East Sand Slough Salmonid Habitat Improvement Project
Hydrology and Hydraulics Report
(July 2019)

## Registered Engineer Stamp

The technical information in this document was prepared by the following registered engineer. The hydraulic model is available upon request at Nancy.Snodgrass@water.ca.gov.


## Overview & Purpose

The East Sand Slough Side Channel Project area is located in Red Bluff, CA (Figure 1). The project involves excavating approximately 100,000 cy of material out of East Sand Slough (Slough) to create a low-flow side channel for winter-run juvenile salmonid rearing habitat. The newly constructed channel would flow about 1-foot deep when the Sacramento River flow is 4,700 cfs at the USGS Bend Gage.

The Slough is a flood channel of the Sacramento River that helps protect the City of Red Bluff from flooding. When the Sacramento River flow is about 20,000 cfs at the USGS Bend Gage, the Slough starts to activate and water flows into existing scour channels. The proposed project would not change the drainage patterns within the site. It would, however, connect the Slough to the mainstem Sacramento River during normal and low-flow conditions.

The primary purpose of this hydrology and hydraulics report is to accurately predict, using the best available data, post-project water surface elevations during the 100-year flood event. Using the predicted water surface elevations, we can verify that the project should not raise the 100-year flood water surface elevation.

The secondary purpose of this report is to accurately predict, using the best available data, the potential for aggradation or degradation of the proposed channel. Analyzing certain hydraulic properties such as depth, velocity, and shear stress can help determine whether or not aggradation or degradation of the channel would occur.

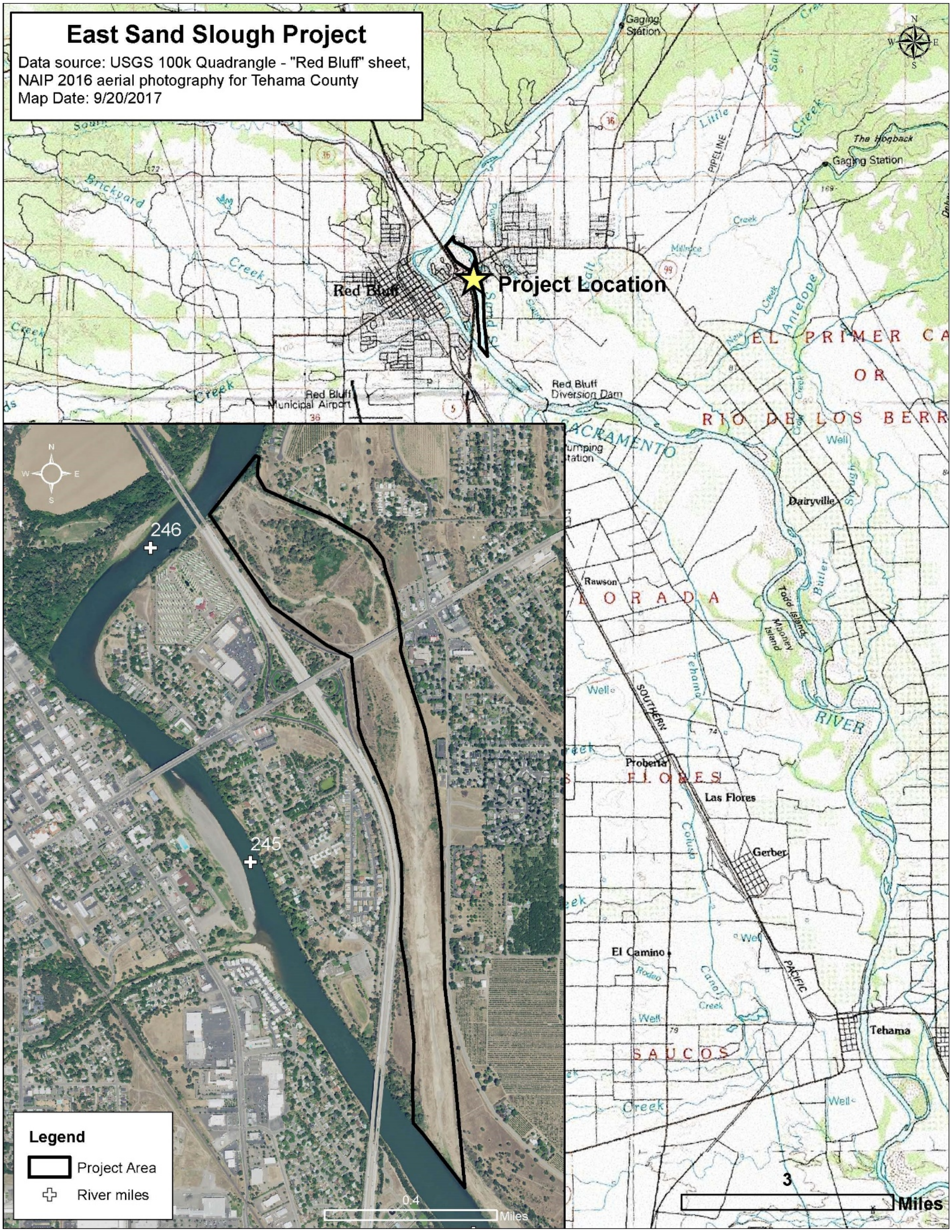


Figure 1. Location map

## Hydraulic Analysis

Two types of hydraulic models were developed for the proposed project: a one-dimensional and a two-dimensional model. A one-dimensional model using HecRAS was developed for the 100-year flood flow of 220,000 cfs. This model was used to predict the 100-year water surface elevation to ensure a no-rise situation.

The two-dimensional model using SRH2D was developed by Reclamation personnel and calibrated to flows up to 33,700 cfs. This model was used for channel design purposes. The SRH2D model results were used to analyze depth and velocity during low flows to help maximize juvenile rearing habitat. The results were also used to analyze the velocity and shear stress at the channel entrance for impacts due to siltation and/or erosion. This model was also used to analyze scour impact to the Caltrans Antelope Boulevard/Highway 36 Bridge piers. The scour analysis was performed by Caltrans personnel and is not discussed in this report.

## Flood Insurance Study

The Federal Emergency Management Agency (FEMA) has provided a flood insurance study (FIS) for Tehama County, CA dated September 29, 2011. This FEMA study provides flood risk data for various areas in the county. According to the FIS report, the hydraulic analysis in the City of Red Bluff is complex and highly sensitive due to growth in the area. During flood events, the Sacramento River overflows into three channels east of Red Bluff: East Sand Slough, Payne Creek Slough, and Samson Slough. East Sand Slough starts to flow at about 20,000 cfs, whereas Paynes Creek Slough and Samson Slough start flowing at about 40,000 cfs and 110,000 cfs, respectively.

The project area is located within Zone AE which means that FEMA has performed a detailed study and determined base flood elevations for the 100-year flood event (1-percent peak discharge). The peak discharges from the FIS report for the streams within the project area are listed in Table 1.

**Table 1. Sacramento River at Red Bluff Peak Discharge**

| | Peak Discharge (cfs) | | |
|---|---|---|---|
| Source | 10-percent (10-yr event) | 2-percent (50-year event) | 1-percent (100-year event) |
| Sac River at Red Bluff Diversion Dam | 141,000 | 194,000 | 220,000 |
| East Sand Slough | 35,000 | 55,000 | 65,000 |
| Payne Creek Slough | 11,400 | 24,500 | 31,000 |
| Samson Slough | 3,300 | 8,000 | 11,750 |

There are a total of 14 cross sections in the Sacramento River and 7 cross sections in the Slough identified in the FIS report within the project area. The vertical datum for the published water surface elevations are in North American Vertical Datum (NAVD 88). The Manning's "n" values used and published in the FIS report are listed in Table 2.

**Table 2. FEMA FIS Report Manning "n" Values**

| Stream | Channel "n" | Overbank "n" |
|---|---|---|
| Sacramento River | 0.022 – 0.150 | 0.030 – 0.150 |
| East Sand Slough | 0.04 – 0.085 | 0.05 – 0.10 |

## Topographic Surface Data

Central Valley Floodplain Evaluation and Delineation (CVFED) Lidar data was used to develop the base topography. CVFED Lidar data was flown during February/March 2010 when the release flows from Keswick were at a minimum flow of 3,250 cfs. Additional GPS, bathymetry, and conventional surveying data were collected to fill in the gaps where data was questionable and/or missing from the Lidar to create the existing base topography for the model.

## Hec-RAS Model Calibration

Using the 100-year event peak discharge from Table 1 and topographic surface data discussed above, a model was generated utilizing Hec-RAS v 5.0.1. Hec-RAS is a computer program developed by the Army Corps of Engineers that models the hydraulics of water flow through natural rivers and other channels.

A total of 42 cross sections and four bridge crossings throughout the project reach was created for the model. The downstream cross section is located at the Red Bluff Diversion Dam and the upstream cross section is about 750 feet upstream of the entrance to the Slough, covering a total of 3.3 miles. A known water surface elevation of 265 feet (NAVD 88) from the FIS report was used for the downstream boundary condition. Manning "n" values used were within the range of the values listed in Table 2.

A split flow was modeled to analyze the flow in the Slough. As a check for accuracy and a method of calibration, model results for existing condition were compared to the FIS published results. From Table 1, the flow in the Slough during the 100-year event is 65,000 cfs. The existing condition model results indicate the flow is 64,588 cfs, which is within 1 percent of the published flow.

A total of 10 cross sections from the FIS report were compared to the existing condition model results. Three cross sections in East Sand Slough and seven cross sections in the Sacramento River were analyzed. The resulting water surface elevations were plotted and are shown in Figure 2. The maximum difference in water surface elevation was 0.2 feet. This difference is well within the error of the model.

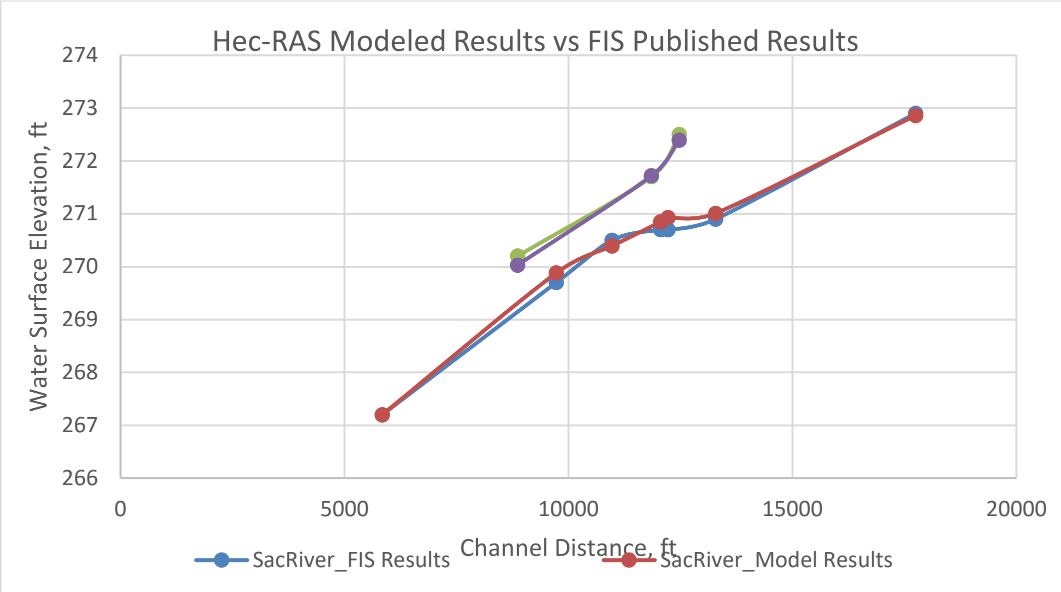

**Figure 2. Model Calibration Graph**

## Hec-RAS Model Results

Once the calibration of the model was complete, the model was then used to analyze the proposed project topography. A total of 29 cross sections in the mainstem Sacramento River and 13 cross sections in East Sand Slough were modeled. The results are shown in Figure 3. The maximum difference in water surface elevation at any cross section was a decrease of 0.1 ft.

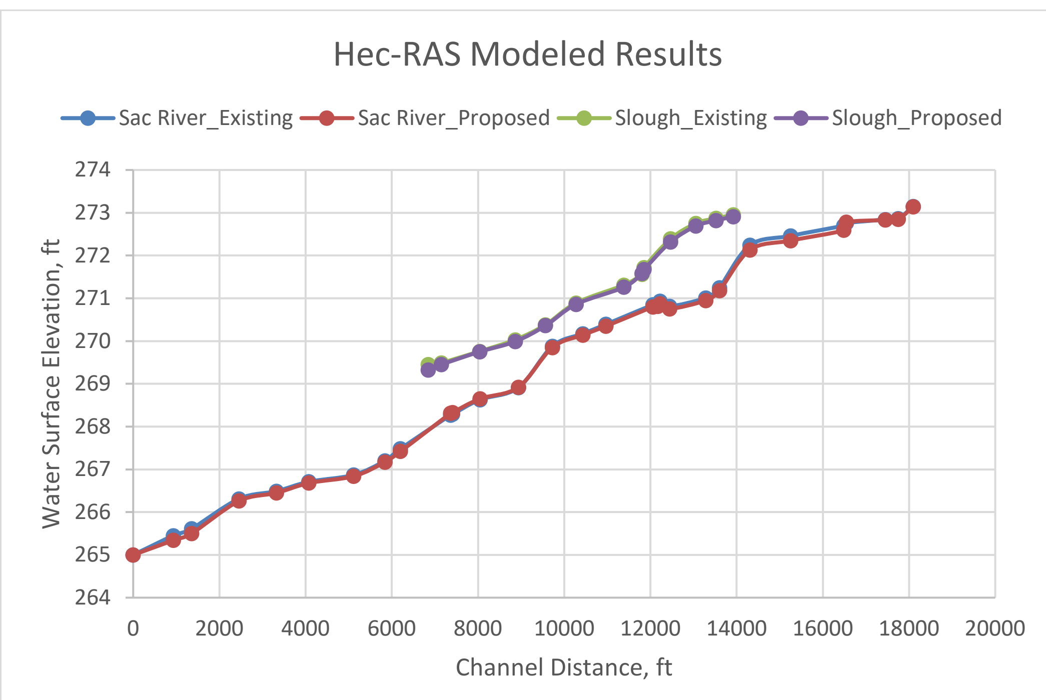

**Figure 3. Hec-RAS Proposed design modeled results**

Shear stress was analyzed to help determine if erosion is a concern. The Hec-RAS resulting average shear stress throughout the project reach was plotted and shown in Figure 4. As shown in the graph, sediment larger than gravel and less than cobble (2.5 inches in diameter) moves through the Slough during the 100-year event. The difference between existing and proposed conditions are minimal.

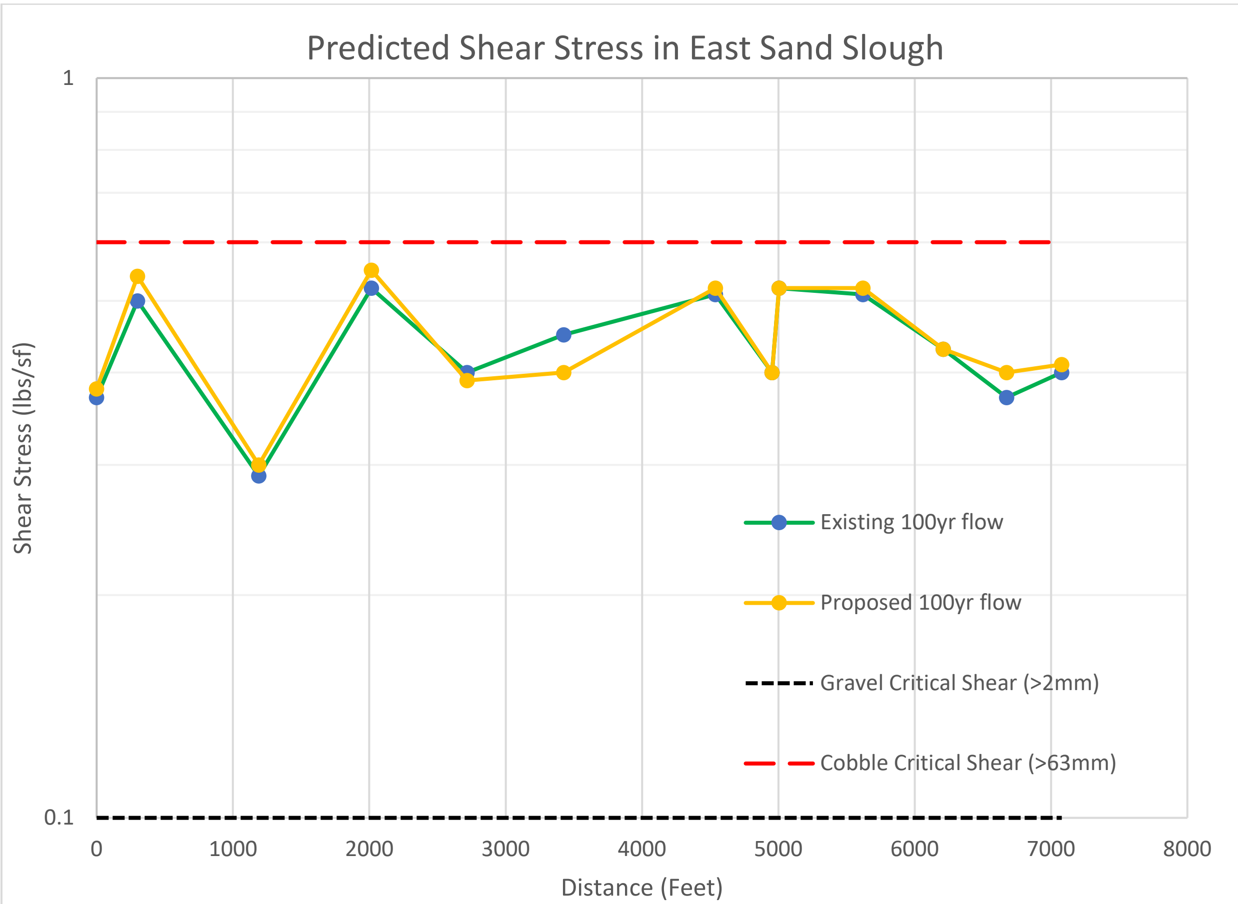


**Figure 4. Hec-RAS Shear Stress results**

Nine test pits were excavated throughout the project reach to determine the grain size distribution. Test pits at the entrance of the channel were coarser than the test pits at the exit of the channel. More than half of the sample at the channel entrance was larger than 38mm (1 ½-inch). The proposed mean velocity at the entrance is about 192 cm/s (6.3 ft/s). Based on the Hjulstrom curve, the channel entrance is within the transport/erosion region. As a result, cobble would be placed along the channel bottom and side slopes to minimize erosion potential.

Test pits at the channel exit had more sand than gravel. Only 3 percent of the sample at the channel exit was larger than 38mm (1 ½ -inch). This area is highly erodible at the same flow speed. This area would be over-excavated, and a mixture of cobble and gravel would line the new channel to a depth of 18 inches.

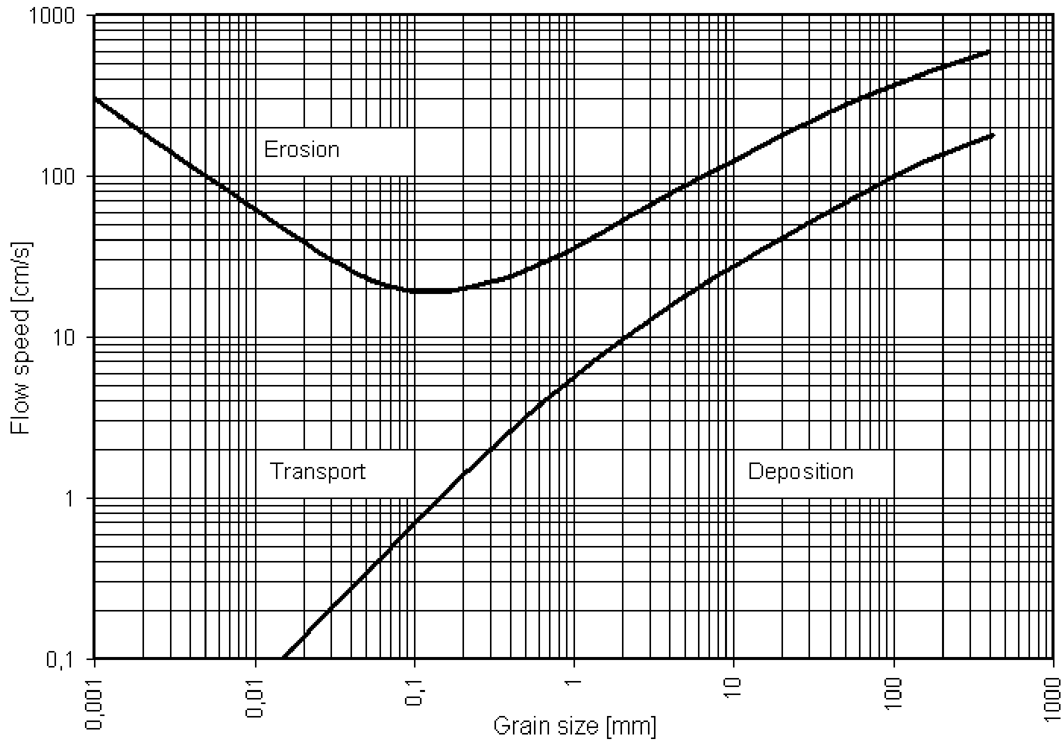


**Figure 5. Hjulstrom Curve**

## SRH2d Model Results

SRH2D, a two-dimensional model developed and calibrated by Reclamation personnel, was used to analyze hydraulic properties such as shear stress, velocity, and water depth for flows ranging from 4,700 cfs to 33,700 cfs. Water depth and velocity were analyzed at low flows to maximize juvenile rearing habitat conditions. Shear stress and velocity were analyzed at higher flows for potential of erosion or deposition.

The shear stress for existing and proposed conditions at the channel entrance at the 33,700 cfs flow regime is shown in Figures 6 and 7, respectively. Although the shear stress would increase slightly in East Sand Slough from existing to proposed, the shear stress in the Sacramento River would be significantly higher, which is a strong indicator that the river would not be likely to capture the new side channel.

The average velocity for existing and proposed conditions for the 33,700 cfs flow regime is shown in Figures 8 and 9, respectively. The velocities in the mainstem range from 6 to 7.5 feet per second (fps) and would remain relatively the same for both existing and proposed conditions. The velocities in the Slough range from 2 to 5 fps for both conditions, but the proposed condition shows an increase of about 2 fps at the entrance which would help maintain the entrance and not let it close off due to potential deposition.

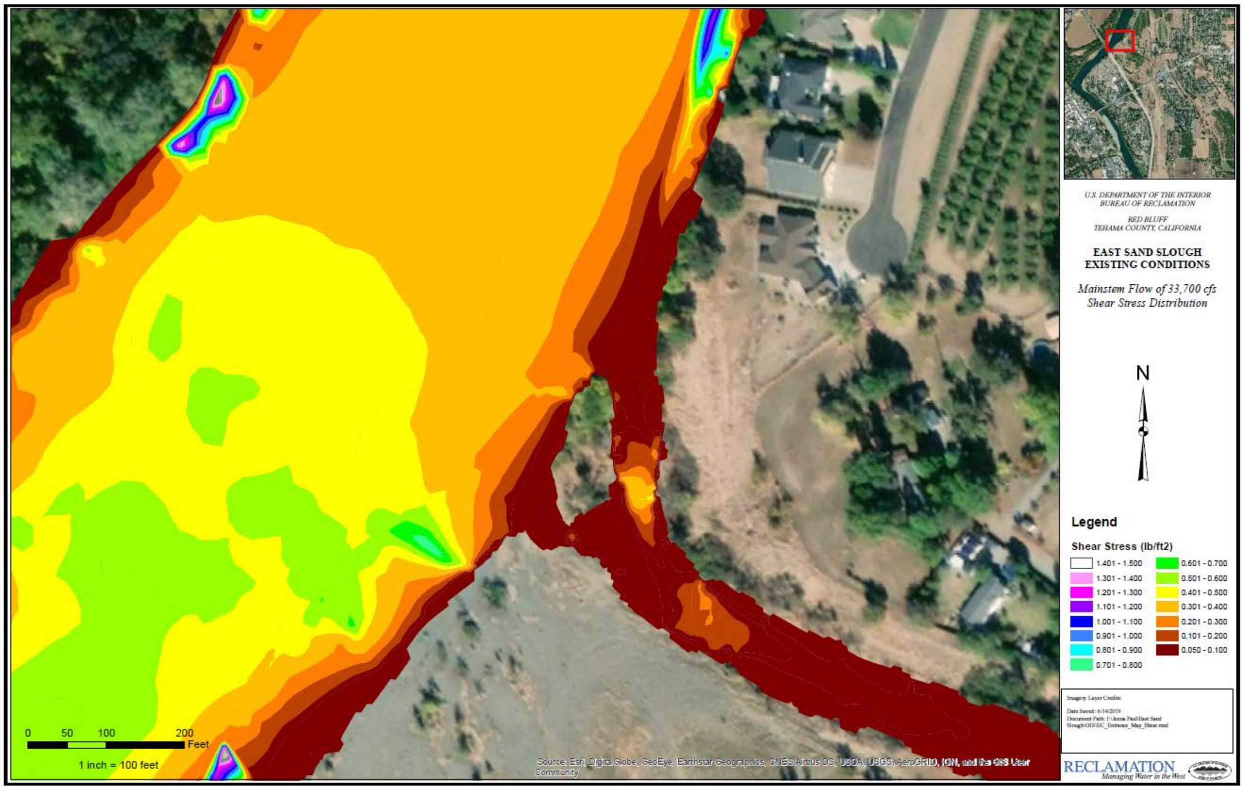


**Figure 6. SRH2D Shear Stress results for existing conditions**

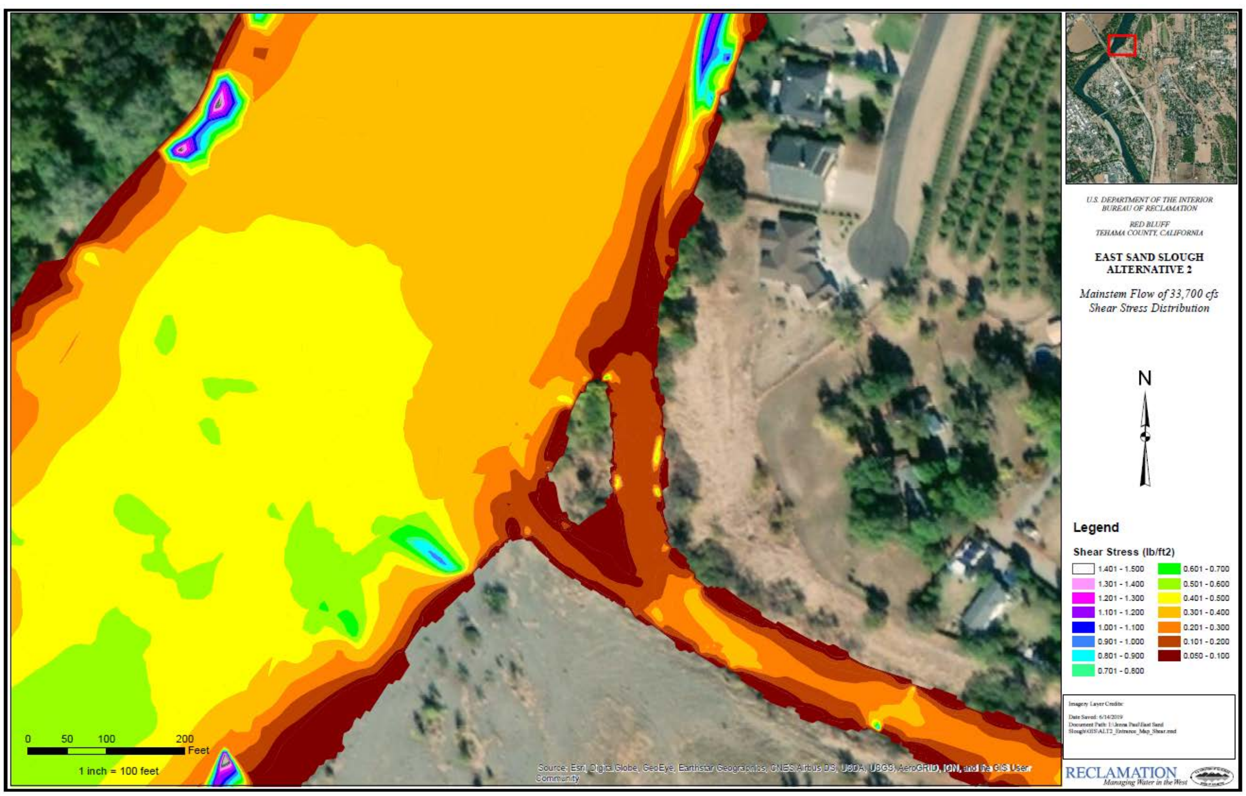


**Figure 7. SRH2D Shear Stress results for proposed conditions**

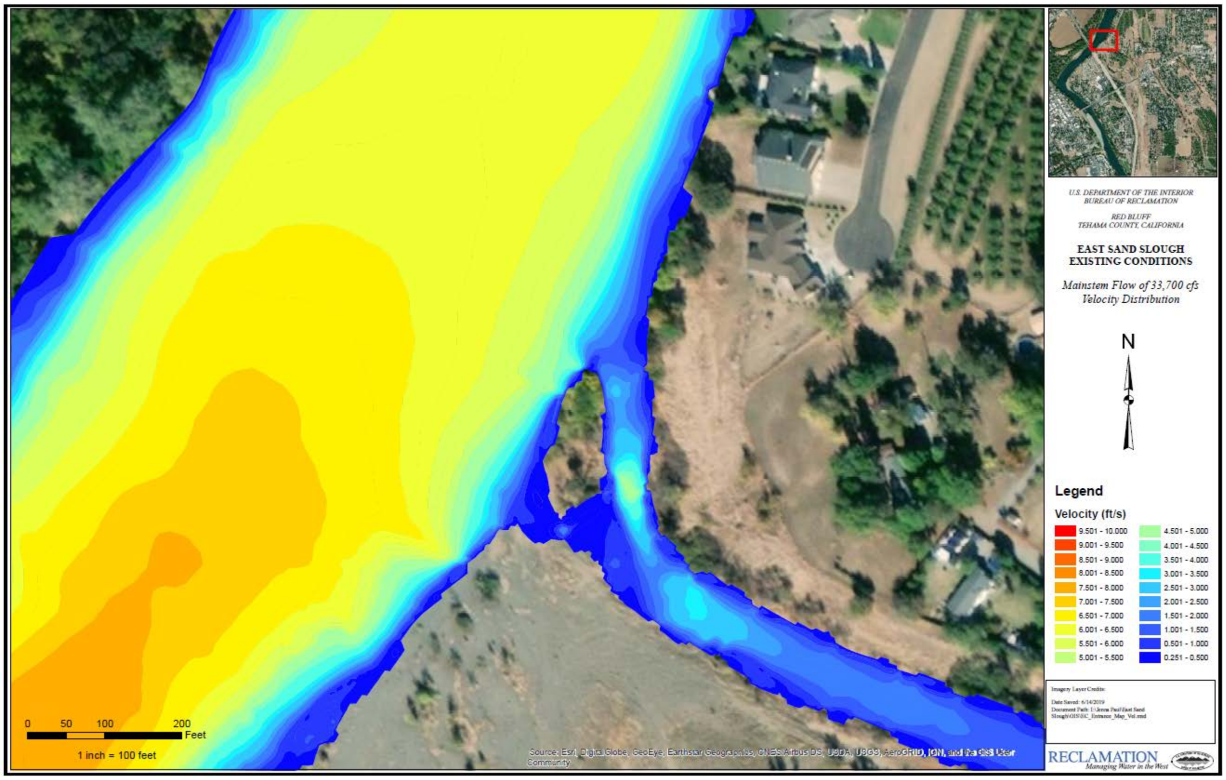


**Figure 8. SRH2D Velocity results for existing conditions**

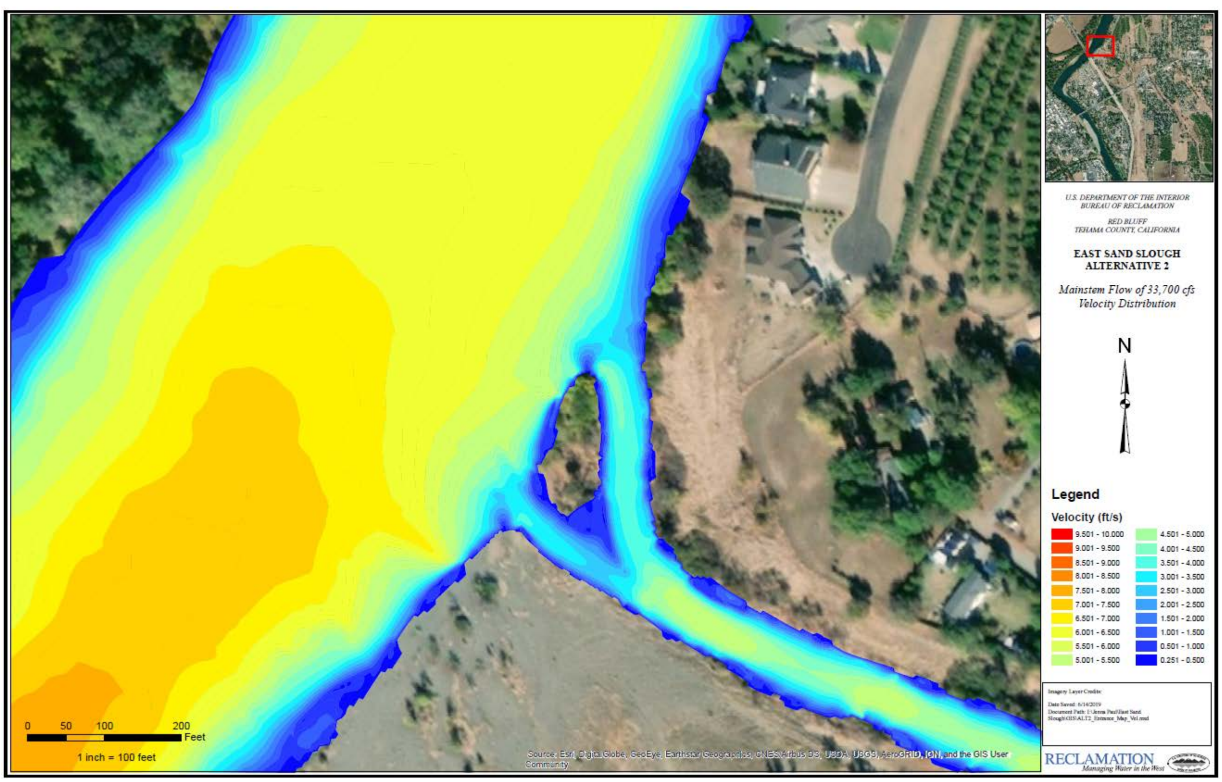


**Figure 9. SRH2D Velocity results for proposed conditions**

## Conclusion

East Sand Slough is a flood channel that experiences annual flooding. The proposed project of creating a low-flow side channel would not increase the 100-year water surface elevation. The project involves removing material from the Slough, so the post-project water surface elevations would be lowered by as much as 0.1 feet. The water surface lowering would not be significant enough to change the flood inundation zone, therefore the FEMA maps would not need to be revised.

Currently, the Slough shows signs of being in equilibrium with some localized scour in areas around the bridge piers. Broken up concrete is piled higher than the channel, causing plunging flow and creating minimal localized scour downstream of the bridge. Old PG&E engineering drawings of the buried gas main dating back to 1967 show the gas main buried 6-feet below existing grade in the Slough. Recent potholing activities exposed the gas main and confirmed that it is still 6 feet deep, which indicates a stable channel.

Based on the SRH2D results, there is no indication that the proposed side channel would capture the mainstem Sacramento River. The mainstem depth, velocity, and shear stress all show a stable section of the river that is not likely to change locations. Historic maps and photography support this determination and show the river has never used the Slough as its main channel. In addition, the project design is such that the width and slope of the channel would be much less than the mainstem Sacramento River, the shear stress and velocities would be significantly lower, and the channel would be connected to a lowered floodplain, all of which should maintain a stable environment.

The entrance to the Slough is located upstream of a riffle which is ideal as the riffle will provide the control for the entrance. Based on the shear stress and velocity at the 33,700 cfs flow regime, the channel would be stable and able to move fine sediment through the channel, minimizing the chance to close up and require maintenance. The new channel entrance would be lined with large rock to create a stable environment for safety concerns for the homes located along the left bank.

The sandy substrate located at the channel exit would be over-excavated and a mixture of larger material would be placed approximately 1.5 feet thick in the channel bottom and side slopes. This area is not anticipated to meander out of banks because of the proximity to the floodplain. During flooding events, the channel becomes extremely wide and the velocity is reduced, causing sediment to fall out and deposit along the floodplain. The channel appears to have enough velocity to move the sediment through the channel, but because of the low gradient, some maintenance likely will be needed to remove sediment.