

Physical and geochemical characteristics of Lower Sunrise side channel restoration project

Final report (2008/2009)

Submitted to the Sacramento Water Forum



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1.0 Introduction and Objectives

Results described in this report are a summary of data collected at the Lower Sunrise side channel after restoration work was completed in the fall of 2008. This work was funded by a grant to the Sacramento Water Forum from the Resources Agency River Parkways Grant program. The grant for \$510,035 was administered by the Water Forum with partnerships from the Department of Fish and Game, Philip Williams and Associates (PWA), Restoration Resources Inc, and the Bureau of Reclamation.

The Lower Sunrise site is the known location (Vyberg, 1997, Hannon 2005) of steelhead trout and Chinook salmon spawning. These fish carve out horseshoe shaped depressions in the riverbed to create their spawning locations known as redds. Peak steelhead spawning is usually in February, when flows are high. This allows steelhead to spawn high on the banks and newly submerged areas. In some years, flows have been managed to enhance habitat or prevent dewatering of redds. Stranding may also be problematic when steelhead trout emerge into pools of water that are no longer connected to the river. These pools quickly become too hot or create easy predation by birds. Steelhead trout are a listed species under the Endangered Species Act, which compels the appropriate federal and state authorities to mitigate circumstances that create negative impacts on fish population levels.

The goals of the side channel project were to minimize dewatering of steelhead redds, and maintain flow in the side channel area to a depth greater than 1 foot with a flow of 1000cfs. To accomplish this, the channel bottom was lowered and neighboring banks were sculpted to discourage redd building on topographic highs where dewatering could occur.

A preliminary site assessment was conducted by Tim Horner in 2005 with similar objectives to the post restoration study. Table 1 shows a summary of significant findings from the study.

Monitoring Point	D.O. (ppm)	E.C. (µS)	Temperature C°
SC00	6.3	49	17.2
SC01	6.7	52	18.2
SC03	7.9	54	17.6
SC04	2.7	60	23.2
SC05	4.0	53	16
SC06	3.9	55	17.2
SC07	3.2	54	18.9
SC08	6.6	51	18.1
SC09	0.5	54	28.3
Mean	4.6	54	19.4

Table 1: Summary of 2005 Conducted by Tim Horner and CSUS for preliminary assessment of the side channel. Several high temperatures are the result of the sample location being very shallow or dry at the surface. Dissolved Oxygen values are consistently lower prior to restoration.

Stream velocity, hyporheic pressure measurements, and grain size analysis were also conducted prior to restoration. All of the tasks conducted in the 2005 assessment were replicated in the 2008/2009 assessment with the exception of temperature analysis. Side channel construction occurred during the last three weeks of October 2008. Field work and analyses conducted during the 2008/2009 field season had six major objectives.

These objectives were described as tasks in a side channel analysis proposal submitted to the Sacramento Water Forum in August 2008 by Tim Horner, and are summarized below:

- Before construction, analyze grain size using: Wolman pebble counts and bulk samples
- After construction, measure hyporheic field parameters (dissolved oxygen, pH, electrical conductivity, and temperature) from installed mini piezometers
- Measure surface water depth and velocity
- Examine gravel mobility using tracer rock studies in the side channel
- Install vertical strings of temperature data loggers upstream and downstream from the project area
- Create GIS maps of the study area with study locations and results
- Compile a written report for the 2008 post restoration analysis

2.0 Background/Previous Work

The Lower American River is 23 miles of unobstructed channel that lie below Nimbus Dam and Folsom Lake, approximately 10 miles east of Sacramento, CA. The upper four miles of the river from Sailor Bar to Lower Sunrise produces approximately one third of the salmon in Northern California (IEP, 2008).

Anthropogenic forces such as dams, artificial levees, and channel modification have altered the natural equilibrium of the river. Previous work (Castleberry et al. 1993; Horner, 2005; Morita, 2005) has shown these changes to be probable causes in the historical reduction of salmon. For the past 20 years, declining salmon populations have caused significant effort to be made to evaluate and restore fish habitat quality (Snider et al., 1992; Snider and Vyverberg, 1996; Vyverberg et al., 1997; DFG Technical Report no. 01-2, Morita, 2005).

3.0 Methods; Grain Analysis

Grain size was measured using the Wolman (1954) pebble count method, but also taking into account Kondolf's (1993) additional comments. Pebble counts were executed by taking a step forward and picking up the rock that is directly below the big toe portion of the field worker's foot. This ensures a random selection of rocks, with the first grain that is touched the grain to be measured. Grains that were selected were then measured with templates of pre-existing size classes from 7 inches in intermediate diameter, to 5/16 of an inch.

One hundred rocks were collected per pebble count and transects followed the Kondolf (1993) suggestion of diagonally crossing riffles in a v shaped pattern. This method was used to collect the 20 pebble counts in the side channel location prior to channel construction. Bulk samples and weighted pebble counts were also used to better characterize the pre-restoration grain sizes in the side channel. Four bulk samples were collected by digging holes to a depth of three times the diameter of the largest grain size in a randomly selected 1 meter circle.

Sample mass was at least 100 times the weight of the largest grain. The material collected was sieved into grain sizes and weighed in the field using large rocker sieves. The weight of each grain size was compared with the total weight of the sample to determine the percent weight distribution. Bulk samples were collected in the upstream part of the side channel, the middle of the side channel, and the downstream portion of the side channel. Samples were collected from the surface (river bottom) and a depth of 30 cm considered the subsurface in this study. Five weighted pebble counts (Appendix C) were conducted to compare grain size and weight.

3.1 Gravel Mobility

Tracer rocks were deployed in the side channel to better understand the movements of discrete gravel sizes during varying flow conditions. Forty rocks of three sizes (2 ½ -3 inch; 1 ¼ to 1 ¾ inch; 5/8 inch) were used for each transect. The rocks were placed in transects across the channel at the locations corresponding with velocity transects and surveyed transects.

The largest rocks were painted bright yellow, the medium size rocks (1 ¼ to 1 ¾ inch) were painted blue, and the smallest rocks were painted red for obvious differentiation from the riverbed. The rocks were deployed in straight line transects across the side channel at upstream, mid side channel , and downstream locations. The transect lines were than mapped with high resolution GPS to within 50 cm horizontal error. The tracer rocks were initially deployed with a flow of 800 cfs. Figures 1 and 2 show pictures of a grouping of the two largest grain sizes used in the tracer rock study.



Figure 1: Picture showing the two largest grain sizes used in the tracer rock study.

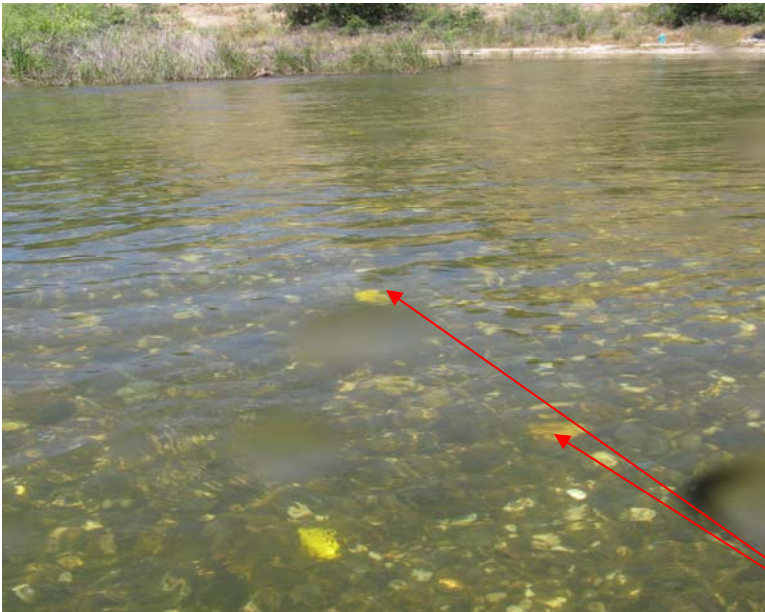


Figure 2: Arrows are pointing to yellow and blue tracer rocks.

3.2 Water Quality

Mini piezometers were installed in December 2008, throughout the side channel after the restoration work was completed to measure changes in water chemistry, temperature, and the vertical pressure gradient. Mini piezometers were installed to a depth of 30 cm below the riverbed (ground surface) to create a well and collect samples using ¼ inch polyethylene tubing and special 3 cm long stainless steel drive point tips that form the mini piezometers. The mini piezometer tips contain sufficient screening to allow adequate flow through the tubing. These tubes were then capped with golf tees to ensure that river water did not mix with the water at the 30 cm depth. Mini piezometers were installed throughout the side channel and upstream and downstream from the restoration site to show natural river conditions and provide a control for the water quality measurements. This is referred to as a BACI study design with Before, After, Control, and Impact measurements that evaluate the effects of the project. Figure 3 shows a piezometer tip with polyethylene tubing.



Figure 3: Picture of the piezometer tip and ¼ inch tubing used for mini piezometers. The mini piezometer is inside of the drive rod device used for mini piezometer installation.

Water was pumped from the piezometers into a sealed flow-through chamber (USGS, 1988) where dissolved oxygen (D.O.), pH, electrical conductivity (E.C.), turbidity and temperature were measured. When measurements were made using the flow-through chamber, hyporheic pore water samples were monitored without any interaction with the atmosphere. Figure 4 shows the equipment used for the field measurements, including the pump and flow-through chamber, meters used, and GPS. Dissolved oxygen concentrations are particularly susceptible to equilibration with the atmosphere, and care must be taken to insure that results are as representative of the subsurface as possible. Instrument probes were inserted into each port of a flow through sampling cell (USGS, 1988); an airtight seal was obtained by tightening a rubber gasket around the individual probes.



Figure 4: Picture of the field equipment with the pump, flow-through cell, and water quality meters.

A peristaltic pump was then used to pump water through the flow-through chamber from each of the mini piezometers. Water was allowed to circulate through the chamber until each of the parameters had adequately stabilized, typically 3 to 5 minutes. Turbidity was measured with a hand held DRT turbidity meter that uses back scattered light to measure the turbidity. An Orion 210 pH meter, YSI 95 DO meter, and an Orion Model 128 Electrical Conductivity (E.C.) meter were calibrated within 30 minutes of data collection prior to each sampling event. Water samples were also collected and filtered with a 0.45 micron filter and samples were immediately frozen for preservation.

Temperature measurements were made using a Fluke thermocouple temperature probe. The temperature probe was inserted to a depth of 30 cm inside the ¼ inch mini piezometers to measure temperatures in the spawning gravel. The temperature probe was calibrated by immersing the probe in boiling water followed by immersion in an ice bath. Temperatures are within one tenth of a degree Celsius.

3.21 Hach Chemistry

Samples collected from each mini piezometer and two random river locations identified as surface samples were analyzed for nitrate, nitrite, ammonia, and phosphate concentrations using a Hach DR/2010 Spectrophotometer. Pre-programmed powder pellet methods specific for the Hach DR/2010 instrument were used for each constituent. Sample blanks were analyzed according to method instructions at the beginning of analysis and periodically through the analysis.

Nitrate, Middle Range (0-4.5 mg/L NO_3^- N)

A 25 ml thick-walled glass sample cell was filled with sample and one NitraVer 5 Nitrate Reagent Powder Pellet, and allowed to react for six minutes before analysis at 400nm.

Nitrate, Low Range (0-0.300 mg/L NO_2^- N)

A 10 ml thick-walled glass sample cell was filled with sample and one NitriVer 3 Nitrite Reagent Powder Pillow, and allowed to react for 20 minutes before analysis at 507nm.

Ammonia, (0-2.50 mg/L NH_3^- N)

A 25 ml aliquot of sample was measured into a 25 ml mixing graduated cylinder, and treated with mineral stabilizer and polyvinyl alcohol dispersing agent. Nessler reagent was added and allowed to react for one minute before analysis at 380nm.

Phosphorous, Reactive (0-2.50 mg/L PO_4^{3-})

Method 8048 – PhosVer3 (Ascorbic Acid) Method

A 10ml thick-walled sample cell was filled with sample and one PhosVer 3 Phosphate Powder Pillow, and allowed to react after mixing for two minutes before analysis at 890nm.

3.3 Hyporheic Pressure Gradient

A manometer board was used to measure the difference in pressure head between the mini piezometers and the bottom of the streambed. The manometer board (Zamora, 2006) consisted of a graduated board with a glass tube in the shape of an inverted “U”.

The glass tube was then attached to the mini piezometer of interest on one side and a baffle bubble on the streambed bottom on the other side. Figure 5 shows the manometer used for measurements. The tubing from the manometer board was then connected to the baffle bubble. The baffle bubble created an environment that easily equilibrated to the pressure of the streambed, but removed the issue of stream flow past the manometer tubing, which can greatly affect readings in the manometer board. At the top of the glass tube, a release valve allowed water to be drawn into the manometer board from the bottom of the streambed and the mini piezometer. All devices used to measure the hyporheic zone were calibrated within 30 minutes of field usage where applicable.

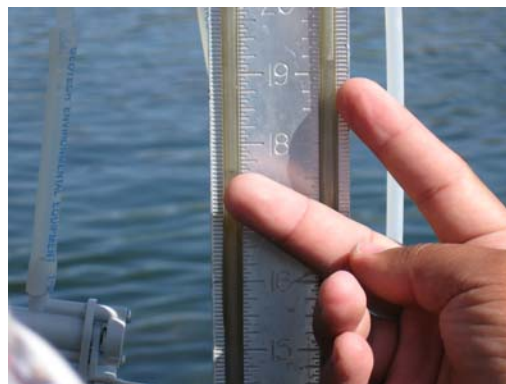


Figure 5: Picture of the manometer used for measuring the upwelling or downwelling for each mini piezometer. The photo to the right shows a close up view of the different pressure heads from a measurement.

3.4 Water Depth and Velocity

A Price AA flow meter and wading rod was used to measure the water depth and velocity at each mini piezometer location in the gravel addition area. Velocity was measured at the 0.2, 0.6, and 0.8 water depth to obtain a representative (average) velocity.

Average velocity can be obtained two ways:

$$(1) V_{average} = \frac{V_{0.2} + V_{0.8}}{2}$$

$$(2) V_{average} = V_{0.6}$$

The average of the 0.2 and 0.8 values are compared with the 0.6 depth for measurement accuracy. The 0.8 depth is also the “snout velocity” for spawning salmonids. Velocity was calculated by counting the revolutions per minute from the flow meter and converting to velocities using the equation: $V = 2.2048R + 0.0178$; where R is the number of revolutions per minute, and V is the velocity in feet per minute (converted to feet per second). Figure 6 shows a picture of the equipment used to measure the velocity and depth of the side channel.



Figure 6: Picture showing the Price AA wading rod stream velocity measuring equipment.

3.5 Inter Gravel Velocity Measurements

Inter gravel velocity was measured in the side channel by conducting salt water tracer tests. The inter gravel velocity of the tracer used was converted to hydraulic conductivity using the following equations:

$$(2) v = -\frac{Kdh}{n_e dl};$$
 This equation describes the seepage velocity, where n_e is the effective

porosity (porosity value of 20% used for this study) and dh/dl is approximated to be the stream gradient.

$$(3) K = \frac{-Q}{A dh/dl};$$
 This equation shows how K is related to Q (streamflow).

In these tests, a main well or injection well of 1 ¾ inch diameter stainless steel pipe was inserted 30 cm into the subsurface. Three 1 ¼ inch diameter stainless steel pipes (monitoring wells) were installed with 30 cm spacing downstream from the injection well also to a depth of 30 cm. Orion Electric Conductivity meters were inserted into the injection well and the three monitoring wells. The meters were calibrated 30 minutes prior to each field day used. The background conductivity was measured in each well to verify the meter's accuracy prior to testing. Figure 7 shows the monitoring well configuration for salt water tracer tests with a 30 cm monitoring well spacing from the injection well.



Figure 7: Picture showing the field set up of the permeability measurements.

During a typical test, two liters of super saturated saltwater solution was injected into the main well. The saltwater solution was created by the addition of 5lbs of rock salt to 3 gallons of water. Salt crystals were still visible in the water 12 hours after the solution was created, and provided visual confirmation that the tracer fluid was saturated. During each test, each EC meter was monitored for an increase in conductivity as time elapsed. Increases in the conductivity readings were recorded with time until the electrical conductivity readings became stable or greater than 30 minutes of time had elapsed since the original increase. The electrical conductivity readings in the saturated solution were usually several orders of magnitude higher than the background (river) conductivity readings, giving an obvious electrical signal as the salt plume arrived to each well.

This tracer test method is used to provide a graph of conductivity versus time at each well. The arrival time of the plume at each well along with the distance from the injection source is used to derive the Darcian (Inter gravel) velocity for the area immediately encompassed by the tracer test. Equations two and three show the derivation and relationship between the inter gravel velocities and the hydraulic conductivity of the tracer test area.

4.0 Results; Pre Restoration Grain Analysis

Figure 8 shows a GIS map of the side channel with the pebble count transects used in this study prior to side channel creation. Figure 9 shows a grain size distribution graph for one of the furthest upstream locations, Figure 10 shows the grain distribution for one of the furthest downstream locations. The majority of the grains counted in the downstream transect are less than 1 inch in diameter. The majority of the grains counted at the upstream location were larger than 1 inch in diameter. The downstream portion also has more grains counted in the smallest diameter sizes of the classification scale used, while the upstream location had larger observed amounts of grain sizes in the largest grain size classifications. Figure 11 shows a map created on March 29, 2009 of areas that contained more than 80% sand by area. The deposition of fine (sand) grains was documented after the creation of the side channel by observing tracer rocks which became buried by fine grained material.

Large areas covered entirely by fine grain materials or sandy river bottom formed at the downstream end of the side channel. Figure 14 shows a comparison between the grain size distributions of an up stream transect versus a down stream transect before side channel creation. Grain size decreased from the upstream to the downstream end of the channel.

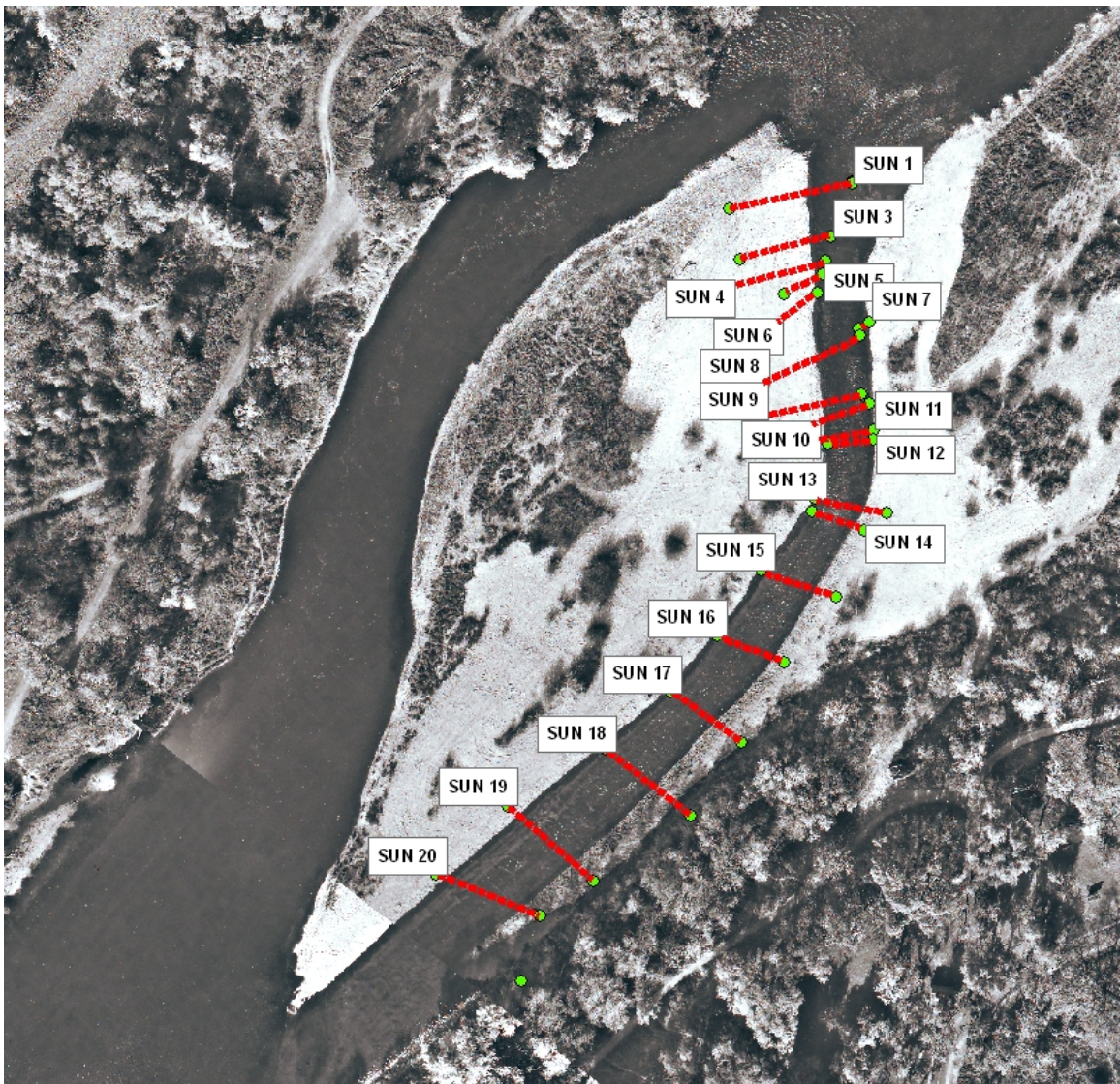


Figure 8: GIS map of the pebble count transect locations conducted before side channel creation.

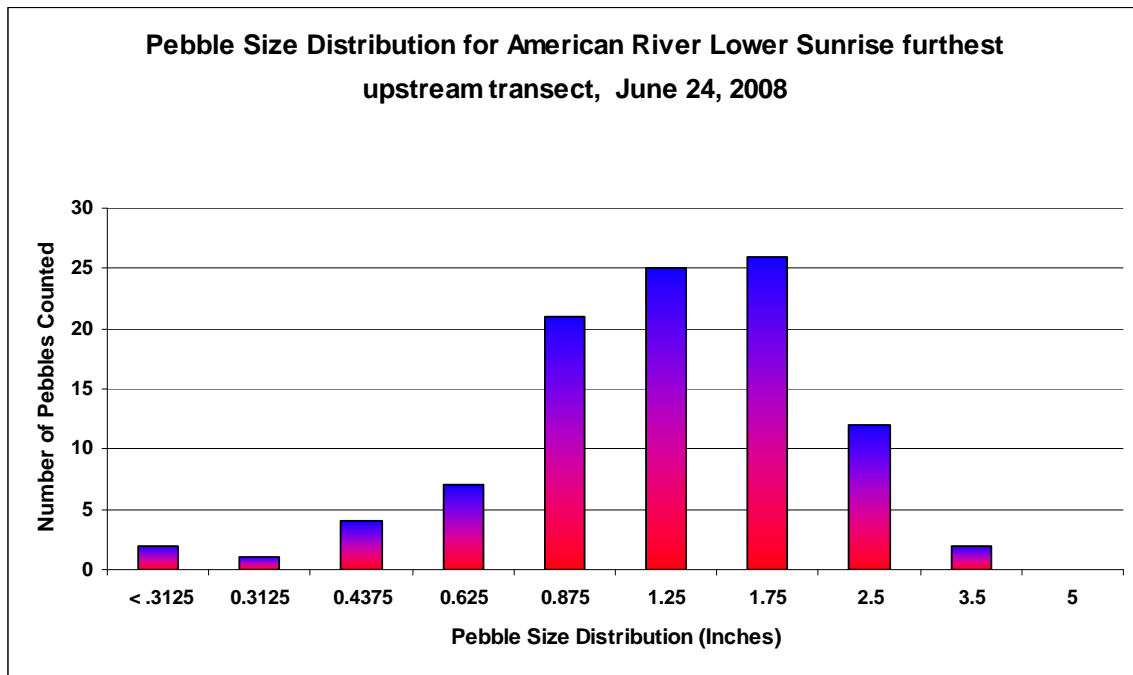


Figure 9: Graph showing the grain size distribution for the furthest upstream transect before side channel creation.

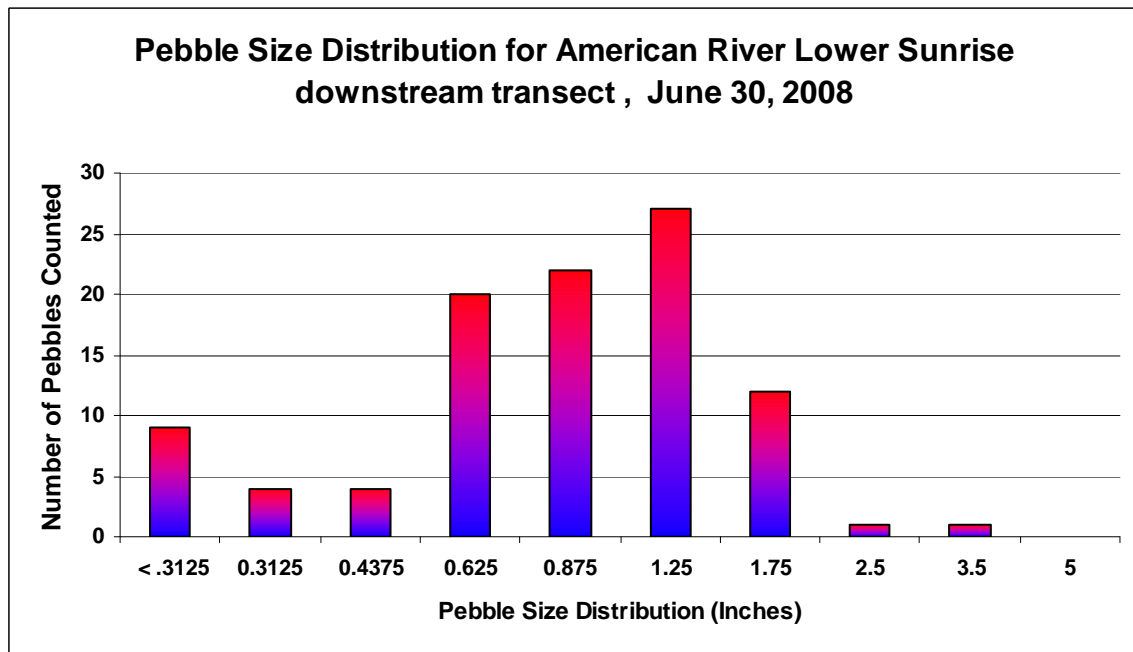


Figure 10: Graph showing the grain size distribution for a downstream transect before side channel creation.

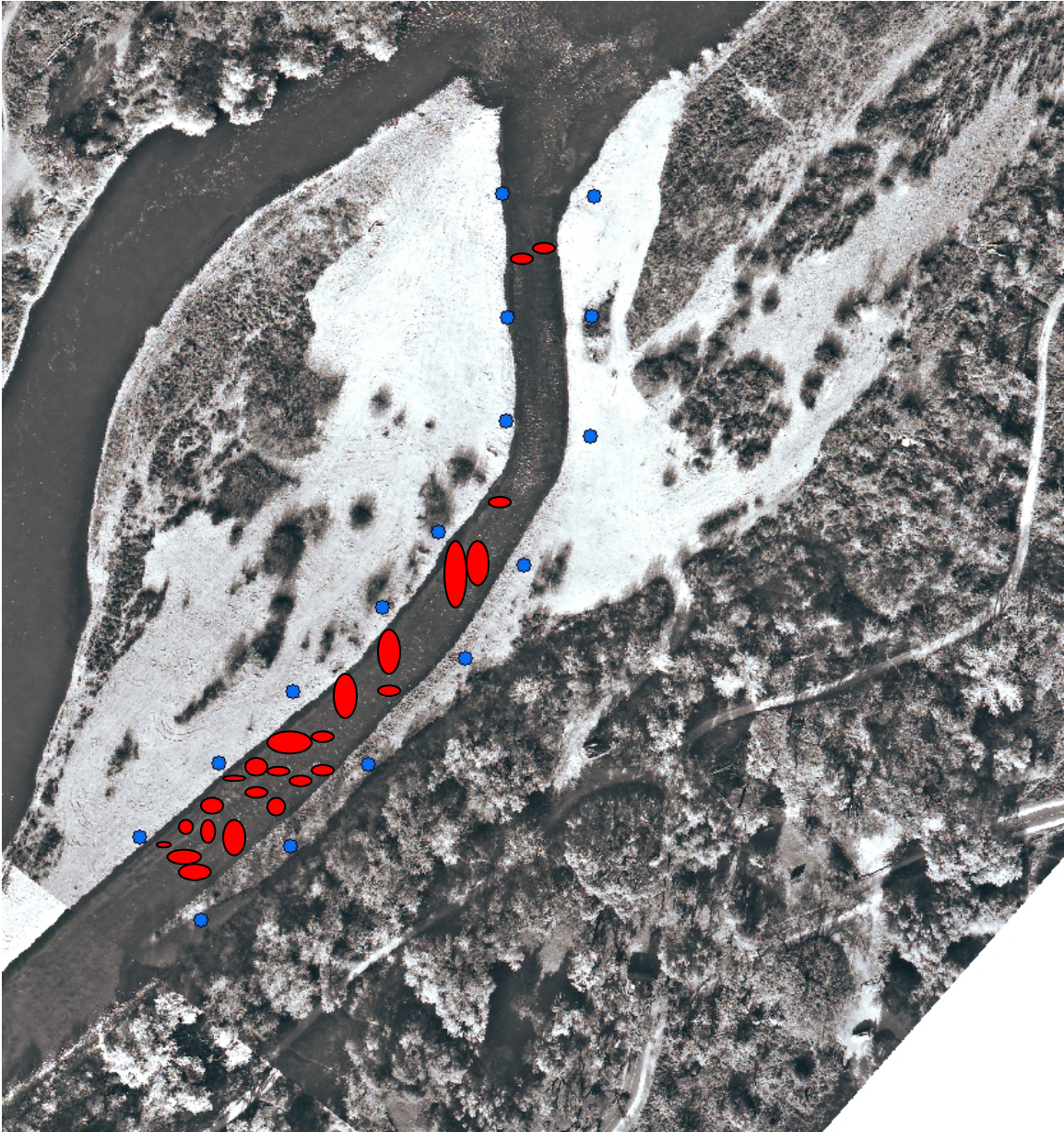


Figure 11: Map showing the locations where the side channel bottom was more than 80% sand by area.

Figure 12 shows a map of the locations for the bulk samples collected before side channel creation. The results for the bulk samples are shown in appendix A. The bulk samples showed larger amounts of 8 mm (fine) grain sizes in the subsurface samples, and small increases in fine grain material compared to the surface samples. All four of the bulk sample locations contained gravel that conforms to the established limits for steelhead spawning. Figure 13 shows a grain size distribution generated from a bulk sample. The dashed black lines are experimentally derived suitable habitat range in terms of minimum and maximum preferred grain sizes.

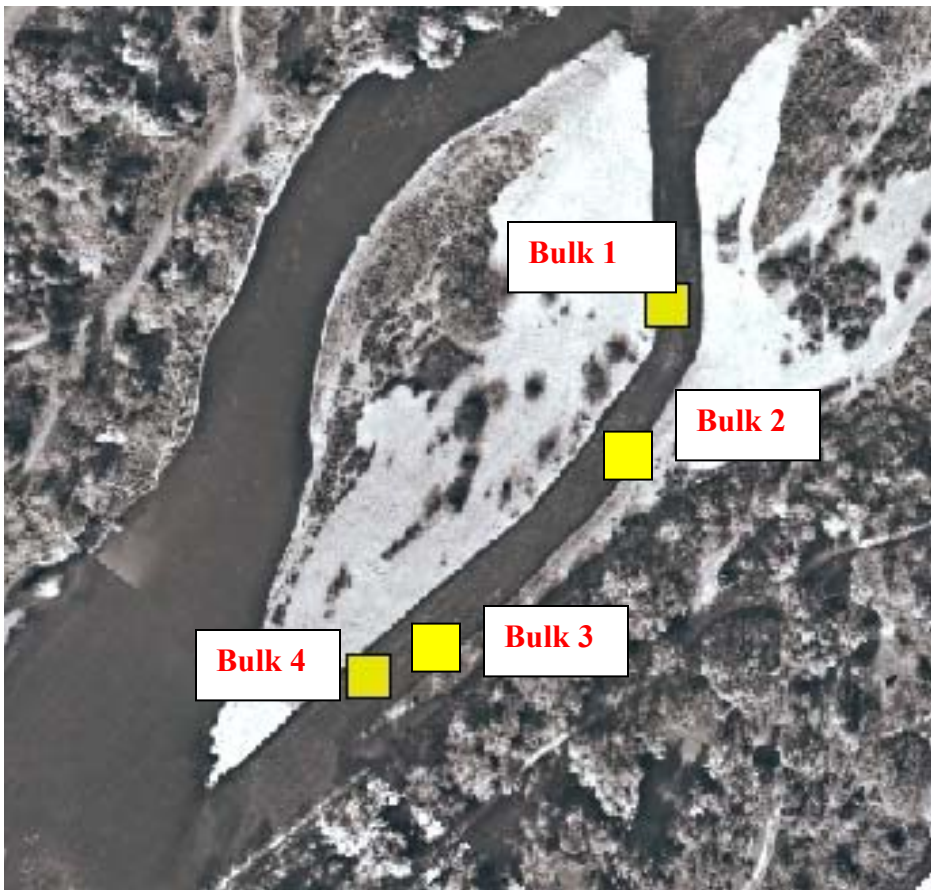


Figure 12: GIS map showing the bulk sample locations before side channel creation.

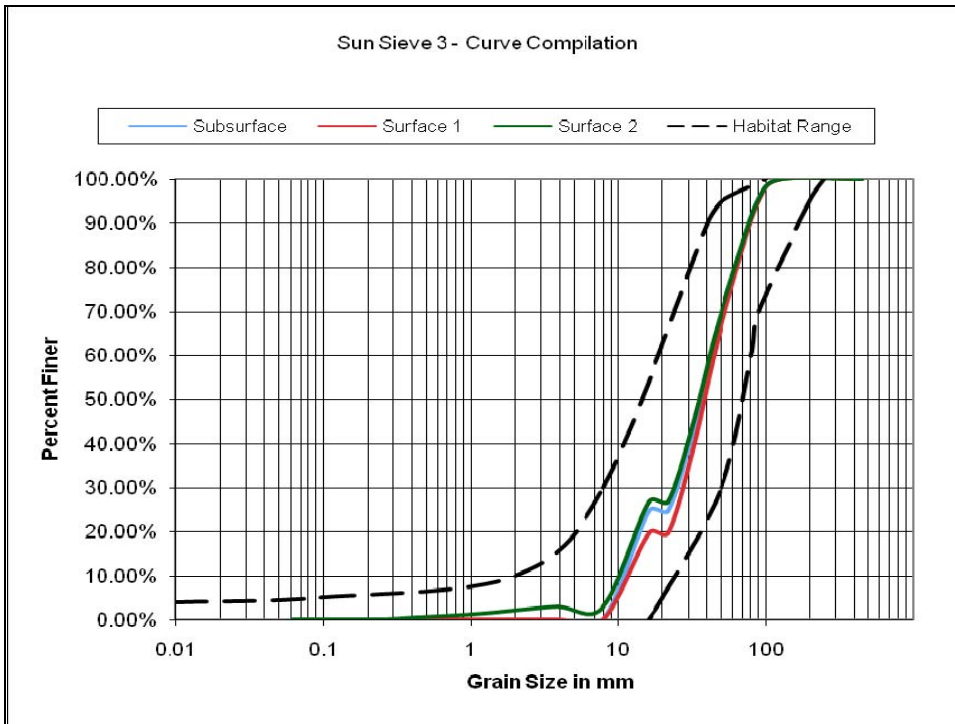


Figure 13: Graph showing the cumulative percent grain size for bulk sample 3, a downstream location before side channel creation.

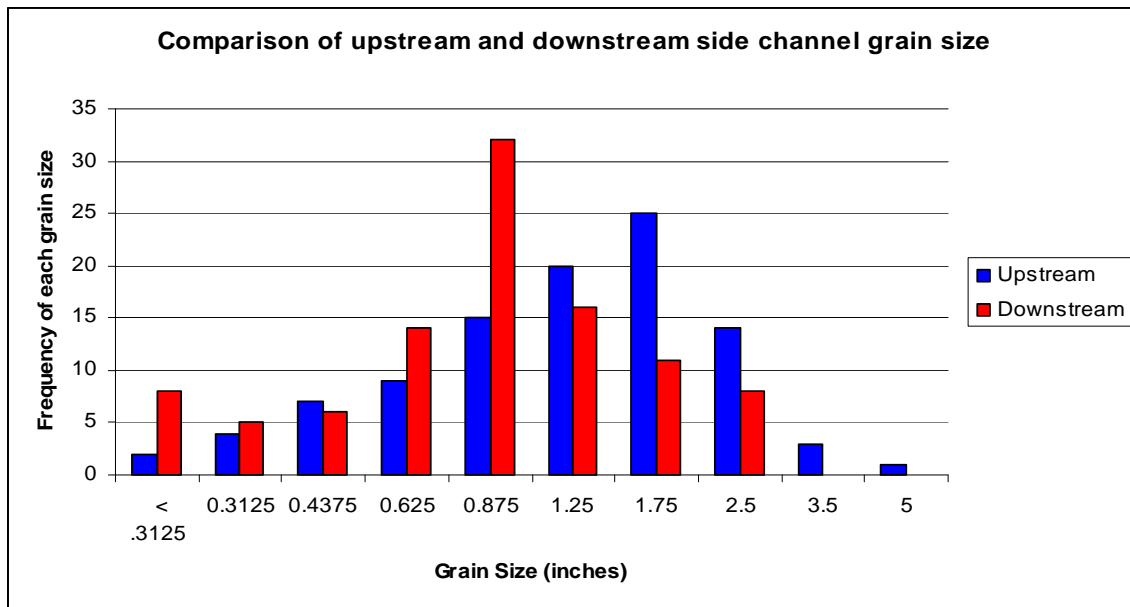


Figure 14: Comparison of the grain size from the upper section of the side channel and the downstream section of the side channel before creation. The red bars (downstream section) show more fine grains. The blue bars (upstream section) show more coarse grains.

4.1 Water Quality

Twelve mini piezometers were installed at the side channel location after side channel construction to measure geochemical parameters related to fish spawning in the channel. Figure 15 shows the location of the mini piezometers in the side channel. Ten mini piezometers were sampled on February 21, 2009 to measure dissolved oxygen (D.O.), pH, Electrical Conductivity (E.C.), temperature, and also collect water samples. The results from the D.O. measurements (Table 2) show a high degree of variability with values ranging from 2 mg/L to over 10 mg/L.



Figure 15: GIS Map showing the side channel mini piezometer locations.

Location	Temp (C deg)	D.O. (mg/L)	E.C. (ms)	pH
MP-1	10	10.1	52.4	7.4
MP-2	10	10.2	55.1	7.39
MP-4	9.8	9.6	50.9	7.23
MP-5	10.1	10.1	55.4	7.33
MP-6	9.9	10.5	51.3	7.4
MP-7	10.4	9.7	42.4	7.04
MP-8	10.5	3.5	40.8	7.13
MP-9	10.3	8.8	44.4	7.1
MP-10	10.8	2.1	56.1	6.8
MP-12	10.4	9.1	56.5	7.02
Mean	10.2	8.4	50.5	7.2
Surface 1	11.8	11.8	54.7	7.72
Surface 2	12.2	12.2	53.7	8.14

Table 2: Summary of data collected from installed mini piezometers, Feb 21, 2009.

Table 2 and Figure 16 show D.O. values higher than 8.0 ppm for eight of the mini piezometers sampled. Two mini piezometer locations showed very low D.O. values of 3.5 ppm and 2.1 ppm. The map showing the locations of sand in the side channel (Figure 11) shows the mini piezometer locations with the low D.O. are in areas that are predominantly sand or fine-grained. The increase in fine grain material is inferred to be creating the low D.O. amounts and preventing the oxygen and pore water from moving through the pore spaces of the substrate.

Mini Piezometers MP-3 and MP-11 were lost or removed from the river prior to data collection. pH values ranged from 7.04 to 7.4 within a temperature range of 9.8-10.8 degrees Celsius. The Electrical conductivity values range from 80.8 to 95.4 micro Siemens/cm.



Figure 16: GIS map showing the D.O. values measured.

The lowest pH, E.C. and D.O. readings are all present at the two locations where fine-grained material has overtaken the mini piezometer locations. Surface samples were taken twice during the sampling event to compare river water to subsurface conditions. The surface samples showed expectedly higher levels of D.O. due to atmospheric mixing. Temperature was also higher by more than 1 degree Celsius in surface water. The gravel formed by the side channel provides a measurably cooler environment at 30 cm depth.

4.2 Hyporheic Pressure



Figure 17: GIS map showing the bubble monometer measurements for the side channel from February 2009.

The manometer measurements (Figure 17) from February 2009 showed less than ½ inch pressure changes, indicating upwelling conditions at the majority of the locations. Several mini piezometers showed “even” pressure readings, with no significant pressure difference between the surface and subsurface. An additional 75 measurements were made in February 2010 using a well spike to create temporary wells to a depth of 30 cm.

Figure 18 shows a map of the locations sampled in February 2010 with up or down arrows indicating direction of the vertical pressure gradient. Figure 19 shows a map of the areas where downwelling or upwelling occurred.

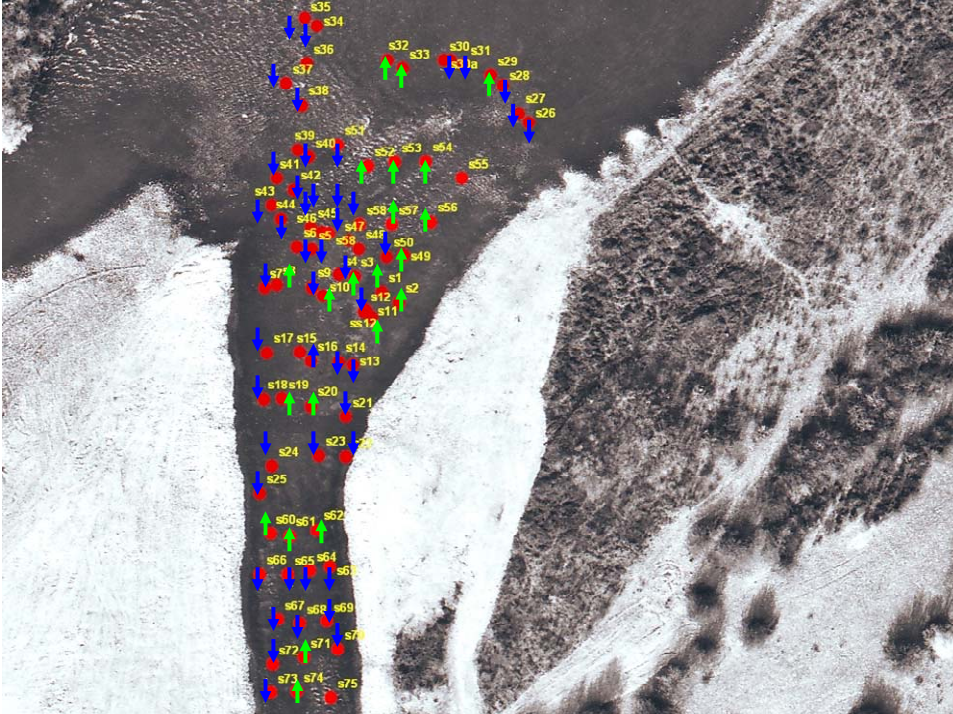


Figure 18: Map showing vertical pressure gradient measurements from February 2010.

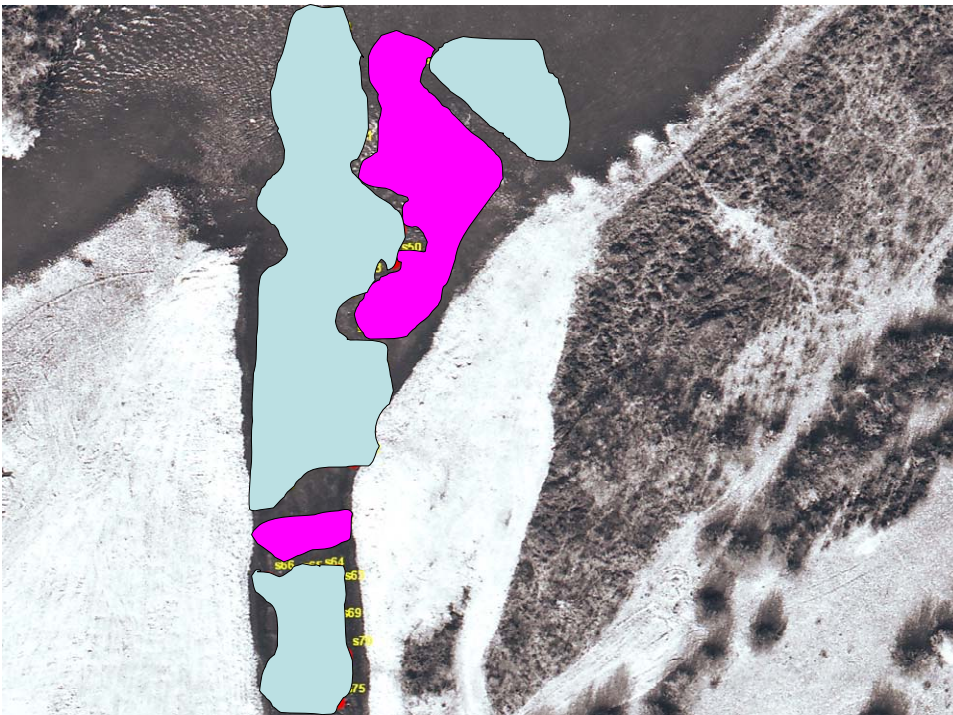


Figure 19: Map showing the areas of upwelling in pink and downwelling in light blue. Measurements were made February 2010.

The results from water samples analyzed using the Hach Spectrophotometer showed values approaching the smallest detectable limits for the Nitrate, Nitrite, Phosphate, and Ammonia tests. Appendix E shows the data collected.

4.2 Water Depth and Velocity

After side channel creation, water depth and velocity were measured at 8 transects across the side channel. Figure 20 shows the location of the transects used to create the streamflow data. Figure 21 shows the velocities measured in feet per second for the 2008 transects. These values ranged from 0.5 feet per second to almost 4 feet per second in the upstream portions of the side channel. Figures 22 and 23 show the depth at each segment of the cross section. Measurements were made for the two sampling events in November 2008 and in June 2009 to show changes in the side channel over time. Stream flow for the 2008 measurements (from the USGS Fair Oaks gage) was 1165 cfs, and 2000 cfs for the 2009 sampling event. The changes in depth shown in Figures 22 and 23 show a general pattern of down cutting and erosion for the upstream portion of the channel and sand deposition for the downstream portion of the channel. This depth difference also shows that the side channel has incised more than 1 foot in some upper portions. The uppermost transect was not measured because several of the measuring points in the transect were too deep (greater than 4.5 feet) for the wading rod. Appendix D shows the data for the flow velocity calculations.



Figure 20: GIS map showing the velocity transects used to determine streamflow in the river.

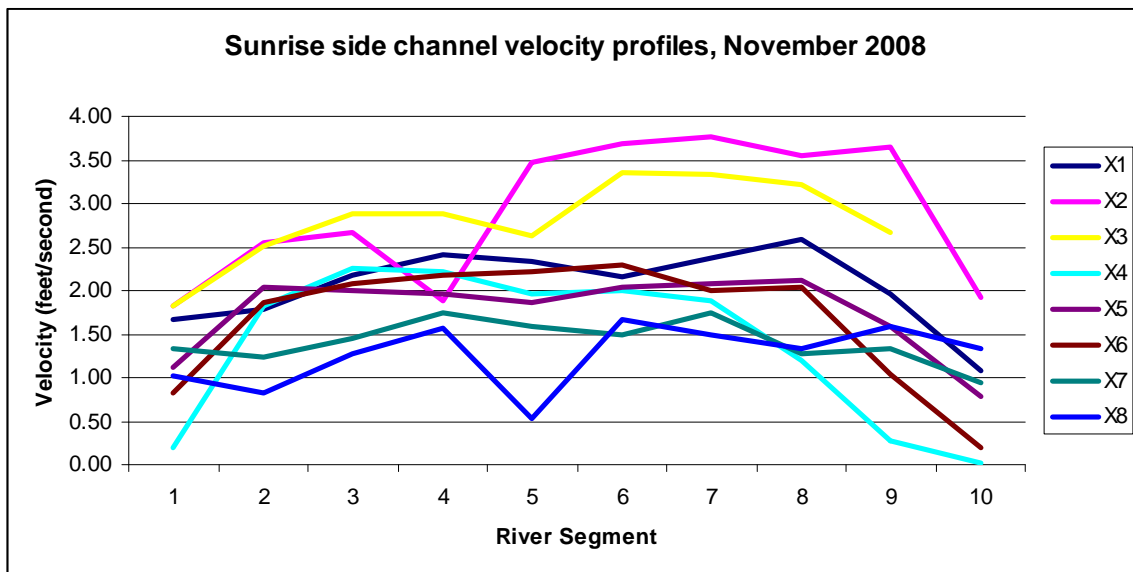


Figure 21: Graph showing the measured stream velocity in feet per second at each transect from November 2008. Flow was 1165cfs.

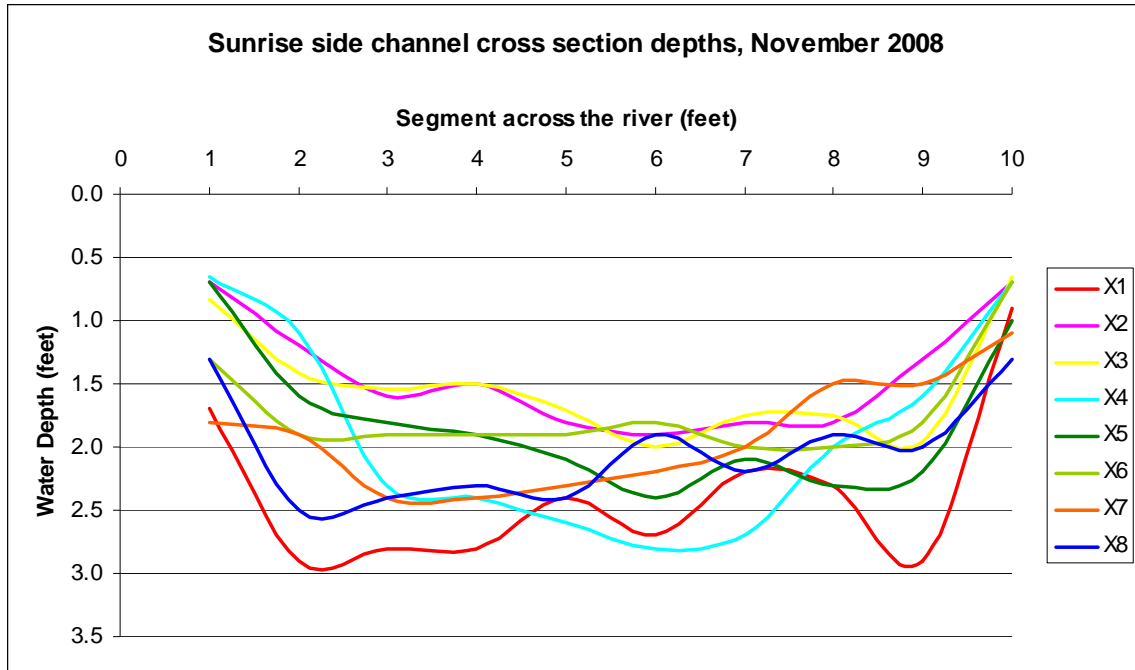


Figure 22: Graph showing the depths of each cross section. X1 is the upper most portion of the side channel and X8 is the furthest downstream transect. Flow was 1165cfs.

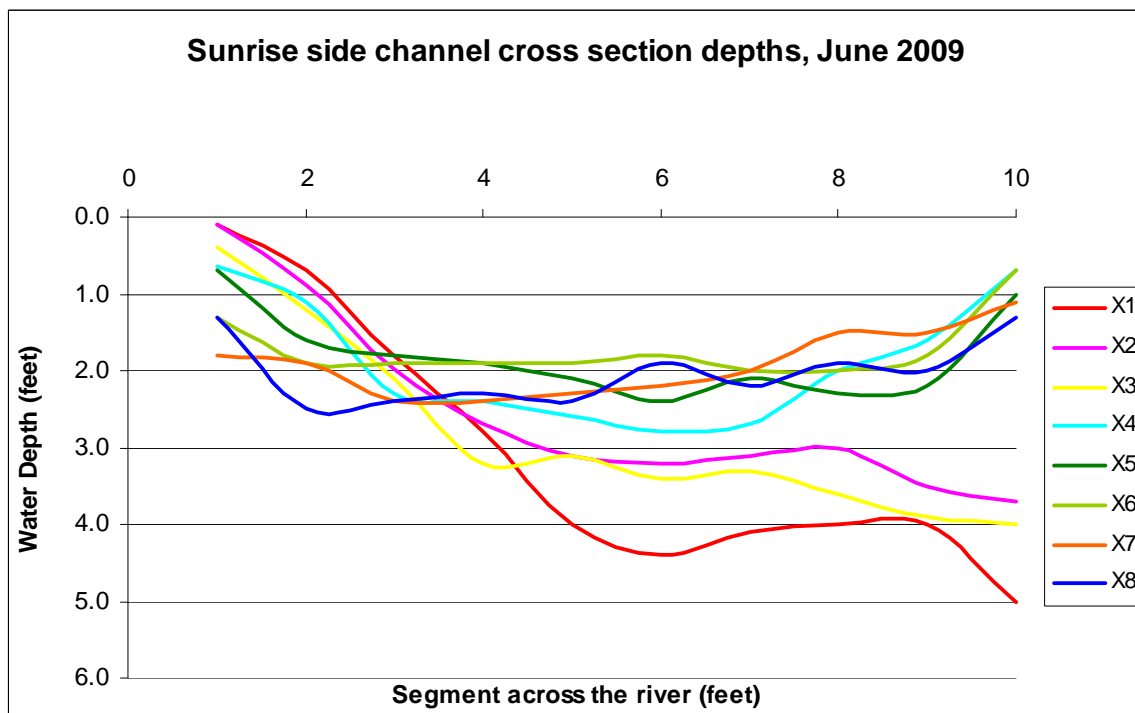


Figure 23: Graph showing the depths of each cross section and significant down cutting 8 months later. X1 is the upper most portion of the side channel and X8 is the furthest downstream transect. Flow was 2000 cfs.

4.3 Gravel mobility Analysis

Tracer rocks were initially deployed in December 2008. The rocks were located on March 29, 2009 when the flow recorded at the USGS Fair Oaks river gage was 1750 cfs and again on April 29, 2009 when the flow was 3000 cfs. The March sampling event showed more movement of larger rocks at the upstream transect (Figure 25). Sixteen out of thirty of the largest size tracer rocks were mapped with an average downstream movement of 3.7 feet. Eight of the intermediate size (blue rocks) and 3 of the smallest size (red rocks) were located with average downstream movements of 8.9 feet and 14.3 feet respectively. A single small sized (red tracer rock) migrated to within 3 feet of the middle transect line. This red rock is probably from the upstream transect showing a downstream movement of 100 feet.

During the March and April sampling events, 18 large (yellow) size rocks were located and mapped along with 7 intermediate (blue) and 6 small (red) rocks at the up stream transect. The tracer rocks on the northern portion of the middle transect were partially or completely covered in fine grained sand and silt (Figure 24).



Figure 24: Picture from the lower transect on March 29, 2009 showing the burial of a yellow rock in fine grained material.

The rocks located at the middle transect did not move further than a few feet from the original transect location. The furthest downstream transect of tracer rocks yielded the smallest return of rocks due to burial from fine grained material. Almost half of the transect's width was consumed by sand and silt along the downstream transect. Figure 25 shows a GIS map of the lower Sunrise study area.



Figure 25: GIS map showing the results from the tracer rock test. Labels show the new position of Upper Transect (UT) rocks and Lower Transect rocks (LT). R is the red colored (smallest size), B represents the Blue (intermediate) rocks, and Y represents the Yellow (largest) rocks. Middle transect rocks did not move a significant distance from origin.

5.0 Discussion

The Lower Sunrise side channel restoration project allowed researchers to examine the physical and geochemical changes that affect steelhead spawning habitat before and after restoration work occurred. Table 3 shows the data collected from 2005 sampling by Tim Horner and data collected in 2009.

Sample Date	D.O. (ppm)	E.C. (μ S)	Temperature C°
2005	4.6	54	19.4
2009	8.4	50.5	10.2

Table 3: Comparison of 2005 Data (Horner) and 2009 data for sunrise side channel.

Table 3 shows that the side channel dissolved oxygen increased after construction. Mean temperature decreased after side channel construction. The methods used in the 2005 study were applied to the side channel after completion. The post restoration monitoring contains data from the incremental increases in flow that occur annually during the spring and early summer, allowing the opportunity to monitor changes to the side channel from the lowest annual river flows to the highest annual flows during 2008/2009.

The side channel continues to change daily in terms of substrate and levee morphology and grain size distribution. The upstream portion of the side channel is eroding due to increased stream velocity (Figure 21) and a lack of sufficient anchoring or support mechanisms to stabilize the mostly less than 1.75 inch diameter grain sizes in the channel. Vertical pressure gradient measurements show the majority of the upstream portion of the side channel is downwelling after side channel construction.

Increased velocities promote the down cutting (erosion) in the upstream portion of the side channel shown in Figures 22 and 23. Tracer rock movements show the largest size tracer rocks moving the furthest amounts in the upper portion of the side channel. The sediment in the side channel is mobile, and finer grained material has been mobilized and re deposited in large areas (Figure 11) of the downstream portion of the side channel. There are many downstream locations that do not have any grains larger than 7/16 inch diameter. Increased fine grained deposition in the lower end of the side channel could be hindering spawning by choking potential spawning areas with excess fine-grained sediment. This leads to decreased dissolved oxygen from a lack of oxygenated surface water that can not move through the sandy material readily. Tracer rocks in the downstream end of the channel moved very little, or were buried by fine-grained sediment deposited by lower water velocities than the upstream end of the channel. Figures 22 and 23 show the depths in the downstream end to be decreasing, indicating that deposition is occurring. The lowest dissolved oxygen values from the site were recorded in the downstream end of the side channel in locations where the mini piezometer had been inundated with fine grains.

The middle portion of the channel is also showing signs of increased fine grain deposition near the bend. The left banks (southern side) of the channel is eroding where the most energy and erosive power is located. This lateral erosion is contributing to the increased fine-grained material downstream.

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Appendix A: Sunrise Bulk sample analysis: Conducted before side channel creation

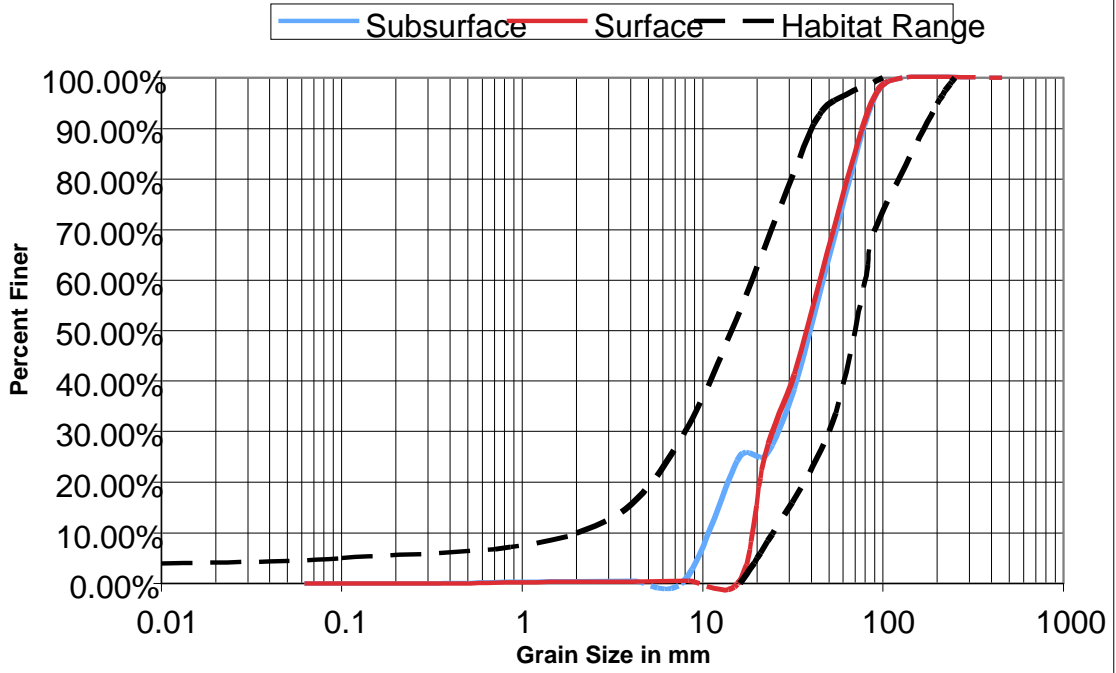
Furthest upstream bulk sample: Surface (7/22/08)

Sieve Size MM	Mass of Sediment Retained (kg)	Percentage of Total Wt	Cumulative Wt %
90 mm	4.20	3.46%	3.46%
64 mm	19.30	15.89%	19.35%
45 mm	24.20	19.93%	39.28%
32 mm	23.50	19.35%	58.64%
22 mm	19.60	16.14%	74.78%
16 mm	30.00	24.71%	99.49%
8.00 mm	0.00	0.00%	99.49%
3.962 mm	0.17	0.14%	99.63%
1.981mm	0.09	0.07%	99.70%
1.00 mm	0.10	0.09%	99.79%
0.425 mm	0.21	0.17%	99.96%
0.250 mm	0.03	0.03%	99.99%
0.12446 mm	0.00	0.00%	100.00%
Residual	0.00	0.00%	100.00%
Total WT.	121.42		

Furthest upstream bulk sample: Sub Surface (7/22/08)

Sieve Size MM	Mass of Sediment Retained (kg)	Percentage of Total Wt	Cumulative Wt %
90 mm	2.70	3.78%	3.78%
64 mm	12.60	17.64%	21.42%
45 mm	14.60	20.44%	41.86%
32 mm	14.10	19.74%	61.60%
22 mm	9.50	13.30%	74.89%
16 mm	0.00	0.00%	74.89%
8.00 mm	17.40	24.36%	99.25%
3.962 mm	0.13	0.19%	99.44%
1.981mm	0.08	0.12%	99.56%
1.00 mm	0.09	0.13%	99.69%
0.425 mm	0.17	0.24%	99.93%
0.250 mm	0.04	0.05%	99.98%
0.12446 mm	0.01	0.01%	99.99%
Residual	0.00	0.01%	100.00%
Total WT.	71.43		

Furthest upstream bulk sample, Sunrise side channel, July 2008



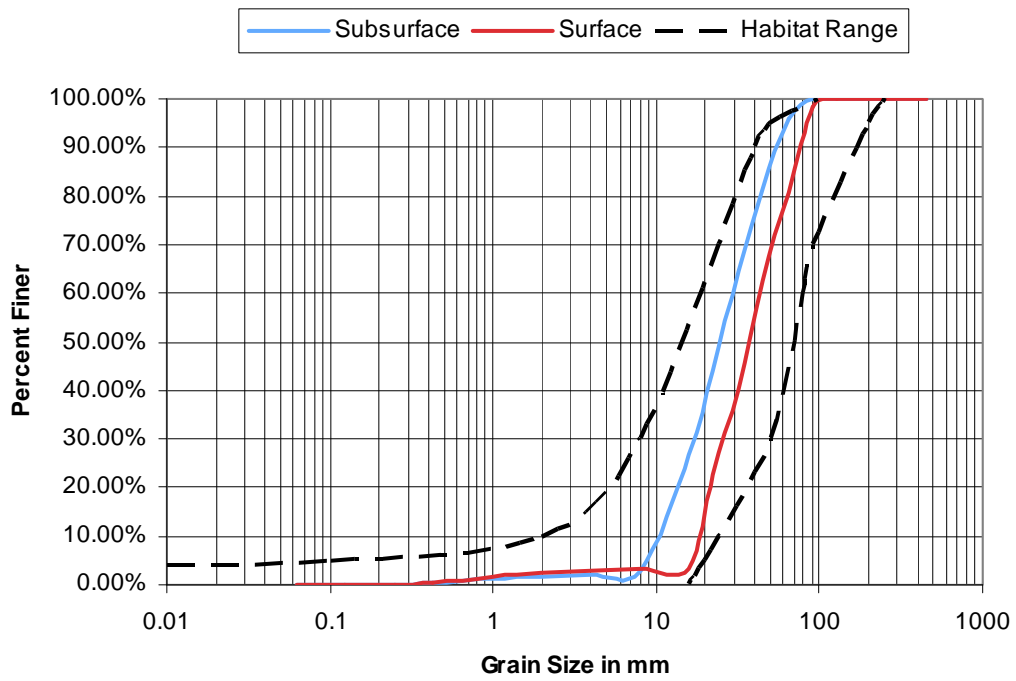
Mid channel (upstream) bulk sample: Surface (7/22/08)

Sieve Size MM	Mass of Sediment Retained (kg)	Percentage of Total Wt	Cumulative Wt %
90 mm	0.40	1.81%	1.81%
64 mm	3.90	17.68%	19.50%
45 mm	4.00	18.14%	37.63%
32 mm	4.90	22.22%	59.85%
22 mm	3.90	17.68%	77.53%
16 mm	4.20	19.04%	96.57%
8.00 mm	0.00	0.00%	96.58%
3.962 mm	0.15	0.67%	97.24%
1.981mm	0.06	0.27%	97.51%
1.00 mm	0.15	0.66%	98.17%
0.425 mm	0.32	1.46%	99.63%
0.250 mm	0.07	0.30%	99.93%
0.12446 mm	0.01	0.05%	99.98%
Residual	0.00	0.02%	100.00%
Total WT.	22.06		

Mid channel (upstream) bulk sample: Sub surface (7/22/08)

Sieve Size MM	Mass of Sediment Retained (kg)	Percentage of Total Wt	Cumulative Wt %
90 mm	0.00	0.00%	0.00%
64 mm	1.20	4.22%	4.22%
45 mm	4.10	14.41%	18.62%
32 mm	4.80	16.87%	35.49%
22 mm	5.80	20.38%	55.87%
16 mm	4.90	17.22%	73.09%
8.00 mm	6.80	23.89%	96.98%
3.962 mm	0.25	0.87%	97.85%
1.981mm	0.11	0.40%	98.25%
1.00 mm	0.13	0.46%	98.71%
0.425 mm	0.28	1.00%	99.70%
0.250 mm	0.07	0.25%	99.95%
0.12446 mm	0.01	0.04%	99.99%
Residual	0.00	0.01%	100.00%
Total WT.	28.46		

Mid channel (upstream) bulk sample, Sunrise side channel, July 2008



Mid channel (downstream) bulk sample: Surface (7/29/08)

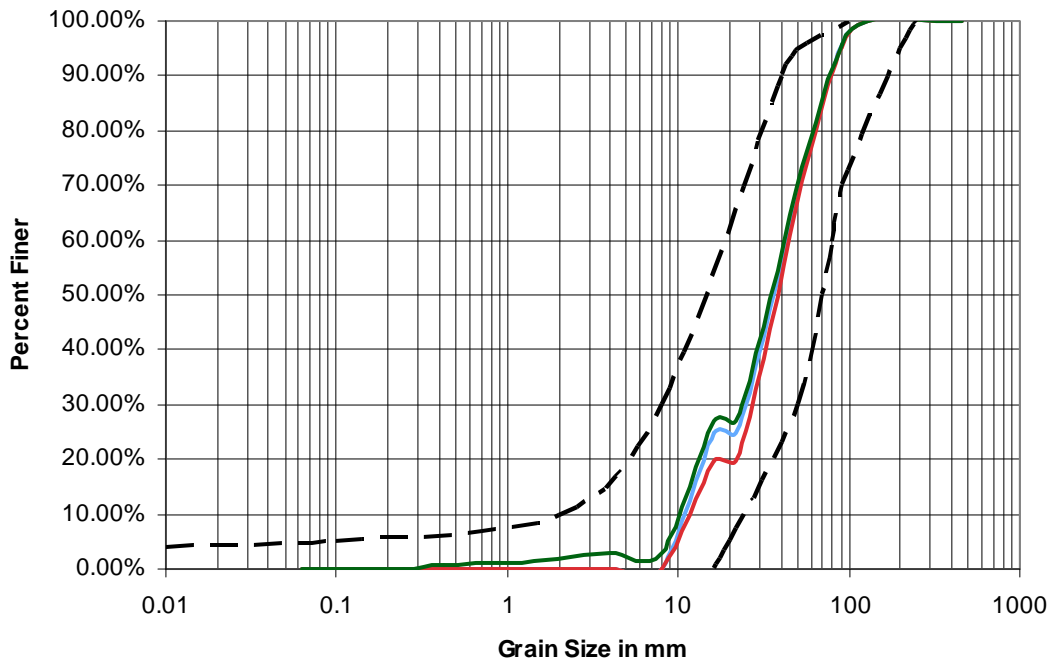
Sieve Size MM	Mass of Sediment Retained (kg)	Percentage of Total Wt	Cumulative Wt %
90 mm	1.2	4.74%	4.74%
64 mm	3.9	15.41%	20.16%
45 mm	4.8	18.97%	39.13%
32 mm	5.7	22.53%	61.66%
22 mm	4.7	18.58%	80.23%
16 mm	0.00	0.00%	80.23%
8.00 mm	5.0	19.76%	100.00%
3.962 mm	0.31	0.00%	100.00%
1.981mm	0.23	0.00%	100.00%
1.00 mm	0.20	0.00%	100.00%
0.425 mm	0.15	0.00%	100.00%
0.250 mm	0.02	0.00%	100.00%
0.12446 mm	0.00	0.00%	100.00%
Residual	0.00	0.00%	100.00%
Total WT.	25.392		

Mid channel (downstream) bulk sample: Sub Surface (7/29/08)

Sieve Size MM	Mass of Sediment Retained (g)	Percentage of Total Wt	Cumulative Wt %
90 mm	1200.00	4.35%	4.35%
64 mm	4100.00	14.85%	19.20%
45 mm	4800.00	17.39%	36.59%
32 mm	5800.00	21.01%	57.61%
22 mm	4900.00	17.75%	75.36%
16 mm	0.00	0.00%	75.36%
8.00 mm	6800.00	24.64%	100.00%
3.962 mm	0.26	0.00%	100.00%
1.981mm	0.16	0.00%	100.00%
1.00 mm	0.14	0.00%	100.00%
0.425 mm	0.15	0.00%	100.00%
0.250 mm	0.05	0.00%	100.00%
0.12446 mm	0.02	0.00%	100.00%
Residual	0.01	0.00%	100.00%
Total WT.	27600.79		

**Mid channel (downstream) bulk sample, Sunrise side
channel, July 2008**

— Subsurface — Surface 1 — Surface 2 — Habitat Range



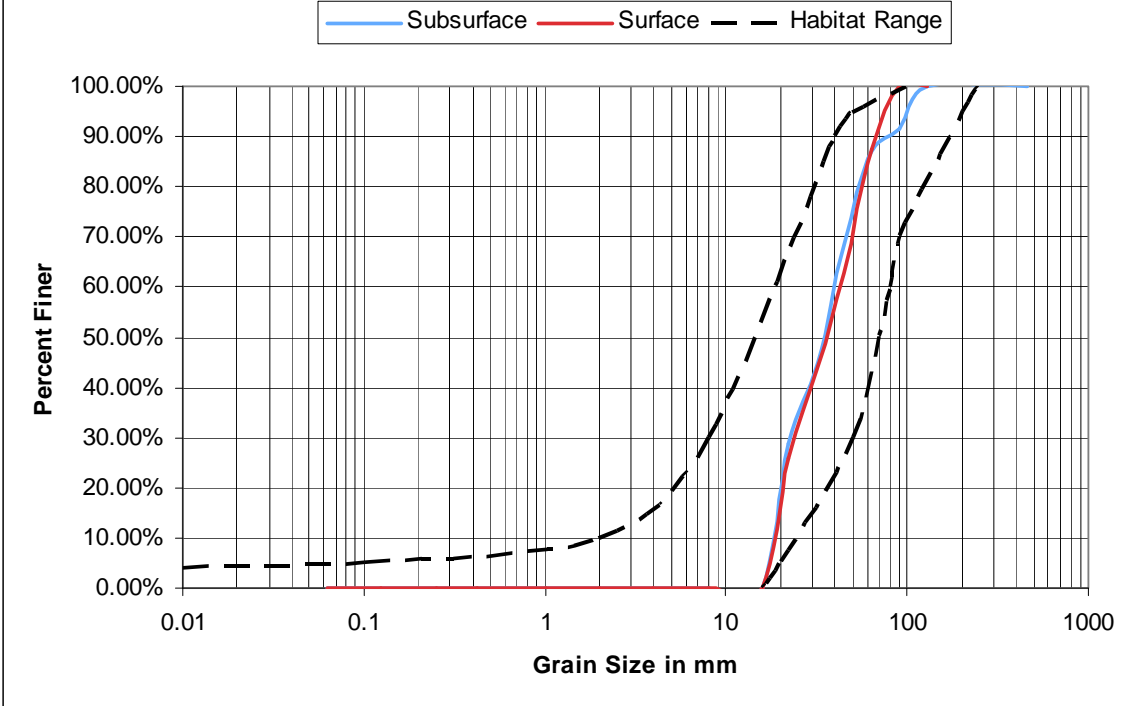
Furthest downstream bulk sample: Surface (7/29/08)

Sieve Size MM	Mass of Sediment Retained (g)	Percentage of Total Wt	Cumulative Wt %
90 mm	1400.00	12.39%	12.39%
64 mm	1100.00	9.73%	22.12%
45 mm	1700.00	15.04%	37.17%
32 mm	2100.00	18.58%	55.75%
22 mm	2100.00	18.58%	74.33%
16 mm	2900.00	25.66%	100.00%
8.00 mm	0.00	0.00%	100.00%
3.962 mm	0.14	0.00%	100.00%
1.981mm	0.11	0.00%	100.00%
1.00 mm	0.13	0.00%	100.00%
0.425 mm	0.12	0.00%	100.00%
0.250 mm	0.02	0.00%	100.00%
0.12446 mm	0.00	0.00%	100.00%
Residual	0.00	0.00%	100.00%
Total WT.	11300.52		

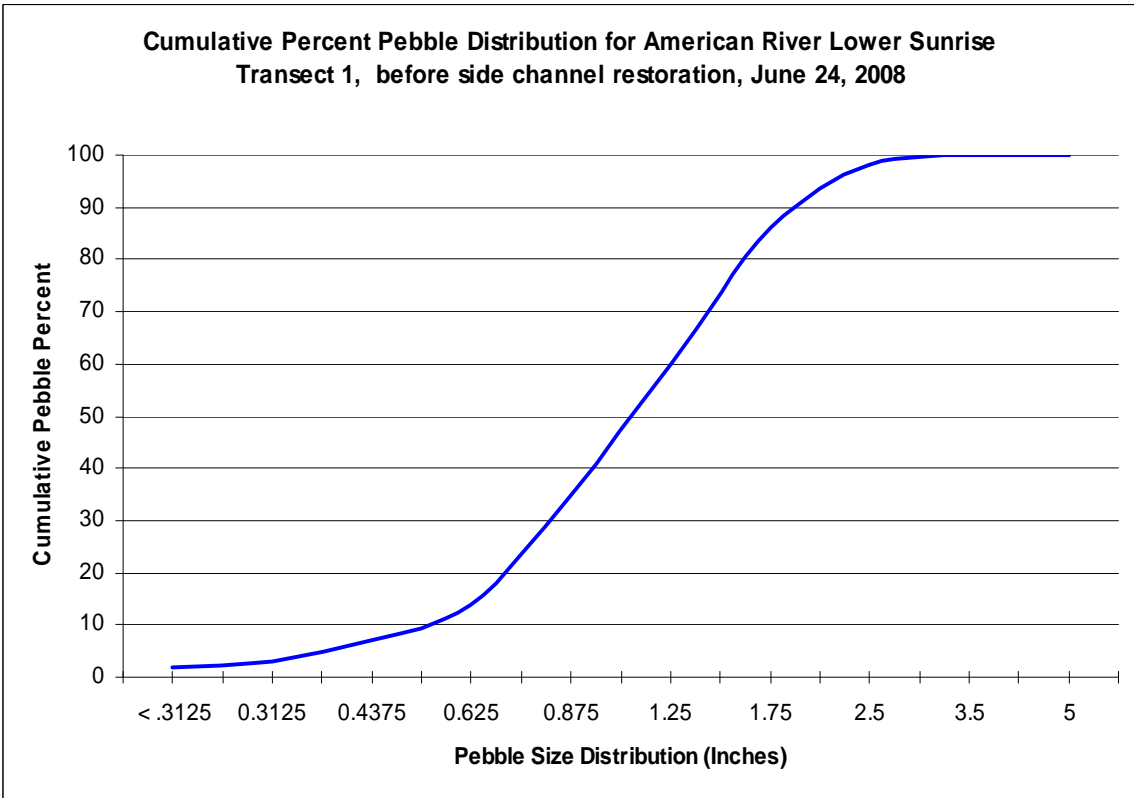
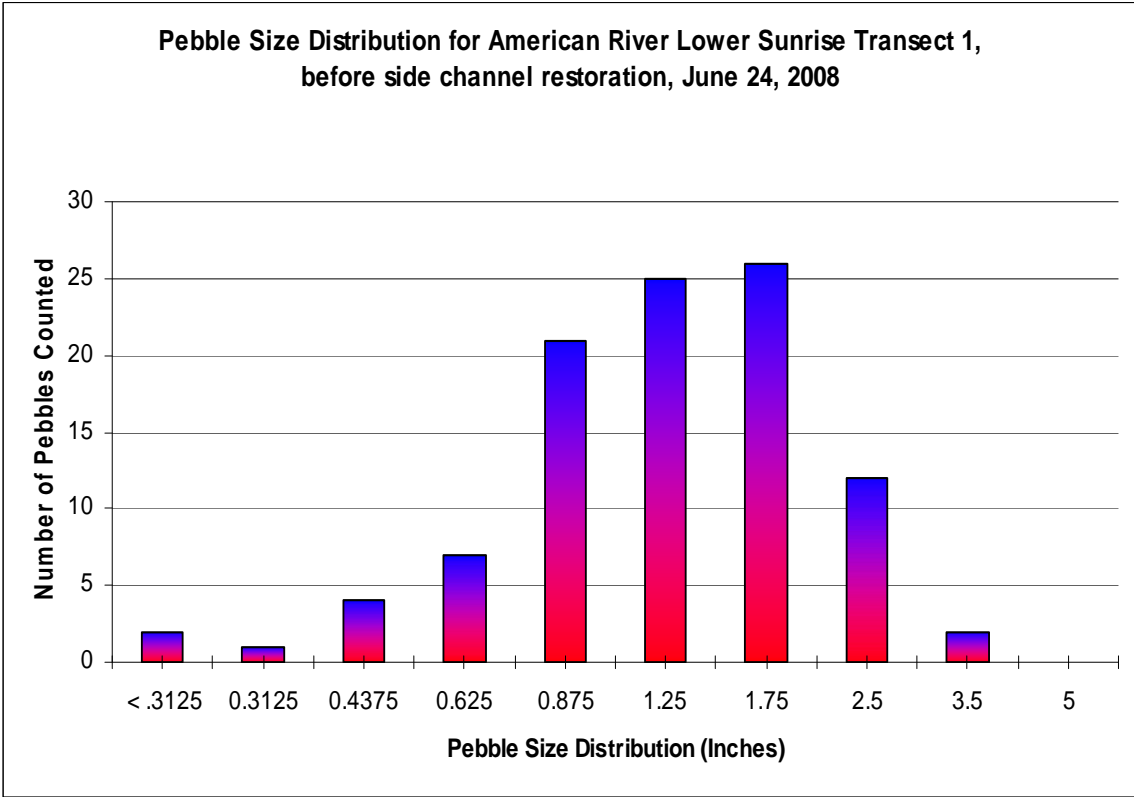
Furthest downstream bulk sample: Sub Surface (7/29/08)

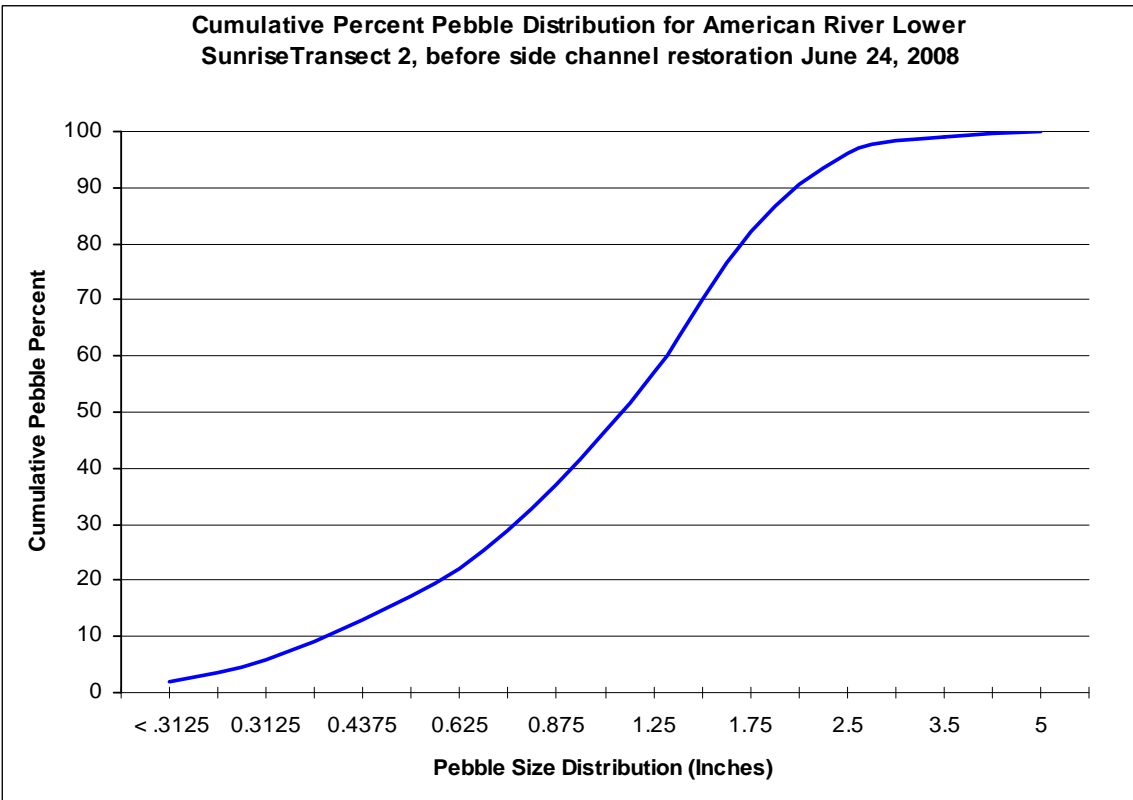
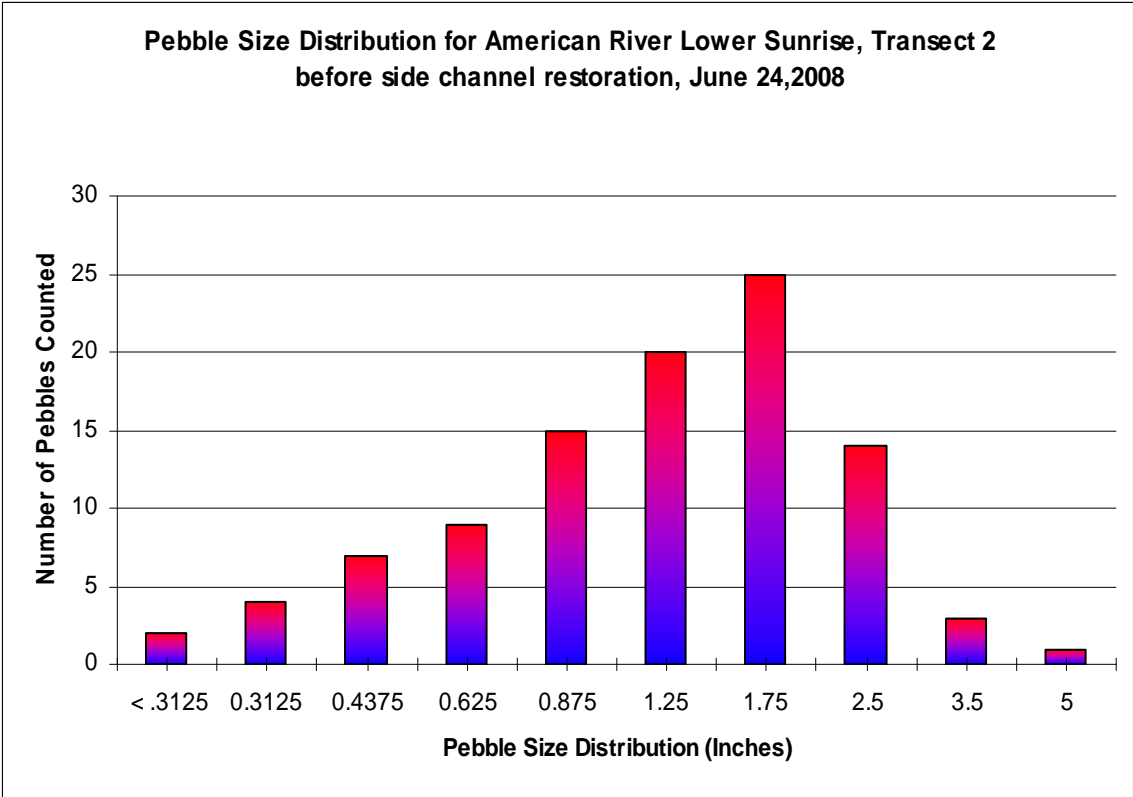
Sieve Size MM	Mass of Sediment Retained (g)	Percentage of Total Wt	Cumulative Wt %
90 mm	1500.00	8.47%	8.47%
64 mm	800.00	4.52%	12.99%
45 mm	3300.00	18.64%	31.64%
32 mm	4100.00	23.16%	54.80%
22 mm	2900.00	16.38%	71.18%
16 mm	5100.00	28.81%	100.00%
8.00 mm	0.00	0.00%	100.00%
3.962 mm	0.18	0.00%	100.00%
1.981mm	0.12	0.00%	100.00%
1.00 mm	0.11	0.00%	100.00%
0.425 mm	0.15	0.00%	100.00%
0.250 mm	0.06	0.00%	100.00%
0.12446 mm	0.02	0.00%	100.00%
Residual	0.01	0.00%	100.00%
Total WT.	17700.64		

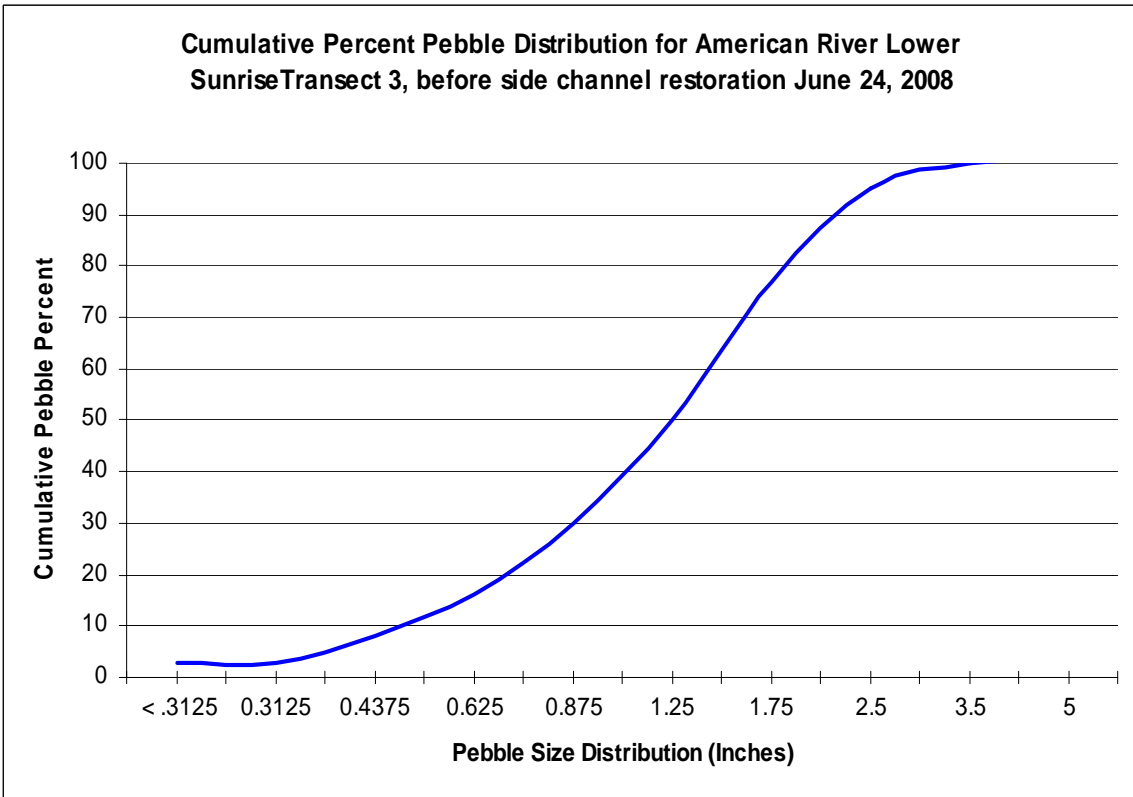
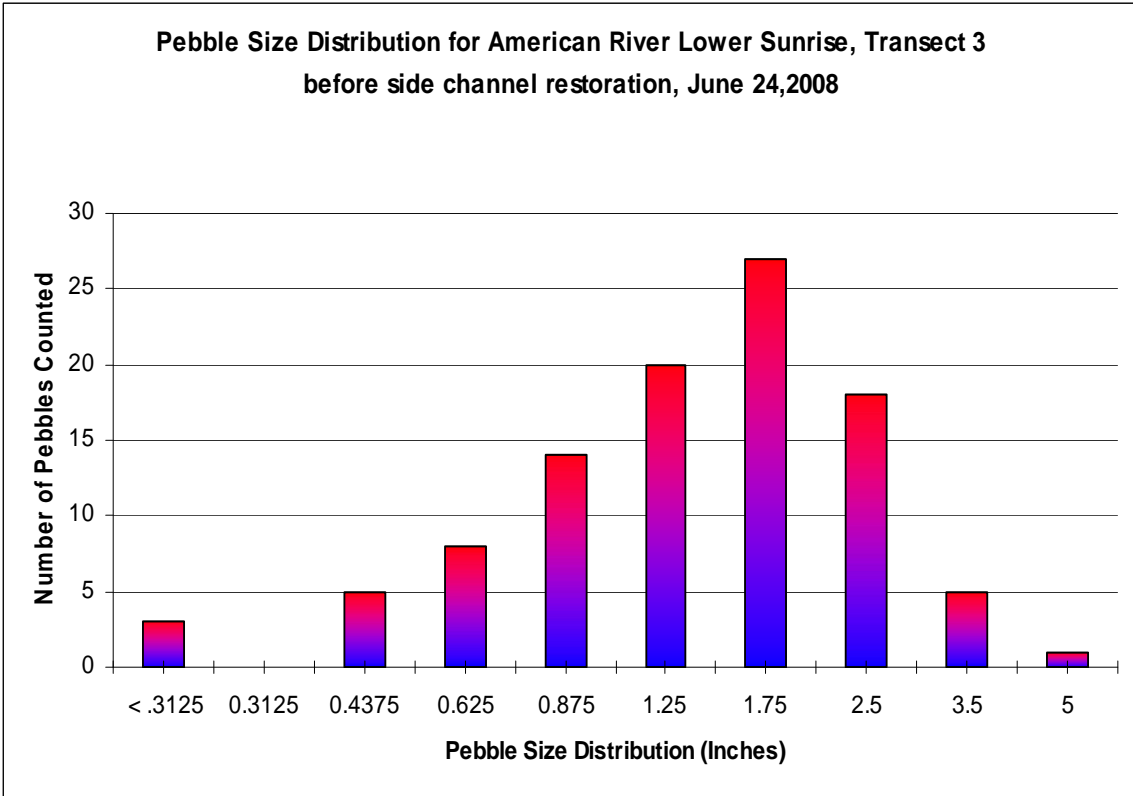
Furthest downstream bulk sample, Sunrise side channel, July 2008

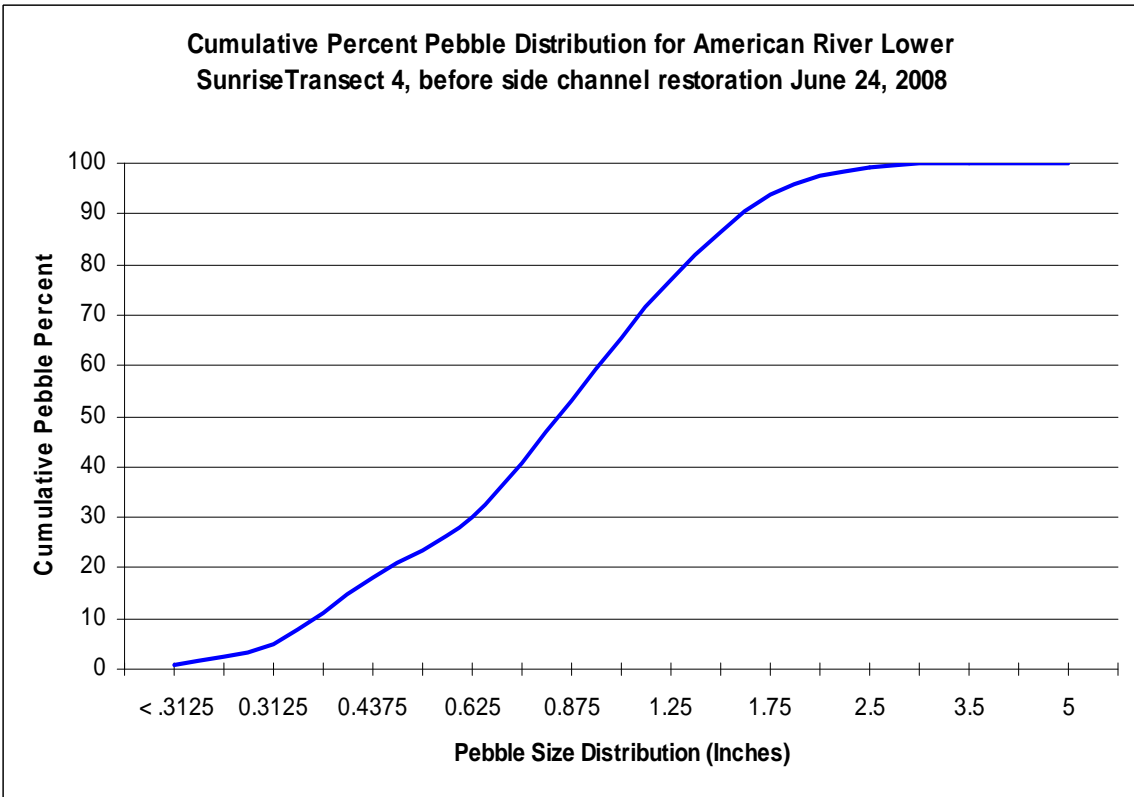
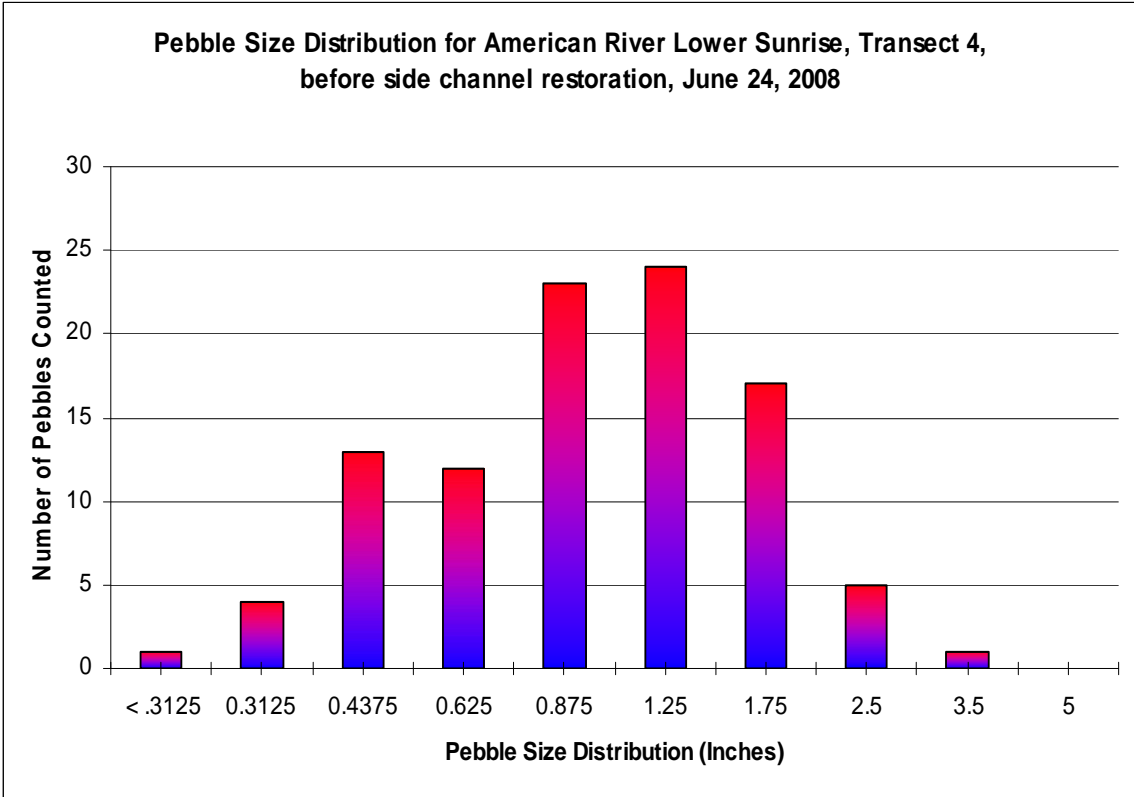


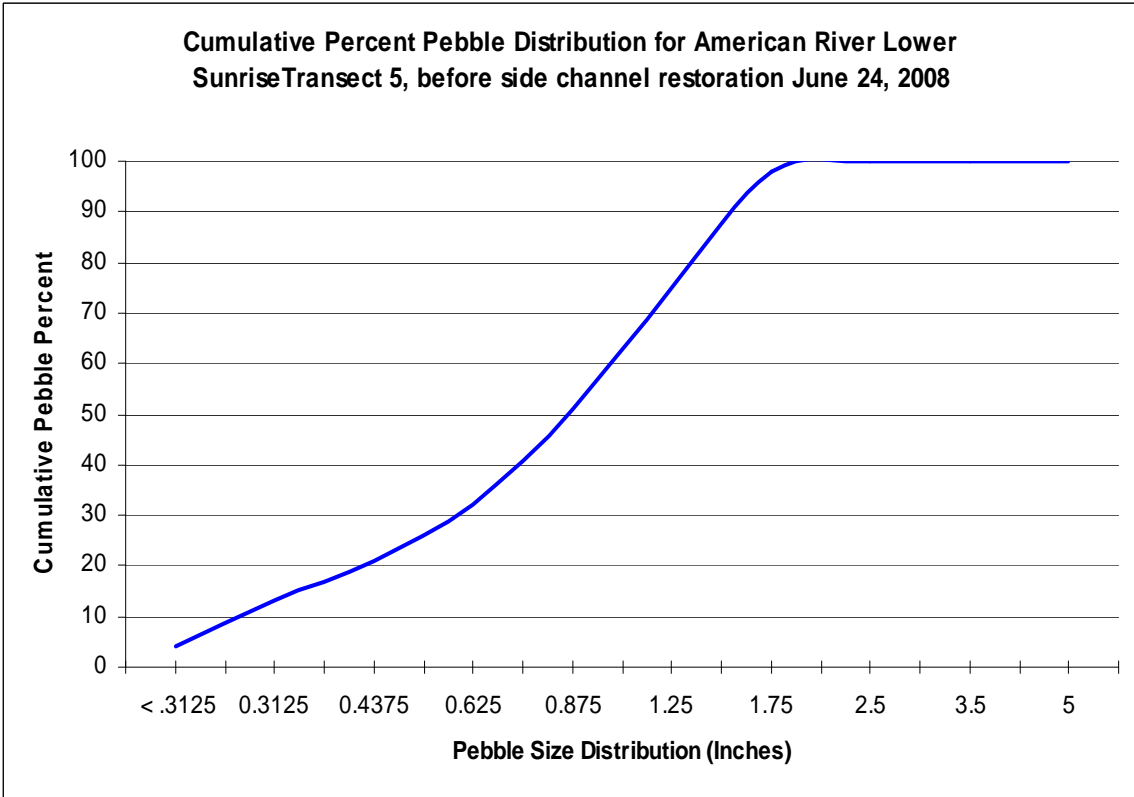
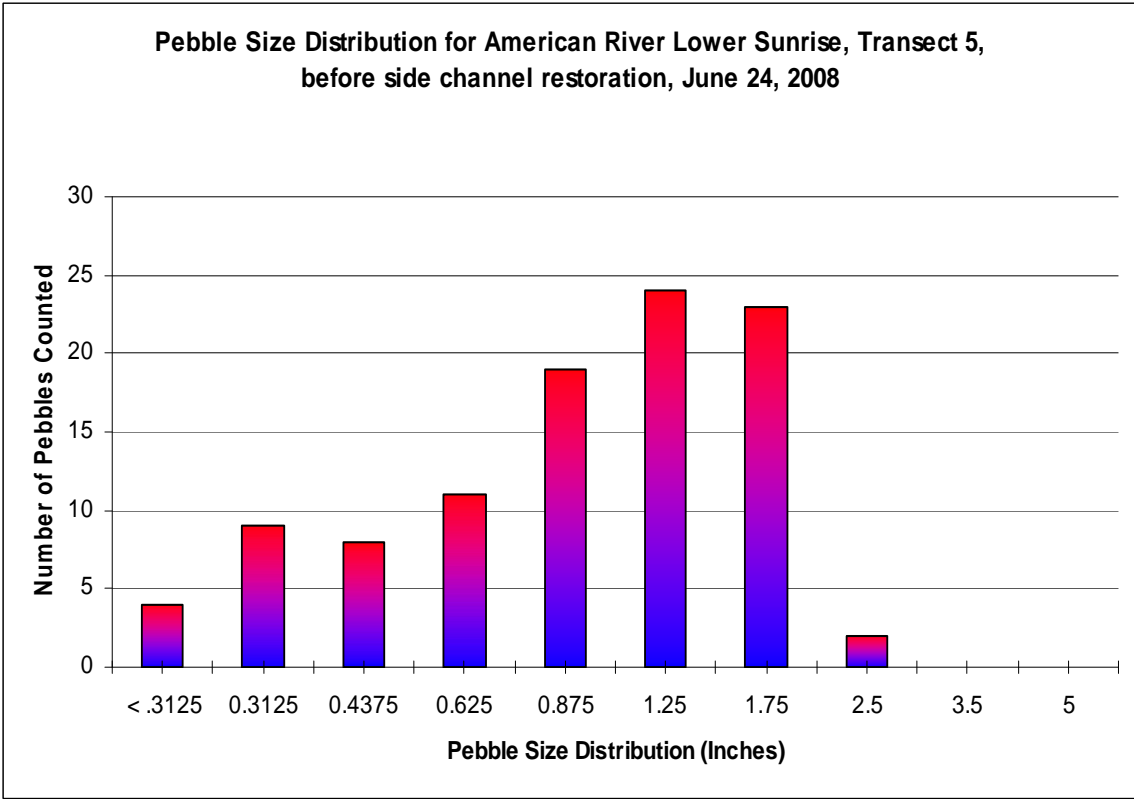
Appendix B: Sunrise Pebble Count: Conducted before side channel construction

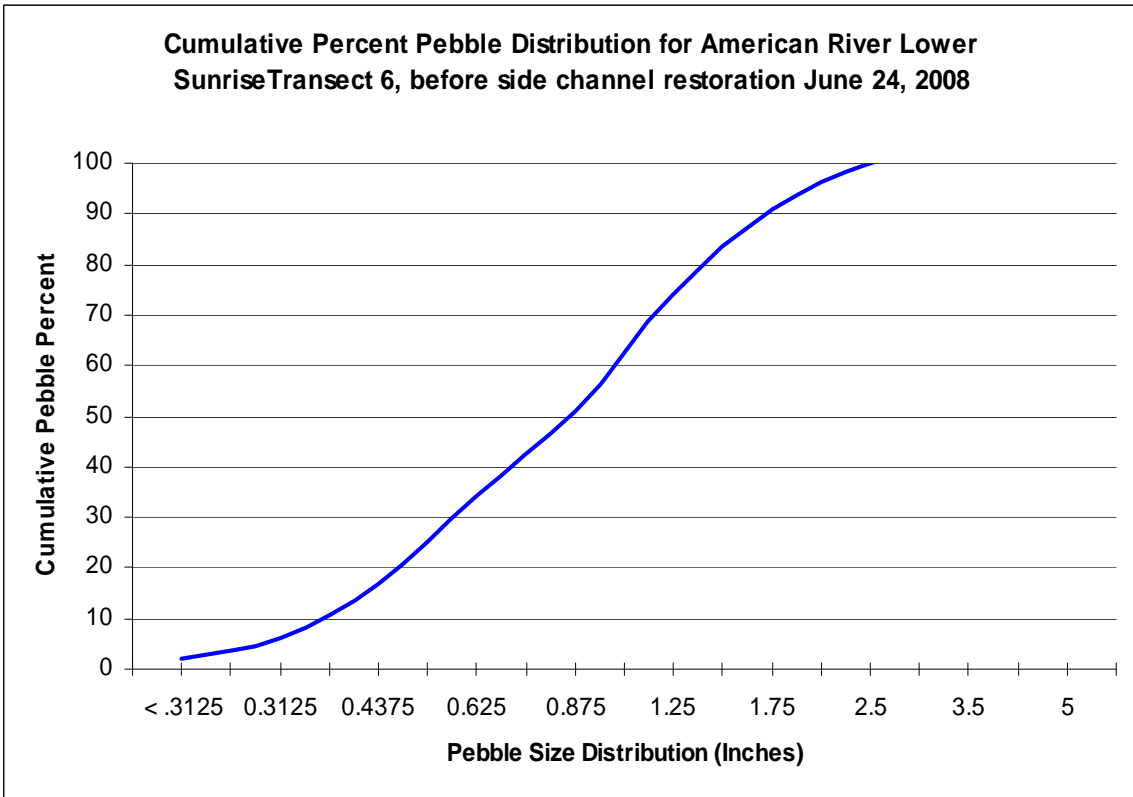
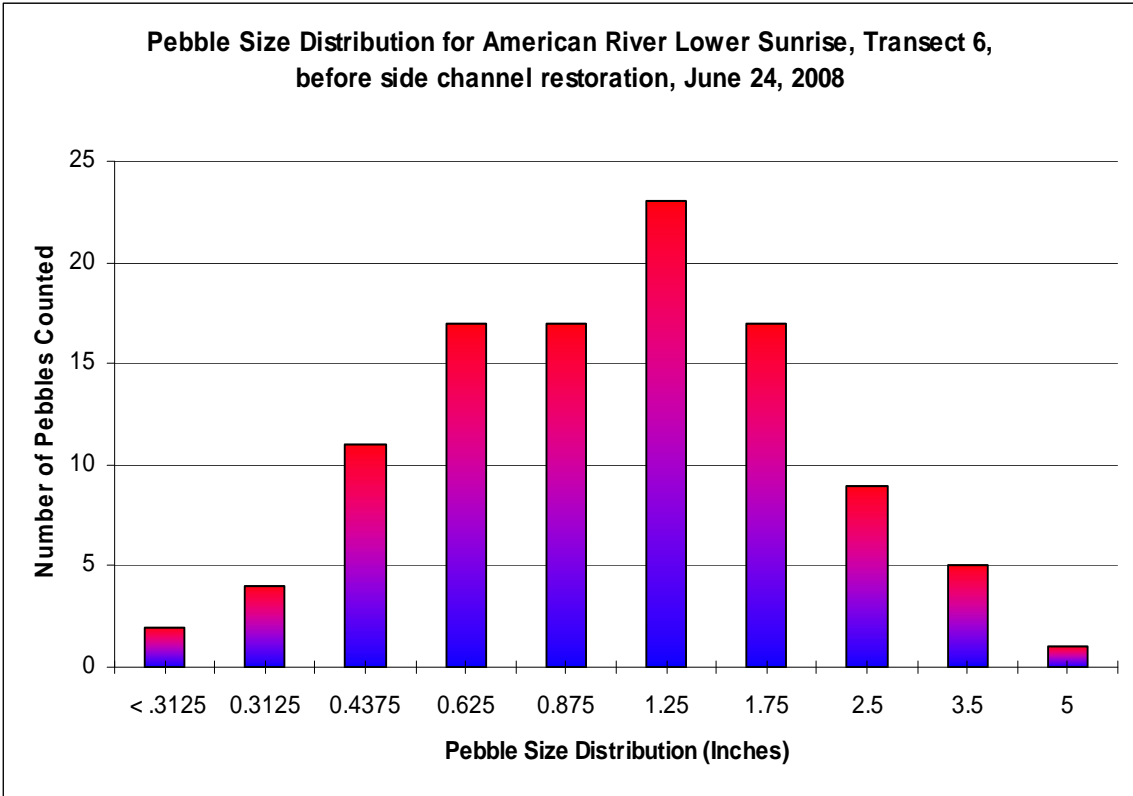


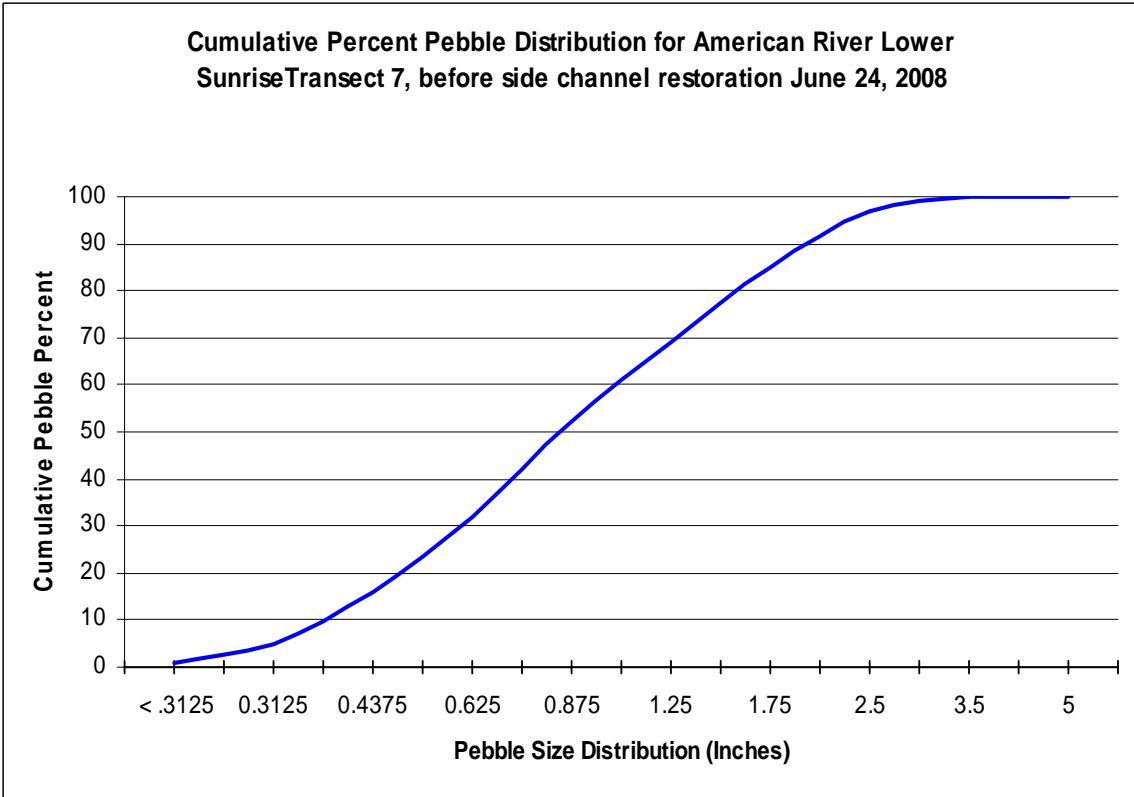
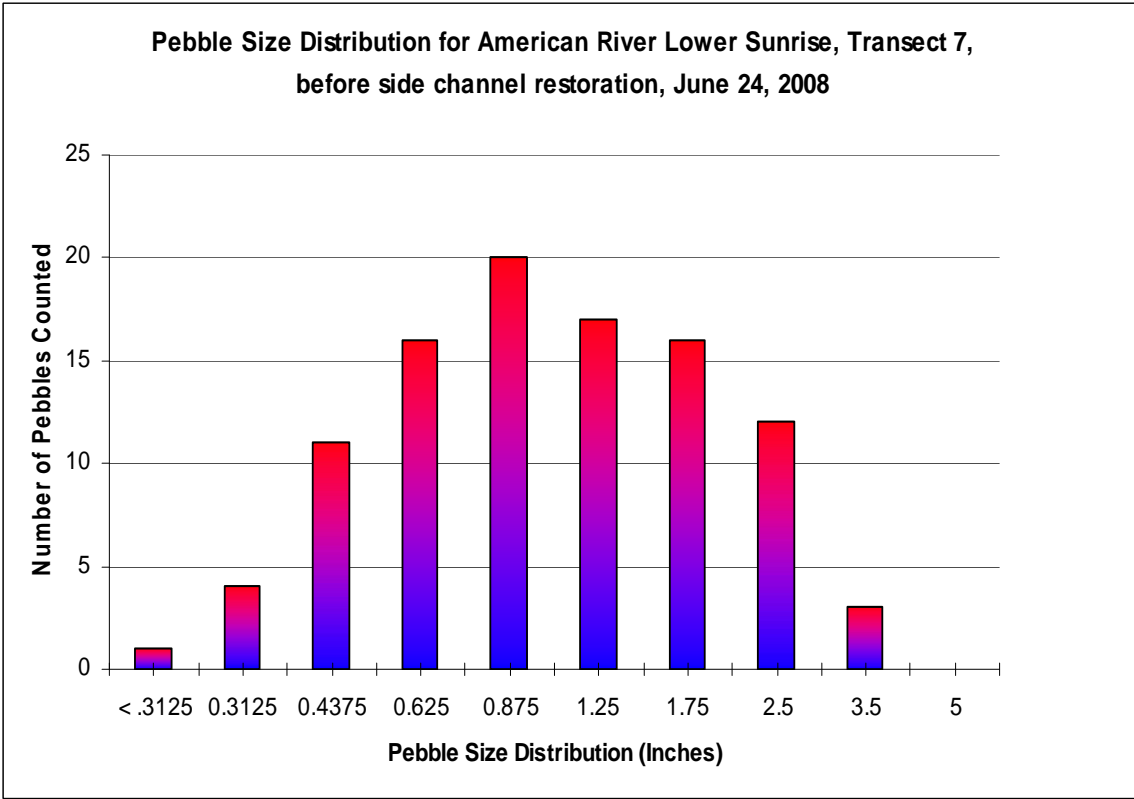


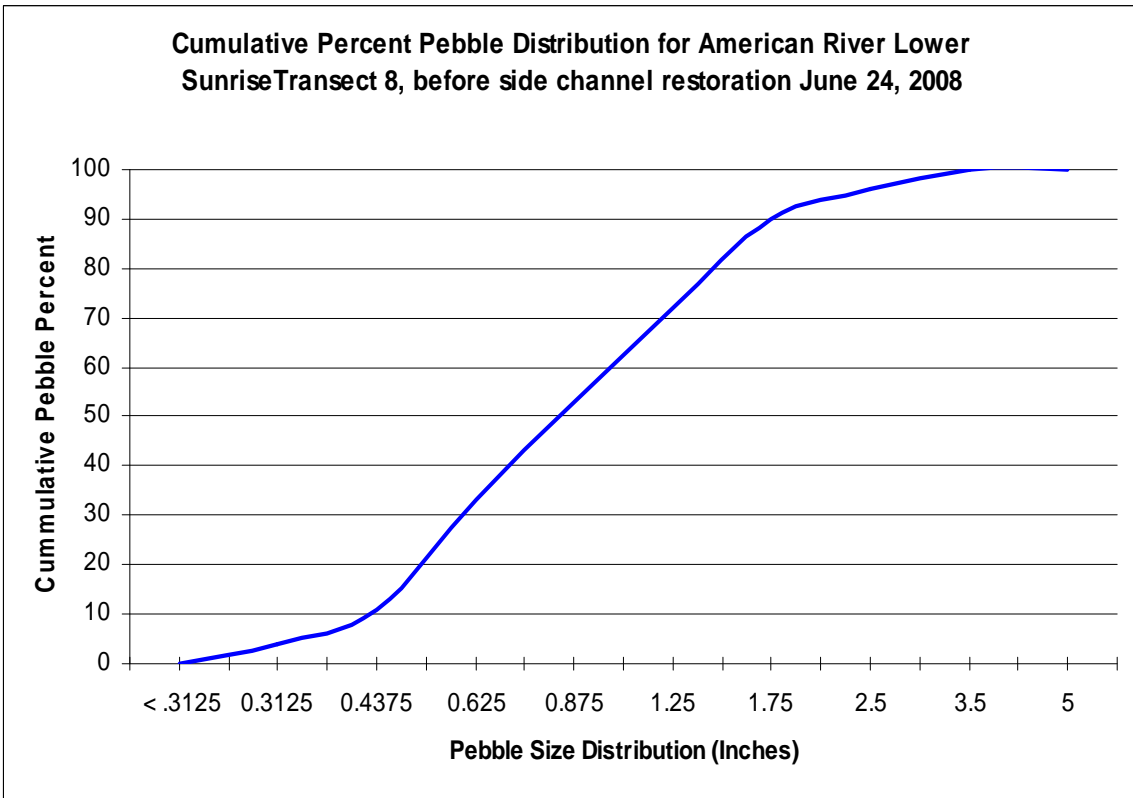
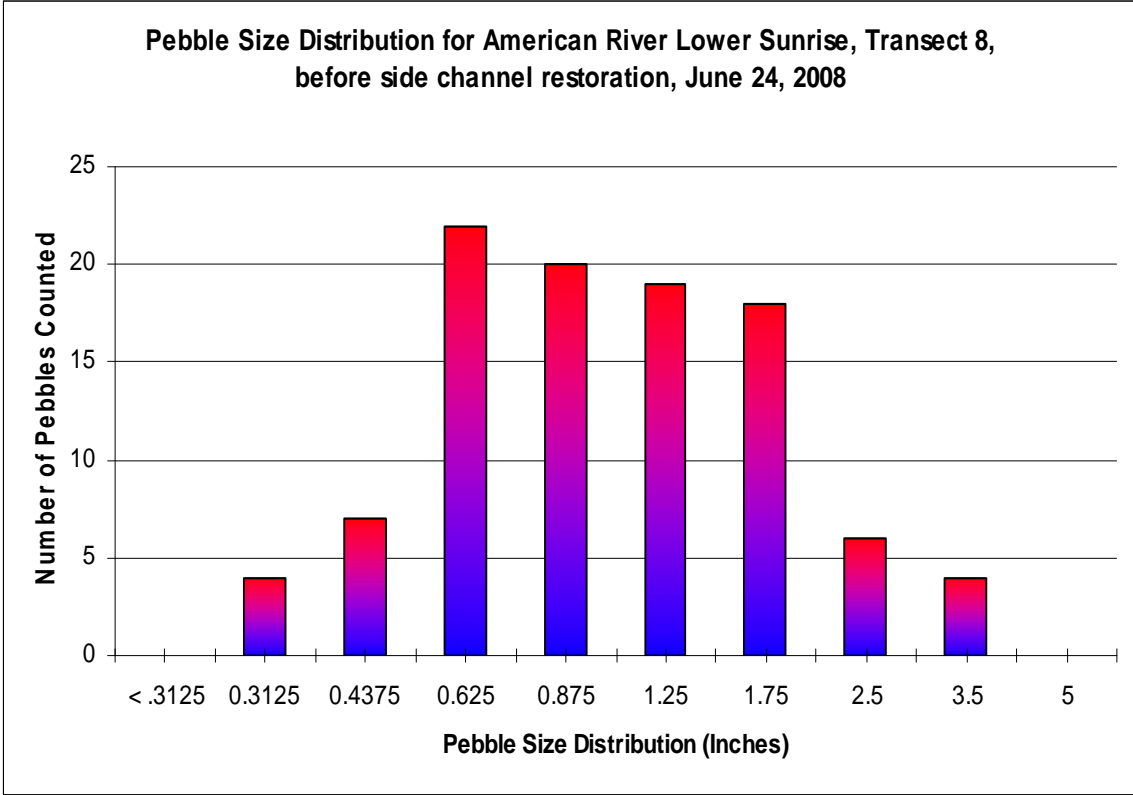


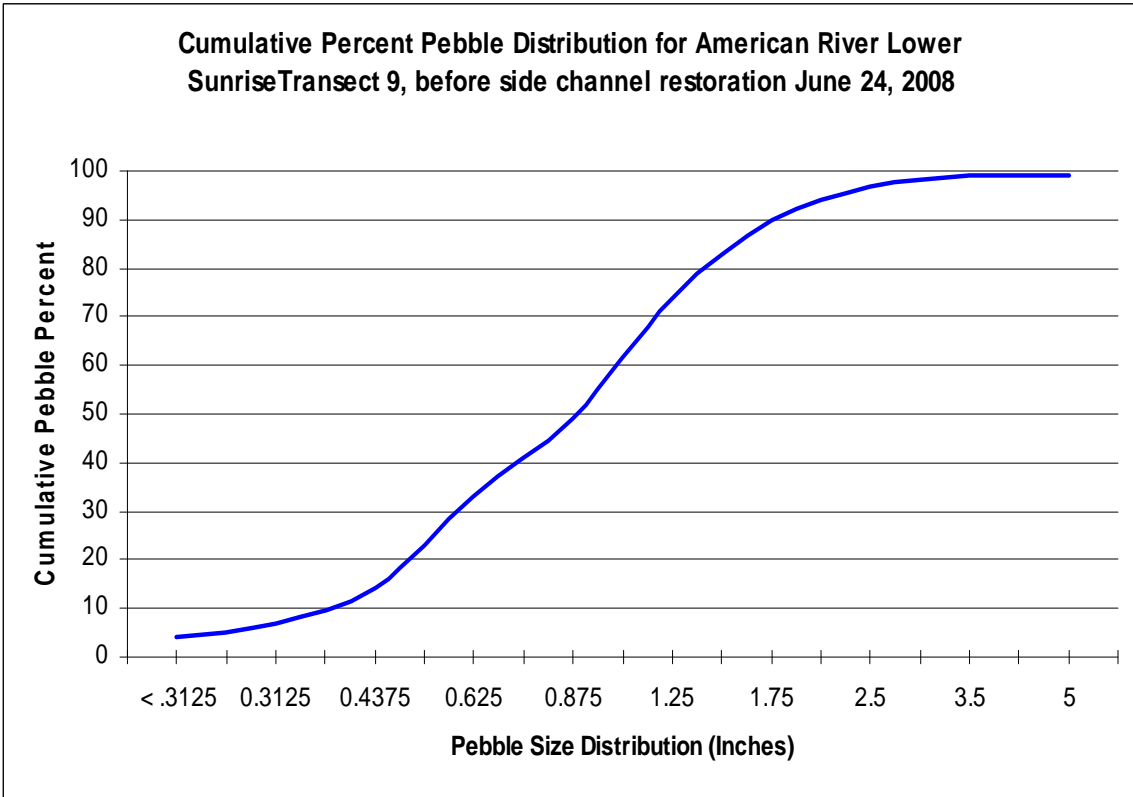
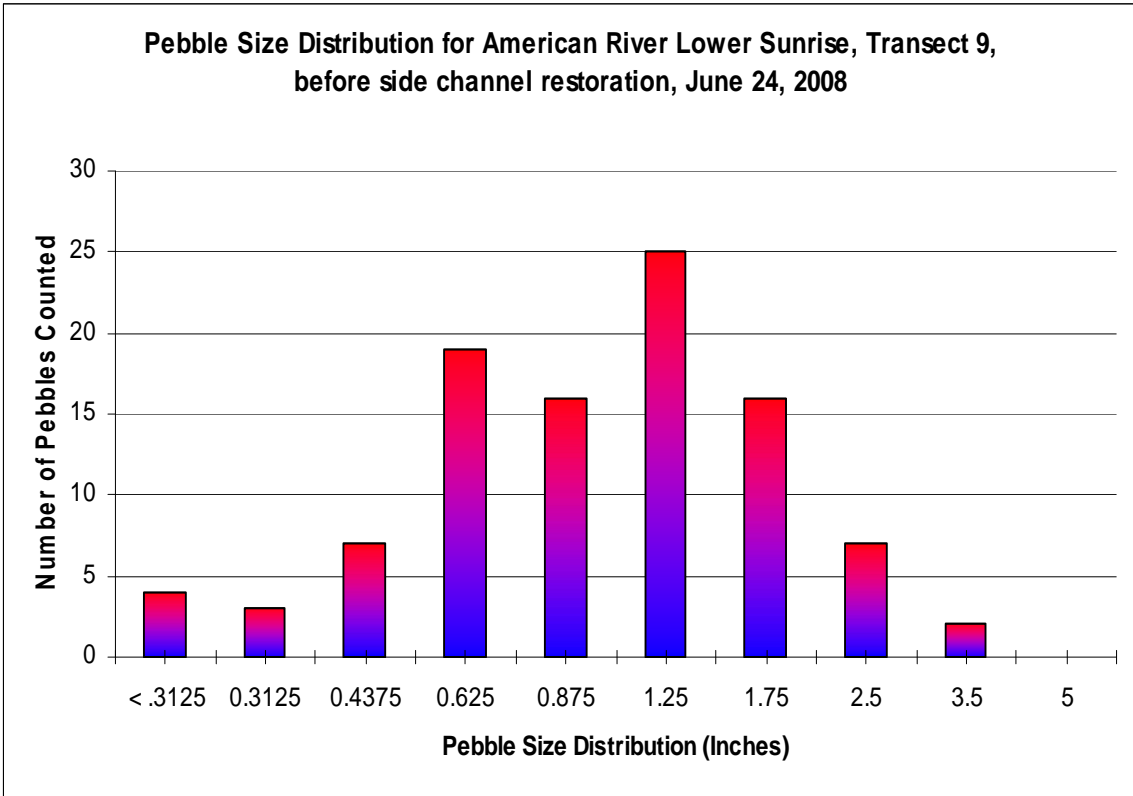


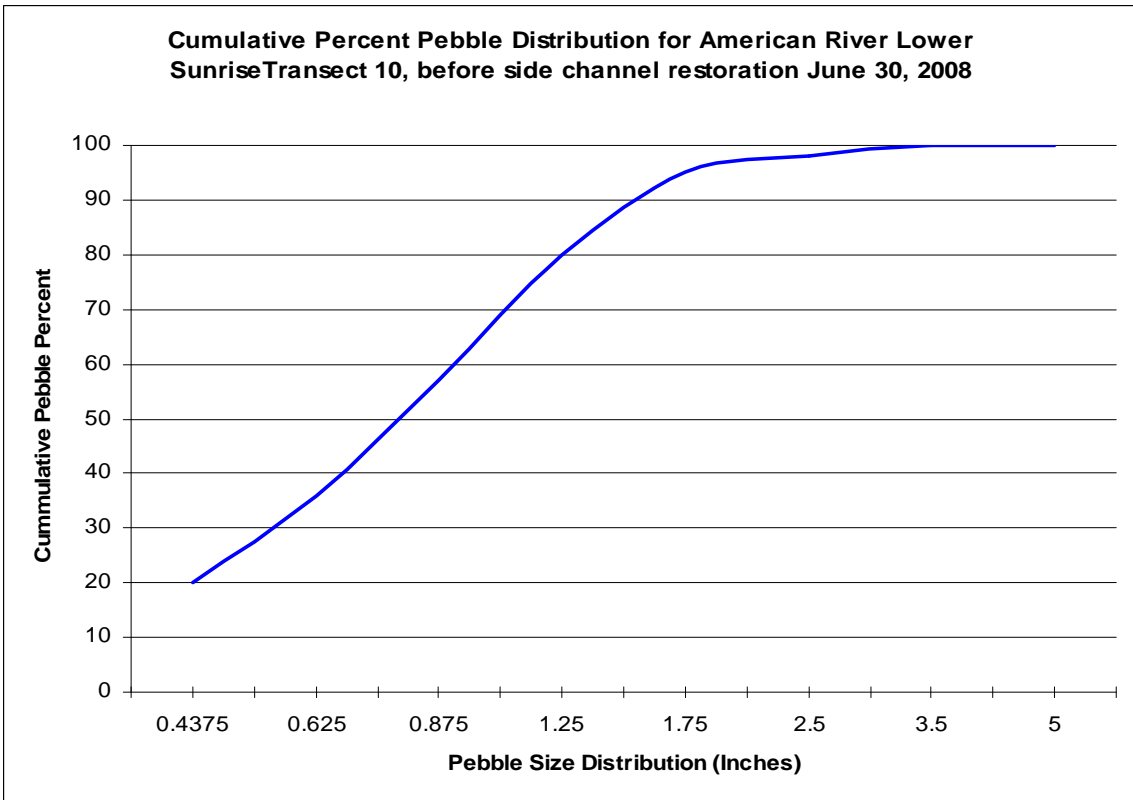
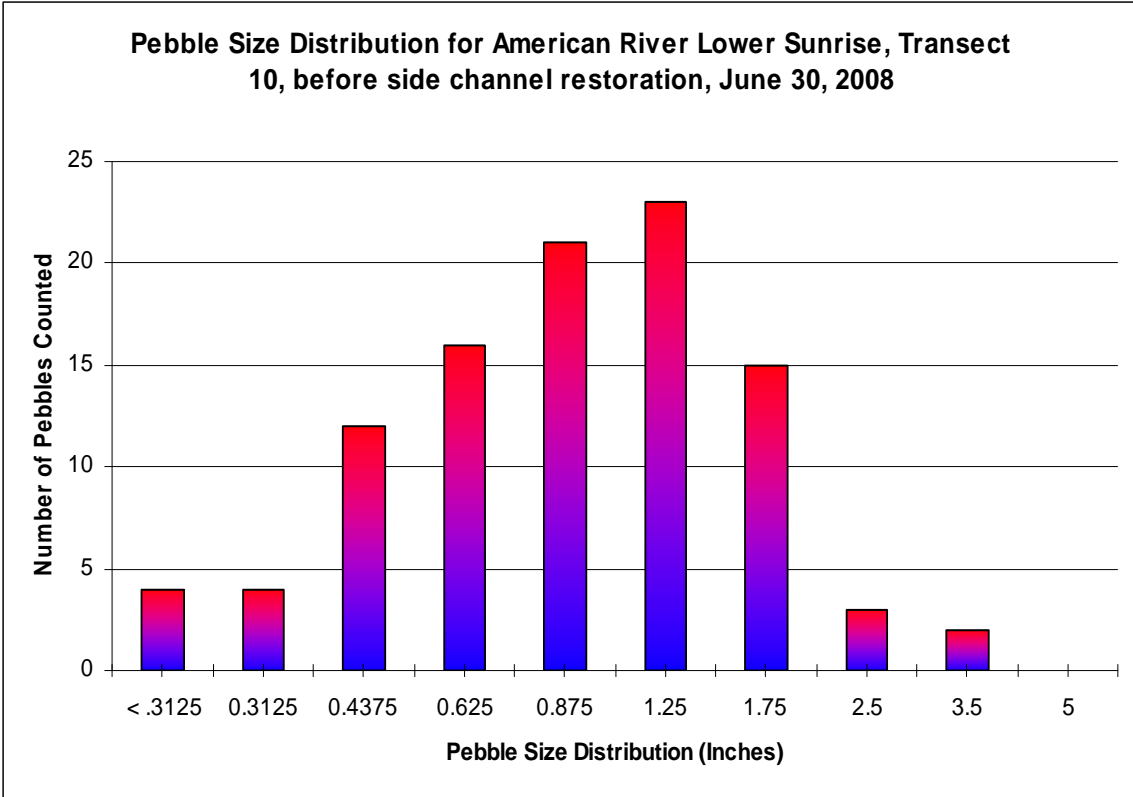


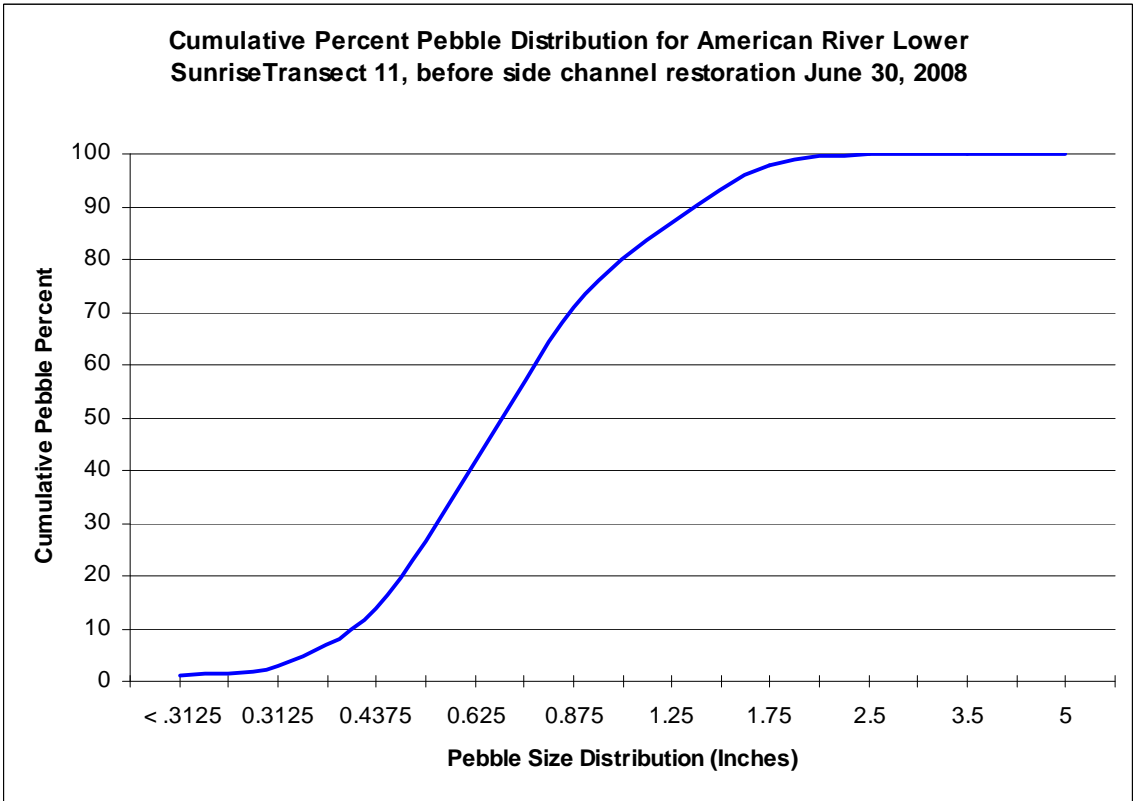
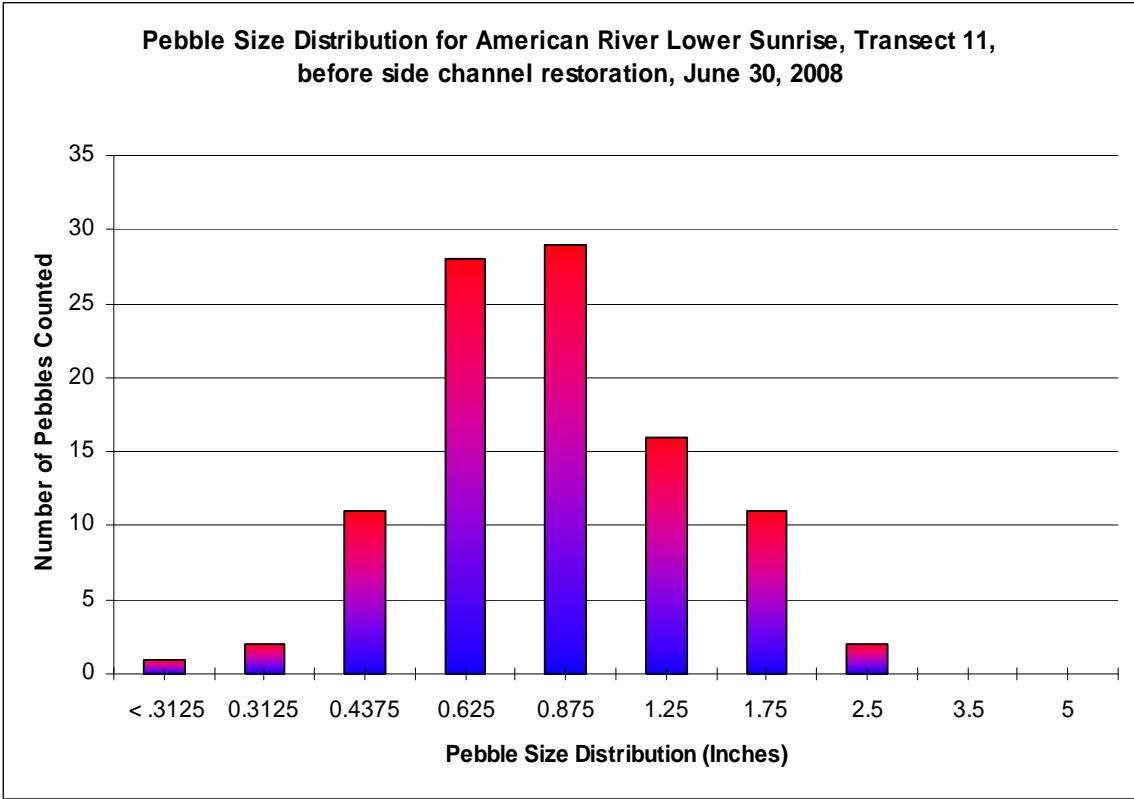


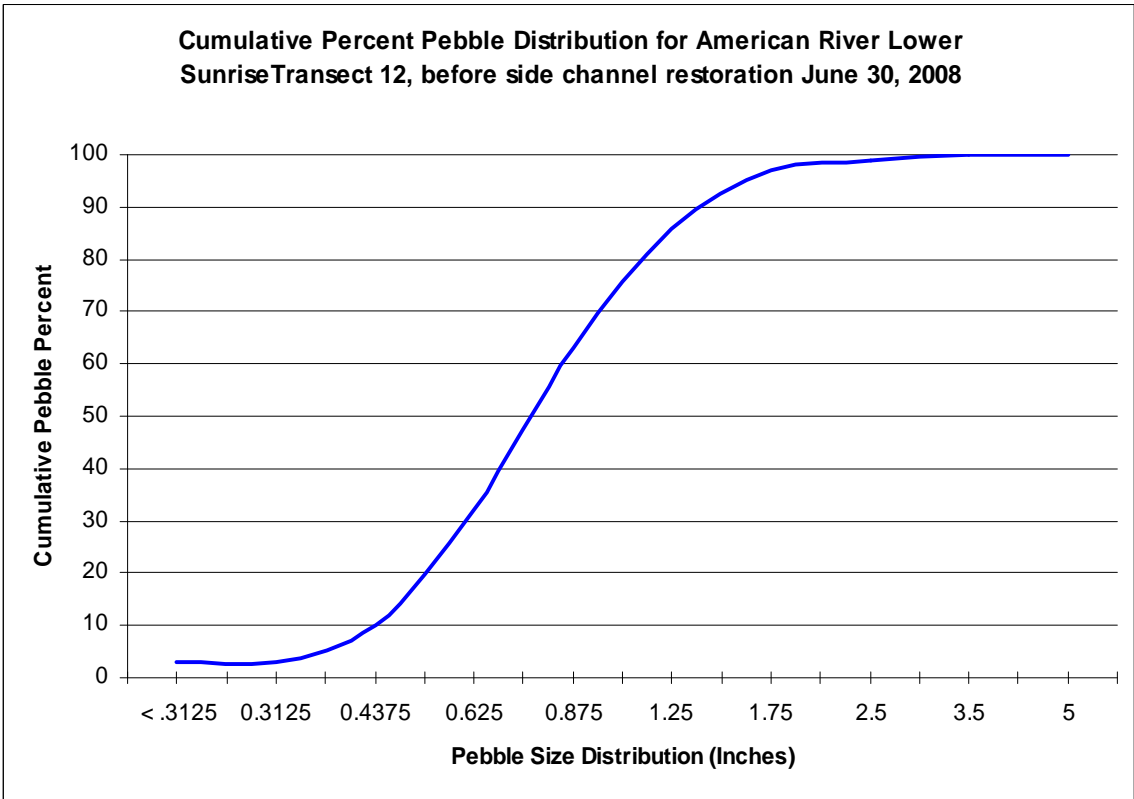
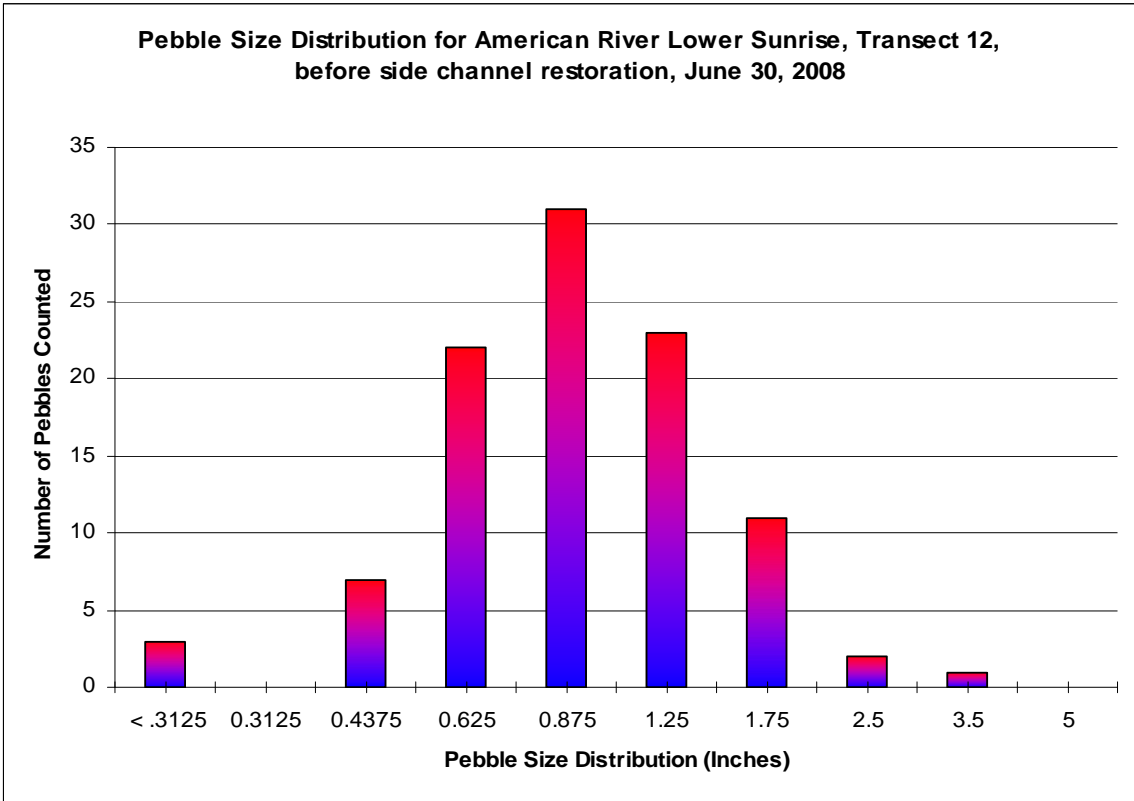


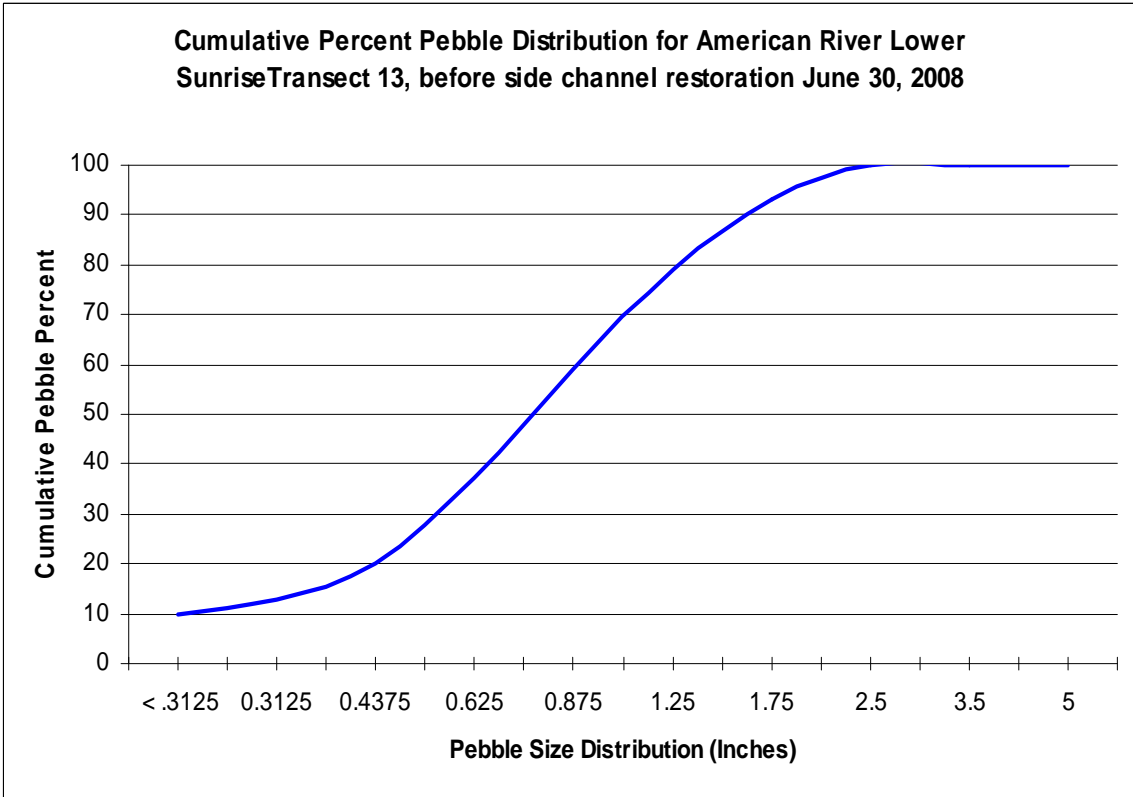
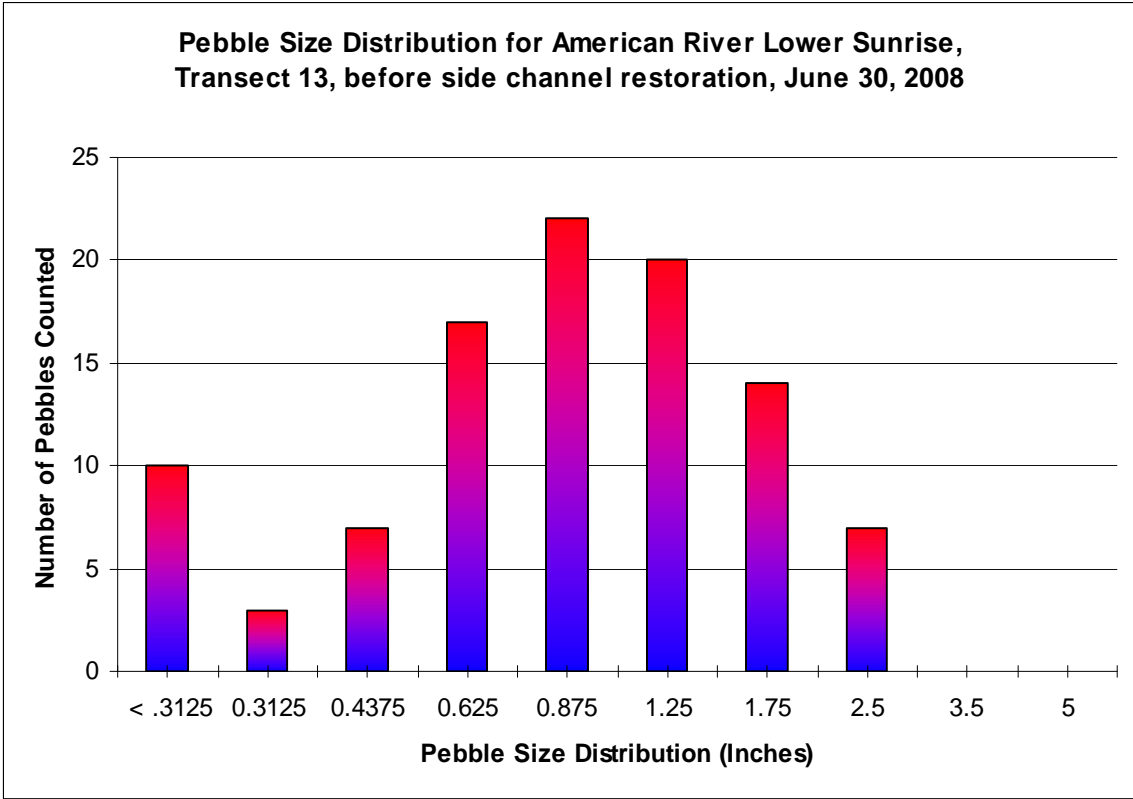


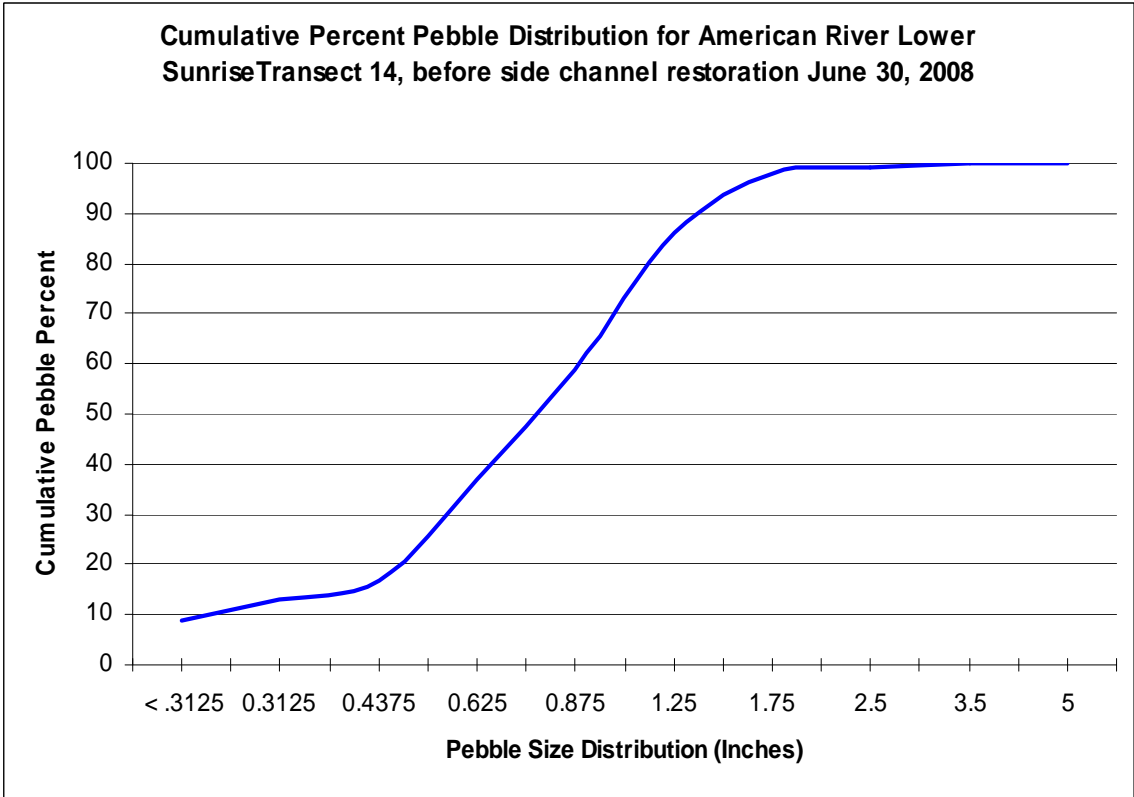
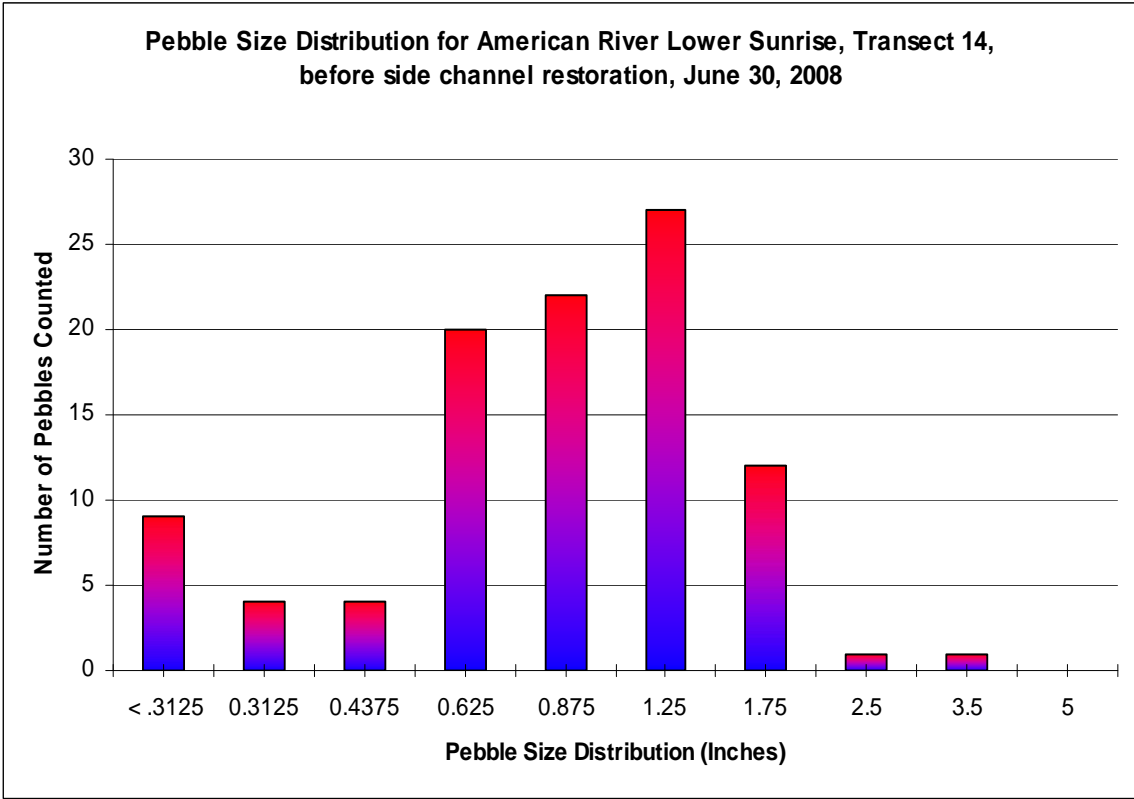


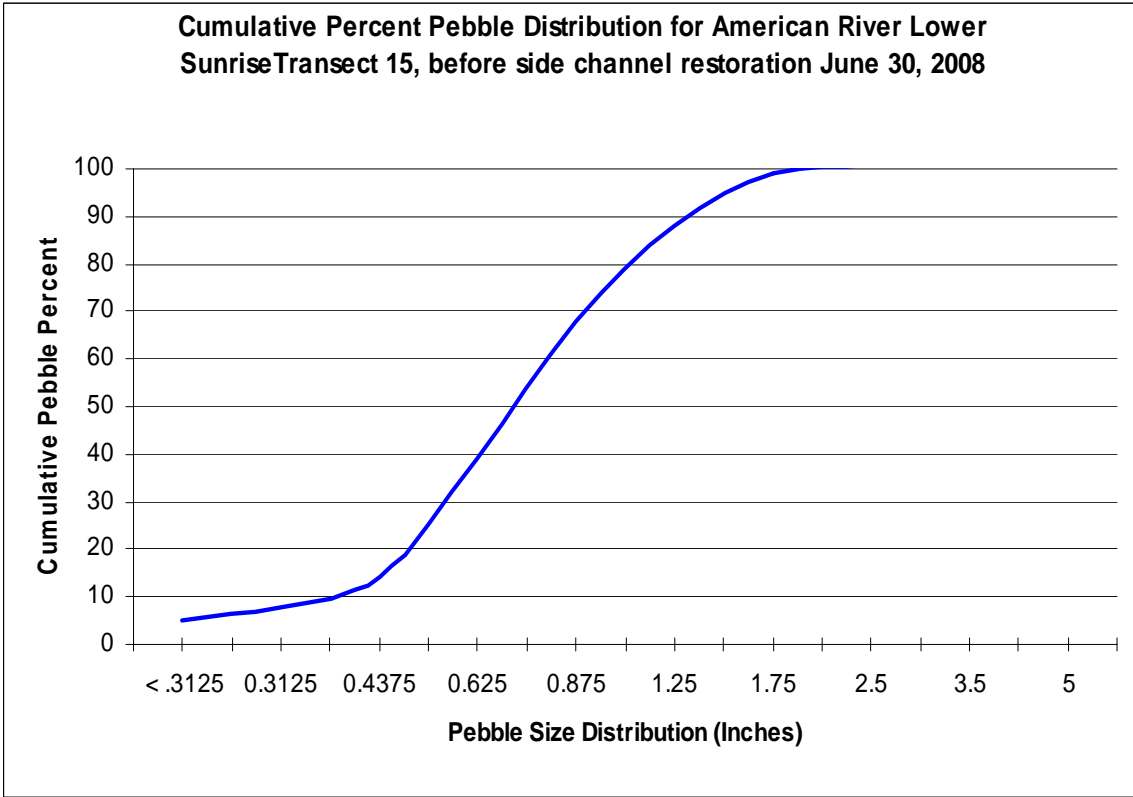
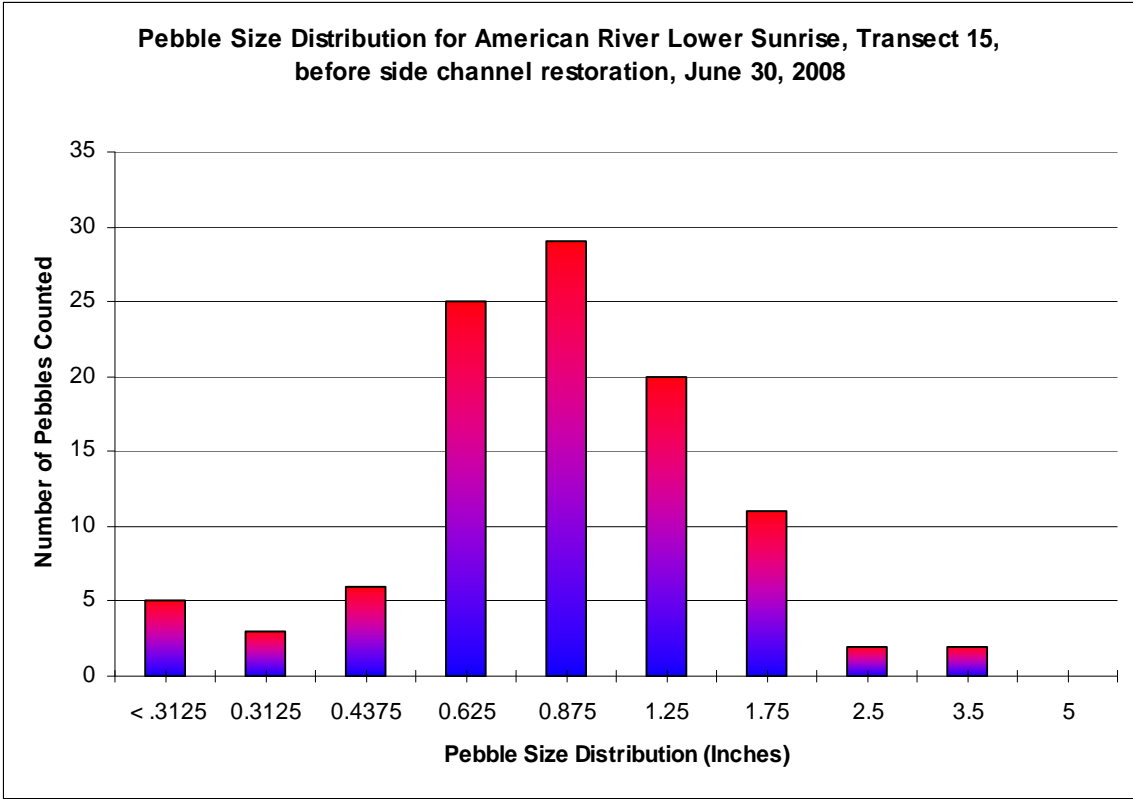


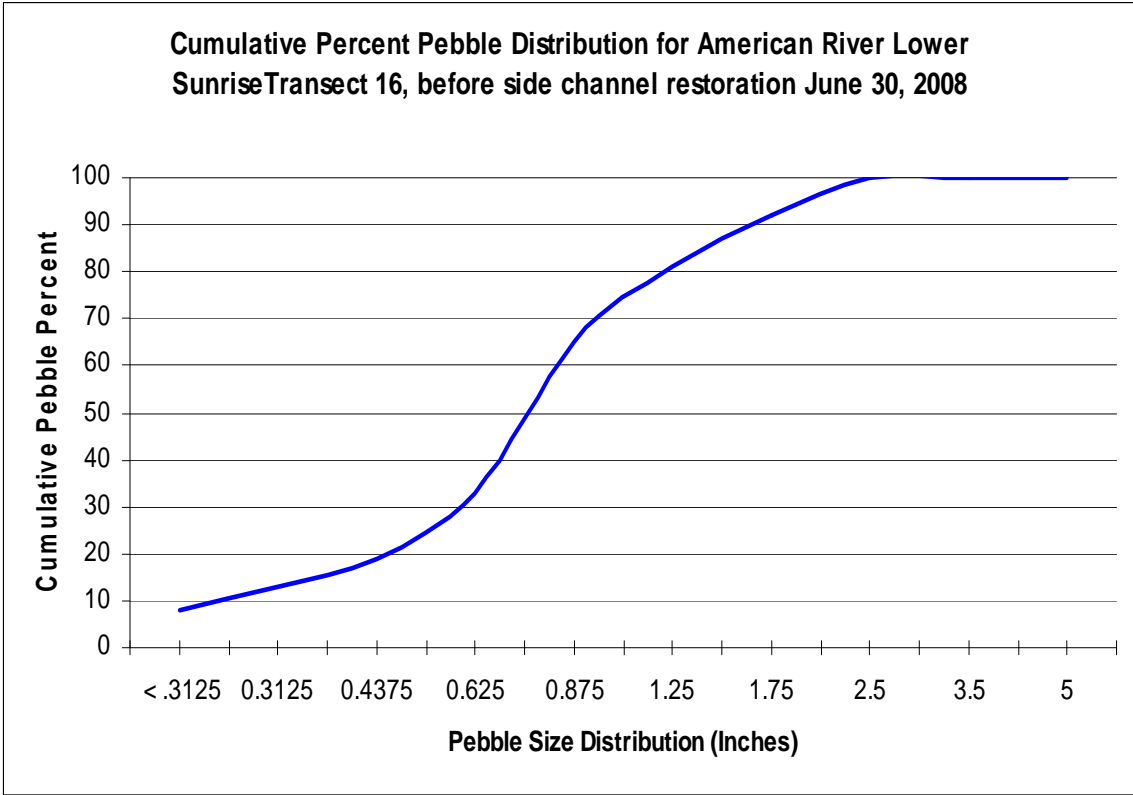
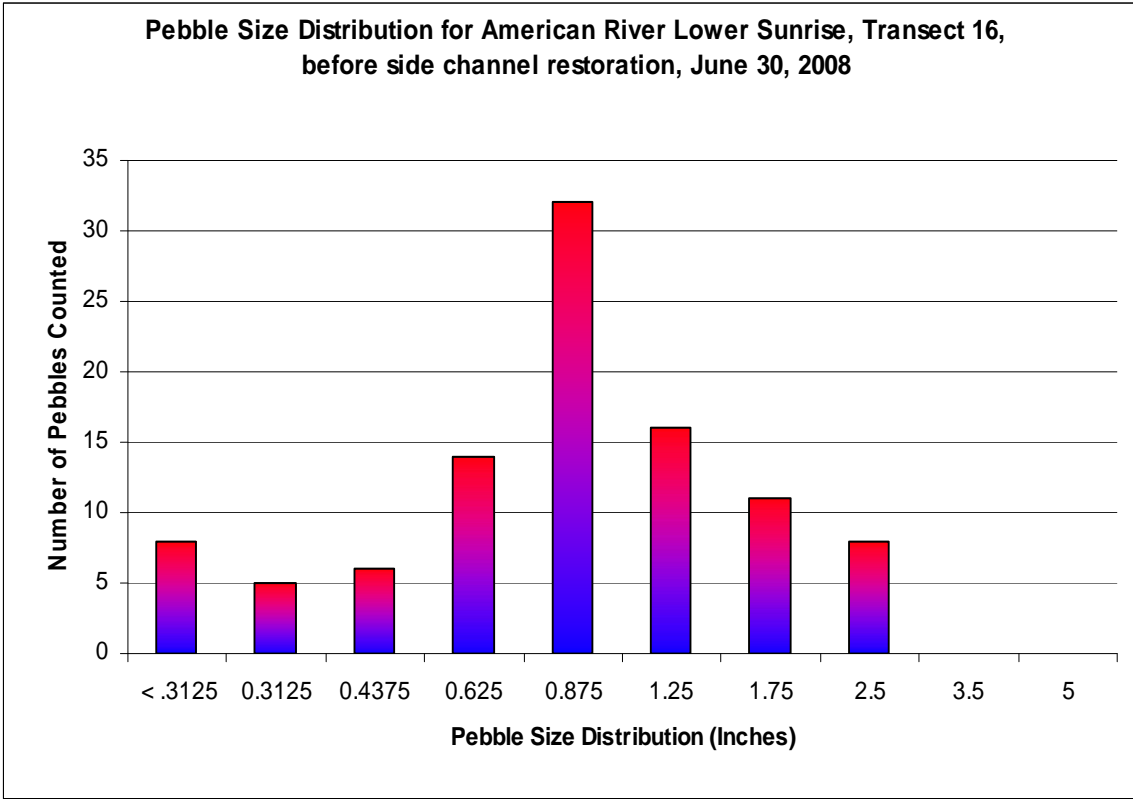


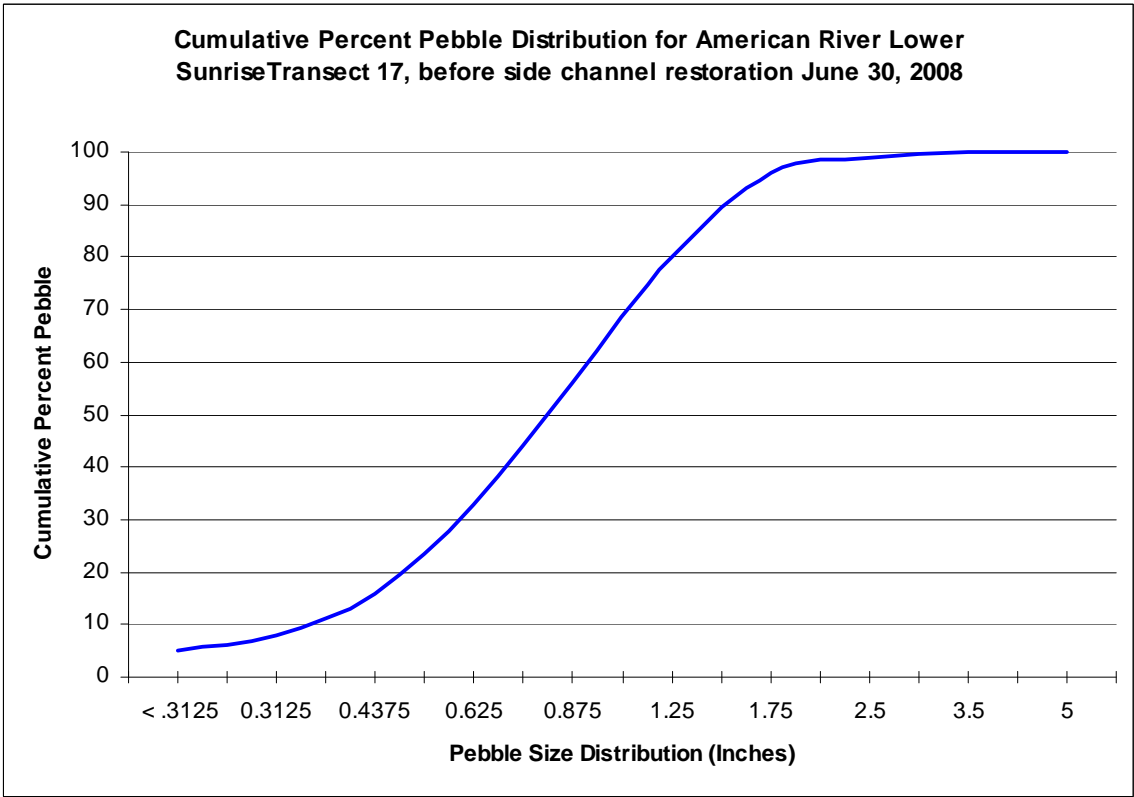
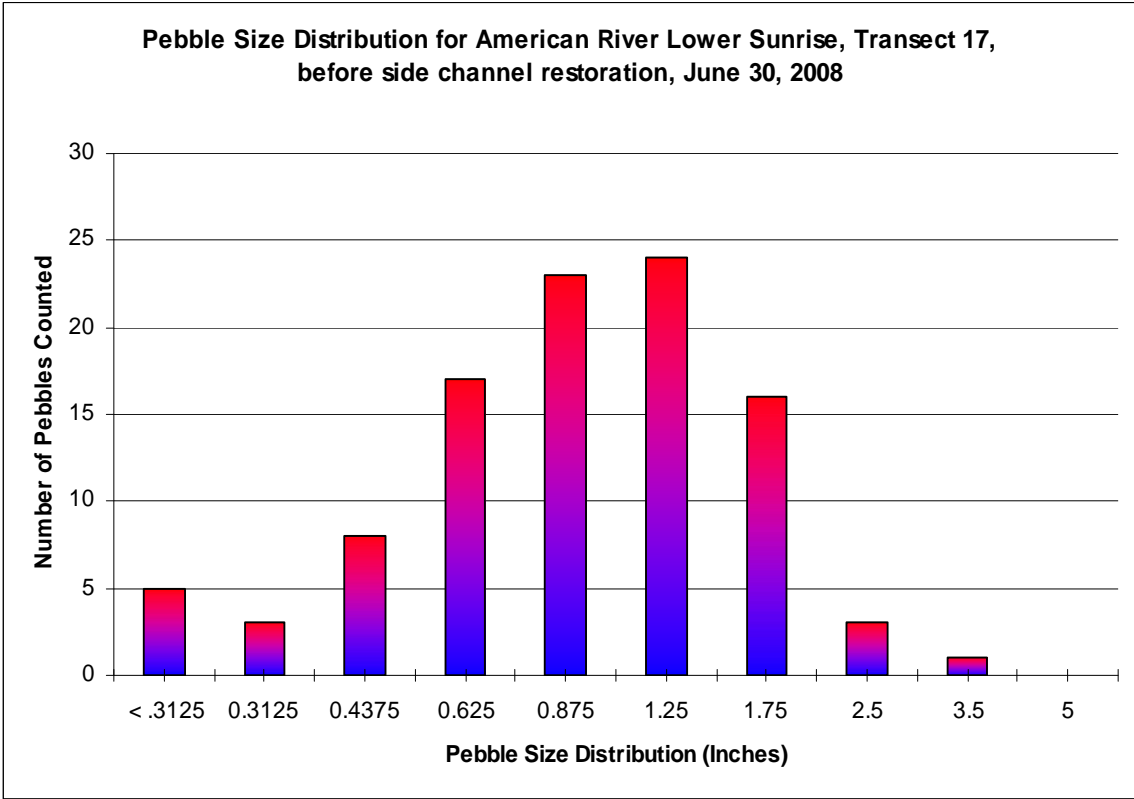


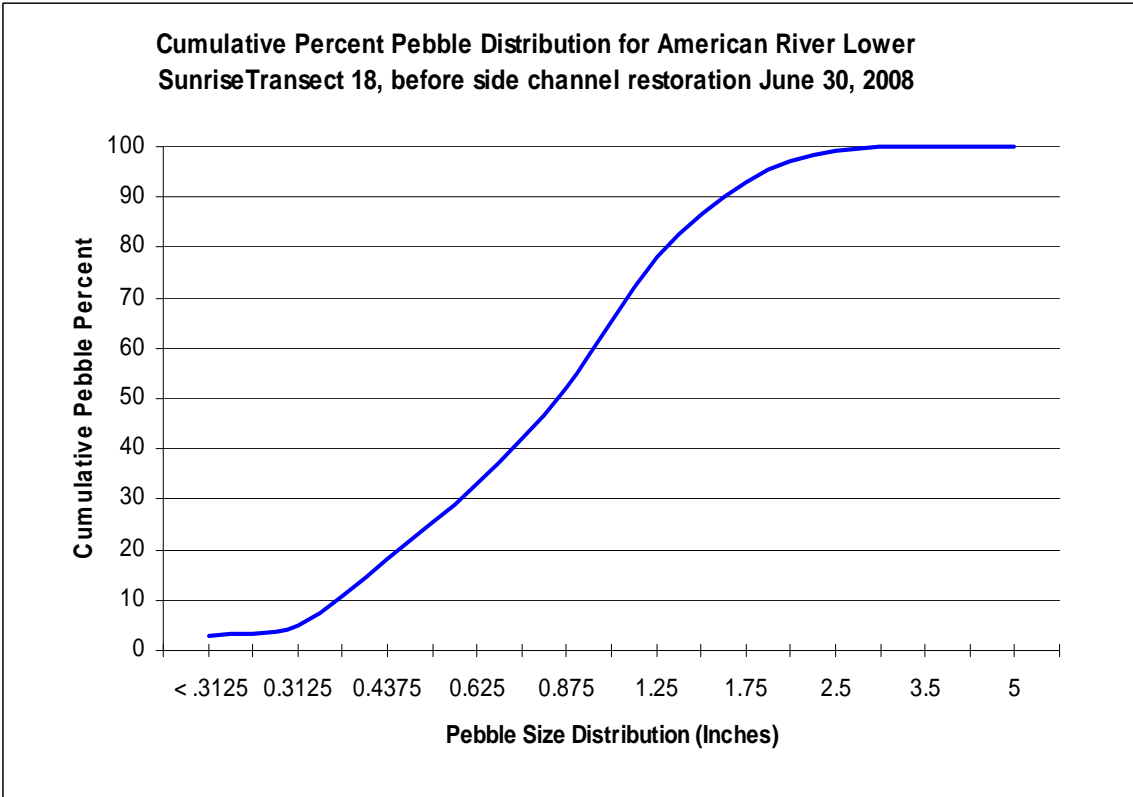
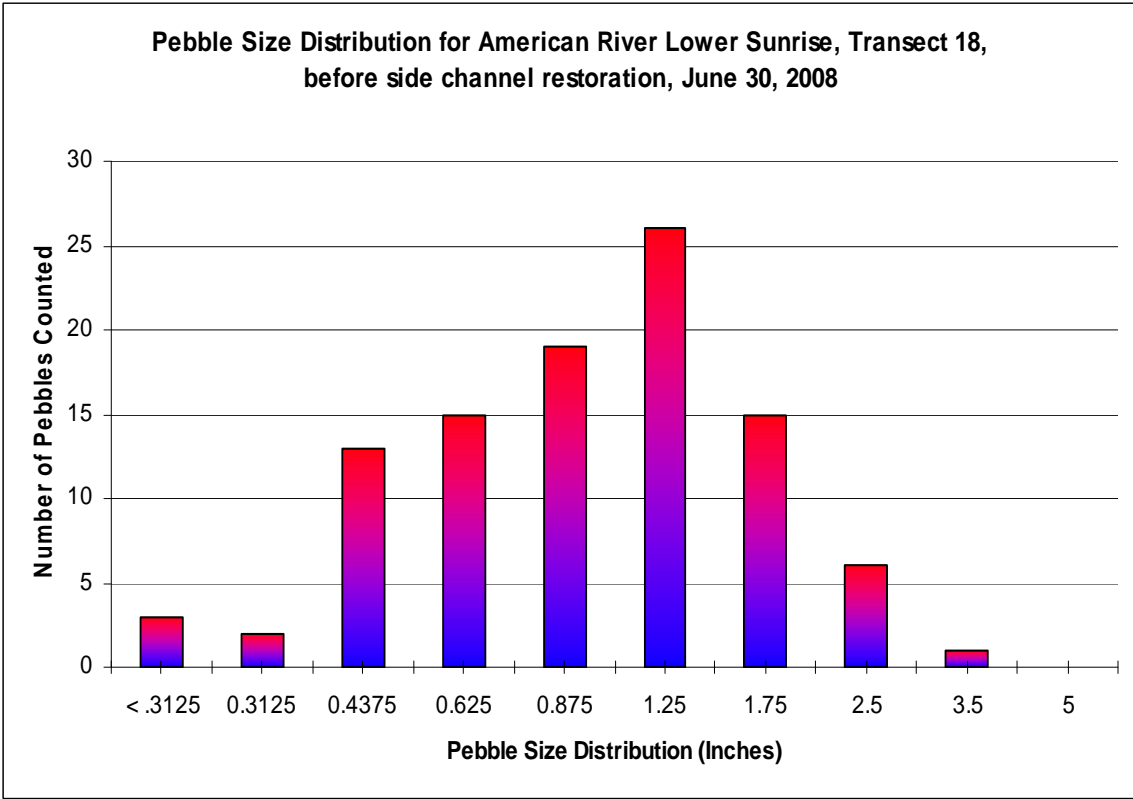


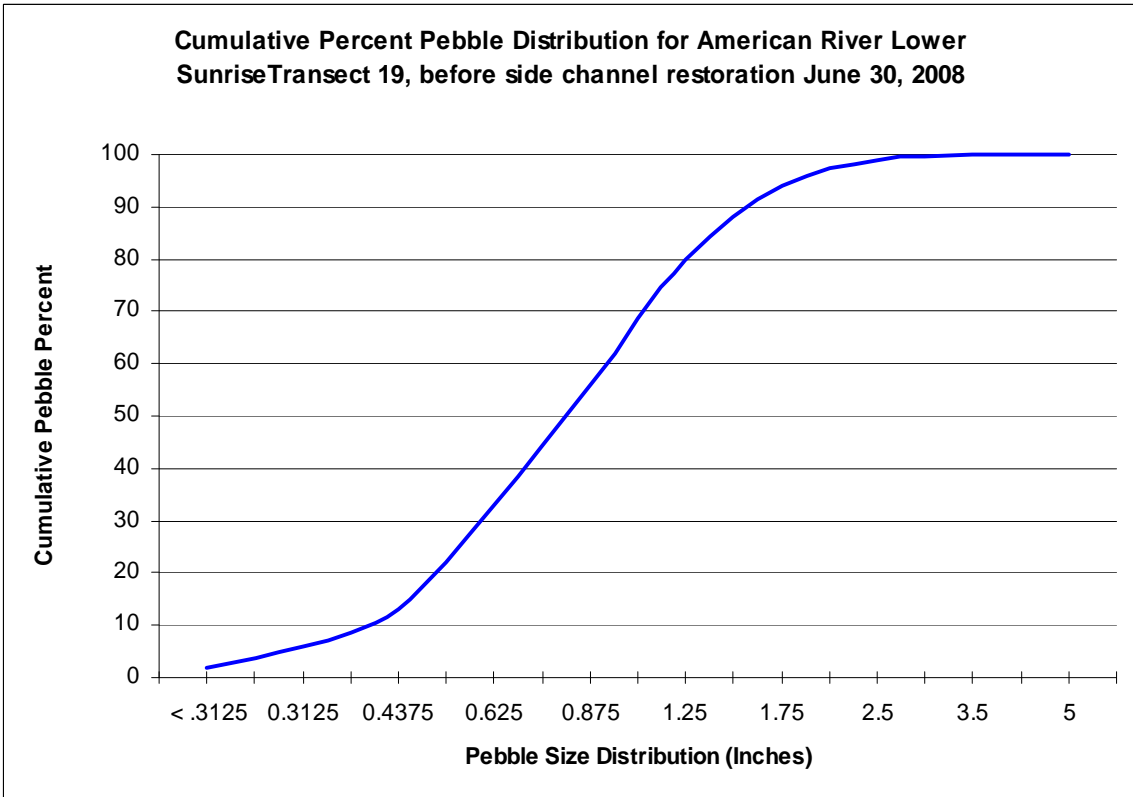
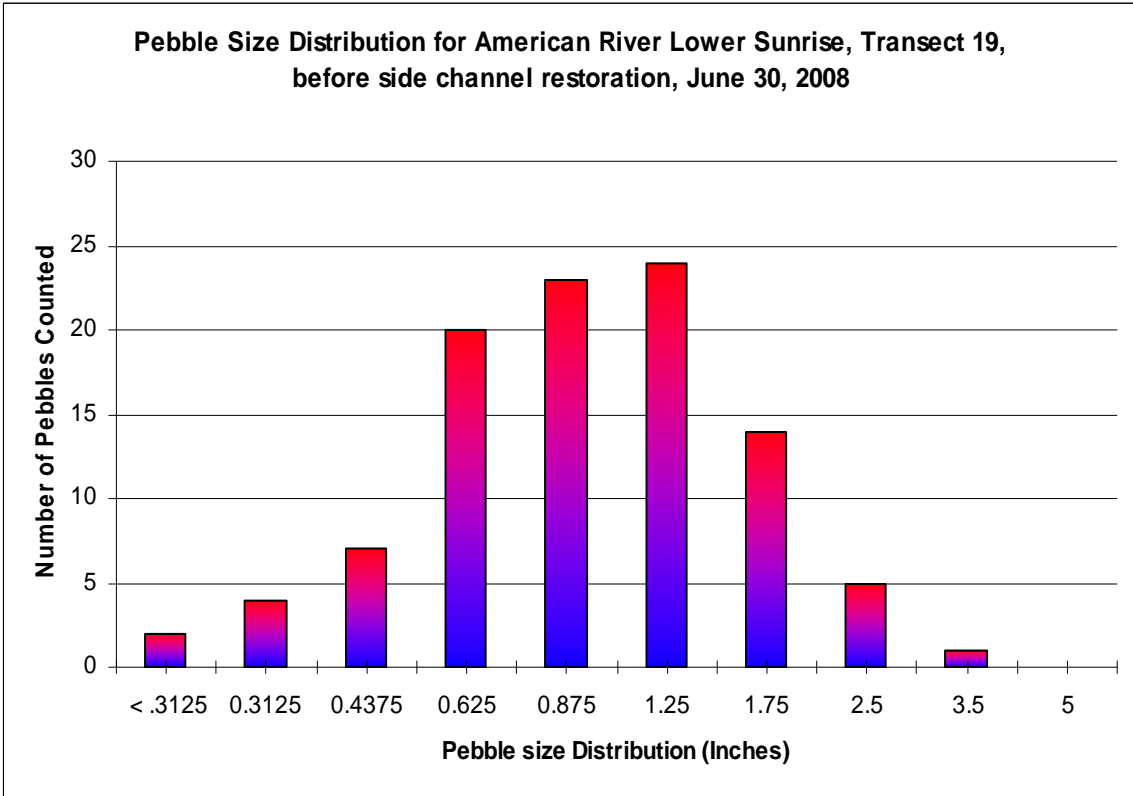


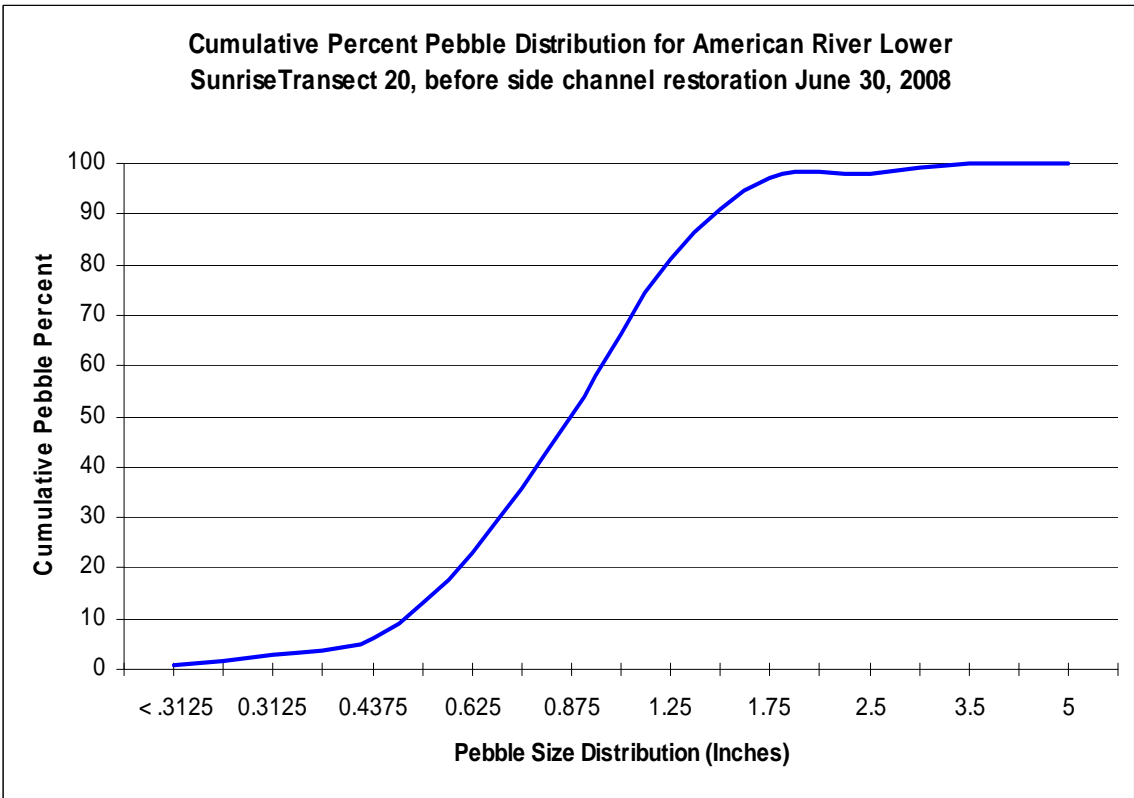
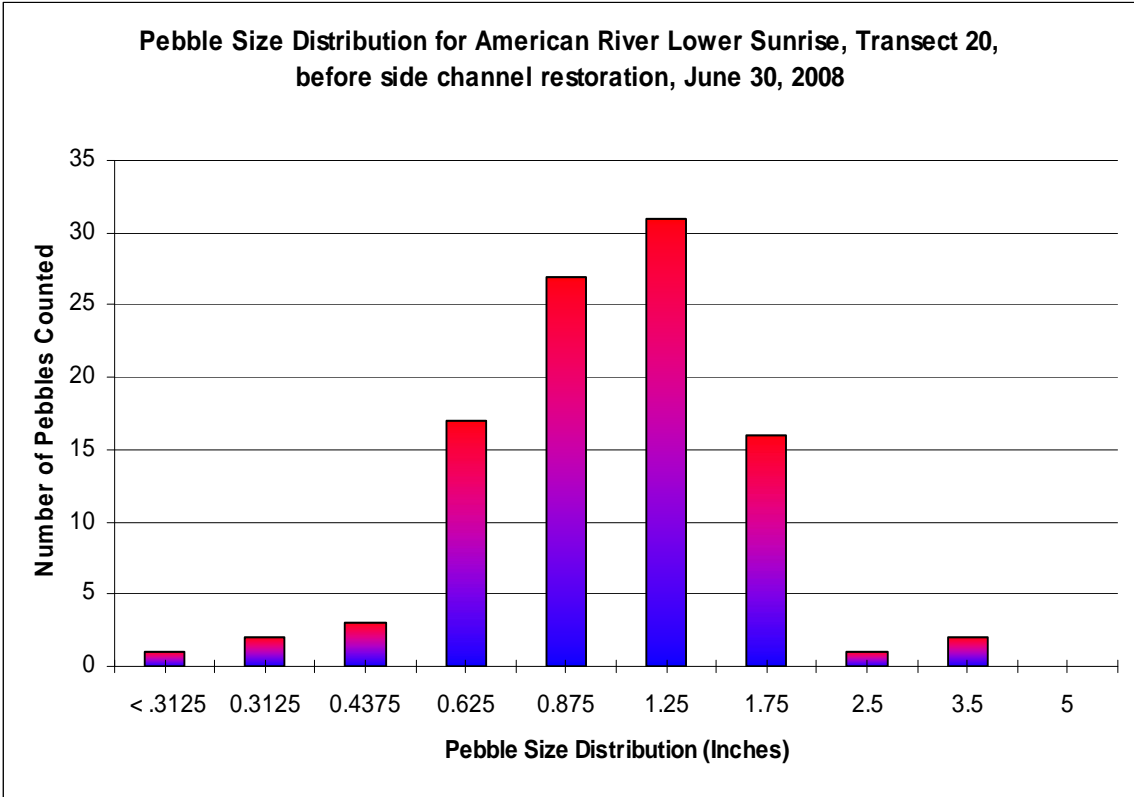




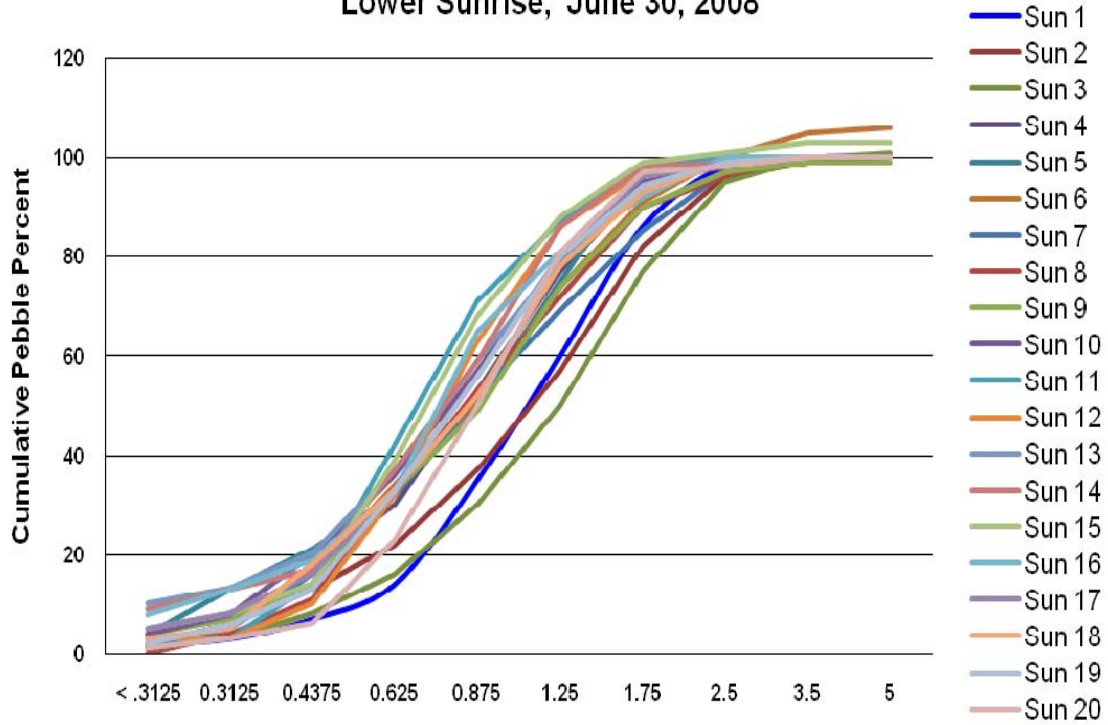








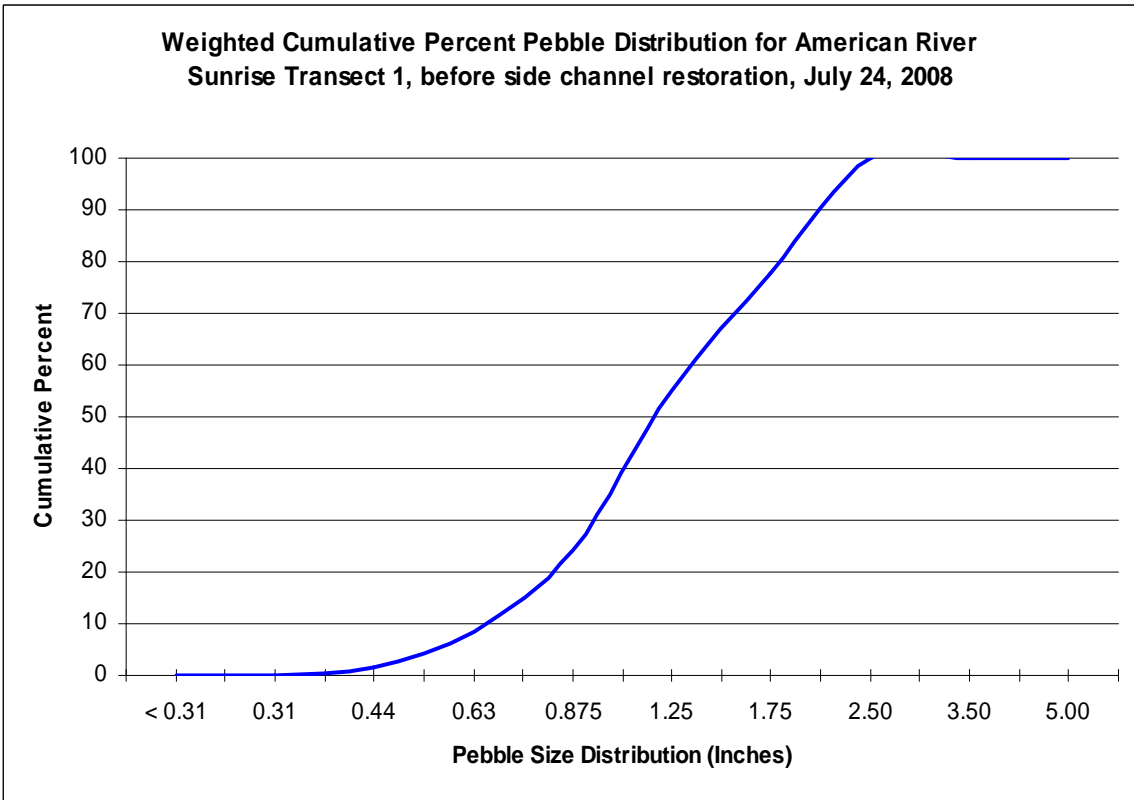
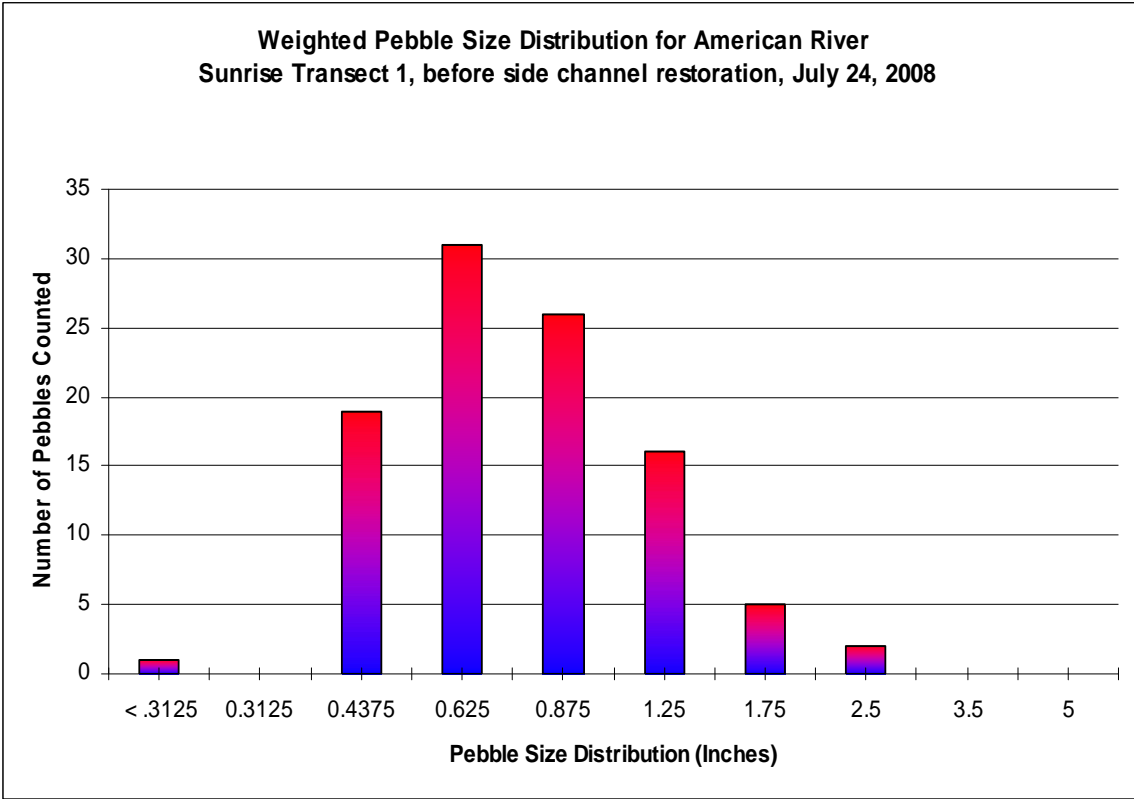
Total Cumulative Percent Pebble Distribution for American River
Lower Sunrise, June 30, 2008



Appendix C: Sunrise Weighted Pebble Counts

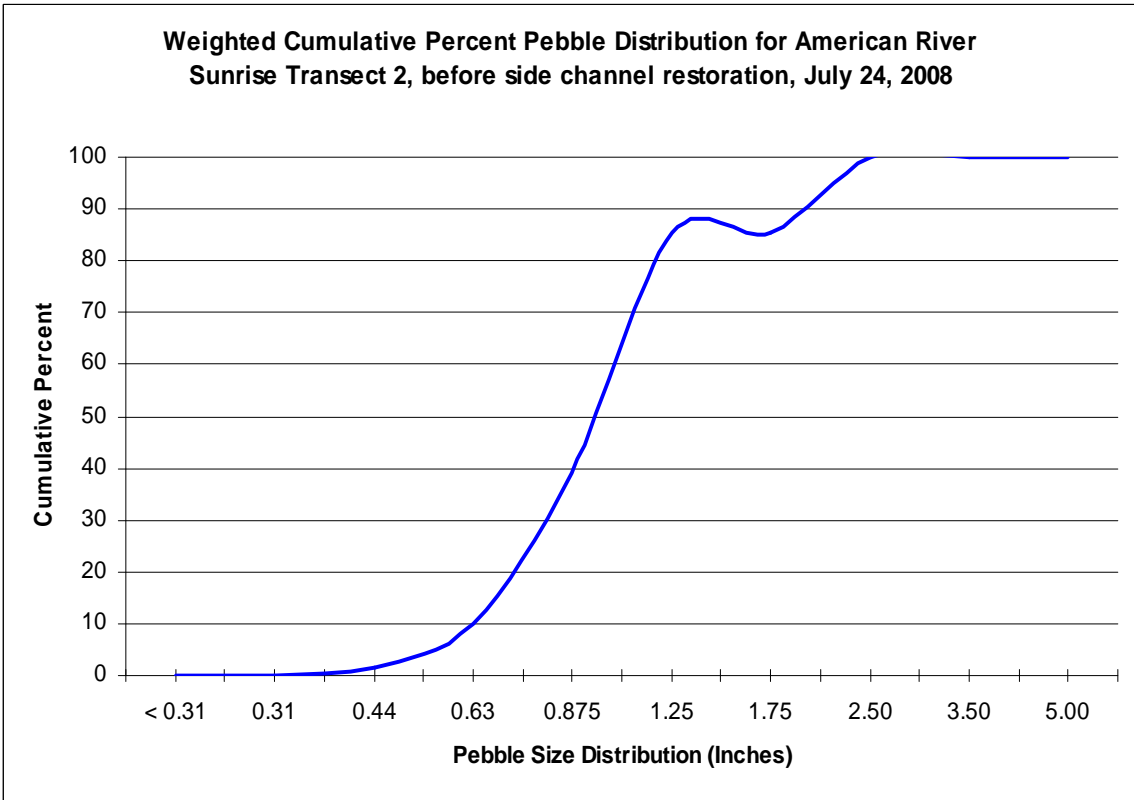
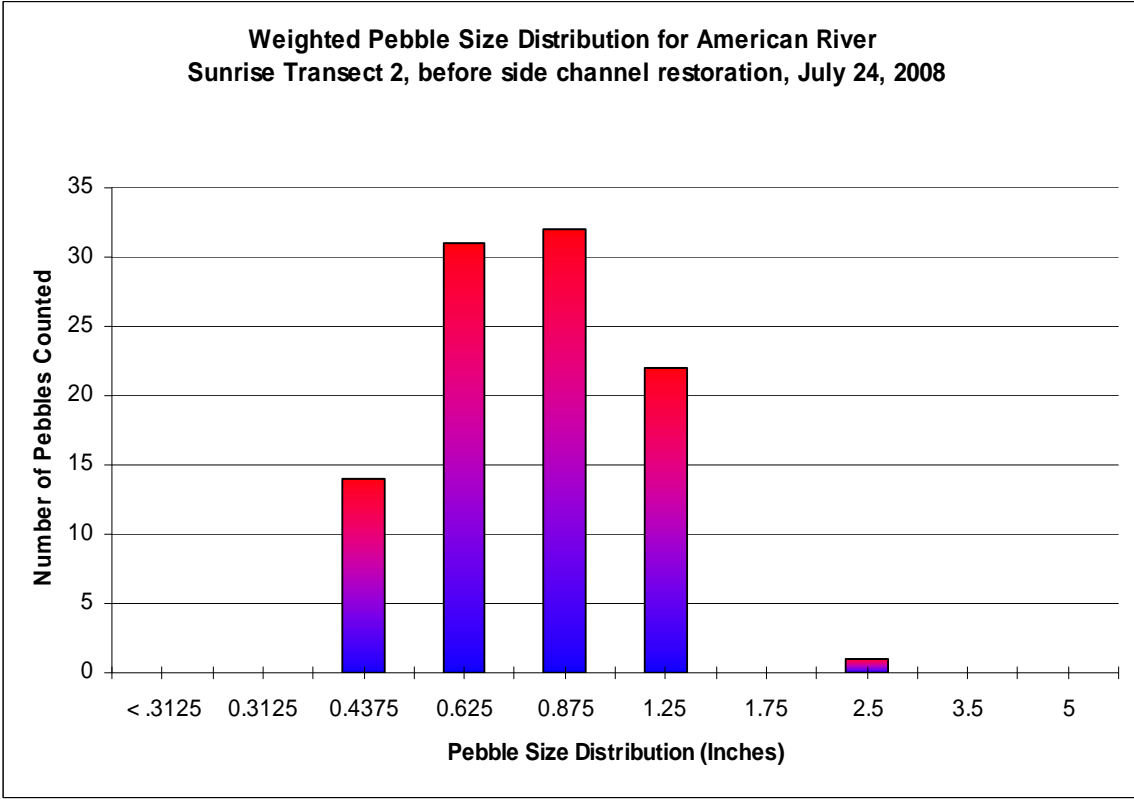
Weighted Pebble Counts from Transect 1, before side channel restoration, July 2008

Pebble Size	Number Counted	Weight	% Total Wt	Cum Wt %
< 0.31	1	0	0	0
0.31	0	0	0	0
0.44	19	0.1	1.72	1.72
0.63	31	0.4	6.9	8.62
0.88	26	0.9	15.52	24.14
1.25	16	1.8	31.03	55.17
1.75	5	1.3	22.41	77.58
2.50	2	1.3	22.41	99.99
3.50	0	0	0	100
5.00	0	0	0	100
Total	100	5.8	99.99	



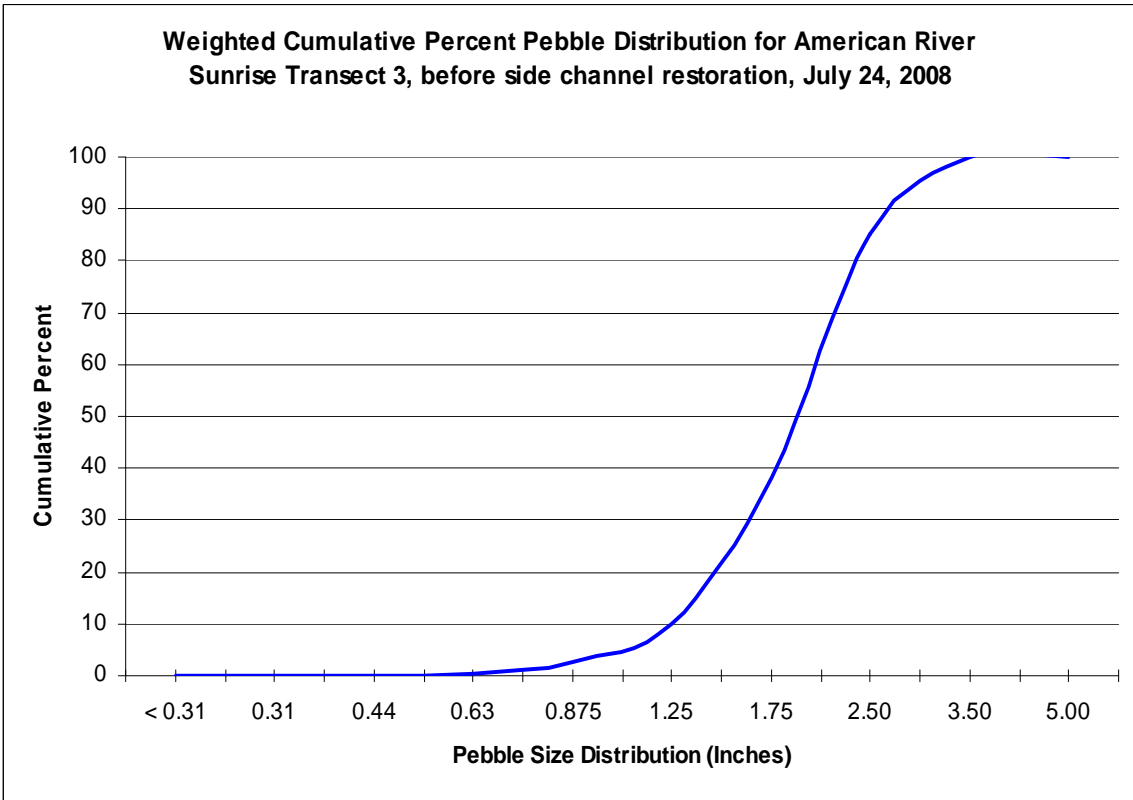
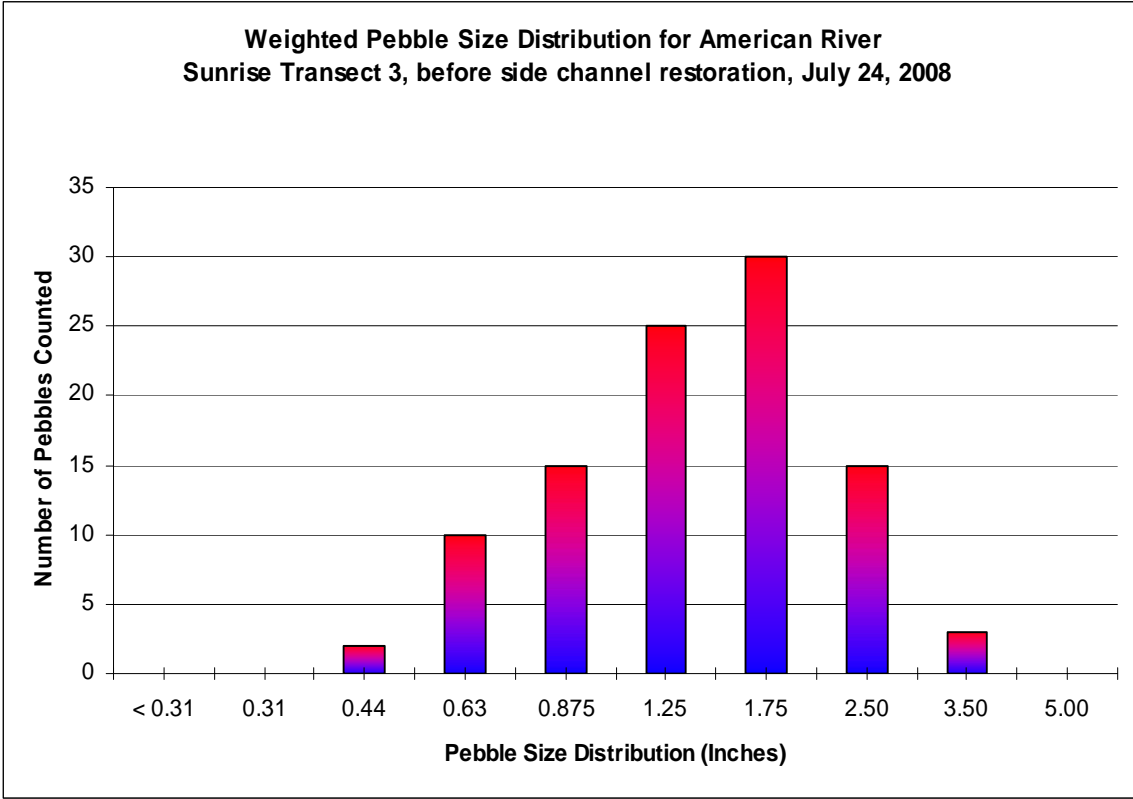
Weighted Pebble Counts from Transect 2, before side channel restoration, July 2008

Pebble Size	Number Counted	Weight	% Total Wt	Cum Wt %
< 0.31	0	0	0	0
0.31	0	0	0	0
0.44	14	0.05	1.45	1.45
0.63	31	0.3	8.70	10.15
0.88	32	1	28.99	39.13
1.25	22	1.6	46.38	85.51
1.75	0	0	0.00	85.51
2.50	1	0.5	14.49	100.00
3.50	0	0	0	100
5.00	0	0	0	100
Total	100	3.45	100.00	



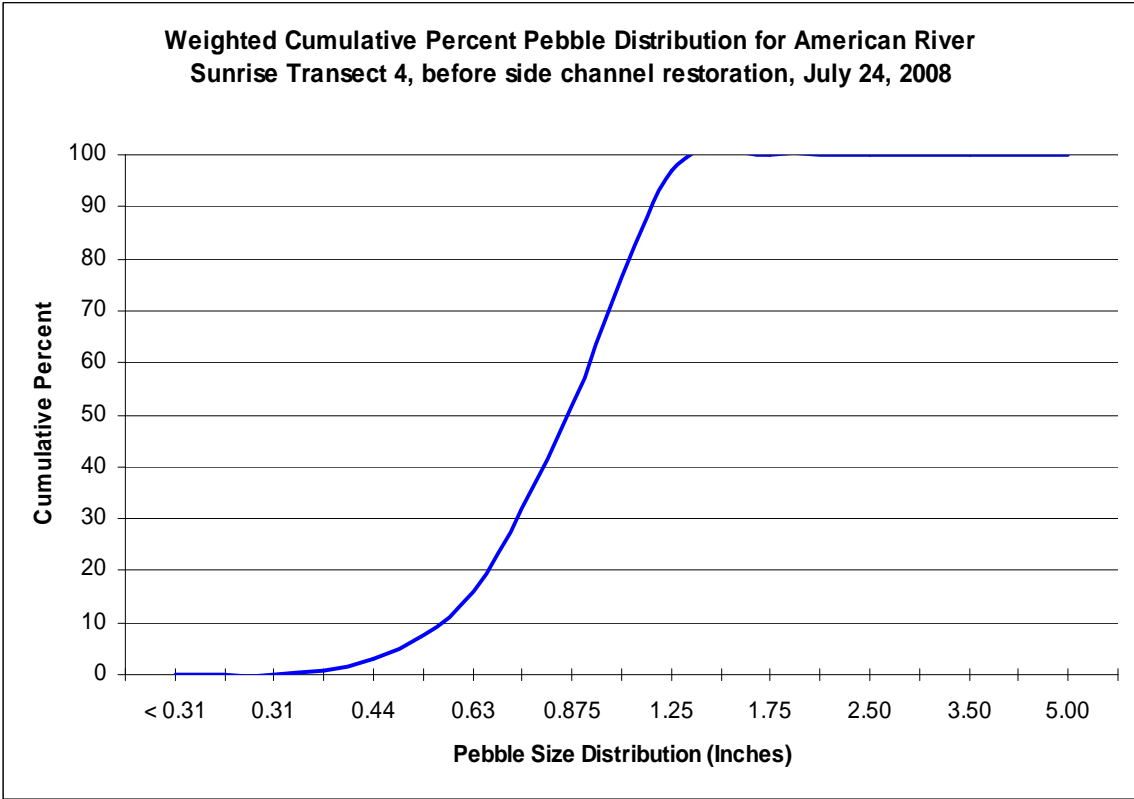
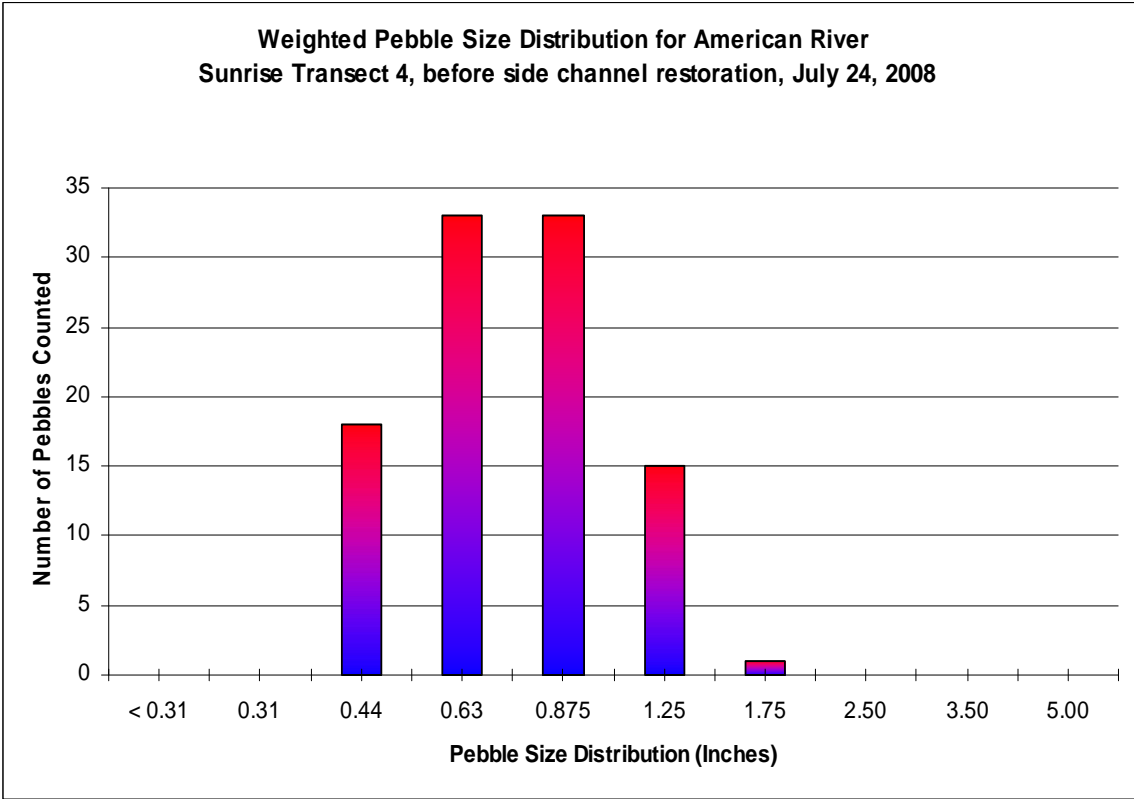
Weighted Pebble Counts from Transect 3, before side channel restoration, July 2008

Pebble Size	Number Counted	Weight	% Total Wt	Cum Wt %
< 0.31	0	0	0	0
0.31	0	0	0	0
0.44	2	0.05	0.19	0.19
0.63	10	0.1	0.38	0.57
0.88	15	0.6	2.26	2.83
1.25	25	1.9	7.16	9.98
1.75	30	7.5	28.25	38.23
2.50	15	12.4	46.70	84.94
3.50	3	4	15.07	100.00
5.00	0	0	0	100
Total	100	26.55	100.00	



Weighted Pebble Counts from Transect 4, before side channel restoration, July 2008

Pebble Size	Number Counted	Weight	% Total Wt	Cum Wt %
< 0.31	0	0	0	0
0.31	0	0	0	0
0.44	18	0.1	3.23	3.23
0.63	33	0.4	12.90	16.13
0.88	33	1.1	35.48	51.62
1.25	15	1.4	45.16	96.78
1.75	1	0.1	3.23	100.00
2.50	0	0	0.00	100.00
3.50	0	0	0.00	100.00
5.00	0	0	0	100
Total	100	3.1	100.00	



Appendix D: After side channel restoration water quality

Location	Temp (C deg)	D.O. (mg/L)	E.C. (ms)	pH
MP-1	10	10.1	52.4	7.4
MP-2	10	10.2	55.1	7.39
MP-4	9.8	9.6	50.9	7.23
MP-5	10.1	10.1	55.4	7.33
MP-6	9.9	10.5	51.3	7.4
MP-7	10.4	9.7	42.4	7.04
MP-8	10.5	3.5	40.8	7.13
MP-9	10.3	8.8	44.4	7.1
MP-10	10.8	2.1	56.1	6.8
MP-12	10.4	9.1	56.5	7.02
Mean	10.2	8.4	50.5	7.2
Surface 1	11.8	11.8	54.7	7.72
Surface 2	12.2	12.2	53.7	8.14

Sunrise side channel water quality data, Feb 2009.

Appendix E: Stream Velocity And Stream Depth

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	4.35	1.7	1.67	12.36
2	4.35	2.9	1.78	22.48
3	4.35	2.8	2.19	26.62
4	4.35	2.8	2.41	29.31
5	4.35	2.4	2.33	24.35
6	4.35	2.7	2.15	25.24
7	4.35	2.2	2.37	22.68
8	4.35	2.3	2.59	25.91
9	4.35	2.9	1.97	24.79
10	4.35	0.9	1.08	4.24
			Qtot =	217.99

Cross Section 1 (11/21/2008), at 1165 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	4.6	0.7	1.82	5.86
2	4.6	1.2	2.55	14.09
3	4.6	1.6	2.66	19.60
4	4.6	1.5	1.89	13.05
5	4.6	1.8	3.47	28.75
6	4.6	1.9	3.69	32.27
7	4.6	1.8	3.77	31.18
8	4.6	1.8	3.55	29.36
9	4.6	1.3	3.66	21.86
10	4.6	0.7	1.93	6.21
			Qtot =	202.24

Cross Section 2 (11/21/2008), at 1165 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	4.56	0.83	1.82	6.91
2	4.56	1.42	2.52	16.26
3	4.56	1.54	2.88	20.27
4	4.56	1.50	2.88	19.73
5	4.56	1.71	2.63	20.46
6	4.56	2.00	3.36	30.66
7	4.56	1.75	3.33	26.53
8	4.56	1.75	3.21	25.65
9	4.56	1.96	2.66	23.79
10	4.56	0.65	NA	0.00
			Qttotal =	190.26

Cross Section 3 (11/21/2008), at 1165 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	5.5	0.65	0.20	0.72
2	5.5	1.1	1.82	11.00
3	5.5	2.3	2.26	28.58
4	5.5	2.4	2.22	29.34
5	5.5	2.6	1.97	28.10
6	5.5	2.8	2.00	30.83
7	5.5	2.7	1.89	28.09
8	5.5	2	1.19	13.13
9	5.5	1.6	0.28	2.42
10	5.5	0.7	0.02	0.07
			Qttotal =	172.29

Cross Section 4 (11/24/2008), at 1165 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	5.5	0.70	1.12	4.31
2	5.5	1.60	2.04	17.94
3	5.5	1.80	2.00	19.82
4	5.5	1.90	1.97	20.54
5	5.5	2.10	1.86	21.43
6	5.5	2.40	2.04	26.91
7	5.5	2.10	2.08	23.97
8	5.5	2.30	2.11	26.72
9	5.5	2.20	1.60	19.33
10	5.5	1.00	0.79	4.34
			Qtot =	185.33

Cross Section 5 (11/24/2008), at 1165 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	5.9	1.3	0.83	6.34
2	5.9	1.9	1.86	20.80
3	5.9	1.9	2.08	23.27
4	5.9	1.9	2.19	24.50
5	5.9	1.9	2.22	24.92
6	5.9	1.8	2.30	24.38
7	5.9	2	2.00	23.63
8	5.9	2	2.04	24.06
9	5.9	1.8	1.05	11.12
10	5.9	0.7	0.20	0.83
			Qtot =	183.84

Cross Section 6 (11/24/2008), at 1165 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	6.6	1.8	1.34	15.93
2	6.6	1.9	1.23	15.43
3	6.6	2.4	1.45	22.98
4	6.6	2.4	1.74	27.64
5	6.6	2.3	1.60	24.26
6	6.6	2.2	1.49	21.60
7	6.6	2	1.74	23.03
8	6.6	1.5	1.27	12.55
9	6.6	1.5	1.34	13.27
10	6.6	1.1	0.94	6.80
			Qtot =	183.49

Cross Section 7 (11/24/2008), at 1165 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	6.6	1.3	1.01	8.67
2	6.6	2.5	0.83	13.63
3	6.6	2.4	1.27	20.07
4	6.6	2.3	1.56	23.70
5	6.6	2.4	0.53	8.43
6	6.6	1.9	1.67	20.96
7	6.6	2.2	1.49	21.60
8	6.6	1.9	1.34	16.81
9	6.6	2	1.60	21.09
10	6.6	1.3	1.34	11.50
			Qtot =	166.47

Cross Section 8 (11/24/2008), at 1165 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	3	0.1	NA	0.00
2	3	0.7	2.00	4.20
3	3	1.8	2.74	14.78
4	3	2.8	2.74	22.99
5	3	4.0	2.96	35.49
6	3	4.4	3.33	43.89
7	3	4.1	3.62	44.51
8	3	4.0	3.40	40.78
9	3	4.0	3.47	41.66
10	3	5.0	NA	0.00
11	3	5.3	NA	0.00
12	3	5.2	NA	0.00
13	3	5.0	NA	0.00
14	3	4.3	3.91	50.48
15	3	4.6	4.43	61.10
16	3	3.0	3.99	35.88
17	3	1.9	3.77	21.47
18	3	1.1	1.86	6.12
19	3	0.3	0.61	0.55
			Q total =	423.90

Cross Section 1 (6/11/2009), at 2000 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	2.7	0.4	NA	0.00
2	2.7	0.9	1.34	3.26
3	2.7	1.5	2.00	8.11
4	2.7	2.1	3.03	17.19
5	2.7	2.3	2.52	15.63
6	2.7	2.4	2.88	18.69
7	2.7	2.5	3.10	20.96
8	2.7	2.4	3.69	23.93
9	2.7	2.8	3.10	23.47
10	2.7	3	3.77	30.50
11	2.7	3	3.47	28.12
12	2.7	3.2	3.77	32.54
13	2.7	3	3.33	26.93
14	2.7	2.8	3.77	28.47
15	2.7	2.5	3.99	26.91
16	2.7	2.8	3.62	27.36
17	2.7	2.1	3.40	19.27
18	2.7	1.5	3.40	13.76
19	2.7	0.9	2.30	5.58
20	2.7	0.1	NA	0.00
			Q total =	370.67

Cross Section 2 (6/11/2009), at 2000 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	2.5	0.40	NA	0.00
2	2.5	1.20	1.41	4.24
3	2.5	1.90	2.22	10.56
4	2.5	2.30	2.81	16.16
5	2.5	2.40	2.81	16.86
6	2.5	2.60	2.96	19.22
7	2.5	2.70	3.33	22.44
8	2.5	2.60	3.40	22.09
9	2.5	2.80	3.40	23.79
10	2.5	3.30	3.55	29.25
11	2.5	3.20	3.47	27.78
12	2.5	3.20	3.55	28.36
13	2.5	3.10	3.84	29.76
14	2.5	2.90	3.84	27.84
15	2.5	2.80	3.91	27.39
16	2.5	2.60	3.40	22.09
17	2.5	2.30	3.62	20.81
18	2.5	1.90	2.96	14.05
19	2.5	1.40	2.15	7.52
20	2.5	0.50	1.19	1.49
			Q total =	371.71

Cross Section 3 (6/11/2009), at 2000 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	2.9	0.4	0.83	0.00
2	2.9	1.4	2.22	9.02
3	2.9	1.9	3.10	17.11
4	2.9	2.6	3.69	27.84
5	2.9	2.8	3.69	29.98
6	2.9	3	3.69	32.12
7	2.9	3.1	3.77	33.86
8	2.9	3.1	3.55	31.87
9	2.9	3.2	3.69	34.27
10	2.9	3	3.25	28.29
11	2.9	2.5	3.40	24.64
12	2.9	2.2	3.47	22.15
13	2.9	1.9	3.33	18.32
14	2.9	1.7	3.25	16.03
15	2.9	1.8	3.03	15.82
16	2.9	1.9	2.44	13.46
17	2.9	1.6	2.37	10.99
18	2.9	1.7	1.71	8.42
19	2.9	1.1	0.09	0.29
20	2.9	0.4	NA	0.00
			Q total =	374.49

Cross Section 4 (6/11/2009), at 2000 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	3.2	0.50	NA	0.00
2	3.2	1.50	1.71	8.20
3	3.2	2.10	2.08	13.95
4	3.2	2.40	2.81	21.58
5	3.2	2.60	3.18	26.44
6	3.2	2.60	3.18	26.44
7	3.2	2.60	3.25	27.05
8	3.2	2.60	3.25	27.05
9	3.2	2.50	3.40	27.19
10	3.2	1.80	3.10	17.88
11	3.2	2.50	3.33	26.60
12	3.2	2.50	3.03	24.25
13	3.2	2.80	3.40	30.45
14	3.2	2.80	2.81	25.18
15	3.2	2.80	2.88	25.84
16	3.2	2.60	2.52	20.94
17	3.2	1.10	1.49	5.24
18	3.2	0.80	0.75	1.93
19	3.2	NA	NA	0.00
			Q total =	356.21

Cross Section 5 (6/11/2009, at 2000 cfs)

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	3.2	0.6	0.97	0.00
2	3.2	1.7	2.30	12.49
3	3.2	2.6	2.59	21.55
4	3.2	2.8	2.66	23.87
5	3.2	2.8	2.88	25.84
6	3.2	2.8	2.96	26.50
7	3.2	2.6	2.88	24.00
8	3.2	2.6	2.96	24.61
9	3.2	2	2.81	17.99
10	3.2	2	2.88	18.46
11	3.2	2	2.96	18.93
12	3.2	2.1	2.44	16.42
13	3.2	2.1	2.52	16.91
14	3.2	2	2.44	15.64
15	3.2	2	2.37	15.17
16	3.2	2.5	2.15	17.19
17	3.2	2.5	2.37	18.96
18	3.2	2	1.49	9.52
19	3.2	1.4	0.53	2.38
20	3.2	0.2	NA	0.00
			Q total =	326.41

Cross Section 6 (6/11/2009), at 2000 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	6.6	1.8	1.34	15.93
2	6.6	1.9	1.23	15.43
3	6.6	2.4	1.45	22.98
4	6.6	2.4	1.74	27.64
5	6.6	2.3	1.60	24.26
6	6.6	2.2	1.49	21.60
7	6.6	2	1.74	23.03
8	6.6	1.5	1.27	12.55
9	6.6	1.5	1.34	13.27
10	6.6	1.1	0.94	6.80

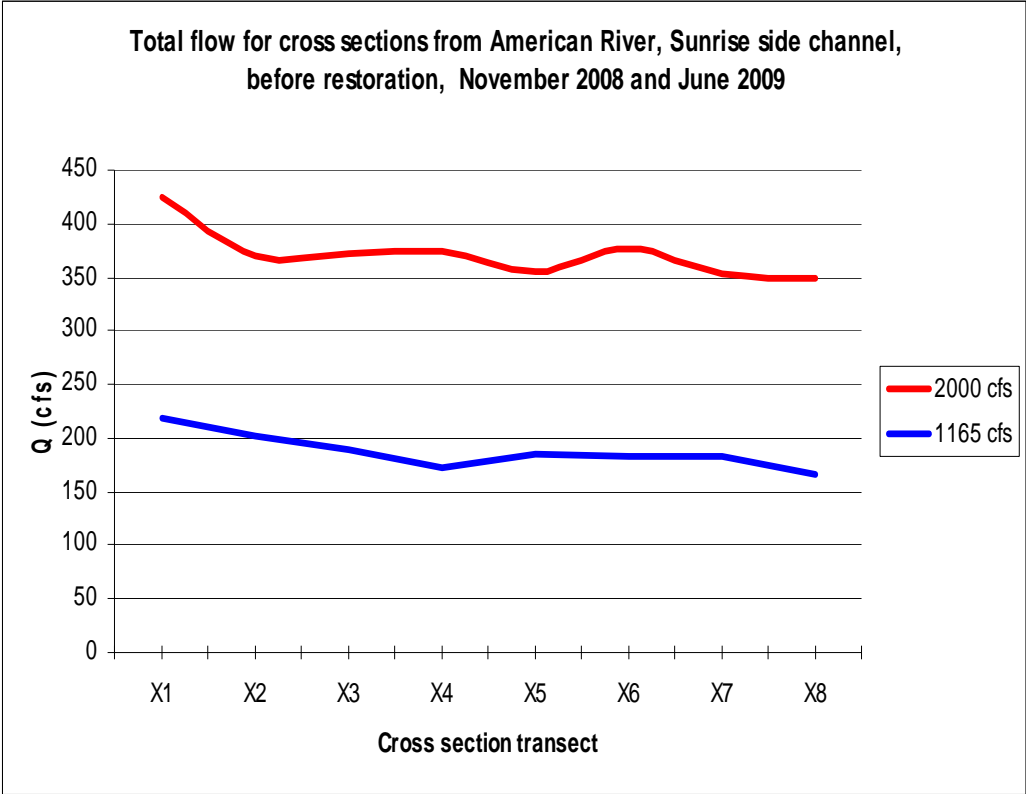
Q total = 351.49

Cross Section 7 (6/11/2009), at 2000 cfs

River Segment	Width (ft)	Water Depth (ft)	V at the 0.6 depth (ft/sec)	Q (ft ³ /sec)
1	6.6	1.3	1.01	8.67
2	6.6	2.5	0.83	13.63
3	6.6	2.4	1.27	20.07
4	6.6	2.3	1.56	23.70
5	6.6	2.4	0.53	8.43
6	6.6	1.9	1.67	20.96
7	6.6	2.2	1.49	21.60
8	6.6	1.9	1.34	16.81
9	6.6	2	1.60	21.09
10	6.6	1.3	1.34	11.50

Q total = 348.47

Cross Section 8 (6/11/2009), at 2000 cfs



Appendix F: Hach Water Chemistry

Location	Date Sampled	Sample ID	Nitrate, mg/L	Nitrite, mg/L	Ammonia, mg/L	Phosphate, mg/L
Sunrise	2/21/2009	Sun Surface	0.6	0.004	0	0.1
Sunrise	2/21/2009	Surface 2	0.6	0.003	0	0.13
Sunrise	2/21/2009	MP-0	0.5	0.005	0	0.1
Sunrise	2/21/2009	MP-1	0.5	0.004	-	0.18
Sunrise	2/21/2009	MP-2	0.6	0.002	0.2	0.24
Sunrise	2/21/2009	MP-4	0.7	-	0.17	0.12
Sunrise	2/21/2009	MP-5	0.6	0.004	0.1	0.1
Sunrise	2/21/2009	MP-7	0.6	-	0.1	0.01
Sunrise	2/21/2009	MP-9	0.6	0.002	0.02	0.13
Sunrise	2/21/2009	MP-10	0.6	0.002	0.1	0.03
Sunrise	2/21/2009	MP-12	0.7	0.003	0.07	0.1

