

# STANISLAUS RIVER MODELING IN SUPPORT OF SEDIMENT MOBILITY AND FLOODPLAIN INUNDATION ESTIMATION

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## HYDRAULIC AND SEDIMENT TRANSPORT MODELING

Currently, it is not known what threshold flow will result in mobilization and refreshing of spawning-sized sediment particles, and this knowledge gap has important implications for restoration of salmonid habitat on the River. We developed a 2-dimensional (2D) hydraulic model of the Stanislaus River extending from Knights’ Ferry to the San Joaquin River confluence to estimate mobility of bed sediments at a variety of flow regimes. We have also applied this model to estimate flooding extents at various flows and develop relationships between flow and inundated floodplain (or potential salmon rearing habitat) area.

While the USFWS has developed a high-resolution 2D model of the Stanislaus River, we reviewed it in detail and determined that this model does not produce accurate water surface elevation predictions nor inundated area estimates due to data gaps inherent in the model construction and other model deficiencies (NewFields 2013). Therefore, we developed a new 2D model of the Stanislaus River using the best available input data. To maintain consistency with other modeling efforts on the River, we used SRH2D, a publicly available model produced by the United States Bureau of Reclamation.

## *APPROACH*

We developed our model to provide both accuracy of hydraulic prediction and fast run times. This was accomplished by using a coarser mesh (e.g., hydraulic predictions at nodes spaced further apart) than used in the USFWS model. Coarser meshes produce hydraulic predictions at greater spatial intervals but require less computation time and therefore model output can be generated faster. This can greatly expedite model setup, troubleshooting, calibration, and analyses and does not necessarily result in poorer accuracy of model predictions. We selected a mesh density appropriate for the analyses performed based on the following factors:

- While very fine mesh densities (1m or less) may be appropriate for fine-scale salmonid habitat modeling such as that performed by Reclamation (Reclamation 2012), much coarser

mesh densities are appropriate for analyses such as water surface elevation prediction, floodplain inundation, sediment transport, etc.

- The width of the Stanislaus River is such that model mesh nodes spaced 4-5 meters apart (as in the NewFields model) produced a near identical model channel geometry than did finer (e.g., 1-2 meter) spacing.
- For modeling questions involving bed mobility on the reach scale (e.g., 50+ meters), mesh densities finer than 4-5 m are unnecessary. Furthermore, mapping of bed sediment particle size classes was only possible to approximately 5-10m of spatial accuracy so increased mesh density would not have resulted in more accurate bed mobility estimates.
- For modeling questions involving water surface elevations (for example inundation mapping), very coarse mesh densities are appropriate because water surface elevations do not significantly vary on the spatial scales of these model meshes (e.g. 1-2m for USFWS and 4-5m for NewFields).
- The best available topographic dataset of the River is a combination of LiDAR in upland areas and SONAR in wetted areas. Due to the timing of data collection, there exist large (as much as 20-150 meters wide) gaps in topography data at the interface between the channel and upland areas. Since elevations must be interpolated in these areas, finer mesh resolution does not lead to more accurate representation of the actual land surface nor predictions of hydraulic properties.

### *MODEL CONSTRUCTION AND SET UP*

Four key pieces of data must be assembled to construct a two-dimensional river hydraulics model. These are described below and summarized in Table 1.

<b>Input Data</b>	<b>Type</b>	<b>Date of Collection</b>	<b>Source</b>	<b>Reference</b>
Land Surface Topography and Channel Bathymetry	Reclamation Digital Elevation Model (DEM) based on Lidar and Sonar Data	2008	Reclamation	Reclamation 2012
Roughness Coefficients	Manning's coefficients based on comprehensive bed sediment surveys and aerial imagery analysis - calibrated to measured hydraulic properties at 1500 and 3000 cfs	May 2013	NewFields	NA
Downstream Boundary Condition	Measured water surface for 1500 and 3000 cfs, Stage/Flow relationship at San Joaquin confluence for others	April 2013	Measured surfaces – NewFields, Stage/Flow relationship – USFWS	NA
Roughness Coefficients	Manning's coefficients based on comprehensive bed sediment surveys and aerial imagery analysis - calibrated to measured hydraulic properties at 1500 and 3000 cfs	May 2013	NewFields	NA

TABLE 1: USFWS MODEL INPUT DATA SUMMARY

### Topography and Bathymetry

Reclamation provided a digital elevation model (DEM) of the Stanislaus River and its floodplain that we used to develop our model (Reclamation 2012). This DEM was developed from LIDAR data collected in March of 2008 and SONAR data collected in spring and summer of 2008. Significant gaps exist between the coverage of the LIDAR data and the SONAR data, and therefore interpolation is required by the model software to “fill in” these areas where elevation data does not exist. The method of interpolation used to fill in these areas is of utmost importance to the model output. The importance of the interpolation method was noted by Reclamation (2012) and this was further investigated by NewFields (2013) when comparing the DEM produced by Reclamation to the topographic dataset and interpolation scheme currently being used by USFWS to create a model for the purposes of estimating floodplain inundation on the Stanislaus River (USFWS 2013). We believe the Reclamation DEM to be the best available topographic dataset covering the Stanislaus River and therefore used it for these analyses.

### Roughness Coefficients

NewFields conducted bed sediment particle size composition (facies) mapping of the Stanislaus River channel throughout the project boundaries. Recent aerial imagery was used to define vegetation types and land cover/use outside of the channel and in floodplain areas. These mapping techniques were combined to create a dataset delineating roughness coefficients in both the channel and floodplain for the project area.

### Boundary Conditions

SRH2D requires user input of upstream and downstream boundary conditions (flowrate or water surface elevation) to run. For example, the upstream boundary condition is the desired volumetric flow rate, and the downstream boundary condition is a known water surface elevation at that flow rate. When the river under analysis has a stream gage or an established rating curve at the downstream end of the model, both boundary conditions for a variety of flows are readily available. For this study, no nearby gage exists on the Stanislaus River, nor does a rating curve for the downstream end of the project reach. We collected water surface elevation data along the full length of the project reach during two elevated flow events in April 2013 of approximately 1500 and 3000 cfs. These data formed the boundary conditions for calibration of the model at these two flows. For other flows modeled, we used the Stanislaus River mouth water surface elevation estimation formula described by USFWS (2013).

The USFWS boundary condition relationship implicitly assumes that elevated water levels in the Stanislaus mean that the San Joaquin River is also flowing in an elevated state (i.e., a storm event that causes flows higher than baseflow in the Stanislaus also occurs in the San Joaquin River basin and elevates its water level). However, the 1500 and 3000 cfs events that NewFields surveyed and based model calibration on were regulated releases that occurred during baseflow conditions on the San Joaquin River. Therefore, the boundary condition water surface elevation inputs for 1500 and 3000 cfs in the NewFields model are lower (by approximately one meter) than they would have been had these been calculated by the USFWS relationship.

### CALIBRATION AND SENSITIVITY TESTING

Numerical models that calculate or predict natural behavior are subject to error from a variety of sources including input data measurement and choice of model settings and other parameters. We completed several procedures to verify that the predictions made by SRH2D were appropriate. These included calibration against known hydraulic conditions and testing to determine the models' sensitivity to roughness coefficients.

#### Calibration

Calibration of a hydrodynamic model is the process of comparing model output to measured conditions to assess the agreement between the model's predictions and reality. The calibration process can include adjustment of model parameters that cannot be measured in the field (such as roughness coefficients) to aid in bringing model predictions closer to reality. We compared our model predictions to surveyed longitudinal profiles of the Stanislaus water surface at both 1500 and 3000 cfs. Because we were able to survey the water surface elevations at more points at 3000 cfs, we used this as our primary flow to calibrate the SRH2D model. We ran the model at 3000 cfs iteratively and modified the Manning's "N" roughness coefficients to progressively obtain better agreement between the modeled and surveyed water surface profile. Figure 1 compares results of the calibrated model to surveyed water surface profiles for both 1500 and 3000 cfs. Agreement between surveyed and modeled elevations was within 20 cm (~5 inches) at ~98% of points surveyed at 3000 cfs and ~70% of points surveyed at 1500 cfs.

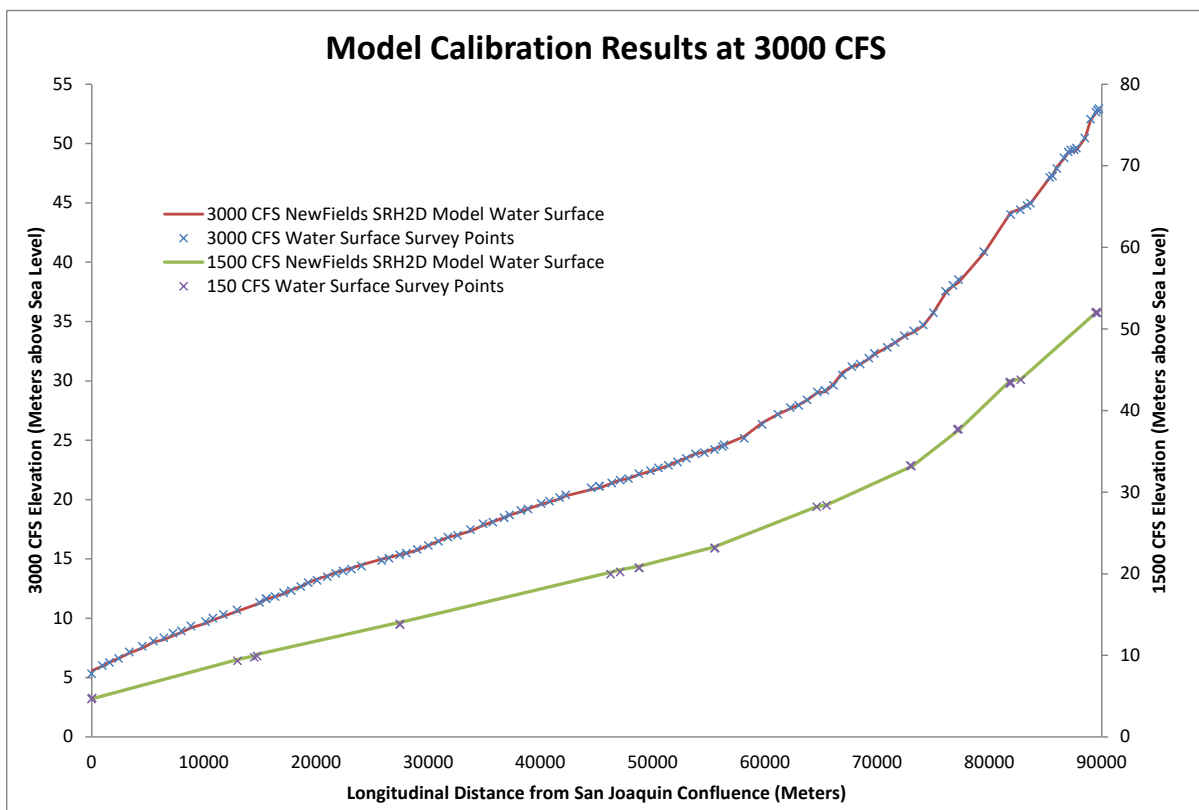


FIGURE 1: CALIBRATION RESULTS FOR 1500 AND 3000 CFS.

\*NOTE THAT EACH FLOW IS PLOTTED ON A SEPARATE VERTICAL AXIS.

### Sensitivity Testing

Because flow velocities and bed shear stresses (which influence sediment mobility) are very difficult or impossible to measure in the field, and are dependent upon the roughness coefficient input parameters, we tested the sensitivity of model shear stress output to Manning's N roughness coefficient. Sensitivity testing on Manning's N, shown in Figure 2, evaluates how much the model predictions of shear stress vary with changes in selected N value. We globally increased and decreased the Manning's N by 10% for the entire Stanislaus River, producing a plot of the shear stress along the longitudinal profile (Figure 2). Figure 2 shows the shear stress sensitivity for the channel for 10 kilometers upstream of the confluence at the San Joaquin River. This example reach displays the typical variation in shear stress observed throughout the rest of the full 90 kilometer model boundary. Generally, a 10% reduction/increase in N value (i.e., 20% total variation) resulted in typically a 10% reduction/increase in predicted shear stress (i.e., 20% total variation), respectively. A 20% variation in Manning's N was deemed appropriate for the level of uncertainty in selection of this parameter on the Stanislaus while up to a 20% variance in predicted shear stress would not be expected to significantly change the predictions of patterns of bed mobility in the Stanislaus, particularly in the upper reaches where spawning gravels and cobbles (which require much higher shear stresses to be mobilized than do the sands and small gravels that predominate closer to the San Joaquin confluence).

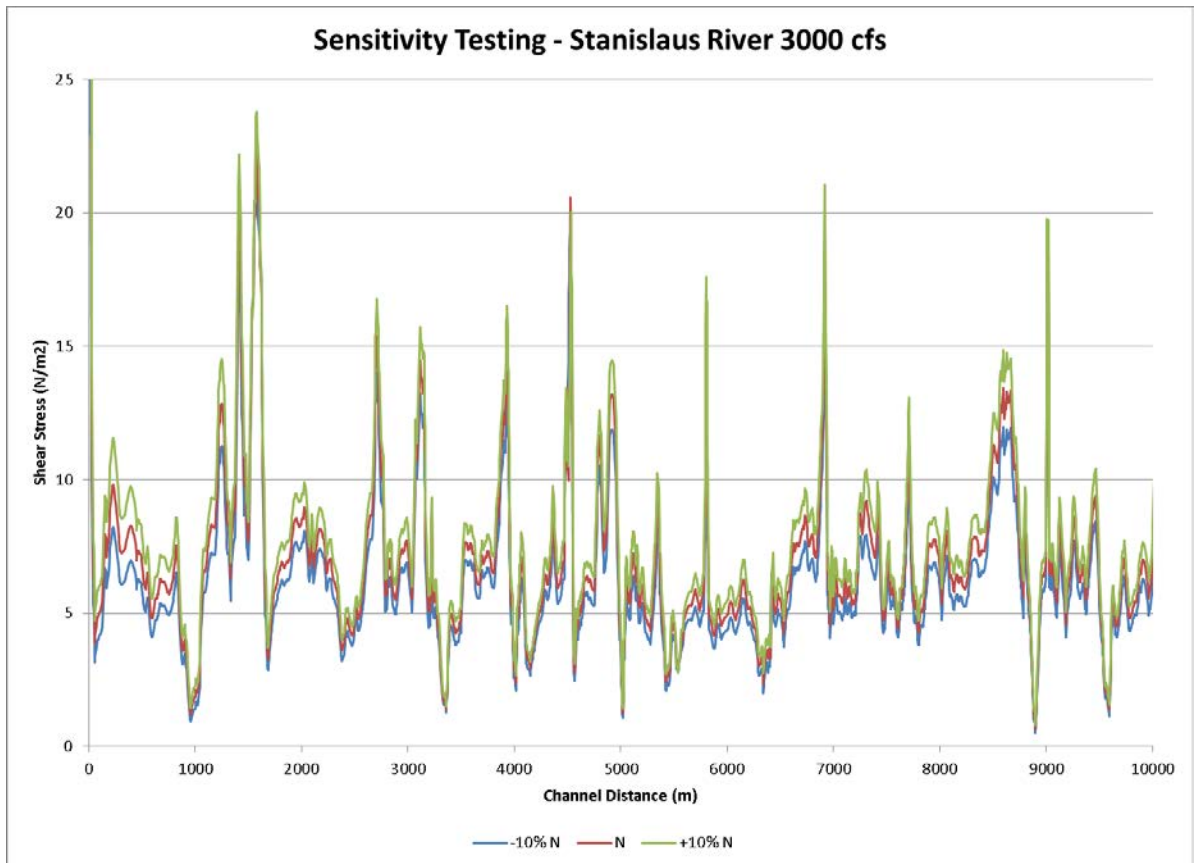


FIGURE 2: SENSITIVITY TESTING ON SHEAR STRESS IN THE MODEL OF THE STANISLAUS RIVER

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