

POTENTIAL RESOURCE ISSUE:

Aquatic and riparian resources.

PROJECT NEXUS:

Project operations and potential Project betterments modify or could potentially modify the flow regime in the bypass reaches below the reservoirs/diversions and in the peaking reach downstream of Oxbow Powerhouse. The modified flow regime in the bypass and peaking reaches may affect the amount and distribution (temporal and spatial) of aquatic and riparian habitat.

POTENTIAL LICENSE CONDITION(S):

- Instream flow releases.
- Facility modifications.

STUDY OBJECTIVE(S):

The overall study objective is to characterize aquatic and riparian habitat as a function of flow using site specific data, ecological principles, and modeling methodologies derived from the literature (e.g., Bovee et al. 1998). The information developed from this study, in combination with other resource studies (e.g., water temperature, bioenergetics, fish passage, fish population, and special-status amphibian and reptile studies), will provide a basis for streamflow-related resource management decisions.

The specific objectives of the study include:

- Quantify the habitat versus flow relationships for fish, special-status amphibian, benthic macroinvertebrate, and riparian resources in the bypass and peaking reaches.
- Use the habitat versus flow relationships to develop a time series analysis of aquatic habitat under existing and unimpaired flow scenarios in the bypass and peaking reaches.
- Identify the time periods, flow conditions, and life stages when habitat may be a limiting factor for fish, benthic macroinvertebrate, special-status amphibian, and riparian populations for the existing and unimpaired scenarios.
- Provide information necessary to quantify the potential effects of other alternative flow scenarios on aquatic and riparian habitat.

EXTENT OF STUDY AREA:

The study area includes the active channel and floodplain in bypass reaches downstream of Project reservoirs/diversions, the peaking reach downstream of Oxbow Powerhouse, and selected reaches upstream of the Project facilities. The study area is identified in Table AQ1-1 and Figure AQ1-1. Some portions of the study area are very difficult to access due to the rugged terrain (see Figure AQ1-1) and, thus, field data will only be collected in portions of the study area that are accessible. The reaches upstream of the Project facilities will be used to

interpret riparian vegetation versus flow relationships; therefore, data collection in these reaches will be limited to that purpose.

### STUDY APPROACH:

The following describes the general instream flow modeling approach for all streams, including specific methods for the peaking reach. The topics are selection of target species and/or guilds, development of habitat suitability criteria, stratification and study site selection, coordination of study site selection, study site modeling, hydrodynamics modeling, habitat modeling, and methods specific to the peaking reach.

### Selection of Target Species and/or Guilds

A species distribution map for special-status amphibians and reptiles, fish, and riparian resources within the bypass and peaking reaches will be generated from the results of the AQ-2 Fish Population, AQ-12 Special-status Amphibian and Reptile, and AQ-10 Riparian technical studies. The Aquatic TWG will use existing information (e.g., literature and qualified biologist observations) and any pertinent study results to develop a life stage periodicity chart (i.e., season of occurrence) for the aquatic species and riparian vegetation present in each study reach.

The species and life stages (and/or guilds) that will be used for instream flow habitat modeling will be selected in collaboration with the Aquatic TWG based on management importance and/or sensitivity to Project operations. PCWA proposes that most life stages (e.g., juvenile rearing, adult rearing, spawning) of rainbow trout, brown trout, and hardhead and breeding and larval development (tadpoles) for foothill yellow-legged frogs (FYLF) will be modeled. All other aquatic species/life stages are proposed to be modeled using a guild approach.

### Development of Habitat Suitability Criteria

Habitat suitability criteria (HSC) for each selected species/life stage will be developed in collaboration with the Aquatic TWG. For fish species, HSC criteria will be developed using a two-stage approach. First, existing HSC data will be compiled to create a database of HSC that can be reviewed for applicability to the Project. If concurrence on acceptable sets of HSC can be achieved for individual species and life stages, no additional data collection will occur. If uncertainty remains regarding habitat suitability for juvenile or adult brown trout, rainbow trout, or hardhead, then PCWA will collect snorkeling-based summer/fall habitat suitability criteria data in the bypass reaches for validating or modifying the existing habitat suitability criteria data sets in question. At least 150 observations, if possible, of each juvenile and adult rainbow trout, brown trout, and/or hardhead will be collected. Data will be collected on an equal-effort basis for at least 6 different depth and velocity categories.

A guild or spatial niche approach will also be developed in collaboration with the Aquatic TWG to provide HSC for the entire species assemblage (fish, amphibians, benthic macroinvertebrates) in the study area. Different categories of depth and velocity (e.g., slow-shallow, fast-shallow, deep-slow) will be developed that approximately correspond to the depths and velocities that different species/life stage guilds (e.g., fry) utilize.

HSC for FYLF breeding and larval development (tadpoles) will be developed as part of the AQ-12 Special-Status Amphibian and Reptile Technical Study. Riparian vegetation requirements, such as flow recession rates and inundation frequencies and durations, will be developed in the Riparian Resources Technical Study.

If there are uncertainties within the Aquatic TWG related to the appropriate suitability criteria to use or if there are alternative suitability criteria, a sensitivity analysis will be conducted to identify the effects of alternative suitability criteria on habitat versus flow relationships.

### Stratification and Study Site Selection

Geomorphology, hydrology, and habitat data collected as part of previous studies (PCWA 2006a; PCWA 2006b; PCWA 2006c) will be used to stratify the bypass and peaking reaches. Instream flow data will be collected and analyzed within these strata. The largest strata will be based on the results of the 2005-2006 geomorphic classification of the river channels (PCWA 2007) and Project hydrological management reaches (i.e., reaches that have similar flow regimes as a result of Project operations). Within these geomorphic/hydrologic reaches, the river will be further stratified based on mesohabitat types. All accessible bypass and peaking reaches (either by aerial video, helicopter, or foot travel) have been mesohabitat mapped (typed) using the most detailed level of mesohabitat typing outlined in McCain et al. (1990) (i.e., a potential of 22 mesohabitat types). These habitat types will be collapsed into a lower level of detail to facilitate river stratification for instream flow modeling. PCWA proposes to aggregate the McCain et al. (1990) mesohabitat types into approximately 5 types (e.g., pool, run, low gradient riffle, high gradient riffle, cascade) for stratification of the study sites and river reaches. The specifics of this aggregation will be determined based on the results of the 2005-2006 Aquatic Habitat Characterization Study (PCWA in progress) and consultation with the Aquatics TWG.

Due to difficult access, study sites used to represent the different geomorphic/hydrologic reaches will be representative reaches stratified by mesohabitat type. The stratified representative reaches will be at least 20 to 40 channel widths in length and will contain a full complement of mesohabitat types that can be used to represent the larger geomorphic reach. Where possible, the sites will overlap the 2006 Geomorphology and Riparian Habitat quantification study sites (PCWA 2006a). The 2006 Aquatic Habitat Characterization Study results will be used to check that the selected study sites contain all major mesohabitat types contained in the larger geomorphic reach and that the mesohabitat units are representative of those in the larger reach.

The preliminary geomorphic/hydrologic management reaches are shown in Table AQ1-1 and Figure AQ1-1. The proposed number and general locations of the study sites within these geomorphic reaches are also shown in Table AQ1-1 and Figure AQ1-1. The specific locations and lengths of the study sites (Table AQ1-1) will be selected in the field with concurrence from the Aquatic Technical Working Group (TWG). Prior to study site selection in the field, PCWA will summarize the geomorphic and hydrological data and work with the Aquatics TWG to finalize the delineation of geomorphic/hydrologic reaches. PCWA will also summarize the aquatic habitat characterization data and study site access data and work with the Aquatics TWG to make a preliminary recommendation of study site locations. A field trip will be scheduled in the late summer of 2007 with the Aquatic TWG to select overall study sites and specific habitat units to model (see below).

### Coordination of Study Site Selection

Study site selection will be coordinated with the Special-Status Amphibian Technical Study to include FYLF habitat, where appropriate, within the study sites. In addition, if unique locations (e.g., breeding site) are identified by the Special-Status Amphibian Technical Study and the Aquatic TWG that require modeling, they will be modeled as part of the Instream Flow Study.

Selection of study sites will also be coordinated with the AQ-10 Riparian Vegetation and AQ-9 Geomorphic Technical Study Plans to provide hydrodynamics modeling data for these studies within the general instream flow study sites. In addition, the Instream Flow Technical Study will coordinate with the Riparian Vegetation Technical Study to provide hydrodynamics modeling input during the selection of several riparian comparison study sites located upstream of selected Project diversions (Table AQ1-1 and Figure AQ1-1).

### Study Site Modeling

Aquatic habitat modeling will be accomplished by sampling and modeling representative mesohabitat types in each study site with one-dimensional and/or two-dimensional hydrodynamics and habitat models. The results for each mesohabitat type will be weighted and combined to develop a representation of hydrodynamics and habitat for the larger geomorphic/hydrologic reach. The weighting will be based on the percentage of each mesohabitat within the geomorphic/hydrologic reach.

The sampling effort within each study site will be coordinated with the Aquatic TWG. The goal is to obtain a relatively accurate representation of the habitat versus flow relationship for each geomorphic/hydrologic reach. Some geomorphic/hydrologic river reaches, however, have greater (or lesser) importance in relation to the amount of habitat they provide (e.g., length of the reach or quality of the habitat) or the potential the Project has to modify habitat; therefore, the sampling effort will be adjusted as appropriate. In addition, there is some difficulty determining *a priori* the sampling effort (number and type of habitat units sampled) necessary to provide accurate habitat versus flow relationships.

In general, it is proposed that within a study site mesohabitat types will be sampled approximately in proportion to their abundance. Adjustments to the proportional sampling may be made based on the importance or variability of particular mesohabitat types. Typically, 10 to 12 mesohabitat units will be sampled (modeled). This provides enough sampling to replicate each major mesohabitat type (e.g., two mesohabitat samples of each type) and provides for additional sampling in abundant and/or important mesohabitat types (e.g., 3 to 5 mesohabitat samples of abundant/important types). Each major mesohabitat type (greater than approximately 5-10% of the geomorphic/hydrologic reach) will be modeled. Rare mesohabitat types (<5%) that provide unique or important habitat (e.g., spawning, passage) will be modeled if they exist in the study site. Mesohabitat types that do not contain significant habitat for the primary target species (e.g., cascades) or rare mesohabitat types (<5%) that do not have unique habitat importance will not be modeled.

The stratified representative study sites may contain more mesohabitat units than will be modeled. The specific mesohabitat units selected for modeling will be those that are most representative of the mesohabitats in the geomorphic/hydrologic reach. Results from the 2005-2006 Aquatic Habitat Characterization Study (PCWA in progress) will be used to compare mesohabitat types in the geomorphic reach (e.g., average length, width, depth, and substrate) with the mesohabitats in the study site. These data, along with a visual assessment of the representativeness of the mesohabitat units within the study site, will be used to select units to model. Final selection of the habitat units will be completed in the field in consultation with the Aquatic TWG. We do not recommend random sampling of mesohabitat units because unrepresentative results can occur when sample sizes are small.

For one-dimensional modeling, typically one to three cross-sections will be visually placed in the mesohabitat units to best represent the habitat units over a range of flows. Additional cross-sections may be placed in highly variable mesohabitat units. Concurrence regarding cross-section placement within mesohabitat units will be obtained from the Aquatic TWG. The study sites where one-dimensional modeling is currently proposed and the approximate number of mesohabitat units to be sampled, assuming there are typically four major mesohabitat types present, is shown in Table AQ1-1.

The proposed sampling effort at three specific study sites is lower (6 mesohabitat units) compared to the effort at other sites due to the flow patterns, diversion operations, and reach length (Table AQ1-1). Specifically, flows in the stream reaches on the North Fork Long Canyon Creek, South Fork Long Canyon Creek, and Long Canyon Creek are not affected by Project operation during the summer and fall low flow periods when the diversions are not operating. As a result, habitat modeling is primarily limited to quantifying habitat in winter and spring when diversion may occur. In addition, the natural summer/fall flows are very low (e.g., <1 cfs), which limits habitat availability.

Two-dimensional modeling will be considered for application at the study sites in the peaking reach (Table AQ1-1), if the habitat and logistics warrant its use. The potential benefits of two-dimensional modeling in the peaking reach are better spatial representation of habitat, better representation of complex flow patterns, and efficient integration of various habitat analyses (fish, amphibians, macroinvertebrates, riparian vegetation, sediment transport). Also, two-dimensional modeling is capable of representing how habitat moves spatially with changes in flow, which is important when flow changes rapidly (e.g., peaking). However, to efficiently collect large amounts of topography for two-dimensional modeling on a large river, good site access and good GPS coverage is typically necessary (the narrow canyon may limit GPS coverage). The most appropriate modeling methodology in the peaking reach (two- or one-dimensional) will be determined on the ground in consultation with the Aquatic TWG when the study sites are selected. Because the mesohabitat units are very long in the peaking reach (larger river) the number of mesohabitat units sampled may need to be reduced (i.e., less than the 10-12 mesohabitat units proposed for one-dimensional modeling sites in the smaller river locations). A reasonable length of river to model at each site in the peaking reach is 0.5 to 1.0 miles.

### Hydrodynamics Modeling

Either PHABSIM (e.g., Milhouse et al. 1989) or equivalent one-dimensional hydraulics modeling procedures, as appropriate for the study site and specific objectives for the site, will be used for modeling water surface elevations and velocities across each cross-section. These procedures include stage-discharge regressions, Manning's equation, backwater step models (e.g., WSP, HecRas), and IFG4. Two-dimensional models, where used, will include River2D (Steffler and Blackburn 2001), MD-SWMS (McDonald et al. 2006), or comparable models.

Hydrodynamics (depth, velocity, water surface elevations) will be modeled over a wide range of discharges, appropriate to the project hydrology of each reach. Specific data to be collected using standard techniques include:

- Channel topography, either in the form of cross-sections or three-dimensional topography. Cross-sections will be marked with semi-permanent headpins and approximate GPS locations will be recorded.
- For one-dimensional modeling, empirical water surface elevations will be measured (surveyed) for at least three discharges at each cross-section. For two-dimensional modeling empirical water surface elevations will be measured along the length of each

study site at three discharges. The discharges will span the range of flows of interest (low summer base flows to high spring flows). (Table AQ1-1).

- Empirical velocity data will be collected across each cross-section (15-20 locations) at the middle discharge. The discharge will be greater than or equal to the anticipated highest summer flow of interest in each reach. In the peaking reach, if cross-section modeling is done, velocity data will also be collected at the high discharge measurement (e.g., 700 – 1,000 cfs). At all two-dimensional study sites, validation velocities will be collected across several cross-sections at an intermediate or low flow. All velocities will be collected with calibrated velocity meters. Discharges will be measured using standard gaging techniques (Rantz 1982) and/or an acoustic doppler current profiler (ADCP).

Substrate height and vegetation polygons for hydrodynamics roughness will be collected at all two-dimensional modeling study sites.

### Habitat Modeling

Habitat modeling will be conducted using an approach consistent with the IFIM approach (Bovee et al. 1998). Where appropriate, the habitat modeling will include an additional bioenergetics based habitat analysis (e.g., Guensch et al. 2001, Hayes et al. 2000) (see Bioenergetics Technical Study). The specific details of the habitat modeling will be developed in consultation with the Aquatic TWG. The general approach will be as follows:

- Collect substrate and cover information for habitat modeling across each cross-section or in polygons at each two-dimensional modeling site that is compatible with the HSC criteria developed in consultation with the Aquatic TWG.
- Develop habitat modeling algorithms or approaches appropriate for each selected species and life stage or guild in consultation with the Aquatic TWG. As part of this process, conduct a small pilot study on large slow-water pools to assist in the development of a logical habitat modeling approach for large pools.
  - Snorkel three large slow-water pools on the Rubicon River and record fish locations and behavior (e.g., drift versus benthic feeding) related to location and water velocity in the pools. Develop a technical memorandum describing the results and suggestions regarding potential modeling approaches for large, slow-water pools. Include a brief literature review of approaches to modeling large pools.
- Develop habitat versus flow relationships for each species life stage or guild over a wide range of flows (15 to 30 flows).
- Complete a habitat time series analysis comparing the seasonal and daily distribution of habitat for the existing and unimpaired project hydrology over the period of record (1975 to 2004). Compare and contrast the amount of habitat during different biologically significant time periods (e.g., reproduction, rearing) and identify potential habitat limiting factors and time periods.
- Coordinate with the Special-status Amphibian and Reptile Study to identify outputs from the instream flow modeling that will assist in analyzing the relationship between instream flow and FYLF habitat.
- Coordinate with the Riparian Resources Technical Study to identify key outputs from the instream flow modeling required for analyzing the relationship between instream flow and establishment and health of riparian vegetation in the bypass and peaking reaches.

### Methods Specific to the Peaking Reach

- Summarize existing and unimpaired hydrology data in the peaking reach to characterize between-day and within-day flow fluctuations.
- Install continuous stage monitors and develop rating curves at 3 to 6 key locations throughout the peaking reach to develop a flow fluctuation travel-time/flow attenuation monitoring and modeling relationship.
- Select the modeling sites (Table AQ1-1) to include representative habitat of fish, benthic macroinvertebrate, amphibian, and riparian resources that is sensitive to flow fluctuations. For example, select sites that have fry rearing habitat, potential fish stranding locations, amphibian breeding habitat, and benthic macroinvertebrate habitat.
- Model fish, special-status amphibian, benthic macroinvertebrate, and riparian habitat to address within-day flow fluctuations that result from hydropower peaking. This includes effective habitat analysis and stranding analysis for fry, spawning, benthic macroinvertebrates, amphibian egg masses, and tadpoles (e.g., Bovee et al. 1998).
- Conduct a one-time stranding evaluation downstream of Ralston Afterbay. Immediately after the first peaking event in late spring/early summer or during some other time period determined in consultation with the Aquatic TWG, quantify stranding of aquatic species in sensitive habitats over a 1,000 m of stream.

### SCHEDULE:

To be developed in early 2007.

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- Hayes, J.W., J.D. Stark, K.A. Shearer. 2000. Development and test of a whole-lifetime foraging and bioenergetics growth model for drift-feeding brown trout. *Trans. Am. Fish. Soc.* 129: 315-332.
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**Table AQ1-1. Instream Flow Study Reaches and Modeling Methods.**

Study Reaches/Sites	Bypass Reaches	Peaking Reach	Reach Upstream of Project Facilities	Number of Instream Flow/ Riparian Study Sites	Approximate Number of Mesohabitat Units to Sample	Approximate Flows for Model Calibration (cfs) <sup>2</sup>			Modeling Methods	
						Aquatic Habitat Modeling		Riparian /Geomorphic Modeling		
						Base	Med			High
<b>Duncan Creek</b>										
Duncan Creek upstream of Diversion			●	1	1-3	NA	NA	NA	TBD	Develop stage-discharge relationship for riparian vegetation comparisons
Duncan Creek below Diversion	●			1	10-12	4	16-24	30-50	TBD	1D
<b>Upper Middle Fork American River</b>										
Middle Fork American River upstream of French Meadows Reservoir			●	1	1-3	NA	NA	NA	TBD	Develop stage-discharge relationship for riparian vegetation comparisons
Middle Fork American River below French Meadows Reservoir	●			1	10-12	4-8	20-35-	115-190	TBD	1D
Middle Fork American River Immediately above Middle Fork Interbay	●			1	TBD	8	30-40	120-200	TBD	1D
Middle Fork American River between Middle Fork Interbay and Ralston Afterbay	●			1-2	10-12	12-23	50-70	220-370	TBD	1D

**Table AQ1-1. Instream Flow Study Reaches and Modeling Methods (continued).**

Study Reaches/Sites	Bypass Reaches	Peaking Reach	Reaches Upstream of Project Facilities	Number of Instream Flow/ Riparian Study Sites	Approximate Number of Mesohabitat Units to Sample <sup>1</sup>	Approximate Flows for Model Calibration (cfs) <sup>2</sup>			Modeling Methods	
						Aquatic Habitat Modeling		Riparian/ Geomorphic Modeling		
						Base	Med	High		
<b>Lower Middle Fork American River Below Ralston Afterbay</b>										
Middle Fork American River below Ralston Afterbay		●		1	10-12 <sup>3</sup> or 0.5-1 mile <sup>4</sup>	75-100	200-300	700-1000	TBD	1D/2D
Middle Fork American River above North Fork American River confluence		●		1	10-12 <sup>3</sup> or 0.5-1 mile <sup>4</sup>	75-100	200-300	700-1000	TBD	1D/2D
<b>Rubicon River</b>										
Rubicon River below Hell Hole Reservoir	●			1	10-12	8-10	40-60	200-330	TBD	1D
Rubicon River Near Ellicott Bridge and Near Ralston Afterbay	●			2	20-24	8-10	40-60	200-330	TBD	1D

**Table AQ1-1. Instream Flow Study Reaches and Modeling Methods (continued).**

Study Reaches/Sites	Bypass Reaches	Peaking Reach	Reaches Upstream of Project Facilities	Number of Instream Flow/ Riparian Study Sites	Approximate Number of Mesohabitat Units to Sample <sup>1</sup>	Approximate Flows for Model Calibration (cfs) <sup>2</sup>				Modeling Methods
						Aquatic Habitat Modeling			Riparian/ Geomorphic Modeling	
						Base	Med	High		
<b>Long Canyon Creek</b>										
North Fork Long Canyon Creek upstream of Diversion			●	1	1-3	NA	NA	NA	TBD	Develop stage-discharge relationship for riparian vegetation comparisons
North Fork Long Canyon Creek below Diversion	●			1	6 <sup>4</sup>	2	8-15	20-30	TBD	1D
South Fork Long Canyon Creek upstream of Diversion			●	1	1-3	NA	NA	NA	TBD	Develop stage-discharge relationship for riparian vegetation comparisons
South Fork Long Canyon Creek below Diversion	●			1	6 <sup>4</sup>	2	8-15	20-30	TBD	1D
Long Canyon Creek below North and South Fork Long Canyon Creek	●			1	6 <sup>4</sup>	4	14-22	30-50	TBD	1D
<b>Other Tributaries</b>										
North Fork Middle Fork American River			●	1	1-3	NA	NA	NA	TBD	Develop stage-discharge relationship for riparian vegetation comparisons
North Fork American River above Lake Clementine			●	1	1-3	NA	NA	NA	TBD	Develop stage-discharge relationship for riparian vegetation comparisons

<sup>1</sup>Number of habitat units to model reduced due to circumstances in the particular reach. See text for details.

<sup>2</sup>Target flows are yet to be determined. These flows are an initial attempt to identify the target flows. The target flows will be developed in consultation with the aquatic TWG.

<sup>3</sup>The number of mesohabitat units sampled may need to be reduced in this reach because habitat units are very long.

<sup>4</sup>If two-dimensional modeling is determined to be the most appropriate method in the reach, up to one mile (0.5 – 1.0 miles) of habitat will be modeled.

**Placeholder for Figure AQ1-1**

**Instream Flow Study Reaches and Geomorphic Delineations**

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