California Department of Water Resources

South Central Region Office

River Restoration and Environmental Compliance Branch

Fall 2009 Interim Flows Monitoring Data Report

For the San Joaquin River Restoration Program

DRAFT

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This document is preliminary and reports provisional data only. Data and report contents are subject to revision.

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Introduction

A draft physical monitoring plan was developed to obtain data that can be used to support analysis, design and implementation of the San Joaquin River Restoration Plan (SJRRP, 2008). The California Department of Water Resources (DWR), with assistance from their consultants [Tetra Tech (Tt-MEI, formerly Mussetter Engineering, Inc.) and Provost and Prichard (P&P)] implemented the following elements of the monitoring plan during the Fall 2009 interim flow releases.

- Establishment of survey control to facilitate other monitoring activities in Reaches 1A and 2A
- Measurement of water-surface profiles in Reach 1A, 2A, and 2B
- Flow Measurements in Reaches 1A, 2A and 2B
- Installation and operation of water-level recorders in Reach 1A
- Bed material sampling in Reach 1A
- Marked-rock tracer studies to assess gravel/cobble mobilization in Reach 1A
- Topographic surveys of monitoring cross sections in Reach 2A
- Installation of scour chains in Reach 2A
- Bed Material sampling in Reach 2

The methods described in Mussetter Engineering, Inc (MEI, 2008) were generally followed in implementing these elements of the plan. This report describes the methods and types of data that were collected, summarizes the data collected to date, and includes a description of lessons-learned that should improve the efficiency and quality of data collection during future restoration flow releases.

Modeling

A key purpose of the data collection and monitoring activities associated with CDWR's efforts is to provide detailed information that can be used to validate the hydraulic models and sediment transport analyses that are being used to plan and design various elements of the restoration plan. The data will assist the project team in addressing the following specific issues that are directly relevant to the physical behavior of the river system under existing and proposed restoration conditions:

1. Improved understanding and validation of the hydrograph routing characteristics of the restoration reach, including:
    a. In- and off-channel storage (e.g., existing gravel pits, overbank/floodplain storage),
    b. Infiltration losses and gains,
    c. Gaged and ungaged tributary inflows,
    d. Diversions.
2. Validation of the existing conditions hydraulic and hydrodynamic models, including water-surface elevations and the flow distribution at flow splits. This also includes validation of methods for estimating the channel roughness for existing and anticipated vegetation conditions.
3. Improved understanding and validation of the sediment-transport behavior of the river, including:
    a. Mobilization of the gravel/cobble bed at potential spawning riffles in Reach 1A.
    b. Sand supply and transport in Reaches 1A and 1B, and its effect on the quality of spawning habitat and the sediment supply to downstream reaches.
    c. Bed-material transport in the sand-bed reaches, and its effect on the long-term vertical and lateral stability of the river, deposition and associated impacts to channel capacity and stability in the vicinity of structures, and bed scour and its effect on water-surface elevations and channel capacity during high flows in reaches with significant riparian vegetation.
4. Monitoring of changes in channel geometry at key locations in the project reach, particularly within the sand-bedded Reach 2 in which the existing bed material is mobilized over a broad range of flows.

The 2009 interim flow releases from Friant Dam consisted of approximately 1-month at 350 cfs (October 2 through November 1), followed by approximately 10-days at 700 cfs (November 2 through November 11), and the data were only collected in a limited area in the upstream portion of the restoration reach. At full implementation, the Settlement Agreement contemplates restoration releases of up to 8,000 cfs; thus, the data collected during the 2009 releases represents only the low end of the restoration release range and only a portion of the overall reach. Complete data sets that can be used to validate the modeling and analysis over the full range of restoration flows and the entire restoration reach will require several additional data collection periods over the next few to several years. The data from 2009 and each subsequent period will be incorporated into the modeling and analysis as they become available to provide incremental verification/improvement of the available analytical tools.

Monitoring Activities and Data Presentation

Each of the several San Joaquin River monitoring activities DWR has performed and managed both before and during Fall 2009 Interim Flows are described in the following sections. These are brief summaries that give a description of the activities, their purpose, some details regarding implementation, and lastly discuss data collected where appropriate.

Control Surveys

Monitoring Task Description

This monitoring task establishes conformity of locations and elevations between all other monitoring tasks that use locations or elevations. Additionally this task places the locations and elevations in a standardized horizontal coordinate system and vertical datum.

Purpose of Monitoring

Control surveys identify specific monuments or iron pins located within each site with a location and elevation. Local surveys are conducted relative to these pins and consequently can have the standardized coordinates and elevations applied to all offset measurements from these pins.

Monitoring Details

Control surveys were conducted to establish a set of known coordinates and elevations at identified monitoring sites in Reaches 1A and 2A. A minimum of three pins were established and identified at each site. Each of the established and identified pins were surveyed using survey grade GPS to provide coordinates and elevations in California state plane Zone III and North American Datum 83.

a. *Procedure* – The control surveys used survey grade GPS to establish control points at each site. The GPS rover used a wireless modem to connect to GPS base data from stations identified as CSUF and Tranquility which are part of a network that is in process of being established as a CORS network. All points were measured using at least one of these base stations, and many of the points used both bases depending on signal availability and conformity to the specific location.

b. *Timing* – Control pins were placed prior to any local surveys such as the topo swaths or section surveys being performed. The Control survey was performed in October prior to the flow releases. All surveys performed from the pins before the control survey were done will be adjusted into the new coordinates measured for the control pins.

c. *Locations* – Control surveys were performed at all identified monitoring sites and several sites identified as future sites. This includes 10 sites in reach 1A, and 12 sites in reach 2A.

d. *Resources* – Control surveys required 1 person to operate a GPS rover and one person to identify the pins. Approximately four days were required to complete the field work for the control survey.

e. *Data* – Control points were recorded generically in the field and further matched up on aerial overlays to aid in identifying the specific monitoring sites and their respective local surveys. Local survey control pin numbers were associated with the control survey points where they referenced the same control pin. Location data is shown in the following table.

Table 1

Point Number	Easting	Northing	Point Elevation	Local survey reference point Number	Full Description	Point Number	Easting	Northing	Point Elevation	Local survey reference point Number	Full Description
201	6649702.11	1742386.49	192.08		Rebar 103	241	6656514.77	1747922.48	194.79	22610100	Rebar 100
202	6649658.58	1742419.74	191.81	22380104	Rebar 104	242	6664357.24	1750334.39	196.45	22830104	Rebar 104
203	6649622.08	1742448.54	191.95	22380105	Rebar 105	243	6664394.64	1750379.10	195.34	22830103	Rebar 103
204	6649698.62	1742497.68	191.76	22380102	Rebar 102	244	6664460.94	1750547.47	195.34	22830101	Rebar 101
205	6649751.99	1742451.62	193.13	22380101	Rebar 101	245	6664220.29	1750672.95	190.50	22830100	Rebar 100
206	6646762.39	1745496.12	188.64	22270101	Rebar 101	246	6664231.03	1750485.35	193.25	22830102	Rebar 102
207	6646757.78	1745469.45	188.00		Rebar	247	6659201.86	1750459.37	200.09	22710105	Rebar 105
208	6646644.85	1745471.41	187.42	22270102	Rebar 102	248	6659277.05	1750409.87	191.64	22710104	Rebar 104
209	6646884.57	1745658.52	186.52	22270100	Rebar 100	249	6659528.27	1750645.86	191.98	22710103	Rebar 103
210	6644037.39	1744314.90	186.81	22180102	Rebar 102	250	6659248.32	1750429.08	192.34		Rebar
211	6644029.90	1744252.56	186.13	22180103	Rebar 103	251	6783702.96	1812017.60	296.99		Rebar 102
212	6644025.48	1744195.10	186.33	22180104	Rebar 104	252	6783809.62	1812250.70	298.42		Rebar 101
213	6643513.30	1744338.68	179.55	22180100	Rebar 100	253	6783765.54	1812510.88	301.46		Rebar 100
214	6643477.99	1744293.51	177.57	22180101	Rebar 101	254	6783378.67	1806700.25	300.98	Bad	Rebar gone
215	6640247.86	1742640.40	181.99	22100102	Rebar 102	255	6783144.35	1806700.56	300.28	Bad	Rebar gone
216	6640215.41	1742600.86	182.04	22100103	Rebar 103	256	6783163.04	1806662.95	299.58	Bad	Rebar gone
217	6640187.76	1742563.98	181.86	22100104	Rebar 104	257	6784190.78	1803056.22	302.04		Rebar 100
218	6640080.24	1742634.36	182.45	22100101	Rebar 101	258	6784230.81	1803271.22	301.95		Rebar 101
219	6640097.43	1742677.22	183.26	22100100	Rebar 100	259	6783827.94	1803234.99	297.44		Rebar 102
220	6638607.13	1738467.96	181.74	22000101	Rebar 101	260	6781672.05	1800508.82	296.85		Rebar 102
221	6638496.59	1738519.77	180.91	22000103	Rebar 103	261	6781681.25	1800577.41	294.34		Rebar 100
222	6638406.75	1738582.39	179.07	22000104	Rebar 104	262	6782073.62	1800385.94	303.38		Rebar 101
223	6635036.76	1739688.29	176.57	21930101	Rebar 101	263	6781727.01	1800536.36	297.27		Rebar 103
224	6634986.71	1739683.81	176.27	21930102	Rebar 102	264	6780745.05	1798165.52	297.13		Rebar 100
225	6634931.73	1739671.79	175.39	21930103	Rebar 103	265	6780774.16	1798071.25	297.50		Rebar 102
226	6634980.82	1739813.88	175.81	21930100	Rebar 100	266	6780739.15	1797991.07	291.71		Rebar 101
227	6631722.42	1739146.88	174.93	21850101	Rebar 101	267	6780200.53	1796221.49	283.23		Rebar 101
228	6631670.00	1739164.75	174.90	21850102	Rebar 102	268	6780163.91	1796280.43	286.10		Rebar 100
229	6631619.53	1739188.05	176.86	21850103	Rebar 103	269	6780191.11	1796339.76	285.59		Rebar 102
230	6631725.76	1739259.68	174.22	21850100	Rebar 100	270	6727923.64	1766294.34	227.44		Rebar 101
231	6629237.36	1739923.99	175.00	21790103	Rebar 103	271	6727913.06	1766198.90	228.99		Rebar 102
232	6629307.99	1739928.72	176.04	21790102	Rebar 102	272	6727974.03	1766477.68	232.25		Rebar 100
233	6629353.32	1739906.53	176.50	21790101	Rebar 101	273	6747976.50	1769766.04	254.79		Rebar 100
234	6629218.29	1739813.22	173.25	21790100	Rebar 100	274	6747879.29	1769768.46	255.14		Rebar 101
235	6653908.42	1743649.90	194.08		Rebar	275	6747992.02	1769925.07	251.35		Rebar 102
236	6653939.80	1743694.25	194.45	22510103	Rebar 103	276	6768397.70	1778247.25	271.19		Rebar 100
237	6653970.92	1743736.18	194.38	22510102	Rebar 102	277	6768280.58	1778195.34	269.59		Rebar 101
238	6654049.35	1743631.37	190.51	22510100	Rebar 100	278	6768252.59	1778138.63	265.46		Rebar 102
239	6656378.02	1747941.25	197.42	22610104	Rebar 104	279	6755885.13	1769908.79	249.06		Rebar 100
240	6656417.83	1747974.58	197.21	22610103	Rebar 103	280	6755857.70	1769958.01	250.72		Rebar 101
						281	6755763.79	1769896.30	247.42		Rebar 102

Access Documentation

Access to Reach 1A sites was via ground and required driving through properties to the river edge. Prior arrangement was obtained from each property owner or controlling agency. Routes were configured to require the least intrusiveness possible and used established roads and trails when available. Site locations in Reach 2A were accessed via a route along the levee road, which required permission for access from the LSJLD.

Coordination

Control pins were placed prior to other monitoring tasks to provide a fixed reference for local surveys at each site. Once these were established, the actual coordinates used were and can be adjusted to the control survey any time after the control survey was finished.

Environmental documentation needs.

No documentation was necessary for this monitoring activity.

Water Surface Profile Surveys

Monitoring Task Description

This monitoring task includes collecting water surface elevations by conducting surface water profile surveys throughout the restoration reaches 1A, 2A, and 2B. For the 350cfs releases, reaches 1A and 2A were surveyed. For 700cfs releases, reaches 1A, 2A, and 2B down to the San Mateo crossing were surveyed. Water levels were recorded at the top and bottom of hydraulic controls and splits, beginning and end of pools, upstream, at, and downstream of pressure transducers, and velocity profile cross sections. An attempt was made to space points so there is no more than one foot of drop between points. However, the number, spacing, and exact locations of the points were prioritized based on hydraulic conditions, resources and access.

Purpose of Monitoring

Water surface monitoring will be combined with collected discharge measurements to validate and calibrate the existing conditions hydraulic models. Water surface elevations will be especially important to validate the model output at structures and flow splits. The additional data will supplement historical information and provide higher resolution data that capture existing channel conditions.

Monitoring Details

a. *Procedure* – Water surface profiles were obtained using a survey-grade GPS (3D quality of 0.1 foot) to record the water surface elevations along the river. The horizontal datum used was the California Coordinate System Zone 3, US Survey Feet, based on California Geodetic Coordinates of 1983, Epoch 2007.0. The vertical datum used was the North American Vertical Datum of 1988. Orthometric heights were derived from RTK observations and application of GEIOD03 to the RTK values. RTK observations were received from either the Fresno State or Tranquility base stations via a cell phone modem attached to the GPS receiver. Existing control points were used to validate the accuracy of the data. Near the DFG hatchery, thick vegetation prohibited the use of the GPS equipment. Control was set in an open area using GPS, and a total station was used to record the water level.

b. *Timing* – The U.S. Bureau of Reclamation began releasing 350cfs on October 2nd, 2009 which continued until November 1st, 2009. On October 19th we surveyed Reach 1A from the Road 206 Bridge (RM266) to Riffle 38 (RM259.5). On October 20th, we surveyed Reach 1A from Riffle 38 (RM259.5) to Sycamore Island (RM251.8), on October 21st we surveyed Reach 1A from Sycamore Island (RM251.8) to Hwy 99 (RM243.2), on October 26th we surveyed Reach 1A at the Hatchery in Friant and on October 28th we surveyed Reach 2A from River Cross Inc. (RM228.3) to RM220.3. The U.S. Bureau of Reclamation began releasing 700cfs on November 2nd, 2009 and ended the release on November 11, 2009. On November 5th, we surveyed the Hatchery in Friant, on November 9th we surveyed Reach 1A from the Road 206 Bridge (RM266) to Hwy 41 (RM255.2), on November 10th we surveyed Reach 1A from Hwy 41 (RM255.2) to Hwy 99 (RM243.2), on November 11th we surveyed Reach 2A from River Cross Inc. (RM228.25) to the Bifurcation Structure (RM216), and on November 12th, we surveyed Reach 2B from the Bifurcation Structure (RM216) to the San Mateo Crossing (RM212.8).

c. *Locations* – Water surface elevations were obtained along Reach 1A, 2A, and 2B. Please refer to the figures in Appendix I for locations and elevations. Elevations in yellow are for the 350cfs flows, and elevations in red are for the 700cfs flows. For the 350cfs flow release, the water did not reach the Bifurcation Structure. Therefore water surface elevations were recorded to where the river stopped. For the 700cfs flows, water levels were recorded as far downstream as the San Mateo crossing in Reach 2B. Survey locations were placed at the top and bottom of hydraulic controls (bridges, riffles, rock weirs) at the top and bottom end of long pools, about 200 feet upstream, at, and 200 feet downstream from pressure transducers and velocity profile cross sections, and at significant split flows. An attempt was made to limit the drop to one foot between two consecutive points.

d. Resources

Reach 1A

350cfs – Approximately 153 survey points were collected. It took three 12-hour days to travel from the Road 206 Bridge to Hwy 99. This included time to:

- load the PVC raft and other equipment into a pickup truck at P&P,
- caravan to the pullout point and drop off a pickup truck,
- drive to the launch point,
- unload all equipment and launch the boat,
- survey the points,
- row the raft,
- pullout at the ending point,
- drive back to P&P, and
- unload the raft and equipment.

Often along the way, the survey team would stop to give the discharge measurement team assistance, or to stop and survey the river since this was the survey team's first time floating the entire reaches.

700cfs – Approximately 132 survey points were collected. After reviewing the 350cfs data it was clear several of the points were redundant and could be removed from the 700cfs survey run. Since the 700cfs release only lasted 9 days, an attempt was made to float Reach 1A in two days instead of three. It took two 12-hour days to travel from the Road 206 Bridge to Hwy 99. This was accomplished by:

- sparing the survey crew from having to caravan to the pullout point and dropping off a vehicle. This was handled by extra personnel.

- Also, the survey crew did not stop to assist the discharge measurement teams. Their help was not necessary because extra personnel were assigned to the measurement teams.

- The velocity of the river at 700cfs is higher than at 350cfs, making is faster to travel from point to point.

- And last, the survey crew was more familiar with the river, and had less need to search around for the best place to take a survey point.

Reach 2A

350cfs – Approximately 44 data points were collected. It took a two-person crew one eight-hour day to collect the data points. The river did not make it all the way down to the Bifurcation

Structure, but only to RM220.3. The survey was done by vehicle. We first accessed the river from the Fresno side at River Cross Inc. We then drove to the Madera side and accessed the river from Road 21 and drove the levee for the remainder of the points.

700cfs – Approximately 86 data points were collected. It took a three-person crew one 12-hour day to collect the data points. At 700cfs the river did make it to the Bifurcation Structure. The survey was done using the PVC raft. We launched the raft from River Cross Inc, just downstream from the USGS Gravelly Ford gage, and pulled out at the Bifurcation Structure.

Reach 2B

700cfs – Approximately 19 data points were collected. It took a four person crew one 8-hour day to survey from the Bifurcation Structure to the San Mateo crossing. A metal John-boat with an outboard motor was used for the first 1.5 miles. The boat kept getting stuck, so two people took the boat back to the structure while the other two people continued down the river by foot (about 2 more miles) until reaching the San Mateo crossing. In hindsight, it probably would have been faster rowing the PVC raft from the structure to the crossing. Access arrangements did not include driving the length of the reach for surveys.

Coordination Efforts

Efforts were made to survey the water level approximately 200 feet upstream, at, and 200 feet downstream from discharge measurements, scour chains, velocity profile locations, and pressure transducers. In addition, reaches were surveyed at the same time flow measurements were scheduled so that timing would coincide as closely as possible.

Environmental Documentation

No documentation was necessary for this monitoring activity.

Data Analysis and Discussion

Data points are shown with recorded elevations on maps in Appendix I. Data tables containing all of the survey point locations and elevations are contained on the data disk.

As established prior to the monitoring effort, the spacing of surveyed water-surface points varied, as necessary, according to channel slope and local conditions. Longitudinal distances between survey points were often reduced significantly at specific locations in order to refine abrupt changes in the water-surface profile by collecting data at the top and bottom of riffles and other hydraulic controls. Larger distances between points were used in the large pools and backwater areas without impacting the accuracy of the water-surface profile.

A preliminary comparison of the surveyed and computed water-surface profiles based on the current 1-D HEC-RAS model indicates that the majority of significant hydraulic controls were sufficiently characterized by the survey data, and that no noticeable gaps in the data exist. Brief comparisons of the survey data and current model results also indicate that additional model calibration is necessary and can now be performed in numerous locations where previous calibration data did not exist.

The preliminary review of the data also indicates that in general, no significant anomalies exist. However, an occasional subtle rise in water-surface elevation in the downstream direction does exist, but the average magnitude of these instances is only approximately 0.1 feet and can be explained by a combination of error tolerance in the equipment and error in the exact placement of the survey rod. In some cases, it could also possibly be a hydraulic jump occurring after a steep riffle or weir. A brief reach-by-reach analysis of data follows.

Reach 1A

Area01 – For the 350cfs flows there seems to be some discrepancies between repeat data points above and below the Road 206 Bridge. The two different sets of shots were taken on two different days. This may be why the elevations are different, since it is unlikely the same amount of water was being released from the dam. Review of dam release records should help answer this question. Also, the water surface elevation in the side channel near the hatchery barely increased from the 350cfs to 700cfs flows. It appears the water surface elevation in the side channel at these flows is governed more by the storm water discharge pipe located at the top end of the side channel, and a weir located about halfway down.

Area02 – For the 350cfs flows at station 7789+00 it appears that not enough data points were recorded to capture the nature of the riffle at the station. For the 700cfs flows, data points were added. Because of the lack of data, the 350cfs and 700cfs profiles cross. It also appears that too many points (8 points total) were recorded at the drop located at station 7719+00 for the 350cfs flows. This was changed for the 700cfs flows (only two points were recorded).

Area04 – For the 350cfs flows just downstream from station 7550+00, the water surface increases from 283.66 to 283.85. Since this is a pool area, the increase in water surface elevation is most likely due to human error or limits in 3D accuracy.

Area06 & Area07 – From stations 7350+00 to 7365+00 the water surface profiles for the 350cfs and 700cfs flows cross. This is most likely due to a lack of 350cfs data. At about station 7370+00 the 350cfs WSE is 267.76, and at station 7345+00 it is 264.22. This is a difference of 3.54 feet. For the 700cfs run, more points were added decrease the drop in WSE between each point.

Area08 – For the 350cfs flows, on the upstream side of the Hwy 41 Bridges, the WSE is 259.02 and on the downstream side, the WSE drops to 257.08, then drops again to 257.05, and last increases to 257.11. The increase in WSE could either be due to a significant decrease in the water's momentum (hydraulic jump) or possibly due to human or equipment error. The WSE was not measure in this area for the 700cfs flows.

Area11 – From station 6940+00 to 6980+00 there is a lot of scarlet wisteria and arundo growing in and around the river. The river is quite swift, and the wisteria and arundo are strainer hazards. As the WSE increases, the wisteria and arundo become more dangerous. At 700cfs, the rafting team felt if the flows were any higher, the river should be accessed from land and not by boat.

Area13 – For the 350cfs flows, there is a minor discrepancy between the two elevations just downstream of the railroad crossing bridge, elevations 224.45 and 224.51, a difference of 0.06 feet. Also, there is a minor discrepancy between the WSE at station 6637+00 with an elevation of 223.72 and station 6615+00 with an elevation of 223.85. The difference is 0.13 feet. Both of these could be a combination of human and equipment error. For both the 350cfs and 700cfs flows, the railroad bridge and the Hwy99 Bridge don't seem to affect the river.

Reach 2A

Area15 – For the 700cfs flows there is a discrepancy between elevation 179.73 at station 5566+00, elevation 179.69 at station 5564+50, and elevation 179.81 at station 5563+00. The source of the error is unknown, but during the 700cfs survey, the surveyor often lost communication with the base station in Tranquility.

Area16 – For the 700cfs flows there is a discrepancy between elevation 174.08, 174.14, and 174.15 between station 5410+00 and 5415+00. The source of the discrepancy is unknown.

Area17 – For the 700cfs flows there is a discrepancy between elevation 166.24, 166.21, and 166.26 located between station 5260+00 and 5275+00.

Area18 – For the 700cfs flows, just upstream of the San Mateo crossing, the elevation increases from 156.11 to 156.19. This might be due to a sudden decrease in momentum because of the culvert.

Discharge Measurements

Monitoring Task Description

This monitoring task includes determining flow discharge by conducting flow velocity and depth measurements at specific locations along the channel during steady flow periods. The discharge measurements were performed in Reaches 1 and 2 at water level recorder locations, gravel mobility locations, and scour chain locations. As resources are available, future measurements may also be made in Reaches 3, 4, and 5. Discharge measurements ideally will be done for a number of flow releases from Friant Dam ranging from 350 to 8,000 cfs.

Purpose of Monitoring

The discharge measurements will be associated with collected water level elevations to validate and calibrate the existing conditions hydraulic models. The measurements will also be used to assist in the determination of flow distribution at flow splits and flow losses. The additional measurements will supplement historical information and provide higher resolution data that captures existing channel conditions. The measurements will also support sediment mobility and transport modeling.

Monitoring Details

Discharge measurements were conducted in tandem with the water surface profile measurements by reach and date. Methods to maintain the linkage between the profile and discharge measurements included surveying the water's edge elevation during the discharge measurement and including the location as a profile point taken by the profile team.

a. *Procedure* – Discharge measurements were collected using either an Acoustic Doppler Current Profiler (ADCP), or Marsh McBirney electromagnetic velocimeter. The approximate minimum measureable depth for a Teledyne RDI Workhorse ADCP with ZedHed and shallow mode configuration works out to approximately 1 ft below the transducer head if velocities are less than 1m/s, and 1.5 ft for faster velocities. A bank operated portable cableway was placed at all measurement locations. The water craft mounted ADCP was then attached to the cableway. A steady, consistent pull was applied to the cableway to move the ADCP across the section to make up a transect. As per USGS standards, a minimum of four transects at each section were performed. If any single discharge measurement deviated from the average by more than 5%, an additional four transects were performed. In cases where the ADCP did not function properly, a Marsh McBirney instrument was used to measure the discharge. Typically the same cableway was used to define the section for the Marsh McBirney measurements. Distance along the cross section was measured by a fiberglass tape measure or total station.

b. *Timing* – Discharge measurements were conducted during releases of approximately 350 and 700 cfs. Discharge measurements for the 350 cfs release began approximately 15 days after the Friant discharge increased to 350 cfs. Measurements for the 700 cfs release began approximately 8 days after the release was increased to 700 cfs. The delay from the start of each release to the beginning of the measurements allowed flows to approach a steady state condition. Discharge measurements were conducted at the same time as the water surface profile survey. In some cases, due to equipment or other logistical problems, discharge measurements were not completed to ensure that the overall measurement schedule kept pace with the profile survey.

c. *Locations* – Discharge measurements were taken near predetermined locations that were established in the field prior to the flow releases (see maps in Appendix II). Two additional locations were added during the field efforts to account for split flows, and one was relocated to improve the quality of the measurement by taking advantage of greater and more conducive measurement depths. At each site, the physical measurement location was often adjusted slightly upstream or downstream to take advantage of depths greater than about 2 ft, and velocities that were not excessively difficult to traverse to set up the cableway or were potentially difficult to measure with an ADCP. Nine sites were measured between Friant and Hwy 99 during the 350 cfs release, including the 2 split flows. Nine sites were measured for the 700 cfs release, with six in Reach 1A, two in Reach 2A, and one in Reach 2B. Due to logistical problems and time constraints, measurements for the 700 cfs release did not include any split flows.

d. *Resources* – Discharge measurement crews with a minimum of 3 to 4 persons were required to conduct each measurement within an approximately 2–hour period. Including travel time and assuming that there are no major difficulties in setting up or conducting the measurement, approximately three sites can be completed per day. The typical breakdown of the time was as follows:

- Approximately 45 minutes to unload the truck, set up the cableway, and lay out and connect equipment.
- 15 minutes to prepare the software for programming the ADCP and setting file saving parameters.
- Approximately 45 minutes to take a measurement consisting of a minimum of 4 transects each taking around 5 to 10 minutes depending on traversal speed and section width. If 8 transects are necessary, the measurement would require approximately an additional 30 minutes
- About 30 minutes to break down and reload the truck.
- Approximately 30 minutes travel time to the next discharge location if that location is within 5 miles and done in a strictly linear fashion. Some locations require more travel time if access switches sides of the river or jumps over a reach of the river i.e. Travel from Reach 1A to Reach 2A, bypassing Reach 1B.

Additionally, equipment resources for each team required an ADCP, small watercraft for stretching the cableway (often canoe or inflatable kayak, laptop computer and wireless interface, temporary cableway and assorted hardware, chest waders and boots, and associated personal safety equipment.

Access

All access for the discharge measurements was over ground and required driving through properties to the river's edge. Prior arrangement was obtained from each property owner or controlling agency. Routes were configured to minimize the intrusiveness as much as possible and used established roads and trails when available.

Environmental Documentation

No documentation or permitting is necessary for this monitoring activity.

Data Analysis and Discussion

Refer to the following table for a summary of initial flow measurement results. Summary data sheets for each measurement are included in Appendix II, and full data files containing raw data and measurement notes are included in the data disk.

Table 2 – Flow Measurement Results

Scheduled Friant Release (cfs)	Measurement Site	Location (RM)	Date/Time	Flow Measured (cfs)	Equipment Used
Reach 1A					
350	Discharge 4	263.6	10/19/2009 10:20 - 11:28	330	ADCP
350			11/19/2009 9:59 - 10:54	365	ADCP
700			11/09/2009 16:00-17:15	610	Marsh McBirney
350	Discharge 6	261.5	10/19/2009 14:27 - 14:55	334	ADCP
350			11/19/2009 12:51 - 13:15	341	ADCP
700			11/09/2009 8:54 - 9:32	718	ADCP
700	Discharge 7	260.8	11/09/2009 12:34 - 13:04	729	ADCP
350	Discharge 8	260.5	10/20/2009 9:07 - 9:41	357	ADCP
350	Discharge 8 split	260.4	10/20/2009 11:30 - 11:57	121	ADCP
350	Discharge 11	255.1	10/20/2009 14:33 - 15:10	337	ADCP
350	Discharge 12	251.2	10/21/2009 13:32 - 14:27	312	ADCP
700	Discharge 12	251.2	11/10/2009 9:58 - 10:12	686	ADCP
350	Discharge 12 split	251.1	10/21/2009 16:30 - N/A	52	Marsh McBirney
350	Discharge 16	248.3	10/22/2009 9:12 - 9:40	295	ADCP
700			11/10/2009 13:13 - 13:34	682	ADCP
350	Discharge 17	245.2	10/22/2009 12:13 - 14:16	269	ADCP
700			11/10/2009 16:11 - 16:38	608	ADCP
Reach 2A					
700	Discharge 22	222	11/11/2009 10:15 - 11:07	356	ADCP
700	Discharge 23	218.2	11/11/2009 13:33 - 14:17	275	ADCP
700			11/11/2009 14:17 - N/A	253	Marsh McBirney
Reach 2B					
700	Discharge 24	214	11/12/2009 9:48 - 10:01	161	ADCP

Discharge data was collected in Reach 1A at seven locations during the initial 350 cfs release and at six locations during the 700 cfs release. As anticipated, the flow measurements generally indicate a decrease in total discharge in the downstream direction. However, during both events the measurements also indicated a slight increase in discharge between Ledger Island (RM 262) and Rank Island (RM 259.5). At the 350 cfs release, this increase was approximately 28 cfs (10 cfs/mile) and at 700 cfs the increase was measured at 129 cfs (45 cfs/mile). The cause of this increase is not currently known, but one explanation could be related to the fact that the two upstream flow measurements near Ledger Island (Sites D4 and D6) are both located adjacent to potential split flows, and that a small portion of the total discharge was not included in the measurements. It is unlikely that the split flows were active at the relatively low flow releases of 350 cfs and 700 cfs, but the cause of this increase should be further investigated. To aid in this further investigation, additional measurements were performed on November 19th during the second 350cfs release to collect additional data points for these sites. One secondary channel (split flow) was successfully measured during the 350 cfs in the vicinity of Rank Island (RM 259.5) to aid in the performance of the hydraulic model. Results indicated that of a total of 357 cfs reaching Rank Island, approximately 121 cfs (i.e. about one third) was measured flowing into the secondary channel.

From the downstream end of Rank Island to Highway 99 (RM 243), the measured discharge decreased during both events. During the 350 cfs event, the flow loss was measured at 5 cfs/mile and during the 700 cfs event, it was measured at about 7 cfs/mile. During the 350 cfs event, the entire flow release was lost to groundwater infiltration shortly after reaching Reach 2A; thus, no discharge measurement could be taken in this area. The total discharge loss over this stretch of river was 269 cfs, which is equivalent to about 12 cfs/mile.

In Reaches 2A and 2B, an additional 3 sites were measured, but only during the 700 cfs event due to the lack of flow reaching these areas during the 350 cfs event. The measured flow loss between Highway 99 and the first measurement in Reach 2A (RM 222) was about 250 cfs (12 cfs/mile). The loss from RM 222 down through the Bifurcation Structure to RM 214.5 in Reach 2B was approximately 195 cfs (26 cfs/mile).

Water Level Recorders

Monitoring Task Description and Purpose

Water level recorders can be installed at any point of interest in the study reach to obtain a continuous record of water stage data. The most rigorous observations allow the maintenance of a continuous record of water stage (water level in the river), and when velocities and depths in the channel are measured, the stage record can be converted into water discharge. Our intent is to collect flow measurement data at each recorder, but it isn't the primary purpose of operating them. The main purpose is to record water surface elevation changes over time in key locations so that the data can be applied to hydraulic and routing models. The recorders will provide a continuous record of stage and water surface elevation that can be used to assess hydrograph translation characteristics and water level elevation for validation of the hydraulic models.

Monitoring Details

To assist in correlating the data from temporary recorders, the time stamp should be synchronized with, and the recording interval set to, the same period as the permanent recorders along the reach. (The main water level recorder located below Friant Dam is currently set to a 15-minute sampling interval). The reliability of the water discharge curve depends on many factors that directly influence the measurements. Changing bed materials, vegetation growth, accumulated floating debris, a flow regime change from laminar to turbulent, and many other obstacles may affect the quality of data.

Installation

Common requirements for Water Level Recorder (WLR) site selection include the following:

1. WLR should be installed on the riverbank with the goal of recording depth at the chosen location and at the predetermined period of recording. The maximum range of water levels and their locations should be estimated by visual observation.
2. It is preferable to avoid installing the WLR in an area where significant bed and bank erosion is predicted or observed.
3. Areas immediately upstream of riffle reaches are more desirable for measuring water depths, velocities, and water discharge than pool sections.
4. In order to improve the accuracy of the WLR measurements, preferred installation locations are characterized by a uniform flow distribution that is free of any significant obstacles or debris for a sufficient distance upstream and downstream of the site.
5. It is preferable that the cross-section channel and riverbank be cleared of any debris or obstacles before WLR installation.
6. The optimum location of the WLR is on a bank with a steep slope that would aid measurement during high flow events.

The most important component of the Water Level Recorder is the transducer or depth detector, which was designed to detect changing water depths throughout the observation period. The procedure followed to install the WLRs include the following (Figure 3):

1. Installation should be done with care to avoid unnecessary impact to vegetation and riverbank soil and gravel and follow all environmental permitting requirements;
2. The entire protective perforated pipe should be set into the channel bed by covering it with gravel and cobble particles. The WLR should be installed inside of the perforated pipe;

3. One end of the pipe, as shown in Figure 2, should be covered with the cap with a small hole drilled in its center. This hole allows a fish line to be used to reposition the transducer for maintenance;
4. The whole fish line should be rolled on a spindle and installed near the end of the pipe and covered with gravel;
5. The pipe must conform to the shape of the cross-section profile by using of flexible tubing or elbows;
6. The WLR switch (data recorder) should be at the end of the pipe at the bank to allow connection to a laptop for data download;
7. Provide about one inch of soil cover to the portion of the pipe that is placed on the riverbank to protect it from tampering;
8. To stabilize the pipe in the riverbed, three anchors (steel bars) are installed to enforce the pipe. The anchors we used were two to three feet in length and ½ inch in diameter;

Required time for installation is about half a day per site and depends on the number of people in the crew.

 

Figure 1 – Two WLR installation sites

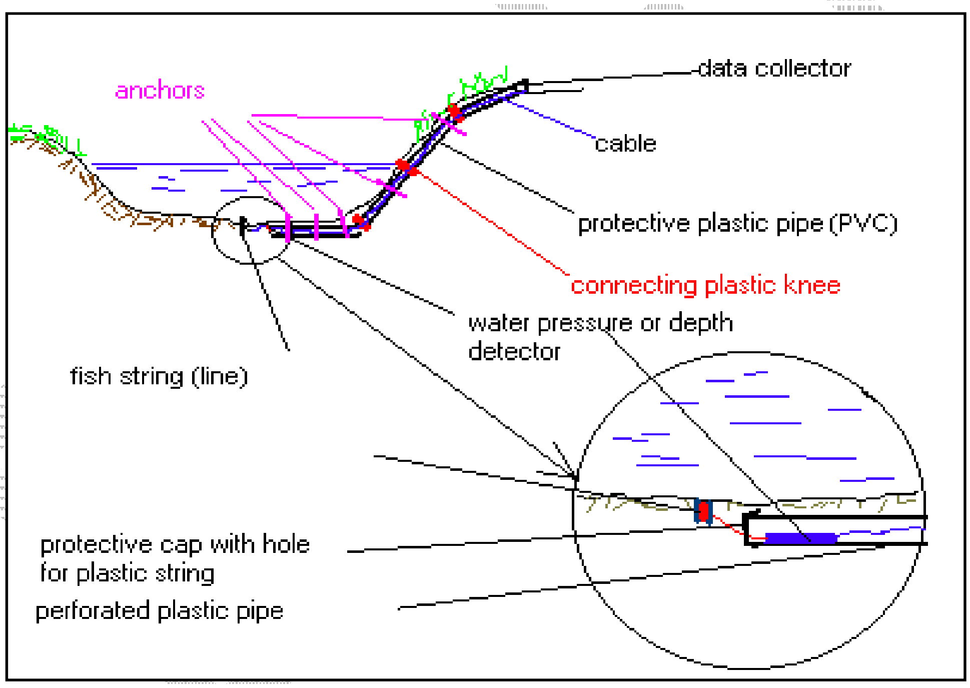

Figure 2 – WLR installation components

Figure 3 – WLR installation

Calibration

After complete installation, the depth detector should be calibrated with measurements of water depth at the transducer location. The time interval between taking readings is 15 minutes, the same interval as numerous gages have on the San Joaquin River.

Coordination Efforts

Coordination for this activity included timing the installations so that flows were still as low as possible for ease of construction and to complete them before interim flow releases began so that full records of the releases could be obtained.

Environmental Documentation

The following permits were obtained for these installations:

- Department of Fish and Game – Stream Alteration Notification (No. 2009-0023-R4), dated 05/11/2009.
- Central Valley Flood Protection Board – Encroachment Permits No. 18472 and 18473, dated 08/05/2009.
- Army Corp of Engineers – Nationwide Permit 5 (NWP 5), dated 05/29/2009.
- California Regional Water Quality Control Board – General 401 Water Quality Certification, dated 03/04/2009.

In order to obtain the permits, applications were submitted to the respective agencies including a detailed description of the project location as well as the activities involved.

To ensure compliance with environmental regulations, staff from DWR's Environmental Services Section of the South Central Region Office accompanied engineering staff during the installation process. After installation was completed it was reported to the appropriate agencies along with photos of installation.

Data

Recorder locations and the recording dates are shown in Table 3.

Table 3 – Water Level Recorder Locations

Recorder	Location	River Mile	Northing	Easting	Date Recorded
1	Head Ledger Island	263.4	1806637.072	6783082.547	9/15/09 - 12/3/09
2	Willow Unit Grade Control	261.5	1800755.550	6781491.581	9/24/09 – 12/3/09
3	Rank Island Grade Control	260.4	1796231.560	6780263.838	9/24/09 - 12/3/09
4	Sycamore Island Flow Split	251.1	1769840.948	6755745.987	9/02/09 - 12/3/09
5	Milburn Unit	248.4	1770054.246	6748034.861	9/15/09 - 12/3/09

Figures 4 and 5 show the stage data adjusted to MSL for each transducer. Recorder 1 showed inconsistent changes during and after the 700cfs release (red oval in figure) with respect to the other recorders. Data for recorder 1 indicates a water level fluctuation between about 11/09/09 and 11/11/09. However, recorders 2 and 3, which are located downstream of recorder 1, do not indicate any significant water level fluctuations. As a result, the accuracy of the measurement data for water recorder 1 during this period of time is suspect. After field investigation, we believe one possible explanation is that vegetation may have accumulated on the support pins during the 700 cfs flow release, causing one to rotate and loosen the end of the pipe (movement of the anchors was evident on inspection). With the end of the pipe being loose, forces could lift it vertically 2-3 inches. We have reinforced the anchors for this transducer and will continue to monitor it for inconsistent readings.

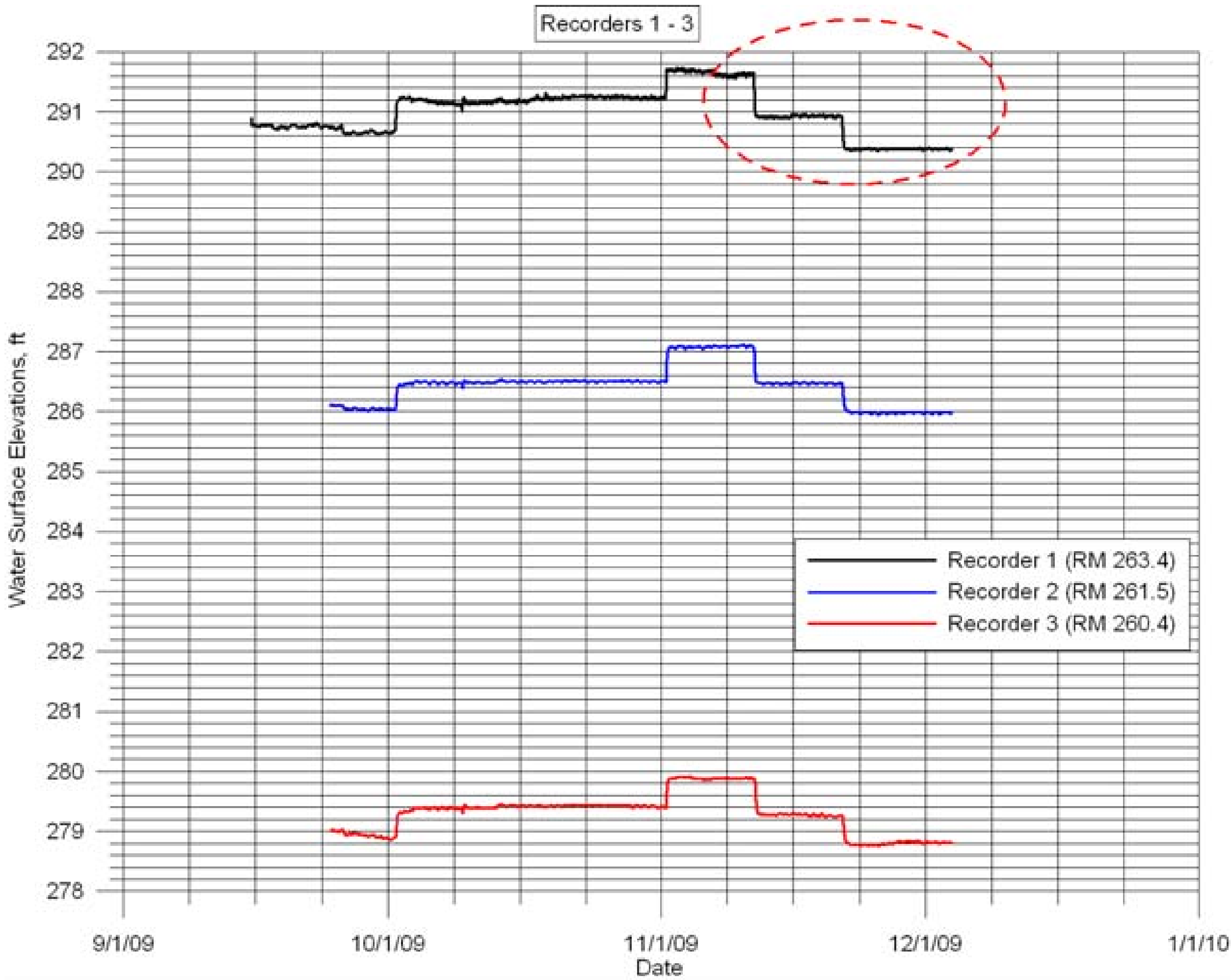

Figure 4 – Recorders 1-3 elevation data

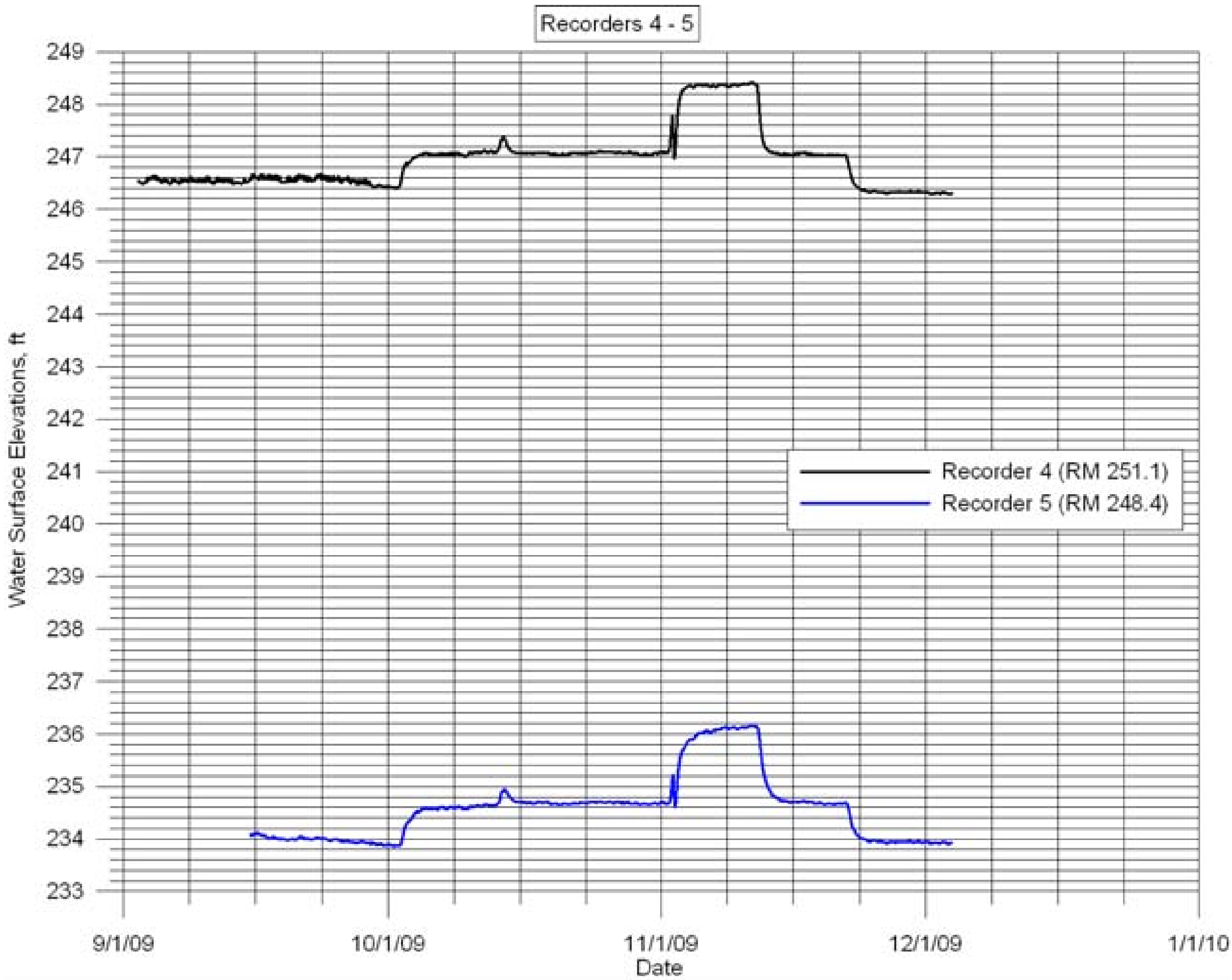

Figure 5 – Recorders 4-5 elevation data

Future Plans

Additional transducers will be installed if needs dictate. One additional transducer is currently planned for installation in Reach 1B in January 2010.

Scour Chains

Monitoring Task Description and Purpose

The scour chains are part of a study to determine if bed mobilization in the sand bed reaches affects rigid boundary hydraulic modeling results. The model being tested will assist in restoration design of the river. Four chains have been installed at each of two cross sections in Reach 2A (Figure 6), which is a sandy reach where significant sediment movement is expected. The scour chains will be used to verify the maximum depth of scour and re-deposition that takes place during a particular flow release.

After a peak flow event, the chains will be carefully excavated to detect the depth of burial and determine the amounts of erosion and deposition. In case there is substantial net erosion or deposition that significantly changes the shape of the cross section, the final bed surface will be re-surveyed to document the changes.

Monitoring Details

Installation

The chains were installed in August 2009 using a 10-ft steel pipe that was pounded into the sand using a post driver; this method limits the amount of impact to the surrounding soil. The galvanized chain was attached to a plugged bell reducer used to hold the chain in place (Figure 7). The bell reducer was also used as a pointy head to help the pipe go into the ground more easily and also to cap the pipe so that no sand gets into it and to prevent the chain from shifting to the side and getting stuck.

An approximately 2.0-ft deep hole was dug before the pipe was driven into the ground. Then the pipe with the chain inside was pounded into the ground with a post driver. The pipe was then pulled out, leaving the chain buried in the ground. The sand that was removed from the hole was then shoveled back into place to bring the surface back as close to original conditions as possible. The length of the excess chain above ground was then measured to determine the length of the chain below the surface. A set of pictures showing the process of installing one of the chains is shown in Figure 8.

The chains were installed to depths between 8.20 and 9.10 ft, with the exception of one chain that was buried to a depth of 7.5 ft due to an obstacle at that depth that prevented the driving pipe from going deeper. At least one of the four chains in each cross section was placed in the low-flow channel. The following table lists the GPS coordinates as well as total and buried lengths of the eight chains.

Table 4 – Scour Chain Information

Point Number	Longitude	Latitude	Date Installed	Total Length (ft)	Buried Depth (ft)
1-XS10	W120°14'17.30"	N36°46'09.80"	8/13/2009	9.80	8.50
2-XS10	W120°14'16.35"	N36°46'10.62"	8/13/2009	9.10	8.20
3-XS10	W120°14'16.07"	N36°46'11.08"	8/13/2009	9.35	8.35
4-XS10	W120°14'15.78"	N36°46'11.51"	8/19/2009	9.90	9.10
1-XS6.5	W120°11'57.19"	N36°46'48.96"	8/11/2009	9.90	8.40
2-XS6.5	W120°11'56.96"	N36°46'49.30"	8/11/2009	9.90	7.50
3-XS6.5	W120°11'56.64"	N36°46'49.80"	8/11/2009	9.50	8.80
4-XS6.5	W120°11'56.42"	N36°46'50.15"	8/11/2009	9.90	8.40

Inspection

The chains were visited on December 14, 2009 to determine if there has been sediment movement at either of the chain sites. Results are shown in Table 5 below.

Table 5 – 12/14/09 Post-flow Inspection Results

		Site and Chain #								
Date of visit		**1-1**	**1-2**	**1-3**	**1-4**		**2-1**	**2-2**	**2-3**	**2-4**
12/14/2009	Previous exposed length (ft)	1.50	2.40	0.70	1.50		1.30	0.90	1.00	0.80
	Chain length to kink (ft)	2.00	N/A	N/A	N/A		2.40	N/A	N/A	N/A
	Depth to kink (ft)	0.66					0.30			
	New exposed length (ft)	1.29					2.10			
	Amount of scour (ft)	0.50					1.10			
	Redeposit (ft)	0.66					0.30			
	Net (-Scour, + Deposit) (ft)	**0.16**					**-0.80**			

*** N/A = No Activity

Environmental Documentation

The following permits were obtained for this task:

- Department of Fish and Game – Stream Alteration Notification (No. 2009-0023-R4), dated 05/11/2009.
- Central Valley Flood Protection Board – Encroachment Permits No. 18472 and 18473, dated 08/05/2009.
- Army Corp of Engineers – Nationwide Permit 5 (NWP 5), dated 05/29/2009.
- California Regional Water Quality Control Board – General 401 Water Quality Certification, dated 03/04/2009.

In order to obtain the permits, applications were submitted to the respective agencies including a detailed description of the project location as well as the activities involved.

To ensure compliance with environmental regulations, staff from DWR's Environmental Services Section of the South Central Region Office accompanied engineering staff during the installation process. After installation was completed it was reported to the appropriate agencies along with photos of installation.

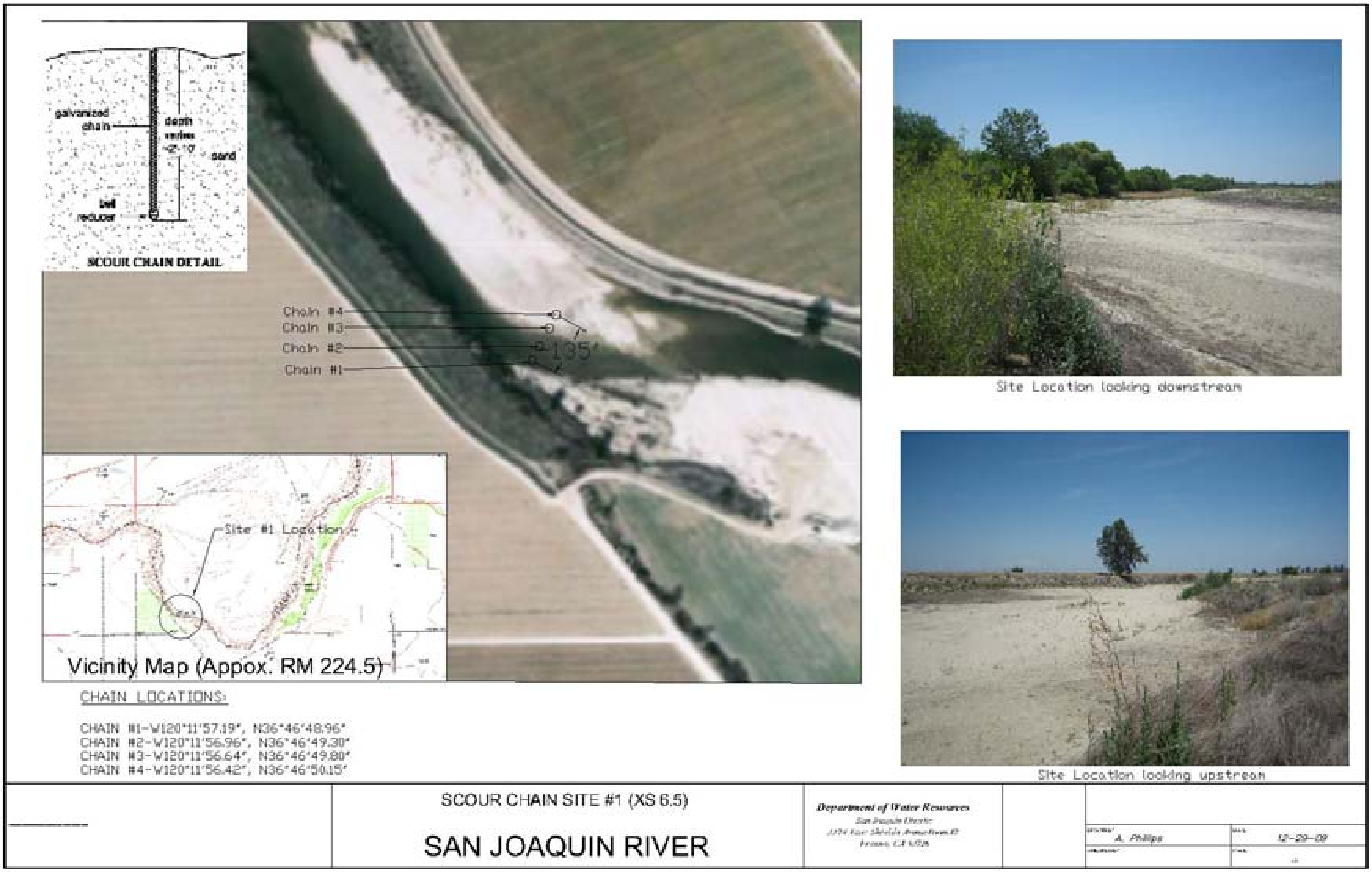

Figure 6a. Location of scour chains at site #1 (more accurately River Mile 223.8)

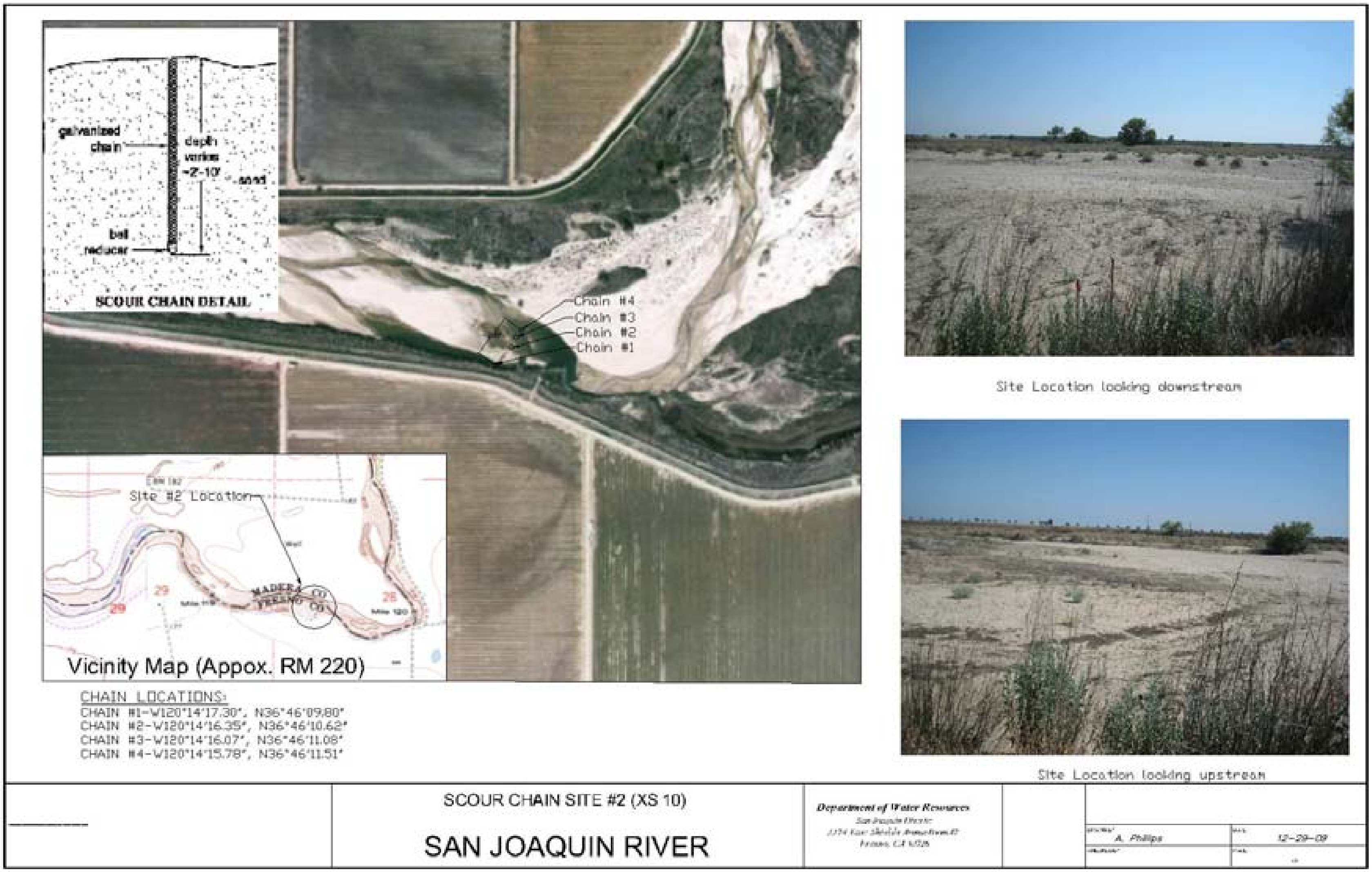

Figure 6b. Location of scour chains at site #2

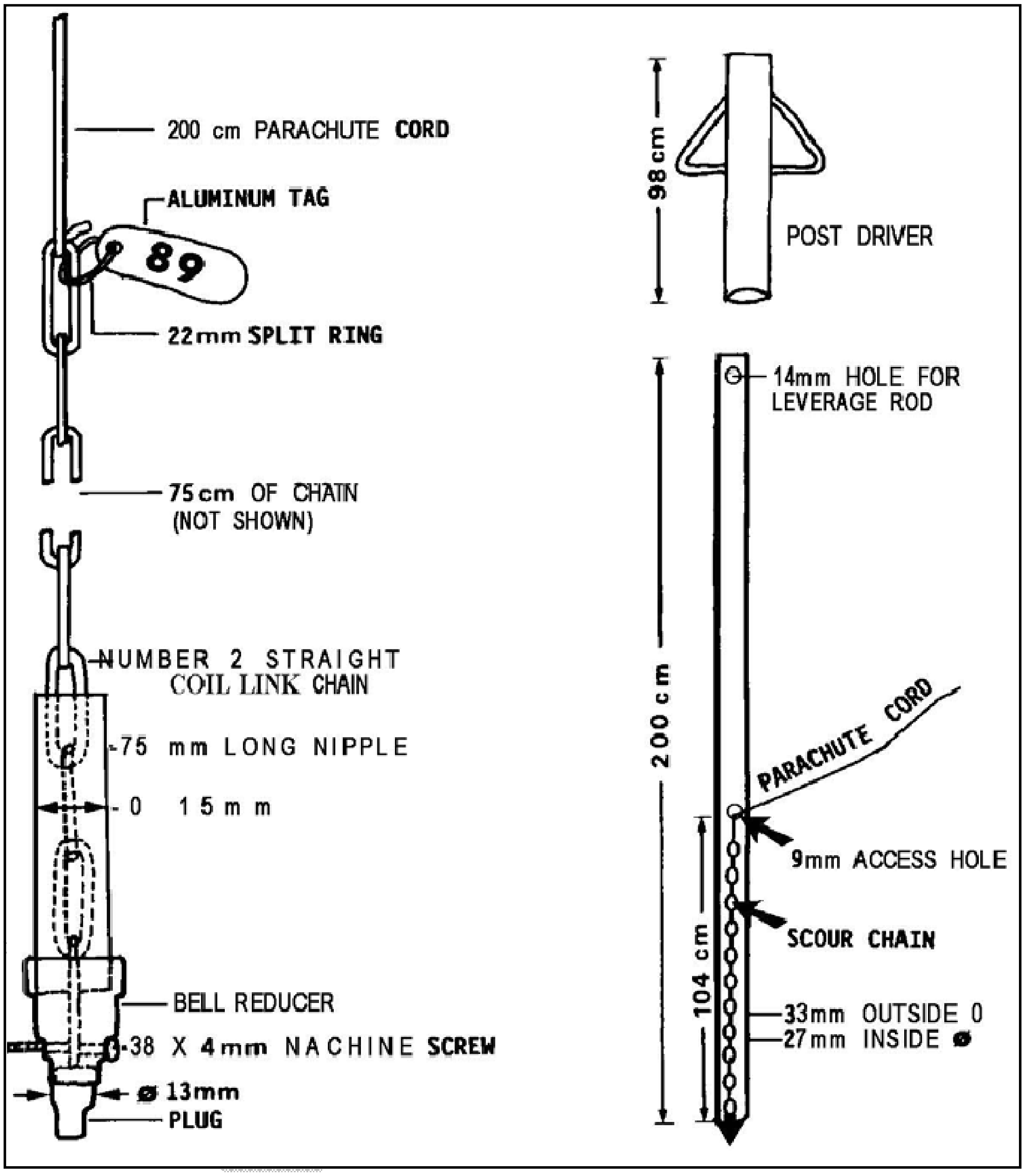

Figure 7. Schematic showing the chain and pipe assembly

Photo 1. Pounding in pipe

Photo 2. Removing pipe

Photo 3. Sand shoveled back in place

Photo 4. Measuring excess chain above ground

Figure 8 – Photos showing chain installation process

Monitoring Section Surveys

Monitoring Task Description

This monitoring task includes collecting cross sectional channel geometry by conducting channel cross section surveys. Geometry was collected at specific sites to establish a baseline condition of the channel. The spacing and exact locations of the surveyed points across the channel depend on the features specific to the monitoring tasks these are supplementing. Current sites are located in Reaches 1 and 2, with future sites to be identified in Reaches 3, 4 and 5. Sites will be resurveyed to evaluate changes in channel geometry after flow releases from Friant Dam ranging from 350 to 8,000 cfs.

Purpose of Monitoring

Cross section surveys will monitor bed aggradation/degradation and bank erosion in response to restoration flows. In some cases the cross section surveys will be used to confirm model geometry and modeling roughness boundaries. The additional information will also provide higher resolution data to calibrate and validate models.

Monitoring Details

Channel surveys to measure a baseline were performed prior to Fall 2009 releases. River conditions will need to be re-assessed after flow releases to determine the need to re-survey the sites.

a. *Procedure* – The cross section surveys used a combination of survey grade GPS to establish control points at each site, and traditional survey equipment to conduct the cross sections and topographic swaths. All surveys were tied to the 2007/2008 topographic mapping by establishing local control points using a GPS rover with phone modem to tie in with an existing network. Previously established and monumented sections were located using hand held GPS devices, maps and ground confirmation of monuments. New cross sections were identified in coordination with sediment mobility monitoring. The new cross sections were monumented at each end with pins whose locations were measured during the cross section survey. Cross sectional surveys measured ground elevations at grade breaks and approximate minimum distances necessary as observed in the field along the sections to characterize their geometry. In addition, cross-sections or topographic swaths may also be established for channel surveys in Reaches 3, 4, and 5. After a significant flow event where channel geometry changes are observed, the sections will be resurveyed.

b. *Timing* – Base line cross section surveys were performed over the summer of 2009 prior to the flow releases in October and November. The need for the next set of surveys will be determined during December and January, and if required; the next set of surveys will be performed before the next flow release scheduled to begin in February 2010.

c. *Locations* – Channel surveys were performed at three sections in one location in Reach 1A and topographic swaths at 12 locations in Reach 2A. The location in Reach 1A coincided with the transport studies at Riffle 38 (see Pilot Tracer Study section). Eleven of the 12 Reach 2A locations coincided with the previously established sites in the 1999 and 2000 pilot flow studies for the San Joaquin River Riparian Habitat Restoration Program. The remaining Reach 2A site was performed at a BOR ground water monitoring site. The specific locations for the Reach 2A topo swaths were further adjusted according to locations of other monitoring equipment and needs within each site.

d. *Resources* – Cross-section surveys required 1 person to operate a total station and 2 to 4 people as rodmen to measure as many as four topo swath sites per day. The cross section survey required 2 people to conduct 3 sections in approximately ½ day. Checks for completeness and adjustments including adjusting these surveys to the control survey were conducted later in the office.

Access

Many of the cross-section locations exist in Reach 2A and only require permission for access from the LSJLD. The remaining survey location in Reach 1A was located at Riffle 38, requiring a check-in process at the CEMEX gravel mining office and coordination with DFG.

Coordination

New cross sections were identified in coordination with sediment mobility monitoring. The specific locations for the Reach 2A topo swaths were adjusted according to locations of other monitoring equipment and needs within each site.

Environmental documentation needs

No documentation is necessary for this monitoring activity.

Data Analysis and Discussion

Refer to Appendix III for location and coverage of surveys. Point locations and elevations are contained in the data disk.

Future Plans

The established monitoring sections will be resurveyed after each significant flow event has receded to summer or winter base flows. The next survey is scheduled for January 2010.

Reach 1A Bed Sampling

Monitoring Task Description

In 2007 and 2008 stream bed samples were collected from the San Joaquin River at locations where conditions are expected to meet Chinook salmon spawning requirements. See the December 14, 2009 San Joaquin River Riffle Particle Size Composition Survey Interim Report River Miles 247 - 267 by the California Department of Water Resources for further information (Appendix IV).

Purpose of Monitoring

The purpose of this survey was to assess the conditions of the streambed substrate and compare with Chinook salmon requirements. Additionally, the data will be used to assess the potential for bed mobility in areas anticipated to be used as Chinook salmon spawning grounds.

Monitoring Details

a. *Procedure* – Bulk samples were collected using a McNeil sampler and the material was sieved to determine the grain size distribution of each sample. Pebble counts were performed using the Wolman method and were typically located in the immediate vicinity of a bulk sample. Both methods were used to estimate the stream bed surface grain size distribution. But bulk samples were also utilized to measure the subsurface grain size distribution.

b. *Timing* – Sampling was conducted during summer low flows in 2007 and 2008.

c. *Locations* – Particle size measurements were made from most of the riffles between river miles 246 and 267. Sample locations were focused at the head of riffles along the channel margins, where Chinook salmon are suggested to preferentially dig redds.

d. *Resources* – To date, the California Department of Water Resources, South Central Region has collected 66 bulk samples and performed 98 pebble counts as part of this on-going effort. Two person crews were necessary to handle the McNeil sampler and sieves during sampling.

e. *Data* – From 66 bulk samples we observed a mean gravel content of 90% with a median particle size of 39 mm. Of these, 40 bulk samples were separated into surface and subsurface samples with surface mean gravel content of 99% and median particle size of 63 mm. The 40 subsurface samples had a subsurface mean gravel content of 87% with a subsurface median particle size of 30 mm. The 98 pebble count samples had a median particle size of 47 mm.

Data Analysis and Discussion

Calculated armor ratios had a mean of 2.4, maximum of 4.8, and minimum of 0.8, indicating that on average the surface is 2.4 times coarser than the subsurface or bedload material and 50% larger than the expected value of 1.6 for a gravel bedded river. Further analysis showed there to be an increase in the coarseness of the bed by about 3 to 4 times the subsurface coarseness between river miles 259 and 260. For undifferentiated bulk samples 7 (11%) samples were determined to have greater than 10% particles finer than 1.0 mm as compared to the total sample weight. An additional 2 (3%) samples were determined to have greater than 21% particles within the range of 0.7 to 4.0 mm. In total, 59 (89%) of the undifferentiated samples were suitable in that they met both conditions regarding percent fine material. From these results it was determined that 50 bulk samples (76%) met all the criteria for suitable spawning sized stream bed material.

Reach 2 Bed Sampling

Monitoring Task Description

This task includes collecting river bed samples at Reach 2 monitoring locations to monitor changes in substrate characteristics.

Purpose of Monitoring:

Improve understanding and validation of the sediment-transport behavior of the river, including:

a. sand supply and transport in Reach 2 and its effect on the quality of habitat and the sediment supply to downstream reaches,
b. bed material transport in the sand-bed reaches and its effect on the long-term vertical and lateral stability of the river,
c. deposition and associated impacts to channel capacity and stability in the vicinity of structures,
d. bed scour and its effect on water-surface elevations and channel capacity during high flows in reaches with significant riparian vegetation.

Monitoring Details

Sampling and Data Collection

Bed samples were collected from topographic monitoring sections (see monitoring section survey section). At each monitoring section, bed samples were taken at representative locations. The river bed samples were collected using a shovel and placed in either 1 gallon Ziploc bags for sandy material or a 5 gallon plastic bucket for coarse material. Only the top six inches of the surface was taken from each sample location. In some instances the samples were taken within close proximity of each other when observed lateral variation in material size of a particular section was minimal. When the sizes were more variable, the sample locations were chosen to represent the variation. Multiple samples (three maximum) were obtained from each section.

A handheld GPS unit (accuracy ±1 ft) was utilized to obtain the coordinate location where each river bed sample. When multiple sample containers (three 1-gallon bags) were filled at one location along the section, only one GPS point was recorded because they were considered part of the same sample. One bag was sufficient for most locations if the material was sandy. However, if the material was coarser, a larger sample was required. Some sections have up to three GPS locations because of multiple sample locations, whereas others may just have one (Figure 9).

Locations

The riverbed samples were located between from River Mile 217.5 and River Mile 228.2. Monitoring sections are designated M3, M4, M5, M6, M6½, M7, M8, M9, M10, M11, M12, and M13. Figure 9 below displays the locations where each sample was taken. Samples that had significant sediment size variation within one section were designated M#-# (ex. M5-2).

Grab Sample Location Map - Reach 2A

Figure 9 – Location Map

Sample Analysis

Method

This test was done in accordance with the California Department of Transportation's Test 202, "Method of Tests for Sieve Analysis of Fine and Coarse Aggregates." The methods described within that document were followed with minor modifications. These modifications include, excluding the use of a mechanical washing vessel, and instead incorporating the use of a No. 200 washing sieve, and assuming that the mechanical shaker-agitator will separate the sample as well as using the hand method. Also a time of 10 minutes was assumed to be enough for optimal sample separation.

Definitions

- **Coarse-Grained:** Soils are smaller than 76.2mm and greater than 4.75mm in diameter.
- **Fine-Grained:** Soils are smaller than 4.75mm and greater than 0.075mm in diameter.

Equations

- $R = 100 * (M_c / M_t)$

  Where:

  R = Percentage of test sample retained on the sieve.
  M_c = Cumulative mass of material retained on the sieve.

M_t = Oven-dried mass of test sample prior to washing

- P = 100 – R

  Where:
  - P = Percentage of test sample passing the sieve.
  - R = Percentage of test sample retained on the sieve.

Apparatus

- Sieves:
  - Coarse-Aggregates:
    - 5”, 3.5”, 2.5”, 1.75”, 1.25”, 0.875”, 0.625”, 0.4375”, 0.25”, Pan
  - Fine-Aggregates:
    - Woven wire cloth; No. 4, 8, 16, 30, 50, 100, 200, Pan
    - No. 200 wash sieve
- Mass Balance:
  - Coarse-Aggregates:
    - A spring loaded balance measuring to the nearest 0.1 pounds.
  - Fine-Aggregates:
    - An electronic mass balance with a precision of 1.0 grams.
- Shaker-Agitator:
  - Tyler Portable sieve shaker, modified according to TL drawing No. D536.
  - Sound enclosure (not required)
- Device to split or quarter fine-aggregates
- Medium size bowl
- Wire brush
- Stiff, short bristled brush
- Oven safe pan
- Bulb aspirator
- Oven, or other heating device, capable of maintaining a temperature of 110± 5°C
- Digital thermometer (not required if heating device has a temperature read out)

Test Preparation

Coarse-aggregates need to free of any fine-aggregates that may have been adhered and fine aggregates need to be free of clots. If the fines on the coarse aggregate appear that they are able to be removed through the sieving process, then no prior washing is needed.

Procedure

1. Weigh the entire sample to be sieved.
2. Stack the coarse grained sieves on top of each other with the smallest sieve at the bottom and a pan underneath that.
3. Pour the sample through the coarse sieves and agitate using the hand method
4. For each sieve used record the weight of the sample retained.
   - For each sieves retained mass, add the accumulated weight from the larger sieves

5. Split or quarter the fine-aggregates retained to achieve a mass of 500 ± 25g. If there is not enough to achieve the desired mass use all that is retained.
6. Oven dry the fine-aggregates at 110± 5°C. Let the sample cool. Mass the fines and this will be the dry weight of the sample.
7. Using the No. 200 wash sieve, wash the entire 500g of the fine-aggregate thoroughly with clean tap water.
8. Rinse out the wash sieve with the clean fines into an oven safe pan. By slightly tipping the pan allow the water to collect and settle to be poured out. Using a bulb aspirator after pouring out most of the water will allow for more water to be extracted, (extracting as much water as possible from the sample allows for faster drying).
9. Allow the clean fines to oven dry at 110± 5°C. When fines are dry they are ready to be sieved.
10. Stack the fine grained sieves with the No. 200 sieve and pan at the bottom.
11. Pour the sample through the sieves.
12. Place the sieves in the shaker-agitator for 10 minutes.
13. For each sieve used record the weight of the sample retained.
    - For each sieves retained mass, add the accumulated weight from the larger sieves

Coordination Efforts

Samples were taken at the time that cross section surveys were being conducted.

Environmental Documentation Obtained

No permitting required for this task.

Data Presentation and Discussion

The D84 and D50 values are shown in Table 6 below. Several sites show that gravel (coarse material) was present within that cross section (higher values). This data was taken pre-event and will be used to compare to future samples at the same locations to monitor change in grain size over time.

Table 6

RM	Cross Section	D84, mm	D50, mm
228.1	M-3 (Sample 1)	34.2	5.9
228.1	M-3 (Sample 2)	1.7	0.8
227	M-4-1	19.4	8.1
227	M-4-2	1.8	1.0
226	M-5-1.5	2.0	0.5
226	M-5-2	6.3	1.1
226	M-5-3	1.2	0.8
224.9	M-6-1	14.3	2.3
224.9	M-6-2	2.1	0.9
224.9	M-6-3	1.3	0.9
224.9	M-6.5	10.8	0.6
222.9	M-7	1.2	0.5
222	M-8 (Sample 1,2)	1.3	0.7
222	M-8 (Sample 3)	13.0	0.7
220.9	M-9	1.1	0.7
219.8	M-10	1.2	0.8
219	M-11	1.2	0.6
218.2	M-12-1	3.1	0.9
218.2	M-12-2	1.7	0.9
217.5	M-13	1.7	0.8

Future Data Collection Plans

Grab samples will continue to be taken when cross sections surveys are conducted. Cross section surveys will be determined following a site assessment. Future samples will be taken as close as possible to the previous sample location. This will be done using the handheld GPS unit.

Pilot Tracer Study

Monitoring Task Description and Purpose

Background: Tracer studies are used to identify the flow in which sediment particles are mobilized and to evaluate the stream bed's suitability as spawning habitat. The data obtained from a tracer study can be used to verify analytical estimates of the critical discharge at key riffles in Reach 1A. Furthermore, riffles that do not show sufficient mobility can then be evaluated further for methods that increase their mobility. Due to many confounding issues related to the methods used and environmental conditions in which they were implemented, a pilot study of a tracer study method was determined to be necessary. Five gravel/cobble riffles in Reach 1A were suggested as potential candidates for assessing the mobility of existing material under the restoration release flows.

Introduction: This monitoring task includes a pilot bed mobility study using tracers in Reach 1A. The pilot tracer study marked sediment particles in a selected riffle to monitor the mobility of the stream bed. Three channel traversing cross-sections were selected to investigate bed particle movement with position within the riffle with the intention of accounting for variance in hydraulic conditions. It is intended that after review of this pilot study's methods and results, the reviewing parties will supply constructive criticism to help in ascertaining its usefulness and, if necessary, alter the method so as to make its results more defendable.

Prediction: Hydraulic and sediment transport analyses by MEI (2002b) indicated that the river bed in Reach 1A is basically armored for the range of flows in the Settlement Agreement, but there is some local reworking of the bed at flows in the 1,000 to 8,000 cubic feet per second (cfs) range. The analysis specifically indicated that bed mobilization would occur at flows less than 3,500 cfs at some riffle clusters that exist in the upper part of Reach 1A between Friant Dam and Hwy 41. It is intended that the MEI (2002b) analysis can be revisited and refined using the results from this pilot study and future tracer studies.

Relevance and Purpose: The data obtained from this monitoring will allow planners to evaluate and shape the flushing flow hydrographs during normal-wet and wet years. Exhibit B of the Stipulation of Settlement states that the primary goal of flushing flows is to mobilize spawning gravels, maintain their looseness, and flush fine sediments. These studies will provide information to support the decisions made on peak releases. The monitoring will also support Paragraph 12 of the Settlement by providing information on actions necessary to augment spawning gravels to enhance success in achieving the restoration goal.

Monitoring Details

<u>Methods</u>

Monitoring mobility of gravels requires a well coordinated plan that involves the following:

1. Selecting measurement locations,
2. Measuring background conditions,
3. Installing tracers,
4. Photo-surveying the stream bed,
5. Surveying topography,
6. Velocity and discharge measurements, and
7. Post-flood surveying of particle movement.

In order to implement the pilot tracer study the following procedures were used to setup and install the tracers.

Procedure

Location

The pilot tracer study selected one of five riffles that was located in the upper portion of Reach 1A, which MEI's models predicted would have general mobility at close to anticipated interim flow levels. The riffle chosen for this pilot study, Riffle Cluster 38, was selected for its potential as suitable spawning habitat, accessibility for Program staff, and because it was less likely than other candidate riffles to be disturbed by the public. Within the Riffle Cluster 38 area (study site), MEI's model predicted low to measurable mobility at 350 cfs and general mobility by 1,500 cfs. At the study site, three cross-sections were positioned, monumented, and surveyed prior to the interim flows to provide baseline geometry. The exact locations of the cross-sections were chosen to account for variance in hydraulic conditions within the riffle complex. In addition, cross-section locations were selected based on depth and velocity at low flow and amount of periphyton on the bed surface. Less depth, velocity, and periphyton was anticipated to be more conducive to installing tracers in order to maintain minimum disturbance to the bed. The cross-sections were located at the head, middle, and tail of this riffle complex and were approximately 100 to 200 feet apart (Figure 13). Three control points in addition to the cross-section monuments were set and located for future use with conventional or GPS survey equipment (see previous section on Control Points). Control points and cross-section monuments are tied to the control network and datum established for the 2007 topographic mapping in Reach 1A.

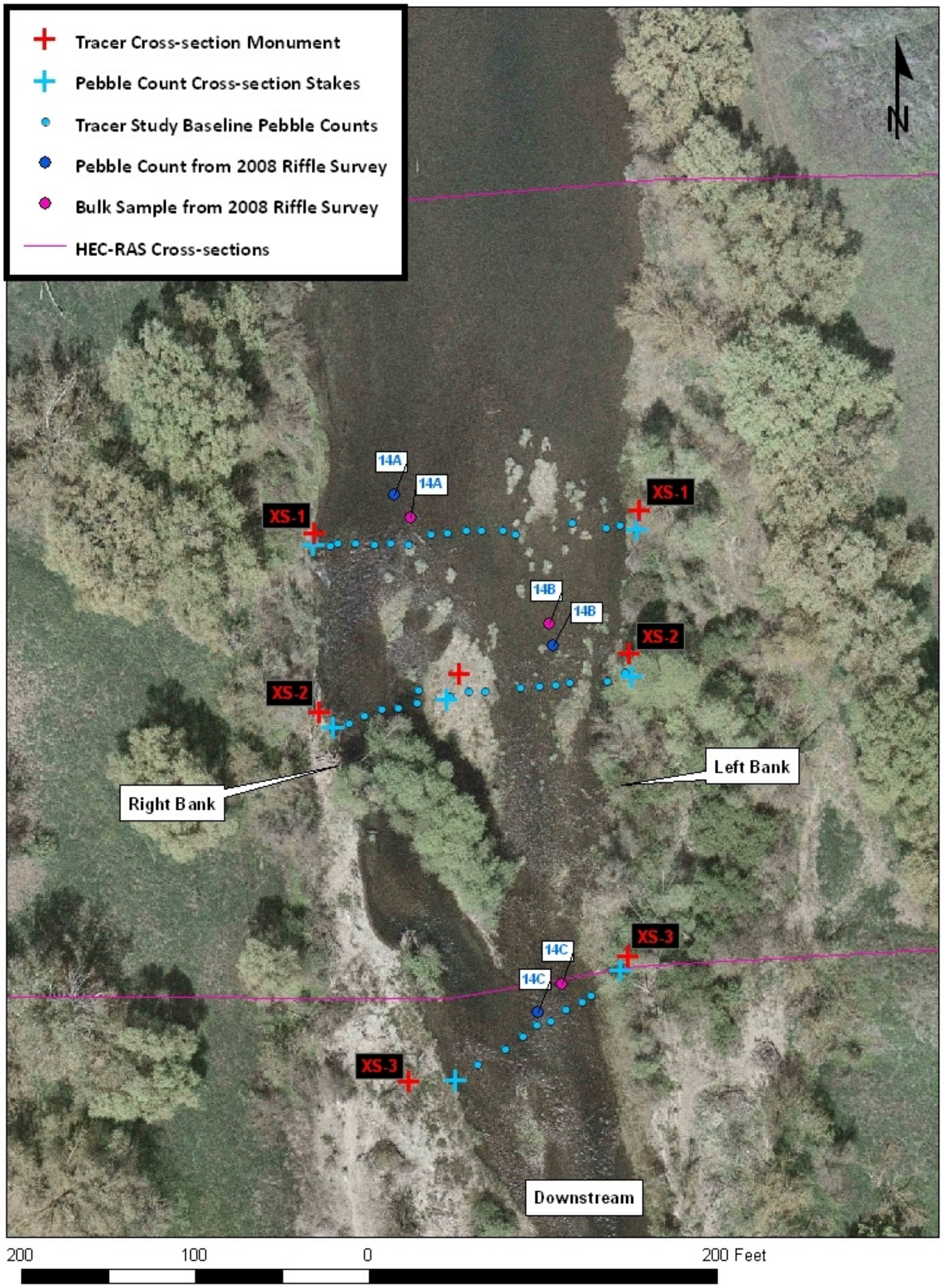

Figure 10 - Tracer study site at Riffle Cluster 38, Reach 1A, San Joaquin River. Tracer monuments indicate the line along which tracers were placed in the active channel. Midpoints of pebble counts traverse are displayed along with bulk sample and associated pebble count locations from the 2008 riffle gravel survey. HEC-RAS cross-sections are shown for potential reference to the 1D model.

Baseline Particle Size Survey

Prior to installing tracers a baseline particle size survey was performed for each cross-section. To avoid disturbing the anticipated tracer areas, pebble counts were performed at least 10 feet downstream of the tracer cross-sections. In order to detect trends in particle size distributions, pebble counts were divided into no more than 10 foot wide areas across the channel. Pebble counts were performed within the channel where the following conditions existed: absence of soil, predominance of gravel to cobble sized particles, and absence of dense vegetation. For example, when beginning a pebble count survey, we extended and tightened a tagline across the stream channel approximately 10 feet downstream of the associated tracer cross-section. Beginning at the closest gravel bedded portion of the tagline to the left bank, the pebble count would commence by sidestepping toward the right bank for ≤ 10 feet, such that upon having traversed 10 feet 100 particles were randomly selected, sized with a pebble-o-meter, and tallied on pre-made forms. After completion of the 10 foot wide pebble count another 10 foot wide pebble count was performed, and so on, until the channel had been completely traversed. In doing so, we were able to observe trends in the data relative to position within the channel (see Appendix V-I). In order to document the position of each pebble count the midpoint of each was surveyed using a handheld GPS unit (Figure 13).

Tracer Installation

To install the tracers, all particles with a visible portion larger than 32 mm within approximately 2 feet upstream of a cross-section tagline were marked with a Kevlar® based epoxy coating (paint). The tagline was stretched tight between either the monuments or a monument and a temporary midchannel stake. Tracers were installed within the channel where the following conditions existed: absence of soil, predominance of gravel to cobble sized particles, and absence of dense vegetation. Due to difficulty painting underwater, particles were evaluated as to whether manipulation would disturb the surrounding bed particles. If so, the particle was measured, scrubbed, painted in-situ, and if it was felt the particle retained enough paint to be recognized in the future, its information was recorded. Otherwise, each particle was carefully plucked from the bed, while carefully noting the particle's position and orientation, measured with a gravel-o-meter to the ½-phi size class and recorded, scrubbed of periphyton and silt, painted, and returned to the bed in its noted original position and orientation (Figure 14). Particles painted in this manner were typically able to accept a generous coat of paint on less than half the particles' surface area. Submerged in-situ painted particles, on the other hand, typically accepted much less paint and it was often questionable whether it would retain any at all with time. A different color of the paint was used for each cross-section to allow the source of mobilized particles to be identified during the data collection phase. At all times, field personnel worked downstream of the tagline and were directed not to walk over or near the planned or installed tracer cross-section areas.

Figure 11 – An example of the bed's condition before and after tracer painting (XS-3, approx bin 30-31)

Tracer Documentation

The tagline is divided into 2 foot units. Each 2 foot unit was considered a bin in which all particles painted within it was tallied according to its respective size class (see Appendix V-II). The total number of marked particles along each cross-section and within each 2 foot wide bin was recorded for later comparison with the post-experiment condition. See Figure 15 for an example of a completed tracer cross-section.

Figure 12 - An example of a completed tracer cross-section (XS-1, bins 33 to 54); viewed looking towards the right bank. In the foreground, most of the tracers are covered by a layer of silt that settled after installing these tracers. Closer to the far bank is seen the more active channel.

Photo-survey

As much as possible the bed along each cross-section was photographed using a high resolution digital SLR camera (Nikon D700), with a 35 millimeter (mm) lens and circular polarizing filter capable of distinguishing between the sand-sized and larger particles. This procedure was aided with the use of an in-house designed and constructed device we have named the photoscope (Figure 16). The photoscope is essentially a stainless-steel cone with a sheet of plexi-glass (the photoscope's lens) sealed onto the larger diameter end of the cone. The smaller diameter end of the cone is approximately 6 inches in diameter and allows one of the operators to insert the camera lens for collection of photos of the river bed particles as the other end is positioned beneath the water's surface. The photoscope allows the water's surface to be smoothed, light reduced, and glare minimized such that the bed particle details can be captured to as high a degree as possible. Included in each photo was a measuring tape (tied taut between the tracer cross-section monuments) so as to be able to determine the position relative to the stakes from the photo. Also, a scale was placed on the bed for the purpose of measuring particle sizes from the photos (Figure 17). Limitations to photographing the bed were related to depth of flow and velocity. If the depth was too shallow, the lens could not be fully submerged and significant reflections could not be overcome. If the flow was too swift, holding the photoscope in place without disturbing the bed became problematic.

Otherwise, photos were able to be collected. It is estimated that upwards of 80% of the cross-sections were photographed.

Figure 13 - Photoscope in use during photo-survey of cross-section 3; viewed looking upstream.

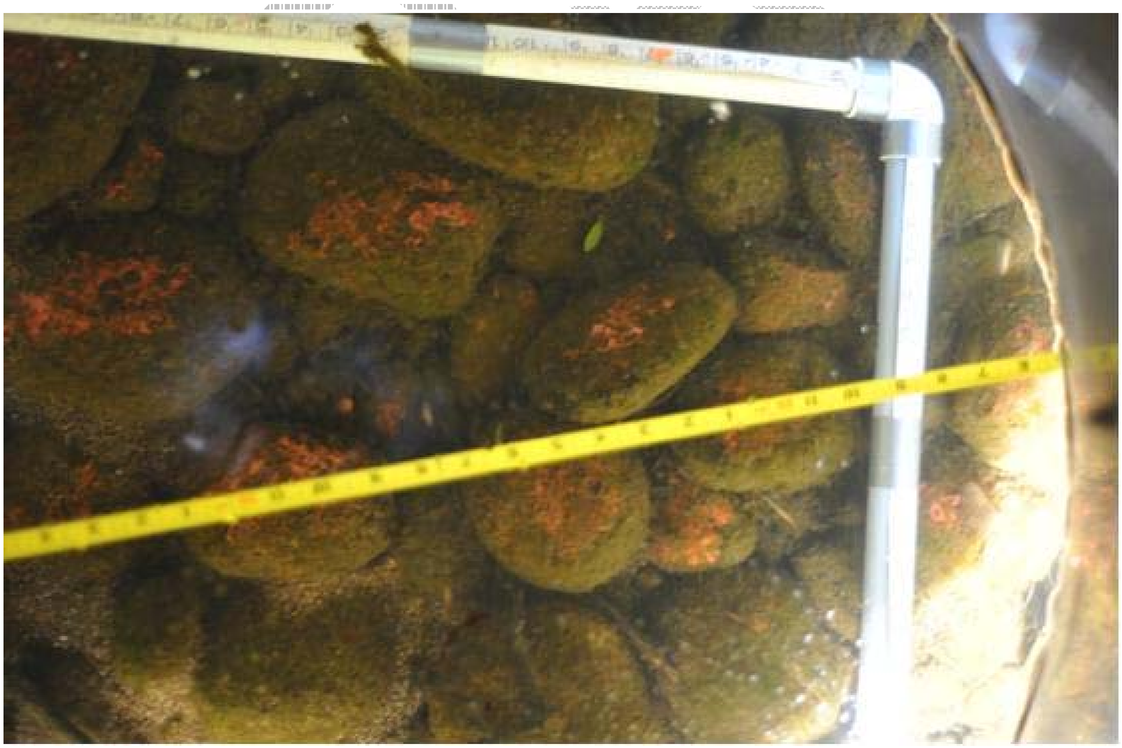

Figure 14 - An example of a photo of the bed shot through the photoscope. The yellow tape indicates the position along the cross-section. The white frame serves as a scale to measure gravel diameters.

Cross-sectional Profile Surveys

Conventional survey equipment was used to measure the northing, easting, and elevation along the tracer cross-sections and approximately 5 foot intervals or at breaks in slope. Additionally the monuments, pebble count stakes, water's edge, and banks were surveyed. For further information on these methods see previous section "Monitoring Section Toposurveys".

Stream Velocity Surveys

An Acoustic Doppler Current Profiler (ADCP) was used to measure the near-bed velocities above each cross-section during the interim flows. For further information on the methods used with the ADCP see the prior section on Flow Measurements.

Timing

The baseline conditions were monitored prior to significant flow releases; no later than October 1, 2009. Interim flow velocity measurements were collected after the associated discharge stabilized as indicated by California Data Exchange Center's (CDEC) gauge downstream of the study site at Highway 41 (H41). Discharge measurements were taken for the same high flow events that the velocity surveys evaluated. For the 350 cfs flow, velocity measurements were collected on October 29, 2009. For the 700 cfs flow, velocity measurements were collected on November 5, 2009. Post-interim flow tracer surveying was performed after flow conditions attributed to the falling limb of the hydrograph had subsided, such that Friant Dam discharge into the San Joaquin River (as gauged at the USGS's Friant gauge: 11251000) matched the discharge measured at the CDEC H41 gauge. Additional evidence that the falling limb had subsided would include a decreased flow at a relatively stable discharge.

Access

The entire study site is within the low-flow channel and is located within State Lands. Similarly, all associated monumenting and baseline surveys are located within State Lands. Prior to entering the State Lands, neighboring private properties must be crossed. In this case, the private property is owned by Cemex, Inc. Prior to crossing their property, Cemex, Inc. requests notification via a sign-in/sign-out sheet located in their onsite office. Therefore, each day work was performed at the study site, DWR personnel signed-in prior to accessing the property and signed-out upon exiting.

Environmental Documentation

Since the paint is not toxic, as per its material safety data sheets (MSDS), no permits were required for this low-impact study. Furthermore, riparian vegetation was left as-is, permanent engineered features were not installed, and wildlife was undisturbed.

Coordination Efforts

For this specific monitoring task, coordination with flow monitoring was critical. It was especially important that tracer studies and associated velocity profile measurements were closely coordinated with pressure transducer locations and discharge measurements. The information provided from these other monitoring efforts was critical for determining the velocities experienced near the bed (as measured from the ADCP) of the placed tracers relative to the discharge. As a result, measured mobility will be better associated with future release scenarios.

Data Presentation

The data collected thus far are relatively raw and, as such, have not been thoroughly analyzed. Still, the data were reviewed using quality assurance/quality control procedures to minimize errors resulting from transcription. Future analysis may present unforeseen anomalies resulting from the data that may result from measurement or recording error while in the field. If, during future analysis, data appears to be anomalous it will be referenced as such with full explanation as to why and where the error's possible source lies in corresponding analytical reports. With this understanding the initial pilot tracer study data is presented below.

Baseline Survey Data

The minimum and maximum median particle sizes (D_{50}) were 24 and 79 mm, respectively.

With regards to Cross-section 1 (XS-1):

- The finest D_{50} was 37 millimeters (mm), located within 2 to 10 feet from the left bank.
- The coarsest D_{50} was 58 mm, located between 126 and 136 feet from the left bank.

With regards to Cross-section 2 (XS-2):

- The finest D_{50} was 24 mm, located within 130 to 140 feet from the left bank, and 20 to 30 feet from the left exposed bank of a midchannel gravel bar that effectively acts as the left bank during low flow conditions (<<700 cfs). During summer low flows (~175 cfs) this area was a sandy back water area with significant eddies.
- The coarsest D_{50} was 69 mm, located between 160 and 170 feet from the left bank and immediately against the right bank.

With regards to Cross-section 3 (XS-3):

- The finest D_{50} was 38 mm, located within 96 to 110 feet from the left bank, and immediately against the right bank feet. It should also be noted that a smaller midchannel gravel bar bounds this pebble count area to the left, putting it in a slight side-channel.
- The coarsest D_{50} was 79 mm, located between 40 and 50 feet from the left bank and immediately against the right bank.

XS-1, XS-2, and XS-3 were measured to be approximately 180, 170, and 110 feet wide, respectively. Pebble count data and associated location and statistical information are tabulated in Appendix V-I. Sample locations are illustrated in Figure 13.

Tracer Installation Data

All surface gravel particles greater than 32 mm and within approximately 2 feet upstream of the tagline were attempted to be painted. Those particles painted sufficiently were measured and tallied according to size class. Each tally was recorded in such a way as to note its position along the cross-section transect to within about 2 feet. No trends were observed in the data nor has any analysis been performed. See Appendix V-II for the tabulated tracer data.

Discussion

Baseline Survey

The baseline survey used the Wolman pebble count method to estimate the surface grain size distribution along the three tracer cross-sections (Wolman, 1954). An arbitrary 10 foot wide traverse of the channel was used to section the channel into units. Each of these units could then have an associated grain size distribution. For the most part, any patchiness of the bed material was therefore ignored in setting boundaries between pebble count units. However, in some instances midchannel vegetation prevented a 10 foot continuous pebble count unit. This thick vegetation covered areas of what is assumed to be gravel material. The presence of the vegetation and its density would have biased the results as compared to the exposed gravel bedded areas. As a result, it is believed performing a random count of particles within the vegetated areas would lead to erroneous results. We therefore terminated a pebble count unit if it reached such an area within the 10 foot traverse. These areas can be delineated by observing breaks in the "tagline interval" on the data table (Appendix V-I).

From the pebble count data it can be generalized that the finest D_{50} was typically found along the channel margins. The coarsest D_{50} typically was observed towards the channel's thalweg, where stream velocities are greatest. Considering that the only D_{50}s less than the 32 mm tracer cutoff were located in a sandy backwater area conveniently makes the cutoff justifiable. The justification lies in that if the surface D_{50} is observed to be mobile it is generally suggestive that the bed is fully mobile (Parker and Toro-Escobar, 2002). Therefore, if the median particles are mobilized then it can be generally assumed that the sediment patch experienced full mobility. Since, the lowest D_{50} was captured by the 32 mm cutoff the entire cross-sections can be evaluated for at minimum full mobility and, in most bins, for partial mobility.

Overall, the baseline survey was straight forward and resulted in data that met expected conditions as casually observed in the field as well as from understanding of the general distribution of particle sizes within river channels.

Pilot Tracer Survey

Since little tracer data has been collected this discussion will focus on the methods used and will include a thorough discussion of the limitations and problems encountered in implementing this pilot study. As mentioned previously, the method used for installing tracers is meant to be a pilot project. The procedures used to gain better understanding of the bed mobility and the success of their outcome depends on many factors. These factors include the physical environment (i.e. stream flow velocity, depth, rock type), biological environment (i.e. periphyton on gravel/cobble surfaces, willow roots), anthropomorphic environment (i.e. people canoeing, kayaking, fishing, recreating, etc.), equipment malfunctions (i.e. subaqueous adhesion of paint), and human error. The following discussion will detail these factors in relation to the method.

Before installing the tracers the physical conditions were the first thing that needed to be considered. Ideally, the bed material would be painted in-situ with negligible disturbance of any potential tracer and surrounding material. However, in order to apply the paint to the potential tracer the gravel/cobble particle needed to be scrubbed clean of any matter on its surface. We used either a wire brush or scrub pad to remove algae and silt from the rock's surface. Attempting to scrub an in-situ particle proved difficult, especially for smaller particles (<64 mm), embedded particles with a small surface exposed, as well as particles that were loosely positioned amongst its surrounding particles. Swifter flowing water and increasing depth only confounded the difficulty. But the greatest problem encountered with painting submerged particles was in getting a sufficient coverage of the particle with paint. It was found that the paint would only stick to small areas of submerged particles. Apparently, these small areas were in places on the rock where the paint found a surface suitable to cling on. Possible suitable surfaces might have been a rough spot, groove, etc. on the particle. As a result of this difficulty, painting tracers in-situ was rare. In fact, it was only attempted when it was deemed otherwise disruptive to the surrounding bed material or if the particle would not be able to be replaced in its original position.

Instead, most of the tracers were installed by plucking the particle from the bed surface and then applying the paint, which was also proven to be somewhat problematic. Particles were thoroughly scrubbed clean of any surface matter and measured. Then the paint was attempted to be applied using ones fingers to forcefully smear the paint onto the surface. Sometimes it was found that the particle wouldn't take any paint. Other times, it was found that the particle would preferentially take paint on a certain side of the particle but not on the other. The rest of the time a sufficient amount of paint would go on relatively easy. There was no obvious reason that could be come up with to suggest why these differences existed.

Another problem often observed was after applying a coat to a particle's surface and upon reaching down to the bed to replace it, the paint would peel off in the flow. The effect would be a particle with very little paint remaining on its surface. Sometimes a large portion of paint would be left flapping in the flow as a part of it retained adherence to the particle. Under these circumstances, a judgment call was required to ascertain whether or not enough paint remained or would remain such that the particle would be noticed as a tracer on a later date.

Further paint issues were observed after having left the tracers in place for a while. It was noticed that a small patch (~4 bins wide) of tracer experienced their paint, though hardened, completely detaching from their surfaces. The paint, still molded in the form of the tracer's surface was found within several feet of the tracer cross-section. About half a dozen to a dozen tracers in this patch showed signs of this. This was witnessed in a shallow, calm, backwater type area of the channel (XS-1, ~ bins 36-40). However, if this condition were to have occurred in the swifter flowing areas such evidence would not be observed and it will likely be assumed that the tracer is absent from where it was placed. The cause of the paint detaching from particles is not known. Though, we suspect two possible reasons: (1) The ratio of base to pigment was too rich in one of these constituents (human error); or (2) The mixed paint was too well cured by the time it was applied (equipment difficulties). The base/pigment mixture ratio should be one-to-one and upon mixing lasts approximately 30 minutes before becoming too viscous and unworkable.

Positioning of field personnel within the swifter flowing channel areas was critical. It was observed that in deep (>2 feet)) swift (~4 feet/second) flow it was possible for a person to inadvertently create a condition that would scour the bed around one's feet. When blocking the flow with one's legs or body flow against it would accelerate around. It was this accelerated flow and possibly shifting feet/knees that aided in the scour. This condition was observed to occur at first on XS-1 at bins 68 through 70. Upon witnessing the bed scour, tracer installation was halted. We observed that the scour in this area extended in to bins 68 through 70 and noted it. Since flow was equally as fast in the remaining bins (70 through the right bank) we decided to install only a couple tracers from each size class in each bin, thereby reducing time spent near each bin and associated scour in to the bins. This tactic succeeded in reducing scour into the bins for bins 70 through 84. Though, scour around our feet, downstream of the tagline, still occurred as evidenced by the bed being left significantly coarsened with cobbles and clean surfaced (i.e. no algae covered or other surface stained bed material). It is not known what influence this has had on mobilizing the tracers.

Anthropomorphic issues may be in the form of vandalism or other more casual disturbance of the measurement instruments. The study site was selected partly because of its remoteness and lack of easy public access. Still evidence of human presence is observed from refuse left on the banks. Also, approximately one group per day of canoes/kayaks passed through the study site during our days in the field. No evidence of intentional disturbance has been observed thus far. Similarly, the effects of unintentional disturbance have not been observed either. But tracers located in the more active portions of the channel are also located in areas where canoes and kayaks pass over. In these areas boaters may scrape the bed at low flows. Also, it was witnessed that boaters will get out of their boat and wade through these swifter moving areas, potentially kicking tracers or otherwise disturbing the bed. There is no way of overcoming these problems but it is worth noting their influence on over predicting flow induced bed mobility.

In regards to human error and this method there are certain issues that were noticed and that should be acknowledged prior to assembling a future field crew. Ideally, all participants would have an interest in seeing the method produce reliable results as well as knowledge of the physical interaction between flow and bed particles. Negligence on anyone's part would lead to less consistency in their tracer installation and/or tracers placed in positions that are more likely to be mobile at lower flows.

Photo-survey

Similar to the pilot tracer study, the photo-survey method is still in the development stages. As much as was possible the tracer cross-sections were photographed such that a photo was taken of the bed at a resolution of approximately a photo for every 1.5 square feet. In the higher velocity flow portions of the cross-sections no photographs were collected using the submersible photoscope. Instead, a photograph was taken that included all the distortions from the water's surface. The distortions include reflection and glare from an uneven surface. Using the photoscope reduced these distortions. However, after reviewing many of the photos taken with the photoscope it is evident that more practice and design modifications are required. Difficulties to be over come will include insuring that the stretched measuring tape is not twisted; designing a better scale; and insuring that the camera is properly focused on the bed and not the surface of the plexi-glass. Even with these problems apparent in many of the photos, they may still prove useful. Though far from perfect, the intention of taking these photos was to document, as much as possible, details regarding the existing bed condition including textures, bedforms, and tracers.

Tracer Cross-section Topographic Survey

Conventional methods were used to survey the latitude, longitude, and elevation of the bed at points along the downstream edge of the tracer cross-sections. In most cases the survey extended beyond the cross-section monuments to measure the topography within the riparian zone. The results from this survey will be compared with post-interim flow bed elevations along the cross-sections to estimate net scour and deposition. Additionally, this data may be used in the future in developing a flow model. See Appendix V-III for the tabulated baseline topographic survey data.

Velocity Measurements

Velocity measurements were collected on October 29 and November 5, 2009 during 350 and 700 cfs flows, respectively. Current profile results from the 350 cfs flow showed that the approximate maximum velocity encountered along XS-1 was 8 feet per second (ft/s); XS-2 was 8 ft/s; and XS-3 was 6 ft/s. Results from the 700 cfs flow showed that the maximum velocity encountered along XS-1 was 8 ft/s; XS-2 was 10 ft/s; and XS-3 was 8 ft/s. It should be noted that discharge measurements, as calculated from the ADCP at the study site, were unreliable due to flow and channel conditions (i.e. eddies along the banks, turbulence, and shallow areas over midchannel bars). Using the velocity data generated by the ADCP post-processing software, particle movement will be better compared with the velocities encountered along each cross-section. This information may be useful in corroborating whether an observed absence of tracers can be substantiated by the velocities or variance in velocity (a proxy for turbulence) measured in a locale.

Future Data Collection

Tracer Mobility Surveys

After the interim flows fall to low flow (~150 cfs) conditions (expected by January 2010) the bed will be examined for evidence of mobility. An Aqua Scope™ will used to assist in viewing the bed under the water's surface. A coarse examination will be performed by stretching the tagline between each cross-sections monuments and counting painted tracers. Each tracer found will be examined to determine if manipulation will disturb neighboring bed material. If it is determined that manipulation will disturb the bed the particle's size class will be estimated. Otherwise, the particle will be plucked from the bed, carefully noting position and orientation, measured with a pebble-o-meter so as to insure against measurement bias, and the information recorded and the tracer replaced in its original position and orientation.

Post-High Flow Surveys

Future monitoring will be performed after a number of flow releases from Friant Dam ranging from 1,000 to 8,000 cfs, which are believed to have the potential to cause sediment mobility in the monitored riffle. After these high-flow releases, the tracers that remain on the cross-section will be counted and re-measured by pebble-o-meter so as to insure against measurement bias. The cross-sections will also be re-surveyed to evaluate changes in topography if scour or deposition occurs. Furthermore, the tracer cross-sections will be photo-surveyed again to compare with bed conditions prior to the high flows. The area downstream from the cross-sections will be examined to locate particles that were mobilized. The locations of all such particles will be resurveyed, and their sizes and source, based on marked color, measured and recorded.

Analysis

It is expected that after the cross-sections are surveyed for presence/absence of tracers and post-flood topography is re-surveyed, a comparison will be made with the corresponding proximal grain size distributions. Since the tracers are all 32 mm and greater, it is important to know the relative abundance of those size classes with respect to the bed's grain size distribution for making conclusions on the overall mobility. Furthermore, this comparison can also be used to correlate mobility to the proximal grain size statistics. Finally, this information should prove useful for evaluating and calibrating MEI's bed mobility model as well as for designing augmentation projects with the intention of mobilizing the bed (cf. Stillwater et al. 2008).

High Flow Surveys

During the high flow releases of various discharge levels flow velocities will again be measured using an ADCP along the tracer cross-sections.

Coordination

To optimize resources, coordination between monitoring efforts is necessary. For this specific monitoring task, coordination with flow monitoring is critical. It is especially important that tracer studies and associated velocity profile measurements are closely coordinated with pressure transducer locations and discharge measurements. This information is critical for determining the velocities experienced near the bed (as measured from the ADCP) of the placed tracers relative to the discharge.

Planning

If the pilot tracer study is deemed a sufficient monitoring method future tracer installation planning should require a maximum of a two to four person team to establish monuments, perform a baseline survey, and install tracers. Two people were required for the baseline survey at a rate of about one day per cross-section. With four people, it was possible to do a tracer cross-section in about 5 days, depending on the width of the channel and the distribution of the bed material. Resurveys of each cross-section after a significant event will likely take 3 people 2 days for each cross-section, or 18 person days total.

Conclusions and Recommendations

Conclusions

A physical monitoring plan developed to obtain data that can be used to support analysis, design and implementation of the San Joaquin River Restoration Plan (SJRRP, 2008) was initiated during the Fall 2009 interim releases. As part of this monitoring effort, the following elements were implemented by the California Department of Water Resources (CDWR), with assistance from their consultants Tt-MEI and P&P, and although a detailed analysis of the various data elements has not yet been conducted, the following conclusions can be made.

<u>Control Surveys in Reaches 1A and 2A</u>

- All control points for the initial phase of the monitoring program were successfully established. Additional control will still need to be established for portions of the river outside of Reaches 1A and 2A.
- An adequate GPS base data signal from network stations was able to be received within at least Reaches 1A and 2A.
- Development of teams consisting of a combination of members from DWR, Tt-MEI, and P&P produced favorable results due to the variable expertise and background of the various members as well as to inherently improving the communication between different monitoring teams.

<u>Measurement of water-surface profiles in Reaches 1A, 2A, and 2B</u>

- Surveyed water-surface elevations were collected at an appropriate density to adequately define the shape of the water-surface profiles at Friant Dam releases of 350 cfs and 700 cfs.
- Surveyed water-surface points appear to have successfully captured all significant hydraulic controls.
- Data collected during this effort is expected to be of significant value in the improved calibration of the hydraulic model.

<u>Flow Measurements in Reaches 1A, 2A, and 2B</u>

- Measured flow data supports the observed decrease in discharge in the downstream direction, and refines the distribution of the flow losses.
- Data collected during this effort is expected to be of significant value in the improved calibration of the hydraulic model.

<u>Installation and operation of water-level recorders in Reach 1A</u>

- A total of 5 water-level recorders were installed.
- Valuable information and insight regarding the best and most efficient method of installing the water-level recorders was obtained during this monitoring session.

<u>Bed material sampling in Reach 1A</u>

- A total of 98 pebble counts and 66 bulk samples were collected in Reach 1A.
- Linear regression models used are likely sufficient to estimate grain size composition trends of short reaches (< 20 miles) but may not be applicable over longer distances.

- Silt and clay were found in negligible amounts. Sand content was between 1.5 percent and 28.9 percent with a mean of 10.2 percent.
- In total, 59 (89 percent) of undifferentiated samples met the criterion for suitable Chinook salmon egg incubation and alevin emergence.
- Linear modeling indicates that Reach 1A is generally characterized by grain size compositions that are suitable for Chinook spawning.

Marked-rock tracer studies in Reach 1A

- A pilot study using tracers was implemented at a single riffle cluster in Reach 1A.
- Baseline evaluation of pebble count results generally agreed with anticipated conditions.
- In-stream conditions made application of tracer paint difficult, and may affect future data collection.
- Valuable information was obtained regarding implementation procedures that will likely lead to improvements during future implementation.
- Although a significant high flow event has not yet occurred since installation of the pilot tracer study, detailed data regarding potential bed mobilization will be collected in January and February 2010 and again after Spring 2010 flows.

Topographic surveys of monitoring cross sections in Reach 2A

- Topographic surveys were conducted at 11 sites in Reach 2A.
- Monitoring wells were included in survey.
- Six to eight cross sections were surveyed at each site.
- Surveys are expected to adequately show localized changes in bed formations due to various flows at each monitoring location after post-flow resurveys.

Installation of scour chains in Reach 2A

- A total of 4 scour chains were installed at each of two cross sections in Reach 2A.
- After the initial Fall 2009 flow releases, the scour chains were re-inspected and were found to indicate scour and re-deposition in two cases.

Bed Material sampling in Reach 2

- Bed material samples were collected at 20 locations along Reach 2.
- Gravels were shown to be present at a few of the locations along Reach 2. As expected, the majority of the bed material consisted of coarse sand.

Recommendations

Control Surveys in Reaches 1A and 2A

- Involvement of professional surveyors with the initial placement of survey control points at each site will help ensure that each location is adequate for survey purposes.
- The amount of human traffic and potential vandalism should be carefully considered, and steps should be taken (e.g. alternative location, more permanent installation, etc.) in high-traffic areas to reduce the potential for disturbance to established control points.
- The importance of collecting survey data in areas where GPS satellite signal might be obscured, such as in close proximity to bridges, should be determined prior to future monitoring efforts to

allow coordination with conventional survey equipment if survey points directly at these locations (i.e. rather than simply nearby) are deemed essential.
- Continue to obtain legal access to additional sites in order to allow additional survey control to be established beyond Reaches 1A and 2A.

<u>Measurement of water-surface profiles in Reaches 1A, 2A, and 2B</u>

- Continue to conduct future surveys of water-surface elevations in a similar manner and based on the same set of guidelines and protocols.
- Consider additional safety measures during future monitoring events that will be conducted at higher discharge releases.

<u>Flow Measurements in Reaches 1A, 2A, and 2B</u>

- Further investigate the cause of a measured increase in flow between Ledger Island and Rank Island. Inspect potential split flow areas for active discharge during future monitoring efforts, or evaluate possibility of adjusting flow measurement location.
- Consider additional safety measures during future monitoring events that will be conducted at higher discharge releases.

<u>Installation and operation of water-level recorders in Reach 1A</u>

- Ensure that protective pipe surrounding the water-level recorder is adequately stabilized, and that the stabilization measures are installed in such a manner as to likely be able to withstand contact with moderate floating debris.
- Continue to evaluate performance of water-level recorders relative to each other as well as to nearby stream gages.

<u>Bed material sampling in Reach 1A</u>

- Investigate apparent surface coarsening in the vicinity of river miles 259 through 260.
- Collect additional bulk samples in areas where the substrate was not discretized, where anomalies in the data exist, and where downstream study limits have not identified the extent of unsuitable conditions for Chinook spawning gravels. In addition, future bulk samples should be collected to provide sufficient data for the purpose of corroborating with the pebble count results.
- Analyze the difference in weight between wet coarse material and dry coarse material to investigate the disparity in the apparent bulk samples in sampling coarser material compared to pebble count method.
- Encourage SJRRP agencies to use this data to begin focused effort to estimate suitable spawning habitat area. Measure spawning areas and collect large enough samples (Bunte and Abt 2001) to verify via statistical significance that areas estimated by observation to be suitable are adequate.

<u>Marked-rock tracer studies in Reach 1A</u>

- Use velocity measurement equipment to provide additional source of velocity information at tracer sites.
- Consider methods of improving the application of tracer paint and consider alternative methods for marking future study sites.

- Implementing an appropriate tracer study is a complex task, and diligence should be stressed and maintained in all aspects of the process.

Topographic surveys of monitoring cross sections in Reach 2A

- Complete a comparison survey after each peak flow event.
- Comparison surveys need to survey area within the wetted perimeter, and sufficient distance outside the wetted perimeter to show that comparison survey blends into previous survey.

Installation of scour chains in Reach 2A

- Plan to collect additional data during higher flow releases to record bed material movement at scour chain sites.
- Consider methods for scour chain recovery in wetted portions of the channel.

Bed Material sampling in Reach 2

- Continue to collect sediment samples in conjunction with cross sectional surveys.

References

1. Bunte, K. and S. R. Abt, 2001. Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. Gen. Tech. Rep. RMRS-GTR-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 428 p.

2. Das, B. M. (2005). *Principles of Geotechnical Engineering 6th.* Florence, KY: Cengage Learning.

3. Mussetter Engineering, Inc, 2008. DRAFT San Joaquin River Data Collection and Monitoring Plan, prepared for California Department of Water Resources, August 27, 31 pp.

4. Parker, G., and C. M. Toro-Escobar, 2002. Equal mobility of gravel in streams: The remains of the day. Water Resour. Res., 38(11), 1264, doi:10.1029/2001WR000669.

5. Transportation, D. o., 2000. *Test 202: METHOD OF TESTS FOR SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES.* Sacramento.

6. San Joaquin River Restoration Program, 2008. Monitoring Plan for Physical Parameters, Draft Technical Memorandum, September – Version II, 98 pp.

7. Stillwater Sciences, University of California Berkeley, and San Francisco State University, 2008. Physical Modeling Experiments to Guide River Restoration Projects: Final Report (Restoration Manuals). Contract No. ERP-02D-P55. Prepared for CALFED Ecosystem Restoration Program, Sacramento.

8. Wolman, M.G., 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union, 35(6):951–956.