BATTLE CREEK FISHERIES STUDIES

TASK 1: INSTREAM FLOW STUDY

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INTRODUCTION

This report documents an instream flow aquatic habitat analysis of the Battle Creek watershed, one of a series of aquatic resource studies conducted by Thomas R. Payne and Associates (TRPA) for the California Department of Fish and Game (CDFG). The objective of the Battle Creek studies is to "assess the impacts of the Battle Creek Hydroelectric Project on the stream's aquatic habitat and dependent fishery resources, and to develop recommendations for project operation which would restore and maintain Battle Creek's aquatic habitat and fishery resources". The major task in this element of the studies is the development of habitat vs. discharge relationships for 52 miles of Battle Creek (Figure 1), using the Physical Habitat Simulation (PHABSIM) system of the Instream Flow Incremental Methodology (IFIM). Habitat index vs. stream discharge relationships may be used to evaluate existing flows and the potential for fisheries under alternative flow regimes. Results will be combined with remaining tasks of the series of studies (species habitat criteria, hydrology, species abundance, water temperature modeling, sediment and gravel recruitment, and hatchery interactions) to determine the feasibility of re-establishing significant anadromous fish populations in the upper watershed.

The instream flow study was coordinated closely with CDFG and many aspects of it were based on CDFG input. Application of the IFIM begins with a scoping process to establish the objectives and analytical framework of the study (Bovee 1982). Representatives of CDFG, the U.S. Fish and Wildlife Service, Pacific Gas and Electric Company (PG&E), and TRPA participated in an initial scoping session on August 16, 1988. Existing conditions of the watershed, projected goals of the various tasks of the multifaceted study, and potential problem areas were addressed. Habitat mapping, macrohabitat classifications, river segmentation into reaches, number and random selection of study transects, flow control and project operation during data collection, constraints on data collection, and agency management goals in the system were also discussed. This meeting laid the groundwork for the remainder of the entire study, including habitat typing of the project area, transect selection and placement, and data collection and analysis. Periodic meetings throughout the different phases of the project were held to discuss progress, problems, and interim results.

This report describes the methods used to relate the habitat index (expressed in terms of weighted usable area, or WUA) to discharge throughout the Battle Creek system. To facilitate additional analysis by CDFG and avoid excessive report length, the hydraulic and habitat model input and output files and habitat mapping data are reported separately in computer files.

METHODS

The IFIM was developed by the Instream Flow Group of the US Fish and Wildlife Service (USFWS) in the late 1970's to allow evaluation of alternative flow regimes for water development projects (Bovee and Milhous 1978). Improvements have subsequently been made in the process of IFIM scoping and results interpretation (Bovee 1982), in approaches to defining study reaches (Morhardt et al. 1984) and transect selection (Payne 1992), and in techniques of Physical Habitat Simulation (PHABSIM) computer modeling and analysis (Milhous et al. 1984, 1989; Milhous and Schneider 1985).

This study included the typical IFIM components of identifying study reaches, habitat mapping, transect selection, collection of hydraulic, substrate, and cover data, hydraulic model calibration, selection of habitat criteria, and development of habitat vs. discharge relationships for each reach. The methods used for each of these steps are discussed below.

Study Reach Identification

For ease of analysis, the Battle Creek system was segmented into seven study reaches. These reaches differ by gradient, flow (estimated unimpaired), and channel character, and were used as the same within all components of the Battle Creek studies. Two of the reaches were considered outside the area of interest for the instream flow study due to lack of flow alteration. These were Battle Creek Mouth (Reach 1), where stream flows are rejoined and are mostly unimpaired by PG&E project operations; and North Fork Battle - Reservoirs (Reach 6), because water is not diverted out-of-stream (although seasonal streamflow patterns are altered somewhate by the

McCumber and North Battle reservoirs. Habitat mapping results for these reaches were, however, obtained and reported here.

The seven study reaches are as follows (some of these reaches were further divided into subreaches for portions of the habitat analysis):

1) Battle Creek Mouth - This study reach starts at the upstream end of the backwater of the Sacramento River (approximately 1.9 miles above the Battle Creek-Sacramento River confluence - elevation 345') and ends at PG&E's Coleman Powerhouse - elevation 490'. In its 6.09 mile length, it is a very low gradient, meandering, evenly-flowing stream unconfined by its very wide valley.

2) Mainstem Battle Creek - The 9.06 mile long reach starts at PG&E's Coleman Powerhouse and ends at the confluence of the North and South forks. This reach is typically low gradient, with occasional short reaches of moderate gradient. The river is confined within a large valley and has cut into the bedrock. The elevation ranges from 490' to 830'.

3) North Fork Battle - Eagle - Originating at the confluence of the North and South forks and ending at the confluence of North Fork Battle and Digger creeks, the 5.45 mile reach has a more moderate gradient (elevation 830' to 1470') and is confined within narrow, steep canyon walls. Within the reach are included two major points of diversion, the Wildcat Diversion (elevation 1070') and the Eagle Canyon Diversion (elevation 1430'). The Wildcat Subreach is between the downstream end of the reach and Wildcat Diversion, and the Eagle Canyon Subreach is between Wildcat Diversion and Eagle Canyon Diversion.

4) North Fork Battle - Digger - Beginning at the confluence of North Fork Battle and Digger creeks and ending 4.26 miles later at the confluence of North Fork Battle and Bailey creeks, it is similar to the Eagle reach in that it is confined within steep canyon walls but has a more moderate stream gradient. One major point of diversion, the North Battle Feeder (elevation 2080'), is

located within the reach near the upper boundary. Elevation of the reach ranges from 1470' to 2110'.

5) North Fork Battle - Bailey - The Bailey reach starts at the confluence of North Fork Battle and Bailey creeks and ends 6.65 miles later at the Al Smith Diversion. The reach is typified by moderate to high gradient, is partially confined by canyon walls. Elevation ranges from 2110' to 3800'. Included within are two major points of diversion, the Keswick Diversion (elevation 3650'), and the Al Smith Diversion.

6) North Fork Battle - Reservoirs - The 12.28 mile study reach starts at the Al Smith Diversion and ends at the face of the dam for the North Fork Battle Creek Reservoir. Beginning stream gradient is moderate and decreases as the stream-confining canyon walls open into a rolling plain. Two major points of storage, McCumber and North Battle Reservoirs impound the creek. Elevation ranges from 3800' to 5560'.

7) South Fork Battle - Beginning at the confluence of the North and South forks, the South Fork Battle Reach ends 14.36 miles later at the South Diversion. Stream gradient varys between low to occasionally moderate gradient, while the creek is partially confined by steep to open canyon walls. Elevation ranges from 830' at the confluence to 2030' at South Diversion. The reach includes three subreaches, defined by major points of diversion: the Coleman Subreach is between the downstream end of the reach and the Coleman Diversion (elevation 1000'), the Inskip Subreach is between Coleman and Inskip diversions (elevation 1415'), and the South Diversion Subreach is between the Inskip and South diversions.

Habitat Mapping

Habitat mapping was used to determine how much weight should be given to different PHABSIM transects in estimating the overall WUA of each stream reach, by allowing computation of the percent abundance of any macrohabitat (e.g. pool, riffle, run) type within the study area. These habitat maps also allowed individual habitat units to be identified for the transect placement process. In addition, habitat mapping identified any discrete accretion points, tributaries, and diversions where significant flow changes occur. Spawning gravel mapping data was concurrently being collected for use in the assessment of stream sedimentation patterns and gravel recruitment for the Battle Creek system (TRPA 1998a).

In 1988, habitat mapping was completed on 52 miles of stream for the Battle Creek study, including the entire distance from the confluence of Battle Creek with the Sacramento River to the South Diversion on the South Fork and the North Battle Creek Reservoir on the North Fork. A hip chain was worn by each field crew and was used to delineate the macrohabitat units to the nearest foot. Reference points were established roughly every 500 feet (to the nearest hydraulic control of a given macrohabitat unit) and marked by an orange painted blaze and identification flag. Field data collected included stream reach name, 500 foot section number, macrohabitat unit classification, starting and ending distance, and whether the unit was suitable for modeling. (The PHABSIM hydraulic models cannot simulate habitat units having very high, turbulent velocities like cascades, and such units are also assumed to provide no fish habitat.)

Macrohabitat was categorized into six types, according to the following definitions:

Riffle - Low to moderate gradient, not exceeding the known limits of hydraulic simulation capability. May contain some whitewater and standing waves, with a fairly uniform choppy surface, a mean column water velocity in excess of 1 ft/sec, and a depth generally less than two feet.

Run/Glide - Generally deeper than a riffle and often with a lower gradient than a riffle, a fairly smooth water surface, and a mean column water velocity generally in excess of 1 ft/s. Often occurs at the tailout of a pool but may occur anywhere.

Shallow Pool - A pool or portion of pool less than three feet in depth, with a mean column water velocity of less than 1 ft/s.

Deep Pool - A pool or portion of pool deeper than three feet with a mean column water velocity of less than 1 ft/s.

Pocket Water - An area of higher gradient generally containing plunge pools with counter-currents and velocity shear zones surrounding velocity chutes. Generally contains large boulders or other obstructions to flow which create eddies or scour holes (pockets) downstream of these obstructions.

Cascade - Any higher gradient riffle or cascade containing abundant white water and very high water velocities. Exceeds the modeling capability of the IFG4 model.

The field data were entered into a database to create a sequential map of habitat units along the mapped sections of stream. (Because of the volume of data included in these maps, they accompany this report on magnetic media in ASCII format. Files for each reach can be identified by their location prefix, and all have the suffix ".MAP".)

Transect Selection

In the five study reaches included in the instream flow analysis, 149 transects were used to model fish habitat. Of these, 14 transects were from a previous study completed by TRPA on the North Fork Battle - Digger Reach (TRPA 1986). Access to most of Battle Creek is extremely difficult and time consuming, so a completely random transect selection process (initially considered) resulting in widely separated transects would have rendered the flow study infeasible under budgetary constraints. Therefore, actual transect placement was accomplished by a combination of random selection and professional judgment.

The transect selection process was designed to ensure adequate simulation of complete pool macrohabitat unit sequences (the deep area of a pool habitat unit, the shallow pool area, and the run/glide that often occurs in the tail of deep pools). Habitat mapping results were examined to locate all occurences of such pool macrohabitat unit sequences. These sequences were identified and numbered and, using a random number generator, several were selected for on-site inspection and possible transect placement. Inaccessible reaches and sequences within very close proximity to previously-selected sequences were eliminated from consideration. In the field, the first selected unit would be located and, if judged to be modelable and reasonably typical, transects were placed that would best represent the deep pool, shallow pool, and run/glide habitat types. Additional transects in the immediate vicinity were selected for the remaining habitat types, until transects were placed in all significant habitat types.

The second randomly selected complete pool sequence was then located and the process repeated until sufficient transects were placed to adequately model each stream reach (roughly 30 transects per reach). Additional spawning transects were not selected randomly; rather, they were placed at locations known to have supported spawning in the past or were placed across or near observed redds. PG&E and resource agency personnel participated in all transect selections.

Each cluster of transects is referred to in the following sections as a "study site". Approximate locations, along with flow accretion data, are presented below ("Results, Habitat Mapping").

Transect Weighting

For modeling how the habitat index of an entire reach will change with flow, a weighting factor is assigned to each transect to reflect what proportion of the entire reach it represents. The transects were weighted using the habitat mapping data. Within a study reach, all transects of the same habitat type were assigned the same weight. This weight was equal to the proportion of the reach length made up of that habitat type (determined from habitat mapping), divided by the number of transects selected of that habitat type. For example, in a reach that is 20% deep pool with 4 deep-pool transects; each transect is assigned a weighting factor of 5% (20%/4) of the reach. (Cascades were not included in the habitat mapping data base used for weighting.) The supplemental transects added to simulate spawning habitat were treated two ways, once equally weighted within a study reach (e.g. four at 25% each), and again merged with all other transects with weights appropriate for their habitat type (mostly riffle).

All the transects placed in a study reach were used to develop WUA vs. discharge relationships for the reach. Some reaches include points of accretion, tributaries, or diversions that alter the flow rate; separate WUA vs. discharge relationships were developed for above and below such points (see "Development of WUA-Discharge Relationships”). To do this, all the transects for a reach were weighted separately for above and below accretion points, using the appropriate habitat mapping results. For example, flow in the Mainstem Battle Creek reach changes at Baldwin Creek. All 32 transects in this reach were weighted twice, once using habitat mapping from downstream of Baldwin Creek, once again using mapping from upstream of the creek, and then results were summed for the reach.

Hydraulic Data Collection

The field data collection and recording generally followed the guidelines established in the PHABSIM field techniques manuals published by the Instream Flow Group, the developers of the PHABSIM system (Trihey and Wegner 1981; Milhous et al. 1984), supplemented by additional quality control checks. Discharge measurement basically followed the guidelines outlined by Rantz (1982). A minimum of 20 wetted stations (velocity measurement points) per stream transect were established, with a goal of no less than 15 wetted stations to be remaining at low flow. The stations along each transect were normally placed at even increments, but significant changes in velocity, substrate, depth, or other important stream habitat features required additional stations.

As a result of the evolution in hydraulic modeling methods recommended by the Instream Flow Group since the beginning of the study, it was agreed by all parties that data collection method would be changed from two complete data (velocity and stage) sets one high flow stage measurement, to three complete data sets. The change allowed a three-flow velocity regression analysis (with mass-balance) for interpolation between measured flows, and a one-flow Mannings analysis for extrapolation beyond measured high and low flows (Payne 1988).

Data collection was timed to occur when regular PG&E operations and natural descending flows in the spring would provide the target flow levels initially specified by CDFG. However, due to very rapid flow drops in some reaches, some target discharges could not be obtained, and PG&E agreed to provide managed flow releases from their diversions on several occasions. In some study reaches (especially the Digger Reach), flow levels fluctuated during the high and middle flow data collection efforts. Through monitoring with a portable gage and using the transects' estimates for discharge, suitable stage/discharge relationships were established which allowed for satisfactory modeling of these reaches.

The standard method for determining mean column velocity was a single measurement at six-tenths of the water depth (from the surface) in depths less than 2.5 feet, and a two-tenths and eight-tenths measurement for depths between 2.5 and 4.0 feet. All three points were measured in depths greater than 4.0 feet or where the velocity distribution in the water column was abnormal and one or two points were not adequate to derive an accurate mean column water velocity.

A top-setting wading rod was used with mechanical velocity meters for water velocity measurement. The meters were vertical-axis, rotating-cup, Scientific Instruments Price AA and Pygmy-type meters. These meters are accurate where flow is turbulent and shifts direction, and where air is entrained in the water column. On one occasion, where two transects had water velocities in excess of 9.0 feet per second, a Montedoro-Whitney PVM-2A electromagnetic velocity meter was used. This meter allowed measurement of extremely high water velocities where a mechanical cup meter would have been more dangerous and possibly less reliable.

Considerable effort was applied to maintain strict quality control throughout all aspects of the hydraulic data collection. The following field data checks were made routinely by trained field biologists and technicians:

1) Daily flow meter calibration, spin tests, and comparison between meters before, during, and after field measurements;

2) Computation of discharge following completion of each transect to identify possible meter or measurement technique error;

3) Frequent monitoring of water surface elevation gages to identify changes of stage during the course of transect measurement;

4) Double-checking of water surface elevation and reference survey computations, and;

5) Comparison of bottom profiles between sampling dates, in reference to both water surface elevations and bench marks, to identify possible substrate movement.

Substrate Data Collection and Coding

The substrate and cover coding systems used in the instream flow study and Task 2 (Species Habitat Criteria) on Battle Creek were developed in consultation with CDFG. (The habitat criteria curves must use the same substrate and cover coding system as the hydraulic modeling.) The systems incorporated elements from previous studies done for CDFG, plus techniques used in numerous previous TRPA studies.

In the field, substrate was visually inspected and described on a cell by cell basis using a 15-class, 4-category substrate descriptor similar to that used by Smith and Aceituno (1987). This method was based upon the volumetric percentages of dominant substrate, subdominant substrate, and substrate in the class adjacent to the dominant substrate; and percent fines. The coding was based on particle sizes, divided into a modified Wentworth scale:

Code	Substrate Size Class and Size Range
1	Organic debris or vegetation
2	Mud or soft clay (<0.002")
3	Silt (<0.002")
4	Fine sand (0.002"-0.1")
5	Coarse sand (0.1"-0.25")
6	Small gravel (0.25"-1.0")
7	Medium gravel (1.0"-2.0")
8	Large gravel (2.0"-3.0")
9	Small cobble (3.0"-6.0")
10	Medium cobble (6.0"-9.0")
11	Large cobble (9.0"-12.0")
12	Small boulder (12.0"-24.0")
13	Medium boulder (24.0"-79.0")
14	Large boulder (>79.0")
15	Bedrock or hardpan

At the time field data was collected, it was not known which substrate coding system might be most appropriate and ultimately used in the modeling. To ensure that adequate information was collected to allow for translation into one of several potential coding systems, the data recorded for each cell consisted of six descriptors: 1) dominant substrate size class, 2) percent of substrate within the dominant size class, 3) subdominant substrate size class, 4) percent of substrate within the subdominant size class, 5) substrate size class most prevelant and adjacent in size (larger or smaller) to dominant (and not the subdominant), and 6) percent of substrate size class adjacent to dominant. From this information numerous final coding systems could be derived, including the Bovee system of dominant, adjacent substrate size, and percent adjacent, the Brusven system of dominant, subdominant, and percent fines (where significant), the TRPA system of dominant, subdominant, and percent dominant, and others.

For the habitat index analysis, data were translated into the less-complex Bovee code because using the 15-class descriptor to generate habitat criteria curves from field observations would have required hundreds more data points over the range of different substrate type mixes. The criteria curves generated in the Species Habitat Criteria portion of this study (TRPA 1998b) were developed using the 15-class substrate descriptor and similarly translated to the Bovee code. This method of substrate coding (Bovee 1978) uses a single digit (corresponding to particle size) and a decimal (corresponding to abundance). The two-digit code describes the mixture of the two adjacent-sized particle classes which dominate a particular cell by assigning the number (1 through 8) of the smaller-diameter size class to the digit place and the volumetric percentage (0 through 9 for 0% to 90%) of the larger-diameter size class to the decimal place.

Substrate Size Code	Substrate Size Range
1	Organic debris or vegetation
2	Mud or soft clay (<0.002")
3	Silt (<0.002")
4	Sand (0.002"-0.25")
5	Gravel (0.25"-3.0")
6	Cobble/Rubble (3.0"-12.0")
7	(>12.0")
8	Bedrock

Cover Data Collection and Coding

Four separate components of cover were evaluated for each PHABSIM cell (and used to develop the habitat criteria curves for cover). These components were depth cover, overhead cover, turbulence cover, and object cover. The first three components were primarily intended to describe the level of protection from terrestrial or aerial predation. The object cover component describes protection from aquatic predation and the use of velocity shelters as feeding stations. The rating is 0 if no protection is provided, 1 if partial protection is provided, and 2 for full protection.

This rating was interpreted as follows for the four components of cover. Depth cover was rated as 0 for depths less than 0.75 feet, as 1 for depths between 0.75 and 1.49 feet, and as 2 for depths equal or greater than 1.5 feet. Overhead cover (objects above, but within two feet of, the water surface) was rated as 0 for no overhead cover, 1 for partial shading of the water surface, and 2 for full shading of the water surface. Turbulence cover was rated as 0 for no visibility limitation due to turbulence, as 1 for roiling currents that distort the stream bottom, and as 2 for entrained air that obscure the stream bottom. Object cover (i.e. cobble, boulders, organic debris, undercut banks) were rated as 0 for no protection from velocity or predators, 1 if some cover is available but not abundant or close, and 2 if cover is abundant and close. Cover was recorded in the field for each cell by type (object cover, overhead cover, depth cover, and turbulence cover) and by rating for each type (no cover, partial cover, and full cover).

The data collected under this method were adaptable to a system previously used by CDFG (Smith and Aceituno 1987), to the TRPA system as used in several studies, or to other potential alternative systems. Based upon observations made during the development of the criteria curve portion of the studies (TRPA 1998b), these values were interpreted into the model with a new system. If a cell was field rated as containing *any* level of object cover it was assigned *full* cover, while a cell not containing object cover, but containing any level of the three remaining cover types (or no cover at all), received a rating of *partial* cover.

Hydraulic Model Calibration

Raw field data on water depths and surface elevations were transcribed from the data sheets for the three full sets of depth and velocity measurements, along with any additional stage/discharge measurements obtained during the field effort. Elevations referenced to an arbitrary benchmark were developed for every station along every transect. The elevations and point velocities from the three flows were entered into the PHABSIM IFG4 hydraulic simulation model for initial calibration.

The goal in calibration is to achieve a "reasonable" simulation over a range of flows, with compromises as necessary at the calibration flow to achieve more realistic results at other flows. The process is subjective and different modelers may be satisfied with slightly different methods. In the final computation of a habitat index, such detailed modifications typically have little practical effect.

Calibration modifications were limited in this study to linearizing log-log stage-discharge relationships and improving flow-velocity relationships within cells. The standard procedures of calibration modification for stage-discharge included adjusting water surface elevations, hydraulic controls, and best estimates of discharge within the range of measured data. Graphics software was used in the evaluation of the log-log stage-discharge relationships.

Cell velocity calibration modifications were limited to allowing occasional edge cell velocities to "float" with a specified water velocity of zero, specifying a near-zero water velocity where no detectable velocity was observed, taking the absolute value of some cell velocities (necessary when negative velocities are predicted), and removing the angular component of any velocities that were not perpendicular to the transect, after linear stage/discharge relationships had been established. All of these modifications allowed the model to better simulate velocities over a wider range of flows. All calibration modifications made to the original data set have been recorded and are available in project files.

The three-flow velocity regression method, together with the one-flow option of the IFG4 model, was employed in this study to simulate depths and velocities at those transects where individual cell velocities were measured (all but deep pool). Three separate composite data sets of the field data were created (three-flow, one-flow high, and one-flow low). The three-flow data set was used for interpolation between the lowest and the highest measured flows, the low-flow one-flow data set was used for simulations to extrapolate from the lowest measured flow down to 40% of the lowest measured flow, and the high-flow one-flow data set was used for extrapolation from the highest measured flow up to 250% of the highest measured flow.

In several transects, the bottom profile was found to have changed between the three field measurements. Although the changes that occurred were not sufficient to invalidate the stage/discharge relationship for the transect, they necessitated that the transect be evaluated with three one-flow calibrations with three different bottom profile sets.

The IFG4 model with the option to simulate velocity based on depth was used on the deep pool transects where cell velocities were not measured due to great depth and very low water velocity. With this option velocities are simulated by allowing discharge to be distributed across all cells on the basis of depth and a fixed Manning's n roughness value.

Computer simulations were performed with the IFG4 hydraulic simulation model and the habitat (HABTAT) model of the USFWS Physical Habitat Simulation System (PHABSIM). The TRPA PHABSIM microcomputer software, version 5-1 of October 1985, as written by the USFWS and translated to microcomputer by TRPA, was used for all computations. This microcomputer version of PHABSIM is identical to the mainframe programs and has been verified as accurate against the USFWS version on the Control Data Corporation Cyber Series computer at Humboldt State University, Arcata, California.

The velocity adjustment factors (VAFs; indicators of simulation quality and the range of flows over which extrapolation is acceptable) were generated for each simulated discharge from the ratio of the simulated discharge to the discharge resulting from predicting velocities using the roughness factors obtained at the calibration flow. (At the calibration flow, the VAF should be approximately 1.0, except in deep pool transects where the IFG4 model was used in no-velocity mode. No standard is set for velocity adjustment factors in this mode.) The VAF compensates for the effect of changing roughness with changing flow by increasing or decreasing simulated velocities so that the flow calculated from initial roughness values equals the simulated flow.

Habitat Criteria Selection

Habitat criteria curves for depth, velocity, substrate and cover for chinook salmon (fall and spring fry, and fall and spring juvenile) and rainbow trout (fry, juvenile, and adult) were developed specifically for the study area in Task 2 of the studies (TRPA 1998b). Other criteria curves were taken from the literature; rainbow trout spawning; winter steelhead fry, juvenile, and spawning; and spring chinook spawning curves were taken from Bovee (1978); fall chinook spawning depth and velocity criteria specific to Battle Creek were taken from Vogel (1982), while substrate criteria for spring chinook from Bovee (1978) were used for fall chinook spawning. Smallmouth bass fry, juvenile, adult, and spawning criteria were taken from Edwards, et. al (1983). Sacramento squawfish criteria for juvenile and adult lifestages were taken from Moyle and Baltz (1985). Appendix A contains the criteria curve data used in this analysis.

Development of WUA-Discharge Relationships

Curves of WUA vs. discharge were generated for each reach (or subreach) using HABTAT with the approved criteria curves and transect weightings. The WUA index was computed with the standard option (multiplication of each variable's suitability), and without velocity scanning (testing for adjacent velocity differentials). These results were generated only for the fish species inhabiting each stream reach. Under some circumstances, although the habitat may be appropriate for a certain species, it may not be available given certain flow conditions, fish ladder operations, etc. (TRPA 1998c). Fish habitat was modeled for those reaches that were appropriate but may not always be accessible to that particular species. Conversely, if habitat was not appropriate even though accessible, it was not modeled. For example, Sacramento squawfish habitat was not simulated for the Bailey reach of the North Fork of Battle Creek because no squawfish have ever been observed there (TRPA 1998d) and the habitat is not likely to be suitable for squawfish (cold water, high elevation).

Two methods were used to deal with significant changes in flow within a study reach. Major tributaries or diversions required dividing a reach into subreaches and developing separate WUA-discharge relationships for the subreaches. In reaches with smaller rates of accretion, the WUA-discharge results were adjusted if necessary to reflect the effect of flow accretion. As discussed above ("Transect Weighting"), all transects from a reach were used, with separate weightings, to simulate habitat both upstream and downstream of a point of accretion. For example, if the upper end of the Bailey Reach were at a level of 43 cfs, approximately 4 cfs accretion entered the stream midway between the middle and upper study sites, resulting in an observed flow of 47 cfs in the Middle and Lower Bailey study sites. Therefore, weighted results (based upon distance represented) from a modeled flow of 43 cfs for the habitat units upstream of the accretion point were combined with results from a modeled flow of 47 cfs for habitat units downstream. This approach was used to account for flow accretion, rather than assuming that flows are uniform throughout the stream reach, an assumption which would make habitat simulations inaccurate. All subreaches and accretion points are identified below under "Results, Habitat Mapping".

RESULTS

The habitat mapping data (*.MAP files), the species criteria curves (file BATFISH.COD, Appendix A), and the IFG4 data decks (*.IFG) used in the analysis for all study reaches are presented on magnetic media and accompany this report. This will allow reanalysis of any reach using alternative criteria curves or alternative weighting of transects, should that be necessary.

Habitat Mapping

The following habitat mapping results were used to weight transects in the PHABSIM analysis. They are listed by study reach. Because cascade habitat is not modelable using IFG4, the percent of habitat in each of the other types was calculated without cascades and used to weight transects. Also identified with habitat mapping results are (1) the points of accretion, tributaries, and diversions used to modify the WUA-discharge relationships; (2) the subreaches for which the WUA-discharge relations were calculated separately due to major changes in flow; and (3) the study site locations (study sites are described in detail below under "Transect Selection").

1) Battle Creek Mouth Study Reach

A total of 32,162 feet (6.09 miles) of stream were habitat mapped on 10/26/88 to 10/27/88, yielding the following breakdown of habitat types. (No habitat modeling was done for this reach.)

Macrohabitat Type	Total Linear Distance	% of Reach	% of Reach Without Cascades
Riffle	7,135’	22.2	22.4
Run/Glide	16,155’	50.2	50.6
Shallow Pool	1,491’	4.6	4.7
Deep Pool	6,752’	21.0	21.2
Pocket Water	377’	1.2	1.2
Cascade	252’	0.8	-
Total	32,162’	100.0	100.0

2) Mainstem Battle Creek Study Reach

A total of 47,855 feet (9.06 miles) of stream were habitat mapped from 8/30/88 to 9/2/88. Approximately 4 cfs enters the mainstem from Baldwin Creek. The WUA was adjusted for this difference, requiring habitat percentages above and below this point to be tallied separately.

Study site and accretion point locations in this reach are:

Site	Location Upstream (Coleman Powrh.=0')
Spawning study site	9,443'
Lower Mainstem study site	3,208'
Middle Mainstem study site	18,424'
Upper Mainstem study site	35,230'
Baldwin Creek accretion	41,593'
North and South fork confluence	47,855'

Habitat types above and below Baldwin Creek are:

Macrohabitat Type	Below Baldwin Total Linear Distance	% of Reach w/o Cascade	Above Baldwin Total Linear Distance	% of Reach w/o Cascade
Riffle	2,915’	7.5	280’	4.8
Run/Glide	9,826’	25.3	1,684’	28.9
Shallow Pool	4,771’	12.3	1,212’	20.8
Deep Pool	10,276’	26.4	1,499’	25.7
Pocket Water	11,100’	28.5	1,161’	19.9
Cascade	2,705’	-	426’	-
Total	41,593’	100.0	6,262’	100.1

3) <u>North Fork Battle - Eagle Study Reach</u>

A total of 28,758 feet (5.45 miles) of stream were habitat mapped from 9/6/88 to 9/8/88. Two subreaches were necessary due to flow changes at the Wildcat Diversion and Eagle Canyon Diversion. Due to the lack of detailed information on the flow contribution of Digger Creek at the upstream end of the reach (Digger Creek to Eagle Canyon Diversion), a habitat index for this short (805') section could not be computed.

Subreach and study site locations are:

Site	Location Upstream (NF & SF conflu.=0')	Subreach
Lower Eagle study site	2,265'	Wildcat
Middle Eagle study site	7,296'	Wildcat
Wildcat Diversion	13,110'	Wildcat
Upper Eagle study site	20,724'	Eagle Canyon
Eagle Canyon Diversion	27,953'	Eagle Canyon
Digger Creek	28,758'	(not modeled)

The habitat types measured in the entire reach are:

Macrohabitat Type	Total Linear Distance	% of Reach	% of Reach Without Cascades
Riffle	1,894'	6.6	7.3
Run/Glide	7,186'	25.0	27.8
Shallow Pool	7,994'	27.8	30.9
Deep Pool	3,405'	11.8	13.1
Pocket Water	5,395'	18.8	20.9
Cascade	2,884'	10.0	-
Total	28,758'	100.0	100.0

Habitat percentages between the confluence of the North and South forks and Wildcat Diversion (Wildcat subreach), and between Wildcat Diversion and the diversion at Eagle Canyon (Eagle Canyon subreach) were summed separately. They are:

Macrohabitat Type	Eagle Subreach Total Linear Distance	% of Subreach w/o Cascade	Wildcat Subreach Total Linear Distance	% of Subreach w/o Cascade
Riffle	1,360’	10.2	534’	4.5
Run/Glide	4,037’	30.2	3,093’	25.9
Shallow Pool	3,885’	29.1	4,083’	34.2
Deep Pool	1,455’	10.9	1,679’	14.1
Pocket Water	2,627’	19.7	2,547’	21.3
Cascade	1,479’	-	1,174’	-
Total	14,843’	100.1	13,110’	100.0

4) North Fork Battle - Digger Study Reach

A total of 22,492 feet (4.26 miles) of stream were habitat mapped on 8/18/88 to 8/25/88. Lack of information on the contribution of Bailey Creek at the upper end of the reach (Bailey Creek to North Battle Feeder Diversion) prevented computation of a habitat index in this approximately 1000’ section. No significant points of accretion or diversion occur within the modeled reach.

The study site locations are:

Site	Location Upstream
	(Digger Ck conflu.=0’)
Lower Digger study site	2,588’
Middle Digger study site	13,424’
Old Digger study site	14,334’
Upper Digger study site	15,680’
North Battle Feeder Diversion	21,449’
Bailey Creek	(not modeled) 22,492’

The habitat types measured in the Digger Reach are:

Macrohabitat Type	Total Linear Distance	% of Reach	% of Reach Without Cascades
Riffle	3,657’	16.3	17.5
Run/Glide	5,871’	26.1	28.1
Shallow Pool	5,372’	23.9	25.7
Deep Pool	2,395’	10.6	11.5
Pocket Water	3,588’	16.0	17.2
Cascade	1,609’	7.2	-
Total	22,492’	100.1	100.0

The following habitat percentages in the modeled reach between the confluence of Digger Creek and the North Battle Feeder were used for transect weighting:

Macrohabitat Type	Total Linear Distance	% of Reach	% of Reach Without Cascades
Riffle	3,654’	16.6	17.8
Run/Glide	5,574’	26.0	27.9
Shallow Pool	5,259’	24.5	26.3
Deep Pool	2,225’	10.4	11.2
Pocket Water	3,362’	15.7	16.8
Cascade	1,465’	6.8	-
Total	21,449’	100.0	100.0

5) North Fork Battle - Bailey Study Reach

A total of 35,134 feet (6.65 miles) of stream were habitat mapped on 9/15/88 to 9/29/88. Flow accretion between the Keswick and Al Smith diversions (a distance of 7,224') is unknown so only that portion of the stream reach between the confluence of Bailey Creek and Keswick Diversion was modeled. An accretion difference of approximately 4 cfs during the low flow period was measured on 5/18/89 between the upper and middle study sites; habitat was modeled separately upstream and downstream of this point.

The study site and accretion point locations are:

Site	Location Upstream (Bailey Ck Conflu.=0’)
Lower Bailey study site	3,660’
Middle Bailey study site	4,607’
Point of accretion	9,737’
Upper Bailey study site	15,025’
Keswick Diversion	27,910’
Al Smith Diversion	(not modeled) 35,134’

The habitat types measured for the entire reach are:

Macrohabitat Type	Total Linear Distance	% of Reach	% of Reach Without Cascades
Riffle	1,788’	5.1	6.7
Run/Glide	2,107’	6.0	7.9
Shallow Pool	6,414’	18.3	23.9
Deep Pool	1,733’	4.9	6.5
Pocket Water	14,760’	42.0	55.1
Cascade	8,332’	23.7	-
Total	35,134’	100.0	100.0

Habitat percentages were tallied above and below the point of accretion between Keswick Diversion and the Bailey Creek confluence:

Macrohabitat Type	Keswick Divr - Accretion Pt. Total Linear Distance	% of Reach w/o Cascade	Accret. Pt. - Bailey Conflu Total Linear Distance	% of Reach w/o Cascd.
Riffle	1,175’	8.5	126’	1.8
Run/Glide	647’	4.9	981’	13.8
Shallow Pool	4,093’	29.5	1,783’	25.0
Deep Pool	780’	5.6	919’	12.9
Pocket Water	7,151’	51.6	3,308’	46.5
Cascade	4,300’	-	2,620’	-
Total	18,173’	100.1	9,737’	100.0

6) North Fork Battle - Reservoirs Study Reach

A total of 64,850 feet (12.28 miles) of stream were habitat mapped on 9/29/88 to 10/27/88. No habitat modeling was done for this reach.

Macrohabitat Type	Total Linear Distance	% of Reach	% of Reach Without Cascades
Riffle	10,052’	15.5	17.4
Run/Glide	7,008’	10.8	12.2
Shallow Pool	16,259’	25.1	28.2
Deep Pool	1,011’	1.6	1.8
Pocket Water	23,322’	36.0	40.4
Cascade	7,198’	11.1	-
Total	64,850’	100.1	100.0

7) South Fork Battle Study Reach

A total of 75,797 feet (14.36 miles) of stream were habitat mapped on 9/9/88 to 9/20/88. An accretion difference of about 15 cfs during low flow was measured on 6/8/89 at Soap Creek between study sites 8 and 10. Since flow changes within this reach also occur at the Coleman Diversion and the Inskip Diversion, three different subreaches were used in the analysis, and habitat was weighted separately upstream and downstream of Soap Creek.

Study site and flow change sites are:

Site	Location Upstream (NF & SF conflu.=0')	Subreach
Spawning study site	10,697'	Coleman
South Fork 2 study site	12,100'	Coleman
Coleman Diversion	13,423'	Coleman
South Fork 4 study site	19,677'	Inskip
South Fork 6 study site	28,831'	Inskip
Inskip Diversion	42,045'	Inskip
South Fork 8 study site	45,970'	South Diversion
Soap Creek accretion point	61,471'	South Diversion
South Fork 10 study site	71,372'	South Diversion
South Diversion	75,797'	South Diversion

The habitat types for the entire reach are:

Macrohabitat Type	Total Linear Distance	% of Reach	% of Reach Without Cascades
Riffle	5,824'	7.7	8.8
Run/Glide	6,582'	8.7	9.9
Shallow Pool	16,061'	21.2	24.1
Deep Pool	11,836'	15.6	17.8
Pocket Water	26,263'	34.6	39.4
Cascade	9,231'	12.2	-
Total	75,797'	100.0	100.0

The habitat weightings for each subreach are (habitat weights are also separated for upstream and downstream of Soap Creek in the South Diversion subreach):

Macrohabitat Type	Coleman Subreach Total Linear Distance	% of Subreach w/o Cascade	Inskip Subreach Total Linear Distance	% of Subreach w/o Cascade
Riffle	1,147’	9.2	1,077’	4.3
Run/Glide	1,458’	11.6	2,334’	9.2
Shallow Pool	4,537’	36.2	6,599’	26.1
Deep Pool	1,419’	11.3	4,692’	18.6
Pocket Water	3,971’	31.7	10,535’	41.7
Cascade	891’	-	3,385’	-
Total	13,423’	100.0	28,622’	99.9

Macrohabitat Type	South Divr. Subreach Below Soap Ck Total Linear Distance	% of Subreach w/o Cascade	South Divr. Subreach Above Soap Ck Total Linear Distance	% of Subreach w/o Cascade
Riffle	2,394’	14.3	1,206’	10.0
Run/Glide	2,289’	13.6	501’	4.2
Shallow Pool	2,532’	15.1	2,393’	19.9
Deep Pool	4,023’	24.0	1,702’	14.2
Pocket Water	5,550’	33.1	6,207’	51.7
Cascade	2,638’	-	2,317’	-
Total	19,426’	100.1	14,326’	100.0

Transect Selection

For each study reach, the PHABSIM hydraulic transects were placed as follows. (Study site locations were identified in the previous section and in Figure 1. The actual location of each transect in each study site is documented in the following section, along with the weighting factors.)

1) Battle Creek Mouth Study Reach - No transects.

2) Mainstem Battle Creek Study Reach

Transects were placed in randomly selected habitat units in three sites. The first of these sites is upstream of the Coleman Powerhouse approximately 0.5 miles at the lower end of the study reach. This study site is referred to as the Lower Mainstem Study Site and contains eleven transects. The second study site is approximately 3.5 miles upstream from Coleman Powerhouse. This site is identified as the Middle Mainstem Study Site and contains nine transects. The third site is approximately 6.5 miles upstream from Coleman Powerhouse. This site is identified as the Upper Mainstem Study Site and contains nine transects. In addition to the first four transects of the Lower Mainstem Study Site, three supplemental transects were selected to represent spawning habitat approximately 2 miles above the Coleman Powerhouse.

3) North Fork Battle - Eagle Study Reach

In the Eagle Reach of the North Fork of Battle Creek, transects were placed in the randomly selected habitat units in three study sites. The first of these sites is approximately 0.4 miles upstream of the North Fork and South Fork confluence, at the lower end of the study reach. This study site is referred to as the Lower Eagle Study Site and contains nine transects. The second study site, approximately 1.4 miles upstream from the confluence, is identified as the Middle Eagle Study Site and also contains nine transects. The third site is approximately 4.0 miles upstream from the confluence and is identified as the Upper Eagle Study Site and contains ten transects. In addition, two supplemental transects were selected for spawning: the first within the Lower Eagle site and the second 0.8 miles above the North Fork and South Fork confluence.

4) North Fork Battle - Digger Study Reach

TRPA completed a previous instream flow study on this reach. It was agreed during scoping to use the previous study and to add some new transects in the assessment of this study reach. Three new study sites were randomly selected for transect placement. The first of these sites is approximately 0.5 miles upstream of the Digger Creek confluence, at the lower end of the study reach. This study site is referred to as the Lower Digger Study Site and contains seven transects. The second site, approximately 2.6 miles upstream from the confluence, is identified as the Middle Digger Study Site and contains seven transects. The third study site is approximately 3.0 miles upstream from the confluence and is identified as the Upper Digger Study Site and contains six transects. The previously completed study included fourteen transects, most in proximity to the Middle Digger Study Site. No spawning transects were selected.

5) North Fork Battle - Bailey Study Reach

Transects were placed in the randomly selected habitat units in three study sites. The first of these sites is approximately 0.7 miles upstream of the Bailey Creek confluence, at the lower end of the study reach. This is referred to as the Lower Bailey Study Site and contains seven transects. The second site is approximately 0.9 miles upstream from the confluence and is identified as the Middle Bailey Study Site, containing seven transects. The third study site is approximately 2.8 miles upstream from the confluence and is identified as the Upper Bailey Study Site, with eight transects. No supplemental transects were selected for spawning.

6) North Fork Battle - Reservoirs Study Reach - No transects.

7) South Fork Battle Study Reach

Transects were placed in the randomly selected habitat units in five study sites. The first of these is approximately 2.3 miles upstream of the North and South Fork confluence, at the lower end of the study reach. This site is referred to as South Fork 2 Study Site and contains three transects. The second is approximately 3.7 miles upstream from the confluence and is identified as the South Fork 4 Study Site and contains eight transects. The third site, approximately 5.5 miles upstream from the confluence, is identified as the South Fork 6 Study Site and contains six transects. The South Fork 8 Study Site is approximately 8.7 miles upstream from the confluence and contains six transects. The South Fork 10 Study Site is approximately 13.5 miles upstream from the confluence and contains five transects. In addition, three supplemental transects were selected for use in modeling spawning and to augment the other 28 transects.

Transect Weighting

The weighting factors for the transects, as calculated from habitat mapping results, are presented for each study reach or subreach, including upstream and downstream of accretion points where appropriate. The location of each transect is also presented, by the study sites that transects were grouped in. The habitat mapping results ("% of Reach") are without cascades. Weightings for spawning are shown only for those transects used to simulate spawning WUA.

1) Mainstem Battle Creek Study Reach

This reach is divided by accretion from the Baldwin Creek tributary. Seven transects were used for spawning habitat analysis, including three that were added specifically for spawning but also used for the rest of the PHABSIM analysis.

Weighting Calculation Below Baldwin Creek Confluence:

Macrohabitat Type	% of Reach	Number of Transects	Transect Weighting by Reach (%)
Riffle	7.5	6	1.25
Run/Glide	25.3	7	3.61
Shallow Pool	12.3	6	2.04
Deep Pool	26.4	6	4.40
Pocket Water	28.5	7	4.08
Cascade	-	0	-
Total	100.0	32	

Weighting Calculation Above Baldwin Creek Confluence

Macrohabitat Type	% of Reach	Number of Transects	Transect Weighting by Reach (%)
Riffle	4.8	6	0.80
Run/Glide	28.9	7	4.12
Shallow Pool	20.8	6	3.46
Deep Pool	25.7	6	4.28
Pocket Water	19.9	7	2.84
Cascade	-	0	-
Total	100.1	32	

Lower Mainstem Study Site Transect Weightings

Transect Number	Location Upstream (Clmn Pwh=0’)	Habitat Type	Below Baldwin Weighting	Above Baldwin Weighting	Spawning Weighting
1	5,895’	Run/Glide	3.61	4.12	14.30
2	5,960’	Riffle	1.25	0.80	14.30
3	2,815’	Riffle	1.25	0.80	14.30
4	2,855’	Run/Glide	3.61	4.12	14.30
5	2,958’	Shallow Pool	2.04	3.46	
6	3,019’	Deep Pool	4.40	4.28	
7	3,119’	Pocket Water	4.08	2.84	
8	3,254’	Pocket Water	4.08	2.84	
9	3,344’	Run/Glide	3.61	4.12	
10	3,507’	Shallow Pool	2.04	3.46	
11	3,602’	Deep Pool	4.40	4.28	

Middle Mainstem Study Site Transect Weightings

Transect Number	Location Upstream (Clmn Pwh=0’)	Habitat Type	Below Baldwin Weighting	Above Baldwin Weighting
12	18,869’	Run/Glide	3.61	4.12
13	18,919’	Shallow Pool	2.04	3.46
14	18,959’	Deep Pool	4.40	4.28
15	18,554’	Pocket Water	4.08	2.84
16	18,224’	Deep Pool	4.40	4.28
17	18,174’	Shallow Pool	2.04	3.46
18	18,125’	Run/Glide	3.61	4.12
19	18,088’	Riffle	1.25	0.80
20	17,888’	Pocket Water	4.08	2.84

Upper Mainstem Study Site Transect Weightings

Transect Number	Location Upstream (Clmn Pwh=0’)	Habitat Type	Below Baldwin Weighting	Above Baldwin Weighting
21	34,790’	Run/Glide	3.61	4.12
22	34,840’	Shallow Pool	2.04	3.46
23	34,864’	Deep Pool	4.40	4.28
24	34,937’	Shallow Pool	2.04	3.46
25	34,986’	Run/Glide	3.61	4.12
26	35,005’	Deep Pool	4.40	4.28
27	35,163’	Pocket Water	4.08	2.84
28	35,415’	Pocket Water	4.08	2.84
29	35,671’	Riffle	1.25	0.80

Mainstem Spawning Transect Weightings

Transect Number	Location Upstream (Clmn Pwh=0’)	Habitat Type	Below Baldwin Weighting	Above Baldwin Weighting	Spawning Weighting
1	9,605’	Pocket Water	4.08	2.84	14.30
2	9,575’	Riffle	1.25	0.80	14.30
3	9,281’	Riffle	1.25	0.80	14.30

2) <u>North Fork Battle - Eagle Study Reach</u>

This reach is divided by the Wildcat Diversion into the Wildcat and Eagle Canyon subreaches. It includes 30 transects, two of which were added specifically for spawning.

Weighting Calculation for Wildcat Subreach

Macrohabitat Type	% of Reach	Number of Transects	Transect Weighting by Reach (%)
Riffle	4.5	5	0.89
Run/Glide	25.9	7	3.70
Shallow Pool	34.2	6	5.70
Deep Pool	14.1	6	2.34
Pocket Water	21.3	6	3.56
Cascade	-	0	-
Total	100.0	30	

Weighting Calculation for Eagle Canyon Subreach

Macrohabitat Type	% of Reach	Number of Transects	Transect Weighting by Reach (%)
Riffle	10.2	5	2.04
Run/Glide	30.2	7	4.32
Shallow Pool	29.1	6	4.85
Deep Pool	10.9	6	1.81
Pocket Water	19.7	6	3.28
Cascade	-	0	-
Total	100.1	30	

Lower Eagle Study Site Transect Weightings

Transect Number	Location Upstream (Conf N&S=0')	Habitat Type	Wildcat Subreach Weighting	Eagle Subreach Weighting
1	1,921'	Run/Glide	3.70	4.32
2	1,927'	Shallow Pool	5.70	4.85
3	1,945'	Deep Pool	2.34	1.81
4	1,992'	Run/Glide	3.70	4.32
5	1,998'	Shallow Pool	5.70	4.85
6	2,012'	Pocket Water	3.56	3.28
7	2,216'	Deep Pool	2.34	1.81
8	2,233'	Pocket Water	3.56	3.28
9	2,610'	Riffle	0.89	2.04

Middle Eagle Study Site Transect Weightings

Transect Number	Location Upstream (Conf N&S=0')	Habitat Type	Wildcat Subreach Weighting	Eagle Subreach Weighting
0	6,930'	Deep Pool	2.34	1.81
1	7,283'	Pocket Water	3.56	3.28
2	7,294'	Riffle	0.89	2.04
3	7,313'	Run/Glide	3.70	4.32
4	7,320'	Shallow Pool	5.70	4.85
5	7,335'	Deep Pool	2.34	1.81
6	7,370'	Pocket Water	3.56	3.28
7	7,626'	Run/Glide	3.70	4.32
8	7,662'	Shallow Pool	5.70	4.85

Upper Eagle Study Site Transect Weightings

Transect Number	Location Upstream (Conf N&S=0’)	Habitat Type	Wildcat Subreach Weighting	Eagle Subreach Weighting
0	20,001'	Deep Pool	2.34	1.81
1	20,072'	Riffle	0.89	2.04
2	20,082'	Riffle	0.89	2.04
3	21,228'	Shallow Pool	5.70	4.85
4	21,255'	Pocket Water	3.56	3.28
5	21,314'	Run/Glide	3.70	4.32
6	21,376'	Pocket Water	3.56	3.28
7	21,414'	Run/Glide	3.70	4.32
8	21,436'	Shallow Pool	5.70	4.85
9	21,446'	Deep Pool	2.34	1.81

Eagle Spawning Transect Weightings

Transect Number	Location Upstream (Conf N&S=0’)	Habitat Type	Wildcat Subreach Weighting	Eagle Subreach Weighting	Spawning Weighting
1	2,093’	Run/Glide	3.70	4.32	50.00
2	4,476’	Riffle	0.89	2.04	50.00

3) <u>North Fork Battle - Digger Study Reach</u>

The Digger reach has 34 transects, including 14 from the previous TRPA PHABSIM study. No transects were used for spawning habitat.

Weighting Calculations

Macrohabitat Type	% of Reach	Number of Transects	Transect Weighting by Reach (%)
Riffle	17.8	6	2.97
Run/Glide	27.9	7	3.98
Shallow Pool	26.3	9	2.92
Deep Pool	11.2	6	1.86
Pocket Water	16.8	6	2.80
Cascade	-	0	-
Total	100.0	34	

Transect Number	Location Upstream (Digger Conf=0’)	Habitat Type	Weighting by Reach (%)
1	10,994’	Riffle	2.97
2	13,847’	Run/Glide	3.98
3	13,851’	Run/Glide	3.98
4	13,873’	Shallow Pool	2.92
5	13,938’	Shallow Pool	2.92
6	13,949’	Riffle	2.97
7	14,094’	Shallow Pool	2.92
8	14,162’	Pocket Water	2.80
9	14,339’	Shallow Pool	2.92
10	14,363’	Run/Glide	3.98
11	14,545’	Shallow Pool	2.92
12	14,570’	Shallow Pool	2.92
13	14,745’	Riffle	2.97
14	14,822’	Run/Glide	3.98

Lower Digger Study Site Transect Weightings

Transect Number	Location Upstream (Digger Conf=0’)	Habitat Type	Weighting by Reach (%)
1	2,414’	Pocket Water	2.80
2	2,503’	Deep Pool	1.86
3	2,582’	Riffle	2.97
4	2,706’	Run/Glide	3.98
5	2,718’	Shallow Pool	2.92
6	2,735’	Deep Pool	1.86
7	2,761’	Deep Pool	1.86

Middle Digger Study Site Transect Weightings

Transect Number	Location Upstream (Digger Conf=0’)	Habitat Type	Weighting by Reach (%)
1	13,706’	Deep Pool	1.86
2	13,664’	Shallow Pool	2.92
3	13,646’	Run/Glide	3.98
4	13,639’	Riffle	2.97
5	13,552’	Pocket Water	2.80
6	13,143’	Deep Pool	1.86
7	13,986’	Pocket Water	2.80

Upper Digger Study Site Transect Weightings

Transect Number	Location Upstream (Digger Conf=0’)	Habitat Type	Weighting by Reach (%)
1	16,159’	Deep Pool	1.86
2	16,117’	Shallow Pool	2.92
3	16,071’	Run/Glide	3.98
4	16,049’	Riffle	2.97
5	15,647’	Pocket Water	2.80
6	15,200’	Pocket Water	2.80

4) <u>North Fork Battle - Bailey Study Reach</u>

This reach is divided by a point of accretion at 9,737' upstream of the Bailey Creek confluence. The reach has 22 transects, none selected for spawning habitat.

Weighting Calculation for Keswick Diversion to Point of Accretion

Macrohabitat Type	% of Reach	Number of Transects	Transect Weighting by Reach (%)
Riffle	8.5	4	2.82
Run/Glide	4.9	3	1.22
Shallow Pool	29.5	6	4.92
Deep Pool	5.6	3	1.87
Pocket Water	51.6	6	8.59
Cascade	-	0	-
Total	100.1	22	

Weighting Calculation for Point of Accretion to Bailey Creek Confluence

Macrohabitat Type	% of Reach	Number of Transects	Transect Weighting by Reach (%)
Riffle	1.8	4	0.59
Run/Glide	13.8	3	3.44
Shallow Pool	25.0	6	4.18
Deep Pool	12.9	3	4.30
Pocket Water	46.5	6	7.75
Cascade	-	0	-
Total	100.0	22	

Lower Bailey Study Site Transect Weightings

Transect Number	Location Upstream (Bailey Conf =0’)	Habitat Type	Keswick Accretion Weighting	Bailey Accretion Weighting
1	3,617’	Pocket Water	8.59	7.75
2	3,638’	Run/Glide	1.22	3.44
3	3,640’	Shallow Pool	4.92	4.18
4	3,649’	Deep Pool	1.87	4.30
5	3,665’	Run/Glide	1.22	3.44
6	3,672’	Pocket Water	8.59	7.75
7	3,702’	Shallow Pool	4.92	4.18

Middle Bailey Study Site Transect Weightings

Transect Number	Location Upstream (Bailey Conf =0’)	Habitat Type	Keswick-Accretion Weighting	Bailey-Accretion Weighting
1	4,529'	Run/Glide	1.22	3.44
2	4,532'	Shallow Pool	4.92	4.18
3	4,541'	Deep Pool	1.87	4.30
4	4,557'	Pocket Water	8.59	7.75
5	4,626'	Pocket Water	8.59	7.75
6	4,651'	Riffle	2.82	0.59
7	4,685'	Shallow Pool	4.92	4.18

Upper Bailey Study Site Transect Weightings

Transect Number	Location Upstream (Bailey Conf =0’)	Habitat Type	Keswick-Accretion Weighting	Bailey-Accretion Weighting
1	14,947’	Riffle	2.82	0.59
2	14,964'	Pocket Water	8.59	7.75
3	14,981’	Shallow Pool	4.92	4.18
4	15,041’	Riffle	2.82	0.59
5	15,045’	Run/Glide	1.22	3.44
6	15,053’	Shallow Pool	4.92	4.18
7	15,067’	Deep Pool	1.87	4.30
8	15,104’	Pocket Water	8.59	7.75

5) South Fork Battle Study Reach

This reach is divided into three subreaches; in addition, accretion from Soap Creek in the South Diversion Subreach results in transects being weighted separately upstream and downstream of this creek. For the Coleman and Inskip subreaches, the 20 transects from study sites South Fork 2, 4, and 6 were used to calculate WUA. For the South Diversion subreach, the 11 transects from study sites South Fork 8 and 10 were used. Therefore, each study site's transects were weighted twice.

Three transects were added for spawning WUA; these were applied to the Coleman and Inskip subreaches.

Weighting Calculations for Coleman Subreach

Macrohabitat Type	% of Reach	Number of Transects	Transect Weighting by Reach (%)
Riffle	9.2	3	3.07
Run/Glide	11.6	5	2.32
Shallow Pool	36.2	5	7.24
Deep Pool	11.3	4	2.83
Pocket Water	31.7	3	10.56
Cascade	-	0	-
Total	100.0	20	

Weighting Calculations for Inskip Subreach

Macrohabitat Type	% of Reach	Number of Transects	Transect Weighting by Reach (%)
Riffle	4.3	3	1.43
Run/Glide	9.2	5	1.84
Shallow Pool	26.1	5	5.22
Deep Pool	18.6	4	4.65
Pocket Water	41.7	3	13.90
Cascade	-	0	-
Total	99.9	20	

Weighting Calculations for South Diversion Subreach below Soap Creek

Macrohabitat Type	% of Reach	Number of Transects	Transect Weighting by Reach (%)
Riffle	14.3	2	7.15
Run/Glide	13.6	3	4.53
Shallow Pool	15.1	2	7.55
Deep Pool	24.0	2	12.00
Pocket Water	33.1	2	16.55
Cascade	-	0	-
Total	100.1	11	

Weighting Calculations for South Diversion Subreach above Soap Creek

Macrohabitat Type	% of Reach	Number of Transects	Transect Weighting by Reach (%)
Riffle	10.0	2	5.00
Run/Glide	4.2	3	1.40
Shallow Pool	19.9	2	9.95
Deep Pool	14.2	2	7.10
Pocket Water	51.7	2	25.85
Cascade	-	0	-
Total	100.1	11	

South Fork 2 Study Site Transect Weightings

Transect Number	Location Upstream (&S Fk Conf =0’)	Habitat Type	Coleman Subreach Weighting	Inskip Subreach Weighting
1	12,072’	Run/Glide	2.32	1.84
2	12,085’	Shallow Pool	7.24	5.22
3	12,127’	Deep Pool	2.83	4.65

South Fork 4 Study Site Transect Weightings

Transect Number	Location Upstream (N&S Fk Conf=0’)	Habitat Type	Coleman Subreach IFG4 Weighting	Inskip Subreach IFG4 Weighting
1	19,149’	Run/Glide	2.32	1.84
2	19,163’	Shallow Pool	7.24	5.22
3	19,212’	Deep Pool	2.83	4.65
4	19,466’	Shallow Pool	7.24	5.22
5	19,478’	Deep Pool	2.83	4.65
6	19,724’	Run/Glide	2.32	1.84
7	19,882’	Riffle	3.07	1.43
8	20,205’	Pocket Water	10.56	13.90

South Fork 6 Study Site Transect Weightings

Transect Number	Location Upstream (N&S Fk Conf=0’)	Habitat Type	Coleman Subreach IFG4 Weighting	Inskip Subreach IFG4 Weighting
1	29,046'	Run/Glide	2.32	1.84
2	29,066'	Shallow Pool	7.24	5.22
3	29,110'	Deep Pool	2.83	4.65
4	28,958'	Shallow Pool	10.56	13.90
5	28,739'	Run/Glide	10.56	13.90
6	28,552'	Riffle	3.07	1.43

South Fork Spawning Transect Weightings

Transect Number	Location Upstream (N&S Fk Conf=0’)	Habitat Type	Coleman Subreach IFG4 Weighting	Inskip Subreach IFG4 Weighting	Spawning Weighting
1	11,303’	Run/Glide	2.32	1.84	33.33
2	10,137’	Riffle	3.07	1.43	33.33
3	10,091’	Shallow Pool	7.24	5.22	33.33

South Fork 8 Study Site Transect Weightings - South Diversion Subreach

Transect Number	Location Upstream (N&S Fk Conf=0’)	Habitat Type	Below Soap Ck IFG4 Weighting	Above Soap Ck IFG4 Weighting
1	46,087’	Run/Glide	4.53	1.40
2	46,130’	Shallow Pool	7.55	9.95
3	46,153’	Deep Pool	12.00	7.10
4	45,938’	Run/Glide	4.53	1.40
5	45,836’	Riffle	7.15	5.00
6	45,790’	Pocket Water	16.55	25.85

South Fork 10 Study Site Transect Weightings - South Diversion Subreach

Transect Number	Location Upstream (N&S Fk Conf=0’)	Habitat Type	Below Soap Ck IFG4 Weighting	Above Soap Ck IFG4 Weighting
1	71,395’	Run/Glide	4.53	1.40
2	71,419’	Shallow Pool	7.55	9.95
3	71,467’	Deep Pool	12.00	7.10
4	71,323’	Riffle	7.15	5.00
5	71,278’	Pocket Water	16.55	25.85

Hydraulic, Substrate, and Cover Data

The depth, velocity, substrate, and cover measurements are recorded in the IFG4 input files submitted on a computer diskette with this report.

A minimum of three complete sets of depths and velocity measurements with some additional stage/discharge data were collected for all transects, except deep pools (Table 1). Data collection for deep pools included measurement of the bottom profile and a minimum of three levels of stage.

Hydraulic Model Calibration

Transect rating curves with mean errors are located in Appendix B. For the 149 study cross-sections, only one had a slope value of 1.94, slightly outside the preferred range of 2.00 to 5.00. All rating curve mean errors were less than the maximum acceptable standard of 10%, with only six slightly more than 5%. The VAFs for all transects at all simulated flows were within acceptable limits for the standard three-flow and one-flow mode IFG4 simulations.

WUA - Discharge Relationships

The WUA in each study reach or subreach was calculated for a range of flows, using the transect weighting factors and habitat criteria described above. The following general results are noted (Figures 2-21; wetted area and weighted usable area by discharge results in tabular form are in Appendix C).

1) <u>Mainstem Battle Creek Study Reach</u>

Rainbow trout fry WUA tends to decrease with an increase in discharge while juvenile and adult WUA maximize with an increase in flow to 24 and 41 cfs, respectively (Figure 2). Rainbow trout spawning habitat maximizes at 61 cfs and slowly decreases thereafter.

Fall/spring chinook salmon fry WUA tends to decrease with an increase in discharge while juvenile WUA climbs sharply with increases in flow to 71 cfs, thereafter WUA falls off (Figure 3). Fall chinook spawning habitat for all transects slowly maximizes to 86 cfs while spring chinook spawning habitat maximizes at 46 cfs and slowly decreases thereafter. Fall chinook spawning habitat derived from only those designated as spawning transects reaches a maximum in the range of 100 to 105 cfs (Figure 4).

Smallmouth bass fry and juvenile habitat decrease with an increase in flow, while adult WUA reaches a peak at 18 cfs and decreases as flow increases in excess of that amount (Figure 5). Spawning maximizes at a flow of 91 cfs, thereafter decreasing.

Sacramento squawfish juvenile habitat decreases with any increase in flow modeled, while adult WUA has bimodal peaks with the greater at 66 cfs and the secondary peak at a flow of 136 cfs (Figure 5).

2) <u>North Fork Battle - Eagle Study Reach</u>

Wildcat Subreach

Rainbow trout fry habitat generally decreases with an increase in discharge, while juvenile WUA is at a maximum at 18 cfs and adult WUA at 30 cfs (Figure 6). Spawning habitat area is at a maximum at 30 cfs.

Steelhead fry WUA peaks at a flow of 12 cfs while juvenile habitat maximizes at 30 cfs and steelhead spawning at 60 cfs (Figure 6).

Fall/spring chinook salmon fry WUA tends to decrease with an increase in discharge above 6 cfs, while juvenile habitat optimizes at 40 cfs (Figure 7). Fall chinook salmon spawning utilizing all transects peaks in the 40 to 45 cfs range while spring chinook salmon spawning peaks at 25 cfs.

Fall chinook salmon spawning using only the two transects specifically selected for spawning yielded bimodal results with the lesser peak occurring in the 18 to 20 cfs range and greater peak at 180 cfs (Figure 4).

Sacramento squawfish fry WUA maximizes at a flow of 6 cfs while adult habitat increases slowly to 40 cfs and generally maintains at this level with any increase in discharge (Figure 8).

Eagle Canyon Subreach

Rainbow trout fry habitat generally decreases with an increase in discharge, while juvenile WUA maximizes in the 16 to 18 cfs range and adult WUA at 30 cfs (Figure 9). Spawning habitat area is also at a maximum at 30 cfs.

Steelhead fry WUA peaks at a flow of 12 cfs while juvenile habitat maximizes at 30 cfs and steelhead spawning at 60 cfs (Figure 9).

Fall/spring chinook salmon fry WUA tends to decrease with an increase in discharge above 6 cfs, while juvenile habitat optimizes at 40 cfs (Figure 10). Fall chinook salmon spawning utilizing all transects peaks at 40 cfs while spring chinook salmon spawning peaks at 25 cfs.

3) North Fork Battle - Digger Study Reach

Rainbow trout fry WUA tends to decrease with an increase in discharge while juvenile and adult WUA maximize at 17 and 25 cfs, respectively (Figure 11). Rainbow trout spawning habitat slowly maximizes at 60 cfs and slowly decreases thereafter.

Steelhead fry WUA peaks at a flow of 25 cfs while juvenile habitat maximizes at 45 cfs and spawning peaks in the 100 to 120 cfs range (Figure 11).

Fall/spring chinook salmon fry WUA tends to decrease with an increase in discharge above 7 cfs, while juvenile habitat optimizes at 50 cfs (Figure 12). Fall chinook salmon spawning utilizing all transects peaks at 80 cfs while spring chinook salmon spawning peaks at 60 cfs.

4) North Fork Battle - Bailey Study Reach

Rainbow trout fry WUA tends to slowly decrease with an increase in discharge while juvenile and adult WUA slowly maximize with an increase in flow to 10 and 25 cfs, respectively (Figure 13). Rainbow trout spawning habitat slowly maximizes at 66 cfs and slowly decreases thereafter.

Steelhead fry WUA peaks at 10 cfs while juvenile habitat maximizes at 26 to 31 cfs and steelhead spawning reaches the maximum WUA at 46 cfs (Figure 13).

5) South Fork Battle Study Reach

Coleman Subreach

Rainbow trout fry WUA tends to decrease with an increase in discharge while juvenile WUA maximizes with an increase in flow to 25 cfs (Figure 14). The adult habitat to flow relationship is bimodal with the maximum WUA at 65 cfs being slightly greater than at 35 cfs. Rainbow trout spawning habitat maximizes at 80 cfs.

Steelhead fry WUA peaks at a flow of 20 cfs while juvenile habitat maximizes at 45 cfs and steelhead spawning at 120 cfs (Figure 14).

Fall/spring chinook salmon fry WUA tends to decrease past 10 cfs while juvenile WUA climbs sharply with increases in flow to a peak at 55 cfs (Figure 15). Fall chinook spawning habitat for all transects slowly maximizes at 90 cfs while spring chinook spawning habitat maximizes at 50 to 55 cfs and slowly decreases thereafter. Fall chinook spawning habitat derived from only those designated as spawning transects quickly reaches a pronounced maximum at 80 cfs (Figure 4).

Sacramento squawfish juvenile habitat reaches a maximum value at 18 cfs and slowly decreases with any increase in flow modeled. Adult WUA is bimodal with the smaller of the two peaks at 30 cfs and with the greater at 70 cfs (Figure 16).

Inskip Subreach

Rainbow trout fry WUA tends to decrease with an increase in discharge while juvenile WUA maximizes with an increase in flow to 25 cfs (Figure 17). Adult rainbow trout habitat is slightly bimodal and peaks first at 40 and then at 65 cfs. Rainbow trout spawning habitat versus flow relationship is also bimodal and maximizes at 60 cfs and then 80 cfs and slowly decreases thereafter.

Steelhead fry WUA peaks at a flow of 18 cfs while juvenile habitat maximizes at 40 cfs and steelhead spawning at 120 cfs (Figure 17).

Fall/spring chinook salmon fry WUA tends to decrease with an increase in discharge above 10 cfs, while juvenile habitat optimizes at 55 cfs (Figure 18). Fall chinook salmon spawning utilizing all transects peaks at 80 cfs while spring chinook salmon spawning peaks in the 40 to 45 cfs range. Both spawning indices decrease slowly at flows above the optimum.

Sacramento squawfish juvenile habitat reaches a maximum value at 18 cfs and slowly decreases with any increase in flow modeled. Adult habitat is bimodal with the smaller of the two peaks at 30 cfs and with the greater at between 90 and 100 cfs (Figure 19).

South Diversion Subreach

Rainbow trout fry WUA tends to decrease with an increase in discharge. Juvenile WUA maximizes in the 10 cfs to 20 cfs range; thereafter, WUA falls off only slightly (Figure 20). Adult rainbow trout habitat peaks at 30 and thereafter remains almost flat. Rainbow trout spawning habitat versus flow relationship maximizes at 75 cfs.

Steelhead fry WUA peaks at a flow of 15 cfs while juvenile habitat maximizes at 30 cfs and steelhead spawning at 105 cfs (Figure 20).

Fall/spring chinook salmon fry WUA tends to decrease with an increase in discharge above 6 cfs, while juvenile habitat optimizes at 45 cfs (Figure 21). Fall chinook salmon spawning utilizing all transects peaks at 75 cfs while spring chinook salmon spawning peaks at 65 cfs.

DISCUSSION

The WUA curves for the fish species and life stages of concern in Battle Creek illustrate how aquatic habitat varies with discharge. Complete interpretation of the results requires integration with stream hydrology to account for water availablilty over time, with water quality parameters such as temperature to evaluate potential limits to cold or warm water species distribution, and with fish species life stage periodicity to evaluate WUA for appropriate periods of the year.

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