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MEANDER MIGRATION MODEL ASSESSMENT FOR THE JANUARY 2005 STORM, WHITMAN PROPERTY, SAN ANTONIO CREEK, VENTURA COUNTY, CALIFORNIA

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INTRODUCTION

David Magney Environmental Consulting (DMEC) was retained by Mr. John Whitman to assist with environmental analysis of project-related changes to San Antonio Creek on his property near Ojai, Ventura County, California. The need for this project arose when San Antonio Creek eroded a large portion of Mr. Whitman's property during the January 2005 storm. For many years prior to the January 2005 storm, the main channel followed along the right bank of the floodway. Prior to the January 2005 storm, fill was placed on the right bank of the floodway, and the main channel subsequently moved to the left bank of the floodway (Figure 1).

Figure 1. Oblique Photograph of the Project Area Looking Downstream with an Arrow Indicating the Fill that Diverted Flow to the Left Bank Just Prior to the January 2005 Storm.

The purpose of this analysis is to determine the potential effects of the placement of fill on the right bank on a reach of San Antonio Creek on bank erosion on the left bank of a reach of San Antonio Creek. To do so, DMEC contracted Dr. Eric Larsen of the University of California, Davis and Dr. Mark Rains of Coshow Environmental, Inc. and the University of South Florida to employ the use of a stream meander migration model (Larsen 1995). Field data documenting existing conditions were collected and used to model expected changes in stream characteristics under two scenarios: the existing condition (i.e., fill placed on the right bank of the channel) and the pre-existing condition (i.e., no fill placed on the right bank of the channel).

Two issues bear discussion. First, the model predicts trends in stream migration. The actual stream migration patterns will be similar to the predicted stream migration patterns. An exact match between the actual and predicted stream migration patterns would be, to a certain extent, fortuitous. Second, this model predicts stream migration patterns on generic time steps. However, stream migration can occur episodically so all or most of the predicted migration can occur in a short period of time. At the most extreme, most of the predicted stream migration could occur in a single storm event. Stream migration is a function of flow strength (e.g., shear stress) applied to a given stream bank. If a great deal of shear stress is applied over a short period of time, or a small amount of shear stress is applied over a long period of time, then the actual trends in stream migration will be the same in both scenarios as long as the total excess shear stress is the same in both scenarios.

DATA COLLECTION

FIELD DATA

Field data at the Whitman project site were collected on 18-19 July 2005 by Dr. Larsen, Dr. Rains, and Ms. Cher Batchelor of DMEC. Two typical cross-sections and a longitudinal profile were surveyed. The bankfull width and mean bankfull depth were calculated from the cross-section data, while channel slope was calculated from the longitudinal profile data. Stream bed material size class distributions are based upon a Wolman Pebble Count (Wolman 1954, Harrelson et al. 1994). The D_{50} is the median particle size, or the size that is greater than or equal to 50 percent of the particles. The D_{50} is typically taken to be the effective length scale of the bed-material load.

ADDITIONAL DATA

The Ventura County Flood Control District (VCFCD – now called Ventura County Watershed Protection District) provided annual peak discharge data and flood frequency analyses for San Antonio Creek at Casitas Springs (VCFCD Gage #605). Data were for water years 1950-1998. The flood frequency analyses were verified by using a lognormal distribution approach. The channel centerline was digitized from serial aerial photographs.

NUMERICAL SIMULATIONS

STREAM MEANDER MIGRATION MODELING

Stream meander migration is controlled by eroding and depositing stream banks. Erosion and deposition are controlled by the water velocity at different locations in the channel and by the structural characteristics of the stream banks. In order to model stream meander migration, the magnitude and spatial pattern of the velocity must be quantified and coupled with some measure of the structural characteristics of the stream banks.

The stream meander migration model used in this report uses a linear theory for velocity distribution in meander bends to predict the velocity field (Johannesson and Parker 1989). This is coupled with a bank erosion theory (i.e., Ikeda et al. 1981) to predict the spatial and temporal patterns of stream migration. Bank erosion involves a variety of complicated processes, including fluvial entrainment of sediment, the influence of soil saturation, bank mass failure, and bank unraveling (Thorne 1982, Osman and Thorne 1988). The hydraulic algorithm for bank erosion was developed by Ikeda et al. (1981). Ikeda et al. (1981) do not explicitly model these processes; rather, they attempt to represent their integrated effects. The model assumes that a vertical bank experiences fluid shear forces due to the water flowing tangentially to the bank. In this view, local erosion occurs in linear proportion to the magnitude of the local shear stress and in inverse proportion to the magnitude of the bank resistive forces. One can visualize that the flowing water directly entrains the bank material. Although the conceptual model and the actual processes differ, the simple model adequately predicts bank erosion (Ikeda et al. 1981, Beck 1984, Johannesson and Parker 1989, Howard 1992, and Larsen 1995).

MODEL ASSUMPTIONS

The model effort included herein makes a few simplifying assumptions.

- The solution for the velocity flow field assumes that there is a relatively small channel centerline curvature, and that nonlinear physical processes can be approximated by linear equations. In addition, the velocity field modeling assumes that there exists no significant sediment sorting, either down or cross stream.
- The bank erosion modeling assumes that the ratio of bank height above the water surface to the depth of the channel below the water surface is the same from one time period to another. The bank erosion algorithm assumes the existence of an equilibrium channel width, equal to the reach-averaged width obtained at the typical cross-section. This algorithm assumes that erosion on one bank is accompanied by equal deposition on the opposite bank.

- The long-term effects of different flow magnitudes and duration can be represented by a single flow, herein chosen to be the 2-year discharge.
- Hydraulic conditions such as slope, particle size, width, and depth, do not change in the period of prediction. This requires that no major watershed or hydrologic changes occur.
- No channel cut-off occurs in the time of modeling.
- The dominant mode of sediment transport and magnitude of the sediment transport rate do not significantly change in the time period of prediction.

RESULTS

CROSS-SECTIONS AND LONGITUDINAL PROFILES

The cross-sections and longitudinal profile are presented as Figures 2 and 3. Bankfull width is approximately 195 feet and mean bankfull depth is approximately 3.3 feet. Slope was measured along the thalweg (i.e., the deepest point of the channel). The channel slope is approximately 0.007 (i.e., 1 percent).

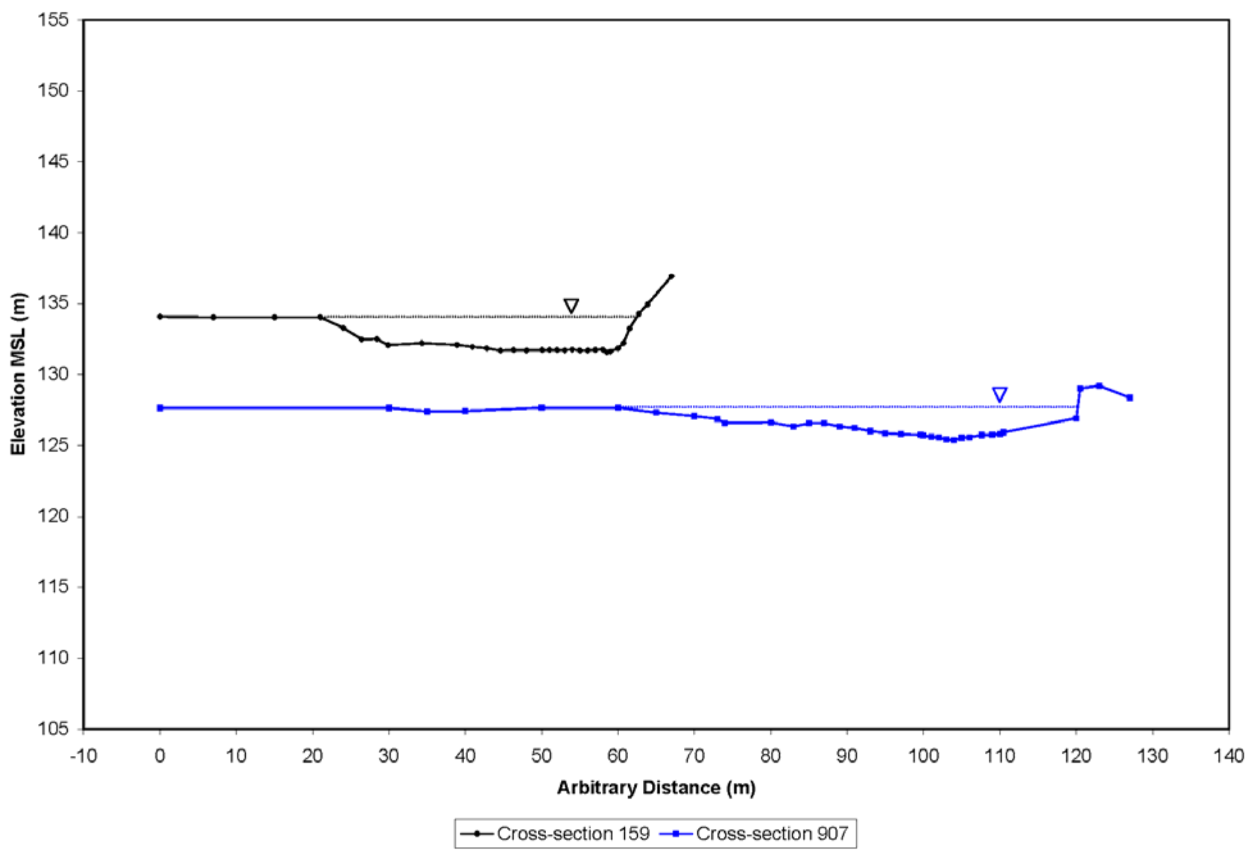

Figure 2. Typical Cross-Sections of San Antonio Creek.

Figure 3. Longitudinal Profile of San Antonio Creek.

FLOOD FREQUENCY ANALYSIS

The VCFCD estimates that the 2-year and 5-year return discharges are 1,590 cfs and 4,750 cfs, respectively. Using a lognormal distribution approach, the 2-year and 5-year return discharges were computed independently to be 1,500 cfs and 5,100 cfs, respectively. The latter independently computed values are used herein.

The meander migration model used herein requires the estimation of a bankfull discharge. The bankfull discharge can be defined as the discharge that determines observed channel geometry (Wolman and Leopold 1957). Depending upon the physiographic characteristics of a region, the bankfull discharge can range from the 1- to 100-year return discharges (Williams 1978). The authors and others have found that the bankfull discharge in the Transverse Range, California is approximately the 5-year return discharge. Therefore, the independently computed 5-year return discharge is used herein.

CHANNEL MATERIALS

The characteristic channel bed material particle size is defined herein as the D_{50}. The D_{50} is the median particle size, or the size that is greater than or equal to 50 percent of the particles. The D_{50} of the channel bed materials at the project site is 23 mm.

MIGRATION PREDICTIONS

Lacking information on detailed bank characteristics, the authors assumed constant bank characteristics in areas that were not restrained, and assumed an erosion resistant bank where the channel was visually observed to be restrained. The migration modeling results presented herein represent the predicted migration pattern over a period of a single storm. First, the model was calibrated to match the migration that was observed in the January 2005 storm. The calibrated migration closely matched the observed migration (Figure 4). Subsequent to that, the model was run to simulate the migration that would have occurred if the channel had not moved to its location prior to the January 2005 storm. The authors have confidence in the general pattern of stream migration (Figure 5).

CALIBRATION MODEL RUN

The calibration model run is presented in Figure 4. Prior to the January 2005 storm, fill was placed on the right bank of the floodway, and the main channel moved to the left bank of the floodway (Figure 1). It was from this location that the bank eroded and the channel meandered during the course of the January 2005 storm. It also was from this location that the bank eroded and the channel meandered during the course of the calibration model run. A typical cross- and downstream channel migration can be seen in Figure 4. The pre-storm channel is in dark blue, the post-storm channel is in light blue, and the modeled channel is in red. The agreement between the post-storm channel and the modeled channel indicates that the model is calibrated and can be used for additional predictions.

PREDICTIVE MODEL RUN

The predictive model run is presented in Figure 5. For many years prior to the January 2005 storm, the main channel followed along the right bank of the floodway (Figure 1). Were it not for the placement of the fill on the right bank of the floodway, it is likely that it would have been from this location that the bank would have eroded and the channel would have meandered during the course of the January 2005 storm. Therefore, it was from this location that the bank eroded and the channel meandered during the course of the predictive model run. Again, a typical cross- and downstream channel migration can be seen in Figure 5. The pre-storm channel is in dark blue, the post-storm channel is in light blue, and the modeled channel is in red. Though the outside bank erodes and the channel migrates, it does not erode nearly as much of Mr. Whitman's property as occurred during the January 2005 storm.

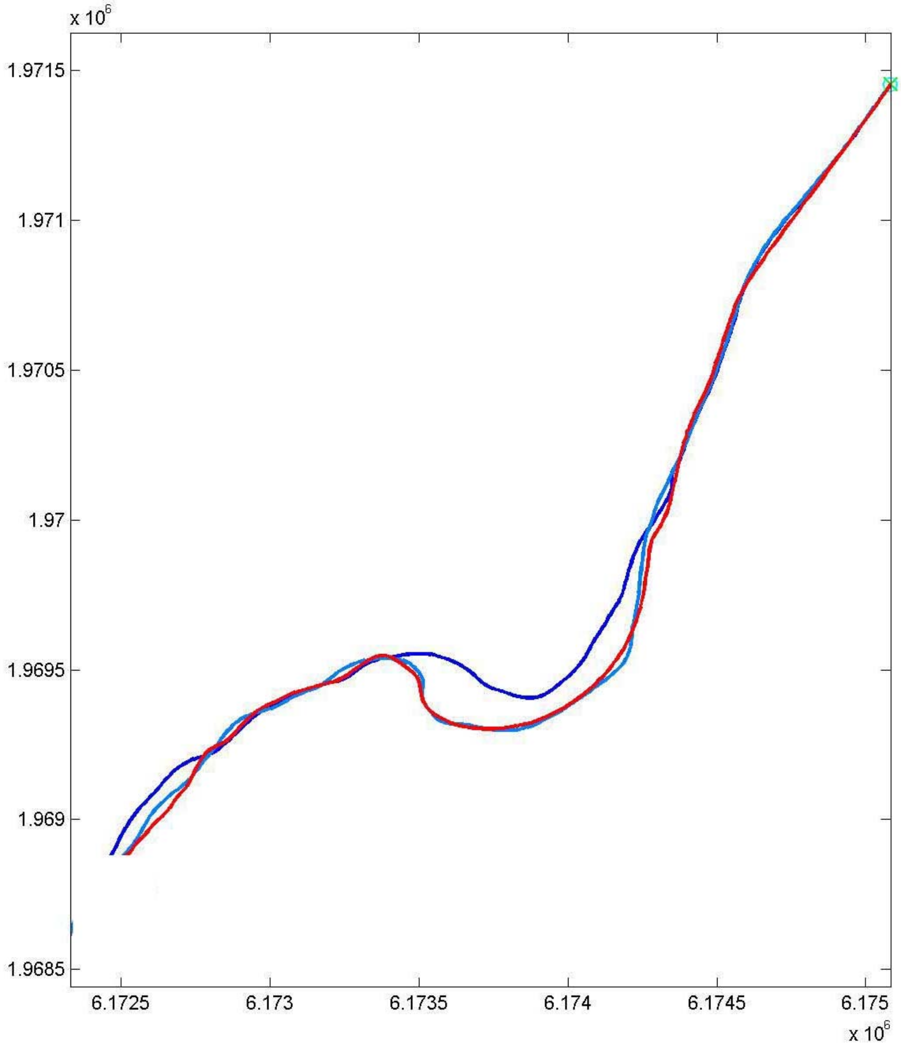

Figure 4. Calibration Model Run with the Pre-Storm Channel in Dark Blue, the Post-Storm Channel in Light Blue, and the Modeled Channel in Red. (Note: In this model run, the pre-storm channel had been diverted to the left bank of the floodway by the placement of fill on the right bank of the floodway.)

This result can be best understood in the following terms. Banks resist erosion and channels resist migration. A certain threshold of shear stress must be exceeded prior to the initiation of bank erosion and channel migration. Once this threshold is exceeded, the absolute amount of bank erosion and channel migration is proportional to the amount of excess shear stress. The primary thing that changed just prior to the January 2005 storm was the starting location of the channel. For many years prior to the January 2005 storm, the main channel followed along the right bank of the floodway. From this location, the channel would have had to first migrate across most of the floodway prior to eroding Mr. Whitman's property. Prior to the January 2005 storm, fill was placed on the right bank of the floodway, and the main channel moved to the left bank of the floodway (Figure 1). From this location, the channel was already across most of the floodway and therefore was able to erode much of Mr. Whitman's property.

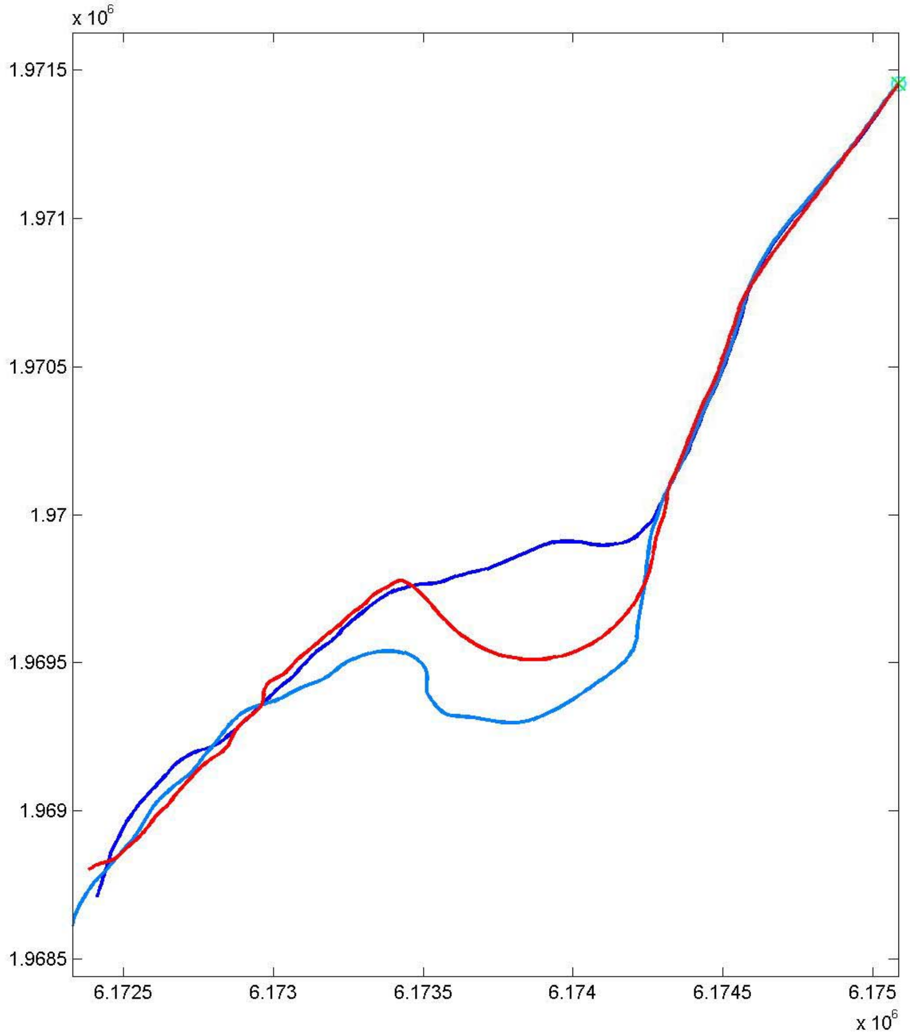

Figure 5. Predictive Model Run with the Pre-Storm Channel in Dark Blue, the Post-Storm Channel in Light Blue, and the Modeled Channel in Red. (Note: In this model run, the pre-storm channel had not been diverted to the left bank of the floodway by the placement of fill on the right bank of the floodway.)

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