GRAVEL QUALITY MONITORING IN THE MAINSTEM TRINITY RIVER

Prepared for:

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Salmon lay their eggs under 1’-2’ of gravel, thereby protecting the eggs from predation and exposure to high flows during their four to eight week incubation period. Crucial to the eggs’ survival is the ability of the gravels to permit water flow through them to supply dissolved oxygen and to remove waste. Once the eggs hatch, the covering gravels must then allow the alevins passage to the open stream above. Spawning gravel is the first habitat encountered by a generation of salmon and the characteristics of that gravel are vital to the eventual success of that run.

The Trinity River Restoration Program recognizes that physical instream habitat restoration and monitoring is an important component of rehabilitation of the mainstem Trinity River. Numerous documents have described the influx of fine sediments to the mainstem Trinity River from the Rush Creek to Indian Creek watersheds that have impacted spawning gravel quality. The Trinity River has been recognized by the State of California and the federal Environmental Protection Agency as an impaired water body under the Clean Water Act, Section 303d, and a Total Maximum Daily Load (TMDL), is being developed by the US Environmental Protection Agency. Despite this, spawning gravel quality on the Trinity River has received little attention and only a few scattered observations since 1993. The focus of this project is to remedy this situation by formally investigating the quality of salmon spawning gravel on the mainstem Trinity River, a critical habitat that lays the foundation for salmon runs.

Since 1923, considerable research effort has focused on the intragravel conditions that are crucial to development and survival of salmonid eggs (Chapman 1988). Physical parameters such as substrate composition, dissolved oxygen, gravel permeability, and water temperature have all been investigated in this regard (Everest et al. 1987; Chapman 1988).

Of these gravel parameters, substrate composition has received the most emphasis since 1923, when C. W. Harrison first demonstrated a relationship between substrate composition and survival of salmonid eggs to survival (Chapman 1988). Many investigators have studied this relationship and found that certain particle size classes, notably the smaller ones, have the most significant effect on embryo survival. Chapman (1988) has thoroughly reviewed these studies and summarized the gravel indexes developed for this relationship. From the particle size distribution of gravel samples, the percentage of particles less than 2 mm, 1 mm, and 0.85 mm have all been shown to affect egg survival in various studies. Other scientists have developed gravel indexes that combine size classes to better describe complex particle size distributions. Most notable are the geometric mean diameter (dg), used by several disciplines and the fredle index (Lottspeich and Everest 1981) derived from the dg and a sorting coefficient.

Two problems that complicate sampling spawning gravels are that the character of the deposits is highly variable and that surface layers are usually coarser than the subsurface (Church et al. 1987). To help remedy these problems, Church et al. (1987) suggest a method where the surface layer (one grain deep) is removed and treated separately, and that the largest particle in the sample represents 1% of the total sample weight. Most spawning gravel studies have used a method developed by McNeil and Ahnell (1964) where a “McNeil” sampler 6” in diameter is worked into the deposit to a particular depth and all material within the sampler is removed for sieve analysis. Other techniques, such as freeze coring, have been tried but most suffer from small sample sizes that do not meet the 1% criteria. Wilcock et al. (1995) used a modified McNeil type sampler with a diameter of 59 cm to try to meet the 1% criteria. For the present study, we used a similar size sampler (2’ diameter), removed and treated the surface layer separate from the subsurface, and took two samples per cross section that yielded per site total subsurface weights of 400 to 700 kg. Although no formal analysis was conducted, we are confident the 1% criterion was met for most sites.

Permeability is a measure of the ability of a porous medium to pass water and as such, is a characteristic of spawning gravel that directly influences the delivery of oxygenated water to, and the removal of wastes from, developing salmon eggs. It is notable that gravel permeability is independent of water discharge. In 1958, Terhune developed an inexpensive method to measure spawning gravel permeability and since then numerous studies have explored the relationship between permeability and other gravel parameters as well as embryo survival. Recent studies have modified Terhune’s methods by using a smaller diameter standpipe (1” diameter rather than 1 ¼”) to decrease gravel disturbance and an electric pump (rather than a hand operated pump) to improve consistency of readings (McBain and Trush 2000). For this study, we used these methods and further modified them by attaching the backpack electric pump to a tripod that permitted one person to conduct the permeability measurements.

OBJECTIVES

The goals of this project are to develop baseline data that will assist in: (1) providing monitoring data for gravel quality between Lewiston Dam and Junction City, (2) providing monitoring data to evaluate the effectiveness of restoration actions to date in various sub-watersheds, (3) providing information useful for completing the TMDL by identifying current substrate quality in high priority portions of the mainstem Trinity River.

The following objectives were developed to accomplish the goals outlined above:

(a) Establish baseline substrate composition and permeability conditions for long-term trend monitoring in the Trinity River and tributaries.

(b) Assess the relationship between substrate composition and permeability.

(c) Evaluate the longitudinal changes to gravel quality along the mainstem Trinity River to assess the influence of tributary derived sediments.

(d) Estimate survival rate of eggs to fry emergence for chinook salmon along the mainstem Trinity River using several indexes.

STUDY SITES

This project focused on the section of the Trinity River from Lewiston Dam to Junction City that receives much of the mainstem salmon spawning and has been the most impacted by reduced flows, and thus tributary-derived sediments. Eight study sites were selected to: 1) represent river sections below key tributaries; 2) sample known spawning areas identified on aerial photos in 1999 by Jay Glase (USFWS) and Scott McBain (McBain and Trush) and/or used by chinook spawners during fall, 2000; and 3) permit access for sampling equipment and removal of substrate for lab treatment. The latter depended on areas where there was public land access (BLM or USFS) or where private landowners allowed admittance. Sample cross sections were selected which exhibited good spawning characteristics and had spawning redds nearby but which were not themselves disturbed by spawning, that is, areas which fish would, but had not yet, selected to spawn.

The study sites (Figure 1) were:

LEWISTON RM 111.5
This run is on an existing cross section, 2500' downstream of the Lewiston Dam in an area which receives major chinook spawning use as well as artificial gravel introduction. Bulk samples were taken between the left bank (looking downstream) and mid-channel.

RUSH CREEK RM 107.4
Downstream of the Rush Creek confluence 900', this riffle exhibited numerous spawning redds. Sampling occurred between the left bank and mid-channel.

POKER BAR RM 102.7
This was a site recovered from the Wilcock et al (1995) flushing flow study. This run is 2000' upstream from the Poker Bar Bridge. Unlike the Steelbridge site, the spawning area has shifted since 1993 and as such we selected an existing cross section upstream of the main sampling cross section from that year. Bulk samples were taken from the middle of the section.

STEELBRIDGE RM 98.95
Near the downstream end of the BLM campground and on the right bank side of a mid-channel island, this shallow run is heavily spawned most years. We recovered a cross section and bulk sampling locations established for a flushing flow study (Wilcock et al. 1995) which used similar methods, and as such this site provides some useful trend monitoring.

INDIAN CREEK RM 95.3
Approximately 300' downstream of the mouth of Indian Creek, the cross section was newly established on a pool tail/riffle crest with several redds nearby. This is a fairly new spawning area as the reach is highly mobile and spawning habitat shifts almost yearly. Sampling was concentrated mid-channel.

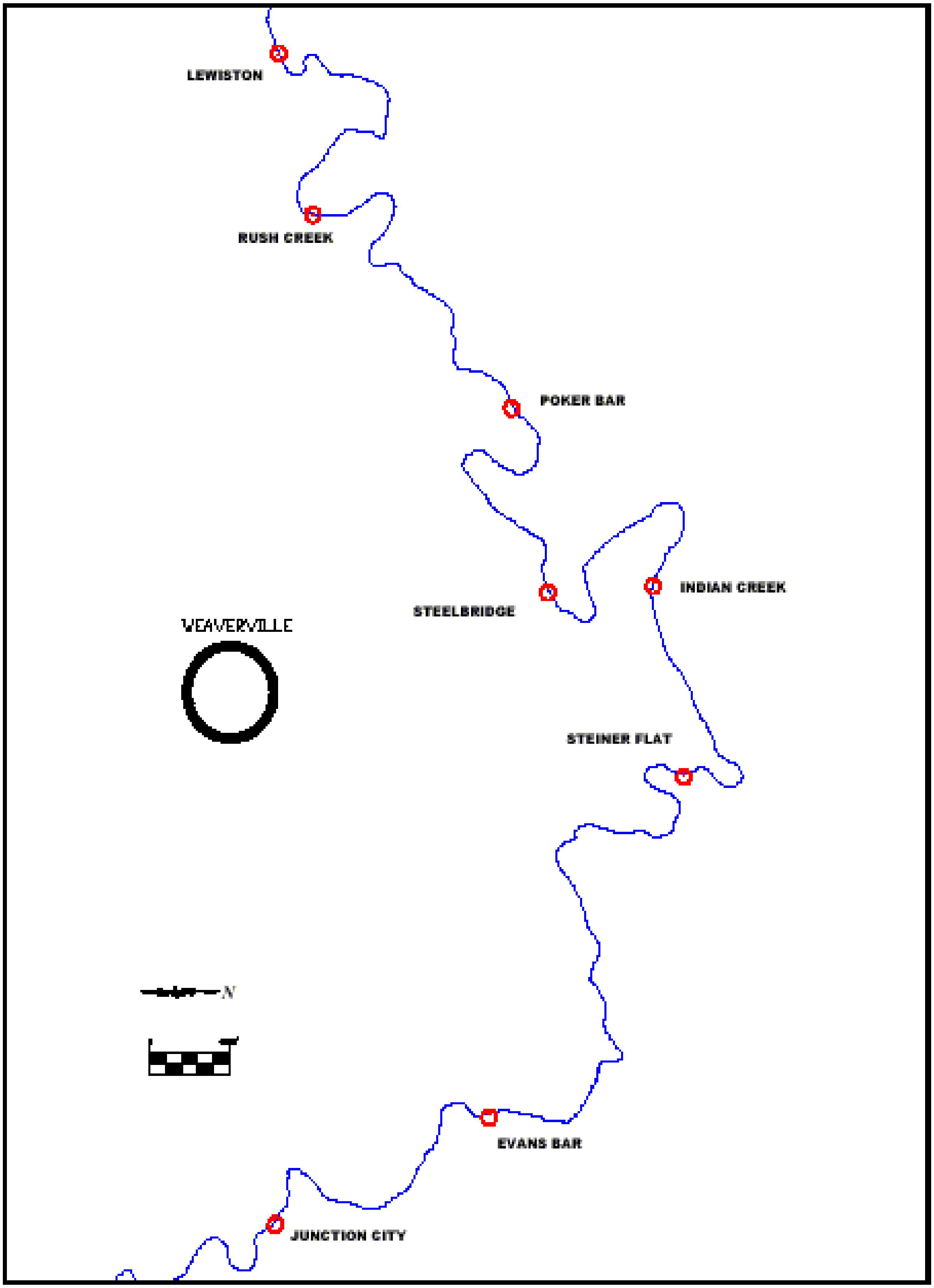


Figure 1: Site Location map for the Mainstem Trinity River Gravel Quality Monitoring Project

STEINER FLAT RM 91.95
This site was established as a study site for a channel maintenance flow study and subsequently underwent bank restoration (feather edging) in 1993 and as such has been heavily investigated by various entities. We recovered an existing uniformly shallow cross section (#1+45) in an area with several redds and distributed the two bulk samples evenly across the channel.

EVANS BAR (BELL GULCH) RM 84.1
This is a long run with a coarse gravel/cobble bed at another bank restoration site. An existing cross section was recovered and the two bulk samples were equally spaced across the channel.

JUNCTION CITY RM 80.3
Upstream 3900' from the Dutch Creek Road bridge in Junction City, this was a riffle crest with suitable spawning characteristics near the left bank where both bulk samples were concentrated.

METHODS

Once a site was selected, a cross section was established using 5/8" rebar on each bank as endpins. A measuring tape was strung between endpins with station 0 on the left bank pin and all further sampling at the site was referenced to the tape. The cross section at each site was surveyed with an autolevel, using the top of one of the rebar endpins (usually the left bank pin) as a relative elevation datum (usually 100.00'), surveying all major slope breaks and points at least every five feet. Pre-existing cross sections were used where they coincided with the spawning areas in order to allow comparisons with previous studies. Prospective bulk sampling locations were identified during this stage (Appendix A).

Surface particle counts were conducted generally between the bulk sample locations following methods described by Wolman (1954). Each of the 100+ particles for each count were measured using a "gravelometer" template with square openings representing phi and half phi sieve sizes which closely duplicates standard sieving methods.

Intragravel permeability was measured at ten locations along or adjacent to each cross section (Figure 2) using a modified Terhune (1958) method with a backpack electric pump (McBain and Trush 2000) mounted on a tripod for use by one person (Figure 3). Two samples were taken within each of the two bulk sample areas. The permeability standpipe was driven into the gravel until the bottom of the perforated portion was 35 cm below the bed surface. This depth was selected because a concurrent freeze core study of chinook salmon spawning indicated this as an average depth of egg deposition (Danni Everson, personal communication).

At each site, two bulk samples were taken along the cross section in undisturbed locations that matched the spawning characteristics of the area. We used a McNeil type method but our samplers were 2.0' cylinders (Figure 4) which were worked down into the gravel bed, removing

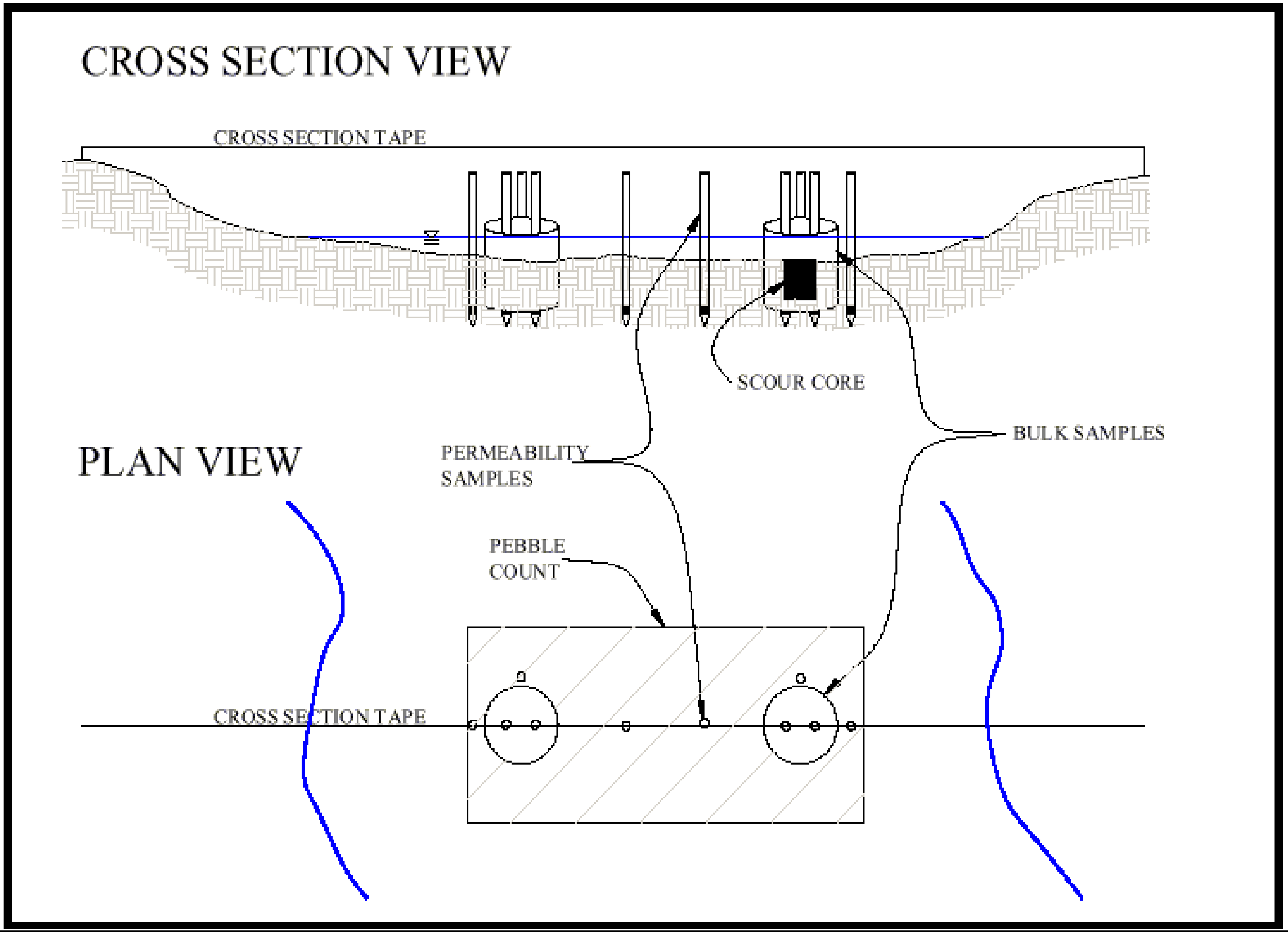


Figure 2: Typical sampling methods used at each site.

Figure 3. Permeability sampling using the backpack pump mounted on a tripod.

Figure 4. Two foot diameter McNeil type bulk sampler.

the bed material into buckets until the hole was excavated to a depth of 1.0-1.4' (Figure 5). The top surface layer, defined as the depth of the largest surface particle was kept separate from the subsurface. Once removed (Figure 6), samples were field sieved in rocker boxes (Gilson Company) through a 16 mm screen (as described in a later paragraph, photo in Figure 7) and the finer fraction bagged for transport to our lab.

After removing the bulk sample in the field, a bucket of ¾" crushed, white dolomite was placed in the hole, the sampler removed and the hole backfilled with bed material to leave a core of tracer pebbles (Figure 8). The scour core surface was level surveyed and the center noted on the cross section tape to allow future recovery and determination of bed scouring during high flows.

All data for each site was entered into a site workbook (MS Excel 2000). The permeability worksheet (adapted from McBain and Trush 2000) took measurements entered as elapsed time and cm of water inflow and converted them to inflow rate (ml/s), raw permeability (cm/hr) from a curve generated by Terhune (1958) and Barnard and McBain (1994), final permeability (cm/hr) adjusted by a water temperature factor (Terhune 1958), mean permeability for each sample location, and mean permeability for the entire site.

The pebble counts were entered as the number of particles retained in each sieve class and converted to the cumulative percentage (by number) finer than the corresponding sieve size. Although no formal statistical analysis was completed, graphic results (see Appendix B) demonstrate that pebble counts do not appear to represent the surface bulk samples, except at the Lewiston site where the substrate is almost completely devoid of sand size particles (<2mm) or smaller.

Each bulk sample was treated in two distinct methods, field and lab. Since sampling was performed during the fall and winter to take advantage of low flow releases on the Trinity River, sieve analysis was adjusted from our "normal" procedure. Many investigators agree that bulk samples should be sun-dried in the field, entirely sieved through an 8 mm sieve, and the larger sizes sieved by rocker boxes and weighed dry. The smaller size fraction (<8 mm) is then weighed in its entirety, split into quarters (or eighths) and one split taken to a lab, shaken and weighed. Weather restrictions prevented our drying samples in the field so we sieved each sample through a 16 mm sieve in a rocker box and took the smaller fraction (3 – 5 buckets per sample) to our lab for drying, splitting, sieving, and weighing. The larger material was wet sieved in rocker boxes, drained of excess water, and weighed wet in the field. From the 16 samples, we retained four samples of each field size class (90, 64, 45.3, 32, 22.6, and 16 mm), reweighed them dry, and calculated a conversion factor to correct wet field weights to dry weights. The conversion factors for this coarse material ranged from 0.9799 for the sample material retained on the 16mm sieve to 0.9974 for the 90mm sieve. Most of the surface samples consisted of a single bucket and were transported entirely to the lab for sieve analysis.

Wet weights for the larger sizes were entered in the bulk sample spreadsheet and converted to dry weights. Dry weights from lab analysis for the smaller sizes were added and all were converted to cumulative percent finer than each sieve size used. Particle size distribution charts (Appendix B) generated for each site show the surface and subsurface curves for each sample and the pebble count

Figure 5. Bulk sampling using modified 2' diameter McNeil-type sampler. Canoe was used to retain buckets during sampling and transport to the bank for sieving.

Figure 6. One bulk sample ready for field sieving. Note green bucket with surface sample.

Figure 7. Initial wet sieving of bulk sample through 16 mm screen in rocker box.

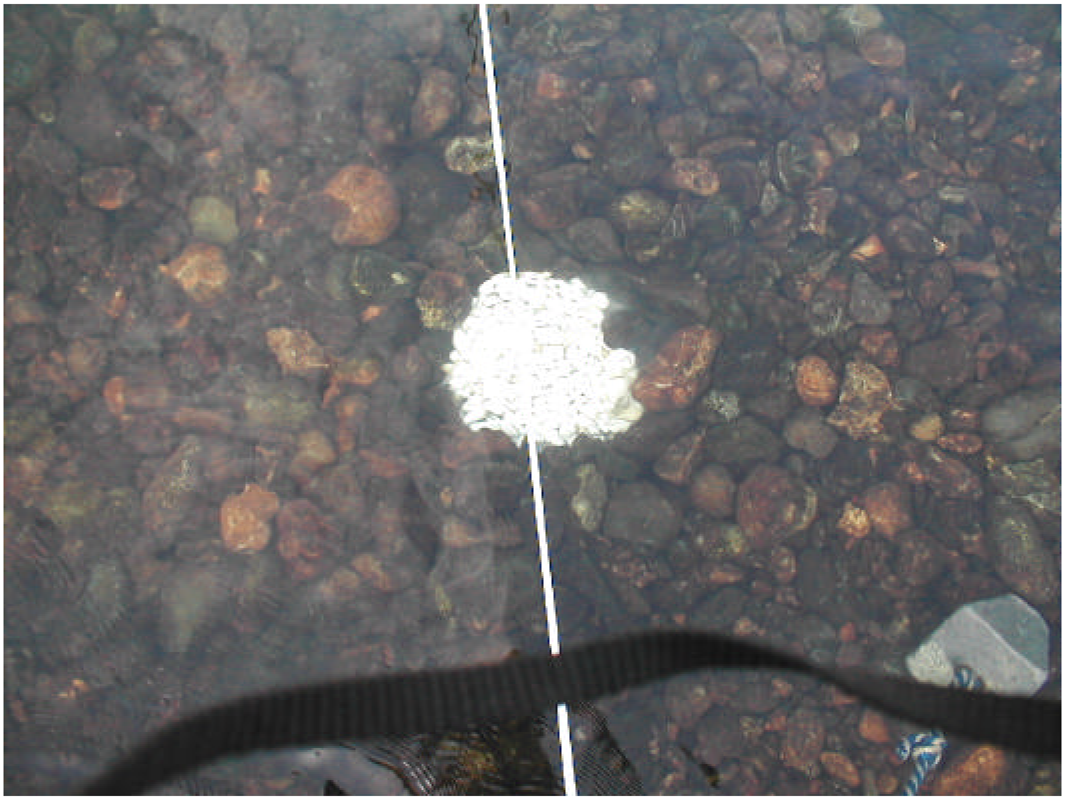


Figure 8. Scour core of ¾” crushed tracer rocks after bulk sample has been removed.

for the site (The pebble count at the Rush Creek site used a ruler method where the b-axis of each particle is measured).

At the lab, the finer material (<16 mm) was thoroughly oven dried, and sieved through 2mm using a Gilson TS-1 Testing Screen. This high volume testing screen allows up to one cubic foot of sample to be sieved in 3-5 minutes. For materials finer than 2 mm, a total weight was first obtained, and then the sample was split into quarters or eighths. A random split was selected and run through 8" sieves with a Gilson SS-15 Sieve Shaker. For several samples, multiple splits were independently sieved to verify that each split was truly representative of the entire fine fraction of the sample.

RESULTS

The results of the individual bulk samples are compiled in Table 1 and include the particle size distributions for the subsurface and for the combined surface and subsurface, several particle size indexes (for subsurface samples only), and the mean value for the two permeability samples within each bulk sample. The particle size distribution curves for these individual samples are included in Appendix B.

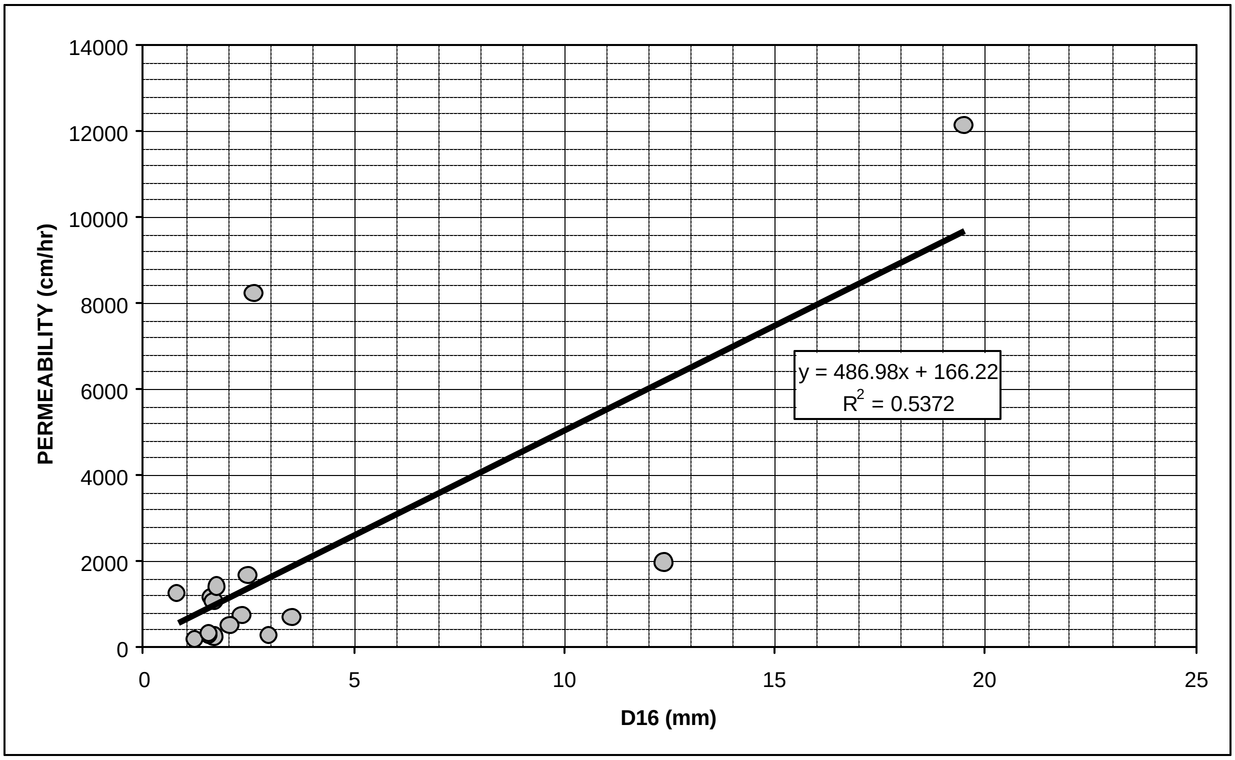
The relationship between permeability and particle size distribution was tested by running a correlation test between them (MS Excel 2000). The resultant r-squared values (Table 2) show the strongest relationship between permeability and D_{16} (0.5372) and the Fredle index (0.4956) although neither is very good. Those regressions are charted in Figure 9 with their corresponding equations and r-squared values.

Table 2. R-squared values for the correlations between mean permeability within bulk samples and several gravel indexes for individual bulk samples.

	D50	**D25**	**D16**	**dg**	**FREDLE**	**%FINES<2 mm**	**% FINES <1mm**	**% FINES <0.85mm**
PERMEABILITY	**0.0661**	**0.4208**	**0.5372**	**0.1915**	**0.4956**	**0.2742**	**0.3258**	**0.3462**

For further analysis, each site was treated as a single unit. Bulk samples were combined to yield a single mean subsurface particle size distribution and all ten permeability samples combined and a mean site permeability calculated. Table 3 includes these and several gravel indexes generated from the mean distribution to describe the baseline gravel quality for each section of the Trinity River for use with long-term trend monitoring.

The mean site values (Table 3) were profiled for longitudinal changes. Figure 10 plots several quality indexes against river miles demonstrating the reduced spawning quality moving downstream. These results are likely due to the influence of tributary derived sediments. Of



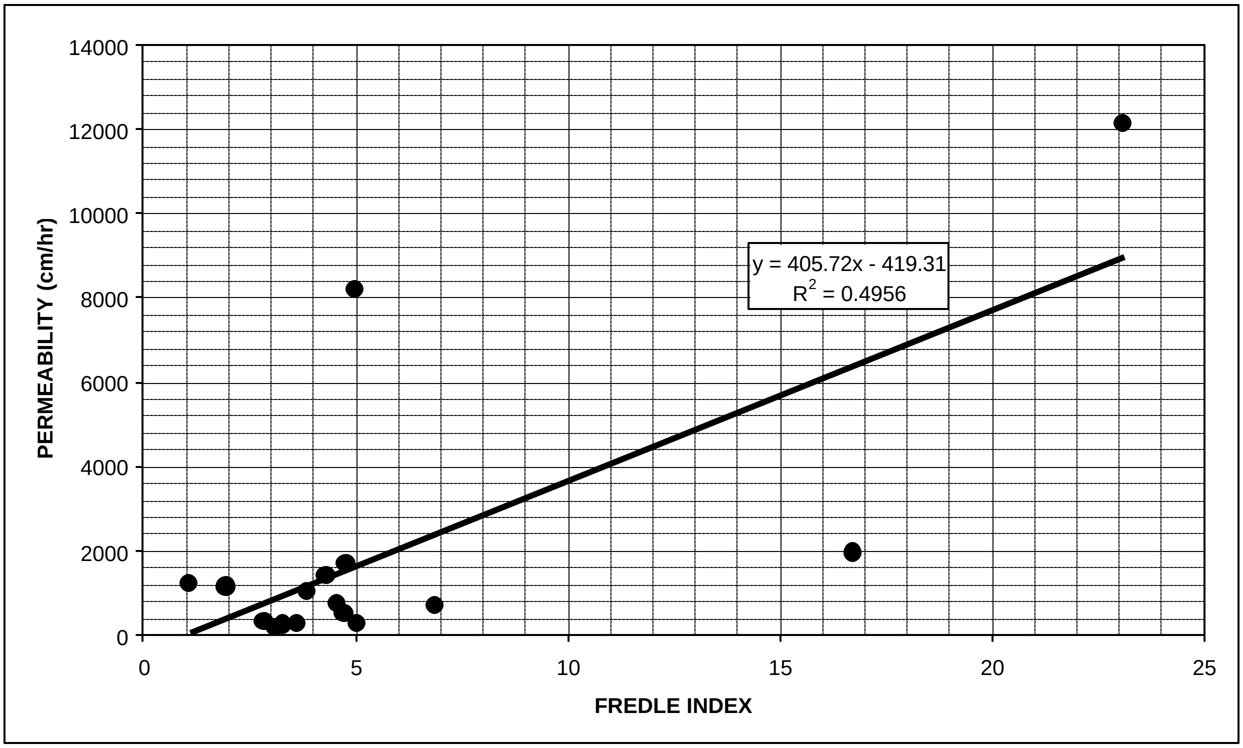


Figure 9: Relationships between permeability and D_{16} and Fredle Index for individual samples.

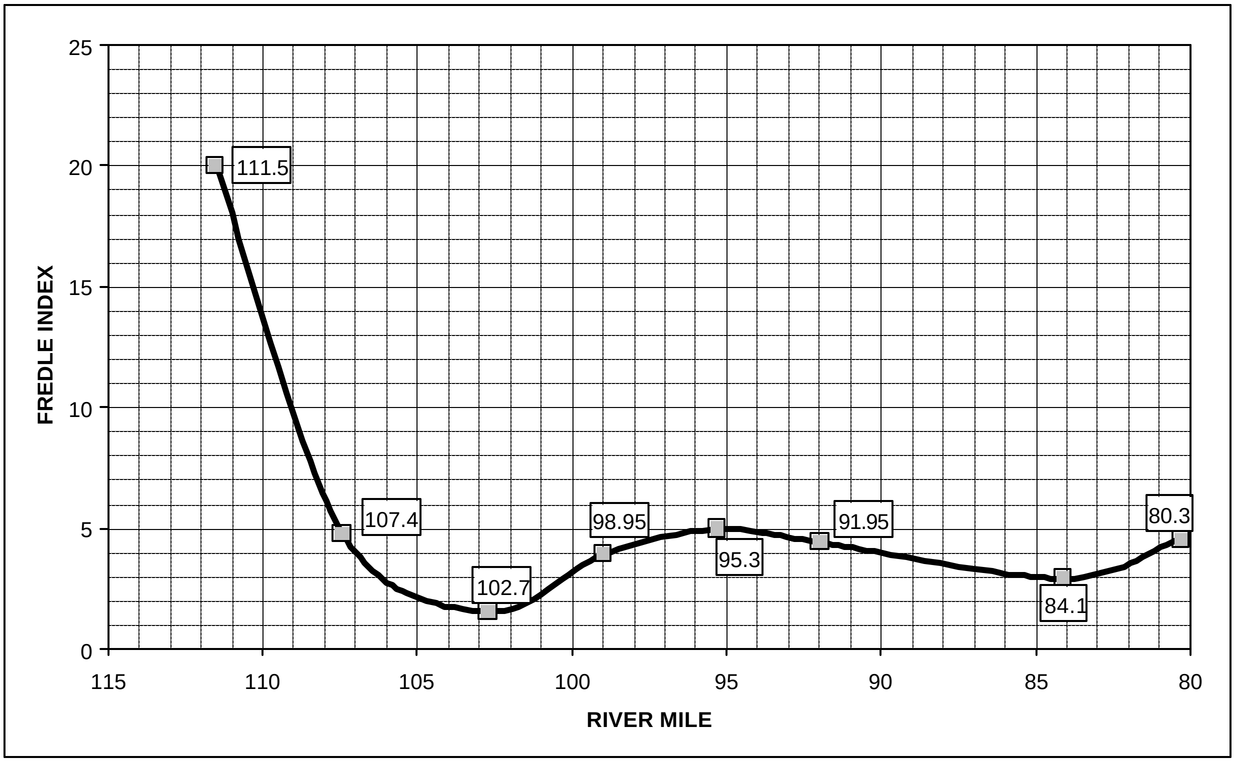


Figure 10a: Mean Fredle index per site compared to river miles for eight mainstem Trinity River sites.

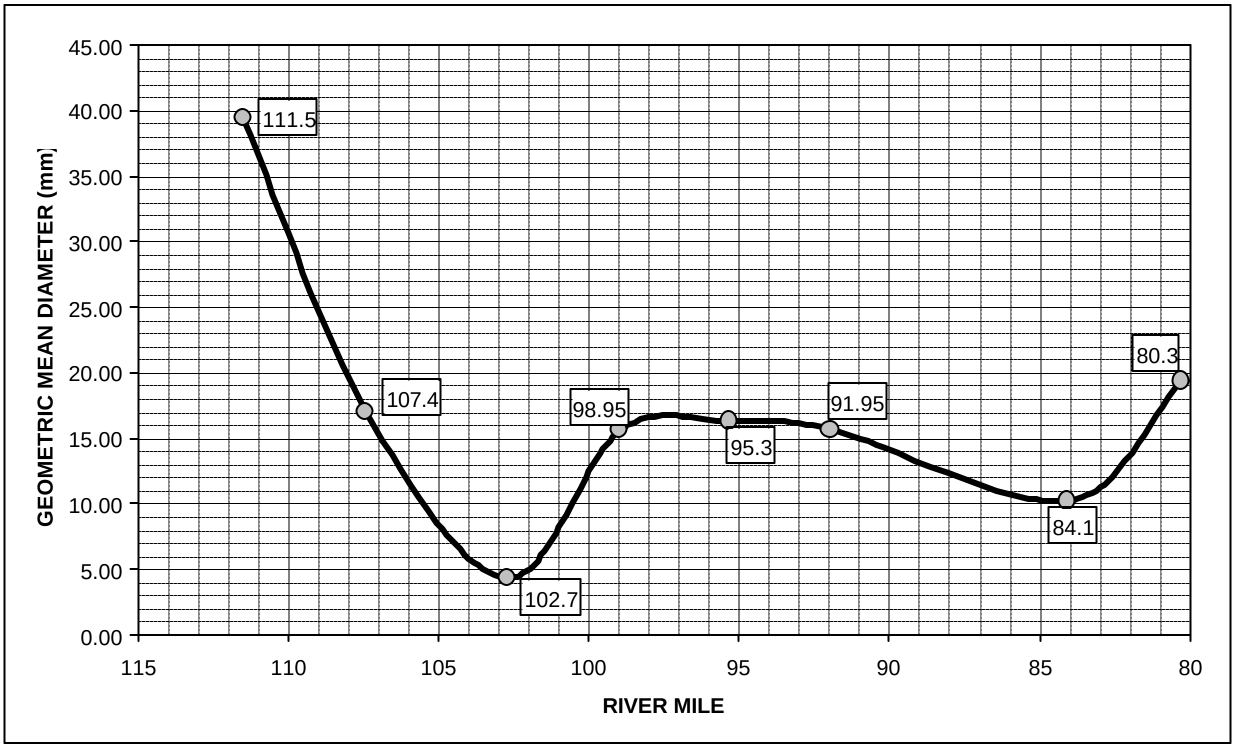


Figure 10b: Mean geometric mean diameter per site compared to river miles for eight mainstem Trinity River sites.

particular note is the dramatic reduction in gravel quality (indicated by increased percentages of fines, decreased D_{84} to D_{16} values, and decreased dg and fredle indexes) between the Rush Creek and Poker Bar site. Poker Bar is the first site downstream of the mouth of Grass Valley Creek, recognized as one of the biggest sediment contributors to the mainstem Trinity River. The index values improve by the Steelbridge site.

Mean site permeability was plotted against river miles (Figure 11) and shows the same general trend of decreasing in a downstream direction. A notable inconsistency exists between the gravel indexes and permeability at Poker Bar (RM 102.7). Although there is a high percentage of fines , the site permeability is not as low as would normally be expected. A partial explanation is that the fines at Poker Bar are large grain decomposed granite (likely from Grass Valley Creek) as confirmed by the much larger difference between percent fines <2 mm and <1 mm at Poker Bar than at the other sites. The larger grain sizes block the gravel interstices (and probably alevin emergence) but allow more water flow than smaller grains and therefore higher permeability.

The relationship between particle size distribution and permeability was tested using the site values. Correlation tests were run for mean permeability and most of the gravel indexes and the R squared values (Table 4) show very strong relationships with D_{25}, D_{16}, dg, and the fredle index. When the fredle/permeability relationship is plotted (Figure 12), it is clear that the strong correlation is largely driven by the high permeability value at the Lewiston site relative to the other sites. So a second correlation test was run with the same measures but after removing the two atypical sites, Lewiston and Poker Bar. Again there are several strong relationships, as evidenced by the R-squared values (Table 5) but now the best correlations are between permeability and percent fines < 1 mm and < 0.85 mm (Figure 13).

Table 4. R-squared values for the correlation between mean site permeability and several gravel indexes for all eight sites.

	D50	**D25**	**D16**	**dg**	**FREDLE**	**%FINES<2 mm**	**% FINES <1mm**	**% FINES <0.85mm**
MEAN PERM. PER SITE	**0.4128**	**0.8888**	**0.9246**	**0.7391**	**0.8889**	**0.5016**	**0.7851**	**0.7689**

Table 5. R-squared values for the correlation between mean site permeability and several gravel indexes for six sites (Lewiston and Poker Bar removed).

	D50	**D25**	**D16**	**dg**	**FREDLE**	**% FINES<2mm**	**% FINES <1mm**	**% FINES <0.85mm**
MEAN PERM. PER SITE	**0.0576**	**0.2029**	**0.5908**	**0.2521**	**0.2490**	**0.5932**	**0.9635**	**0.9757**

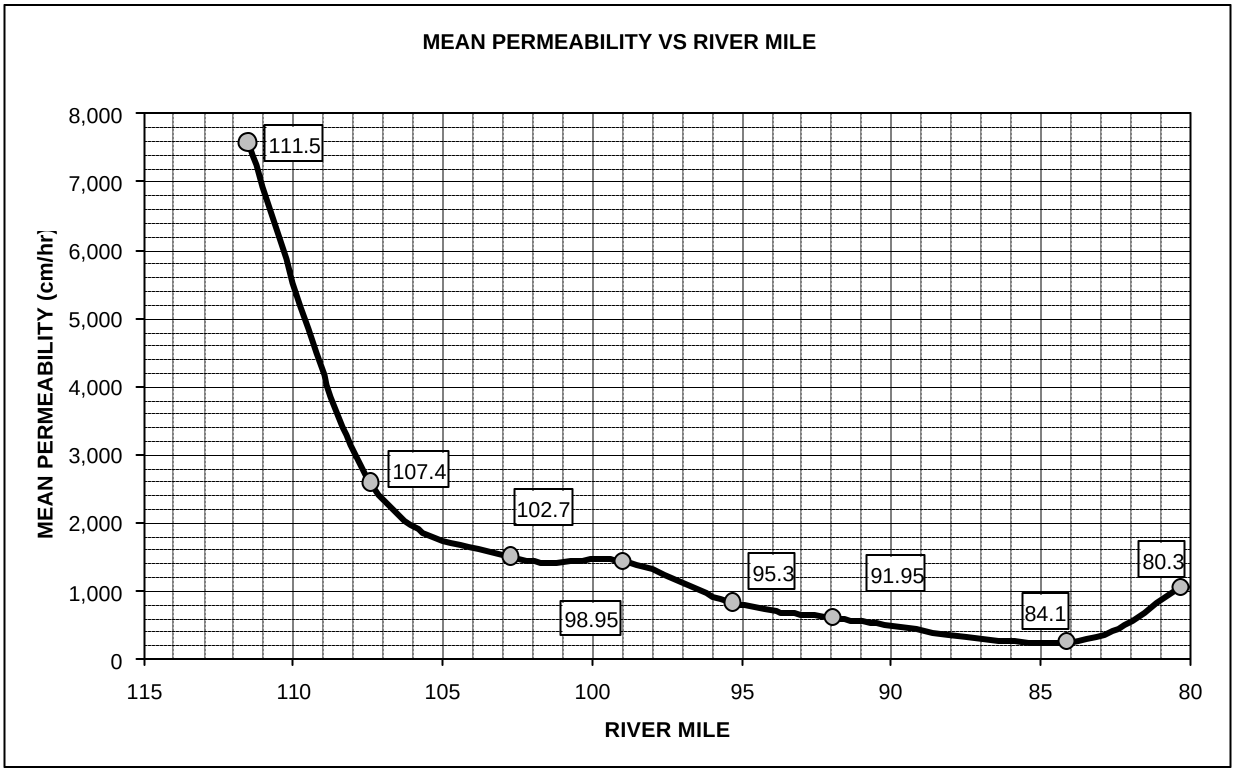


Figure 11: Mean permeability per site compared to river miles for eight mainstem Trinity River Sites.

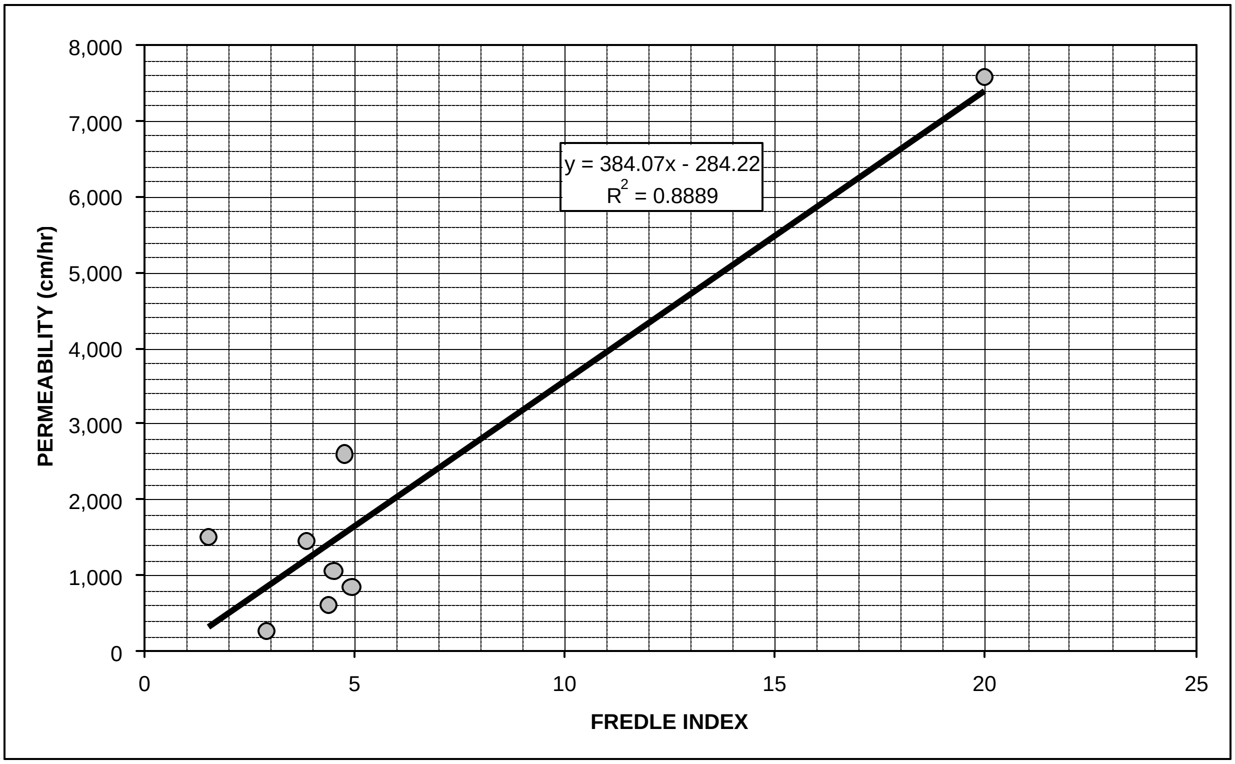


Figure 12: Simple regression between mean site permeability and site fredle index for all eight mainstem Trinity River sites

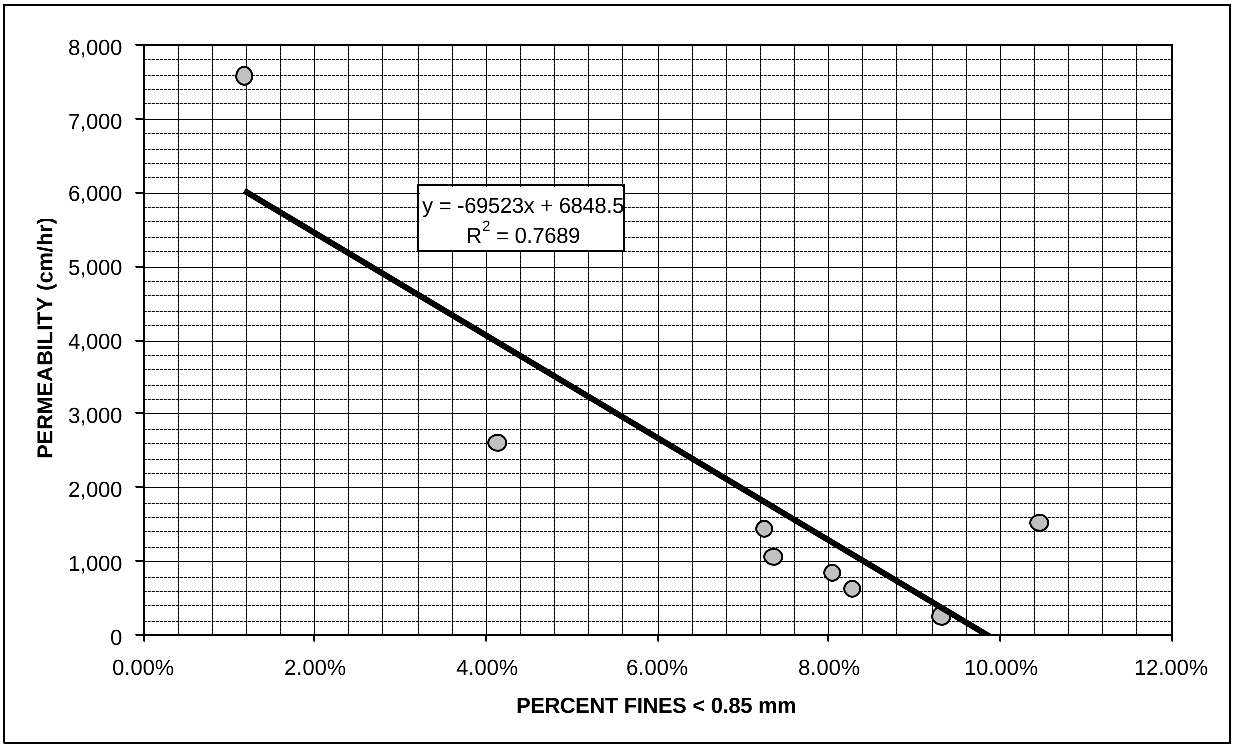


Figure 13a: Simple regression between mean site permeability and site percent fines < 0.85mm for all eight mainstem Trinity River sites.

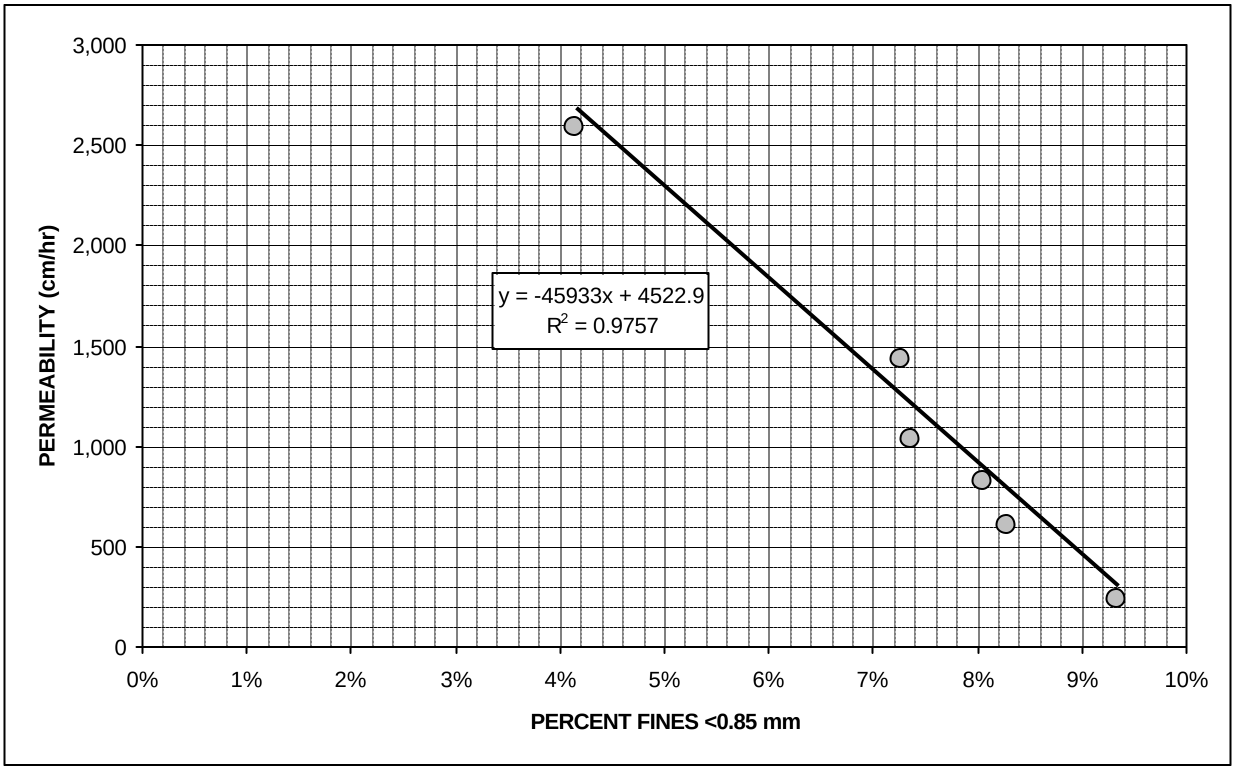


Figure 13b: Simple regression between mean site permeability and site percent fines <0.85mm for six mainstem Trinity River sites (Lewiston and Poker Bar removed).

DISCUSSION

Study of Chinook spawning on the Trinity River has been limited to enumerating spawning redds and adults and identifying spawning areas over the last several years. These are important data but fail to allow accurate estimates of number of emergent fry for the river. This project begins to fill a crucial gap in modeling for run sizes by quantifying the actual quality of the spawning gravels and with it the potential survival of deposited eggs to emergent fry. Using Chapman's (1988) review, we informally examined the gravel composition vs. survival relationships using the geometric mean diameter (dg), fredle index, and the percentage of fines < 0.85 mm from this study. They indicate the quality of the spawning gravel at the Trinity River study sites would generally support good survival. Spawning in the Lewiston area just below the dam has been augmented by the introduction of clean gravels that appears to be working well, which is important since the area receives a high percentage of the total spawning activity. Downstream of the first tributaries, survival to emergence appears to drop and are lowest below Grass Valley Creek (Poker Bar site), likely due to increased tributary derived fine sediment.

In addition to the gravel indexes, we used an equation presented by McBain and Trush (2000) based on work by McCuddin (1977) to estimate chinook survival to emergence using mean site permeability (Table 3). These values should be interpreted as an index of quality rather than a strict predictor of survival. Their trend is to decrease in a downstream direction much as the other gravel indexes although they suggest a much lower survival percentage than suggested by the gravel distribution indexes. The permeability index drops in steps below Rush Creek, Grass Valley Creek, Indian Creek, and to 0% survival at the Evans Bar site, suggesting deteriorating conditions due to increased fines contributed by tributaries.

The Poker Bar and Steelbridge sites were selected to allow comparison to similar work in 1991-93 (Wilcock et al. 1995). Our source for the early work was the 1995 report that had figures representing the particle size distributions for bulk samples but not the original data. At Poker bar, we used one of the 1991 study cross sections but not the main study cross section because the spawning area had apparently shifted upstream since then. The 1995 report does not include information on our cross section so we were unable to measure changes.

Our Steelbridge cross section duplicates the main study section of the 1991 work and our bulk samples were removed from two of the same spots along the tape. Unfortunately, the original data was unavailable for this report and the only usable data for the whole distribution was taken from a figure (Wilcock et al. 1995, Figure 3.2.3) that apparently combines 1992 sample data from two of their cross sections and fails to mention whether they include surface layers with subsurface. Although the particle size distribution is plotted on the Steelbridge chart (Appendix B), no comparisons can be drawn without the original field data. However, Wilcock et al. (1995) do include D_{90} and D_{50} values from their 1992 bulk samples that can directly compare to our data (assuming their values were calculated from the subsurface samples). Our Steelbridge sample #1 had a D_{90} of 124.8 mm and a D_{50} of 19.9 mm while in 1992, the D_{90} was 125 mm and the D_{50} was 35 (post flushing flow). Our sample #2 had a D_{90} of 109.7 mm and a D_{50} of 22.6 mm while the corresponding 1992 values were 140 mm and 33 mm. The comparison indicates that both locations and likely the entire cross section show an increase in the smaller fractions since 1992.

The methods we used were developed in discussion with many investigators and literature review to reduce errors associated with other techniques commonly practiced. Most would agree that our large substrate samples, although intensive, are necessary to reduce sampling error and accurately characterize habitat that is highly variable. Although no formal analysis of pebble counts has yet been conducted, we suggest that they did not adequately represent either the surface or subsurface bulk samples (see Appendix B).

Permeability continues to show promise as a surrogate to substrate sampling for characterizing spawning gravels except in conditions, such as at Poker Bar, where the fines portion of gravels are so large (> 1 mm) that they allow water movement, yet, we suspect, prevent the emergence of alevins. Although the sample size was small (six or eight sites), mean site permeability derived from numerous samples seems strongly dependent on the smaller gravel sizes in a spawning site. In further support of permeability, it should be mentioned that the method used here was modified to be practical for a single person to successfully conduct numerous tests, thus making it an even more attractive substitute to cost-intensive bulk sampling. In fact, a single person can perform all of the methods in this study, except for surveying cross sections.

CONCLUSIONS

This study begins to quantify spawning gravel conditions in the mainstem Trinity River, providing a database to monitor trends and an early gauge to areas needing further study. Gravel and permeability indexes suggest decreasing quality downstream of major tributaries. We suggest that further investigations of spawning habitat quality be conducted with more focus on the mainstem Trinity River below Grass Valley Creek and extended downstream of our lowest site, Junction City.

The Steelbridge site (and Poker Bar to a lesser extent) provides some ability to compare changes between 1992 and the present based on the work of Wilcock et al. (1995). At both sites, fines appear to have increased and spawning quality decreased. While this may not be surprising given the extent of flow manipulation by the Trinity River Division, there are reasons why improved substrate conditions might expected to be the case:

Beginning in 1992, high flow (up to 6800 cfs) releases have periodically been made from the reservoirs upstream. Observations by Wilcock et al. (1995) during such flushing flows, indicated substantial improvement of surface layers from these high flow releases. In particular, between 1995 and 2000, a number of natural high flow peaks and reservoir releases have occurred, as listed below. Many of these days of high flows were Safety of Dams releases due to reservoir storage encroachment into the designated flood control pool.

Water Year	# Days > 5000 cfs release at Lewiston
1995	24
1996	6
1997	38
1998	20
1999	0
2000	10

Given the extent of prolonged periods of high flows, one might expect significant improvements in gravel quality. Since this has not been observed, we can suggest two explanations: (a) flows between 5000 and 7000 cfs are ineffective at achieving any sub-surface flushing, or (b) continued tributary sediment inflows have been sufficient to maintain the substrate in a degraded condition. Certainly we know that Grass Valley Creek contributed a fair amount of fine sediment in 1997 and 1998, when the sedimentation ponds completely filled and spilled an undetermined amount of sand-sized material into the mainstem. No appreciable bedload sediment delivery into the mainstem occurred from Grass Valley in either WY1999 or 2000.

RECOMMENDATIONS

The following recommendations have been developed in the course of this study:

1. Additional sampling of substrate suitable for spawning would help refine, extend and verify the results of this study. Such sampling would best be accomplished through additional longitudinal sampling (new sites), and additional site sampling (more samples per site). The reach between Rush Creek and Junction City should be targeted, although sampling as far downstream as the North Fork Trinity confluence would also be warranted. Additional sample sites between major tributaries would help refine whether fine and coarse sediment delivered from each of these tributaries is having a beneficial or detrimental effect on the local spawning habitat downstream. Additional sampling at a given site would allow for improved confidence in the results, as well as allowing statistical analysis of sample results, which requires a minimum of 3 samples per site.

2. The removal of fines during the spawning process should be investigated by comparing the particle size distribution and permeability in undisturbed spawning gravel (this study) with that of actual redds. Once the relationship is established, the redd sampling would not need to be repeated. Monitoring could then focus on suitable but otherwise un-utilized substrate. This type of destructive redd sampling would ideally occur

immediately after emergence, so that the conditions facing the alevins would be best represented. In practice this would be difficult, since flows have often increased by the time of emergence, rendering this type of sampling unfeasible until late summer and fall. Various researchers have noted that redd gravel quality may deteriorate rapidly over a period of winter/spring flows.

3. The relationship between future flow releases and spawning gravel quality should be further investigated to help refine the optimum release schedule for flushing of spawning gravels, as one factor in the adaptive management of the Trinity River. Available evidence from this study suggests that releases in the vicinity of 5000-6000 cfs, whether from Safety of Dams releases or from planned high flow releases, have been able to accomplish relatively little in terms of cleansing spawning gravels.

4. The relationship between sample particle size descriptors and permeability warrants further evaluation. The results of this study provide some of the highest correlations seen to date in the literature, probably as a result of the large size of each individual sample, thus providing improved resolution of substrate particle size variability. Since permeability testing requires a small fraction of the time and effort of bulk sampling, the development of such a relationship could greatly facilitate future substrate monitoring efforts.

5. The direct relationship between permeability and survival to emergence should be further investigated. The current trend requires a two-step process to relate permeability to particle size distribution and then to survival. There is apparently an effort currently underway to study survival to emergence versus permeability on several California rivers (Darren Mierau, pers. comm. 2000) and it seems timely to include the Trinity River in this investigation.

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TABLE 1

Individual bulk sample subsurface and combined surface/subsurface particle size distributions, particle size indexes, and mean permeability within each bulk sample

SITE	LEWISTON	LEWISTON	RUSH	RUSH	POKER	POKER	STEELBRIDGE	STEELBRIDGE
SAMPLE #	1	2	1	2	1	2	1	2
TOTAL DRY WEIGHT (KG) SUBSURFACE	233.35	301.00	318.99	314.53	269.99	167.17	370.67	336.96

CUM. % FINER THAN (SUBSURFACE)

360	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
256	100.00%	92.45%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
180	100.00%	84.97%	100.00%	94.15%	100.00%	100.00%	94.36%	96.62%
128	98.84%	70.29%	94.04%	88.73%	100.00%	100.00%	90.57%	94.39%
90.5	96.43%	60.62%	82.66%	79.53%	99.72%	100.00%	80.63%	81.57%
64	88.87%	54.35%	74.48%	74.07%	98.37%	99.05%	75.12%	75.40%
45.3	71.09%	45.41%	67.41%	68.53%	94.96%	95.02%	68.92%	66.20%
32	45.58%	36.85%	59.13%	60.16%	90.30%	86.18%	59.82%	57.57%
22.6	24.57%	28.31%	52.04%	51.66%	85.93%	77.27%	52.64%	50.04%
16	7.84%	20.34%	44.42%	43.63%	81.76%	69.56%	45.40%	43.31%
11.2	2.49%	14.46%	37.85%	36.82%	77.49%	64.53%	39.70%	36.57%
8	0.62%	10.98%	31.56%	30.76%	73.48%	60.46%	34.96%	30.88%
5.6	0.21%	8.93%	26.13%	25.69%	69.23%	56.69%	31.19%	26.39%
4	0.18%	7.34%	22.15%	21.66%	61.83%	51.94%	27.64%	22.50%
2.83	0.16%	5.70%	18.04%	16.92%	45.13%	44.50%	22.80%	17.57%
2	0.15%	4.36%	14.13%	12.06%	25.82%	36.78%	18.14%	13.10%
1.4	0.14%	3.13%	9.69%	7.19%	11.39%	28.83%	13.62%	9.14%
1	0.13%	2.31%	6.23%	4.26%	6.96%	21.03%	10.44%	6.56%
0.85	0.13%	2.00%	4.94%	3.33%	6.19%	17.37%	8.91%	5.43%
0.5	0.10%	1.24%	2.15%	1.53%	4.56%	6.98%	4.17%	2.19%
0.25	0.05%	0.49%	0.49%	0.40%	1.33%	1.05%	0.90%	0.43%
0.125	0.02%	0.13%	0.10%	0.10%	0.26%	0.20%	0.22%	0.11%
0.063	0.01%	0.04%	0.03%	0.03%	0.07%	0.06%	0.07%	0.04%
Pan	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

CUM. % FINER THAN (COMBINED SURFACE AND SUBSURFACE)

360	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
256	100.00%	92.95%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
180	100.00%	85.96%	100.00%	94.61%	100.00%	100.00%	94.72%	97.00%
128	98.96%	72.25%	94.55%	89.63%	100.00%	97.71%	91.17%	95.01%
90	96.09%	63.23%	83.36%	80.30%	99.73%	96.77%	81.01%	80.83%
64	85.51%	57.02%	72.62%	73.34%	98.19%	94.76%	74.50%	72.28%
45	67.23%	47.10%	64.77%	66.85%	94.39%	89.08%	67.87%	62.47%
32	42.17%	36.80%	55.90%	57.63%	88.55%	79.11%	58.15%	53.66%
22.4	22.41%	27.69%	48.74%	49.02%	83.37%	70.39%	50.65%	46.26%
16	7.03%	19.49%	41.44%	41.19%	78.97%	62.90%	43.47%	39.85%
11.2	2.23%	13.60%	35.17%	34.63%	74.60%	58.08%	37.94%	33.62%
8	0.56%	10.27%	29.27%	28.85%	70.58%	54.25%	33.37%	28.38%
5.6	0.19%	8.34%	24.20%	24.05%	66.41%	50.80%	29.78%	24.27%
4	0.16%	6.86%	20.49%	20.26%	59.24%	46.50%	26.37%	20.69%
2.8	0.15%	5.33%	16.67%	15.81%	43.20%	39.81%	21.74%	16.18%
2	0.14%	4.07%	13.04%	11.28%	24.72%	32.92%	17.29%	12.08%
1.4	0.13%	2.93%	8.94%	6.74%	10.93%	25.87%	13.00%	8.48%
1	0.13%	2.17%	5.76%	4.02%	6.68%	18.96%	9.98%	6.13%
0.85	0.12%	1.88%	4.57%	3.14%	5.94%	15.72%	8.53%	5.09%
0.5	0.10%	1.16%	2.00%	1.45%	4.36%	6.39%	4.00%	2.11%
0.25	0.05%	0.46%	0.46%	0.38%	1.28%	0.97%	0.86%	0.48%
0.125	0.02%	0.12%	0.10%	0.09%	0.25%	0.19%	0.21%	0.11%
0.063	0.01%	0.04%	0.03%	0.03%	0.07%	0.06%	0.07%	0.04%
Pan	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

PARTICLE SIZE DISTRIBUTION INDEXES (SEDSIZE)

D84	**57.07**	**176.66**	**93.57**	**105.85**	**19.34**	**29.24**	**100.47**	**95.21**
D75	**48.15**	**141.14**	**65.30**	**67.68**	**9.09**	**20.32**	**63.53**	**62.96**
D50	**33.90**	**54.07**	**20.63**	**21.07**	**3.13**	**3.66**	**19.94**	**22.58**
D25	**22.82**	**19.74**	**5.14**	**5.34**	**1.97**	**1.20**	**3.33**	**5.02**
D16	**19.51**	**12.38**	**2.35**	**2.64**	**1.61**	**0.82**	**1.69**	**2.50**
dg	**33.57**	**44.78**	**16.26**	**17.82**	**4.22**	**4.52**	**14.49**	**16.94**
FREDLE	**23.11**	**16.75**	**4.56**	**5.01**	**1.96**	**1.10**	**3.32**	**4.78**
% FINES<2mm	**0.15%**	**4.36%**	**14.13%**	**12.06%**	**25.82%**	**36.78%**	**18.14%**	**13.10%**
% FINES <1mm	**0.13%**	**2.31%**	**6.23%**	**4.26%**	**6.96%**	**21.03%**	**10.44%**	**6.56%**
% FINES <0.85mm	**0.13%**	**2.00%**	**4.94%**	**3.33%**	**6.19%**	**17.37%**	**8.91%**	**5.43%**

MEAN PERMEABILITY WITHIN BULK SAMPLE (cm/hr)								
	12112	1947	731	8192	1145	1221	232	1669

TABLE 1 (cont.)

Individual bulk sample subsurface and combined surface/subsurface particle size distributions, particle size indexes, and mean permeability within each bulk sample

SITE	INDIAN	INDIAN	STEINER	STEINER	EVANS	EVANS	JUNCTION	JUNCTION
SAMPLE #	1	2	1	2	1	2	1	2
TOTAL DRY WEIGHT (KG) SUBSURFACE	343.93	245.47	319.57	270.33	136.68	250.53	298.60	282.94

CUM. % FINER THAN (SUBSURFACE)

360	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
256	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
180	100.00%	96.95%	97.56%	97.10%	100.00%	100.00%	90.34%	93.88%
128	98.06%	88.47%	93.85%	83.98%	98.89%	97.12%	83.28%	82.48%
90.5	87.29%	81.89%	84.79%	78.14%	96.08%	89.23%	75.21%	73.65%
64	80.13%	72.70%	79.25%	72.57%	91.29%	84.99%	69.38%	67.10%
45.3	71.28%	59.11%	69.79%	66.29%	83.41%	80.36%	61.57%	58.32%
32	60.08%	49.51%	60.59%	57.57%	72.01%	70.00%	53.95%	51.02%
22.6	51.14%	42.61%	52.04%	50.33%	60.73%	61.30%	46.36%	44.85%
16	43.52%	36.36%	44.42%	42.83%	51.54%	57.81%	39.86%	39.08%
11.2	38.10%	31.04%	38.41%	36.64%	43.45%	49.46%	34.68%	34.25%
8	32.96%	25.87%	33.23%	30.52%	36.63%	41.98%	29.70%	30.06%
5.6	28.36%	21.03%	28.90%	24.61%	30.95%	35.34%	25.41%	26.55%
4	24.72%	17.23%	25.76%	19.78%	27.09%	30.17%	22.17%	23.86%
2.83	20.94%	13.56%	22.48%	15.14%	23.58%	24.81%	18.77%	20.85%
2	17.45%	10.77%	18.97%	11.79%	20.52%	19.89%	15.55%	17.63%
1.4	14.32%	8.72%	14.79%	9.30%	17.30%	14.31%	12.19%	13.29%
1	10.94%	6.97%	10.81%	7.93%	13.52%	9.86%	9.06%	9.03%
0.85	9.40%	6.16%	9.16%	7.25%	11.50%	8.13%	7.59%	7.12%
0.5	4.93%	3.50%	4.59%	4.00%	4.92%	3.34%	3.26%	2.41%
0.25	1.30%	0.97%	1.25%	0.83%	0.82%	0.68%	0.57%	0.40%
0.125	0.31%	0.24%	0.32%	0.18%	0.20%	0.16%	0.12%	0.10%
0.063	0.15%	0.08%	0.10%	0.06%	0.08%	0.14%	0.04%	0.03%
Pan	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

CUM. % FINER THAN (COMBINED SURFACE AND SUBSURFACE)

360	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
256	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
180	100.00%	97.44%	97.78%	92.74%	100.00%	100.00%	88.98%	94.49%
128	96.78%	80.68%	93.46%	79.35%	99.06%	95.72%	79.97%	80.98%
90	84.06%	71.94%	81.57%	74.29%	90.51%	84.96%	69.66%	68.51%
64	75.89%	63.58%	75.56%	67.94%	84.06%	79.76%	61.95%	61.42%
45	66.15%	51.48%	66.01%	61.48%	75.57%	74.99%	54.39%	53.31%
32	55.23%	42.96%	56.68%	52.71%	64.69%	64.78%	47.42%	46.42%
22.4	46.84%	36.92%	48.54%	45.73%	54.11%	56.52%	40.66%	40.73%
16	39.67%	31.35%	41.31%	38.61%	45.75%	53.03%	34.93%	35.43%
11.2	34.62%	26.73%	35.59%	32.79%	38.44%	45.29%	30.36%	31.01%
8	29.90%	22.30%	30.74%	27.20%	32.32%	38.38%	25.97%	27.19%
5.6	25.69%	18.15%	26.72%	21.87%	27.26%	32.29%	22.20%	24.01%
4	22.36%	14.88%	23.80%	17.55%	23.83%	27.55%	19.37%	21.58%
2.8	18.91%	11.70%	20.76%	13.42%	20.72%	22.65%	16.39%	18.85%
2	15.73%	9.26%	17.51%	10.44%	18.00%	18.15%	13.57%	15.94%
1.4	12.86%	7.45%	13.65%	8.22%	15.15%	13.07%	10.64%	12.01%
1	9.79%	5.92%	9.98%	6.98%	11.81%	9.01%	7.91%	8.16%
0.85	8.40%	5.23%	8.45%	6.38%	10.03%	7.42%	6.63%	6.44%
0.5	4.39%	2.96%	4.25%	3.51%	4.29%	3.05%	2.86%	2.18%
0.25	1.16%	0.82%	1.15%	0.73%	0.72%	0.62%	0.50%	0.36%
0.125	0.27%	0.20%	0.29%	0.16%	0.18%	0.15%	0.11%	0.09%
0.063	0.14%	0.07%	0.10%	0.05%	0.08%	0.13%	0.03%	0.03%
Pan	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

PARTICLE SIZE DISTRIBUTION INDEXES (SEDSIZE)

D84	**76.72**	**100.72**	**86.52**	**128.31**	**46.47**	**59.73**	**132.68**	**132.89**
D75	**51.92**	**69.30**	**54.31**	**74.05**	**34.72**	**37.46**	**89.30**	**94.98**
D50	**21.49**	**32.57**	**20.63**	**22.29**	**14.98**	**11.57**	**26.72**	**30.23**
D25	**4.11**	**7.54**	**3.70**	**5.80**	**3.27**	**2.87**	**5.42**	**4.65**
D16	**1.69**	**3.54**	**1.56**	**3.00**	**1.25**	**1.57**	**2.07**	**1.75**
dg	**13.69**	**20.89**	**13.92**	**18.02**	**10.11**	**10.31**	**19.25**	**19.51**
FREDLE	**3.85**	**6.89**	**3.63**	**5.04**	**3.10**	**2.85**	**4.74**	**4.31**
% FINES<2mm	**17.45%**	**10.77%**	**18.97%**	**11.79%**	**20.52%**	**19.89%**	**15.55%**	**17.63%**
% FINES <1mm	**10.94%**	**6.97%**	**10.81%**	**7.93%**	**13.52%**	**9.86%**	**9.06%**	**9.03%**
% FINES <0.85mm	**9.40%**	**6.16%**	**9.16%**	**7.25%**	**11.50%**	**8.13%**	**7.59%**	**7.12%**

MEAN PERMEABILITY WITHIN BULK SAMPLE (cm/hr)								
	1036	681	262	268	163	293	489	1397

TABLE 3

Mean cumulative particle size distribution, gravel quality indexes, and mean permeability per site for eight mainstem Trinity River sites.

SITE	LEWISTON	RUSH	POKER	STEELBRIDGE	INDIAN	STEINER	EVANS	JUNCTION
RIVER MILE	**111.5**	**107.4**	**102.7**	**98.95**	**95.3**	**91.95**	**84.1**	**80.3**
TOTAL DRY WEIGHT (KG) COMBINED SUBSURFACE	**534.34**	**633.52**	**437.16**	**707.63**	**589.40**	**589.90**	**389.21**	**581.54**
SIEVE SIZE	**CUM. % FINER THAN (COMBINED SUBSURFACE)**							
360	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
256	95.75%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
180	91.53%	97.09%	100.00%	95.44%	98.73%	97.35%	100.00%	92.06%
128	82.75%	91.41%	100.00%	92.39%	94.07%	89.33%	97.75%	82.89%
90.5	76.26%	81.10%	99.82%	81.08%	85.04%	81.74%	91.67%	74.45%
64	69.43%	74.27%	98.63%	75.26%	77.04%	76.19%	87.24%	68.27%
45.3	56.62%	67.97%	94.98%	67.62%	66.21%	68.19%	81.45%	59.99%
32	40.66%	59.64%	88.72%	58.75%	55.68%	59.21%	70.72%	52.53%
22.6	26.68%	51.85%	82.62%	51.40%	47.59%	51.26%	61.10%	45.63%
16	14.88%	44.03%	77.09%	44.40%	40.54%	43.69%	55.57%	39.48%
11.2	9.23%	37.34%	72.53%	38.21%	35.16%	37.60%	47.32%	34.47%
8	6.46%	31.16%	68.50%	33.01%	30.00%	31.99%	40.07%	29.87%
5.6	5.12%	25.91%	64.43%	28.91%	25.31%	26.93%	33.78%	25.96%
4	4.21%	21.91%	58.05%	25.19%	21.60%	23.02%	29.07%	22.99%
2.83	3.28%	17.48%	44.89%	20.31%	17.87%	19.12%	24.38%	19.78%
2	2.52%	13.10%	30.01%	15.74%	14.67%	15.68%	20.11%	16.56%
1.4	1.83%	8.45%	18.06%	11.49%	11.99%	12.27%	15.38%	12.72%
1	1.36%	5.25%	12.34%	8.59%	9.29%	9.49%	11.17%	9.04%
0.85	1.19%	4.14%	10.47%	7.25%	8.05%	8.29%	9.33%	7.36%
0.5	0.74%	1.84%	5.49%	3.23%	4.33%	4.32%	3.90%	2.85%
0.25	0.30%	0.45%	1.22%	0.68%	1.16%	1.06%	0.73%	0.49%
0.125	0.08%	0.10%	0.24%	0.17%	0.28%	0.25%	0.18%	0.11%
0.063	0.03%	0.03%	0.07%	0.06%	0.12%	0.08%	0.12%	0.04%
Pan	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

PARTICLE SIZE DISTRIBUTION VALUES FROM SEDSIZE

D84	**133.88**	**98.51**	**24.45**	**97.56**	**86.57**	**99.68**	**52.59**	**132.94**
D75	**84.59**	**66.24**	**13.59**	**63.18**	**59.63**	**60.57**	**36.38**	**92.38**
D50	**39.21**	**20.85**	**3.24**	**21.12**	**25.09**	**21.37**	**12.66**	**28.18**
D25	**21.68**	**5.24**	**1.75**	**3.95**	**5.5**	**4.79**	**2.97**	**5.07**
D16	**16.56**	**2.51**	**1.25**	**2.02**	**2.29**	**2.04**	**1.47**	**1.89**
dg	**39.49**	**17.01**	**4.33**	**15.61**	**16.33**	**15.67**	**10.23**	**19.37**
FREDLE	**19.99**	**4.78**	**1.55**	**3.90**	**4.96**	**4.41**	**2.92**	**4.54**
% FINES<2mm	**2.52%**	**13.10%**	**30.01%**	**15.74%**	**14.67%**	**15.68%**	**20.11%**	**16.56%**
% FINES <1mm	**1.36%**	**5.25%**	**12.34%**	**8.59%**	**9.29%**	**9.49%**	**11.17%**	**9.04%**
% FINES <0.85mm	**1.19%**	**4.14%**	**10.47%**	**7.25%**	**8.05%**	**8.29%**	**9.33%**	**7.36%**

MEAN PERMEABILITY/SITE

	7,568 cm/hr	**2,587 cm/hr**	**1,500 cm/hr**	**1,431 cm/hr**	**827 cm/hr**	**605 cm/hr**	**244 cm/hr**	**1,039 cm/hr**

ESTIMATED CHINOOK SURVIVAL/SITE FROM PERMEABILITY

	49%	**33%**	**26%**	**25%**	**17%**	**13%**	**0%**	**20%**

APPENDIX A

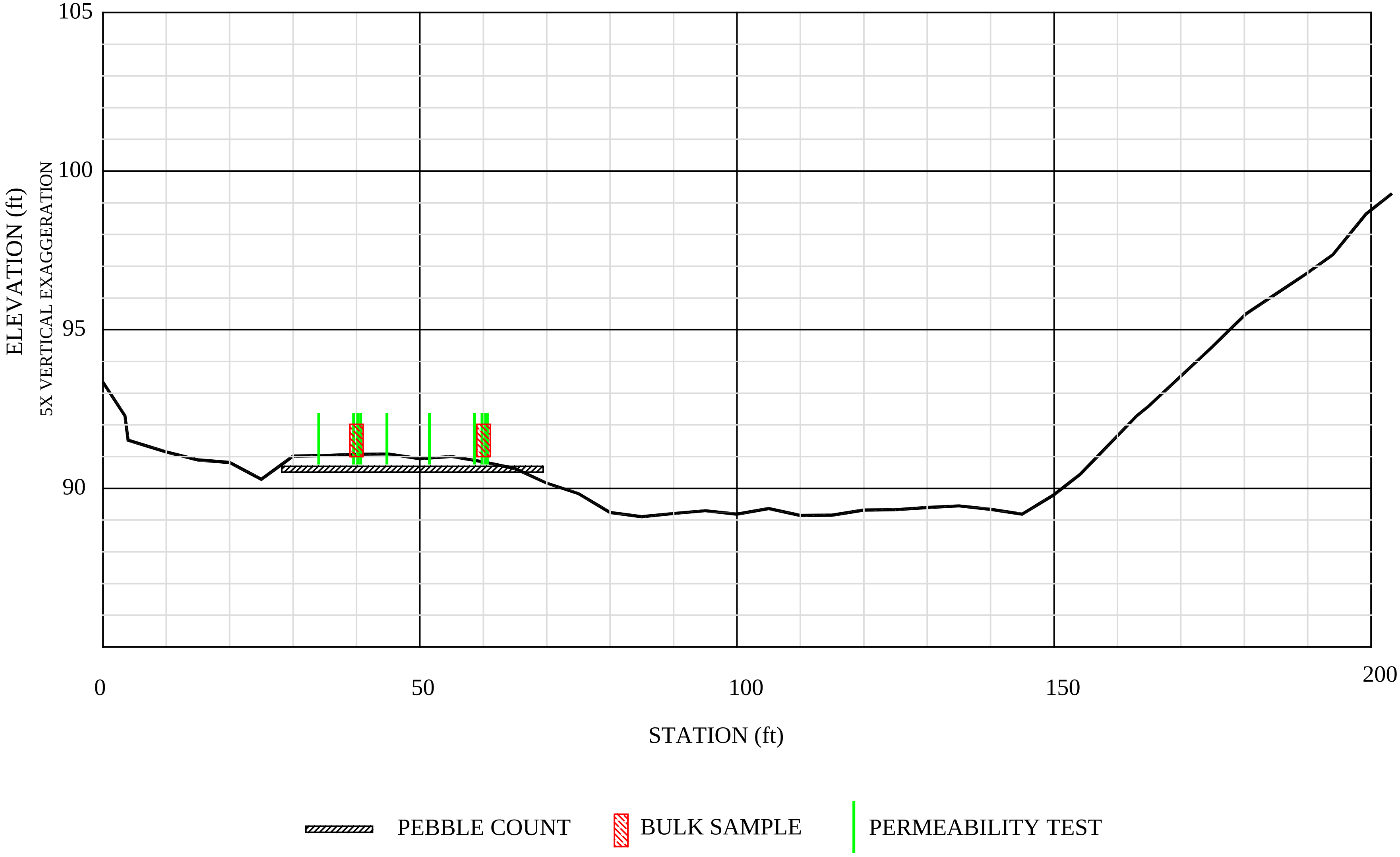
MAINSTEM TRINITY RIVER
GRAVEL QUALITY SAMPLING 2000

SITE CROSS SECTIONS AND SAMPLING LOCATIONS

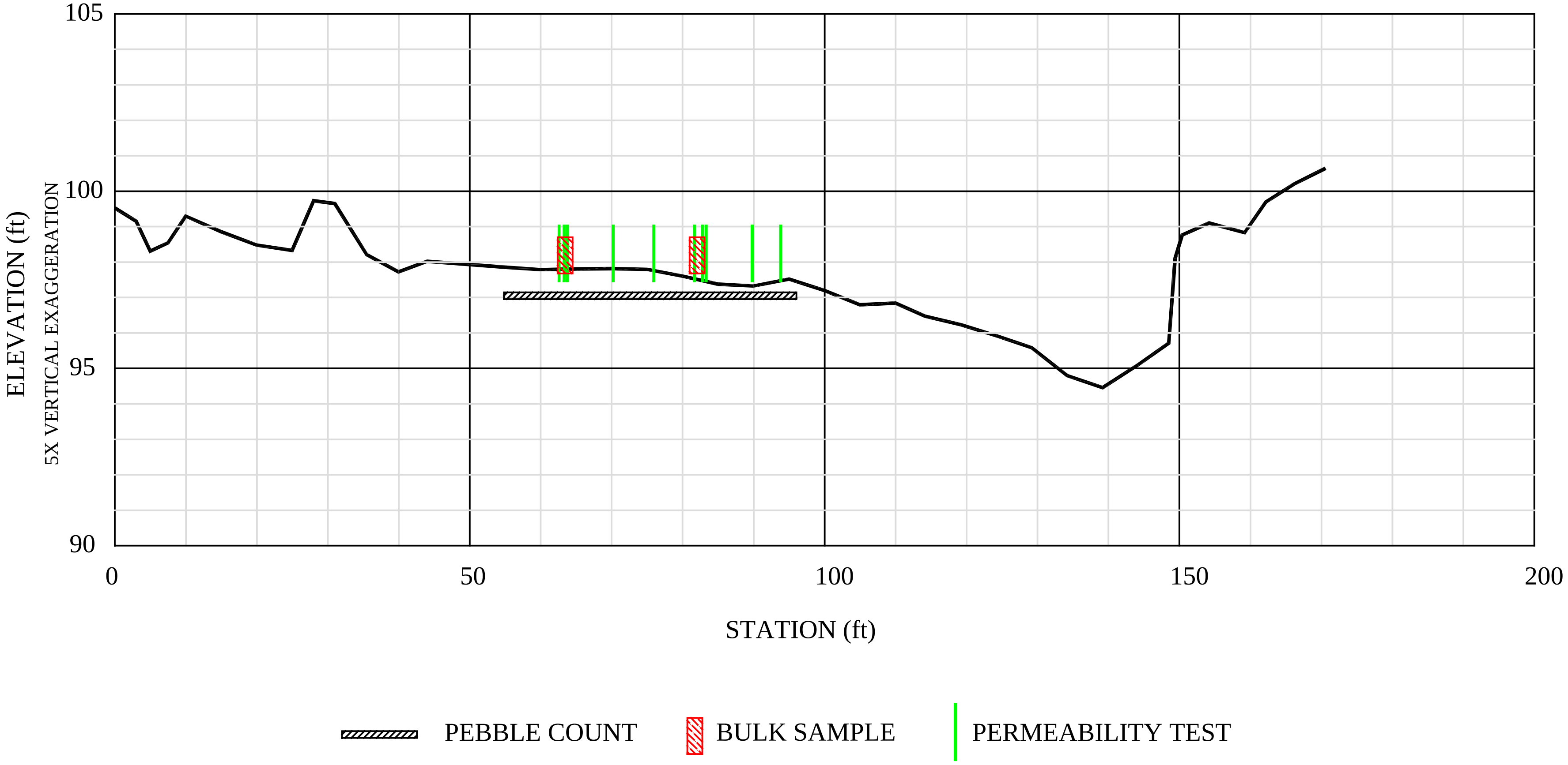
SITES:

Lewiston
Rush Creek
Poker Bar
Steelbridge
Indian Creek
Steiner Flat
Evans Bar
Junction City

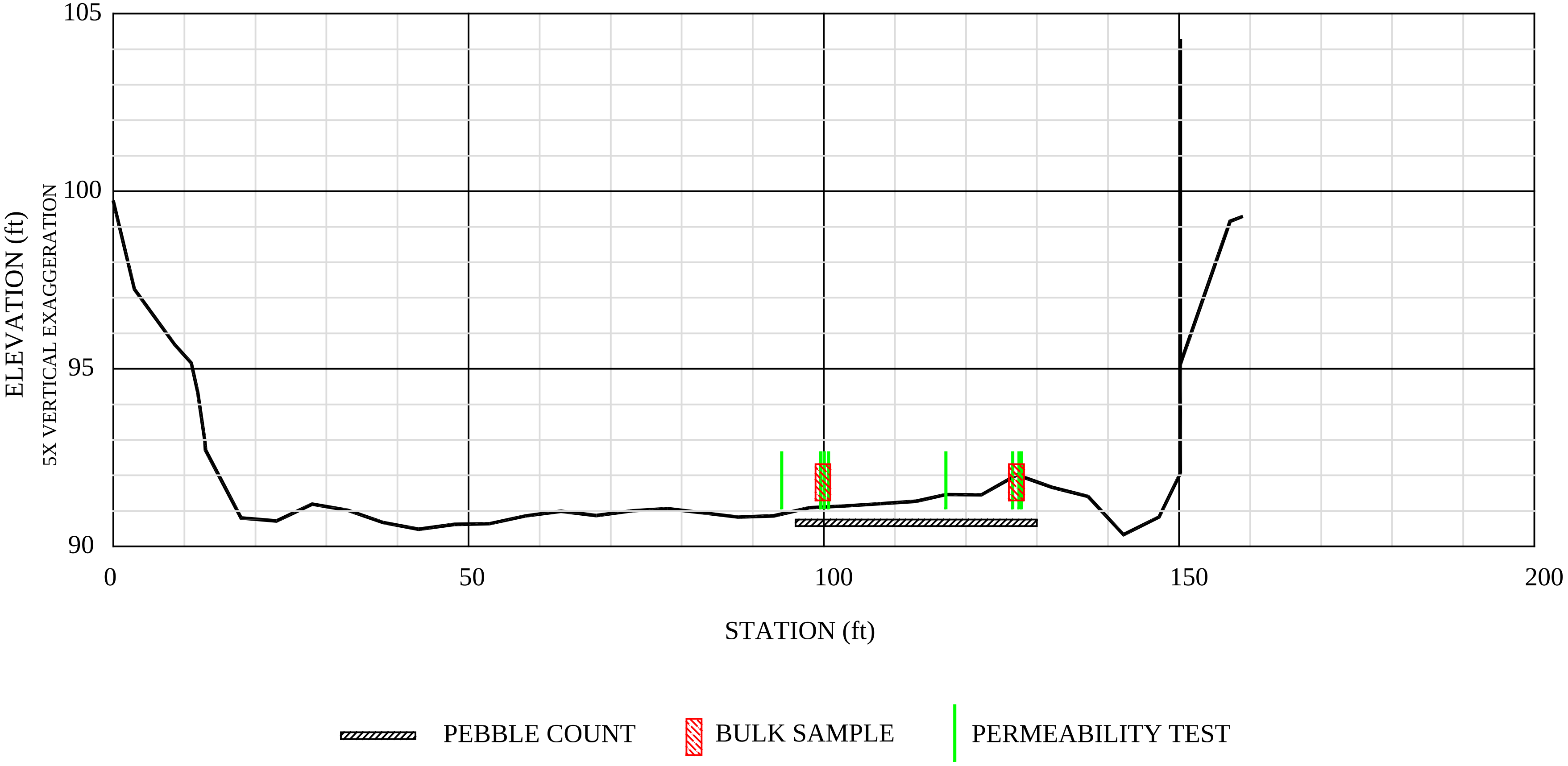
LEWISTON DAM SITE CROSS SECTION



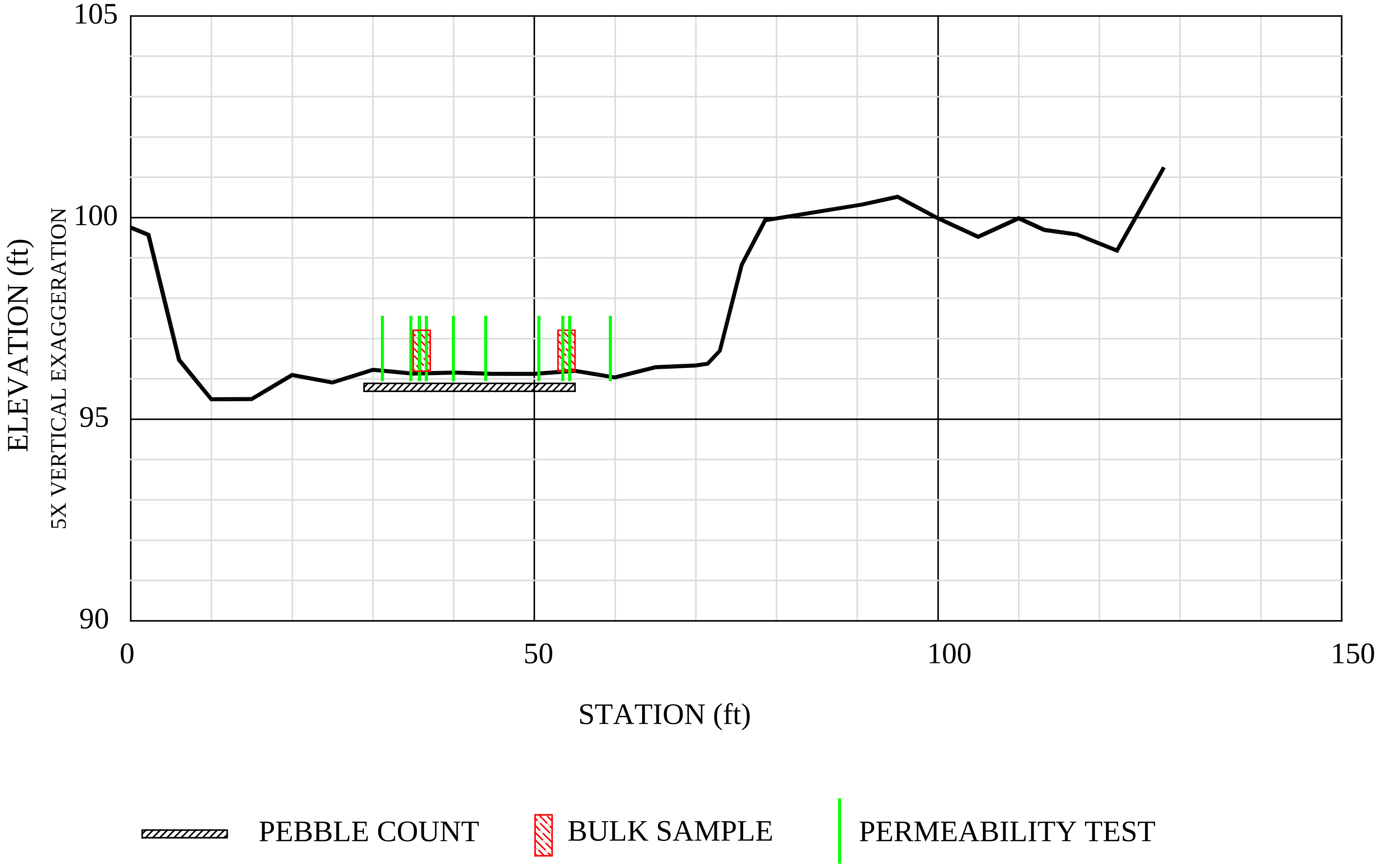
RUSH CREEK SITE CROSS SECTION



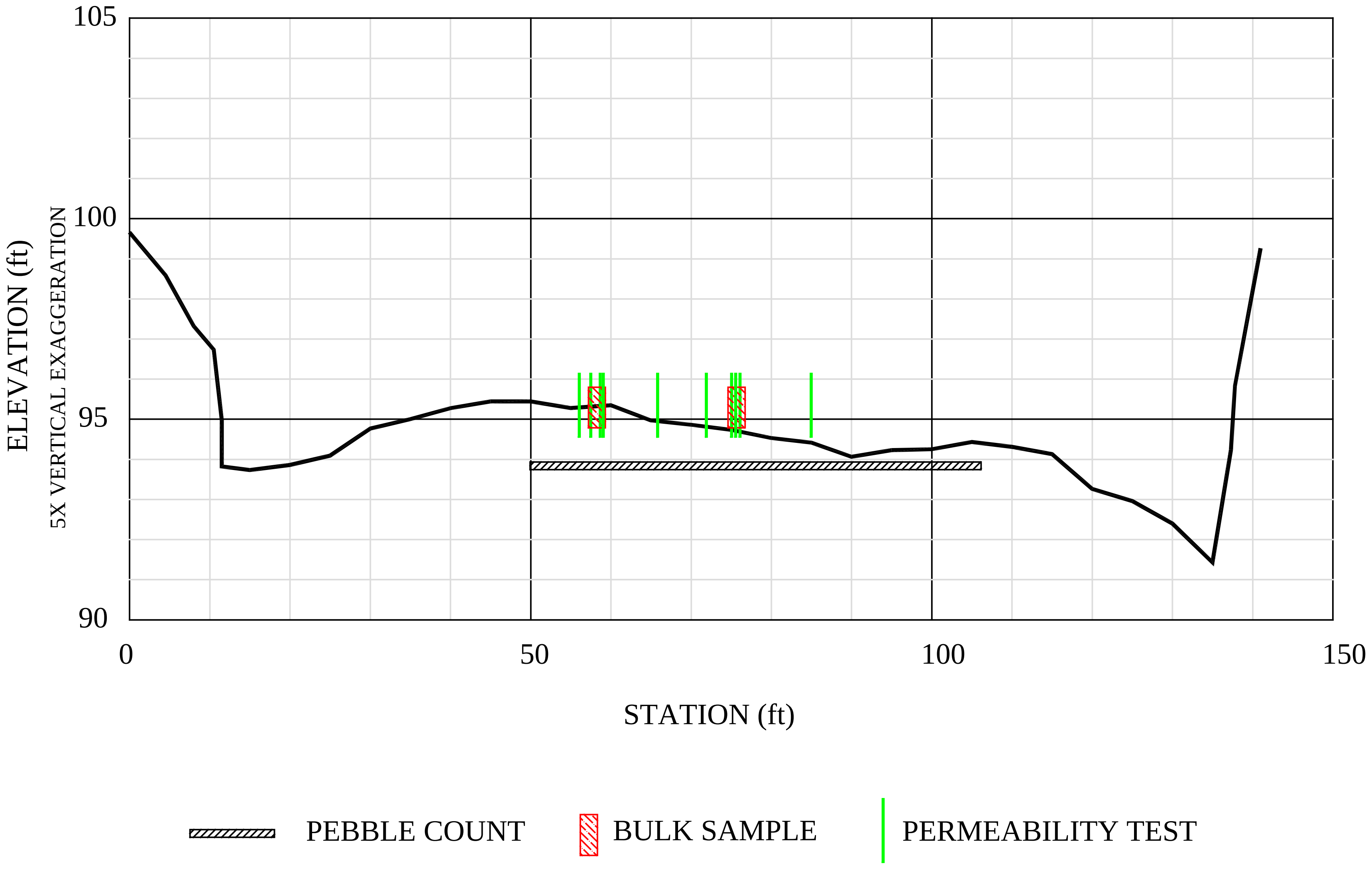
POKER BAR SITE CROSS SECTION



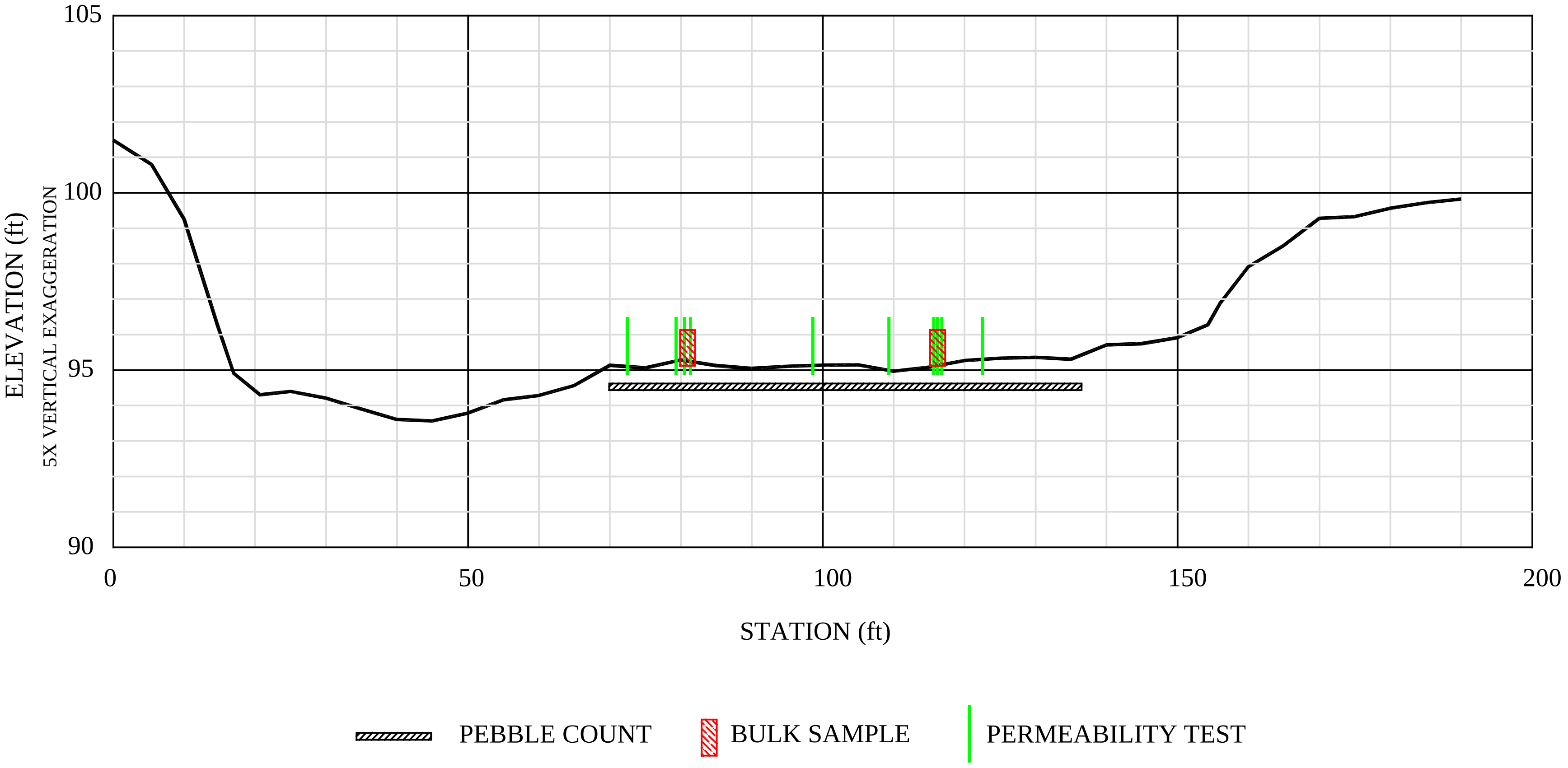
STEELBRIDGE SITE CROSS SECTION



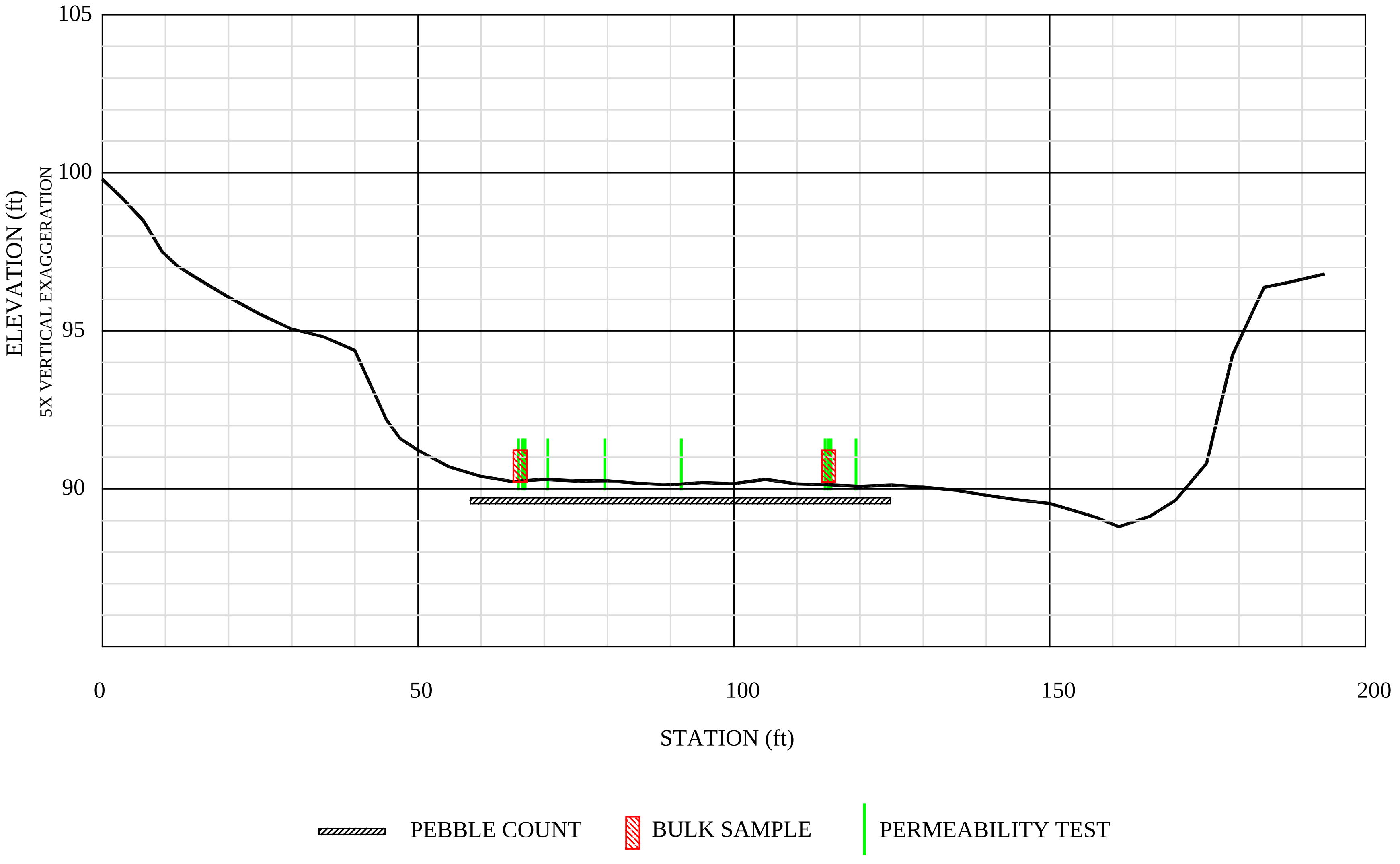
INDIAN CREEK SITE CROSS SECTION



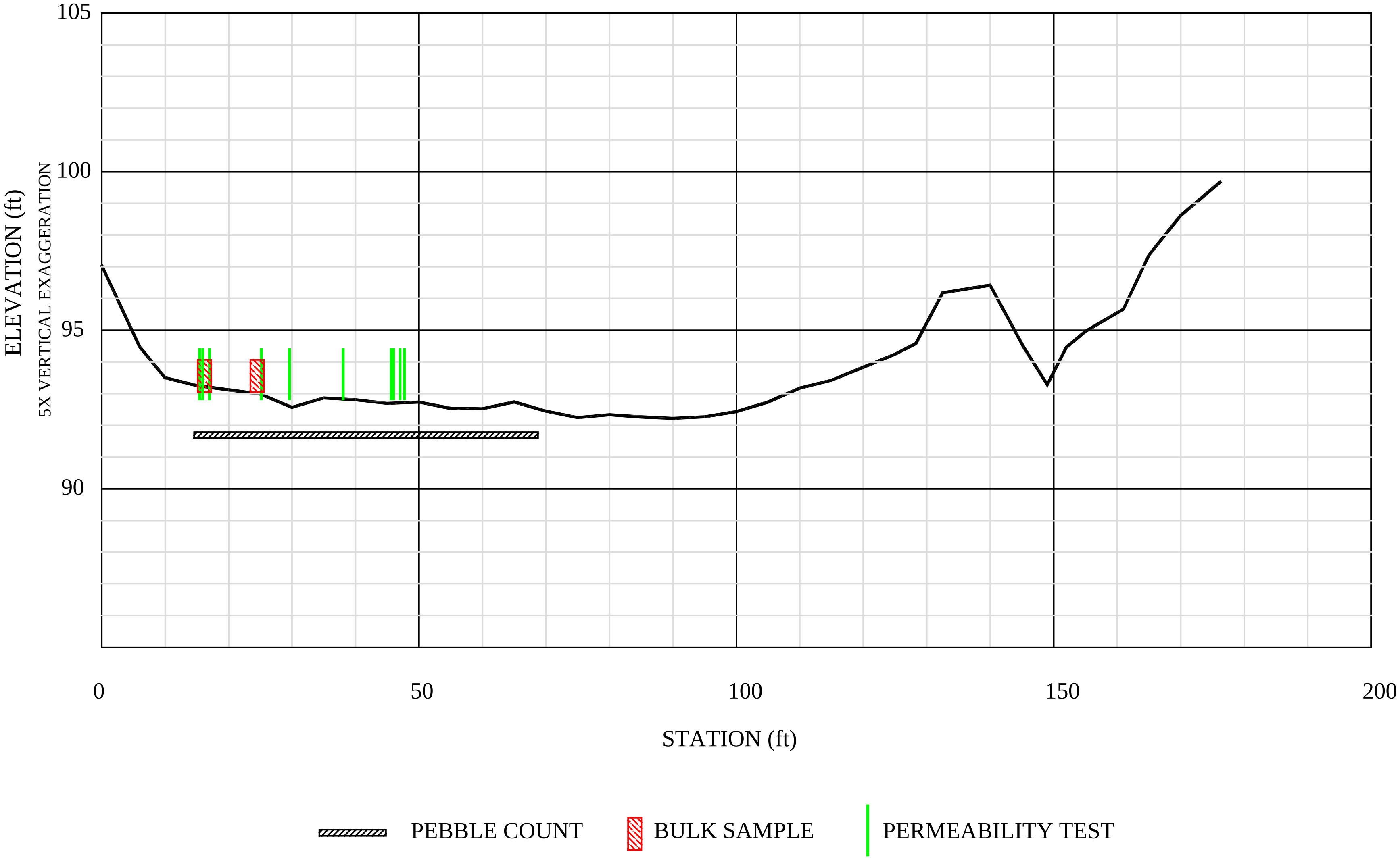
STEINER FLAT SITE CROSS SECTION



EVANS BAR SITE CROSS SECTION



JUNCTION CITY SITE CROSS SECTION



APPENDIX B

MAINSTEM TRINITY RIVER
GRAVEL QUALITY SAMPLING 2000

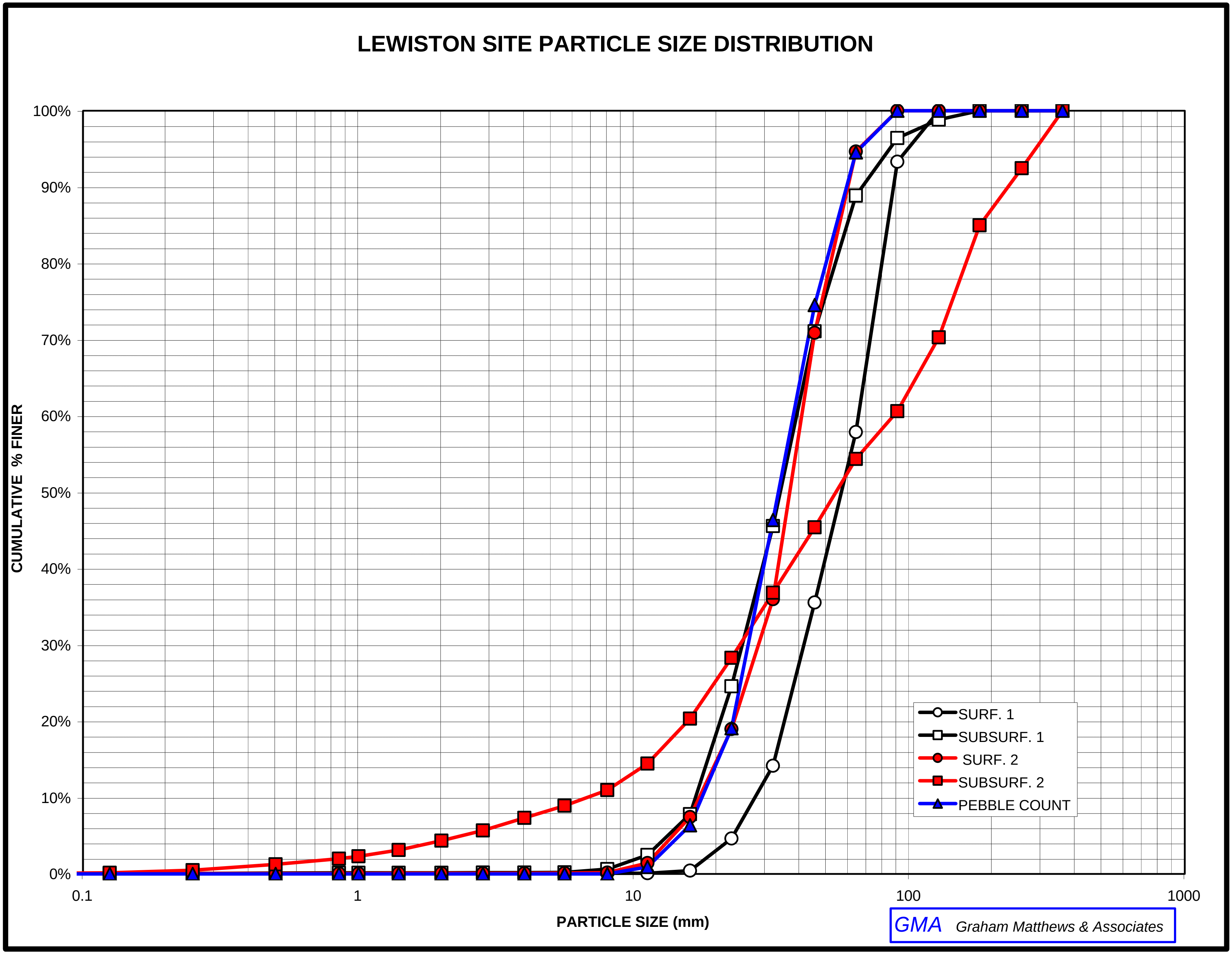
PARTICLE SIZE DISTRIBUTIONS

SITES:

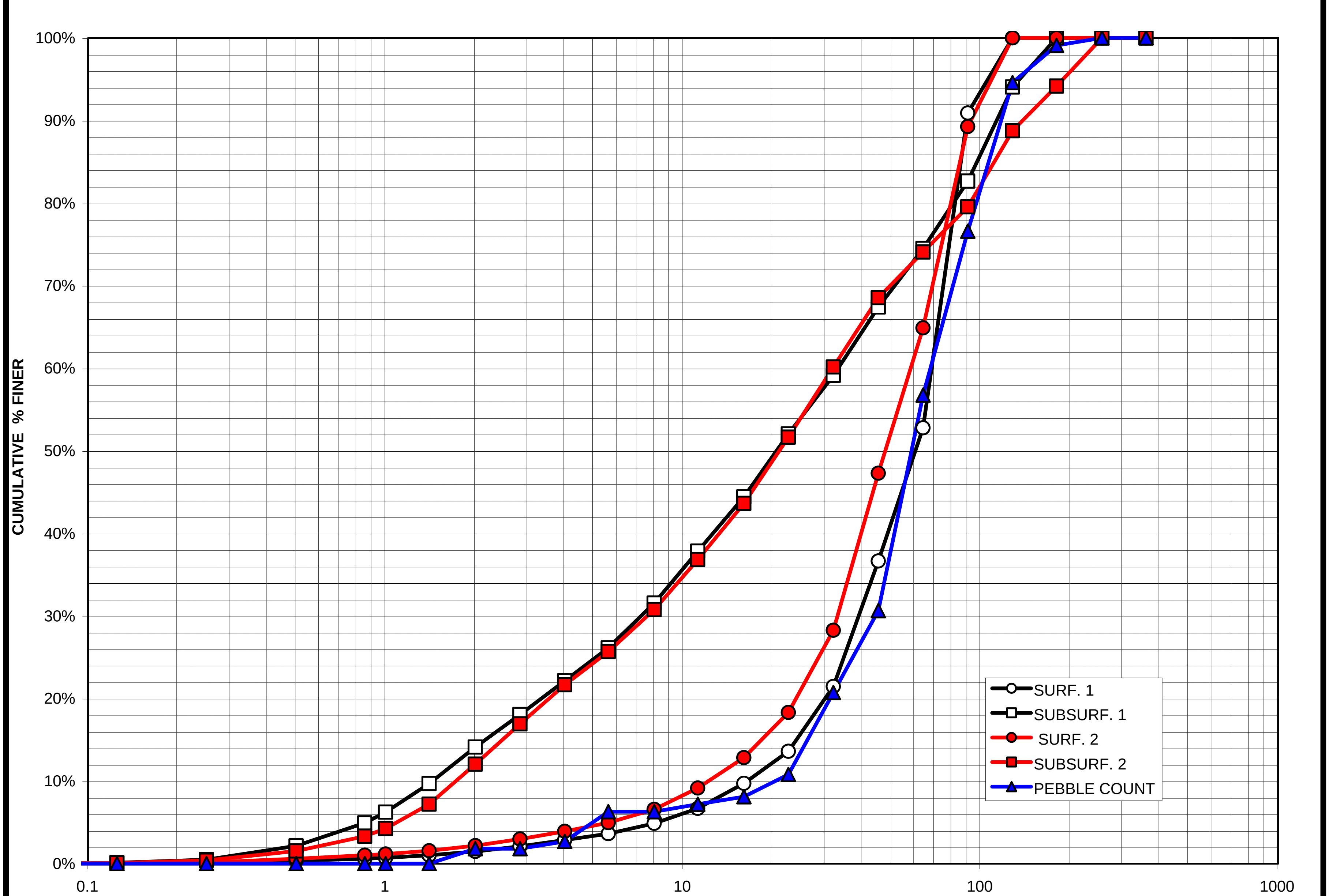
Lewiston
Rush Creek
Poker Bar
Steelbridge
Indian Creek
Steiner Flat
Evans Bar
Junction City

All Sites Contain:

Surface and Subsurface Distributions for 2 Samples
Pebble Count

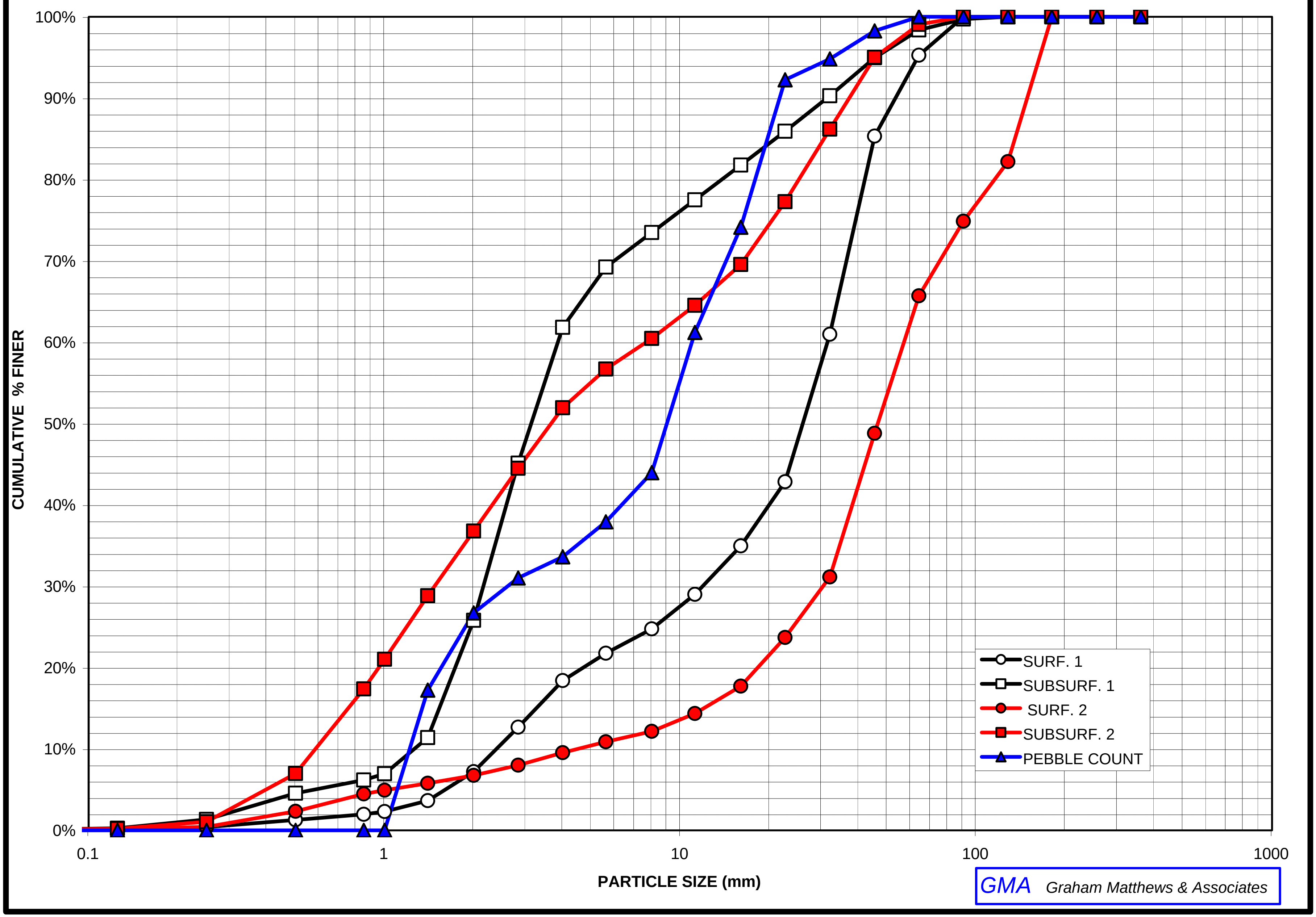

LEWISTON SITE PARTICLE SIZE DISTRIBUTION
CUMULATIVE % FINER
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.1
1
10
100
1000
PARTICLE SIZE (mm)
SURF. 1
SUBSURF. 1
SURF. 2
SUBSURF. 2
PEBBLE COUNT
GMA Graham Matthews & Associates

RUSH CREEK SITE PARTICLE SIZE DISTRIBUTION

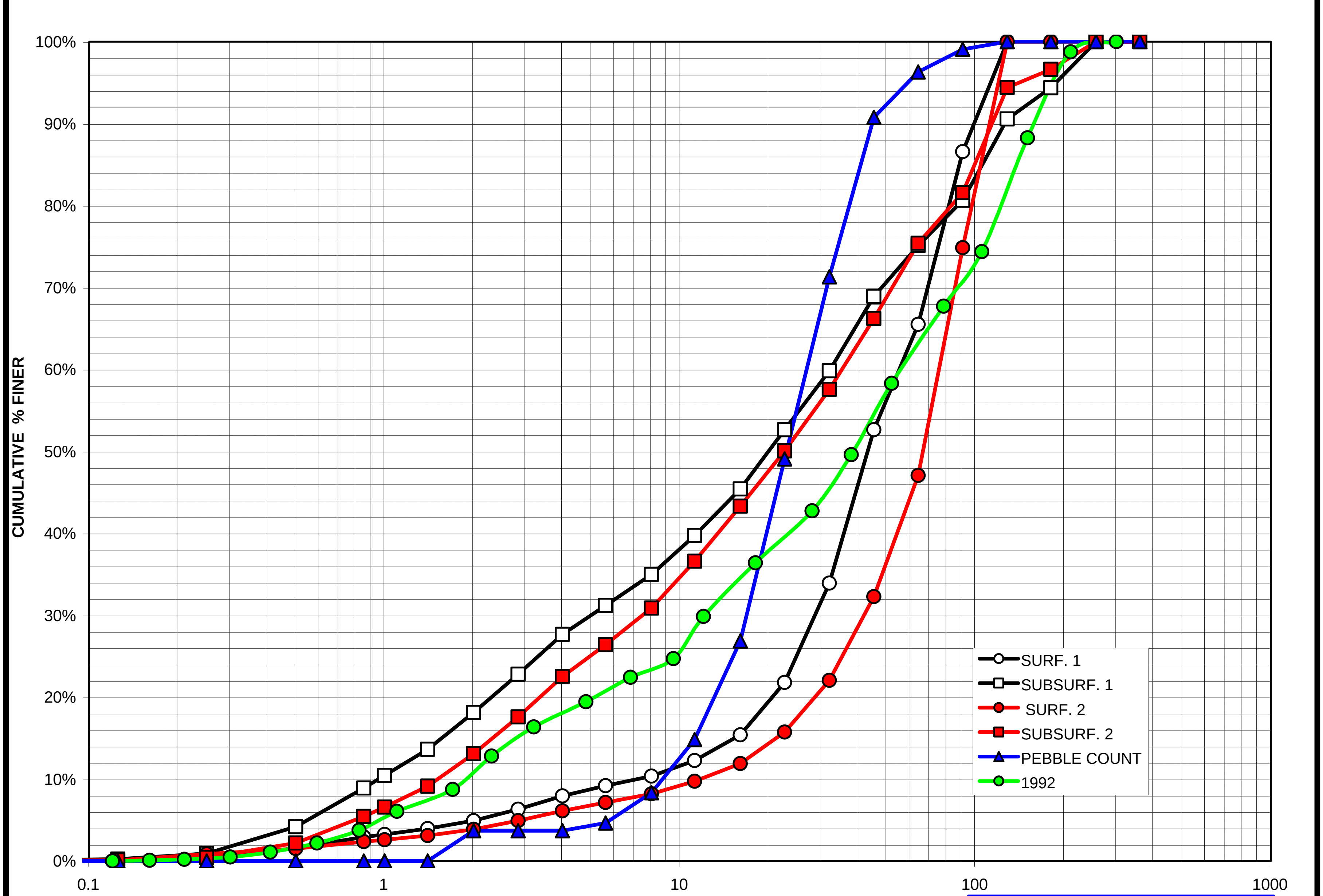


GMA Graham Matthews & Associates

POKER BAR SITE PARTICLE SIZE DISTRIBUTION

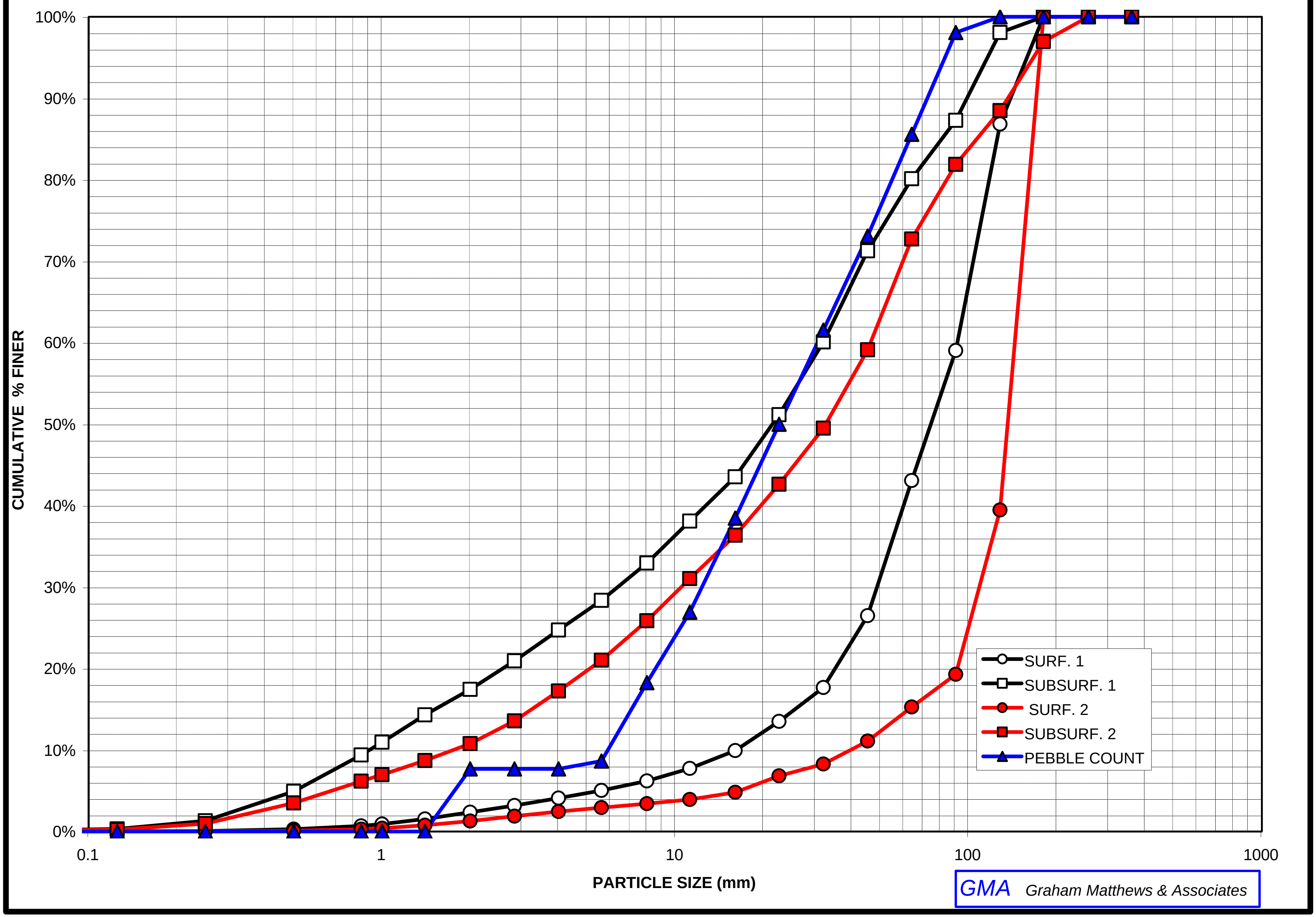


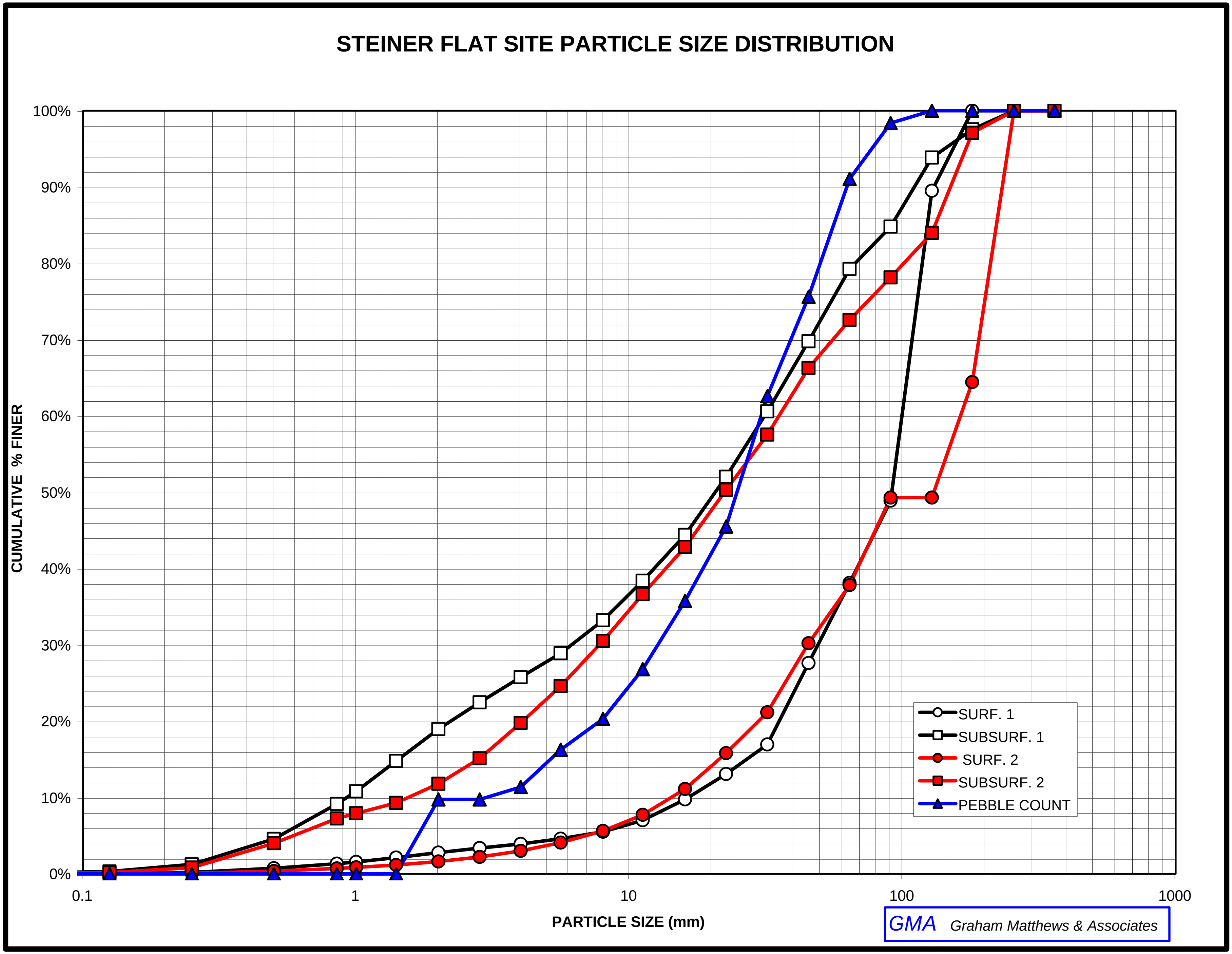
STEELBRIDGE SITE PARTICLE SIZE DISTRIBUTION

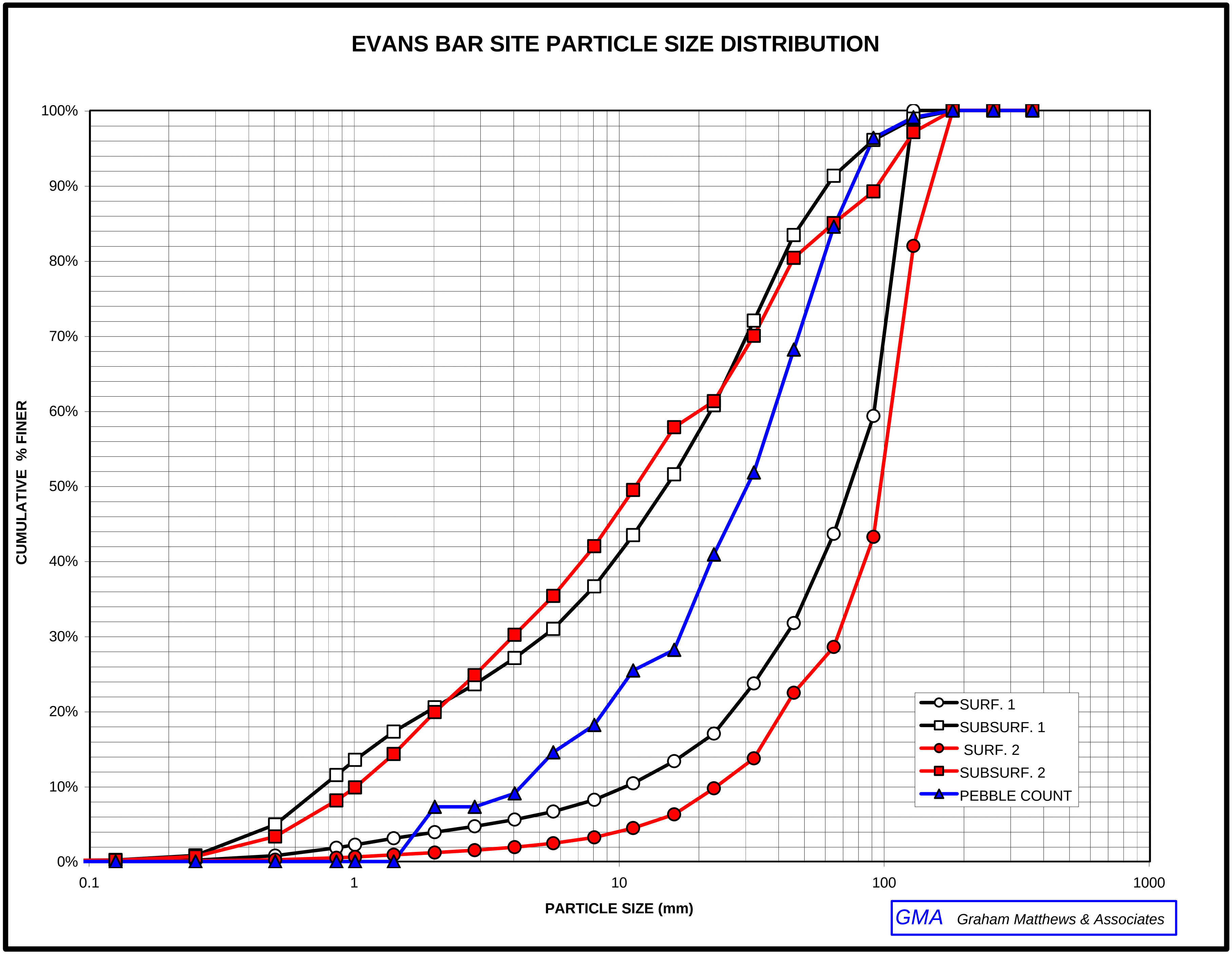


GMA Graham Matthews & Associates

INDIAN CREEK SITE PARTICLE SIZE DISTRIBUTION

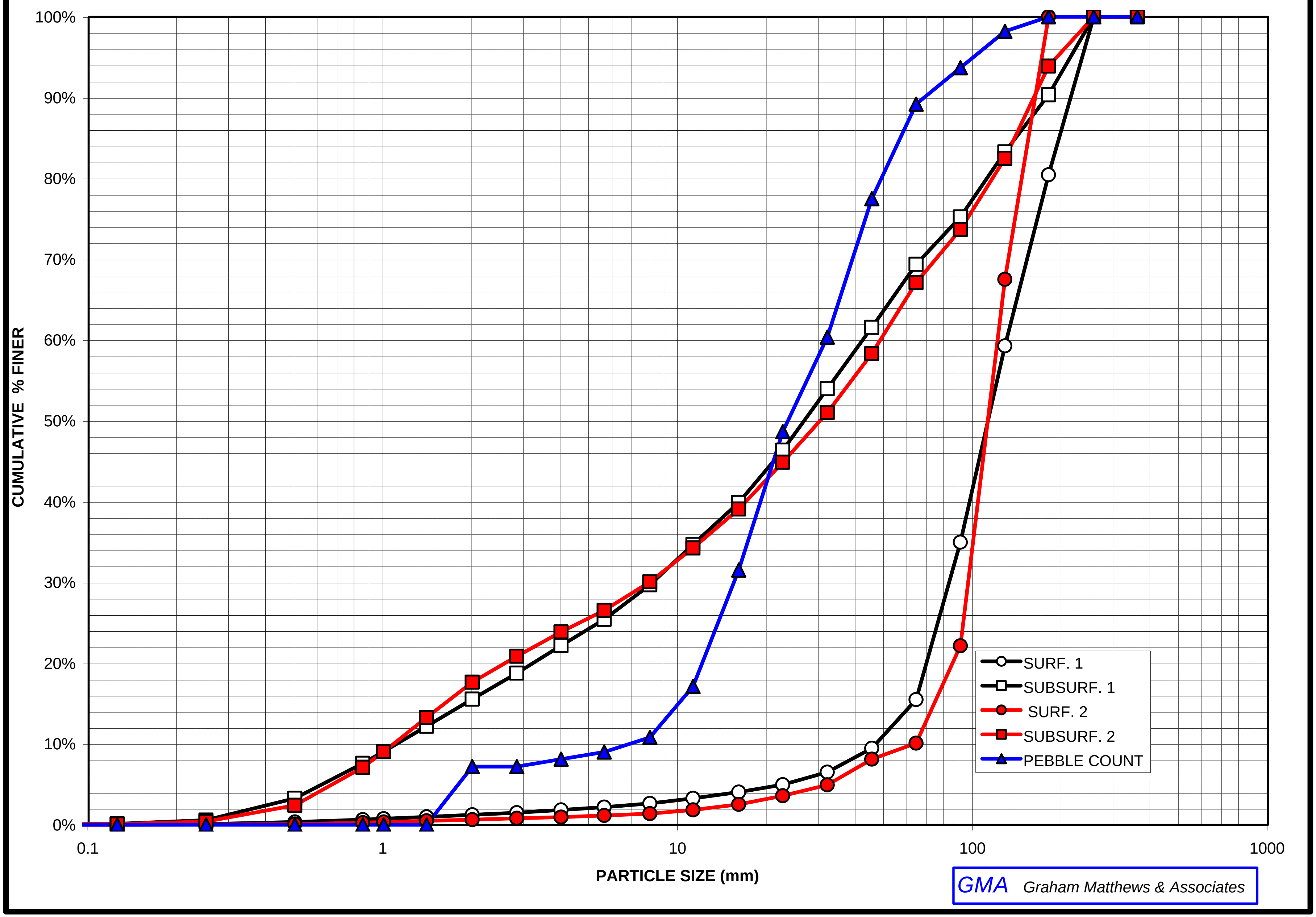



STEINER FLAT SITE PARTICLE SIZE DISTRIBUTION
CUMULATIVE % FINER
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.1
1
10
100
1000
PARTICLE SIZE (mm)
SURF. 1
SUBSURF. 1
SURF. 2
SUBSURF. 2
PEBBLE COUNT
GMA Graham Matthews & Associates



EVANS BAR SITE PARTICLE SIZE DISTRIBUTION
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
CUMULATIVE % FINER
0.1
1
10
100
1000
PARTICLE SIZE (mm)
SURF. 1
SUBSURF. 1
SURF. 2
SUBSURF. 2
PEBBLE COUNT
GMA Graham Matthews & Associates

JUNCTION CITY SITE PARTICLE SIZE DISTRIBUTION



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