M & T Ranch Intake

Channel Dredging Alternatives

Executive Summary

A gravel bar is expanding and threatening to block the M & T intake on the Sacramento River at RM 192.7. To provide a reliable water supply to the intake, three options were chosen for further investigation. One of these is to excavate and maintain an open channel from the river to the intake. This report discusses the analysis of this option.

The location of the gravel bar was estimated for the next 40 years based on historical bar movement. The present river energy slope and gravel bar height were assumed to apply in the future. Three alternatives to maintain an open channel were developed. These were:

- A 400 cfs channel to the intake and a 250 cfs bypass channel from the intake back to the river.
- A 150 cfs channel from the river to the intake with no bypass channel back to the river.
- A channel from the river to the intake with a flow velocity of 0.33 fps to allow juvenile fish the ability to return to the river.

Uniform flow was assumed to determine the size of the channels. The amount of excavation was calculated for each year in the future assuming that major channel excavation would take place once every three years on average.

The cost of each alternative consists of capital costs to purchase a high capacity, long reach excavator and fish screen modifications (Alternative 2 only). Annual costs consist of channel excavating, hauling, and spreading excavated material and obtaining permits once every five years. To determine first costs from annual costs, it was assumed that the cost of money (discount rate) equaled inflation.

Alternative 2 was not acceptable for fish protection since fish could be trapped at the end of the channel in front of the fish screen. Total present value costs for each alternative showed that Alternative 3 was least expensive. Alternative 3 appears to be the most attractive alternative, however excessive sedimentation in the channel from bedload across the bar is a problem for flows above about 100,000 cfs.

If the dredging alternative is to move forward, Alternative 1 is recommended for further study. Alternative 3 should also be analyzed to obtain a qualitative estimate of the amounts of sediment that must be removed to keep the channel open. See Section 5 for further discussion of the results, conclusions, and recommendations.

1. Introduction

1.1. Background

The M & T Ranch Fish Screen intake was constructed in 1997 at River Mile RM192.5 on the left Bank of the Sacramento River. The gravel bar, presently located above the confluence of the Sacramento River and Big Chico Creek, has become larger in the downstream direction since 1995. At the same time, the right bank has eroded about 270 feet over a 0.5 mile length of the river bank across from the M & T intake upstream (Mussetter Engineering). By about 2001 the gravel bar was beginning to encroach on the M & T Fish Screens. In November 2001 much of the gravel bar was removed from the M & T Fish Screens upstream. In 2003 a Steering Committee was convened to investigate ways to prevent river deposition from restricting flow to the M & T intake. Reports were written to define the problem and propose solutions (Strand, Harvey, et al, Mussetter Engineering, Larson). The panel recommended three alternatives, given below in order of preference.

1. Install Ranney Wells and pump water into the M & T canal. It was estimated that three or four wells would be required.
2. Placement of spur dikes or revetment on the right bank from a point 700 feet upstream of the M & T intake to about 500 feet upstream of the head of the gravel bar. See Mussetter (2005) for a further description.
3. Dredging and Fish Screen Modification to provide flow to the M & T intake across the gravel bar.

Studies of providing Ranney wells were conducted by MWH (2004). During subsequent studies and meetings it was determined that the cost of construction and operation of the Ranney well system were too high. The placement of spur dikes to deflect the river channel toward the left bank was the second preferred alternative. However, placing rock in the river is a sensitive issue and obtaining permits to do so would be difficult. Therefore, the Steering Committee decided to look into this dredging option in more detail.

1.2. Objective

The objective of this report is to perform a reconnaissance level feasibility investigation of alternatives to provide water to the existing intake by excavating and maintaining a channel from the river to the intake.

2. Assumptions and Criteria

To assess dredging alternatives it is first necessary to predict the progress of gravel bar migration and estimate its size. In addition, one must predict the behavior of Big Chico Creek in the face of gravel bar growth. For the purposes of this analysis some general assumptions were made. These are listed below.

2.1. Gravel Bar Movement

The assumptions, which drive this alternative's size and cost, are the estimates of the location and size of the gravel bar over the life of the project. The assumptions regarding the gravel bar are based on the following:

- The gravel bar is moving downstream as the right bank erodes (Mussetter). Based on Figure 3.19 in Mussetter (2005), the right bank bend has moved downstream about half a mile or 2,500 feet from 1979 to 2003. It is assumed that the gravel will continue to migrate downstream at this rate, which is about 100 feet every year.
- The southern tip of the gravel bar moved downstream about 136 feet per year from 1995 through 1999 as measured on a DWR aerial photo showing the river with the gravel bar and river bank locations for the years 1995 through 2003. The gravel bar was excavated and reduced in size in 2002. The DWR photo also shows the gravel bar position after the excavation. The gravel bar shows minimal movement between July 2003 and June 2005, even though the west bank of the river opposite the gravel bar receded about 100 feet over the same period.
- The channel width of the river and width of the gravel bar will remain the same.
- No future measures will be undertaken to direct the river back toward the M & T intake. Therefore, dredging a channel to the intake will be required for the life of the project.
- As the gravel bar moves downstream, Big Chico Creek will probably cut a new channel through the gravel bar. Prior to this time it is envisioned that access to all points along the channel will have been constructed. Therefore, even after Big Chico Creek cuts through the gravel bar, access will be possible to all parts of the channel.
- The gravel bar after moving will be at the same height as the present gravel bar.

2.2. Assumptions and Criteria

The basic assumptions and criteria for this analysis are provided below:

- The available head drop for the channel is .00065 feet per foot. This was determined from the water surface elevations from the RMA2 model run by Mussetter Engineering. See Mussetter Engineering (April 12, 2006).
- The life of the project is 40 years. It is assumed that the project life of the M & T intake and pump is 50 years. By the time this project is implemented, it will have been 10 years since the M & T project has been placed on line.
- The inflation rate and cost of money are equal. Therefore, the annual cost is multiplied by the number of years it is expected to occur to obtain first cost.

- The diverted flows by month are:

Month	Flow (cfs)
January	70
February	70
March	70
April	100
May	150
June	150
July	150
August	150
September	120
October	120
November	100
December	100

- Access can be obtained across State Park lands at the head of the gravel bar.
- The length of channels are as shown on the figures in this report.
- No environmental mitigation costs have been included.
- Permits can be obtained for cleaning the channel over the life of the project.
- An acceptable fish screen approach velocity with no sweeping flow is 0.22 fps. This assumes that this figure will be approved by the fishery agencies.
- The screen approach velocity with the appropriate sweeping velocity is a maximum of 0.33 fps per California Department of Fish Game (2000).
- Access to the river can be obtained in the vicinity of the M & T intake, as required for channel and intake excavation. The maximum grade is a one-to-four slope.
- The channel will be accessible at all points along its length by a Gradall excavator purchased for the purpose of cleaning the channel.
- Excavation of a channel cannot be done efficiently with a clamshell crane because the gravel bar material is hard and well compacted (McAmis).
- The channel at the fish screens will be excavated to maintain a sweeping velocity of 0.66 fps with a flow of 250 cfs.
- To facilitate immediate channel cleaning, it is assumed that the permitting agencies will grant permits for an extended period of time with renewable clauses. This eliminates the requirements to obtain permits whenever the channel needs cleaning.

2.2.1. Hydraulic and Sediment Transport Considerations

The river inundates the gravel bar at flows between 30,000 and 40,000 cfs. This is based on cross section plots of the HEC RAS backwater model furnished by Mussetter Engineering. For flows below about 35,000 cfs, access can be gained onto the gravel bar to clean the channel across the bar. This access to clean the channel is available about 95% of the time as shown on the flow exceedence curve in Mussetter (2006).

Concerning gravel deposition the following assumptions were made:

- Significant sediment transport does not occur below 75,000 cfs (Mussetter, 2006), which flows about 1.5% of the time and occurs about 2 out of every three years. So, it is unlikely that the approach and bypass channels will be filled every year on average.
- Based on plots of cross sections in the vicinity of the gravel bar furnished by Mussetter Engineering, the height of the gravel bar above low water level was found to be 10 feet. This was used in calculations of material to be excavated.
- The shear stress on the gravel bar will not move material during a once per two year even (90,000 cfs) (Mussetter, 2006). Therefore, significant deposition is assumed to occur once every three years or at flows of about 100,000 cfs or above. It is assumed that major cleaning is required every three years.
- Since the proposed channel for Alternatives 1 and 2 is along the northern boundary of the gravel bar, sediment cannot travel through the wooded state park immediately upstream. So, deposition will occur mainly at the entrance to the channel near the river. In addition, gravel deposition has not occurred in the Big Chico Creek channel at the upstream end of the gravel bar. For these reasons, we assume that, on average, 67% of the channel has to be excavated.
- Three quarters of the excavation volume will be excavated at the end of the high-water season. A quarter of the excavated volume will have to be removed during the high-water season to keep the channel open for refuge water of up to 100 cfs during the winter season.
- Based on the above, the following assumptions were used to calculate sediment removed:

  Alternatives 1 and 2 – 67% of the channel length must be cleaned every three years.

  Alternative 3 – 100% of the channel length will be cleaned every three years.

3. Alternatives

3.1. Alternative 1 Channel with Bypass Flow

This alternative calls for delivering the required flows to the M & T intake plus enough additional flow to provide a sweeping velocity past the screens of twice the approach velocity as required by the CDFG fish screening criteria.

3.1.1. Approach and Bypass Channels

The maximum intake design flow of 150 cfs plus a sweeping flow of 250 cfs constitute the design flow for the approach channel. The flow of 250 cfs would provide minimum sweeping velocity of 0.67 fps. The Manning's n value is 0.023 and the energy slope available is 0.00064 feet per foot for both the approach and bypass channels (Dai). The approach channel would have a conveyance area of 112 square feet. This is a channel with a bottom width of 12 feet and 2:1 side slopes flowing at a velocity of 3.6 fps and depth of 5.1 feet. The bypass channel would have a conveyance area of 80 square feet. This is a channel with a bottom width of 12 feet and 2:1 side slopes flowing at a velocity of 3.1 fps and depth of 4.0 feet.

The location and size of the gravel bar were estimated at four years in the future, 2010, 2020, 2030, and 2040. The channel was assumed to have the same length and height at the end of the project life in 2050. See Figures 1 through 4. This time span approximately coincides with the assumed 40-year life of the project. These were drawn assuming that the gravel bar is moving downstream at 100 feet per year. The location and size of the gravel bar were calculated based on data described in subsection 2.1, above. The channel across the gravel bar for each of these years was designed on the alignment shown in Figures 1 through 4. The gravel bar was assumed to be ten feet above the low water surface for the purposes of computing the excavation quantities. This alignment utilizes the additional flow from Big Chico Creek to keep the channel scoured. At a future time Big Chico Creek might form a new channel across the bar and approach channel. See subsection 2.2.1 for assumptions used in calculating the gravel bar excavation quantities. The Table 3.1 below shows the length of channels and estimated amount of material removed to create the channels.

Table 3.1
Alternative 1 Channel Excavation Quantities

Year	Channel	Average Channel Length (ft)	Average Volume Removed per Year (cu yd)	Total Volume removed per year (cu yd)
2010	Approach	1,750	9,180	
to 2020	Bypass	300	1,390	10,570
2020	Approach	2750	14,420	
to 2030	Bypass	650	3,010	17,430
2030	Approach	2,750	14,420	
to 2040	Bypass	900	4,160	18,580
2040	Approach	2,750	14,420	
to 2050	Bypass	1,100	5,090	19,510

The channel would be kept open with a long reach, high capacity excavator to maximize the reach. Even with a longer reach, the excavator would require access to both sides of the channel in order to clean a channel this wide. Culverts would be placed in the channel at the upstream end of the gravel bar, so that the excavator could access the south and west sides of the channel. The culverts would be removed after the work is completed. Additional access points would be required down the levee both upstream and downstream of the fish screens. The maximum slope of the access ramp would be about one to four.

At the fish screens, the channel would be allowed to encroach on the screens slightly as shown by the embankment on the left side of Figure 5. At low water conditions in the river, this encroachment allows for a sweeping velocity of about 0.76 fps, which is greater than twice the approach velocity, for a bypass flow of 250 cfs. It would be very difficult to clean between and around the screens. If the screens become impacted by gravel deposition, staging areas would have to be constructed around the screens for access by smaller excavators.

3.1.2. Alternative 1 Costs

The excavation costs were estimated on a cost per volume basis. It was assumed that the channel would be excavated once every three years. See subsection 2.2.1 for assumptions regarding excavation amounts. The excavator would be a high capacity, long reach excavator with a 1 cubic yard bucket. This would be a machine such as a Gradall XL5200. It would be purchased at the beginning of the project. The excavation cost per cubic yard would cover all operating expenses including replacing the machine during the life of the project. It is assumed that excavation could be accomplished at the rate of 160 cubic yards per hour with a three-yard bucket. The cost per cubic yard of excavation is assumed to be $3.51 from RS Means Heavy Construction Cost Data. It is assumed that the excavated material could be deposited on the downstream side of the channel using the long reach of the excavator. A bulldozer would spread the material out on the gravel bar. The bulldozer would move the material an average of 50 feet at the cost of $1.54 per cubic yard. Therefore, the haul cost would be eliminated. $1.00 per cubic yard was added for mobilization and demobilization and installing the culverts.

Another of the first costs would be to obtain the necessary permits to allow channel maintenance whenever the channel became restricted. These permits are assumed to be written for a ten-year period, are assumed to be renewable, and their costs are covered by the "Obtain Permits" first cost in Table 3.2.

Table 3.2 shows very rough cost figures to indicate the relative life cycle cost differences between alternatives assuming a 40-year life.

Table 3.2
Alternative 1 Costs (Present Value)

Purchase of Excavator	$450,000
Obtain Permits	$350,000
Channel Excavation (50-year present value)	$3,998,000
Haul Excavation (50-year present value)	-*-
Total Present Value Cost	$4,798,000

* No haul is assumed to be required since the excavated material would be deposited on the river-side of the channel.

3.1.3. Variation Alternative 1

This variation consists of reducing the cross section at the fish screens by re-constructing the cylindrical fish screen arrangement. The four cylinder screens would be placed in line, upstream to downstream. This would reduce the flow area at the screens, reducing the amount of flow to provide sweeping velocities. The sweeping flow could be reduced from 250 cfs to about 135 cfs. Reducing the approach channel excavation quantities by about 40%. However, the fish screen piping would have to be rearranged, which would require cofferdamming the area and adding new pipes. The steel pilings and protective steel would have to be removed and replaced. This should be investigated, if it is decided that further study of the dredging alternatives, is warranted.

3.2. Alternative 2 Channel with Diverted Flow and Modified Fish Screen

This alternative differs from Alternative 1 in that only the intake design flow is conveyed in the approach channel. This would reduce the size of the approach channel, and a bypass channel back to the river downstream of the screens is not required. However, without a bypass flow the sweeping flow over the screens would vary from about 0.33 to 0.0 fps. Published CDFG screening criteria for screens in non-flowing waters states: "The specific screen approach velocity shall be determined for each installation, based on species and life stage of fish being protected." California Department of Fish and Game (2000).

3.2.1. Approach Channel

For this alternative the maximum design flow in the approach channel is 150 cfs. The energy slope available is 0.00064 feet per foot. The approach channel would have a conveyance area of 55 square feet. This is a channel with a bottom width of 12 and 2:1 side slopes flowing at a velocity of 2.7 fps and depth of 3.0 feet. No channel would be maintained downstream of the intake since there is no bypass flow in this alternative.

This channel would require less excavation than in Alternative 1. The process for excavating the channel would be the same as in Alternative 1 and is explained in subsection 3.1.1. Table 3-3 shows the amount of annual excavation needed to keep the channel open for each of the future years of operation.

Table 3.3
Alternative 2 Approach Channel Excavation Quantities

Year	Channel Length (ft)	Total Volume removed per year (cu yd)
2010 to 2020	1,750	7,180
2020 to 2030	2,750	11,280
2030 to 2040	2,750	11,280
2040 to 2050	2,750	11,280

3.2.2. Fish Screen Modification

To accommodate this alternative, the approach velocity to the screens must be decreased to decrease the chance of fish impingement on the screen. The fish screening criteria from CDFG (2000) states that, for screens in non-flowing waters, the approach velocity is to be determined on a case-by-case basis. For the purposes of this analysis, it is assumed that an approach velocity of 0.22 fps would be acceptable to the fishery agencies. This means that an additional 50% of screen area below the low water level is required to meet this negotiated standard. The area around and near the existing screens would be dewatered to construct an additional set of T screens. A cofferdam, sheet pile wall, extending from the levee around and beyond the existing screens would be constructed. The concrete foundation and a new T-screen assembly would be installed off the end of the existing manifold. See Figure 6. This would add an additional 50% of screen area. At 150 cfs, the approach velocity to the screens would be reduced to about 0.22 fps. No additional pipe would be required through the levee, since the maximum flow would remain at 150 cfs. The piping for the air-burst cleaning system would be extended to the third set of cylindrical screens from the compressor and air receiver tank. The cleaning system would have an additional 50% of screens to clean increasing the minimum time between cleanings by 50%. Instead of cleaning the screens every 5 minutes, the screens would be cleaned every 7.5 minutes. An additional set of air pipes would have to be run from the air receiver over the levee to the new cylindrical screens.

3.2.3. Alternative 2 Costs

Table 3.4 shows rough cost figures estimated to indicate the relative life cycle cost differences between alternatives.

Table 3.4
Alternative 2 Costs (Present Value)

Fish Screen Expansion	$1,100,000
Obtain Permits	$350,000
Channel Excavation (40-year present value)	$2,483,000
Haul (50-year present value)	*
Excavator Purchase	$450,000
Total	$4,383,000

* No haul is assumed to be required since the excavated material would be deposited on the river-side of the channel.

First costs in this alternative include fish screen modifications and excavator purchase. Another first cost is obtaining the necessary permits to allow channel maintenance whenever the channel became restricted. These permits are assumed to be written for a ten-year period and are assumed to be renewable. The cost for the initial permits and re-obtaining them in future years is assumed to be covered in the “Obtain Permits” cost in Table 3.4.

The method of excavation and cleaning the channel is the same as described for Alternative 1 above. The costs per cubic yard for excavation and spreading are also the same as those in Alternative 1.

3.3. Alternative 3 Dead-end Channel (V=0.33 fps)

3.3.1. Approach Channel

This alternative involves constructing a channel from the river to the fish screens. It would have a velocity of 0.33 fps, which allows juvenile fish to swim out of the cul de sac and back to the river. This alternative is shown on Figures 1 through 4.

The channel excavation requirements are calculated in the same manner as in Alternatives 1 and 2. For this alternative the maximum design flow in the approach channel is 150 cfs, and a minimal slope is required due to the low velocity. The approach channel would require a conveyance area of 450 square feet. This is a channel with a bottom width of 50 and 2:1 side slopes flowing at a velocity of 0.33 fps and depth of 7.1

feet. No channel would be maintained downstream of the intake since there is no bypass flow in this alternative.

As in the other alternatives, it is assumed that the top of the gravel bar is 10 feet above the low water elevation. The top width of the excavated channel is 118 feet. A long reach, high capacity excavator with an extension arm would be required. First, ramps would have to be built down from the top of the levee down to the gravel bar. In addition, temporary work pads would be constructed at points along one side of the channel to reach the whole channel width. Hauling half of the excavation from the upstream side of the channel is assumed to be necessary. Excavated material from the downstream side would be spread on the gravel bar with a bulldozer, similar to the approach in Alternatives 1 and 2.

Table 3.5
Alternative 3 Approach Channel Excavation Quantities

Year	Channel Length (ft)	Total Volume removed per year (cu yd)
2010 to 2020	250	2,220
2020 to 2030	300	5,320
2030 to 2040	400	7,100
2040 to 2050	400	7,100

The channel for this alternative is shown on Figures 1 through 4. For the purposes of this study, it was assumed that the approach channel would be excavated perpendicular to the river channel. However, for possible reduction of sedimentation in the channel, another alignment might be selected. Another idea to possibly reduce maintenance is to extend a rock barrier wall from levee into the river just upstream of the fish screens. This could protect the channel near the screens from sedimentation.

3.3.2. Alternative 3 Costs

Table 3.6 shows rough cost figures estimated to indicate the relative life cycle cost differences between alternatives.

Table 3.6
Alternative 3 Costs (Present Value)

Excavator Purchase	$450,000
Obtain Permits	$350,000
Channel Excavation (50-year present value)	$930,000
Haul (50-year present value)	$1,196,000
Total	$2,926,000

The material excavated from the south half of the channel will be placed on the downstream side of the channel where it will be available for redistribution by the river. The excavation unit costs are the same as those for Alternatives 1 and 2. The material taken from the north side of the channel is assumed to be hauled off site five miles at a cost of $11.00 per cubic yard.

4. Other Alternatives

4.1. Different Approach Channel Layout

In their technical memo Stillwater Sciences (2001) showed a different layout for a dredged approach channel. Its inlet on the river is located at the upstream end of the state park just south of River Road. It would be cut through the state park to Big Chico Creek. This alternative has the advantage that the channel inlet is located in a back eddy at the downstream end of a rip rap embankment. This back eddy could reduce sediment deposition at the inlet decreasing maintenance costs. The reason that this alternative was not carried further is that the approach channel would divide the park in half and it is doubtful that the land rights could be obtained from California State Parks.

4.2. Dredging Option

MWH held discussions with Ben Pennock of GCID regarding GCID's approach to maintaining the inlet channel to their screens. He made a quick estimate of dredging based on use of a suction dredge on a barge as employed by GCID. The cost of this alternative was very expensive and was not considered further.

5. Results and Conclusions

The following conclusions can be drawn from this analysis:

- For Alternative 1, if the bypass flow can be reduced, the total flow in the approach channel would be lower, decreasing the channel size and, therefore, reducing the excavation quantities. Permission would have to be obtained from the fishery agencies.

- Alternative 2 provides a dead end for downstream migrating fish. After entering and traveling down the channel, these migrants cannot return up the channel against the velocity. Therefore, they are trapped without a means of escape. This alternative should not be considered further for this reason.
- For all alternatives a Section 1601 Streambed Alteration Agreement from CDFG and Corps 404 permits must be obtained. It is assumed that permits for all alternatives can be issued for long periods, 5 to 10 years and that the permits can be renewed over the life of the project.
- The channel excavation requirements are dependent on the frequency of high flow events and, therefore, cannot be accurately predicted.
- The excavator purchased for the project is dedicated to this project. The bulldozers and dump trucks will have to be rented.
- Alternative 3 is the least expensive. However, it is most susceptible to accumulating sediment in the channel since the channel lies across the exposed gravel bar. The approach channels in Alternatives 1 and 2 are protected to some extent from bedload by the vegetation upstream in the state park. To protect the Alternative 3 channel, it could be beneficial to place a rock wall on the upstream side of the approach channel to prevent bedload from entering the channel. However, greater amounts of bedload will move around the end of the wall into the channel. This rock wall suffers from the same objections as the groins, although it would be much smaller.
- In all alternatives, there is a risk of sediment settling under and around the screens. This sediment would be very difficult to remove without damaging the screens. So, an effective way of eliminating sediment settlement at the screens must be devised.
- Alternatives 1 and 2 involve cutting a channel across the upper end of the gravel bar, which state parks considers to be park land. Obtaining permission to construct such a channel could be difficult.
- All the alternatives call for depositing excavated material on the gravel bar downstream of the channels and spreading it with a bulldozer. It is assumed that this activity would be allowed. Hauling the material would cost a considerable amount of money.
- Any dredging alternative allows the gravel bar to migrate onto the fish screens at the M & T intake. It is the intent to keep the channel as clean as possible, but some gravel will be deposited in and around the fish screens. This area would be difficult to clean, because using excavating equipment could damage the screens. For Alternative 3 the rock wall from the levee outward could keep gravel away from the screens.

- Alternative 1 is preferred. The feasibility of Alternative 3 depends on the amount and frequency of sediment accumulation in the channel and the ability to gain access to clean it out. It should be evaluated in a physical model. See the recommendation below.
- Alternatives 1 and 3 should be evaluated with a movable bed, physical hydraulic model to ascertain the location and size of the channels and to obtain a qualitative estimate of the amounts of sediment that must be removed to keep the channels open.

References

California Department of Fish and Game, Fish Screening Criteria, June 19, 2000 (from web site: www.dfg.ca.gov/nafwb/fishscreencriteria.html)

California Department of Water Resources, Sacramento River Bank Erosion Study, M & T Ranch (RM193), June 14, 1999 Aerial Photo, Filename*: BigChicoCreek—M&TranchBaseMap-2005-7-22.dwg*, Plotted July 22, 2005

Dai, Thomas, Mussetter Engineering, e-mail April 19, 2006.

Harvey, M.D., Larsen, E.W., Mussetter, R.A., and Cui, Y, Channel and Sediment Transport Dynamics near River Mile 193, Sacramento River, 2004

Larsen, Eric W., Future Meander Bend Migration and Floodplain Development Patterns near River Miles 200 to 191 of the Sacramento River, 2005

McAmis, John, Personal Communication, April 12, 2006

Mussetter Engineering, Two Dimensional Modeling to Evaluate Potential River Training Works at M & T Pumping Plant Sacramento, RM192.5, January 2005

Mussetter Engineering, Two Dimensional Modeling to Evaluate Potential River Training Works at M & T Pumping Plant Sacramento River, RM192.5, 2005 (Topography and Bed Material), Revised April 12, 2006

Stillwater Sciences, Technical Memorandum, Final Draft of M&T Ranch and Llano Seco Wildlife Refuge Pump Intake, 2001

Strand, Robert I, Existing Studies – M & T/Llano Seco Fish Screen Facility, a memorandum to Neil Schild, MWH, November 11, 2003

Zirkle, Olen, Letter to Leann Androvich, GCAP Services, Re:Amendment Request #3 (Level 3) for Recipient Agreement #ERP-02-P08-D, February 25, 2005