Study 3.10

INSTREAM FLOW ABOVE ENGLEBRIGHT RESERVOIR

November 2010

1.0 Project Nexus

Yuba County Water Agency's (YCWA or Licensee) continued operation and maintenance (O&M) of the existing Yuba River Development Project (Project) has a potential to affect stream habitat for fish upstream of Englebright Reservoir. [1]

2.0 Resource Management Goals of Agencies and Indian Tribes with Jurisdiction Over the Resource Studied

[Relicensing Participants - This section is a placeholder in the Pre-Application Document (PAD). Section 5.11(d)(2) of 18 CFR states that an applicant for a new license must in its proposed study *"Address any known resource management goals of the agencies or Indian tribes with jurisdiction over the resource to be studied."* During 2010 study proposal development meetings, agencies advised License that they would provide a brief written description of their jurisdiction over the resource to be addressed in this study. If provided before Licensee files its Proposed Study Plan and Licensee agrees with the description, Licensee will insert the brief description here stating the description was provided by that agency. If not, prior to issuing the Proposed Study Plan, Licensee will describe to the best of its knowledge and understanding the management goals of agencies that have jurisdiction over the resource addressed in this study. Licensee]

3.0 Study Goals and Objectives

The goal of the study is to quantify fish habitat as a function of stream flow.

The objectives of the study include: 1) estimate the habitat index versus flow relationships (Weighted Useable Area, or WUA) using the Physical Habitat Simulation system (PHABSIM) for fish in Project-affected reaches upstream of the United States Army Corps of Engineer's (USACE) Englebright Reservoir; and 2) use WUA relationships and the hydrologic record to develop habitat duration or time series analyses of fish habitat over time under existing (regulated) and unimpaired (un-regulated) flow scenarios.

[1] Englebright Dam was constructed by the California Debris Commission in 1941, is owned, operated and maintained by the United States Army Corps of Engineers; and is not included as a Project facility in FERC licenses for the Yuba-River Development Project.

4.0 Existing Information and Need for Additional Information

Considerable information for Project-affected reaches exists that is important to conducting the study. Much of this information has been obtained or developed by Licensee and is provided in the Pre-Application Document (PAD). The information includes but is not limited to:

- Topographic, geologic, and hydrographic maps of the Project-affected reaches (PAD, Section 3.0, General Description of River Basin and Appendix D - Project Maps)
- Hydrologic modeling and statistics for Project-affected reaches (PAD, Section 7.2, Water Resources and Appendix F - Hydrology)
- Operations procedures for Project facilities (PAD, Section 6.0, Project Location, Facilities and Operations)
- Results of stream habitat mapping conducted by Licensee in 2009 (YCWA Stream Habitat Mapping Report, Attachment 3.10A to this study proposal).
- Low altitude aerial video of all Project-affected reaches and facilities (PAD, Appendix E - Project Helicopter Video)
- Existing information regarding the composition and distribution of fish species that occur in Project-affected reaches (Preliminary Application Document, Section 7.3, Aquatic Resources)

To achieve the study goals, information that is needed includes but is not limited to:

- Confirmation of current and historic composition and distribution of fish species. This information will be developed as part of Licensee's Stream Fish Populations Upstream of Englebright Dam Study.
- Habitat suitability criteria for target fish species and life stages
- Field measurement of physical parameters required for PHABSIM modeling

5.0 Study Methods and Analysis

5.1 Study Area

For the purpose of this study, the study area includes the following six reaches:

- Middle Yuba River
  - Our House Diversion Dam Reach. Approximately 7.5 miles of the Middle Yuba River from Our House Diversion Dam at RM 12.0 to the confluence of the Middle Yuba River and Oregon Creek at RM 4.5.
  - Oregon Creek Reach of the Middle Yuba River. Approximately 4.5 miles of the Middle Yuba River from the confluence of the Middle Yuba River and Oregon Creek at RM 4.5 to the confluence of the Middle Yuba River with the North Yuba River at RM 0.0.

- Oregon Creek
  - Log Cabin Diversion Dam Reach. Approximately 4.1 miles of Oregon Creek from RM 4.1 to the confluence of Oregon Creek with the Middle Yuba River. The Log Cabin Diversion Dam Reach includes two sub-reaches; the Log Cabin Sub-reach and the Celestial Valley Sub-reach. The inset Celestial Valley sub-reach extends from RM 2.0 to RM 3.1.

- North Yuba River
  - New Bullards Bar Dam Reach. Approximately 2.3 miles of the North Yuba River from the New Bullards Bar Minimum Flow Release Powerhouse at RM 2.3 to the confluence of the North Yuba River with the Middle Yuba River at RM 0.0.

- Yuba River
  - Middle/North Yuba River Reach. Approximately 5.8 miles of the Yuba River from the confluence of the North Yuba River with the Middle Yuba River at RM 39.7 to the New Colgate Powerhouse at RM 33.9.
  - New Colgate Powerhouse Reach. Approximately 1.7 miles of the Yuba River from New Colgate Powerhouse at RM 33.9 to the normal maximum water surface elevation of USACE's Englebright Reservoir at RM 32.2.

If YCWA proposes an addition to the Project, the study area will be expanded if necessary to include areas potentially affected by the addition.

5.2 General Concepts and Procedures

The following general concepts and practices apply to the study:

- Personal safety is the most important consideration of each fieldwork team.
- Licensee will make a good faith effort to obtain permission to access private property where needed well in advance of entering the property.
- Field crews may make minor variances to the FERC-approved study in the field to accommodate actual field conditions and unforeseen problems. When minor variances are made, Licensee's field crew will follow the protocols in the FERC-approved study.
- When Licensee becomes aware of major variances to the FERC-approved study, Licensee will issue an e-mail to the Relicensing Contact List describing the variance and reason for the variance. Licensee will contact by phone the Forest Service (if the variance is on National Forest System land), USFWS, SWRCB and CDFG to provide an opportunity for input regarding how to address the variance. Licensee will issue an e-mail to the Relicensing Contact List advising them of the resolution of the variance. Licensee will summarize in the final study report all variances and resolutions.
- Licensee's performance of the study does not presume that Licensee is responsible in whole or in part for measures that may arise from the study.

- Global Positioning System (GPS) data will be collected using either a Map Grade Trimble GPS (sub-meter data collection accuracy under ideal conditions), a Recreation Grade Garmin GPS unit (3 meter data collection accuracy under ideal conditions), or similar units. GPS data will be post-processed and exported from the GPS unit into Geographic Information System (GIS) compatible file format in an appropriate coordinate system using desktop software. The resulting GIS file will then be reviewed by both field staff and Licensee's relicensing GIS analyst. Metadata will be developed for deliverable GIS data sets.
- Licensee's field crews will record incidental observations of aquatic and wildlife species observed during the performance of this study. All incidental observations will be reported in the appropriate Licensee report (e.g., incidental observations of special-status fish recorded during fieldwork for the Special-Status Turtles – Western Pond Turtle Study will be reported in Licensee's Stream Fish Populations Study report). The purpose of this effort is not to conduct a focus study (i.e., no effort in addition the specific field tasks identified for the specific study) or to make all field crews experts in identifying all species, but only to opportunistically gather data during the performance of the study.
- Field crews will be trained on and provided with materials (e.g. Quat) for decontaminating their boots, waders, and other equipment between study sites. Major concerns are amphibian chytrid fungus, and invasive invertebrates (e.g. zebra mussel, *Dreissena polymorpha*). This is of primary importance when moving: 1) between tributaries and mainstem reaches; 2) moving between basins (e.g. Middle Yuba River, Yuba River, and North Yuba River); and 3) moving between isolated wetlands or ponds and river or stream environments.

5.3 Study Methods

Licensee will use the PHABSIM method to model the response of fish habitat to flow in the study area. PHABSIM is the most widely accepted and applied fish habitat model in California and across the United States.

Physical habitat and hydraulic parameters will be measured and modeled using a combination of standard techniques of the United States Department of Interior, Fish and Wildlife Service (USFWS) methodology (Trihey and Wegner 1981; Bovee 1982, and Milhous *et al.* 1984); and the United States Geological Survey (Bovee 1997, Bovee *et al.* 1998, and Rantz 1982).

The general steps in the study (not necessarily in the order specified below) include: 1) selection of target species and life stages; 2) determination of target species/lifestage periodicity; 3) Project-affected stream reach identification, segmentation, and consolidation; 4) study site and transect selection; 5) field data collection; 6) selection of Habitat Suitability Criteria (HSC); 7) hydraulic and habitat modeling; 8) habitat duration analysis; and 9) prepare study report. Each of these steps, including report preparation, is described below.

Licensee will obtain all necessary permits prior to fieldwork.

5.3.1 Step 1 - Target Species and Life Stages

The species and life stages that will be included in PHABSIM modeling are based on management importance and/or sensitivity to Project operations. Target species and life stages are shown in Table 5.3.1-1.

Table 5.3.1-1. Target species and life stages to be analyzed in the PHABSIM models.

Species	Life Stages	Location
Rainbow Trout *Oncorhynchus mykiss*	Spawning Juvenile Adult Rearing	All PHABSIM reaches
Hardhead *Mylopharodon conocephalus*	Juvenile Adult Rearing	In PHABSIM reaches where Sacramento sucker is found during Licensee's Stream Fish Populations Upstream of Englebright Dam Study
Sacramento Pikeminnow *Ptychocheilus grandis*	Juvenile/Adult	In PHABSIM reaches where Sacramento sucker is found during Licensee's Stream Fish Populations Upstream of Englebright Dam Study
Sacramento Sucker *Catostomus occidentalis*	Juvenile/Adult	In PHABSIM reaches where Sacramento sucker is found during Licensee's Stream Fish Populations Upstream of Englebright Dam Study

5.3.2 Step 2 - Target Species/Lifestage Periodicity

The period of year when the life stages of the target species life stages will be modeled in the study is an important component of the habitat duration model. Table 5.3.2-1 shows the periodicity that will be used in the study for each target species and lifestage.

Table 5.3.2-1. Periodicity of target species/lifestages to be analyzed in the PHABSIM models.

Species	Lifestage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	Spawning				■ ■	■ ■	■ ■						
	Juvenile	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■
	Adult	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■
Hardhead	Juvenile	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■
	Adult	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■
Sacramento Pikeminnow	Juvenile	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■
	Adult	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■
Sacramento Sucker	Juvenile	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■
	Adult	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■

5.3.3 Step 3 - Project-affected Stream Reach Identification, Segmentation, and Consolidation

Project-affected stream reaches are delineated as described in Section 5.1, above. This delineation is based on Project flow control points and junctions of major inflows and is consistent with the delineations for the other Yuba River Development Project relicensing studies. The need for segmentation of these reaches into sub-reaches for the purposes of the PHABSIM study was evaluated by the Licensee using results from the habitat mapping study (Attachment 3.10A) topographic maps, low elevation aerial video, the Project hydrologic record, and tributary inflow calculations. The Licensee determined that for the purposes of the PHABSIM study, segmentation of the Project-affected reaches into sub-reaches was only necessary for the Log Cabin Diversion Dam Reach. Reasons for segmentation decisions are discussed below.

The characteristic feature of a PHABSIM study reach is homogeneity of the channel structure and flow regime. Generally, a ten percent or greater increase in discharge from a tributary inflow is enough to warrant a reach or sub-reach break (Bovee 1982). This general rule is most appropriate in alluvial channels rather than bedrock dominated channels. In the upper foothill and montane regions of the Projects, channel characteristics are primarily formed by bedrock control rather than fluvial processes. Bedrock channels are generally insensitive to short-term changes in sediment supply or discharge. Only a persistent decrease in discharge and/or an increase in sediment supply sufficient to convert the channel to an alluvial morphology would significantly alter fluvial bedrock channels (Montgomery and Buffington 1993). For this reason, flow accretion was not used as a dominant factor in river segmentation for this study but was evaluated as presented below in table 5.3.3-1. As table 5.3.3-1 illustrates within the Project-affected river reaches no single tributary is likely to increase total river flow by more than 10%.

Changes in gross channel structure were evaluated next as a basis for segmentation. These included gradient, channel type, sediment supply, and other factors derived from the Initial Channel Classification report (YCWA 2009c) and the Habitat Mapping Study Report (Attachment 3.10A).

Table 5.3.3-1. Potential tributary flow contribution based on drainage area.

River	Reach Name	Named Tributaries	Percent Contribution (by drainage area[1])
Middle Yuba River	Our House Diversion Dam Reach	Grizzley Creek	5.32%
		Nevada Creek	0.68%
	Oregon Creek Reach of the Middle Yuba River	Moonshine Creek	2.04%
		Clear Creek	1.48%
		Yellow Jacket Creek	0.81%
Oregon Creek	Log Cabin Diversion Dam Reach	Mosquito Creek	3.82%
North Yuba River	New Bullards Bar Dam Reach	None	
Yuba River	Middle/North Yuba River Reach	Sweetland Creek	0.74%
	New Colgate Powerhouse Reach	Dobbins Creek	1.62%

1/ percent of contributing drainage to total drainage area upstream

Table 5.3.3-2 below describes the longitudinal similarities and dissimilarities in channel structure and fluvial process within the designated Project-affected reaches.

Table 5.3.3-2. Longitudinal similarities and dissimilarities in channel structure and fluvial processes

River	Reach Name	Longitudinal Similarities and Dissimilarities in Channel Structure and Fluvial Processes	Sub-reach Waranted?
Middle Yuba River	Our House Diversion Dam Reach	100% of this 7.5 mile reach is classified as Rosgen "B" type channel with an average gradient of 1% to 3%.	No
	Oregon Creek Reach	100% of this 4.5 mile reach is classified as Rosgen "B" type channel with an average gradient of 1% to 3%	No
Oregon Creek	Log Cabin Diversion Dam Reach	Approximately 68% (3.6 mi) of this 4.1 mile reach is in the vicinity of Celestial Valley and is classified as Rosgen B, confined with a gradient or 1% to 3% while the remaining 32% is classified as Rosgen A, confined with a gradient of 3%-8%.	Yes – reach is segmented into two sub-reaches

Table 5.3.3-2. (continued)

River	Reach Name	Longitudinal Similarities and Dissimilarities in Channel Structure and Fluvial Processes	Sub-reach Waranted?
North Yuba River	New Bullards Bar Dam Reach	Approximately 93% of this 2.3 mile reach is classified as "confined, Rosgen "B" type channel with a gradient of 1-3%. A short (0.2 mile section) is classified as a Rosgen "A" type channel with a gradient of 3% to 8%.	No
Yuba River	Middle/North Yuba River Reach	100% of this 5.8 mile reach is classified as "confined, Rosgen "B" type channel with a gradient of 1-3%.	No
	New Colgate Powerhouse Reach	100% of this 1.7 mile reach is classified as "confined, Rosgen "C" type channel with a gradient of <1%.	No

Study sites (transect or transect cluster locations) will be selected within each reach listed in Section 5.1 to represent the range of channel and habitat types in that reach.

5.3.3.1 Mesohabitat Stratification

Mesohabitat stratification is based primarily on 2009 in-river habitat mapping (channel metrics and meso habitat typing) results and the 2009 low-altitude aerial video survey (YCWA 2009a). Low-altitude video surveys were only used to type meso habitats where they were clearly visible. Aerial video was not be used to estimate channel metrics.

Video mapping was used to quantify the frequency of meso habitats within entire PHABSIM reaches where visible. In combination, video mapping and field mapping covered 100 percent of the reach length. The mapping data was used to develop a habitat unit frequency analysis for the instream flow studies. This cumulative frequency sampling approach is an extremely efficient way to inventory meso habitats over long distances (Bovee 1997).

Using the video, habitat for an entire reach was assessed at a set interval within a range of 3-5 seconds depending on the stream width and meso-habitat length (e.g., PHABSIM reaches with short habitat units were counted at 3-second intervals, while reaches with long habitat units were counted at 5- second intervals). The video was stopped at every interval and the habitat type that was directly across the channel at the middle of the computer screen was defined and documented. A line drawn across the video screen determined the dominant habitat at that "point." Ground-truth data for every unit that was seen in the video and mapped on the ground was used to "calibrate the eye" so that features seen in the video have a ground-based reference.

Mesohabitats mapped using the in-river method were typed to the most detailed level of mesohabitat typing outlined in Table 5.3.3-3.

Table 5.3.3-3. Habitat types used in ground and video habitat mapping for Project-affected reaches.[1]

FAST WATER HABITAT TYPES	RIFFLES, RAPIDS, SHALLOW STREAM SECTIONS WITH STEEP WATER SURFACE GRADIENT
Turbulent Flow	Channel units having swift current, high channel roughness (large substrate), steep gradient, and non-laminar flow, and characterized by surface turbulence
Fall	Steep vertical drop in water surface elevation. Generally not modelable.
Cascade	Series of alternating small falls and shallow pools; substrate usually bedrock and boulders. Gradient high (>4%). Generally not modelable.
Chute	Narrow, confined channel with rapid, relatively unobstructed flow and bedrock substrate
Rapid	Deeper stream section with considerable surface agitation and swift current; large boulder and standing waves often present. Generally not modelable.
Riffles	Shallow, lower-gradient channel units with moderate current velocity and some partially exposed substrate (usually cobble) • Low-gradient – Shallow with swift flowing, turbulent water. Partially exposed substrate dominated by cobble. Gradient moderate (<4%). • High-gradient – Moderately deep with swift flowing, turbulent water. Partially exposed substrate dominated by boulder. Gradient steep (>4%). Generally not modelable.
Non-turbulent Flow	Channel units having low channel roughness, moderate gradient, laminar flow, and lack of surface turbulence
Sheet	Shallow water flowing swiftly over smooth bedrock
Run	Swiftly flowing (deep) with little surface agitation (run); can appear as flooded riffles.
Step/Run	Runs separated by short steps. Runs and step-runs will be combined in the video mapping as steps are often so short that the dominant characteristic is the "run" section.
Glide	Wide, shallow, smooth flow; little to no surface agitation; usually cobble or smaller substrate
Pocket Water	Swift flowing water with large boulder or bedrock obstructions creating eddies, small backwater, or scour holes. Gradient low to moderate.
SLOW WATER HABITAT TYPES	**POOLS; SLOW, DEEP STREAM SECTIONS WITH NEARLY FLAT WATER SURFACE GRADIENT**
Scour Pool	Formed by scouring action of current
Trench	Formed by scouring of bedrock
Mid-channel	Formed by channel constriction or downstream hydraulic control
Convergence	Formed where two stream channels meet
Lateral	Formed where flow is deflected by a partial channel obstruction (stream bank, rootwad, log, or boulder), generally in deformable substrate that creates deposition of mobile sediment on the inside of the bend
Plunge	Formed by water dropping vertically over channel obstruction

[1] Adapted from McCain et al. 1990, Armantrout 1998, Payne 1992, McMahon et al. 1996, and Hawkins et al. 1993

The habitat types shown in Table 5.3.3-3 have been aggregated to a lower level of detail for the purpose of transect placement, hydraulic data collection, and transect weighting consistent with river stratification for PHABSIM modeling. The aggregated meso habitat types were split into two categories - modelable and non-modelable and may be different for large, medium, or small rivers. These are listed below:

- Modelable Habitat Types
  - High Gradient Riffle (where channel hydraulics permit – identified in the field during transect selection)
  - Low Gradient Riffle
  - Run/Step-run
  - Glide
  - Pocket Water (where channel hydraulics permit – identified in the field)
  - Pools (Mid-channel, Trench, Lateral, Plunge)

- Non-Modelable Habitat Types
  - Falls
  - Cascade
  - Chute
  - Sheet Flow
  - High Gradient Riffle (where channel hydraulics do not permit – identified in the field during transect selection)

Modelable habitat type length and frequency based on habitat mapping results are presented in Tables 5.3.3-4 through 5.3.3-10.

Table 5.3.3-4. Our House Diversion Dam Reach PHABSIM habitat frequency (from video mapping).

PHABSIM Habitat	Number	Number Frequency	Adjusted Number Frequency	Potential # Target Transects
High gradient riffles	29	10%	11%	2
Low gradient riffles	45	16%	17%	3
Runs/Step-Runs	67	24%	25%	4
Glides	11	4%	0%	0
Pocket Water	4	1%	0%	0
Pools	129	45%	48%	8
Total	**285**	**100%**	**100%**	**17**

Table 5.3.3-5. Oregon Creek Reach of the Middle Yuba River PHABSIM habitat frequency (from video mapping).

PHABSIM Habitat	Number	Number Frequency	Adjusted Number Frequency	Potential # Target Transects
High gradient riffles	73	29%	29%	5
Low gradient riffles	22	9%	9%	2
Runs/Step-Runs	25	10%	10%	2
Glides	6	2%	0%	0
Pocket Water	12	5%	5%	2
Pools	116	46%	47%	8
Total	**254**	**100%**	**100%**	**18**

Table 5.3.3-6. Log Cabin Diversion Dam Reach, Log Cabin Sub-reach (RM 0.0 - 2.0 and RM 3.1 to 4.2) PHABSIM habitat frequency (from ground mapping)

PHABSIM Habitat	Length	Length Frequency	Adjusted Length Frequency	Potential # Target Transects
High gradient riffles	647	4%	0%	0
Low gradient riffles	2,236	16%	17%	3
Runs/Step-Runs	1,906	13%	14%	2
Glides	551	4%	0%	0
Pocket Water	2,505	17%	19%	3
Pools	6,540	45%	50%	8
Total	14,384	100%	100%	17

Table 5.3.3-7. Log Cabin Diversion Dam Reach, Celestial Valley Sub-reach (RM 2.0 - 3.2) PHABSIM habitat frequency (from ground mapping)

PHABSIM Habitat	Length	Length Frequency	Adjusted Length Frequency	Potential # Target Transects
High gradient riffles	26	0%	0%	0
Low gradient riffles	1,934	36%	39%	7
Runs/Step-Runs	147	3%	0%	0
Glides	395	7%	8%	2
Pocket Water	156	3%	0%	0
Pools	2,677	50%	53%	9
Total	5,335	100%	100%	18

Table 5.3.3-8. New Bullards Bar Dam Reach PHABSIM habitat frequency (from video and ground mapping)

PHABSIM Habitat	Number	Number Frequency	Adjusted Number Frequency	Potential # Target Transects
High gradient riffles	5	8%	8%	2
Low gradient riffles	7	11%	11%	2
Runs/Step-Runs	4	6%	6%	2
Glides	0	0%	0%	0
ocket Water	19	29%	29%	5
Pools	31	47%	47%	8
Total	**66**	**100%**	**100%**	**19**

Table 5.3.3-9. Middle/North Yuba River Reach PHABSIM habitat frequency (from video mapping).

PHABSIM Habitat	Number	Number Frequency	Adjusted Number Frequency	Potential # Target Transects
High gradient riffles	18	13%	14%	2
Low gradient riffles	7	5%	5%	2
Runs/Step-Runs	6	4%	0%	0
Glides	0	0%	0%	0
Pocket Water	42	31%	32%	5
Pools	64	47%	49%	8
Total	**137**	**100%**	**100%**	**18**

Table 5.3.3-10. New Colgate Powerhouse Reach PHABSIM habitat frequency (from video mapping)

PHABSIM Habitat	Number	Number Frequency	Potential # Target Transects
High gradient riffles	0	0%	0
Low gradient riffles	4	16%	3
Runs/Step-Runs	6	24%	4
Glides	4	16%	3
Pocket Water	0	0%	0
Pools	11	44%	7
Total	**25**	**100%**	**17**

5.3.5 Step 4 - Study Site and Transect Selection

Licensee will select final study sites and transects in the field in consultation with Relicensing Participants. The goal in study site and transect selection is to obtain a relatively accurate representation of the habitat index versus flow relationship for each PHABSIM reach. This goal will be achieved by distributing study sites (transects and transect clusters) in such a way that all modelable habitat types are represented with at least two representative habitat units. For habitat types with a high diversity in a particular reach, such as pool mesohabitat type, the habitat type may need to be represented by three or more representative units. The number of transects allocated for each habitat type will be in proportion to the frequency of that habitat type according to habitat mapping results (Tables 5.3.3-4 through 5.3.3-10).

Meso habitat unit and transect selection is made in conjunction with field review for two reasons. The first is that some PHABSIM reaches 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. The second reason is because of the difficulty in determining *a priori* sampling effort (number and type of habitat units sampled) necessary to provide accurate habitat index versus flow relationships.

The specific locations and lengths of the study sites and transects will be selected in the field as described below in consultation with the interested and available Relicensing Participants.

Licensee will consult with interested and available Relicensing Participants regarding specific study sites and transects. Licensee will make a good faith effort to schedule the consultation on a day or days convenient to Licensee and interested Relicensing Participants (ideally, scheduling meetings at least 30 days in advance of the meeting or site visit to allow all Relicensing Participants to participate), and will provide an email notice confirming the meeting at least 10 days in advance of the meeting or site visit. If agreement regarding study sites and transects is not reached, Licensee will note the disagreements in its final report, including why Licensee did not adopt the recommendation. Licensee will offer a pre-field presentation and orientation meeting ahead of each field visit. The pre-field meeting will include a description of the study site, meso habitat units, and possibly preliminary selected transects. The basis for selection, still photos, aerial video (if available), and maps of these features will also be provided.

Based on habitat mapping results (Habitat Mapping Report Attachment 3.10A) and road access, Licensee has identified potential river sections for PHABSIM sites as shown in Table 5.3.4-1. These river sections for potential study site location may change if access is not permitted by private landowners. Licensee will contact landowners and request permission to access selected study sites. If access is not permitted substitute study sites will be identified, if needed.

Table 5.3.4-1. Potential river sections for PHABSIM study sites based on road or reasonable hiking access.

River	Reach	River Sections for Potential Study Site Locations
Middle Yuba River	Our House Dam Reach	Our House Dam (RM 12.0) Emory Island (RM 7.5) Oregon Creek Confluence (RM 4.5)
		Oregon Creek Confluence (RM 4.5) Middle/North Yuba Confluence (RM 0.0)
Oregon Creek	Log Cabin Diversion Dam Reach	No known access limitations
North Yuba	New Bullards Bar Dam Reach	North/Middle Confluence (RM 39.6) New Bullards Bar Dam (RM 2.3)
Yuba River	Middle/North Yuba River Reach	North/Middle Confluence (RM 39.6) New Colgate Powerhouse (RM 34.0)
	New Colgate Powerhouse Reach	New Colgate Powerhouse (RM 34.0)

5.3.4.1 Mesohabitat Unit Sampling

In general, within a study reach, meso habitat 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 meso habitat types. While the number of transects is dependent on the diversity of channel and habitat types in a study reach, the target number of transects per PHABSIM reach or sub-reach will generally be in the range of 17-20, up to as many as 25. This provides enough sampling flexibility to replicate each of the 4-5 predominant modelable mesohabitat types. Mesohabitat types with a frequency of less than 5% will not be sampled. If warranted in reaches of low habitat type diversity, such as in the Celestial Valley Sub-reach, fewer transects may be selected with agreement by Relicensing Participants. Meso habitat types with complex hydraulics (e.g. cascades, falls, chutes, and sheet flow) that cannot be modeled using standard PHABSIM and do not contain significant habitat for the primary target species will not be sampled with transects.

5.3.5.2 Transect Selection and Placement

The location of transect placement to represent the different geomorphic and hydraulic conditions will be selected in consultation with Relicensing Partieipants using a stratified random sampling approach based on the least-available sampled meso habitat type (Payne 1992). Other more-available meso habitat types will be represented using transects placed in meso habitat units in close proximity to the least-available selector. This approach minimizes the effect of selection bias, results in transect clustering that limits travel time, and assures transect representation in proportion to habitat availability.

Actual transect selection and placement is typically accomplished with a combination of random selection and professional judgment through the following procedure:

- All project-affected reaches that are accessible and open to study are identified and designated for random transect placement.
- Within the accessible areas, the habitat type with the lowest percentage of abundance (from the habitat mapping data) is used as the basis for random selection (provided that the habitat

type is ecologically significant and modelable). If the distribution of the initial least common selector is too limited to provide an adequate choice of representative habitats, the next least common selector will be used.

- All habitat units of this type within the accessible distance and that are judged to be modelable during the habitat survey are sequentially numbered and a minimum of five units selected by random number.
- In the field, the first selected unit is relocated and, if it was judged to be modelable and reasonably typical of that particular habitat type within the study reach, one or more transects is/are placed to best represent the habitat type.
- At least one example of each remaining habitat type is then located in the immediate vicinity of the random transect (upstream or downstream) until transects are placed in all significant types.
- This process is repeated with the second, third, fourth or higher random selector to place additional clusters until the different geomorphic and hydraulic conditions are adequately characterized (as determined in consultation with interested and available Relicensing Participants) or the target total number of transects is reached.

Although the outlined steps are fairly rigorous, all decisions regarding transect placement are subject to revision through the exercise of professional judgment, including the specific inclusion of desirable study areas not randomly selected and the placement of transects across appropriate spawning gravels. The overall objective of the method is to assure that satisfactory representation of study reaches is achieved.

To facilitate the field-based transect selection process, a field package including reach maps, proposed study site and possible transect locations, photos (aerial and on the ground), and habitat mapping data results will be distributed to Relicensing Participants providing the necessary information for decision making.

Meso-habitat distribution, based on habitat mapping, in each reach or sub-reach is presented in Figures 5.3.4-1 through 5.3.4-5. Green bar shading indicates the areas where potential study sites are located based on road or reasonable hiking access. Access to private land has not been established at this time. If accessible locations identified to date do not include the diversity of habitat types necessary to represent the reach the Licensee is amenable to select study sites in other less accessible locations provided it is necessary as determined in consultation with Relicensing Participants and is appropriate in terms of private land ownership and safety.

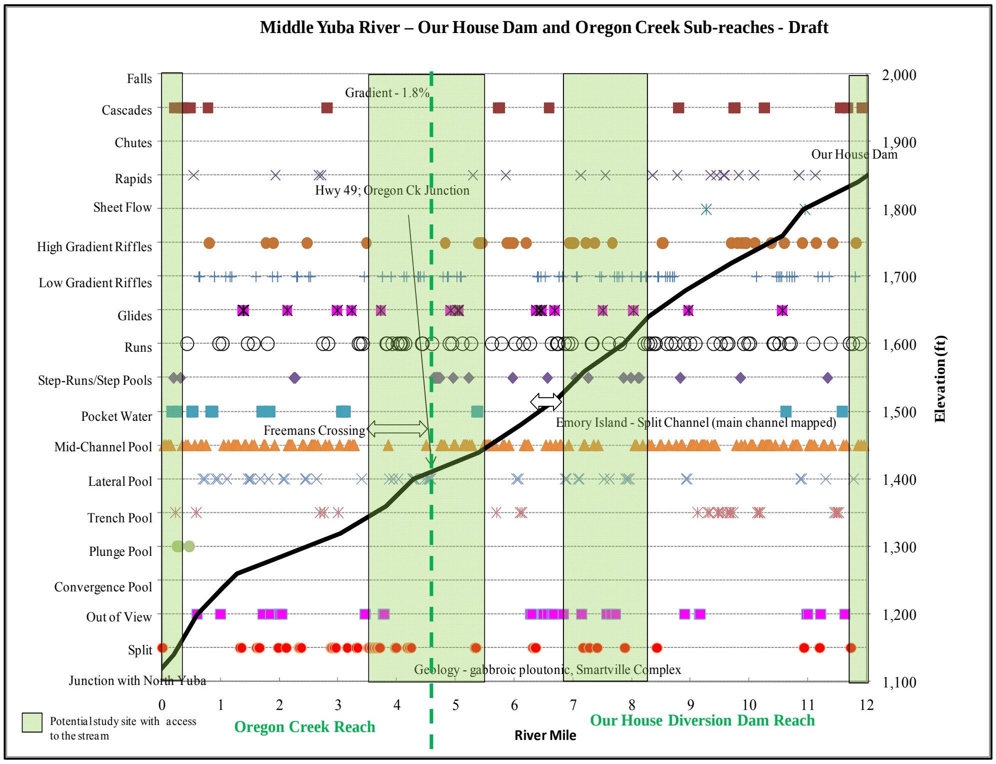

Figure 5.3.4-1. Our House Diversion Dam Reach longitudinal profile and mesohabitat distribution (from video mapping).

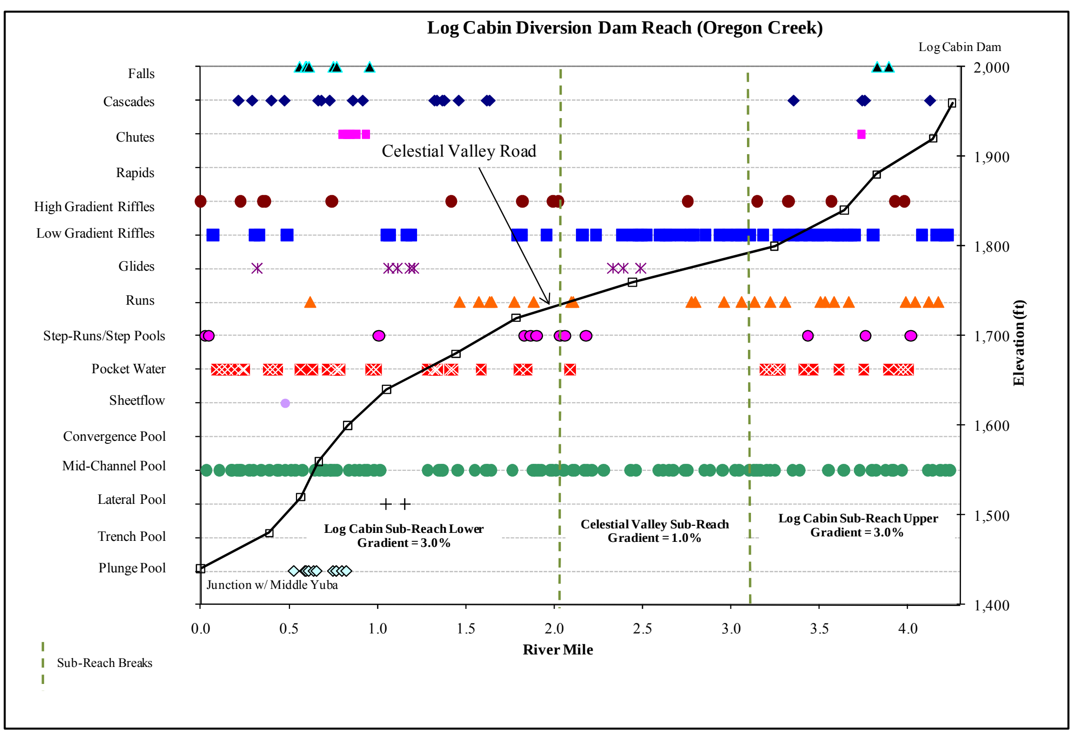

Figure 5.3.4-2. Log Cabin Diversion Dam Reach longitudinal profile and mesohabitat distribution (from ground mapping)

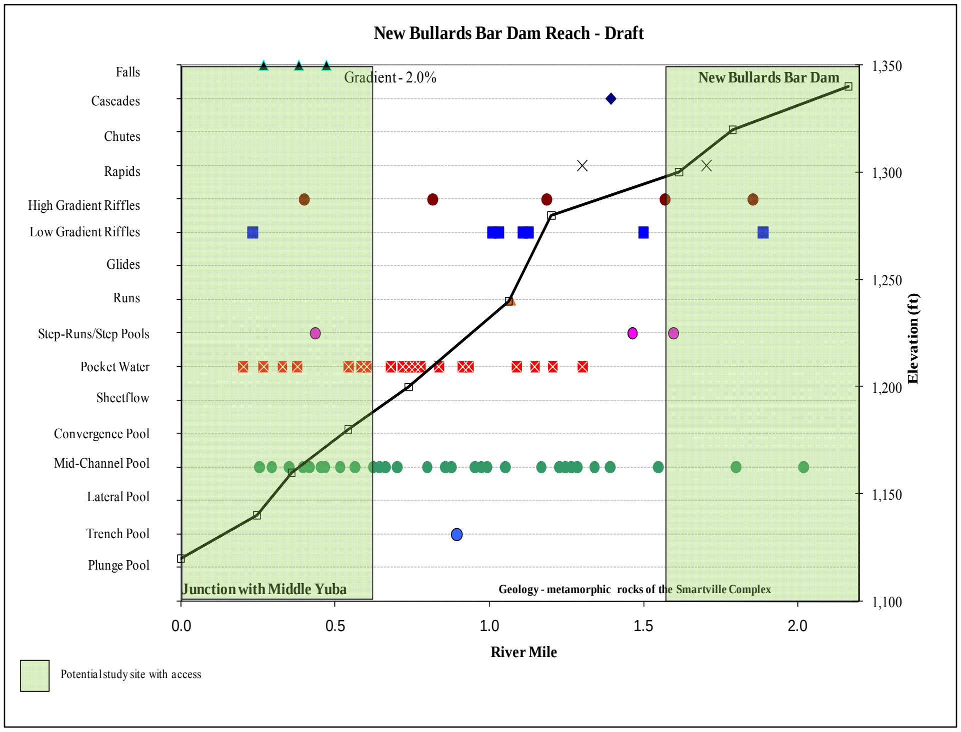

Figure 5.3.4-3. New Bullards Bar Dam Reach PHABSIM longitudinal profile and mesohabitat distribution (from video and ground mapping)

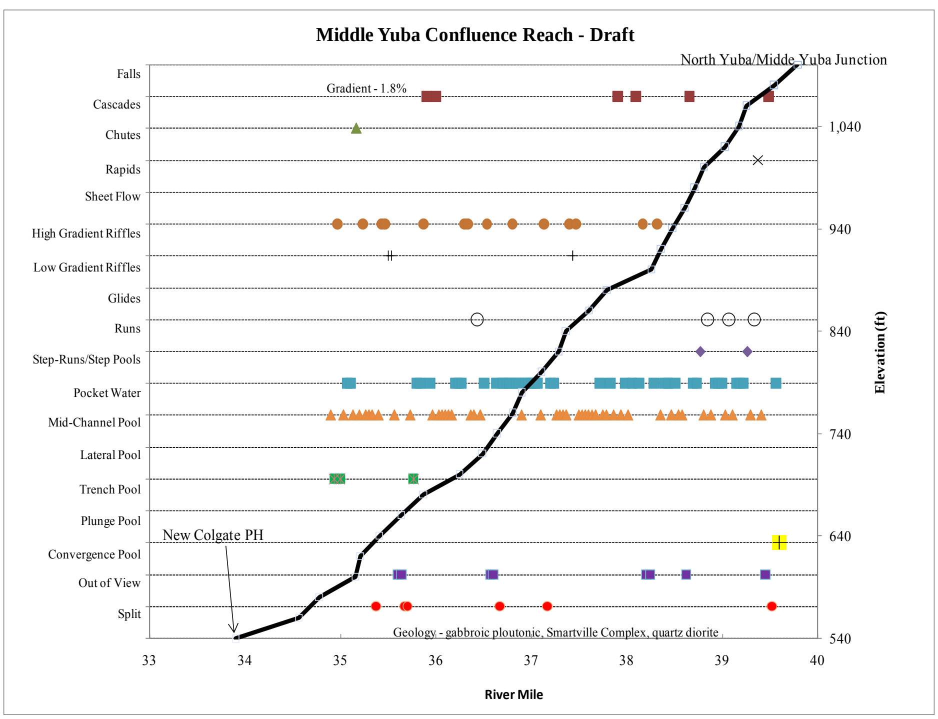

Figure 5.3.4-4. Middle/North Yuba River Reach longitudinal profile and mesohabitat distribution (from video mapping).

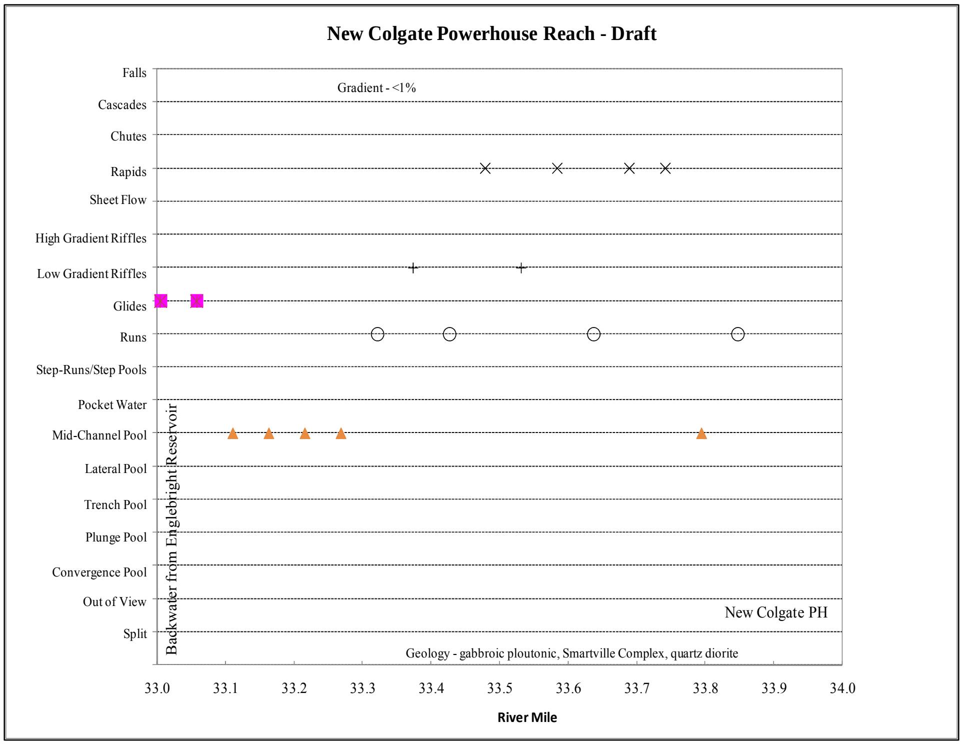

Figure 5.3.4-5. New Colgate Powerhouse Reach mesohabitat distribution (from video mapping). Because this reach is very short (~1.5 miles) and the gradient in this reach is less than 1percent, there are insufficient map contours to provide a longitudinal profile.

5.3.5 Step 5 - PHABSIM Field Data Collection

5.3.5.1 General Method

Physical habitat and hydraulic parameters will be measured using a combination of standard techniques of the USFWS methodology (Trihey and Wegner 1981; Bovee 1982) and the United States Geological Survey (USGS) (Bovee 1997, Bovee *et al.* 1998, and Rantz 1982).

5.3.5.2 Target Calibration Flows

For PHABSIM modeling, three calibration flows (i.e., low, middle and high) are normally selected with the goal of achieving an even, logarithmic spacing of flows that allows for development of an adequate stage/discharge relationship in the PHABSIM model.[2] In other words, the stage change between calibration flows should be sufficient to test for a linear relationship between the log of discharge and log of stage minus stage of zero flow (IFG-4), or through the use of hydraulic conveyance modeling (MANSQ). Other general guidelines for selecting calibration flows include:

[2] An additional (fourth) stage/discharge measurement will be taken in all reaches and sub-reaches.

- The low, middle, high, and high-high calibration flows should all be within the range of Project flow control.
- Incremental differences between the calibration flows should be within the control capabilities of the flow control mechanism.
- The low calibration flow should be low enough to model down to the current instream flow requirement and adequately capture low flows that are currently released or expected to be released by the Project.
- The middle calibration flow should be the approximate logarithmic midpoint between the high and low calibration flow targets, thus providing the necessary spread to assess the relationship between stage and discharge.
- Where possible, considering safety and physical limitations, the high calibration flow should be high enough to model up to 5 percent or greater of the unimpaired flow exceedance curve or the highest flow anticipated in the reach during the new license, whichever is less.
- A fourth stage-discharge point (high-high) and margin velocities will be collected in all reaches and sub-reaches to improve the high range of extrapolation.
- The high calibration flow should be within the physical limits of field measurement options using manual meters or an acoustic Doppler current profiler (ADCP).

Table 5.3.5-1 shows Licensees preliminary target calibration flows for the study based on the above guidelines and the current operations of the Project. Licensee will confirm target calibration flows in consultation with the Relicensing Participants.

Table 5.3.5-1. Target calibration flows by PHABSIM reach.

Reach	Existing Lowest Minimum Flow Requirement	Target % Exceedance [Unregulated (u) or Regulated (r)]	Target Calibration Flow[1]			
			Low	Mid	High	High-High
	cfs	cfs	cfs	cfs	cfs	cfs
MIDDLE YUBA RIVER						
Our House Diversion Dam Reach	30	2 (u)	75	150	300	600
OREGON CREEK						
Log Cabin Diversion Dam Reach	8	2 (u)	20	50	100	150
NORTH YUBA RIVER						
New Bullards Bar Dam Reach	5	5 (u)	20	175	600	1,535
YUBA RIVER						
Middle/North Yuba River Reach	5	10 (u)	100	300	600	1,570
New Colgate Powerhouse Reach	5	10 (r)	100	600	1,570	3,260

[1] Values are target flows. Measured flows may vary by +/- 10%. Team safety will be evaluated at each flow. Relicensing participants will be notified of any significant changes in target flows.

5.3.5.3 Surveying and Controls

All elevations will be surveyed by standard differential survey techniques using an auto-level or total station instrument. Headpin and tailpin elevations, water surface elevations (WSE), hydraulic controls, and above-water bed and bank elevations will be referenced to a temporary benchmark serving a single transect or transect cluster. The surveyed portion of the streambed will extend up to the flood-prone elevation of both banks on all riffles and on other cross sections as stipulated in the Channel Morphology Above Englebright Reservoir study plan. Where reasonable (line of sight or one turning point), benchmarks will be tied together. At a minimum, all transects surveyed in a single mesohabitat unit will have a common datum. Transect locations will be fixed, to the accuracy level possible, using a handheld GPS instrument.

5.3.5.4 Water Surface Elevation-Discharge

Stage/discharge measurements will be obtained at four discharges. Water surface elevations will be measured at multiple points across the channel except when conditions are unsafe at high flow. In these circumstances measurements will only be taken as far out from the accessible shoreline as is safe and physically possible. When only a stage/discharge measurement is taken, discharge through the study site will be measured using manual velocity meters or a combination of an ADCP (described below) and manual velocity meters at an appropriate cross section(s).

5.3.5.5 Velocity Calibration

One velocity calibration set will be collected at the high flow at each transect; or at middle flow if safety or physical conditions are limiting at the high flow. Additional velocity data will be collected on the stream margins (when accessible) at the fourth stage-discharge measurement (high-high). If personnel safety is a concern at high flow, all or a portion of the velocity calibration will be measured at middle flow with WSE/discharge collected at high and low flows. This determination will be made in the field by Licensee.

Velocities will be measured using hand-held current meters and/or ADCP, depending on the depth and width of the stream. Hand-held velocity measurements will use calibrated digital Swoffer® brand, Price AA, or pygmy velocity meters mounted on standard USGS top-set wading rods in depths less than approximately 3.0 ft or where use of the ADCP is not practical. At cross-sections and flows where predominant depths are greater than 3.0 ft, velocity distributions will be measured using an ADCP mounted on a small inflatable cataraft or a rigid trimaran.

Both the Swoffer and Price AA meters are accurate in velocities ranging from 0.1 to 25.0 ft per second, while Pygmy meters are accurate from 0.1 to 4.9 ft per second. Published technical specifications for the Teledyne RDI Rio Grand ADCP are: velocity accuracy: ±0.25% of the (water + boat) velocity ±0.25cm/s at a minimum] velocity resolution of 0.1cm/s and up to a maximum water velocity of ±20m/s.

ADCP data collection will follow US Geological Survey standards for measuring discharge (Mueller, et al. 2009). Exceptions may be made as certain guidelines are not necessarily applicable in all PHABSIM data collection situations. In addition to these guidelines, simultaneous readings from a nearby upstream or downstream active stream gage (if it exists) will be recorded and included along with the stream gage number in the instream flow report(s).

Post processing of ADCP data for purposes of PHABSIM modeling requires that: 1) velocities in each ADCP ensemble (vertical) be reported as a mean column value in the horizontal plane (magnitude and direction); 2) mean column velocities be interpolated or averaged to user defined stations across the transect; 3) mean column velocities at each station from 'good' passes will be averaged together, and; 4) discharge will be calculated using averaged data.

To assure adequate characterization of microhabitat for all lifestages (e.g., adult, juvenile, and spawning), during manual velocity measurements, sample sites (verticals) along the transect will be purposefully placed to describe points where changes in substrate, bed elevation, and velocity occur. The number of verticals will be adjusted in the field to accomplish microhabitat stratification as dictated by site-specific conditions. The placement and number of verticals will be designed to limit discharge in any one cell to no more than 10 percent of total discharge.

Temporary staff gages will be installed and the stage and time of day will be recorded at the beginning and end of each transect measurement to note potential changes in stage during the survey of each transect.

Where project operations allow, all calibration measurements will be collected within a 3 - to 4-day period. If operations do not allow, several weeks or months may elapse between flow measurements.

5.3.5.6 Substrate

Substrate will be classified according to a standard procedure, and will be evaluated visually during low flow conditions. Percent occurrence of all substrate sizes withing the immediate vicinity of each vertical (1-2 feet radius from vertical) will be recorded.

The substrate data will then be converted into the Bovee substrate code system (Bovee and Cochnauer 1978) to be compatible with the codes used for the HSC. The Bovee substrate code is written as "x.y," where "x" is the code number for the smaller of the two dominant and adjacent particle sizes, and "y" is the percentage (i.e., from 0.0 to 0.9) of the larger of the two dominant and adjacent particle sizes. Particle size classification and coding are shown in Table 5.3.5-2.

Table 5.3.6-2. Substrate particle size classification and coding.

Substrate Type	Size (inches)	Code
Organics, vegetation	--	0
Clay, silt (fines)	<0.1	1
Sand (coarse)	0.1-0.2	2
Small gravel	0.2-1.0	3
Medium gravel	1-2	4
Large gravel	2-3	5
Small cobble	3-6	6
Medium cobble	6-9	7
Large cobble	9-12	8
Boulder	>12.0	9
Bedrock	--	10

5.3.5.7 Miscellaneous Field Data Collection Methods

Photographs will be taken of all transects from downstream and other points as necessary at each measured flow. To the extent possible, each photograph will be taken from the same location at each of the three levels of flow.

Data sheets for each study site will be completed as follows:

- Photo Log – for each flow/visit
- Site Documentation – sketch or aerial video capture showing location, type, and numbering of transects – completed once
- GPS UTM Coordinates for each headpin (or mid-channel if headpin reading could not be obtained) and benchmark – completed once
- Water Surface Elevation and Level Loop – WSE completed at each calibration flow, level loop completed once, pin heights validated at each visit
- Cover Description – completed once
- Discharge – for each flow, at one two or more transects
- Depth and Velocity – at each transect for one calibration flow (middle or high)
- Stage of Zero Flow – collected once for each transect
- Cross Section Profile and Substrate – completed once for each transect
- Task Completion Checklist – in field for every visit

5.3.6 Step 6 - Selection of Habitat Suitability Criteria

Flow/habitat models will be developed for target species/lifestages using HSC that were recently developed for small, medium, and large rivers in Nevada Irrigation District's Yuba-Bear Hydroelectric Project (FERC Project No. 2266) and PG&E's Drum-Spaulding Project (FERC Project No. 2310). Both of the relicensings are on the Yuba and Bear rivers in California.

Project stream sizes fall into the large and small classifications. The stream size designations for each of the PHABSIM sites are presented in Table 5.3.6-3. The HSC employed in these analyses are presented in Tables 5.3.6-4 through 5.3.6-6. Note that substrate was only considered a variable for rainbow trout spawning habitat simulations; for all other species/life stages all substrates were considered fully suitable (i.e., suitability was set equal to 1.0).

Table 5.3.6-3. Project-affected reaches designated for application of "large," or "small" channel size rainbow trout juvenile and adult rearing HSC.

Project-affected Reach	Channel Size[1]	Approximate Elevation (feet)		Average Bankfull Channel Width (ft)	Regime Type[2]	% Mean Slope
		Minimum	Maximum	Mean		
MIDDLE YUBA RIVER						
Our House Diversion Dam Reach	LRG	1,500	2,000	83.5	D	1.1
Oregon Creek Reach of the Middle Yuba River	LRG	1,120	1,500	54.7	D	1.2
OREGON CREEK						
Log Cabin Diversion Dam Reach	SML	1,500	2,180	29.4	D	2.3
NORTH YUBA RIVER						
New Bullards Bar	LRG	1,120	1,360	70	D	2.0
YUBA RIVER						
North/Middle Yuba River Reach	LRG	560	1,120	105	D	1.8
New Colgate Powerhouse Reach	LRG	525	560	127	R	<1.0

[1] Approximate criteria (average width):
SML <30 ft
LRG >50 ft

[2] D = Diverted
R = Re-regulated
A = Augmented

Table 5.3.6-2. Rainbow trout suitability for spawning, fry, juvenile, and adult lifestages.

Lifestage	Channel Size	Velocity	Suitability	Depth	Suitability	Substrate	Suitability
Spawning	Large and Small	0.00	0.00	0.15	0.00	0.0	0.00
		0.60	1.00	0.60	1.00	2.3	0.00
		2.00	1.00	1.50	1.00	2.4	0.25
		4.00	0.00	3.00	0.00	2.5	0.50
		--	--	--	--	2.6	0.75
		--	--	--	--	2.7	1.00
		--	--	--	--	5.3	1.00
		--	--	--	--	5.4	0.50
		--	--	--	--	5.5	0.00
		--	--	--	--	10.0	0.00
Juvenile	Small	0.00	0.70	0.20	0.00	N/A	N/A
		0.10	1.00	1.00	1.00	--	--
		0.35	1.00	1.60	1.00	--	--
		0.90	0.50	2.00	0.60	--	--
		1.50	0.10	2.75	0.30	--	--
		2.50	0.00	3.50	0.10	--	--
		--	--	30.00	0.10	--	--
	Large	0.00	0.50	0.20	0.00	N/A	N/A
		0.30	1.00	1.20	1.00	--	--
		0.70	1.00	2.20	1.00	--	--
		1.20	0.60	2.60	0.50	--	--
		1.50	0.30	4.00	0.10	--	--
		2.25	0.10	30.00	0.10	--	--
		3.50	0.00	--	--	--	--

Table 5.3.6-2. (continued)

Lifestage	Channel Size	Velocity	Suitability	Depth	Suitability	Substrate	Suitability
Adult	Small	0.00	0.50	0.20	0.00	N/A	N/A
		0.20	1.00	1.20	1.00	--	--
		0.40	1.00	2.00	1.00	--	--
		1.20	0.30	3.50	0.30	--	--
		1.70	0.10	30.00	0.30	--	--
		3.00	0.00	--	--	--	--
	Large	0.00	0.00	0.50	0.00	N/A	N/A
		0.50	0.80	2.30	1.00	--	--
		0.70	1.00	3.10	1.00	--	--
		1.30	1.00	3.80	0.60	--	--
		1.80	0.50	5.00	0.30	--	--
		2.50	0.20	30.00	0.30	--	---
		4.00	0.00	--	--	--	--

Table 5.3.6-3. Hardhead/Sacramento pikeminnow suitability for juvenile and adult lifestages.

Lifestage	Channel Size	Velocity	Suitability	Depth	Suitability	Substrate	Suitability
Juvenile	Large and Small	0.00	1.00	0.50	0.00	N/A	N/A
		0.25	1.00	0.67	1.00	--	--
		1.75	0.25	3.67	1.00	--	--
		2.60	0.00	8.71	0.10	--	--
		--	--	18.00	0.10	--	--
Adult	Large and Small	0.00	0.82	0.66	0.00	N/A	N/A
		0.20	1.00	2.62	1.00	--	--
		0.90	1.00	18.00	1.00	--	--
		2.13	0.22	--	--	--	--
		3.50	0.00	--	--	--	--

Table 5.3.6-4. Sacramento sucker suitability for juvenile and adult lifestages.

Lifestage	Channel Size	Velocity	Suitability	Depth	Suitability	Substrate	Suitability
Juvenile	Large and Small	0.00	1.00	0.64	0.00	N/A	N/A
		1.20	1.00	0.65	1.00	--	--
		1.21	0.00	2.90	1.00	--	--
		--	--	2.91	0.00	--	--
Adult	Large and Small	0.00	1.00	1.99	0.00	N/A	N/A
		1.50	1.00	2.00	1.00	--	--
		1.51	0.00	4.70	1.00	--	--
		--	--	4.71	0.00	--	--

5.3.7 Step 7 - PHABSIM Modeling

5.3.7.1 Water Surface Elevations

The hydraulic model will be calibrated in the HYDSIM routine of RHABSIM 3.0. Hydraulic modeling procedures appropriate to the study site and level of data collection will be used for modeling water surface elevations and velocities across each transect. For water surface elevations, these procedures will include: the development of stage/discharge rating curves using log-log regression (IFG4); Manning's formula (MANSQ); and/or step backwater models (WSP, HecRas); direct comparison of results; and selection of the most appropriate and accurate method. Log-log and MANSQ will be run for each transect, with MANSQ set as the default modeling method. If individual transects do not calibrate sufficiently well using MANSQ, based on general guidelines of maximum Beta (0.5), and/or professional judgment, then log/log will be chosen. Data file construction, calibration, and simulation will follow standard procedures and guidelines outlined in the PHABSIM Reference Manual Version II, Instream Flow Information Paper No.26 (Milhous, R.T., M.A. Updike, and D.M. Schneider 1989).

Licensee will consult with interested and available Relicensing Participants regarding hydraulic calibration of each PHABSIM model. Licensee will make a good faith effort to schedule the consultation on a day or days convenient to Licensee and interested Relicensing Participants (ideally, scheduling meetings at least 30 days in advance of the meeting to allow all Relicensing Participants to participate), and will provide an email notice confirming the meeting at least 10 days in advance of the meeting. If agreement regarding the hydraulic calibration is not reached, Licensee will note the disagreements in its final report, including why Licensee did not adopt the recommendation. Calibration reports will be provided to the Relicensing Participants at least 30 days prior to the meeting.

5.3.7.2 Velocities

The hydraulic model utilizes two basic methods for predicting velocities over a range of flow simulations. The primary approach, termed the “one-velocity set” method, uses measured velocities across a given transect and estimates a Manning’s N value for each cell. Calibration techniques include adjustments to the Manning’s N to obtain accurate predictions of measured velocities, as well as reasonable predictions of velocities at simulated flows. An alternative approach to modeling velocities, termed the “depth-calibration” method, can be used in the absence of measured velocities. In general, depth calibration procedures will be used to model large sections of a transect if very high velocities and/or entrained air preclude data measurement.

The purpose of the velocity calibration is to accurately simulate the measured velocities and water surface elevations at the observed flows while at the same time providing reasonable velocities and water surface elevations at the range of simulated flows. Changes to velocities will be kept to a minimum and the decks revised only when specific changes improve model performance.

5.3.7.3 Model Extrapolation

Extrapolation of flows beyond the highest calibration measurement is often necessary to achieve as much of the range of the hydrograph as possible. Extrapolation beyond the measured calibration stage/discharge pairs collected in the field will typically be 0.4 times (or 40% of the lowest stage/discharge pairs) and 2.5 times (or 250% of the highest stage/discharge pairs). The limits of extrapolation beyond these factors will depend on model performance, channel shape, and modeling methods; all of which contribute to establishing reasonable extrapolation limits within the hydraulic model.

5.3.8 Step 8 - Habitat Duration Analysis

The WUA function is a static relationship between discharge and habitat and does not represent how often a specific flow/habitat relationship occurs seasonally or under different operational regimes. For this reason, WUA is not the final result of an instream flow study. A Habitat Duration Analysis (HDA), from which frequency of habitat occurrence can be derived, is the product. An HDA integrates WUA with hydrology over time to provide a dynamic analysis of flow versus habitat.

Habitat duration curves are particularly useful for assessing the impacts of alternative flow regimes over the complete range of discharges that may be considered as alternative flow scenarios (Waddell 2001, Bovee 1982, Bovee et al. 1998). They are also useful for examining habitat changes due to artificial influences for the time periods identified as critical in the species/lifestage periodicity analysis or on a seasonal basis by simply sampling from the appropriate portions of the time series to build the habitat duration curve (Waddell 2001).

A habitat duration curve is constructed in exactly the same way as a flow duration curve, but uses habitat values instead of discharges as the ordered data. Although habitat duration curves look like and are based on flow duration curves, there is no direct correspondence between the two. For example, the habitat value that is exceeded 90 percent of the time usually does not correspond to the discharge that has the same exceedance probability. This discordance happens because of the normal bell-shaped data relationship between total habitat and discharge (Bovee et al. 1998). Consequently, some confusion can arise from reading habitat duration curves because a habitat area with a given exceedance probability might be related to more than one discharge (all having different probabilities of exceedance). The habitat duration curve should be used to quantify the differences in habitat between baseline and alternative conditions (Bovee et al. 1998).

The product of a habitat duration analysis is a record of mean daily habitat over the hydrologic period of record. A habitat exceedance curve (also referred to as a habitat duration curve) is then calculated from the mean daily habitat for the hydrology period of record. A metric for any portion of the habitat duration curve is calculated by averaging the exceedance values at one percent increments for that portion of the curve. This is equivalent to calculating the Area Under the Curve (AUC) or some portion of it.

5.3.8.1 WUA Extrapolation

In order to calculate habitat frequency for every day of the full hydrology period of record, the WUA function needs to extend from highest mean daily flow in the record to the lowest (i.e., 100% to 0% flow exceedance). For the Project, habitat duration analyses will be extrapolated to zero percent exceedance in two steps. First, flows will be modeled in PHABSIM to the maximum extent acceptable within model calibration parameters established during the model calibration review process. Second, WUA will be extrapolated from the highest modeled flow in PHABSIM to zero percent exceedance using a step-wise approach in consultation with the Relicensing Participants.

First, a non-linear exponential extrapolation equation will be applied to the last three points of each WUA data set. The non-linear option for extrapolation follows the trend of the regression and never completely bottoms out, which is the most realistic trend line for WUA. However, in some cases, the WUA function rises or is relatively flat over the last three points on the curve. In this instance, the non-linear exponential extrapolation causes an unrealistic growth of available habitat with increasing discharge. If this occurs, increasing or decreasing the number of data points to be used in the extrapolation will be evaluated. If this does not produce realistic results, a linear function using the last two points will be applied. If the linear function does not produce results as expected, a flat-line approach will be employed whereby the WUA function will be extended at a constant magnitude from the last data point. The foregoing approach is general and is subject to modification as needed.

5.3.8.2 Habitat Duration Metric

While there are several metrics that can be derived from the habitat duration curve, such as whole-series mean, Index A, Index B, Index C, and others (Bovee *et al.* 1998 and Waddell 2001), the Licensee proposes the whole-series mean as the metric for the habitat duration analysis. Whole-series mean is the average value of all habitat events in the series that fall between the 0 and 100 percent exceedance levels. This is the most common and easily understood habitat metric (Bovee *et al.* 1998). The whole-series mean is proposed for two reasons: 1) because Licensee believes in general that, if possible, no part of the hydrologic record should be excluded from the habitat duration analysis; and, 2) effects of flow modifications would be unknown for the portion of the curve that was excluded.

5.3.8.3 Habitat Duration Analysis Program and Inputs

Habitat duration will be calculated using the program "Multi-flow Habitat Duration" (HDR|DTA 2002).[3] The Multi-flow Habitat Duration program will be demonstrated to interested Relicensing Participants upon request. Licensee will consult with Relicensing Participants regarding all habitat duration analysis input parameters, scenario assumptions, and desired output in consultation with Relicensing Participants.

Several inputs are required for the Habitat Duration Program. These are described below.

- <u>Hydrologic Node Locations.</u> A hydrologic node is a specific location (e.g., river mile) where hydrology is calculated for the HDA. Two nodes will be selected in each reach, one immediately below the upper end of the reach and one that represents the average accretion in the reach.

[3] Flow Habitat Duration is a flexible and fast program that allows the user to input all necessary data and then select which sets or sub-sets of data to use based on project operation specifics and analysis needs. The program has been used in numerous FERC relicensings (including Tri-Dam's Beardsley-Donnells Project,) involving complex projects with multiple points of regulation, 75 years of mean daily hydrologic files, and more than 30 species/life stages, each with different life history periodicities. Multi-flow Habitat Duration will be made available to Relicensing Participants, FERC, and NGOs at no cost with the understanding that the Multi-flow Habitat Duration program will not be further distributed for use on other projects or distributed to other consultants.

- Target Species and Lifestages. Species and lifestages to be included in the habitat duration analysis will be the target species and life stages described in Table 5.3.1-1.
- Periodicity**.** Lifestage periodicity input to the habitat duration program enables the program to calculate habitat frequency for only the time of year when the lifestage of interest is present. Proposed periodicity is shown in Figure 5.3.2-1.
- Hydrology. The HDA generally factors in four sources of flow data in calculating habitat duration (all based on a mean daily time step): 1) regulated instream flow releases at the dam or powerhouse; 2) spillage at the dam; 3) accretion or tributary/intervening watershed inflow between the dam or powerhouse at each hydrology node; and 4) unimpaired flow at the dam or powerhouse.

Hydrology data for each of these four flow sources will be generally derived as follows:

- Regulated releases. Regulated releases are the mean daily flows immediately below the dam from plant generation, minimum instream flow releases, or a combination of both. These records will be calculated from measured or synthesized data or a combination of both.
- Daily Spillage at Dam. Daily spill is the mean daily uncontrolled flow past the dam or powerhouse. Mean daily spill is derived from project operation discharge records. Spill is incorporated into the record of regulated releases.
- Accretion Between the Dam and Each Hydrologic Node. Mean daily inflow at each node is computed by adding synthesized mean daily accretion of the intervening drainage area between the node and the dam or powerhouse.
- Unimpaired Flow at the Dam or Powerhouse. Unimpaired flow is the flow that would occur absent all existing development.
- Source Hydrology. Source hydrology, both regulated and unimpaired, for the habitat duration analyses will be based on the relicensing hydrology database for the period of record from Water Year 1970 through Water Year 2008 (YCWA 2009a). The habitat duration analyses program will be set to calculate habitat frequency for the full period of record (whole-series mean) on a mean daily time step.

The Multi-flow Habitat Duration program will be configured to run alternative managed flow regimes for the full period of record (whole-series mean). The Habitat Duration Analysis program will generate habitat duration metrics and calculate the differences between the managed flow alternative and both the regulated and unimpaired conditions based on a mean daily habitat time step.

5.3.9 Step 9 – Prepare Study Report

Licensee will prepare a study reports that will include both modeling procedures and habitat results. Below is a list of primary outputs to be included in the report. This list is not an exclusive list.

- Weighted Useable Area tables and graphs (tables will include indicators of peak and 80% of WUA and graphs will include normalized percent of WUA)
- Habitat duration figures and tables
- Habitat duration charting program
- Cross section profiles showing water surface elevation at the four calibration flows and 40 percent and 250 percent of the low and high calibration flows, respectively. Additional flows will be added in consultation with Relicensing Participants
- Stage/discharge regression graphs for each transect
- Photos of each transect organized and labeled for easy use
- Channel-cross section and water surface elevation for selected transects

Licensee will consult with Relicensing Participants regarding the output tables and graphics to be included in the report.

6.0 Study-Specific Consultation

The following are specific areas for which the Licensee will consult with the Relicensing Participants:

- Licensee will consult with interested and available Relicensing Participants regarding specific study sites and transects. Licensee will make a good faith effort to schedule the consultation on a day or days convenient to Licensee and interested Relicensing Participants (ideally, scheduling meetings at least 30 days in advance of the meeting or site visit to allow all Relicensing Participants to participate), and will provide an email notice confirming the meeting at least 10 days in advance of the meeting or site visit. If agreement regarding study sites and transects is not reached, Licensee will note the disagreements in its final report, including why Licensee did not adopt the recommendation. Licensee will offer a pre-field presentation and orientation meeting ahead of each field visit. The pre-field meeting will include a description of the study site, mesohabitat units, and possibly preliminary selected transects. The basis for selection, still photos, aerial video (if available), and maps of these features will also be provided. (Step 4.)

- Licensee will consult with interested and available Relicensing Participants regarding hydraulic calibration of each PHABSIM model. Licensee will make a good faith effort to schedule the consultation on a day or days convenient to Licensee and interested Relicensing Participants (ideally, scheduling meetings at least 30 days in advance of the meeting to allow all Relicensing Participants to participate), and will provide an email notice confirming the meeting at least 10 days in advance of the meeting. If agreement regarding the hydraulic calibration is not reached, Licensee will note the disagreements in its final report, including why Licensee did not adopt the recommendation. Calibration reports will be provided to the Relicensing Participants at least 30 days prior to the meeting. (Step 7.)

- The Multi-flow Habitat Duration program will be demonstrated to interested Relicensing Participants upon request. Licensee will consult with Relicensing Participants regarding all habitat duration analysis input parameters, scenario assumptions, and desired output in consultation with Relicensing Participants. Step 8)

- Licensee will consult with Relicensing Participants regarding the output tables and graphics to be included in the report Step 9).

7.0 Schedule

Licensee anticipates the schedule to complete the study as follows assuming the PAD is filed on November 1, 2010, and FERC issues its Study Determination by October 4, 2011:

Study Site and Transect Selection..October 2011
Field Work .... April through August 2012
Data Entry, QA/QC, & Analysis... June through August 2012
Report Preparation .... September through October 2012

8.0 Consistency of Methodology with Generally Accepted Scientific Practices

The study methods discussed above are consistent with the study methods followed in several other relicensings. The methods presented in this study plan also are consistent with those used in recent relicensings in California.

9.0 Level of Effort and Cost

[Relicensing Participants – Licensee will include a cost range estimate for this study in its Proposed Study Plan. Licensee]

10.0 References Cited

Armantrout, N.B. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, Maryland.

Bovee, K. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Instream Flow Information Paper No. 12. FWS/OBS-82/26. U.S. Fish and Wildlife Service, Office of Biological Services, Fort Collins, Colorado.

_____. 1997. Data collection procedures for the Physical Habitat Simulation System. U.S. Geological Survey, Biological Resources Division, Fort Collins, Colorado.

Bovee, K.D. and T. Cochnauer. 1978. Development and evaluation of weighted criteria, probability-of-use curves for instream flow assessments. Instream flow Information Paper No. 3. Cooperative Instream Flow Service Group, Fort Collins, CO.

Bovee, K., B.L. Lamb, J.M. Bartholow, C.B. Stalnaker, J. Taylor and J. Henriksen. 1998. Stream habitat analysis using the instream flow incremental methodology. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD-1998-0004.

Hawkins, C.P., J.L. Kershner, P.A. Bisson, M.D. Bryant, L.M. Decker, S.V. Gregory, D.A. McCullough, C.K. Overton, G.H .Reeves, R.J. Steedman, and M.K. Young. 1993. A hierarchical approach to classifying habitats in small streams. Fisheries. 18(6): 3-12.

McCain, M., D. Fuller, L. Decker, and K. Overton. 1990. Stream habitat classification and inventory procedures for northern California. FHR Currents: R-5's fish habitat relationships technical bulletin. No. 1. U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, Arcata, California.

McMahon, T. E., A.V. Zale, and D. J. Orth. 1996. Aquatic habitat measurements. Pages 83–120 in B. R. Murphy and D. W. Willis, editors, Fisheries techniques, second edition. American Fisheries Society, Bethesda, Maryland.

Milhous, R.T., D.L. Wegner, and T. Waddle. 1984. User's Guide to the Physical Habitat Simulation System (PHABSIM). Instream Flow Information Paper No. 11. U.S. Fish and Wildlife Service. FWS/OBS-81/43 Revised.

Milhous, R.T., M.A. Updike, and D.M. Schneider. 1989. Physical Habitat Simulation System Reference Manual-Version II. Instream Flow Information Paper No. 26. U.S. Fish and Wildlife Service. Biological Report. 89(16).

Montgomery, D.R. and J.M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition. Report TFW-SH10-93-002 prepared for the SHAMW committee of the Washington State Timber/Fish/Wildlife Agreement.

Mueller, D.S., and C.R. Wagner. 2009. Measuring discharge with acoustic Doppler current profilers from a moving boat: U.S. Geological Survey Techniques and Methods 3A-22, 72 p. (available online at http://pubs.water.usgs.gov/tm3a22)

Morlock, S.E. 1996. Evaluation of Acoustic Doppler Current Profiler measurements of river discharge. USGS Water-Resources Investigations Report 95-4218. Indianapolis, Indiana.

Payne, T.R. 1992. Stratified random selection process for the placement of Physical Habitat Simulation (PHABSIM) transects. Paper presented at AFS Western Division Meeting, July 13-16, in Fort Collins, CO.

Rantz, S.E. 1982. Measurement and computation of stream flow: Volume 1. Measurements of stage and discharge. USGS Water Supply Paper 2175.

Trihey, E.W., and D. Wegner. 1981. Field data collection procedures for use with the Habitat Simulation System of the Instream Flow Group, USFWS, Fort Collins, Colorado.

Waddle, T.J., ed. 2001. PHABSIM for Windows: User's Manual and Exercises: Fort Collins, CO, USGS.

Yuba County Water Agency (YCWA). 2009a. Yuba County Water Agency, Yuba River Development Project (FERC No. 2246) Relicensing Pre-Application Document, 2009.

_____. 2009b. Yuba County Water Agency, Yuba River Development Project (FERC No. 2246). Aerial Video Taped: 7/13/09. Public Information. ©2009 Yuba County Water Agency.

Section 10, Licensee's Preliminary Proposed Studies Fish Instream Flow Upstream of Englebright Reservoir Study (Study 3.10) Attachment 3.10A, Habitat Mapping Report - Attachment on DVD

This attachment to the Habitat Mapping Report includes for each of the Middle Yuba River, North Yuba River, Oregon Creek and Yuba River large folders that contain spreadsheet files and photo logs that cannot be easily uploaded to FERC's e-Library. Therefore, YCWA has filed this material as a DVD under separate cover with FERC. Parties interested in obtaining a copy of the video DVD should contact:

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