Study 28

Reach 1A Spawning Gravel Mobility

Final
2015 Monitoring and Analysis Plan

SAN JOAQUIN RIVER
RESTORATION PROGRAM

January 2015

1.0 Reach 1A Spawning Gravel Mobility

Theme(s):

- Flow management
- Spawning and incubation

Related Question(s):

- SI-001a: Is spawning habitat quality in Reach 1A sufficient to support adequate egg survival and healthy emergent fry for both spring- and fall-run Chinook salmon?
- SI-001d: Are gravel surfaces in Reach 1 capable of being mobilized, or are they sufficiently reinforced or embedded, in such a way that a loose and permeable stream bed is insufficient for spawning habitat?
- SI-003b: Is gravel recruitment sufficient for spawning habitat in Reach 1A?
- SI-015: What are the bed transport rates at various flows? How would this change with the addition of new spawning habitat or rehabilitation of existing habitat? How would you schedule gravel augmentation with different flows and quantities of gravel in the system?
- SI-015b: What is quantity of existing spawning gravel in Reach 1?
- SI-015c: At what flows do spawning gravels begin to mobilize in riffles in Reach 1?
- SI-015d: What is the gravel transport rate out of Reach 1?

1.1 Statement of Need

The San Joaquin River Restoration Program (SJRRP) Restoration Goal is to "restore and maintain fish populations in good condition in the main stem of the San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally-reproducing and self-sustaining populations of salmon and other fish." The SJRRP Fisheries Management Plan (SJRRP 2009) identifies spawning and incubation as life stages to be supported for successful completion of the salmon life cycle. The SJRRP Spawning and Incubation Group agreed on a process for ensuring adequate spawning habitat is available to support fish populations, and a central effort in that process involves identifying the quality and quantity of spawning habitat. Several uncertainties exist as to the suitability for successful spawning in the existing stream bed within Reach 1A, which include adequate (1) hyporheic and surface water exchange, (2) flow depth and velocity, (3) sediment attributes, and (4) hyporheic water quality. The channel area that currently contain and is expected to maintain each of these attributes in high quality should be used to quantify the amount of suitable spawning habitat. Most of these attributes and their contribution to spawning and incubation habitat quality are dependent on the maintenance of the spawning bed's surface texture. This maintenance is performed by occasional flows that are capable of dislodging the coarse grains (i.e., gravel and cobble), flushing the finer particles (e.g., sand and silt), and recruiting additional gravel.

1.2 Background

After the completion of Friant Dam in the 1940s the reduced instream flow that ensued downstream resulted in a coarsened bed texture as finer grains were typically the only grains capable of being eroded. Several studies have concluded that mobilizing this coarsened bed surface as required to maintain salmon spawning 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 confirms the expected armored condition (DWR, 2009). Since the expectation is that the majority of the riffles exhibit an immobile condition in anticipated Restoration release scenarios, gravel beds that would otherwise be considered 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.

Multiple studies are currently underway or have been completed to help identify the quality of the hyporheic environment as it relates to successful spawning, incubation, and fry emergence (see SJRRP 2013). These include efforts to evaluate water quality within the hyporheic zone (DO, water temperature, fine sediment accumulation), egg survival, spawning habitat use by trapped-and-hauled fall-run Chinook, bed material size and mobility, scour and deposition, and channel morphology changes associated with alteration to the flow regime. Recently, the USBR has proposed quantifying the spawnable area based on a layered approach of the above compilation of characteristics (see USBR 2013).

In 2012, the USGS began monitoring the contribution of sediment provided by two intermittent tributaries within upper Reach 1A called Cottonwood Creek and Little Dry Creek. Though little, if any, coarse sediment is likely being supplied by these ephemeral streams, it is possible that they are providing sand-sized sediment to the main-stem San Joaquin River. Future monitoring results will provide information to quantify their contribution.

1.3 Anticipated Outcomes

The objective of this study is to determine the force necessary to mobilize the coarsened bed. From this determination will come the ability to quantify the aerial extent of mobilization by varying the flow level. This area will be used in the layered approached to quantifying spawning gravels that are maintained by dislodging the gravel-cobble surface and flushing the interstitial sand and silt. The study will result in several outcomes:

- Dimensionless critical shear stress which is the primary input parameter for sediment transport formulae. It is the metric used for determining the onset of entrainment. The results of this study will produce the dimensionless critical shear stress as a function of relative grain size. This will make it more useful for other sites with differing grain size distributions. Additionally, other studies that are measuring the bedload transport rate will be able to (1) validate their onset of motion observation, and (2) use this dimensionless critical shear stress to determine the best performing sediment transport rate equation.

- By applying the output from the 2d hydraulic model each computational node that exceeds a critical shear stress can be determined. Given the dimensionless critical shear stress function with respect to relative grain size we can determine the grain diameter that will be at the onset of motion from the locally measured surface grain size distributions. This will allow determination of the percent of the grain size distribution (and therefore the percent of the bed surface at each node) that will be mobile.

- The fully mobile threshold (see Wilcock and McArdell 1993, 1996) will also be defined as a function of relative grain size for both sites. This will be useful for calculating the active depth of transport which will define the flushing depth. Similar to the onset of motion, this active depth will be calculated per grid node of the 2D model.

- Using the output from the 2d model the grain size at the onset of motion and the active depth will be delineated into polygons for a range of anticipated flow levels. Each flow levels can then be considered for use in the layered approach to defining spawning habitat quality.

- Transport distance and depositional locations were determined from the tracers. These will be used to (1) determine if mobilized gravels are replenishing spawning beds; and (2) quantify channel change that will occur as a result of erosion and deposition during the Program's altered flow scenario. See Study 26 - Effect of Altered Flow Regime on Channel Morphology in Reach 1A.

1.4 Methods

Type of Study: This is a field study supported by modeling efforts.

Reach(es): Upper Reach 1A at RM 260.7 and 261.6

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 were collected such that their combination can be used to develop a predictive model of the mobility of the bed surface gravels and cobbles. 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.

Field measures including bed load samples and water surface elevation will be incorporated from other studies. Similarly, other studies that have local measurements useful to testing the sediment transport prediction or as input to the flow model will be used.

Force Gaging

Force measurements and particle characterization surveys were conducted at the onset of the study. Force gaging was performed using submergible, spring-resisting, push-pull force measuring devices. Force gaging was performed in areas delineated within approximately 20 feet of monitoring cross sections. Particles were selected at random by the "selecting a particle without looking" method. All attempts were made to test undisturbed water-worked particles. Additionally, roughly 100 particles of each size class (32 mm, 45 mm, 64 mm, 90 mm, 128 mm) were gaged to determine a representative distribution of forces for each class for each area that typifies a channel feature (e.g., riffle surface, pool tail-out). All gaged particles were measured for mass, axial lengths, orientation, and qualitatively described for rounding. Each particle's gaged force, mass, and size was used to predict the friction angles with respect to the median particle size determined from local pebble counts.

Pebble Counts

Pebble counts were performed along channel traversing cross-sections. A pebble count of at least 100 particles was performed at intervals of approximately every 10 to 20 feet. Width depended on the variance exhibited in the cross-sectional profile and surface texture. This level of resolution provided adequate information on trends in grain size with location along the cross-section. Grain size statistics were calculated from the pebble count results. The statistics will be used to calculate the critical shear stress for particle mobility.

Topographic Surveys

Conventional and Real Time Kinematic (RTK) GPS survey equipment was used to survey the channel bathymetry. The channel bathymetry was used to create a digital terrain model (DTM). Included in these surveys was the 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 were used to calibrate the flow model. The repeated cross-sectional topographic surveys will also be used as a means of validating the sediment transport equation's predictions, active layer depth, and channel change as a function of the alter flow.

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) was used to measure channel flow hydraulics for elevated flows within the model's domain and at the study sites. Results from the survey will be used to validate the calibrate flow model's prediction of flow depth and velocity.

Scour Chain Monitoring

Scour chains were installed in the vicinity of the tracer cross sections and surveyed to 2 cm of horizontal accuracy to assist in future location. They were placed at distances suited to cover the range in lateral topographic variation and are 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 active transport depth prediction.

Gravel and Cobble Tracers

Particles greater than 32 mm in intermediate diameter were collected from areas where they were later placed as tracers. These particles were transported back to the laboratory for measurement of size, mass, and roundness, and inserted with an inductively charged RFID tag. The RFID tag's unique identification code was recorded with its measurements. Additionally, the tracer was painted for ease of locating, especially when buried so as to record the burial depth. Placement of the tracers was along the monitoring cross-sections spanning the channel's width. Each tracer was positioned on the bed such that it replaced a similar particle's size, shape, orientation, and relative position to surrounding particles. Tracers were placed before high-flow events, and their initial locations were surveyed using RTK GPS equipment. The surveyed latitude, longitude, and elevation were recorded with other measurements and RFID code. After flows returned to safe levels for accessing the channel, the tracers were relocated and their new position surveyed as before. The extent of bed material mobilization was then compared to flow levels as recorded at Friant Dam and the USGS Friant gauge. The results of the tracer movements and the calibrated flow model were used to compare with the dimensionless critical shear stress as produced from the force gauge measurements. Finally, by mapping grain size distribution using the pebble counts results we will be able to calculate the area and degree (i.e., non-mobile, partial mobility, fully mobile) of the bed mobilized for differing flow scenarios.

Flow and Sediment Transport Model

A 2d flow model was used to predict hydraulic forces acting on the tracers. A computational grid with a 3 mile long domain containing the two study sites was developed using the USGS's Multidimensional Surface Water Modeling System (MD_SWMS) and the computed hydraulic conditions were simulated using FaSTMECH's 2-D flow software (Nelson and Smith, 1989). Drag coefficients are the variable of adjustment to calibrate the model to water surface elevations as measured during the peak of tracer monitored flows. Validation of the calibrated model's predicted hydraulics was performed using the ADCP-measured velocity and flow depths. The tracers were then assigned to the model's nearest grid node based on tracer location prior to the monitored flow event. Assigning the model produced shear stress to each tracer for each peak flow allows determination of the critical shear stress when treating particles by size class.

1.5 Deliverables and Schedule

A report detailing investigation activities, analysis, results, and conclusions as they pertain to the Project will be provided as a technical memorandum (TM). The TM is currently in preparation and is anticipated to be completed by December 2014. The TM will (1) define the dimensionless critical shear stress functions for each site; and (2) provide a useful example of its use (e.g., spatial distribution of active layer depth and grain size mobility for a relevant flow) with the 2D hydraulic model output. Description and defense of the methodology and theoretical implications will be provided as a peer reviewed journal article. The journal article is also in preparation but will require additional time to get through the review and publication process (December 2015?).

Shape files delineating polygons of (1) grain size and/or percent of bed at onset of mobility and (2) active transport depth will be provided in collaboration with the USBR 2d hydraulic modeling team as needed per the requests of the Sediment Group, Spawning and Incubation SIG, or others.

1.6 Budget

The total cost estimate is $30,000 for 2015.

Table 1-1. Proposed 2015 Budget

Task	Cost
Reporting	$30,000
Total	$30,000

1.7 Point of Contact / Agency Principal Investigator

Matthew A. Meyers, P.G. / Department of Water Resources
(559) 230-3329
mmeyers@water.ca.gov

1.8 References

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