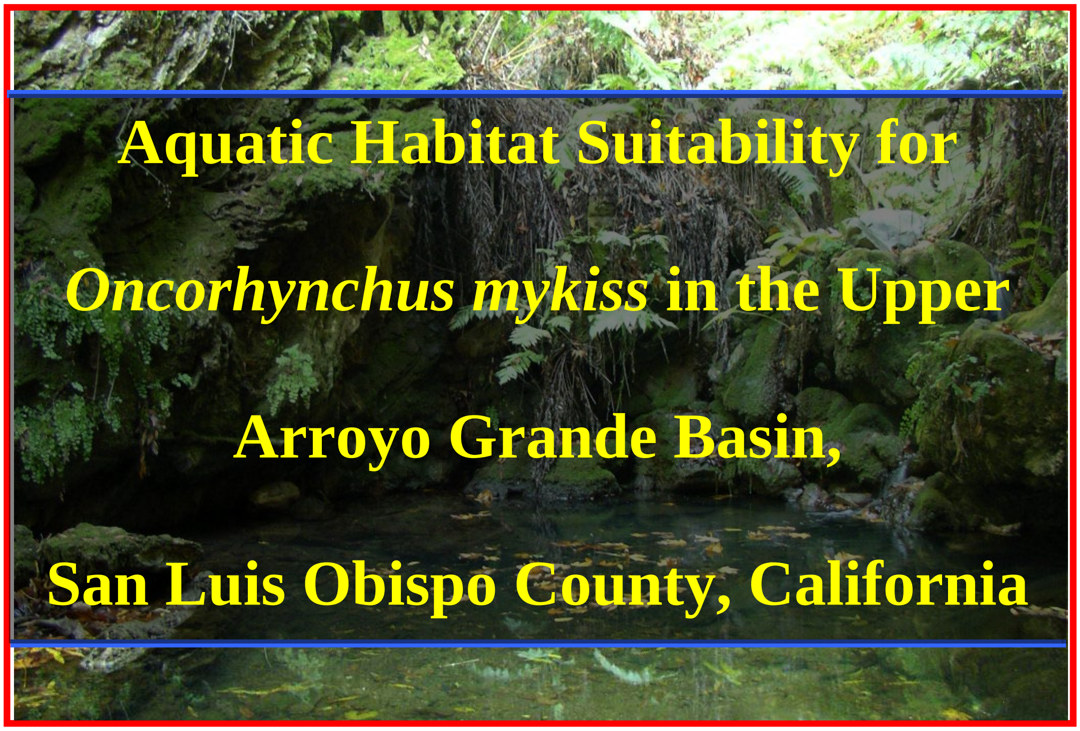

Aquatic Habitat Suitability for *Oncorhynchus mykiss* in the Upper Arroyo Grande Basin, San Luis Obispo County, California

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Introduction

The County of San Luis Obispo, California (County) contracted Thomas R. Payne and Associates (TRPA) to conduct an instream habitat assessment of tributaries within the upper watershed of the Arroyo Grande Basin, San Luis Obispo County, California (Figure 1). Although lower Arroyo Grande Creek is accessible to anadromous salmonids, the upper basin described in this report is above Lopez Dam and lake, which is impassable to anadromous *Oncorhynchus mykiss* (steelhead). Consequently, the upper Arroyo Grande Basin only supports the resident form of *O. mykiss*, generally referred to as rainbow trout, as well as other native and exotic freshwater fish species. The County and other entities are in the process of developing a Habitat Conservation Plan for steelhead in the Arroyo Grande Basin below Lopez Dam, and as part of this process the National Marine Fisheries Service (NMFS) requested that the suitability of instream habitat for resident *O. mykiss* be assessed in the upper basin above Lopez Dam. This report describes the use and development of a Habitat Suitability Index (HSI) model for the upper Arroyo Grande Basin, generally following procedures detailed in Raleigh et al. (1984).

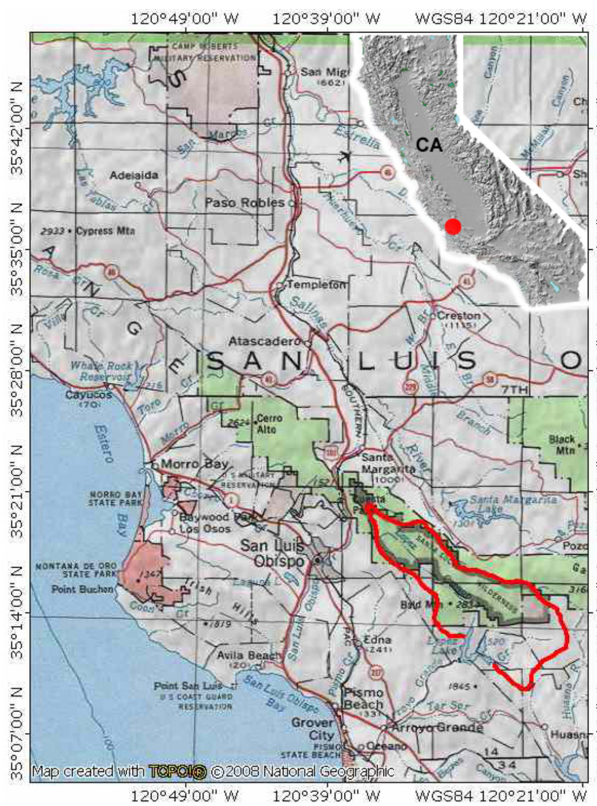


Figure 1. Area map of the Upper Arroyo Grande Basin, California.

The HSI Model

Numerous methodologies have been devised to assess habitat quality for stream fishes (Wesche and Rechard 1980, Fausch et al. 1988), however habitat assessments are rarely standardized beyond basic tools such as channel typing (Rosgen 1985) or habitat typing (Flosi et al. 1998, McCain et al. 1990). Although various habitat rating systems have been applied towards Southern California steelhead streams (Entrix 2002, Dagit et al. 2003, etc.), comparison of results is difficult due to differences in methodologies and subjectivity in the interpretation of results. The U.S. Fish and Wildlife

Service developed the *H*abitat *E*valuation *P*rocedures (HEP) in order to provide standardized assessment tools for use in multiple geographic locations and for a multitude of aquatic species (USFWS 1980).

A component of the HEP process produces a *H*abitat *S*uitability *I*ndex (HSI) value that rates overall habitat quality on a scale of 0 (no habitat) to 1 (optimal habitat), based on a model incorporating 18 individual variables. This HSI methodology was chosen to assess habitat quality because the model utilizes a wide range of habitat variables that are summarized into a single quantitative value (i.e., the HSI score), which can be easily and consistently compared among streams. The rainbow trout / steelhead HSI model (Raleigh et al. 1984) incorporates several variables that are particularly important to steelhead populations in the southern portion of their range, such as water temperature, pool habitat characteristics, and riparian coverage. The HSI model and its individual variables and components will be described in a following section of this report.

Uncertainty in the HSI Methodology

Although the HSI methodology has been routinely applied in other areas of the United States, validation of this model for south-central California Coastal steelhead has not, to our knowledge, been conducted. An HSI validation study was performed in the Ventura/Matilija Basin and did show a positive and statistically significant relationship between reach-specific HSI scores and fish densities, with R^2 values of 0.6-0.7 for juvenile and fry *O. mykiss*, respectively (TRPA 2008). However, the application of the HSI model for steelhead near the limit of their natural range required modification of several HSI variables, a process encouraged by the model authors (Raleigh et al. 1984). Variable modification was essential for some water temperature variables which did not accurately represent suitability for fish adapted to warmer climates, because unmodified variables routinely produced zero suitability values where fish were commonly found (TRPA 2008). Consequently, the modification of existing HSI variables, or the introduction of new HSI variables, introduces uncertainty into model performance for locations outside of the validation area.

An additional limitation of the HSI methodology occurs when combining the HSI scores (which represents habitat quality only) with estimates of habitat quantity in an attempt to estimate overall habitat "value". Simple multiplication of the quality and quantity scores may produce the same value for a large amount of low quality habitat as for a smaller amount of higher quality habitat. Although such a relationship may exist, it is highly unlikely to be a linear relationship and thus comparison of quality/quantity scores can be misleading. For example, a large quantity of low quality habitat can, in effect, overshadow the presence and/or importance of a smaller amount of higher quality habitat. For this study, overall habitat "value" scores were calculated by weighting reach-specific habitat quality values (the HSI scores) by habitat quantity only within each respective tributary or sub-basin (i.e., mountain versus valley), which was anticipated to give a clearer comparison of average habitat quality scores in addition to facilitating the comparison of overall habitat value between the different tributaries and basin areas.

The successful application of the HSI methodology for *O. mykiss* in the southern extent of their range is further complicated by the high variability in annual rainfall and its associated effects on habitat parameters, such as habitat availability, thalweg depths, instream cover, riparian vegetation, water temperature, etc. This study attempted to account for this uncertainty by calculating alternative HSI scores that either *included* dry portions of stream channels, which lowered sub-basin scores due to inclusion of habitat with zero-suitability, or else *excluded* dry channels, which did not allow the zero-suitability areas to influence sub-basin scores. Similarly, this HSI model also had to make assumptions regarding the upstream limits of *O. mykiss* distributions in each of the basins tributaries, because actual determination of distribution limits was beyond the scope of this study.

Additional uncertainty is introduced when expanding reach-specific HSI scores to represent unsampled areas. A goal of the study was to develop an HSI score that represented the entire basin above Lopez Dam, however it was not possible to collect HSI data within each of the major tributaries under the given level of effort and funding. Consequently, a stratified design was employed to partition the upper Arroyo Grande Basin into representative strata from which reach-specific HSI scores were assigned to unsampled areas.

Description of Study Area

The Upper Arroyo Grande Basin was sub-divided into four sub-basins representing the main arms of Lopez Lake (Figure 2): the Arroyo Grande Sub-basin; the Whittenberg Sub-basin; the Vasquez Sub-basin; and the Lopez Canyon Sub-basin.

The Arroyo Grande sub-basin includes the mainstem Arroyo Grande Creek, Clapboard Creek, Phoenix Canyon Creek, Potrero Creek, and Saucelito Creek. With the exception of Clapboard Creek, most of the Arroyo Grande sub-basin streams are low gradient and flow through wide valleys that are privately owned and intensively managed for agriculture and/or grazing. The mainstem Arroyo Grande Creek, Phoenix Canyon Creek, and Saucelito Creek were all flowing during the April site visit (Table 1), however dry or intermittent channels were present in late fall in portions of the upper mainstem and in Saucelito Creek, and Phoenix Canyon Creek contained only a trickle of surface flow in its lower reaches. Clapboard Creek and Potrero Creek were not visited during this study, but it is likely that Potrero Creek was also dry or intermittent during the summer months.

The Whittenberg sub-basin contains Whittenberg Creek, Huffs Hole Creek, and Dry Creek (Figure 2). All three streams were flowing in April 2010 (Table 1), but lower reaches of all streams were dry or intermittent in November (Whittenberg appeared to go intermittent by early June, according to temperature logger data). Unlike the Arroyo Grande sub-basin, most of the Whittenberg sub-basin streams are confined in narrow canyons within the Los Padres National Forest and Santa Lucia Wilderness area.

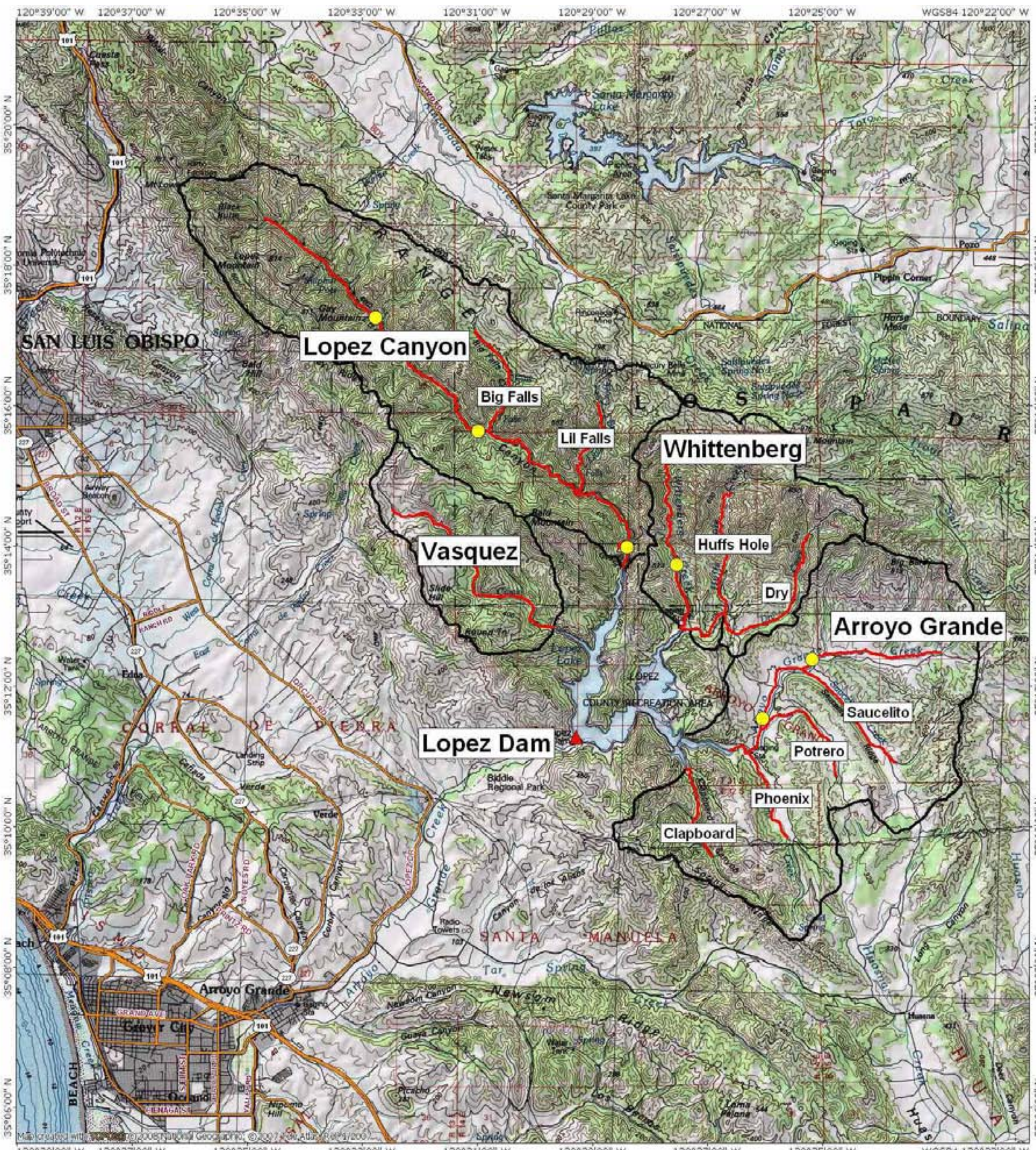


Figure 2. Sub-basins and principal tributaries in the upper Arroyo Grande watershed. Yellow circles show approximate locations of temperature data loggers.

The Vasquez sub-basin is the smallest of the four and only contains Vasquez Creek, which was not visited during this study due to difficulty of access. This tributary descends through a narrow canyon and is presumed to be perennial in flow.

The Lopez Canyon sub-basin is the largest sub-basin (approximately 21 mi^2) and includes the mainstem Lopez Canyon Creek as well as several perennial tributaries, including Little Falls Creek and Big Falls Creek. Although the lower four miles of Lopez Canyon Creek flows along a gravel road with numerous private residences, the upper half and the principal tributaries all occur within the Santa Lucia Wilderness area. Flow appeared perennial in the mainstem and the two falls tributaries except for short stretches of intermittent flow during the late fall (Table 1).

Table 1. Estimated streamflows observed in stream reaches during April and November 2010 site visits.

Sub-basin	Stream	Elevation *ft*	April Flow *cfs*	Nov Flow *cfs*
Arroyo Grande	Arroyo Grande	600	1.9	0.2
	" " "	680	1.6	0.6
	" " "	750	n/a	0.0
	Phoenix	560	0.3	0.1
	Saucelito	680	0.3	<0.1
Whittenberg	Whittenberg	640	n/a	0.0
	" " "	850	0.8	0.2
	Huffs Hole	570	0.8	0.0
	Dry	720	0.2	0.0
Lopez Canyon	Lopez Canyon	570	8.4	1.8
	" " "	800	3.5	0.7
	" " "	1100	2.4	1.2
	Little Falls	690	0.7	0.2
	Big Falls	810	1.9	<1.0

Study Methodologies

The quantity and quality of aquatic habitat for rainbow trout in the upper Arroyo Grande Basin was assessed by the following process:

1. stratifying the upper basin into similar stream segments;
2. randomly selecting a stream reach to represent each stream segment;
3. mapping each selected stream reach using the California Department of Fish & Game (CDFG) level II habitat typing definitions;
4. collecting HSI data to calculate a reach and segment-specific HSI score, and;
5. weighting each segment HSI score by the estimated availability of each segment type in the upper basin to calculate an overall basin-wide HSI score.

Basin Stratifications and HSI Reach Selection

Project scoping allowed the selection of six HSI reaches, therefore the upper Arroyo Grande Basin was stratified into six segment types, based roughly on valley confinement, channel size, channel gradient, and elevation (Table 2). For the purpose of this HSI study, emphasis was placed on the two principal tributaries: Arroyo Grande Creek and Lopez Canyon Creek, which represented approximately 60% of the upper watershed area. Consequently, two HSI sites were selected on mainstem Arroyo Grande Creek, and three sites were selected on mainstem Lopez Canyon Creek.

Within each basin segment, the available stream channels were divided into sub-segments on the basis of changes in gradient, confinement, or tributary confluence. These sub-

Table 2. Summary of segment and sub-segment characteristics in the Upper Arroyo Grande Basin. Sub-segments marked with an asterisk contained the selected HSI reaches. Italicized sub-segments represent dry, intermittent, or otherwise non-suitable summer stream habitat.

Basin Segment	Basin Sub-segments	Length *mi*	Elevations *ft msl* top	bottom	Channel Gradient %
Mountain High Gradient	* Whittenberg c	1.38	1132	709	5.8
	Whittenberg d	0.43	1280	1,132	6.5
	Dry a	*0.92*	*890*	*579*	*6.4*
	Dry b	0.29	965	890	4.9
	Dry c	0.95	1329	965	7.3
	Huffs Hole c	0.55	761	638	4.2
	Huffs Hole d	0.78	1119	761	8.7
	Huffs Hole e	0.57	1319	1,119	6.6
	Little Falls a	*0.20*	*717*	*669*	*4.5*
	Little Falls b	0.59	948	717	7.4
	Little Falls c	0.32	1018	948	4.1
	Little Falls d	0.76	1280	1,018	6.5
	Big Falls b	0.85	1199	852	7.7
	Vasquez a	2.16	1007	568	3.8
	Segment Total Length:	**10.75**	**1,069**	**< Means >**	**6.0**
	% of Basin Total:	**27%**			
Mountain Medium Gradient	Upper Lopez Canyon a	0.51	1155	1,102	2.0
	* Upper Lopez Canyon b	2.14	1516	1,155	3.2
	Vasquez b	1.92	1426	1,007	4.1
	Big Falls a	0.25	852	799	4.0
	Big Falls c	1.01	1365	1,199	3.1
	Segment Total Length:	**5.83**	**1,263**	**< Means >**	**3.3**
	% of Basin Total:	**15%**			
Mountain Low Gradient	* Middle Lopez Canyon a	0.91	902	799	2.1
	Middle Lopez Canyon b	*0.65*	*955*	*902*	*1.5*
	Middle Lopez Canyon c	0.48	991	955	1.4
	Middle Lopez Canyon d	0.95	1102	991	2.2
	Whittenberg b	*1.08*	*709*	*568*	*2.5*
	Huffs Hole b	*0.54*	*637*	*579*	*2.0*
	Segment Total Length:	**4.61**	**883**	**< Means >**	**2.0**
	% of Basin Total:	**12%**			
Mountain Mainstem	Lower Lopez Canyon a	0.80	574	563	0.3
	Lower Lopez Canyon b	0.83	618	574	1.0
	Lower Lopez Canyon c	1.07	721	618	1.8
	* Lower Lopez Canyon d	1.57	799	721	0.9
	Whittenberg a	*0.39*	*568*	*540*	*1.4*
	Huffs Hole a	*1.07*	*579*	*540*	*0.7*
	Segment Total Length:	**5.73**	**643**	**< Means >**	**1.0**
	% of Basin Total:	**15%**			
Upper Valley	* Upper Arroyo Grande a	0.87	750	660	2.0
	Upper Arroyo Grande b	*1.84*	*952*	*750*	*2.1*
	Saucelito	*2.00*	*930*	*679*	*2.4*
	Lower Potrero	*2.13*	*1035*	*569*	*4.1*
	Phoenix	*1.66*	*719*	*543*	*2.0*
	Clapboard	*1.64*	*732*	*529*	*2.3*
	Segment Total Length:	**10.14**	**853**	**< Means >**	**2.5**
	% of Basin Total:	**26%**			
Lower Valley	* Low Arroyo Grande	2.17	660	522	1.2
	Segment Total Length:	**2.17**	**660**	**< Means >**	**1.2**
	% of Basin Total:	**6%**			
	Basin Total Length:	**39.2**	**25.1** *(excluding dry channels)*		

segments were then allocated into one of the six major segment types (Table 2). Sub-segments excluded all headwater channels that were over 1,200-1,500 ft mean sea level (msl) and possessed gradients greater than 10% due to uncertainty in the extent of perennial flow and/or the suitability of habitat for fish rearing (those channels are not listed in Table 2 or shown in Figure 2). The sub-segments shown in Table 2 do include lower elevation and lower gradient portions known or suspected to be dry during summer months (italicized rows), however those sub-segments were not included in the selection process for HSI reaches.

The “Lower Valley” and “Upper Valley” segments both represented channels in the Arroyo Grande sub-basin within wide, unconfined valleys (except for Clapboard Creek). The “Lower Valley” segment only contained the lower mainstem of Arroyo Grande Creek, whereas the “Upper Valley” segment contained upper Arroyo Grande Creek as well as its four principal tributaries, all of which were expected to be dry or possess limited habitat over the summer base flow period (Figure 3). The Lower Valley and Upper Valley segments of Arroyo Grande Creek were divided into one-half mile reaches, and one HSI reach was selected at random from each segment.

The “Mountain High Gradient” segment represented higher elevation (mostly >1,000 ft msl), higher gradient (mean=6%) channels within steep valley walls, but excluded the highest, steepest channels as described above (Table 2, Figure 3). Whittenberg Creek was subjectively chosen to represent this upper tributary habitat, because of public access to that streams upper watershed and its central location between Lopez Canyon’s principal tributaries (Little Falls and Big Falls creeks) and the major tributaries to the east (Huffs Hole and Dry creeks). Consequently, upper Whittenberg Creek was divided into one-half mile reaches and a single reach was randomly selected to represent HSI data for this segment type.

The “Mountain Medium Gradient” segment represented confined stream channels at higher elevations (mostly >1,000 ft msl), but with moderate gradients of 2-4% (mean=3.3%). This segment included the upper mainstem of Lopez Canyon Creek, and some reaches on Big Falls and Vasquez creeks (Table 2, Figure 4). To represent this segment, upper Lopez Canyon Creek was divided into one-half mile reaches (up to the large horseshoe bend), and one reach was randomly selected for HSI data collection.

The “Mountain Low Gradient” segment was also composed of confined stream reaches, but at lower elevation (mostly <1,000 ft msl) and lower gradient (mean=2.0%), and included reaches in the middle portion of Lopez Canyon Creek as well as middle portions of Huffs Hole and Whittenberg creeks (Table 2, Figure 4). The latter two reaches were expected to be dry or intermittent during summer base flows; consequently this segment was represented by a randomly chosen one-half mile reach on middle Lopez Canyon Creek.

The sixth segment, “Mountain Mainstem”, was composed of the lower mainstem of Lopez Canyon Creek as well as the lowermost reaches of Whittenberg and Huffs Hole creeks (Table 2, Figure 4). This segment was characterized by confined, low gradient (mean=1%) channels at low elevations (<800 ft msl), and was represented by a one-mile HSI reach non-randomly selected in Lopez Canyon Creek just below the confluence with Big Falls Creek. This reach was purposively selected because lower Huffs Hole and

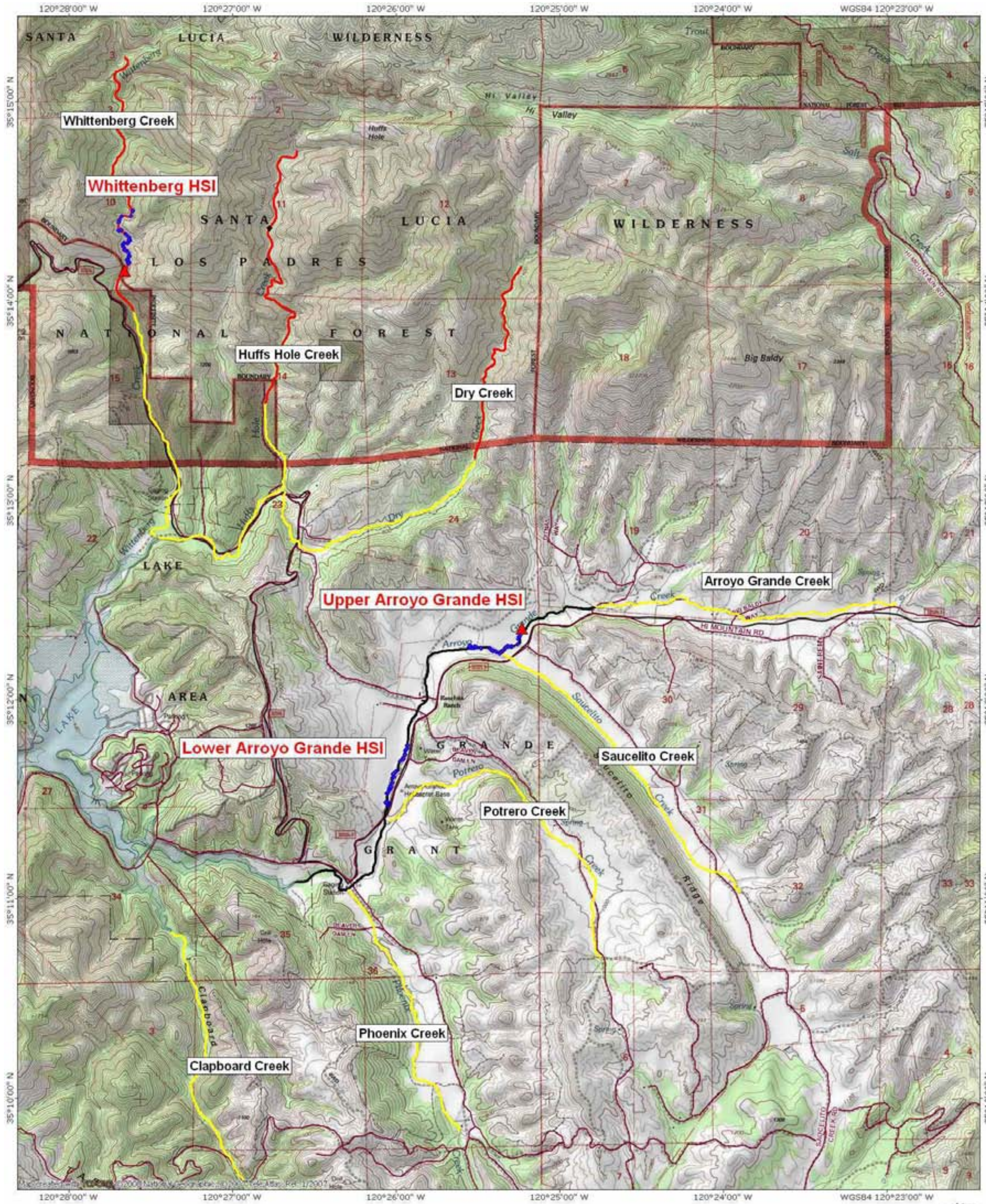


Figure 3. Map showing channel sub-segment types in the Arroyo Grande and Whittenberg sub-basins. Black lines=Lower and Upper Valley, red=Mountain High Gradient, yellow=dry channel. HSI reaches and sampling units are shown by small blue diamonds. Red triangles are barriers to upstream migration.

Whittenberg creeks were expected to be dry during summer months, and the lower three miles of Lopez Canyon Creek was continuously bordered by private residences.

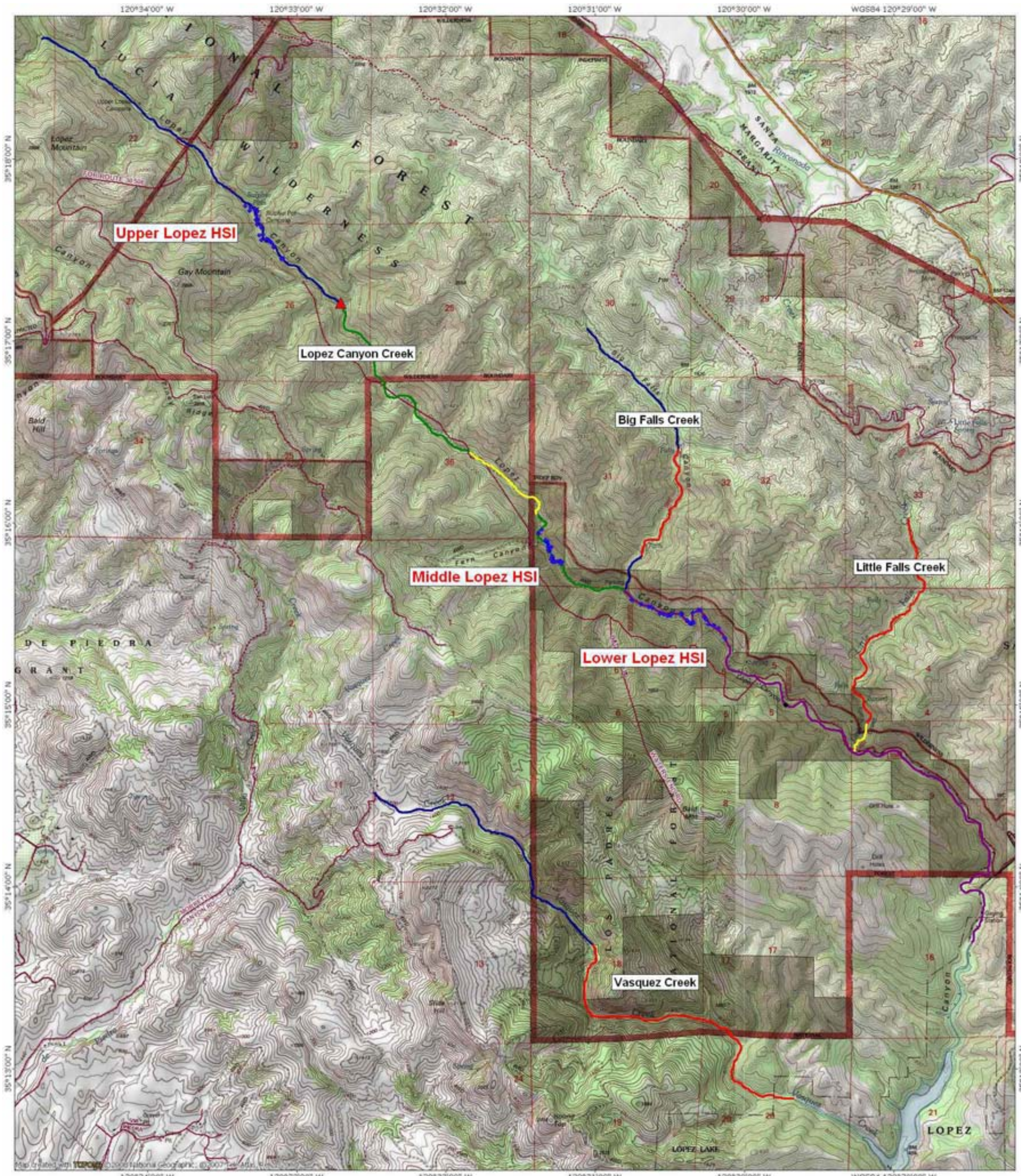


Figure 4. Map showing channel sub-segment types in the Lopez Canyon and Vasquez sub-basins. Purple lines=Mountain Mainstem, green=Mountain Low Gradient, blue=Mountain Medium Gradient, red=Mountain High Gradient, yellow =dry channel. HSI reaches and sampling units are shown by small blue diamonds. Red triangles are barriers to upstream migration.

Habitat Typing

Each of the six selected HSI reaches were mapped in April 2010 into individual habitat types (Table 3) using the California Department of Fish and Game's habitat classification system (Flosi et al. 1998). A hip chain filled with biodegradable cotton string was used to measure the lengths of each habitat unit within the GPS coordinate-defined boundaries of the HSI reach. In addition to habitat type classifications, notes were taken to describe general stream channel characteristics, areas of degraded habitat, landmarks, potential barriers to migration, or other pertinent features. Digital photographs, water temperatures, dissolved oxygen (using an YSI 550A meter) readings were taken periodically. HSI data was collected at spawnable gravel patches where encountered (see below for discussion of HSI data). Streamflow was estimated at each HSI site by measuring width, mean depth, and eye-estimating velocity at locations possessing laminar flow conditions.

Table 3. Habitat type codes used in HSI reach mapping. See Flosi et al. (1998) for habitat type definitions. Note that an additional scour pool type, LS"D" for "Dirt", was added to this list.

Category	Code	Habitat Type
POOLS	TRP	trench pool
	MCP	mid-channel pool
	CCP	channel confluence pool
	STP	step pool
	CRP	corner pool
	LSL	lateral scour pool - log enhanced
	LSR	lateral scour pool - root wad enhanced
	LSBk	lateral scour pool - bedrock formed
	LSBo	lateral scour pool - boulder formed
	PLP	plunge pool
	DPL	dammed pool
FLAT WATERS	POW	pocketwater
	GLD	glide
	RUN	run
	SRN	step run
RIFFLES	LGR	low gradient riffle (<4%)
	HGR	high gradient riffle (>4%)
	CAS	cascade
	BRS	bedrock sheet

After assessment of habitat availability through the map-based stratification process and field-based habitat typing, 30 individual sampling units (e.g., pools, riffles, or flatwaters) were selected from each HSI reach by simple random sampling for assessment of habitat quality using the HSI methodology (Raleigh et al. 1984). Pools, riffles, and flatwaters can be generally described as follows:

Pools. Deeper reaches with pronounced areas of bottom scour, dominated by slow velocities, smooth surface, and substrates including fines.

Riffles. Shallow reaches of swift, turbulent water with gravel, cobble, boulder, or bedrock substrates.

Flatwaters. Moderately to swiftly flowing reaches of uniform depth (glides) or with shallow thalweg (runs), with low (glides) to moderate (runs) turbulence, and substrate ranging from fines and gravel (glides) to cobble-boulder substrates (runs, pocketwaters).

See Flosi et al. (1998) for descriptions of the habitat sub-types listed in Table 3.

Habitat Quality

The HSI methodology was chosen to assess habitat quality because this model utilizes a wide range of habitat variables that are summarized into a single quantitative value (the HSI score, Figure 5), which can be easily and consistently compared among streams. The rainbow trout / steelhead HSI model incorporates several variables that are particularly important to *O. mykiss* populations in the southern portion of their range, such as water temperature, pool habitat characteristics, and riparian coverage.

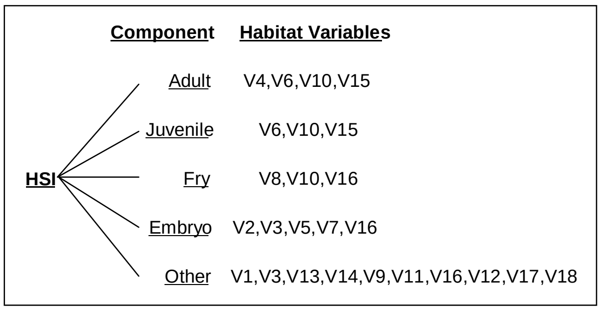


Figure 5. Model components and variable names in the rainbow trout/steelhead HSI model.

The HSI for rainbow trout / steelhead consists of five components with 18 variables (Raleigh et al. 1984). The five components (Figure 5) address four life stages (adult, juvenile, fry, and embryo), with an “other” component that includes additional variables not specific to a single life stage (Table 4). This study used the rainbow trout “equal-components” option to calculate HSI scores, which assumes that each of the five components exerts equal influence in determining the overall HSI score. Steelhead-specific HSI variables, such as V1a (adult upstream migration temperature), V2b (smolt migration temperature), and V18 (adult migration flows) were not used in this resident trout model.

Most of the variables listed in Table 4 are best measured during low flow conditions that typically exist from late summer into early winter, but some variables are best measured during periods of higher flows (e.g., spring spawning-related habitat and temperature variables). Consequently, spawning habitat variables were assessed during the April habitat typing survey, which occurred under elevated flow conditions that appeared representative of average spawning conditions. Also, continuously recording temperature data loggers (Onset Hobo U22 loggers) were deployed in all six segments in mid-April 2010 and retrieved in November (yellow circles in Figure 2).

The 18 HSI variables are shown in Figure 6. Raleigh et al. (1984) contains descriptions of each habitat variable as well as all model formulas, however those HSI curves that were modified from the “original” published curves (see Table 4) for application to upper Arroyo Grande Basin streams are described below. Modifications were deemed necessary for several of the variables due to the perceived difference in tolerances of *O. mykiss* in the southern portion of their range to the harsh environmental conditions characteristic of southern and central California. Without such modifications, HSI scores will frequently calculate to zero suitability, despite the persistence of *O. mykiss* populations. Most of the modified curves described below were developed and applied during previous HSI studies (TRPA 2004, 2007). General descriptions of field procedures used to estimate each variable are found in those reports.

Table 4. Description of HSI model variables (see Raleigh et al. 1984 for more details and for model formulas). Modified curves are described in text, strikeout variables were not used for resident trout model.

Variable Label	Variable Description	Model Component	*O. mykiss* Lifestage	HSI Curve Modified ?
V1 a,b	Avg Max Water Temperature	~~Adult~~, Other	~~migration (adult)~~, rearing	Y
V2 a,~~b~~	Avg Max Water Temp (Eggs & ~~Smolts~~)	Embryo, ~~Juvenile~~	incubation, ~~migration (smolt)~~	Y
V3	Avg Min Dissolved Oxygen	Embryo, Other	incubation, rearing	N
V4	Avg Thalweg Depth	Adult	rearing	N
V5	Avg Velocity Over Spawning Areas	Embryo	incubation	Y
V6 a,j	% Instream Cover	Adult, Juvenile	rearing	N
V7	Avg Substrate Size in Spawning Areas	Embryo	incubation	N
V8	% Substrate 10-40cm in Diameter	Fry	overwintering, rearing	Y
V9	Dominant Substrate in Riffles	Other	food production	N
V10	% Pools	Adult, Fry, Juvenile	rearing	N
V11	Avg % Vegetation & Canopy Coverage	Other	food production	N
V12	Avg % Rooted Veg or Rock on Banks	Other	all	N
V13	Annual Max/Min pH	Other	all	N
V14	Avg Annual Base Flow	Other	rearing	N
V15	Pool Class Rating	Adult, Juvenile	rearing	N
V16 i,f	% Fines in Riffles and Spawning Areas	Fry, Embryo, Other	incubation, food prod	N
V17	% Overhead Shading	Other	rearing, food prod	Y
~~**V18**~~	~~Avg % Flow During Adult Migration~~	~~Other~~	~~adult migration~~	~~N~~

Variable Explanations:

V1 r	avg max temp during fry, juv, and adult rearing
~~**V1 a**~~	avg max temp during adult (steelhead) upstream migration (this variable not used for resident trout model)
V2 e	avg max temp during egg incubation
~~**V2 s**~~	avg max temp during smolt downstream migration (this variable not used for resident trout model)
V3 e	avg min DO during egg incubation
V3 r	avg min DO during fry, juv, and adult rearing
V4	avg thalweg depth during low flows
V5	avg velocity over spawning areas during incubation
V6 a	% instream cover at depths >15cm and vels <15 cm/s during low flows for adult trout
V6 j	% instream cover at depths >15cm and vels <15 cm/s during low flows for juvenile trout
V7	avg substrate size in spawning areas
V8	% of substrate 10-40 cm diameter for fry and juv overwintering and escape cover
V9	predominant substrate size in riffle-run food producing areas (3 classes: rubble & sml boulders dominant = best score, fines or bedrock or lrg boulders dominant = worst score, gravel dominant or even mixture of all types = medium score)
V10	% pools during low flows
V11	avg % vegetation ground cover and canopy closure along streambanks during low flows (shrubs give highest rating, grass medium, and trees lowest)
V12	avg % stable streambanks due to rooted vegetation or rock substrate (optional variable)
V13	annual max or min pH value (use lowest HSI score)
V14	ratio of avg base flow : avg annual flow
V15	pool class rating during low flows (3 classes: large/deep w cover highest, small/shallow w/out cover lowest)
V16 i	% fines (<3mm) in spawning areas during low flows
V16 f	% fines (<3mm) in riffle-run food producing areas during low flows
V17	% of stream channel shaded between 1000-1400 hrs (optional variable)
~~**V18**~~	ratio of avg flow during adult steelhead upstream migration : avg annual flow (this variable not used for resident trout model)

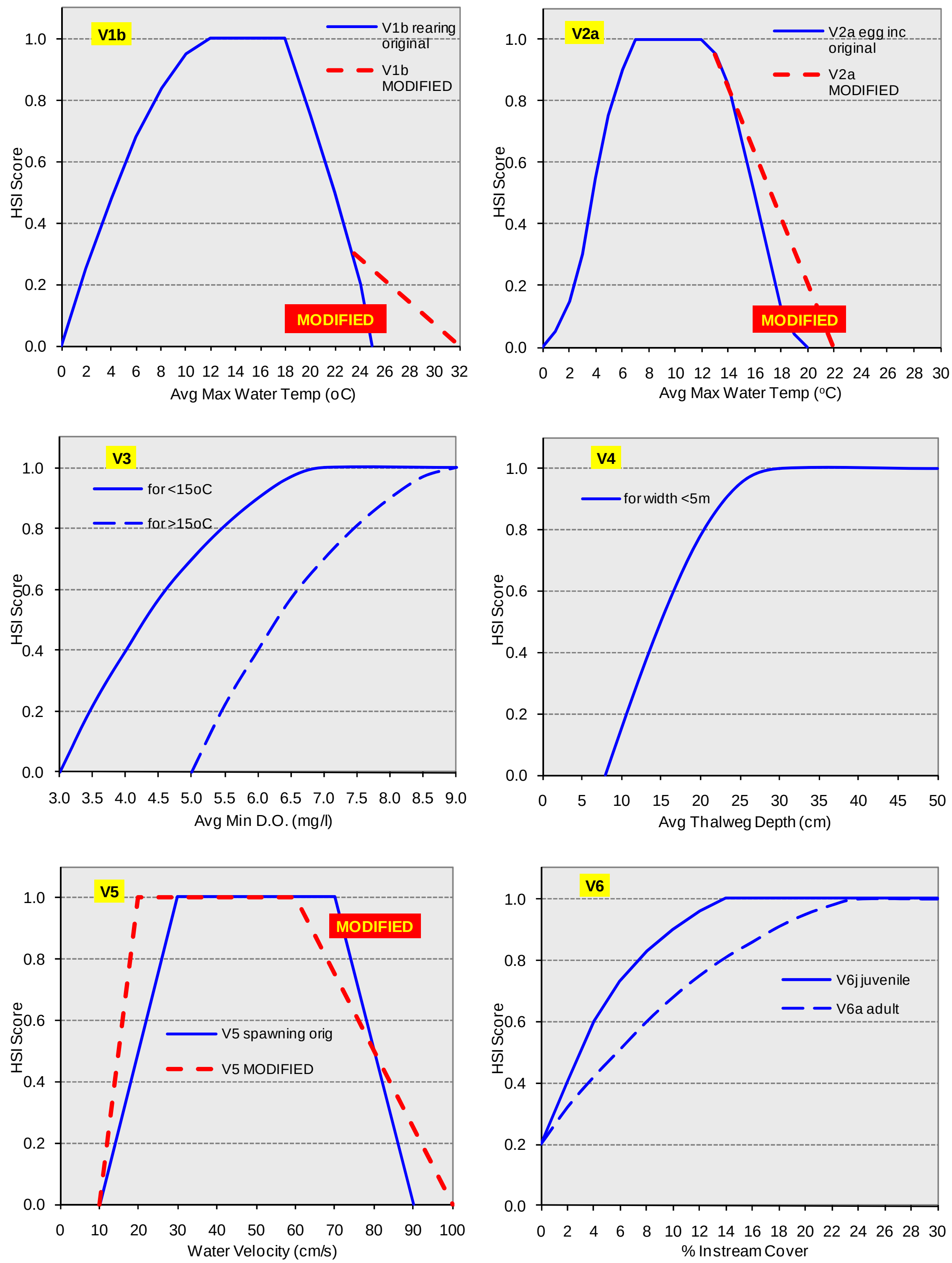


Figure 6. Original HSI variable curves from Raleigh et al. (1984). Curves modified for use in this study are shown. See Table 4 for variable descriptions.

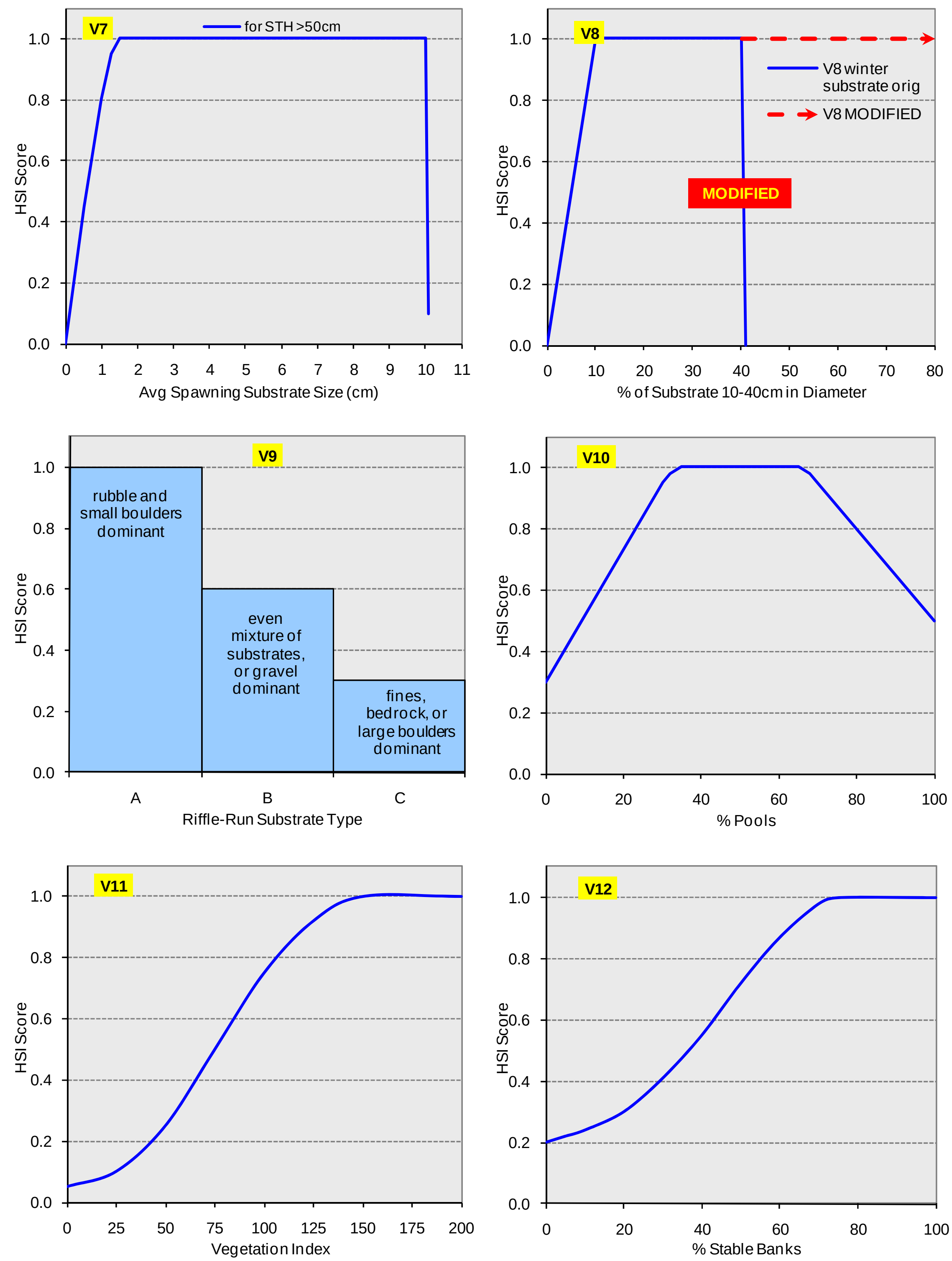


Figure 6. (continued).

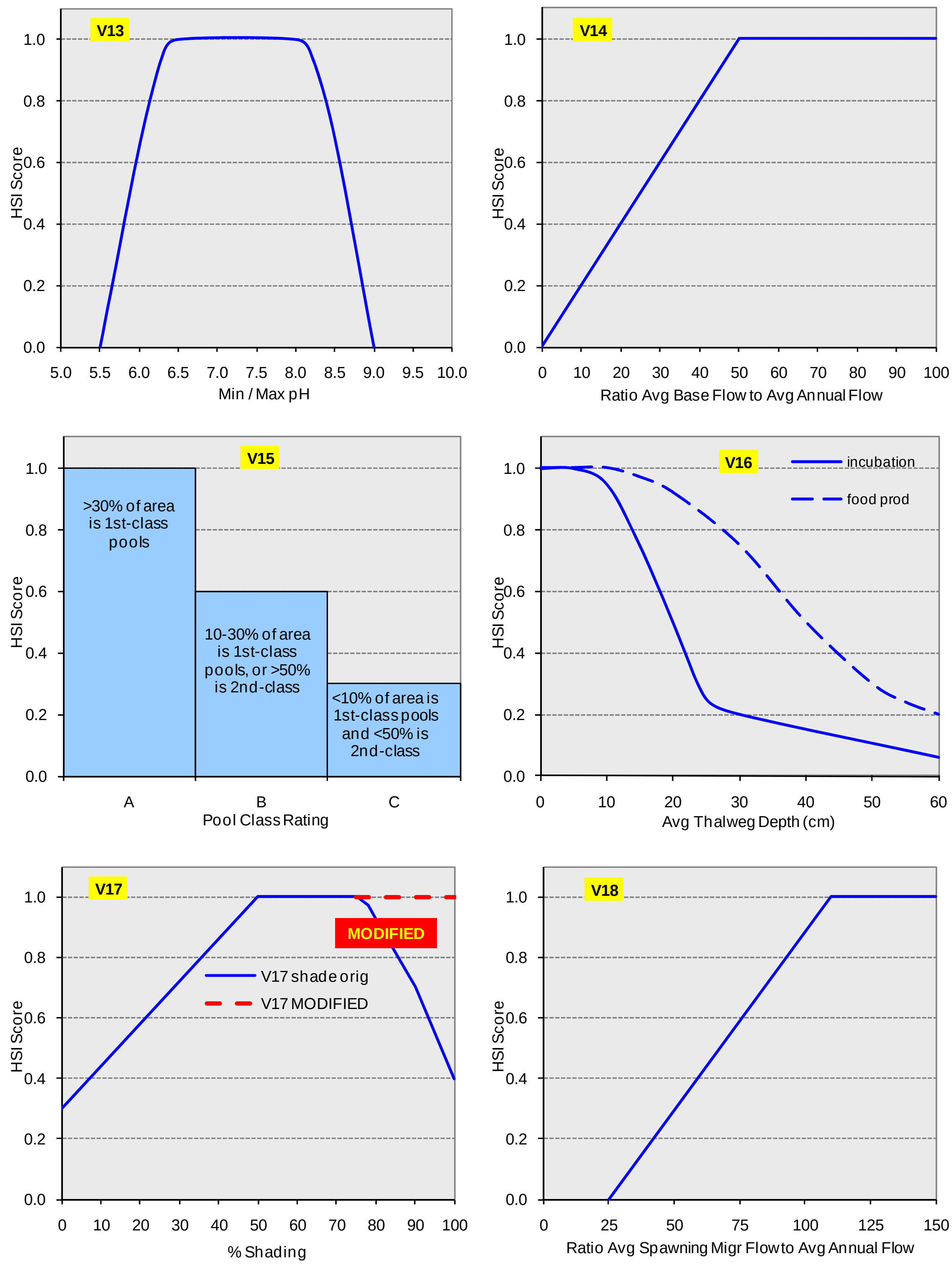


Figure 6. (continued).

Average Maximum Water Temperature for Rearing (*V1b*): The warm stream temperatures prevalent in most southern and central California steelhead streams and the "cool" temperature HSI curves ("original" curves in Figure 6) proposed by Raleigh et al. (1984) frequently produce zero HSI scores (TRPA 2004). Given the continued persistence and sometimes high densities of trout or steelhead in many such streams, the "original" HSI curves did not appear to adequately represent temperature suitability for southern or south-central *O. mykiss*. Because of this unrealistic fit and because of the high genetic variability and the ability of California populations to exist in seemingly unfavorable environments (Moyle 2002), the HSI curves for average maximum temperatures (*V*1 and *V*2) were modified from those in Raleigh et al. (1984).

These curves were modified using professional judgment and temperature data from several warm streams in California known to contain abundant *O. mykiss*. For example, the rearing curve (*V1r*) was modified using available temperature data from the Ventura River (TRPA unpublished data), the lower Klamath River at Seiad Valley (USFWS Arcata, website data), Topanga Creek (Spina 2007), and maximum temperatures reported in Moyle (2002) and Myrick and Cech (2000). The upper end of the temperature curve was extended from the original suitability of 0.3 at 23.5^{o}C to a new zero point at 32^{o}C (Figure 6).

It is recognized that these curve modifications are not based on rigorous scientific experiments, and they may not account for a fish's ability to actively seek out temperature refuges and thereby avoid some of the maximum temperatures described above. Although the temperature requirements of southern steelhead during various life stages is poorly understood, it appears that the temperature graphs presented by Raleigh et al. (1984) are inappropriate for southern and central populations of *O. mykiss* for several life stages, including adult migration (*V1a*) and juvenile rearing (*V1b*), egg incubation (*V2a*), and smolt out-migration (*V2b*).

The average maximum water temperature for rearing (V1b) was estimated in each HSI reach by calculating the average of daily maximum temperatures recorded by the instream temperature loggers over the months of July and August 2010. Summer water temperatures for the Whittenberg HSI site had to be estimated from the upper Lopez Canyon data logger because lower Whittenberg Creek (where the Whittenberg logger was deployed) became dry by early June. The approximate locations of the six temperature loggers are shown in Figure 2.

Average Maximum Water Temperature for Incubation (*V2a*): As described above, the original HSI curves for winter and spring egg incubation commonly produce zero suitability scores for *O. mykiss* in southern and central California streams, and the same modification procedures described for variable *V1* were again applied to variable *V2*. Information was not collected on incubation temperatures in warm salmonid streams, therefore the shown modification was drawn entirely by eye and the proposed change is relatively minor, giving a shift in the zero point from 20^{o}C to 22^{o}C (Figure 6). The mean of daily maximum temperatures, as recorded by the instream data loggers, was calculated over the period of mid-April (when the loggers were deployed) to the end of May 2010.

Spawning Area Velocity (*V5*). Mean velocities over potential spawning areas in upper Arroyo Grande Basin study reaches were visually estimated by measuring the distance and speed at which floating objects (e.g., sticks or leaves) passed over gravel patches. Raleigh et al (1984) proposed a single curve to represent the suitability of water velocity over spawning gravels for both rainbow trout and the (typically) much larger steelhead. The original curve appeared much too restrictive for steelhead, which are commonly known to spawn in velocities faster than indicated by the original HSI curve, and too rapid for smaller stream resident trout, similar to those found in the headwater streams in this study. TRPA's habitat suitability library contains a large collection of habitat suitability curves to represent velocities selected by spawning rainbow trout. These curves were plotted against the original HSI curve (TRPA 2007b), and the HSI curve was modified by professional judgment to better represent suitability for small adult trout spawning in headwater streams (Figure 6).

Percent Large Rearing Substrate (*V8*). Winter hiding substrate was defined by Raleigh at al. (1984) as substrate particles 10cm to 40cm in diameter (but suitability for larger sizes was not defined). Because overwintering salmonids are frequently observed to utilize larger cover elements (e.g., boulders, rip-rap, LWD, etc.), we re-defined winter cover as any substrate particle >10cm in diameter, thus including larger cover elements as well as undercut banks (Figure 6).

Percent Overhead Shading (*V17*). Midday shading was eye-estimated from one or more locations in each selected habitat unit, with the number depending upon unit size and riparian complexity. The HSI curve used in this study was modified from the original curve presented in Raleigh et al. (1984), by extending the area of maximum habitat suitability to include areas with greater canopy closure (Figure 6). Although closed canopies would typically result in lower invertebrate production, the added benefit of cooling the water temperatures in southern and central California streams might be expected to offset the reduced food production. Consequently, the HSI score of 1.0 was extended to include shade values from 75% to 90%.

Calculation of HSI Scores

HSI scores were calculated, using the resident rainbow trout equal components model (Raleigh et al. 1984), at different spatial scales. At the finest scale, HSI scores were calculated for each individual HSI reach. Reach-specific HSI scores were then applied to the length of channel within each of the six associated stream segment types to calculate weighted HSI scores for each segment (i.e., the Whittenberg HSI reach score was applied to all sub-segments in the Mountain High Gradient segment type, Table 2). Weighted HSI scores were also calculated separately for each sub-basin (except Vasquez, which was not sampled), and for the valley vs mountain segment types, to contrast habitat quality in the agricultural areas with mountainous areas. Finally, an overall HSI score was calculated to represent habitat quality in the entire basin above Lopez Lake. All segment, sub-basin, or basin-wide HSI scores were calculated either including the length of dry or intermittent channels (which were given a score of 0.0) in the weighted calculations, or by excluding those channels. For HSI scores including dry channels, those segments or sub-basin types that contained more dry channel (e.g., the Arroyo Grande and Whittenberg sub-basins) were more affected by the inclusion of habitat containing zero suitability. As previously stated, none of the weighted HSI scores included headwater areas that were not inspected, because no information was available to assess potential habitat quantity or quality.

Migration Barriers

Several barriers to the upstream migration of adult trout (or steelhead) were observed and qualitatively assessed through the course of the habitat typing and HSI field surveys. However, because the field surveys did not encompass the entire channels of each selected stream, the barriers described may not represent the only or the lowest barrier to upstream migrant salmonids. Encountered barriers were evaluated by measuring the jump pool depth, the vertical height of the drop, and the lateral breadth of the drop, using a calibrated rod. Photos were also taken of each encountered barrier.

Fish Abundance

Quantitative estimates of fish abundance were not assessed during this study. Instead, qualitative notes on the presence and gross abundance of fish were made while walking upstream, and recorded in the habitat typing data (Appendix A). However, these observations are not adequate to assess actual or relative abundance should not be used to compare abundance of trout within the upper Arroyo Grande Basin, or with other basins.

Results

The habitat typing, spawning HSI data collection and temperature data logger deployment was conducted in the upper Arroyo Grande Basin streams between 13-17 April 2010. Low flow HSI data collection and temperature data logger retrieval occurred between 1-6 November 2010. Estimated streamflows at the HSI reaches and other tributary locations during both surveys are shown in Table 1. November flows in lower Arroyo Grande Creek were lower than flows in the upper site, presumably due to water diversion or a higher proportion of subsurface flow. Likewise, estimated flows in the middle Lopez Canyon HSI reach were lower in November than flows in the upper site. This effect is likely due to increased subsurface flow, because the middle Lopez Canyon HSI site was in an area of rising groundwater immediately below a 0.7 mi stretch of dry channel (Figure 4).

Daily maximum/minimum water temperature profiles for the five in-water loggers (the Whittenberg logger site became dry by early June) are shown in Figure 7. The daily temperature plots show that all sites remained well below 68°F (20°C), except for brief periods in Lower Lopez Canyon Creek (Figure 8). Besides being the warmest site, Lower Lopez also displayed the widest daily fluctuation in temperatures, often showing a 6-8°F range. In contrast, the Upper Lopez and the two Arroyo Grande locations generally showed a daily range of <5°F. The Middle Lopez site was notable in having the most

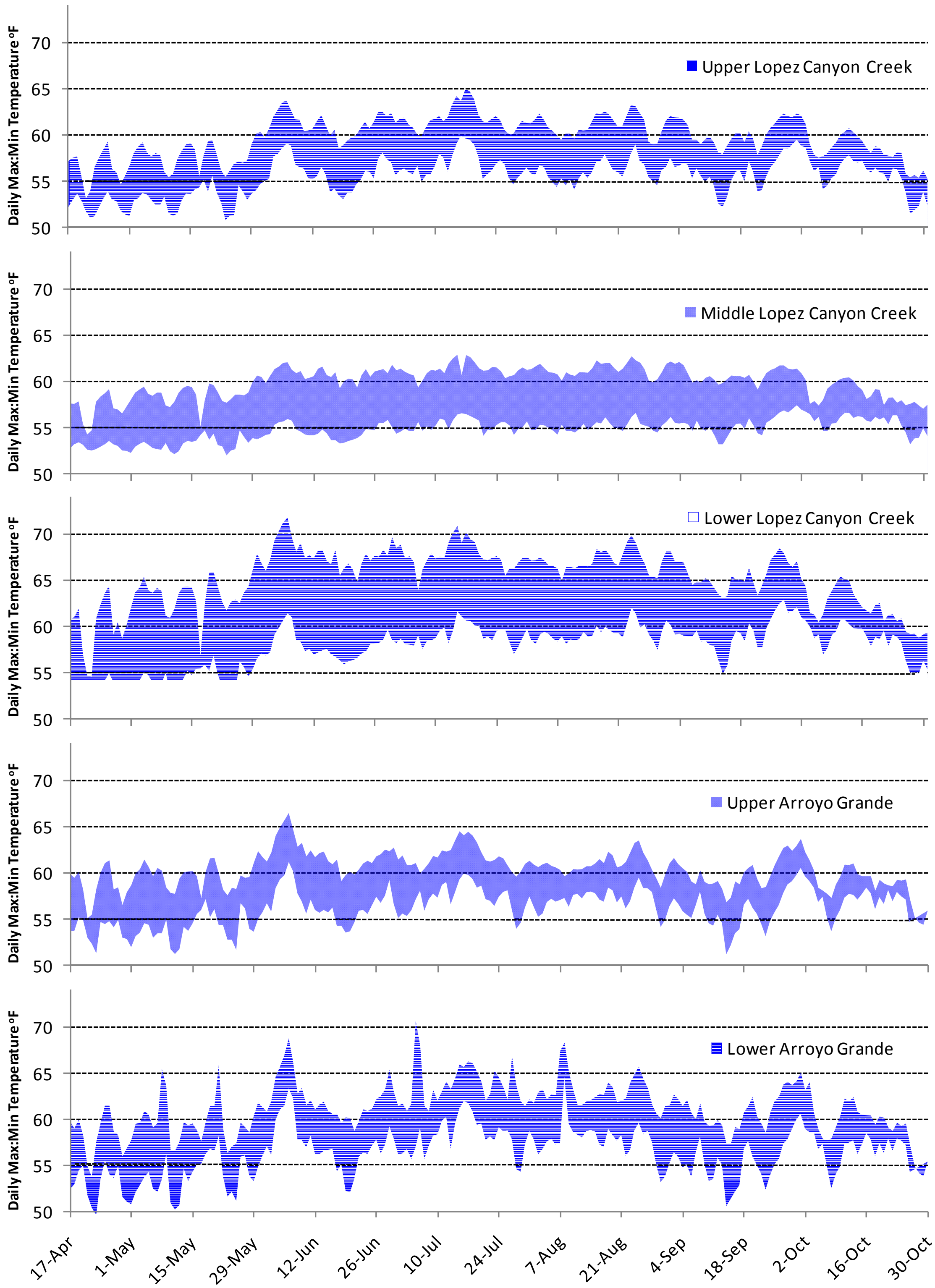
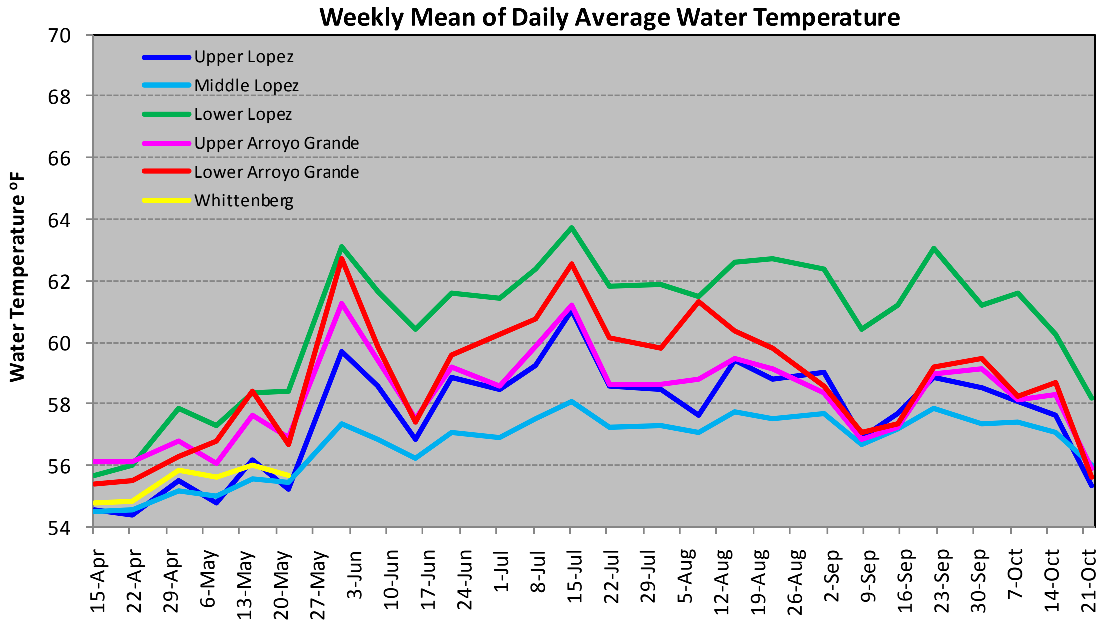


Figure 7. Daily maximum:minimum water temperatures in five basin segments (see Figure 2 for temp logger locations).



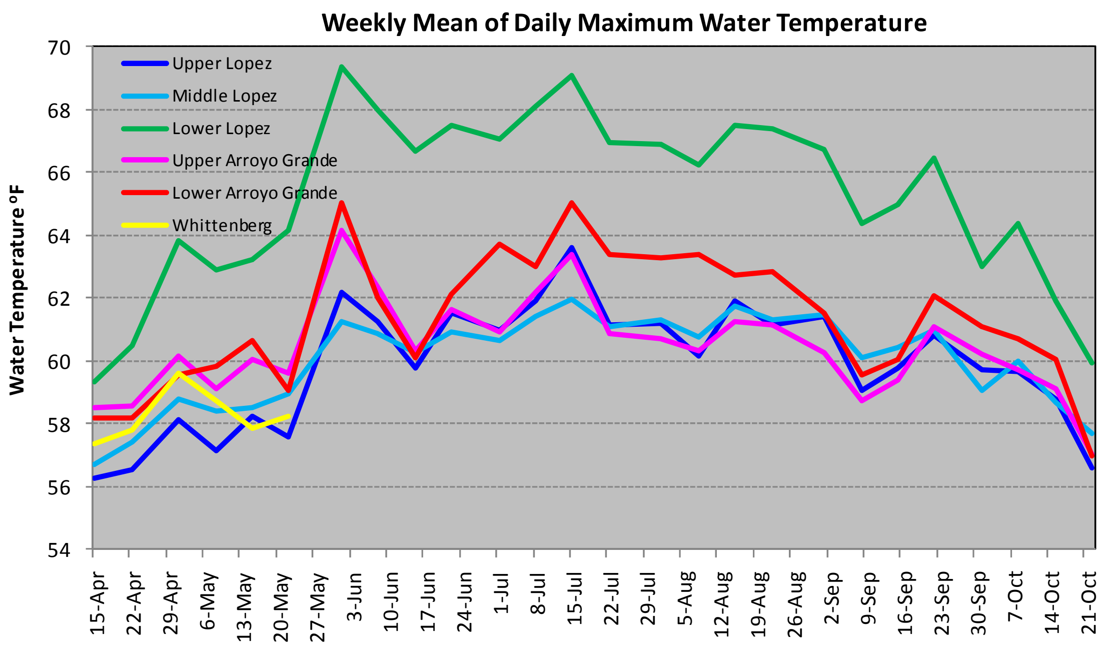


Figure 8. Weekly mean values of daily average (upper graph) and daily maximum (lower graph) water temperatures in the upper Arroyo Grande Basin (see Figure 2 for temp logger locations).

even temperature profile of all sites, where the weekly average of daily mean and daily maximum temperatures generally changed by only 1-2^{o}F throughout June, July, and August (Figure 8). This feature is likely due to the moderating effects of increased groundwater in the Middle Lopez site, as described above.

Afternoon dissolved oxygen (D.O.) levels in April 2010 were typically $\geq$7.8 mg/l in the Lopez Canyon sites, with higher levels ($\geq$8.3 mg/l) during morning hours and in

Whittenberg Creek. D.O. levels under the lower flow conditions in Huffs Hole, Phoenix, and Saucelito creeks were less at about 7 mg/l, and critical levels likely occurred in those tributaries as the streams became intermittent.

Habitat Typing

Habitat mapping identified all 20 of the main channel habitat types (Table 3) in the upper Arroyo Grande Basin, although frequency distributions differed between study reaches (Figure 9). The Upper and Middle Lopez Canyon HSI reaches had very similar habitat type distributions, dominated by low gradient riffles (at ~50%) with a relatively low proportion (<20%) of pools. The Lower Lopez Canyon and the Whittenberg HSI reaches possessed the most even distribution of pools, flatwaters, and riffles, although the Whittenberg site had the most even distribution among the 20 habitat types and contained a relatively high proportion (41%) of pools and the greatest occurrence of cascades and bedrock sheets. The two Arroyo Grande HSI reaches had similar proportions of riffle habitat, but differed in proportions of pool and flatwater types. The upper Arroyo Grande HSI reach had a particularly high proportion of glide habitat (30%), whereas the lower Arroyo Grande site had the highest proportion of pools (47%), which was uniquely comprised of corner pools. As will be seen in the following discussion of HSI scores, the proportion and character of pool habitats has an important effect on the magnitude of the overall score, particularly in smaller streams where pool size and depth may be limiting for adult trout.

Detailed habitat mapping data for each HSI reach is presented in Appendix A. The GPS waypoints associated with each sampling unit are given in Appendix B, and representative photos from each HSI reach are found in Appendix C (photos of all 180 sampling units are available on CD upon request).

Barriers to Upstream Migration

Barriers to upstream migration of juvenile and adult *O. mykiss* were incidentally observed on all three tributaries while mapping the six HSI reaches. Because intervening and downstream reaches between and below the six HSI study sites were not surveyed, these barriers may not represent the lowermost barriers that would affect upstream migration of adult spawners. However, given that a significant length of lower Whittenberg Creek was surveyed in November for surface flow characteristics, and given the low gradient nature of mainstem Lopez Canyon Creek, it is likely (but not certain) that the barriers observed on those streams may be the first significant barriers to upstream migrants. Likewise, the barrier on Arroyo Grande Creek may be the lowermost barrier, unless an ag-related diversion structure occurs downstream of the HSI study reaches.

The barrier on Lopez Canyon Creek occurs at the mouth of upper Potrero Creek, approximately 7.3 mi above the Lopez Lake high water elevation (Figure 4). It consists of a series of bedrock chutes and pools with a total vertical drop of seven ft over a longitudinal distance of 27 ft (Figure 10). The lowermost pool and bedrock chute may be passable by large trout, but the intervening bedrock pool is only two ft deep, narrow, and

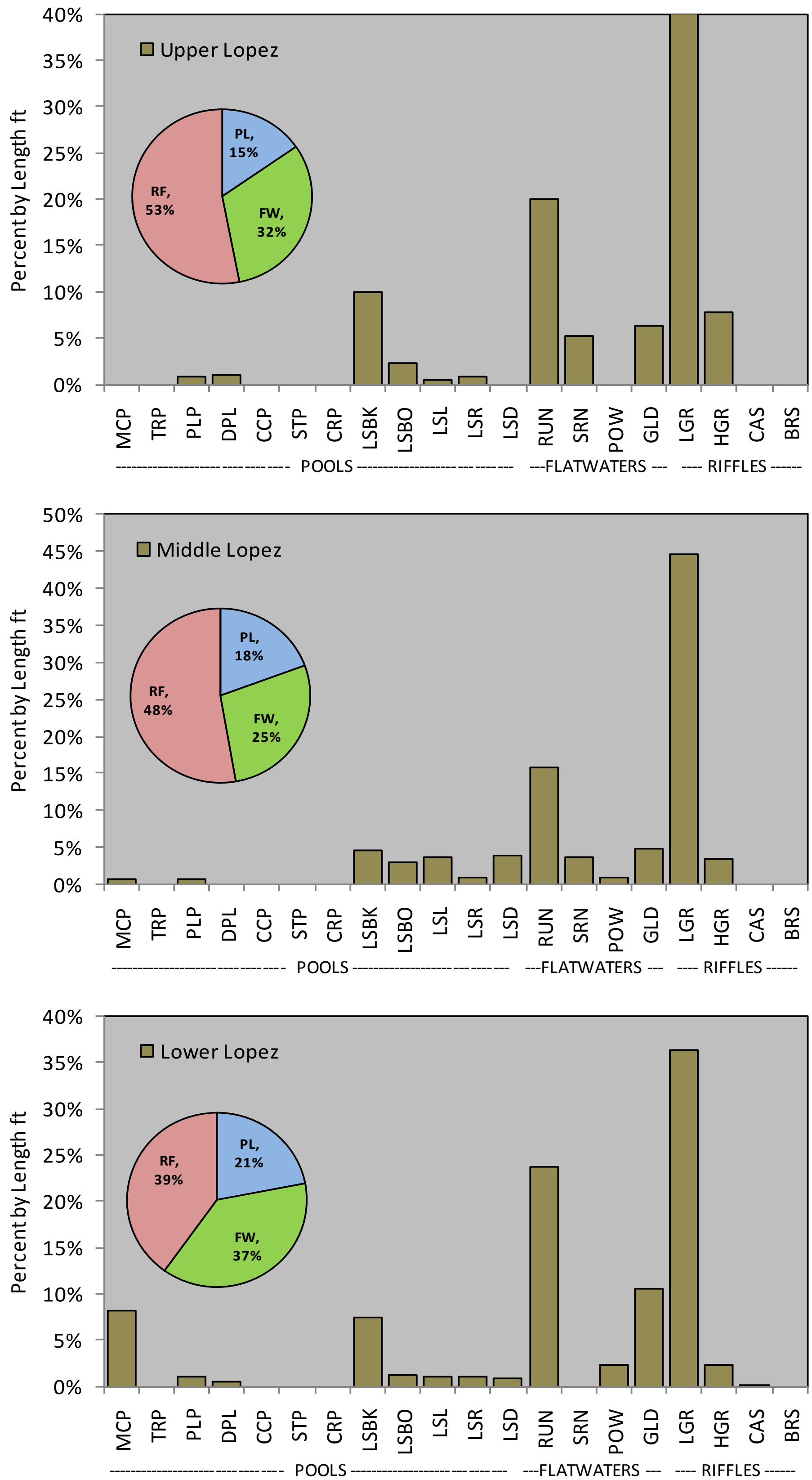


Figure 9. Habitat typing data according to HSI reach.

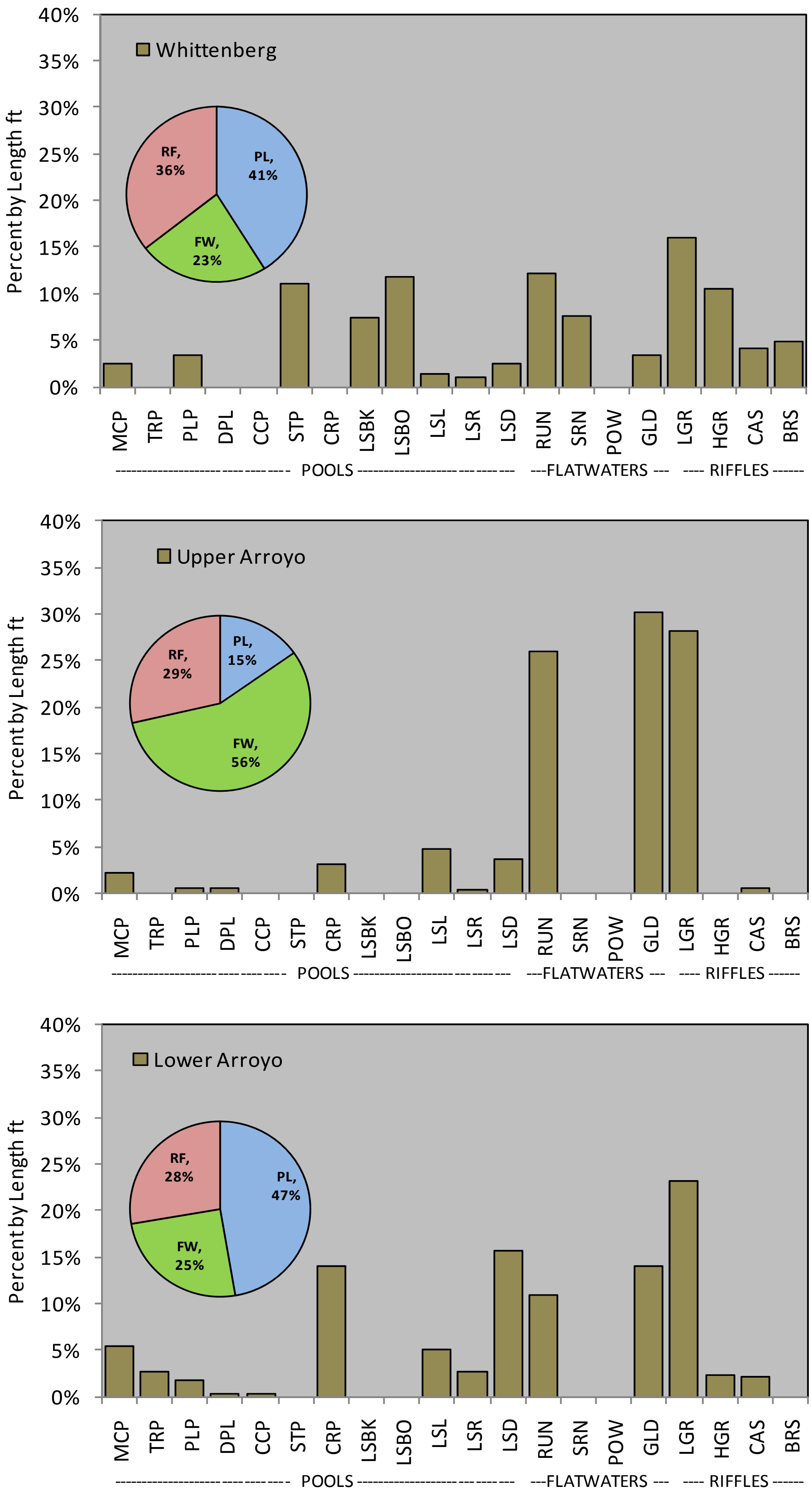


Figure 9. (continued)

highly turbulent, and leads to a bedrock chute five ft in height and 12 ft in length. Overall, this upper Lopez Canyon Creek barrier appears impassable at all flows to both small resident and larger adfluvial or anadromous *O. mykiss*.

The barrier on Whittenberg Creek occurs at the mouth of the narrow canyon adjacent to where the Upper Lopez Canyon Road cuts over the divide, 1.7 mi above Lopez Lake and just downstream of the HSI site (Figure 3). This bedrock barrier is a steep bedrock falls/chute with a total vertical drop of 13 ft and a horizontal length of 22 ft, with a five ft deep pool at its bottom (Figures 12 and 13). Although deep, the downstream pool does not appear as though it will significantly increase in depth at higher flows; consequently this barrier appears to be impassable for adult *O. mykiss* of resident or anadromous origen at all flows. Two additional bedrock falls up to four ft in height occur just upstream of this barrier.

The bedrock barrier on Arroyo Grande Creek was located 2.6 mi above Lopez Lake near the top of the upper HSI reach (Figure 3). Although significantly lower (3.5 ft high) than either of the two preceeding barriers, the lateral length of the shallow chute (13.5 ft) and the shallow jump pool (1.0 ft) suggests that this barrier is also impassable to upstream migrant *O. mykiss* (Figures 14 and 15). A large overhead log located at the pool bottom could back-up the water surface at high flows to create a deeper pool with a shorter jump distance, however the characteristics of this barrier at such flow levels is highly uncertain. Overall, this upper Lopez Canyon Creek barrier appears impassable at all flows to both small resident and larger adfluvial or anadromous *O. mykiss*.

<u>Habitat Characteristics</u>

A summary of habitat characteristics is shown in Table 5 and Figure 16. The box plots illustrate the large and often statistically significant differences, based on non-overlapping confidence intervals (red notched boxes), among the six HSI sites (Figure 16). Most notable are the variables describing percentage fines in riffle and flatwater habitats, and percentage of bank cover (Table 5). In both cases, the two Arroyo Grande HSI sites showed much higher levels of fines and a much lower degree of bank cover, which is also associated with the preponderance of fine substrate and relative lack of harder rock substrate and which is not unexpected given the location of those sites in wide, alluvial valleys with intensive agricultural-related management. The high level of fines and the lack of cobble and boulder substrate in the Arroyo Grande sites also resulted in lower values for percentage of winter substrate, instream cover, and pool bottom obscurity. In contrast, the Arroyo Grande HSI sites possessed high percentages of overhanging shrub and tree cover with associated shade ratings, due both to the dense (although narrow) strip of riparian vegetation and the deep (~10-15 ft) and highly incised nature of the stream channel.

The lower Lopez Canyon study site was notable in having larger units dimensions (length, width, etc.) with a deeper thalweg and deeper pools, all of which was expected given its larger drainage area and channel size (Table 5, Figure 16). The lower percentages of tree cover and overall shading was not due to a relative lack of riparian vegetation, but rather to the wider channel and subsequently greater proportion of the stream that was exposed to the open sky. The middle and upper reaches of Lopez Canyon Creek generally possessed very similar habitat characteristics, although the middle site had significantly more instream cover and less shade than did the upper site. Those two study sites had the lowest percentages of fine substrates in riffle and flatwater habitats of all six study reaches.

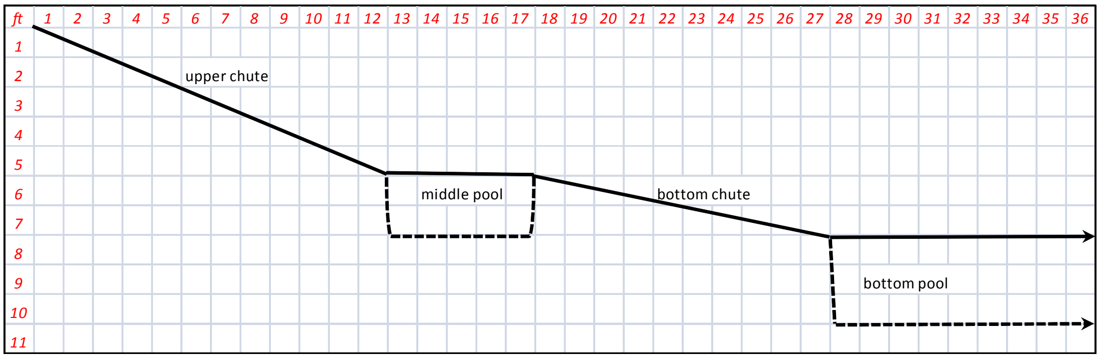


Figure 10. Lateral view of barrier on Lopez Canyon Creek (scale approximate).

Figure 11. Photos of Lopez Creek barrier from below (left photo) and above (right photo). Rod in photo is 4 ft in length.

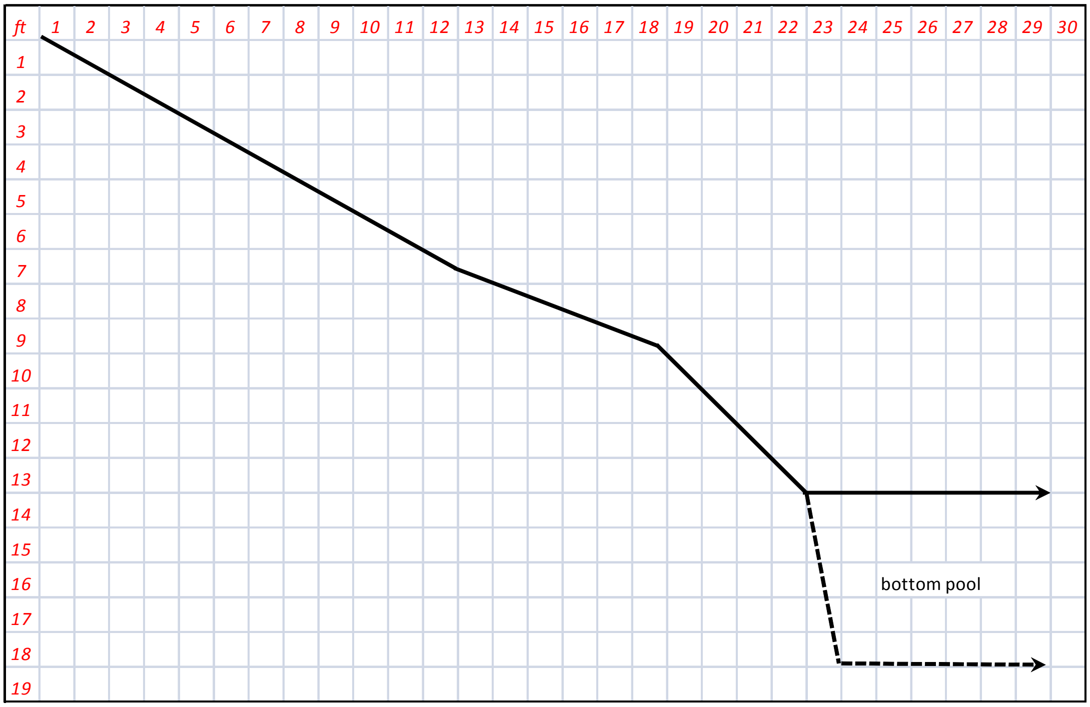


Figure 12. Lateral view of barrier on Whittenberg Creek (scale approximate).

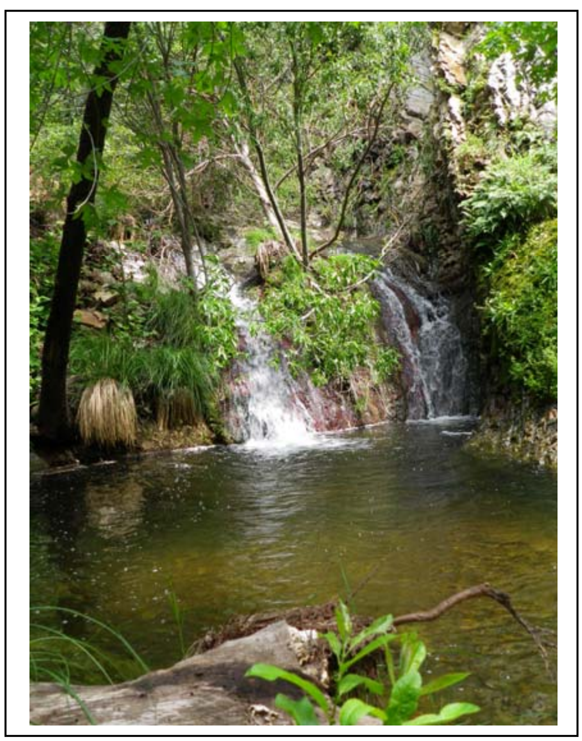


Figure 13. Photo of Whittenberg Creek barrier.

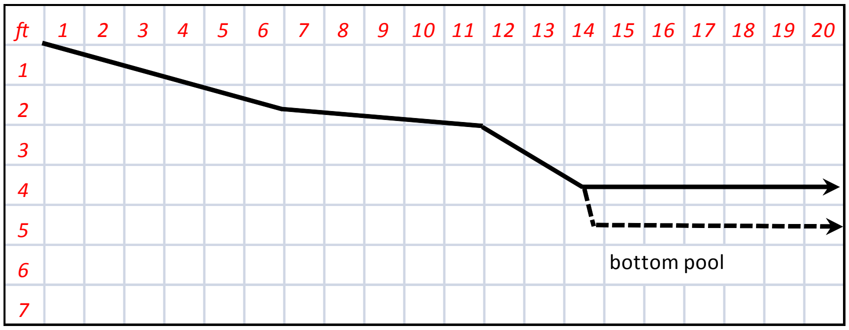


Figure 14. Lateral view of barrier on Upper Arroyo Grande Creek (scale approximate).

Figure 15. Photo of barrier on Upper Arroyo Grande Creek. Rod in photo is 4 ft in length.

Whittenberg Creek was notable in having the highest percentagle of bank cover, which was more due to the abundance of cobble, boulder, and bedrock substrate rather than density of bankside shrubs, for which Whittenberg Creek was the lowest of all sites (Table 5, Figure 16). The percentage of channel shading, however, was high in Whittenberg Creek, due to the streams narrow channel and the high percentage of large, mature trees.

Table 5. Summary statistics of physical habitat in the six HSI reaches.

HSI Reach	Statistic	Unit Length *ft*	Unit Width *ft*	Thalweg Depth *ft*	Pool Max Depth *ft*	% Winter Substrate	% Fines RF / FW	% Instream Cover
Whittenberg	N	30	30	30	13	30	17	30
	Mean	19.8	5.4	0.76	1.89	21	12	12
	Std Error	3.2	0.6	0.12	0.37	3.2	2.4	2.0
	Median	16.0	5.0	0.63	1.30	18	15	10
	Std Dev	17.4	3.3	0.65	1.35	17.5	10.0	10.8
	Minimum	3.0	1.0	0.13	0.70	0	0	0
	Maximum	80.0	15.0	2.90	5.50	80	30	40
Upper Lopez	N	30	30	30	9	30	21	30
	Mean	26.2	7.1	0.61	1.23	14	8	8
	Std Error	1.4	0.3	0.04	0.18	1.5	1.1	0.9
	Median	26.0	7.0	0.55	1.10	15	5	5
	Std Dev	7.9	1.4	0.24	0.54	8.4	4.9	5.0
	Minimum	11.0	5.0	0.33	0.60	5	0	0
	Maximum	43.0	10.0	1.33	2.20	30	20	20
Middle Lopez	N	30	30	30	9	30	21	30
	Mean	25.2	7.5	0.64	1.22	15	7	11
	Std Error	2.7	0.4	0.03	0.12	1.7	0.7	1.1
	Median	20.0	7.0	0.56	1.20	15	5	10
	Std Dev	14.5	2.1	0.18	0.36	9.4	3.4	5.9
	Minimum	10.0	5.0	0.40	0.70	0	0	0
	Maximum	80.0	13.3	1.13	2.00	50	15	20
Lower Lpoez	N	30	30	30	7	30	23	30
	Mean	38.9	9.7	0.84	1.79	19	19	10
	Std Error	4.4	0.4	0.07	0.22	2.6	3.2	1.3
	Median	38.0	10.3	0.70	1.70	15	15	5
	Std Dev	23.9	2.3	0.40	0.58	14.0	15.2	7.1
	Minimum	5.0	5.7	0.45	1.00	0	5	0
	Maximum	121.0	15.0	2.10	2.80	60	60	30
Upper Arroyo Grande	N	30	30	30	12	30	18	30
	Mean	26.9	5.3	0.54	0.97	6	81	7
	Std Error	5.8	0.3	0.05	0.11	1.4	7.2	1.4
	Median	19.5	5.0	0.46	0.95	0	100	5
	Std Dev	31.8	1.4	0.26	0.38	7.4	30.7	7.6
	Minimum	6.0	3.0	0.23	0.40	0	0	0
	Maximum	178.0	9.3	1.40	1.90	25	100	30
Lower Arroyo Grande	N	30	30	30	9	30	21	30
	Mean	21.4	3.8	0.56	1.57	5	64	9
	Std Error	1.9	0.3	0.08	0.17	1.5	7.7	2.2
	Median	19.0	3.7	0.45	1.40	0	75	5
	Std Dev	10.6	1.5	0.43	0.51	8.4	35.2	11.9
	Minimum	5.0	1.0	0.10	0.80	0	0	0
	Maximum	63.0	7.3	1.67	2.20	30	100	40

Table 5. (continued)

HSI Reach	Statistic	% PL Btm Obscured	% Shrubs	% Grass	% Trees	Vegetation Ratio	% Shade	% Bank Cover
Whittenberg	N	13	30	30	30	30	30	30
	Mean	13	37	12	84	175	88	77
	Std Error	2.1	4.7	3.3	3.2	10.1	2.4	4.1
	Median	10	40	0	90	175	90	80
	Std Dev	7.5	25.6	17.8	17.5	55.3	13.1	22.4
	Minimum	0	0	0	25	58	50	20
	Maximum	25	80	60	100	260	100	100
Upper	N	9	30	30	30	30	30	30
Lopez	Mean	18	56	1	89	202	90	60
	Std Error	2.9	5.6	1.0	2.8	11.0	2.2	3.7
	Median	20	60	0	100	200	90	60
	Std Dev	8.7	30.6	5.5	15.5	60.1	11.8	20.0
	Minimum	5	0	0	50	100	60	20
	Maximum	30	100	30	100	300	100	100
Middle	N	9	30	30	30	30	30	30
Lopez	Mean	17	67	0	78	211	77	71
	Std Error	3.1	3.8	0.0	4.8	9.5	3.1	2.4
	Median	15	70	0	90	210	80	70
	Std Dev	9.4	21.1	0.0	26.1	52.0	17.0	13.0
	Minimum	10	20	0	0	60	20	50
	Maximum	40	100	0	100	300	100	100
Lower	N	7	30	30	30	30	30	30
Lpoez	Mean	13	60	10	60	194	69	60
	Std Error	2.9	4.4	2.5	5.3	8.3	4.1	4.1
	Median	15	60	5	60	203	70	60
	Std Dev	7.6	23.9	13.8	29.3	45.5	22.2	22.5
	Minimum	5	0	0	10	100	20	10
	Maximum	20	100	50	100	285	100	100
Upper	N	12	30	30	30	30	30	30
Arroyo	Mean	11	79	8	78	247	87	11
Grande	Std Error	2.0	3.8	3.5	4.9	6.9	2.9	1.8
	Median	13	85	0	90	259	90	10
	Std Dev	7.0	20.6	19.2	26.7	38.0	15.8	9.8
	Minimum	0	40	0	10	160	40	0
	Maximum	20	100	90	100	300	100	30
Lower	N	9	30	30	30	30	30	30
Arroyo	Mean	18	84	12	66	253	85	17
Grande	Std Error	5.9	3.9	3.7	5.7	7.2	3.2	2.6
	Median	5	100	0	80	260	90	18
	Std Dev	17.6	21.3	20.2	31.4	39.6	17.5	14.2
	Minimum	1	30	0	0	160	25	0
	Maximum	50	100	80	100	335	100	50

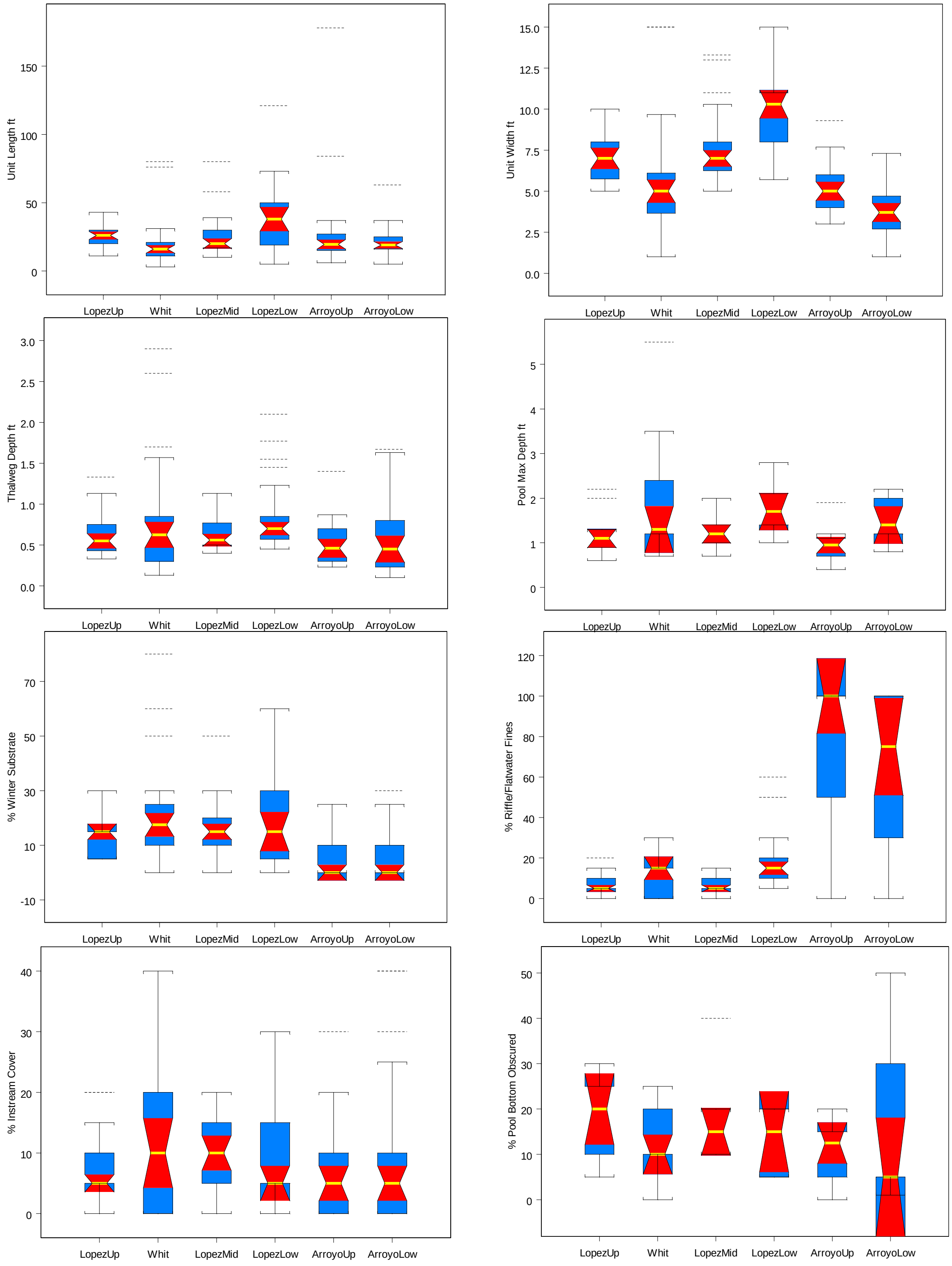


Figure 16. Boxplots of habitat characteristics according to HSI reach. Yellow lines are medians, red notched boxes are 95% confidence intervals, blue boxes are upper/lower quartiles, and whiskers show ranges (dashed lines represent outliers).

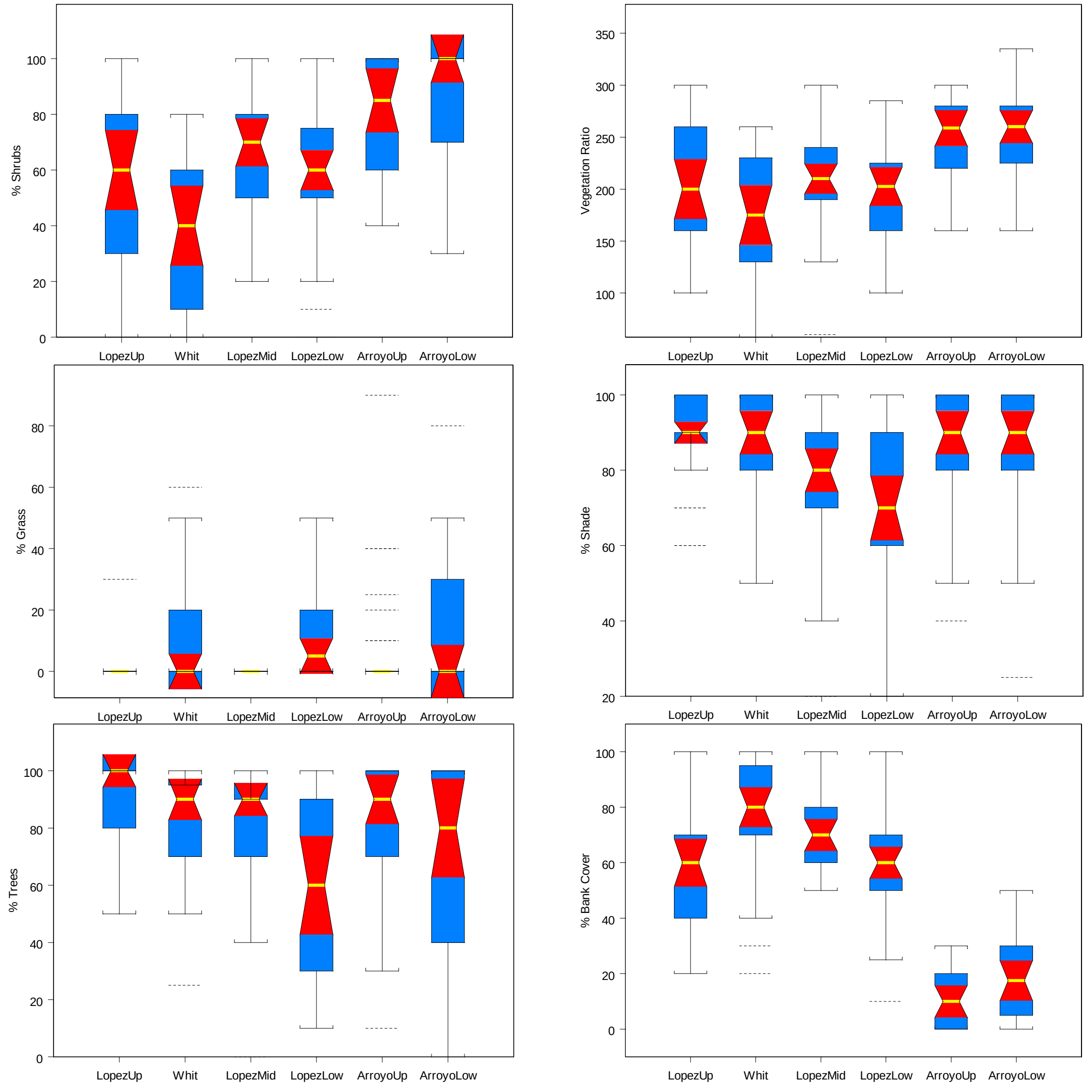


Figure 16. (continued)

Rainbow Trout Spawning Habitat

The abundance and quality of spawning gravels was assessed in each HSI reach during the April habitat typing survey. Resident *O. mykiss* spawn from February into April in many coastal drainages of central and southern California, including Coon Creek just north of San Luis Obispo (TRPA, unpublished data) and tributaries to the Ventura River south of Arroyo Grande (TRPA 2003). Streamflows that occurred in the lower reaches of Lopez Canyon Creek during March and April of 2010 (5-15 cfs) and during the April survey (Table 1) were intermediate to March-April flows from 2005-2009, and therefore habitat characteristics of measured gravel patches appeared representative of conditions typically experienced by spawning *O. mykiss* in this basin.

Redds were not commonly observed during the April survey, although trout were abundant in Whittenberg Creek and in the three Lopez Canyon Creek study reaches. One positive redd was observed in the upper Lopez Canyon HSI reach, and one probable redd was observed in the lower Arroyo Grande HSI site. It is unknown if most spawning had occurred previous to the April mapping survey and redds were not longer obvious, or if most spawning had not yet commensed.

In general, high quality spawning gravel was rare in the two Arroyo Grande study sites, due both to the general lack of rock substrate materials, and to the high levels of fines that covered the bottom of most habitat units. Twelve gravel patches averaging 20 ft^2 in area were observed in the Lower Arroyo Grande Creek HSI reach, and 17 patches averaging 48 ft^2 were assessed in the upper reach. Surface fines in those gravel patches averaged 30% in both reaches.

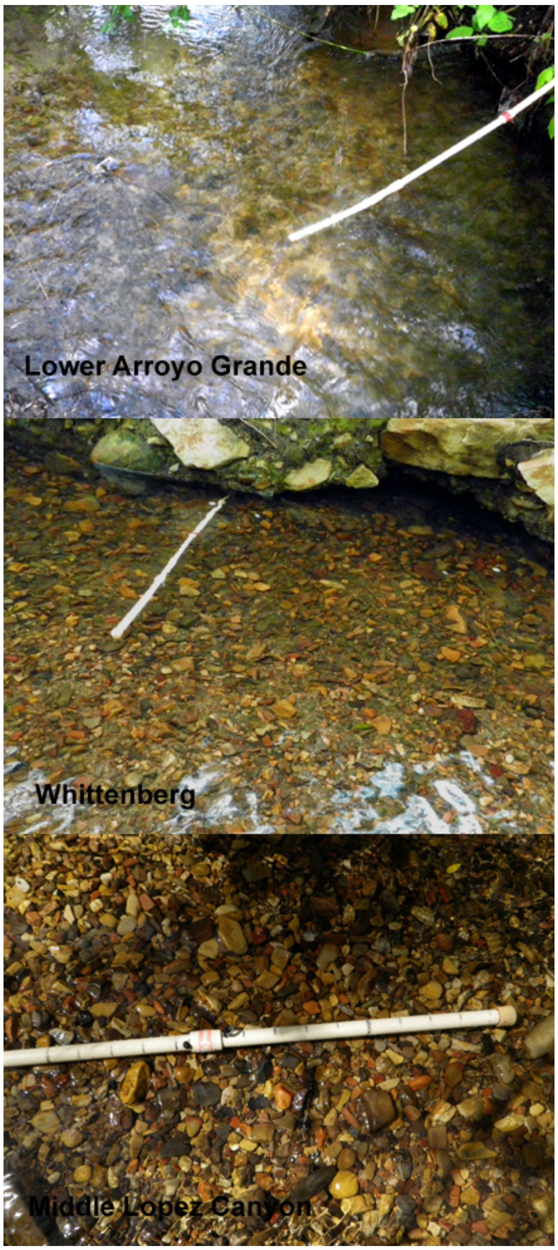


Figure 17. Example of gravel patches in Lower Arroyo Grande, Whittenberg, and Middle Lopez Canyon creeks.

Spawning gravel was generally very abundant in all three Lopez Canyon HSI reaches, and patches were larger in size with less fines. A partial enumeration of spawning gravel patches in each of those reaches yielded data on 23 patches (with a mean patch size of 90 ft^2), 17 patches (at 60 ft^2 each), and 16 patches (at 72 ft^2 each) in the lower, middle, and upper HSI reaches, respectively. Fines comprised less than 10% of the gravel patches in all three reaches. In Whittenberg Creek, 22 gravel patches averaging 45 ft^2 in size also contained less than 10% fines. Photos of representative gravel patches in Lower Arroyo Grande, Whittenberg, and Middle Lopez Canyon creeks are shown in Figure 17.

Fish Observations

O. mykiss were commonly observed in many HSI reaches. In Whittenberg Creek, trout were observed in most pools both above and below the waterfall barrier, including pools in the lower reaches that were isolated under intermittent flows. Most trout in Whittenberg Creek appeared small (i.e., <4 inches), suggesting slow growth. Newts were also commonly observed throughout the HSI reach, and a large adult red-legged frog was seen in the barrier pool (red triangle on Whittenberg Creek, Figure 3)

Trout were frequently observed in pools throughout all three Lopez Canyon HSI reaches, including a few individuals up to 6-8 inches in length. Suckers were also observed in several areas of Lower Arroyo Grande reach during the April survey, including the downsteam end above Lopez Lake, and a pool just below Big Falls Creek. Cursory surveys revealed the presence of trout above and below the first major waterfalls on Big Falls Creek, and below the first waterfall on Little Falls Creek (the stream above this falls was not surveyed).

Water visibility was reduced in both of the Arroyo Grande Creek HSI sites during the spring habitat mapping, due in part to the high level of fines and also to rains that occurred a couple of days prior to the mapping. Only a single trout, approximately four inches in length, was observed in the upper HSI reach during the April survey. A probable redd was also observed in the lower reach, indicating the presence of trout in that reach. Despite the poor visibility, the near complete lack of trout observations in the two Arroyo Grande study sites during both the April and the November surveys suggests that densities of *O. mykiss* are indeed very low in that sub-basin.

Although unmeasured, it is likely that the high proportion of fine sediments throughout both reaches is limiting the successful reproduction of trout as well as the production of invertebrate prey species. Successful trout spawning and egg incubation and the development of a healthy invertebrate population both require unembedded rock substrate with a low percentage of fines. Also, the highly incised streambanks with a general lack of floodplain or overbank areas (except for the highly perched ag fields) likely leads to very high velocities during high flow events, although dense vegetation may afford sufficient refuge from the short-duration storm flows.

Reach-Specific HSI Scores

HSI scores were estimated at a variety of spatial scales, from each individual variable to a habitat-weighted HSI score representing the entire upper Arroyo Grande Basin (see methods). Individual variable metrics and their associated HSI scores are given in Table 6. The individual variable scores were used to calculate model component scores, which represent suitability for various lifestages (Figure 5, Table 4). Component scores and the overall HSI reach scores are shown in Table 7 and Figure 18.

Whittenberg Creek had the highest overall HSI score at 0.90 (Figure 18), a result of consistently high scores (>0.8) for each component, except for the “Other” component which was slightly lower at 0.78 (Table 7). The “Other” component score was slightly degraded due to the low flow characteristics of Whittenberg Creek, where the ratio of base flow to mean annual flow was calculated to be only 5% (based on eight years of historical flow data from USGS gage #11141160). The Whittenberg score exceeded the

Table 6. HSI variable values and associated HSI scores for each HSI study reach.

HSI Variable		Lower Arroyo Grande Value	Lower Arroyo Grande Score	Upper Arroyo Grande Value	Upper Arroyo Grande Score	Lower Lopez Canyon Value	Lower Lopez Canyon Score	Middle Lopez Canyon Value	Middle Lopez Canyon Score	Upper Lopez Canyon Value	Upper Lopez Canyon Score	Whittenberg Value	Whittenberg Score
max rearing temp ° *C*	V1 r	17.5	1.00	16.3	1.00	19.7	0.82	16.3	1.00	16.4	1.00	16.4	1.00
max adlt migration temp ° *C*	V1 am	*used for steelhead only*											
max smolt migration temp ° *C*	V2 sm	*used for steelhead only*											
max incubation temp ° *C*	V2 inc	15.1	0.78	15.2	0.78	16.8	0.60	14.5	0.80	14.0	0.85	14.6	0.85
min DO during rearing *mg/l*	V3 r	7.0	0.70	7.0	0.70	7.8	0.87	7.8	0.87	8.3	0.95	9.5	1.00
min DO during incubation *mg/l*	V3 inc	8.3	0.95	7.7	0.85	7.8	1.00	7.8	1.00	8.3	1.00	8.3	1.00
avg thalweg depth *cm*	V4	21.7	0.86	14.0	0.43	24.0	0.93	18.3	0.70	16.6	0.63	22.6	0.90
avg spawning area veloc *cm/s*	V5	*enters into Vs score*											
% instream cover-juvenile	V6 jv	14.6	1.00	4.8	0.67	9.6	0.90	9.8	0.90	7.6	0.83	13.0	0.98
% cover-adult	V6 ad	14.6	0.83	4.8	0.47	9.6	0.68	9.8	0.68	7.6	0.60	13.0	0.78
spawning substrate size *cm*	V7	*enters into Vs score*											
% winter substrate	V8	7.4	0.70	4.6	0.50	19.9	1.00	14.7	1.00	15.5	1.00	19.4	1.00
avg riffle substrate type	V9	C	0.30	C	0.30	B	0.60	B	0.60	B	0.60	B	0.60
% pools	V10	0.5	1.00	0.2	0.63	0.2	0.75	0.2	0.72	0.2	0.63	0.4	1.00
vegetation ratio	V11	250.2	1.00	253.2	1.00	186.8	1.00	210.2	1.00	205.5	1.00	175.1	1.00
% bank cover	V12	18.3	0.28	9.3	0.24	57.9	0.85	70.2	0.98	59.8	0.87	76.7	1.00
annual max/min pH	V13	*n/a*	1.00	*n/a*	1.00	*n/a*	1.00	*n/a*	1.00	*n/a*	1.00	*n/a*	1.00
ratio base flow/avg flow	V14	34.0	0.68	34.0	0.68	30.0	0.60	30.0	0.60	30.0	0.60	5.0	0.10
pool class rating	V15	B	0.60	B	0.60	A	1.00	B	0.60	A	1.00	A	1.00
%fines in spawning areas	V16 sp	*enters into Vs score*											
%fines in riffles & flatwaters	V16 rr	66.5	0.20	77.2	0.20	17.4	0.96	7.2	1.00	7.3	1.00	11.5	1.00
% shade	V17	84.7	1.00	88.0	1.00	65.8	1.00	77.3	1.00	90.7	1.00	87.6	1.00
ratio migration flow/avg flow	V18	*used for steelhead only*											

Table 7. Component and overall HSI scores for each HSI reach.

HSI Reach	HSI Component Scores						HSI Score
	Adult	Juvenile	Fry	Embryo	V_s	Other	Overall
Upper Arroyo Grande	0.51	0.63	0.45	0.58	0.58	0.66	**0.56**
Lower Arroyo Grande	0.82	0.87	0.61	0.61	0.61	0.67	**0.71**
Upper Lopez Canyon	0.71	0.82	0.79	0.85	0.94	0.89	**0.81**
Middle Lopez Canyon	0.68	0.74	0.85	0.80	0.96	0.89	**0.79**
Lower Lopez Canyon	0.90	0.88	0.86	0.60	0.94	0.86	**0.81**
Whittenberg	0.95	0.99	1.00	0.82	0.82	0.78	**0.90**

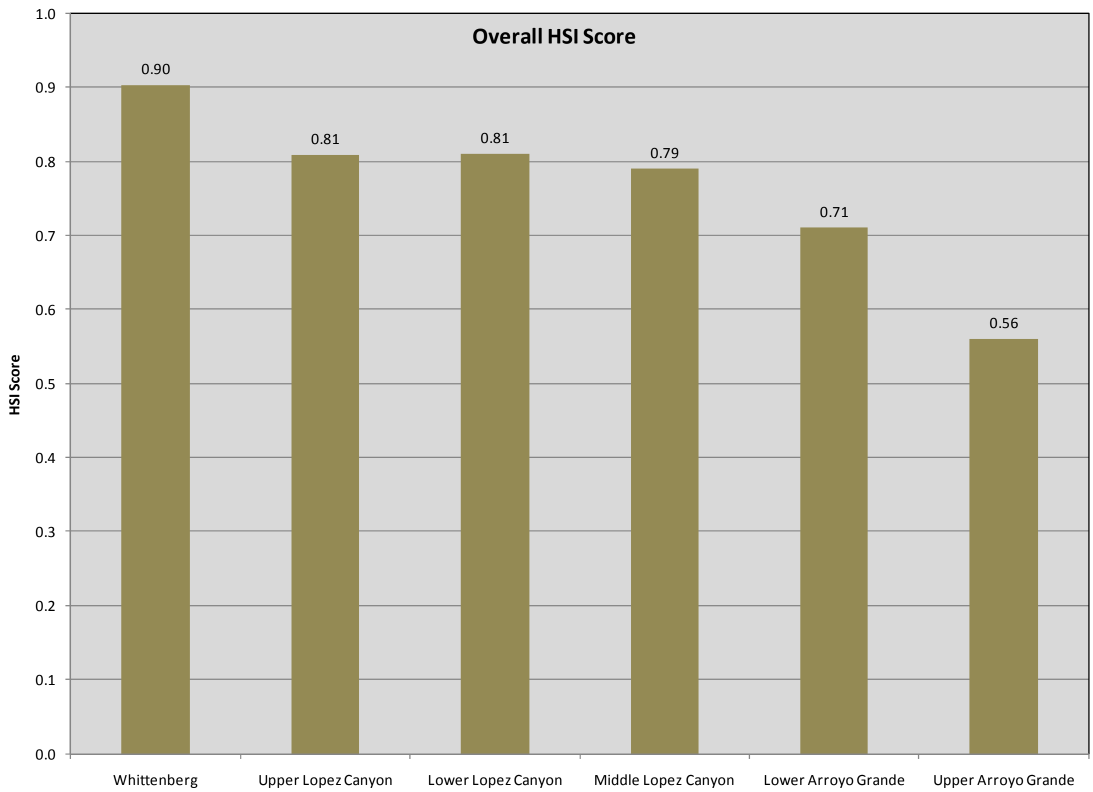


Figure 18. Overall HSI study reach scores in the Upper Arroyo Grande Basin.

scores for all Lopez Canyon Creek HSI sites largely because of higher variable scores for % pools and % instream cover, both likely due to Whittenberg Creeks higher gradient and associated boulder/bedrock channel form.

The three Lopez Canyon HSI reaches all produced overall scores of about 0.8 (Figure 18), although individual component scores differed (Table 7). The Lower Lopez Canyon reach received high scores for each component except for the Embryo component (at 0.60), which was largely due to a low variable score for maximum incubation temperature (Table 6). Maximum water temperatures during spring and summer were warmer in Lower Lopez Canyon Creek than in any of the other HSI locations (Figure 8).

The overall HSI score for Middle Lopez Canyon was slightly degraded by moderate scores for both Adult and Juvenile components. Both Upper and Lower Lopez Canyon HSI reaches received maximum scores for pool habitat quality, but fewer pools in the Middle Lopez Canyon reach were given the highest quality rating (based on pool size, depth, and cover characteristics), and thus both the Adult and Juvenile component scores were degraded. The reach score for Upper Lopez Canyon Creek was also affected by the Adult component, which was degraded due to a combination of shallow thalweg depths, less overall cover for adult trout, and a lower proportion of pool habitat (Table 6).

The Lower Arroyo Grande HSI reach received a relatively low overall score of 0.71 (Figure 18), with low scores (<0.7) in three of the five components, as well as for the Embryo's spawning sub-component V_s (Table 7). The Embryo component was degraded by the low V_s score, which was largely due to the high amount of fines (mean=30%) present in the observed gravel patches. The Other compoent was degraded by low variable scores in riffle/flatwater substrate type (also due to the abundance of fines) and by a low percentage of bank cover (Table 6). The Fry component was likewise affected by the high percentage of fines in riffles and flatwaters.

The Upper Arroyo Grande HSI site possessed the lowest overall score in the basin of only 0.56 (Figure 18), which was a result of low scores (<0.7) in all components (Table 7). In addition to the degrading effects of fines on the Fry, Embryo (with associated V_s), and Other component scores, the Fry, Juvenile, and Adult components were also degraded by shallow thalweg depths, low instream cover values, and a low proportion of pool habitat (Table 6).

<u>Expanded Basin-Wide HSI Scores</u>

Reach-specific HSI scores were expanded to represent the remaining portions of the Upper Arroyo Grande Basin, according to the stratified design described in the study methodology. As previously noted, the expanded HSI estimates do not include headwater areas due to uncertainty surrounding the presence of surface flow and/or the availability of suitable rearing habitat for *O. mykiss*. Alternative expanded HSI values were calculated, however, that either included or did not include those lower elevation channels that were determined not to provide *O. mykiss* rearing habitat because they were dry or intermittent during the summer of 2010 (e.g., all yellow channels in Figures 3 and 4). Including those dry channels might give a better overall representation of the basins or sub-basins relative suitability, but large areas of dry channel could sufficiently degrade an HSI score to overshadow shorter reaches of high quality habitats that are highly productive and are important sources of recruitment to the surrounding areas.

For example, a basin that contains a high abundance of intermittent channels would be expected to have a low overall suitability value, since dry or intermittent channels provide little or no year-round habitat for rearing *O. mykiss*. But if short segments of high quality habitat (with year-round flow) exist within the basin, a low overall score could mask the importance of those limited habitat areas. Consequently, alternative HSI scores are also presented that exclude dry and intermittent reaches in order to illustrate and compare the quality of tributaries and sub-basins where year-round surface flow is present.

A comparison of expanded HSI scores between mountainous stream reaches and valley stream reaches shows higher suitability of mountainous areas for *O. mykiss*, as expected (Figure 19). The difference is particularly dramatic when the dry channels are included, which are more numerous in the valley stream reaches. A comparison of the sub-basin HSI scores shows a different trend depending upon the inclusion or exclusion of dry channels. The Lopez Canyon sub-basin retains a high HSI score either way (0.79-0.83), since a very minor proportion of the habitat area is expected to be dry or intermittent (only a 0.7 mi stretch above the Middle Lopez HSI reach was dry in the fall 2010). The Whittenberg sub-basin HSI score, however, changed significantly due to the large expected presence of dry or intermittent channels in the lower elevations. If excluded, the Whittenberg sub-basin retained the highest HSI score of 0.90, since the Whittenberg HSI reach score is applied to all reaches in the sub-basin. If dry channels are included, the sub-basin score is reduced by almost one-half to 0.50. The Arroyo Grande sub-basin HSI score is moderate at 0.67 if only wetted channels are included, but the score decreases dramatically to only 0.16 when the large proportion of dry reaches and tributaries are included.

The decrease in the Whittenberg sub-basin score by including the lower elevation channels illustrates how including large extents of low quality habitat (i.e., dry or intermittent channels) can override the effects of high quality habitat. The comparative HSI scores for the Arroyo Grande sub-basin illustrates how predicted habitat quality is moderate, at best, and very low at worst. In contrast to these two sub-basins, the constant year-round flow and consistently good habitat in the Lopez Canyon sub-basin produced high HSI scores using either alternative.

When data is combined across all sub-basins, the overall Upper Arroyo Grande Basin HSI score is 0.53 if dry channels are included, but is much higher at 0.83 if only the wetted channels are considered. These overall basin scores are more similar to the Mountain-type scores than the Valley-type scores because the upper basin is predominantly comprised of mountain-type stream channels (at 27 miles) vs. valley stream channels (at 12 miles) (Table 2).

Comparison of Arroyo Grande HSI Scores with Other Basins

HSI scores have been calculated for a wide number of other stream reaches in central and southern California (Table 8), mostly using the same field and analytical methodologies except for the choice of model type (e.g., steelhead vs. rainbow trout). An exception is the San Luis Obispo Creek HSI score, which relied on much more restrictive temperature curves, whereas a current revision of that score using the modified temperature curves in Figure 6 would likely increase it substantially. Figure 20 illustrates that the HSI score for

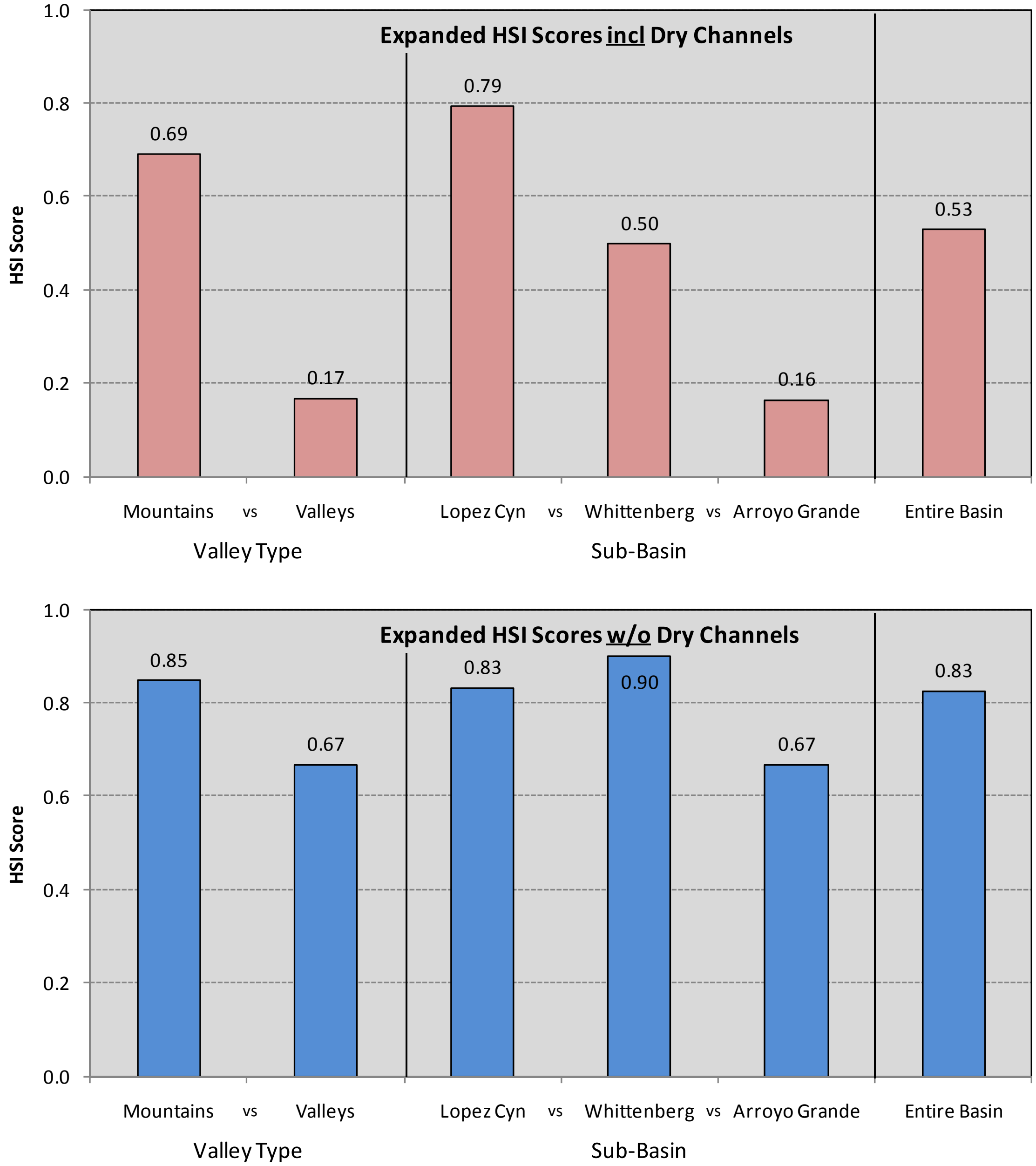


Figure 19. Expanded HSI scores according to valley type, sub-basin, or overall basin, depending on the inclusion or exclusion of dry and intermittent stream reaches and tributaries.

Whittenberg Creek is among the highest of all scores, and the scores for the three Lopez Canyon Creek HSI reaches are also in the upper 1/3 of all scores. The Lower Arroyo Grande HSI score is centrally located in the distribution of scores, placing higher than several locations known to support relatively high numbers of *O. mykiss* (e.g., San Antonio Creek and the Ventura 3 reach at Casitas Springs). The HSI score for Upper Arroyo Grande Creek was among the lowest of all scores.

Table 8. Comparison of reach-specific HSI scores from Upper Arroyo Grande Basin with scores from other central and southern California basins (TRPA data). *Note that HSI scores for Pole Creek and most of the Ventura Basin reaches are still under development and are therefore interim.*

Basin	HSI Reach	Label	HSI Score	HSI Model	Year
Arroyo Grande	Lower Arroyo Grande	Low Arroyo	0.71	RBT	2010
Arroyo Grande	Upper Arroyo Grande	Up Arroyo	0.56	RBT	2010
Arroyo Grande	Lower Lopez Canyon	Low Lopez	0.81	RBT	2010
Arroyo Grande	Middle Lopez Canyon	Mid Lopez	0.79	RBT	2010
Arroyo Grande	Upper Lopez Canyon	Up Lopez	0.81	RBT	2010
Arroyo Grande	Whittenberg	Whittenbrg	0.90	RBT	2010
Chorro	San Luisito	San Luisito	0.82	STH	2006
Coon	Coon	Coon	0.94	STH	2000
San Luis Obispo	Lower SLO	Low SLO	0.34	STH	2000
Santa Clara	Pole	Pole	0.68	STH	2010
Ventura	Lower NF Matilija Low	LNF Low	0.73	STH	2003
Ventura	Lower NF Matilija Mid	LNF Mid	0.74	STH	2007
Ventura	Lower NF Matilija New	LNF New	0.76	STH	2007
Ventura	Lower NF Matilija Up	LNF Up	0.78	RBT	2003
Ventura	Matilija 3	Mat 3	0.68	RBT	2007
Ventura	Matilija 5	Mat 5	0.69	RBT	2007
Ventura	Matilija 6	Mat 6	0.63	RBT	2003
Ventura	Matilija 7	Mat 7	0.71	RBT	2007
Ventura	Murrietta	Murrietta	0.69	RBT	2003
Ventura	Old Man	Old Man	0.64	RBT	2003
Ventura	San Antonio	San Antonio	0.69	STH	2010
Ventura	Upper NF Matilija 2	UNF 2	0.74	RBT	2003
Ventura	Upper NF Matilija Low	UNF Low	0.73	RBT	2003
Ventura	Upper NF Matilija New	UNF New	0.82	RBT	2007
Ventura	Upper NF Matilija Up	UNF Up	0.83	RBT	2003
Ventura	Ventura 1	Ven 1	0.63	STH	2007
Ventura	Ventura 2	Ven 2	0.69	STH	2007
Ventura	Ventura 3	Ven 3	0.67	STH	2007
Ventura	Ventura 5	Ven 5	0.65	STH	2007
Ventura	Ventura 6	Ven 6	0.51	STH	2003

Because quantitative fish population data was not collected in the Upper Arroyo Grande study sites, data is currently unavailable to validate the relationship between HSI scores and *O. mykiss* carrying capacity. However, recent studies in the Ventura River Basin have shown a statistically significant and positive relationship between reach-specific HSI scores and *O. mykiss* densities (TRPA 2008), although the model appears to have relatively little discernment of fish abundance for scores between 0.5 and 0.7, where many scores, including the Lower Arroyo Grande scores, occur. Overall, the qualitative observation of abundant *O. mykiss* in the Whittenberg and the three Lopez Canyon HSI sites, and the rare observation of *O. mykiss* in the Arroyo Grande HSI sites, suggests that the current HSI model for this basin may, to some degree, be representative of *O. mykiss* populations in the various sub-basins.

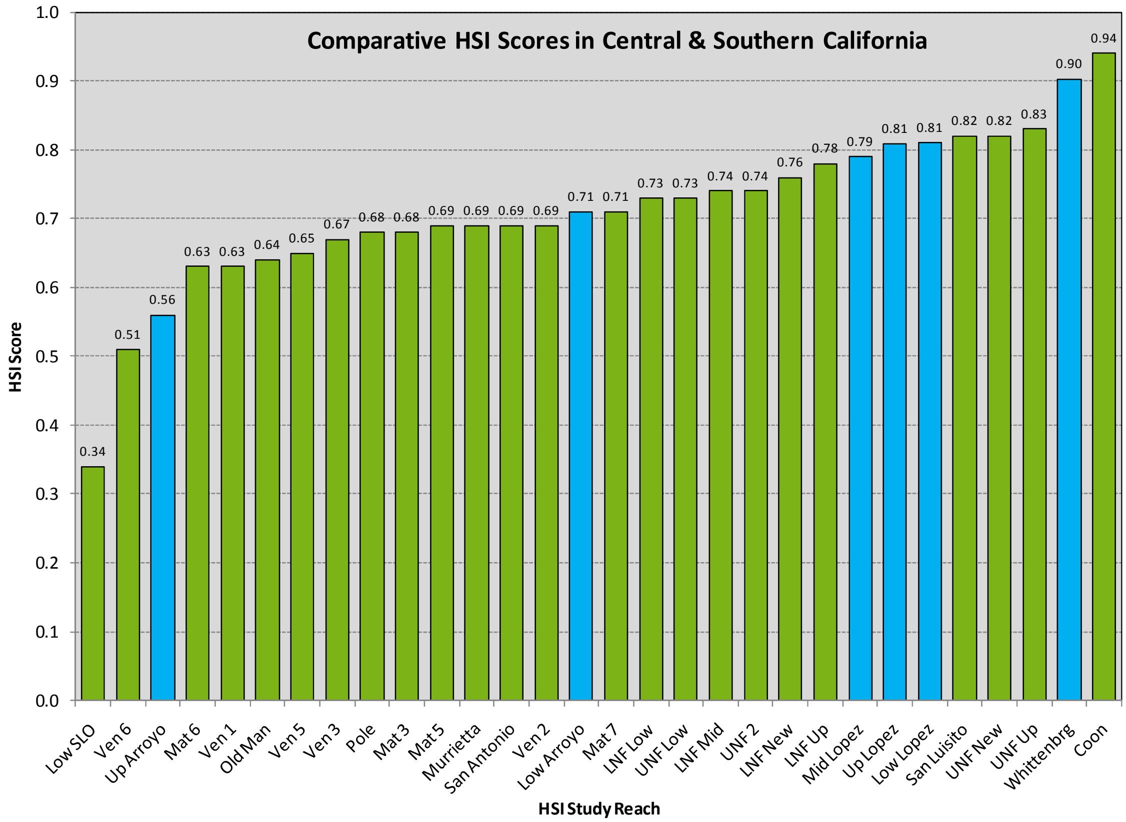


Figure 20. Comparison of reach-specific HSI scores from Upper Arroyo Grande Basin with scores from other central and southern California basins.

Conclusions

This HSI study demonstrated high quality habitat for resident *O. mykiss* throughout Lopez Canyon Creek and in upper Whittenberg Creek. It is assumed that high quality habitat also occurs in similar (but unsurveyed) reaches of Big and Little Falls Creeks, Vasquez Creek, upper Huffs Hole Creek, and upper Dry Creek. HSI scores for reaches in Lopez Canyon Creek and Whittenberg Creek were in the upper 1/3 (at 0.79-0.90) of scores from over 20 HSI reaches in other central and southern California streams. In contrast, low elevation reaches of Whittenberg, Huffs Hole, and Dry creeks were dry or intermittent during the summer and fall of 2010 and thus did not appear to provide significant year-round rearing habitat (HSI scores = 0.0). Lower quality habitat, primarily associated with high quantities of fine sediments, occurred in Arroyo Grande Creek, where HSI scores were intermediate (0.71) to low (0.56) in comparison with other basins. Portions of Upper Arroyo Grande Creek, as well as Saucelito Creek and Phoenix Creek were either dry, intermittent, or contained insufficient flows to provide suitable rearing habitat during the summer and fall of 2010.

Qualitative observations of *O. mykiss* abundance generally matched the calculated HSI scores, with numerous trout observed in the three Lopez Canyon Creek study reaches and the Whittenberg Creek reach, but a near complete lack of trout observations in the two Arroyo Grande study reaches.

Water temperatures during the spring, summer, and fall of 2010 remained well within the range of temperatures inhabited by *O. mykiss* in central and southern California streams, with maximum temperatures well below 70^{o}F (21^{o}C) throughout most of the summer. Incidental observations of barriers to upstream migration of adult *O. mykiss* were made on the three tributaries surveyed; the Lopez Creek barrier was 7.3 mi above Lopez Lake, the Whittenberg barrier was at river mile 1.7, and the Arroyo Grande barrier was 2.6 mi above the lake. All barriers appeared to be total barriers to both smaller resident trout as well as larger adfluvial or anadromous trout . These barriers are likely the lowermost barriers encountered by fish migrating from Lopez Lake, although lower barriers may exist (particularly in Arroyo Grande Creek). Instream habitat in the lower 7.3 mi of Lopez Canyon Creek (below the barrier) was of high quality with abundant spawning gravels, whereas habitat in Arroyo Grande Creek between the identified barrier and Lopez Lake (2.6 mi downstream) was of lower quality with very limited spawning habitat. Instream habitat below the Whittenberg barrier appeared to be of good quality with available spawning gravels, but was limited during the summer/fall low flow period due to intermittent flows (surface flows continued only about 1,500 ft below the barrier in 2010).

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Appendix A. Habitat typing data for six HSI study reaches in the Upper Arroyo Grande Basin. Highlighted boxes are HSI sample units.

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Arroyo Grande low	F	1	GLD	8	8	LAG3	start 4/13/10 at 9:40, 30' below single OVH
Arroyo Grande low		2	LSD	20	12	138	line & W-bank pole w 2 transformers
Arroyo Grande low		3	LGR	40	20	139	**[LB/RB LOOKING UPSTREAM]**
Arroyo Grande low		4	RUN	75	35	140	
Arroyo Grande low		5	LGR	90	15		
Arroyo Grande low		6	MCP	109	19	141	sulpher seep RB
Arroyo Grande low		7	LGR	119	10	142	
Arroyo Grande low		8	GLD	135	16		3 OVH lines nr here
Arroyo Grande low	F	9	LSD	154	19	143	
Arroyo Grande low		10	PLP	167	13	144	log-formed
Arroyo Grande low		11	DPL	177	10		
Arroyo Grande low		12	RUN	199	22		
Arroyo Grande low		13	GLD	212	13		
Arroyo Grande low		14	LSR	224	12		
Arroyo Grande low		15	GLD	294	70		photo 10:02, photo silt 10:03
Arroyo Grande low		16	MCP	320	26		
Arroyo Grande low		17	LGR	325	5		
Arroyo Grande low		18	GLD	340	15		2' OVH log
Arroyo Grande low	F	19	LSD	365	25		
Arroyo Grande low		20	GLD	390	25		
Arroyo Grande low		21	CRP	424	34		
Arroyo Grande low		22	CAS	426	2		
Arroyo Grande low		23	RUN	445	19	145	12" white pipe LB, photo 10:15
Arroyo Grande low		24	PLP	452	7		log-formed
Arroyo Grande low		25	RUN	488	36		
Arroyo Grande low		26	LGR	507	19		
Arroyo Grande low		27	RUN	522	15	146	
Arroyo Grande low		28	CRP	556	34		
Arroyo Grande low		29	RUN	567	11		
Arroyo Grande low	F	30	LSL	582	15		more slate-type gravel
Arroyo Grande low		31	LGR	597	15	147	
Arroyo Grande low		32	LGR	611	14		
Arroyo Grande low		33	GLD	631	20	148	
Arroyo Grande low		34	LSD	645	14		
Arroyo Grande low		35	LGR	665	20		
Arroyo Grande low		36	RUN	685	20	149	
Arroyo Grande low		37	LGR	704	19	150	
Arroyo Grande low	F	38	CRP	747	43		gravel in pool tail
Arroyo Grande low		39	GLD	777	30	151	
Arroyo Grande low		40	RUN	798	21	152	
Arroyo Grande low		41	GLD	817	19		
Arroyo Grande low		42	LSL	826	9		
Arroyo Grande low		43	XGLD	870	44		
Arroyo Grande low	F	44	LSL	889	19		
Arroyo Grande low		45	LGR	923	34	153	2 OVH logs
Arroyo Grande low			"				
Arroyo Grande low		46	RUN	978	55		
Arroyo Grande low		47	XLSD	981	3		too short ~13ft
Arroyo Grande low		48	LGR	995	14		
Arroyo Grande low		49	LSL	1007	12		11:06
Arroyo Grande low		50	LGR	1030	23		
Arroyo Grande low	F	51	CRP	1045	15		

Appendix A. (continued)

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Arroyo Grande low		*52*	LGR	1065	20		
Arroyo Grande low		*53*	LSL	1075	10		
Arroyo Grande low		*54*	LGR	1080	5		
Arroyo Grande low		*55*	CCP	1090	10		split, Q 50:50
Arroyo Grande low		*56*	LGR	1108	18	154	split
Arroyo Grande low		*57*	XLSD	1122	14		
Arroyo Grande low		*58*	XHGR	1144	22		
Arroyo Grande low	F	*59*	LSL	1170	26	155	scour under log, jam at top
Arroyo Grande low		*60*	LGR	1186	16	156	possible access RB
Arroyo Grande low		*61*	CRP	1198	12		
Arroyo Grande low		*62*	LGR	1214	16	157	sml boulders
Arroyo Grande low		*63*	LGR	1227	13		
Arroyo Grande low		*64*	LSD	1255	28		**maybe accessible LB via vinyard**
Arroyo Grande low		*65*	TRP	1289	34		drain ditch LB, probable 4-6" trout
Arroyo Grande low		*66*	LGR	1310	21		
Arroyo Grande low		*67*	LSD	1325	15		OVH fallen trees
Arroyo Grande low		*68*	LGR	1345	20	158	log at top
Arroyo Grande low		*69*	HGR	1364	19	159	flows over roots
Arroyo Grande low	F	*70*	TRP	1383	19	160	**periwinkle RB, open to rd RB?**
Arroyo Grande low		*71*	XLGR	1439	56		
Arroyo Grande low		*72*	CRP	1475	36		**w LSR, OVH line good access LB "well 3"**
Arroyo Grande low		*73*	TRP	1494	19		
Arroyo Grande low		*74*	LGR	1500	6		
Arroyo Grande low		*75*	LSD	1524	24		
Arroyo Grande low		*76*	LGR	1576	52		
Arroyo Grande low		*77*	XCRP	1603	27		
Arroyo Grande low		*78*	XCRP	1627	24		
Arroyo Grande low		*79*	LGR	1691	64		w RN/LGR
Arroyo Grande low	F	*80*	CRP	1704	13		
Arroyo Grande low		*81*	LGR	1718	14		
Arroyo Grande low		*82*	CRP	1734	16		
Arroyo Grande low		*83*	LGR	1740	6		
Arroyo Grande low		*84*	CRP	1754	14		3.5' deep w rootwad
Arroyo Grande low		*85*	CAS	1772	18		
Arroyo Grande low		*86*	RUN	1787	15		**open to vinyard LB over brushpile**
Arroyo Grande low		*87*	LSR	1850	63	161	
Arroyo Grande low		*88*	GLD	1870	20		
Arroyo Grande low		*89*	LSD	1910	40		possible 2-3" trout??
Arroyo Grande low		*90*	GLD	1935	25	162	
Arroyo Grande low		*91*	XLSD	2009	74		
Arroyo Grande low		*92*	LGR	2013	4		
Arroyo Grande low	F	*93*	MCP	2035	22		
Arroyo Grande low		*94*	RUN	2050	15		
Arroyo Grande low		*95*	LSL	2070	20	163	
Arroyo Grande low		*96*	LGR	2086	16		
Arroyo Grande low		*97*	MCP	2110	24		
Arroyo Grande low		*98*	CAS	2115	5		access up LB?
Arroyo Grande low		*99*	MCP	2145	30		
Arroyo Grande low		*100*	LGR	2156	11		13:07
Arroyo Grande low		*101*	GLD	2188	32		
Arroyo Grande low		*102*	LGR	2225	37	164	
Arroyo Grande low		*103*	LSD	2250	25	165	

Appendix A. (continued)

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Arroyo Grande low		104	GLD	2260	10		
Arroyo Grande low	F	105	LSD	2274	14		
Arroyo Grande low		106	RUN	2286	12	166	
Arroyo Grande low		107	LSL	2310	24		
Arroyo Grande low		108	RUN	2330	20		
Arroyo Grande low		109	PLP	2345	15		formed by tree roots xing channel
Arroyo Grande low		110	CAS	2350	5	167	exit LB by w ell #2
Arroyo Grande low		111	PLP	2363	13		tree roots
Arroyo Grande low		112	CAS	2390	27		
Arroyo Grande low		113	XMCP	2400	10		
Arroyo Grande low		114	LGR	2415	15		
Arroyo Grande low		115	GLD	2434	19		probable redd at bottom
Arroyo Grande low	F	116	XCRP	2518	84		
Arroyo Grande low		117	GLD	2533	15		
Arroyo Grande low		118	XMCP	2550	17		lots of WD & PO
Arroyo Grande low		119	XHGR	2555	5		PO
Arroyo Grande low		120	LSD	2670	115		
Arroyo Grande low		121	LGR	2680	10		
Arroyo Grande low	F	122	CRP	2710	30		difficult exit
Arroyo Grande up	F	1	LGR	10	10	UAG1	start 4/13/10 at 15:06
Arroyo Grande up		2	RUN	22	12		
Arroyo Grande up		3	MCP	45	23	177	
Arroyo Grande up		4	GLD	72	27	178	
Arroyo Grande up		5	LGR	76	4		
Arroyo Grande up		6	GLD	99	23		
Arroyo Grande up		7	LSD	133	34		
Arroyo Grande up		8	RUN	153	20	179	
Arroyo Grande up		9	LGR	171	18		
Arroyo Grande up		10	GLD	200	29		
Arroyo Grande up		11	LSL	210	10	180	
Arroyo Grande up		12	GLD	234	24	181	
Arroyo Grande up		13	RUN	254	20	182	
Arroyo Grande up		14	LGR	271	17	183	
Arroyo Grande up		15	GLD	295	24		
Arroyo Grande up		16	XLGR	325	30		
Arroyo Grande up	F	17	RUN	386	61		
Arroyo Grande up		18	GLD	564	178	184	drainage ditch LD, long/sandy
Arroyo Grande up	F	19	CRP	579	15		
Arroyo Grande up		20	RUN	642	63		
Arroyo Grande up		21	GLD	661	19		
Arroyo Grande up		22	LGR	680	19		small boulders, photo
Arroyo Grande up		23	GLD	698	18	185	
Arroyo Grande up		24	RUN	717	19	186	
Arroyo Grande up		25	XLGR	767	50		
Arroyo Grande up		26	RUN	795	28		
Arroyo Grande up		27	LGR	807	12		
Arroyo Grande up		28	GLD	828	21	187	
Arroyo Grande up	F	29	MCP	839	11	188	
Arroyo Grande up		30	LGR	845	6	189	
Arroyo Grande up		31	LSL	878	33	15	
Arroyo Grande up		32	RUN	897	19		split
Arroyo Grande up		33	LGR	927	30		slide LB (possible access?)

Appendix A. (continued)

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Arroyo Grande up		34	LSD	954	27	190	
Arroyo Grande up		35	LGR	980	26	191	
Arroyo Grande up		36	GLD	1007	27		
Arroyo Grande up	F	37	CRP	1027	20	16	
Arroyo Grande up		38	LGR	1062	35		animal trail LB (brushy)
Arroyo Grande up		39	CRP	1079	17	192	
Arroyo Grande up		40	XRUN	1107	28		Saucelito Crk confluence (trickle in Nov)
Arroyo Grande up		41	LGR	1117	10		4" RBT observed
Arroyo Grande up		42	RUN	1154	37	193	
Arroyo Grande up		43	LGR	1162	8		
Arroyo Grande up		44	XMCP	1184	22		
Arroyo Grande up		45	GLD	1200	16		
Arroyo Grande up		46	LGR	1208	8	194	
Arroyo Grande up		47	LSR	1216	8		
Arroyo Grande up		48	LGR	1225	9		
Arroyo Grande up		49	CRP	1240	15	195	
Arroyo Grande up	F	50	GLD	1324	84	18	access both banks-cattle xing
Arroyo Grande up		51	RUN	1360	36	196	
Arroyo Grande up		52	XGLD	1390	30		
Arroyo Grande up		53	LSL	1406	16		
Arroyo Grande up		54	RUN	1436	30		
Arroyo Grande up		55	LSL	1449	13	197	
Arroyo Grande up		56	XLGR	1480	31		
Arroyo Grande up		57	GLD	1495	15	198	
Arroyo Grande up		58	XLSL	1514	19		slide RB, LWD
Arroyo Grande up		59	LGR	1525	11	199	
Arroyo Grande up		60	LSL	1538	13		
Arroyo Grande up		61	LGR	1550	12		
Arroyo Grande up	F	62	GLD	1577	27		
Arroyo Grande up		63	LGR	1600	23		
Arroyo Grande up		64	GLD	1640	40		
Arroyo Grande up		65	XLGR	1662	22		
Arroyo Grande up		66	XRUN	1745	83		
Arroyo Grande up		67	GLD	1773	28	200	possible access thr LB periw inkle
Arroyo Grande up		68	XRUN	1870	97		
Arroyo Grande up	F	69	GLD	1912	42		open both banks - access??
Arroyo Grande up		70	LSL	1926	14	201	
Arroyo Grande up		71	LGR	1942	16		
Arroyo Grande up		72	RUN	1971	29		
Arroyo Grande up		73	LGR	1991	20		
Arroyo Grande up		74	LSD	2006	15	202	
Arroyo Grande up	F	75	LGR	2030	24		slide RB w game trail
Arroyo Grande up			"				
Arroyo Grande up		76	PLP	2045	15	203	
Arroyo Grande up		77	CAS	2057	12		slide debris - passage barrier?
Arroyo Grande up			"				3-4ft vert x 13ft horiz
Arroyo Grande up		78	XRUN	2090	33		
Arroyo Grande up		79	GLD	2157	67		
Arroyo Grande up		80	LGR	2180	23		access RB??
Arroyo Grande up		81	RUN	2201	21		
Arroyo Grande up		82	LGR	2247	46		
Arroyo Grande up	F	83	LSD	2260	13		

Appendix A. (continued)

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Arroyo Grande up		84	LGR	2267	7		
Arroyo Grande up		85	CRP	2275	8		
Arroyo Grande up		86	XLGR	2343	68		big tree down LB
Arroyo Grande up		87	DPL	2355	12		temp logger in WD
Arroyo Grande up	F	88	LGR	2448	93		end 17:30, access straight to rd RB
Arroyo Grande up		"					fines under surface gravel
Lopez Canyon low	X	1	RUN	88	88	LL4	start 9:20 4/15/10 at top rd xing, no flag
Lopez Canyon low		2	LGR	160	72		
Lopez Canyon low		3	LGR	196	36		
Lopez Canyon low		4	RUN	238	42		
Lopez Canyon low	F	5	LSBO	255	17		
Lopez Canyon low		6	LGR	298	43		
Lopez Canyon low		7	RUN	316	18		
Lopez Canyon low		8	LGR	337	21		
Lopez Canyon low		9	RUN	389	52		along eroded bank RB, RF @ low Q?
Lopez Canyon low		10	LGR	406	17		
Lopez Canyon low		11	GLD	432	26		
Lopez Canyon low		12	LGR	474	42		
Lopez Canyon low	RD	13	XRD	505	31		road xing
Lopez Canyon low		14	LGR	542	37		
Lopez Canyon low		15	MCP	591	49		
Lopez Canyon low		16	PLP	621	30		mapped as "LSP" - ?
Lopez Canyon low		17	LGR	669	48		lots of larger STH gravel thruout (not mapped)
Lopez Canyon low		18	LSBK	715	46		
Lopez Canyon low		19	LGR	747	32		
Lopez Canyon low	RD	20	XRD	830	83		
Lopez Canyon low		21	MCP	890	60		approx L
Lopez Canyon low		22	RUN	928	38	78	
Lopez Canyon low		23	LGR	988	60		photo 9:47
Lopez Canyon low		24	RUN	1025	37		
Lopez Canyon low		25	LGR	1103	78		
Lopez Canyon low		26	GLD	1130	27		tree in channel @ top
Lopez Canyon low		27	MCP	1174	44		
Lopez Canyon low		28	POW	1228	54		sml trout seen in several units
Lopez Canyon low		29	RUN	1272	44		
Lopez Canyon low		30	LSBK	1306	34		undercut RB
Lopez Canyon low		31	POW	1344	38	79	
Lopez Canyon low		32	LSBO	1359	15		undercut RB
Lopez Canyon low		33	RUN	1387	28		
Lopez Canyon low		34	POW	1429	42		
Lopez Canyon low		35	MCP	1458	29	80	opposite solar panels on house
Lopez Canyon low		36	LGR	1495	37	81	
Lopez Canyon low		37	RUN	1565	70		
Lopez Canyon low		38	LSD	1578	13		undercut RB
Lopez Canyon low		39	RUN	1596	18		
Lopez Canyon low		40	LGR	1635	39		
Lopez Canyon low		41	LGR	1701	66	82	
Lopez Canyon low		42	GLD	1738	37		
Lopez Canyon low	F	43	LSBK	1782	44		
Lopez Canyon low		44	XRUN	1796	14		OVH tree
Lopez Canyon low		45	HGR	1845	49		
Lopez Canyon low		46	LSBK	1886	41	83	3ft deep, undercut,several trout

Appendix A. (continued)

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Lopez Canyon low		47	LGR	2007	121	84	
Lopez Canyon low		48	RUN	2034	27		open on LB by rd
Lopez Canyon low		49	GLD	2076	42		
Lopez Canyon low		50	LSL	2099	23		scour by w illow /bank
Lopez Canyon low		51	LGR	2130	31		
Lopez Canyon low		52	GLD	2161	31		
Lopez Canyon low		53	MCP	2202	41		several 2-4" trout
Lopez Canyon low		54	LGR	2217	15		
Lopez Canyon low		55	RUN	2258	41		
Lopez Canyon low		56	LGR	2274	16	85	
Lopez Canyon low		57	MCP	2306	32		
Lopez Canyon low		58	LGR	2332	26		
Lopez Canyon low		59	RUN	2375	43		trout
Lopez Canyon low	F	60	LSBO	2398	23		
Lopez Canyon low		61	RUN	2425	27	86	
Lopez Canyon low		62	LGR	2537	112		some RUN
Lopez Canyon low		63	LSBO	2552	15	87	
Lopez Canyon low		64	LGR	2586	34		
Lopez Canyon low		65	LSBK	2640	54		cliff uncercut at top RB, trout + 6" suckers
Lopez Canyon low		66	LGR	2666	26		photo 10:51
Lopez Canyon low		67	LSR	2701	35		tree roots LB OW, trout
Lopez Canyon low		68	RUN	2720	19		
Lopez Canyon low		69	LGR	2732	12		
Lopez Canyon low		70	MCP	2756	24		
Lopez Canyon low		71	RUN	2777	21		
Lopez Canyon low		72	HGR	2791	14		
Lopez Canyon low		73	RUN	2808	17		trout
Lopez Canyon low		74	LGR	2830	22		
Lopez Canyon low	RD	75	XRD	2871	41		
Lopez Canyon low		76	RUN	2891	20		
Lopez Canyon low		77	LSBK	2940	49	88	cliff LB, 5ft break in middle bend
Lopez Canyon low		78	HGR	2954	14	89	
Lopez Canyon low		79	RUN	2976	22		
Lopez Canyon low		80	HGR	2993	17		
Lopez Canyon low		81	GLD	3016	23		12" suckers
Lopez Canyon low		82	LSBK	3055	39	90	several trout 2-5"
Lopez Canyon low		83	RUN	3074	19		
Lopez Canyon low		84	LGR	3105	31	91	
Lopez Canyon low		85	RUN	3161	56	92	
Lopez Canyon low		86	LGR	3195	34		
Lopez Canyon low		87	RUN	3220	25	93	
Lopez Canyon low		88	LGR	3255	35		gravel assoc w road?
Lopez Canyon low	RD	89	XRD	3295	40		heavy sand input from this road crossing
Lopez Canyon low		90	GLD	3338	43		
Lopez Canyon low		91	LGR	3365	27		
Lopez Canyon low		92	LSBK	3448	83		trout
Lopez Canyon low		93	RUN	3480	32		striped bedrock RB
Lopez Canyon low		94	CAS	3485	5	94	
Lopez Canyon low		95	LSBK	3494	9		
Lopez Canyon low		96	GLD	3510	16	95	
Lopez Canyon low		97	LSBK	3532	22		
Lopez Canyon low		98	RUN	3558	26	96	

Appendix A. (continued)

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Lopez Canyon low		99	HGR	3585	27		over bedrock
Lopez Canyon low		100	LGR	3606	21		
Lopez Canyon low		101	GLD	3625	19		
Lopez Canyon low		102	MCP	3657	32		
Lopez Canyon low		103	XLGR	3707	50		brushy
Lopez Canyon low		104	RUN	3730	23		
Lopez Canyon low		105	XRUN	3779	49		brushy
Lopez Canyon low	F	106	RUN	3818	39		
Lopez Canyon low		107	LSD	3831	13		undercut RB, turtle
Lopez Canyon low		108	LGR	3846	15	97	lrg log LB
Lopez Canyon low		109	RUN	3894	48	98	short RF break in middle
Lopez Canyon low		110	LGR	3955	61		
Lopez Canyon low		111	RUN	3974	19	99	
Lopez Canyon low		112	LGR	3980	6		
Lopez Canyon low		113	XDPL	4008	28		LWD jam, many 3-4" trout
Lopez Canyon low		114	GLD	4022	14		
Lopez Canyon low		115	PLP	4032	10	100	formed by LWD, split LB (split dry in Nov)
Lopez Canyon low		116	LSL	4046	14		
Lopez Canyon low		117	LGR	4065	19		
Lopez Canyon low		118	GLD	4082	17		trout
Lopez Canyon low		119	LSR	4111	29		roots above w ater, many 3-4" trout
Lopez Canyon low	F	120	MCP	4128	17		
Lopez Canyon low		121	RUN	4152	24		
Lopez Canyon low		122	LGR	4197	45	101	
Lopez Canyon low		123	LSD	4223	26		many 2-3" trout
Lopez Canyon low		124	LGR	4269	46		
Lopez Canyon low		125	GLD	4310	41	102	log along RB
Lopez Canyon low		126	LSL	4331	21		log along RB
Lopez Canyon low		127	RUN	4401	70		some RF breaks
Lopez Canyon low		128	LGR	4562	161		
Lopez Canyon low		129	GLD	4635	73	103	larg patch w mixed gravel, trout
Lopez Canyon low		130	MCP	4685	50	104	\/ homogenous area \/
Lopez Canyon low		131	GLD	4729	44		
Lopez Canyon low		132	LGR	4798	69	105	opposite gate w sign "no parking", 4" trout
Lopez Canyon low		133	GLD	4850	52		
Lopez Canyon low		134	MCP	4876	26		trout
Lopez Canyon low		135	RUN	4934	58		bedrock RB, 1.5ft log OVH
Lopez Canyon low		136	LGR	5030	96		incl some RUN
Lopez Canyon low		137	PLP	5048	18		RB RUN
Lopez Canyon low		138	HGR	5061	13		
Lopez Canyon low		139	RUN	5115	54	106	short RF in middle
Lopez Canyon low		140	LGR	5170	55		some RUN
Lopez Canyon low		141	LGR	5223	53		
Lopez Canyon low		142	MCP	5280	57		open LB w riprap, 6" suckers & trout
Lopez Canyon low		143	LGR	5336	56		
Lopez Canyon low		144	GLD	5400	64		trout
Lopez Canyon low		145	RUN	5455	55	107	
Lopez Canyon low		146	LGR	5500	45		
Lopez Canyon low		147	GLD	5530	30		
Lopez Canyon low		148	LGR	5615	85		
Lopez Canyon low		149	RUN	5649	34		
Lopez Canyon low		150	LGR	5670	21		
Lopez Canyon low		151	RUN	5712	42		Big Falls Crk confl, end @ 12:30

Appendix A. (continued)

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Lopez Canyon mid	F	1	LSBO	10	10	ML1B	start 8:55 4/17/10 by lrg square chunk of
Lopez Canyon mid		2	LGR	42	32	204	\ bedrock, photo ~8:55, trout
Lopez Canyon mid		3	LSD	60	18	205	also log/roots formed
Lopez Canyon mid		4	HGR	82	22	206	
Lopez Canyon mid		5	RUN	102	20	207	
Lopez Canyon mid		6	LGR	150	48		
Lopez Canyon mid		7	GLD	168	18		
Lopez Canyon mid		8	LGR	185	17	208	
Lopez Canyon mid		9	RUN	199	14	209	
Lopez Canyon mid		10	MCP	216	17		OVH tree
Lopez Canyon mid		11	RUN	251	35	210	upper 1/2 LSB? Trout
Lopez Canyon mid		12	HGR	267	16	211	modified by rock dams
Lopez Canyon mid	RD	13	XRD	290	23		road xing
Lopez Canyon mid		14	RUN	300	10	212	
Lopez Canyon mid		15	LSBK	323	23	213	2ft OVH log, LWD at top, many trout
Lopez Canyon mid		16	RUN	347	24		
Lopez Canyon mid		17	XLGR	395	48		brushy
Lopez Canyon mid	F	18	LSBO	407	12	43	
Lopez Canyon mid		19	LGR	487	80	214	MG at top
Lopez Canyon mid		20	RUN	519	32	215	w steps
Lopez Canyon mid		21	LGR	547	28		1ft OVH log nr top
Lopez Canyon mid		22	LGR	598	51		
Lopez Canyon mid		23	GLD	621	23		
Lopez Canyon mid		24	SRN	660	39		
Lopez Canyon mid		25	LGR	688	28	216	
Lopez Canyon mid		26	RUN	704	16		
Lopez Canyon mid		27	POW	731	27	217	w boulders
Lopez Canyon mid		28	LSBO	750	19	218	trout
Lopez Canyon mid		29	HGR	777	27	219	
Lopez Canyon mid	F	30	GLD	816	39	44	redds? Trout
Lopez Canyon mid		31	LSBO	855	39	220	undercut LB
Lopez Canyon mid		32	SRN	913	58	221	
Lopez Canyon mid		33	HGR	930	17	222	
Lopez Canyon mid	RD	34	XRD	948	18		
Lopez Canyon mid		35	LSBK	966	18		bedrock RB, several trout
Lopez Canyon mid		36	LGR	982	16	223	
Lopez Canyon mid		37	LSBK	1005	23		bedrock both banks, trout
Lopez Canyon mid		38	RUN	1025	20	224	more RF
Lopez Canyon mid		39	LSBK	1043	18	225	also boulder scour
Lopez Canyon mid		40	RUN	1060	17		RB undercut
Lopez Canyon mid		41	HGR	1068	8		formed by RB slide
Lopez Canyon mid		42	LGR	1087	19	226	grav patch partly OW
Lopez Canyon mid		43	LSBK	1101	14		bedrock RB
Lopez Canyon mid		44	LGR	1131	30	227	
Lopez Canyon mid	RD	45	XRD	1301	170		road follow s channel
Lopez Canyon mid		46	RUN	1322	21		top under log/rootw ad
Lopez Canyon mid		47	LGR	1380	58		
Lopez Canyon mid		48	LSL	1398	18		trout
Lopez Canyon mid		49	LGR	1458	60		
Lopez Canyon mid	F	50	LSL	1473	15		trout
Lopez Canyon mid		51	LGR	1526	53		
Lopez Canyon mid		52	LSD	1544	18	228	

Appendix A. (continued)

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Lopez Canyon mid	RD	53	XRD	1566	22		
Lopez Canyon mid		54	LGR	1576	10		
Lopez Canyon mid		55	RUN	1592	16		lrg downed tree in channel, trout
Lopez Canyon mid		56	LSL	1611	19	229	also bedrock RB, 1/2 gravel OW
Lopez Canyon mid		57	LGR	1675	64		
Lopez Canyon mid		58	XRUN	1703	28		brushy
Lopez Canyon mid		59	RUN	1723	20		or LSL
Lopez Canyon mid		60	LGR	1762	39		
Lopez Canyon mid		61	LSD	1788	26		RB undercut
Lopez Canyon mid		62	LGR	1865	77		
Lopez Canyon mid		63	LGR	1907	42		50:50 split, map RC
Lopez Canyon mid	F	64	PLP	1927	20		over LWD logs xing chan, BWP abv RB
Lopez Canyon mid		65	RUN	1966	39		gravel extends abv pool, split ends
Lopez Canyon mid		66	LGR	1987	21		surface flow begins receeding (Nov)
Lopez Canyon mid		67	GLD	2012	25		
Lopez Canyon mid		68	XLSD	2027	15		brushy
Lopez Canyon mid		69	XLGR	2042	15		brushy
Lopez Canyon mid		70	XLSL	2062	20		brushy
Lopez Canyon mid		71	XLGR	2109	47		brushy, old orange flag
Lopez Canyon mid		72	XGLD	2135	26		not sure of hab type
Lopez Canyon mid		73	LSD	2145	10		LB undercut
Lopez Canyon mid		74	LGR	2182	37		
Lopez Canyon mid		75	LSD	2202	20		deep undercut RB
Lopez Canyon mid		76	LGR	2214	12		
Lopez Canyon mid	F	77	LSR	2240	26		noticably lower Q (Nov)
Lopez Canyon mid		78	XLGR	2260	20		
Lopez Canyon mid		79	XLSL	2287	27		LWD
Lopez Canyon mid		80	XLGR	2314	27		
Lopez Canyon mid		81	LGR	2355	41		
Lopez Canyon mid		82	XLGR	2396	41		
Lopez Canyon mid	RD	83	XRD	2409	13		minimal flow in Nov
Lopez Canyon mid		84	RUN	2440	31		
Lopez Canyon mid		85	XLGR	2457	17		
Lopez Canyon mid		86	LGR	2525	68		
Lopez Canyon mid		87	LSBK	2550	25		lower 1/2 GLD
Lopez Canyon mid		88	LGR	2563	13		split
Lopez Canyon mid		89	RUN	2582	19		
Lopez Canyon mid		90	LGR	2596	14		
Lopez Canyon mid		91	XRUN	2656	60		
Lopez Canyon mid	RD	92	LGR	2673	17		top @ rd xing, end @ 10:55, btm of Nov dry
Lopez Canyon mid			" "				channel, UW photos of gravel w rod
Lopez Canyon up	F	1	LSBK	22	22	UL2	start 10:45 4/16/10 after ~1.5-2hr hike, photo
Lopez Canyon up		2	RUN	50	28	111	
Lopez Canyon up		3	LGR	85	35	112	
Lopez Canyon up		4	GLD	100	15		redd 1.5x2ft, 4-6" trout
Lopez Canyon up		5	LSBO	113	13		
Lopez Canyon up		6	LGR	146	33		
Lopez Canyon up		7	RUN	165	19		thick OVH dogwood
Lopez Canyon up		8	XLGR	246	81		too brushy
Lopez Canyon up		9	LGR	280	34		
Lopez Canyon up		10	XRUN	318	38		lrg fallen tree
Lopez Canyon up		11	RUN	333	15		big grv bar RB, OW

Appendix A. (continued)

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Lopez Canyon up		12	LGR	402	69		
Lopez Canyon up		13	GLD	457	55		
Lopez Canyon up		14	XRUN	482	25		
Lopez Canyon up		15	XLGR	500	18		
Lopez Canyon up		16	HGR	576	76		trail RB, open both banks
Lopez Canyon up		17	GLD	606	30	113	2ft OVH log at top
Lopez Canyon up		18	LGR	652	46		
Lopez Canyon up		19	GLD	670	18		
Lopez Canyon up		20	LSBK	685	15		cliff LB, many 2-3" trout
Lopez Canyon up		21	LGR	722	37	114	
Lopez Canyon up		22	XLGR	788	66		
Lopez Canyon up		23	LGR	835	47		4" branch xing btm
Lopez Canyon up		24	LGR	855	20	115	
Lopez Canyon up		25	GLD	881	26	116	
Lopez Canyon up	F	26	LSBK	899	18	39	bedrock RB
Lopez Canyon up		27	XRUN	950	51		debris jam and brushy
Lopez Canyon up		28	LGR	976	26	117	
Lopez Canyon up		29	LSL	990	14		
Lopez Canyon up		30	XRUN	1031	41		
Lopez Canyon up		31	LGR	1074	43		narrow MC bar
Lopez Canyon up		32	LSBK	1099	25	118	bedrock LB, several 3" trout
Lopez Canyon up		33	RUN	1118	19		
Lopez Canyon up		34	LGR	1137	19	119	
Lopez Canyon up		35	RUN	1165	28		
Lopez Canyon up		36	LGR	1219	54		trail xing?
Lopez Canyon up		37	RUN	1234	15		
Lopez Canyon up	F	38	LSBK	1245	11	120	dirt/bldr scour
Lopez Canyon up		39	LGR	1268	23		
Lopez Canyon up		40	LSR	1288	20		downed tree LB
Lopez Canyon up		41	LGR	1392	104		lrg shade tree LB
Lopez Canyon up		42	LSBK	1403	11		bedrk RB, trout
Lopez Canyon up		43	LGR	1449	46		trail LB
Lopez Canyon up		44	LGR	1471	22		
Lopez Canyon up		45	LSBK	1491	20	121	bk RB
Lopez Canyon up		46	RUN	1512	21	122	sulpher seep LB
Lopez Canyon up		47	LGR	1530	18	123	
Lopez Canyon up		48	LGR	1557	27		
Lopez Canyon up	F	49	LSBK	1590	33		bk RB, 2.5ft deep
Lopez Canyon up		50	HGR	1627	37	124	
Lopez Canyon up		51	SRN	1697	70		trout
Lopez Canyon up		52	LSBK	1723	26		lrg OVH trunk, trout
Lopez Canyon up		53	LGR	1752	29	125	
Lopez Canyon up		54	RUN	1782	30	126	
Lopez Canyon up		55	LGR	1798	16		
Lopez Canyon up		56	RUN	1831	33		
Lopez Canyon up		57	LGR	1885	54		trail xing
Lopez Canyon up		58	LSBK	1913	28		bk LB w sulpher, many 3" trout
Lopez Canyon up		59	XRUN	1929	16		
Lopez Canyon up	F	60	LSBK	1955	26	41	~fast RN, 5" trout
Lopez Canyon up		61	RUN	1978	23	127	
Lopez Canyon up		62	HGR	2002	24		
Lopez Canyon up		63	LSBO	2014	12	128	

Appendix A. (continued)

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Lopez Canyon up		64	LGR	2020	6		trail xing
Lopez Canyon up		65	PLP	2041	21		2.5ft deep, log-formed, many trout up to 5"
Lopez Canyon up		66	SRN	2068	27	129	
Lopez Canyon up		67	HGR	2076	8		
Lopez Canyon up		68	LSBK	2102	26	130	bk RB, 4-6" trout
Lopez Canyon up		69	SRN	2144	42	131	
Lopez Canyon up		70	RUN	2189	45		sulpher w orks RB
Lopez Canyon up		71	HGR	2214	25	42	sulpher w orks RB
Lopez Canyon up		72	LSBO	2231	17	132	
Lopez Canyon up		73	XLGR	2283	52		
Lopez Canyon up		74	RUN	2312	29		
Lopez Canyon up		75	HGR	2345	33	133	
Lopez Canyon up		76	LGR	2388	43	134	trail
Lopez Canyon up		77	LSBO	2406	18		trail
Lopez Canyon up		78	RUN	2437	31	135	trail aong LB bedrock, 2" trout
Lopez Canyon up		79	XLGR	2490	53		
Lopez Canyon up		80	RUN	2509	19		trail xing
Lopez Canyon up		81	XLGR	2550	41		lrg fallen tree w debris
Lopez Canyon up		82	DPL	2578	28	136	2-7" trout, sandy bottom
Lopez Canyon up		83	GLD	2600	22	137	
Lopez Canyon up		84	LGR	2632	32		end trail xing at 12:55 (nr UL3)
Whittenberg	F	1	PLP	18	18	WB4	start 9:05 4/14/10, 30ft below WP, photo
Whittenberg		2	CAS	23	5		3ft
Whittenberg		3	PLP	35	12	49	trout seen in many pools below here
Whittenberg		4	CAS	51	16		
Whittenberg		5	RUN	68	17	50	
Whittenberg		6	PLP	79	11		
Whittenberg		7	CAS	81	2		
Whittenberg		8	RUN	95	14	71	
Whittenberg		9	LGR	115	20		
Whittenberg		10	LSBO	131	16		
Whittenberg		11	CAS	141	10		
Whittenberg		12	RUN	152	11		
Whittenberg		13	HGR	156	4	70	
Whittenberg		14	LSBO	172	16		most gravel good but angular
Whittenberg		15	CAS	183	11		
Whittenberg		16	PLP	194	11	69	
Whittenberg		17	CAS	199	5		
Whittenberg	F	18	PLP	215	16		
Whittenberg		19	STP	241	26	68	
Whittenberg		20	LGR	248	7		
Whittenberg		21	LSBO	272	24		large perched gravel deposit
Whittenberg		22	CAS	283	11		
Whittenberg		23	RUN	290	7		
Whittenberg		24	LSBO	299	9		
Whittenberg		25	CAS	305	6	67	
Whittenberg		26	LSBO	320	15		~1/2 perched
Whittenberg		27	LGR	353	33		
Whittenberg		28	MCP	375	22		
Whittenberg	F	29	LSBO	389	14		
Whittenberg		30	LGR	410	21		
Whittenberg		31	LSL	431	21	66	2ft log Xing

Appendix A. (continued)

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Whittenberg		32	HGR	453	22		
Whittenberg		33	LSBO	463	10		small split
Whittenberg		34	CAS	465	2		high Q channel LB
Whittenberg		35	MCP	484	19	65	" "
Whittenberg		36	RUN	500	16		
Whittenberg		37	HGR	509	9		
Whittenberg		38	PLP	520	11		
Whittenberg		39	CAS	533	13		fallen tree w gravel above
Whittenberg		40	LGR	556	23		~1/2 perched
Whittenberg		41	GLD	580	24		
Whittenberg	F	42	LSBK	600	20		bedrock w moss LB
Whittenberg		43	RUN	615	15	64	
Whittenberg		44	LGR	642	27	63	
Whittenberg		45	RUN	660	18		
Whittenberg		46	LGR	701	41		
Whittenberg		47	LSBO	720	19		trout
Whittenberg		48	CAS	727	7		
Whittenberg		49	LSBK	745	18	62	
Whittenberg		50	STP	776	31	61	
Whittenberg	F	51	LSBO	795	19		Q location, newts very common, fewer RBT
Whittenberg		52	SRN	816	21	60	trout
Whittenberg		53	LSD	842	26		w deep undercut
Whittenberg		54	HGR	868	26		
Whittenberg		55	LSBO	882	14		
Whittenberg		56	CAS	885	3	59	
Whittenberg		57	RUN	913	28		
Whittenberg		58	LSD	953	40		photo of gravel w rod, bank-embedded bldrs
Whittenberg		59	MCP	962	9		
Whittenberg		60	XHGR	995	33		
Whittenberg		61	LGR	1008	13		trib RB (~1/5-1/10 Q) - dry in Nov
Whittenberg		62	GLD	1024	16		
Whittenberg	F	63	LSBO	1039	15	27	trout
Whittenberg		64	CAS	1045	6	58	
Whittenberg		65	STP	1071	26		
Whittenberg		66	BRS	1086	15		bedrock ledges
Whittenberg		67	PLP	1097	11	57	
Whittenberg		68	CAS	1100	3		
Whittenberg		69	LSL	1113	13		bedrock pt/wall LB
Whittenberg		70	HGR	1122	9		" "
Whittenberg		71	LSBK	1139	17		" "
Whittenberg		72	LGR	1163	24		" "
Whittenberg		73	LSBK	1187	24		" "
Whittenberg		74	CAS	1194	7		slide debris covers channel in Nov
Whittenberg		75	LSBK	1211	17		" "
Whittenberg		76	XRUN	1236	25		fallen tree
Whittenberg		77	LGR	1248	12	56	end wall
Whittenberg	F	78	LSR	1274	26		bedrock pt RB
Whittenberg		79	LGR	1283	9	55	
Whittenberg		80	LSBK	1292	9		
Whittenberg		81	HGR	1312	20		
Whittenberg		82	RUN	1328	16		very similar
Whittenberg		83	LGR	1353	25		" "

Appendix A. (continued)

HSI Study Site	Flag?	Unit #	Habitat Type	Hipchain Distance	Unit Length	Way-point	Comments
Whittenberg		84	SRN	1378	25		" "
Whittenberg		85	STP	1397	19		" "
Whittenberg		86	LGR	1424	27		" "
Whittenberg	F	87	LSBO	1447	23		square bldr in channel
Whittenberg		88	STP	1464	17	54	
Whittenberg		89	CAS	1466	2		
Whittenberg		90	LGR	1480	14		broken bedrock cliff LB
Whittenberg		91	LSBO	1492	12		
Whittenberg		92	BRS	1547	55		bedrock ledges xing at angle
Whittenberg		93	LSBO	1583	12	53	
Whittenberg		94	XLGR	1596	37		
Whittenberg		95	RUN	1602	6		
Whittenberg		96	HGR	1615	13		bedrock ledges
Whittenberg		97	GLD	1635	20		
Whittenberg		98	LSBO	1654	19		
Whittenberg		99	XHGR	1696	42		bedrock LB
Whittenberg		100	XRUN	1725	29		
Whittenberg		101	XRUN	1780	55		under fallen tree
Whittenberg		102	XLGR	1809	29		" " , Q subsurface
Whittenberg		103	LGR	1846	37		
Whittenberg		104	SRN	1926	80	52	
Whittenberg	F	105	GLD	1955	29	30	iron seep RB
Whittenberg		106	RUN	1967	12		
Whittenberg		107	LGR	1987	20		
Whittenberg		108	MCP	2004	17		
Whittenberg		109	HGR	2032	28		iron seep RB
Whittenberg		110	LSBO	2057	25		1/2 perched, dry trib LB, 4" trout
Whittenberg		111	HGR	2074	17		sharp turn to rt
Whittenberg		112	STP	2094	20		
Whittenberg		113	SRN	2170	76	51	cliff RB
Whittenberg	F	114	LSBK	2186	16		
Whittenberg		115	RUN	2203	17		
Whittenberg		116	LGR	2218	15		
Whittenberg		117	LSBK	2233	15		leaves bedrock cliff
Whittenberg		118	BRS	2285	52		
Whittenberg		119	RUN	2303	18		
Whittenberg		120	STP	2339	36		
Whittenberg		121	LGR	2350	11		
Whittenberg	F	122	LSBO	2367	17	32	RBT observed
Whittenberg		123	HGR	2378	11		
Whittenberg		124	LSBO	2387	9		
Whittenberg		125	STP	2415	28		over bedrock
Whittenberg		126	HGR	2443	28		
Whittenberg		127	LSBK	2462	19		
Whittenberg		128	BRS	2469	7		
Whittenberg		129	LSBK	2491	22		start high bedrock cliffs LB
Whittenberg		130	STP	2578	87		
Whittenberg		131	HGR	2592	14		
Whittenberg		132	XRUN	2610	18		
Whittenberg	F	133	LSBK	2629	19		cliff RB, end 11:30

Appendix B. GPS coordinates for HSI sampling units, temperature data loggers, and observed barriers (NAD 83). See Appendix A for HSI unit locations.

HSI	Latitude			Longitude		
Unit	Deg	Min	Sec	Deg	Min	Sec
15	35	12	15	-120	25	24
16	35	12	14	-120	25	22
18	35	12	15	-120	25	20
27	35	14	18	-120	27	38
30	35	14	24	-120	27	42
32	35	14	26	-120	27	37
39	35	17	33	-120	33	11
41	35	17	40	-120	33	16
42	35	17	43	-120	33	17
43	35	15	49	-120	31	17
44	35	15	52	-120	31	19
49	35	14	12	-120	27	38
50	35	14	12	-120	27	38
51	35	14	26	-120	27	41
52	35	14	24	-120	27	42
53	35	14	21	-120	27	42
54	35	14	21	-120	27	41
55	35	14	20	-120	27	39
56	35	14	20	-120	27	39
57	35	14	19	-120	27	38
58	35	14	19	-120	27	38
59	35	14	17	-120	27	39
78	35	15	22	-120	30	8
79	35	15	25	-120	30	10
80	35	15	26	-120	30	12
81	35	15	26	-120	30	12
82	35	15	26	-120	30	14
83	35	15	28	-120	30	15
84	35	15	29	-120	30	16
85	35	15	31	-120	30	17
86	35	15	32	-120	30	19
87	35	15	30	-120	30	21
88	35	15	27	-120	30	20
89	35	15	27	-120	30	20
90	35	15	27	-120	30	21
91	35	15	27	-120	30	22
92	35	15	27	-120	30	22
93	35	15	28	-120	30	23
94	35	15	30	-120	30	25
95	35	15	30	-120	30	25
96	35	15	30	-120	30	26
97	35	15	30	-120	30	30
98	35	15	30	-120	30	29
99	35	15	30	-120	30	30
100	35	15	29	-120	30	31
101	35	15	30	-120	30	32
102	35	15	30	-120	30	34
103	35	15	32	-120	30	37
104	35	15	32	-120	30	37
105	35	15	32	-120	30	38
106	35	15	33	-120	30	41
107	35	15	35	-120	30	45
111	35	17	27	-120	33	5
112	35	17	27	-120	33	6
113	35	17	31	-120	33	9
114	35	17	32	-120	33	10
115	35	17	33	-120	33	11

Appendix B. (continued)

HSI	Latitude			Longitude		
Unit	Deg	Min	Sec	Deg	Min	Sec
116	35	17	33	-120	33	11
117	35	17	33	-120	33	12
118	35	17	33	-120	33	14
119	35	17	35	-120	33	15
120	35	17	35	-120	33	14
121	35	17	38	-120	33	16
122	35	17	37	-120	33	14
123	35	17	37	-120	33	14
124	35	17	38	-120	33	14
125	35	17	39	-120	33	16
126	35	17	40	-120	33	16
127	35	17	39	-120	33	18
128	35	17	41	-120	33	16
129	35	17	43	-120	33	16
130	35	17	42	-120	33	16
131	35	17	43	-120	33	16
132	35	17	44	-120	33	17
133	35	17	43	-120	33	19
134	35	17	43	-120	33	19
135	35	17	44	-120	33	18
136	35	17	44	-120	33	21
137	35	17	44	-120	33	21
138	35	11	28	-120	26	3
139	35	11	28	-120	26	3
140	35	11	28	-120	26	3
141	35	11	29	-120	26	3
142	35	11	29	-120	26	3
143	35	11	29	-120	26	3
144	35	11	29	-120	26	4
145	35	11	32	-120	26	3
146	35	11	32	-120	26	3
147	35	11	33	-120	26	2
148	35	11	33	-120	26	2
149	35	11	33	-120	26	2
150	35	11	34	-120	26	2
151	35	11	34	-120	26	2
152	35	11	34	-120	26	2
153	35	11	35	-120	26	1
154	35	11	37	-120	26	1
155	35	11	37	-120	26	1
156	35	11	37	-120	26	1
157	35	11	38	-120	26	1
158	35	11	38	-120	26	0
159	35	11	38	-120	26	0
160	35	11	38	-120	26	0
161	35	11	42	-120	25	58
162	35	11	42	-120	25	57
163	35	11	43	-120	25	57
164	35	11	45	-120	25	56
165	35	11	45	-120	25	56
166	35	11	45	-120	25	56
167	35	11	46	-120	25	56
177	35	12	16	-120	25	33
178	35	12	16	-120	25	33
179	35	12	16	-120	25	32
180	35	12	16	-120	25	31
181	35	12	16	-120	25	31

Appendix B. (continued)

HSI	Latitude			Longitude		
Unit	Deg	Min	Sec	Deg	Min	Sec
182	35	12	16	-120	25	30
183	35	12	16	-120	25	31
184	35	12	15	-120	25	29
185	35	12	15	-120	25	25
186	35	12	15	-120	25	26
187	35	12	15	-120	25	25
188	35	12	14	-120	25	25
189	35	12	15	-120	25	24
190	35	12	14	-120	25	23
191	35	12	14	-120	25	23
192	35	12	14	-120	25	22
193	35	12	12	-120	25	21
194	35	12	15	-120	25	20
195	35	12	15	-120	25	21
196	35	12	16	-120	25	20
197	35	12	16	-120	25	19
198	35	12	16	-120	25	18
199	35	12	16	-120	25	17
200	35	12	17	-120	25	15
201	35	12	18	-120	25	15
202	35	12	19	-120	25	15
203	35	12	19	-120	25	14
204	35	15	47	-120	31	13
205	35	15	47	-120	31	14
206	35	15	48	-120	31	14
207	35	15	47	-120	31	14
208	35	15	47	-120	31	15
209	35	15	47	-120	31	16
210	35	15	47	-120	31	17
211	35	15	47	-120	31	17
212	35	15	48	-120	31	17
213	35	15	47	-120	31	17
214	35	15	48	-120	31	18
215	35	15	49	-120	31	17
216	35	15	51	-120	31	18
217	35	15	51	-120	31	18
218	35	15	51	-120	31	19
219	35	15	52	-120	31	17
220	35	15	52	-120	31	19
221	35	15	52	-120	31	19
222	35	15	53	-120	31	19
223	35	15	53	-120	31	19
224	35	15	54	-120	31	20
225	35	15	54	-120	31	19
226	35	15	54	-120	31	20
227	35	15	54	-120	31	20
228	35	15	57	-120	31	23
229	35	15	58	-120	31	21
ML1b	35	15	47	-120	31	13
WB4	35	14	12	-120	27	38

Appendix B. (continued)

	Latitude			Longitude		
Data Logger	Deg	Min	Sec	Deg	Min	Sec
AG low	35	11	25	-120	26	5
AG up	35	12	22	-120	25	12
Lopez low	35	13	58	-120	28	23
Lopez mid	35	15	37	-120	30	58
Lopez up	35	17	14	-120	32	46
Whittenberg	35	13	43	-120	27	32
	Latitude			Longitude		
Barrier	Deg	Min	Sec	Deg	Min	Sec
Whittenberg	35	14	8	-120	27	39
Arroyo Grande	35	12	19	-120	25	14
Lopez Canyon	35	17	13	-120	32	41

Appendix C. Representative photographs of HSI study reaches (photos of all HSI sampling units available only on CD).

Lower Arroyo Grande – Pools


Lower Arroyo Grande – Flatwaters


Lower Arroyo Grande – Riffles


Appendix C. (continued)

Upper Arroyo Grande – Pools


Upper Arroyo Grande – Flatwaters


Upper Arroyo Grande – Riffles


Appendix C. (continued)

Lower Lopez Canyon – Pools

Lower Lopez Canyon – Flatwaters

Lower Lopez Canyon – Riffles

Appendix C. (continued)

Middle Lopez Canyon – Pools


Middle Lopez Canyon – Flatwaters


Middle Lopez Canyon – Riffles


Appendix C. (continued)

Upper Lopez Canyon – Pools

Upper Lopez Canyon – Flatwaters

Upper Lopez Canyon – Riffles

Appendix C. (continued)

Whittenberg – Pools


Whittenberg – Pools


Whittenberg – Pools