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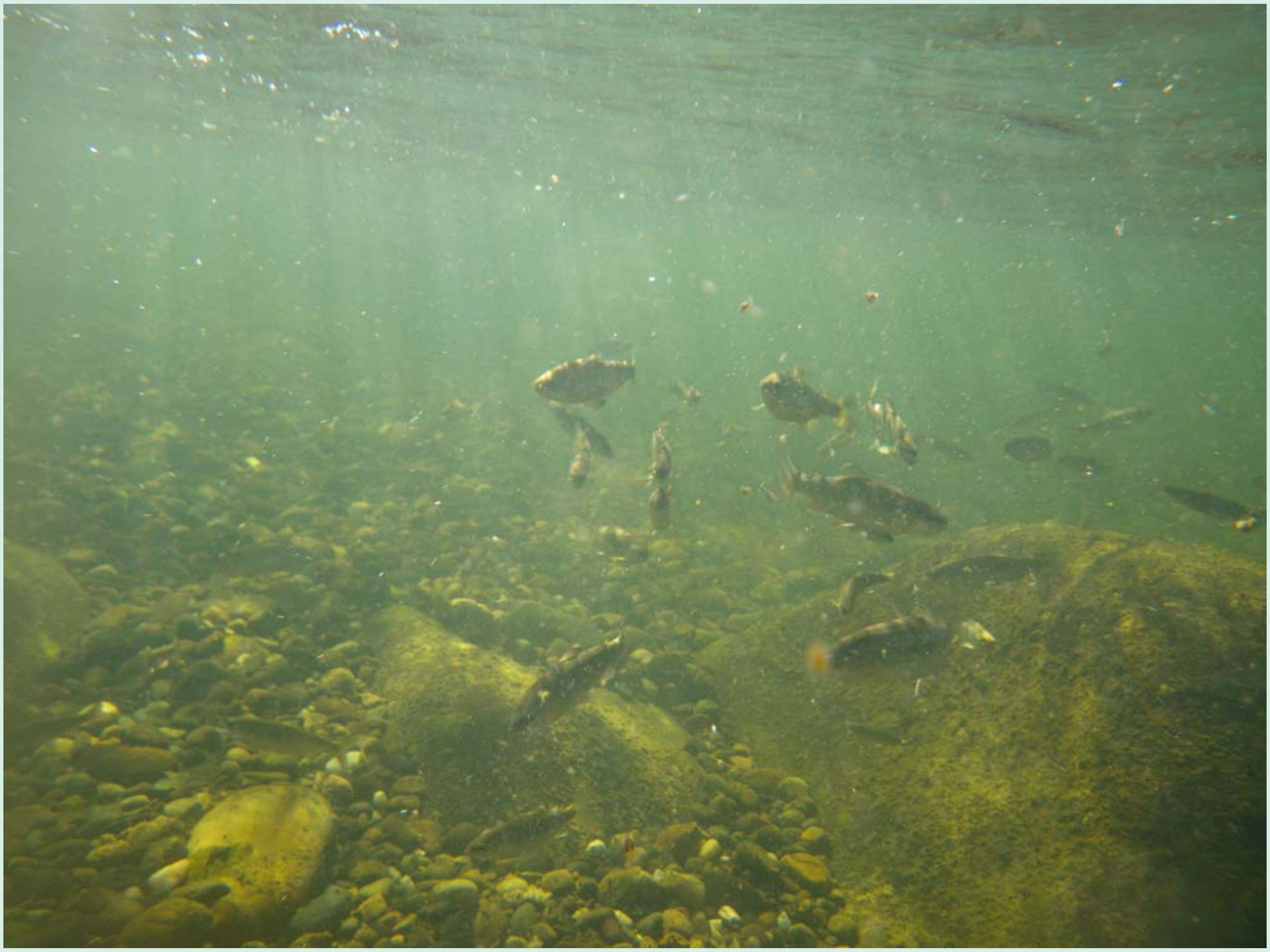
September 2011 Population Size Estimates of *Oncorhynchus mykiss* in the Lower Tuolumne River



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SUMMARY

In September 2011, the final population size estimate of *Oncorhynchus mykiss* was developed in the lower Tuolumne River in accordance with the 3 April 2008 Delegated Order issued by the Federal Energy Regulatory Commission (FERC) implementing elements of a study plan previously developed in coordination with California Dept. of Fish and Game (CDFG), National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) biologists, and submitted to FERC on 16 July 2007.

Snorkel surveys were conducted during daylight hours from 20 to 24 September 2011 to estimate *O. mykiss* population size within the Tuolumne River. In addition to snorkel survey observations of *O. mykiss*, data for Chinook salmon (*O. tshawytscha*) and other species was also collected. Snorkel surveys were conducted using a two-phase survey design to sample five different habitat strata (i.e., riffle, run head, run body/tail, pool head, and pool body/tail) found downstream of La Grange Dam at river mile (RM) 51.8 using habitat typing from surveys performed in June 2008 (ending at RM 39.5) and March 2009 (from RM 39.5 down to RM 29.0). The study reach extended from RM 51.8 to RM 35.0, approximately 4.9 miles downstream of Robert's Ferry Bridge. A total of 32 of 245 sampling units in the study reach upstream of RM 35.0 were selected for either single pass or multi-pass snorkel surveys in September 2011.

O. mykiss Population Estimates

Based upon the maximum count obtained over all dive passes in each sampled unit, a total of 4,913 young-of-the-year/juvenile (<150 mm total length [TL]) and 813 larger (≥150 mm TL) *O. mykiss* were observed in September 2011. Using a bounded counts population estimator (BCE) for the September 2011 survey period, a total of approximately 47,432 juvenile and 9,541 larger *O. mykiss* were present within the study reach (RM 51.8–35). The population estimates for both juveniles and larger fish exceeded estimates from all previous years (2008–2010) during which these surveys have been conducted.

Chinook Salmon Population Estimates

For Chinook salmon encountered during the September 2011 snorkel surveys, a maximum count of 2,576 juveniles (<150 mm TL) were observed within all habitat types along the study reach. This corresponded to bounded counts population estimates of 24,299 juvenile Chinook salmon, which exceeded the population estimates from all previous years (2008–2010). There were also 157 larger (≥150 mm TL) Chinook salmon observed in September 2011.

Other Species

A combination of native minnows (hardhead and Sacramento pikeminnow), along with native Sacramento sucker accounted for approximately 96% of non-salmonid fish observed for both the September sampling period, with very low counts of non-native centrarchid species (largemouth bass, smallmouth bass) observed. Striped bass were found in low numbers in pool habitat throughout the reach. Native minnows and suckers were found in the highest densities downstream of RM 40.

Relationship between Temperature and *O. mykiss* Habitat Use

To test the hypothesis that the summertime distribution of suitable habitat by observed life stages of *O. mykiss* is related to ambient river water temperature, water temperature data from thermographs deployed in the Tuolumne River were compared to juvenile and adult *O. mykiss* density from the September 2011 survey along the study reach. The data show that temperatures increased in the downstream direction, from 12.7ºC (54.8°F) to 16.8ºC (62.2°F) (maximum weekly average temperature [MWAT]), and that *O. mykiss* density of both larger fish and juveniles generally decreased along this same gradient. Although this pattern is similar to what was observed in all previous years (2008–2010), suitable temperatures below 18.7°C were maintained throughout the study reach (RM 51.8–35.0) suggesting additional factors may be restricting the distribution of *O. mykiss* downstream of RM 44.0.

O. Mykiss Habitat Use at Restoration Sites

A second hypothesis that habitat use by *O. mykiss* juveniles and adults observed in the Tuolumne River occurred at the same density in both restored and nearby reference sites was tested based on observed densities of *O. mykiss* juveniles and larger fish in habitat types (riffle, run head, and pool head) common to both groups in the September survey. For juveniles, this comparison showed riffle habitat use at upstream restoration sites was greater than that of other riffle habitats. Juvenile habitat use within run head habitats was similar or reduced at the restoration sites in comparison to reference sites, with low use of pool head habitat. For larger fish, this comparison showed a potential increase of habitat use of riffle habitat at restoration sites, with diminished use of run head habitat, and insufficient data for a comparison of pool head habitat use at restoration sites.

Comparison with September 2011 Reference Count Survey Results

A comparison was made of *O. mykiss* and juvenile Chinook data collected during the September 2011 BCE survey to the reference count snorkel survey data collected in September 2011. The comparison shows a similar longitudinal trend, with overall densities decreasing in the downstream direction for both species, although densities in the upstream portion of the reach varied between surveys, especially for Chinook juveniles. Along the study reach common to both surveys, a total of 836 *O. mykiss* “juveniles” (< 150 mm) and 343 larger fish (>150 mm) were observed in the September reference count snorkel survey, while 4,587 juveniles and 742 larger fish were observed in the September BCE survey. A total of 66 juvenile (< 150 mm) Chinook were seen in the September reference survey with 2,413 seen in the September 2011 BCE survey.

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1 INTRODUCTION

Routine fisheries monitoring surveys for the Don Pedro Project (FERC Project No. 2299) by the Turlock Irrigation District (TID) and Modesto Irrigation District (MID) have long documented the presence of *Oncorhynchus mykiss* in the lower Tuolumne River (TID/MID 2005). Summer snorkel surveys, conducted in most years since 1988, have documented an increased *O. mykiss* presence and relative abundance that is associated with the more consistent and higher summer flows provided since 1997 (TID/MID 2008).

On 19 March 1998, the National Marine Fisheries Service (NMFS) first listed the Central Valley steelhead as threatened under the Endangered Species Act (ESA). After several court challenges, NMFS issued a new final rule relisting the Central Valley steelhead on 5 January 2006 (71 FR 834). In a separate process resulting from terms of the 1996 FERC license amendment for the Project, NMFS staff provided input to a draft limiting factors analysis for Tuolumne River salmonids (Mesick et al. 2007) and included recommendations for developing abundance estimates, habitat use surveys, and anadromy determination of resident *O. mykiss*. These recommendations were conceptually used to develop the Districts' FERC Study Plan (TID/MID 2007), which was the subject of a 3 April 2008 FERC Order. As part of the Order, the Districts were required to conduct population estimate surveys in winter (February/March) and summer (June/July), with the first surveys starting in summer 2008 to determine *O. mykiss* population abundance by habitat type.

The Districts first submitted a detailed *O. mykiss* population estimate study plan (Stillwater Sciences 2008a) to FERC on 3 July 2008 to provide information on the abundance and habitat requirements within the lower Tuolumne River. A report on the July 2008 population size estimate (Stillwater Sciences 2008b) was submitted as part of the Districts' 2008 annual report to FERC (TID/MID 2009). An updated study plan (Stillwater Sciences 2009) was prepared in 2009 for the population estimate surveys and is attached to this report as Appendix A. In addition to providing data to develop population size estimates under current conditions, the study plan examined the following hypotheses:

- Hypothesis 1: Summertime distribution of suitable habitat by observed life stages of *O. mykiss* is related to ambient river water temperature.
- Hypothesis 2: Habitat use by *O. mykiss* juveniles and adults observed in the Tuolumne River occurs at the same density in both restored and nearby reference sites.

The *O. mykiss* snorkel surveys employed a two-phase sampling approach for the development of a reach-wide population estimate (Hankin and Mohr 2001) in the lower Tuolumne River. Survey sites were selected using a stratified random sampling approach, where the strata were major habitat types. In September 2011, the overall sampling "universe" from which sampling strata were delineated extended from near La Grange Dam at river mile (RM) 51.8 to RM 35.0, approximately 4.9 miles downstream of Robert's Ferry Bridge (Figure 1). This reach coincides with the downstream areas where *O. mykiss* were observed (Riffle 41A at RM 35.3) during the September 2011 reference count snorkel surveys (TID/MID 2012).

The two-phase stratified sampling design involved snorkeling pre-selected sampling units (e.g., riffle, run, pool, etc.) multiple times in order to quantify the variance associated with density and subsequent population estimates. As in a typical Phase I sampling approach, primary snorkel surveys (Edmundson et al. 1968, Hankin and Reeves 1988, McCain 1992, Dolloff et al. 1996) were conducted across a subset of the all sampling units. In Phase II, approximately 20–70% of each habitat type sampled was randomly selected for replicated surveys by repeated dive counts.

The methods presented by Stillwater Sciences (2009) discussed using a combined approach of both repeated dive counts and electrofishing. Current ESA permit restrictions for NMFS Section 10(a)(1)(A) permit No. 1282 (Stillwater Sciences) did not allow sufficient incidental take to conduct the second-phase surveys using electrofishing. Consequently, the surveys used only snorkel surveys, as provided for in the 2007 study plan and identified in letters provided by the Districts to FERC dated 3 July 2008 and 31 March 2009.

2 METHODS

2.1 Habitat Characterization

2.1.1 Habitat mapping

Habitat maps were compiled from an analysis of past habitat surveys, historical and more recent aerial photographs, and field surveys conducted in 2008, with results superimposed within a geographic information system (GIS). Field maps for the September 2011 BCE snorkel surveys were created using an orthorectified aerial photo and accompanying Light Detection and Ranging (LiDAR) topographic data from 21 September 2005 recorded at river flows of 321 cfs. Preliminary sampling unit boundaries of common habitat features (pools, riffles, and runs) were estimated from the LiDAR and bathymetric data between RM 52–38 within GIS by calculating locations corresponding to major water depth transitions (Table 2-1).

Table 2-1. Coarse-scale habitat types used during snorkel surveys.

Habitat type	Description[a]	Approximate depth
Riffle	Shallow with swift flowing, turbulent water. Partially exposed substrate dominated by cobble or boulder. Gradient moderate (less than 4%).	0–4 ft
Run	Fairly smooth water surface, low gradient, and few flow obstructions. Mean column velocity generally greater than one foot per second (fts^{-1}).	4–10 ft
Pool	Slow flowing, tranquil water with mean column water velocity less than 1 fts^{-1}.	>10 ft

[a] Major habitat types determined based upon observed hydraulic conditions (McCain 1992, Thomas and Bovee 1993, Cannon and Kennedy 2003)

As an initial validation of these coarse scale habitat types, we compared the habitat types mapped in July 2008 (Appendix B) with previous habitat type maps (Appendix C) developed by McBain and Trush (2004) between 1999–2001 on a base-layer map corresponding to a wetted perimeter of 622 cfs flown on 20 May 1991. Appendix C shows major habitat types (i.e., riffle, run, pool) encountered during the 1999–2001 surveys along with past and planned gravel introduction locations included in the *Tuolumne River Coarse Sediment Management Plan* (McBain and Trush 2004).

In general, habitat typing shown by McBain and Trush (Appendix C) indicates larger proportions of "pool" habitat types than those determined during this effort (Appendix B), which reserved the pool habitat designation for water depths greater than 10 ft. Additionally, because *O. mykiss* tend to congregate at transitions between habitat types, Appendix B shows a further division of pool and run body habitats into smaller, transitional habitat sampling units (pool head, pool tail, run head, and run tail) based upon location of slope channel slope break at the upstream and downstream end of the unit. For the September 2011 surveys, pool tail and run tail habitats were consolidated into corresponding upstream pool body or run body habitat. This action was based on low use of the pool tail and run tail habitats as discrete sampling units in prior surveys (July 2008 and March 2009) and results in a reduced number of sampling units having low potential for use by salmonids available for habitat selection, thereby increasing the number of sampling units having a higher potential use, while not eliminating them from the area surveyed (see Section 2.2.1 for a complete description of sampling unit selection).

2.1.2 Habitat data collection

Float surveys were conducted in July 2008 and February 2009 to further refine and validate the preliminary habitat maps (Appendix B) described above at flows of approximately 106 cfs and 168 cfs, respectively. In addition to refining the locations and sizes of potential habitat sampling units, we collected habitat data (Table 2-2) at several locations within each sampling unit. Starting at upstream end of the study reach just downstream of La Grange Dam (Figure 1), habitat units were assigned a natural sequence order (NSO), a number, beginning with NSO 001, and incremented this identifier at each habitat transition (e.g., NSO 001 pool head, NSO 002 pool body, etc). The upstream and downstream end of each unit was located and marked on field maps, the location recorded with a handheld GPS unit, and labeled with flagging indicating the date, unit number, and habitat type.

Table 2-2. Habitat data collected at each unit.

Parameter	Method	Metric/Descriptor	Method reporting limit
Natural Sequence Order (NSO—Habitat unit #)	N/A	NSO-1, NSO-2, NSO-3, …	N/A
Latitude/Longitude	Handheld GPS receiver	UTM	N/A
Habitat type	Visual estimation	See Table 2-1	N/A
Average unit width	Horizontal distance	Meters (feet) (measured at multiple transects)	0.01 m (0.1 ft)
Average unit length	Horizontal distance	Meters (feet)	0.01 m (0.1 ft)
Maximum/minimum depth	Vertical distance	Meters (feet)	0.15 m (0.5 ft)
Bed substrate composition	Visual estimation	Bedrock, boulder, cobble, gravel, organic, sand, silt	10%
Cover type	Visual estimation	None, boulder, cobble, IWM, bedrock ledges, overhead vegetation, aquatic vegetation	10%

Note that although the wetted perimeter of the 2009 habitat maps corresponds to a 2005 air photo at flows of 321 cfs, in order to provide a more accurate channel edge boundary for the September 2011 surveys, the channel edge of the habitat unit boundaries shown in Appendix B correspond to a wetted perimeter of 230 cfs previously digitized from air photos taken in 1986–1987 and later refined to adjust for channel migration. The average daily flow during the September 2011 sampling was 308 cfs. Because the estimated wetted perimeter of the habitat unit boundaries did not vary more than a few feet in most cases at these two flows, the channel edge boundary for 230 cfs was used for both the September 2011 surveys. For each habitat unit shown, habitat unit length and width were subsequently determined in GIS. Appendix D shows accompanying field habitat data collected in all habitat units mapped, including maximum depth and average width (usually at 1/3 and 2/3 of the unit's length), bed substrate composition, and instream cover type.

2.2 Snorkel Surveys

2.2.1 Study design and survey unit selection

After habitat typing and collecting habitat data in all units, a subset of units of each habitat strata was selected for single-pass snorkel surveys. The survey units were selected to balance the habitat sampling unit replication, total available number of units to draw from, coverage of at least 10% of the total length of a given habitat type, as well as sampling effort. The selection process involved random selection of one of the most upstream units of each habitat type, followed by a systematic uniform sampling of the remaining units in the study reach. After the first dive pass was completed, a tab was then pulled to determine if the unit was included in the second phase of sampling.

For the September 2011 surveys, a subset of 6–7 units were selected for each of the 5 habitat types were selected (Table 2-3).

Table 2-3. Sample unit selection and survey count for September 2011.

Habitat	Phase I dives		Phase II survey	
	Initial units	**Passes**	**Repeat units**	**Passes**
Riffle	7	1	3	2
Pool head	6	1	3	2
Pool body /tail	6	1	3	2
Run head	6	1	3	2
Run body /tail	7	1	3	2
Total	**32**		**30**	

2.2.2 Snorkel data collection

Snorkel surveys were conducted during daylight hours from 20 to 24 September 2011. A two-phase survey design was used to survey the various riffle, run, and pool strata. For the first phase, single-pass dive surveys were conducted by a four-person team. Sampling units were sampled from downstream to upstream in dive lanes using a zigzag pattern, passing fish and allowing them to escape downstream of the diver. If fish were observed to escape upstream, the diver took care to avoid counting these individuals twice. Divers recorded the type, length, and number of fish

(Table 2-4). Total lengths were estimated in 50 mm size ranges (called “bins”) using markings on dive slates to correct for underwater size distortion.

Table 2-4. Fish data collected within each unit during snorkel surveys.

Parameter	Method	Metric/Descriptor	Method reporting limit
Date; start and end time	N/A	Day/month/year; hour/minute	N/A
Number of individuals	Visual estimation	Number	1
Fish length	Visual estimation	Millimeter	50-mm bins

The second phase of sampling required the collection of repeat dive counts and fish size data during each of two subsequent passes through the selected habitat units. These data were later used to statistically expand the dive counts to total population estimates for each habitat type. The Phase 2 dive pass replication was established at 2 passes in 2009 surveys to reduce sampling effort within particular sampling units while increasing the overall sample unit coverage (Stillwater Sciences 2010). Lastly, the occurrence of other non-salmonid native and non-native fish species was recorded as presence/absence and abundance.

2.3 Water Quality and Flow

At fish sampling locations, in addition to noting the type, length, and number of fish (Section 2.2), we collected spot measurements of *in situ* water quality data (temperature, dissolved oxygen, and conductivity) using a pre-calibrated multi-probe (YSI 85, Yellow Springs Instruments, Yellow Springs, OH) (Table 2-5). Dissolved oxygen (DO) probes were recalibrated each day and checked for accuracy in the laboratory against DO concentrations measured in aerated tap water. Changes in underwater visibility were monitored horizontally using a Secchi disk oriented both toward and away from the sun. Daily average flow data for each day were obtained from the stream gage below the La Grange powerhouse at RM 51.8 (USGS No. 11289650).

Table 2-5. Water quality data collected during snorkel surveys.

Parameter	Method	Metric/Descriptor	Method reporting limit
Temperature	EPA 170.1	°C	0.1 °C
Dissolved oxygen	SM 4500-O	mg/L	0.01 mg/L
Conductivity	SM 2510A	umhos/cm	1.0 umhos/cm
Visibility	Secchi depth	meters (feet)	0.01 m (0.1 ft)

2.4 Water and Air Temperatures

From spring 1987 to present, TID/MID has collected water temperature data from various locations in the lower Tuolumne River using recording thermographs (Hobo Pro V2 thermographs, OnSet Computer Corporation, Bourne, MA). The thermographs measured and stored water temperature data at one-hour intervals, with data downloads occurring at least twice a year.

Water temperature data collection during September 2011 also included spot measurements taken during snorkel surveys. The measurements were recorded over the course of the day as divers moved further downstream; as such, it was anticipated that these water temperatures would not be as representative as hourly thermograph recordings. The data do provide a general description of relative temperature conditions during dive surveys, however.

Regional air temperature data were obtained from the National Weather Service (NWS) station at Modesto Airport near RM 18. Water and air temperature data for the August through September 2011 period is presented in this report (Figure 2).

2.5 Data analysis

2.5.1 Bounded counts population estimate

Water quality and fish observation counts were summarized by habitat unit type with initial density estimates calculated based upon the area searched within each habitat unit sampled. In addition to comparisons of fish density between habitat types, the density estimates and uncertainties were propagated across the unsampled areas for an overall reach-wide population estimate.

Population estimates were made for each stratum and size class using the general methods of Hankin and Mohr (2001). For units receiving multiple dives, the bounded counts formulae are used to produce an estimate of the unit population and an estimate of the variance of this estimate. Specifically, when there are r passes, and the counts of these are sorted in increasing order as $m_1 \le m_2 \le \ldots \le m_r$, the population is estimated as

$$\tilde{y}_B = m_r + (m_r - m_{r-1}),$$

and the mean squared error of this is estimated as

$$\tilde{\mathrm{MSE}}(\tilde{y}_B) = (m_r - m_{r-1})^2 .$$

The total population of multiply dived units is estimated as the sum of the bounded-counts estimates for the individual units. The total population of the survey region is estimated by expanding this, first to *all* dived units (singly or multiply dived) on the basis of mean dive counts, and then to all units (dived or undived) on the basis of area. An estimator of the variance of this is constructed from estimates of the mean-squared errors of the bounded-counts estimates for the multiply dived individual units, and the variance of the bounded-counts estimates around their common mean. The final formulae are included in Hankin and Mohr (2001). A nominal confidence interval for each stratum and size class was calculated formally as

$\hat{Y} \pm 1.96\sqrt{\hat{V}}$, where $\hat{Y}$ and $\hat{V}$ are the mean and variance estimates, *except* that the lower bound of this interval was “trimmed” to the number of fish actually observed.

2.5.2 Comparisons with September 2011 reference count snorkel surveys

Data collected during the September 2011 snorkel surveys (20–24 September) were compared to reference count snorkel survey data collected during 16–19 September 2011 (TID/MID 2012). Although the sampled areas of these surveys differ, these data were collected only a few days prior to the data collected for this report, allowing for a general comparison of presence/absence and the relative proportions of larger and smaller size classes of *O. mykiss* and Chinook salmon in sampling units sampled during both surveys. Further, although TID/MID has sampled the same reference locations since 2001, the comparison is limited to the September 2011 data as these are the most directly comparable.

3 RESULTS

3.1 Habitat Characterization

For the total reach surveyed in September 2011 (RM 51.8–35.0), "run body/tail" habitat type occupied the greatest length of channel along the study reach, followed by pool body/tail and riffles (Table 3-1). The "pool body/tail" habitat type, while less abundant than other habitat types (e.g., run head), occupied the third greatest length of channel. Other transitional habitat types (e.g., run head and pool head) accounted for only 7.2% of the total reach length. Habitat maps and data for the entire study reach are shown in Appendices B and D. The longitudinal distribution of the area of each of the major habitat types within bins of 2 river miles is shown in Figure 3. The distribution of each of the major habitat types sampled in September 2011 is presented in Figure 4.

Table 3-1. Summary of habitat types from RM 51.8 to 35.0, September 2011.

Habitat type	Count	% by count	Total length (ft)	Total length (mi)	% reach length	Area (ft^2)
Riffle	53	21.6	18,408	3.49	20.7	1,557,614
Pool head	13	5.3	1,330	0.25	1.5	107,495
Pool body/tail	32	13.1	14,580	2.76	16.4	1,564,680
Run head	49	20.0	4,169	0.79	4.7	376,205
Run body/tail	98	40.0	50,247	9.52	56.6	5,053,173
Total	**245**	**100.0**	**88,733**	**16.81**	**100.0**	**8,659,167**

3.2 Water Quality and Flow

As water quality data were collected exclusively within units chosen for snorkel survey, data are presented by river mile, rather than by sampling unit, or summarized for the entire reach (Table 3-2). Water quality data for sampling units selected for snorkel surveys are shown in Appendix E.

Because of the influence of ambient air temperatures (Sullivan et al. 1990), temperatures of water released from the cold water pool of Don Pedro Reservoir increase in a downstream direction for the spot measurements (Table 3-2) and in the continuous thermograph record during the September survey period (Appendix F). Note that the water temperature ranges shown in Table 3-2 represent changes over the course of the sampling day, and do not include nighttime temperatures or lows that are shown at representative thermograph locations in Appendix F.

Daily average flow during the September 2011 survey period was 308 cfs as recorded at the USGS station near the La Grange powerhouse (No. 11289650). No dissolved oxygen readings were recorded due to instrument malfunction. Horizontal visibility was reduced at the most downstream locations due to local turbidity sources.

Table 3-2. Range of water quality data collected at snorkel sites during fish surveys in September 2011.

River miles	Sample date	Flow (cfs)[a]	Water temp °C [°F]	DO (mg/L)	Horizontal visibility (ft)	Specific conductivity (uS/cm)
49.2−48.0	20 September	318	13.9–15.5 [57.0–59.9]	--	28–26	25.7–27.3
51.6−50.1	21 September	319	12.6–14.7 [54.7–58.5]	--	30–26	25.3–25.7
45.9−38.0	22 September	315	14.1–16.7 [57.4–62.1]	--	21–15	27.7–37.4
49.7−36.2	23 September	305	15.1–18.0 [59.2–64.4]	--	26–11	25.7–38.5
45.3−44.8	24 September	281	14.2 [57.6]	--	18	28.9

[a] Daily average flow data are measured from the stream gauge below La Grange powerhouse at RM 51.8 (USGS No. 11289650).

3.3 Water and Air Temperature

The daily average water temperature for all thermographs and the daily minimum, maximum, and average air temperature (from the NWS station at the Modesto Airport) are shown in Appendix F. The range of daily averages, instantaneous maximum temperature, maximum weekly average temperature (MWAT), and the seven-day average of daily maximum temperature (7dayMAX) for the 20–24 September study period was determined, and all three metrics for both periods showed a similar trend of increasing in the downstream direction. The MWAT is the seven-day rolling average of average daily temperatures, and describes ambient water temperature conditions over the previous week. It is a standard used in water quality studies and total maximum daily load (TMDL) estimations of allowable temperature. The 7dayMAX is the seven-day rolling average of the daily maximum temperatures, and is a potentially more accurate indicator of conditions affecting survival and growth of salmonids (Sullivan et al. 2000, Stillwater Sciences 2002).

During the September 2011 survey period, water temperature data collected by thermographs followed similar trends to spot temperature data collected during snorkel surveys, showing an increase in the downstream direction (Table 3-3). Along the study reach, the MWAT increased from 12.7°C (54.8°F) at Riffle A7 to 16.8°C (58.0°F) at the Ruddy Gravel site (Table 3-3). The 7dayMAX temperature ranged from 13.7°C (56.7°F) at the Riffle A7 location to 18.4°C (65.2°F) at the Ruddy Gravel site. The hourly, mean weekly average (MWAT), and 7dayMAX water temperatures for Riffle A7 (RM 50.8), Riffle 13B (RM 45.5), Roberts Ferry Bridge (RM 39.6), and Ruddy Gravel (RM 36.5) from 1 August to 30 September 2011 are presented graphically in Appendix F.

Table 3-3. Maximum weekly average temperature, seven-day average of daily maximum temperatures, and instantaneous maximum temperatures recorded by thermographs in the survey reach of the lower Tuolumne River during September 2011.

Monitoring location	RM	MWAT ºC [°F] (week ending)	7dayMAX ºC [°F] (week ending)	Instantaneous maximum ºC [°F] (date)
Riffle A7	50.8	12.7 [54.8] (24 Sept)	13.7 [56.7] (24 Sept)	13.8 [56.9] (21 Sept)
Riffle 13B	45.5	14.4 [58.0] (24 Sept)	16.0 [60.8] (24 Sept)	16.2 [61.1] (20 Sept)
Roberts Ferry Bridge[a]	39.6	15.9 [60.6] (24 Sept)	16.7 [62.0] (24 Sept)	17.1 [62.7] (24 Sept)
Ruddy Gravel	36.5	16.8 [62.2] (24 Sept)	18.4 [65.2] (24 Sept)	18.7 [65.6] (22 Sept)

Note: Thermographs used have a reported error of ±0.2°C.
[a] Thermograph located approximately 0.75 miles upstream of bridge.

The average daily Modesto Airport air temperatures over the study period ranged from 25.0 to 26.78 ºC (77.0 to 80.0 °F) with a high temperature of 37.2 °C (99.0 °F) (

Table 3-4). The warmest day of September occurred before the study period on 10 September with an average daily temperature of 28.9 °C (84.0 °F) (Figure 2) and a daily high temperature of 37.8 °C (100.0 °F).

Table 3-4. Daily average, minimum, and maximum air temperature recorded at the NWS station at the Modesto Airport during the September 2011 snorkeling study period.

Date	Average air temperature ºC [°F]	Minimum air temperature ºC [°F]	Maximum air temperature ºC [°F]
20 September 2011	26.1 [79]	15.6 [60]	36.7 [98]
21 September 2011	26.7 [80]	16.1 [61]	37.2 [99]
22 September 2011	26.7 [80]	16.7 [62]	36.7 [98]
23 September 2011	27.8 [82]	17.8 [64]	37.2 [99]
24 September 2011	25.0 [77]	16.1 [61]	33.3 [92]

Hourly water temperature for several monitoring stations along the length of the study reach and daily air temperature from the Modesto Airport station was compared (Figure 2). With flow being stable throughout period, Figure 2 shows that at the upstream-most monitoring station, water and air temperature are more independent of each other than at thermographs located farther downstream. That is, water temperature becomes more influenced by air temperature in the downstream direction, with water and air temperature peaks and troughs occurring at the same times of day at the downstream monitoring site at Ruddy Gravel (RM 39.6).

3.4 Snorkel Surveys

3.4.1 *O. mykiss* observations

During the September 2011 survey period, divers observed 5,929 *O. mykiss* ranging from 0–500 mm (50 mm size bins) based upon maximum counts of all dive passes in each sampling unit (Table 3-5, Table 3-6 and Figure 5). These included 5,065 fish classified as a juvenile in the <150 mm size categories, with the other 864 observed in the larger (≥150 mm) size classes (Table 3-5 and Table 3-6). The *O. mykiss* were observed all but two of the sampling units from RM 51.6 to RM 36.2. The *O. mykiss* were observed in all habitat types, with the highest numbers seen in a riffle habitat unit at RM 50.6 (Table 3-5 and Table 3-6). Complete fish observation data by sampling unit and dive pass is presented in Appendix G.

The *O. mykiss* were observed in 28 different sampling units from RM 51.8 to RM 36.3 and in all habitat types (Table 3-5). Habitat use for both juvenile and larger *O. mykiss*, based on the maximum count from dive passes, was highest in riffle and run body/tail habitats (Figure 6a). Fish densities (Figure 6b) for juvenile size classes (<150 mm) highest in riffle and run head habitats. Juvenile size classes were also observed in each of the other habitat types, with lowest density in pool body habitats (Figure 6b). Larger size classes (>150 mm) were observed in highest density in run head habitats, with lower densities found in each of the other habitat types (Figure 6b).

Habitat use for *O. mykiss* was concentrated at upstream sampling units (above RM 44.0) and primarily occurred at transitional run head and riffle habitats (Figure 7 and Figure 8).

Table 3-5. Maximum count of *O. mykiss* by sampling unit, September 2011 (data are divided into 50 mm total length size classes).

RM	Sampling Unit	Habitat	Multiple pass survey (Y/N)	0–49 mm	50–99 mm	100–149 mm	150–199 mm	200–249 mm	250–299 mm	300–349 mm	350–399 mm	400–449 mm	450–499 mm
51.6	4	Pool head	Y						4	4	1		
50.9	11	Pool body	Y		1				2	15	6	3	
50.6	14	Riffle	N	2	1,192	528	75	8	5	16	1		
50.3	19	Run head	Y	7	58	28	5	3	4	9	12	2	
50.1	20/21	Run body/tail	Y	166	316	224	29	22	9	8			
49.7	27	Pool head	Y	1	99	27	3	2	1				
49.6	28/29	Pool body/tail	Y	9	179	101	20	6	3	18	5		
49.3	31/32	Run body/tail	N	3	20	232	128	8	12	17	24	1	3
49.2	33	Riffle	Y	3	391	242	58	18	2	4	4	2	1
49.1	38	Run head	Y		18	46	6			1			
48.7	43/44	Run body/tail	Y	10	94	151	59	24	15	4	5	3	
48.0	53	Riffle	N		28	16	1						
48.0	54	Pool head	Y		45	22	4	1		4	2		
45.9	70	Riffle	Y	1	240	125	27	6	3	6			
45.9	71	Run head	N		27	31	18	9	6	6	4		
45.8	72/73	Run body/tail	Y	10	82	41	18	11	6	2			
45.3	81	Pool body	Y		31	16	3	2		4	2		
44.8	90	Run head	N		25	5							
44.8	91/92	Run body/tail	N		132	34	3	3		1			
39.4	161	Run head	Y			2	3						
39.3	162/163	Run body/tail	N								1		

RM	Sampling Unit	Habitat	Multiple pass survey (Y/N)	0–49 mm	50–99 mm	100–149 mm	150–199 mm	200–249 mm	250–299 mm	300–349 mm	350–399 mm	400–449 mm	450–499 mm
39.2	164	Riffle	N										
39.2	165	Pool head	N			1							
38.3	182/183	Pool body/tail	N			1							
38.1	192	Pool head	N										
38.0	193/194	Pool body/tail	N							1			
36.8	217	Riffle	N		1			1					
36.8	218	Run head	N				1						
36.7	219/220	Run body/tail	N					1					
36.3	225	Riffle	Y			1	2	1		1			
36.2	230	Pool head	N										
36.2	231/232	Pool body/tail	Y										
Total (maximum unit count of all passes)				**212**	**2,979**	**1,874**	**463**	**126**	**72**	**121**	**67**	**11**	**4**

Table 3-6. Maximum count of *O. mykiss* by habitat type, September 2011 (data are divided into 50 mm total length size classes).

Habitat	0–49 mm	50–99 mm	100–149 mm	150–199 mm	200–249 mm	250–299 mm	300–349 mm	350–399 mm	400–449 mm	450–499 mm	Total (max. unit count of all passes)
Pool body/tail	9	211	118	23	8	5	38	13	3		428
Pool head	1	144	50	7	3	5	8	3			221
Riffle	6	1,852	912	163	34	10	27	5	2	1	3,012
Run body/tail	189	644	682	237	69	42	32	30	4	3	1,932
Run head	7	128	112	33	12	10	16	16	2		336
Totals by size class	212	2,979	1,874	463	126	72	121	67	11	4	5,929

3.4.2 *O. mykiss* population estimate

Table 3-7 shows the September 2011 *O. mykiss* population estimate for the lower Tuolumne River by length (<150 mm for young-of-year/juvenile and ≥150 mm for larger fish) and habitat type using the method of bounded counts (Hankin and Mohr 2001) for the study reach from RM 51.8 to RM 35.0. From an observed 4,913 smaller *O. mykiss* in September 2011, an estimated population of 47,432 smaller fish (with a 95% CI of 36,334–58,530) was determined (Table 3-7). From an observed 813 larger *O. mykiss* in September 2011, an estimated population of 9,541 larger fish (with a 95% CI of 7,188–11,895) was determined (Table 3-7). The population estimates for both juveniles and larger fish exceeded estimates from all previous years (2008–2010) during which these surveys have been conducted (Stillwater Sciences 2012). Both size classes of *O. mykiss* were observed in all habitat types, with the highest observations of smaller fish in riffle habitat and the highest observations of larger fish in run body/tail habitat.

Table 3-7. *O. mykiss* September 2011 bounded counts population estimates between RM 51.8 and 35.0 by fish length and habitat type.

Habitat	*O. mykiss* < 150 mm				*O. mykiss* ≥ 150 mm			
	Obs.[a]	Est.	St. dev.	95% CI[b]	Obs.	Est.	St. dev.	95% CI[b]
Pool head	192	416	250.3	192–207	22	53	12.7	28–78
Pool body/tail	332	2,951	2,775.5	332–8,391	81	742	461.1	81–1,646
Riffle	2,739	26,371	4,431.8	17,684–35,057	224	2,570	616.8	1,361–3,779
Run head	243	3422	1,249.3	974–5,871	80	980	245.5	499–1,461
Run body/tail	1,407	14,271	1,758.6	10,825–17,718	406	5,196	888.0	3,456–6,937
Total	**4,913**	**47,432**	**5,662.2**	**36,334–58,530**	**813**	**9,541**	**1200.9**	**7,188–11,895**

[a] Largest numbers seen in any single dive pass for each unit, summed over units. Note that because of the potential for the same fish to be assigned to different size classes on subsequent passes, summation of the largest numbers assigned to individual (50 mm) size bins yields may overestimate total fish observed.
[b] Nominal confidence intervals calculated as + 1.96 standard deviations.

3.4.3 Chinook salmon observations

Table 3-8 and Table 3-9 show the number of juvenile (<150 mm) Chinook salmon observed within the study reach during the September 2011 surveys, based on the maximum count by pass, resulting in a total of 2,665 observations. These salmon were seen in 21 different sampling units ranging from RM 51.6 to RM 36.3 (Table 3-8) and all habitat types (Table 3-9).

Table 3-8. Maximum counts of juvenile Chinook salmon by size class and sampling unit, September 2011.

River mile	Sampling unit	Habitat type	Multiple pass survey (Y/N)	0–49 mm	50–99 mm	100–149 mm
51.6	4	Pool head	Y			2
50.9	11	Pool body	Y			
50.6	14	Riffle	N		142	114
50.3	19	Run head	Y		21	20
50.1	20/21	Run body/tail	Y		111	86
49.7	27	Pool head	Y		92	45
49.6	28/29	Pool body/tail	Y		206	106
49.3	31/32	Run body/tail	N		260	93

River mile	Sampling unit	Habitat type	Multiple pass survey (Y/N)	0–49 mm	50–99 mm	100–149 mm
49.2	33	Riffle	Y		247	188
49.1	38	Run head	Y		34	20
48.7	43/44	Run body/tail	Y	2	140	370
48.0	53	Riffle	N		1	2
48.0	54	Pool head	Y		4	8
45.9	70	Riffle	Y		82	48
45.9	71	Run head	N		14	9
45.8	72/73	Run body/tail	Y		28	23
45.3	81	Pool body	Y		53	8
44.8	90	Run head	N			5
44.8	91/92	Run body/tail	N		46	26
39.4	161	Run head	Y			2
39.3	162/163	Run body/tail	N			
39.2	164	Riffle	N			
39.2	165	Pool head	N			
38.3	182/183	Pool body/tail	N			
38.1	192	Pool head	N			
38.0	193/194	Pool body/tail	N			
36.8	217	Riffle	N		1	2
36.8	218	Run head	N			
36.7	219/220	Run body/tail	N			
36.3	225	Riffle	Y		4	
36.2	230	Pool head	N			
36.2	231/232	Pool body/tail	Y			
Total (max. unit count of all passes)				**2**	**1,486**	**1,177**

Table 3-9. Maximum counts of juvenile Chinook salmon by size class and habitat type, September 2011.

Habitat	0–49 mm	50–99 mm	100–149 mm	Total (maximum unit count of all passes)
Pool body/tail		259	114	373
Pool head		96	55	151
Riffle		477	354	831
Run body/tail	2	585	598	1,185
Run head		69	56	125
Totals by size class	**2**	**1,486**	**1,177**	**2,665**

There were an additional 160 observations of larger Chinook salmon (≥150 mm) with the majority (n=141) in the 150–200 mm size range. The complete Chinook salmon observation data by pass are shown in Appendix G.

3.4.4 Chinook salmon population estimate

Table **3-10** shows the September 2011 Chinook salmon population estimate for the lower Tuolumne River by length (<150 mm for juvenile; >150 mm for larger fish) and habitat type using the method of bounded counts (Hankin and Mohr 2001). From an observed 2,576 juvenile salmon in September 2011, an estimated population of 24,299 juveniles (with a 95% CI of 10,674–37,950) was determined (Table 3-10). From an observed 157 larger salmon in September 2011, an estimated population of 2,015 larger fish (with a 95% CI of 833–3,197) was determined (Table 3-10). The population estimates for both juveniles and larger fish exceeded estimates from all previous years (2008–2010) during which these surveys have been conducted (Stillwater Sciences 2012). Both size classes of Chinook salmon were observed in all habitat types, with the exception of the run head habitat where no larger fish were observed.

Table 3-10. Chinook salmon September 2011 bounded count population estimates between RM 51.8 and 35.0 by fish length and habitat type.

Habitat	Chinook salmon < 150 mm				Chinook salmon ≥ 150 mm			
	Obs.[a]	Est.	St. dev.	95% CI[b]	Obs.[a]	Est.	St. dev.	95% CI[b]
Pool head	151	321	290.0	151–890	3	6	6.1	3–18
Pool body/tail	373	3,500	3,114.2	373–9,604	7	71	59.8	7–188
Riffle	755	6,316	1,495.7	3,384–9,248	77	1,039	300.4	451–1,628
Run head	125	1,802	869.2	125–3,506	0	--	--	--
Run body/tail	1,172	12,360	5,978.2	1,172–24,077	70	899	519.5	151–890
Total	**2,576**	**24,299**	**6,965.2**	**10,647–37,950**	**157**	**2,015**	**603.1**	**833–3,197**

[a] Largest numbers seen in any single dive pass for each unit, summed over units. Note that because of the potential for the same fish to be assigned to different size classes on subsequent passes, summation of the largest numbers assigned to individual (50 mm) size bins yields may overestimate total fish observed.

[b] Nominal confidence intervals calculated as + 1.96 standard deviations.

3.4.5 Non-salmon observations

Several other fish species were observed and counted during the September 2011 survey period (Table 3-11). Most other fish seen within the study reach were native species in the minnow (*Cyprinidae*) and sucker (*Catostomidae*) families, with the highest concentrations downstream of RM 40. A combination of hardhead and Sacramento pikeminnow, along with Sacramento sucker accounted for 95.7%. The complete non-salmonid fish observation data are in Appendix G.

Table 3-11. Maximum counts of non-salmonid species by sampling unit, September 2011.

RM	Sampling unit	Habitat	BG	CP	GAM	HH/PM	LMB	SB	SC	SMB	SS
50.9	11	Pool body							1		
49.6	28/29	Pool body/tail						1			
49.3	31/32	Run body/tail				4					
49.2	33	Riffle							17		1
49.1	38	Run head							1		1
48.7	43/44	Run body/tail							1		
48.0	53	Riffle							2		1
48.0	54	Pool head				1	1				1
45.9	70	Riffle									8

RM	Sampling unit	Habitat	BG	CP	GAM	HH/PM	LMB	SB	SC	SMB	SS
45.9	71	Run head							2		5
45.8	72/73	Run body/tail				2			6		2
45.3	81	Pool body				1					
44.8	90	Run head									1
39.4	161	Run head				12					80
39.3	162/163	Run body/tail				1					1,000
39.2	164	Riffle			10	51			1		100
38.3	182/183	Pool body/tail				50		1		2	151
38.1	192	Pool head				20					50
38.0	193/194	Pool body/tail	1			1					30
36.8	218	Run head		5		200					300
36.7	219/220	Run body/tail		42		16	1			1	22
36.3	225	Riffle		3		70			1		105
36.2	230	Pool head						1			
36.2	231/232	Pool body/tail						1		2	20
Total (all sampled units)			**1**	**50**	**10**	**429**	**2**	**4**	**32**	**5**	**1,878**

BG=bluegill; CP=common carp; GAM=gambusia species; HH/PM=hardhead/Sacramento pikeminnow; LMB=largemouth bass; SB=striped bass; SC=sculpin; SMB=smallmouth bass; species; SS=Sacramento sucker.

4 DISCUSSION

4.1 Bounded Counts Study Assumptions

It should be noted that the bounded counts method was developed for use in smaller stream systems (Hankin and Mohr 2001) and applying the methodology to a larger system such as the Tuolumne River is only feasible provided key assumptions are satisfied. One critical assumption of the bounded counts approach is that all individuals have an equal probability of being observed. This assumption may be challenged in locations with large numbers of juvenile fish, low visibility conditions in deeper pool habitats, or low visibility due to light and background turbidity variations within the river from upstream to downstream. For these reasons, the resulting population estimates may be low-biased and misidentification of salmonid species in large schools may result in over- or under-estimates of the true population size.

A second assumption of the bounded counts method is that observation efficiency is not 100%, so the number of fish seen in any single dive pass is, in general, an underestimate of the true number of fish present. For a closed population where fish do not migrate into or out of the unit between dives, the maximum number of fish seen over multiple passes is a low-biased estimator of the true population. Although complete dive coverage of all sampled units in 2011 was achieved, because larger habitat units were subsampled in prior years (i.e., run habitats in 2008), the resulting density expansions may have introduced a high-biased estimate of the true population size since fish are able to migrate freely into and out of the searched area.

4.2 Variations in *O. mykiss* Population Estimates

The September 2011 population estimates for both juvenile and larger fish were substantially higher than in previous years. Most fish were observed within the upper seven miles of the reach (upstream of RM 44.8), with extremely high numbers of juveniles (<150 mm) observed at the upstream riffle location near RM 50.6. The high number of observations of larger fish (≥ 150 mm) was dominated by fish in the 150–200-mm size class (54% of all observations). As is more typically seen, very few juvenile or larger fish were observed downstream of RM 40.0 (near Robert's Ferry Bridge), even though suitable water temperatures (<18.7° C) were present.

Although favorable conditions as the result flood control releases extending from January into September may have allowed for significantly higher recruitment, survival, and growth of juveniles, there is no clear indication as to why the downstream portion of the survey reach did not see similar increases in observed fish. Considering that fish in the 150–200 mm size range would not be part of the 2011 year class suggests the origin of these fish may be related to upstream flood control releases. The larger sized fish (>250 mm) may have arrived from upstream, or by migration from downstream locations in the Tuolumne River or San Joaquin Basin.

4.3 *O. mykiss* Distribution in Relation to Water Temperature

During the September 2011 snorkel surveys, maximum water temperatures remained below 18.7°C throughout the study reach, with daily average temperatures exceeding 17.0°C only at the lowest thermograph site (RM 36.5) on 24 September 2011 (Appendix F). These temperature conditions are not thought to particularly affect the distribution of *O. mykiss* and it is likely that some other factor may also explain the decreasing *O. mykiss* density with distance downstream of La Grange Dam. All *O. mykiss* observed were found at or upstream of RM 36.3, similar to previous surveys.

To test Hypothesis #1 that summer/fall distribution of observed life stages of *O. mykiss* across suitable habitat is related to ambient river water temperature, a comparison was made of water temperature data taken from thermographs to fish density in the sampled units. The data show that temperatures increase in the downstream direction (Section 3.3, Figure 9) and that the density of all *O. mykiss* is lower downstream of RM 44 (Section 3.3, Figure 9), suggesting a covariation of observed density and water temperature. However, although sampling units downstream of RM 44 showed low *O. mykiss* density, water temperatures were below 18.7°C throughout the study reach. Among sampling units where fish were seen upstream of RM 44, densities of *O. mykiss* showed no discernable pattern relative to water temperatures (Figure 9). The consistent pattern of reduced densities downstream of RM 44, despite suitable water temperatures in 2011 suggests that additional factors may be restricting the distribution of *O. mykiss* downstream of RM 44.

Results from a counting weir deployed at RM 24 show no detections of *O. mykiss* during the operational period from September 9, 2010 through December 1, 2010 (TID/MID 2011) and the weir was re-deployed on September 16, 2011. Although high flows necessitate removal of the counting weir, the operational period is intended to extend from September through March to capture the period of peak adult upstream migration for anadromous (non-resident) *O. mykiss* and is also used as an indication of both the presence/absence of *O. mykiss* in the downstream portion of the river and the potential recruitment of fry and juveniles. Since beginning operations in 2009, only one *O. mykiss* has been detected in November 2009 (Stillwater Sciences 2012).

4.4 Habitat Associations of *O. mykiss* and Chinook Salmon Observations

Table 4-1 and Table 4-2 show the range of cover and substrate components observed during habitat mapping for each habitat type where *O. mykiss* and Chinook salmon were present during the September 2011 surveys. Variations of cover types and amounts were limited in all sampling units, with higher percentages of sampling units with no cover found throughout the reach (Appendix D). Therefore cover results do not provide a meaningful basis for establishing a relationship with habitat use by juveniles or adults of either species. Nevertheless, *O. mykiss* and Chinook salmon were observed primarily in riffle and run body/tail habitats where higher percentages of cobble were reported relative to other substrates associated with those habitat types (Table 4-1 and Table 4-2).

Table 4-1. Cover and substrate type found in sampling units with *O. mykiss* present during the September 2011 snorkel surveys.

Cover type	Pool body/tail	Pool head	Riffle	Run body/tail	Run head
Cover type range (%)					
Boulder	10–10	10–10	5–10	0–0	0–0
Wood	5–5	0–0	0–0	5–5	5–5
Ledge	0–0	0–0	10–10	0–0	0–0
Overhang	5–5	5–5	5–10	5–10	5–5
Aquatic vegetation	20–50	0–0	0–0	0–0	0–10
No cover	40–85	85–100	80–100	90–100	90–100
Substrate type range (% covering channel bed)					
Bedrock	20–30	20–50	0–0	0–0	0–0
Boulder	5–20	10–20	10–10	10–40	10–20
Cobble	20–50	30–60	20–70	20–60	30–70
Gravel	10–30	5–60	20–70	20–40	20–50
Sand	10–30	5–10	10–10	10–40	10–30
Silt	0–0	0–0	0–0	0–0	0–0
Organic	0–0	0–0	0–0	0–0	0–0

Table 4-2. Cover and substrate type found in sampling units with Chinook salmon present during the September 2011 snorkel surveys.

Cover type	Pool body/tail	Pool head	Riffle	Run body/tail	Run head
Cover type range (%)					
Boulder	10–10	10–10	5–10	0–0	0–0
Wood	5–5	0–0	0–0	5–5	5–5
Ledge	0–0	0–0	10–10	0–0	0–0
Overhang	5–5	5–5	5–10	5–10	5–5
Aquatic vegetation	50–50	0–0	0–0	0–0	10–10
No cover	40–100	85–100	80–100	90–100	90–95
Substrate type range (% covering channel bed)					
Bedrock	20–30	20–50	0–0	0–0	0–0
Boulder	20–20	10–20	10–10	10–40	10–20
Cobble	20–40	30–60	20–70	40–60	30–70
Gravel	10–60	5–10	20–70	20–40	20–50
Sand	10–30	5–10	10–10	20–20	10–30
Silt	0–0	0–0	0–0	0–0	0–0
Organic	0–0	0–0	0–0	0–0	0–0

4.5 Habitat Use at Restored Sites by *O. mykiss* and Chinook salmon

Hypothesis #2 states that the density of *O. mykiss* juveniles and adults is the same in restored sites as in nearby reference sites in the Tuolumne River. This hypothesis was originally formulated with the intention of testing habitat use at planned gravel augmentation sites (TID/MID 2007). However, only three gravel addition projects have been completed over the past 10 years. Two have been constructed near Old La Grange Bridge by CDFG (2001–2003). An additional project at Bobcat Flat (RM 43) was initiated in two phases by the Friends of the Tuolumne (now Tuolumne River Conservancy) in 2005 and completed in the weeks leading up to the September 2011 surveys. Due to concerns regarding low visibility due to turbidity from newly placed gravels, no sampling was conducted along a one-mile reach between approximately RM 42.5 and RM 43.5 where Phase II of the Bobcat Flat project was being completed. The habitat types within this reach will be remapped following completion of the project as part of 2012 spawning gravel and *O. mykiss* studies for the Don Pedro Relicensing. The limited number of gravel augmentation projects completed during the 2008–2011 period has, in turn, limited the sampling replication and statistical power to detect any differences between restored and reference sites. Nevertheless, as s a means to evaluate habitat use at completed restoration sites, observed densities of *O. mykiss* juveniles and adults were compared at the three habitat types that were sampled within the restoration sites to the same habitat types surveyed elsewhere in September 2011.

Figure 10 shows the *O. mykiss* density of juveniles and adults at pool head, riffle, and run head habitats types sampled in September 2011 from sampling units found at both the restoration sites and from all similar sample units within the study reaches upstream of RM 36.0. For juvenile *O. mykiss* the densities show a relatively high use of riffle habitat at restoration sites when compared with other riffle sampling units; with relatively similar use of run head habitat at the upstream restoration sites; and diminished density in pool head habitats (Figure 10). For larger fish, this comparison showed a potential increase of riffle habitat use at restoration sites, with slightly diminished use of run head habitat, and insufficient data for a comparison of pool head habitats. Sampling sites downstream of RM 40 show very low or zero density of both juvenile and larger *O. mykiss*.

A similar evaluation was done using juvenile Chinook salmon. Figure 11 shows juvenile Chinook densities as sampled in September 2011 for the same three habitat types. In September 2011, juvenile Chinook densities at the restoration sites were similar in riffle habitat types and run head habitat types when compared to the reference sampling units (Figure 11), with insufficient data to describe pool head habitats. Similar to *O. mykiss*, there were very low or density of Chinook downstream of RM 40.

Considering the similar habitat preferences for juvenile *O. mykiss* and juvenile Chinook salmon, it appears that salmonid use of restoration sites is similar, or possibly enhanced within riffle habitats, when compared with nearby reference sites. Additional replication through either an increased number of gravel augmentation sites, or an increased number of survey events would be needed to improve the statistical power enough to detect whether significant differences in habitat use exist.

4.6 Comparison to September 2011 Reference Count Snorkel Surveys

Results from the September 2011 snorkel data were compared to observations made during the September 2011 reference count snorkel survey (TID/MID 2012) for the sampled reach common to both surveys and within sampling units surveyed during both sampling events (Table 4-3 and Table 4-4). The September 2011 BCE data are observations from the first pass of the multiple pass bounded count estimation method to allow for a more direct comparison to September 2011 reference survey, which came from single pass snorkel surveys that employ catch-per-unit-effort (CPUE) methodology.

Table 4-3. Salmonid observations in September reference count (single pass) and September BCE (first pass) surveys in 2011 within the reach sampled during both studies.

September 2011 reference count snorkel survey					September 2011 BCE snorkel survey				
Location	**RM**	**<150 mm *O. mykiss* count**	**≥150 mm *O. mykiss* count**	**<150 mm *O. tshawytscha* count**	**Sampling units**	**RM**	**<150 mm *O. mykiss* count**	**≥150 mm *O. mykiss* count**	**<150 mm *O. tshawytscha* count**
Riffle A7—R41A	50.7–35.3	836	343	66	1–245	51.8–35.0	4,587	742	2,413

Table 4-4. Salmonid counts and estimated densities in September reference count (single pass) and September BCE (first pass) surveys in 2011 for units snorkeled during both dates.

Location	**RM**	**September 2011 reference count snorkel survey**									**September 2011 BCE snorkel surveys**									
		Site	**Habitat type**	**Area (ft^2)**	**<150 mm *O. mykiss***		**≥150 mm *O. mykiss***		**<150 mm *O. tshawytscha***		**Sample Unit**	**Habitat type**	**Area (ft^2)**	**<150 mm *O. mykiss***		**≥150 mm *O. mykiss***		**<150 mm *O. tshawytscha***	
					#	**#/ft^2**	**#**	**#/ft^2**	**#**	**#/ft^2**				**#**	**#/ft^2**	**#**	**#/ft^2**	**#**	**#/ft^2**
Riffle A7	50.6	1	Riffle	3,000	50	0.017	110	0.037	10	0.186	14	Riffle	45,697	1,722	0.038	105	0.002	256	0.006
Riffle 2	49.9	2	Pool-Run	4,500	52	0.012	7	0.002	0	0.000	28,29	Pool body/tail	23,848	251	0.011	38	0.002	312	0.013
Riffle 2	49.9	3	Run-Pool	10,000	57	0.006	33	0.003	0	0.000	31	Run body/tail	184,289	255	0.001	193	0.001	353	0.002
Riffle 3B	49.1	1	Riffle	4,000	81	0.020	13	0.003	0	0.000	33	Riffle	69,547	509	0.007	74	0.001	366	0.005
Riffle 5B	46.9	3	Run-Pool	10,000	35	0.004	17	0.002	0	0.000	54	Pool head	14,381	64	0.004	8	0.001	8	0.001

4.6.1 *O. mykiss* observations

A total of 836 juvenile (<150 mm) and 343 larger (≥150 mm) *O. mykiss* were observed in the September 2011 reference count survey, while 4,587 juveniles and 742 larger fish were observed in the September 2011 BCE survey (Table 4-3). With the exception of the upstream riffle location near RM 50.6, where a significantly larger number of juveniles were observed during the BCE survey, the between-site comparison shows a generally similar observation trend for juveniles (Table 4-4). There are no discernable trends in the distribution of larger fish (Table 4-4). It should be noted that the September 2011 reference count survey data were collected from sites established in past years and targeted based on prior years' data as likely areas of relatively high *O. mykiss* abundance. The area surveyed during the September BCE surveys was greater (by an order of magnitude in most cases) than in the reference count surveys (Table 4-4).

The reference count snorkel survey reoccupies the same sampling units and areas on an annual basis, produces a yearly index with which to evaluate yearly trends, assuming reoccupied sampling units and areas are representative of the entire reach. The BCE methodology (Hankin and Mohr 2001) produces a population estimate, with appropriate confidence intervals, that, due to the incorporation of multiple passes in each unit and greater area searched in each unit and along the reach, can be used to evaluate habitat- and reach-wide distribution patterns.

4.6.2 Chinook salmon observations

A total of 66 Chinook salmon juveniles were observed during the September 2011 reference survey, while a total of 2,413 juveniles were observed during the September BCE survey (Table 4-3). Although Chinook salmon juveniles were observed in low numbers throughout the survey reach during the September 2011 reference count snorkel surveys (TID/MID 2012), the between-site comparison with the BCE surveys shows juvenile salmon absent at all but the upstream riffle location near RM 50.6. The BCE survey shows juvenile salmon in relatively large numbers downstream to near RM 49.1 (Table 4-4).

Although a stream-type life history strategy is not believed to be common for Chinook salmon in the Tuolumne River, the presence of juveniles in September indicates that conditions (e.g., water temperature, food availability) in summer 2011 were suitable for over-summering in upper portions of the reach.

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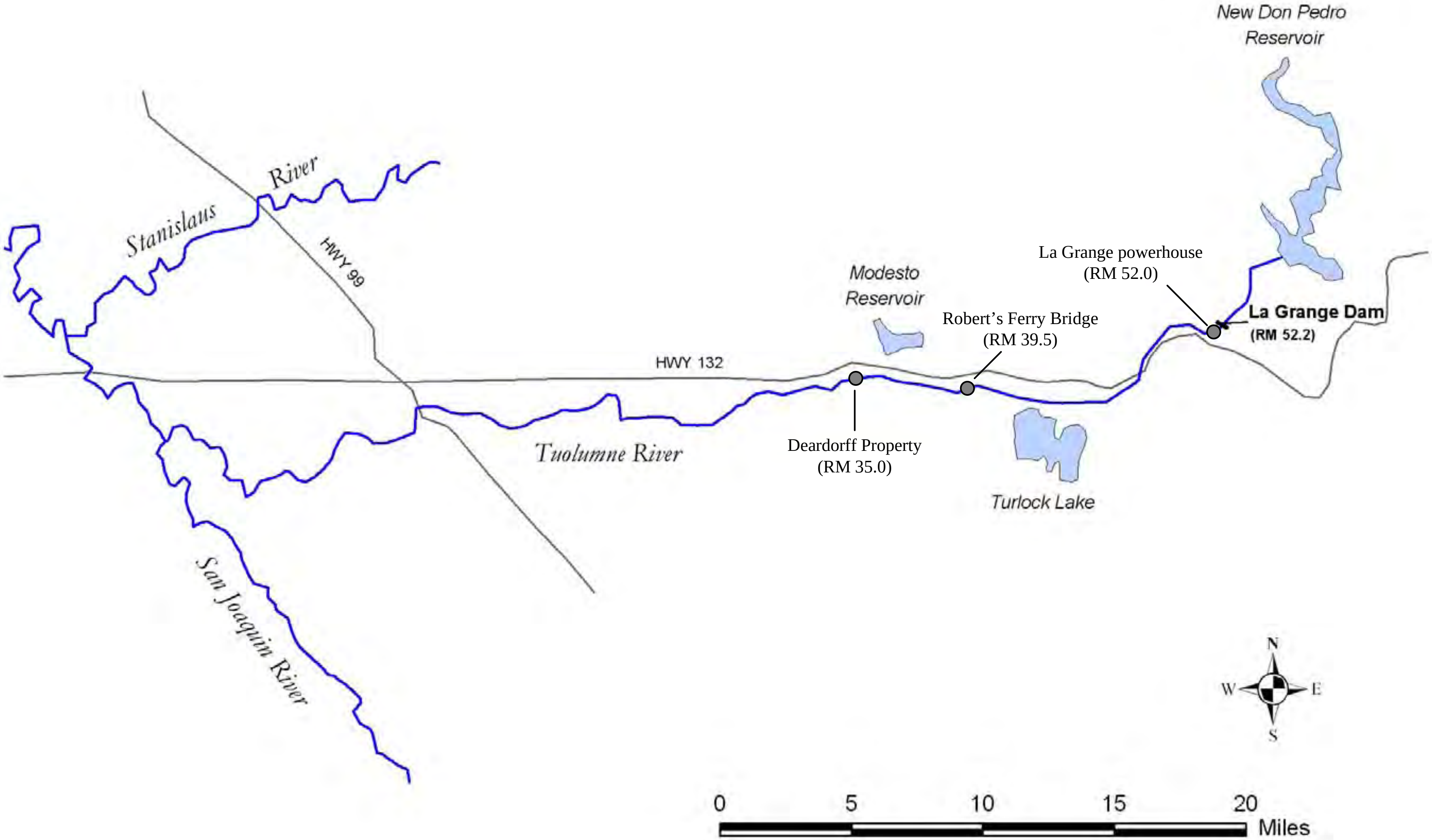

Figure 1. BCE study reach on the lower Tuolumne River, September 2011.

Stillwater Sciences

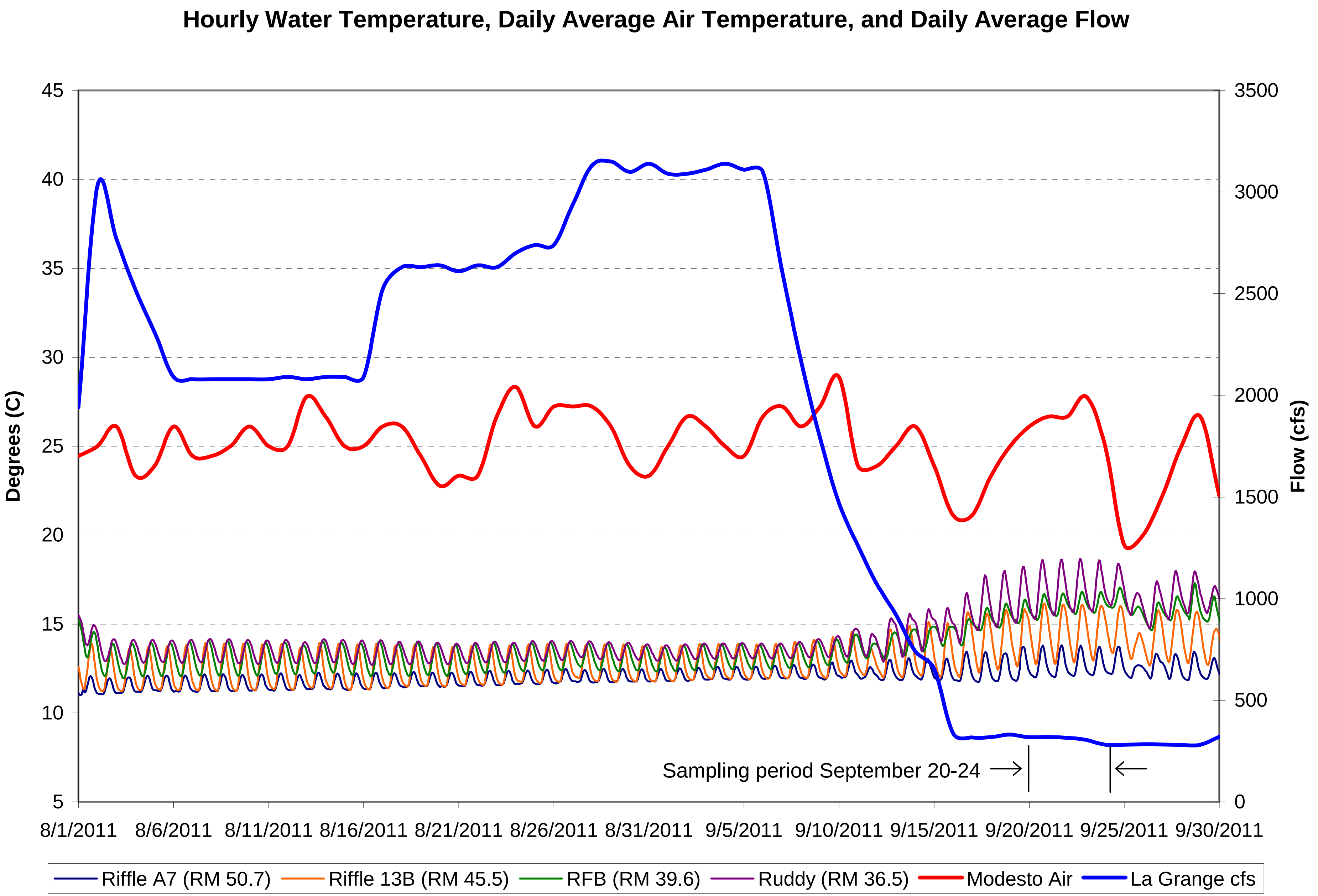

Figure 2. Hourly water temperature, daily average air temperature, and daily average flow for the study reach from 1 August to 30 September 2011.

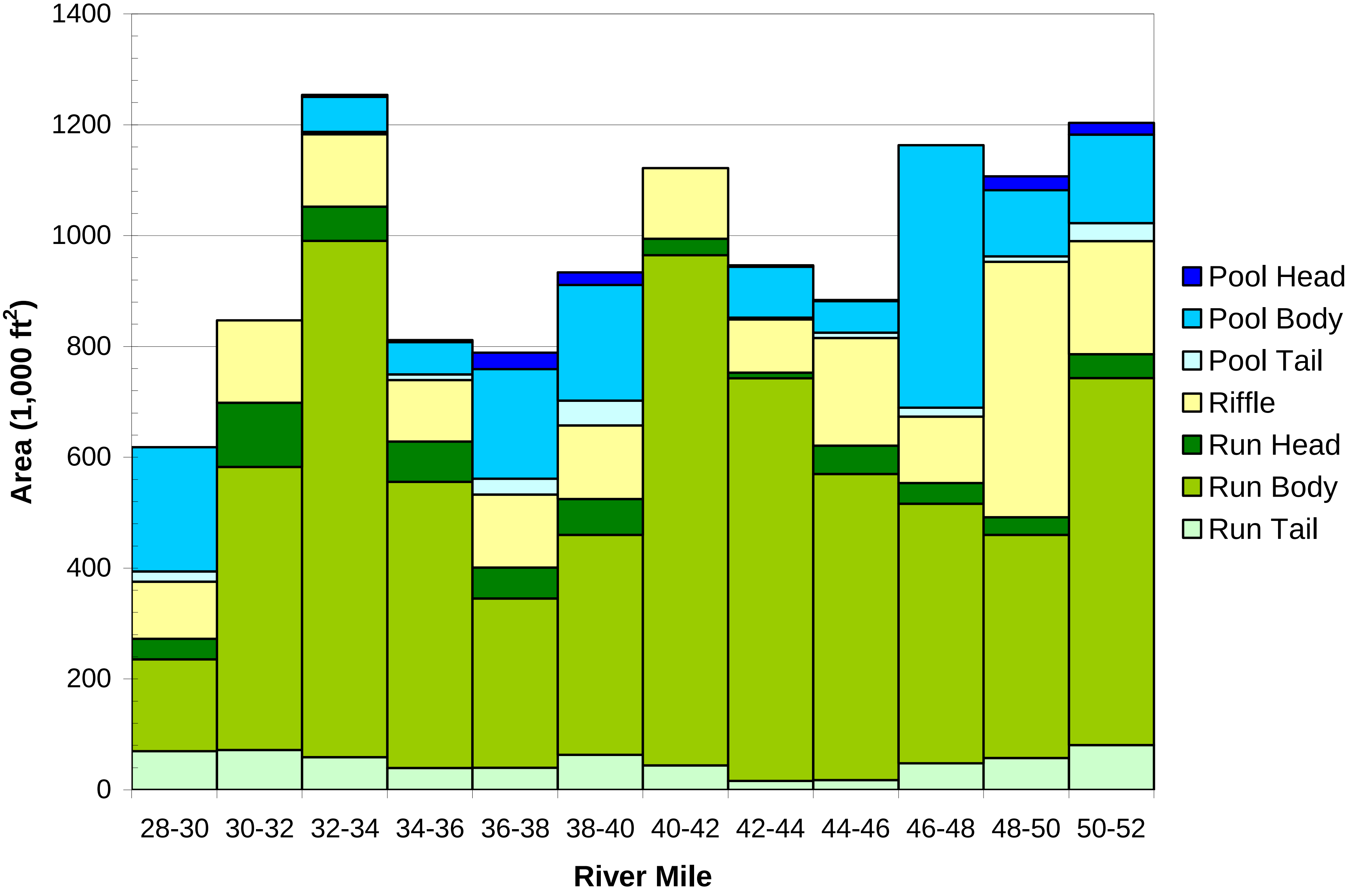

Figure 3. Longitudinal distribution of major habitat type areas by river mile in the lower Tuolumne River (RM 52–30) for September 2011 survey.

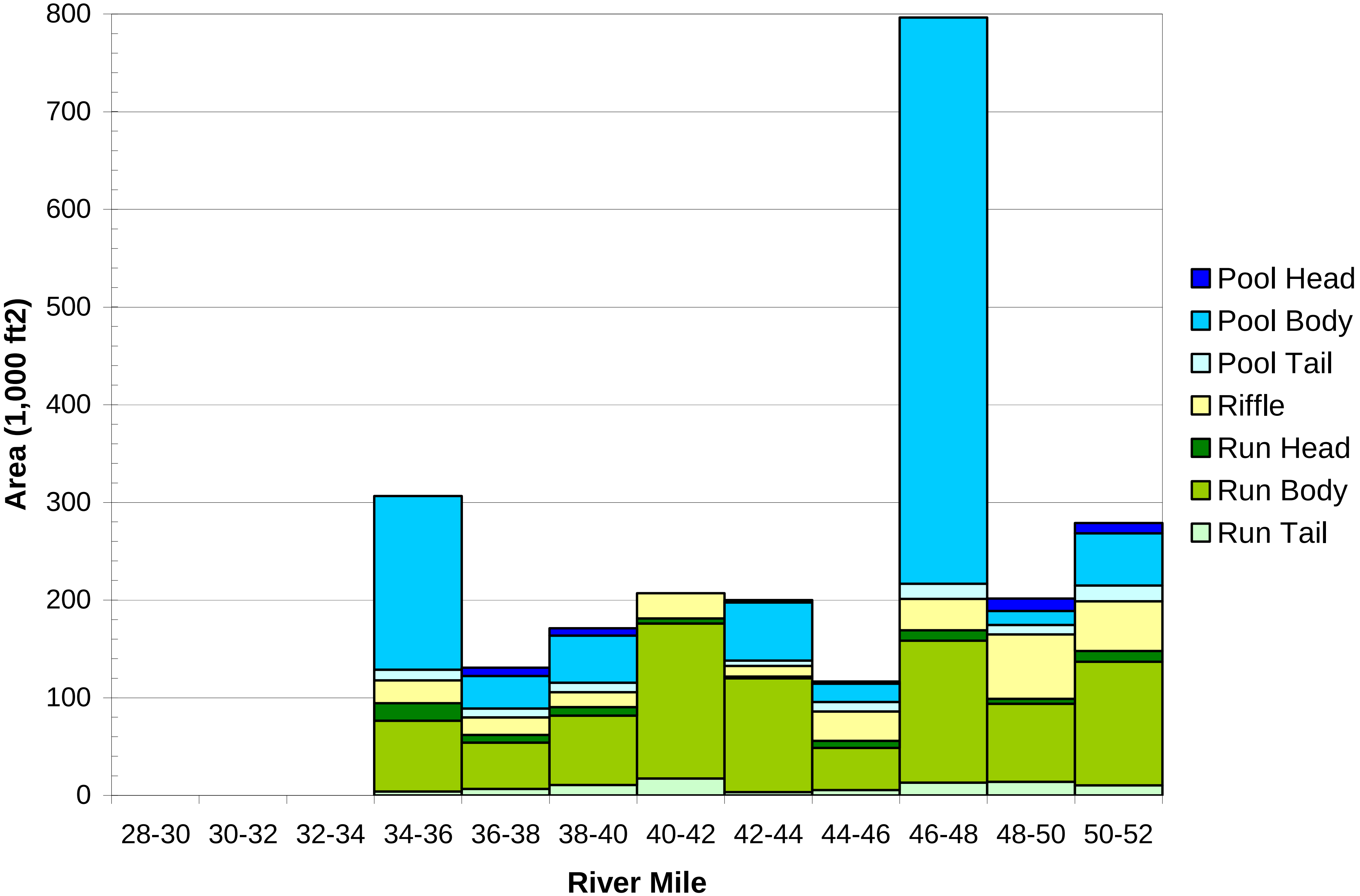

Figure 4. Longitudinal distribution of major habitat type areas sampled by river mile in the lower Tuolumne River (RM 52–38) for September 2011 survey.

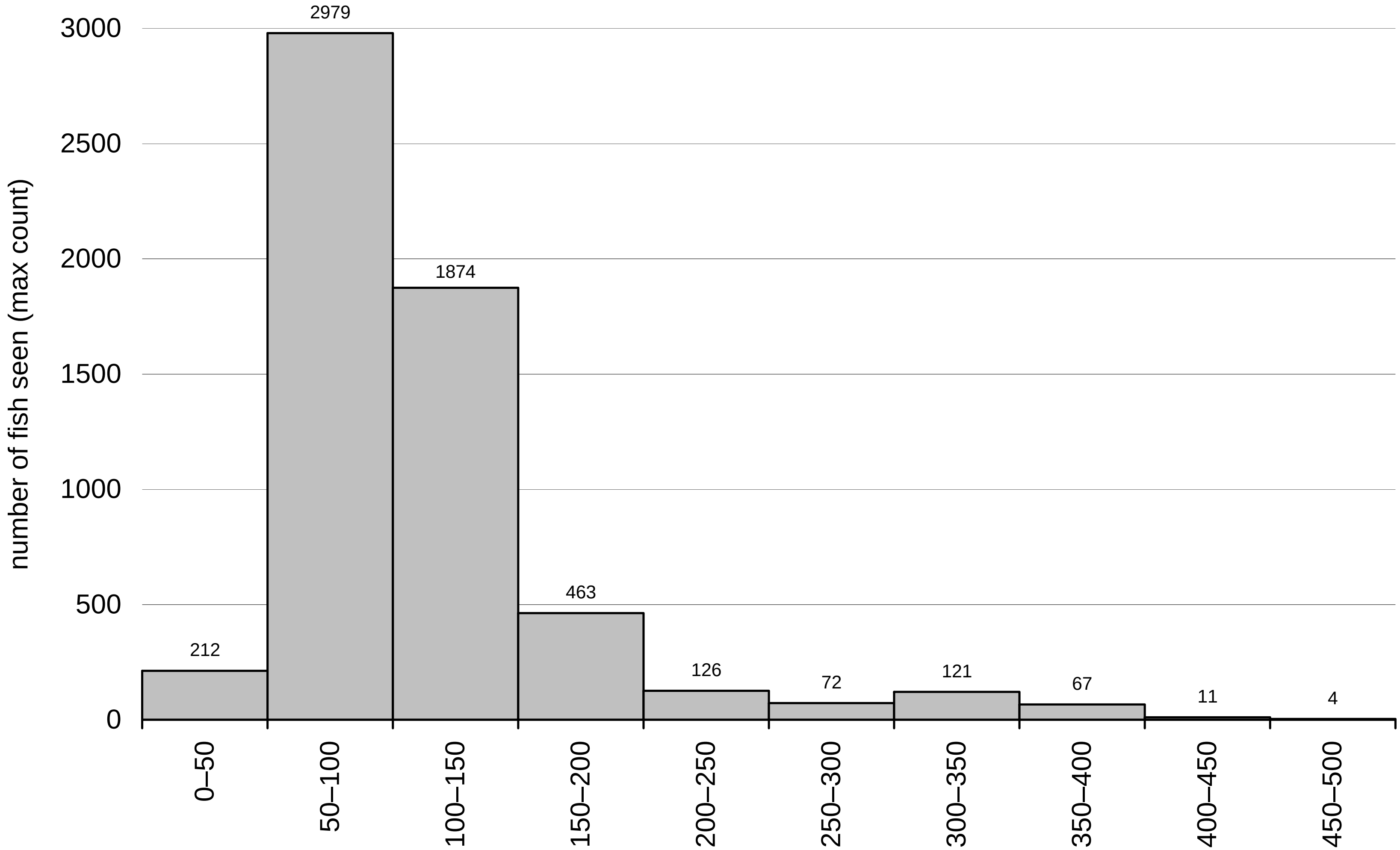

Figure 5. Size distribution of *O. mykiss* observed in Tuolumne River snorkel surveys, September 2011. For units receiving multiple passes, the count is from the pass with the largest count for that size class.

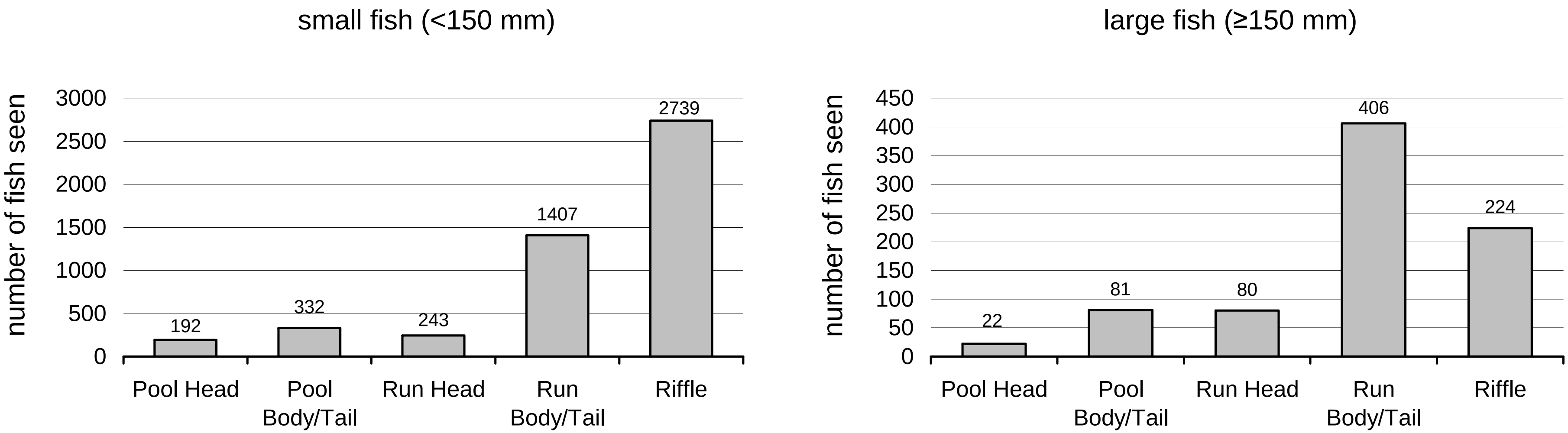

Figure 6a. Distribution of observed *O. mykiss* counts among habitat types, by size class in September 2011. For units receiving multiple passes, the count is from the pass with the largest count.

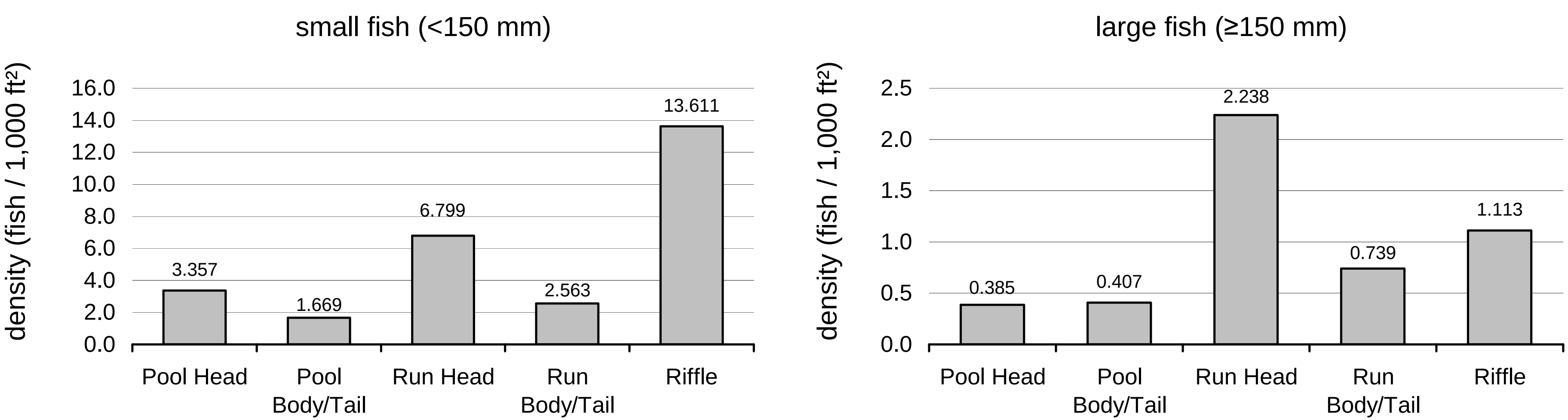

Figure 6b. Distribution of observed *O. mykiss* density based on maximum count among habitat types, by size class in September 2011.

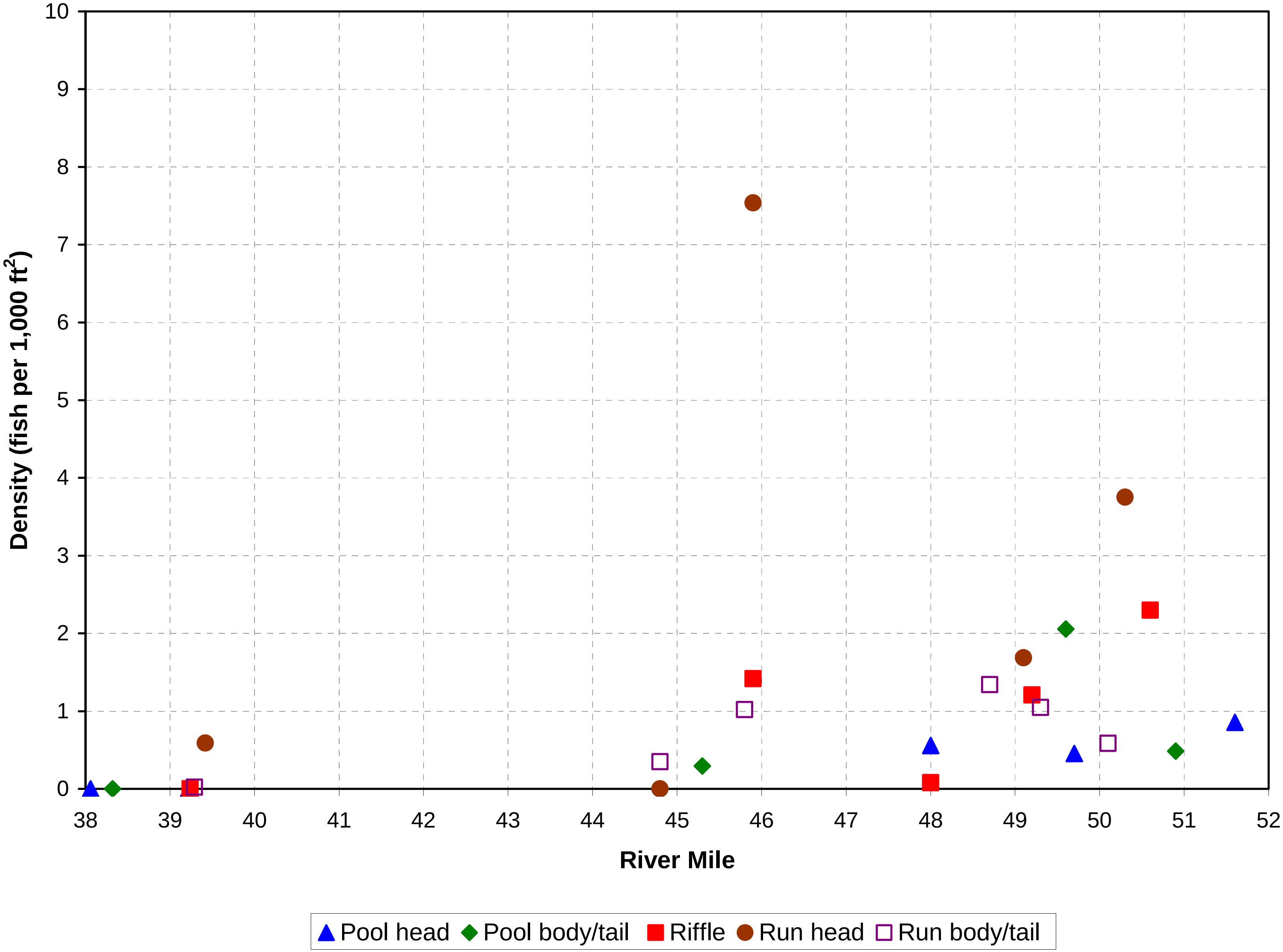

Figure 7. September 2011 adult *O. mykiss* density by river mile based upon maximum count in sampling units of each habitat type.

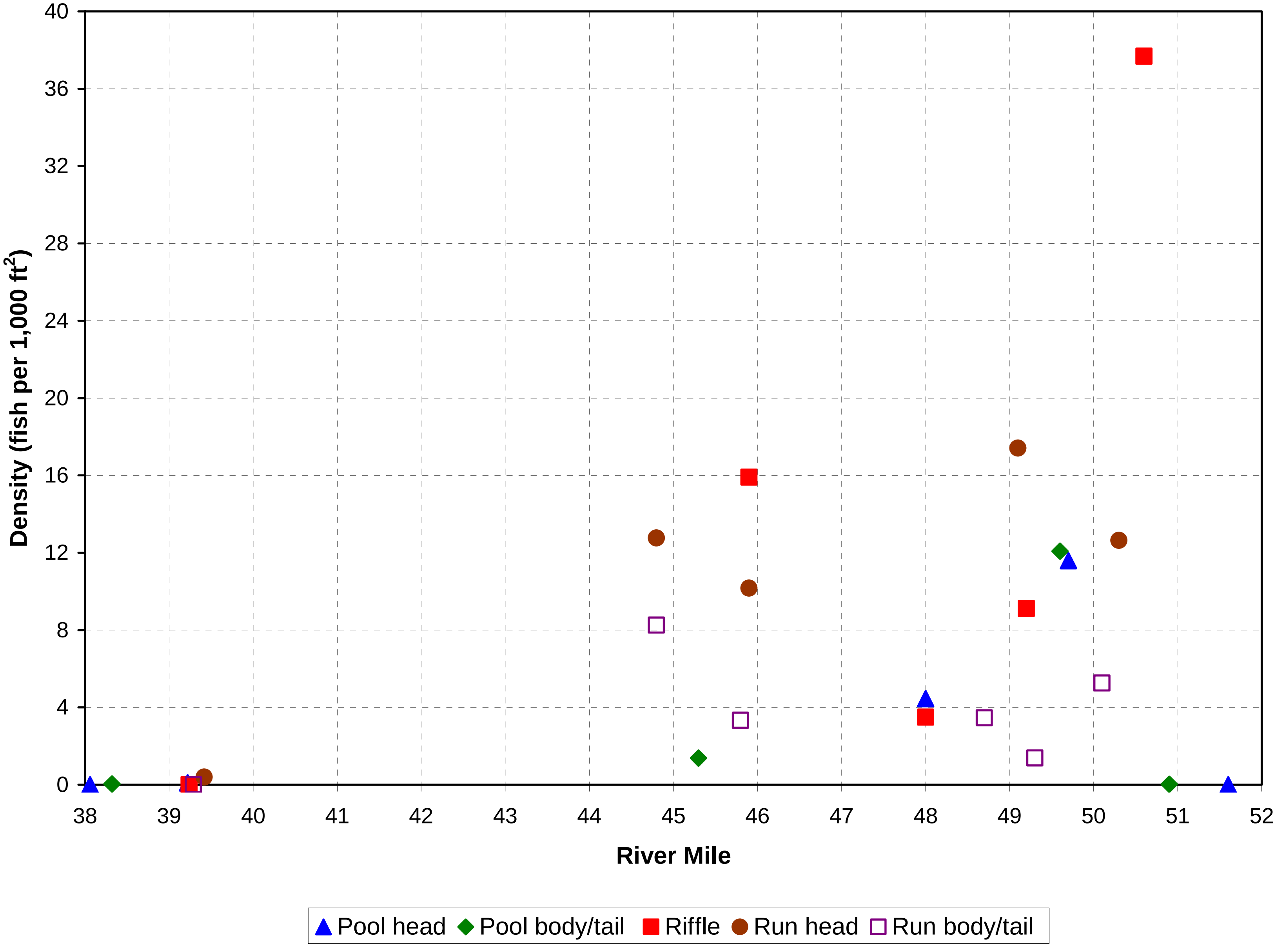

Figure 8. September 2011 juvenile *O. mykiss* density by river mile based upon maximum count in sampling units of each habitat type.

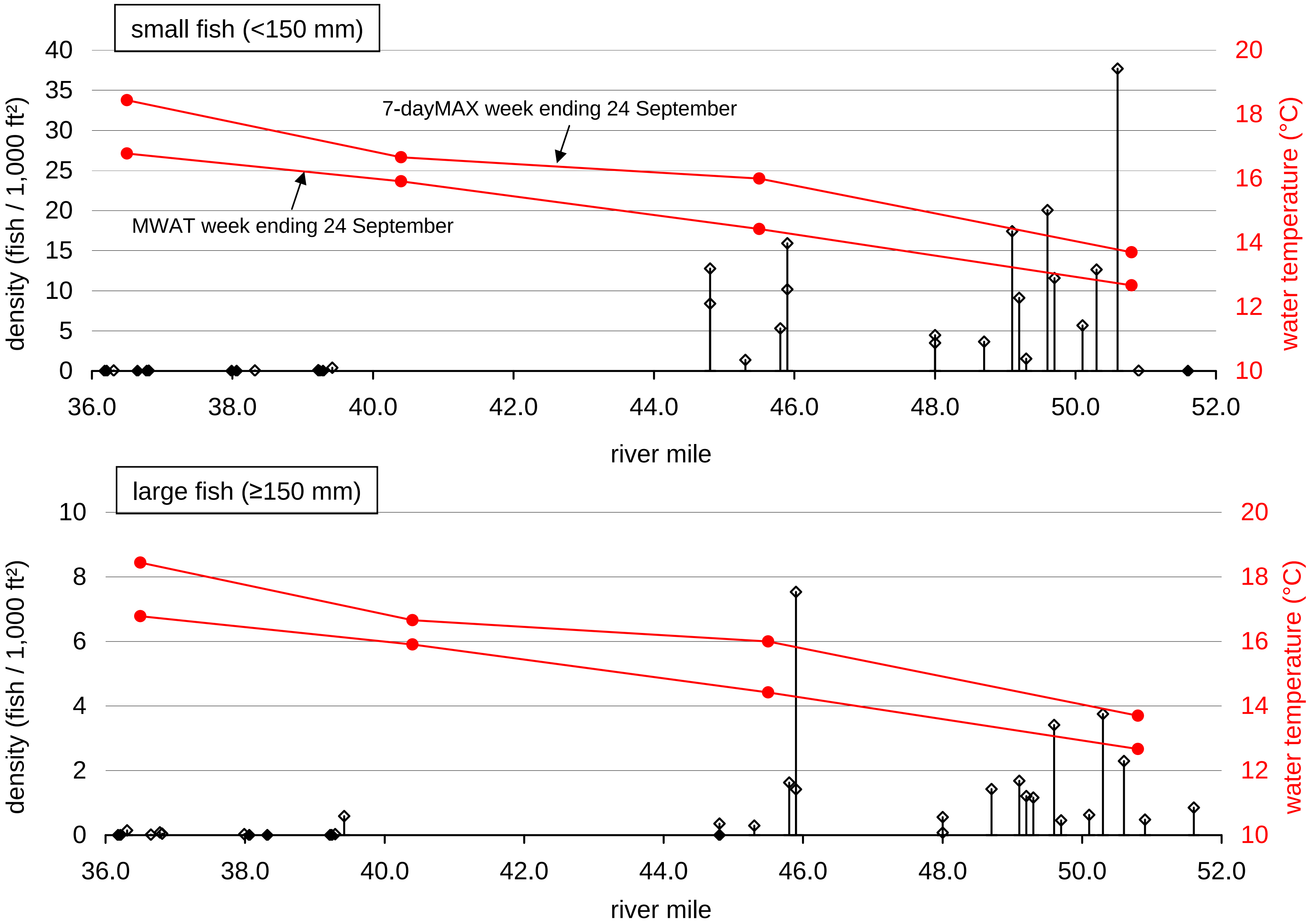

Figure 9. Longitudinal distribution of observed *O. mykiss* and water temperature in the lower Tuolumne River, September 2011. Solid diamonds are observed zeros, open diamonds are observed non-zero values.

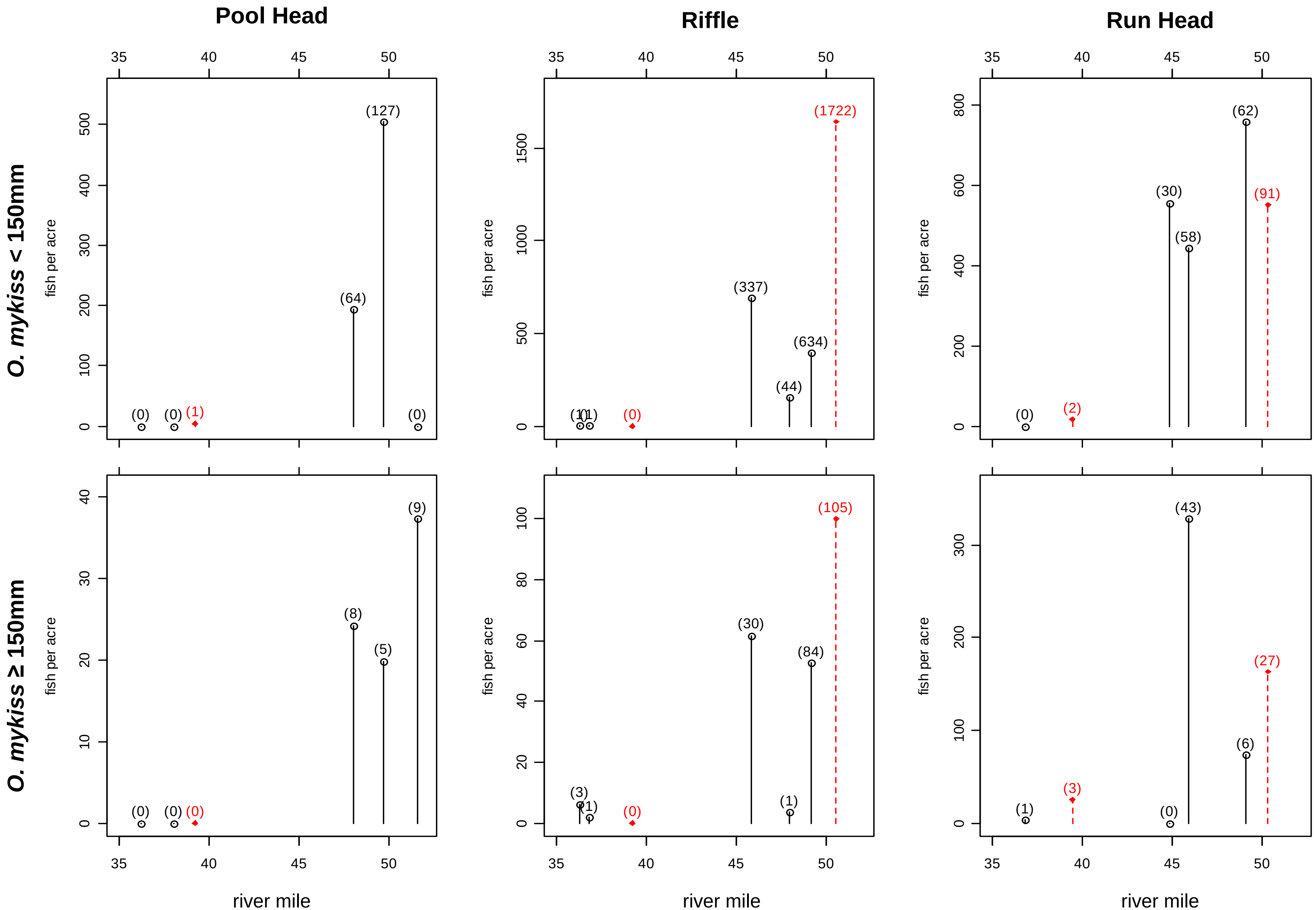

Figure 10. Observed densities of *O. mykiss* in individual sampling units in the September 2011 surveys. Densities are maximum dive counts (in parenthesis) divided by the area sampled. Restoration sites are shown with broken lines (7-11 [RM 39.0], CDFG 2001 [RM 50.3], CDFG 2003 [RM 50.6]). Non-restoration sites are shown with solid lines.

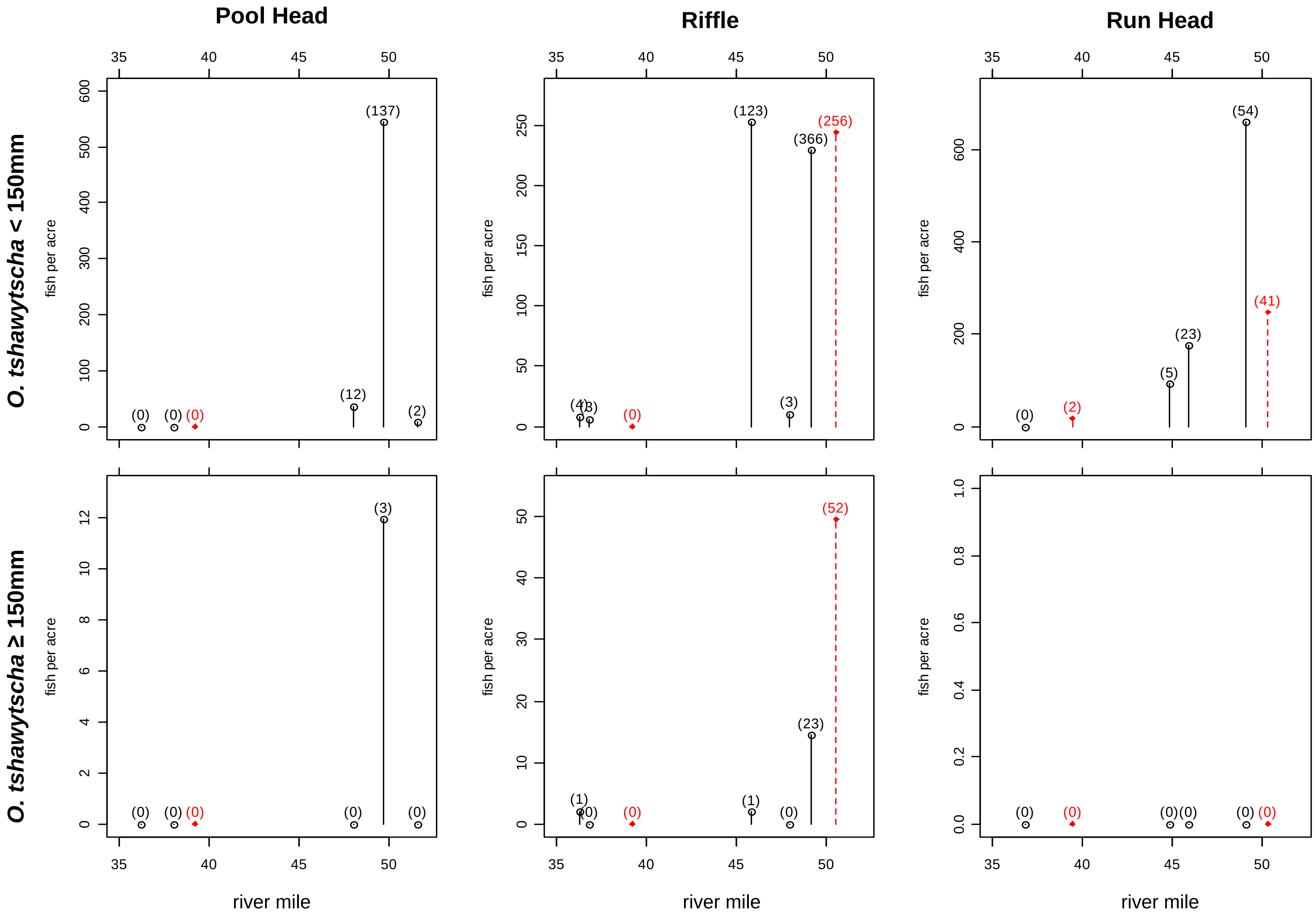

Figure 11. Observed densities of *O. tshawytscha* in individual sampling units in the September 2011 surveys. Densities are maximum dive counts (in parenthesis) divided by the area sampled. Restoration sites are shown with broken lines (7-11 [RM39.0], CDFG 2001 [RM 50.3], CDFG 2003 [RM 50.6]). Non-restoration sites are shown with solid lines.

Appendices

Appendix A: Study Plan (2009)

Study Plan for Population Size Estimates of *O. mykiss* in the lower Tuolumne River

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Appendices

1 BACKGROUND AND PURPOSE

Fisheries monitoring for the Don Pedro Project (FERC Project No. 2299) by the Turlock Irrigation District (TID) and Modesto Irrigation District (MID) has long documented the presence of *Oncorhynchus mykiss (O. mykiss)* in the lower Tuolumne River (TID/MID 2005). On March 19, 1998 the National Marine Fisheries Service (NMFS) first listed the Central Valley steelhead as threatened under the Endangered Species Act (ESA). After several court challenges, NMFS issued a new final rule relisting the Central Valley steelhead on January 5, 2006 (71 FR 834). In a separate process regarding terms of the 1996 FERC license amendments for the Project, NMFS staff provided input to a draft limiting factors analysis for Tuolumne River salmonids (Mesick et al 2007) and included recommendations for developing abundance estimates, habitat use surveys and anadromy determination of resident *O. mykiss*. These recommendations were conceptually used to develop the Districts FERC Study Plan (TID/MID 2007) which was the subject of an April 3, 2008 FERC Order. As part of the Order, the Districts are required to conduct population estimate surveys in summer (June/July) and winter (February/March), starting in summer 2008 to determine *O. mykiss* population abundance by habitat type.

The purpose of the proposed *O. mykiss* population surveys is to provide population size estimates over several sampling seasons of differing environmental conditions to determine habitat use and needs within the lower Tuolumne River. The surveys will be used to examine the following hypotheses:

> <u>Hypothesis 1</u>: Summertime distribution of suitable habitat by observed life stages of *O. mykiss* is related to ambient river water temperature.
>
> <u>Hypothesis 2</u>: Habitat use by *O. mykiss* juveniles and adults observed in the Tuolumne River occurs at the same density in both restored and nearby reference sites.

As recommended by Stillwater Sciences (Stillwater), the surveys will employ a two-phase sampling approach of potential *O. mykiss* habitat using snorkel surveys for the development of a "bounded count" population estimate (Hankin and Mohr 2001). Although the methodology presented below discusses both repeated dive counts and calibration by depletion electrofishing, current ESA permit restrictions for both NMFS Section 10(a)(1)(A) permit No's 1280 (TID) and 1282 (Stillwater) do not allow sufficient incidental take to conduct the second phase surveys at this time using electrofishing. Discussions with NMFS permitting staff and Stillwater have occurred since submittal of the 2007 FERC Study Plan, resulting in a pending formal request to NMFS by Stillwater for modification of Permit 1282 (see Section 6 below). The Section 10 Permit 1280 issued to TID in 2005 authorized only up to 5 juvenile *O. mykiss* annually by electrofishing that was further restricted to River Mile 25–30 during September to November. Thus that permit is not applicable or adequate to the season, location, and fish numbers needed to conduct the electrofishing for this population estimate study. Consequently, the July 2008 survey was conducted using snorkel surveys only as provided for in the 2007 study plan. It is not anticipated that the pending permit amendment request will be resolved prior to the winter 2009 survey, as such this will be conducted using snorkel surveys. If the pending amendment request is resolved prior to July 2008, then summer 2009 surveys will be conducted using the combined method presented below.

2 FIELD SAMPLING AND DATA COLLECTION

The two-phase stratified sampling design involves snorkeling pre-selected habitat units (e.g., riffle, run, pool, etc.) multiple times in order to quantify the variance associated with density and subsequent population estimates. Habitat units are selected using stratified random sampling where the habitat types possess a pre-determined probability of occurrence within areas where *O. mykiss* have been frequently observed during the summer in the lower Tuolumne River, extending from approximately river mile (RM) 52–40 during summers and potentially extending to near the city of Waterford (RM 30) during colder winter conditions.

In a typical Phase 1 sampling approach, primary snorkel surveys (Edmundson et al. 1968, Hankin and Reeves 1998, McCain 1992, Dolloff et al. 1996) will be conducted across a subset of all habitat units. In Phase 2, approximately 20–70% of each habitat type sampled will be randomly selected for replicated surveys by either repeated dive counts or depletion electrofishing (Reynolds 1996). Although the bounded counts methodology was developed for use in smaller stream systems (Hankin and Mohr 2001), applying the methodology to a larger system such as the Tuolumne River is feasible provided key assumptions are satisfied. A critical assumption of the bounded counts approach is that all individuals have a chance of being observed. This may not be practically attainable due to the depths of some of the in-channel mining pits and also potentially due to low visibility conditions occurring at downstream locations or due to winter-time sediment inputs during rain events. Hankin and Mohr (2001) found that their survey designs were suitable for coho salmon (*O. kisutch*), but they were less confident about applying the methodology to *O. mykiss* juveniles because the fish's furtive nature may violate the assumption that all fish have an observation probability >0. Sampling sites and methods may be modified following initial surveys because local conditions cannot be anticipated and may dictate the use of other schedules, locations, or techniques. Stillwater Sciences will notify TID, FERC, and permitting authorities if substantive changes in the study design, methods or schedule are anticipated.

2.1 Habitat Typing

On-the-ground mapping of potential habitat for *O. mykiss* will be delineated on digital ortho-rectified aerial photographs and information from previous habitat mapping efforts. Appendices A and B shows preliminary habitat units from RM 52–30 based upon habitat mapping conducted by Stillwater Sciences (2008) between La Grange Dam (RM 52) and Roberts Ferry Bridge (RM 40) (Appendix A) as well as preliminary habitat units from RM 40 to Waterford (RM 30) based upon mapping conducted by McBain & Trush (2004) and EA Engineering (1997) shown in Appendix B. The Appendix B habitat maps will be updated for flow and morphological characteristics in the field in late February and late June in each year. The final habitat maps will delineate all potential *O. mykiss* habitats according to the major types listed in Table 1, as well as transitional habitats that may be preferentially used by various size classes (i.e., pool heads, pool bodies, pool tails, run heads, run bodies, run tails, and riffles).

Table 1. Coarse scale habitat types to be used during snorkel surveys

Habitat Type	Description[a]	Approximate Depth
Riffle	Shallow with swift flowing, turbulent water. Partially exposed substrate dominated by cobble or boulder. Gradient moderate (less than 4%).	0–4 ft
Run	Fairly smooth water surface, low gradient, and few flow obstructions. Mean column velocity generally greater than one foot per second (fts^{-1}).	4–10 ft
Pool	Slow flowing, tranquil water with mean column water velocity less than 1 fts^{-1}.	>10 ft

[a]Major habitat types determined based upon observed hydraulic conditions (McCain 1992, Thomas and Bovee 1993, Cannon and Kennedy 2003)

A Geographic Information System (GIS) will be used to update and refine habitat maps prior to thorough field verification of flow, depth, and habitat conditions in the river. Within each reach, individual habitat units will be digitized as two-dimensional features of varying shapes, or polygons, where each unit is a discrete functional habitat, as defined above. This approach is consistent with the general techniques of McCain (1992), Thomas and Bovee (1993), and Cannon and Kennedy (2003) and allows a flexible approach to evaluating habitat and habitat use patterns at a scale that can be easily delineated given available data, readily depicted, and is ecologically meaningful for aquatic species.

Habitat units will be assigned a natural sequence order (NSO), starting at one which is the first unit at the upstream end of the site, and a habitat type unit number (1…N pools, runs and riffles). The maximum depth, length and width (usually at 1/3 and 2/3 of the units length) will be recorded and flagging tied at both upstream and downstream ends of units to be surveyed. Pertinent information such as date, unit number, and type is included on the flag. Lastly, the upper and lower end of each unit will be located by GPS and mapping from previous efforts will be verified or updated.

2.2 Sample Site Selection

After all potential habitat units are typed and all pertinent information recorded, a subset of each habitat unit type will be selected for single-pass snorkel surveys. Although additional units may be selected at gravel augmentation and other in-channel restoration sites (See Hypothesis 2), selection for sampling proceeds by random selection of the starting sampling unit in the upper survey section, followed by a systematic uniform sampling of the remaining units in the survey reach. For example, every 3rd, 4th or larger selection interval will be used to distribute the selected units uniformly across the survey reach.

Because the total length of river sampled affects the confidence bounds of the resulting *O. mykiss* population estimates, at least 10% of the total length of a given habitat type and a minimum of 5 units of each type will be sampled. Based upon preliminary habitat mapping and median unit lengths of various habitat types, Table 2 shows that 63 sampling units for the winter surveys will be selected from representative locations between RM 52–30 to meet the minimums above. This estimate further assumes that, since detailed habitat type mapping has not been conducted from RM 40–30, habitat type distribution and median length from RM 40–30 are similar to RM 52–40, as determined by summer 2008 habitat type mapping (Stillwater Sciences 2008). The exact number sampled will be determined after random selection of the habitat units prior to study implementation.

During summer, an estimated 35 units will be selected for single-pass snorkel survey from representative locations between RM 52–40 (Table 2). For both winter and summer surveys, the number and location of habitat units may be adjusted if initial systematic sampling does not allow the study to adequately to test Hypothesis 2.

Table 2. Estimated number of sampling units that will meet study design assumption of sampling at least 10% of the total length of a given habitat type.

Habitat Type	Total length (ft) RM 52-40[a]	Estimated total length (ft) RM 40-30[b]	Estimated total length (ft) RM 52-30	Median length (ft)[c]	# of units to be sampled Winter 2009 RM 52-30[d]	Estimated sampled Length Winter 2009	# of units to be sampled Summer 2009 RM 52-40[d]	Estimated sampled Length Summer 2009
Riffle	14,320	13,590	27,910	322	9	10%	5	11%
Pool head	619	618	1,237	106	9	77%	5	86%
Pool body	6,741	6,795	13,536	393	9	26%	5	29%
Pool tail	781	618	1,399	124	9	80%	5	79%
Run head	2,067	1,853	3,920	51	9	12%	5	12%
Run body	37,350	35,829	73,179	843	9	10%	5	11%
Run tail	2,393	2,471	4,864	54	9	10%	5	11%
Total	**64,271**	**61,775[e]**	**126,046**		**63**		**35**	

[a]From Stillwater Sciences (2008)
[b]Assumes same proportion of habitat types as from RM 52-40
[c]Assumes median habitat unit lengths from RM52-40 are proportional to median lengths along RM 40-30.
[d]Assumes at least 10% of the total length of each habitat type will be sampled; Estimates based upon 10% of the total length of a habitat type by median habitat unit length to determine a minimum number of units
[e]Actual river length from RM 40-30

2.3 Sampling Period

Winter sampling will begin in late February with systematic random selection of habitat units from RM 52-30, based upon summer 2008 maps (Appendix A) and previous habitat typing between RM 40–30 (Appendix B). Following habitat selection, Stillwater will use single-pass snorkel surveys and second phase calibration surveys within units of each type to develop uncertainty and bias estimates. Second phase sampling will be conducted using multi-pass snorkel surveys and/or depletion electrofishing methods as allowed under applicable permits (See Section 6).

Summer sampling will use habitat maps from RM 52–40 developed in summer 2008 (Appendix A). Although no additional habitat mapping is anticipated following winter 2009 surveys, habitat unit flagging will be established in advance of each snorkel survey effort and seasonal changes in habitat distribution may force revision of habitat type maps, specifically the upper and lower boundaries of habitat units and/or channel margins, prior to summer 2009 surveys.

2.4 Measurement Parameters and Sampling Methods

Multiple parameters will be measured in order to meet the objectives for this study (Table 3). Photos and GPS locations will be taken at each site, and site locations identified on GIS maps corresponding to mapped aquatic habitat units. General site information recorded at fish sampling locations will include site name, GPS coordinates, time, date, and crew member names. *In situ* water quality parameters (Temperature, dissolved oxygen, and conductivity) will be collected using a pre-calibrated multi-probe (YSI 85, Yellow Springs Instruments, Yellow Springs, OH). Underwater visibility will also be estimated into the sun and away from the sun using a Secchi disk to monitor any changes in visibility. Dissolved oxygen probes will be recalibrated at each site and checked for accuracy against concentrations measured in Winkler titrations (Grasshoff et al 1983) at the beginning and end of the sampling effort using a dissolved oxygen test kit.

Table 3. Measurement parameters and methods for snorkel surveys

Parameter	Method	Metric/Descriptor	Method Reporting Limit
		Habitat Typing Attributes	
Natural sequence order (Reach ID – Habitat unit #)	N/A	A-1, A-2, A-3, …	N/A
Latitude/Longitude	Handheld GPS receiver	UTM	N/A
Habitat type	Visual estimation	See Table 1	N/A
Average unit width	Horizontal distance	meters (feet) (measured at multiple transects)	3 ft (1 m)
Average unit length	Horizontal distance	meters (feet)	3 ft (1 m)
Maximum/minimum depth	Vertical distance	meters (feet)	1 ft (0.3 m)
Bed substrate composition	Visual estimation	bedrock, boulder, cobble, gravel, organic, sand, silt	10%
Cover type	Visual estimation	none, boulder, cobble, IWM, bedrock ledges, overhead vegetation, aquatic vegetation	10%
		Field Data During Snorkel Surveys	
Temperature	EPA 170.1	°C	0.1 °C
Dissolved Oxygen	SM 4500-O	mg/L	0.0 mg/L
Conductivity	SM 2510A	umhos/cm	1.0 umhos/cm
Visibility	Secchi depth	meters (feet)	0.01 m (0.1 ft)
Date/Start time/End time	N/A	Day/month/year	N/A
Number of Individuals	Visual estimation	Number	1
Fish length – snorkeling	Visual estimation	millimeter	50 mm
Fish length – electrofishing	Fork length	millimeter	1 mm
Weight - electrofishing	Electronic balance	gram	0.1 g

2.4.1 Snorkel Surveys

Snorkel surveys will be conducted during daylight hours (7:00am–5:00pm winter; 6:00am–8:00pm summer). A two phase survey design will be used to survey the seven different strata (Table 4). At the first phase, single-pass dive surveys will be conducted by a four to five person crew depending upon river flows and underwater visibility. Sampling units will generally be sampled from downstream to upstream in dive lanes using a zigzag pattern, passing fish and allowing them to escape downstream of the diver. If fish are observed to escape upstream, the diver will take care to avoid counting these fish twice. Divers will record their observations of pertinent attributes (Table 3) and numbers of *O. mykiss* and Chinook salmon (*O. tshawtscha*) observed; with fish lengths to be estimated in 50 mm size ranges using a scale model or markings on the slates to correct for underwater size distortion. After the first dive pass is completed a tab is then pulled to determine if the unit is included in the second phase of sampling.

Table 4. Preliminary sample unit selection and survey count.

	Winter 2009				Summer 2009			
	Phase I Dives		Phase II Survey		Phase I Dives		Phase II Survey	
Habitat	Initial Units	Passes	Repeat Units	Passes	Initial Units	Passes	Repeat Units	Passes
Riffle	9	1	2	2	5	1	2	2
Pool head	9	1	2	2	5	1	2	2
Pool body	9	1	2	2	5	1	2	2
Pool tail	9	1	2	2	5	1	2	2
Run head	9	1	2	2	5	1	2	2
Run body	9	1	2	2	5	1	2	2
Run tail	9	1	2	2	5	1	2	2
	Total	63	Total	28	Total	35	Total	28

The second phase of sampling collects data that will later be used to extrapolate dive counts to total population estimates by three passes of either repeated dive counts or depletion electrofishing. Ideally, if the count of *O. mykiss* from the Phase 1 snorkel survey is less than or equal to 20 individuals then three additional dive passes are made. If electrofishing is permitted, all units with a count of juvenile *O. mykiss* counts greater than 20 individuals will be surveyed by electrofishing. Lastly, occurrence of other native and non-native fish species will be recorded as presence/absence.

2.4.2 Electrofishing at Riverine Sites

If employed during the summer 2009 survey, electrofishing will be conducted by a 4 person crew during the daylight hours (6:00am-8pm) following the dive surveys. Ideally, 3-pass electrofishing will be used on all second phase dive units where the first dive pass exceeded 20 *O. mykiss*. Dive units that require electrofishing for dive calibration will be completed as soon as possible after the dive survey.

Shallow water habitat may be sampled using back pack electrofishing units while deep water habitat may be sampled using a boat electrofishing unit. Back pack electrofishing in shallow waters less than 3–4 ft depth will be conducted using two or more Smith-Root back pack electrofishers (Model LR-24 or Model 12 with 11-inch anode rings and standard “rat-tail” cathodes). Boat electrofishing may be used in deeper riverine habitats using a boat mounted Smith Root 1.5 KVA electrofishing unit. To ensure the health of all fish captured during electrofishing, all electrofishing will be conducted in accordance with NMFS (2000) electrofishing guidelines and an electrofishing logbook will be maintained and updated at each sampling site.

Depending upon river flows and depth, electrofishing will use block nets placed at the upstream and downstream ends of the unit to be fished, taking care to avoid disturbance of the unit during net set-up. Block nets will be set up where possible to prevent fish from moving out of the unit. If block nets are not feasible, then a snorkeler may be stationed at the upstream end of a unit to observe any fish moving out of the unit.

First pass electrofishing will proceed slowly and deliberately upstream from the downstream end of the unit; members of an electrofishing crew will move to the top and back down to the bottom working closely together. To maintain equal effort on subsequent passes, electrofishing time (seconds) will be recorded to allow for any adjustments in sampling effort. A fourth pass will be conducted if one of the following applies:

1. The number of *O. mykiss* caught on the 2nd pass exceeds the number of *O. mykiss* caught on the 1st pass.
2. The number of *O. mykiss* caught on the 3rd pass is greater than or equal to 25 percent of number caught on the 2nd pass.

The procedure may be modified in riffle habitats to facilitate capture of shocked fish in fast water. In the riffle strata, a pass consists of a sweep from the top to the bottom of the unit. Depending on the water velocity, block nets may or may not be set at the upstream end of riffle units.

2.4.3 Fish Handling Protocols

Any fish captured during electrofishing surveys will be processed, and information collected regarding species identification, fork length (FL, mm), weight (g), and, if applicable, notes on general condition. All fish will be rapidly retrieved using dip nets and placed immediately into aerated live wells or buckets with water. Large fish will be kept separate from juvenile fish to avoid confinement predation. Fish will be identified to species and origin (hatchery or wild stock) where possible. Fish that are weighed and measured will be anesthetized using clove oil to minimize handling stress. After all fish are identified, counted, and measured, fish will be held for approximately 10 minutes, until they show signs of "normal" swimming patterns and behavior.

2.5 Hypothesis Testing

The purpose of the proposed *O. mykiss* population surveys is to provide population size estimates over several sampling seasons of differing environmental conditions to determine habitat use and needs within the lower Tuolumne River. The surveys will be used to examine the following hypotheses:

> <u>Hypothesis 1</u>: Summertime distribution of suitable habitat by observed life stages of *O. mykiss* is related to ambient river water temperature.
>
> <u>Hypothesis 2</u>: Habitat use by *O. mykiss* juveniles and adults observed in the Tuolumne River occurs at the same density in both restored and nearby reference sites.

While the selection for sampling proceeds by random selection of the starting sampling unit in the upper survey section, followed by a systematic uniform sampling of the remaining units in the survey reach, additional units adjacent to or near restoration sites may be non-randomly selected to provide treatment and control locations to test Hypothesis 2, especially during winter 2009 surveys when low ambient river water temperatures obviate the need to test Hypothesis 1.

2.6 Field Work Notification

To ensure field staff safety and to satisfy scientific collecting permit requirements, the parties listed in Table 5 will be notified in advance of the proposed sampling in as required to confirm sampling dates.

Table 5. Field Work Notification

Contact	Affiliation	Address	Phone and Email
Tim Ford	TID	333 East Canal Dr. Turlock, CA 95380	209.883.8275 tjford@tid.org
Tim Heyne	CDFG	P.O. Box 10 La Grange, CA 95329	209.853.2533 x1# theyne@dfg.ca.gov
Jeffery Jahn	NMFS	777 Sonoma Ave. Rm 325 Santa Rosa, CA 95404	707.575.6097 Jeffrey.Jahn@noaa.gov

Prior to mobilization, planned river operations by the Districts will be checked to determine if fish sampling would be safe under the anticipated flow and all parties will be notified of any delay or modification to the sampling schedule.

3 QUALITY ASSURANCE

The objective of data collection for this Project is to produce data that represent as closely as possible, *in situ* conditions of the Tuolumne River with respect to river flow conditions, water quality, abundance and habitat use by *O. mykiss*. To meet this objective, field sampling, sample preparation, and analysis will follow general guidelines outlined in USEPA (2002) by ensuring that:

- the project's objectives, hypotheses and data quality objectives are identified and agreed upon,
- the intended measurements and methods are consistent with project objectives,
- the assessment procedures are sufficient for determining if data of the type and quality needed and expected are obtained, and
- any potential limitations on the use of the data can be identified and documented.

Aquatic environments are inherently variable, but management decisions must be based on a data from a limited number of locations and often collected in short time periods. How well the information collected represent the reach or river-wide fish population depends upon a systematic approach to quality assurance.

3.1 Data Quality Objectives for Measurement Data

The data quality parameters used to assess the acceptability of the data are precision, accuracy, representativeness, comparability, and completeness. Precision measures the reproducibility of measurements under a given set of conditions. Analytical precision is limited to water quality and physical habitat characteristics (Table 6). Accuracy is an expression of the degree to which a measured or computed value represents the true value. Field accuracy is controlled by adherence to sample collection procedures.

Table 6. Data quality objectives for field parameters

Parameter	Units	Accuracy	Precision	Completeness
Dissolved Oxygen	mg/L	$\pm$ 0.5	10%	90%
Temperature	^{o}C	$\pm$ 0.5	5%	90%
Conductivity	umhos/cm	$\pm$ 5%	$\pm$ 5%	90%
Depth	meters	$\pm$ 0.2	N/A	N/A
Visibility (Secchi)	meters	$\pm$ 0.05	N/A	N/A

- Representativeness expresses the degree to which data accurately and precisely represent an environmental condition. For this study, monitoring site selection will be conducted based on physical habitat attributes. Additionally, specific measurement parameters have been identified as relevant based on numerous studies indicating factors associated with species distribution.

- Comparability expresses the confidence with which one data set can be evaluated in relation to another data set. For this biological assessment, comparability of data will be established through the use of standard analytical methodologies and reporting formats.

- The project goal for completeness, a measure of the amount of data that is determined to be valid in proportion to the amount of data collected, will be 90% for analytical water quality parameters. The data quality objective for completeness for all components of this study is 90%.

3.2 Training Requirements/Certification

Specialized training is required for the proposed sampling activities, however none of the sampling activities require outside certification from an agency or another entity. Required permits for biological sampling are discussed in Section 5. Field crews will be staffed by a variety of qualified personnel, which due to the nature of extended field activities, will necessarily be rotated in and out of the field.

3.3 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

To ensure proper equipment performance in the field, maintenance and operational procedures, including preventative maintenance, will be performed on all YSI multiprobes (temperature, dissolved oxygen, and conductivity). YSI maintenance will be recorded in a logbook with the date the maintenance was performed and the initials of the technician. When the instruments are not deployed, the calibration or storage cup will be used to protect sensors from damage and desiccation.

3.4 Instrument Calibration and Frequency

Field probes used for field sampling will be calibrated prior to use, midway through each sampling event, and at the end of each sampling event. Measurement devices for conductivity will be checked against a standard whose source is different than that selected for calibration. Dissolved oxygen will be checked against aerated water whose oxygen content is established by the Winkler method (Grashoff et al 1983). Temperature does not require calibration because of the unvarying nature of the temperature sensor and its conditioning circuitry.

3.5 Reconciliation with Data Quality Objectives

If data do not meet the project's specifications, the following actions will be taken. First, the task leaders working with the field crew leaders (in some cases they will be the same person) will review the errors and determine if the problem is equipment failure, calibration/maintenance techniques, or monitoring/sampling techniques. They will suggest corrective action. If the problem cannot be corrected by training, revision of techniques, or replacement of supplies/equipment, then the task leaders will review the data quality objectives (DQOs) and determine if the DQOs are feasible. If the specific DQOs are not achievable, they will determine whether the specific DQO can be relaxed, or if the parameter should be eliminated from the monitoring program.

3.6 Data Management

All field data will be amassed in a quality-checked database and summarized. QA checks will be applied to all data before data entry and data will be stored on Stillwater Sciences servers. Full backup of data from all offices is done on a weekly basis, while differential backup (files that have changed since the last full backup) is done on a nightly basis. The backup process is accomplished with a Fast Tape Library and backup processes are completed during off-peak hours. Two sets of tapes are taken offsite by two Information Technology (IT) staff members on a weekly basis to ensure recovery in case of failure or catastrophe.

4 DATA ANALYSIS

Data analysis will be conducted to summarize *in situ* water quality and fish counts in each sampling strata. Bounded counts or depletion estimators will be used to determine populations and linear density for each sampled unit, together with estimates of uncertainty. In addition to comparisons of fish density between sampling strata, the density estimates and uncertainties will be propagated across the unsampled areas for an overall population estimate. Exploratory multiple regression analysis will also be used to determine relationships between fish density and recorded habitat variables.

5 REPORTING

A data report will be prepared for use with permitting authorities that includes: date, time, and location of sampling activities; species and number of species collected; and a copy of field data sheets. Results of the winter 2009 surveys will be transmitted to TID electronically within three weeks of the survey completion (April/May 2009). A client review draft of the technical report covering the results of both winter and summer 2009 surveys will be submitted to TID by August 24, 2009. Assuming an internal and Agency review comments are received within one and three weeks of issuance of the client review and Agency review drafts, respectively, the Agency review draft will be available by September 8, 2009 and final report will be complete by October 16, 2009.

6 PERMITTING REQUIREMENTS

Stillwater Sciences will maintain the following permits to sample fish populations that may be present:

- NMFS Section 10(a)(1)(A) permit 1282
- California Department of Fish and Game individual Scientific Collection Permits.

A NMFS Section 10(a)(1)(A) permit 1282 has been obtained and all NMFS guidelines (e.g., notification, data gathering, preservation) will be followed if any Central Valley steelhead are captured. Under that existing NMFS permit, electrofishing is limited to an authorized incidental take of 40 juvenile *O. mykiss* and the <5% unintentional mortality limit, and no adults. An amendment to the sampling description was submitted to NMFS on June 2, 2008 with increased take limits for handling electrofishing of 100 adults and 200 juveniles at an unintentional mortality rate of <10%. Mr. Jeffrey Jahn of NMFS will be notified at least two weeks prior to applicable sampling to confirm sampling dates and locations. Electrofishing under an amended permit will be suspended in the event that the authorized incidental take limits were exceeded and all subsequent calibration surveys would be made by repeat dive surveys. Annual reporting will be provided to Mr. Jeffrey Jahn of NMFS by March 1, of each year.

CDFG Scientific Collecting Permits (SCPs) will be maintained for species potentially present in the project area. CDFG guidelines (e.g., notification, data gathering, and preservation) will be followed if special-status species are captured and the CDFG 24-hr dispatch (916.446.0045) will be notified should unrelated events result in fish kills.

No intentional mortality or removal of special-status species from the wild is included in this study plan. In the event unintentional mortality occurs beyond the take permit limits, NMFS staff will be contacted within 24 hrs and a fin-clip will be provided to the Salmonid Genetic Repository. CDFG will also be contacted to determine the disposition of the individual specimen and whether the individual may be retained for otolith analysis.

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Appendix B: 2008 Habitat Maps

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 01

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

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Tile 02

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

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Tile 03

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Runs
Riffles
Pools
Tile Boundary (shown white on the map)
River Miles

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
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Tile 04

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

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River Miles

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Tile 05

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Runs
Riffles
Pools
Tile Boundary (shown white on the map)
River Miles

0 125 250 500 Feet

Stillwater Sciences
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METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

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Tile 06

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

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Tile 07

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

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Tile 08

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

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Tile 09

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

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River Miles

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Tile 10

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

0 125 250 500 Feet

Stillwater Sciences
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METADATA
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Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

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Tile 11

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
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Tile 12

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
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Tile 13

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
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Tile 14

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

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Tile 15

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

0 125 250 500 Feet

Stillwater Sciences
www.stillwatersci.com

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

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Tile 16

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools
Tile Boundary (shown white on the map)
River Miles

METADATA
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Tile 17

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
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Tile 18

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Runs
Riffles
Pools
Tile Boundary (shown white on the map)
River Miles

0 125 250 500 Feet

Stillwater Sciences
www.stillwatersci.com

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
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Tile 19

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
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0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 20

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 21

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 22

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 23

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 24

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 25

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 26

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 27

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

0 125 250 500 Feet

Stillwater Sciences
www.stillwatersci.com

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)

Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 28

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Runs | Riffles | Pools

Tile Boundary (shown white on the map)

River Miles

0 125 250 500 Feet

Stillwater Sciences
www.stillwatersci.com

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were first based on EA_mapping data (1986-87) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 29

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

0 125 250 500 Feet

Stillwater Sciences
www.stillwatersci.com

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were first based on EA_mapping data (1986-87) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 30

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Runs
Riffles
Pools
Tile Boundary (shown white on the map)
River Miles

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were first based on EA_mapping data (1986-87) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 31

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were first based on EA_mapping data (1986-87) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 32

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were first based on EA_mapping data (1986-87) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 33

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were first based on EA_mapping data (1986-87) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 34

Tuolumne River - O. mykiss BCE Surveys, 2008-2011

Runs
Riffles
Pools

Tile Boundary (shown white on the map)
River Miles

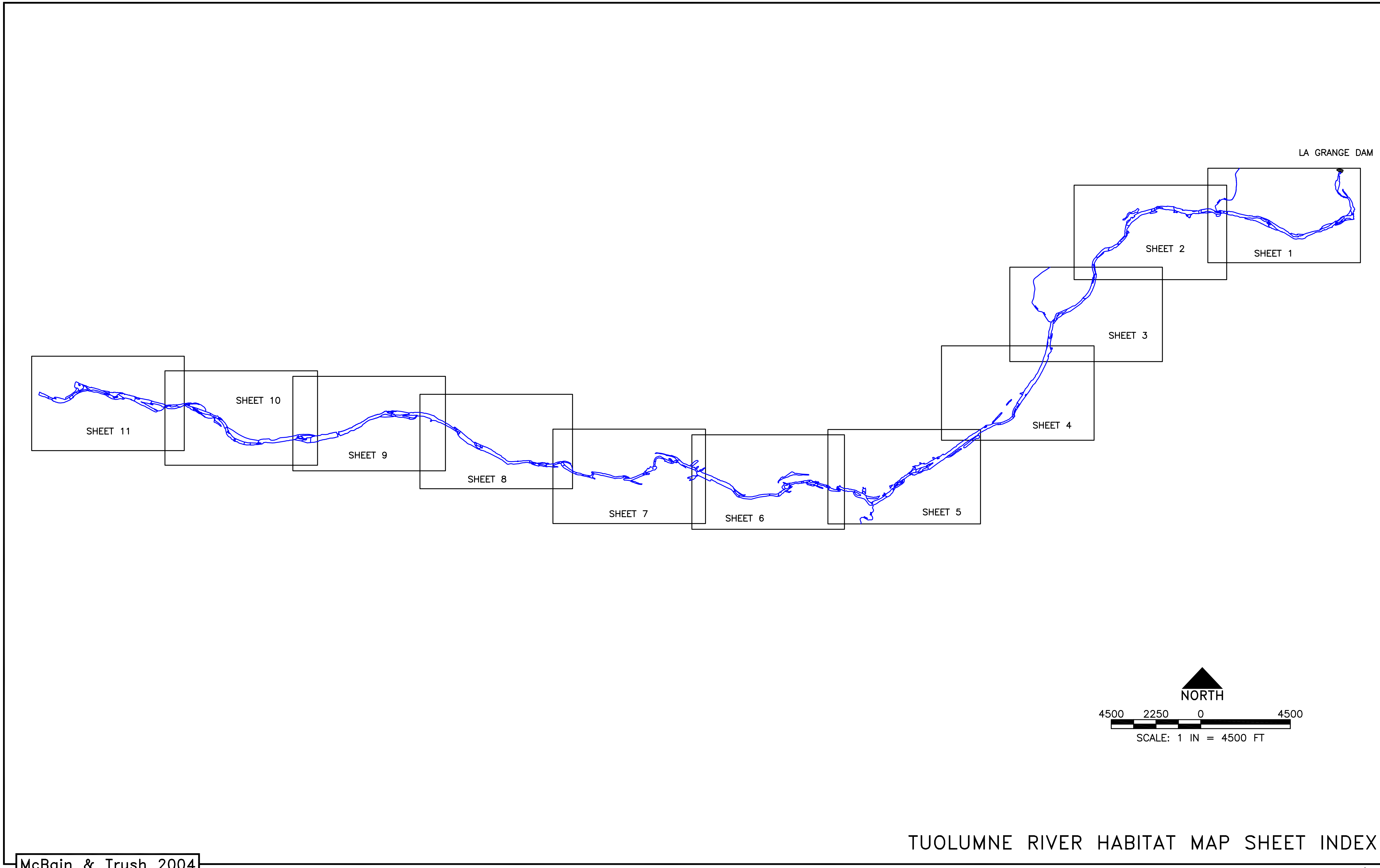
Stillwater Sciences
www.stillwatersci.com

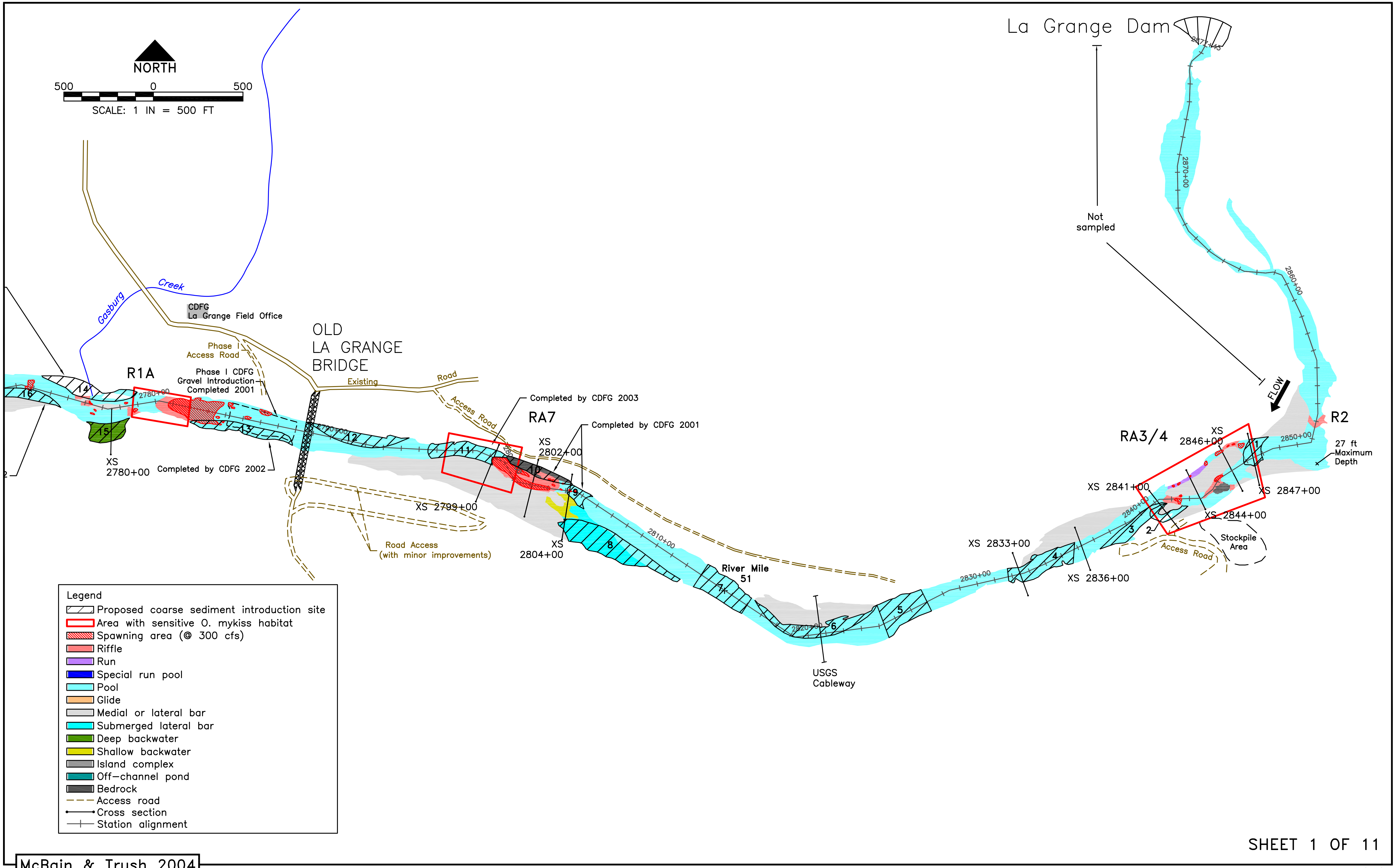
0 125 250 500 Feet

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were first based on EA_mapping data (1986-87) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

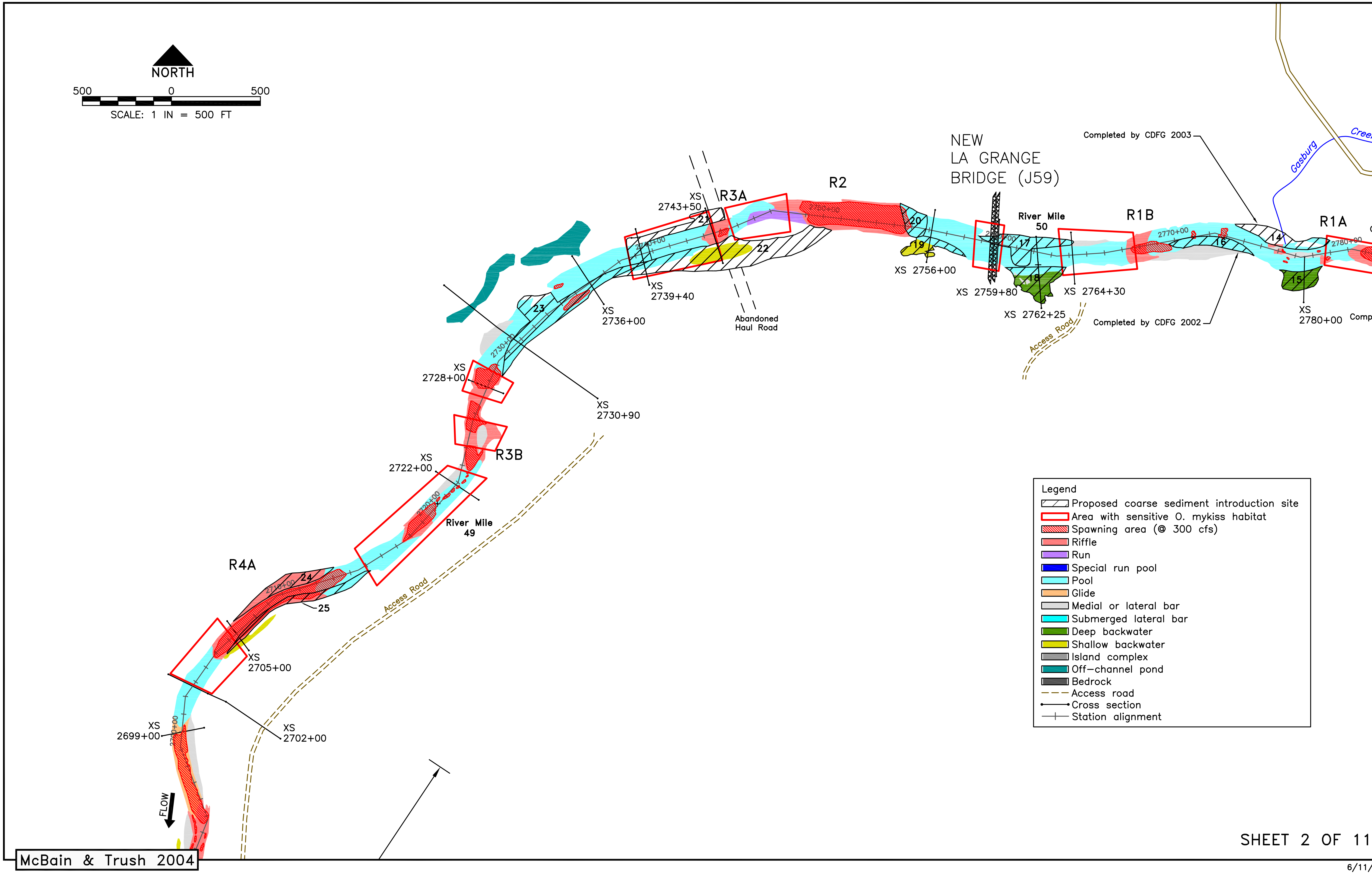
Tile 35

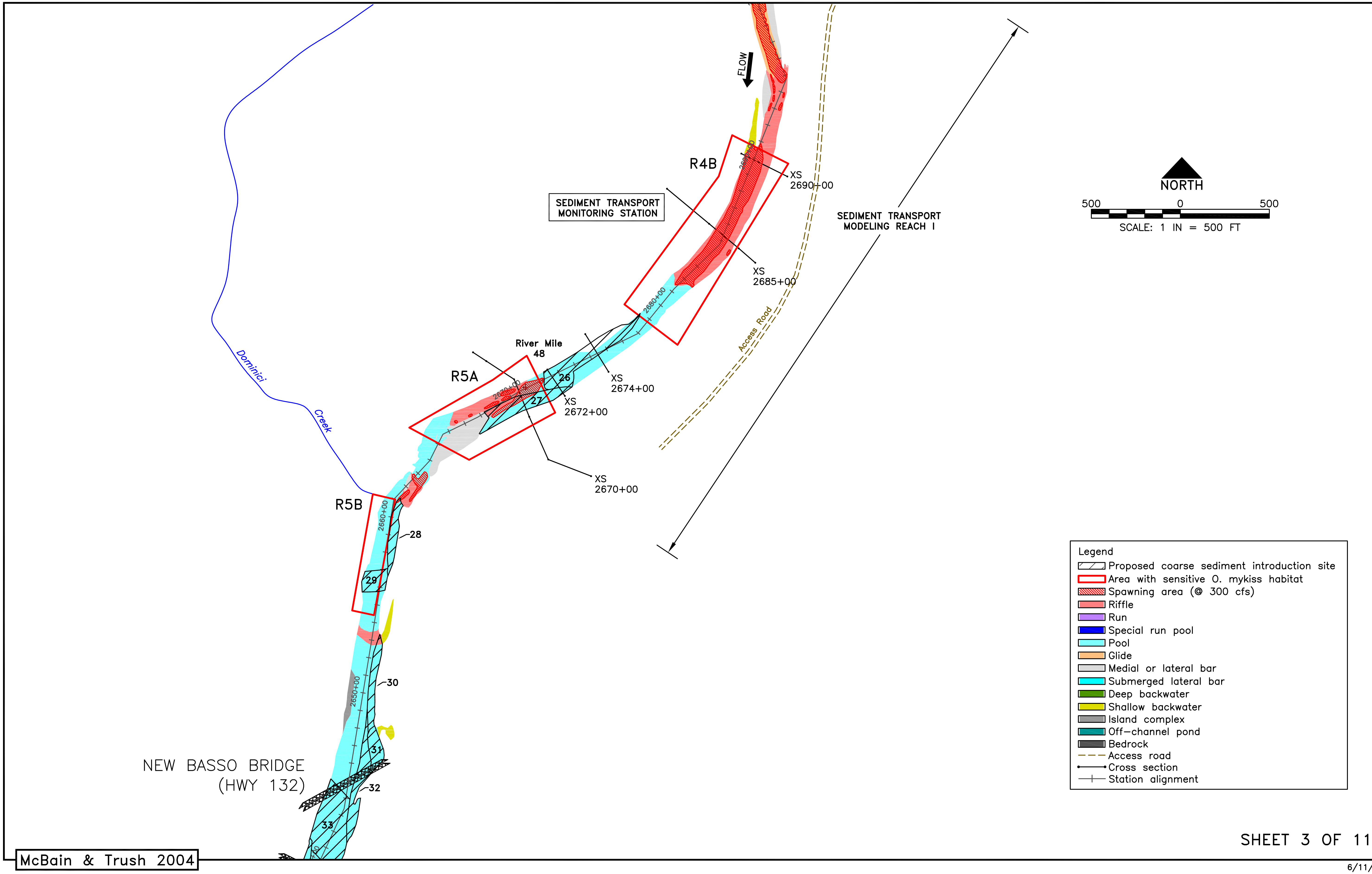
Appendix C: 2004 Habitat Maps

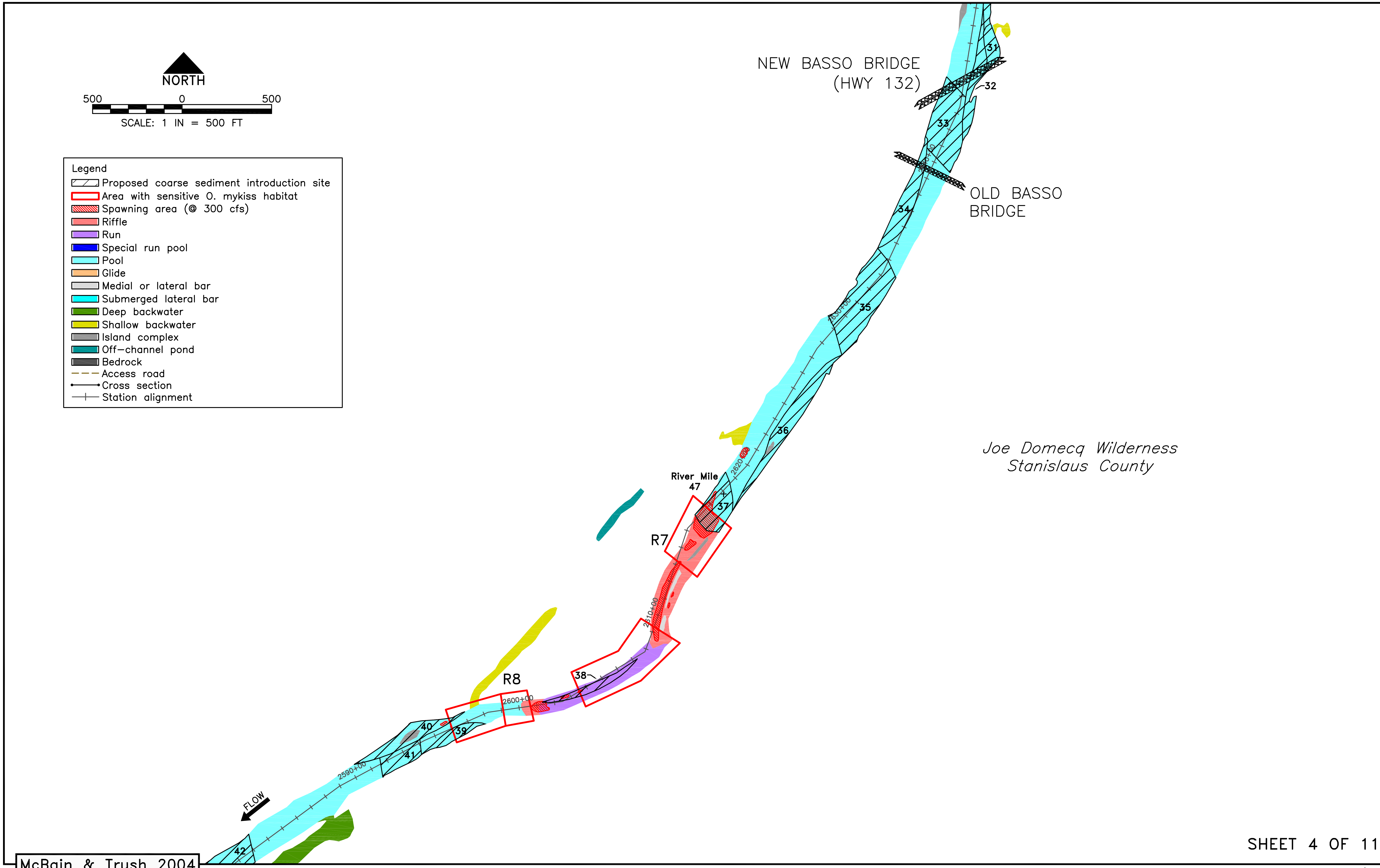

LA GRANGE DAM
SHEET 1
SHEET 2
SHEET 3
SHEET 4
SHEET 5
SHEET 6
SHEET 7
SHEET 8
SHEET 9
SHEET 10
SHEET 11
NORTH
4500 2250 0 4500
SCALE: 1 IN = 4500 FT
TUOLUMNE RIVER HABITAT MAP SHEET INDEX
McBain & Trush 2004
6/11/04

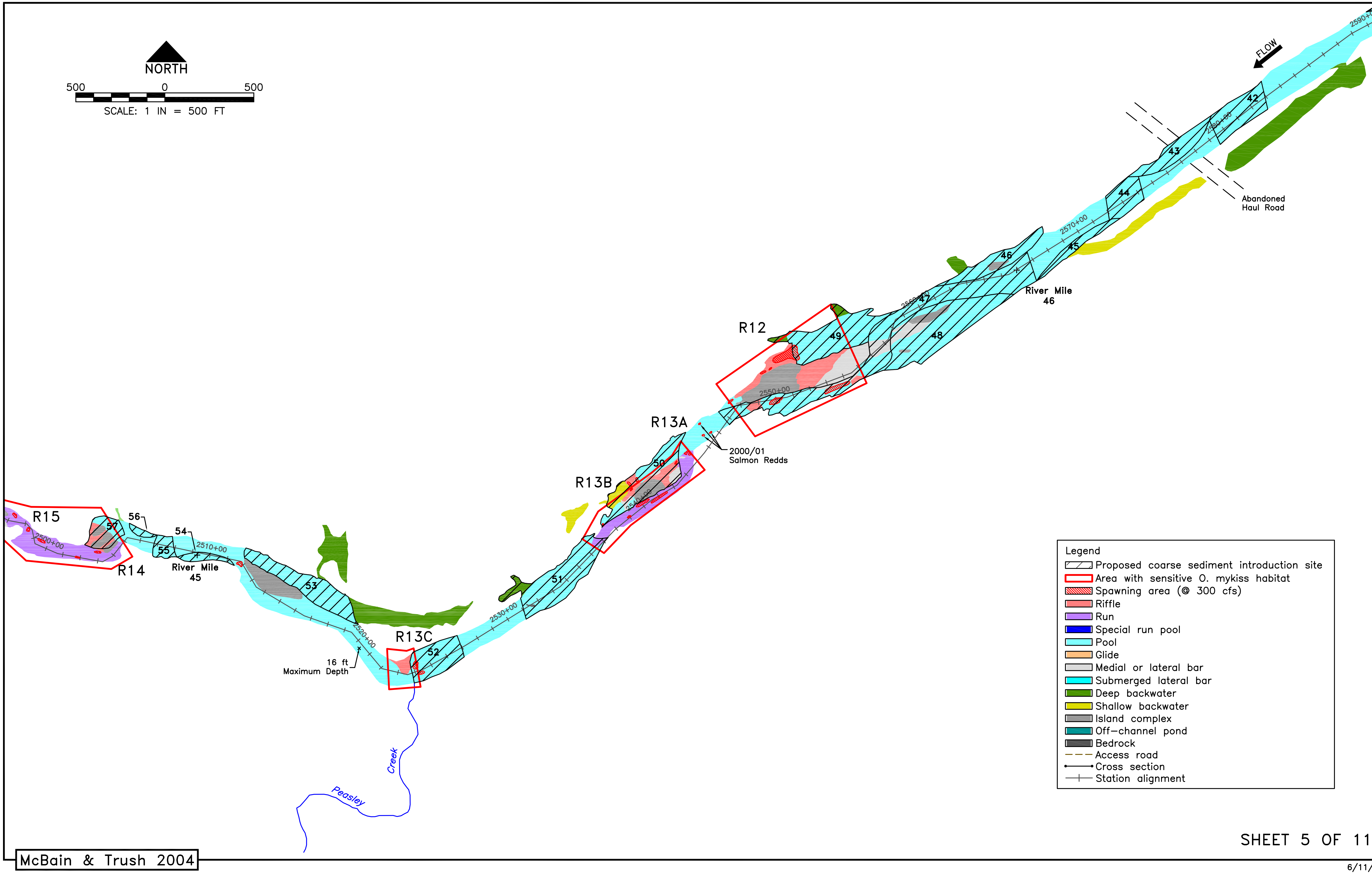


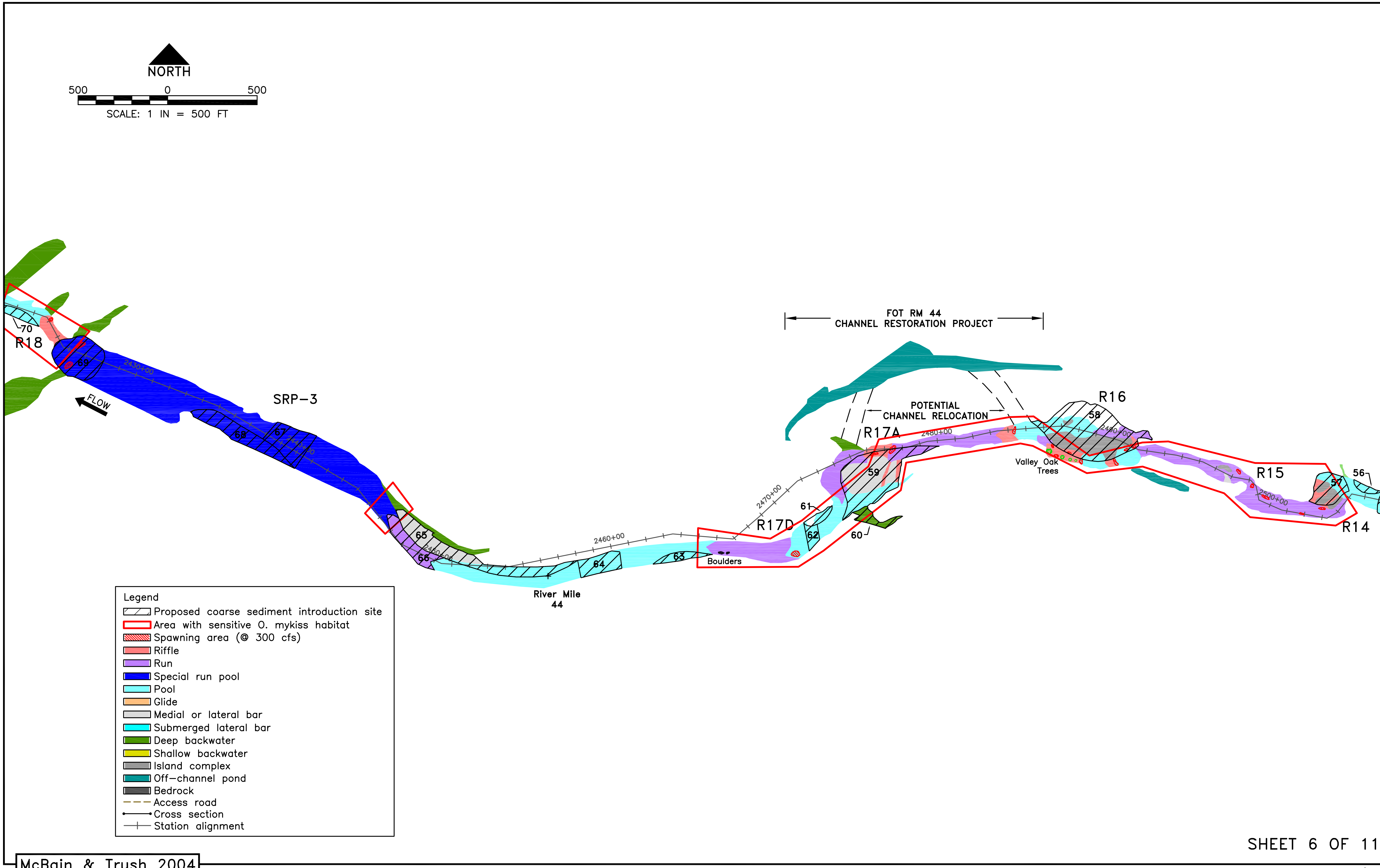
La Grange Dam
NORTH
500 0 500
SCALE: 1 IN = 500 FT
Not sampled
FLOW
R2
27 ft Maximum Depth
RA3/4
XS 2846+00
XS 2841+00
XS 2847+00
XS 2844+00
Stockpile Area
Access Road
XS 2833+00
XS 2836+00
USGS Cableway
River Mile 51
RA7
Completed by CDFG 2003
Completed by CDFG 2001
XS 2802+00
XS 2799+00
XS 2804+00
Road Access (with minor improvements)
OLD LA GRANGE BRIDGE
Existing Road
Access Road
CDFG La Grange Field Office
Gasburg Creek
Phase I Access Road
Phase I CDFG Gravel Introduction Completed 2001
R1A
XS 2780+00
Completed by CDFG 2002
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off−channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 1 OF 11
McBain & Trush 2004
6/11/04

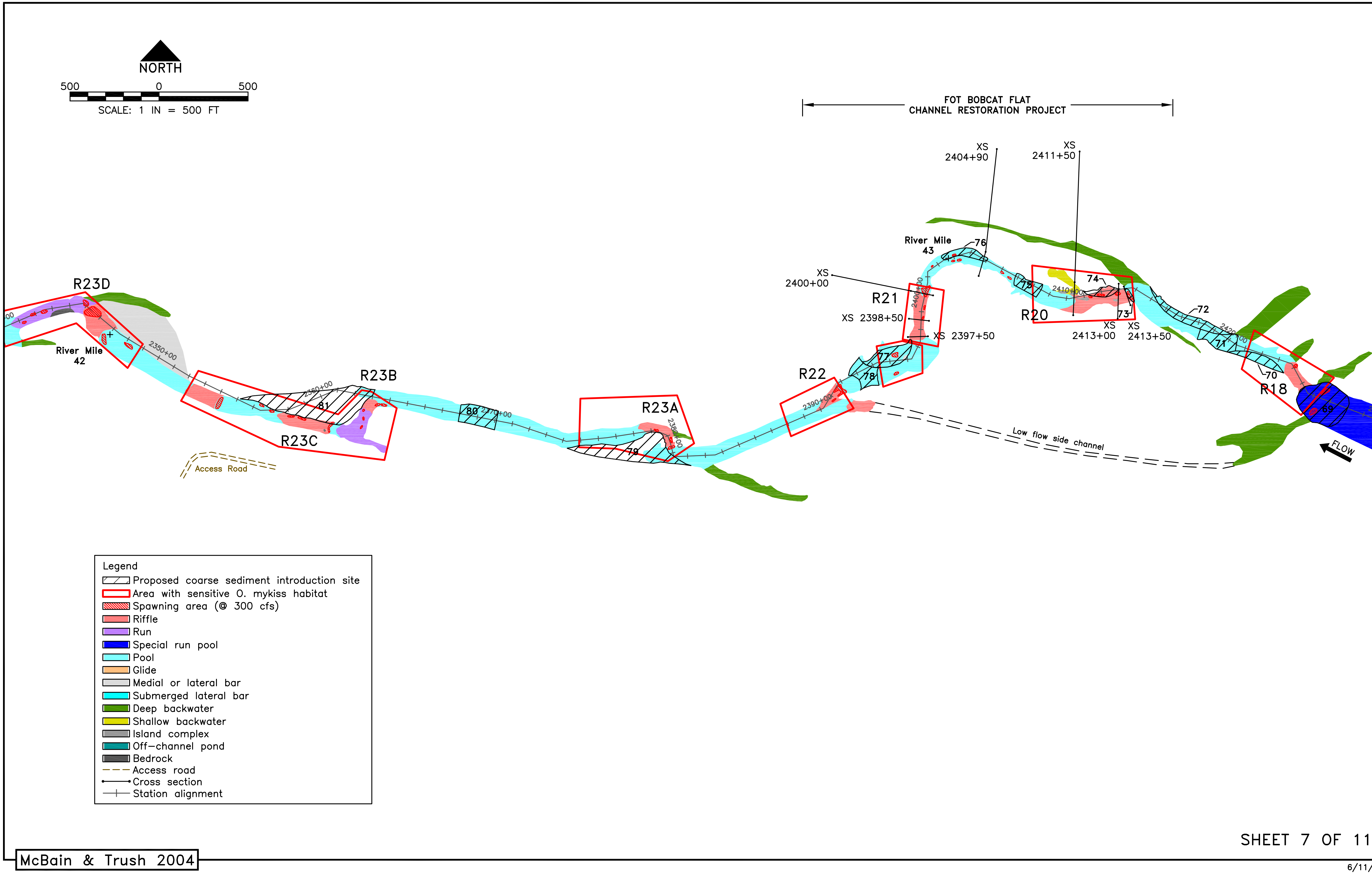

NORTH
500 0 500
SCALE: 1 IN = 500 FT
NEW
LA GRANGE
BRIDGE (J59)
Completed by CDFG 2003
Gasburg
Creek
R3A
R2
R1B
R1A
River Mile
50
XS
2743+50
XS
2739+40
XS
2736+00
Abandoned
Haul Road
XS 2756+00
XS 2759+80
XS 2762+25
XS 2764+30
Completed by CDFG 2002
XS
2780+00
Access Road
XS
2728+00
XS
2730+90
R3B
XS
2722+00
River Mile
49
R4A
XS
2705+00
XS
2699+00
XS
2702+00
FLOW
Access Road
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 2 OF 11
McBain & Trush 2004
6/11/04

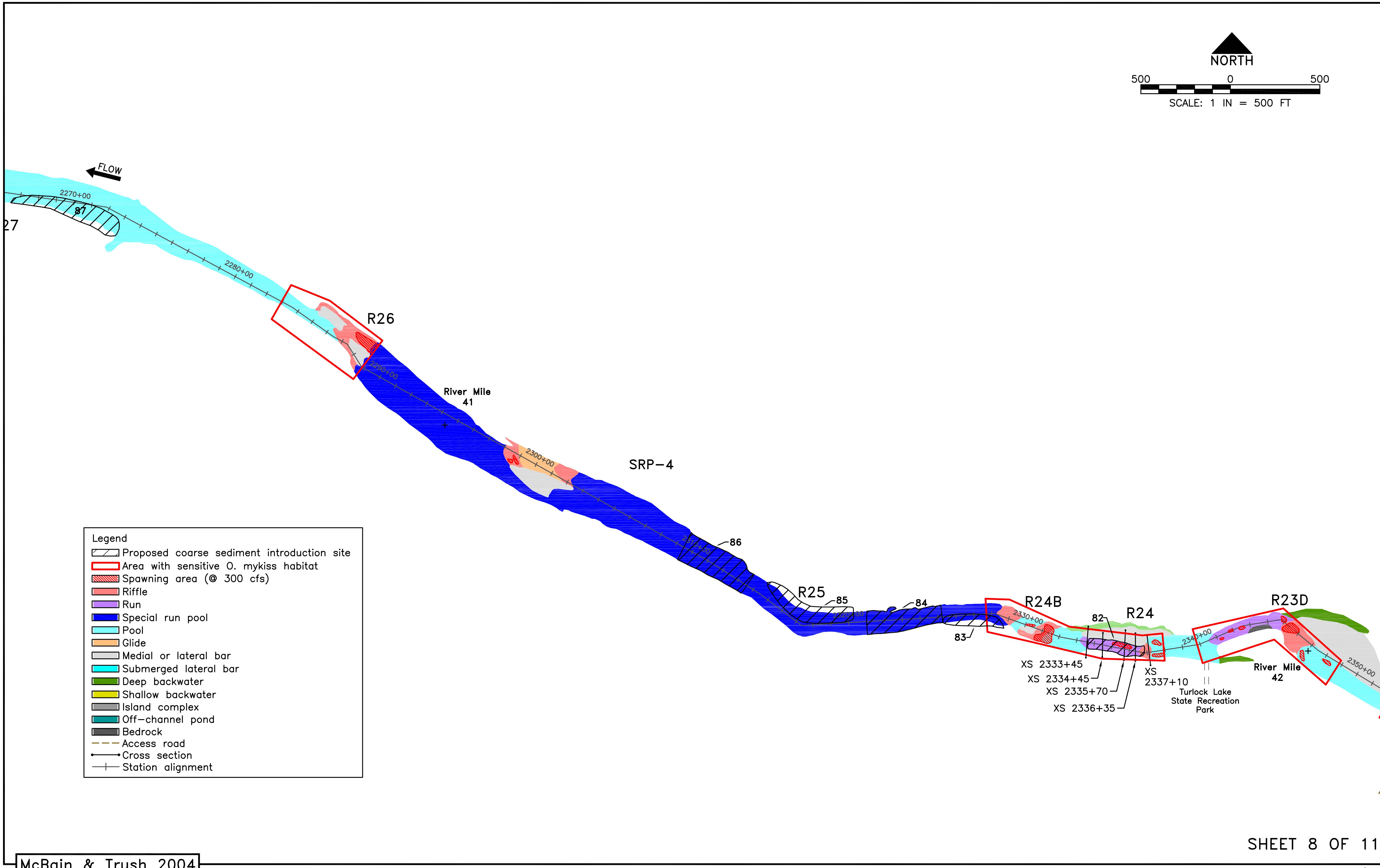

FLOW
R4B
XS
2690+00
SEDIMENT TRANSPORT
MONITORING STATION
SEDIMENT TRANSPORT
MODELING REACH I
NORTH
500
0
500
SCALE: 1 IN = 500 FT
XS
2685+00
Access Road
River Mile
48
R5A
26
27
XS
2674+00
XS
2672+00
XS
2670+00
Dominici
Creek
R5B
2660+00
28
29
30
2650+00
31
32
33
NEW BASSO BRIDGE
(HWY 132)
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 3 OF 11
McBain & Trush 2004
6/11/04

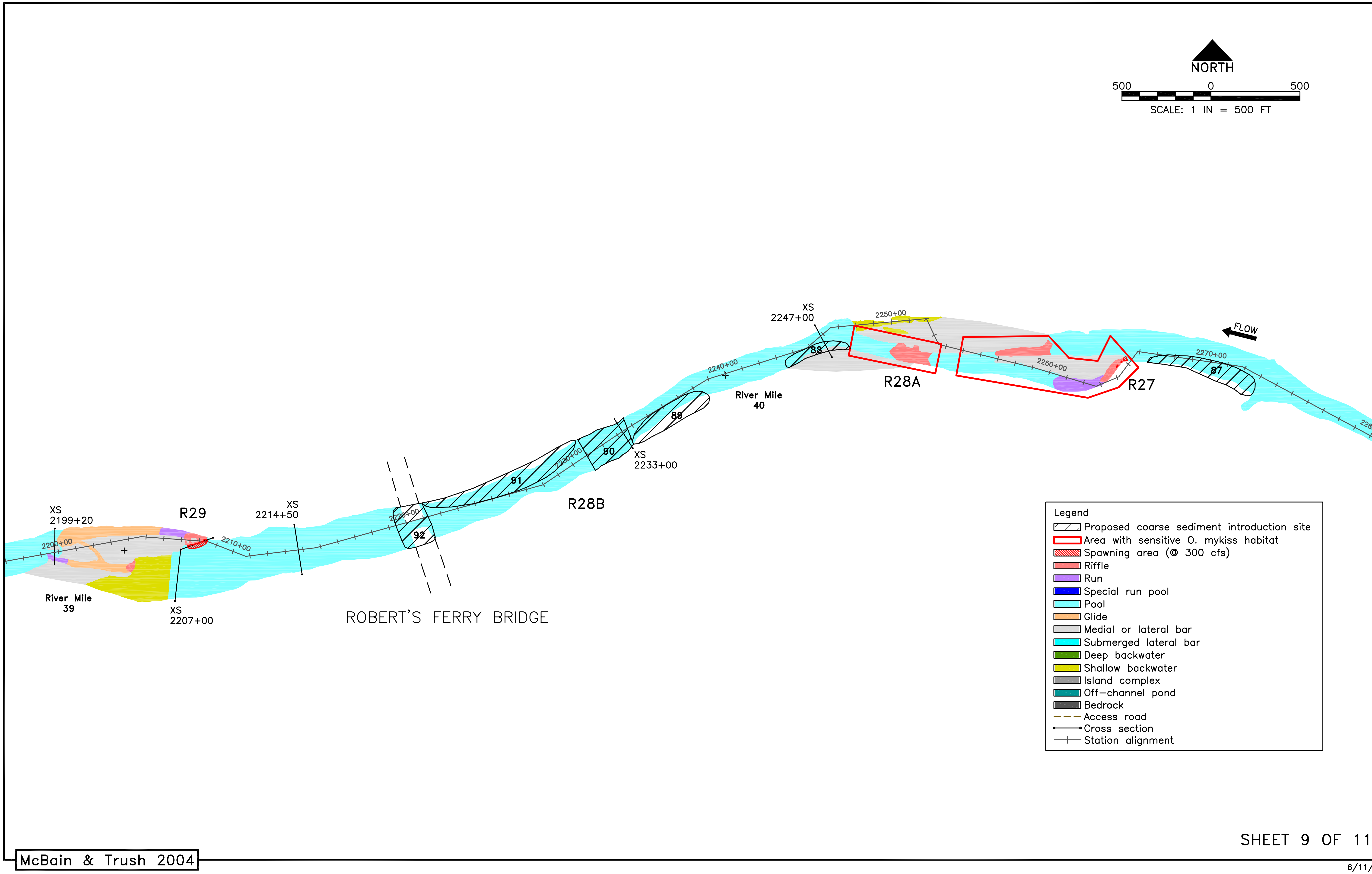

NORTH
500
0
500
SCALE: 1 IN = 500 FT
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
NEW BASSO BRIDGE
(HWY 132)
OLD BASSO
BRIDGE
Joe Domecq Wilderness
Stanislaus County
River Mile
47
R7
R8
FLOW
31
32
33
34
35
36
37
38
39
40
41
42
2620+00
2610+00
2600+00
2590+00
SHEET 4 OF 11
McBain & Trush 2004
6/11/04

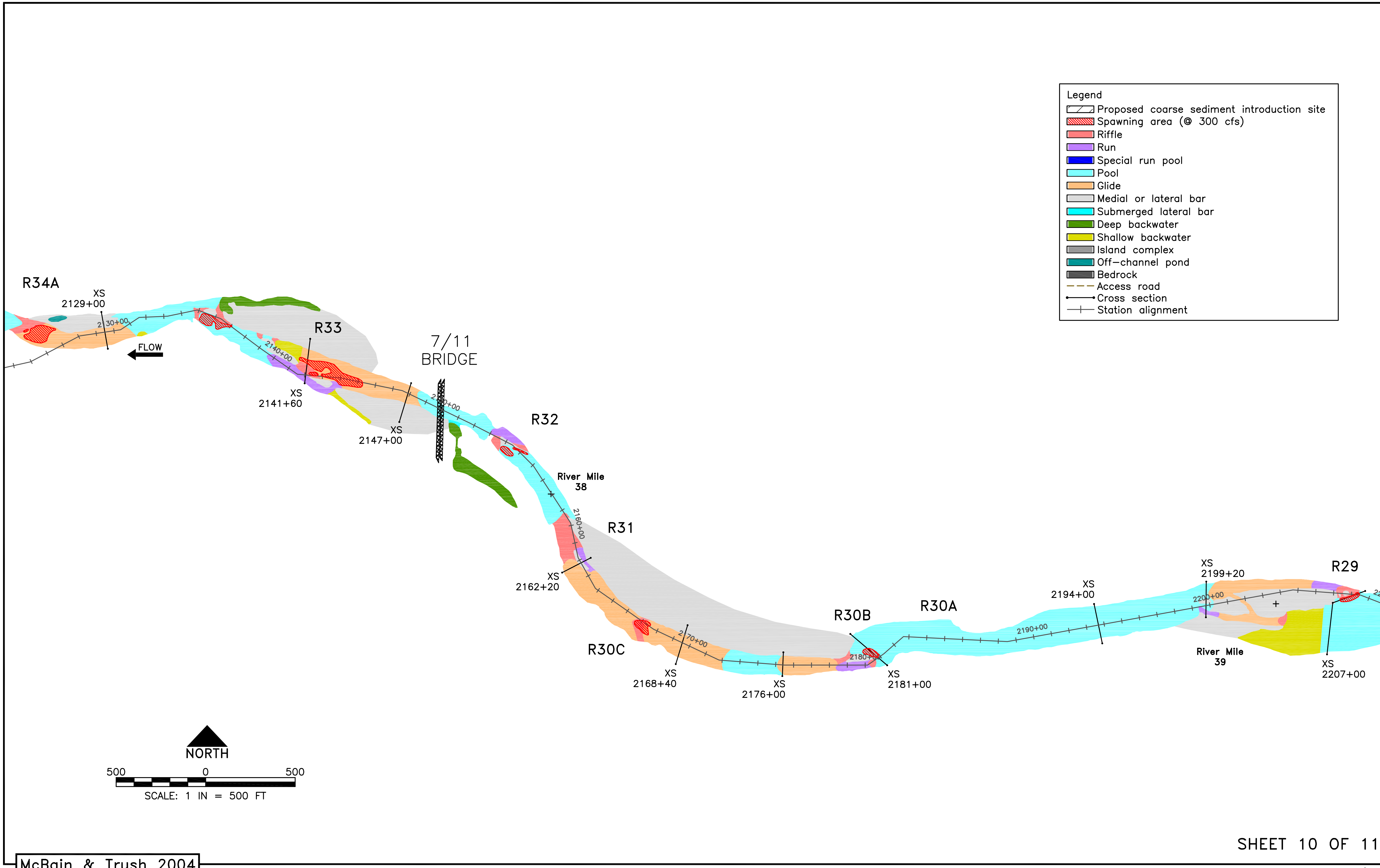

NORTH
500 0 500
SCALE: 1 IN = 500 FT
FLOW
Abandoned Haul Road
River Mile 46
River Mile 45
R12
R13A
R13B
R13C
R14
R15
2000/01 Salmon Redds
16 ft Maximum Depth
Peasley Creek
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
2500+00
2510+00
2520+00
2530+00
2540+00
2550+00
2560+00
2570+00
2580+00
2590+00
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off−channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 5 OF 11
McBain & Trush 2004
6/11/04

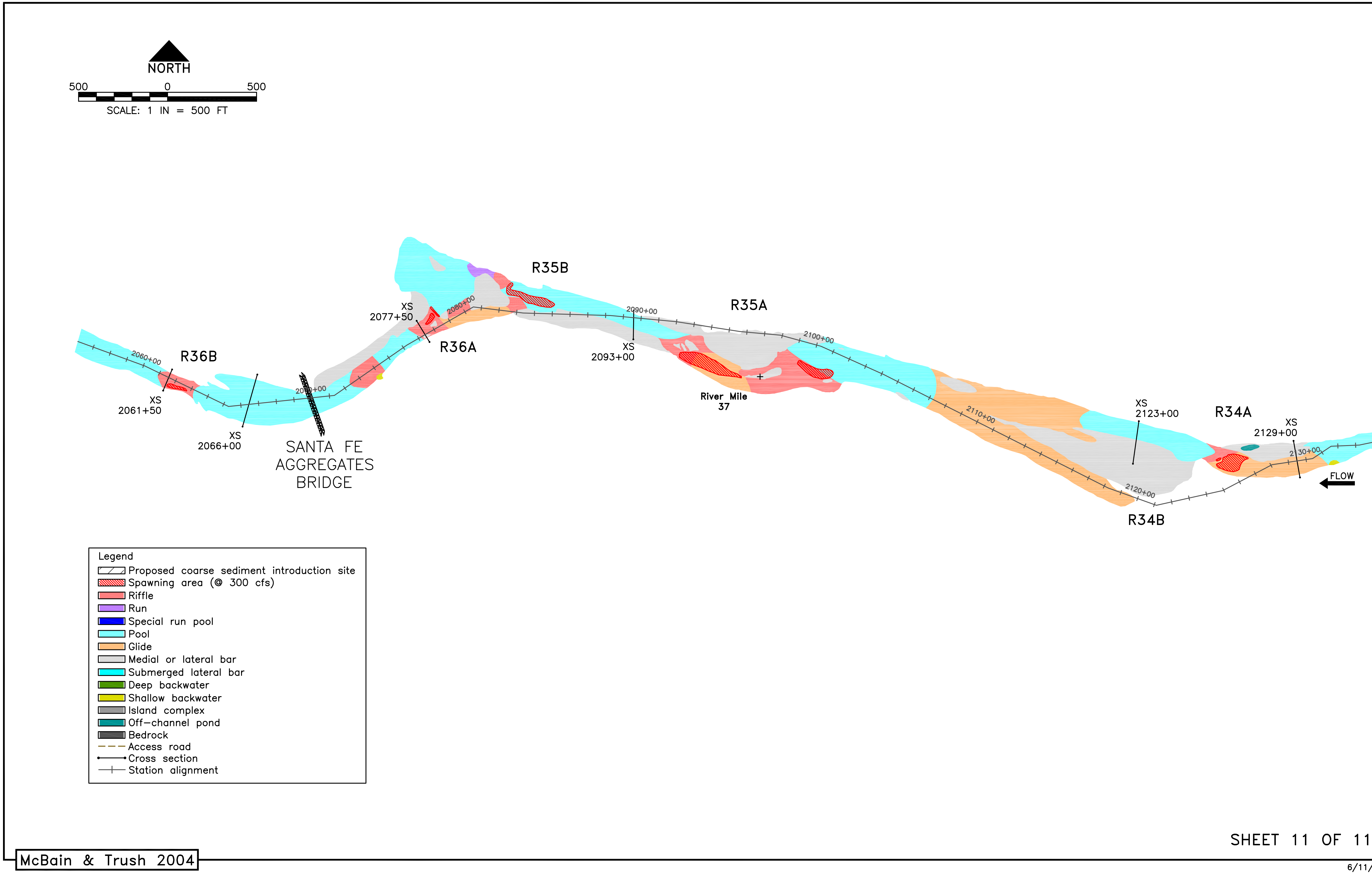

NORTH
500 0 500
SCALE: 1 IN = 500 FT
FOT RM 44
CHANNEL RESTORATION PROJECT
POTENTIAL
CHANNEL RELOCATION
R18
70
69
2430+00
FLOW
SRP-3
68
67
65
66
2460+00
64
63
River Mile
44
Boulders
R17D
61
62
60
2470+00
R17A
59
2480+00
Valley Oak
Trees
R16
58
R15
2500+00
56
57
R14
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off-channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 6 OF 11
McBain & Trush 2004
6/11/04


NORTH
500 0 500
SCALE: 1 IN = 500 FT
FOT BOBCAT FLAT
CHANNEL RESTORATION PROJECT
XS 2404+90
XS 2411+50
XS 2400+00
XS 2398+50
XS 2397+50
XS 2413+00
XS 2413+50
River Mile 43
River Mile 42
R23D
R23C
R23B
R23A
R22
R21
R20
R18
Access Road
Low flow side channel
FLOW
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off−channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 7 OF 11
McBain & Trush 2004
6/11/04


NORTH
500 0 500
SCALE: 1 IN = 500 FT
FLOW
2270+00
87
27
2280+00
R26
River Mile
41
2300+00
SRP–4
86
R25
85
84
83
R24B
2330+00
82
R24
XS 2333+45
XS 2334+45
XS 2335+70
XS 2336+35
XS
2337+10
2340+00
Turlock Lake
State Recreation
Park
R23D
River Mile
42
2350+00
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 8 OF 11
McBain & Trush 2004
6/11/04


NORTH
500
0
500
SCALE: 1 IN = 500 FT
FLOW
XS
2199+20
R29
XS
2214+50
River Mile
39
XS
2207+00
ROBERT'S FERRY BRIDGE
R28B
XS
2233+00
River Mile
40
XS
2247+00
R28A
R27
92
91
90
89
88
87
2200+00
2210+00
2220+00
2230+00
2240+00
2250+00
2260+00
2270+00
2280+00
Legend
Proposed coarse sediment introduction site
Area with sensitive O. mykiss habitat
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 9 OF 11
McBain & Trush 2004
6/11/04


Legend
Proposed coarse sediment introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off–channel pond
Bedrock
Access road
Cross section
Station alignment
R34A
XS 2129+00
FLOW
R33
XS 2141+60
7/11 BRIDGE
XS 2147+00
R32
River Mile 38
R31
XS 2162+20
R30C
XS 2168+40
XS 2176+00
R30B
XS 2181+00
R30A
XS 2194+00
XS 2199+20
R29
River Mile 39
XS 2207+00
NORTH
500 0 500
SCALE: 1 IN = 500 FT
SHEET 10 OF 11
McBain & Trush 2004
6/11/04


NORTH
500
0
500
SCALE: 1 IN = 500 FT
R35B
R35A
R36B
R36A
R34A
R34B
XS
2077+50
XS
2093+00
XS
2061+50
XS
2066+00
XS
2123+00
XS
2129+00
2060+00
2070+00
2080+00
2090+00
2100+00
2110+00
2120+00
2130+00
SANTA FE
AGGREGATES
BRIDGE
River Mile
37
FLOW
Legend
Proposed coarse sediment introduction site
Spawning area (@ 300 cfs)
Riffle
Run
Special run pool
Pool
Glide
Medial or lateral bar
Submerged lateral bar
Deep backwater
Shallow backwater
Island complex
Off−channel pond
Bedrock
Access road
Cross section
Station alignment
SHEET 11 OF 11
McBain & Trush 2004
6/11/04

Appendix D: Habitat Data

Table D-1. Physical habitat types and dimensions of surveyed areas in the lower Tuolumne River (RM 51.8–29.0).

Sampling Unit	RM	September 2011 BCE site	Length (ft)	Average width (ft)	Area (ft^2)	Average depth (ft)	Maximum depth (ft)	July 2008 habitat type
1	51.8		140	75	10,537	5.0	8.0	Pool head
2	51.7		450	143	64,161	18.0	28.0	Pool body
3	51.7		157	61	9,600	1.5	3.0	Pool tail
4	51.6	Yes	85	124	10,506	3.0	5.0	Pool head
5	51.6		393	129	50,702	18.0	25.0	Pool body
6	51.5		250	89	22,309	4.0	6.0	Pool tail
7	51.5		292	68	19,851	3.0	6.0	Riffle
8	51.4		117	82	9,562	5.0	6.0	Run head
9	51.1		2047	97	199,103	6.0	8.0	Run body
10	51.0		182	86	15,733	3.5	4.5	Run tail
11	50.9	Yes	457	99	45,397	10.0	16.0	Pool body
12	50.8		843	128	107,699	4.0	7.0	Run body
13	50.8		93	86	7,988	1.5	3.0	Run tail
14	50.6	Yes	708	65	45,670	1.5		Riffle
15	50.6		161	85	13,760	6.0	7.0	Run head
16	50.5		704	132	92,609	5.0	8.0	Run body
17	50.4		59	146	8,600	2.5	3.0	Run tail
18	50.3		941	130	121,948	1.5	2.0	Riffle
19	50.3	Yes	59	109	7,193	4.0	8.0	Run head
20	50.1	Yes	848	151	107,630	3.0	4.0	Run body
21	50.1		70	119	8,333	1.5	2.0	Run tail
22	50.1		132	127	16,750	1.0	1.5	Riffle
23	50.0		93	133	12,379	4.0	6.0	Run head
24	49.9		1007	199	200,462	4.0	8.0	Run body
25	49.8		274	154	42,115	2.0	4.0	Run tail
26	49.7		527	139	72,991	1.5	2.0	Riffle
27	49.7	Yes	127	86	10,955	4.0	6.0	Pool head
28	49.6	Yes	161	89	14,345	6.0	9.0	Pool body
29	49.6		112	85	9,490	1.5	2.5	Pool tail
30	49.6		50	110	5,520	3.0	5.0	Run head
31	49.3	Yes	1440	115	166,115	2.5	3.5	Run body
32	49.3		132	137	18,071	2.0	2.5	Run tail
33	49.2	Yes	552	126	69,509	1.5	2.5	Riffle
34	49.2		112	65	7,283	2.0	3.0	Run head
35	49.1		321	82	26,475	3.0	5.0	Run body
36	49.1		44	103	4,532	1.5	2.0	Run tail
37	49.1		78	97	7,594	1.5	2.0	Riffle
38	49.1	Yes	43	83	3,559	2.0	3.5	Run head
39	49.1		240	81	19,424	2.5	4.0	Run body
40	49.0		23	95	2,180	2.5	3.0	Run tail
41	48.8		1080	114	122,953	1.5	3.0	Riffle

Sampling Unit	RM	September 2011 BCE site	Length (ft)	Average width (ft)	Area (ft^2)	Average depth (ft)	Maximum depth (ft)	July 2008 habitat type
42	48.8		36	97	3,505	1.5	2.0	Run head
43	48.7	Yes	749	93	69,528	2.5	4.0	Run body
44	48.7		39	110	4,304	2.0	3.0	Run tail
45	48.4		1275	117	149,495	1.5	2.0	Riffle
46	48.4		92	102	9,378	1.5	2.0	Run head
47	48.3		915	111	101,397	3.5	5.0	Run body
48	48.2		153	127	19,368	1.5	2.0	Run tail
49	48.2		346	75	25,887	1.5	2.0	Riffle
50	48.2		40	60	2,392	2.0	2.0	Run head
51	48.1		380	53	20,027	5.0	8.0	Run body
52	48.1		114	56	6,430	3.0	3.5	Run tail
53	48.0	Yes	234	54	12,554	1.5	2.0	Riffle
54	48.0	Yes	164	89	14,569	5.0	7.0	Pool head
55	47.2		4036	143	579,150	7.0	15.0	Pool body
56	47.2		136	115	15,575	1.5	2.5	Pool tail
57	47.1		740	80	58,852	1.5	2.0	Riffle
58	47.0		136	85	11,535	2.0	3.0	Run head
59	46.9		472	76	36,067	4.0	6.0	Run body
60	46.9		137	86	11,760	1.5	2.5	Run tail
61	46.9		318	81	25,666	1.0	2.0	Riffle
62	46.9		64	85	5,428	1.5	2.0	Run head
63	46.8		188	90	16,848	2.0	3.0	Run body
64	46.8		126	131	16,480	1.0	2.5	Run tail
65	46.8		100	123	12,268	0.8	1.5	Riffle
66	46.8		153	96	14,675	1.5	2.0	Run head
67	46.0		3829	97	370,148	4.0	6.0	Run body
68	46.0		89	133	11,835	1.5	2.0	Run tail
69	45.9		234	95	22,286	4.0	7.0	Run body
70	45.9	Yes	277	76	21,181	1.5	2.0	Riffle
71	45.9	Yes	61	93	5,701	2.0		Run head
72	45.8	Yes	243	94	22,751	2.5	3.5	Run body
73	45.8		125	64	7,976	1.5	2.0	Run tail
74	45.7		243	40	9,820	0.8	1.8	Riffle
75	45.7		90	35	3,141	1.5	2.0	Run head
76	45.7		88	50	4,433	1.5	4.0	Run body
77	45.7		32	99	3,153	1.5	2.0	Run tail
78	45.6		675	109	73,797	1.5	2.0	Riffle
79	45.6		85	178	15,127	1.5	2.0	Run head
80	45.4		1040	120	124,357	3.5	5.0	Run body
81	45.3	Yes	301	101	30,519	7.0	11.0	Pool body
82	45.3		126	220	27,658	2.0	3.0	Run head
83	45.1		1182	97	114,144	4.0	6.0	Run body
84	45.1		94	113	10,640	1.5	5.0	Run tail
85	45.0		394	52	20,673	1.5	2.0	Riffle

Sampling Unit	RM	September 2011 BCE site	Length (ft)	Average width (ft)	Area (ft^2)	Average depth (ft)	Maximum depth (ft)	July 2008 habitat type
86	45.0		53	41	2,181	2.0	3.0	Pool head
87	44.9		101	71	7,213	5.0	8.0	Pool body
88	44.9		80	121	9,661	3.0	4.0	Pool tail
89	44.8		734	59	43,114	1.5	2.5	Riffle
90	44.8	Yes	22	107	2,350	0.8	1.5	Run head
91	44.8	Yes	318	62	19,745	1.5	2.5	Run body
92	44.8		15	25	368	1.0	1.5	Run tail
93	44.7		100	30	3,032	1.5	2.0	Riffle
94	44.7		47	26	1,217	1.0	1.5	Run head
95	44.7		248	67	16,708	4.0	8.0	Run body
96	44.7		34	87	2,950	1.5	2.0	Run tail
97	44.6		417	52	21,741	1.5	2.5	Riffle
98	44.6		20	49	984	2.0	2.5	Run head
99	44.6		203	53	10,740	3.0	4.0	Run body
100	44.5		20	59	1,182	1.0	1.5	Run tail
101	44.5		472	59	27,744	1.5	2.0	Riffle
102	44.5		10	68	681	2.0	2.5	Run head
103	43.9		3209	82	261,993	3.0	3.0	Run body
104	43.7		683	144	98,065	6.0	15.0	Pool body
105	43.3		2173	146	316,376	4.0	6.0	Run body
106	43.3		50	110	5,487	1.5	2.0	Run tail
107	43.2		326	81	26,534	1.5	2.0	Riffle
108	43.2		41	74	3,020	1.0	2.0	Run head
109	43.1		906	62	56,464	2.5	6.0	Run body
110	43.1		36	49	1,771	2.0	2.5	Run tail
111	43.0		238	42	10,077	0.8	1.2	Riffle
112	43.0		50	48	2,392	1.5	2.5	Pool head
113	43.0		159	166	26,397	5.0	7.0	Pool body
114	43.0		46	169	7,767	1.5	5.0	Pool tail
115	43.0		33	154	5,097	2.0	3.0	Run head
116	42.9		309	124	38,258	4.0	10.0	Run body
117	42.9		18	84	1,518	1.0	1.5	Run tail
118	42.9		77	57	4,403	1.0	2.0	Riffle
119	42.9		31	45	1,395	2.0	2.5	Run head
120	42.7		978	87	84,726	1.0	8.0	Run body
121	42.7		12	78	932	1.5	2.5	Run tail
122	42.7		89	48	4,288	1.0	3.0	Riffle
123	42.7		18	55	991	2.5	3.0	Run head
124	42.4		1571	77	120,609	2.0	5.0	Run body
125	42.4		69	96	6,600	1.5	2.0	Run body
126	42.3		227	55	12,478	1.0	3.0	Riffle
127	42.3		84	23	1,953	1.5	4.0	Run body
128	42.3		265	32	8,417	1.5	2.3	Riffle
129	42.2		25	28	699	1.5	3.0	Run head

Sampling Unit	RM	September 2011 BCE site	Length (ft)	Average width (ft)	Area (ft^2)	Average depth (ft)	Maximum depth (ft)	July 2008 habitat type
130	42.1		1066	62	65,871	2.0	4.0	Run body
131	42.0		53	60	3,196	1.0	1.5	Run tail
132	41.9		521	64	33,202	1.0	1.5	Riffle
133	41.9		41	46	1,877	2.0	2.5	Run head
134	41.8		940	82	77,063	2.0	4.0	Run body
135	41.8		47	96	4,525	0.8	1.5	Run tail
136	41.7		300	90	27,080	0.8	1.5	Riffle
137	41.7		59	70	4,133	1.5	2.0	Run head
138	41.2		2512	123	308,848	3.0	6.0	Run body
139	41.2		125	151	18,858	1.0	1.3	Run tail
140	41.1		312	107	33,422	1.0	1.5	Riffle
141	41.1		102	163	16,604	1.5	2.0	Run head
142	41.0		666	185	122,933	2.0	4.5	Run body
143	41.0		83	182	15,121	0.8	1.3	Run tail
144	40.9		189	32	6,116	0.8	1.5	Riffle
145	40.9		62	39	2,425	1.5	2.0	Run head
146	40.5		2207	101	223,893	5.0	9.0	Run body
147	40.5		54	53	2,861	1.5	2.0	Run tail
148	40.4		638	53	33,978	1.5	2.5	Riffle
149	40.4		37	83	3,076	1.5	2.0	Run head
150	40.3		502	94	47,268	2.5	4.0	Run body
151	40.3		34	81	2,767	1.0	1.5	Run tail
152	40.2		503	53	26,860	0.8	1.5	Riffle
153	40.2		51	68	3,462	1.5	2.0	Run head
154	39.7		2569	123	317,216	3.0	7.0	Run body
155	39.7		26	142	3,699	1.5		Run tail
156	39.7		219	91	19,859	0.8	1.0	Riffle
157	39.6		86	62	5,294	3.0	4.0	Run head
158	39.5		857	97	82,763	6.0	6.6	Run body
159	39.5		98	81	7,993	2.5	3.0	Run tail
160	39.4		84	62	5,246	1.0	1.5	Riffle
161	39.4	Yes	123	41	5,102	3.5	4.5	Run head
162	39.3	Yes	713	50	35,662	5.0	7.5	Run body
163	39.3		151	80	12,041	3.5	5.0	Run tail
164	39.2	Yes	104	98	10,131	1.0	1.5	Riffle
165	39.2	Yes	93	117	10,818	3.5	4.0	Pool head
166	38.9		1496	90	134,259	6.5	9.9	Pool body
167	38.9		99	91	9,033	3.0	4.0	Pool tail
168	38.9		73	92	6,682	1.5	3.0	Riffle
169	38.9		76	108	8,227	4.0	5.0	Run head
170	38.8		498	77	38,331	5.5	7.2	Run body
171	38.8		121	83	10,096	7.0	10.5	Pool body
172	38.8		87	98	8,506	3.0	4.0	Run head
173	38.7		324	85	27,545	4.0	5.0	Run body

Sampling Unit	RM	September 2011 BCE site	Length (ft)	Average width (ft)	Area (ft^2)	Average depth (ft)	Maximum depth (ft)	July 2008 habitat type
174	38.7		99	100	9,935	3.0	4.0	Run tail
175	38.7		61	118	7,163	1.5	2.3	Riffle
176	38.6		148	105	15,607	2.5	3.5	Run head
177	38.6		219	91	19,976	4.0	4.8	Run body
178	38.6		115	57	6,513	2.0	2.5	Run tail
179	38.5		412	55	22,840	1.2	2.0	Riffle
180	38.5		75	68	5,113	4.0	6.0	Run head
181	38.4		657	39	25,600	4.0	5.0	Run body
182	38.3	Yes	205	68	13,869	8.5	10.5	Pool body
183	38.3		183	66	12,189	4.5	10.5	Pool tail
184	38.3		129	102	13,154	2.5	6.0	Run head
185	38.2		137	139	18,966	2.0	2.5	Run body
186	38.2		134	149	19,976	2.0	2.0	Run tail
187	38.2		285	143	40,886	1.0	1.5	Riffle
188	38.1		86	93	7,964	2.5	4.0	Pool head
189	38.1		235	81	19,027	6.0	10.0	Pool body
190	38.1		55	145	7,947	2.5	4.0	Pool tail
191	38.1		89	115	10,283	1.0	2.0	Riffle
192	38.1	Yes	46	89	4,147	4.0	6.0	Pool head
193	38.0	Yes	378	83	31,490	8.0	13.0	Pool body
194	38.0		81	91	7,365	2.0	3.5	Pool tail
195	38.0		63	64	4,010	3.0	3.5	Run head
196	37.9		271	72	19,591	4.0	5.5	Run body
197	37.9		84	92	7,736	3.0	3.5	Run tail
198	37.8		227	75	17,099	2.0	2.5	Riffle
199	37.8		115	42	4,779	4.0	4.5	Pool head
200	37.7		926	78	72,513	4.0	6.6	Pool body
201	37.6		114	117	13,311	3.0	4.0	Pool tail
202	37.6		163	97	15,857	0.8	1.5	Riffle
203	37.6		130	88	11,423	2.0	3.0	Run head
204	37.5		618	91	55,953	2.5	3.5	Run body
205	37.4		102	77	7,851	2.0	3.0	Run tail
206	37.3		769	50	38,658	1.7	2.5	Riffle
207	37.3		99	58	5,710	2.5	4.0	Run head
208	37.1		916	57	51,803	3.5	4.5	Run body
209	37.1		58	52	3,054	2.0	3.0	Run tail
210	37.0		266	40	10,767	1.5	2.0	Riffle
211	37.0		127	36	4,530	5.0	7.0	Run head
212	36.9		370	80	29,741	5.5	7.6	Run body
213	36.9		85	98	8,321	2.0	3.0	Run tail
214	36.9		70	83	5,779	3.0	5.0	Pool head
215	36.9		126	58	7,330	7.0	10.5	Pool body
216	36.9		94	48	4,471	4.0	5.0	Pool tail
217	36.8	Yes	357	60	21,436	1.5	2.0	Riffle

Sampling Unit	RM	September 2011 BCE site	Length (ft)	Average width (ft)	Area (ft^2)	Average depth (ft)	Maximum depth (ft)	July 2008 habitat type
218	36.8	Yes	157	75	11,815	3.0	4.0	Run head
219	36.6	Yes	675	97	65,353	3.0	6.0	Run body
220	36.6		62	86	5,313	3.0	4.0	Run tail
221	36.6		178	74	13,173	1.0	1.5	Riffle
222	36.6		181	71	12,919	3.0	5.0	Run head
223	36.4		1047	90	94,576	6.5	8.3	Run body
224	36.3		115	97	11,107	3.0	3.5	Run tail
225	36.3	Yes	224	92	20,644	1.5	2.0	Riffle
226	36.3		69	79	5,484	2.0	2.5	Run head
227	36.3		213	65	13,878	2.0	2.5	Run body
228	36.2		70	58	4,092	1.5	2.0	Run tail
229	36.2		74	54	4,022	1.2	2.0	Riffle
230	36.2	Yes	89	72	6,363	4.0	9.8	Pool head
231	36.2	Yes	175	131	22,846	6.0	12.3	Pool body
232	36.2		106	107	11,336	4.0	6.0	Pool tail
233	36.1		211	78	16,529	2.0	3.0	Pool head
234	35.7		2458	72	177,862	9.0	13.4	Pool body
235	35.6		210	53	11,010	3.0	3.5	Pool tail
236	35.5		353	97	34,136	1.0	1.5	Riffle
237	35.5		368	126	46,431	2.0	3.0	Run head
238	35.2		1394	100	139,804	3.5	7.0	Run body
239	35.2		48	84	4,006	3.0	4.0	Run tail
240	35.2		81	79	6,351	2.0	3.0	Riffle
241	35.2		70	60	4,157	3.0	4.0	Run head
242	35.2		74	68	5,054	4.5	5.8	Run body
243	35.1		62	65	3,996	1.5	2.0	Run tail
244	35.1		501	54	27,305	2.0	3.0	Riffle
245	35.0		79	82	6,466	1.5	2.5	Run head
246	35.0		302	65	19,636	2.0	3.0	Run body
247	35.0		114	31	3,548	1.5	2.0	Run tail
248	34.9		62	50	3,125	1.5	2.0	Riffle
249	34.9		151	50	7,602	3.0	4.0	Run head
250	34.7		1255	62	78,340	3.5	7.0	Run body
251	34.6		351	66	23,058	6.5	10.5	Pool body
252	34.6		119	82	9,791	3.0	4.0	Pool tail
253	34.5		293	77	22,628	1.0	2.0	Riffle
254	34.5		61	63	3,879	8.0	12.0	Pool head
255	34.4		445	79	35,344	4.0	8.0	Pool body
256	34.1		1722	91	157,333	3.0	4.0	Run body
257	34.1		137	81	11,136	1.5	2.0	Run tail
258	34.1		130	70	9,152	1.0	1.5	Riffle
259	34.0		103	79	8,137	2.0	2.5	Run head
260	34.0		452	59	26,907	2.5	3.5	Run body
261	33.9		142	38	5,468	1.5	2.0	Run tail

Sampling Unit	RM	September 2011 BCE site	Length (ft)	Average width (ft)	Area (ft^2)	Average depth (ft)	Maximum depth (ft)	July 2008 habitat type
262	33.8		505	32	16,314	1.0	1.5	Riffle
263	33.8		86	53	4,509	2.0	2.5	Run head
264	33.8		265	52	13,757	3.0	3.5	Run body
265	33.8		59	57	3,342	2.0	2.5	Run tail
266	33.7		524	43	22,663	2.0	4.0	Riffle
267	33.6		241	67	16,237	3.0	4.0	Run head
268	33.5		690	116	79,804	2.5	5.0	Run body
269	33.4		231	79	18,336	1.0	2.0	Run tail
270	33.4		163	63	10,208	1.0	1.5	Riffle
271	33.4		49	74	3,588	6.0	7.5	Pool head
272	33.2		898	71	63,477	9.0	12.0	Pool body
273	33.2		102	39	3,988	2.0	3.0	Pool tail
274	33.2		190	55	10,514	1.0	1.5	Riffle
275	33.2		103	71	7,311	1.5	2.5	Run head
276	33.1		343	105	35,908	2.0	2.5	Run body
277	33.1		136	118	16,054	1.5	2.0	Run tail
278	33.0		312	62	19,368	1.0	1.5	Riffle
279	33.0		209	35	7,298	3.5	6.0	Run head
280	32.1		4454	174	776,561	5.5	9.2	Run body
281	32.1		143	124	17,763	4.0	5.5	Run tail
282	32.0		293	100	29,228	1.0	1.5	Riffle
283	32.0		163	107	17,489	2.5	3.0	Run head
284	32.0		294	86	25,244	3.5	4.0	Run body
285	31.9		41	86	3,565	2.0	3.7	Run tail
286	31.9		290	87	25,317	1.0	2.0	Riffle
287	31.9		157	43	6,710	2.5	3.0	Run head
288	31.7		838	55	45,952	3.5	5.0	Run body
289	31.7		112	85	9,543	2.5	3.0	Run tail
290	31.6		181	100	18,051	1.0	2.0	Riffle
291	31.6		148	108	15,990	4.0	5.5	Run head
292	31.5		475	89	42,320	5.0	6.0	Run body
293	31.5		154	62	9,597	1.5	2.5	Run tail
294	31.5		175	74	13,012	1.0	1.5	Riffle
295	31.4		210	100	21,058	3.0	4.5	Run head
296	31.3		567	87	49,612	4.0	5.5	Run body
297	31.3		139	54	7,465	2.5	4.0	Run tail
298	31.2		538	44	23,863	1.5	2.5	Riffle
299	31.2		122	70	8,583	3.5	4.5	Run head
300	31.1		240	61	14,568	3.5	5.0	Run body
301	31.1		41	72	2,974	2.0	3.0	Run tail
302	31.1		206	66	13,664	1.3	2.0	Riffle
303	31.1		98	75	7,324	3.0	4.0	Run head
304	30.7		1892	85	160,847	4.0	5.5	Run body
305	30.7		200	102	20,508	1.5	2.5	Run tail

Sampling Unit	RM	September 2011 BCE site	Length (ft)	Average width (ft)	Area (ft^2)	Average depth (ft)	Maximum depth (ft)	July 2008 habitat type
306	30.6		113	83	9,452	1.2	2.0	Riffle
307	30.6		113	69	7,775	2.0	3.5	Run head
308	30.5		513	74	37,874	3.5	6.5	Run body
309	30.5		157	95	14,947	2.5	3.5	Run tail
310	30.4		259	37	9,478	1.0	2.0	Riffle
311	30.4		71	40	2,836	2.5	3.0	Run head
312	30.4		188	47	8,790	2.5	3.0	Run body
313	30.4		59	49	2,887	1.5	3.0	Run tail
314	30.2		946	43	40,519	1.2	2.0	Riffle
315	30.2		263	49	12,952	2.5	3.0	Run head
316	30.1		123	60	7,371	2.5	5.0	Run body
317	30.1		52	71	3,674	2.0	3.0	Run tail
318	30.1		189	298	56,219	1.5	2.0	Riffle
319	30.0		329	171	56,219	2.0	3.0	Run head
320	29.7		1444	155	224,395	5.0	8.0	Run body
321	29.7		68	59	3,978	3.0	4.0	Run tail
322	29.6		681	329	223,763	11.0	15.7	Pool body
323	29.6		222	84	18,626	3.0	7.0	Pool tail
324	29.5		109	38	4,188	1.0	2.0	Riffle
325	29.5		110	55	6,041	4.0	5.0	Run head
326	29.5		190	51	9,726	3.0	4.0	Run body
327	29.5		52	63	3,270	2.0	3.0	Run tail
328	29.5		70	58	4,066	1.2	2.0	Riffle
329	29.4		88	40	3,575	3.5	4.0	Run head
330	29.4		301	53	15,958	3.5	4.5	Run body
331	29.4		169	79	13,387	1.5	2.5	Run tail
332	29.3		192	168	32,257	1.2	2.0	Riffle
333	29.3		131	139	18,145	2.0	3.8	Run head
334	29.2		402	110	44,240	3.0	5.0	Run body
335	29.2		51	135	6,896	2.0	3.5	Run tail
336	29.2		247	92	22,792	1.0	1.5	Riffle
337	29.1		103	88	9,057	2.5	3.0	Run head
338	29.1		168	89	14,954	3.5	4.5	Run body
339	29.0		331	127	42,219	2.0	2.5	Run tail
340	29.0		447	90	40,119	1.5	2.0	Riffle

Table D-2. Percent cover and type for habitat units within the study area.

River mile	Sampling unit	Habitat type	Habitat survey date	No cover (%)	Boulder (%)	Wood (%)	Ledge (%)	Overhang (%)	Aquatic vegetation (%)
51.8	1	Pool head	7/8/2008	90	5			5	
51.7	2	Pool body	7/8/2008	80					20
51.7	3	Pool tail	7/8/2008	100					
51.6	4	Pool head	7/8/2008	100					
51.6	5	Pool body	7/8/2008	90					10
51.5	6	Pool tail	7/8/2008	100					
51.5	7	Riffle	7/8/2008	90	5			5	
51.4	8	Run head	7/8/2008	85				5	10
51.1	9	Run body	7/8/2008	60	10				30
51.0	10	Run tail	7/8/2008	90					10
50.9	11	Pool body	7/8/2008	50					50
50.8	12	Run body	7/8/2008	45	5				50
50.8	13	Run tail	7/8/2008	90				10	
50.6	14	Riffle	7/8/2008	80	10		10		
50.6	15	Run head	7/8/2008	90	10				
50.5	16	Run body	7/8/2008	95				5	
50.4	17	Run tail	7/8/2008	90				5	
50.3	18	Riffle	7/8/2008	90	5				5
50.3	19	Run head	7/8/2008	90					10
50.1	20	Run body	7/8/2008	95				5	
50.1	21	Run tail	7/8/2008	90	5			5	
50.1	22	Riffle	7/8/2008	95					5
50.0	23	Run head	7/8/2008	95				5	
49.9	24	Run body	7/8/2008	95				5	
49.8	25	Run tail	7/8/2008	95				5	
49.7	26	Riffle	7/8/2008	90	5			5	
49.7	27	Pool head	7/8/2008	85	10			5	
49.6	28	Pool body	7/8/2008	85	10			5	
49.6	29	Pool tail	7/8/2008	85	10			5	
49.6	30	Run head	7/8/2008	100					
49.3	31	Run body	7/8/2008	95		5			
49.3	32	Run tail	7/8/2008	95				5	
49.2	33	Riffle	7/8/2008	90	5			5	
49.2	34	Run head	7/8/2008	85	5			10	
49.1	35	Run body	7/8/2008	85	5			10	
49.1	36	Run tail	7/8/2008	95				5	
49.1	37	Riffle	7/8/2008	95				5	
49.1	38	Run head	7/8/2008	90		5		5	
49.1	39	Run body	7/8/2008	90	5			5	
49.0	40	Run tail	7/8/2008	95				5	
48.8	41	Riffle	7/8/2008	95				5	
48.8	42	Run head	7/8/2008	75				5	20
48.7	43	Run body	7/8/2008	90				10	

River mile	Sampling unit	Habitat type	Habitat survey date	No cover (%)	Boulder (%)	Wood (%)	Ledge (%)	Overhang (%)	Aquatic vegetation (%)
48.7	44	Run tail	7/8/2008	95				5	
48.4	45	Riffle	7/8/2008	90				10	
48.4	46	Run head	7/8/2008	90				10	
48.3	47	Run body	7/8/2008	90				10	
48.2	48	Run tail	7/8/2008	90				10	
48.2	49	Riffle	7/8/2008	90				10	
48.2	50	Run head	7/8/2008	90		5		5	
48.1	51	Run body	7/8/2008	95	5				
48.1	52	Run tail	7/8/2008	95	5				
48.0	53	Riffle	7/8/2008	95				5	
48.0	54	Pool head	7/8/2008	85	10			5	
47.2	55	Pool body	7/8/2008	85	10			5	
47.2	56	Pool tail	7/8/2008	95				5	
47.1	57	Riffle	7/8/2008	100					
47.0	58	Run head	7/8/2008	100					
46.9	59	Run body	7/8/2008	95				5	
46.9	60	Run tail	7/8/2008	90				10	
46.9	61	Riffle	7/8/2008	95				5	
46.9	62	Run head	7/8/2008	90				10	
46.8	63	Run body	7/8/2008	95				5	
46.8	64	Run tail	7/8/2008	95				5	
46.8	65	Riffle	7/8/2008	95				5	
46.8	66	Run head	7/8/2008	100					
46.0	67	Run body	7/8/2008	95				5	
46.0	68	Run tail	7/8/2008	95				5	
45.9	69	Run body	7/8/2008	100					
45.9	70	Riffle	7/8/2008	90				10	
45.9	71	Run head	7/8/2008	95				5	
45.8	72	Run body	7/8/2008	95				5	
45.8	73	Run tail	7/8/2008	100					
45.7	74	Riffle	7/8/2008	95				5	
45.7	75	Run head	7/9/2008	90				10	
45.7	76	Run body	7/9/2008	90				10	
45.7	77	Run tail	7/9/2008	100					
45.6	78	Riffle	7/9/2008	95				5	
45.6	79	Run head	7/9/2008	85				5	10
45.4	80	Run body	7/9/2008	80	15			5	
45.3	81	Pool body	7/9/2008	40		5		5	50
45.3	82	Run head	7/9/2008	45				5	50
45.1	83	Run body	7/9/2008	35		5		10	50
45.1	84	Run tail	7/9/2008	75		5		20	
45.0	85	Riffle	7/9/2008	70		5		25	
45.0	86	Pool head	7/9/2008	85		5		10	
44.9	87	Pool body	7/9/2008	90		5		5	
44.9	88	Pool tail	7/9/2008	95					5

River mile	Sampling unit	Habitat type	Habitat survey date	No cover (%)	Boulder (%)	Wood (%)	Ledge (%)	Overhang (%)	Aquatic vegetation (%)
44.8	89	Riffle	7/9/2008	90				10	
44.8	90	Run head	7/9/2008	90		5		5	
44.8	91	Run body	7/9/2008	100					
44.8	92	Run tail	7/9/2008	85				15	
44.7	93	Riffle	7/9/2008	80				20	
44.7	94	Run head	7/9/2008	90				10	
44.7	95	Run body	7/9/2008	100					
44.7	96	Run tail	7/9/2008	95				5	
44.6	97	Riffle	7/9/2008	90				10	
44.6	98	Run head	7/9/2008	95				5	
44.6	99	Run body	7/9/2008	95				5	
44.5	100	Run tail	7/9/2008	95				5	
44.5	101	Riffle	7/9/2008	95				5	
44.5	102	Run head	7/9/2008	100					
43.9	103	Run body	7/9/2008	90				10	
43.7	104	Pool body	7/9/2008	65				5	30
43.3	105	Run body	7/9/2008	65				5	30
43.3	106	Run tail	7/9/2008	90				5	5
43.2	107	Riffle	7/9/2008	85		5		10	
43.2	108	Run head	7/9/2008	95				5	
43.1	109	Run body	7/9/2008	95				5	
43.1	110	Run tail	7/9/2008	90				10	
43.0	111	Riffle	7/9/2008	95				5	
43.0	112	Pool head	7/9/2008	65		5			30
43.0	113	Pool body	7/9/2008	60		10			30
43.0	114	Pool tail	7/9/2008	70		25		5	
43.0	115	Run head	7/9/2008	70		20		10	
42.9	116	Run body	7/9/2008	100					
42.9	117	Run tail	7/9/2008	95				5	
42.9	118	Riffle	7/9/2008	95				5	
42.9	119	Run head	7/9/2008	95				5	
42.7	120	Run body	7/9/2008	95				5	
42.7	121	Run tail	7/9/2008	95				5	
42.7	122	Riffle	7/9/2008	90				5	5
42.7	123	Run head	7/9/2008	95				5	
42.4	124	Run body	7/9/2008	95				5	
42.4	125	Run body	7/9/2008	95				5	
42.3	126	Riffle	7/9/2008	80				20	
42.3	127	Run body	7/9/2008	100					
42.3	128	Riffle	7/9/2008	75	5	5		15	
42.2	129	Run head	7/9/2008	90				10	
42.1	130	Run body	7/9/2008	90				10	
42.0	131	Run tail	7/9/2008	95				5	
41.9	132	Riffle	7/9/2008	95				5	
41.9	133	Run head	7/9/2008	95				5	

River mile	Sampling unit	Habitat type	Habitat survey date	No cover (%)	Boulder (%)	Wood (%)	Ledge (%)	Overhang (%)	Aquatic vegetation (%)
41.8	134	Run body	7/9/2008	95				5	
41.8	135	Run tail	7/9/2008	95				5	
41.7	136	Riffle	7/9/2008	95				5	
41.7	137	Run head	7/9/2008	90				10	
41.2	138	Run body	7/9/2008	100					
41.2	139	Run tail	7/9/2008	95				5	
41.1	140	Riffle	7/9/2008	95				5	
41.1	141	Run head	7/9/2008	80					20
41.0	142	Run body	7/9/2008	95				5	
41.0	143	Run tail	7/9/2008	95				5	
40.9	144	Riffle	7/9/2008	95				5	
40.9	145	Run head	7/9/2008	100					
40.5	146	Run body	7/9/2008	65				10	25
40.5	147	Run tail	7/9/2008	85				15	
40.4	148	Riffle	7/9/2008	70				30	
40.4	149	Run head	7/9/2008	75				5	20
40.3	150	Run body	7/9/2008	100					
40.3	151	Run tail	7/9/2008	100					
40.2	152	Riffle	7/9/2008	95				5	
40.2	153	Run head	7/9/2008	100					
39.7	154	Run body	7/9/2008	95				5	
39.7	155	Run tail	7/9/2008	95				5	
39.7	156	Riffle	2/10/2009	95					5
39.6	157	Run head	2/10/2009	100					
39.5	158	Run body	2/10/2009	80					20
39.5	159	Run tail	2/10/2009	80					20
39.4	160	Riffle	2/10/2009	95					5
39.4	161	Run head	2/10/2009	95					
39.3	162	Run body	2/10/2009	95				5	
39.3	163	Run tail	2/10/2009	95				5	
39.2	164	Riffle	2/10/2009	95					5
39.2	165	Pool head	2/10/2009	100					
38.9	166	Pool body	2/10/2009	90					10
38.9	167	Pool tail	2/10/2009	100					
38.9	168	Riffle	2/10/2009	100					
38.9	169	Run head	2/10/2009	100					
38.8	170	Run body	2/10/2009	100					
38.8	171	Pool body	2/10/2009	90				5	5
38.8	172	Run head	2/10/2009	95				5	
38.7	173	Run body	2/10/2009	95				5	
38.7	174	Run tail	2/10/2009	100					
38.7	175	Riffle	2/10/2009	100					
38.6	176	Run head	2/10/2009	100					
38.6	177	Run body	2/10/2009	100					
38.6	178	Run tail	2/10/2009	100					

River mile	Sampling unit	Habitat type	Habitat survey date	No cover (%)	Boulder (%)	Wood (%)	Ledge (%)	Overhang (%)	Aquatic vegetation (%)
38.5	179	Riffle	2/10/2009	100					
38.5	180	Run head	2/10/2009	90					10
38.4	181	Run body	2/10/2009	100					
38.3	182	Pool body	2/10/2009	80					20
38.3	183	Pool tail	2/10/2009	90				5	5
38.3	184	Run head	2/10/2009	100					
38.2	185	Run body	2/10/2009	100					
38.2	186	Run tail	2/10/2009	100					
38.2	187	Riffle	2/10/2009	95				5	
38.1	188	Pool head	2/10/2009	95				5	
38.1	189	Pool body	2/11/2009	90					10
38.1	190	Pool tail	2/11/2009	100					
38.1	191	Riffle	2/11/2009	100					
38.1	192	Pool head	2/11/2009	90					10
38.0	193	Pool body	2/11/2009	70					30
38.0	194	Pool tail	2/11/2009	100					
38.0	195	Run head	2/11/2009	100					
37.9	196	Run body	2/11/2009	100					
37.9	197	Run tail	2/11/2009	100					
37.8	198	Riffle	2/11/2009	100					
37.8	199	Pool head	2/11/2009	85		15			
37.7	200	Pool body	2/11/2009	100					
37.6	201	Pool tail	2/11/2009	100					
37.6	202	Riffle	2/11/2009	100					
37.6	203	Run head	2/11/2009	100					
37.5	204	Run body	2/11/2009	100					
37.4	205	Run tail	2/11/2009	100					
37.3	206	Riffle	2/11/2009	100					
37.3	207	Run head	2/11/2009	100					
37.1	208	Run body	2/11/2009	100					
37.1	209	Run tail	2/11/2009	100					
37.0	210	Riffle	2/11/2009	100					
37.0	211	Run head	2/11/2009	100					
36.9	212	Run body	2/11/2009	100					
36.9	213	Run tail	2/11/2009	100					
36.9	214	Pool head	2/11/2009	100					
36.9	215	Pool body	2/11/2009	100					
36.9	216	Pool tail	2/11/2009	100					
36.8	217	Riffle	2/11/2009	100					
36.8	218	Run head	2/11/2009	100					
36.6	219	Run body	2/11/2009	100					
36.6	220	Run tail	2/11/2009	100					
36.6	221	Riffle	2/11/2009	100					
36.6	222	Run head	2/11/2009	100					
36.4	223	Run body	2/11/2009	100					

River mile	Sampling unit	Habitat type	Habitat survey date	No cover (%)	Boulder (%)	Wood (%)	Ledge (%)	Overhang (%)	Aquatic vegetation (%)
36.3	224	Run tail	2/11/2009	100					
36.3	225	Riffle	2/11/2009	100					
36.3	226	Run head	2/11/2009	100					
36.3	227	Run body	2/11/2009	100					
36.2	228	Run tail	2/11/2009	100					
36.2	229	Riffle	2/11/2009	100					
36.2	230	Pool head	2/11/2009	100					
36.2	231	Pool body	2/11/2009	100					
36.2	232	Pool tail	2/11/2009	100					
36.1	233	Pool head	2/11/2009	100					
35.7	234	Pool body	2/11/2009	100					
35.6	235	Pool tail	2/11/2009	100					
35.5	236	Riffle	2/11/2009	100					
35.5	237	Run head	2/11/2009	100					
35.2	238	Run body	2/11/2009	100					
35.2	239	Run tail	2/12/2009	95				5	
35.2	240	Riffle	2/12/2009	100					
35.2	241	Run head	2/12/2009	100					
35.2	242	Run body	2/12/2009	100					
35.1	243	Run tail	2/12/2009	100					
35.1	244	Riffle	2/12/2009	100					
35.0	245	Run head	2/12/2009	95				5	
35.0	246	Run body	2/12/2009	95				5	
35.0	247	Run tail	2/12/2009	100					
34.9	248	Riffle	2/12/2009	100					
34.9	249	Run head	2/12/2009	95		5			
34.7	250	Run body	2/12/2009	100					
34.6	251	Pool body	2/12/2009	75				5	20
34.6	252	Pool tail	2/12/2009	100					
34.5	253	Riffle	2/12/2009	95				5	
34.5	254	Pool head	2/12/2009	100					
34.4	255	Pool body	2/12/2009	100					
34.1	256	Run body	2/12/2009	100					
34.1	257	Run tail	2/12/2009	95				5	
34.1	258	Riffle	2/12/2009	100					
34.0	259	Run head	2/12/2009	100					
34.0	260	Run body	2/12/2009	100					
33.9	261	Run tail	2/12/2009	100					
33.8	262	Riffle	2/12/2009	100					
33.8	263	Run head	2/12/2009	100					
33.8	264	Run body	2/12/2009	100					
33.8	265	Run tail	2/12/2009	100					
33.7	266	Riffle	2/12/2009	100					
33.6	267	Run head	2/12/2009	100					
33.5	268	Run body	2/12/2009	100					

River mile	Sampling unit	Habitat type	Habitat survey date	No cover (%)	Boulder (%)	Wood (%)	Ledge (%)	Overhang (%)	Aquatic vegetation (%)
33.4	269	Run tail	2/12/2009	100					
33.4	270	Riffle	2/12/2009	100					
33.4	271	Pool head	2/12/2009	100					
33.2	272	Pool body	2/12/2009	70					30
33.2	273	Pool tail	2/12/2009	100					
33.2	274	Riffle	2/12/2009	100					
33.2	275	Run head	2/12/2009	100					
33.1	276	Run body	2/12/2009	95					5
33.1	277	Run tail	2/12/2009	100					
33.0	278	Riffle	2/12/2009	100					
33.0	279	Run head	2/12/2009	100					
32.1	280	Run body	2/12/2009	60					40
32.1	281	Run tail	2/12/2009						
32.0	282	Riffle	2/12/2009						
32.0	283	Run head	2/12/2009						
32.0	284	Run body	2/12/2009						
31.9	285	Run tail	2/12/2009						
31.9	286	Riffle	2/12/2009						
31.9	287	Run head	2/12/2009						
31.7	288	Run body	2/12/2009						
31.7	289	Run tail	2/12/2009						
31.6	290	Riffle	2/12/2009						
31.6	291	Run head	2/12/2009						
31.5	292	Run body	2/12/2009						
31.5	293	Run tail	2/12/2009						
31.5	294	Riffle	2/12/2009	100					
31.4	295	Run head	2/12/2009	100					
31.3	296	Run body	2/12/2009	100					
31.3	297	Run tail	2/12/2009	100					
31.2	298	Riffle	2/12/2009	100					
31.2	299	Run head	2/13/2009	100					
31.1	300	Run body	2/13/2009	100					
31.1	301	Run tail	2/13/2009	100					
31.1	302	Riffle	2/13/2009	100					
31.1	303	Run head	2/13/2009	100					
30.7	304	Run body	2/13/2009	100					
30.7	305	Run tail	2/13/2009	90					10
30.6	306	Riffle	2/13/2009	100					
30.6	307	Run head	2/13/2009	100					
30.5	308	Run body	2/13/2009	100					
30.5	309	Run tail	2/13/2009	100					
30.4	310	Riffle	2/13/2009	85				15	
30.4	311	Run head	2/13/2009	100					
30.4	312	Run body	2/13/2009	100					
30.4	313	Run tail	2/13/2009	100					

River mile	Sampling unit	Habitat type	Habitat survey date	No cover (%)	Boulder (%)	Wood (%)	Ledge (%)	Overhang (%)	Aquatic vegetation (%)
30.2	314	Riffle	2/13/2009	90				10	
30.2	315	Run head	2/13/2009	100					
30.1	316	Run body	2/13/2009	100					
30.1	317	Run tail	2/13/2009	100					
30.1	318	Riffle	2/13/2009	100					
30.0	319	Run head	2/13/2009	100					
29.7	320	Run body	2/13/2009	70					30
29.7	321	Run tail	2/13/2009	90					10
29.6	322	Pool body	2/13/2009	100					
29.6	323	Pool tail	2/13/2009	100					
29.5	324	Riffle	2/13/2009	100					
29.5	325	Run head	2/13/2009	95	5				
29.5	326	Run body	2/13/2009	85					15
29.5	327	Run tail	2/13/2009	100					
29.5	328	Riffle	2/13/2009	100					
29.4	329	Run head	2/13/2009	100					
29.4	330	Run body	2/13/2009	100					
29.4	331	Run tail	2/13/2009	100					
29.3	332	Riffle	2/13/2009	90				10	
29.3	333	Run head	2/13/2009	100					
29.2	334	Run body	2/13/2009	100					
29.2	335	Run tail	2/13/2009	100					
29.2	336	Riffle	2/13/2009	100					
29.1	337	Run head	2/13/2009	100					
29.1	338	Run body	2/13/2009	90					10
29.0	339	Run tail	2/13/2009	100					
29.0	340	Riffle	2/13/2009	100					

Table D-3. Substrate types for sampling units within the study area.

River mile	Unit	Habitat type	Habitat survey date	Bedrock (%)	Boulder (%)	Cobble (%)	Gravel (%)	Sand (%)	Silt (%)	Organic (%)
51.8	1	Pool head	7/8/2008	10	50	40				
51.7	2	Pool body	7/8/2008	50	40	10				
51.7	3	Pool tail	7/8/2008	20	30	50				
51.6	4	Pool head	7/8/2008	50	20	30				
51.6	5	Pool body	7/8/2008	50	20	25		5		
51.5	6	Pool tail	7/8/2008	40	30	30				
51.5	7	Riffle	7/8/2008		30	60	10			
51.4	8	Run head	7/8/2008		20	60	10	10		
51.1	9	Run body	7/8/2008	15	15	60	10			
51.0	10	Run tail	7/8/2008			60	30	10		
50.9	11	Pool body	7/8/2008	20	10	50		20		
50.8	12	Run body	7/8/2008	20	10	50		20		
50.8	13	Run tail	7/8/2008			60	30	10		
50.6	14	Riffle	7/8/2008			60	30	10		
50.6	15	Run head	7/8/2008		10	50	40			
50.5	16	Run body	7/8/2008	10	10	60	20			
50.4	17	Run tail	7/8/2008		20	60	20			
50.3	18	Riffle	7/8/2008		20	60	20			
50.3	19	Run head	7/8/2008		20	60	20			
50.1	20	Run body	7/8/2008		20	60	20			
50.1	21	Run tail	7/8/2008		20	60	20			
50.1	22	Riffle	7/8/2008		20	60	20			
50.0	23	Run head	7/8/2008		20	60	20			
49.9	24	Run body	7/8/2008		60	20	20			
49.8	25	Run tail	7/8/2008		40	40	20			
49.7	26	Riffle	7/8/2008		20	60	20			
49.7	27	Pool head	7/8/2008	20	20	40	10	10		
49.6	28	Pool body	7/8/2008	20	20	40	10	10		
49.6	29	Pool tail	7/8/2008	10	20	60	10			
49.6	30	Run head	7/8/2008		20	60	20			
49.3	31	Run body	7/8/2008		20	60	20			
49.3	32	Run tail	7/8/2008		10	70	20			
49.2	33	Riffle	7/8/2008		10	70	20			
49.2	34	Run head	7/8/2008		10	70	20			
49.1	35	Run body	7/8/2008		10	70	20			
49.1	36	Run tail	7/8/2008		10	70	20			
49.1	37	Riffle	7/8/2008		10	70	20			
49.1	38	Run head	7/8/2008		10	70	20			
49.1	39	Run body	7/8/2008		10	70	20			
49.0	40	Run tail	7/8/2008		10	70	20			
48.8	41	Riffle	7/8/2008		10	70	20			
48.8	42	Run head	7/8/2008		10	70	20			
48.7	43	Run body	7/8/2008		40	40	20			

River mile	Unit	Habitat type	Habitat survey date	Bedrock (%)	Boulder (%)	Cobble (%)	Gravel (%)	Sand (%)	Silt (%)	Organic (%)
48.7	44	Run tail	7/8/2008		40	40	20			
48.4	45	Riffle	7/8/2008		20	60	20			
48.4	46	Run head	7/8/2008		10	40	50			
48.3	47	Run body	7/8/2008		10	50	40			
48.2	48	Run tail	7/8/2008		10	70	20			
48.2	49	Riffle	7/8/2008		10	70	20			
48.2	50	Run head	7/8/2008		10	70	20			
48.1	51	Run body	7/8/2008	20	10	50	20			
48.1	52	Run tail	7/8/2008	20	10	50	20			
48.0	53	Riffle	7/8/2008		10	70	20			
48.0	54	Pool head	7/8/2008	20	10	60	5	5		
47.2	55	Pool body	7/8/2008	20	10	60	5	5		
47.2	56	Pool tail	7/8/2008		10	70	20			
47.1	57	Riffle	7/8/2008		10	70	20			
47.0	58	Run head	7/8/2008		10	70	20			
46.9	59	Run body	7/8/2008	20	10	50	20			
46.9	60	Run tail	7/8/2008		20	60	20			
46.9	61	Riffle	7/8/2008		10	70	20			
46.9	62	Run head	7/8/2008		10	70	20			
46.8	63	Run body	7/8/2008		10	70	20			
46.8	64	Run tail	7/8/2008		10	60	30			
46.8	65	Riffle	7/8/2008		10	60	30			
46.8	66	Run head	7/8/2008		10	50	30	10		
46.0	67	Run body	7/8/2008		20	50	20	10		
46.0	68	Run tail	7/8/2008		10	70	20			
45.9	69	Run body	7/8/2008		10	70	20			
45.9	70	Riffle	7/8/2008			20	70	10		
45.9	71	Run head	7/8/2008			30	40	30		
45.8	72	Run body	7/8/2008			40	40	20		
45.8	73	Run tail	7/8/2008			40	50	10		
45.7	74	Riffle	7/8/2008			40	50	10		
45.7	75	Run head	7/9/2008		10	60	20	10		
45.7	76	Run body	7/9/2008		10	60	20	10		
45.7	77	Run tail	7/9/2008		10	60	20	10		
45.6	78	Riffle	7/9/2008			70	20	10		
45.6	79	Run head	7/9/2008		10	10	30	50		
45.4	80	Run body	7/9/2008	20	20	30		30		
45.3	81	Pool body	7/9/2008	30	20	20		30		
45.3	82	Run head	7/9/2008			10	30	50	10	
45.1	83	Run body	7/9/2008	10	20	50	10	10		
45.1	84	Run tail	7/9/2008		10	70	20			
45.0	85	Riffle	7/9/2008		10	60	30			
45.0	86	Pool head	7/9/2008		10	60	30			
44.9	87	Pool body	7/9/2008			60	20	20		
44.9	88	Pool tail	7/9/2008			60	20	20		

River mile	Unit	Habitat type	Habitat survey date	Bedrock (%)	Boulder (%)	Cobble (%)	Gravel (%)	Sand (%)	Silt (%)	Organic (%)
44.8	89	Riffle	7/9/2008		20	60	20			
44.8	90	Run head	7/9/2008			40	50	10		
44.8	91	Run body	7/9/2008		10	60	30			
44.8	92	Run tail	7/9/2008		10	60	30			
44.7	93	Riffle	7/9/2008			60	30	10		
44.7	94	Run head	7/9/2008			60	30	10		
44.7	95	Run body	7/9/2008							
44.7	96	Run tail	7/9/2008			40	10	50		
44.6	97	Riffle	7/9/2008		10	50	40			
44.6	98	Run head	7/9/2008		10	50	40			
44.6	99	Run body	7/9/2008		10	40	40	10		
44.5	100	Run tail	7/9/2008		10	40	40	10		
44.5	101	Riffle	7/9/2008	10	10	50	30			
44.5	102	Run head	7/9/2008		10	50	30	10		
43.9	103	Run body	7/9/2008	40	10	30	10	10		
43.7	104	Pool body	7/9/2008	20	10	20		50		
43.3	105	Run body	7/9/2008	20	10	20		50		
43.3	106	Run tail	7/9/2008		10	60	20	10		
43.2	107	Riffle	7/9/2008		10	60	30			
43.2	108	Run head	7/9/2008		10	60	20	10		
43.1	109	Run body	7/9/2008		10	60	30			
43.1	110	Run tail	7/9/2008		10	60	30			
43.0	111	Riffle	7/9/2008		10	60	30			
43.0	112	Pool head	7/9/2008		10	50	30	10		
43.0	113	Pool body	7/9/2008		10	50	30	10		
43.0	114	Pool tail	7/9/2008		10	50	30	10		
43.0	115	Run head	7/9/2008		10	50	30	10		
42.9	116	Run body	7/9/2008		10	60	30			
42.9	117	Run tail	7/9/2008		10	60	30			
42.9	118	Riffle	7/9/2008		10	60	30			
42.9	119	Run head	7/9/2008		20	50	30			
42.7	120	Run body	7/9/2008		20	50	30			
42.7	121	Run tail	7/9/2008		10	60	30			
42.7	122	Riffle	7/9/2008		10	50	40			
42.7	123	Run head	7/9/2008		10	50	40			
42.4	124	Run body	7/9/2008		10	50	40			
42.4	125	Run body	7/9/2008		10	50	40			
42.3	126	Riffle	7/9/2008		10	50	40			
42.3	127	Run body	7/9/2008	50		40	10			
42.3	128	Riffle	7/9/2008	15	10	50	20	5		
42.2	129	Run head	7/9/2008	15	10	50	20	5		
42.1	130	Run body	7/9/2008		10	60	30			
42.0	131	Run tail	7/9/2008		10	50	40			
41.9	132	Riffle	7/9/2008		15	50	35			
41.9	133	Run head	7/9/2008	15	15	45	25			

River mile	Unit	Habitat type	Habitat survey date	Bedrock (%)	Boulder (%)	Cobble (%)	Gravel (%)	Sand (%)	Silt (%)	Organic (%)
41.8	134	Run body	7/9/2008	15	15	40	20	10		
41.8	135	Run tail	7/9/2008		10	60	30			
41.7	136	Riffle	7/9/2008		10	60	30			
41.7	137	Run head	7/9/2008	15	10	50	25			
41.2	138	Run body	7/9/2008	15	10	50	25			
41.2	139	Run tail	7/9/2008		10	60	20	10		
41.1	140	Riffle	7/9/2008		10	50	30	10		
41.1	141	Run head	7/9/2008		10	50	30	10		
41.0	142	Run body	7/9/2008		10	50	30	10		
41.0	143	Run tail	7/9/2008		10	60	20	10		
40.9	144	Riffle	7/9/2008		10	60	20	10		
40.9	145	Run head	7/9/2008		10	50	40			
40.5	146	Run body	7/9/2008		50	20		30		
40.5	147	Run tail	7/9/2008		10	60	30			
40.4	148	Riffle	7/9/2008		10	50	40			
40.4	149	Run head	7/9/2008		10	50	30	10		
40.3	150	Run body	7/9/2008							
40.3	151	Run tail	7/9/2008		20	50	30			
40.2	152	Riffle	7/9/2008		20	50	30			
40.2	153	Run head	7/9/2008		20	50	30			
39.7	154	Run body	7/9/2008	20	10	50	10	10		
39.7	155	Run tail	7/9/2008		10	50	40			
39.7	156	Riffle	2/10/2009			50	40	10		
39.6	157	Run head	2/10/2009			30	20	50		
39.5	158	Run body	2/10/2009			30	20	50		
39.5	159	Run tail	2/10/2009			30	20	50		
39.4	160	Riffle	2/10/2009			50	40	10		
39.4	161	Run head	2/10/2009		10	50	30	10		
39.3	162	Run body	2/10/2009		10	50	30	10		
39.3	163	Run tail	2/10/2009	5		55	30	10		
39.2	164	Riffle	2/10/2009			50	40	10		
39.2	165	Pool head	2/10/2009			30	60	10		
38.9	166	Pool body	2/10/2009			20	50	30		
38.9	167	Pool tail	2/10/2009			50	40	10		
38.9	168	Riffle	2/10/2009			50	40	10		
38.9	169	Run head	2/10/2009			60	25	15		
38.8	170	Run body	2/10/2009			30	40	30		
38.8	171	Pool body	2/10/2009		5	60	20	15		
38.8	172	Run head	2/10/2009			60	30	10		
38.7	173	Run body	2/10/2009			60	30	10		
38.7	174	Run tail	2/10/2009			60	30	10		
38.7	175	Riffle	2/10/2009			60	30	10		
38.6	176	Run head	2/10/2009			60	30	10		
38.6	177	Run body	2/10/2009			60	30	10		
38.6	178	Run tail	2/10/2009			60	30	10		

River mile	Unit	Habitat type	Habitat survey date	Bedrock (%)	Boulder (%)	Cobble (%)	Gravel (%)	Sand (%)	Silt (%)	Organic (%)
38.5	179	Riffle	2/10/2009			60	30	10		
38.5	180	Run head	2/10/2009			50	20	30		
38.4	181	Run body	2/10/2009			60	30	10		
38.3	182	Pool body	2/10/2009		5	45	20	30		
38.3	183	Pool tail	2/10/2009		5	60	20	15		
38.3	184	Run head	2/10/2009			60	30	10		
38.2	185	Run body	2/10/2009			70	20	10		
38.2	186	Run tail	2/10/2009			60	30	10		
38.2	187	Riffle	2/10/2009			70	20	10		
38.1	188	Pool head	2/10/2009			60	30	10		
38.1	189	Pool body	2/11/2009		5	60	25	10		
38.1	190	Pool tail	2/11/2009			60	20	10	10	
38.1	191	Riffle	2/11/2009			70	20	10		
38.1	192	Pool head	2/11/2009			50	20	20	10	
38.0	193	Pool body	2/11/2009	20		20	30	30		
38.0	194	Pool tail	2/11/2009			40	40	20		
38.0	195	Run head	2/11/2009			50	40	10		
37.9	196	Run body	2/11/2009			60	30	10		
37.9	197	Run tail	2/11/2009			60	30	5	5	
37.8	198	Riffle	2/11/2009			60	30	10		
37.8	199	Pool head	2/11/2009			60	30	10		
37.7	200	Pool body	2/11/2009	10			60	30		
37.6	201	Pool tail	2/11/2009			5	75	20		
37.6	202	Riffle	2/11/2009	5		5	80	10		
37.6	203	Run head	2/11/2009			10	60	20	10	
37.5	204	Run body	2/11/2009			30	60	10		
37.4	205	Run tail	2/11/2009			40	60			
37.3	206	Riffle	2/11/2009			40	60			
37.3	207	Run head	2/11/2009			50	40	10		
37.1	208	Run body	2/11/2009			50	40	10		
37.1	209	Run tail	2/11/2009			50	50			
37.0	210	Riffle	2/11/2009			60	40			
37.0	211	Run head	2/11/2009			50	40	10		
36.9	212	Run body	2/11/2009			10	60	30		
36.9	213	Run tail	2/11/2009			20	70	10		
36.9	214	Pool head	2/11/2009			20	70	10		
36.9	215	Pool body	2/11/2009			20	50	30		
36.9	216	Pool tail	2/11/2009			10	60	30		
36.8	217	Riffle	2/11/2009			30	60	10		
36.8	218	Run head	2/11/2009			40	50	10		
36.6	219	Run body	2/11/2009			20	40	40		
36.6	220	Run tail	2/11/2009			20	60	20		
36.6	221	Riffle	2/11/2009			30	60	10		
36.6	222	Run head	2/11/2009			40	60			
36.4	223	Run body	2/11/2009			20	60	20		

River mile	Unit	Habitat type	Habitat survey date	Bedrock (%)	Boulder (%)	Cobble (%)	Gravel (%)	Sand (%)	Silt (%)	Organic (%)
36.3	224	Run tail	2/11/2009			30	60	10		
36.3	225	Riffle	2/11/2009			30	60	10		
36.3	226	Run head	2/11/2009			30	60	10		
36.3	227	Run body	2/11/2009			30	60	10		
36.2	228	Run tail	2/11/2009			30	60	10		
36.2	229	Riffle	2/11/2009			30	60	10		
36.2	230	Pool head	2/11/2009			30	60	10		
36.2	231	Pool body	2/11/2009			30	60	10		
36.2	232	Pool tail	2/11/2009			20	60	20		
36.1	233	Pool head	2/11/2009				80	20		
35.7	234	Pool body	2/11/2009	25		20	40	15		
35.6	235	Pool tail	2/11/2009			30	60	10		
35.5	236	Riffle	2/11/2009			30	60	10		
35.5	237	Run head	2/11/2009			30	60	10		
35.2	238	Run body	2/11/2009		5	15	20	60		
35.2	239	Run tail	2/12/2009			30	60	5	5	
35.2	240	Riffle	2/12/2009			35	60	5		
35.2	241	Run head	2/12/2009			35	60	5		
35.2	242	Run body	2/12/2009			30	65	5		
35.1	243	Run tail	2/12/2009			20	80			
35.1	244	Riffle	2/12/2009			20	60	20		
35.0	245	Run head	2/12/2009			20	70	10		
35.0	246	Run body	2/12/2009			40	50	10		
35.0	247	Run tail	2/12/2009			20	70	10		
34.9	248	Riffle	2/12/2009			10	80	10		
34.9	249	Run head	2/12/2009			20	70	10		
34.7	250	Run body	2/12/2009	5		25	60	10		
34.6	251	Pool body	2/12/2009	40		20	20	20		
34.6	252	Pool tail	2/12/2009	30		30	20	20		
34.5	253	Riffle	2/12/2009	5		30	65			
34.5	254	Pool head	2/12/2009	40		10	20	30		
34.4	255	Pool body	2/12/2009			30	50	20		
34.1	256	Run body	2/12/2009			30	60	10		
34.1	257	Run tail	2/12/2009			40	60			
34.1	258	Riffle	2/12/2009			30	60	10		
34.0	259	Run head	2/12/2009			40	50	10		
34.0	260	Run body	2/12/2009			30	40	30		
33.9	261	Run tail	2/12/2009			30	50	20		
33.8	262	Riffle	2/12/2009			30	60	10		
33.8	263	Run head	2/12/2009			40	60			
33.8	264	Run body	2/12/2009			40	50	10		
33.8	265	Run tail	2/12/2009			40	60			
33.7	266	Riffle	2/12/2009			40	50	10		
33.6	267	Run head	2/12/2009			10	70	20		
33.5	268	Run body	2/12/2009			20	40	40		

River mile	Unit	Habitat type	Habitat survey date	Bedrock (%)	Boulder (%)	Cobble (%)	Gravel (%)	Sand (%)	Silt (%)	Organic (%)
33.4	269	Run tail	2/12/2009			20	50	30		
33.4	270	Riffle	2/12/2009			30	60	10		
33.4	271	Pool head	2/12/2009			40	40	20		
33.2	272	Pool body	2/12/2009	10		20	30	30	10	
33.2	273	Pool tail	2/12/2009			40	50	10		
33.2	274	Riffle	2/12/2009			40	50	10		
33.2	275	Run head	2/12/2009			50	40	10		
33.1	276	Run body	2/12/2009			25	60	5	10	
33.1	277	Run tail	2/12/2009			40	50	10		
33.0	278	Riffle	2/12/2009			20	70	10		
33.0	279	Run head	2/12/2009			20	40	40		
32.1	280	Run body	2/12/2009				50	50		
32.1	281	Run tail	2/12/2009	No data collected						
32.0	282	Riffle	2/12/2009	No data collected						
32.0	283	Run head	2/12/2009	No data collected						
32.0	284	Run body	2/12/2009	No data collected						
31.9	285	Run tail	2/12/2009	No data collected						
31.9	286	Riffle	2/12/2009	No data collected						
31.9	287	Run head	2/12/2009	No data collected						
31.7	288	Run body	2/12/2009	No data collected						
31.7	289	Run tail	2/12/2009	No data collected						
31.6	290	Riffle	2/12/2009	No data collected						
31.6	291	Run head	2/12/2009	No data collected						
31.5	292	Run body	2/12/2009	No data collected						
31.5	293	Run tail	2/12/2009	No data collected						
31.5	294	Riffle	2/12/2009			40	50		10	
31.4	295	Run head	2/12/2009			20	70	10		
31.3	296	Run body	2/12/2009			10	60	30		
31.3	297	Run tail	2/12/2009			10	60	30		
31.2	298	Riffle	2/12/2009			30	60	10		
31.2	299	Run head	2/13/2009			40	50	10		
31.1	300	Run body	2/13/2009			30	40	30		
31.1	301	Run tail	2/13/2009			30	60	10		
31.1	302	Riffle	2/13/2009			30	60	10		
31.1	303	Run head	2/13/2009	10		40	40	10		
30.7	304	Run body	2/13/2009	10		40	40	10		
30.7	305	Run tail	2/13/2009			40	40	20		
30.6	306	Riffle	2/13/2009			40	50	10		
30.6	307	Run head	2/13/2009			40	50	10		
30.5	308	Run body	2/13/2009			40	50	10		
30.5	309	Run tail	2/13/2009			40	50	10		
30.4	310	Riffle	2/13/2009			30	50	20		
30.4	311	Run head	2/13/2009			30	60	10		
30.4	312	Run body	2/13/2009			40	50	10		
30.4	313	Run tail	2/13/2009		5	35	50	10		

River mile	Unit	Habitat type	Habitat survey date	Bedrock (%)	Boulder (%)	Cobble (%)	Gravel (%)	Sand (%)	Silt (%)	Organic (%)
30.2	314	Riffle	2/13/2009			30	60	10		
30.2	315	Run head	2/13/2009			30	60	10		
30.1	316	Run body	2/13/2009			30	60	10		
30.1	317	Run tail	2/13/2009			30	60	10		
30.1	318	Riffle	2/13/2009			40	50	10		
30.0	319	Run head	2/13/2009			5	15	80		
29.7	320	Run body	2/13/2009				30	70		
29.7	321	Run tail	2/13/2009				30	70		
29.6	322	Pool body	2/13/2009				20	80		
29.6	323	Pool tail	2/13/2009				30	70		
29.5	324	Riffle	2/13/2009			30	60	10		
29.5	325	Run head	2/13/2009			40	60			
29.5	326	Run body	2/13/2009				20	80		
29.5	327	Run tail	2/13/2009				60	40		
29.5	328	Riffle	2/13/2009			30	70			
29.4	329	Run head	2/13/2009			20	60	10	10	
29.4	330	Run body	2/13/2009			10	70	20		
29.4	331	Run tail	2/13/2009			10	70	20		
29.3	332	Riffle	2/13/2009			10	80	10		
29.3	333	Run head	2/13/2009			10	70	20		
29.2	334	Run body	2/13/2009			20	70	10		
29.2	335	Run tail	2/13/2009			10	70	20		
29.2	336	Riffle	2/13/2009			10	80	10		
29.1	337	Run head	2/13/2009			10	60	30		
29.1	338	Run body	2/13/2009	15		30	30	25		
29.0	339	Run tail	2/13/2009	40		20	20	20		
29.0	340	Riffle	2/13/2009	20		10	60	10		

Appendix E: Water Quality Data

Table E-1. Water quality data for the sampling units selected for snorkel sampling, September 2011.

RM	Unit	Habitat type	Sample date	Start time	Water temperature (C)	DO (ppm)	Specific conductivity (mS)	Horizontal visability (ft)	Vertical visability (ft)	Average depth (ft)	Maximum depth (ft)
51.6	4	Pool Head	21-Sep	10:20	12.6		25.5	29.5	8.0	6.0	8.0
50.9	11	Pool Body	21-Sep	12:45	13.7		25.5	27.5	16.0	8.0	16.0
50.6	14	Riffle	21-Sep	11:30	13.7		25.3	27.5	4.0	1.5	4.0
50.3	19	Run Head	21-Sep	14:15	14.7		25.3	26.0	9.0	5.0	9.0
50.1	20	Run Body	21-Sep	14:50	14.7		25.3	26.0	10.0	6.0	10.0
49.7	27	Pool Head	23-Sep	15:45	15.1		25.7	26.3	6.0	3.0	6.0
49.6	28	Pool Body	23-Sep	14:50	15.1		25.7	26.3	20.0	5.0	20.0
49.3	31	Run Body	23-Sep	14:10	15.1		25.7	26.3	8.0	4.0	8.0
49.2	33	Riffle	20-Sep	14:40	15.1		25.7	26.3	4.0	1.5	4.0
49.1	38	Run Head	20-Sep	13:05	13.9		27.3	27.0	4.5	2.5	4.5
48.7	43	Run Body	20-Sep	10:45	13.9		27.3	27.0	5.0	2.5	5.0
48.0	53	Riffle	20-Sep	17:05	15.5		26.6	28.0	4.0	1.3	4.0
48.0	54	Pool Head	20-Sep	17:20	15.5		26.6	28.0	10.0	6.0	10.0
45.9	70	Riffle	22-Sep	15:10	14.1		27.7	21.0	3.0	1.5	3.0
45.9	71	Run Head	22-Sep	14:05	14.1		27.7	21.0	4.0	2.0	4.0
45.8	72	Run Body	22-Sep	14:15	14.1		27.7	21.0	4.0	2.0	4.0
45.3	81	Pool Body	24-Sep	10:15	14.2		28.9	17.5	15.0	10.0	15.0
44.8	90	Run Head	24-Sep	9:15	14.2		28.9	17.5	3.0	1.5	3.0
44.8	91	Run Body	24-Sep	9:25	14.2		28.9	17.5	4.0	2.0	4.0
39.4	161	Run Head	22-Sep	9:15	15.9		35.9	15.5		2.5	4.0
39.3	162	Run Body	22-Sep	9:30	15.9		35.9	15.5		4.0	9.0
39.2	164	Riffle	22-Sep	10:10	15.9		35.9	15.5		1.5	3.5
39.2	165	Pool Head	22-Sep	10:25	15.9		35.9	15.5	3.5	2.0	3.5
38.3	182	Pool Body	22-Sep	12:05	16.7		37.4	15.0	12.0	4.0	12.0
38.1	192	Pool Head	22-Sep	11:00	16.7		37.4	15.0	7.0	2.5	7.0
38.0	193	Pool Body	22-Sep	11:10	16.7		37.4	15.0	12.0	8.0	12.0
36.8	217	Riffle	23-Sep	11:00	18.0		38.5	13.0	4.0	1.5	4.0

RM	Unit	Habitat type	Sample date	Start time	Water temperature (C)	DO (ppm)	Specific conductivity (mS)	Horizontal visability (ft)	Vertical visability (ft)	Average depth (ft)	Maximum depth (ft)
36.8	218	Run Head	23-Sep	11:25	18.0		38.5	13.0		4.0	6.0
36.7	219	Run Body	23-Sep	11:35	18.0		38.5	13.0		7.0	18.0
36.3	225	Riffle	23-Sep	10:20	18.0		38.5	13.0	6.0	3.0	6.0
36.2	230	Pool Head	23-Sep	9:45	16.6		37.9	10.5	8.0	3.0	8.0
36.2	231	Pool Body	23-Sep	10:00	16.6		37.9	10.5	14.0	6.0	14.0

Appendix F: Water Temperature Data

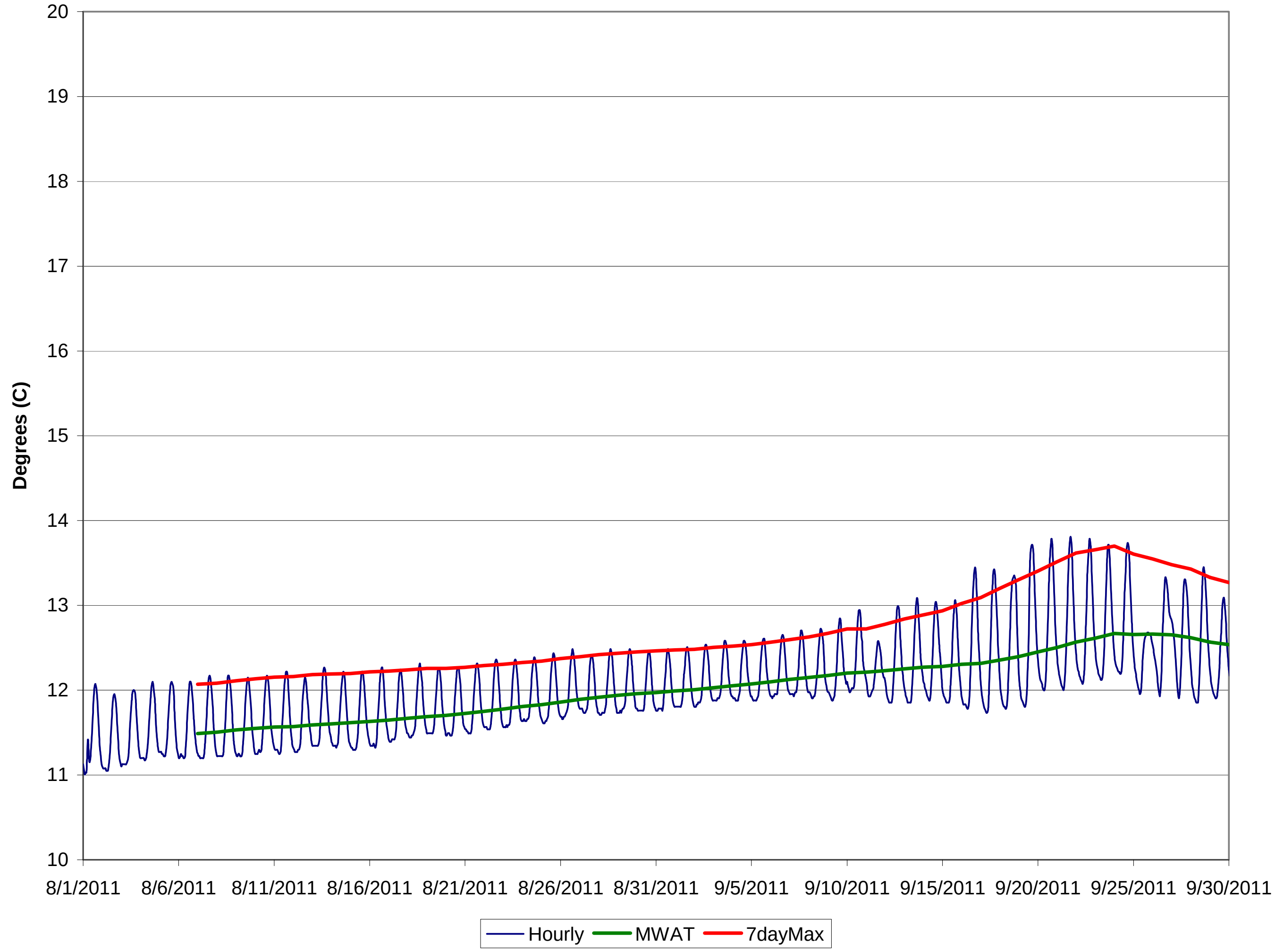


Figure F-1. Hourly, mean weekly average, and 7-day average of daily maximum temperatures at Riffle A7 (RM 50.8), August-September 2011.

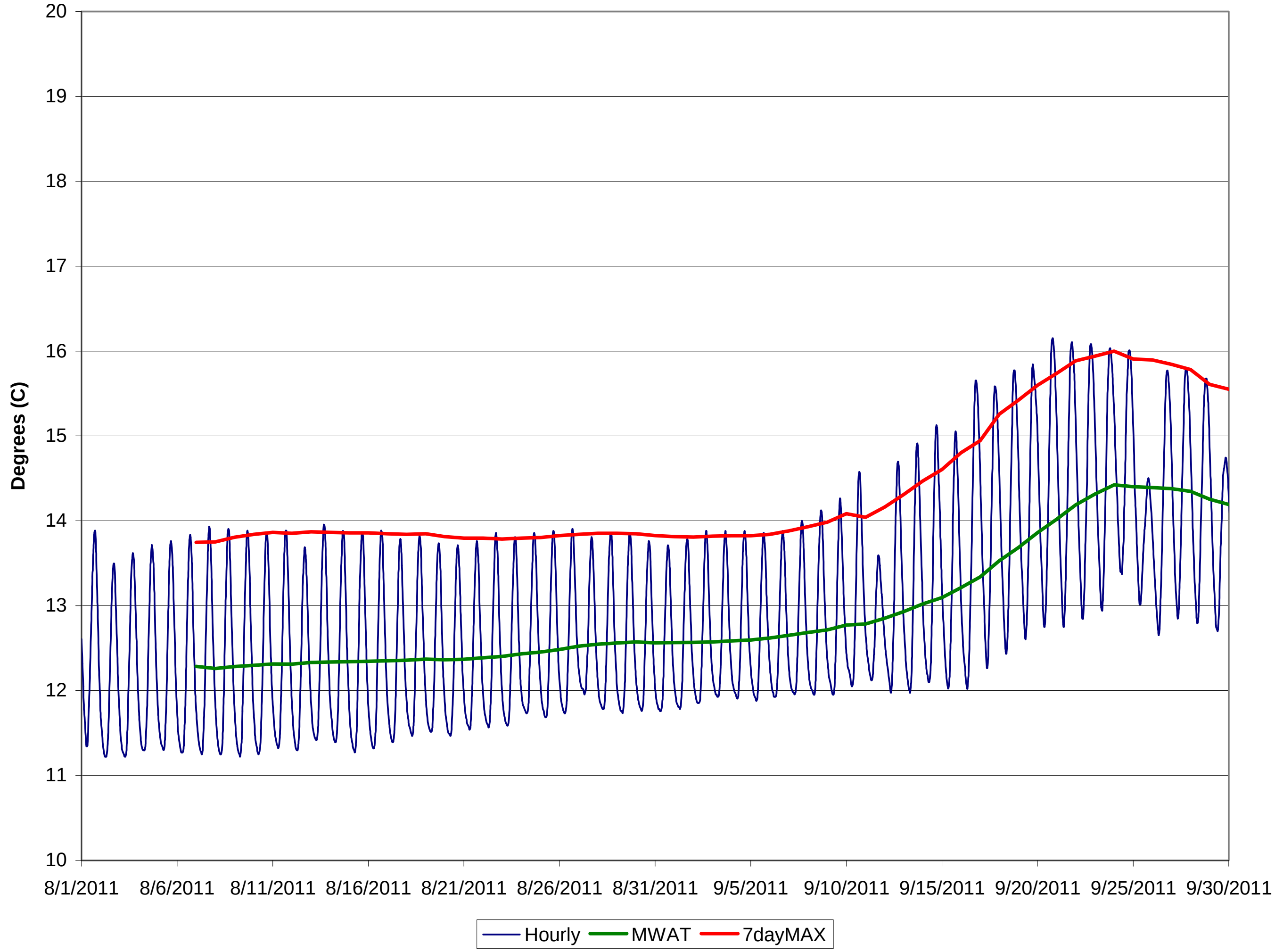


Figure F-2. Hourly, mean weekly average, and 7-day average of daily maximum temperatures at Riffle 13B (RM 45.5), August-September 2011.

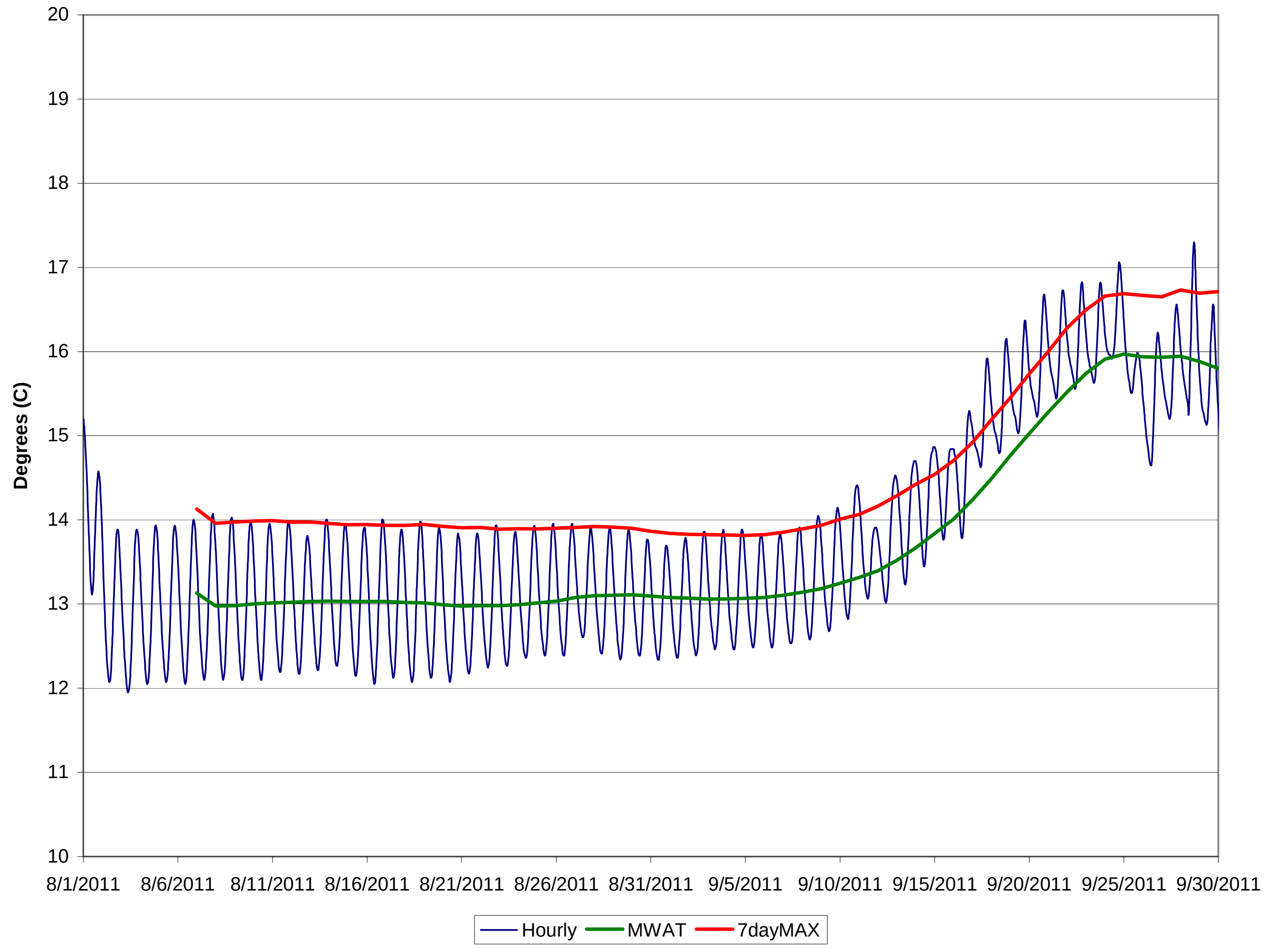


Figure F-3. Hourly, mean weekly average, and 7-day average of daily maximum temperatures at Roberts Ferry Bridge (RM 39.6), August-September 2011.

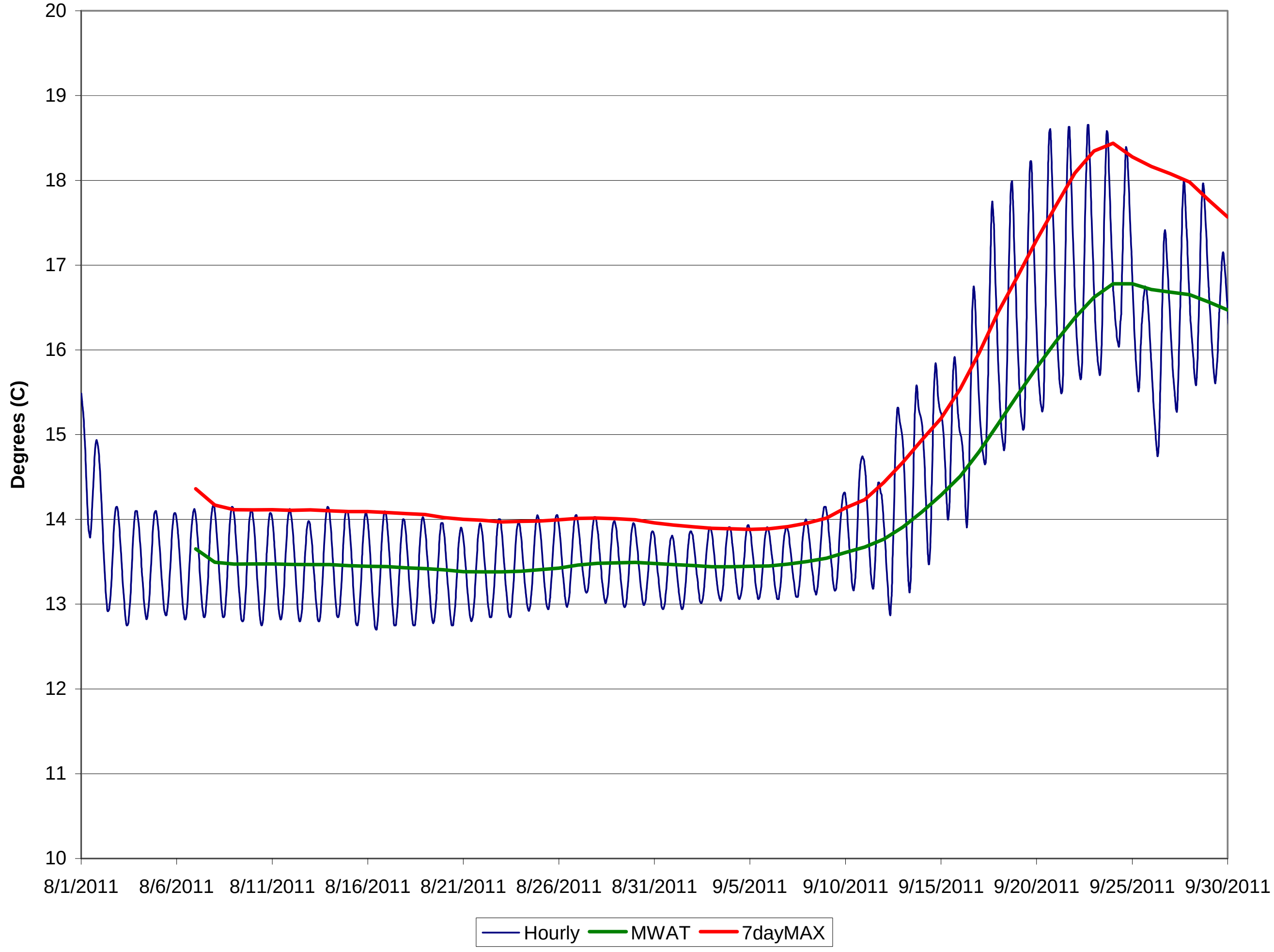


Figure F-4. Hourly, mean weekly average, and 7-day average of daily maximum temperatures at Ruddy Gravel (RM 36.5), August-September 2011.

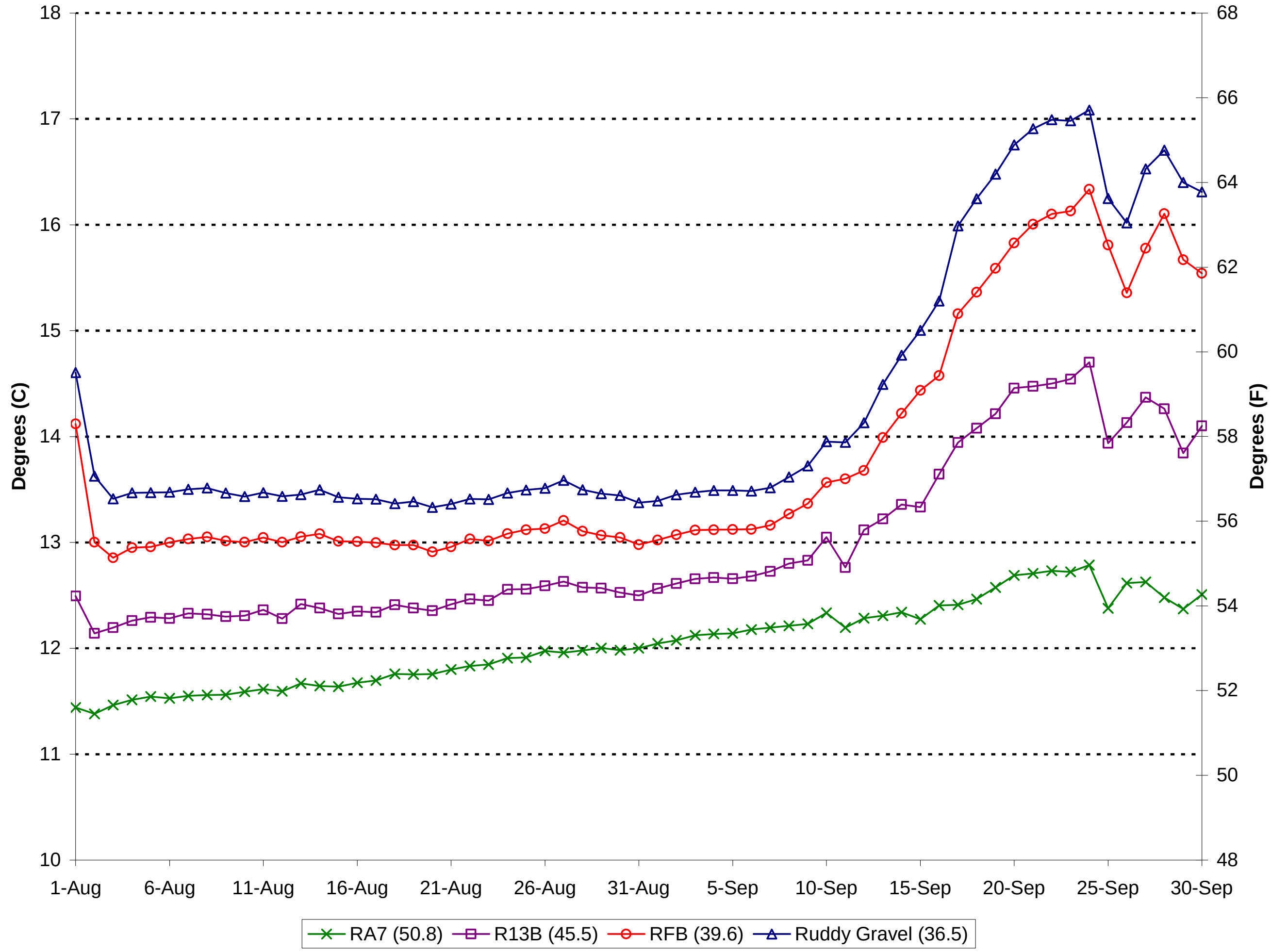


Figure F-5. Average daily water temperature from thermographs, August-September 2011.

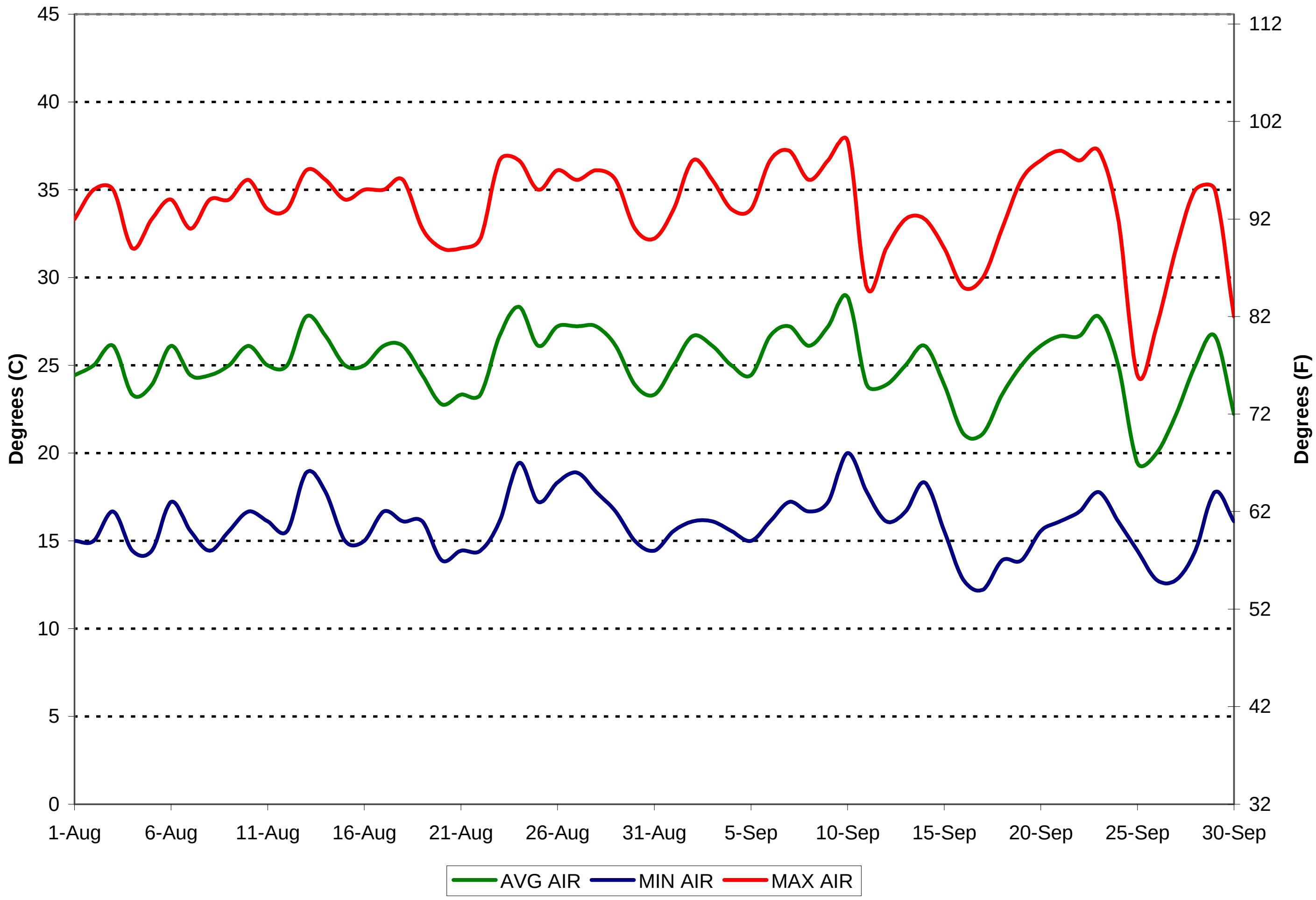


Figure F-6. Daily average, minimum, and maximum air temperature at the Modesto Airport, August-September 2011.

Appendix G: Fish Observation Data

Table G-1. *O. mykiss* observation data for the sampling units, September 2011.

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Sum of count	Size range
51.6	4	Pool Head	M	1	4	250-300
51.6	4	Pool Head	M	1	4	300-350
51.6	4	Pool Head	M	1	1	350-400
51.6	4	Pool Head	M	2	4	250-300
51.6	4	Pool Head	M	2	2	300-350
51.6	4	Pool Head	M	3	4	250-300
51.6	4	Pool Head	M	3	1	300-350
51.6	4	Pool Head	M	3	1	350-400
50.9	11	Pool Body	M	1	1	50-100
50.9	11	Pool Body	M	1	2	250-300
50.9	11	Pool Body	M	1	12	300-350
50.9	11	Pool Body	M	1	5	350-400
50.9	11	Pool Body	M	1	2	400-450
50.9	11	Pool Body	M	2	15	300-350
50.9	11	Pool Body	M	2	4	350-400
50.9	11	Pool Body	M	2	3	400-450
50.9	11	Pool Body	M	3	2	250-300
50.9	11	Pool Body	M	3	12	300-350
50.9	11	Pool Body	M	3	6	350-400
50.9	11	Pool Body	M	3	1	400-450
50.6	14	Riffle	S	1	2	0-50
50.6	14	Riffle	S	1	1192	50-100
50.6	14	Riffle	S	1	528	100-150
50.6	14	Riffle	S	1	75	150-200
50.6	14	Riffle	S	1	8	200-250
50.6	14	Riffle	S	1	5	250-300
50.6	14	Riffle	S	1	16	300-350
50.6	14	Riffle	S	1	1	350-400
50.3	19	Run Head	M	1	6	0-50
50.3	19	Run Head	M	1	57	50-100
50.3	19	Run Head	M	1	28	100-150
50.3	19	Run Head	M	1	5	150-200
50.3	19	Run Head	M	1	3	200-250
50.3	19	Run Head	M	1	3	250-300
50.3	19	Run Head	M	1	7	300-350
50.3	19	Run Head	M	1	7	350-400
50.3	19	Run Head	M	1	1	400-450
50.3	19	Run Head	M	2	5	0-50
50.3	19	Run Head	M	2	58	50-100

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Sum of count	Size range
50.3	19	Run Head	M	2	14	100-150
50.3	19	Run Head	M	2	3	150-200
50.3	19	Run Head	M	2	1	200-250
50.3	19	Run Head	M	2	9	300-350
50.3	19	Run Head	M	2	12	350-400
50.3	19	Run Head	M	2	2	400-450
50.3	19	Run Head	M	3	7	0-50
50.3	19	Run Head	M	3	40	50-100
50.3	19	Run Head	M	3	8	100-150
50.3	19	Run Head	M	3	2	150-200
50.3	19	Run Head	M	3	4	250-300
50.3	19	Run Head	M	3	6	300-350
50.3	19	Run Head	M	3	5	350-400
50.1	20	Run Body	M	1	166	0-50
50.1	20	Run Body	M	1	208	50-100
50.1	20	Run Body	M	1	135	100-150
50.1	20	Run Body	M	1	8	150-200
50.1	20	Run Body	M	1	8	200-250
50.1	20	Run Body	M	1	7	250-300
50.1	20	Run Body	M	1	8	300-350
50.1	20	Run Body	M	2	105	0-50
50.1	20	Run Body	M	2	286	50-100
50.1	20	Run Body	M	2	205	100-150
50.1	20	Run Body	M	2	29	150-200
50.1	20	Run Body	M	2	22	200-250
50.1	20	Run Body	M	2	9	250-300
50.1	20	Run Body	M	2	8	300-350
50.1	20	Run Body	M	3	70	0-50
50.1	20	Run Body	M	3	316	50-100
50.1	20	Run Body	M	3	224	100-150
50.1	20	Run Body	M	3	10	150-200
50.1	20	Run Body	M	3	8	200-250
50.1	20	Run Body	M	3	8	250-300
50.1	20	Run Body	M	3	8	300-350
49.7	27	Pool Head	M	1	82	50-100
49.7	27	Pool Head	M	1	25	100-150
49.7	27	Pool Head	M	1	2	150-200
49.7	27	Pool Head	M	1	2	200-250
49.7	27	Pool Head	M	1	1	250-300
49.7	27	Pool Head	M	2	76	50-100
49.7	27	Pool Head	M	2	27	100-150

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Sum of count	Size range
49.7	27	Pool Head	M	2	2	150-200
49.7	27	Pool Head	M	3	1	0-50
49.7	27	Pool Head	M	3	99	50-100
49.7	27	Pool Head	M	3	27	100-150
49.7	27	Pool Head	M	3	3	150-200
49.6	28	Pool Body	M	1	9	0-50
49.6	28	Pool Body	M	1	156	50-100
49.6	28	Pool Body	M	1	86	100-150
49.6	28	Pool Body	M	1	15	150-200
49.6	28	Pool Body	M	1	6	200-250
49.6	28	Pool Body	M	1	2	250-300
49.6	28	Pool Body	M	1	13	300-350
49.6	28	Pool Body	M	1	2	350-400
49.6	28	Pool Body	M	2	8	0-50
49.6	28	Pool Body	M	2	179	50-100
49.6	28	Pool Body	M	2	101	100-150
49.6	28	Pool Body	M	2	20	150-200
49.6	28	Pool Body	M	2	5	200-250
49.6	28	Pool Body	M	2	3	250-300
49.6	28	Pool Body	M	2	18	300-350
49.6	28	Pool Body	M	2	3	350-400
49.6	28	Pool Body	M	3	1	0-50
49.6	28	Pool Body	M	3	172	50-100
49.6	28	Pool Body	M	3	75	100-150
49.6	28	Pool Body	M	3	16	150-200
49.6	28	Pool Body	M	3	1	200-250
49.6	28	Pool Body	M	3	2	250-300
49.6	28	Pool Body	M	3	15	300-350
49.6	28	Pool Body	M	3	5	350-400
49.3	31	Run Body	S	1	3	0-50
49.3	31	Run Body	S	1	20	50-100
49.3	31	Run Body	S	1	232	100-150
49.3	31	Run Body	S	1	128	150-200
49.3	31	Run Body	S	1	8	200-250
49.3	31	Run Body	S	1	12	250-300
49.3	31	Run Body	S	1	17	300-350
49.3	31	Run Body	S	1	24	350-400
49.3	31	Run Body	S	1	1	400-450
49.3	31	Run Body	S	1	3	450-500
49.2	33	Riffle	M	1	3	0-50
49.2	33	Riffle	M	1	377	50-100

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Sum of count	Size range
49.2	33	Riffle	M	1	129	100-150
49.2	33	Riffle	M	1	58	150-200
49.2	33	Riffle	M	1	18	200-250
49.2	33	Riffle	M	1	2	300-350
49.2	33	Riffle	M	1	4	350-400
49.2	33	Riffle	M	1	2	400-450
49.2	33	Riffle	M	2	1	0-50
49.2	33	Riffle	M	2	391	50-100
49.2	33	Riffle	M	2	242	100-150
49.2	33	Riffle	M	2	37	150-200
49.2	33	Riffle	M	2	8	200-250
49.2	33	Riffle	M	2	2	250-300
49.2	33	Riffle	M	2	4	300-350
49.2	33	Riffle	M	2	4	350-400
49.2	33	Riffle	M	2	1	400-450
49.2	33	Riffle	M	3	369	50-100
49.2	33	Riffle	M	3	102	100-150
49.2	33	Riffle	M	3	12	150-200
49.2	33	Riffle	M	3	1	200-250
49.2	33	Riffle	M	3	3	300-350
49.2	33	Riffle	M	3	4	350-400
49.2	33	Riffle	M	3	1	450-500
49.1	38	Run Head	M	1	16	50-100
49.1	38	Run Head	M	1	46	100-150
49.1	38	Run Head	M	1	4	150-200
49.1	38	Run Head	M	1	1	300-350
49.1	38	Run Head	M	2	18	50-100
49.1	38	Run Head	M	2	27	100-150
49.1	38	Run Head	M	2	2	150-200
49.1	38	Run Head	M	3	16	50-100
49.1	38	Run Head	M	3	14	100-150
49.1	38	Run Head	M	3	6	150-200
48.7	43	Run Body	M	1	10	0-50
48.7	43	Run Body	M	1	94	50-100
48.7	43	Run Body	M	1	151	100-150
48.7	43	Run Body	M	1	48	150-200
48.7	43	Run Body	M	1	20	200-250
48.7	43	Run Body	M	1	10	250-300
48.7	43	Run Body	M	1	1	300-350
48.7	43	Run Body	M	1	5	350-400
48.7	43	Run Body	M	1	3	400-450

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Sum of count	Size range
48.7	43	Run Body	M	2	2	0-50
48.7	43	Run Body	M	2	88	50-100
48.7	43	Run Body	M	2	114	100-150
48.7	43	Run Body	M	2	47	150-200
48.7	43	Run Body	M	2	24	200-250
48.7	43	Run Body	M	2	15	250-300
48.7	43	Run Body	M	2	1	300-350
48.7	43	Run Body	M	2	4	350-400
48.7	43	Run Body	M	2	3	400-450
48.7	43	Run Body	M	3	3	0-50
48.7	43	Run Body	M	3	52	50-100
48.7	43	Run Body	M	3	110	100-150
48.7	43	Run Body	M	3	59	150-200
48.7	43	Run Body	M	3	22	200-250
48.7	43	Run Body	M	3	10	250-300
48.7	43	Run Body	M	3	4	300-350
48.7	43	Run Body	M	3	4	350-400
48.0	53	Riffle	S	1	28	50-100
48.0	53	Riffle	S	1	16	100-150
48.0	53	Riffle	S	1	1	150-200
48.0	54	Pool Head	M	1	42	50-100
48.0	54	Pool Head	M	1	22	100-150
48.0	54	Pool Head	M	1	4	150-200
48.0	54	Pool Head	M	1	2	300-350
48.0	54	Pool Head	M	1	2	350-400
48.0	54	Pool Head	M	2	45	50-100
48.0	54	Pool Head	M	2	10	100-150
48.0	54	Pool Head	M	2	3	150-200
48.0	54	Pool Head	M	2	4	300-350
48.0	54	Pool Head	M	3	34	50-100
48.0	54	Pool Head	M	3	21	100-150
48.0	54	Pool Head	M	3	3	150-200
48.0	54	Pool Head	M	3	1	200-250
48.0	54	Pool Head	M	3	3	300-350
45.9	70	Riffle	M	1	1	0-50
45.9	70	Riffle	M	1	229	50-100
45.9	70	Riffle	M	1	77	100-150
45.9	70	Riffle	M	1	17	150-200
45.9	70	Riffle	M	1	6	200-250
45.9	70	Riffle	M	1	3	250-300
45.9	70	Riffle	M	1	2	300-350

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Sum of count	Size range
45.9	70	Riffle	M	2	212	50-100
45.9	70	Riffle	M	2	125	100-150
45.9	70	Riffle	M	2	19	150-200
45.9	70	Riffle	M	2	5	200-250
45.9	70	Riffle	M	2	6	300-350
45.9	70	Riffle	M	3	240	50-100
45.9	70	Riffle	M	3	80	100-150
45.9	70	Riffle	M	3	27	150-200
45.9	70	Riffle	M	3	2	200-250
45.9	71	Run Head	S	1	27	50-100
45.9	71	Run Head	S	1	31	100-150
45.9	71	Run Head	S	1	18	150-200
45.9	71	Run Head	S	1	9	200-250
45.9	71	Run Head	S	1	6	250-300
45.9	71	Run Head	S	1	6	300-350
45.9	71	Run Head	S	1	4	350-400
45.8	72	Run Body	M	1	10	0-50
45.8	72	Run Body	M	1	60	50-100
45.8	72	Run Body	M	1	41	100-150
45.8	72	Run Body	M	1	18	150-200
45.8	72	Run Body	M	1	11	200-250
45.8	72	Run Body	M	1	6	250-300
45.8	72	Run Body	M	1	2	300-350
45.8	72	Run Body	M	2	80	50-100
45.8	72	Run Body	M	2	37	100-150
45.8	72	Run Body	M	2	18	150-200
45.8	72	Run Body	M	2	7	200-250
45.8	72	Run Body	M	2	2	300-350
45.8	72	Run Body	M	3	82	50-100
45.8	72	Run Body	M	3	39	100-150
45.8	72	Run Body	M	3	11	150-200
45.8	72	Run Body	M	3	3	200-250
45.8	72	Run Body	M	3	1	300-350
45.3	81	Pool Body	M	1	31	50-100
45.3	81	Pool Body	M	1	11	100-150
45.3	81	Pool Body	M	1	2	150-200
45.3	81	Pool Body	M	1	3	300-350
45.3	81	Pool Body	M	2	21	50-100
45.3	81	Pool Body	M	2	16	100-150
45.3	81	Pool Body	M	2	2	150-200
45.3	81	Pool Body	M	2	2	200-250

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Sum of count	Size range
45.3	81	Pool Body	M	2	1	300-350
45.3	81	Pool Body	M	2	2	350-400
45.3	81	Pool Body	M	3	15	50-100
45.3	81	Pool Body	M	3	10	100-150
45.3	81	Pool Body	M	3	3	150-200
45.3	81	Pool Body	M	3	1	200-250
45.3	81	Pool Body	M	3	4	300-350
45.3	81	Pool Body	M	3	1	350-400
44.8	90	Run Head	S	1	25	50-100
44.8	90	Run Head	S	1	5	100-150
44.8	91	Run Body	S	1	132	50-100
44.8	91	Run Body	S	1	34	100-150
44.8	91	Run Body	S	1	3	150-200
44.8	91	Run Body	S	1	3	200-250
44.8	91	Run Body	S	1	1	300-350
39.4	161	Run Head	M	1	2	150-200
39.4	161	Run Head	M	2	3	150-200
39.4	161	Run Head	M	3	2	100-150
39.4	161	Run Head	M	3	3	150-200
39.3	162	Run Body	S	1	1	350-400
39.2	164	Riffle	S	1	0	--
39.2	165	Pool Head	S	1	1	100-150
38.3	182	Pool Body	S	1	1	100-150
38.1	192	Pool Head	S	1	0	--
38.0	193	Pool Body	S	1	1	300-350
36.8	217	Riffle	S	1	1	50-100
36.8	217	Riffle	S	1	1	200-250
36.8	218	Run Head	S	1	1	150-200
36.7	219	Run Body	S	1	1	200-250
36.3	225	Riffle	M	1	2	150-200
36.3	225	Riffle	M	2	2	150-200
36.3	225	Riffle	M	2	1	300-350
36.3	225	Riffle	M	3	1	100-150
36.3	225	Riffle	M	3	1	150-200
36.3	225	Riffle	M	3	1	200-250
36.2	230	Pool Head	S	1	0	--
36.2	231	Pool Body	S	1	0	--

Table G-2. *O. tshawyschta* observation data for the sampling units, September 2011.

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Sum of count	Size range
51.6	4	Pool Head	M	1	0	
51.6	4	Pool Head	M	2	0	
51.6	4	Pool Head	M	3	2	100-150
50.9	11	Pool Body	M	1	0	
50.9	11	Pool Body	M	2	0	
50.9	11	Pool Body	M	3	0	
50.6	14	Riffle	S	1	142	50-100
50.6	14	Riffle	S	1	114	100-150
50.6	14	Riffle	S	1	50	150-200
50.6	14	Riffle	S	1	2	200-250
50.3	19	Run Head	M	1	21	50-100
50.3	19	Run Head	M	1	20	100-150
50.3	19	Run Head	M	2	18	50-100
50.3	19	Run Head	M	2	7	100-150
50.3	19	Run Head	M	3	15	50-100
50.3	19	Run Head	M	3	11	100-150
50.1	20	Run Body	M	1	111	50-100
50.1	20	Run Body	M	1	59	100-150
50.1	20	Run Body	M	1	9	150-200
50.1	20	Run Body	M	2	109	50-100
50.1	20	Run Body	M	2	77	100-150
50.1	20	Run Body	M	3	84	50-100
50.1	20	Run Body	M	3	86	100-150
49.7	27	Pool Head	M	1	77	50-100
49.7	27	Pool Head	M	1	34	100-150
49.7	27	Pool Head	M	1	3	150-200
49.7	27	Pool Head	M	2	92	50-100
49.7	27	Pool Head	M	2	45	100-150
49.7	27	Pool Head	M	2	3	150-200
49.7	27	Pool Head	M	3	88	50-100
49.7	27	Pool Head	M	3	35	100-150
49.7	27	Pool Head	M	3	2	150-200
49.6	28	Pool Body	M	1	206	50-100
49.6	28	Pool Body	M	1	106	100-150
49.6	28	Pool Body	M	1	5	150-200
49.6	28	Pool Body	M	1	1	400-450
49.6	28	Pool Body	M	2	180	50-100
49.6	28	Pool Body	M	2	81	100-150
49.6	28	Pool Body	M	2	3	150-200

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Sum of count	Size range
49.6	28	Pool Body	M	2	1	400-450
49.6	28	Pool Body	M	2	1	550-600
49.6	28	Pool Body	M	3	158	50-100
49.6	28	Pool Body	M	3	93	100-150
49.6	28	Pool Body	M	3	3	150-200
49.3	31	Run Body	S	1	260	50-100
49.3	31	Run Body	S	1	93	100-150
49.3	31	Run Body	S	1	6	150-200
49.3	31	Run Body	S	1	1	350-400
49.3	31	Run Body	S	1	4	550-600
49.2	33	Riffle	M	1	178	50-100
49.2	33	Riffle	M	1	188	100-150
49.2	33	Riffle	M	1	16	150-200
49.2	33	Riffle	M	1	5	200-250
49.2	33	Riffle	M	1	2	500-550
49.2	33	Riffle	M	2	174	50-100
49.2	33	Riffle	M	2	156	100-150
49.2	33	Riffle	M	2	10	150-200
49.2	33	Riffle	M	2	3	200-250
49.2	33	Riffle	M	2	1	350-400
49.2	33	Riffle	M	3	247	50-100
49.2	33	Riffle	M	3	103	100-150
49.2	33	Riffle	M	3	13	150-200
49.2	33	Riffle	M	3	1	200-250
49.1	38	Run Head	M	1	34	50-100
49.1	38	Run Head	M	1	20	100-150
49.1	38	Run Head	M	2	34	50-100
49.1	38	Run Head	M	2	13	100-150
49.1	38	Run Head	M	3	0	--
48.7	43	Run Body	M	1	119	50-100
48.7	43	Run Body	M	1	339	100-150
48.7	43	Run Body	M	1	31	150-200
48.7	43	Run Body	M	1	1	450-500
48.7	43	Run Body	M	2	140	50-100
48.7	43	Run Body	M	2	370	100-150
48.7	43	Run Body	M	2	42	150-200
48.7	43	Run Body	M	3	2	0-50
48.7	43	Run Body	M	3	97	50-100
48.7	43	Run Body	M	3	362	100-150
48.7	43	Run Body	M	3	36	150-200
48.0	53	Riffle	S	1	1	50-100

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Sum of count	Size range
48.0	53	Riffle	S	1	2	100-150
48.0	54	Pool Head	M	1	2	50-100
48.0	54	Pool Head	M	1	6	100-150
48.0	54	Pool Head	M	2	4	50-100
48.0	54	Pool Head	M	2	8	100-150
48.0	54	Pool Head	M	3	1	50-100
48.0	54	Pool Head	M	3	6	100-150
45.9	70	Riffle	M	1	51	50-100
45.9	70	Riffle	M	1	41	100-150
45.9	70	Riffle	M	1	1	150-200
45.9	70	Riffle	M	2	68	50-100
45.9	70	Riffle	M	2	48	100-150
45.9	70	Riffle	M	2	1	150-200
45.9	70	Riffle	M	3	82	50-100
45.9	70	Riffle	M	3	41	100-150
45.9	70	Riffle	M	3	1	150-200
45.9	71	Run Head	S	1	14	50-100
45.9	71	Run Head	S	1	9	100-150
45.8	72	Run Body	M	1	5	50-100
45.8	72	Run Body	M	1	19	100-150
45.8	72	Run Body	M	1	2	150-200
45.8	72	Run Body	M	2	28	50-100
45.8	72	Run Body	M	2	23	100-150
45.8	72	Run Body	M	2	1	150-200
45.8	72	Run Body	M	3	11	50-100
45.8	72	Run Body	M	3	22	100-150
45.8	72	Run Body	M	3	4	150-200
45.3	81	Pool Body	M	1	53	50-100
45.3	81	Pool Body	M	1	8	100-150
45.3	81	Pool Body	M	2	11	50-100
45.3	81	Pool Body	M	2	5	100-150
45.3	81	Pool Body	M	3	35	50-100
45.3	81	Pool Body	M	3	5	100-150
44.8	90	Run Head	S	1	5	100-150
44.8	91	Run Body	S	1	46	50-100
44.8	91	Run Body	S	1	26	100-150
44.8	91	Run Body	S	1	4	150-200
39.4	161	Run Head	M	1	1	100-150
39.4	161	Run Head	M	2	1	100-150
39.4	161	Run Head	M	3	2	100-150
39.3	162	Run Body	S	1	0	--

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Sum of count	Size range
39.2	164	Riffle	S	1	0	--
39.2	165	Pool Head	S	1	0	--
38.3	182	Pool Body	S	1	0	--
38.1	192	Pool Head	S	1	0	--
38.0	193	Pool Body	S	1	0	--
36.8	217	Riffle	S	1	1	50-100
36.8	217	Riffle	S	1	2	100-150
36.8	218	Run Head	S	1	0	--
36.7	219	Run Body	S	1	0	--
36.3	225	Riffle	M	1	0	--
36.3	225	Riffle	M	2	0	--
36.3	225	Riffle	M	3	4	50-100
36.3	225	Riffle	M	3	1	150-200
36.2	230	Pool Head	S	1	0	--
36.2	231	Pool Body	S	1	1	450-500

Table G-3. Non-salmonid fish observation data for the sampling units, September 2011.

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Species	Sum of count	Size range
50.9	11	Pool Body	M	3	Sculpin sp.	1	0-50
49.6	28	Pool Body	M	1	Striped bass	1	350-400
49.3	31	Run Body	S	1	Pikeminnow/Hardhead	4	450-500
49.2	33	Riffle	M	1	Sculpin sp.	8	50-100
49.2	33	Riffle	M	2	Sculpin sp.	5	50-100
49.2	33	Riffle	M	2	Sacramento sucker	1	0-50
49.2	33	Riffle	M	3	Sculpin sp.	1	100-150
49.2	33	Riffle	M	3	Sculpin sp.	17	50-100
49.1	38	Run Head	M	1	Sculpin sp.	1	50-100
49.1	38	Run Head	M	3	Sacramento sucker	1	50-100
48.7	43	Run Body	M	2	Sculpin sp.	1	50-100
48.0	53	Riffle	S	1	Sculpin sp.	1	0-50
48.0	53	Riffle	S	1	Sculpin sp.	2	50-100
48.0	53	Riffle	S	1	Sacramento sucker	1	50-100
48.0	54	Pool Head	M	1	Largemouth bass	1	200-250
48.0	54	Pool Head	M	1	Sacramento sucker	1	250-300
48.0	54	Pool Head	M	1	Sacramento sucker	1	350-400
48.0	54	Pool Head	M	2	Largemouth bass	1	200-250
48.0	54	Pool Head	M	2	Pikeminnow/Hardhead	1	400-450
48.0	54	Pool Head	M	2	Sacramento sucker	1	350-400
48.0	54	Pool Head	M	3	Largemouth bass	1	50-100
48.0	54	Pool Head	M	3	Sacramento sucker	1	250-300
45.9	70	Riffle	M	1	Sacramento sucker	8	0-50
45.9	71	Run Head	S	1	Sculpin sp.	2	50-100
45.9	71	Run Head	S	1	Sacramento sucker	5	0-50
45.8	72	Run Body	M	1	Sculpin sp.	6	50-100
45.8	72	Run Body	M	2	Sacramento sucker	2	0-50
45.8	72	Run Body	M	3	Pikeminnow/Hardhead	2	250-300
45.8	72	Run Body	M	3	Sculpin sp.	1	50-100
45.8	72	Run Body	M	3	Sacramento sucker	1	0-50
45.3	81	Pool Body	M	1	Pikeminnow/Hardhead	1	300-350
44.8	90	Run Head	S	1	Sacramento sucker	1	300-350
39.4	161	Run Head	M	1	Pikeminnow/Hardhead	2	200-250
39.4	161	Run Head	M	1	Pikeminnow/Hardhead	12	250-300
39.4	161	Run Head	M	1	Pikeminnow/Hardhead	10	300-350
39.4	161	Run Head	M	1	Sacramento sucker	50	0-50
39.4	161	Run Head	M	2	Pikeminnow/Hardhead	11	250-300
39.4	161	Run Head	M	2	Pikeminnow/Hardhead	4	350-400
39.4	161	Run Head	M	2	Sacramento sucker	32	0-50

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Species	Sum of count	Size range
39.4	161	Run Head	M	3	Pikeminnow/Hardhead	1	100-150
39.4	161	Run Head	M	3	Pikeminnow/Hardhead	9	250-300
39.4	161	Run Head	M	3	Pikeminnow/Hardhead	1	350-400
39.4	161	Run Head	M	3	Sacramento sucker	80	0-50
39.3	162	Run Body	S	1	Pikeminnow/Hardhead	1	250-300
39.3	162	Run Body	S	1	Sacramento sucker	1000	0-50
39.3	162	Run Body	S	1	Sacramento sucker	3	200-250
39.2	164	Riffle	S	1	Gambusia sp.	10	0-50
39.2	164	Riffle	S	1	Pikeminnow/Hardhead	51	0-50
39.2	164	Riffle	S	1	Sculpin sp.	1	0-50
39.2	164	Riffle	S	1	Sacramento sucker	100	0-50
38.3	182	Pool Body	S	1	Pikeminnow/Hardhead	50	0-50
38.3	182	Pool Body	S	1	Pikeminnow/Hardhead	2	150-200
38.3	182	Pool Body	S	1	Pikeminnow/Hardhead	5	200-250
38.3	182	Pool Body	S	1	Pikeminnow/Hardhead	2	250-300
38.3	182	Pool Body	S	1	Pikeminnow/Hardhead	7	350-400
38.3	182	Pool Body	S	1	Striped bass	1	400-450
38.3	182	Pool Body	S	1	Smallmouth bass	2	200-250
38.3	182	Pool Body	S	1	Sacramento sucker	151	0-50
38.3	182	Pool Body	S	1	Sacramento sucker	6	250-300
38.3	182	Pool Body	S	1	Sacramento sucker	1	300-350
38.1	192	Pool Head	S	1	Pikeminnow/Hardhead	20	0-50
38.1	192	Pool Head	S	1	Sacramento sucker	50	0-50
38.0	193	Pool Body	S	1	Bluegill	1	0-50
38.0	193	Pool Body	S	1	Pikeminnow/Hardhead	1	250-300
38.0	193	Pool Body	S	1	Pikeminnow/Hardhead	1	400-450
38.0	193	Pool Body	S	1	Sacramento sucker	30	0-50
38.0	193	Pool Body	S	1	Sacramento sucker	4	400-450
36.8	218	Run Head	S	1	Common carp	5	300-350
36.8	218	Run Head	S	1	Pikeminnow/Hardhead	200	0-50
36.8	218	Run Head	S	1	Sacramento sucker	300	0-50
36.7	219	Run Body	S	1	Common carp	10	300-350
36.7	219	Run Body	S	1	Common carp	36	350-400
36.7	219	Run Body	S	1	Common carp	2	400-450
36.7	219	Run Body	S	1	Common carp	42	450-500
36.7	219	Run Body	S	1	Largemouth bass	1	150-200
36.7	219	Run Body	S	1	Pikeminnow/Hardhead	2	150-200
36.7	219	Run Body	S	1	Pikeminnow/Hardhead	5	200-250
36.7	219	Run Body	S	1	Pikeminnow/Hardhead	16	250-300
36.7	219	Run Body	S	1	Pikeminnow/Hardhead	11	300-350

RM	Unit	Habitat	Single (S) or multiple (M) pass	Pass	Species	Sum of count	Size range
36.7	219	Run Body	S	1	Pikeminnow/Hardhead	5	350-400
36.7	219	Run Body	S	1	Smallmouth bass	1	150-200
36.7	219	Run Body	S	1	Sacramento sucker	2	200-250
36.7	219	Run Body	S	1	Sacramento sucker	22	350-400
36.7	219	Run Body	S	1	Sacramento sucker	10	400-450
36.3	225	Riffle	M	1	Common carp	2	500-550
36.3	225	Riffle	M	1	Pikeminnow/Hardhead	15	0-50
36.3	225	Riffle	M	1	Pikeminnow/Hardhead	2	100-150
36.3	225	Riffle	M	1	Pikeminnow/Hardhead	1	150-200
36.3	225	Riffle	M	1	Pikeminnow/Hardhead	16	250-300
36.3	225	Riffle	M	1	Sacramento sucker	100	0-50
36.3	225	Riffle	M	1	Sacramento sucker	8	450-500
36.3	225	Riffle	M	2	Common carp	1	200-250
36.3	225	Riffle	M	2	Common carp	2	450-500
36.3	225	Riffle	M	2	Pikeminnow/Hardhead	60	0-50
36.3	225	Riffle	M	2	Pikeminnow/Hardhead	1	100-150
36.3	225	Riffle	M	2	Pikeminnow/Hardhead	1	150-200
36.3	225	Riffle	M	2	Pikeminnow/Hardhead	1	200-250
36.3	225	Riffle	M	2	Pikeminnow/Hardhead	7	250-300
36.3	225	Riffle	M	2	Sacramento sucker	9	0-50
36.3	225	Riffle	M	3	Common carp	1	150-200
36.3	225	Riffle	M	3	Common carp	3	500-550
36.3	225	Riffle	M	3	Pikeminnow/Hardhead	70	0-50
36.3	225	Riffle	M	3	Pikeminnow/Hardhead	1	100-150
36.3	225	Riffle	M	3	Pikeminnow/Hardhead	4	150-200
36.3	225	Riffle	M	3	Pikeminnow/Hardhead	8	250-300
36.3	225	Riffle	M	3	Sculpin sp.	1	0-50
36.3	225	Riffle	M	3	Sacramento sucker	105	0-50
36.3	225	Riffle	M	3	Sacramento sucker	1	400-450
36.2	230	Pool Head	S	1	Striped bass	1	350-400
36.2	231	Pool Body	S	1	Striped bass	1	400-450
36.2	231	Pool Body	S	1	Smallmouth bass	2	150-200
36.2	231	Pool Body	S	1	Smallmouth bass	1	200-250
36.2	231	Pool Body	S	1	Smallmouth bass	1	300-350
36.2	231	Pool Body	S	1	Sacramento sucker	11	350-400
36.2	231	Pool Body	S	1	Sacramento sucker	20	400-450
36.2	231	Pool Body	S	1	Sacramento sucker	10	450-500