Stillwater Sciences

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TECHNICAL MEMORANDUM

DATE: August 13, 2001

TO: Les Heringer (M & T Ranch); Burt Bundy (Sacramento River Conservation Area) and Stacey Cepello (CDWR)

CC: Paul Uncapher (North State Resources)

FROM: Christian Braudrick, Jennifer Vick, and Yantao Cui

SUBJECT: Final Draft of M & T Ranch and Llano Seco Wildlife Refuge Pump Intake

ATTACHMENTS: Sierra_View Divers1.PDF
Sierra_View Divers2.PDF
Sierra_View Divers3.PDF
Diamond_Oaks.PDF
1997 photo.pdf
1999 photo.pdf
Other maps referred to in this report will be made available at the Sacramento River Conservation Area website:
http://www.sacramentoriver.ca.gov/index.html

Background

In 1997 the M & T Chico Ranch/Llano Seco Ranch and Refuge moved their pumping facility from Big Chico Creek to the east bank of the Sacramento River, just downstream of the creek's confluence with the Sacramento River. The pumps had been located on Big Chico Creek, 0.5 miles upstream of the confluence with the Sacramento River since the early 1900s. The new pump supplies water from the Sacramento River to M & T Ranch, Llano Seco Ranch, and the State and Federal Llano Seco Wildlife Refuge. The pumping plant has a capacity of 150 cfs and pumps water year-round. The City of Chico's wastewater treatment outfall is located on the same bank of the Sacramento River approximately 300 feet downstream of the M & T/Llano Seco pump.

Operation of the pumping facility and the City of Chico outfall is currently threatened by deposition of alluvial sediment at the pump intake and the City outfall. Deposition of sediment at the pumps threatens operation of both the pumps and their associated fish screens. M & T Ranch, Llano Seco Ranch, and The Sacramento River Conservation Area have requested that Stillwater Sciences identify near-term and long-term alternatives to maintain operation of the pump and outfall.

This technical memorandum summarizes near-term and long-term alternatives that have been identified by Stillwater Sciences. These alternatives are based on reconnaissance-level site visits, review of aerial photographs and maps, and coordination with the California Department of Water Resources (CDWR), CALFED, M & T Ranch, Llano Seco Wildlife Refuge, and the

California Department of Parks and Recreation. This document is not intended to provide detailed engineering-level information on the feasibility or cost of any of the alternatives.

A discussion draft of this memorandum was provided to M & T Ranch, the Conservation Area, and CDWR on April 30, 2001. The current memorandum addresses questions and comments received to the discussion draft.

Methods

The alternatives presented in this memorandum were developed based on two reconnaissance-level site visits; review of aerial photographs, maps, flow data, and additional supporting materials; and coordination with agency staff and others familiar with the project and the project site. Stillwater Sciences participated in a stakeholder meeting at the site on January 16, 2001. The objective of this visit was to obtain information from stakeholders and to gather initial field information. A second visit was conducted on April 9, 2001, to gather additional field information on noted flow patterns in the Sacramento River channel, the gravel bar at the mouth of Big Chico Creek, and the erosion conditions on the west bank of the Sacramento River.

Aerial photographs, maps, and flow data were reviewed to develop an understanding of historic and current conditions in the site vicinity. Materials included in this review are shown in Table 1. Flow data was compiled from the U.S. Geological Survey Sacramento River at Colusa, California gauge (number 11389500). Additional supporting materials included the following:

- report of diver observations of burial of the pump intake and City outfall (Sierra View Divers 2001)[1];
- letter from the pumping plant construction contractor regarding the feasibility of extending the pump intake further into the Sacramento River (Diamond Oaks Construction 2001)[2]; and
- report summarizing documented erosion at the site during the winter 2001 (CDWR 2001).

Table 1. Aerial Photographs and Maps Reviewed. Some of these maps will be made available at the Sacramento River Conservation Area website http://www.sacramentoriver.ca.gov/index.html

Map Name	Map or Photograph Year	Scale	Bank locations Plotted on Aerial Photographs or Maps	Source
Map A	1999	1:2,400	1995, 1997, 1999, 2000	CDWR 2001
Map B	1999	Unknown	1964, 1979, 2000	NorthStar Engineering 2000
Map C	1997 1937	1:3,000	1908, 1923, 1935, 1946, 1964, 1991, 1999	CDWR 2000
Map D[3]	1997 1999	1:6,000	1995, 1997, 1999, 2001	CDWR 2001
Map E	1997	Unknown	N/A	CDWR 1999
Map F	1993	Unknown	1896, 1937, 1946, 1969, 1991	CDWR Northern District 1993

[1] attached as *Sierra_View Divers1.PDF*, *Sierra_View Divers2.PDF*, and *Sierra_View Divers3.PDF*
[2] attached as *Diamond_Oaks.PDF*
[3] attached as *1997 photo.pdf* and *1999 photo.pdf*

Summary of Findings

The Sacramento River is a meandering alluvial system. Historical maps and aerial photographs compiled by CDWR indicate that the river has not meandered east of its current location at the pumping plant, which is located on a geologic control, since at least 1896, (Map F). Because the bank is relatively stable, it was chosen as the site for the new pumping plant. At this location, however, the Sacramento River has historically migrated to the west. As recently as 1935, the east bank was approximately 1,000 feet west of its current location (Map C). Between 1995 and 2001, the Sacramento River shifted 500 feet toward the right (west) bank (or an average of 83 feet/year). As the river has migrated to the west, flow velocities at the pump intake and outfall have been reduced and sediment deposition has increased. In addition, aerial photographs indicate that the mouth of Big Chico Creek has shifted both upstream and downstream from its current location over recent decades.

Concurrent with the lateral migration of the channel, the gravel bar at the apex of the meander has migrated downstream toward the pump facility. Between 1995 and 1999, the gravel bar that is currently aggrading at the pump intake migrated over 1,100 feet downstream (Map A). Between 1999 and 2001, the bar moved an additional 600 feet downstream (Map D). Diving surveys in May 2001 show that the riverbed aggraded approximately 5 feet relative to past surveys at the City of Chico diffuser, and 2 of the 7 diffuser nozzles were buried by sediment (Sierra View Divers 2001). Sediment deposition at the City of Chico outfall is exacerbated by the presence of a large log that was deposited at the site. A similar survey conducted in May 2001 at the M & T/Llano Seco pumps revealed that the channel bed is encroaching on the fish screen. These surveys noted that sediment deposition has reduced clearance under the intake from 6 feet to 2–3 feet. The date of the previous survey was not given in the report, but the divers estimated that the screens will stop functioning normally within two years if the current rate of deposition continues (Sierra View Divers 2001).

The bar at the pump intake and City outfall is not visible on aerial photographs taken in 1964, suggesting that the bar may have been deposited in the 1964 floods. By 1979 (the next year of photographs reviewed), the bar was located approximately halfway between its current location and the hard point created by revetment at River Road. Although the bar is currently located at the mouth of Big Chico Creek, it appears to be composed primarily of sediment from the Sacramento River (i.e., it is not a delta deposit from the creek). Erosion of the east bank immediately upstream of the bar is likely providing a portion of the bar's sediment, but the majority is likely is being supplied from further upstream. As such, the bar will likely continue to migrate downstream, forcing the mouth of the creek to shift downstream as well. Eventually, the creek will likely cut a new, steeper channel across the bar.

At the request of the Sacramento River Conservation Area, we examined the reach upstream of the pump location for evidence that upstream changes (including hard points in the channel) are contributing to planform changes at the pumping plant and City outfall. We examined CDWR maps of historical bank location obtained from aerial photographs between 1923 and 1999 from the pumping plant to river mile 195 (approximately 2 miles upstream). These maps have not been checked for accuracy, and quantitative measurements of channel migration rates cannot be made. These maps do indicate, however, that river migration historically occurred upstream of the pumping plant. Historical river migration upstream of the pumping plant is also evident from the current photographs which show old meander channels along the west bank of the river. Based upon available information, we cannot assess the effects of upstream hard points on the bar that is threatening the pumping plant. It is important to note, however, that the Sacramento River will continue to migrate within its historical meander corridor at the pumping plant site.

The deposition of the gravel bar at the pump intake and the City outfall is not the result of localized processes. Rather, the deposition of this bar is the result of large-scale channel migration processes. As such, measures that address only short-term, local conditions or processes will likely provide only short-term, stop-gap benefits. Larger-scale measures that address longer-term, larger-scale processes will likely provide more persistent benefits.

Alternatives

The following is a summary of alternatives identified by Stillwater Sciences. These alternatives are not intended to provide engineering details or cost estimates, which are beyond the scope of this memorandum. The descriptions of the advantages and disadvantages of each alternative focus on the effects of geomorphic processes on the potential success of each measure in reducing threats to the pumping plant and the City outfall.

Alternative 1: Dredge sediment from the bar upstream of the pump intake and City outfall. Under this alternative, sediment would be excavated/dredged from the bar encroaching onto the pump intake and City outfall. High flows in 1997 and 1999 caused the bar to migrate downstream approximately 1,100 feet. Under this alternative, the bar would be excavated/dredged to its 1995 location to reduce the likelihood that sediment from one storm event could bury the pump intake and City outfall. Because detailed topographic data of the bar are not available, we cannot provide estimates of the volume of sediment to be removed. The bar would be excavated/dredged to a depth of 5 feet below the low-flow water surface. This depth may need to be adjusted somewhat, as we did not have topographic surveys of the bar and have not conducted sediment transport or hydraulic modeling. The submerged portions of the bar would be suction dredged, while the dry portions would be excavated. This excavation/dredging would remove the immediate threat of burial of the pump intake and City outfall. Frequent (at least annual) excavation/dredging, however, would likely be required. During wet years (i.e., years with several large storm events), maintenance dredging may be required to prevent burial of the pump and outflow during winter high flows. Suction dredging would be used to remove sediment at the pump site during winter storms to minimize turbidity associated with the dredging. Monitoring of sediment deposition following large storms would be required to identify and plan for dredging needs.

In the long-term, this alternative would not prevent burial of the pump intake and City outfall, because removing the bar would not affect flow direction of the Sacramento River. Therefore, even with dredging, erosion of the west bank will likely continue and the river will continue to migrate to the west, abandoning the pump and City outfall. Dredging would not reduce the erosion of the west bank, and deposition, therefore, would continue on the east bank near the pump intake and City outfall.

Advantages of this alternative include:

- Excavation/dredging would temporarily reduce the threat of sediment burial at the pump intake and City outfall and would allow operation until a long-term solution can be implemented.

Potential disadvantages of this alternative include:

- Excavation/dredging would not provide a long-term solution because sediment would continue to deposit in the vicinity of the pump intake and City outfall.
- The pump intake and City outfall could be buried by a few large storm events.
- The bar would have to be dredged at frequent intervals, depending on flow conditions in the river.
- Dredging operations could potentially increase turbidity and suspended sediment concentrations in the river, potentially conflicting with water quality and Endangered Species Act regulations. The extent, duration, and magnitude of this increase are unknown.
- Suction dredging required for maintenance could result in entrainment of salmonid fry and juveniles particularly if maintenance dredging is required following winter and early spring storms.

Alternative 2: Cut a channel across the bar to redirect flow in Sacramento River.
Under this alternative, a channel would be cut across the bar to redirect flow from the Sacramento River to the pump intake and City outfall. The likelihood of success of this alternative is low because the flow path of the Sacramento River responds to both local and upstream factors. The cut channel would be on the inside of the channel bend, away from the main flow area of the channel. This new channel, therefore, would have low water velocities, and sediment deposition would likely be chronic. Additionally, high flow velocities would continue to be directed onto the west bank, causing the bank to erode as the river continues to migrate away from the pump intake and City outfall.

No advantages of this alternative have been identified.

Potential disadvantages of this alternative include:

- In the absence of annual dredging, this alternative would not likely reduce sediment deposition in either the short- or long-term because sediment would continue to deposit in the vicinity of the pump intake and City outfall.
- The pump intake and City outfall could be buried during one large storm event.

Alternative 3. Dredge the bar and armor the west bank across from the pump intake and City outfall.
Under this alternative, the west bank of the river across from the pump intake and City outfall would be armored with revetment and the bar would be excavated/dredged to remove sediment. The revetment would halt erosion of the west bank, but likely would not reduce sediment deposition at the intake. As noted earlier, upstream changes have altered the direction of the bend in the channel, and sediment is currently being deposited on the inside of the bend at the pump intake and City outfall. Because the current location of the bank allows sediment to deposit very close to the intake and outfall, preventing additional erosion on the west bank would not likely prevent the bar from threatening the pump intake and City outfall in the near future. Revetment could be used in combination with annual dredging as described in Alternative 1.

Another potential bank protection measure is to construct setback rock slots in the west bank of the river. Under this approach, rock revetment would be placed in a trench set back approximately 20 feet from the river bank. These setback slots would not immediately impact the Sacramento River, but would act as revetment if the river bank erodes to the location of the slots. These slots would essentially act as insurance against erosion beyond the location of the slots. As with the traditional revetment approach described above, annual dredging would likely be required to limit the bar to its 1995 extent.

Advantages of this alternative include:

- These measures would prevent the river from further migration away from the pump intake and City outfall.

Potential disadvantages of this alternative include:

- Hard points in the channel such as bank revetment and setback slots (if bank erosion continues to the slot location) could increase bank erosion downstream and could threaten downstream properties. These downstream effects would likely be limited to approximately one-half a meander wavelength (about 1 mile) downstream of the revetment.
- Dredging operations could potentially increase turbidity and suspended sediment concentrations in the river, potentially conflicting with water quality and Endangered Species Act regulations. The extent, duration, and magnitude of this increase are unknown.
- Suction dredging required for maintenance could result in entrainment of salmonid fry and juveniles particularly if maintenance dredging is required following winter and early spring storms.

Alternative 4: Excavate/dredge sediment from the bar and install spur dikes on the west bank.

Under this alternative, a series of three spur dikes would be constructed on the west bank to reduce erosion of the west bank and redirect flow toward the pump intake and City outfall. The dikes would be placed between the upper end of the exposed bar to the pumping plant. The number, size, and placement of the spur dikes would have to be investigated using physical modeling during the design phase of the project. The dikes would be designed to withstand the 100-year flood. The bar would be excavated/dredged to its 1995 extent to a depth of 5 feet below the low-flow water surface elevation. A similar alternative was evaluated by Parker et al. (1988) on the Minnesota River, where sediment deposition threatened the cooling intake for the Wilmarth Power Plant. Similar to the M&T Ranch/Llano Seco intake and City of Chico outfall, the Wilmarth Power Plant was constructed on the bank of a meandering river, and was abandoned as the bend migrated away from the power plant. Parker et al. (1988) used scale-model flume experiments to test the success of forced channel constrictions and various spur dike configurations on reducing sediment deposition at the plant and found that placing three spur dikes on the opposite bank stopped the erosion of the bank and forced the thalweg back toward the pump intake. In this particular case, the property owner decided not to implement the spur dikes due to the high cost. Several years later, the intake was almost completely covered (Gary Parker, personal communication). We are not aware of existing similar applications on the Sacramento River.

While spur dikes would reduce sediment deposition in the long-term, initial dredging of sediment from the bar would be required to reduce sediment deposition over the intake in the short-term.

Advantages of this alternative include:

- This alternative has the highest likelihood of success in halting erosion of the west bank and maintaining flow over the pump intake and City outfall.
- Excavation/dredging would be required only in the short-term because the spur dikes would preclude the need for repeated dredging.

Potential disadvantages of this alternative include:

- Construction of spur dikes on the west bank would limit future bank migration.
- Hard points in the channel such as spur dikes and bank revetment can increase bank erosion downstream, and can threaten downstream properties. These downstream effects would likely be limited to approximately one-half a meander wavelength (about 1 mile) downstream of the revetment.
- Dredging operations could potentially increase turbidity and suspended sediment concentrations in the river, potentially conflicting with water quality and Endangered Species Act regulations. The extent, duration, and magnitude of this increase are unknown.
- Suction dredging required for maintenance could result in entrainment of salmonid fry and juveniles particularly if maintenance dredging is required following winter and early spring storms.

Alternative 5: Redesign or replace the pumping plant.
The Sacramento River is a dynamic alluvial system that migrates across a broad meander zone. Bank revetment and other bank protection measures implemented on a large migrating river such as the Sacramento River have an inherent risk of failure. Additionally, revetment added to the channel could have downstream effects. Under this alternative, the pump facility would be redesigned or relocated. Potential pumping plant intake modifications could include converting the intake to a infiltration gallery or Raney collector, extending the intake further out into the river, or converting to a shallow groundwater system. We are not aware of any infiltration galleries or Raney collectors that pump 150 cfs. A shallow groundwater system could potentially pump 150 cfs, but is likely not feasible with the existing pumping plant.

Extending the intake further into the river is not considered to be feasible because the pumping plant was not designed to allow an extension of the intake (Diamond Oaks Construction 2001). Addressing the feasibility or costs of this alternative is beyond the scope of this memorandum.

In the discussion draft, one component of this alternative was to relocate the pumping plant. Historical maps of bank locations indicate that the riverbanks have been shifting and migrating along the length of the Sacramento River both upstream and downstream of the pumping plant and City outfall. Therefore, finding a more stable nearby location for the pumping plant and City outfall does not seem likely and this option has been eliminated from the final draft.

Advantages of this alternative include:

- This alternative would not add hard points to the Sacramento River and would allow the channel to migrate.

Potential disadvantages of this alternative include:

- This alternative would be very costly.
- The City of Chico’s outfall would also have to be redesigned.

Conclusions and Recommendations

The two alternatives most likely to succeed in the long-term at this site are alternatives 4 and 5. The spur dikes (in combination with dredging) proposed under Alternative 4 would force flow over the pump intakes and City outfall. Sediment deposition currently occurs at the intake and City outfall because water velocities are too low to maintain sediment transport. Focusing flow away from the west bank would increase flow velocity and decrease sediment deposition at the intake and outfall. Dredging would be required as a short-term solution until the spur dikes could be constructed, which would likely require several years for permitting, design, and implementation. Simply dredging the bar (Alternative 1) or dredging the bar in combination with bank revetment or setback slots (Alternative 3) would not prevent continued sediment deposition at this site.

Redesigning or replacing the pumping plant as either a Raney collector or shallow groundwater system would not require additional armoring of the bank in this location. Determining the feasibility of potential designs requires extensive physical data which are not currently available and beyond the scope of this memorandum.

References

Diamond Oaks Construction. 2001. A one-page letter from James S. Pelletier to the M & T Ranch describing the feasibility of extending the pump intake further into the Sacramento River.

Parker, G., M. Garcia, H. Johannesson, and K. Okabe. 1998. Model Study of the Minnesota River near Wilmarth Power Plant, Minnesota. University of Minnesota, St. Anthony Falls Hydraulic Laboratory Project Report No. 284.

Sierra View Divers. 2001. A three-page report to the City of Chico and M & T Ranch regarding diver observations of sedimentation at the M & T Ranch/Llano Seco pumps and the City of Chico outfall.

CDWR. 2001. A letter from Koll Buer to Les Heringer (M & T Ranch) documenting erosion at the M & T/Llano Seco pump intake.