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Initial Hydraulic Modeling and Levee Stability Analysis of the Triple M Ranch Restoration Project

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Advanced Watershed Science & Policy: CSUMB Class ESSP 660:

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Executive Summary

"Advanced Watershed Science and Policy (ESSP 660)" is a graduate class taught in the Master of Science in Coastal and Watershed Science & Policy program at California State University Monterey Bay (CSUMB). In 2007, the class was taught in four 4-week modules, each focusing on a local watershed issue. This report is one outcome of one of those 4-week modules taught in the fall 2007 session-

Review of Carneros Creek and wetland restoration concepts.

The Agriculture and Land Based Training Association (ALBA) owns and manages a reach of Carneros Creek and floodplain located near the point where the watershed enters Elkhorn Slough. ALBA is evaluating restoration opportunities on their property that optimizes wetland habitat and function. The class activities included

1) a critical review of technical reports detailing conceptual restoration design plans and biological assessments for a reach of the Carneros Creek valley bottom, and
2) initial work on modeling the potential shear stress on existing river-bounding berms and on the future berms under a scenario of fully repaired berms. The module was led by Doug Smith (CSUMB) and Bryan Largay (Largay Hydrologic Sciences, LLC).

The final report is chiefly the work and writing of the graduate students of ESSP 660, with edits and additional writing by Dr. Smith. An appendix includes the summarized work of several undergraduate student reports that were presented in another CSUMB course taught in the same semester (Geomorphic Systems; GEOL 360).

Data used in the report include

1) consulting reports containing biological data and restoration design concepts,
2) benchmarked student surveys from fall 2007,
3) benchmarked surveys from January 2007 provided by Bryan Largay,
4) sediment size analysis,
5) hydrologic gage data summaries from Largay (2007), and
6) unpublished hydrologic gage data from Dr. Marc Los Huertos (CSUMB).

Analyses include

1) critical evaluation of proposed restoration concepts for Carneros Creek and associated wetlands,
2) flood frequency analysis to determine recurrence period for key flows in the study area,
3) hydrologic modeling to obtain water surface slopes and flooding discharge,
4) comparison of berm material mobility and theoretical shear stress along the berms, and

5) sediment transport modeling to assess the time to fill a proposed floodplain bedload trap

ALBA has potentially mutually exclusive restoration goals of floodplain/wetland function and floodplain agriculture. Other competing goals may be present. Carneros Creek floods both the northeastern and southern floodplains when flow exceeds approximately 40 cfs, which occurs several times each year on average. An existing short berm breach is essential to future berm stability. Without the breach, the berm would be exposed to high shear stresses relative to the berm materials. Without the berm breach, the berm would be topped at approximately 1400 cfs, potentially leading to catastrophic berm failure and creek avulsion to low-standing floodplain topography. ALBA should weigh the respective benefits of creek-side agriculture and floodplain function. If agriculture is favored, future management options might need to include engineered levees and periodic channel excavation to reduce the flood risk. Theoretically, the proposed bedload trap in the northeastern floodplain would fill in approximately two weeks of constant channel-full flow. Although the work reported here is of a high standard, the results should be considered tentative, pending improved data sets (hydrologic and topographic) and model calibration.

Acknowledgements

We are grateful for the assistance of:

- Largay Hydrologic Sciences, LLC (Bryan Largay)
- Agriculture and Land Based Training Association
- CSUMB Geomorphic Systems (Bruce Cyr, Bryce Kantz, Mosaáti Fotu, Jared Paul, Keith Bennett, Louie Okamoto, Sean Castorani, Crystal Covell, Phillip Reyes, Lauren Grounds, and David Franco)

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1 Introduction

1.1 Overview

The Triple M Ranch is located in a key landscape position in the Elkhorn Slough watershed. It is in the transition zone between fluvial and estuarine systems on Carneros Creek, the main tributary to Elkhorn Slough (Figure 1). The Ranch is managed by the Agriculture and Land Based Training Association (ALBA), with multiple goals of promoting and training farmers in sustainable agriculture, as well as preserving and restoring natural habitat and ecosystem functions. To advance these objectives ALBA has identified several specific goals and potential alternative management actions.

Figure 1. Oblique western view up the Carneros Watershed (outline). Study site is Triple M Ranch (TMR). Ancestral mouth of Carneros Creek is now flooded by high sea level to form Elkhorn Slough (ES), which drains to the sea at Moss Landing (ML). .

The Carneros Creek watershed in California's central coast has experienced major impacts in the last century as a result of human modifications to the landscape. The creek itself has been ditched and straightened in order to utilize floodplain acreage for agriculture, grazing, or other human uses. The straightened channel has been maintained through dredging and the formation of dredge spoil berms along the sides of the channel. The system is out of equilibrium, so regular maintenance and management is required to foster the historic goals of floodplain and wetland reclamation. The modifications have also resulted in loss of wetland habitat and function in the floodplain areas.

1.2 Physical Setting

The Physiography of the portion of the Carneros Creek that feeds water and sediment to the Triple M Ranch is characterized in Table 1 and shown in Figure 2.

Table 1: Watershed morphology upstream from Triple M Ranch (Figure 2)

	Metric	English
Drainage area	60 km^2	24 mi^2
Aspect	west	west
Min elevation	5 m	15 ft
Max elevation	400 m	1300 ft
Mean elevation	116 m	380 ft
Relief	390 m	1290 ft
Length	13110 m	43000 ft
Average Slope	0.03	0.03

The watershed geology is dominated by easily eroded Quaternary sand dune deposits (Qa; Figure 3) and creeping soil (colluvium; Figure 3). These units are relatively young and not well lithified, and so are highly susceptible to erosion. Figure 4 shows typical erosion potential in the watershed, with an abundance of red high erosion-risk zones.

Land use in the Carneros Creek watershed also contributes to excessive erosion and flashy runoff. A significant portion of the watershed is devoted to strawberry farming, and the plastic mulch used for this crop acts as an impervious surface (Largay 2007). Rainfall is funneled into gullies, and large storm events can release massive amounts of sediment. Greenhouses in the watershed function hydrologically as suburban pavement, enabling rainfall to quickly run off without saturating the ground. These impervious surfaces result in higher peak floods and more erosion (Largay, 2007).

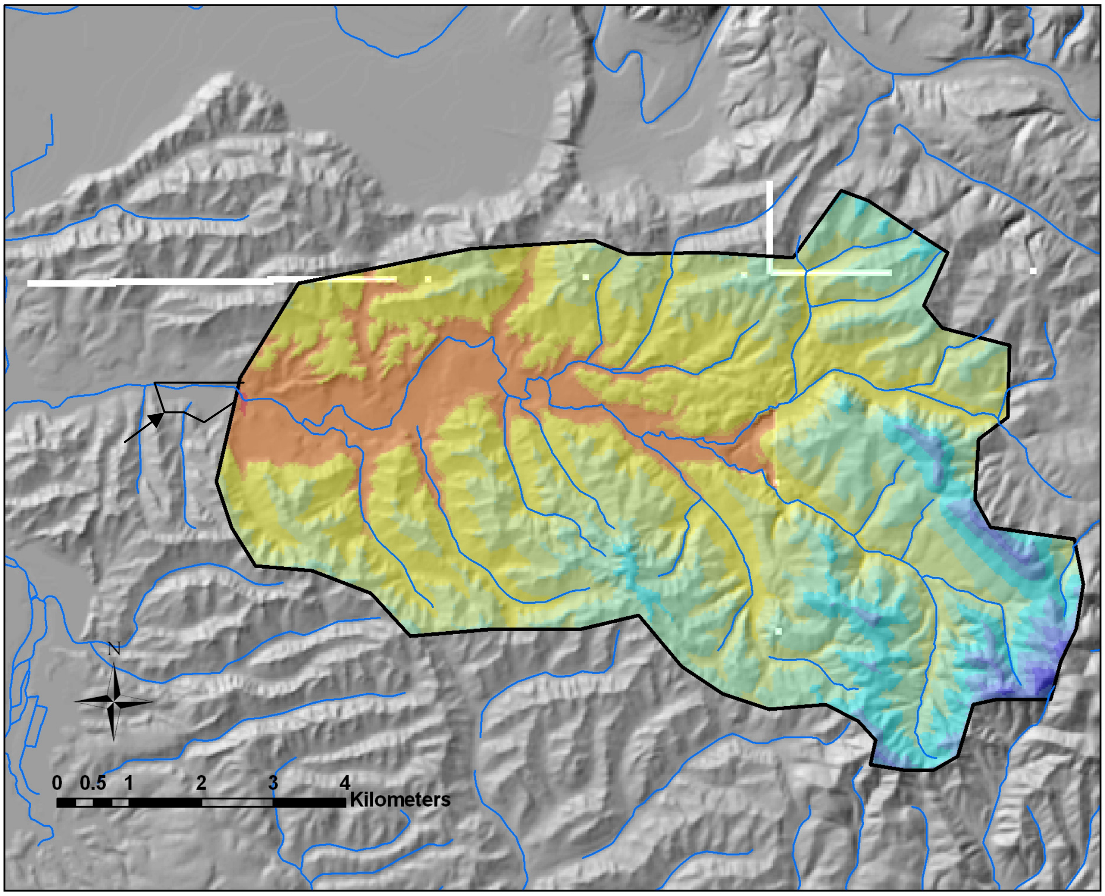

Figure 2: Watershed physiography upstream from Triple M Ranch restoration project (arrow). Color changes show elevation increments of 50 m (165 ft), starting at 5 m (15 ft). Base map is 30 m USGS digital elevation model.

1.3 Restoration Goals

ALBA and the many stakeholders involved with the Triple M Ranch have committed to restoring, preserving and/or creating wetland habitat at the Triple M Ranch. In accordance with ALBA's mission to contribute to a more just and sustainable food system, including the enhancement of biological diversity and protection of natural resources, they are moving toward a Wetland Design and Restoration Plan. ALBA as the lead has partnered with the US Department of Agriculture's Natural Resource Conservation Service (NRCS), the Resource Conservation District of Monterey County (RCDMC), and the Elkhorn Slough Foundation (ESF). Consultants Bryan Largay and Dawn Reis were hired to develop conceptual designs for restoration, focusing on hydrology and physical systems (Largay, 2007) and special status amphibians (Reis, 2007a;

2007b). Several goals were identified for the wetland restoration project, including improving water quality, managing a more natural sediment balance, restoring diverse native plant communities, providing flood storage, reconnecting the creek to its floodplain, providing more open water habitat for water fowl and special status amphibian species and mosquito control, and demonstrating a Safe Harbors Agreement.

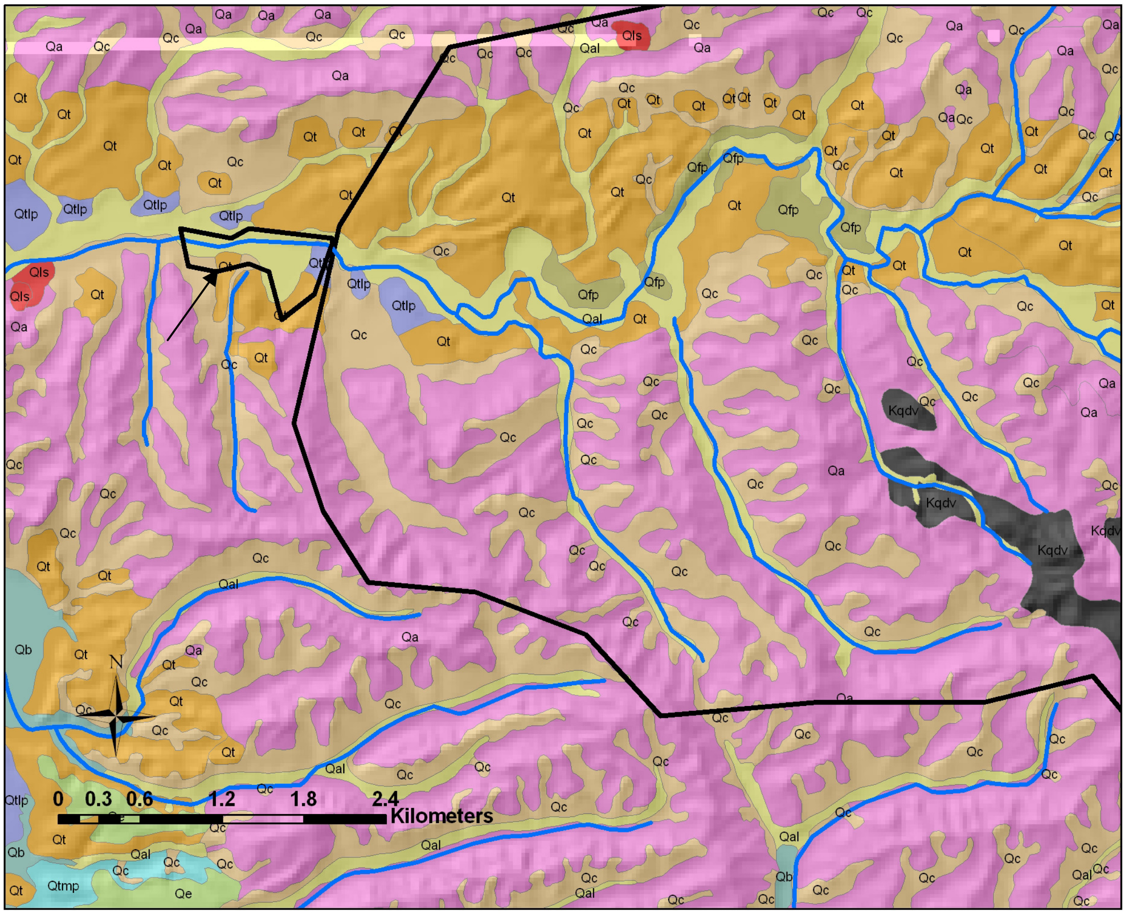

Figure 3. Geologic units exposed in lower Carneros Watershed. The substrate is chiefly old sand dune deposits of the Aromas Fm. (Qa), Fluvial terrace deposits (Qt), and Colluvial soils derived from the previous two units (Qc). Ancillary units are Cretaceous “granitic” rocks (Kqdv) and modern stream deposits (Qal). Data from Rosenberg (2001)

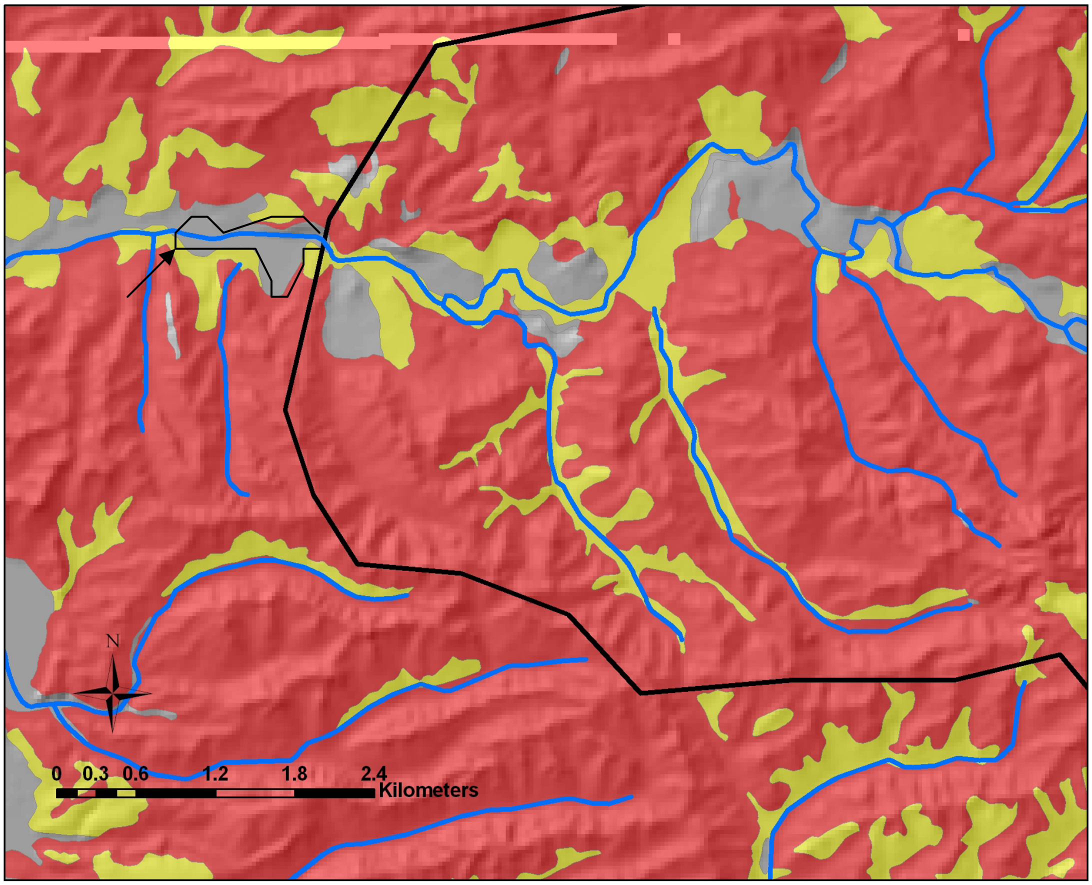

Figure 4: Susceptibility to erosion. Red is high susceptibility, yellow is moderate, grey is low. Data from Rosenberg (2001).

To achieve the management goals for the Triple M Ranch, several alternative management actions were proposed. A Technical Advisory Committee (TAC) was organized to provide expert opinions on the project. The TAC met on November 29, 2007 to discuss the restoration plan. There was extensive discussion on the special status amphibians at the Ranch. The oxbow pond on the Ranch is designated habitat for Santa Cruz Long-toed Salamanders and California Tiger Salamander. There is concern that Carneros Creek could escape the dredge spoil berms and re-occupy the oxbow, impairing water quality in the oxbow and potentially delivering excess sediment. The risk of channel avulsion, or an abrupt change in the route of the Carneros Creek main channel, is unknown.

More information and analysis of the hydrology structure and behavior on the Triple M Ranch is crucial to inform the restoration design and management. We need to know where flood waters will go, the magnitude of future floods, and how the system (including berms) will respond to these floods. Hydrologic modeling is a useful tool to inform these analyses. This study uses HEC-RAS to model flows under different barrier berm scenarios. This paper reports on the initial results of the model runs, and notes where additional data and analysis is necessary.

2 Methods

2.1 Overview

Carneros Creek is locally bounded by linear berms built from the spoil of incremental channel dredging. The overarching purpose of this study was to model channel flow with an updated hydrologic data set in order to determine the integrity of the berm system (Figure 5) at a location of concern as identified by Largay (2007). To achieve this goal we compared the strength (mobility) of the berm material with the theoretical shear stress imparted by the creek. We used sediment grain-size analysis of the berm material and hydraulic modeling results from HEC-RAS.

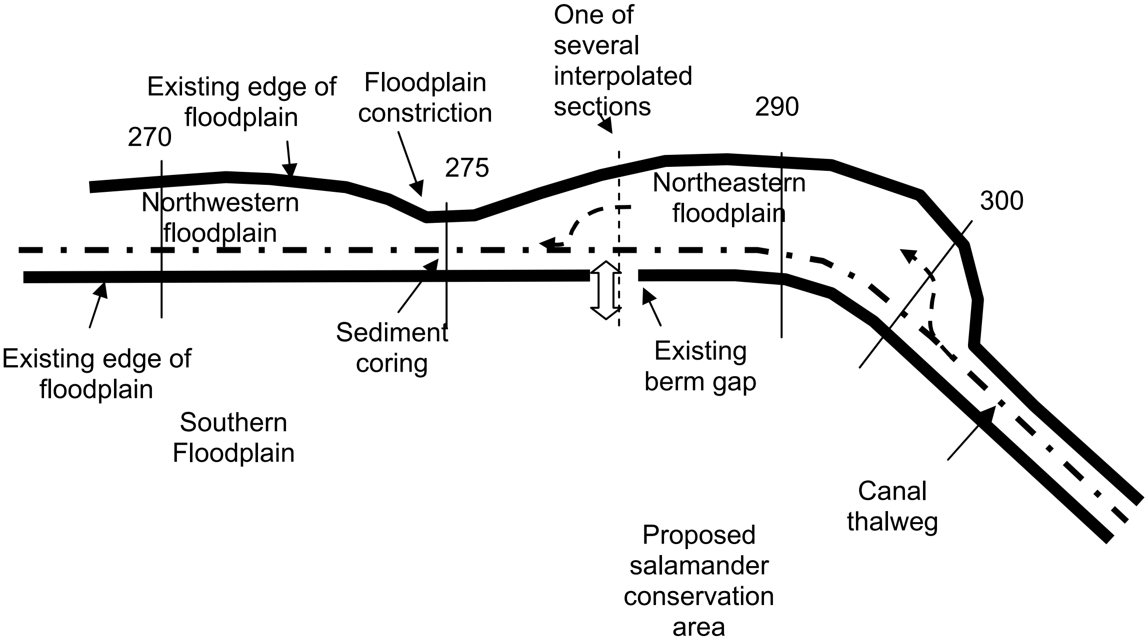

Figure 5: Schematic map of site showing the upstream (Cross-section 300) and downstream (Cross-section 270) extents of the modeled channel. “Floodplain Constriction” is the location of concern mentioned in Largay (2007). Flow is from right to left.

2.2 Reconnaissance

Initial work included discussions with Bryan Largay, a critical review of consulting documents related to wetland restoration design concepts and feasibility on the Triple M Ranch (Largay, 2007; Reis, 2007a, 2007b), and several site visits. Field data stemmed from foot reconnaissance, sediment sampling (described below), and leveling surveys (Appendix A).

2.3 Flood Frequency Analysis

To determine realistic design flows for use in our HEC-RAS model, a flood frequency analysis for Carneros Creek was conducted. We used continuous (15-minute time-step) streamflow data for Carneros Creek at San Miguel Canyon Road for water years 2002 - 2007. Mean daily streamflow data was available for Carneros Creek for water years 1986 - 1993. However, we chose not to include these data in our analysis because averaged records (e.g mean daily streamflow) make it impossible to know the actual magnitude of a peak flow. In small watersheds producing "flashy" peak flows, such as Carneros Creek, the magnitude of a peak flow can be much greater than the mean daily flow will be for the day that peak occurred. This makes mean daily streamflow records unreliable for determining peak flow magnitude.

Because Carneros Creek has only a very brief period of streamflow records available, we performed a partial duration series analysis of peak flows rather than using the traditional frequency analysis based on annual maximum flows. Partial duration series analysis determines the average flow return periods (RI) for all peak flows in a record that exceed a chosen threshold. The average return period of the selected peak flows is estimated using Weibull plotting positions ($RI = (n+1)/m$), where n is the number years of record, and m is the rank order of the peak in question. If multiple peaks are selected from some of the years, there will exist some peaks for which, $M > (n+1)$, leading to estimated return periods more frequent than one year. A further advantage of using a partial duration series analysis is we estimate the absolute probability of occurrence for an event of a certain magnitude, whereas frequency analysis using annual maximum series estimates the probability of occurrence *as an annual maximum flow* (Dunne and Leopold 1978). However, the brief period of record makes any frequency analysis particularly error-prone and unreliable.

For our partial duration series analysis of Carneros Creek, we included all flows > 95 cfs. The threshold of 95 cfs was chosen because it represented the smallest annual maximum flow for the period of record. The peak flows were then ranked and their recurrence intervals calculated as described by Dunne and Leopold (1978).

2.4 Sediment Sampling

If the berms fail, it will be a result of either the shear stress applied by the water (boundary shear stress) exceeding the shear strength of the berm material (critical shear) for a sustained period of time, or because the water tops the berm and races down the steep slope toward the southern floodplain (Figure 5). While the boundary shear stress will be estimated later, the critical shear for the berm material can be approximated here. Critical shear stress is estimated as

$\tau c = \tau^* D (\gamma s - \gamma w)$,

where D is the dominant grain size composing the berm, and γs (2650 N/m^2)and γw (9807 N/m^2) are the specific weights of sediment and water, respectively. Dimensionless critical shear (τ^*) must be chosen from a range of typical values. Since we are assessing risk of berm failure, we used a conservatively low value of 0.035. For comparison, we also calculated critical shear values using a dimensionless critical shear value of 0.05. The assumption is that the particles composing the berm are cohesionless grains that will experience incipient motion when boundary shear stress exceeds critical shear stress. A more thorough discussion of the primary literature associated with this model is in Elliot (2002)

We sampled sediment in two places, a deep vertical core into the berm, and along a transect down the surface of the berm. We cored vertically at the top of the left bank berm at approximately XS 275 (figure 5) to a depth of 1.35 m and collected 15 sediment samples at successive depths (Fig. 6). Surface sediment was also characterized along the near-channel side slope of the left bank berm near XS-275. Using a smaller coring device, 8 samples were collected at a depth of 0.15 m along a 3.5 m transect. Dominant sediment size and other parameters were determined with a standard sediment grain comparator. These samples are representative the materials composing the berm at the point of concern identified in Largay (2001).

Figure 6: View of coring team at top of the berm from the floodplain upstream from XS275 (Figure 5).

2.5 Hydraulic Modeling

As noted above the general approach is to compare boundary shear stress with material shear strength. Here we use HEC-RAS to model water surface slope as a key input to boundary shear stress estimates. The U.S. Army Corps of Engineers HEC-RAS (Hydrologic Engineering Center River Analysis System) program was used to model flow in the current channel. HEC-RAS is a hydraulic computer run model designed to aid engineers with stream channel design analyses by calculating the water surface profiles for a designed channel at different discharge levels.

The required inputs of HEC-RAS, a one-dimensional flow model, include cross-section geometry, channel geometry, Manning's n, and discharge data. To analyze stream flow, HEC-RAS represents the stream as a set of cross-sections along the channel. At each cross-section, bank stations are identified. These points are used to divide the cross-section into segments of the left floodway, the main channel, and the right floodway

(Figure 3). The model is driven by steady flow data and yields graphic and numeric water surface level calculations at each cross-section.

The inputs used for our HEC-RAS hydraulic model included the following:

- Cross-sectional data from a January 2007 survey by Largay. We used 4 cross-sections to represent the channel at the area of concern (Figure 5) and interpolated several cross-sections between the actual data points. Cross-section 280, part of Largay's original data set, was omitted from this study because it lacked realistic representation of the existing berm.
- The distance between cross-sections.
- Manning's n: a roughness coefficient that quantifies the resistance of the river channel to liquid flow. Manning's n was characterized by our best professional judgment for both the channel and the right and left floodplains.
- Discharge data was input iteratively to determine the berm exceeding flow. The slope downstream of the final cross-section was assumed to be 0.002, in keeping with the overall gradient of the floodplain along Triple M Ranch.

The HEC-RAS computational procedure produces water surface levels between cross-sections by determining the amount of energy lost to friction from one cross-section to the next. This energy loss is termed "energy head loss", a variable derived through a series of equations which can be found in the published report of the theoretical basis of the HEC-RAS modeling program (USACE 2002). Using the Energy equation with an iterative procedure, the program solves for the downstream water depth (Y_2).

Energy Equation: $$Y_1 + Z_1 + \frac{\alpha * V_1}{2g} = Y_2 + Z_2 + \frac{\alpha * V_2}{2g} + h_e$$

Y = depth of water at cross-sections
Z = elevation of the main channel
α = velocity weighting coefficient
V = average velocities (total discharge/total flow area)
g = gravitational acceleration
h_e = energy head loss

We iteratively determined the discharges at which water would exit the channel to the southern flood plain under two scenarios. Scenario one represented the channel under existing conditions, with the berm gap between Cross-sections 275 and 290. Scenario two simulates the hydraulics if the gap is repaired, creating a new berm at the appropriate height as determined by the elevation of the berm located at cross section 275.

Berm Shear Stress

In order to assess risk of berm failure during high flows, boundary shear stress was calculated on the berm at cross-section 275. First, sediment analysis was conducted to characterize berm sediment properties (see Method *Sediment Sampling*).The HEC-RAS model was then used to determine the depth and water surface slope at a hypothetical high flow (e.g. a flow close to overtopping the berm). With the sediment and flow information, we calculated the boundary shear stress acting on the berm in this scenario using the equation:

$$\tau o= \gamma w*d*S$$

τo: mean boundary shear stress (N/m2)

γw: specific weight of water (9807 N/m^3)

d flow depth (m)

S: energy gradient or water surface slope (m/m)

If boundary shear stress is greater than critical shear stress $\tau c = \tau^* D (\gamma s - \gamma w)$, (see "Sediment Sampling"), then the berm material may become entrained by that flow and the berm is at risk for failure. An assessment of the relative risk can be made by examining the magnitude of the difference between the boundary and critical shear stresses.

3 Results

3.1 Reconnaissance

The combination of discussions, document review, and leveling surveys resulted in overall praise of the efforts, a short list of concerns and data needs, and several benchmarked leveling surveys that can be used for future environmental monitoring following restoration activities (Appendix A).

3.2 Hydrology

Results from the partial duration series flood frequency analysis are presented in Table 2 and Figure 7.

Table 2: Partial duration series analysis on 7 years of discharge record at San Miguel Road. Peak flows are determined by San Miguel discharge data scaled by watershed area to Johnson Rd. (Watershed area ratio at Johnson Rd. is 1.1 (Largay, 2007)

Date	Peak (cfs)	Peak_JR (cfs)	Return period (yr)	Annual Exceedance Probability
4/4/2006	440	484	7.00	0.14
1/2/2006	382	420	3.50	0.29
12/21/2001	367	403	2.33	0.43
3/25/2006	259	285	1.75	0.57
3/31/2006	237	261	1.40	0.71
2/25/2004	226	249	1.17	0.86
12/31/2005	205	225	1.00	1.00
1/11/2005	171	188	0.88	1.14
12/31/2004	155	170	0.78	1.29
12/29/2001	143	158	0.70	1.43
12/2/2001	140	154	0.64	1.57
3/17/2006	131	144	0.58	1.71
1/1/2004	115	126	0.54	1.86
12/30/2001	112	123	0.50	2.00
12/29/2003	105	115	0.47	2.14
1/8/2005	104	115	0.44	2.29
1/10/2003	104	115	0.41	2.43
1/2/2002	99	109	0.39	2.57
2/28/2007	95	105	0.37	2.71

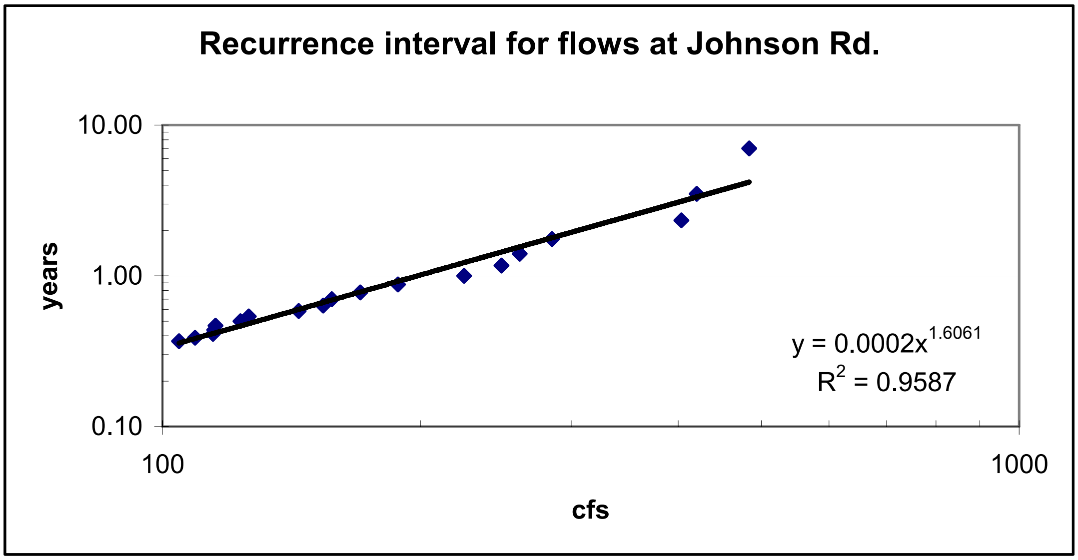

Figure 7: Partial duration series analysis for Carneros Creek at Johnson Rd.

The maximum flood for the period analyzed (water years 2002 – 2007) was 440 cfs and had a predicted recurrence interval of 7 years. Peak flows ranging from 205 cfs – 382 cfs had estimated recurrence intervals from 1 year to 3.5 years based on our analysis. Peak flows from 95 cfs – 171 cfs had recurrence intervals of less than one year, indicating flows in this range may occur multiple times in a given year. Results of a Log-Pearson III flood frequency analysis (using annual maximum flows from mean daily streamflow for water years 1986 – 1993) reported in Largay (2007) found peak flows with recurrence intervals of 1.01, 1.5, and 2 years to be 0.5, 37, and 83 cfs, respectively. The disparity between the two different flood frequency analyses illustrate both the poor results of modeling frequent events with Log-Pearson III analysis, and the enormous uncertainty that comes from a short period of record.

A 1400 cfs flow in Carneros Creek at Johnson Road, located just upstream from the property, has a return period of approximately 23 years according to the power function calculated for the relationship between peak discharge and return period

$RP = 0.0002 * PQ^{1.6061}$

where PQ is peak discharge (Table 2; Figure 7). In contrast Log-Pearson III analysis of Largay (unpublished data; Table 3) indicates that the 1400 cfs flow has an average return period of between 25 and 50 years. Both analyses are imprecise because seven years of data are insufficient for flood frequency analysis. Largay (2007) emphasized the uncertainty associated with analyzing short periods of record.

Table 3: Log-Pearson III analysis of 7 years of gage record at San Miguel Road scaled by watershed area to Johnson Road (Largay, unpublished data).

Peak discharge	Return period
0.5	1.01
37	1.5
83	2.0
340	5
650	10
1200	25
1720	50
2330	100
4030	500

3.3 Sediment Sampling

Results of the berm sediment analysis are in Tables 3 and 4.

Table 3: Results from sediment coring at top of left bank berm upstream from cross section 275 (Figure 5).

Sample	Depth (m)	Grain Size (mm)	Grain Size (narrative)	Sorting	Roundness
1	0.17	0.30	Med Sand w Granules + Fines	poor	sub-rounded
2	0.23	0.30	Med Sand w Granules + Fines	poor	sub-rounded
3	0.30	0.30	Med Sand w Granules + Fines	poor	sub-rounded
4	0.48	0.40	Med Sand w Granules	med	sub-rounded
5	0.64	0.40	Med Sand w Granules	med	sub-rounded
6	0.79	0.40	Med Sand w Granules	med	sub-rounded
7	0.85	0.40	Med Sand w Silt chunk	med	sub-rounded
8	0.91	0.40	Med Sand w Silt chunk	med	sub-rounded
9	1.02	0.40	Med Sand w Granules	med	sub-rounded
10	1.07	0.40	Med Sand w Silt chunk & Granules	med	sub-rounded
11	1.24	0.40	Med Sand w Silt/Clay chunk	med	sub-rounded
12	1.31	0.40	Med Sand w Clay chunk & Granules	med	sub-rounded
13	1.32	0.40	Med Sand w Clay chunk & Granules	med	sub-rounded
14	1.32	0.40	Med Sand w Clay chunk & Granules	med	sub-rounded
15	1.35	0.25	Med/Fine Sand w Granules	med	sub-rounded

Grains sizes from the core sampling taken at the top of the berm ranged from 0.25 - 0.40 mm, with the majority in the 0.30 -0.40 mm range. The sediment was very homogeneous throughout and consisted primarily of medium sand with many samples containing bits of silt and clay.

Table 4: Results from surface sediment analysis upstream from cross section 275 (Figure. 5) on north side of berm. “Distance” is slope distance from berm top.

Distance (m)	Grain Size (mm)	Grain Size (narrative)	Sorting	Roundness
0.0	0.25	Med/Fine Sand w organics	Poor	Sub-rounded
0.5	0.25	Med/Fine Sand w organics	Poor	Sub-rounded
1.0	0.3	Med Sand w organics	Poor	Sub-rounded
1.5	0.3	Med Sand w Granules	Poor	Sub-rounded
2.0	0.3	Med Sand w Silt & Pebble	Poor	Sub-rounded
2.5	0.3	Med Sand w Silt	Poor	Sub-rounded
3.0	0.05	Silt w Med Sand	Poor	Sub-rounded
3.5	<.05	Silt/Clay	Med	n/a

Sediment from the berm side slope consisted primarily of medium to fine sand and ranged in grain size from 0.05 - 0.30 mm, with the majority falling in the 0.25 - 0.30 mm range. The sediment found here was slightly finer and somewhat more varied than the berm top core and contained more organics and even some pebbles.

3.4 Hydraulic Modeling

Our study showed that under the first Scenario, with the existing gap present in the model, the channel would carry a flow of up to 40 cfs before spilling to the northeastern and southern floodplains. The partial duration series analysis suggests that this flow will occur several times a year. Flows in excess of 40 cfs are accommodated by the floodplain, accessed through the gap, so the stage at cross section 275 does not easily reach the berm.

Under the second scenario of a filled gap, the results of our model suggest that the channel could carry up to a 1400 cfs flow before the levees are overtopped. The highest energy grade at this discharge is downstream of the pinch, suggesting that this reach may be the most susceptible to undercutting and subsequent berm failure.

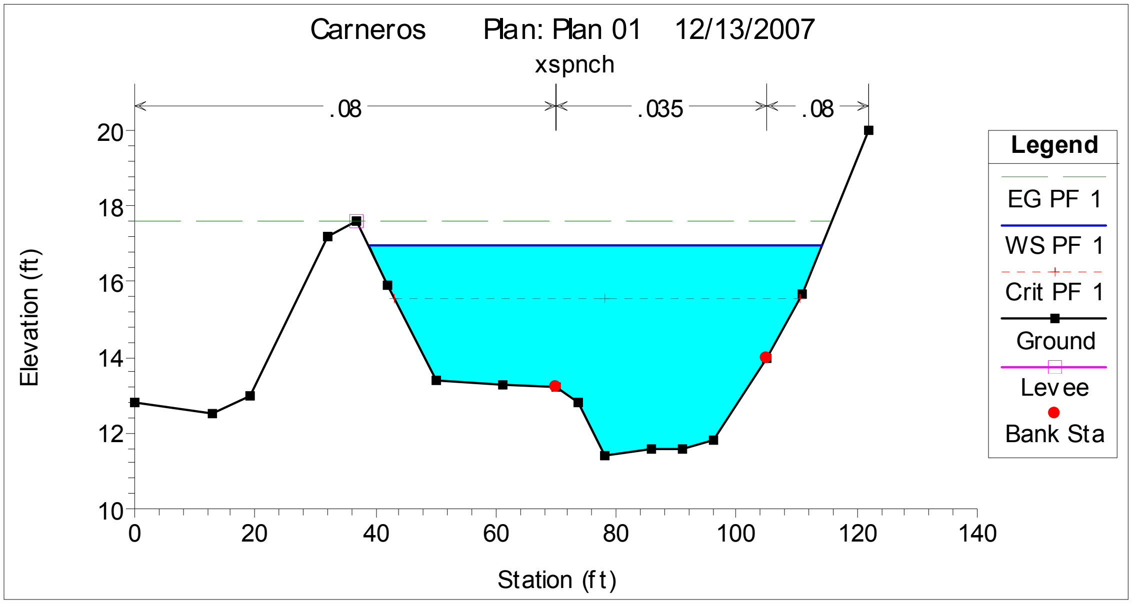

Figure 8: Cross-section 275 at a flow of 1400 cfs. Water surface elevation is within 6 inches of levee top which constitutes levee exceedence given the uncertainty inherent in or model.

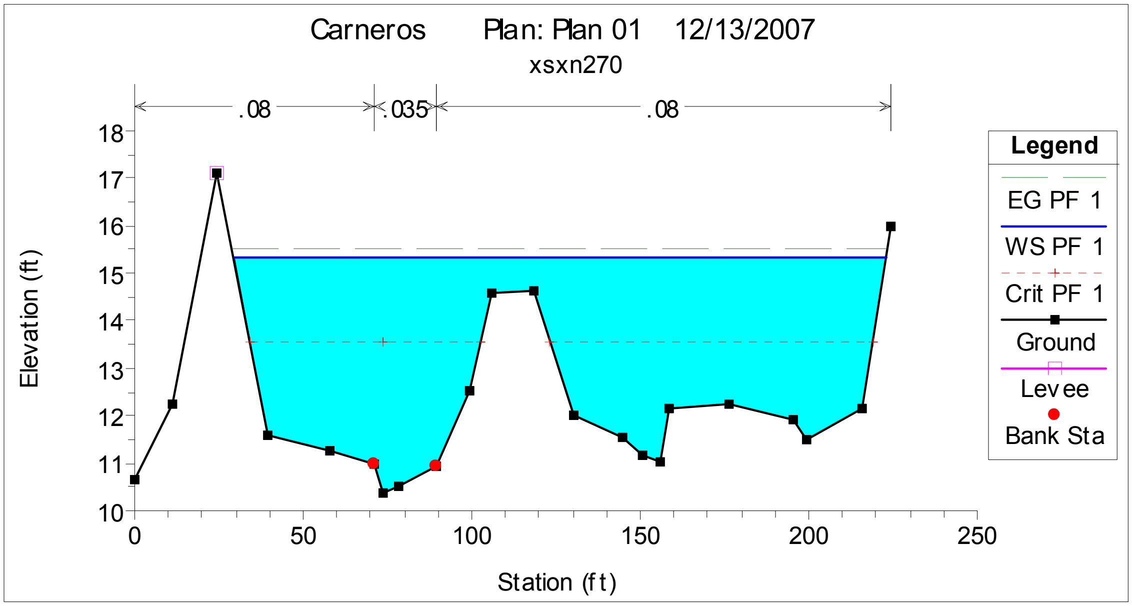

Figure 9: The channel and northwestern flood plain at a flow of 1400 cfs. at cross section 270 in Figure 5.

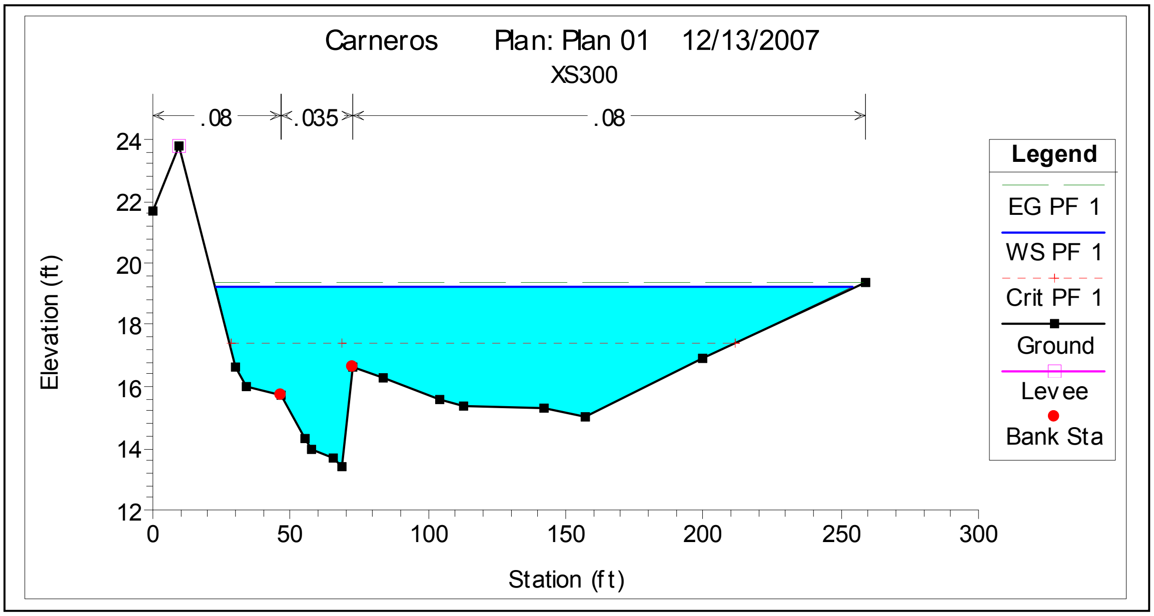

Figure 10: The channel and northeastern flood plain at a flow of 1400 cfs. at cross section 300 in Figure 5.

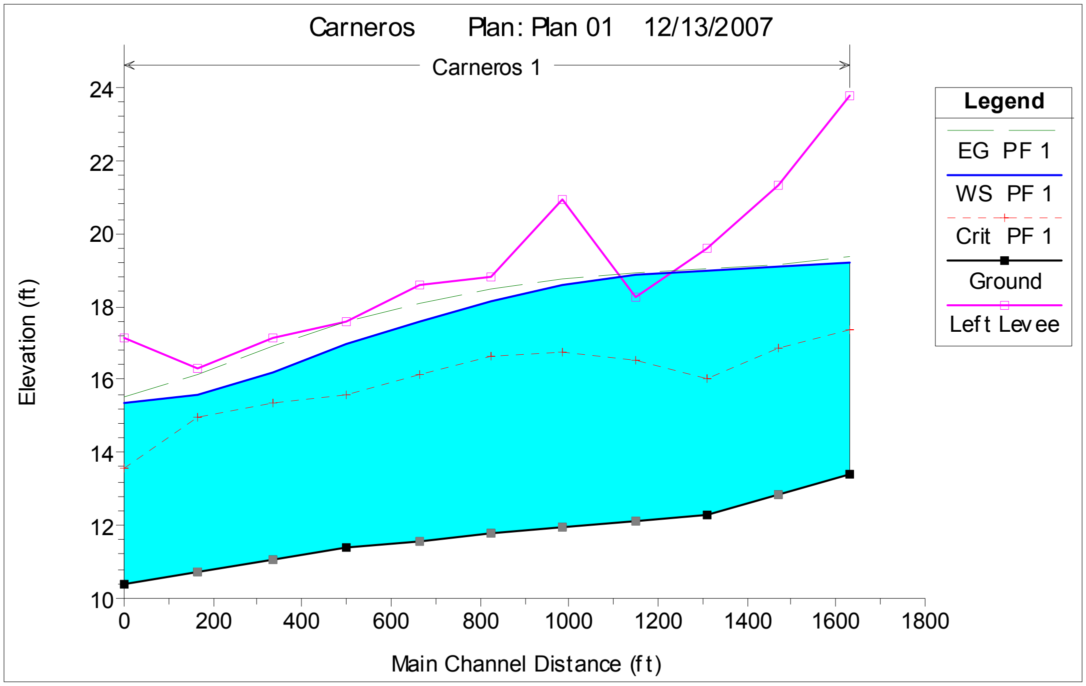

Figure 11: Energy grade (green dotted line), water surface elevation (blue line) and left levee elevation (purple line) profiles from downstream (x=0 ft.) to upstream (x near 1600 ft.).

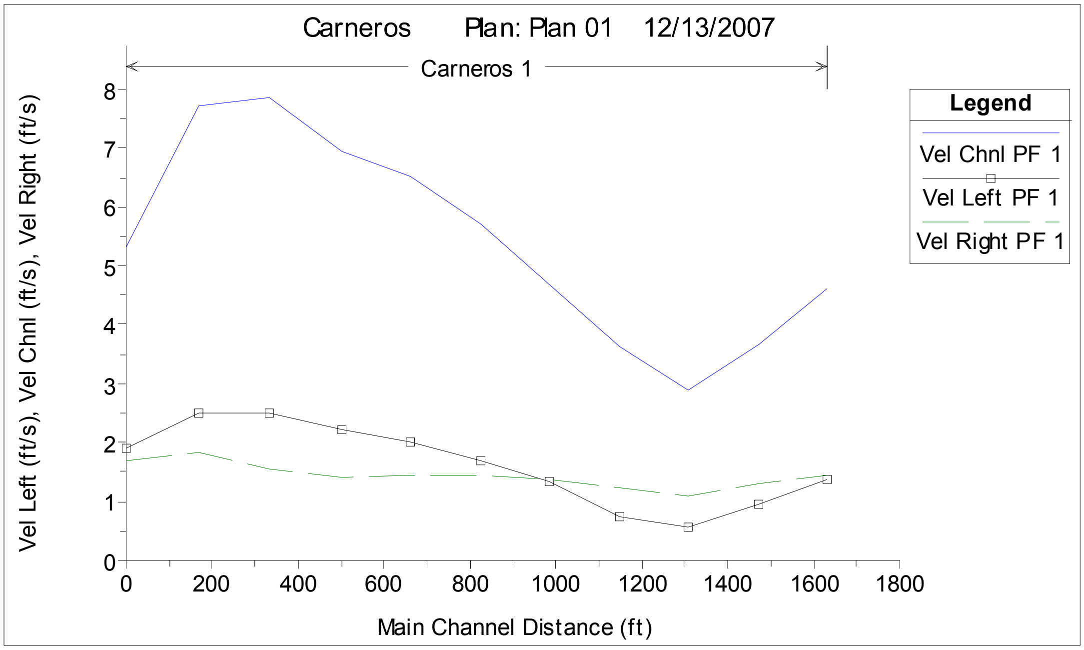

Figure 12: Channel velocity (blue line) velocity rising through pinch (Cross-section 275), and highest after the pinch. Channel velocity near the berm of concern is near 7 ft/s and the left floodplain, touching the berm, is near 3 ft/s downstream of the berm of concern.

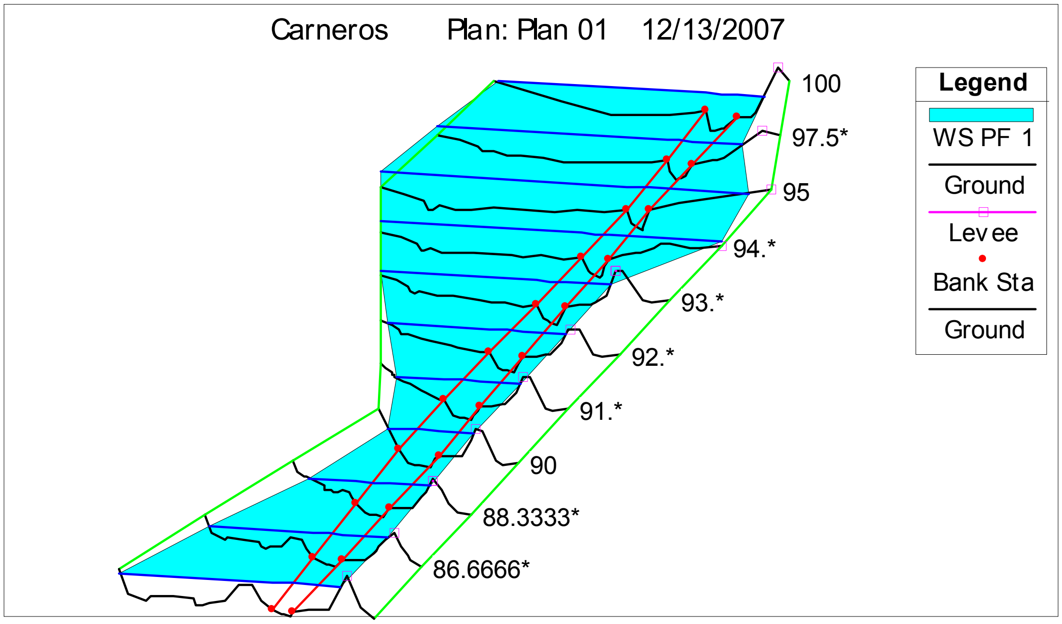

Figure 13: Oblique view of modeled channel at 1400 cfs with under Scenario 2 with no gap.

3.5 Berm Sheer Stress

The results from the berm shear stress analysis are presented in Table 5.

Table 5. Calculated boundary and critical shear stresses for berm at 1400 cfs flow

Distance from top of berm (m)	Water Depth (m)	Grain Size (mm)	Boundary Shear Stress (N/m^2)	$\tau^*c = 0.05$ Critical Shear Stress (N/m^2)	$\tau^*c = 0.035$ Critical Shear Stress (N/m^2)
1.2	0.62	0.25	18	0.20	0.14
1.7	0.88	0.25	26	0.20	0.14
2.2	1.14	0.30	34	0.24	0.17
2.7	1.40	0.30	41	0.24	0.17
3.2	1.66	0.30	49	0.24	0.17
3.7	1.92	0.30	57	0.24	0.17
4.2	2.18	0.05	64	0.04	0.03

According to our HEC-RAS model, the peak flow that nearly overtops the berm is approximately 1400 cfs. At this flow, calculated boundary shear stress on the berm ranged from 18 N/m^2 near the top of the berm to 64 N/m^2 at the bottom. The boundary shear stress was far greater than the calculated critical shear stress, which ranged from 0.03 - 0.24 N/m^2. These calculations indicate that there is ample energy to entrain the berm material at the design high flow, which could put the berm at risk of failure if the gap is filled.

4 Discussion

This study was generated by the temporal coincidence of the restoration planning process at ALBA's Triple M Ranch and the need for a real-world issue to study in graduate and undergraduate courses at CSUMB. Based upon statements in Largay (2007) the focus of our work became the risk of berm failure in the vicinity of the constricted floodway near cross section 275 (Figure 5), and other factors in the conceptual plans were considered. We first discuss the importance and limitations of the berm failure analysis; then we list other concerns discovered during the study. Appendix A provides a summary of survey data. We note that this study should be considered preliminary, and some of the results should be considered tentative, given the short period of flow data and data needs. The scope of this study did not allow an analysis of precision.

4.1 Berm Failure Analysis

Berms are currently being used at Triple M Ranch to protect the southern floodplain agriculture fields and sensitive habitat areas from flooding. Likewise, restoration concepts presented in Largay (2007) include various berm modification scenarios. We determined that the berm system is, in general, a discontinuous dredge-spoil ridge comprising weakly-consolidated, cohesionless, sand (0.3 mm typical diameter). Therefore the berm system is well connected to both northern floodplains and does not supply much security from flooding on the southern floodplain. The berm is not an engineered flood-control structure; it is the incidental result of channel excavation.

Natural levee systems, engineered levees, and incidental berms (present on study site) are susceptible to failure from two primary causes (Nelson 2004):

1) Overtopping – where discharge flows over the top of the berm and erodes the backside of berm until a channel runs through the berm (e.g., Slingerland and Smith, 2004).
2) Undercutting – where high discharge leads to higher velocities that can lead to high rates of erosion along inner parts of berm until it fails.

In present conditions, where a significant berm breach is maintained, the risk of either failure mode is low. This margin of safety results from the flood accommodation space on the northern and southern floodplains, which keeps overall water depth low during discharge events (> 40 cfs).

If the existing gap were repaired in place as part of the restoration implementation, high discharge flows will result in deep, swift flows along the length of the berm (Figures 8 through 11). This scenario could lead to failure from either overtopping when discharge exceeds approximately 1400 cfs (Figure 8, Table 3), or undercutting as high shear stress strongly exceeds the erosion threshold of the sand composing the berms (Table 5). Although we are not familiar with the history of the site, the presence of the berm gap suggests that our modeled failure may have actually occurred in the past when such high flows apparently occurred within the context of continuous berms.

Our results strongly indicate that there would be a high risk of berm failure and avulsion if significant berm gaps are not maintained. We also note that the channel bottom elevation is not very different from the elevation of swales in the southern floodplain. If sediment aggrades within the channel, the elevation difference will diminish further increasing the risk of catastrophic avulsion (Slingerland and Smith, 2004). Existing benchmarked cross sectional surveys (Largay, unpublished data), and surveys performed during this study (Appendix A) can be used to monitor channel changes so that the risk can be monitored and re-evaluated through time. Highly erodible soils in the watershed, and poorly managed sediment control in upland farms leads to the potential for significant channel aggradation. While it may lead to habitat disruption, we suggest that episodic channel excavation may need to be part of the management plan if berms are present in the design.

Limitations in this analysis include:

1. Uncalibrated Manning's roughness coefficient
2. Too few surveyed cross sections in the model
3. Too few years of hydrologic gage record
4. Non-specified gap width in our hydraulic model

4.2 Other Concerns

4.2.1 Sustainability

The design concepts presented by Largay (2007) honor a set of restoration goals presented by ALBA. Two overarching management outcomes are apparent in the plans: 1) expanded, high-quality wetland habitat for endangered amphibians and 2) improved water quality for runoff to the Elkhorn Slough. The resulting design options necessarily represent a highly managed system, rather than a sustainable restoration. Management includes a bedload sediment basin, floodplain restriction to foster floodplain agriculture, treatment wetlands, and flow regulation at the downstream terminus of the property. The resulting design concepts do not emphasize naturally evolving systems; rather, they focus on constructing a water treatment setting that extracts bedload, suspended load, and water pollution from the watershed effluent. Given this situation, it is important to not confuse this project with a naturally evolving system that might eventually evolve to a maintenance-free sustainable system of water and sediment flow. We predict that continual management will become a part of the project maintenance. Given the multiple uncertainties present in any hydro-geomorphic modification to the landscape, a realistic adaptive management plan should be explicit in the project plans, including specification of the time-scale when referring to the system as "sustainable."

Bedload transport is difficult to study, so in-stream bedload sediment basins pose interesting problems for sustainability. The power of El Nino-driven floods has the potential to reset the geometry of constructed berms, wetland ponds, and sediment basis. El Nino conditions are not rare, producing significant floods on a decadal scale. In this regard, it will be hard to predict where, and how much, bedload sediment will accumulate during rare high-magnitude events. A sediment basin planned for the northeastern floodplain needs fleshing out before an evaluation can be made. If a functional sediment trap is deemed essential to the success of the system during large runoff events, the following questions should be addressed. Is the sediment transport event that leads to the design capacity the appropriate event for which to design? What is the bedload sediment transport rate of the creek? How long will it take to fill the basin? Under what conditions will the basin be bypassed or fail in other ways? Rudimentary sediment transport modeling suggests that Carneros Creek would need to flow at channel-full conditions (approximately 40 cfs) for 13 days to fill the sediment basin indicated by Largay (2007). More sophisticated modeling that includes floodwave geometry and larger floods can be done to augment our evaluation of the basin design.

4.2.2 Competing goals

The stated desire to foster creek-floodplain connections while maintaining floodplain space for agriculture potentially creates a set of competing goals that lead to the use of berms in the project. If berms are to be used, we recommend that the berms be set back from the channel along the length of the bermed reach, with enough width to allow natural floodplain functions and channel evolution to occur within the berms.

The desire to develop two sets of wetlands, those that are exposed to floodwaters, and some that are protected from floodwaters, is at odds with the desire to protect salamaders from potentially polluted Carneros Creek water. Salamanders will not be restrained to in the protected wetlands, so the goal is not enforceable.

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6 Appendix A: Survey data

Coming…