Study 28

Reach 1A Spawning Area Bed Mobility

Public Draft
2013 Monitoring and Analysis Plan

SAN JOAQUIN RIVER
RESTORATION PROGRAM

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28.0 Reach 1A Spawning Area Bed Mobility

28.1 Statement of Need

The Problem Statement for Healthy Fry Production expresses the need to understand the limiting factors to healthy fry production, which include egg survival and redd superimposition (SJRRP, 2009). Egg survival is dependent on intragravel flow delivery of DO, which is influenced by the fine sediment content within the gravel interstices. Redd superimposition is dependent on availability of suitable spawning gravels relative to the number of spawning pairs. The suitability of spawning gravels is not only based on grain size composition but also the looseness of the bed material such that it allows ease of redd construction. Therefore, understanding the condition of the stream bed (i.e., texture, amount of sand and silt, and the degree of bed reinforcement) in areas that are otherwise expected to be suitable for spawning (i.e., have sufficient flow velocity and depth during spawning and incubation periods) is pertinent to the success of the restoration effort.

Bed surface coarsening (a.k.a. armoring) is often exacerbated by the installation of dams that reduce sediment supply to downstream reaches. An armored bed effectively traps finer sediment beneath and between the stable surface particles. These fine sediments inhibit intragravel flow and therefore reduce DO delivery as well as metabolic waste removal. By entraining coarsened surface particles, fine sediments (sand, silt, and clay) trapped within the bed framework can be flushed (Reisser, et al., 1989). Theoretically, there are two beneficial outcomes of this process. The first is that by reducing the concentration of fine sediment the stream bed is better ventilated thereby increasing oxygen delivery to and waste removal from incubating embryos (Kondolf, 2000). The second is that the armored surface is often in a locked pavement-like state, and by breaking it apart, a looser structure is then created that facilitates redd construction (Wilcock et al., 1996). Loose, mobile gravels allow spawning salmon to construct a redd of sufficient depth so as to protect their eggs from predation and physical stream processes. A reinforced bed condition will limit, redd construction to looser areas. If such areas are limited relative to available spawners redd superimposition will be encouraged. Therefore, where the stream bed is reinforced to such a degree as to inhibit redd construction spawning areas quantified solely by flow conditions and surficial grain size composition, the amount of spawning area will be overestimated. For both these reasons, a stream bed surface that is able to be mobilized is a condition necessary to maintain suitable salmon spawning and incubation habitat.

28.2 Background

Several studies have concluded that bed material mobilization required to maintain salmon spawning habitat and create in-channel and channel-margin habitat in Reach 1A generally requires flows in the range of 12,000 to 16,000 cfs (MEI, 2002; JSA and MEI, 2002; McBain and Trush, 2002; Stillwater Sciences, 2003), well above the maximum Restoration releases called for in the Settlement. Hydraulic and sediment transport analysis by MEI (2002), however, showed that some local reworking of the bed should occur at flows in the 3,000 to 8,000 cfs range. This analysis specifically indicated that bed mobilization would occur at flows of less than 3,500 cfs at riffle clusters 38 (RM 260.6), 40 (RM 261.4), 43 (RM 264.7), 46 (RM 266.6), and 47 (RM 266.7). Grain size analysis of the San Joaquin River's bed near riffle crests indicates an armored condition (DWR, 2009). Since the expectation is that the majority of the riffles exhibit a nonmobile condition in anticipated Restoration release scenarios, spawnable areas are predicted to be reinforced and have reduced intragravel flow. Therefore, it is necessary to quantify the extent of those areas that are mobile and thereby maintained by more frequent flow levels. In addition, measurements will be collected to allow for a reliable prediction of the discharge necessary to disrupt the reinforced bed surfaces and flush the trapped fine sediment.

28.3 Anticipated Outcomes

Results of this study will provide information to accomplish the following:

- Characterize bed material relative to requirements for incubating embryos proximal to anticipated spawning areas (i.e., riffles, runs, and pool tail-outs) at finer resolution than is currently available.

- Measure the frictional resistance of the existing bed surface.

- Calculate the threshold shear stress for incipient motion specific to critical areas.

- Calibrate and validate a sediment transport and flow model that can be extended throughout upper Reach 1A.

- Use the calculated threshold shear stress to predict the rare high-magnitude flow events necessary to entrain the reinforced channel beds and maintain suitable habitat.

- Develop the requisite understanding of the relationship between stream discharge and stream habitat maintenance.

- Refine the estimated quantity of available spawning gravels based on: (1) area maintained by anticipated pulse flow levels, (2) bed material characteristics, (3) flow depth, and (4) velocity during spawning and incubation relevant flow levels. Provide information for alternatives to maintain a sufficient quantity of productive spawning gravels.

28.4 Methods

At least two monitoring sites were selected at locations where analytical modeling suggests bed mobilization will occur at flows of less than 3,500 cfs (MEI, 2008). To assess bed mobility, several measurements will be collected such that their combination can be used to develop a predictive model of bed material mobility. These tasks will include measuring the force required to mobilize surface gravel particles, characterizing particle size, deploying and monitoring radio frequency identification tagged (RFID) gravel and cobble tracers, repeated topographic surveys, monitoring scour chains, surveying flow hydraulics, and developing a calibrated and tested flow and sediment transport model (Figure 28-1).

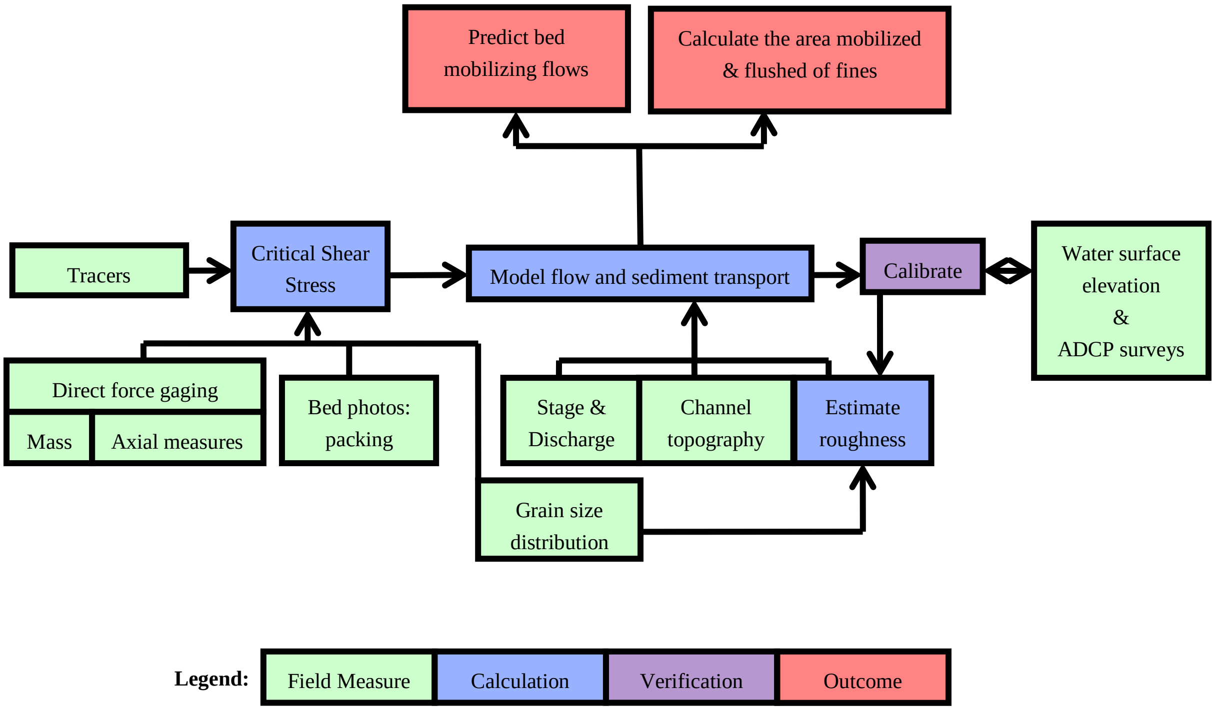

Figure 28-1.
Flow Diagram for Predicting Bed Mobility and Flushing Flow Maintained Habitat

28.4.1 Force Gaging

Force measurements and particle characterization surveys will be conducted at the onset of the study. Force gaging will be performed using submergible, spring-resisting, push-pull force measuring devices. Force gaging will be performed in areas delineated within approximately 20 feet of monitoring cross sections. Particles will be selected at random by the "selecting a particle without looking" method. All attempts will be made to test undisturbed water-worked particles. Additionally, roughly 20 particles of each size class (32 mm, 45 mm, 64 mm, 90 mm, 128 mm) will be gaged to determine a representative distribution of forces for each class for each area that typifies a channel feature (e.g., thalweg, bar head, bar chute, bar toe) that traverses the cross sections. All gaged particles will be measured for mass, 3D axes, and qualitatively described for rounding. Each particle's gaged force, mass, and size will be used to predict the friction angles with respect to the median particle size determined from a local pebble count and/or bed photographs.

28.4.2 Bed Photographs

Photographs of the bed will be taken to produce a high-resolution grain size analysis that includes the superficial sand-sized portion of the bed's surface. Additionally, from these photos we will determine the degree of packing on the bed surface, which may assist with calculating the critical shear stress for incipient motion of a particle. The photographs will be taken through a scope with a plexiglass bottom. The scope will straddle a measuring tape stretched between the two monuments that delineate the cross section so as to note the distance from the left bank's monument. Attempts will be made to photograph as much of the bed along the monitoring cross sections as possible, with the main constraints being flow depth and velocity.

28.4.3 Pebble Counts

Pebble counts will be performed along the monitoring cross sections, not to exceed 30 feet distance from the cross section. A pebble count will be performed at intervals of approximately every 10 to 20 feet of width parallel to the cross sections. Width will depend on the variance exhibited in the cross-sectional profile and surface texture. This level of resolution should provide adequate information on trends in grain size with location along the cross section. Grain size statistics will be calculated from the pebble count results. The statistics will be used in calculating the critical shear stress for particle mobility as well as for calibrating the roughness in the flow model.

28.4.4 Topographic Surveys

Conventional and Real Time Kinematic (RTK) GPS survey equipment will be used to survey the channel bathymetry. The channel bathymetry will be used to create the topographic mesh boundary condition within the flow model). Included in these surveys will be water's edge, edge of banks, and staked cross sections intended for repeated survey so as to observe changes in channel geometry with time. Water's edge measurements will be used to calibrate the flow model. The repeated cross-sectional topographic surveys will also be used as a means of validating the sediment transport model and channel evolution predictions.

28.4.5 Flow Profile Surveys

An acoustic Doppler current profiler (ADCP) fitted with either a differential GPS (1 meter horizontal accuracy) or RTK GPS (2 cm horizontal accuracy) will be used to measure channel flow hydraulics for elevated flows in the vicinity of the tracer cross sections and study sites. Results from the survey will be used to compare flow attributes in the vicinity of the tracers with their movement or lack thereof. Also, the ADCP velocity results will be used to calibrate the flow model.

28.4.6 Scour Chain Monitoring

Scour chains will be installed in the vicinity of the tracer cross sections and surveyed to 2 cm of horizontal accuracy to assist in future location. They will be placed at distances suited to cover the range in lateral topographic variation and will likely be on the order of every 20 feet across the channel width. Similar to the repeat topographic surveys, the results from the scour chains will be used as a means of validating the sediment transport and channel evolution model's predictions.

28.4.7 Gravel and Cobble Tracers

Particles greater than 32 mm in intermediate diameter will be collected from areas where they will later be placed as tracers. These particles will be transported back to the laboratory for measurement of size, mass, and roundness, and inserted with inductively charged RFID tag. The RFID tag's unique identification code will be recorded with its measurements. Additionally, the tracer will be painted for ease of locating, especially when buried so as to record the burial depth. Placement of the tracers will be along the monitoring cross sections spanning the channel's width. Each tracer will be positioned on the bed such that it replaces a similar particle's size, shape, and relative position to surrounding particles. Tracers will be placed before high-flow events, and their initial locations will be surveyed using RTK GPS equipment. The surveyed latitude, longitude, and elevation will be recorded with other measurements and RFID code. During high flows, hydraulic properties proximal to the tracer lines will be surveyed using an ADCP with the primary intention of recording near-bed velocities as well as for calibrating a 2D flow model. After flows return to safe levels for accessing the channel, the tracers will be relocated and their new position surveyed as before. The extent of bed material mobilization will then be compared to discharge levels as recorded from local pressure transducers maintained by DWR. The results of the tracer movements and the calibrated flow model will be used to test the computed critical shear stress. Finally, by mapping grain size distribution using the pebble count and bed photography results it will be able to calculate the area and degree (i.e., nonmobile, partial mobility, fully mobile) of the bed mobilized for differing flow scenarios.

28.4.8 Flow and Sediment Transport Model

A flow and sediment transport model will be used to predict flows capable of producing mobilization of the reinforced bed material. These rare, elevated flows will expand the area of usable spawning gravels and therefore provide a management alternative to enhancing the bed surface for restoration purposes. A computational grid was developed using the USGS's Multi Dimensional Surface Water Modeling System (MD_SWMS) and computed hydraulic conditions using FaSTMECH's 2-D flow software (Nelson and Smith, 1989). The FaSTMECH model will be used as a predictive tool for (1) calculating local hydraulic parameters (i.e., shear stress and velocity) as they vary laterally and longitudinally in the channel, and (2) predicting the conditions experienced under rare, high-magnitude discharge events. Drag coefficients are the variable of adjustment to calibrate the model. Surveyed roughness elements (i.e., bed forms, vegetation patches) and measured bed texture will be used as the basis for specifying the channel roughness. Additional tuning of the model will be performed using the ADCP-measured velocity vectors to adjust local roughness elements (e.g. LWD and vegetation). Tracer gravels will be used to determine locations that incurred mobility under differing flow levels and determine the critical shear stress for grain entrainment. Assigning the calculated critical shear stress into the sediment transport component of the model the transport rate will be calculated. Additional validation of the model results will include the scour chain and repeat topographic surveys as they will confirm FaSTMECH's channel evolution component.

28.5 Schedule

These field tasks have been commenced at two riffle clusters (Riffle Cluster 38 and 40, MEI, 2008) located at RM 260.7 and RM 261.6 in January 2010 and July 2010, respectively. Six cross sections at each site have been staked across the channel width for future comparison. Each has had repeated topographic surveys, ADCP measurements of cross-sectional hydraulic measures, tracers deployed, force gage surveys, pebble counts, and bed photo-surveys.

With the recent high-flow levels (approximately 7,800 cfs) we expect to be able to quantify the maximum bed area maintained under the Restoration flow levels at the monitored sites. Ideally, the tracers would be used in flow conditions that are close to the conditions needed for incipient motion so as to better estimate the critical shear stress component of the transport function. Therefore, we will attempt to survey the locations of all tracers that have been deployed and replace those that have been mobilized with the intention of verifying the critical shear stress calculated from direct field measurements.

Each of the field measurements listed in the methods section may be repeated and/or extended to additional sites. Reasons for repeating these measurements would include (1) changes in bed texture from scour and or deposition, (2) changes to channel geometry, (3) to acquire additional information (e.g., data points for mobilizing flows), and/or (4) bed armor disruption that causes a suspected change in the resistance of the bed's surface material. Additional sites may be added to the study to (1) expand our understanding of mobility under conditions that are not bracketed by the two sites; (2) to test the model's predictions; or (3) to monitor gravel augmentation or restored sites. It is the intention of this study to be able to expand the model's predictive capability throughout Reach 1A, or at least to those areas expected to have flow conditions suitable for channel and habitat maintenance and successful spawning and incubation.

28.6 Deliverables

The results of each component in the methods, including force gaging, bed material characterization, pilot tracer study, and flow hydraulic survey methods, and preliminary results are presented in the February 2010 ATR. Results from the tracer studies, topographic surveys, hydraulic surveys, and force gage measurements are presented in the February 2011 ATR. A report detailing investigation activities, analysis, results, and conclusions will be presented as an appendix of the 2013 ATR. Similarly, additional data collected as a part of this investigation will be presented as an attachment of the 2013 ATR.

28.7 Point of Contact/Agency

Matthew A. Meyers, P.G./DWR
(559) 230-3329
mmeyers@water.ca.gov

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