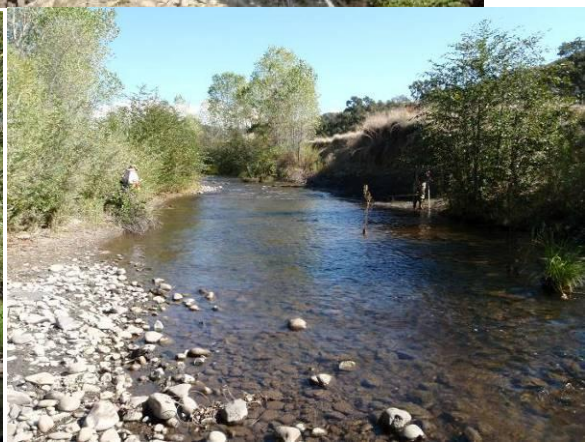
Clover Creek Habitat Assessment

August 2012



Department of Water Resources Fish Passage Improvement Program

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Introduction

The California Department of Water Resources (DWR) Fish Passage Improvement Program (FPIP) completed a stream habitat assessment on approximately eight miles of Clover Creek in 2008-2011. Information was collected to characterize the type of habitat that exists upstream of Millville Diversion Dam (MDD). The MDD, built in the 1920's, is a structural barrier to upstream anadromous fish migration. The habitat assessment was completed between the MDD and Clover Creek Falls, a 150 ft tall natural waterfall barrier located approximately ten miles upstream of the dam. This project was funded by the California Department of Fish and Game (CDFG) (Ecosystem Restoration Program Contract Agreement E1083004) to assist in their decision-making process regarding the proposed effort to provide anadromous fish access to habitat upstream of the MDD.

Watershed Description

Clover Creek (8-digit Hydrologic Unit Code: 18020118) is one of five major tributaries to Cow Creek and is located in Shasta County at the northern end of California's Central Valley. Clover Creek is 27.5 miles long. There is approximately 10 miles of stream between Clover Creek Falls and the MDD, although only approximately eight miles were assessed due to access constraints. The Clover Creek watershed originates at Clover Mountain (elevation: 5,500 feet) and drains approximately 54 mi^2 (~35,000 acres) or 13% of the Cow Creek watershed. Clover Creek does not currently have a stream gauge to monitor hydrometric measurements of water surface elevation (stage) and volumetric discharge (flow). However, a regression analysis was developed by the U.S. Fish and Wildlife Service to estimate Clover Creek flows (USFWS 2009) and is discussed further in the 'Methods' section of this report.

Land use within the watershed is largely characterized by three main types: agriculture/grazing, commercial forest, and rural residential. Land use adjacent to the portion of Clover Creek assessed in this report (lower watershed) consists primarily (>70%) of agriculture/grazing. Upper watershed land use is primarily characterized by agriculture/grazing and commercial forest used for timber harvesting (see Figure 3-1 in SHN 2001). There are 23 diversion points in the Clover Creek System; the majority existing in the upper half of the watershed and above Clover Creek Falls (see Figure 5-9 in SHN 2001). Clover Creek water quality is listed by the U.S. Environmental Protection Agency (EPA) and the California State Water Resource Control Board as impaired for pathogens. The leading cause of impairment is bacteria and the most probable source(s) contributing to impairment is listed as agriculture/grazing (USEPA 2004). Water temperature has been identified as a limiting factor to Chinook salmon and Central Valley steelhead abundance in the Cow Creek watershed (SHN 2001). Impaired water quality combined with elevated water temperatures can have a major effect on the ability of a stream to provide adequate habitat for spawning and early juvenile rearing, as well as disrupt migration routines. High water temperatures have primarily been observed in the lower reaches of Cow Creek tributaries and are likely a function of higher air temperatures occurring at lower elevations combined with reduced flows from diversions and land use, introduction of tailwater returns, and reduced riparian canopy (Hannaford 2000, SHN 2001).

Clover Creek is located within the geographical boundaries of National Marine Fisheries Service (NMFS) designated critical habitat for Central Valley steelhead. Central Valley steelhead are listed as threatened under the federal Endangered Species Act (ESA). Although the percentage of Central Valley steelhead utilizing Clover Creek is unknown (SHN 2001), Clover Creek is currently listed by the NMFS as Central Valley steelhead spawning grounds (NMFS 2009). Cow Creek watershed's annual steelhead spawning population was estimated in 1965 to be approximately 500 steelhead, although current populations are expected to be much lower (SHN 2001). Current steelhead populations have not been estimated, and it is unknown how many steelhead return to Clover Creek each year. The migration period of Central Valley steelhead[1] into the Cow Creek watershed has not been determined but is typically dependent on increasing flows during the late fall and winter from November – February (SHN 2001).

In addition to Central Valley steelhead, two runs of Chinook salmon (fall run, late-fall run) are known to spawn in Clover Creek[2] (CBDP 2000). Both runs are ESA listed species of concern and California State Species of Concern. Data related to Chinook spawning and population estimates within the Cow Creek watershed are very limited (SHN 2001). However, recent observations of fall run Chinook spawning below the MDD verify salmonids are returning to Clover Creek to spawn (Jensen et al. 2012). The migration period of fall run and late-fall run Chinook salmon occurs from June – December and October-April, respectively, with peak migration occurring in September - October and December, respectively (Yoshiyama, Fisher, Moyle 1998). The fall-run and late-fall run spawning period occurs from late September – December and early January – April, respectively, with peak spawning occurring in October– November and February – March, respectively.

Regulatory Background

Restoring and establishing available critical habitat for salmonid migration, spawning, and rearing are essential components of the (NMFS) recovery strategy to reverse trends towards extinction.

> *"Critical habitat for listed salmonids is comprised of physical and biological features essential to the conservation of the species including: space for the individual and population growth and for normal behavior; cover; sites for breeding, reproduction and rearing of offspring; and habitats protected from disturbance or are representative of the historical geographical and ecological distribution of the species. The primary constituent elements considered essential for the conservation of listed Central Valley salmonids are: (1) freshwater spawning sites; (2) freshwater rearing sites; (3) freshwater migration corridors; (4) estuarine areas; (5) nearshore marine areas; and (6) offshore marine areas" (NMFS 2009, p.18-19).*

The CALFED Bay-Delta Program (CALFED) includes a programmatic element, the Ecosystem Restoration Program Plan (ERPP) that identifies several ecological management zones. Clover Creek is within the

[1] Steelhead can be classified into two races, winter and summer steelhead, depending on migration timing. Only winter steelhead occur in the Sacramento River tributaries and mainstem. However, due to genetic modification and the influence of water temperature and flow impacts, Central Valley steelhead can currently be found in fresh water year-round (SHN 2001).

[2] The Cow Creek watershed is not part of the present range and distribution of spring and winter run Chinook salmon, although spring run may have been part of the historic distribution and range (SHN 2001). In addition, Clover Creek conditions are not suitable for late-fall run Chinook to finish their rearing through the summer months. However, they likely spawn in Clover Creek when conditions are suitable and migrate to the Sacramento River to rear when conditions in Clover Creek become unfavorable (A. Jensen, pers comm).

Cow Creek Ecological Management Unit (EMU), a subunit of the Northern Sacramento Valley Ecological Management Zone (CBDP 2000). The *ERPP Final Programmatic EIS/EIR Technical Appendix* summarizes the restoration vision for Clover Creek including "reducing adverse effects of timber harvest, erosion, and cattle grazing on the stream and riparian system and maintaining or restoring stream flows during important periods of the year to allow fish migration, spawning, and rearing of fall run Chinook salmon and steelhead trout" (CBDP 2000, p. 197). The Clover Creek habitat assessment was funded by Propositions 50 and 84 and addresses ERP Goals 1 and 3 (ERPP Year 12 Annual Report, July 2011).

The Cow Creek watershed is also identified in the Central Valley Project Improvement Act (CVPIA) (USFWS 1992), and the CVPIA Anadromous Fish Restoration Program (AFRP) has restoration objectives for the watershed (USFWS 2001). A primary goal of the CVPIA and AFRP is to double natural production of anadromous fish populations in California's Central Valley rivers on a long-term sustainable basis (Section 3406(b)(1)] of the CVPIA, USFWS 1992). Pursuant to this goal, the U.S. Fish and Wildlife Service (USFWS) and CDFG are examining opportunities to increase Chinook salmon and steelhead populations throughout the northern Sacramento River valley. Although accurate counts are not available, it is believed that current salmonid populations are far below historic numbers (NMFS 2009, Yoshiyama 1998). According to the CDFG, the Cow Creek watershed has the potential to support 5,000 to 10,000 fall-run Chinook salmon, and a minimal number of steelhead (SHN 2001).

Project Objectives and Methods

A current project proposal to modify the MDD and its associated siphon would allow upstream migration and access to an additional 10 miles of Clover Creek. The habitat assessment of those additional 10 stream miles is useful in: characterizing existing habitat conditions, quantifying the abundance and quality of habitat, and identifying limiting factors and opportunities for restoration. The FPIP task objectives and survey methods used to conduct the Clover Creek habitat assessment are discussed below.

Objectives

The Clover Creek habitat assessment objectives can be found in Task 2 of the Ecosystem Restoration Program Contract Agreement Number E1083004.

1. Complete stream habitat assessments on eight miles of Clover Creek upstream of the Millville Diversion and downstream of Clover Creek Falls.
2. Summarize habitat data in report form.
3. Produce Geographic Information System (GIS) maps to summarize and quantify habitat types.

The objective of the stream habitat assessment was to identify habitat types and characterize habitat conditions for target species (Chinook salmon and Central Valley steelhead). Characterization of those habitat conditions was guided by and limited to the parameters described in the "Stream Habitat Classification and Inventory Procedures for Northern California" (McCain et al. 1997, Appendix A), while an additional protocol (Appendix B) created by the United States Forest Service (USFS) guided applied methods. The purpose of this habitat assessment and report is not to provide information related to the feasibility of modifying the MDD or associated actions but to summarize habitat data describing the stream reach above the MDD (see Objective 2). Likewise, the assessment does not include a detailed

Clover Creek watershed assessment or specify restoration actions, although observations are detailed that may assist stakeholders in identifying and prioritizing restoration opportunities.

Methods

Methods used to meet each objective are discussed below. The protocols that guided habitat data collection were determined in collaboration with USFWS and CDFG staff and are identified in ERP Contract Agreement Number E1083004, Task 2.

Objective 1. Complete stream habitat assessments on approximately eight miles of Clover Creek upstream of the Millville Diversion Dam and downstream of Clover Creek Falls.

Stream Habitat Assessment Timing and Locations

Stream habitat assessments of approximately eight miles of Clover Creek were conducted during the following time periods: November 5, 19-21 in 2008, October 7-8 in 2009, August 8-11, 22-25, October 4, 19, 26-27 in 2011. The broad range of time between survey efforts was due to changes in project personnel, funding availability, and weather conditions. Although the majority of stream habitat between Clover Creek Falls and the MDD was assessed, approximately two miles of stream adjacent to the Shufelberger property was not assessed because landowner access was not provided (see Appendix E, Figure A for assessment location).

Estimation of Clover Creek Flows

While there are no stream gauges and detailed history of flow measurements on Clover Creek, a regression analysis was conducted by the USFWS to estimate Clover Creek flows (USFWS 2009). The USFWS collected flow measurements in 2008-2011, which were used to develop flow regression equations correlated to the Cow Creek United States Geological Survey (USGS) gauge near Millville, California (#11374000). Regression analysis was used to estimate Clover Creek flows on the dates of the assessment and are available in Table 2.

Protocols and Sampling Methods

Defining the number and type of habitat units in a reach is important to understanding the type of habitat available to salmonids (e.g., pools offer holding and early juvenile rearing habitat). Habitat typing gives information on the sequence, distribution, and availability of habitat. The United States Forest Service's technical bulletin *Stream Habitat Classification and Inventory Procedures for Northern California* (McCain et al. 1990) classifies 22 (common to Northern California) habitat types according to channel morphology within three main units (categories) that proceed from shallow to deep water: riffles, runs, and pools (Appendix A). During the 2008 surveys, field personnel encountered many low gradient areas consisting primarily of swift moving water flowing over shallow bedrock substrate and therefore recorded an additional habitat type termed bedrock sheet (BRS). These habitat areas had been scoured of all complex substrate (e.g., sand, gravel, cobble, boulders); otherwise they would have been most similar to low gradient riffle (LGR) habitat types. In order to categorize the entire stream reach into three habitat categories and for data comparability and analysis purposes, all BRS types (14 total occurrences) were relabeled as LGR habitat types and compose 10% of all riffle habitat types.

Important habitat variables such as instream cover (canopy, large woody debris), substrate composition, flow, riparian vegetation and condition, and water quality are limiting factors that have major implications on the quality and functional value of a stream reach as salmonid habitat (Kerwin 2001, NMFS 1996). The Klamath National Forest Aquatic Habitat Assessment Protocol FY93 (Appendix B) was used to collect data on several important habitat variables. Additional data was collected at pools only (per protocol guidance). Table 1 shows the habitat variables and the lateral location of assessment within the stream channel.

TABLE 1. SPATIAL LOCATION OF HABITAT ASSESSMENT WITHIN THE CHANNEL

Habitat	***Habitat Variables***	***Lateral Channel Location of Variable Assessment***
All Habitat Types	Habitat Type Length, exposed bedrock %, gravel substrate[3] area	Wetted Perimeter
	LWD, gravel substrate area (ocular estimate)	Bankfull Perimeter
Pools	Maximum depth, riffle crest depth, in-stream cover, cover/habitat complexity	Wetted Perimeter
Index Reaches	Mean bankfull width/depth, substrate composition, cobble embeddedness %, shade %, exposed bedrock %	Bankfull Perimeter
Index Reaches: Riffles and Pool Tail-outs only	Fines %	Bankfull Perimeter

Eight "index" reaches were selected in order to conduct a more detailed assessment of Clover Creek habitat. Index reach length was determined based upon the average bankfull channel width at that location (*index reach length = average bankfull width (rounded to nearest ft) x 10*). Due to time and shoreline access constraints, each mile of stream between Clover Creek Falls and MDD was not represented by detailed index reach assessments. Within the eight index reach assessments conducted, ten evenly spaced transects were delineated perpendicular to the stream channel and spanned the channel's bankfull width. Detailed assessment methods can be found in Appendix B. Canopy closure (closure density over the stream or shade) percentages were estimated using a spherical densitometer along transects. Data collection and analysis of canopy closure followed riparian habitat evaluation methods developed by Platts et al. (1987).

Objective 2. Summarize habitat data in report form.

Descriptive statistics were used to characterize the type, frequency, and proportion of habitat types and to summarize important habitat variables found within index reaches. To gain a more accurate perspective of in-stream habitat proportion and distribution, stream and habitat type length were used to calculate most descriptive statistics. Habitat type occurrence values were also provided for general

[3] Gravel substrate was measured within the wetted perimeter in all habitat types. Outside the wetted perimeter, field personnel also recorded ocular estimates of gravel substrate area occurring within the bankfull channel. These additional gravel estimates are discussed in the 'Results' section of this report and can be found in Figure 7. Gravel within the bankfull channel represents gravel potentially available for recruitment or for utilization by spawning salmonids at higher flows than those estimated to occur on assessment dates.

information purposes. Residual pool depth values were obtained by subtracting riffle crest depth from maximum pool depth.

Objective 3. Produce Geographic Information System (GIS) maps to summarize and quantify habitat types.

Base maps of the Clover Creek watershed were created with Esri ArcGIS v. 10.1 Geographic Information System (GIS) software using spatial data layers that show: USGS 7.5 topographic maps, Shasta County assessor's parcel data, the USGS National Hydrography Dataset, and 2010 aerial photographs from the USDA National Agriculture Imagery Program (NAIP). Global Positioning System (GPS) units were used to record locations of waypoints that were used in mapping habitat types.

A line shapefile layer representing Clover Creek was digitized from a NAIP 2010 base map. In reaches where shoreline tree cover on the aerial imagery made it difficult to accurately digitize the stream channel, USGS topographic quadrangles were used for increased precision. A dynamic segmentation process based on habitat unit lengths recorded on data sheets, combined with GPS waypoints collected in the field, was used to assign habitat types and categories to the Clover Creek line. A subset of GPS waypoints was used to verify the accuracy of the dynamic segmentation process.

Results and Discussion

Estimation of Clover Creek Flows

Estimated Clover Creek flows on the survey dates are given in Table 2. Throughout the assessment, Clover Creek flow rates allowed clear identification of habitat types and safe field assessment conditions. Even though low flows can create difficulties in differentiating habitat types, habitat assessments were able to be completed by observing channel characteristics such as shape/slope, residual depth, and substrate. Stream flows ranged from 15.8 cubic feet per second (cfs) to 25.4 cfs and were sufficient for identification of habitat types. The estimated flows and assessment dates shown in Table 2 are significant because several assessments occurred during the peak spawning period (Oct-Nov) for fall-run Chinook salmon and in the earliest steelhead migration window. Therefore, the habitat conditions witnessed in October and November are a snapshot of flow and habitat conditions that spawning fall-run Chinook salmon would experience. In fact, on October 19, 2011, fall-run Chinook salmon were observed spawning 50 ft downstream from the MDD (Jensen et al. 2012) at an estimated 22.7 cfs (Table 2).

TABLE 2. ESTIMATED DAILY AVERAGE CLOVER CREEK FLOWS ON ASSESSMENT DATES

Assessment Date	***Clover Creek Flows (cfs) ****
Nov 5, 2008	25.4
Nov 19, 2008	19.3
Nov 20, 2008	19.3
Nov 21, 2008	19.4
Oct 7, 2009	15.6
Oct 8, 2009	15.8
Aug 8, 2011	21.3

Aug 9, 2011	21.1
Aug 10, 2011	21.1
Aug 22, 2011	19.9
Aug 23, 2011	19.7
Aug 24, 2011	19.7
Aug 25, 2011	19.7
Oct 4, 2011	20.0
Oct 19, 2011	**22.7**
Oct 26, 2011	21.8
Oct 27, 2011	21.9
*Flows estimated using regression analysis (USFWS 2009).	

Stream Areal Description

The total length of stream surveyed including all side channels and intermittent channels was approximately 42,934 ft (8.13 mi) (Table 3). Average bankfull width was 45 ft (13.82 m) (n=19), with a range of 20 - 88 ft. Mean channel slope was 1.5% (n=15) with a range from 0.5-5%. Side channel lengths were also measured in the field and represent intermittent channels that are inundated periodically. The side channel measurements are not an estimate of available or potential floodplain habitat. Descriptive statistics are provided for other parameters according to habitat category: riffles, pools, and runs (Table 3).

TABLE 3. HABITAT CATEGORY DESCRIPTIVE STATISTICS

Stream Reach	***Calculation***	***Habitat Type Categories***			***Total***
		Riffles	Pools	Runs	
All Assessed Habitat	Total Length (ft)	10749	4658	27527	42934
	Percent Habitat (%)	25	11	64	100
	Occurrences	138	56	184	378
	Mean Depth (ft)*	0.7	3.3	1.2	n/a
	Mean Depth SE**	0.1	0.2	0.2	n/a
	Wetted Width (ft)	30	30	33	n/a
	Wetted Width SE**	0.1	5.8	2.3	n/a
Side Channels	Total Length (ft)	1747	1166	668	3581
Index Reach Habitat Types	Total Number Assessed	10	1	16	27

*Mean Depth was calculated at every 5th habitat category encountered.
**SE (Standard Error of the Mean=Sample estimate of population standard deviation/sqrt(n)

Habitat Types

Out of a possible 22 habitat types described in the habitat typing protocol *Stream Habitat Classification and Inventory Procedures for Northern California*, 18 were observed during the stream habitat assessment. The occurrence of habitat types and their relative proportion (by stream length) within each habitat category are provided in Table 4 (also see Figure 1).

TABLE 4. HABITAT TYPE OCCURRENCE AND HABITAT CATEGORY LENGTH PROPORTION					
Habitat Category	***Habitat Type***	***Acronym***	***Occurrence***	***Percent Occurrence***	***Category Proportion (Length)****
Riffles	Low Gradient Riffles**	LGR	130	34	0.96
	High Gradient Riffles	HGR	3	1	0.03
	Cascade	CAS	5	1	0.01
	TOTAL RIFFLES	**--**	**138**	**36**	**1**
Pools	Secondary Channel Pool	SCP	13	3	0.21
	Backwater Pool Root Wad Formed	BWPr	2	1	0.02
	Backwater Pool Log Formed	BWPl	1	0	0.01
	Plunge Pool	PLP	5	1	0.05
	Lateral Scour Pool Root Wad Formed	LSPr	6	2	0.10
	Lateral Scour Pool Bedrock Formed	LSPbe	3	1	0.03
	Dammed Pool	DPL	3	1	0.15
	Mid Channel Pool	MCP	18	5	0.37
	Channel Confluence Pool	CCP	2	1	0.03
	Lateral Scour Pool Boulder Formed	LSPbo	1	0	0.02
	Corner Pool	CRP	1	0	0.01
	Trench / Chute	TRC	1	0	0.01
	TOTAL POOLS	**--**	**56**	**15**	**1**
Runs	Glides	GLD	66	17	0.43
	Run	RUN	89	24	0.36
	Step Run	SRN	29	8	0.21
	TOTAL RUNS	**--**	**184**	**49**	**1**
Total		**18**	**378**	**100**	**3**

*Category Proportion (Length) = Stream length of individual habitat type/total stream length of habitat category (e.g., stream length of low gradient riffles (LGR)/total stream length of all riffles=0.96. I.e., LGR make up 96% of all riffles).
**Low Gradient Riffle occurrence and proportion by length include bedrock sheet (BRS) habitat types.

Habitat type categories consisted of riffles, pools, and runs. Runs comprised the majority of habitat types in the assessed stream reach (64%), while riffles were second (25%) and pools were least represented (11%) (see percent habitat in Table 3). A combination of riffles and runs comprised 89% of the length of assessed stream.

Runs

As the dominant habitat feature, runs were well distributed throughout the assessed portion of Clover Creek (Appendix E, Figure A) and between types of runs (Table 4). Field personnel noted that glides, the predominant type of run habitat, were characterized by very little habitat complexity or features that

would provide in-stream cover (e.g., boulders, whitewater, undercut banks, LWD, terrestrial and aquatic vegetation). Glides were typically shallow with little surface agitation, and substrate was composed primarily of shallow bedrock sheets or lacked more complex substrate composition (e.g., sand, gravel, cobbles, boulders). Glide habitat is not commonly associated with spawning areas, but can be utilized as holding habitat for spawning adults (Bjornn and Reiser 1991).

Bank failures, also known as mass-wasting, landslides, and active bank erosion, were a frequent occurrence on Clover Creek. In 2008, field personnel measured the length of bank failures in the lower 3.1 miles of assessed habitat. Bank failure was evident in 27% of the 3.1 miles of stream where bank failure length was determined (0.84/3.1=27). The bank failures mainly ranged in height from 5 - 25 ft, although a 100 ft high bank failure was observed adjacent to the Oilar property. 85% of the total length of bank failures occurred adjacent to habitat units classified as glides (GLD within the "runs" category) or bedrock sheets (low-gradient riffles absent of all substrate). NMFS provides a streambank stability salmonid habitat condition rating of "poor" for stream reaches that have over 20% actively eroding shoreline (NMFS 1998 as cited in Kerwin 2001). Although stream bank stability and bank erosion were not measured on the higher reaches of Clover Creek, field personnel did note that upstream bank erosion was also significant and frequent.

Riffles

Low-gradient riffles (LGR) made up the majority of riffle habitat (96%). LGR are swift flowing stretches of turbulent water, further characterized by some partially exposed substrate that is usually cobble dominated in stream areas with gradient less than 4% (McCain et al. 1991). These areas deliver food to juvenile salmonids, and surface agitation may provide juvenile salmonids with cover from predators. However, transition of pool habitat into riffle habitat decreases rearing habitat and has been shown to cause a decrease in the relative proportion of older age salmonids (Hicks et al. 1991).

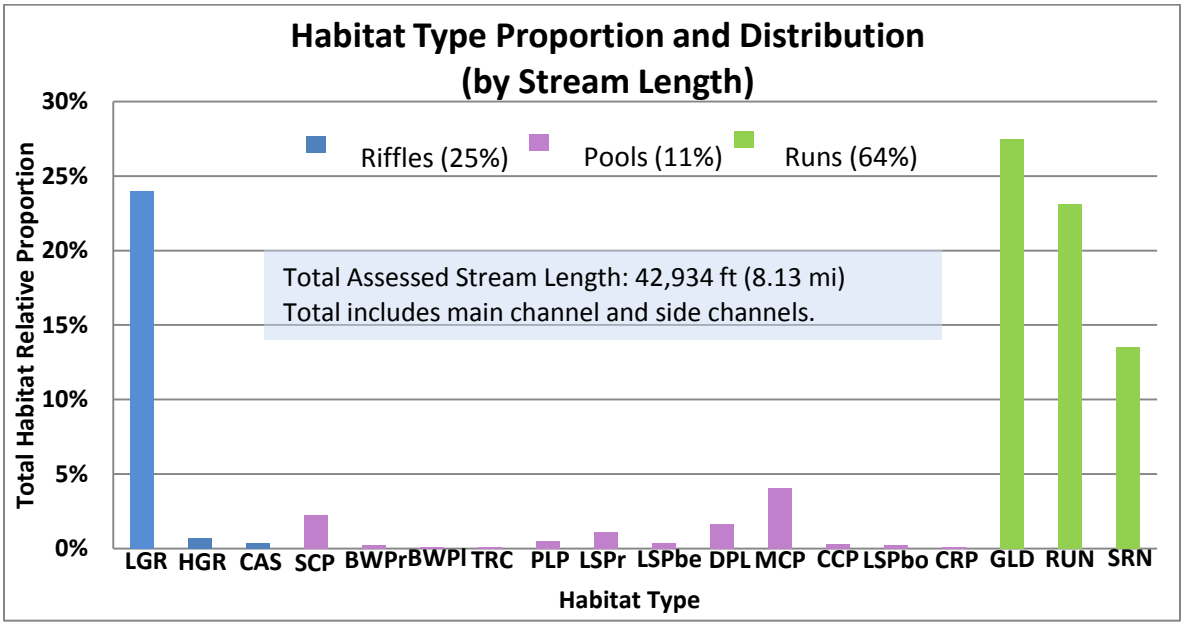

Figure 1. Habitat Type Proportion and Distribution, by Stream Length

Pools

Pools provide early juvenile rearing and holding habitat for salmonids and are an important component of a stream that provides overall high quality salmonid habitat. Generally, streams located in disturbed watersheds (i.e., heavily influenced by watershed land use) have a lower percentage of pool habitat as degradation of stream banks and increased sediment transfer leads to localized aggradation of deep stream areas (Hicks et al. 1991, Lisle 1982). Subsequently, the carrying capacity of rearing habitat for juvenile salmonids may be reduced as pool habitat area decreases (Bjornn et al. 1977 in Ligon et al. 1999).

Distribution

A diversity of pool types is needed to meet the requirements of salmonids at various life stages. In Clover Creek, pool habitat types were not well distributed across the 12 pool habitat types found. 73% of pool types were found in only three pool habitat types (mid-channel (37%), secondary channel (21%), dammed pool (15%) habitat). In contrast, the least represented pool habitat types found were backwater pool - log formed (0.90%), trench/chute (0.86%), and corner pools (1.0%). Backwater pool - boulder formed and lateral scour - log formed pools were not evident in any part of the stream reach surveyed. See Table 4 and Figure 1 for a proportionate distribution between pool types.

The assessed portion of Clover Creek also had a low occurrence frequency of seven pools per mile. The average measured bankfull width of Clover Creek was approximately 45 ft but ranged from 20 - 88 ft. NMFS (1998) recommends an occurrence standard of 26 pools per mile be used to define fair and good salmonid habitat condition in channels that are 50 ft wide. NMFS (1998) recommendations for channels ranging in bankfull width (BFW) from 20 – 100 ft are 56 – 18 pools per mile (56 p/mi: 20 ft BFW; 18 p/mi: 100 ft BFW).

Pool Depth and In-Stream Cover

Standards for pool depth related to properly functioning salmonid habitat conditions are not well defined. NMFS (1998) provides a vague “good” habitat quality standard that requires “sufficient pools with greater than 1 m (3.28 ft) depth with good cover and cool water”. Pool depth is also used as an indicator of channel condition as it is linked to stream bank erosion and subsequent pool aggradation (Kerwin 2001). It should be noted that maximum pool depth is related to water level and changes frequently depending on existing flow conditions. Residual pool depth represents the depth at which a pool would be completely filled but water would not flow past the downstream riffle crest. Residual pool depth is therefore independent of flow and river stage (water level) (Lisle 1987). Both maximum and residual pool depths are given in Figures 2 and 3.

Figures 2-4 are box and whisker plots showing the 25th percentile, median (where the box splits), and 75th percentile with minimum and maximum for residual pool depths and pool in-stream cover values. The majority (75%) of pools in Clover Creek at the time of assessment had a maximum depth greater than 3 ft deep (Figure 2). However, the majority of residual pool depths were below 3.1 ft (Figure 3). One large outlier existed in the pool at the base of Clover Creek Falls. This pool was not assessed, although field personnel said it was probably 6-8 ft deep and on average appeared to be approximately 10-12 ft wide. Of all the pools assessed, field personnel noted this pool would provide excellent habitat

for salmonids as it was well oxygenated, had cool water temperatures, was deep, and had good cover from boulders, whitewater, and other sub-surface features such as bedrock ledges.

Seventy five percent of pools had less than 30% in-stream cover (Figure 4). In-stream cover was determined through ocular estimation of the percentage of the pool that was covered by the following eight in-stream features: undercut banks, small woody debris, large woody debris, terrestrial vegetation, aquatic vegetation, whitewater, boulders, and bedrock ledges.

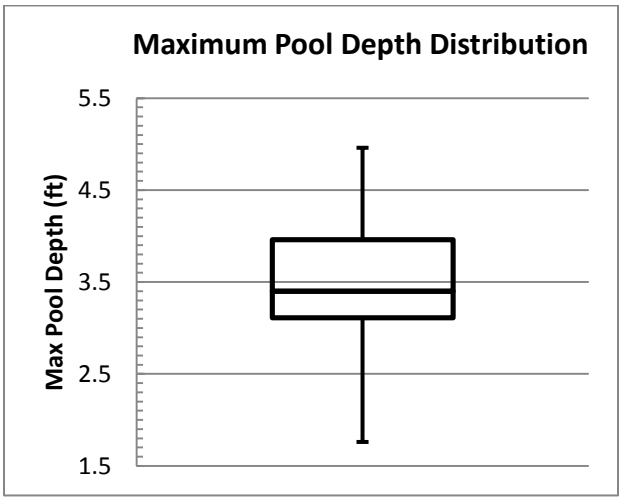

Figure 2. Maximum Pool Depth Distribution

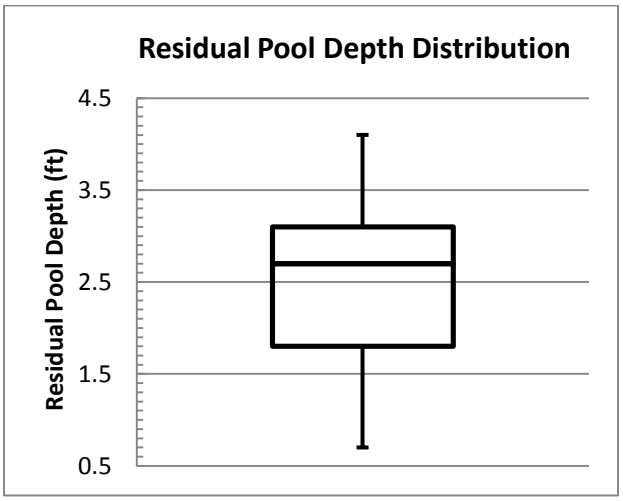

Figure 3. Residual Pool Depth Distribution

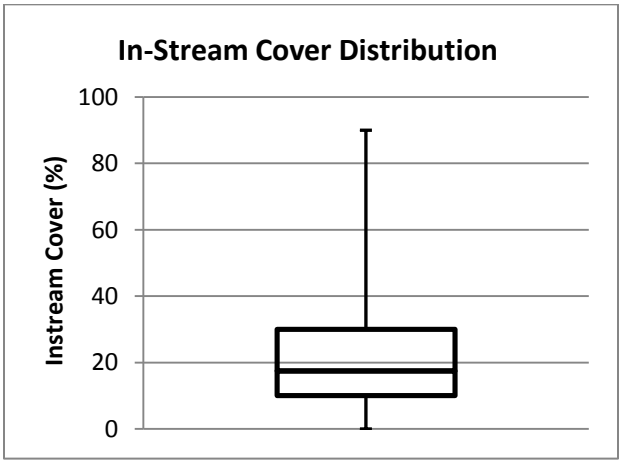

Figure 4. Pool In-stream Cover Distribution

Cover/Habitat Complexity

Pool cover/habitat complexity or the distribution of in-stream cover percentage across multiple features (see Pool Depth and Cover) was categorized into low, medium, and high complexity ratings based on protocol guidance. For example, if a pool only had in-stream cover provided by undercut banks (i.e., one feature), then it was determined to have "low" habitat complexity while a pool with three or more features was rated as having "high" quality habitat complexity. The majority of pools (48%) had medium

cover complexity (two – three features) and 14% had high quality habitat complexity (Figure 5). The majority of complexity consisted of terrestrial vegetation, undercut banks, and boulders.

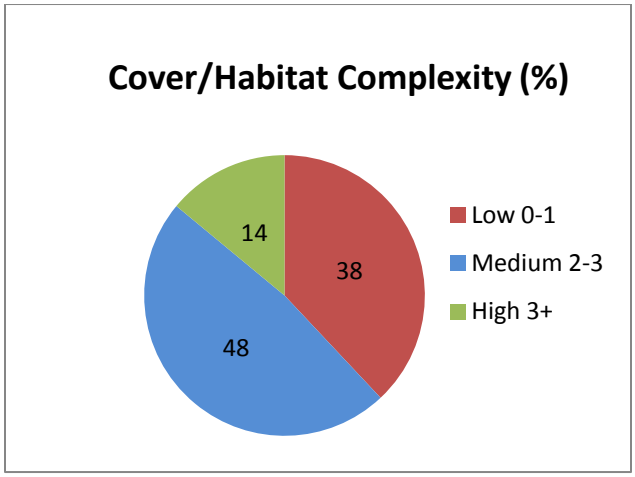

Figure 5. Pool Cover Complexity

Spawning Habitat

Several factors influence successful spawning, incubation, and fry emergence (Ligon et al. 1999). These factors include substrate size composition, the degree appropriately sized substrate are embedded in fine sediments, rate of intergravel flow (or percolation rate of water through the substrate), and water temperature, depth, and velocity. Gravel size substrate is suitable for spawning as it is small enough to be moved in redd creation and allows intergravel flow, providing incubating eggs and alevin with essential elements such as better water quality, dissolved oxygen, and food. If high quality substrate is not available or is embedded, spawning salmon may still spawn and juvenile rearing may occur but there is generally a significant reduction in survival rates due to factors such as entombment (the obstruction of alevin emergence), bacterial growth, and thermal factors (higher water temperatures and decreased dissolved oxygen) (Geist and Dauble 1998).

Spawning Gravel

In this assessment, gravel size substrate was used as a surrogate for spawning habitat availability and was measured within the wetted perimeter at each sampling station throughout the assessed reach. In addition, field personnel noted ocular estimates of gravel patches outside the wetted perimeter but within the bankfull channel. However, this single surrogate should be used with caution in predicting spawning potential as other essential site elements are required by salmonids (e.g., intergravel/hyporheic flow) (Geist and Dauble 1998, Geist et al. 2001). As a result, the area suitable for spawning is generally less than the total area of substrate suitable for spawning in a stream (Bjornn and Reiser 1991). Other predictors of spawning potential were not investigated given project scope and limitations.

Figure 6 shows the sum of area (ft^2) and area per mile within the wetted channel containing gravel sized (protocol size class: 2-64mm) substrate and the distribution of that area between riffles, pools, and runs. This figure represents the gravel potentially available to spawning salmonids at flow conditions on the

survey dates. Figure 7 shows the sum of additional gravel substrate area (ft^2) and area per mile that would be available to salmonids during flow events that would fill the bankfull channel. It also represents gravel with potential for recruitment and transport to suitable spawning areas (e.g., pool tail-outs). This bankfull estimation of gravel sized substrate (Figure 7) was based on ocular estimates from 24 habitat types where field personnel noted additional gravel above the wetted perimeter but within the bankfull perimeter. The amount of additional gravel available within the bankfull channel almost doubles the amount of gravel within the wetted channel alone (i.e., the gravel available at flows between 15-26 cfs). There were also an additional 11 habitat types where surveyors noted gravel recruitment potential but did not specify a quantitative amount. However, we do not know at what flows the bankfull channel would be filled and if high flow events would provide other suitable spawning conditions for targeted salmonids (most likely late-fall run Chinook and steelhead). Potential spawning habitat may be further limited in the context of gravel patch size, location, water temperature, and velocity (Bjornn and Reiser 1991).

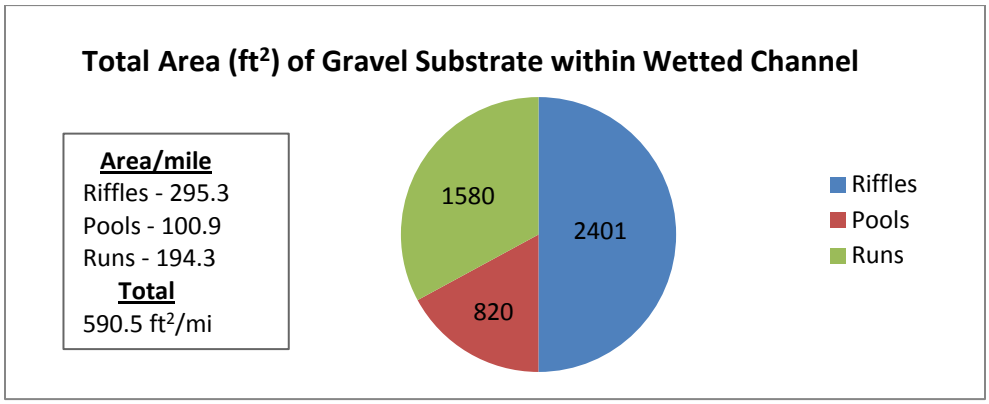

Figure 6. Total Area of Gravel Substrate[4] within Wetted Channel

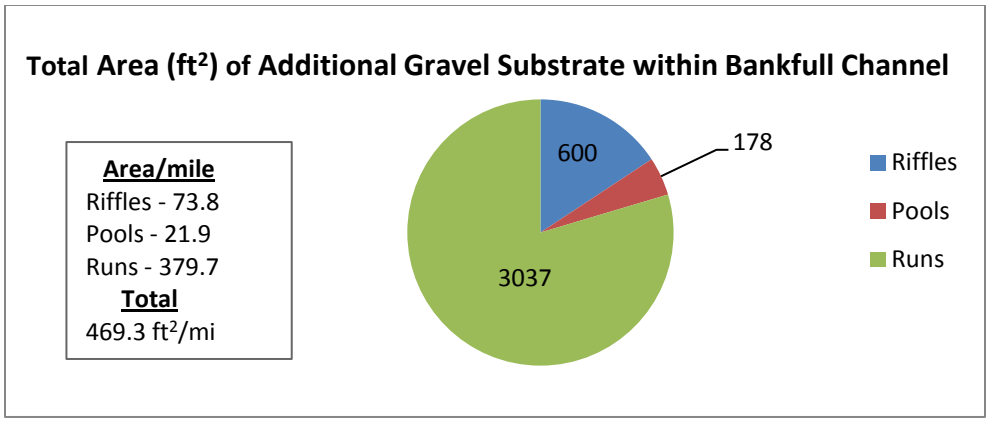

Figure 7. Total Area of Additional Gravel Substrate within Bankfull Channel

[4] In some portions of the wetted channel, gravel was present but not recorded for the following reasons: substantial embeddedness and gravel completely armored with cobbles and larger rocks. However, small amounts of gravel without the previous stated limitations were recorded. These small gravel amounts included gravel found in less than 1 ft^2 aggregation within isolated pockets and between cobbles and boulders (Kleinfelter, J. report draft update).

Spawning Gravel Patch Size

Gravel patch size was measured because spawning Chinook and Central Valley steelhead have patch size requirements for redd construction. Redd size ranges from approximately 0.84-15 m^2 (3-50 ft^2) for Chinook salmon (Burner 1951, Bjornn and Reiser 1991) and 2.4-11.2 m2 (8-37 ft^2) for steelhead (Orcutt 1968, Gallagher and Gallagher 2005). It appears that spawning patch size is heavily dependent on the size of the female (Bjornn and Reiser 1991). Various researchers have observed minimum patch sizes to be in the range of 6-22 ft^2 (Orcutt 1968, Bjornn and Reiser 1991). Burner (1951) recommends a minimum area of 20.1 m^2 (37 ft^2) per spawning pair.

Limited data exists on the size of Chinook and steelhead in the Cow Creek watershed, and the size of spawning salmonids in Clover Creek has not been documented (SHN 2001). Therefore, we chose to focus on patch sizes greater than the smallest patch size (6 ft^2) documented in related literature to estimate the occurrence of gravel patches with potential utility to spawning salmonids. Overall, the vast majority (79%) of habitat did not have any gravel size substrate in patch sizes potentially usable by salmonids[5]. Patch size distribution within the remaining 21% of Clover Creek habitat that contained gravel patches greater than 6 ft^2 can be seen in Figure 8.

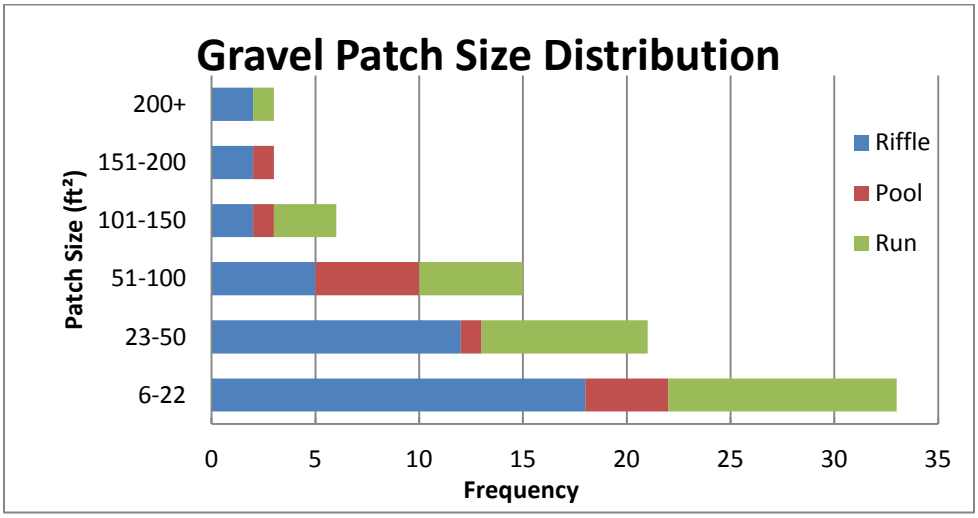

Figure 8. Gravel Patch Size Distribution

Large Woody Debris (LWD)

Large Woody Debris (LWD)[6] was measured and recorded throughout all habitat types. LWD is defined as tree trunks, branches, whole trees, etc. that interact and are generally located within the active stream channel. Scientific literature generally defines LWD minimum size dimensions as wood with a diameter of 4 in and length of 3 ft (Opperman et al. 2006), although various sizes may have different functional roles (e.g., ability to trap sediments, re-shape the channel, and to provide cover, protection, and food

[5] There were eight habitat units that had a gravel patch = 5 ft^2, which were not included. Field personnel noted all gravel recorded in patches of 5 ft^2 did not occur in aggregate (i.e., in a patch) but was distributed throughout the habitat type in small pockets. Also see footnote 4.

[6] Also called Coarse Woody Material (CWM) in the protocol.

for salmonids). Clover Creek's LWD consisted mostly of smaller sized wood (Table 5). Larger (>18in x >24 ft) LWD was not well represented (6% of total LWD) and occasionally existed in aggregate (i.e., logjams or large piles of wood) on the side of the stream channel but within the bankfull extent. The location of LWD within the stream channel suggests large flow events are capable of relocating large wood to the stream's perimeter, thereby reducing its in-stream functional value to salmonids (e.g., creating and backwatering pools, providing complexity and cover). This inference is supported by the low distribution of pool diversity and extremely low occurrence of backwater pools - log formed (less than 1%). Overall, the assessed portion of Clover Creek had 55 single pieces/mile and approximately three pieces in the >18in diameter x >24 ft length size category per mile (sum of the grey cells/8.13 mi). Key pieces that would remain stable either due to location or size were not determined.

TABLE 5. LWD SINGLE PIECE FREQUENCY AND SIZE DISTRIBUTION				
Length	***Diameter***			
	4-18"D	18-24"D	>24"D	Total LWD (row sum)
3 - 24 ft	305	49	10	364
25 - 50 ft	53	17	6	76
>50 ft	2	3	1	6
Total LWD (col sum)	360	69	17	446
LWD/ Mile*	44.3	8.5	2.1	55
*8.13 total miles assessed				

Percent Exposed Bedrock

The percentage of exposed bedrock was estimated in all habitat categories throughout the Clover Creek habitat assessment. Table 6 shows the percentage of bedrock that comprised the length of riffles, runs, and pools. These percentages were obtained by dividing the bedrock length (Row 1) by the total length of assessed stream (Row 2). While this information could not be compared against quality standards for salmonid habitat condition, it should be noted that although this is a low-gradient stream, 9% of complex substrate (e.g., sand, gravel, cobbles, boulders) has been scoured away. The amount of total bedrock substrate provided in Table 6 should not be confused with the amount of bedrock estimated within index reaches surveys (Figure 9).

TABLE 6. PERCENTAGE OF BEDROCK SUBSTRATE				
	Riffles	***Runs***	***Pools***	***Total***
Bedrock Length (ft)	751	3039	232	4022
Total Length Assessed Stream (ft)	10749	27527	4658	42934
Percent of Bedrock (%)	7	11	5	9

Index Reaches

A detailed assessment of habitat variables was conducted along ten evenly spaced transects within eight index reaches. A summary of this data can be viewed in Appendix C.

Substrate Size Composition

Pebble counts (n=100) conducted along every other transect (n=5, excluding pools) were used to determine substrate composition size class and distribution within index reaches (n=8) (Figure 9). Also see earlier discussion about Spawning Habitat.

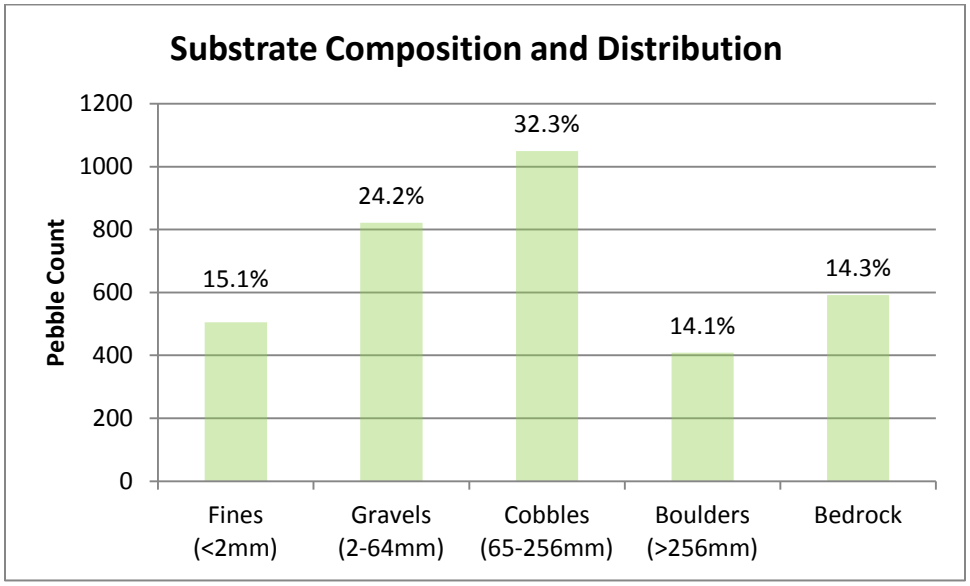

Figure 9. Index Reach Substrate Composition and Distribution

Embeddedness

Embeddedness, a simple but commonly used method for evaluating salmonid spawning habitat quality, was estimated by picking up ten cobble-sized rocks and recording the percentage of rock that was buried in fine sediments. Rocks were chosen at random and were not necessarily in straight line transects. Embeddedness was measured primarily in riffles and pool tail outs occurring within an index reach but was also measured in index reaches B and D, which consisted mostly of run habitat. When more than one riffle or pool occurred in an index reach, embeddedness was measured at each occurrence.

Figure 10 shows embeddedness values in Clover Creek ranged from 10-40%, with an overall average of 25% (pool and run habitat types -average <25%; riffle – 29%; total average – 25%). Cobble embeddedness less than 25% indicates good spawning habitat (CDFG 1998).

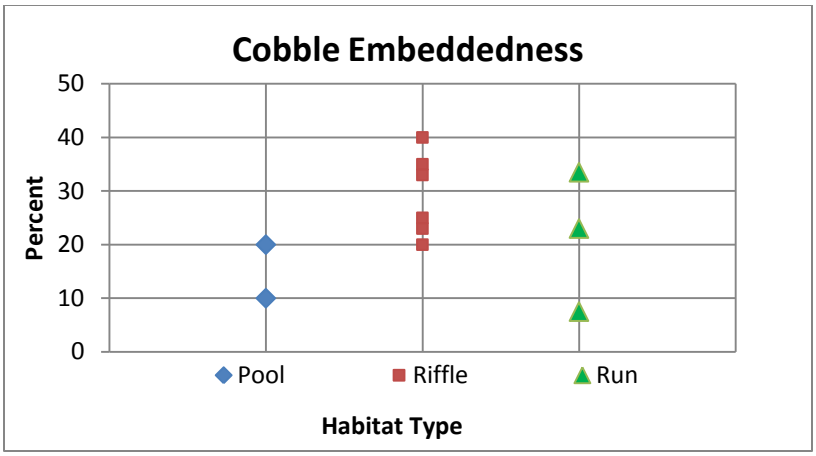

Figure 10. Index Reach Cobble Embeddedness

Fines

The percentage of fines in gravel substrates has a limiting effect on intergravel flow and subsequently the amount of gravel suitable for spawning (Healey 1991). The average percentage of fine sediments found in each index reach can be found in Appendix C. Overall, the highest percentage of fines (17.7%) was found in low-gradient riffles in Index Reach B (Appendix C). However, the second highest percentage of fines was 13.3%, two index reaches had a percentage of 0% and 1%, and all other index reaches show a percentage of <12%. According to NMFS' (1996) habitat condition standards, habitat with >17%, 12-17%, <12% of fines (diameter less than 0.85mm) can be rated as poor, fair, and good habitat, respectively (NMFS 1996 in Kerwin 2001). Taking into consideration the substrate size we used (per protocol) to define fine sediment was <2mm (i.e., included sediments >0.85mm and <2mm) and the NMFS standards, fine sediments did not appear to be a limiting factor to Clover Creek's habitat condition. One index reach was in poor condition, one in fair condition, and six in good condition related to fines. It is also logical that fine sediments would not be a limiting factor since coarser substrate is dominant throughout the reach, while smaller substrate (gravel and sand) appears to get flushed downstream during high flow events.

Canopy Cover (Shade)

Mean percent of riparian shade for each index reach (encompassing possibly more than one habitat category) is provided in Appendix C. Shade values range from 26-69% (standard deviation 14.68) out of a possible 100% canopy closure. Thus, it is probable that shade values vary dramatically throughout the entire Clover Creek reach with some areas having poor, fair, and good shade cover depending on the width of riparian buffer.

Summary

DWR FPIP assessed stream habitat on approximately eight miles of Clover Creek to characterize habitat conditions for salmonids. The assessment included describing the type and distribution of habitat units, quantifying the areal extent of gravels and patch sizes suitable for spawning, and gathering data on other factors that impact successful spawning, rearing, and holding, including: cover and habitat complexity, embeddedness, coarse woody material, and percent exposed bedrock.

Overall, runs were the dominant habitat type and pools were the least represented. The majority of pools in Clover Creek were formed by mid-channel scour and lacked sufficient in-stream cover and high habitat complexity. Based on a spawning suitability surrogate of gravel sized substrate presence and patch size greater than 6 ft^2, 79% of Clover Creek habitat did not have gravel size substrate occurring in a patch size potentially large enough to be utilized by a spawning pair of Chinook salmon or Central Valley steelhead. Within the 21% of habitat where gravel did occur in an adequate patch size, additional limiting spawning suitability factors (e.g., intergravel flow) (Geist et al. 2001) were not determined.

At the flows we witnessed during the assessment, there is some potential for gravel recruitment from within the bankfull perimeter (see Figure 7). Above the bankfull perimeter, gravel recruitment appears to be limited and appears to come primarily from stream bank erosion and complete bank failure (i.e., mass-wasting). Detailed assessments in index reaches show that substrate composition is comprised of mainly coarser substrate (>64mm) and 14.3% of the channel bottom had been scoured either down to bedrock or was devoid of other types of substrate (Figure 9). Embeddedness at pool tail-outs (n=2) within the index reaches was below 25% and in the limited sampling size did not appear to be a limiting factor for spawning potential.

This habitat classification information descriptively stratifies Clover Creek habitat units to provide stakeholders with information related to habitat type and conditions for Chinook salmon and Central Valley steelhead upstream of the MDD. This information can also be used to draw attention to the influence of watershed land use on habitat availability and function from the perspective of salmonids that may utilize it in the future. From a systems perspective, inter-related factors such as channel incision, stream bank erosion, loss of habitat complexity, lack of floodplain (lateral) connectivity, changes in peak flow events (i.e., as a result of increased overland flow), and historical or extant watershed use (e.g., timber harvesting, agriculture/grazing) create or exacerbate factors that can limit suitable spawning habitat. These factors combined with natural variation and high flow events appear to play a significant role in the availability and suitability of salmonid habitat in Clover Creek.

Recent observations of fall-run Chinook below the MDD show there are salmonids accessing the Clover Creek system that could potentially utilize any existing habitat above the MDD once access is provided. The results of this habitat assessment do not predict the number of salmonids that could spawn in the limited existing habitat observed. The results and field observations suggest targeted restoration actions would be necessary to improve properly functioning creek processes. Stakeholders could consider actions (e.g. limiting livestock access to reduce erosion, stabilizing eroding shoreline, reconnecting the stream channel to its floodplain) to restore impaired habitat-forming biophysical processes. Restoring biophysical processes may assist in expanding Clover Creek habitat utility and function for salmonids at

various life stages. Identification of the relative importance of factors that limit the amount of properly functioning salmonid habitat (including those not investigated in this assessment) is recommended as an initial planning strategy to prioritize potential habitat restoration opportunities in the Clover Creek watershed. Most of this information can be garnered from a synthesis of existing information including the data derived from FPIP's habitat assessment of Clover Creek, other information related to watershed hydrology and geomorphology (e.g. flood events, channel incision), riparian condition, and watershed land use.

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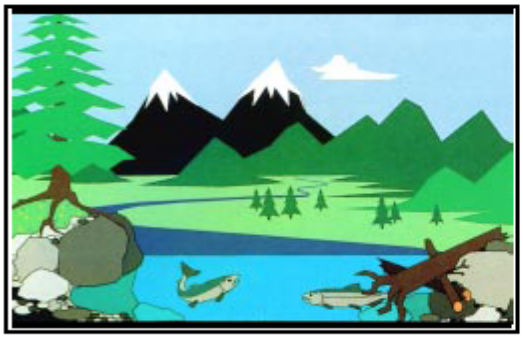
Appendix A. Stream Habitat Classification and Inventory Procedures For Northern California



FHR

CURRENTS...

R-5's FISH HABITAT RELATIONSHIPS TECHNICAL BULLETIN

NUMBER ONE

FHR Currents...Purpose

The Fish Habitat Relationships (FHR) Program of R-5 USFS has been established to research and develop information on fish ecology and to coordinate effective applications of this knowledge in managing and protecting our fisheries. By relating life stage requirements of specific species to physical habitat parameters, we are aiming at our main objective: developing a methodology to manage fisheries through the management of habitat.

STREAM HABITAT CLASSIFICATION AND INVENTORY PROCEDURES FOR NORTHERN CALIFORNIA

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Introduction

The objective of this bulletin is to describe a stream habitat inventory procedure that will classify and quantify fish habitat in terms of channel features. The procedure is based on information gathered in gravel and boulder-bed streams in the western Cascade Mountains of Oregon and Washington and in the Klamath Mountains of California (Bisson et al., 1981; Sullivan, 1986, Grant et al., in review; Decker et al., in progress). A stream habitat inventory as outlined here can give information on the sequence, distribution, and availability of pool, riffle and run habitat units, and yields a graphic picture of the stream channel (Figure 1). Areas which may be limited in terms of specific habitat (spawning, rearing, etc.) can be identified.

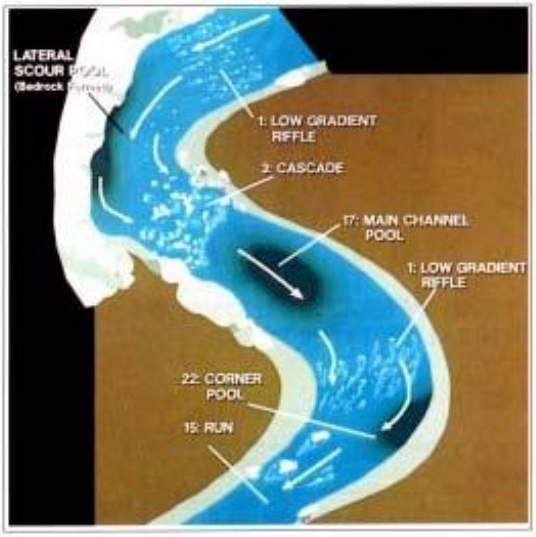


Figure 1. Illustrated above are habitat types in association with channel features such as large boulders, gradient, bedrock and meander.

Present day fishery management is very complex, involving several different agencies, user groups and land managers. While millions of dollars are being spent annually to restore and enhance anadromous fisheries, man's effect on stream habitat is increasing through the ever growing demands on timber, water, and other resources. A key to effectively protecting, maintaining, restoring, and enhancing anadromous fisheries in light of these demands is an understanding of the relationships between physical habitat parameters (e.g. channel morphology) and fish production factors (food and habitat requirements) for all age classes of each species for the duration of stream residency. Habitat requirements of anadromous salmonids rearing in streams are known to differ between species, age classes, and seasons (Everest and Chapman, 1972; Reiser and Bjornn, 1979).

Because of the diversity in management groups, several different habitat survey or assessment techniques are employed in northern California. This lack of standardization complicates the comparison of information between agencies and often creates barriers in developing and implementing efficient management strategies. This bulletin outlines a standardized habitat assessment procedure with built in flexibility to be workable with varying budgets and manpower.

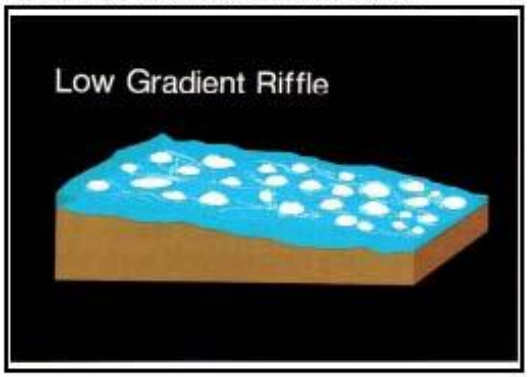
Background

This system of naming habitat is derived from work on stream channel morphology, pool-riffle and step-pool formation, and fish habitat utilization in western Washington and Oregon (Bisson et al., 1981; Sullivan, 1986; Grant et al., in review). The development of pool-riffle or step-pool sequences is a fundamental stream channel process (Ying 1971). These main channel features, along with others fitted by smaller scale local effects (e.g. logjams and slides), can be recognized as distinct channel units or habitat types. A total of 22 habitat types have been identified and delineated in northern California to date as the refinement of the system continues *(figure 2, following pages)*.

Figure 3 illustrates how the 22 types are classified. Three categories (proceeding from shallow to deep water) are riffles, runs and pools. All of the 22 types are members of the 3 main categories. Riffles are differentiated on the basis of water surface gradient. Pools are differentiated at two levels: (1) the position of the pool in the stream channel (secondary channel, backwater, lateral, or main channel), and then (2) the cause of the scour (obstruction, blockage, constriction, or merging flows). Run habitat types have low gradients, and are differentiated on the basis of depth and velocity. The five-pointed star plots of each type in *Table 1* illustrate the ratio of five physical habitat variables (mean depth, width, and length, and area and volume) for Hurdygurdy Creek, California. The eastern of the starplot describes the "mean shape" of the habitat types. Types with similar star plots have similar morphometry.

Generally, a given stream won't contain all 22 habitat types, instead the mix will be dominated by a few habitat types which are reflective of the overall channel gradient, flow regime, cross-sectional profile, and substrate particle site. (Grant et al. in review) found that the mix of habitat types in western Cascade streams with gradients in excess of 2% and large boulder substrate consisted of 4 types: pool, riffle, rapid, and cascade. Bisson et al. (1981) recognized 14 distinct habitat types in small streams with gradients less than 2%. Basins that exhibit a wide range in channel gradient will also have a broad mix of habitat types. Stratifying

Figure 2. List of 22 habitat types in Northern California.

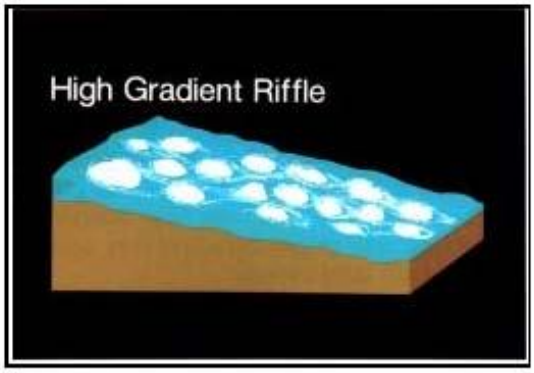


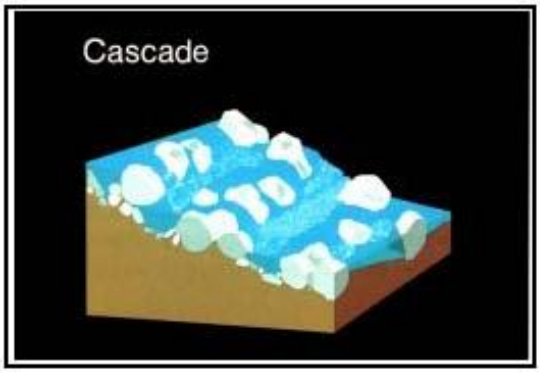
1 -- Low Gradient Riffles "LGR"

Shallow reaches with swiftly flowing, turbulent water with some partially exposed substrate. Gradient <4%, substrate is usually cobble dominated.

2 -- High Gradient Riffles "HGR"

Steep reaches of moderately deep, swift, and very turbulent water. Amount of exposed substrate is relatively great. Gradient is >4%, and substrate is boulder dominated.





3 -- Cascade "CAS"

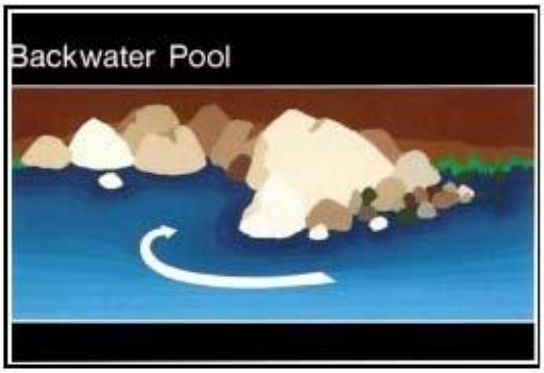
The steepest riffle habitat, consists of alternating small waterfalls and shallow pools. Substrate is usually bedrock and boulders.

4 -- Secondary Channel Pool "SCP"

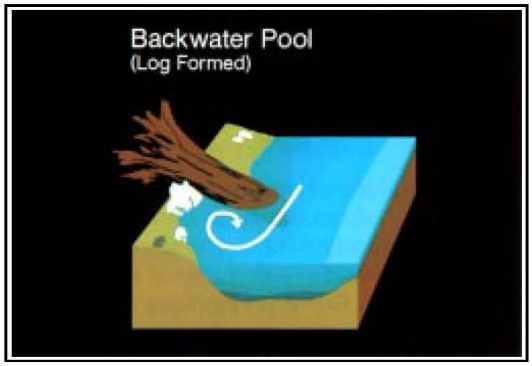
Pools formed outside of the average wetted channel. During summer these pools will dry up or have very little flow. Mainly associated with gravel bars and may contain sand and silt substrates.

5 -- Backwater Pool "BWP" Boulder Formed

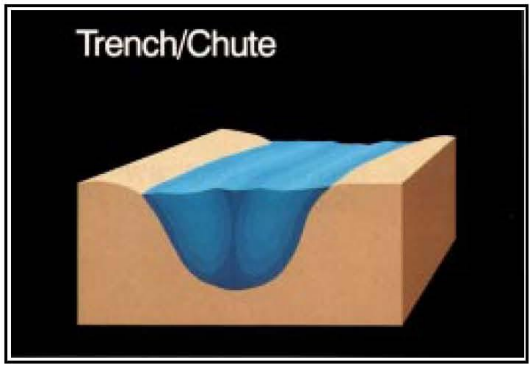
Found along channel margins and caused by eddies around obstructions such as boulders, rootwads, or woody debris. These pools are usually shallow and are dominated by fine-grain substrates. Current velocities are quite low.



6 -- Backwater Pool "BWP" Root Wad Formed



7 -- Backwater Pool "BWP"
Log Formed

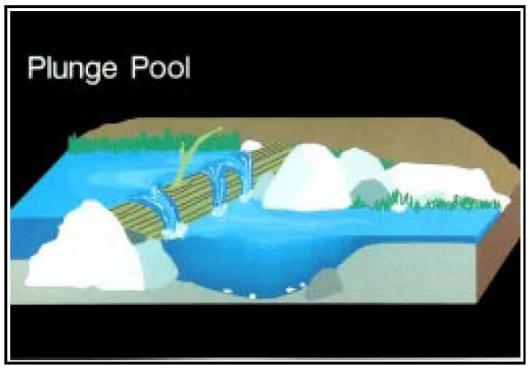


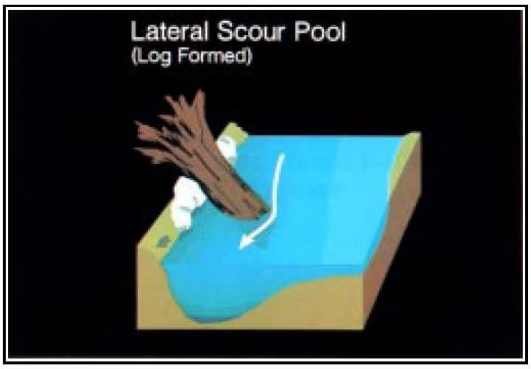
8 -- Trench/Chute "TRC"

Channel cross sections typically U-shaped with bedrock or coarse grained bottom flanked by bedrock walls. Current velocities are swift and the direction of flow is uniform. May be pool-like.

9 -- Plunge Pool "PLP"

Found where stream passes over a complete or nearly complete channel obstruction and drops steeply into the streambed below, scouring out a depression, often large and deep. Substrate size is highly variable.

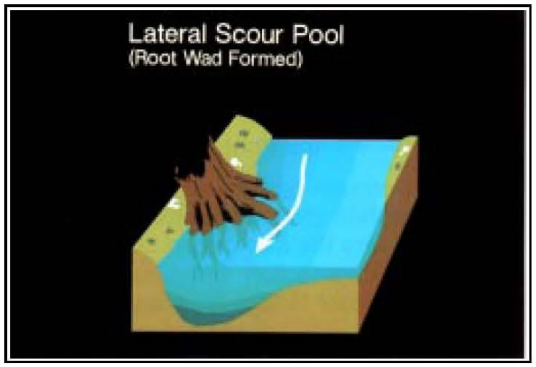




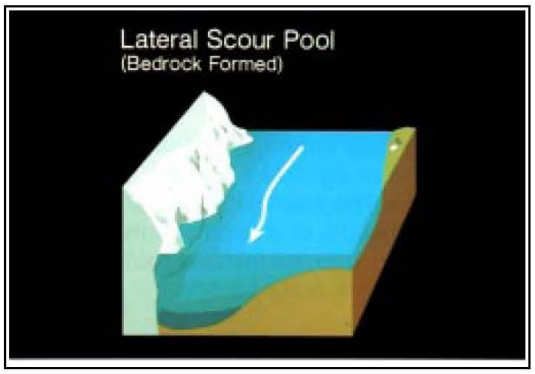
10 -- Lateral Scour "LSP" Log Formed

Formed by flow impinging against one stream bank or against a partial channel obstruction. The associated scour is confined to <60% of wetted channel width. Channel obstructions include rootwads, woody debris, boulders, and bedrock.

11 -- Lateral Scour Pool "LSP" Root Wad Formed



12 -- Lateral Scour Pool "LSP" Bedrock Formed

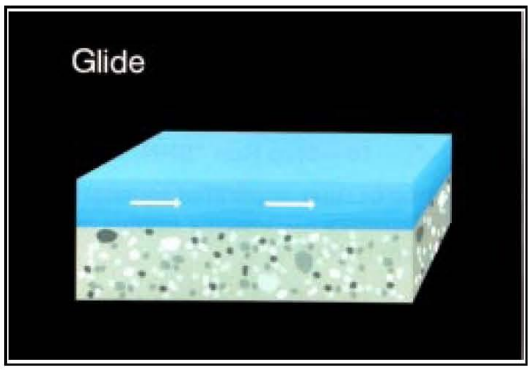


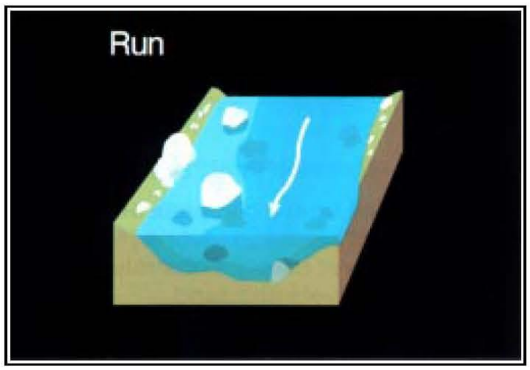
13 -- Dammed Pool "DPL"

Water impounded from a complete or nearly complete channel blockage (debris jams, rock landslides or beaver dams). Substrate tends toward smaller gravels and sand.

14 -- Glides "GLD"

A wide shallow pool flowing smoothly and gently, with low to moderate velocities and little or no surface turbulence. Substrate usually consists of cobble, gravel and sand.



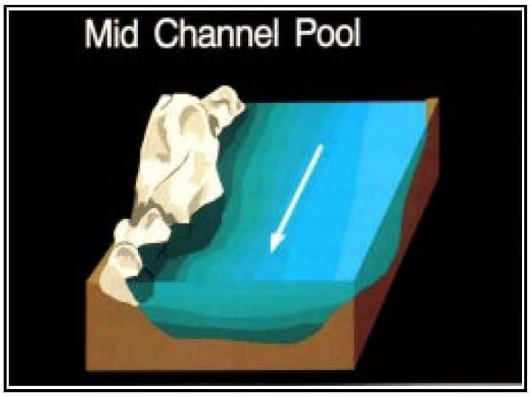


15 -- Run "RUN"

Swiftly flowing reaches with little surface agitation and no major flow obstructions. Often appears as flooded riffles. Typical substrates are gravel, cobble and boulders.

16 -- Step Run "SRN"

A sequence of runs separated by short riffle steps. Substrates are usually cobble and boulder dominated.

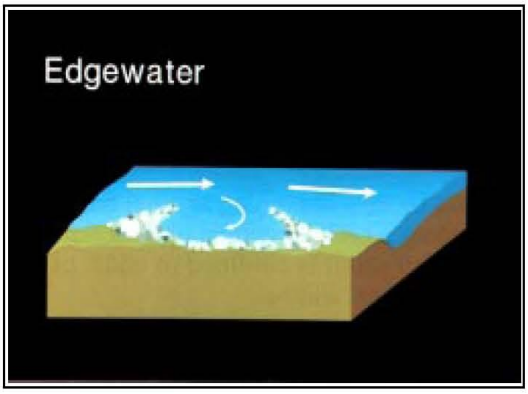


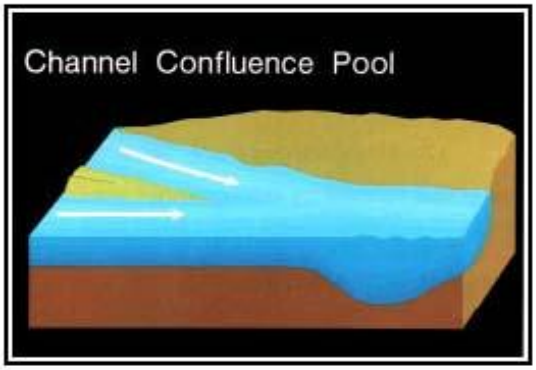
17 -- Mid-Channel Pool "MCP"

Large pools formed by mid-channel scour. The scour hole encompasses more than 60% of the wetted channel. Water velocity is slow, and the substrate is highly variable.

18 -- Edgewater "EGW"

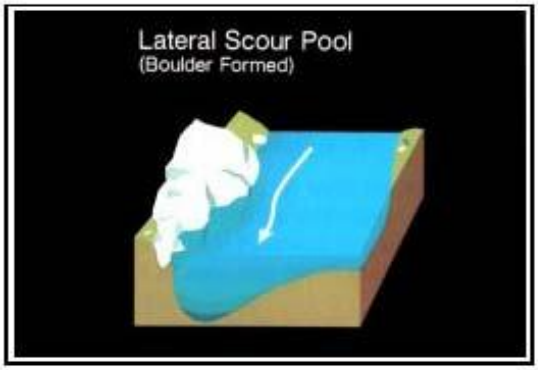
Quiet, shallow area found along the margins of the stream, typically associated with riffles. Water velocity is low and sometimes lacking. Substrate varies from cobbles to boulders.





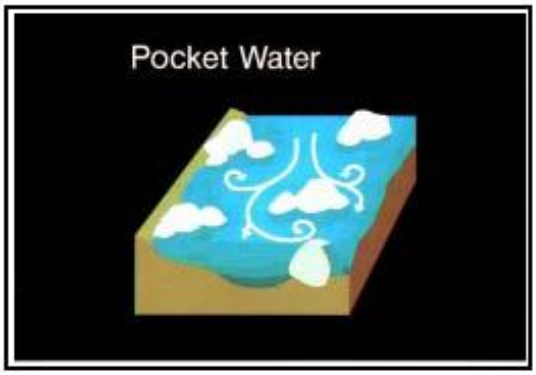
19 – Channel Confluence Pool "CCP"

Large pools formed at the confluence of two or more channels. Scour can be due to plunges, lateral obstructions or downscour at the channel intersections. Velocity and turbulence are usually greater than those in other pool types.



20 – Lateral Scour Pool "LSP"
Boulder Formed

Formed by flow impinging against boulders that create a partial channel obstruction. The associated scour is confined to < 60% of wetted channel width.

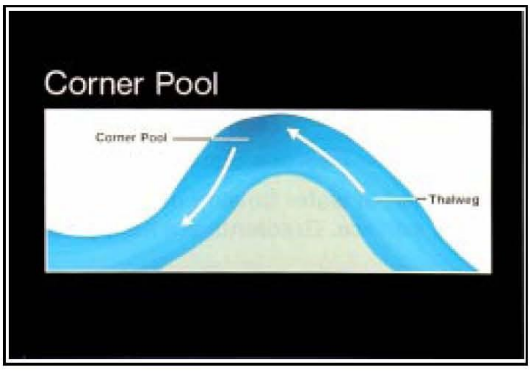


21 – Pocket Water "POW"

A section of swift flowing stream containing numerous boulders or other large obstuctions which create eddies or scour holes (pockets) behind the obstructions.

22 -- Corner Pool "CRP"

Lateral scour pools formed at a bend in the channel. These pools are common in lowland valley bottoms where stream banks consist of alluvium and lack hard obstructions.



such a basin by gradient and confinement is therefore suggested to aid in predicting the location of certain habitat types (see Rosgen, 1985).

Procedures

Inventory Scale

In assessing habitat for a stream reach or an entire basin, the intent is to gather information that will adequately describe the area of interest. Conducting a habitat inventory can be time consuming, so work must be carried out quickly and efficiently. The level or scale of inventory to be employed is dependent on the project objectives. We have employed this system at two scales: basin level and project level. Basin level habitat classification is on the scale of a stream's naturally occurring pool-riffle-run units, where habitat unit size depends on stream size and order . As a general rule in a basin level inventory, homogeneous areas of habitat that are approximately equal or greater in length than one channel width are recognized as distinct habitat units. In comparison, project level habitat assessment operates on a scale of less than one channel width for use on reaches of intense management or study. Project level habitat typing is used to evaluate and quantify changes in habitat as the result of fish habitat restoration/enhancement projects *(figure 4)*. This information, in combination with juvenile rearing population estimates or spawning ground surveys, documents and quantifies the project's ability to provide the necessary habitats for fish production. Project level habitat size delineation depends on the nature and objectives of the particular study or work being done, which depends on the niche, size, life stage(s), etc. of the targeted species. Both levels use the same habitat types *(figure 2)*.

Data Collection

Habitat typing can be accomplished efficiently by two or three field people. Describing and measuring all 22 habitat types is very labor intensive; an average of one mile per day can be accomplished by trained surveyors. Decisions are best reached by a consensus among the team after a discussion of the facts. This approach balances out the biases inherent in each observer and insures quality in the data collected.

The basic method of habitat typing is relatively simple. Starting at the mouth of a stream and working upstream insures a known starting point. Use a measuring device (tape, rod, optical rangefinder, or hip chain) to measure mean length and width of each unit.

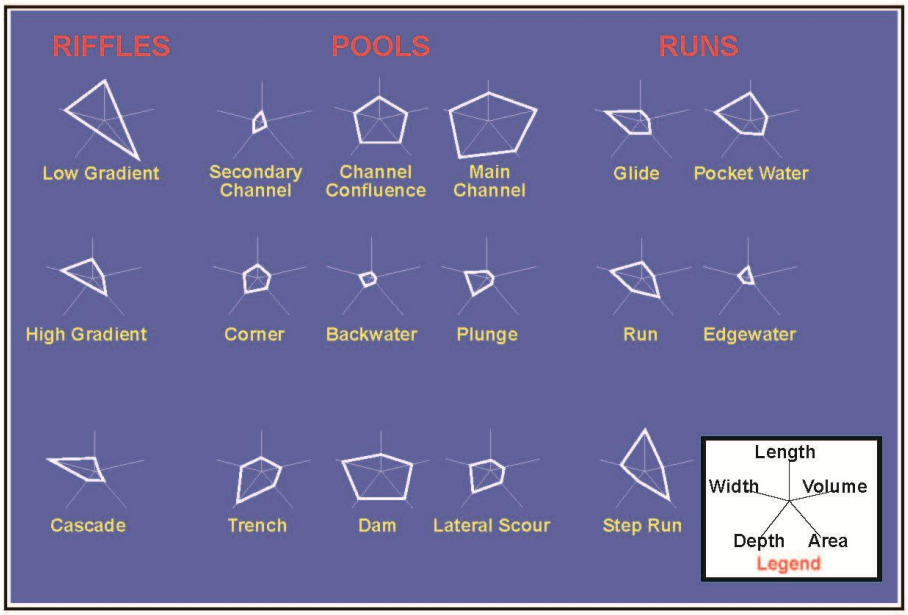


Table 1 --
Starplots of 5 main physical habitat variables. These show ratios of: mean depth, width, length, area and volume for each habitat type. Examples are from Hurdygurdy Creek, CA for Decker et al. 1984.

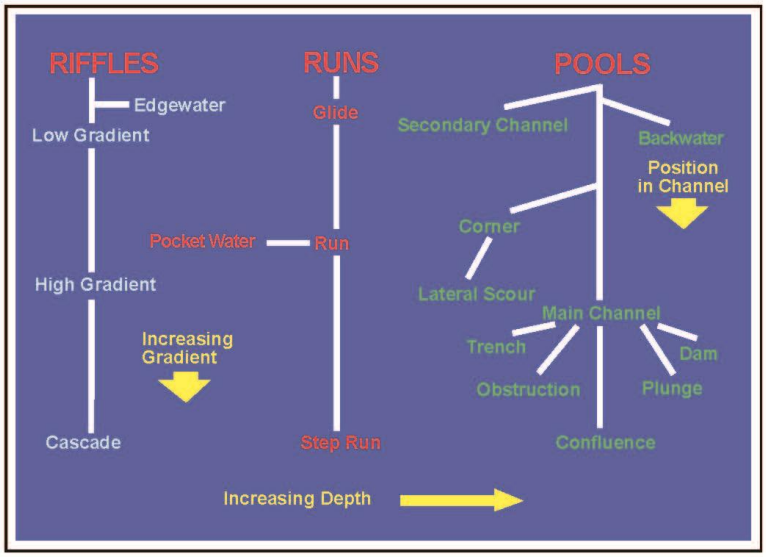


Figure 3 --
A diagram of the habitat classification system used for inventory in northern California.

Three to five width measurements are sufficient. Along each width measurement transect use a gradient leveling rod (or similar device) to take several depth measurements from bank to bank and estim ate mean depth. If a significant port ion (>10%) of the measured habitat includes exposed boulders and/ or islands, that portion should be estimated and subtracted from calculations of area (total area - exposed area = wetted area) . Other variables such as stream substrate, in-stream cover elements and abundance, canopy cover, riparian quality, etc. can be collected along with the habitat type data.

As with any classification system an occasional habitat unit may not fit distinctly into any one habiat type. In an inventory, a certain amount of subjective decision making is involved and accuracy depends heavily on a basic understanding of stream processes, a good knowledge of the classification system, and consistency (see Beschta and Platts, 1986; Lisle, 1986; and Ying, 1971).

Discussion

The basin level habitat classification and inventory procedures will provide a channel descriptor of fish habitat availability (number, length, area, volume) and its relationship to channel features. Measurement of all 22 types gives a clear picture of the streams make-up, the type and quantity of scour forming material (logs,

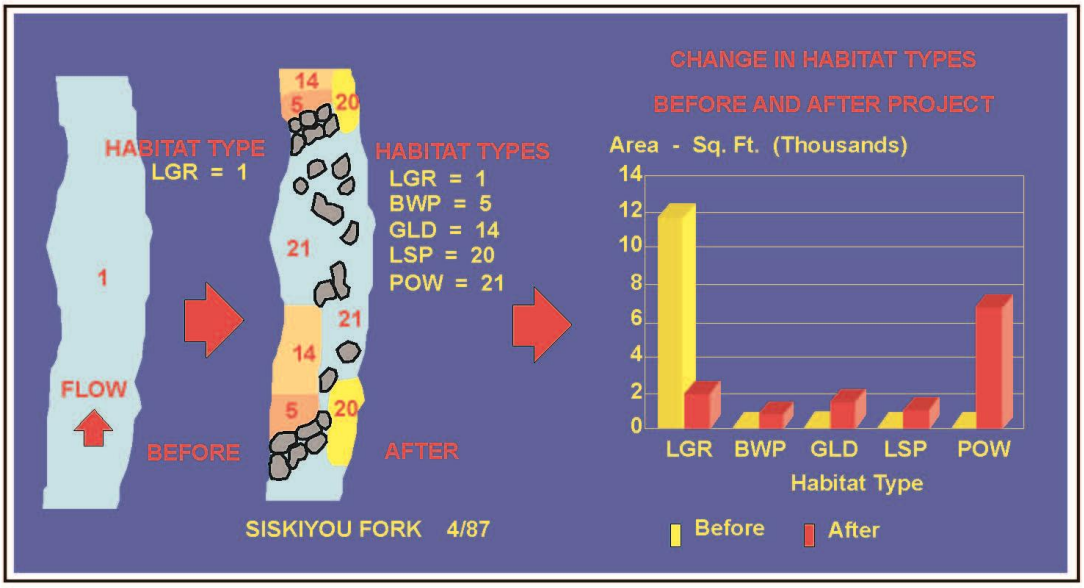


Figure 4 --
Project level habitat typing is utilized to quantify changes in specific habitat types resulting from habitat restoration/ enhancement work.

boulders, bedrock, etc.) that governs the mix and availability of certain habitat units. When pairing this informatiotion with population estimates per habitat unit and with fish-habitat relationship studies, the manager has the basic data for limiting factor analysis and fish production estimates *(figure 5)*.

Fish-Habitat Relationship Studies

Models are being developed and tested by the Fish Habitat Relationships (FHR) program of the USFS to aid in predicting potential fish production in a basin. Physical and biological habitat variables such as depth, velocity, substrate, cover, temperature, and food availability are being investigated in terms of their relation and relative importance to fish distribution, abundance, and community structure. The links between biological attributes such as food availability, survival, growth, age structure and physical habitat attributes such as water velocity and temperature, channel morphology, substrate particle size distribution, and habitat complexity can help managers predict the potential impacts on the fishery from watershed disturbances (logging, mining, grazing, hillslope failures and slides). The database needed to build such a predictive model must include a standardized basin level inventory of fish populations and habitat availability (Parsons, 1984) . Figure 6 illustrates seasonal critical habitat needs for different fish species and life stages, serving as a basis for determining factors limiting fish production and planning habitat restoration/ enhancement projects.

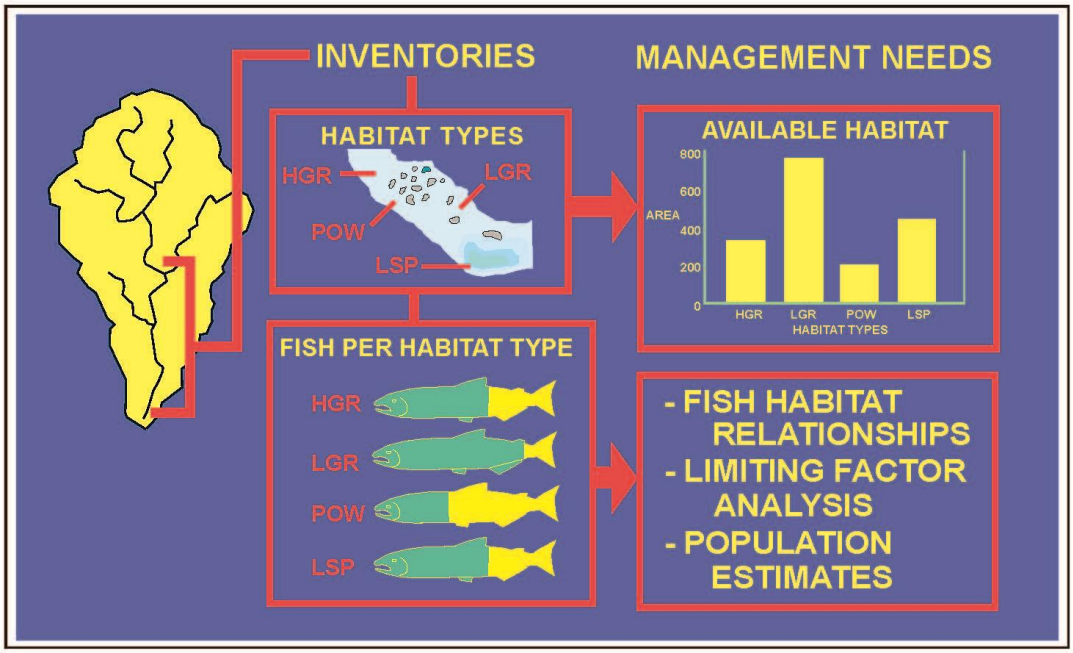


Figure 5 --
Habitat typing inventories, in conjunction with population estimates per habitat units, provide fishery managers with basic information (habitat availability, watershed fish production) for evaluating the status and potential of the watershed to produce fish.

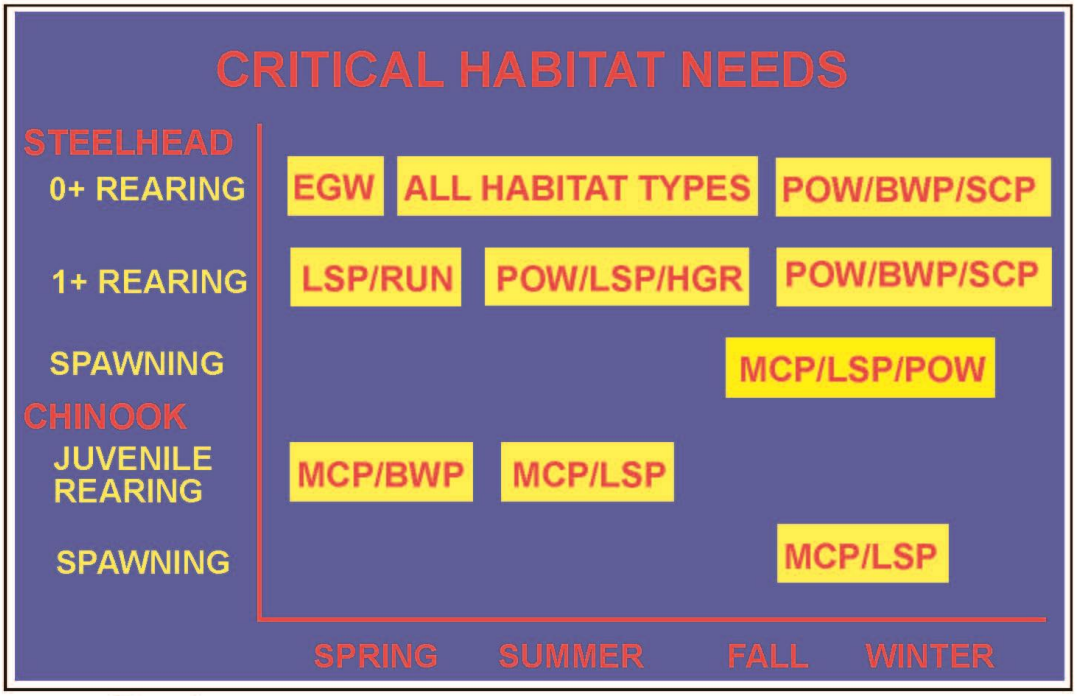


Figure 6 --
An example of seasonal habitat needs for different life stages of anadromous salmonids.

Conclusion

Habitat classification and inventories can be applied at different scales or levels and can provide basic information with which to determine the availability and importance of habitats to fish, and therefore further our understanding of fish-habitat relationships. Development of fish-habitat relationship models will increase the value of habitat information to both researchers and managers by allowing insight into their relative importance and function of physical and biological habitat parameters in the ecology of stream fishes. Aquatic habitat inventory information can serve as valuable baseline data. For example, project level habitat type information provides the habitat restoration/ enhancement project designer with insight on the relationship between channel features and habitat development, and allows projects to be evaluated by quantifying the changes in habitat created by the project. Basin level information can enable researchers to develop sampling schemes based on natural habitat units.

There is a need for standardized methods in collecting stream habitat inventory information. Our fishery resources cross several management jurisdictional boundaries. Therefore, proper use and management of this resource requires responsible agencies to communicate and work together through shared information.

Appendix B. Habitat Assessment Protocol FY93

Habitat Assessment Protocol FY93

The following information describes the Aquatic Habitat Assessment protocol used on the Klamath National Forest during FY93. This protocol is intended to act as a reference for field investigators and those performing data analysis. It is not intended as a surrogate for technical training.

Several changes have been made from the FY92 protocol. The most prominent of these changes are in the sampling approach and departure from use of ocular estimation techniques. There are also two, two-sided forms necessary for recording data. This has resulted in an integrated approach in record keeping during the biological and physical assessment phases.

The FY93 protocol relies upon data collected in three ways: (1) a continuous basis, (2) stratified systematic interval, and (3) random index reach selection. This approach fits the data collection schedule to the spatial properties displayed by individual parameters while minimizing sample size.

For each data parameter described, a short description of the measurement technique, sampling interval, and data record is provided. Parameters are described as the occur on the data forms and grouped according to sampling method.

All spaces on the data sheet must be accounted for. There will be no blank spaces, zeroes or null (---) must be in every field.

I. Continuously Recorded Data

Header Information :

Enter information for all fields on every sheet. Be sure to note time when temperatures are taken. Circle name of crew person recording data.

Adjusted Station :

This field is the only field that does not get filled out on the stream. This is used to adjust station numbers when two or more crews are working the same stream in tandem (one crew starting at the mouth, and the other starting at a known point upstream). Denotes consecutive order of habitat stations from mouth of stream.

Field Station :

This is a unique number, starting with "1" and continuing throughout the survey. All habitat units must have a station number. Braided channels will be denoted as decimals (12.1, 12.2, etc.).

% Slope :

This is the average water slope in the channel. The reading may extend over several habitat units. Measured from water surface to water surface.

Bankfull Channel Width :

Enter the channel width occupied at bankfull discharge water surface elevation. This is the channel forming (channel maintaining) discharge represented by a recurrence interval of approximately 1.5 years.

Channel Type :

Enter the alpha numeric code which best describes the channel type using Rosgen classification. When describing channel type, a minimum reach length of approximately 30 times the bankfull width provides a good general guideline.

Sample # :

Enter the unique number for the sample. This is the dive unit number and is recorded on flagging to mark the boundary of the unit. This is a unique number starting with "1" and continuing throughout the survey. The sample is derived by systematic occurrence (generally 1:4 or 1:5) after an initial random start.

Habitat Type :

Enter the habitat type number. Use the Region 5 key to determine habitat type. Do not create new habitat types. Twenty-five (25) habitat types are distinguishable for FY93.

Spawning Area :

Determine the number of square feet of actual spawning area in the habitat unit. Species and size of gravel will be dependant upon criteria set by the District biologist.

Mean Length :

Measure mean habitat unit length along thalweg, record to nearest foot. Habitat length must be recorded for all stations.

II. Continuous Data Record (Pools Only)

Max Depth :

Measure and record the max depth occurring within the habitat unit to the nearest tenth of a foot. (Note: Shaded areas represent data taken and recorded for pool habitats only.)

Riffle Crest Depth :

This measurement is only taken at the tail of a pool where the surface flow beaks into the riffle. This measure is used to determine residual pool depth.

Instream Cover-Total % :

Determine the percentage of the habitat unit that has overhead cover.

Undercut banks, swd, lwd, terrestrial vegetation, aquatic vegetation, white water, boulders, bedrock ledges : Breakdown the Instream cover into its component parts. The sum of these 8 components must equal 100.

Cover Complexity :

Enter: 1 for low complexity, 2 for moderate complexity, or 3 for high complexity.

In general, one cover component alone will rate Low complexity, two to three components will rate Moderate complexity, and more than three components will rate High. Examples of highly complex cover may include rootwads, logjams and willow rootwads associated with it.

III. Index Reach Parameters (Random Selection)

Index reaches are selected on a random basis from within the channel stratum (channel type and size) being described. In general, it is desirable to select a minimum of three index sections per channel stratum or approximately two per mile as a sampling baseline. Other sampling schedules (ie systematic dive unit selection) are maintained through index section.

The Index Section length is determined from the average bankfull channel width within the stratum to be described. Round the average bankfull width to the nearest 10 feet and multiply by 10 to calculate the Index Section length. For example, an average BF width of 23 feet would produce an index reach equaling 200 feet in length.

Given your calculation of Index Section length, you then need to estimate the location of each of 10 evenly spaced transects perpendicular to the channel within the section. Canopy closure estimates will be made at each of the 10 transects. Using the index sample above (200 feet) you would select transects at 20 foot intervals starting at 20 feet. Note that the "local" block on the reverse side of form B is meant to correspond to the transect location in feet within the Index Section (ie. 20, 40, 60.....). The "station" block below "local" corresponds to the habitat unit station number the transect falls within (it is possible to have multiple transects with the same station number). There is space provided (form B) to perform 5 pebble counts, although a minimum of 3 are necessary. Perform these counts within the habitat unit type the transect falls within, noting the station number as before. Choose these transects systematically from the 10 canopy closure transects.

Substrate Composition :

Collect, measure (across the intermediate axis), and record (using dot tally) the size class of 100 pebbles within sample habitat units and bankfull elevation (Form B). Record the number of total occurrences by pebble size class as fines, gravel, cobble, boulder/bedrock (Form A).

Percent Bedrock :

Ocularly estimate the surface area occupied by bedrock within bankfull channel within habitat unit described by accompanying pebble count.

% Substrate Embeddedness :

Take this observation only in pool tail outs and in low gradient riffles. Estimate the surface area covered by fines on ten samples of the substrate to determine the degree of embeddedness. A pool tail must be less than 3' in depth. Bedrock will be excluded and treated as a null value.

Percent Shade (Canopy Closure):

Percent shade will be estimated from canopy closure measurements using a spherical densiometer at each of 10 transects determined as described above (Form B). Enter the corrected canopy closure measurement from transect corresponding to the appropriate field station (Form A). Record the average of the transects where more than one occur within a station.

Percent Evergreen :

Estimate the percentage of the riparian vegetation that is evergreen (conifer, live oak, pacific madrone, etc.). Observation will be limited to the up and downstream unit boundaries extended 200 ft up each slope from the bankfull width. Estimated by crown cover, not the number of trees.

Percent Deciduous :

Estimate the percentage of the riparian vegetation that is deciduous (alder, maple, willow, black oak, etc.). Observation will be limited to the up and downstream unit boundaries extended 200 ft from the bankfull width. Estimated by crown cover, not the number of trees.

Fines :

Enter the number of grid intersects which correspond to substrate particle diameters less than 2 mm diameter in riffle habitat and pool tail outs from a total of 49 possible intersects. Record the number of "fines" intersects for each of 3 random frame tosses within the wetted habitat perimeter (form A).

LWD Recruitment (#'s) :

Determine the number of trees greater than 24" (west side) and 18" (east side) recruitable to the stream channel. Standing at the stream margin, face perpendicular to the channel bank, view through the clinometer with one eye while using the other eye to focus on the base of standing trees meeting the diameter criteria stated above. Standing at the same spot, elevate the clinometer to the top of the tree(s) and take a reading. When the difference between to base and top readings equals or exceeds 100% the tree is counted as in. Using this method record the total number of trees from both slopes which are recruitable throughout the length of the Index Reach.

IV. Form B.

Header Information :

Enter information for all fields on **every** sheet. Be sure to note time when temperatures are taken.

Adjusted Station :

This field is the only field that does not get filled out on the stream. This is used to adjust station numbers when two or more crews are working the same stream in tandem (one crew starting at the mouth, and the other starting at a known point upstream).

Field Station :

This is a unique number, starting with "1" and continuing throughout the survey. All habitat units must have a station number. Braided channels will be denoted a decimals (12.1, 12.2 etc.).

Habitat Type :

Enter the same habitat type recorded for the station on Form A.

Percent Exposed Substrate:

Enter the percentage of the habitat unit area that has substrate that is above the existing water level within the wetted perimeter.

Mean Width, Depth :

Enter the average values. Length and width are taken to the nearest foot. Average and max depth is taken to the nearest tenth. To determine average depth, divide the habitat into three and take three to four measurements along the transect.

Course Woody Material :

Maintain a continuous record (dot tally) of all wood meeting the minimum size criteria (4"x39") by dimension class occurring within the lateral bankfull margin. Count all pieces of wood that have any portion (meeting minimum size criteria) within BF, measuring the entire piece length (not just the portion within BF). Also, tally pieces as single or aggregate (3 or more). This record is maintained through the beginning of a sample (dive) unit (ie. the station number provides an address for the CWM talley preceeding it to the last sample). At the start of a sample unit a new CWM tally is initiated.

Biological Observations (fish counts) :

Record the observers initials in the column heading their fish counts, and dive start time. Indicate with an "R" counts which are performed as two-pass or replicates. Otherwise, all counts are assumed to be single pass. Record the number of individuals by species and age-class observed within the sample unit.

Comments :

The comment field is a very important portion of the data. Certain guidelines to its use are needed to make it effective. Data entry people will not interpret or correct statements. Make use of full sentences and keywords wherever possible. Cryptic comments are not appropriate. Be sure to include structural conditions in comment for habitat units that have enhancements. Keywords will be employed to assist in using the data collected.

HT Tally :

Maintain an accurate count of habitat types surveyed so that the proper number of habitat units are sampled.

Rosgen Channel Class :

When the channel classification changes, check off the appropriate values for observations made.

Channel Cross Section :

Every time the channel type changes, a cross section, drawn to scale must be included.

Guidelines for Keyword Use

1. Keywords are not substitutes for a complete description of the feature.

2. Avoid comments that are cryptic. Be concise and clear. One word comments and comments like "lots of fish" are inadequate.

3 .Use keywords in the comments field whenever possible.

4. The comments field and maps must correspond. Always include known geographic features in the comment field to tie the habitat unit to it.

5. Note amphibians in the comment field. This is to determine presence or absence of species.

6. New keywords may be added to the list as needed by the biologist. Please recommend words that will assist in finding important data.

Recommended Key Words

Keyword	**Use**
Weir	Man-made weir. Always note what the weir is made of (boulders, logs, gabions, etc)
Group	Man-made boulder, boulder-rootwad groups. These may be typed as POW (pocket water), but not in all instances.
Deflector	Man-made deflectors of any kind. These may be typed into several different habitat types, depending on their location.
Cover	Any man-made cover structure. Describe stream location, condition, and type of structure.

****** NOTE: Always include structure condition information in comments. ******

Trib	Confluence of a tributary. Include stream name, flow estimate, temperature. Also indicate if the tributary is an intermittent, perennial, or ephemeral stream. Be sure to note whether it enters the stream on the left or right.
Bridge	Note road number, type of construction, and any effects on the stream channel.
LWC	Low Water Crossing. Be sure to note impact to the stream, and a measure of how often it is being used; continuous use, occasional, rarely.
Falls	Waterfalls. The description should also have the keyword `barrier' in it if applicable.
Dredge	Location of dredging activity. The dredge does not have to be present, just the indications of its use.
Mining	Mining activity that is out of the stream, but may be affecting the riparian areas. The name of the claim would be good to include in the comments field.
Camp	Obvious campsites that are being regularly used by the public. This includes campgrounds as well as seasonal primitive sites. Include campground name.

Recommended Key Words (continued)

Keyword	Use
Culvert	Include culverts that are tributary, as well as those that the stream flows through. Note potential barriers, and erosion problems.
Diversion	Include vital information: Amount of flow diverted (CFS), barrier potential, presence of screens.
Barrier	Fully describe the barrier or potential barrier. Include what the barrier is formed by, height, affected species, etc.
Frog	Note the presence of frogs and a count if possible. Include tailed frogs seen in direct observation.
LWD	Large Woody Debris--24" x 10' in minimum length, rootwads with stumps greater than 24" (West Side). Or 12" x 10' in minimum length, rootwads with stumps greater than 12" (East Side).
Topo	Enter comment for shde created by topographic features, as opposed to vegetation created shade.

Habitat Typing Survey Form A

Date:__/__/__ Stream:_____ Crew: _____.
Temperature: AM=H_2O _____ Air ____ Time_____ Noon= H_2O____ Air ____ Time _____ .
AM___ Flow _____ PM _____ Flow _____ Legal: T ___ R ___ Sec ___ River Mile ____.

Adjusted Station										
Field Station										
Slope (Avg)										
Bankfull Channel Width										
Channel Type										
Sample #										
Habitat Type										
Spawning Area (m^2)										
Mean Length (m)										
Max Depth (m)										
Riffle Crest Depth (m)										
Instream Cover Total										
undercut banks										
swd (d<1.0 ft)										
lwd (d>1.0 ft, RW)										
terr. vegt. (ht 1.0 ft)										
aqua. vegt										
white water										
boulders (d≥1.0 ft)										
bedrock ledges										
Cover Complexity										
# Fines (<2mm)										
# Gravel (2-64mm)										
# Cobble (65-256 mm)										
# Boulder/bedrock (>256mm)										
Percent Bedrock										
Substrate Embeddedness										
Percent Shade										
Percent Evergreen										
Percent Deciduous										
Fines: # intersects rif #1										
rif #2										
rif #3										
LWD Recruitment (#'s)										
Comments:										

rif	
run	
pool	

Page ____ of ____.

Habitat Typing Survey Form B

Date:__/___/___ Stream:_____ Crew: _____.

Temperature: AM=H_2O____ Air ____ Time_____ NOON= H_2O ____ Air _____ Time_____.

Legal:T ___ R____ Sec ____ River Mile_____ .

Adjusted Station									
Field Station									
Habitat Type									
Percent Exposed Substrate									
Mean Width (m)									
Mean Depth (m)									
Coarse Woody Material ∞	0.1m	0.46	0.61	0.1m	0.46	0.61	0.1m	0.46	0.61
1 – 2m									
2 - 4									
4 - 8									
8 - 11									
11 – 15									
15 – 23									
23 – 38									
38 – 53									
53 – 76									
76+									
single piece									
aggregate									
Observer									
Dive Time (start of dive)									
# Chinook 0+									
# Steelhead 0+									
# Steelhead 1+									
# Coho 0+									
# Brook Trout 0+									
# Brook Trout 1+									
# Chinook Adult									
# Steelhead Adult									
Comments:									

Canopy Closure

Obtain variance estimates for Canopy Closure by sampling 10 transects within designated reach. Hold densiometer level, 12 inches above water surface and count the number of line intersect points intercepting vegetation at each of 4 locations along transect.

	Number Intersect Points Intercepting Vegetation									
Local:										
Station:										
RR										
MU										
MD										
RL										
Sum										
x 1.5										
Adj										
CC										

Substrate Composition ---- Pebble Count

Collect, measure (across the intermediate axis), and record (using dot tally) 100 pebbles at each sample location.

Pebble Count						
Particle	Metric (mm)	Station Number				
Fines/Sand	<2					
Gravels	2 – 64					
Cobbles	64 – 256					
Boulders	>256					
Bedrock						
	Total:					

Appendix C: Index Reach Data Summary

Index Reach		A					B			C			D			
Date		11/20/08					11/5/08			8/10/11			8/11/11			
Habitat Type		1	15	14	1	14	23	1	14	15	14	16	1	15	6	1
Adjusted Station		22	21	20	19	18	64	63	62	183	184	185	202	203	204	205
Total Length	*Ft*	110	53	233	29	235	99	124	424	202	91	258	69	287	41	110
Temp Time		9:30 AM					10:30 AM			9:20 AM			9:30 AM			
Water Temp	*°C*	5					8			15			14			
Air Temp	*°C*	13					14			22			20			
Bankfull Width	*Ft*	50					60			49			53			
Reach Length	*Ft*	500					600			490			530			
Surface Area	*Ft²*	25000					36000			24010			28090			
Percent Shade	*%*	38.5					26			68.7			52.7			
% bedrock	*%*	0	0	0	0	0	0	40	0	35	95	60	0	35	0	70
Sub. Embed. (%)	*%*							40					20		20	25
Fines (%)		13.3					17.7						6.4			
GPS Point mE		573723					574658			580718			581283			
GPS Point mN		4492210					4492953			4497635			4497780			
Photos		1	2	3	4	5	6	7,8	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Index Reach	Comments
A	22: Complex habitat type see photos1-5; 20:length from GIS pt 48. Small riffle 1/2 way through the glide; 18:length from GIS pt 50; side channel that starts at log jam only at higher flows.
B	63: Pebble counts average of 2 sets; 62: Long glide with average depth of 3'. Length adjusted to 424 (393+31) 1/13/09;
C	183: On LB near top of stream is 10'x8' LCP; 184: GLD uniform bottom, no cover, yet surface looks like a run; 185: SRN above GLD, not bedrock bottom, more boulders, trench & cover more complex; steep eroded bank LB in middle 50' of run.
D	202: Started at LGR below access road crossing on Oilar property. GPS WP#15; 203: Small riffle in middle of run ~40' long w/ ~25ft2 spawning gravel; 205: Riffle descends into bedrock chute for 20' then into a bedrock dominated riffle (index reach ends 36' short of top of riffle not including bedrock chute)

Index Reach		E				F				G			H
Date		10/27/11				10/27/11				10/26/11			10/26/11
Habitat Type		15	1	15	1	1	15	1	15	14	15	14	16
Adjusted Station		224	225	226	227	IR-B1	IR-B2	IR-B3	IR-B4	IR-C1	IR-C2	IR-C3	297
Total Length	*Ft*	86	41	273	65	32	35	45	211	96	96	128	360
Temp Time		2:30 PM				11:00 AM				4:45 PM			10:30 AM
Water Temp	*°C*	7				5				8			6
Air Temp	*°C*	17				15				16			17
Bankfull Width	*Ft*	43				32				32			36
Reach Length	*Ft*	430				320				320			360
Surface Area	*Ft²*	18490				10240				10240			12960
Percent Shade	*%*	46.3				53.9				64.6			34.9
% bedrock	*%*	0	10	0	0	0	0	0	0	0	0	0	0
Sub. Embed. (%)	*%*		35		33		33.5		23				7.5
Fines (%)		11.3				4							1
GPS Point mE		582031				582428				582602			583101
GPS Point mN		4498157				4498904				4499596			4500237
Photos		10	11,12	13	14, 15	AS unknown 16-22				AS unknown 23-25			26-30

Index Reach	Comments
E	Transects 1-3 are w/in DS run @ start of index, transitions into glide (glide lumped with run not seperate habitat unit). Transect 3 is @ interface of Run @ start of reach & LGR above run. Transect 4 is in LGR above DS Run @ beginning of Index Reach; Transect 10 is 30' into the LGR @ US end of Index Reach. LGR is 65' long.
F	GPS WP10 @DS end photo 17. @US end stream splits equally around island & flows into LB on both channels & has eroded the bank to about 25' & scoured large holes or semi-caves into the LB. (photos 18,19); photo 16 is from transect 3 US; Gravel between transect 5-7 fairly scattered among cobble & boulders & not enough area for suitable spawning bed, but gravels are present in pebble count. above transect 7 has 35'x5' gravel bed (w/spawning gravel) on LB (photo 22).
G	GPS @ US end of reach; short cascade in middle of run (photo IRG_3); %Bedrock at transect #1, #3: 16%, 40% respectively
H	Is the FS above the LGR that is immediately above the very long (760' step run) %bedrock recorded along transects #1, #3, #5, #7, #9: 2%, 1%, 26%, 51%, 0% respectively

Appendix D: Photographs

Index Reach A

Photo: 1

Photo: 2

Photo: 3

Photo: 4

Photo: 5

Index Reach B

Photo: 6

Photo: 7

Photo: 8

Photo: 9

Index Reach E

Photo: 10

Photo: 11

Photo: 12

Photo: 13

Photo: 14

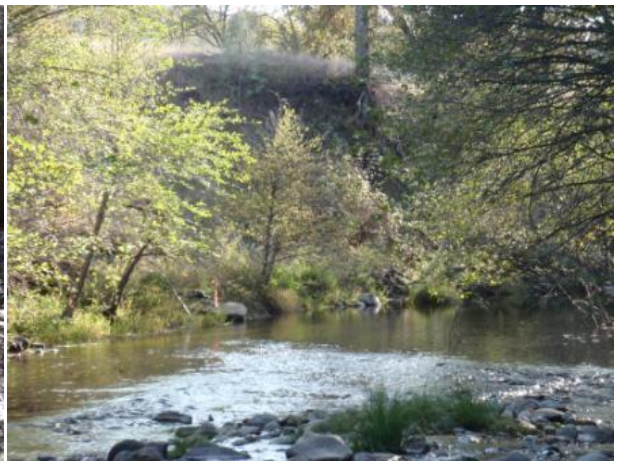


Photo: 15

Index Reach F

Photo: 16

Photo: 17

Photo: 18

Photo: 19

Photo: 20

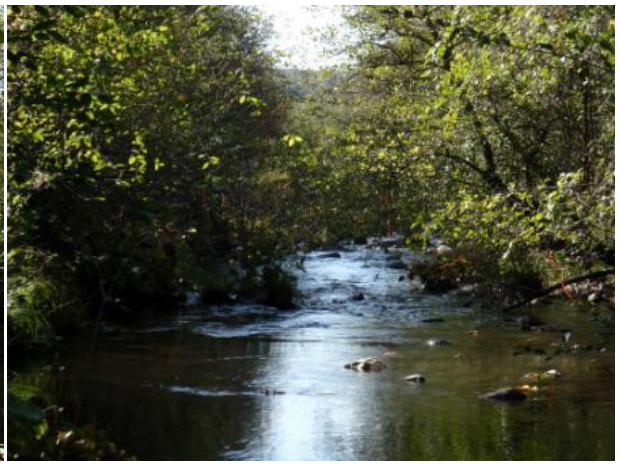


Photo: 21

Index Reach F (cont.)

Photo: 22

Index Reach G

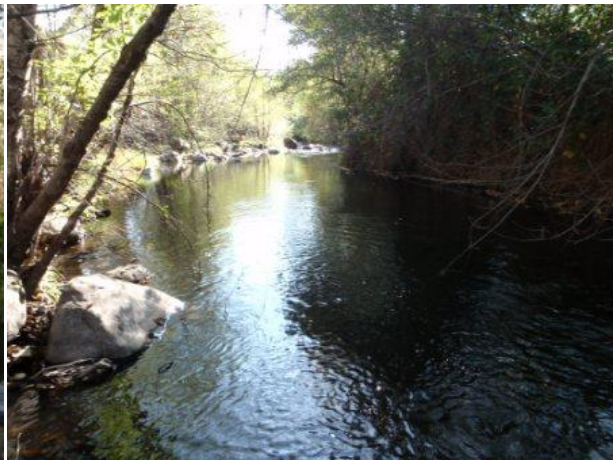


Photo: 23

Photo: 24

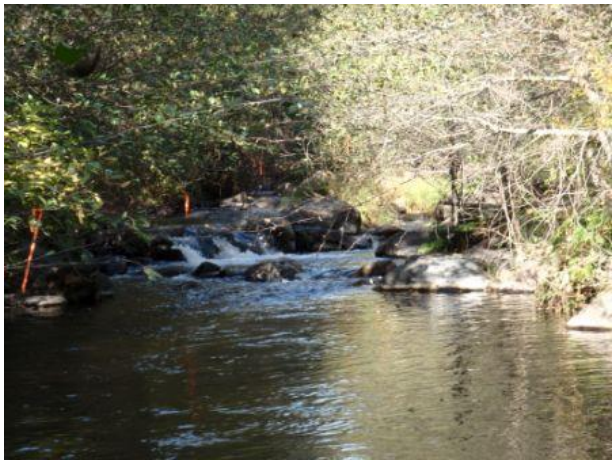


Photo: 25

Index Reach H

Photo: 26

Photo: 27

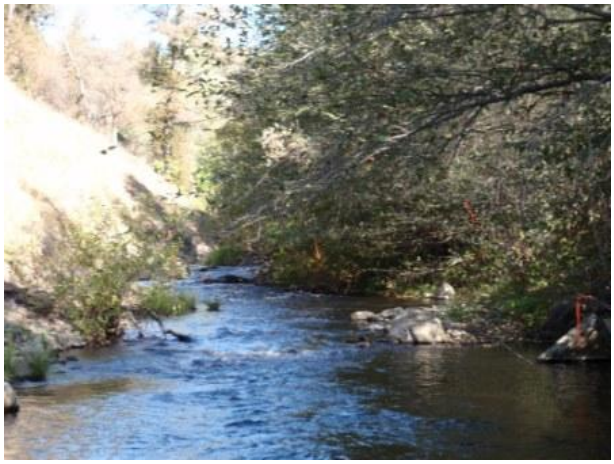
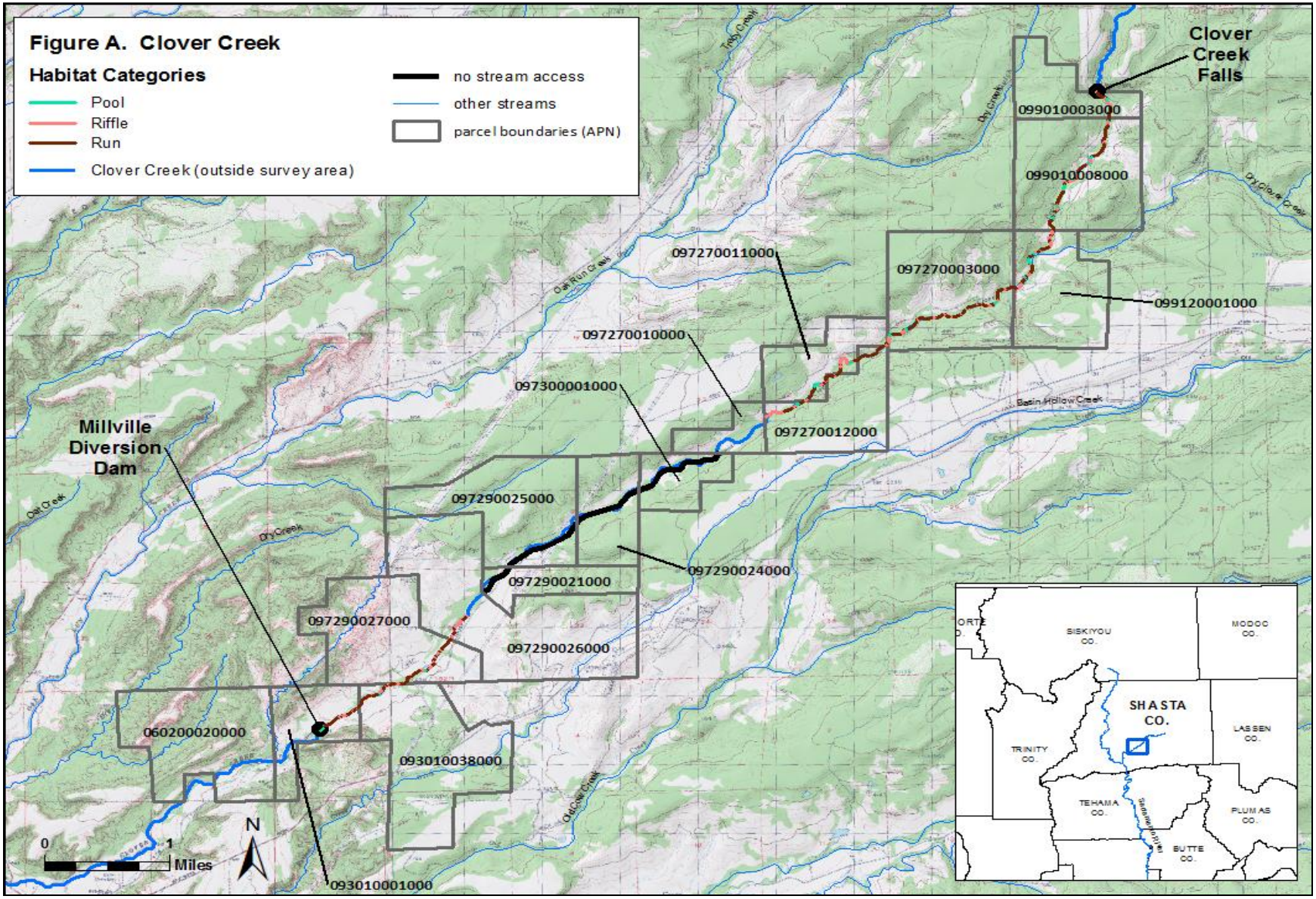


Photo: 28

Photo: 29

Photo: 30

Appendix E: Clover Creek Overview and Habitat Map