APPENDIX K

Geomorphic Assessment of the Feather River from RM 6.9 to RM 12.5

TECHNICAL MEMORANDUM

Date:	December 5, 2011
To:	Steve Chainey, AECOM
From:	John Stofleth, M.S. EIT, Chris Campbell, M.S. EIT, Lilly Allen, Chris Bowles Ph.D. PE
Project:	11-1009 – Lower Feather River Corridor Management Plan
Subject:	Geomorphic Assessment of the Feather River from RM 6.9 to RM 12.5

INTRODUCTION

The Lower Feather River Corridor Management Plan (LFRCMP) is being developed to describe a long-term vision and an integrated strategy for managing the 20-mile river corridor between the cities of Yuba City / Marysville and the Sutter Bypass. The LFRCMP will provide guidance and recommendations for planners, land managers and decision-makers to manage the lower Feather River in a way that protects public safety, facilitates flood protection system management and maintenance of flood control facilities, and conserves and enhances or restores habitat and ecosystem functions. Secondarily, the plan is intended to promote economic sustainability, land use compatibility, and recreational opportunities.

As a component to the LFRCMP, cbec conducted a geomorphic assessment of the lower Feather River below the Bear River to extend a previous geomorphic assessment performed by PWA (2008). The prior assessment conducted by PWA on the Feather River was from Yuba City / Marysville (River Mile (RM[1]) 34) downstream to the confluence with the Bear River (RM 12.5). This assessment extends the previous effort from the confluence of the Bear River downstream to the Sutter Bypass (RM 6.9) to provide a geomorphic assessment for the entire 20-mile river corridor.

PHYSICAL SETTING

The Feather River watershed is 3,600 square miles above Oroville and is the single largest tributary to the Sacramento River. It is located along the western portion of the Sierra Nevada mountain range. The climate is characterized as Mediterranean with mild, wet winters and hot, dry summers. Average annual

[1] River Mile (RM) stationing used in this document is specified per stationing identified on US Geological Survey (USGS) quadrangles, consistent with the PWA (2008) and Ayres (1997) report. Correlation to Comprehensive Study (USACE, 2002) RM stationing can be found in the PWA (2008) report.

precipitation ranges from 30 inches in the lower watershed to 75 inches in the upper water watershed. Major tributaries to the Feather River include the Yuba River, whose watershed area is 1,300 square miles, and the Bear River, whose watershed area is 292 square miles. Several flood control facilities exist within the watershed and include the Oroville and Thermalito Complex Reservoirs on the Feather River, New Bullards Bar and Englebright Reservoirs on the Yuba River, and the Rollins and Camp Far West Reservoirs on the Bear River. These reservoirs generally reduce flood peaks and the coarse sediment load while increasing the base flow during the summer months. During large flood events, the lower Feather River (below USGS RM 7.5) comingles with the Sutter Bypass. As a result of this confluence during large flood events, the lower reaches of the Feather River (above and below RM 7.5) are subject to backwater conditions and increased sedimentation.

HISTORIC INFLUENCES TO THE PROJECT REACH – 1840'S TO PRESENT

The morphology of the lower Feather River has been largely affected by historic perturbations within the watershed that have significantly impacted both the sediment and hydrologic regime over the last 150 years. As a result of hydraulic mining in the mid to late 1800s, over 950 million cubic yards of sediment were delivered from the upper Feather, Yuba and Bear River watersheds into the lower Feather River corridor, which caused up to 20 feet of aggradation near Marysville (Ayres, 1997). With the cessation of hydraulic mining in the early 1900s, and the construction of dams through the middle of the 20th century, the supply of sediment to the system was dramatically reduced. As a result of the reduced sediment supply and extensive levee projects, dredging, and channelization, a period of channel incision occurred from the early to mid 20th century, after which the channel began to rest upon pre-hydraulic mining era deposits, which are significantly more resistant to erosion. The extensive aggradation of floodplain deposits during the hydraulic mining era, followed by post-mining incision, has dramatically reduced the frequency and duration of natural floodplain inundation that persisted prior to the hydraulic mining era. While bed incision has arrested in the last 20 to 30 years, lateral bank erosion is an ongoing concern and is controlled by the composition of the river banks, bank armoring (riprap), and the supply of sediment from the watershed below the major reservoirs (Ayres, 1997).

A more detailed discussion on the historical influences of the project reach is presented in Chapter 2 of the PWA (2008) report and in the Ayres (1997) report. Please refer these to these documents for additional information on historical influences to the project reach.

GEOLOGY AND SOILS

The surficial geology of the project reach is comprised largely of recent alluvium[2] and stream channel deposits (see Figure 1) and is confined within the river corridor by the Riverbank and Modesto formations, which are typically more resistant to erosion than the more recent hydraulic mining deposits. The processes of meander migration and bank erosion are often controlled by the subsurface formations that are exposed along the vertical bank of the river, especially at the toe. Generally, bank

[2] Alluvium is loose, unconsolidated (not cemented) soil or sediments, which have been eroded, deposited, and reshaped by water.

erosion rates are dependent upon geologic composition of the banks, with non-cohesive sands being the least resistant to erosion followed by the coarser non-cohesive substrate. Banks that have high clay content are typically cohesive and generally have a high resistance to erosion. Figure 2 shows an illustration of a stratigraphic section taken on Feather River below Shanghai Bend (James et al., 2009). Note the silts and clays present within the lower bank at depth, which represent pre-hydraulic mining era deposits. The presence of these cohesive deposits along the lower bank and toe of meander bends plays a significant role in controlling the lateral rate of erosion of a given meander bend. Also note that the hydraulic mining era deposits are up to 11 feet thick below Shanghai Bend. Similar deposits are up to 20 feet thick above Shanghai Bend and further upstream towards Marysville, and less than 3 feet thick near Boyd's Pump Boat Ramp (James et al., 2009). The native Modesto Formation tends to be less prevalent downstream of the Bear River in the lower bank profile compared to reaches near Shanghai and Star Bends. For additional information on bank material composition, please refer to preliminary mapping of bank material composition conducted by DWR (2004) and the geomorphic study conducted by PWA (2008).

Soil development within the Feather River floodplain between the Bear River and the Sutter Bypass is related to the parent material and fluvial processes that include erosion and deposition of river alluvium on the floodplain. The current soils mapping for Sutter County was published in 1988 by the USDA Natural Resources Conservation Service (NRCS) as a detailed update to a 1965 reconnaissance level survey for the county. These data (NRCS, 2007) were cataloged in a Geographic Information System (GIS) and are displayed in Figures 3a and 3b. A selected portion of these data will be used to provide information on particle size distributions for future sediment transport modeling efforts.

HISTORIC RIVER BANK LINE ANALYSIS

cbec examined historic maps and aerial photographs from 1873 to 2010 for the Feather River between the Bear River confluence and the Sutter Bypass. These historic maps were rectified and the historic river banklines were delineated in GIS as displayed in Figure 4. Significant changes in the channel planform include the relocation of the Bear River confluence from RM 10.8 to RM 12.5 and the cutoff and simplification of the Nelson Bend. These modifications were a result of continued sedimentation from hydraulic mining era sediments and channelization projects conducted between 1909 and 1937 (Ayres, 1997). Over the entire time period analyzed there is a general trend towards a simplified planform with an overall decrease in sinuosity. This decreasing sinuosity trend is likely the channel's response to high sediment loads that resulted from the hydraulic mining that occurred during the late 1800s. Schumm (1977) examined the effects of a significant change in sediment load on channel morphology and showed that an increasing load will result in a reduction in sinuosity and depth with an increase in channel slope and width.

CROSS SECTIONAL ANALYSIS

Ayres Associates (1997) conducted a geomorphic and sediment transport study of the Feather River for the USACE that included comparison of historic channel cross sections. Using data presented in the Ayres report, along with recent topographic and bathymetric data collected as a part of the

Comprehensive Study (USACE, 2002) in 1998 (photogrammetric and bathymetric surveys) and Central Valley Floodplain Evaluation and Delineation (CVFED) Program efforts in 2008 (LiDAR survey) and 2010 (bathymetric cross sections), cbec updated this analysis for the Feather River at RMs 6.9, 8.8, 10.4 and 12.2 (see Figure 5 for cross section locations). As shown by Figure 6, cross section comparisons at RMs 6.9 and 8.8 indicate significant channel incision from the 1912 to 1992 with little subsequent change in the bed elevation or cross sectional area since the 1992 survey. Incision occurred through an aggraded bed condition caused by previous deposition of hydraulic mining sediments (James et al., 2009) induced by backwater conditions (reduced velocity) at the confluence of the Feather River with the Sutter Bypass and Sacramento River. As shown by Figure 7, cross section comparisons at RMs 10.4 and 12.2 indicate that channel widening occurred between 1912 and 1992 with a minimal change in the channel morphology since 1992. The relatively deep and narrow channel observed in 1912 at RMs 10.4 and 12.2 was likely a result of channel filling and narrowing that occurred after the hydraulic mining era in the early 1900s (James et al., 2009). Alternating point bars were mapped on the Feather River below the Bear River confluence in the 1909 California Debris Commission surveys (CDC, 1912). These post-mining era sand bars indicate that the channel narrowing was likely due to deposition of bed material in large alternating point bars. These bars seem to be transient features through the middle of the 20th century, often disappearing after large flood events. This would suggest cyclical scouring and redeposition through this reach due to the transport of large volumes of sediment through this reach (James et al., 2009).

KNICKPOINT MIGRATION AT SHANGHAI BEND (SHANGHAI RAPIDS)

cbec examined historic aerial photographs of the Shanghai Rapids (RM 24.6) from 1973 to 2008 in an effort to determine its upstream knickpoint migration rate. The aerial photographs were rectified and the historic knick zone (headcut) was delineated in GIS, as shown by Figure 8. Using the upstream most portion of the knickpoint (channel center), a distance was measured from a given year to next year to calculate the migration rates (see Table 1). The average migration rate over the 35 year period from 1973 to 2008 was 11.1 feet per year. Information on the spatial extent of the erosion resistant Modesto Formation creating the knick zone is not known, and is important in predicting the future geomorphic stability of the headcut. However, we estimate that complete breaching of the Modesto Formation outcrop, which represents a natural grade control feature, would likely occur in the next 50 to 100 years. An initial chute extension (knickpoint migration) reaching the upstream side of the Modesto Formation outcrop could occur within the next 10 years.

Table 1. Shanghai Rapids knickpoint migration rates

Year	Migration Distance (ft)	Migration Rate (ft)
1973 - 1987	160	11.4
1987 - 1999	130	10.8
1999 - 2008	100	11.1

Ayres (1997) and James et al. (2009) suggested that the upstream migration of the knickpoint through Shanghai Bend to the older channel position may have potentially serious ramifications since channel incision here could lower the base level approximately 10 feet and expose a less resistant deposit beneath the cohesive native formation, allowing channel incision to migrate upstream at a more rapid rate. Other consequences of a knickpoint failure would include a decrease in the water surface elevation for a given flow upstream from Shanghai Bend, most notably at lower flows, thus reducing the frequency and duration of floodplain inundation that serves to provide important habitat for several native fish species and other natural river ecosystem processes.

The erosion and / or removal of the knickpoint / headcut at Shanghai Bend was investigated as a part of a study conducted by Mussetter Engineering Inc. (MEI) for the USACE as part of the Shanghai Bend levee setback project (Mussetter, 1999). Excerpts from that report are included below, which summarize the potential impacts on channel hydraulics and sediment transport:

> "Erosion of the Modesto Formation outcrop will have a significant effect on upstream hydraulic conditions during low to medium flows, with the effects becoming minimal at higher discharges as the existing outcrop becomes drowned out. At 10,000 cfs, the water-surface elevation is lowered about 3.7 feet just upstream of the outcrop, reducing to about a 0.6-foot drop at the 5th and 10th Street bridges. Corresponding increase in main-channel velocities at 10,000 cfs range from 1.3 ft/s just upstream of the outcrop to 0.1 ft/s in the vicinity of the 5th and 10th street bridges. At the peak of the 100-year event, changes in water-surface elevations and velocities associated with the outcrop removal are minimal because the existing riffle drowns out."
>
> "Erosion and removal of the Modesto Formation outcrop will result in increased degradation upstream (or reduced aggradation) in reaches upstream from the outcrop, with increased aggradation in the downstream reaches. The increase degradation potential is greatest just upstream of Shanghai Bend, where increased bank heights along the berm that flanks the west bank levee may result in greater bank instability. Future protection of this bank, which is primarily composed of hydraulic mining debris, may be required as the river erodes through the outcrop. Due to the complex interaction of flows at the Feather/Yuba River confluence, only minor changes in bed elevations along the lower Yuba River are expected as a result of changes in the Feather River."
>
> "Erosion of the outcrop occurs under low to moderate flow (10,000 to 50,000 cfs) when the water-surface slopes across the headcut is steep, and the hydraulic energy is highest."

Based on these preliminary findings, water levels associated with low to moderate flows (10,000 to 50,000 cfs), which support important habitat functions in the river, would be most impacted on the order of 1.3 feet just upstream of the eroded rapids with diminishing impact further upstream near the 5th and 10th Street bridges on the Feather River. However, at even lower flows, water levels could drop by as much as 8 feet just upstream of the outcrop based on interpretation of the 2008 LiDAR data. These

declines in low to moderate flow water levels would also be accompanied by a 2 to 4 foot lowering of the bed level that would propagate up to the 5th and 10th Street bridges (Mussetter, 1999).

To better understand the implications and potential effects of erosion and / or removal of the knickpoint at Shanghai Rapids as it relates to restoration and habitat enhancement opportunities as part of the LFRCMP, cbec is currently conducting additional detailed analysis using a 2-dimensional sediment transport model extending from upstream of the Yuba River downstream into the Sutter Bypass. The results of this analysis will be presented in a subsequent geomorphic modeling report.

REACH CHARACTERIZATION

cbec conducted a geomorphic reconnaissance of the Feather River and surrounding floodplain areas from the Sutter Bypass at RM 6.9 to the Bear River at RM 12.5 to augment the geomorphic reconnaissance performed by PWA (2008) above the Bear River. The reconnaissance was conducted by boat on August 11, 2011 and by ATV on August 12, 2011. Additional habitat restoration opportunity areas were also investigated at this time; however, these areas are not discussed herein and will be further discussed in a subsequent geomorphic modeling report.

The methods used in this effort included identifying areas of channel bank erosion and deposition and assessing the relative severity of the erosion levels. Erosion was qualitatively classified into low, medium, and high categories based on bank height, bank angle, bank cohesion, and presence or absence of vegetation cover. Using recent aerial photographs, specific geomorphic features within the reach were identified as target areas for the investigation. This field assessment should be considered a reconnaissance level only.

Overall, the instream portion of the river from RM 6.9 to RM 12.5 was characterized by the presence of alternate bars on the channel margins and large sand waves within the channel (see Figure 9). Generally, the frequency of the sand waves increases upstream of RM 10.

Beer Can Beach: Feather River at the Sutter Bypass between RM 7.2 and RM 7.6.

The Feather River in this reach is characterized by medium levels of erosion on the right bank (outside of the meander bend) with obvious signs of deposition on the inside of the meander bend on the left bank (known locally as 'Beer Can Beach'). There is active channel erosion on the left bank immediately upstream of Beer Can Beach classified by high levels of erosion with near vertical banks composed of non-cohesive sands at the levee toe which is currently devoid of any cobble size rip rap.

Nelson Slough: Feather River upstream of the Sutter Bypass from RM 7.6 to RM 8.6

The Feather River in this reach is characterized by medium to high levels of erosion on the right bank immediately upstream of the meander bend at the confluence with Sutter Bypass. The erosion on the right bank is likely being redistributed and deposited on the left bank thereby forming the sand bar at Beer Can Beach. There is no discernable evidence or geomorphic features (sand bars etc) observed that

indicate recent deposition on the right bank floodplain within this reach. However, historic mapping revealed a large meander bend (Nelson Bend) on the current right bank floodplain visible in this reach in 1910 (see Figure 4). There is currently little evidence of a large scale depression feature at this location. This suggests that the historic channel has filled in overtime with alluvium, indicating the reach has been subject to floodplain aggradation. Other evidence showed nearly 10 feet of aggradation occurred during the 1986 flood in the eastern portion of the Sutter Bypass near the confluence with the Feather River at RM 6.5 (Singer et al., 2008). This evidence also suggests that the backwater conditions at the confluence, along with the relatively coarse sediment loads (i.e., medium to coarse sands) from the Feather River, are promoting aggradation within the Sutter Bypass and the lower Feather River in the vicinity of their confluence.

The historic floodplain channel that is located on the right bank floodplain, partially within Garwood Ranch, and oriented perpendicular to the Feather River at RM 8.1, which is now connected to the borrow ditch feeding into Nelson Slough, was also investigated within this effort. The floodplain channel is surrounded by thick riparian vegetation. Standing water was observed in the low flow channel at its northern extents nearest the project levee borrow ditch and diminished southwards towards the Feather River mainstem upon approach to Garwood Ranch. This would suggest that the channel is aggradational during high flows since it is sloping away from the Feather River towards the north. During the August reconnaissance survey, the south end of the floodplain channel was approximately 14 feet higher than the adjacent water surface in the Feather River.

Historic and Active Bear River Channels: Along the Feather River from RM 10.6 to RM 12.5

The present day Bear River channel at its confluence with the Feather River (RM 12.5) is backwatered and deeply incised with low levels of bank erosion. The invert elevation of the historic Bear River channel is approximately 10 to 15 feet higher at its confluence with the present day Bear River channel (Figures 4 and 7). The discrepancy in the invert elevations between the historic and present day channel is likely related to the fact that the channel was rerouted westward in the early 1900s when the Bear River was still elevated due to the effects of hydraulic mining. When the sediment supply was reduced as a result of the cessation of hydraulic mining and the construction of dams in the upper watershed, the base level was lowered on the Feather and Bear Rivers, leaving the historic channel elevated relative to the active channel.

Feather River Pinch Point: Feather River between RM 14.7 to RM 15.2

The Feather River in this reach is characterized by medium to high levels of active erosion on the right bank. The right bank is near vertical and has migrated to within less than 180 feet of the levee toe. There is no existing revetment within this reach and the bank material does not consist of erosion resistant substrate. There is a predominant sand bar that has formed on the left bank opposite the right bank erosion that is in the wake of eroding high ground co-located with the historic left bank levee (as seen on CDC (1912) mapping), which is oriented slightly diagonal to the principle flow direction during flood conditions. This relic levee feature is as little as 5 feet shorter than the west project levee crest elevation and likely contributes to flow deflection and erosion of the right bank during flood conditions.

The low flow channel, as well as the overall floodway corridor in this reach, is the narrowest within the lower Feather River below the Yuba River confluence.

CONCLUSIONS

cbec conducted a geomorphic assessment of the lower Feather River below the Bear River to extend a previous geomorphic assessment performed by PWA (2008). Findings from this investigation suggest that legacy sediment from the hydraulic mining era combined with backwater conditions that persist during high flow events in the vicinity of the Feather River confluence with the Sutter Bypass has had a significant impact on channel and floodplain morphology within this reach. Below is a summary of the key findings of this investigation:

- As a result of the deposition of hydraulic mining debris transported from the Yuba River and Bear Rivers between 1850 and 1910, the Feather River aggraded by up to 20 feet near Marysville and reduced its sinuosity thereby increasing the overall channel gradient. With subsequent reductions of sediment loads following cessation of hydraulic mining and dam construction, the river incised by 4 to 20 feet by the end of the 1960s and is currently resting on its native (erosion resistant) formation (Ayres, 1997). This aggradation followed by incision has left the floodplain of the Feather River largely disconnected (elevated) from the mainstem, thereby reducing the duration and frequency of floodplain inundation, which is essential to the ecological function of the river corridor.
- A knickpoint exists at Shanghai Rapids at RM 24.6, which is migrating at an average rate of 11.1 feet per year, and is predicted to completely erode through the formation within the next 50 to 100 years. The potential ramification of the erosion and / or removal of the knickpoint / headcut includes a significant drop in the water surface elevation upstream of the outcrop, which will have implications for upstream restoration and habitat enhancement opportunities. There is also an increased risk for channel incision and lateral channel instability upstream from Shanghai Bend if the base of the channel erodes through the native Modesto Formation.
- The lower reach of the Feather River between Bear River and the Sutter Bypass is characterized by the presence of alternate bars on the channel margins and large sand waves within the channel. This reach has reduced its sinuosity overtime due to high sediment yields from the hydraulic mining era and engineering works. The reach is also subject to backwater conditions from the Sutter Bypass with overbank sedimentation that has completely filled the historic channel at Nelson Bend. There are no major bendways within this reach and significant meander migration is not expected in the 50 to 100 year time frame. However, there are locations where the channel bank is close enough to the levee to raise concern about localized levee stability if the bank erodes closer to the levee.

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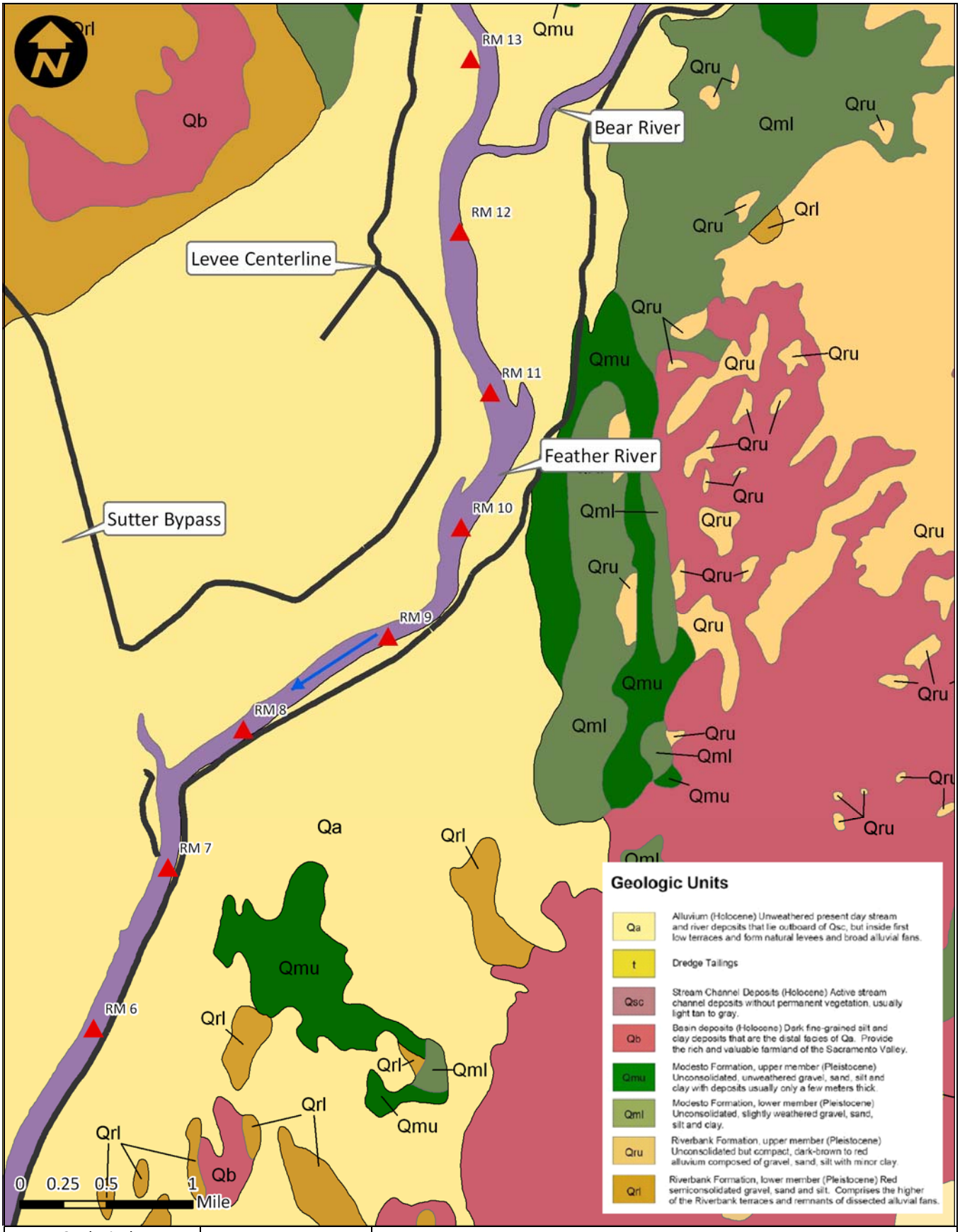

Notes: Geologic data courtesy of DWR.		*Feather River Corridor Management Plan - Geomorphic Assessment*		
		Geologic Map of Project Reach		
		Project No. 11-1009	Created By: LA	**Figure 1**

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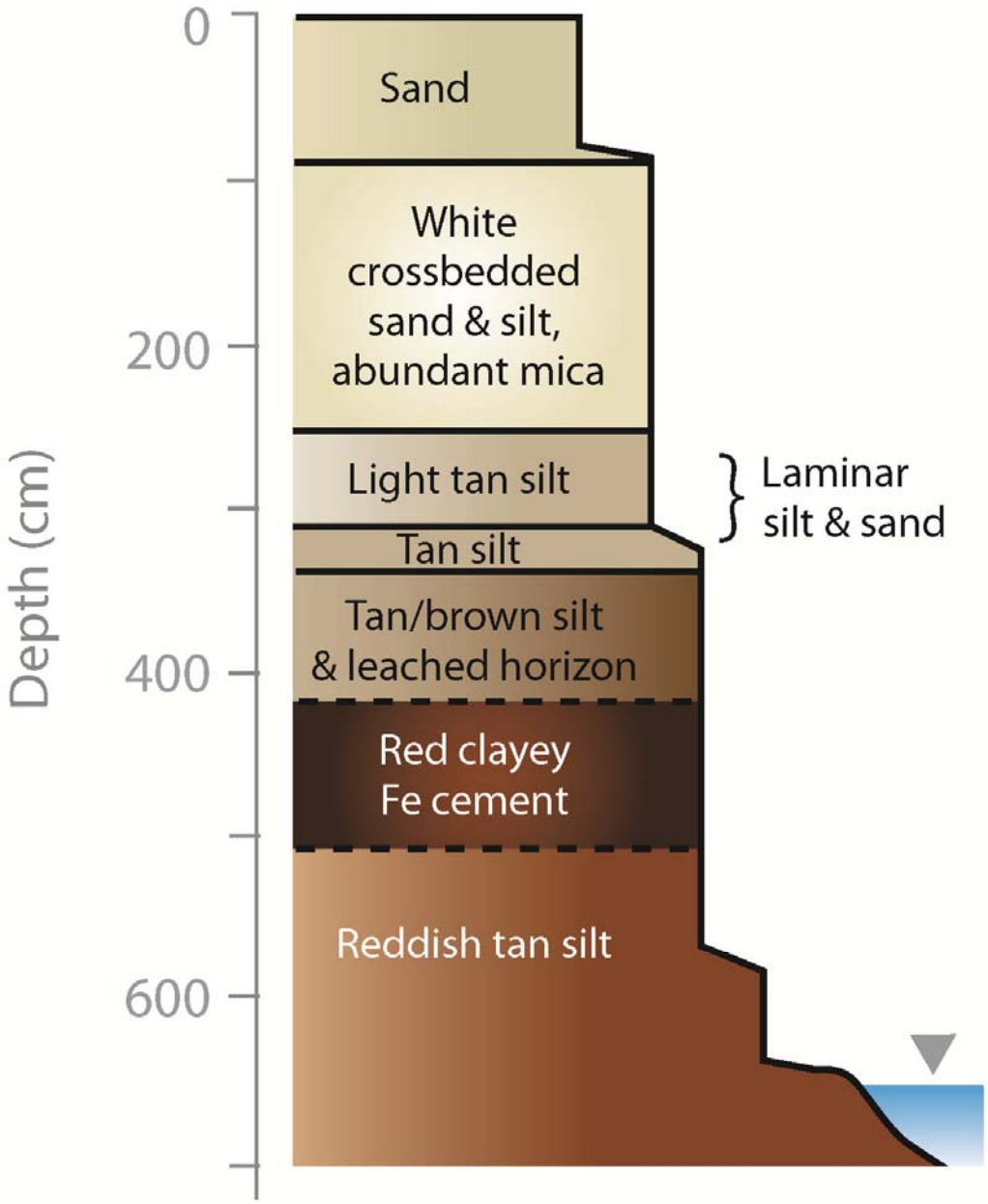
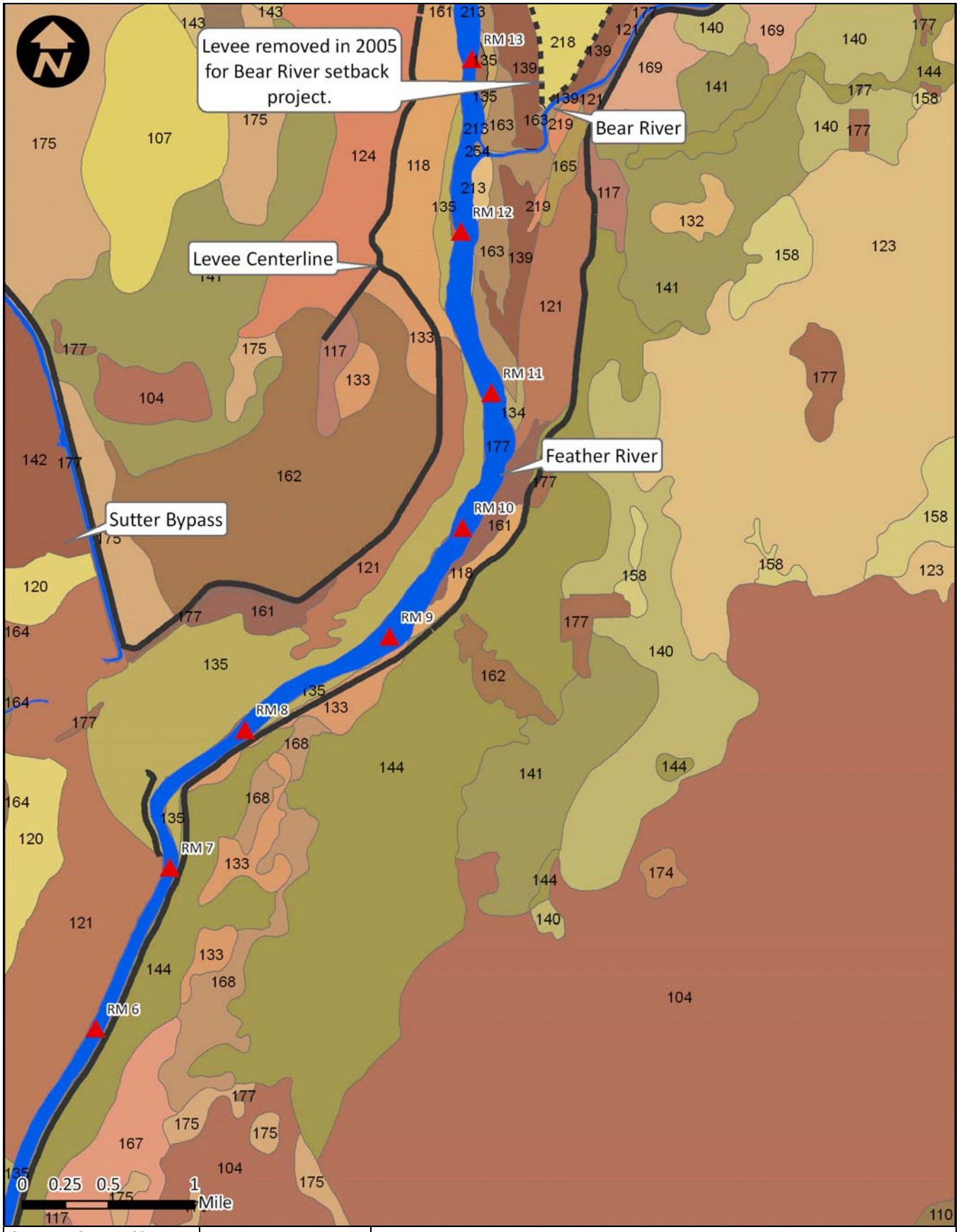


Notes: Right bank exposure downstream of Shanghai Bend (James et al 2009).	cbec eco engineering	*Feather River Corridor Management Plan - Geomorphic Assessment* **Stratigraphic Section of the Feather River Bank**		
		Project No. 11-1009	Created By: JS	**Figure 2**



Source: USDA NRCS

Feather River Corridor Management Plan-Geomorphic Assessment

Soil Classification in the Project Area

Project No. 11-1009	Created By: LA	**Figure 3a**

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Legend

Water

Yolo County Soils

139, Columbia fine sandy loam, 0 to 1 percent slopes, frequently flooded
163, Holillipah loamy sand, 0 to 1 percent slopes, frequently flooded
213, Riverwash
218, Shanghai silt loam, 0 to 1 percent slopes
219, Shanghai silt loam, 0 to 1 percent slopes, occasionally flooded
254, Water

Sutter County Soils

103, Byington silt loam, 0 to 2 percent slopes
104, Capay silty clay, 0 to 2 percent slopes
105, Capay silty clay, occassionally flooded, 0 to 2 percent slopes
107, Capay silty clay, siltstone substratum, 0 to 2 percent slopes
109, Capay clay, hardpan substratum, 0 to 2 percent slopes
110, Clear Lake silt loam, 0 to 2 percent slopes
111, Clear Lake silt loam, frequently flooded, 0 to 2 percent slopes
112, Clear Lake clay, 0 to 2 percent slopes
113, Clear Lake clay, frequently flooded, 0 to 2 percent slopes
117, Columbia fine sandy loam, 0 to 2 percent slopes
118, Columbia fine sandy loam, channeled, 0 to 2 percent slopes
120, Columbia fine sandy loam, clay substratum, frequently flooded, 0 to 2 percent slopes
121, Columbia fine sandy loam, frequently flooded, 0 to 2 percent slopes
123, Cometa loam, 0 to 2 percent slopes
124, Conejo loam, 0 to 2 percent slopes
132, Gridley clay loam, 0 to 1 percent slopes
133, Holillipah loamy sand, 0 to 2 percent slopes
134, Holillipah loamy sand, channeled, 0 to 2 percent slopes
135, Holillipah loamy sand, frequently flooded, 0 to 2 percent slopes
140, Marcum clay loam, 0 to 2 percent slopes
141, Marcum clay loam, siltstone substratum, 0 to 1 percent slopes
142, Marcum clay loam,occasionally flooded,0 to 2 percent slopes
143, Marcum-Gridley clay loams, 0 to 1 percent slopes
144, Nueva loam, 0 to 1 percent
145, Nueva loam, occasionally flooded, 0 to 1 percent slopes
153, Oswald clay, 0 to 2 percent slopes
158, San Joaquin sandy loam, 0 to 2 percent slopes
161, Shanghai fine sandy loam, channeled, 0 to 2 percent slopes
162, Shanghai silt loam, 0 to 2 percent slopes
163, Shanghai silt loam, clay substratum, 0 to 2 percent slopes
164, Shanghai silt loam, clay substratum, frequently flooded, 0 to 2 percent slopes
165, Shanghai silt loam, frequently flooded, 0 to 2 percent slopes
166, Shanghai silt loam, wet, 0 to 2 percent slopes
167, Shanghai silty clay loam, 0 to 2 percent slopes
168, Shanghai variant loamy sand, 0 to 1 percent slopes
169, Snelling loam, 0 to 2 percent slopes
170, Snelling loam, occasionally flooded, 0 to 2 percent slopes
174, Tisdale clay loam, 0 to 2 percent slopes
175, Yuvas loam, 0 to 2 percent slopes
176, Yuvas loam, frequently flooded, 0 to 2 percent slopes
177, Water

Notes: USDA NRCS

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Feather River Corridor Management Plan - Geomorphic Assessment

Soil Classification Legend

Project No. 11-1009	Created By: LA	**Figure 3b**

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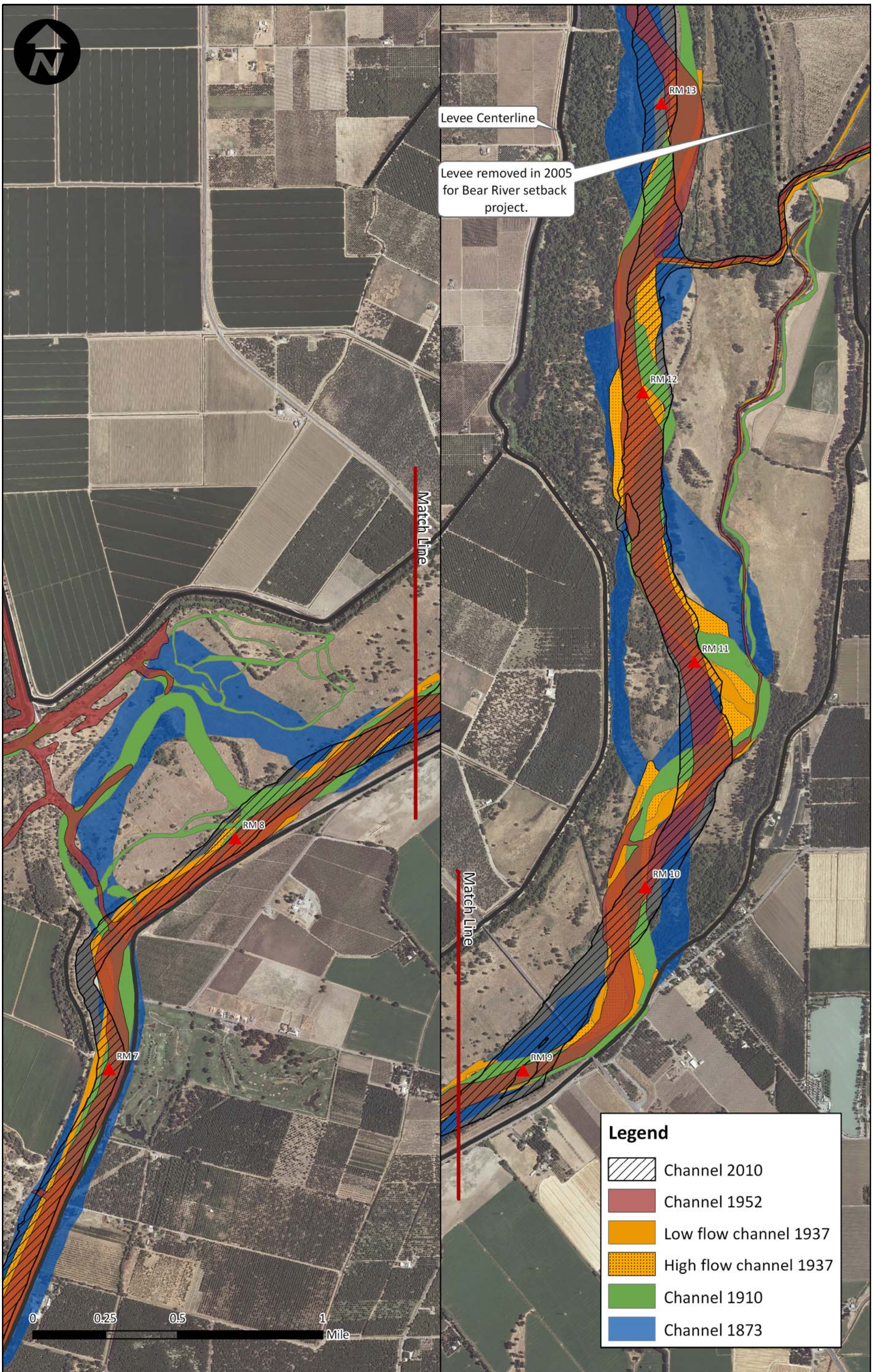

Notes: Courtesy of NAIP 2010

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Feather River Corridor Management Plan Geomorphic and Ecological Assessment

Feather River Historic Bank Lines

Project No. 11-1009	Created By: LA	**Figure 4**

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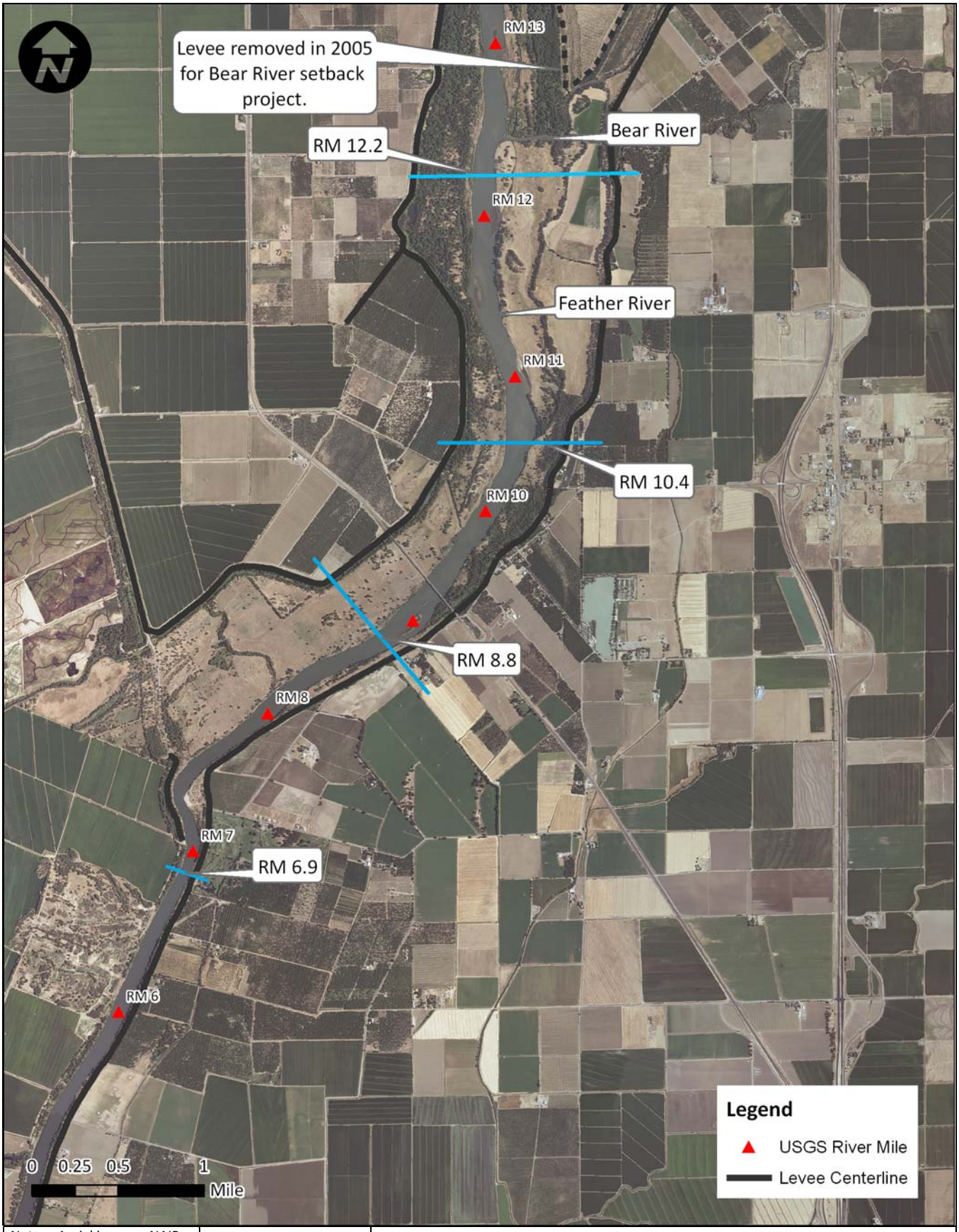

Notes: Aerial imagery NAIP 2010.

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Feather River Corridor Management Plan - Geomorphic Assessment

Cross Section Locations

Project No. 11-1009	Created By: JS	**Figure 5**

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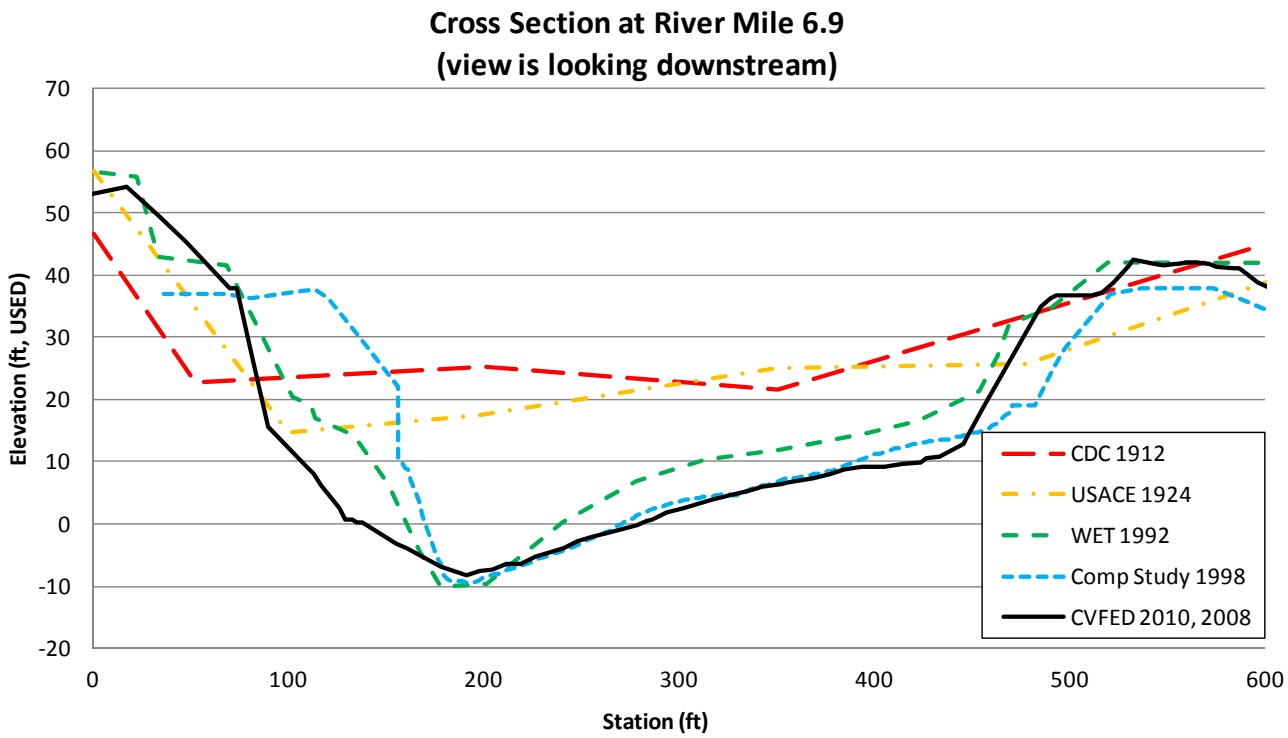
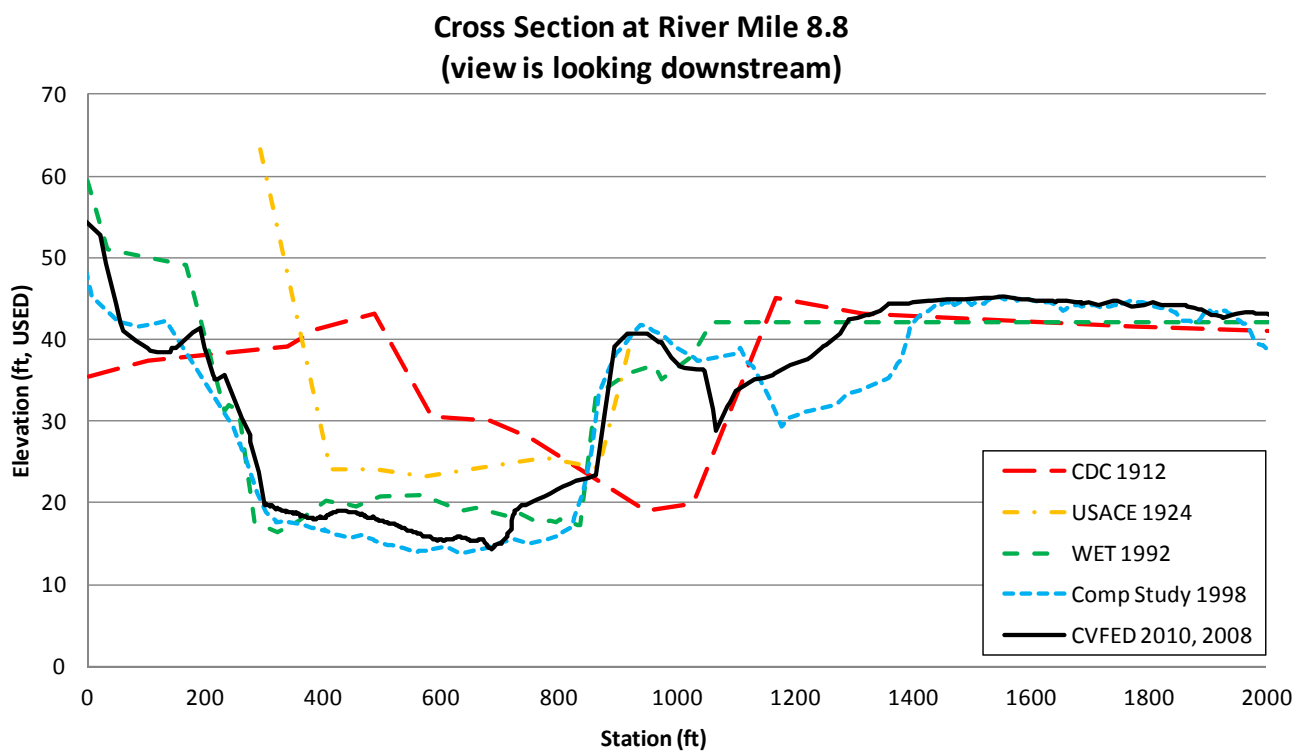




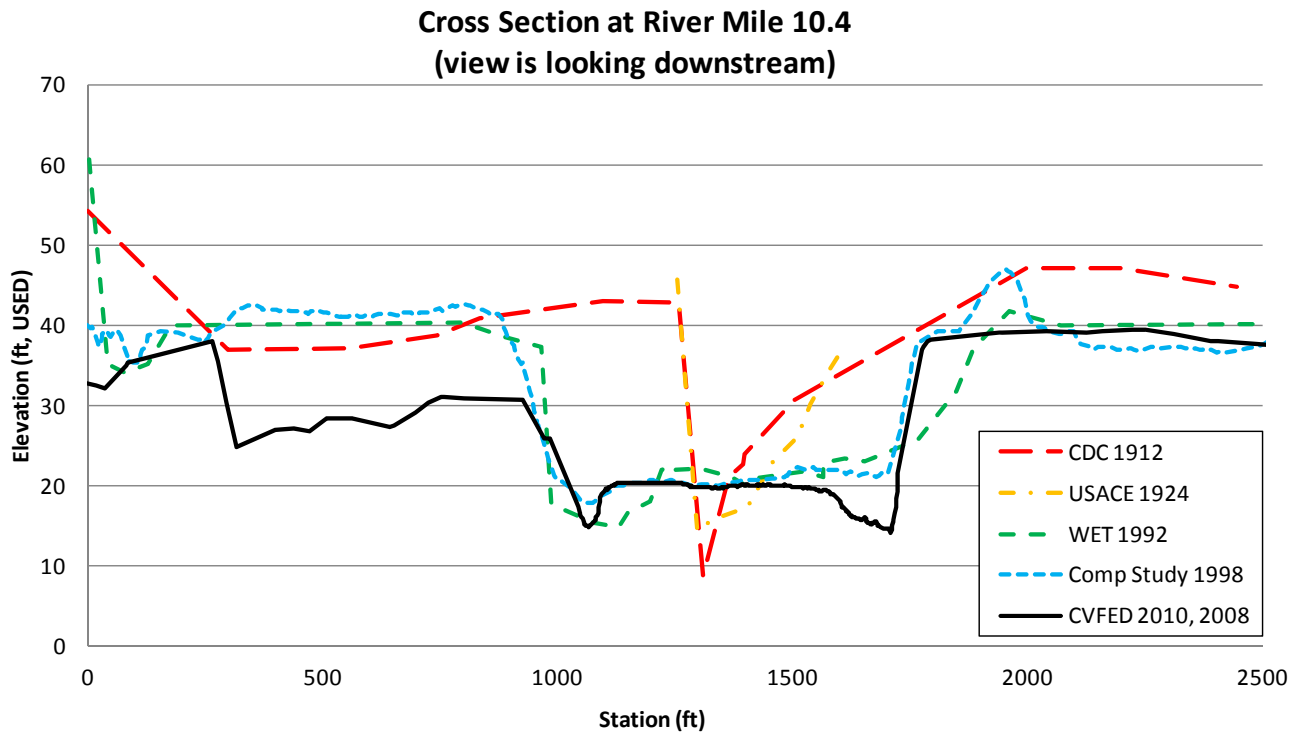
Notes: Historic cross section data courtesy of Ayres, 1997

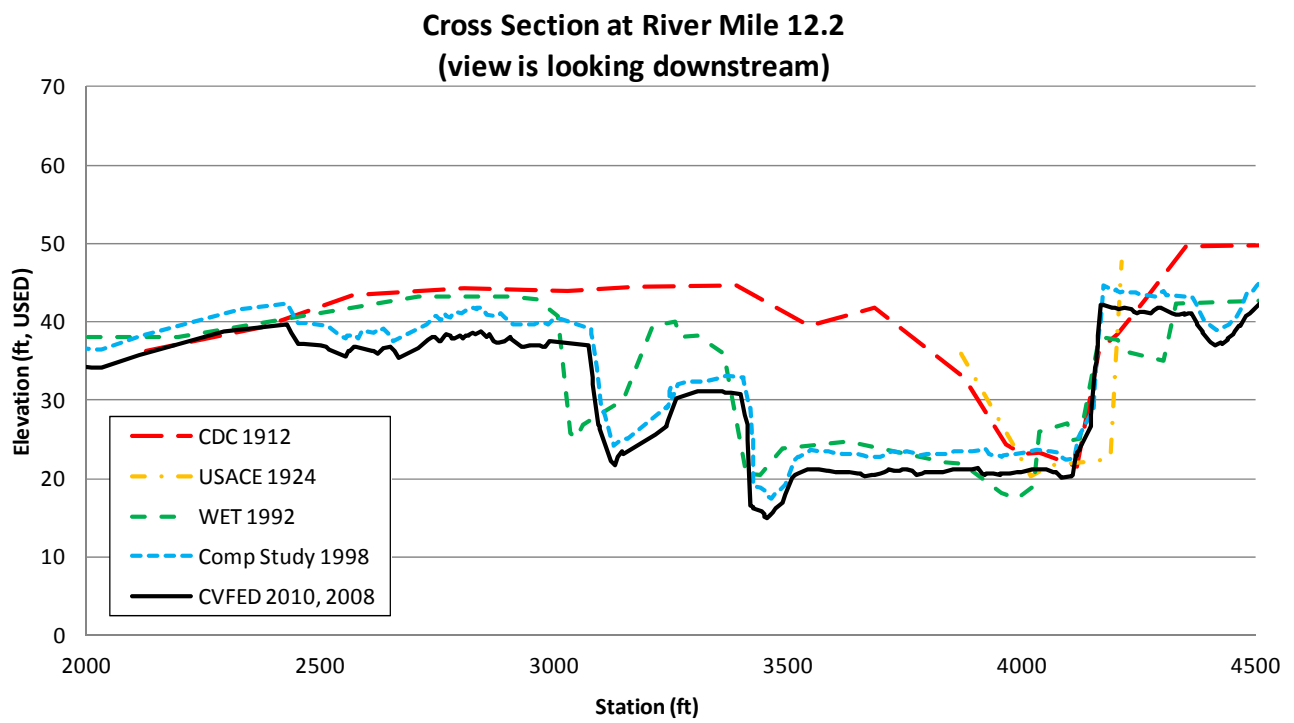
Feather River Corridor Management Plan - Geomorphic Assessment

Historic and Current Cross Sections

Project No. 11-1009	Created By: LA	**Figure 6**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Geomorph\Figures\Fig_6_Xscn1.docx
12/4/2011





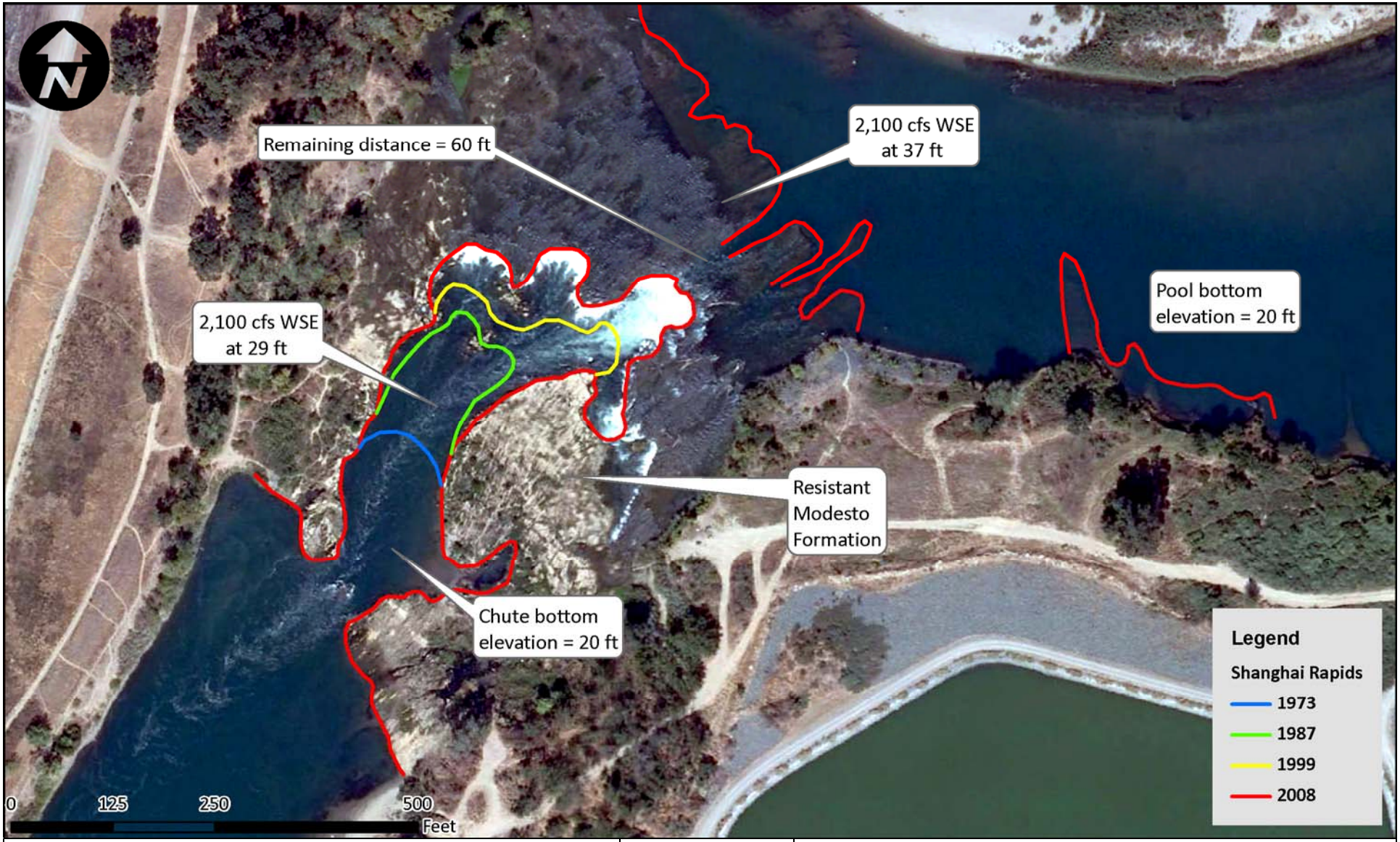
Notes: Historic cross section data courtesy of Ayres, 1997

Feather River Corridor Management Plan - Geomorphic Assessment

Historic and Current Cross Sections

Project No. 11-1009	Created By: LA	**Figure 7**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Geomorph\Figures\Fig_7_Xscn2.docx
12/4/2011



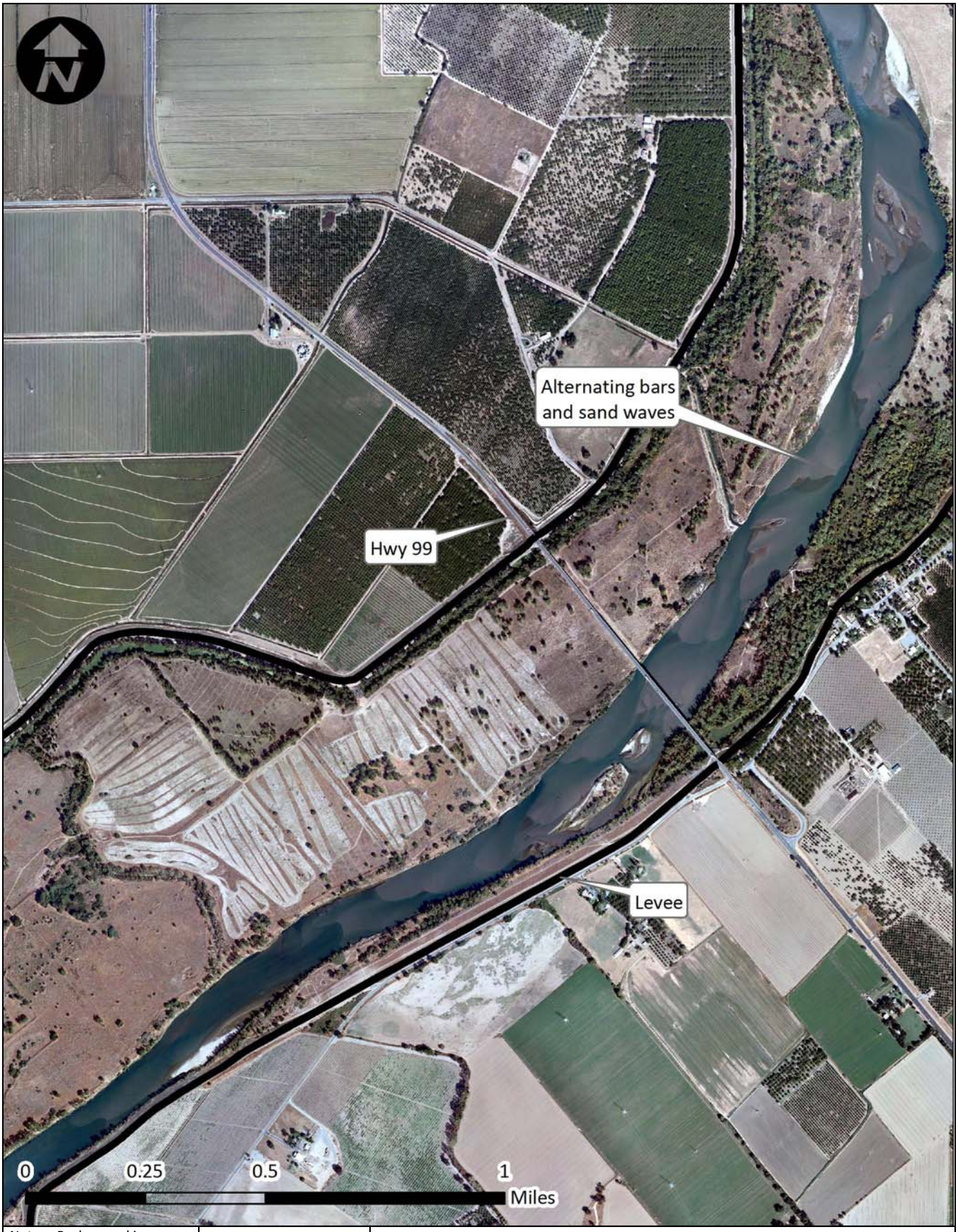
Notes: Background image courtesy Digital Globe (2008). Elevations reference NAVD88. WSE reference 2008 flows. Water surface elevations and discharge estimated from date of LiDAR flight in 2008.

Feather River Corridor Management Plan - Geomorphic Assessment

Shanghai Rapids Knickpoint Migration, 1973 to 2008

Project No. 11-1009	Created By: LA	**Figure 8**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Geomorph\Figures\Fig_8_Shanghai_Rapids.docx
12/4/2011



Notes: Background image courtesy Digital Global (2008).

Feather River Corridor Management Plan - Geomorphic Assessment

Alternating Bars on the Lower Feather River

Project No. 11-1009	Created By: CC	**Figure 9**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Geomorph\Figures\Fig9_Alternating_Bars.docx
12/5/2011