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TECHNICAL MEMORANDUM

TO: Erwin Van Nieuwenhuyse, USFWS – AFRP
John Raine, New Hogan Lake Conservancy

FROM: Jennifer Vick and Dirk Pedersen

DATE: February 2, 2000

RE: Calaveras River Spawning Gravel Assessment

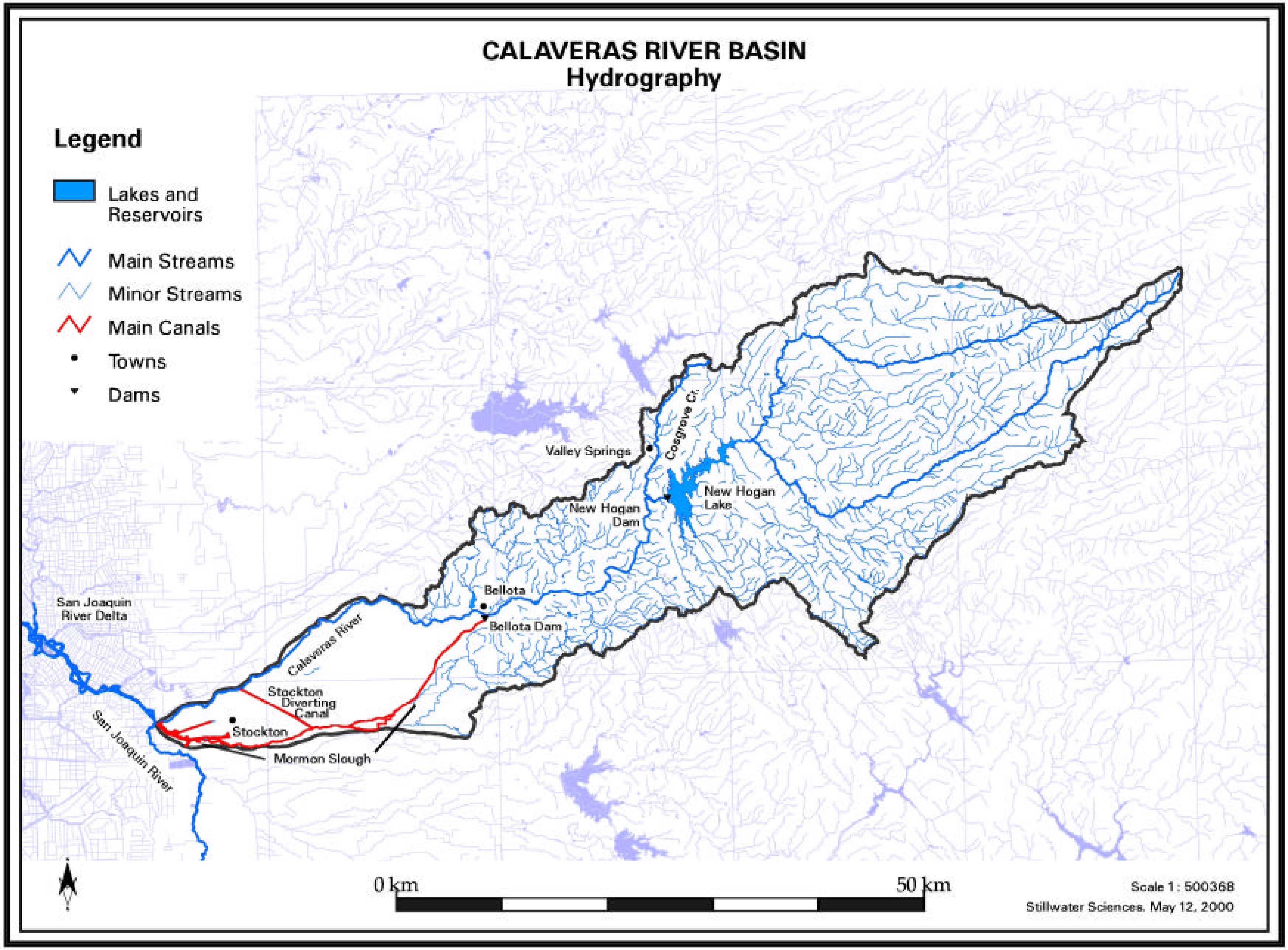
The U.S. Fish and Wildlife Service Anadromous Fish Restoration Program (AFRP) retained Stillwater Sciences to conduct a reconnaissance-level evaluation of chinook salmon spawning habitat quality and carrying capacity in the Calaveras River immediately downstream of New Hogan Dam and to provide a technical memorandum summarizing our field observations and analysis. Our approach included habitat mapping throughout the entire study reach, detailed evaluation of a subset of potential spawning riffles, and superimposition modeling. This memorandum summarizes our findings and analysis and provides our field data. Please let us know if you have any questions.

Overview

Chinook salmon spawning habitat was assessed in the 1.5-mile reach of the Calaveras River downstream of New Hogan Dam. Few potentially suitable spawning riffles were identified during the assessment, and conditions at these locations indicate relatively poor gravel quality. Permeability measurements were generally low indicating relatively high levels of subsurface sands and fines. Predicted survival-to-emergence based on substrate permeability was less than 50% at all locations. Modeling results suggest that spawning habitat availability in the assessment reach is not likely limiting, given the low escapement into the Calaveras River observed in recent years, and the apparent preference for habitat downstream. Additionally, increasing spawning habitat availability, if utilized, may not provide significant benefits to salmon production in the long-term due to relatively poor subsurface conditions. We recommend assessing habitat conditions downstream of the gorge to set the stage for a limiting factors assessment to evaluate the importance of spawning gravel quality and quantity throughout the Calaveras River basin relative to other factors.

Setting

The Calaveras River watershed drains approximately 362 mi^2 (928 km^2) of the west slope of the Sierra Nevada foothills and is situated just to the south of the Mokelumne River watershed. The average annual runoff of the Calaveras River is approximately 166,000 acre-feet (af) (2.05×10^8 m^3). Flows in the lower Calaveras River are controlled by releases from New Hogan Dam, which is located near the town of Valley Springs, approximately 34 miles (54 km) from the confluence with the San Joaquin River in western Calaveras County (see Map 1). The reservoir created by the dam, New Hogan Lake, has a gross pool



Map 1. Calaveras River Basin

capacity of approximately 325,000 af ($4.01x10^8$ m^3); about twice the average annual runoff from the watershed. New Hogan Dam was constructed in 1964 by the U.S. Army Corps of Engineers and is currently operated by the U.S. Bureau of Reclamation for municipal and agricultural use. Bellota Dam, located approximately 15 miles (21 km) downstream of New Hogan Dam, diverts flows into the Stockton East Irrigation system. The Calaveras River flows through the city of Stockton before entering the San Joaquin River in the Delta.

The Calaveras River watershed receives runoff primarily as rainfall, with about 93 percent of the runoff occurring from November through April (CALFED 1999). The average annual streamflow is 240 cfs (6.8 m^3/s). During extremely wet winters, peak average monthly flows can approach 3,000 cfs (85.0 m^3/s). Reports suggest that under both current and historical conditions, summer and early fall flows are very low, and in low rainfall years the channel may be dry from July through October (CALFED 1999; Clark 1929, as cited in Yoshiyama et al. 1996). Because of the large capacity of New Hogan Lake relative to the average annual inflow, spills occur only in wet years. Currently, instream flow releases during the irrigation season (May–September) generally range from 150 to 250 cfs (4.2–7.1 m^3/s) (Reynolds et al. 1993, CALFED 1999).

There are three migration routes that adult chinook salmon may use to access the mainstem Calaveras River upstream of Bellota Dam: (1) the historical Calaveras River channel below Bellota Dam, (2) Mormon Slough, and (3) Mormon Slough via the Stockton Diverting Canal (see Map 1). However, numerous irrigation dams along these migration routes create partial or complete migration barriers to chinook salmon (CALFED 1999), and therefore limit salmon access to the habitat in the mainstem Calaveras River, between Bellota Dam and New Hogan Dam. Prior to 1999, Bellota Dam formed a barrier to upstream migration at flows less than approximately 200 cfs (CALFED 1999). A semi-permanent fish passage structure was placed at Bellota Dam (i.e., the upstream end of Mormon Slough) in 1999 to facilitate fish passage into the mainstem Calaveras River above Bellota Dam. Currently, the majority of chinook salmon migrate through the Stockton Diverting Canal and Mormon Slough to access the mainstem Calaveras River because there are generally higher flows in these diversion channels than in the historical Calaveras River channel.

Little information is available regarding current or historical abundance of chinook salmon in the Calaveras River. Fall run and winter run chinook salmon have been known to return irregularly to the Calaveras River. It is reported, however, that conditions in this river were likely always marginal for salmon (E. Gerstung, pers. obs., as cited in Yoshiyama et al. 1996). The intermittency of returns is likely dependent on streamflow, with salmon returning only during wet years. Since construction of New Hogan Dam in 1964, there have been occasional observations of both fall and winter run chinook in the river. Between 1972–1984, winter run chinook salmon were documented in six years (1972, 1975, 1976, 1978, 1982, 1984) (CALFED 1999). In recent years, fall run salmon have been observed in the Calaveras River when suitable streamflows have occurred. In the fall of 1995, “several hundred” fall run chinook were observed below Bellota Dam in Mormon Slough, near the town of Bellota (CDFG unpubl. data, as cited in Yoshiyama. et al. 1996) (see Map 1). Regular surveys of adult escapement or spawning have not been conducted in the Calaveras River. However, CDFG conducted seining surveys in 1998 and found age 0+ chinook salmon rearing in the lower river (M. Fjelstad, pers. com., 1999).

We evaluated the spawning conditions for chinook salmon in the 1.5-mile reach downstream of New

Hogan Dam. The purpose of this investigation was to provide the AFRP with baseline information on chinook salmon spawning conditions and enable AFRP to better assess the potential benefits of gravel augmentation in this reach. A gravel augmentation project is currently being considered that would consist of adding approximately 2,200 cubic yards (1,682 m^3) of gravel to the river at two locations along a roughly 1,200-feet (366-m) reach from about one half mile downstream of New Hogan Dam to about 450 feet (137 m) downstream of the flow gage near the New Hogan Dam Road bridge. The purpose of the augmentation is to enhance chinook salmon spawning habitat in the Calaveras River.

Methods

The assessment included habitat mapping of the whole reach, assessment of potential spawning habitat suitability and quality, and modeling of spawning habitat limitations. Aerial photographs from 1998 (1:2,000 scale) were evaluated prior to field investigations and used to assess general site characteristics including: valley confinement, channel planform, vegetation characteristics, and depositional locations. Chinook salmon spawning gravel conditions in the 1.5-mile survey reach were assessed in the field by delineating stream habitat units and mapping the extent of potentially suitable spawning habitat. Surveys were conducted when flow conditions were similar to those expected during the chinook salmon spawning period. The mapping effort provided a large-scale spatial context from which to assess habitat availability and to select locations to conduct intensive evaluation of spawning gravel conditions. Spawning gravel conditions were assessed on two levels: (1) the coarse framework materials were evaluated to assess spawning suitability; and (2) substrate permeability was assessed to predict survival-to-emergence of salmon eggs and alevins.

Habitat Mapping

Habitat surveys were conducted from New Hogan Dam to approximately 1.5 miles (3.9 km) downstream on 29–30 September 1999. Both walking and canoe surveys were used to map this reach. During the survey period, flows within the reach averaged 120 cfs. The geomorphically-based habitat classification system developed for the Lower American River (Snider et al. 1992) was used to delineate study reaches, major channel features, channel feature types, and habitat types. This classification system was chosen because of its broad applicability to mainstem Central Valley alluvial rivers and to maintain consistency with other recent or ongoing projects in the Central Valley. Habitat and channel features were drawn onto laminated copies of 1998 black and white aerial photographs enlarged 129 percent to 1:1,550 scale (original scale 1:2,000). The mapping allowed us to delineate potentially suitable spawning locations and identify substrate sampling sites. A summary of the habitat classification system is provided in Table 1.

Table 1. Geomorphically-based habitat classification system developed for the American River (Snider et al. 1992).

LEVEL 1 - STUDY REACH This is the broadest level of classification based on gradient, tidal influence and general characteristics.	
LEVEL 2 - MAJOR CHANNEL FEATURES This level is based on areas of hydraulic control and areas in between. There are three categories within this level.	
Bar Complexes	River areas in which submerged and emergent bars are the primary channel feature.
Flatwater	Areas where primary channel is uniform and without gravel bars or any channel control.
Off-Channel	Areas distinctly separate from main channel.

LEVEL 3 - CHANNEL FEATURE TYPES This is the most descriptive level in terms of channel structure and includes eleven categories.	
Island Complex	Stable island located in main channel; supports established riparian vegetation.
Mid-Channel Bar	Temporary island located in main channel; generally lacks established riparian vegetation.
Lateral Bar	Contiguous with one main-channel bank, does not span channel; less built up than island complex; lacks established riparian vegetation.
Channel-Spanning Bar	Spans entire channel at approximate right angle.
Transverse Bar	Spans entire channel at approximate acute angle.
Channel Bend	Main channel primarily curved.
Straight Channel	Main channel primarily without curvature.
Split Channel	Main channel split into two or more channels.
Contiguous	Off-channel area contiguous with main channel.
Non-Contiguous	Off-channel area not contiguous with main channel.
Chevron Bar	Describes habitat enhancement structures .
LEVEL 4 - HABITAT UNITS This level includes the classic pool, riffle, run, and glide habitats.	
Pool Head	Transition area from fast water unit to a pool; water surface slope decrease and bed slope increases.
Pool Body	Very slow velocity; generally contains deepest portion of pool.
Pool Tail	Transition area into fast water unit; depth decreases and velocity increases.
Glide	Relatively low gradient and below average depths and velocities; no turbulence.
Run	Moderate gradient with above average depths and velocities; low to moderate turbulence.
Riffle	Relatively high gradient with above average velocities, below average depths; surface turbulence and channel controls.
Backwater	Low-velocity areas not contiguous with the main channel; often associated with downstream ends of lateral bars, and shaded by riparian vegetation.

Assessment of Spawning Habitat Quality

Substrate conditions were assessed in detail at five riffles. This assessment involved documenting coarse particle size distribution using pebble counts (Wolman 1955), measuring permeability, and photographing surface and subsurface substrates. Substrate permeability was measured using a modified Mark IV standpipe (Terhune 1958, Barnard and McBain 1994) and an electric pump assembly (see Attachment B: Photo 1). The standpipe used was 46.5 inches (118 cm) long, 1.0 inch (2.5 cm) inside diameter and 1.25 inch (3.8 cm) outside diameter. To measure permeability, the standpipe was driven into the substrate to a depth of 1.0 ft (30 cm) below the top of the bed surface layer (measured to the middle of the band of perforations on the standpipe). To reduce the potential for water 'slippage' down the pipe, the standpipe was not forced in any direction during the driving process. Five consecutive permeability measurements were taken at each site, and two sites were sampled within each riffle.

At each riffle sampled, photos were taken of bed surface and subsurface materials at the locations in the river where permeability was measured. Locations were photographed by first taking photos of the surface layer, then clearing away the surface layer and photographing the subsurface. Individual pieces of the surface layer were removed by hand to expose the subsurface substrate. Methods of photographic analysis are described by Church (1987). Analysis of the photography, however, was beyond the scope of this project.

Photos were taken using a Nikonos-IV self-contained 35 mm underwater camera fitted with a single extender tube for closeup photography, and an Ikelite 50 strobe flash system (see Attachment B: Photo 2). A field frame was attached to the camera and rested against the substrate to allow a precise, fixed camera-to-subject distance for all photographs. The area of substrate depicted in each photograph is approximately 9.9 in^2 (63.6 cm^2). The photographs were saved for future analysis, if needed.

Spawning Habitat Limitations

To assess potential limitations in spawning habitat quantity, a redd superimposition model developed by Stillwater Sciences was used to predict adult spawner carrying capacity. The model is an individual-based spatially explicit model of chinook salmon spawning dynamics that estimates egg mortality caused by redd superimposition. Using information on adult escapement, observed preference of fish for particular reaches, available spawning gravel area, and redd construction behavior and phenology, the model estimates the number of viable eggs in suitable locations at the end of the spawning season. A similar model was used in combination with extensive field studies on redd superimposition as part of the assessment of the population dynamics of fall chinook salmon in the Tuolumne River, California, and demonstrated that reducing redd superimposition would be one of the most important steps that could be taken to improve salmon production in the Tuolumne River (Ligon 1997). Because the number of successfully deposited eggs predicted by the model is directly related to the number of spawners, the model can generate stock-production relationships. Output from the redd superimposition model can be expressed as the percent of eggs killed by superinposition or as the number of viable eggs deposited both as a function of population size.

Due to the lack of life history information available for chinook salmon populations in the Calaveras River, female fecundity, redd construction behavior and migration timing parameters used in the model were based on the fall run chinook salmon population in the Tuolumne River. We have no reason to believe that the characteristics of chinook populations used to parameterize the model would vary substantially between the Calaveras and Tuolumne rivers. The size of individual patches of potential spawning habitat in the Calaveras River was measured from the habitat maps generated for this project.

Other Field Measurements

In addition to the field surveys discussed above, supplementary information was collected to provide additional insight on chinook salmon spawning habitat conditions in the reach surveyed. Channel slope was measured at representative locations along the reach using a hand level and stadia rod. Water temperature was measured at each riffle for which permeability measurements were collected. Ground level photographs were also taken to document habitat conditions observed during the surveys (see Attachment B: Photos 3–13). In addition to these measures, incidental observations of substrate characteristics such as differences in particle angularity, were used to qualitatively assess spawning gravel quality.

Results and Discussion

The length of the Calaveras River surveyed for this project can be divided into two distinct reaches — (1) from New Hogan Dam to Cosgrove Creek and (2) from Cosgrove Creek to the downstream end of the survey. The reach from New Hogan Dam to Cosgrove Creek is alluvial and exhibits an alternate bar-pool morphology, although this morphology has been modified by vegetation encroachment that has resulted from a reduction in peak flows. Average channel gradient in this reach is approximately 0.005 (based on USGS 1:24,000 topographic maps) (Figure 1). Typical channel width is 85 feet (26 meters), and the bed is composed of gravel, cobble, and sand. Bedrock outcrops in the channel bed and banks are common at the upstream end of this reach (immediately downstream of New Hogan Dam). Throughout this reach, the channel bed surface contains large quantities of fine sediment (<2mm) (based on visual inspection), which is likely a result of lack of bed mobilization downstream of the dam. Downstream of Cosgrove Creek, the channel enters a steep, bedrock confined gorge. In this reach, average channel gradient is 0.013 (based on USGS 1:24,000 topographic maps), nearly a 3-fold increase from the alluvial reach upstream (Figure 1). The channel is highly confined with channel bed and banks composed primarily of bedrock. Riffles in this reach are steep and composed of large boulders, and no gravel deposits suitable for spawning were observed. Pools, which are suitable for adult salmon holding, are common in this reach.

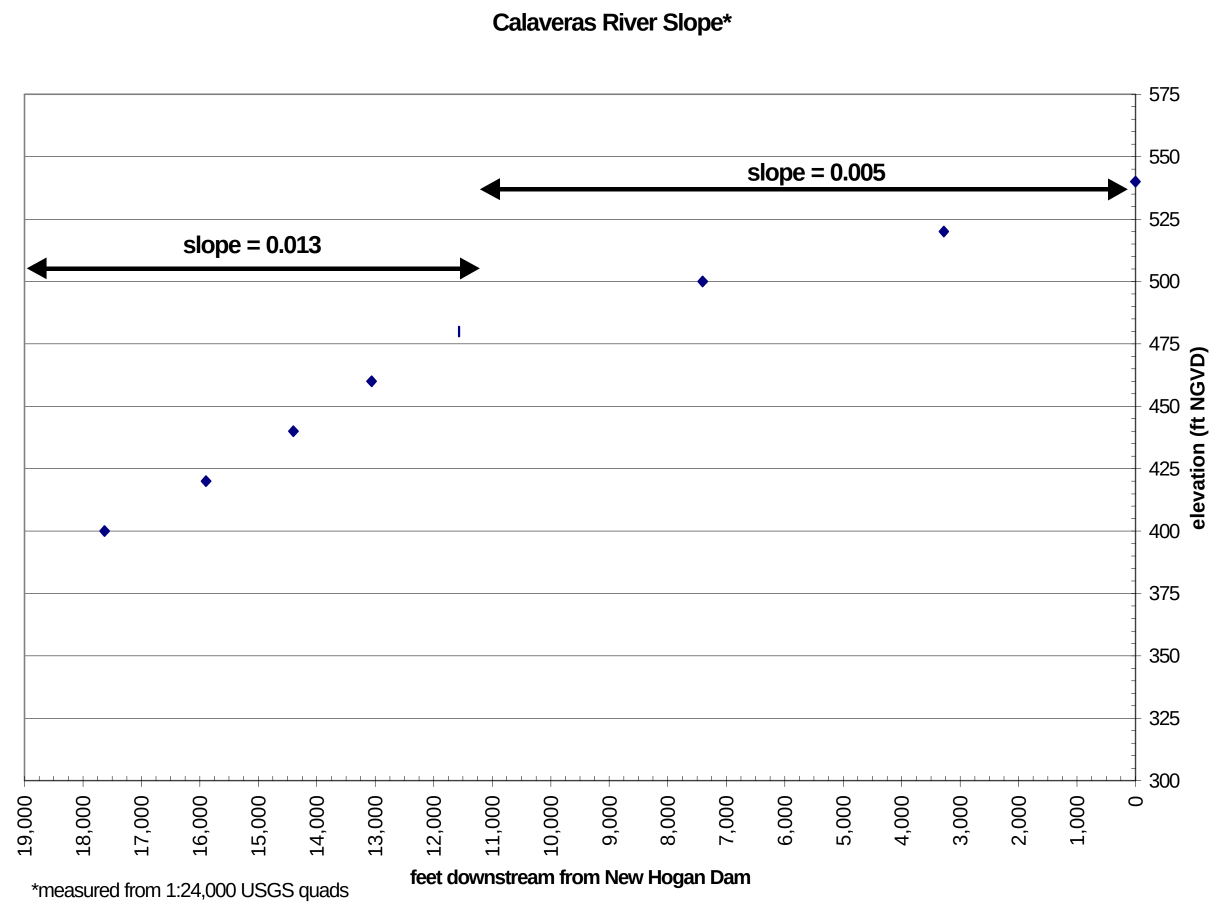


Figure 1. Channel gradient (slope) of the Calaveras River downstream of New Hogan Dam

The reach upstream of Cosgrove Creek can be further divided into two subreaches — (1a) from New Hogan Dam to New Hogan Bridge (approximately 3,275 ft [998 m] downstream of New Hogan Dam) and (1b) from New Hogan Bridge to Cosgrove Creek (approximately 5,550 ft [1,692 m] downstream of New Hogan Dam). The basis for this division is a grade control occurring at New Hogan Bridge. The gradient in reach 1a is controlled by a concrete weir located at New Hogan Bridge. This grade control reduces channel slope and, therefore, reduces channel shear stresses in the upstream reach. Upstream of the grade control, riffle slope is typically 0.002; downstream of the grade control, riffle slope ranges from 0.007 to 0.011. As a result, riparian vegetation encroachment in the upstream reach is greater than downstream. Upstream of the grade control, all formerly active bars have been encroached by riparian vegetation. Downstream of the grade control, active lateral and midchannel bars occur in the channel.

Aerial photographs with transparent overlays showing habitat units, substrate composition, and sample sites are included in Attachment A. A total of 11 riffles were identified by the field surveys. Of these, five riffles with potentially suitable habitat for chinook salmon spawning were assessed in detail. The results of these assessments are summarized in Table 2.

Table 2. Results of Detailed Riffle Assessments

Riffle No.	Temperature[1] (ºF) [EC]	WSE Slope (%)	Depth (ft)[2] [m]	Substrate Size (mm)		Permeability (cm/hr)
				d_{50}	d_{84}	
RF 3	12.5 [54.5]	--	1.2 [0.37]	48	70	3837 6993
RF 4	12.5 [54.5]	0.2	1.7 [0.52]	68	105	572 463
RF 5	12.5 [54.5]	0.2	0.6 [0.18]	68	90	217 1380
RF 6	12.5 [54.5]	1.1	1.4 [0.43]	73	130	112 n/d
RF 9a	12.5 [54.5]	0.7	0.4 [0.12]	55	75	2722 217
RF 9b	--	--	--	38	55	--

[1] spot measurements taken with permeability samples
[2] average

Macrohabitat Suitability

Evaluation of chinook salmon spawning habitat suitability was based on macrohabitat preference and depth, velocity, and substrate particle size criteria. Chinook salmon prefer pool tails and riffles for spawning (Healey 1991). Preferred water depth for spawning ranges from 12 to 22 inches (0.3 to 0.56 m) (Healey 1991). Average velocities in spawning areas range from 1 ft/s (30 cm/s) to over 3 ft/s (100 cm/s), with an observed range of 0.3 to 6.2 ft/s (10 to 190 cm/s) (Healey 1991, Thompson 1972, as cited in Bjornn and Reiser 1991).

Based on information available in the literature, it is difficult to define the substrate size range that is suitable for salmon spawning. Preferred spawning substrate size for fall chinook salmon is generally cited to range from 0.5 to 4 inches (13 to 102 mm) (Platts et al. 1979, Bell 1986, as cited in Bjornn and Reiser 1991). However, available studies generally do not provide information critical to interpreting and applying their results. First, the size of particles a salmon can use are strongly related to the size of the fish (Kondolf and Wolman 1993). Studies available in the literature, however, generally do not indicate the size of the fish evaluated by the study. Because different populations of chinook vary considerably in size, it is difficult to apply this range to any given population. Second, most studies do not indicate the substrate size metric that is being reported. For example, it in not clear whether the reported sizes reflect the median particle size (d_{50}) of the bed, the maximum particle size, or some other metric. The difference between these metrics is substantial. Because of the lack of a clear metric for assessing whether substrate particles are too coarse for chinook salmon spawning, we used surface particle size distributions from the Tuolumne River that are known to be used by chinook salmon for spawning as a reference for evaluating substrate suitability.

Pebble counts were conducted at five riffles in the surveyed reach. Two pebble counts were conducted at riffle 9. Cumulative particle size distribution curves are provided in Attachment 3. The d_{50} and d_{84} of the riffles surveyed ranged from 38 to 73 mm and 55 to 130 mm, respectively (Table 2). A combined plot of cumulative particle size distribution curves from spawning locations in the Tuolumne River used extensively by chinook salmon and the six curves from potential spawning habitat in the Calaveras River is provided in Attachment 3. Comparison of substrate composition of the Calaveras River with that of Tuolumne River spawning areas indicates that potential spawning substrates in the Calaveras River are generally within the range used by chinook salmon. Substrates at three locations in the Calaveras were, however, coarser that conditions observed in the Tuolumne River. There is insufficient information available to determine whether these substrates are too coarse for chinook salmon in the Calaveras River to utilize.

Water temperature measured during the surveys ranged from 54.5 to 55.2EF (12.5 to 13EC), which is within the range considered optimal for chinook salmon spawning and incubation. However, these spot measurements should not be interpreted as indicating that water temperature is not limiting to salmon production in the Calaveras River. Several years of stream temperature data covering a range of flow and meteorological conditions would be required to evaluate temperature suitability for salmon spawning, incubation, and rearing.

Substrate angularity exhibited a decreasing downstream trend and may be an important consideration in spawning gravel preference. Highly angular substrates have the tendency to form tighter packing arrangements which, in turn, can translate into reduced subsurface permeability (Shirazi et al. 1981). The highly angular substrate particles in the Calaveras are likely recruited directly from the bedrock bank materials near New Hogan Dam.

Substrate Permeability

Subsurface gravel quality is a key determinant in the successful incubation of salmonid eggs and subsequent emergence of fry. Researchers have long recognized the relationship between the amount of fine sediment in spawning gravel and successful incubation and emergence. The intrusion of sands and fines (i.e., silts and clays) into the gravel interstices of redds reduces intergravel flow by reducing gravel permeability, resulting in reduced delivery of dissolved oxygen to and removal of metabolic wastes from the eggs and alevins.

Salmonid spawning gravel quality is most often characterized by an index of particle size distribution. Extensive laboratory and some field research have related particle size distribution to salmonid survival-to-emergence (e.g., Shelton and Pollock 1966, Koski 1981, Weaver and Fraley 1993). However, determining particle size distribution requires bulk sampling, which is time consuming and expensive. Gravel permeability, on the other hand, can be measured in the field rapidly and cost-effectively, at perhaps ten percent of the cost of bulk sampling. Only a limited number of studies currently use permeability to assess gravel quality; however, we believe that in addition to being less expensive, it is a better measure of intragravel incubation conditions than bulk sample analysis. Permeability is a direct measure of the quality of incubation enviroment because interstitial flow is a function of permeability and hydraulic head. The size composition of the spawning gravel is an indirect means of assessing permeability. Chapman and McLeod (1987), in their development of fine sediment criteria in the Rocky Mountain region, identified permeability as a useful tool for correlating fine sediment with survival as well as assessing the intrusion of fines into the gravel substrate.

Few studies that directly relate survival-to-emergence to substrate permeability are available in the literature. Stillwater Sciences identified two studies that evaluated this relation. McCuddin (1977) assessed survival-to-emergence for chinook salmon in laboratory troughs. Tagart (1976) assesed survival-to-emergence for coho salmon by trapping fry emerging from redds in the field. We combined these data sets to develop a relationship that could be used to predict survival-to-emergence from measurements of substrate permeability (Figure 2). Ideally this relationship would be based on studies of chinook salmon only. It was necessary, however, to combine the two data sets to provide a suitable sample size covering an adequate range of permeabilities to develop the relationship.

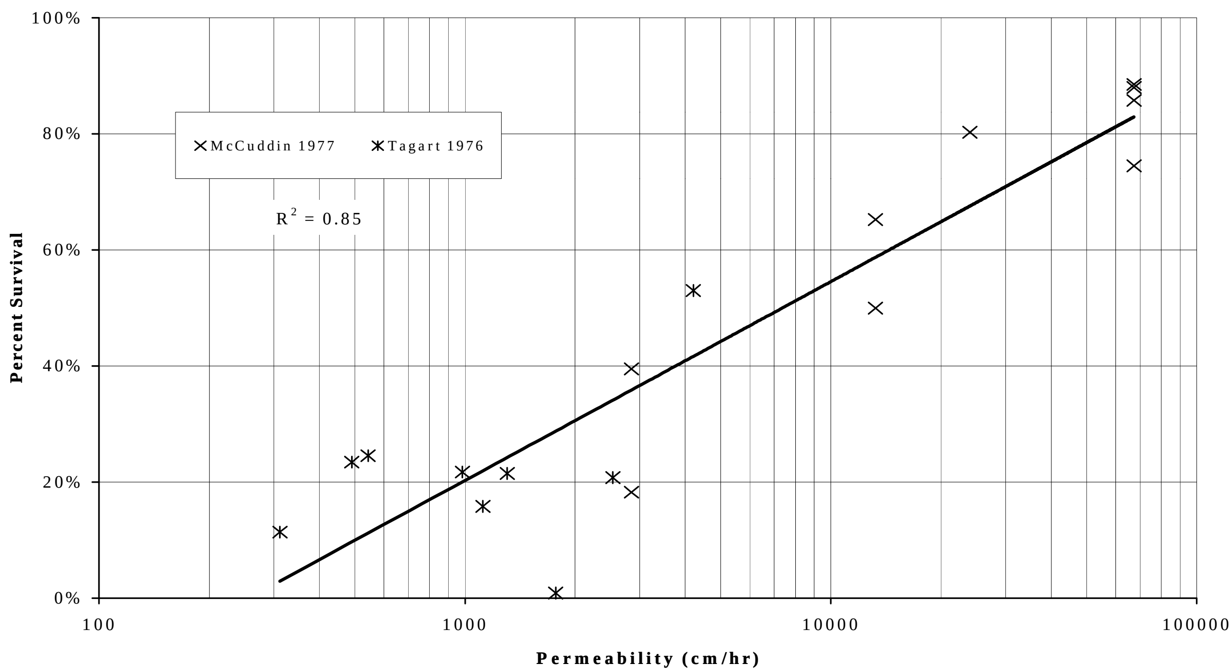


Figure 2. Relationship of salmonid survival to substrate permeability.

In general, permeability at the Calaveras River riffle evaluation sites was low to moderate. Substrate permeability ranged from 112 cm/hr to 6,993 cm/hr for the five riffles sampled, and permeability measured at one site in riffle 6 was below the calibrated limit of the equipment (Table 3). Predicted survival-to-emergence ranged from effectively zero in riffles 5, 6 and 9 to 49 percent in riffle 3 (Table 3). Although predicted survival was highest at riffle 3, the substrate at this site was angular and potentially unsuitable for spawning.

Predicted survival-to-emergence was below that which would be expected under favorable intragravel conditions. For example, McCuddin (1977) incubated eggs of chinook salmon and steelhead trout in experimental troughs containing varying amounts of sand. For control, he also incubated eggs in hatchery incubation trays. In the control (incubation tray) samples, he found that 93 and 95 percent of the eggs survived to the swim-up stage of development in the first and second year of the study. The survival of both chinook salmon and steelhead trout in the troughs with no sand was very close to the controls, ranging from 87 to 91 percent in the first year of the study and from 84 to 91 percent in the second year. Tappel and Bjornn (1983) documented chinook egg-to-emergence survival as high as 99 percent. These studies suggest that favorable spawning habitat conditions should produce survival-to-emergence near 90 percent.

Table 3. Modeled smolt survival for measured permeabilities

Site	Sample	Median Permeability	Predicted Survival (with Confidence Limits)		
			Estimate	Lower 95%	Upper 95%
RF 3	1	3837	0.40	0.34	0.46
RF 3	2	6993	0.49	0.43	0.55
RF 4	1	572	0.12	0.03	0.21
RF 4	2	463	0.09	-0.01	0.19
RF 5	1	217	-0.02	-0.14	0.09
RF 5	2	1380	0.25	0.18	0.32
RF 6	1	112	-0.12	-0.26	0.02
RF 6	2	n/d	--	--	--
RF 9	1	2722	0.35	0.29	0.41
RF 9	2	217	-0.02	-0.14	0.09

Survival as a linear function of log permeability, fitted to data in McCuddin (1977) and Tagart (1976)

Spawning Habitat Limitation Modeling

Limitations on spawning gravels for salmonids can result in superimposition of redds, whereby later arriving female salmon dig redds on top of existing redds, causing substantial mortality of eggs deposited earlier (Hayes 1987, McNeil 1964). Spawning gravel availability has been found to be an important factor limiting chinook salmon populations in streams where dams capture sediments and reduce supply of gravel to downstream reaches (TID/MID 1992). The potential effects of spawning gravel availability on chinook salmon egg production were analyzed using a redd superimposition model to evaluate whether gravel supply to the Calaveras River may limit the chinook population, and whether increasing the availability of spawning gravels could increase chinook salmon production.

Five of the eleven riffles (i.e., RF3, RF4, RF5, RF6, RF9) identified during the surveys were considered potentially suitable for chinook salmon spawning and used in the analysis. The combined habitat area of these five riffles was approximately 15,800 ft^2. Parameters used in the model are provided in Table 4. As discussed above, the parameters used in the model were based on fall run chinook salmon populations from the Tuolumne River. Female fecundity was estimated to be 5,586 eggs/female based on the fecundity of a 740-mm fish — the median length of female spawners in the Tuolumne River. There is no indication that the characteristics of chinook populations used in the model would vary substantially between the Calaveras and Tuolumne rivers. If, however, data specific to the Calaveras River chinook salmon population becomes available, parameters in the model could be easily modified.

Table 4. Input parameter descriptions and values for the superimposition model.

Parameter	Description (units)	Value
Spatial Parameters		
defended area	area actively defended from other spawners (ft^2)	200
redd area	area disturbed during redd construction (ft^2)	50
egg pocket area	area of egg deposition (ft^2)	50
Temporal Parameters		
defense time	redd defense period (days)	7
spawning time	length of spawning run (days)	84
spawning distribution	distribution of spawning run over the spawning time period	normal
development time	length of egg development (days)	135
Other Parameters		
eggs per female	average fecundity (eggs/female)	5,586
fraction female	% of escapement composed of spawning females	50

Results from the redd superimposition model indicate that egg mortality is about nine percent when female escapement reaches about 100 and that egg mortality increases to about 23 percent when female escapement reaches about 250 (Figure 3). Model results expressed as fry production suggest that, given ideal spawning gravel conditions, female escapements of 50, 100 and 250 could result in production of up to approximately 0.3, 0.6, and 1.1 million fry, respectively (Figure 4).

Since current observed escapement to this reach is much less than 100 females per year, these results suggest that spawning habitat availability is not limiting chinook salmon production in the Calaveras River. Gravel augmentation, therefore, would not likely increase juvenile production in this reach. However, if chinook salmon escapement into the Calaveras River were to increase dramatically in the future, populations could be limited by habitat availability in this reach. It is important to note that these results only indicate potential mortality due to redd superimposition and that gravel quality is not considered.

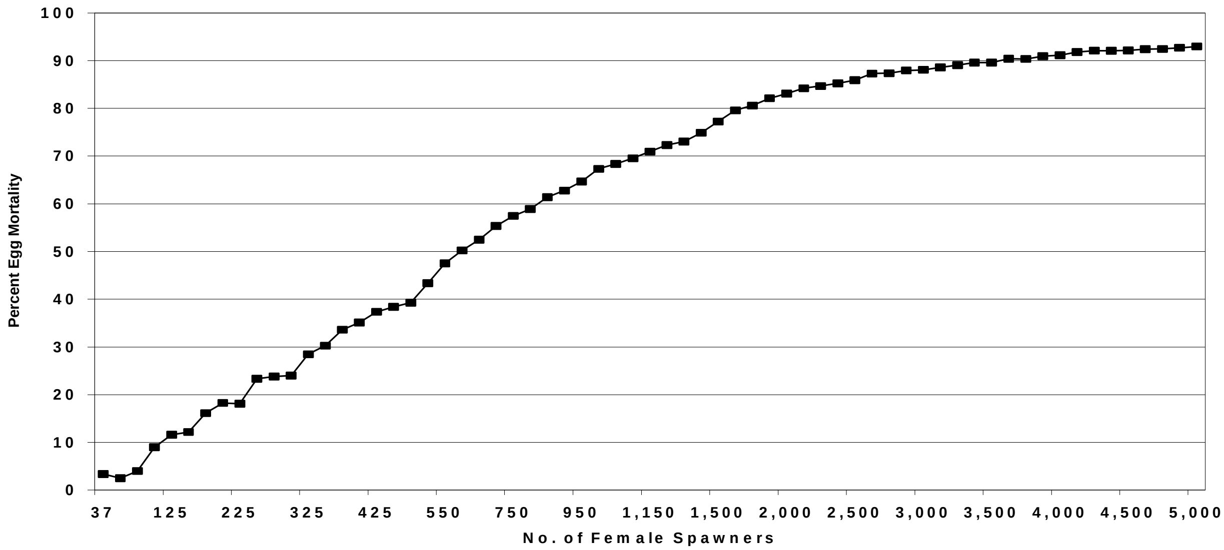


Figure 3. Potential egg mortality resulting from redd superimposition in the 1.5-mile reach of the Calaveras River downstream of New Hogan Dam.

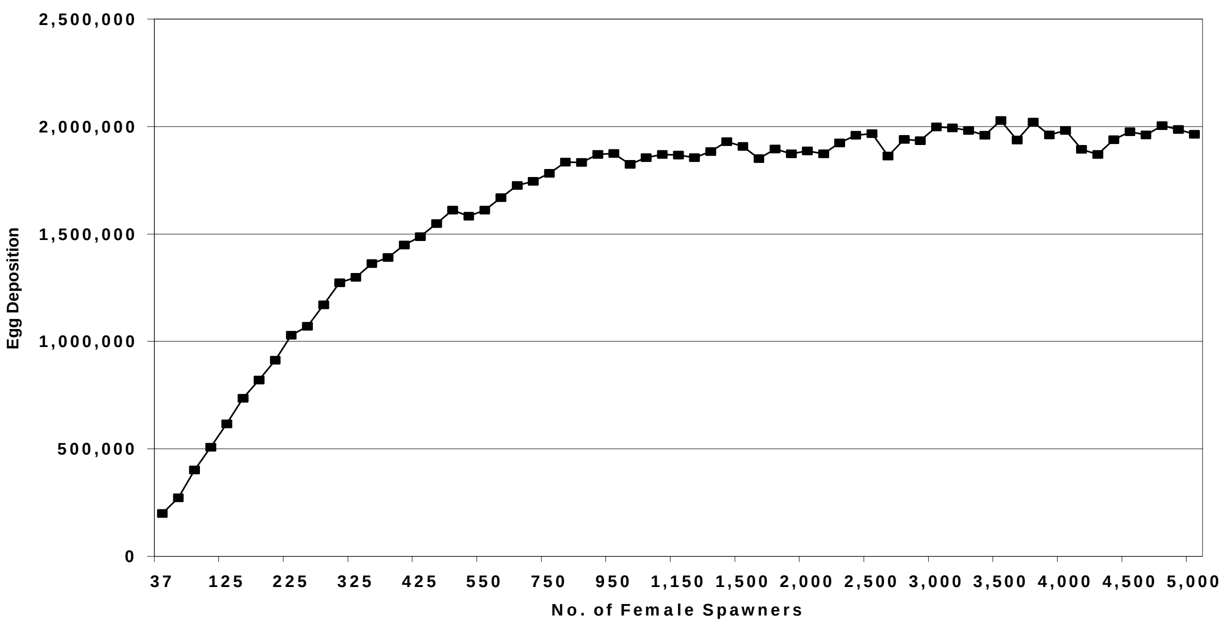


Figure 4. Number of viable eggs potentially deposited at the end of the spawning season in the 1.5-mile reach of the Calaveras River downstream of New Hogan Dam.

Substrate Photos
A quantitative analysis of the substrate photos was not proposed or conducted in the scope of work for this project. Surface and subsurface photographs for each riffle sampled are presented in Attachment B (photos 13–22) and provide a relative comparison of surface and subsurface conditions. At all riffles sampled, those photographs depict relatively large volumes of sand accumulated in the bed substrate. In addition to the bed substrate conditions, underwater photographs indicated potentially high aquatic macroinvertebrate production (see Attachment B: photo 23). These site-specific qualitative observations, however, do not provide sufficient information to determine actual levels of benthic macroinvertebrate production.

Recommendations
The Calaveras River within the surveyed reach provides limited area suitable for chinook salmon spawning, and predicted survival-to-emergence from redds constructed in potential spawning areas is low. These conditions likely result from lack of flows sufficient to mobilize the channel bed downstream of the dam and flush out fine sediments and sand. The proposed gravel addition may increase suitable spawning area and survival-to-emergence in the short-term. However, lacking flows adequate to mobilize the introduced sediment, it is likely that continued sand infiltration would degrade the quality of the introduced sediment and would return incubation conditions to their current state.

More importantly, this reach appears to provide relatively minor chinook salmon production potential compared to reaches downstream of the gorge because (1) few adult salmon migrate through the gorge to this reach, and (2) extensive potential spawning areas are available downstream of the gorge. With very few adult salmon arriving to spawn in this reach, the potential benefits of providing relatively short-term improvement to spawning habitat quality in this reach are minor. The majority of adult salmon that reproduce in the Calaveras River likely spawn downstream of the gorge. Assessing spawning habitat carrying capacity and the potential need for improvement downstream of the gorge, therefore, is more important than implementing measures to increase habitat suitability upstream of the gorge.

Stillwater Sciences supports an approach to riverine habitat and salmon population restoration and management that is based on an understanding of salmon population dynamics and limiting factors combined with an understanding of geomorphic and ecological conditions and processes in the river. That is, we believe that successful salmon population restoration and management must incorporate an understanding of factors limiting the population combined with an understanding of the biological, physical and ecological conditions that contribute to or cause these limiting factors. With this underlying framework in mind, we recommend the following steps:

1. conduct a reconnaissance-level evaluation of chinook salmon habitat conditions throughout the river to identify potentially important habitat areas and potential habitat limitations;
2. conduct a reconnaissance assessment of chinook salmon population dynamics in the river; and
3. develop a prioritized list of actions and further evaluations needed to improve ecological processes and chinook salmon abundance in the river.

REFERENCES

Barnard, K., and S. McBain. 1994. Standpipe to determine permeability, dissolved oxygen, and vertical particle size distribution in salmonid spawning gravels. Fish Habitat Relationships Technical Bulletin No. 15. USDA Forest Service.

Bell, M. C., editor. 1986. Fisheries handbook of engineering requirements and biological criteria. Report No. NTIS AD/A167-877. Fish Passage Development and Evaluation Program, U. S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.

Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 *in* W. R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication No. 19. American Fisheries Society, Bethesda, Maryland.

CALFED Bay-Delta Program. 1999. Ecosystem restoration program. CD-ROM. CALFED Bay-Delta Program, Sacramento, California.

Chapman, D. W., and K. P. McLeod. 1987. Development of criteria for fine sediment in the Northern Rockies ecoregion. Final Report EPA 919/587-162. U. S. Environmental Protection Agency, Water Division.

Church, M. A., D. G. McLean, and J. F. Wolcott. 1987. River bed gravels: sampling and analysis. Pages 43-88 *in* C. R. Thorne, J. C. Bathurst and R. D. Hey, editors. Sediment transport in gravel-bed rivers. John Wiley and Sons, New York.

Clark, G. H. 1929. Sacramento-San Joaquin salmon (*Oncorhynchus tshawytscha*) fishery of California. California Department of Fish and Game Fish Bulletin 17: 20-63.

Fjelstad, M. 1999. Personal communication. Fisheries Biologist, California Department of Fish and Game, Rancho Cordova.

Hayes, J. W. 1987. Competition for spawning space between brown (*Salmo trutta*) and rainbow trout (*S. gairdneri*) in a lake inlet tributary, New Zealand. Canadian Journal of Fisheries and Aquatic Sciences 44: 40-47.

Healey, M. C. 1991. Life history of chinook salmon (*Oncorhynchus tshawytscha*). Pages 311-393 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver, British Columbia.

Kondolf, G. M. and M. G. Wolman 1993. The sizes of salmonid spawning gravels. Water Resources Research 29: 2275-2285.

Koski, K. V. 1981. The survival and quality of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence. Rapports et Proces-Verbaux des Reunions, Conseil International pour L'Exploration de la Mer 178: 330-333.

Ligon, F. K. 1997. Forensic ecology: a research program to enhance salmon production in the Tuolumne River. Pages 581-586 *in* S. S. Y. Wang, editor. Environmental and coastal hydraulics: protecting the aquatic habitat. Volume 1: Proceedings of Theme B. Water for a changing global community. The 27th Congress of the International Association for Hydraulic Research. American Society of Civil Engineers, New York.

McCuddin, M. E. 1977. Survival of salmon and trout embryos and fry in gravel-sand mixtures. Master's thesis. University of Idaho, Moscow.

McNeil, W. J. 1964. Redd superimposition and egg capacity of pink salmon spawning beds. Journal of the Fisheries Research Board of Canada 21: 1385-1396.

Platts, W. S., M. A. Shirazi, and D. H. Lewis. 1979. Sediment particle sizes used by salmon for spawning with methods for evaluation. Ecological Research Series EPA-600/3-79-043. U. S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, Oregon.

Reynolds, F. L., T. J. Mills, R. Benthin, and A. Low. 1993. Restoring Central Valley streams: a plan for action. California Department of Fish and Game, Inland Fisheries Division, Sacramento.

Shelton, J. M. , and R. D. Pollock. 1966. Siltation and egg survival in incubation channels. Transactions of the American Fisheries Society 95: 183-187.

Shirazi, M. A., W. K. Seim, and D. H. Lewis. 1981. Characterization of spawning gravel and stream system evaluation. Pages 227-278 *in* Salmon-spawning gravel: a renewable resource in the Pacific Northwest? Report No. 39. State of Washington Water Research Center, Washington State University, Pullman, and the University of Washington, Seattle.

Snider, W. B., D. B. Christophel, D. L. Jackson, and P. M. Bratovich. 1992. Habitat characterization of the lower American River. MOU between Beak Consultants and California Department of Fish and Game.

Tagart, J. V. 1976. The survival from egg deposition to emergence of coho salmon in the Clearwater River, Jefferson County, Washington. Master's thesis. University of Washington, Seattle.

Tappel, P. D., and T. C. Bjornn. 1983. A new method of relating size of spawning gravel to salmonid embryo survival. North American Journal of Fisheries Management 3: 123-135.

Terhune, L. D. B. 1958. The Mark VI groundwater standpipe for measuring seepage through salmon spawning gravel. Journal of the Fisheries Research Board of Canada 15: 1027-1063.

Thompson, K. 1972. Determining stream flows for fish life. Pages 31-50 *in* Proceedings of the instream flow requirement workshop. Pacific Northwest River Basin Commission, Vancouver, Washington.

TID/MID. 1992. Lower Tuolumne River spawning gravel availability and superimposition. Appendix 6 to Don Pedro Project Fisheries Studies Report (FERC Article 39, Project No. 2299). *In* Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project, No. 2299. Vol. IV. Prepared by EA Engineering, Science, and Technology, Lafayette, California.

Weaver, T. M., and J. J. Fraley. 1993. A method to measure emergence success of westslope cutthroat trout fry from varying substrate compositions in a natural stream channel. North American Journal of Fisheries Management 13: 817-822.

Wolman, G. M. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union 35: 951-956.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 1996. Historical and present distribution of chinook salmon in the Central Valley drainage of California. Pages 309-362 *in* Sierra Nevada Ecosystem Project: final report to congress. Volume III: Assessments, commissioned reports, and background information. University of California, Center for Water and Wildland Resources, Davis.

Attachment A: Maps of existing habitat conditions in the Calaveras River from New Hogan Dam to approximately 3,000 feet (915 m) downstream of Cosgrove Creek

Table A–1 Summary table of abbreviations used in the habitat mapping field effort

Habitat Feature	Abbreviation
pool	PL
riffle	RF
run	RN
bedrock	BDRK
boulder	BLDR, BLD
large cobble	LGC, LG CBL
cobble	CBL
small cobble	SM CBL, S CBL
very coarse gravel	VC GRV
medium coarse gravel	M/C GRV, MC GRVL
gravel	GR, GRV
fine gravel	FGRV
cottonwood (*Populus fremontii*)	PF
narrow leaf willow (*Salix sp.*)	NLW
black willow (*Salix sp.*)	BLW

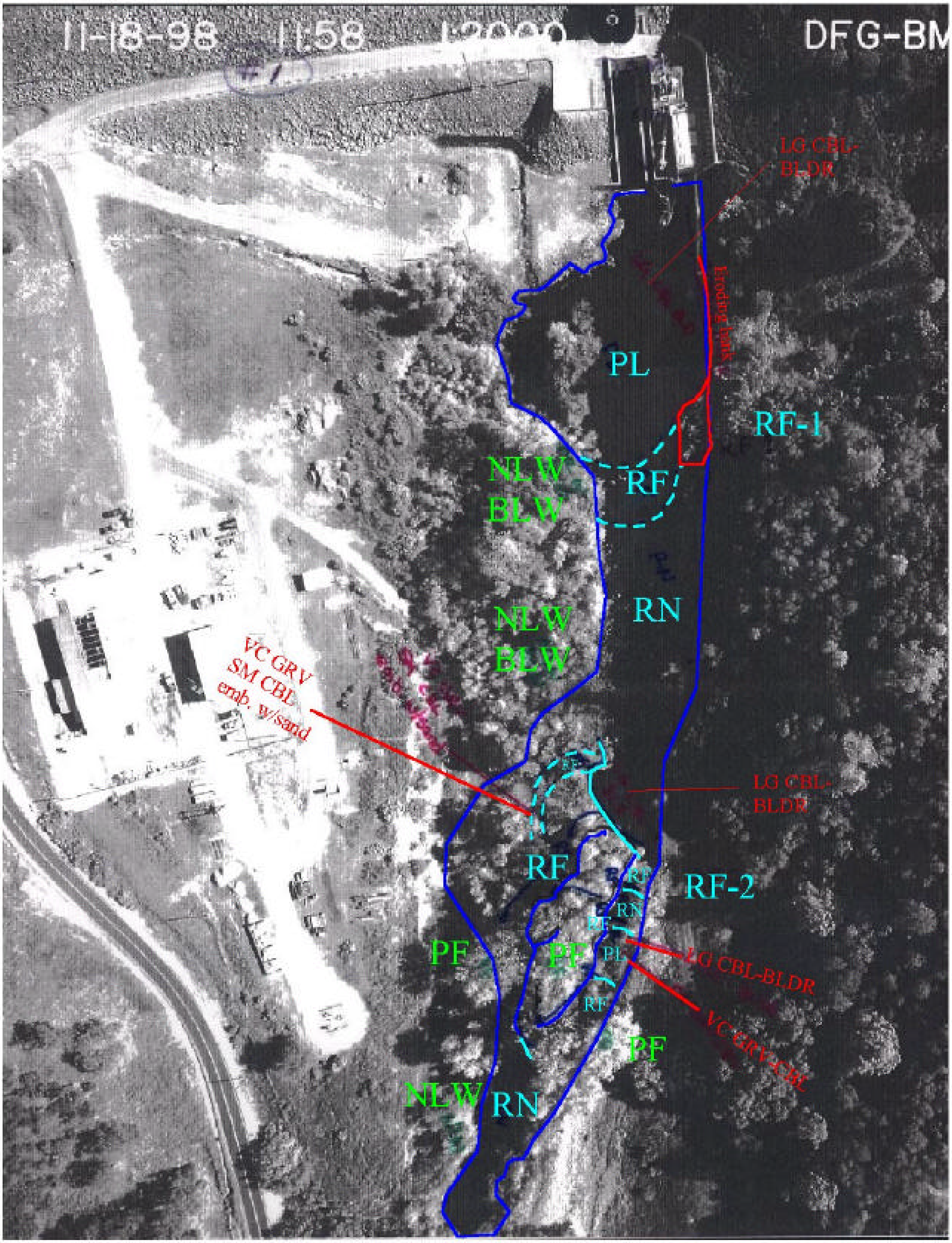


Photo 1 of 9.

A complete set of photos and habitat mapping is available upon request.

Scale = 1:2,000

Stillwater Sciences

Attachment B: Photographs - field equipment, riffle evaluation sites, and substrate conditions

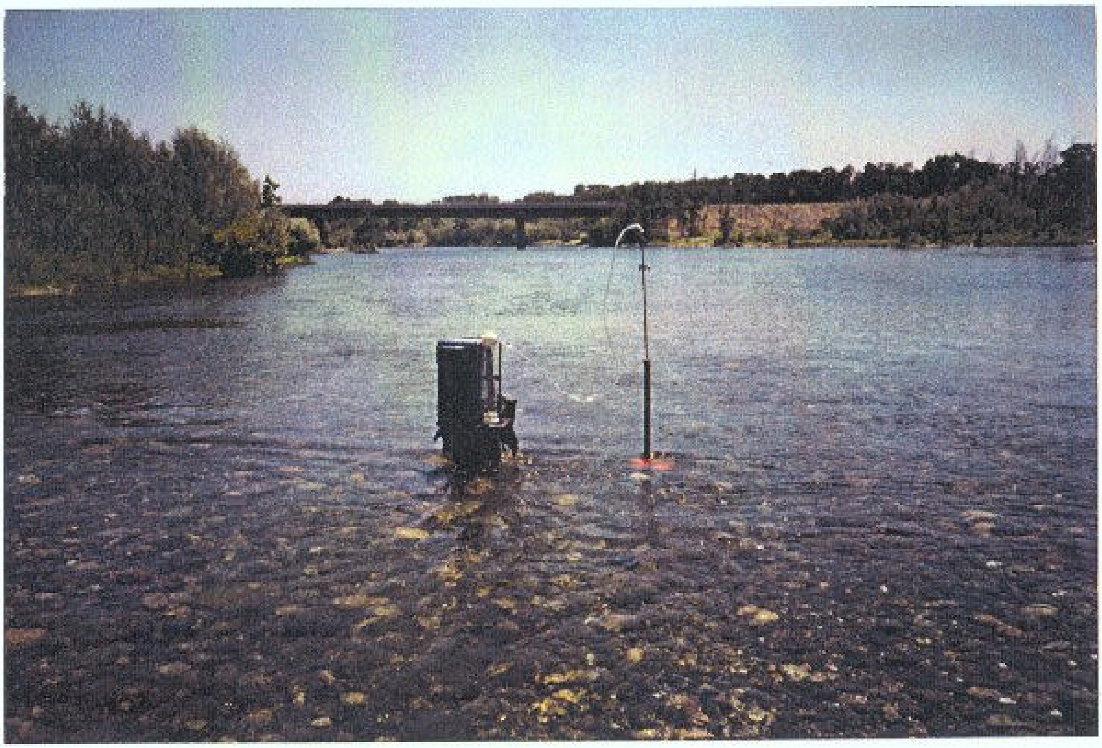


Photo 1. Modified Mark IV standpipe and electric pump assembly

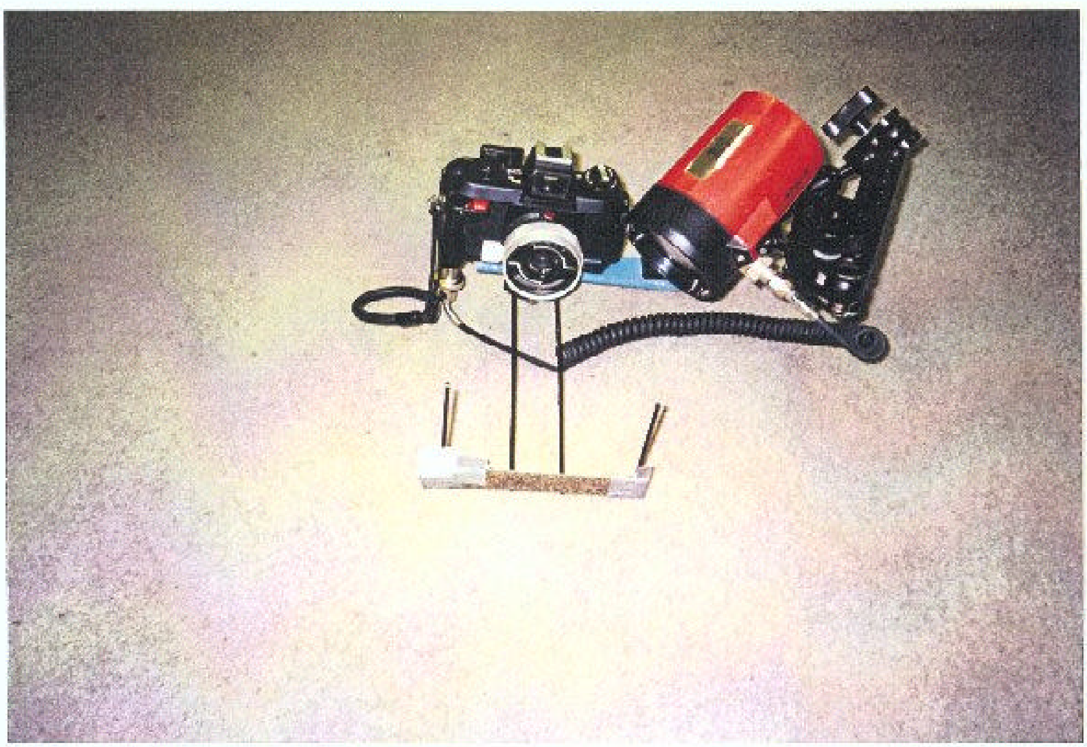


Photo 2. Underwater still camera and flash

Photo 3. Looking downstream to Riffle 1

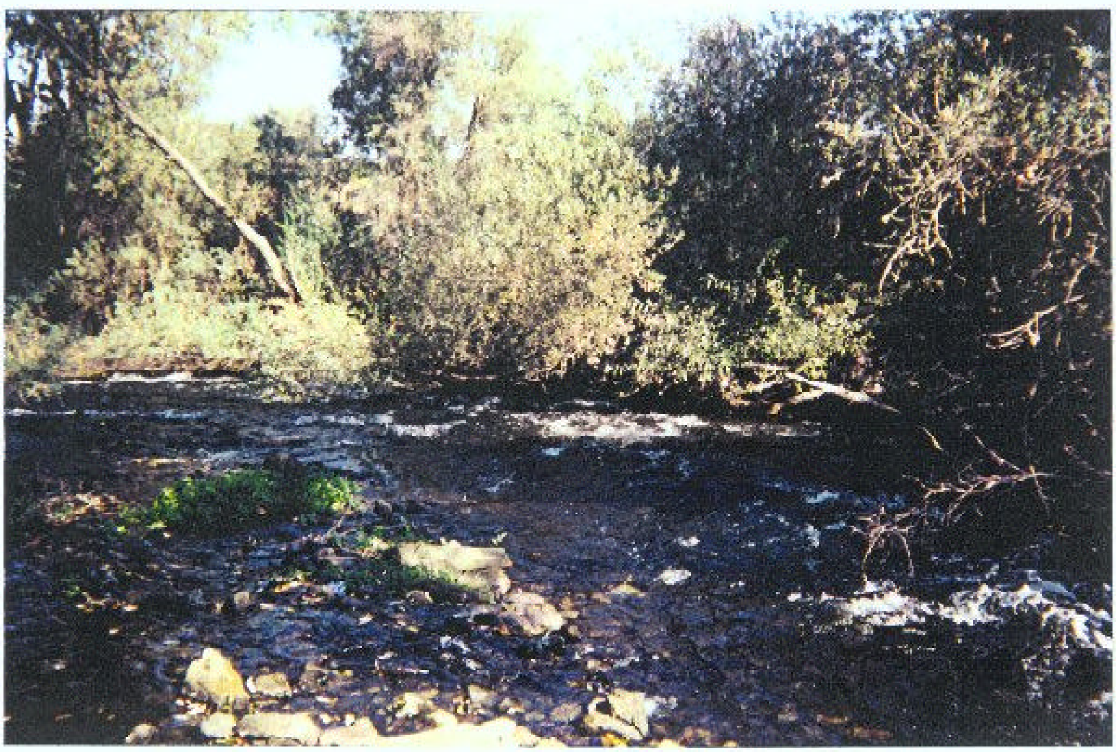


Photo 4. Looking from left bank to right bank at Riffle 2

Photo 5. Pool upstream of Riffle 3, looking upstream

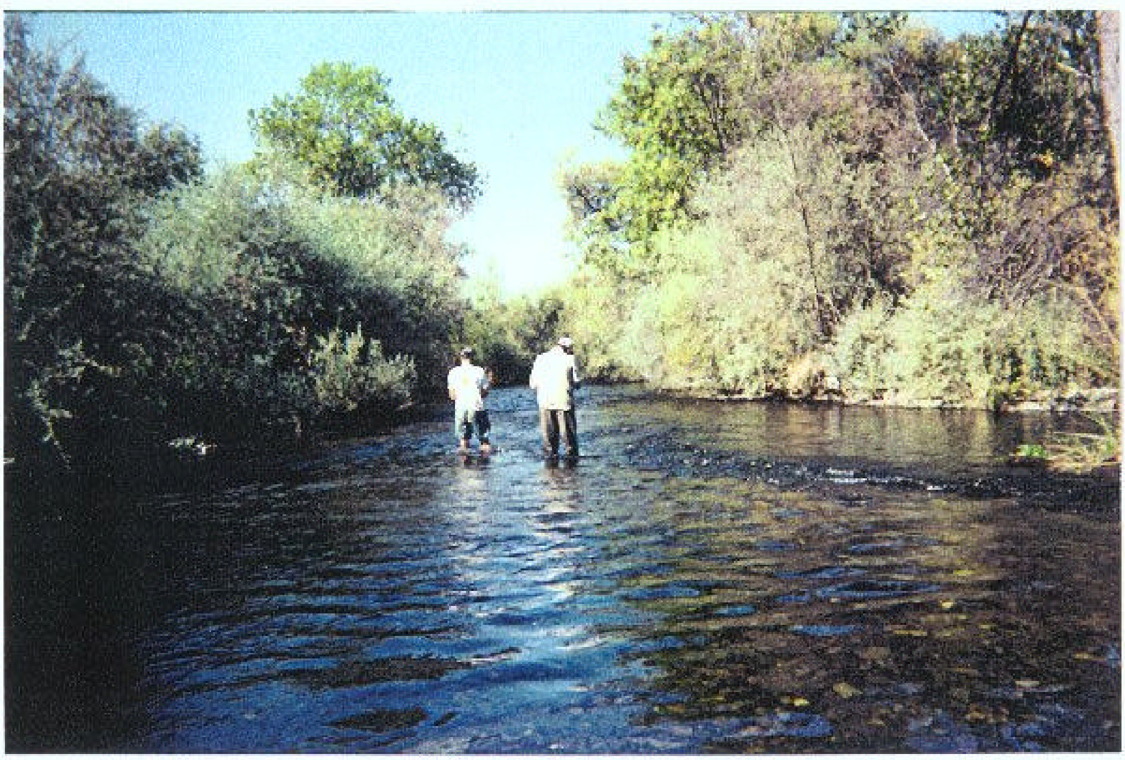


Photo 6. Riffle 3, looking downstream

Photo 7. Riffle 4, looking downstream

Photo 8. Riffle 5, looking downstream

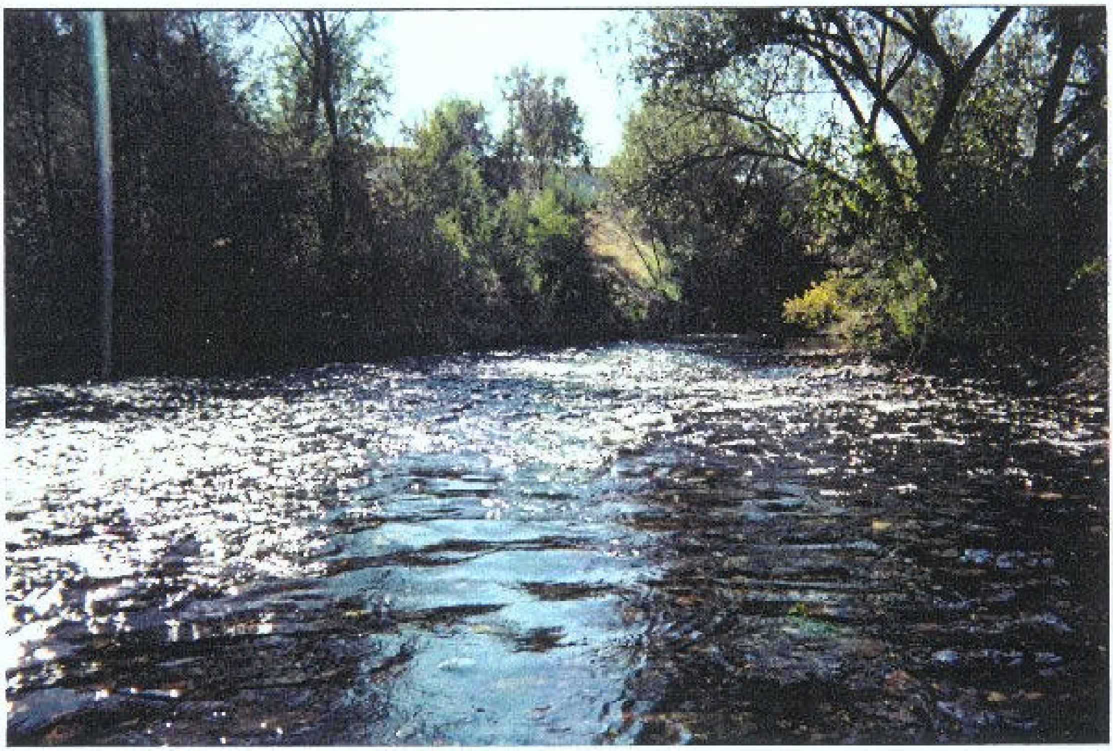


Photo 9. Riffle 6, looking downstream

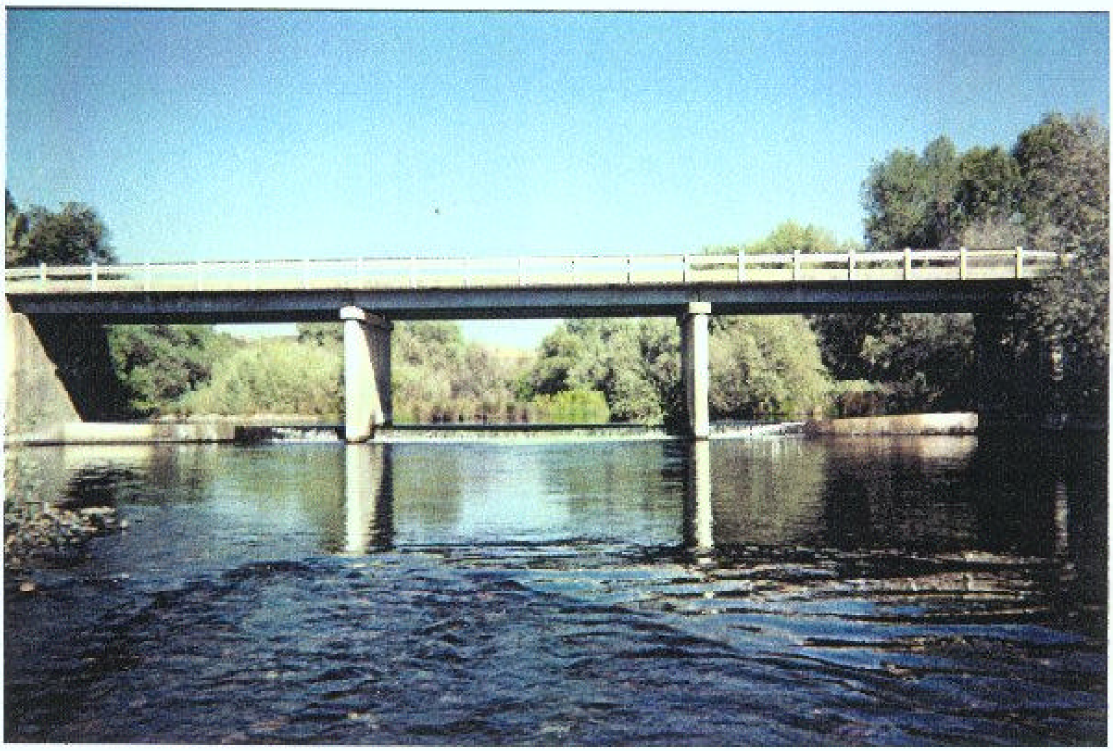


Photo 10. Looking upstream from Riffle 6 to Army Corps of Engineers weir at New Hogan Road

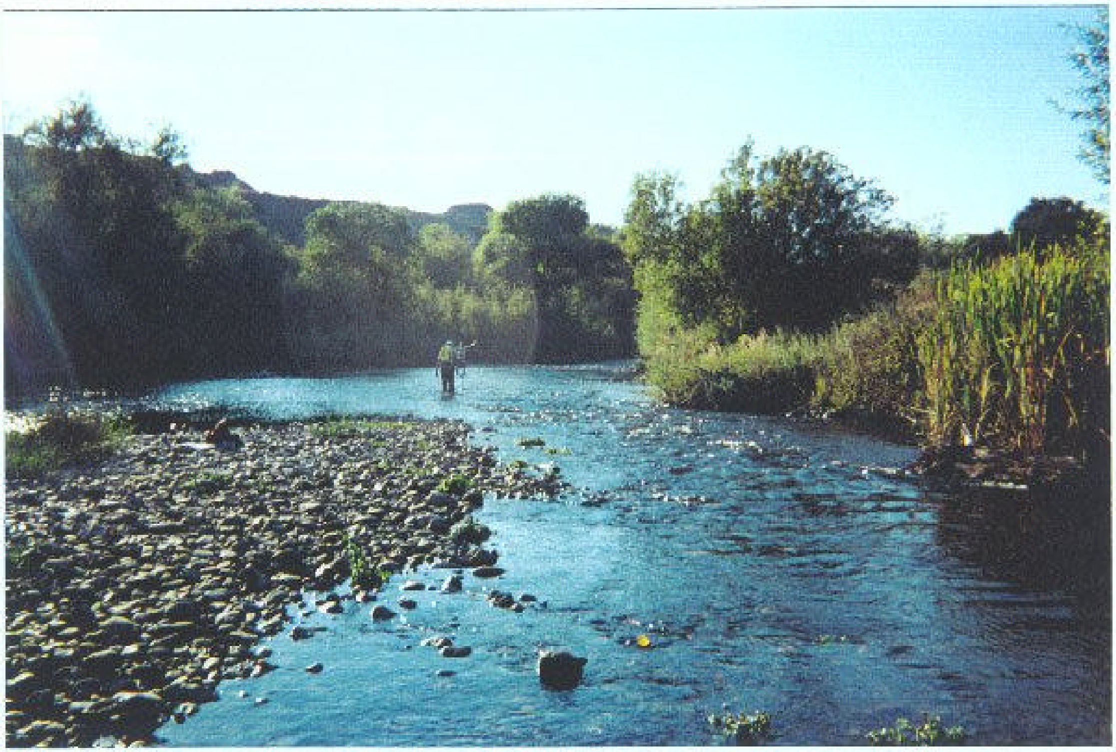


Photo 11. Riffle 9, looking downstream

Photo 12. Riffle 9, looking downstream

Photo 13. Riffle 3 (1) surface substrate

Photo 14. Riffle 3 (1) subsurface substrate

Photo 15. Riffle 4 (1) surface substrate

Photo 16. Riffle 4 (1) subsurface substrate

Photo 17. Riffle 5 (1) surface substrate

Photo 18. Riffle 5 (1) subsurface substrate

Photo 19. Riffle 6 (2) surface substrate

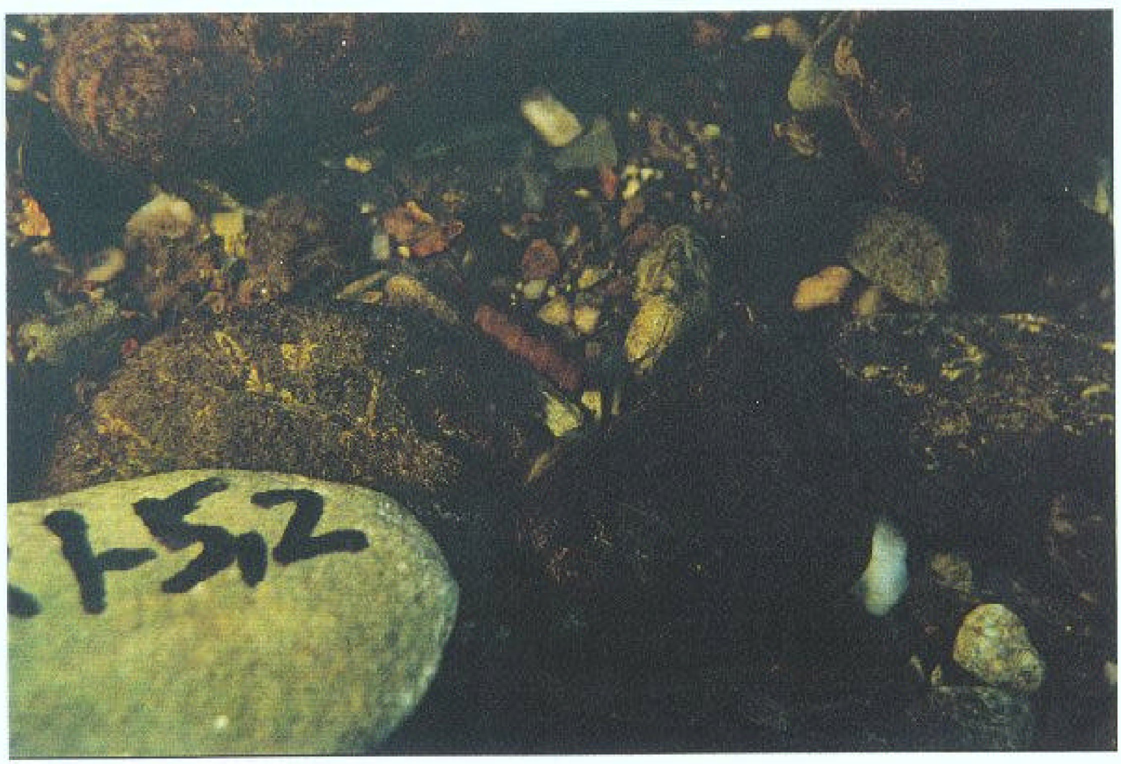


Photo 20. Riffle 6 (2) subsurface substrate

Photo 21. Riffle 9 (2) surface substrate

Photo 22. Riffle 9 (2) subsurface substrate

Photo 23. Evidence of high invertebrate production (caddisfly larvae [Tricoptera])

Attachment C. Cumulative particle size distribution curves

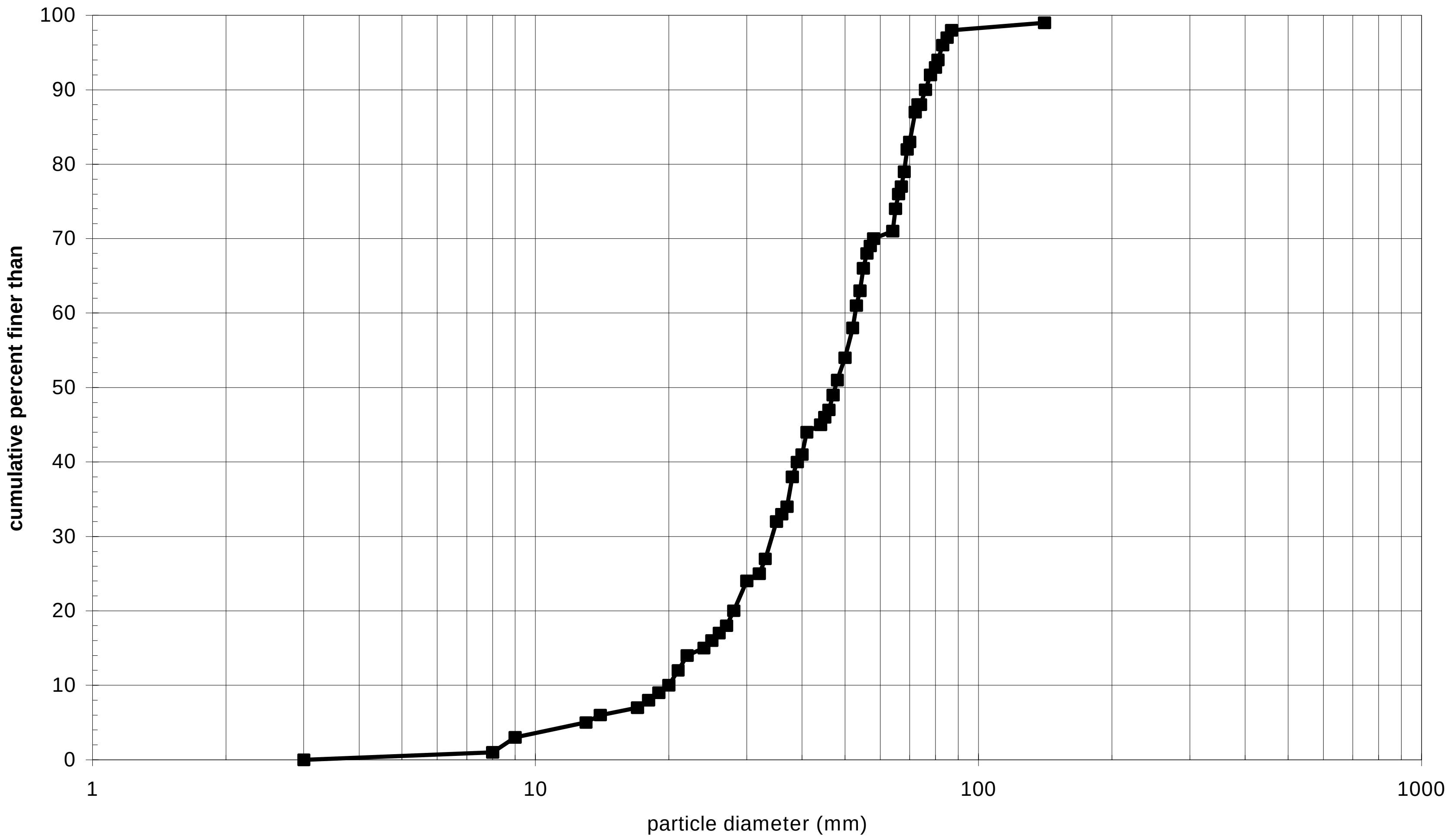


Figure C-1. Surface particle size distribution at Riffle 3

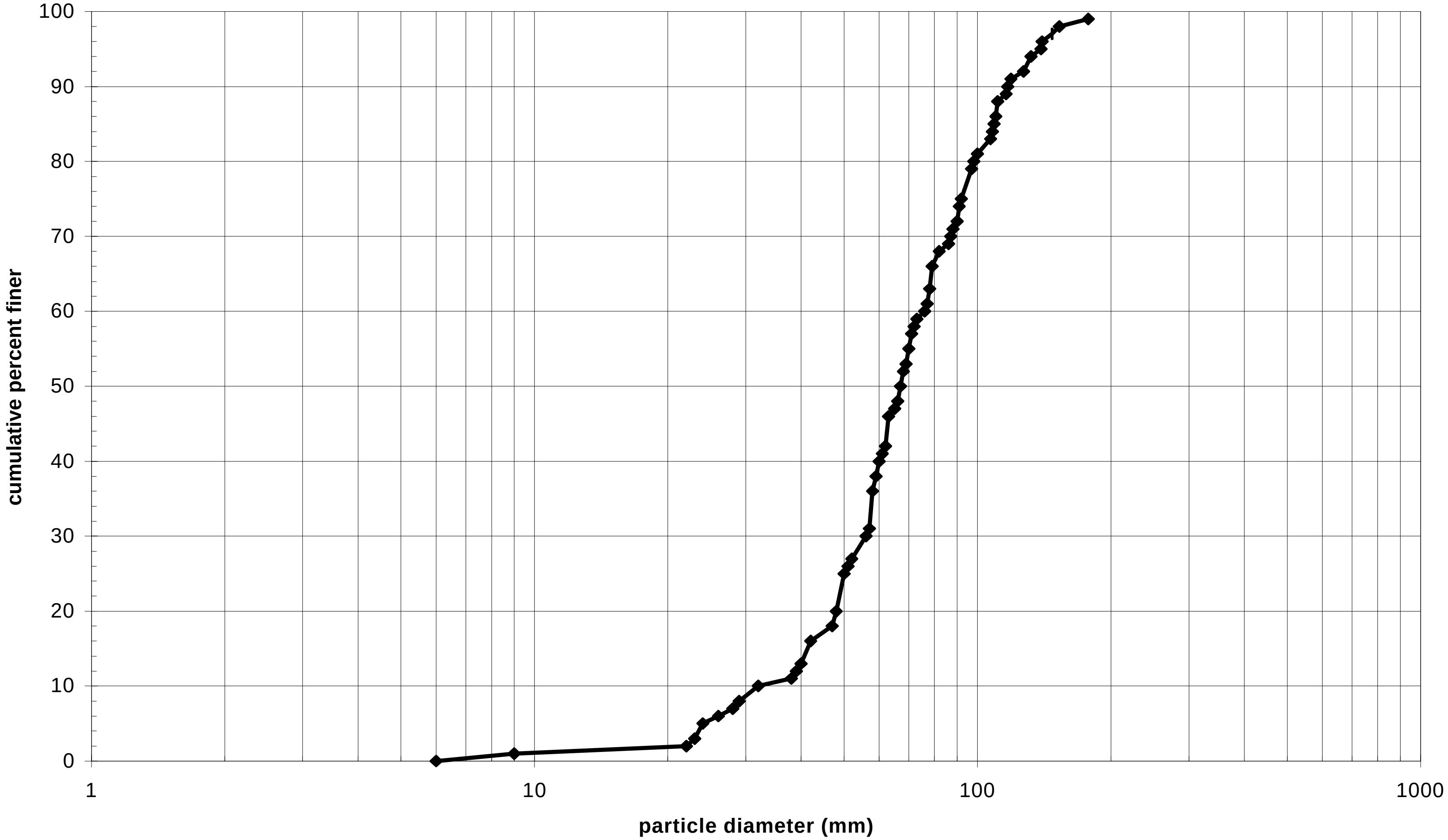


Figure C-2. Surface particle size distribution at Riffle 4

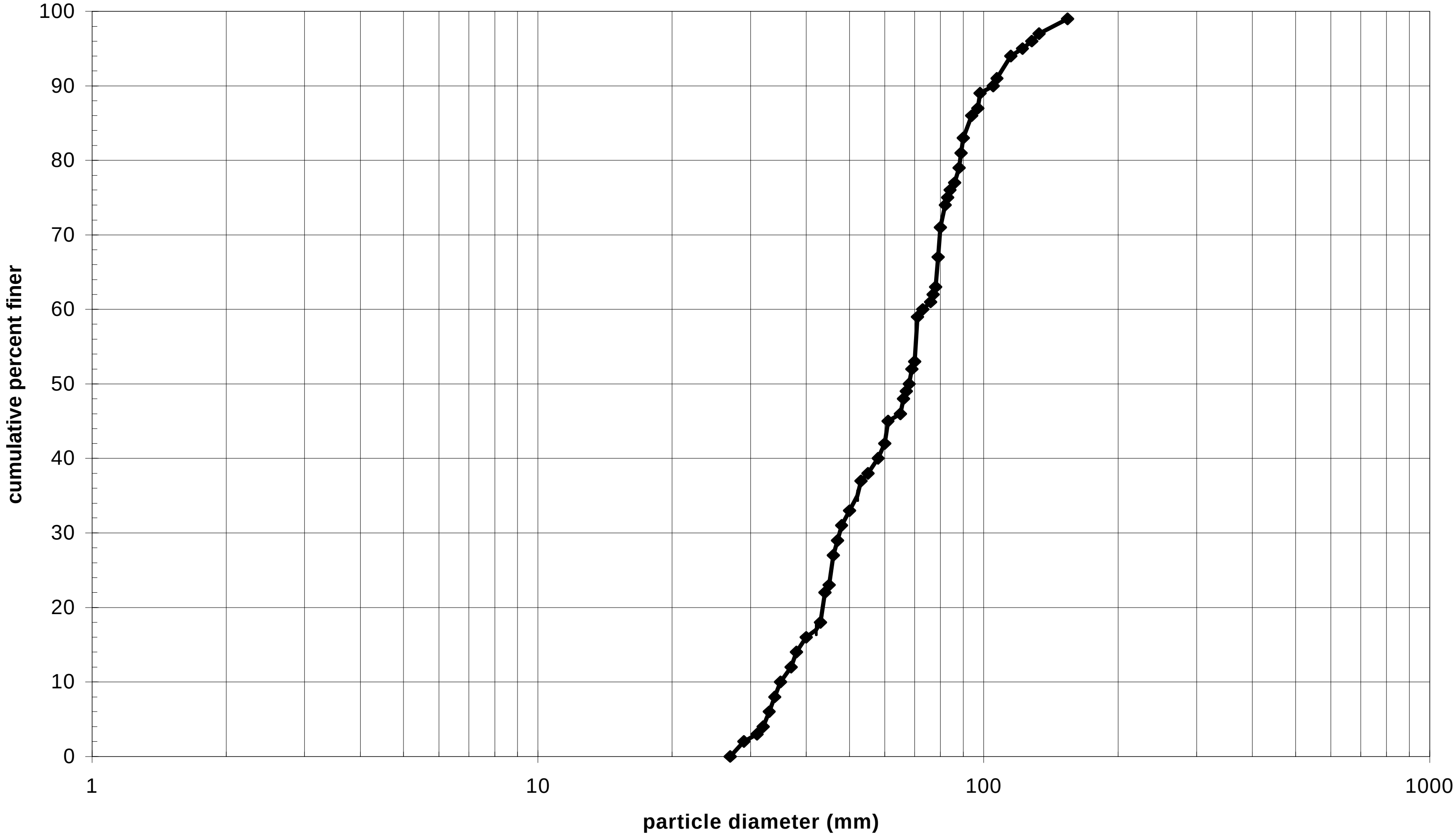


Figure C-3. Surface particle size distribution at Riffle 5

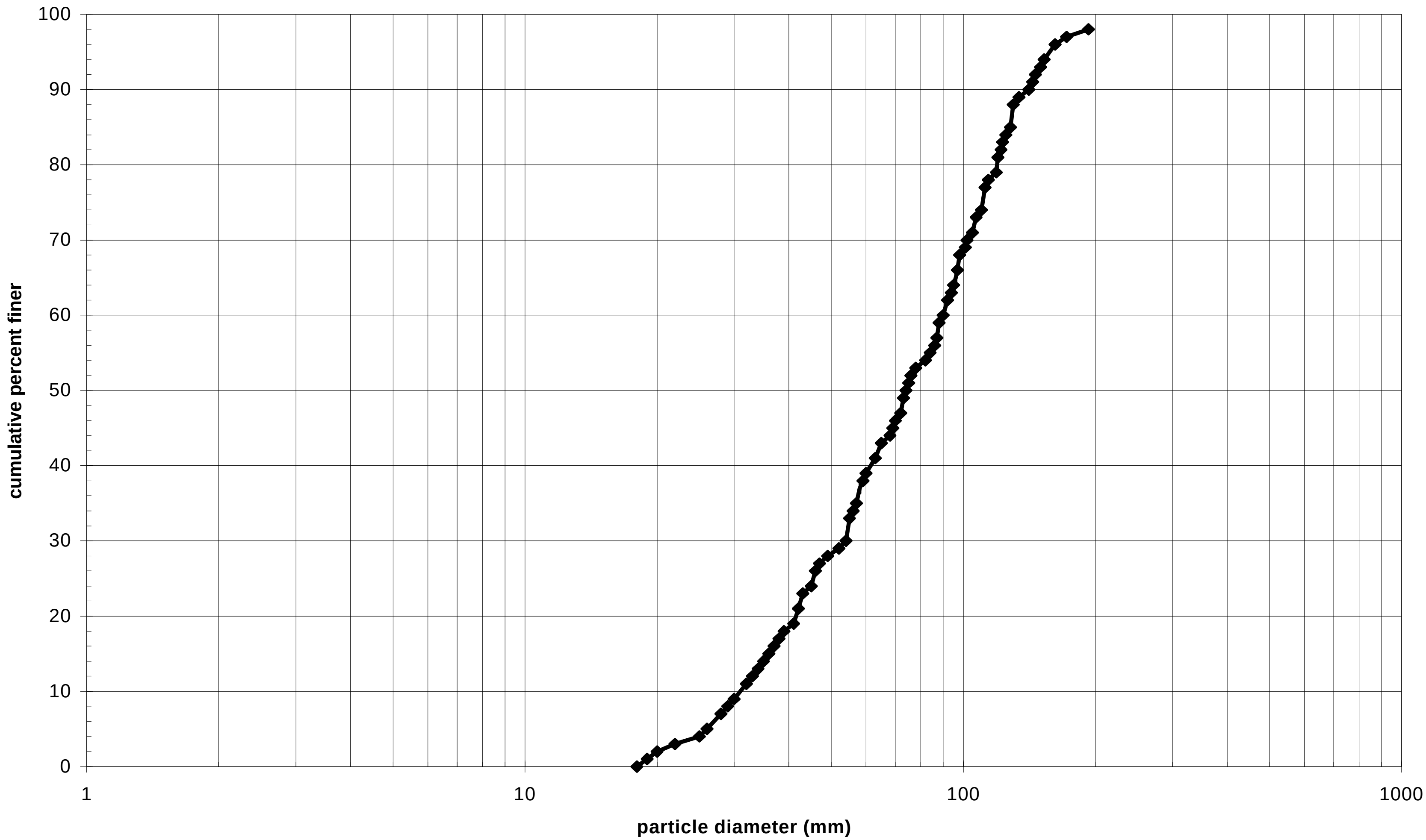


Figure C-4. Surface particle size distribution at Riffle 6

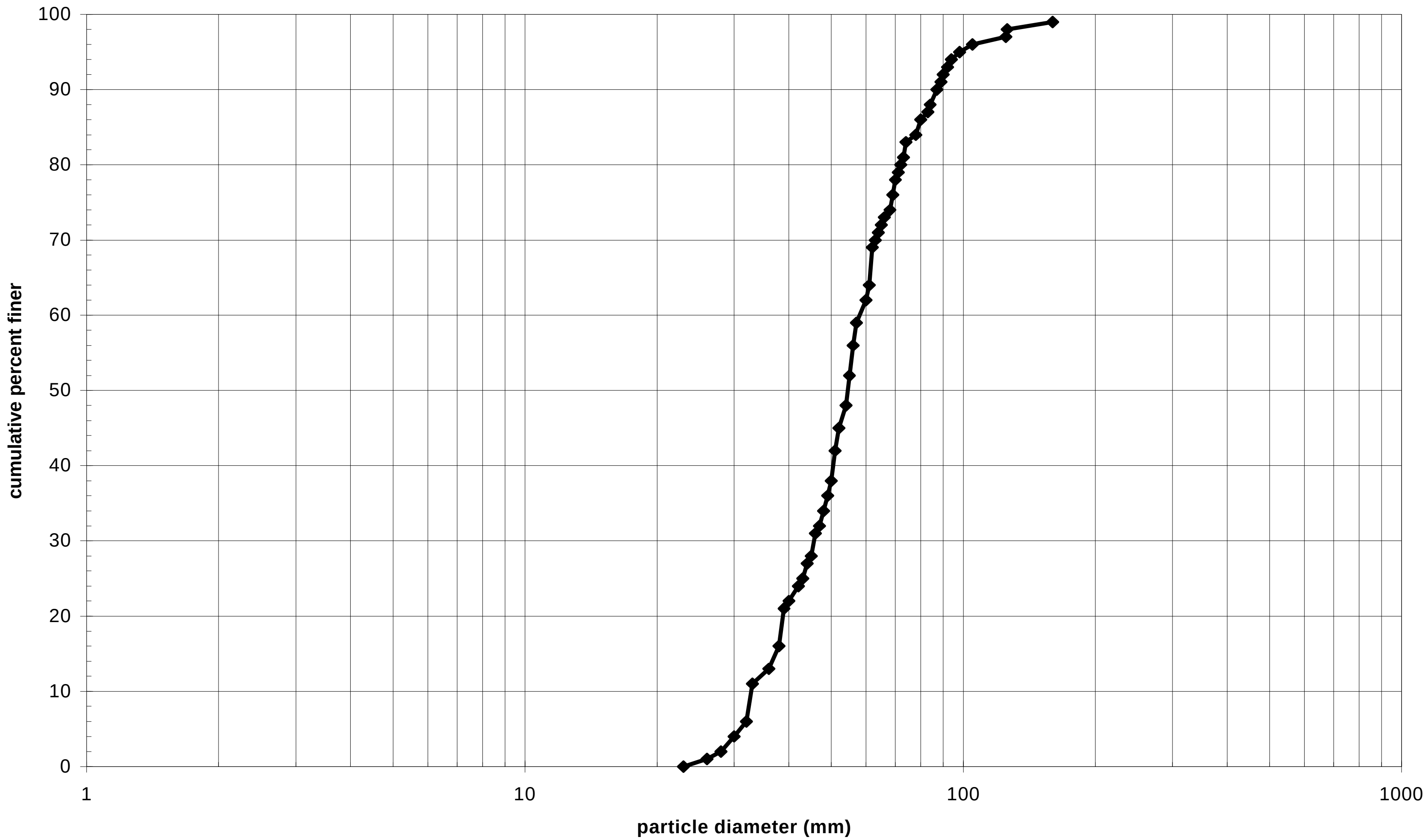


Figure C-5. Surface particle size distribution at Riffle 9a

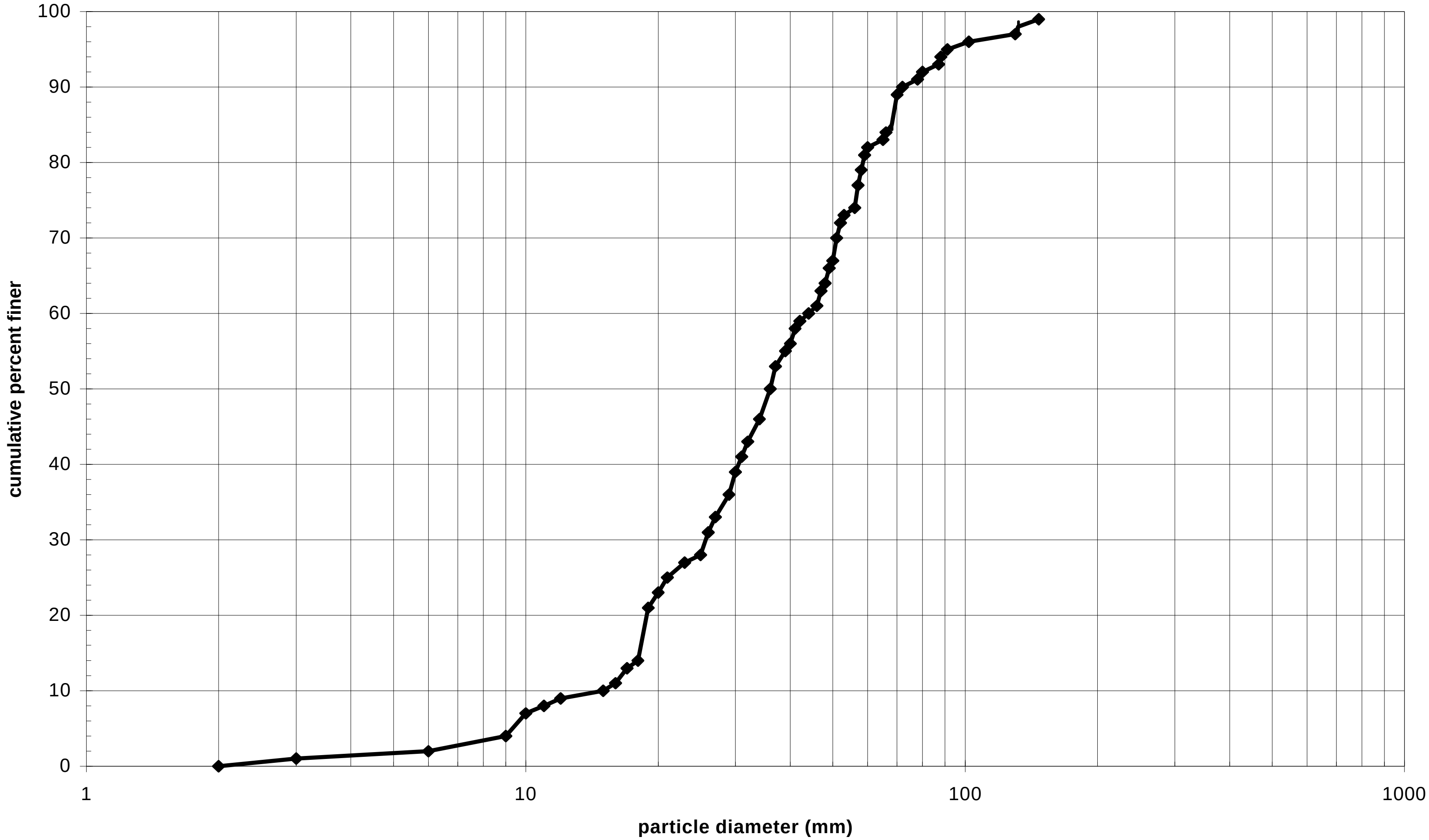


Figure C-6. Surface particle size distribution at Riffle 9b

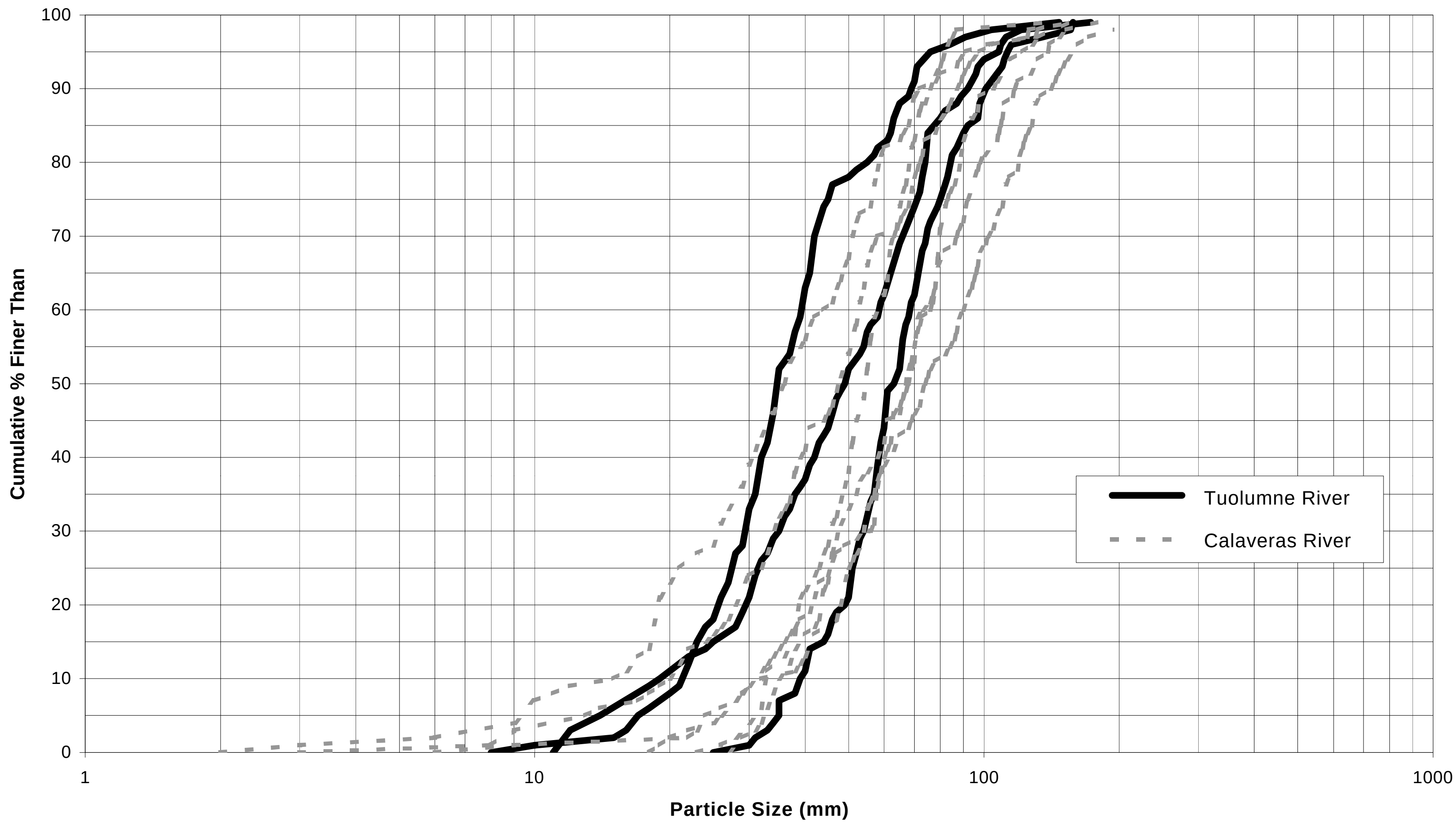


Figure C-7. Comparison of cumulative particle size distribution curves of spawning gravels used extensively by chinook salmon in the Tuolumne River, with potentially suitable spawnig gravels in the Calaveras River