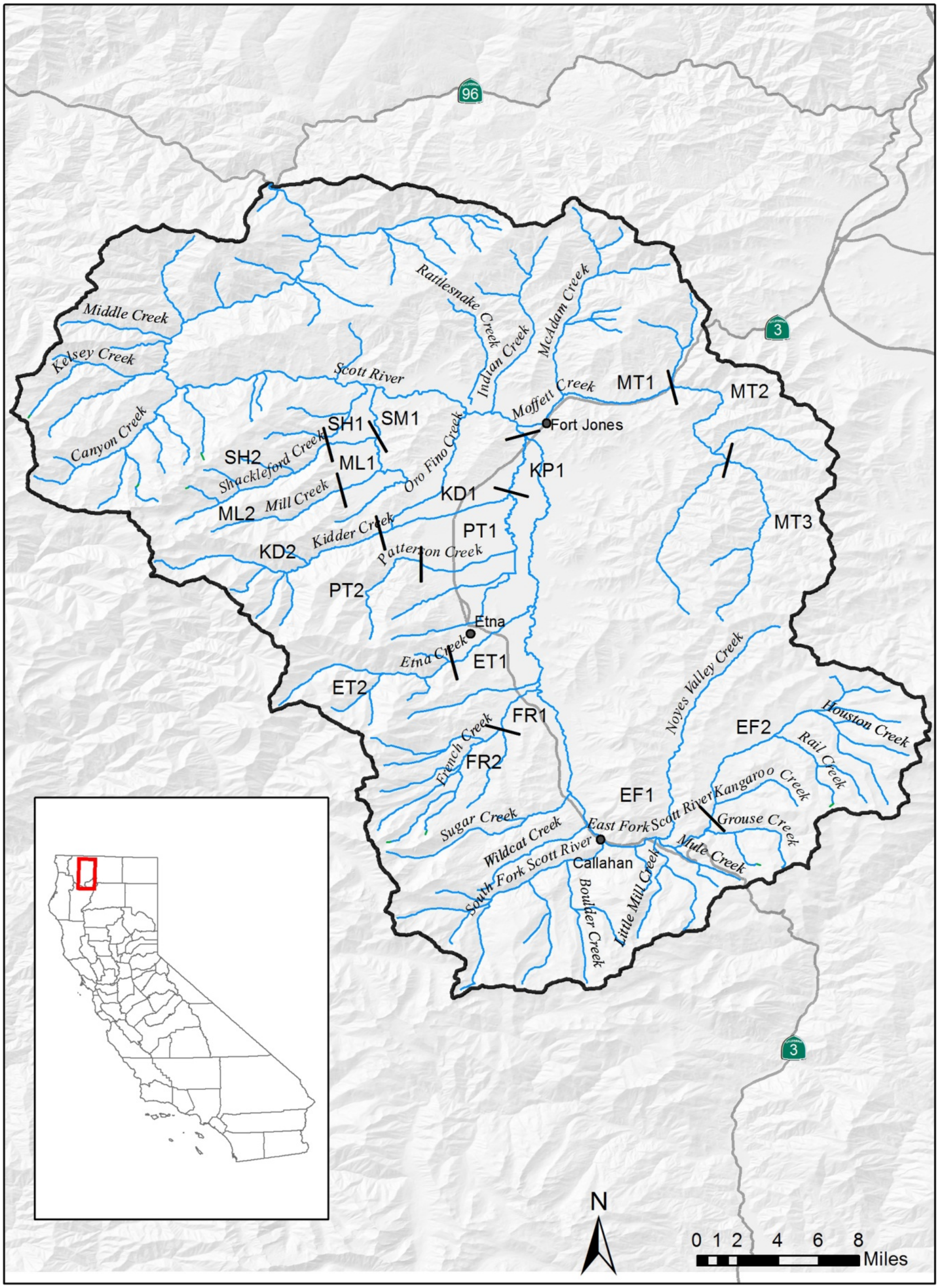

Figure 2. Scott River Tributary Reaches.

4.0 Study Methods

The following methods are focused on evaluation of structural and hydraulic fish passage barriers only. Integration and coordination with other study plans that cover hydrology, groundwater, and water temperature will likely be required to address the full range of fish barriers that may affect passage. These other barriers may include dry channel and thermal blockages.

4.1. Field Surveys

Reconnaissance-level field surveys will be conducted to identify potential fish barriers, evaluate the current status of known barriers, and determine the need for additional data and/or analyses to evaluate the flow and/or structural requirements for successful fish passage at these barriers based on the species and life stages of concern. These surveys will focus on the reaches and sites identified through review of existing information and coordination with the management team. A fish passage inventory data sheet will be developed in coordination with California Department of Fish and Wildlife (CDFW) to classify potential passage barriers, collect preliminary field measurements, and prioritize barriers for subsequent fish passage evaluation based on a set of filtering criteria. An example of a fish passage inventory data sheet for stream crossings and a description of the filtering process (passage evaluation filter) can be found in Part IX of the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 2010).

General types of fish passage barriers include 1) critical riffles and other non-structural, low-flow passage barriers, including dewatered channels; 2) artificial structural barriers such as diversion dams, culverts, and road crossings, and 3) natural structural barriers such as falls, chutes, cascades, and beaver dams. Depending on barrier type and site characteristics, initial field measurements may include water depths, fall heights, water column velocity, and passage route profiles and distances. This task should be coordinated with habitat mapping surveys described in the *Scott River Mesohabitat Delineation Study Plan*.

4.2. Fish Passage Implementation Strategy

Once potential fish passage barriers have been identified through review of existing information and field surveys, the contractor will coordinate with CDFW to finalize the selection of study site and fish passage assessment methods for each study site or reach. The implementation strategy will include summary descriptions of each study site, including barrier type, target species/life stages, and key physical and hydraulic attributes potentially limiting fish passage. A draft implementation strategy report will be prepared and submitted to CDFW for review and comment before finalizing and submitting the strategy to CDFW for approval.

4.3. Fish Passage Assessment Methods

The selection of an appropriate fish passage assessment method depends on barrier type, site conditions, evaluation flow range, and species and life stage of concern. The following methods are generally recommended by CDFW to identify streamflows that support passage of anadromous fish based on existing channel or structural conditions. However, an engineered approach may be identified as the most practical or effective solution to restoring passage at certain sites or structures following review of site-specific information.

The methods described below should be guided by consideration of the timing of the passage needs for the species and life stages of concern (see *Scott River Hydraulic Habitat Modeling*

Study Plan) and an analysis of hydrologic conditions within the study reaches to define the range of flows during which these species and life stages typically migrate (see *Scott River Hydrologic and Water Balance Modeling Study Plan*). As a starting point, CDFW (2015) recommends targeting flows between 20% and 80% exceedance flows as determined from a flow exceedance probability curve based on unimpaired flow conditions.

4.3.1. Fish Passage at Critical Riffles

CDFW developed a critical riffle analysis (CRA) procedure (CDFG 2015) to evaluate and identify stream flows needed to protect anadromous salmonid passage and overall riverine habitat connectivity in California streams and rivers. The evaluation procedure draws from the Thompson (1972) method in procedural scope with the application of regional species- and lifestage-specific criteria relevant to California salmonids. The Thompson (1972) method is based on over a decade of extensive field observations spanning all 18 drainages of Oregon by ODFW, including several hundred of the most important salmonid streams in the state. Critical riffle analysis is used to identify protective flows for physical movement (passage) of salmon and trout through natural critical riffles (CDFG 2015) and may be applicable to other sites where shallow depths may impede upstream or downstream passage (e.g., tributary mouths). CDFW's Standard Operating Procedure for critical riffle analysis includes the following overview and general criteria for application of the method:

"This SOP applies only to wadeable streams having low gradient riffles with less than 4% gradient and substrates dominated by gravel and cobble. This procedure is used to identify flows that support physical movement of salmonids through critical riffle sites. Other factors that may be important to evaluate overall migratory success include length of riffle, availability of rest areas, condition of fish, water temperature, and others. This SOP is not applicable to high gradient riffles greater than 4% gradient and boulder dominated substrates (Flosi et al. 1998 [2010]). It does not apply to river or stream channels that do not have riffles, such as those dominated by silt and sand substrates with particle sizes less than 0.1 inches. Finally, this procedure is not applicable to culverts, weirs, bedrock ledges, or anticlines with associated drops." (Page 6, Scope of Application, CDFG 2015).

"Salmon and trout passage flows are determined by locating a critical riffle, identifying a transect along the riffle's shallowest course from bank to bank, and measuring water depth at multiple locations across the transect. Adequate water depths of sufficient width are necessary to identify passage flows and promote passage of adult and juvenile salmonids at critical riffle sites. Field data are compared to species- and lifestage-specific water depth criteria meeting the percent total and percent contiguous proportion (see Section 3 for more information) of the critical riffle width available for fish passage. After a minimum of three to six field events have been completed over a wide range of discharges, stream discharge rates and percent of transect meeting the minimum depth criteria for the species and lifestages are plotted to determine flow rates necessary for passable flows. Both the criteria (percent total and the percent contiguous) must be met and then the higher flow rate among the two criteria that are found to meet the minimum depth for the target species and lifestage may be used to identify the passage flows for the target salmon and trout at the critical riffle site. Water velocities may also be measured across the passage transect, including the thalweg, to evaluate suitability of velocities that support passage of the target species and lifestage." (Page 7, Method Overview, CDFG 2015).

"The IFP has established two criteria for development of passage flows for salmon and trout:

1. *At least 10% of the entire length of the transect must be contiguous for the minimum depth established for the target fish; and*
2. *A total of at least 25% of the entire transect must be at least the minimum depth established for passage of the target fish." (Page 19, Criteria for Fish Passage, CDFG 2015).*

"The minimum water depth needed for adequate adult and juvenile salmonid passage through a critical riffle is established in Table 1[4]. Depth passage criteria for adults (Table 1[4]) are based upon a literature review conducted by R2 Resources (2008) and are intended to provide protective conditions for passage. Ideally, there should be sufficient clearance underneath the fish so that contact with the streambed and abrasion are minimized, which R2 Resources (2008) considered to be 0.1 ft. When selecting the appropriate criteria, use the minimum depth for the adult fish if both adult and juvenile fish are known to be in the system at the same time." Page 20, Criteria for Fish Passage, CDFG 2015).

Table 4. Minimum depth criteria for adult and juvenile salmonid passage to be used in critical riffle analysis. (Page 20, Table 1, CDFG 2015).

Species	*Minimum Passage Depth (ft)*
Steelhead (adult)	*0.7*
Coho salmon (adult)	*0.7*
Chinook salmon (adult)	*0.9*
Trout (adult, including 1-2+ juvenile steelhead)	*0.4*
Salmonid (young of the year juvenile)	*0.3*

CDFW recommends including an evaluation of velocity conditions across the passage transect and comparison with fish swimming threshold values for the target species and lifestage. This Critical Riffle SOP is best suited for riffles with relatively simple geometry where fish passage conditions can be evaluated at single transects, and where water depths and velocities can be measured safely and effectively at three to six flows bracketing the range of target flows. CDFW also recommends evaluation of length of riffle, water temperature, existence of rest areas and other factors which could limit or impair fish passage at natural critical riffle sites. However, where sufficient field measurements are not possible or practical, hydraulic modeling may be required to assess fish passage down to very low drought flows. 2D hydraulic modeling may be required for sites with complex physical and hydraulic characteristics that require relatively high-resolution modeling to accurately characterize fish passage conditions over the full range of target flows (see *Hydraulic Modeling* below).

4.3.2. Fish Passage Analysis at Artificial and Natural Structural Barriers

The following methods are applicable to artificial and natural structural barriers that may pose partial or complete barriers to passage of adult and juvenile salmonids. Potential structural barriers in the Scott River watershed include permanent and seasonal dams or weirs and natural features (e.g., falls, chutes, cascades, beaver dams) where vertical drops or steep, swift and/or turbulent passage conditions may impede or block upstream passage of adults or juveniles.

The procedure described by Powers and Orsborn (1985) will be used to analyze upstream fish passage conditions for adult salmonids and guide design of proposed modifications at structural barriers. This procedure considers the swimming and leaping capabilities of the target species and life stages in relation to the physical and hydraulic characteristics of culverts, waterfalls, and other jump barrier. The general components of this procedure are described below.

1) Define the swimming capabilities of the target species. Powers and Orsborn (1985) summarize the swimming capabilities a number of species in terms of the upper limits of swimming speeds, leaping capabilities, and swimming performance based on published literature and information on fish size, condition, water temperatures, and other factors that may limit or impair fish passage success.
2) Classify fish passage barriers. Powers and Orsborn (1985) developed a classification system for fish passage barriers based on key characteristics that affect passage success. This classification system consists of four components: class, type, magnitude, and discharge. *Classes* are defined as falls, chutes, and cascades and further subdivided according to their degree of difficulty based on the number of passage routes, variation in bed slope, hydraulic diversity (e.g. presence of resting areas), and turbulence. *Type* is used to further rank passage conditions based on site geometry, bed slopes, and water depths encountered by fish during passage of the site. *Magnitude* and *discharge* include measurements of elevation differences, water velocities, slope lengths, and discharges at the time of observation or migration season.
3) Evaluate factors affecting fish passage. Powers and Orsborn (1985) describe field and analytical procedures for evaluating specific physical, hydraulic, and biological conditions that can affect fish passage success at structural barriers based on the passage requirements of the species and life stage of concern. These methods can be used in conjunction with site-specific hydrologic analyses to evaluate the flows supporting fish passage under existing conditions or identify structural modifications to improve fish passage conditions within the range of evaluation flows.

The same general procedure can be used to evaluate upstream passage conditions for juvenile salmonids based on current CDFW guidelines for juvenile passage at stream crossings (Flosi et al. 2010). In the Scott River, juvenile passage is an important consideration at artificial and natural structures that may impede or block upstream movement of juveniles into critical over-summer rearing habitat (e.g. non-natal spring streams) where adequate temperatures or other habitat conditions would promote rearing success. Potential downstream passage impediments created by low flows or artificial structures (e.g. diversion dams) should also be considered as part of this assessment.

Similar to the procedures described above for adult passage, evaluation of juvenile passage will require information on the swimming speeds, leaping capabilities, and behavior of juvenile salmonids, field measurements or modeling of the physical and hydraulic conditions potentially affecting passage success (e.g., hydraulic drops, water depths, velocities), and hydrologic analysis to identify the range of flows under which juveniles typically migrate. Current CDFW upstream passage guidelines for juvenile salmonids at culverts include maximum average water velocities of 1 foot per second, minimum flow depths of 0.5 feet, and maximum hydraulic drops of 1 foot (Flosi et al. 2010).[1] The recommended flow range for evaluation of juvenile fish passage are flows between the 10% and 95% exceedance flows as determined from a flow exceedance probability curve (Flosi et al. 2010).

[1] Ongoing CDFW studies in the Shasta River (CDFW 2013b) using PIT-tagged juveniles may also provide insight into juvenile coho passage requirements in the Scott and Shasta Rivers.

At locations where significant barriers exist to both adult and juvenile passage, comparative analyses may be needed to identify appropriate flow or structural solutions that address the passage requirements for both life stages. This may include consideration of potential differences in passage requirements as a function of migration timing, fish size, swimming ability, and other behavioral attributes.

4.3.3. Hydraulic Modeling

The review of existing information and field survey results will be used to identify potential passage barriers that require hydraulic modeling. 2D hydraulic models are recommended by CDFW in such applications.

2-D hydraulic modeling may be warranted for some sites because of their physical extent and complexity and associated hydraulic complexity over the range of target flows. For example, because 2-D models consider the river as a spatial continuum rather than a number of independent cross sections (Leclerc et al. 1995), 2-D modeling may be particularly applicable to braided channels or long, boulder-dominated riffles where rapidly varying hydraulic conditions require finer resolution modeling of depths and velocities along potential fish passage routes within the site.

The procedures for application for 2-D modeling using River2D are described by USFWS (2011). The identification of protective flows supporting fish passage will be similar to that described above for CRA, although the 2-D modeling results will permit a more detailed spatial analysis of the suitability of potential passage and habitat connectivity pathways based on consideration of the CRA minimum depth criteria, swimming ability of the target species, and the distances between resting areas or cover. ArcGIS may be a useful tool for analysis of potential fish passage routes based on the 2-D modeling results.

4.4. Fish Passage Duration Analysis

Following identification of flows supporting fish passage within specific study reaches or at specific sites, potential fish passage success will be evaluated using a habitat duration or time series analysis (see *Scott River Hydraulic Habitat Modeling Study Plan*) to evaluate the frequency and duration of protective passage flows under existing, unimpaired, and alternative flow scenarios. Existing hydrologic conditions should include the operation of both seasonal and year-round diversions.

5.0 Deliverables

The fish passage study products will include:

1) Fish passage inventory data sheets, including flow/depth/velocity profiles, maps, and photographs of potential fish passage barriers.
2) An implementation strategy report describing selected study sites/reach, barrier types, and fish passage assessment methods.
3) Draft and final fish passage evaluation reports, including study sites, fish passage assessment methods and results (e.g., graphic and/or tabular displays of relationships between river discharge and fish passage metrics), and the results of fish passage duration analysis.

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