

M&T/Llano Seco Fish Screen Facility, Short-Term/ Long-Term Protection Project

TECHNICAL MEMORANDUM: WORKSHOP 4 SUMMARY

1. INTRODUCTION

In 1997, the M&T/Llano Seco Pumping and Fish Screen Facility (M&T Pumps) was moved from Big Chico Creek to the east bank of the Sacramento River just south of Bidwell State Park and downstream from the mouth of the creek at RM 192.75 (**Figure 1**). The pumps had previously been located in Big Chico Creek about 0.5 miles upstream from the confluence with the Sacramento River. Since 1997, geomorphic changes have occurred in the Sacramento River channel that pose a significant risk to the continued operation of the M&T Pumps and the adjacent City of Chico's Wastewater Treatment Plant Outfall (City of Chico Outfall) that is located about 300 feet downstream. Geomorphic changes include erosion and lateral migration of the west bank of the river and concomitant downstream growth of the large gravel bar that is located at the mouth of Big Chico Creek, just upstream from the intake. The bank-attached bar on the east side of the river migrated 850 feet downstream towards the M&T and City of Chico facilities between 1995 and 2001 (Stillwater Sciences, 2001). Comparative aerial photography and survey measurements by the Department of Water Resources show that the west bank of the Sacramento River eroded by up to 330 feet just upstream from the M&T Pumps and City of Chico Outfall between 1996 and 2006 (**Figure 2**). In 2001, 189,000 tons of material was dredged from the gravel bar as a short-term solution to limit sedimentation at the M&T and City of Chico facilities.

Analyses conducted by an Expert Panel that was appointed by the California Bay Delta Authority (CBDA) to evaluate and guide the selection of an appropriate long-term solution to the problems detailed the historic changes of the river in the project area and identified the hydraulic factors that are responsible for creation and continued development of the gravel bar and the resulting sedimentation problems at the M&T Pumps and City of Chico Outfall (Harvey, Larsen, Mussetter and Cui, 2004). The Expert Panel concluded that:

The sediment-transport analyses confirm that the locus of sediment deposition on the bar immediately upstream of the M&T pump inlets is due to local hydraulic conditions that favor deposition. These conditions can be expected to persist under the existing channel morphology, and will most likely become worse if the right bank is allowed to continue to erode. If the difference in sediment-transport capacities at the head and toe of the bar is a reasonable estimate of the volume of material deposited on the gravel bar on an average annual basis, then the bar could rebuild to its 2000 pre-dredged configuration within about four years. On the other hand, if an infrequent flood event like the 1974 flood were to occur (a 2-percent chance exists of a flood of this magnitude occurring), the bar could be rebuilt within a single event.

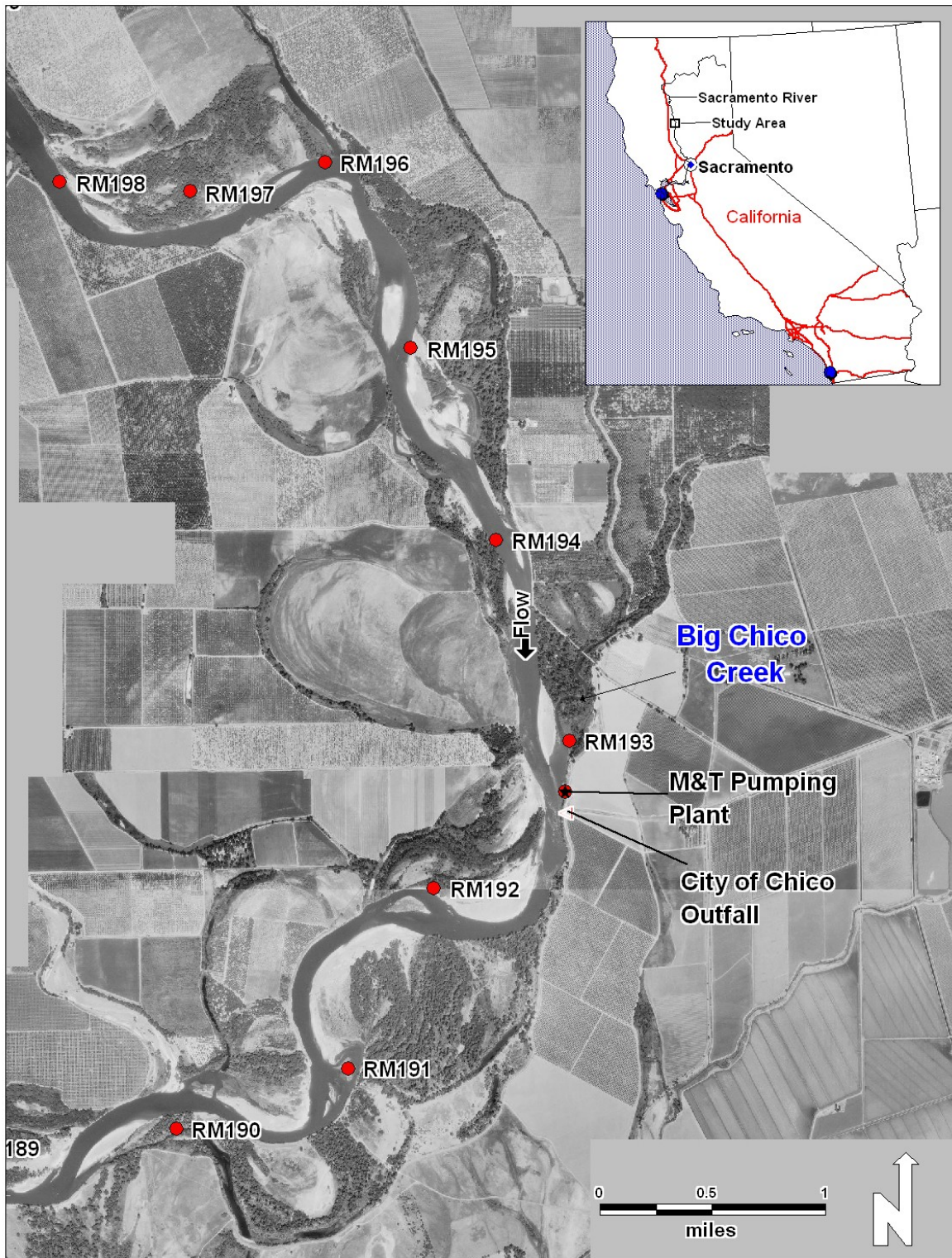


Figure 1. Location of the Sacramento River and the M&T Pumping Plant and City of Chico Wastewater Treatment Plant Outfall.



SACRAMENTO RIVER BANK EROSION STUDY

M & T RANCH (RM 193)

June 14, 1999 Aerial Photo

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Figure 2. Bank erosion and bar growth between 1995 and 2005 at the M&T site.

Consequently, a large number of both in- and out-of-river alternatives for solving the problems at the M&T Pumps and City of Chico Outfall have been identified and evaluated by the Expert Panel and a Steering Committee over the course of four workshops in 2003, 2004, 2005 and 2006.

The in-river alternatives evaluated included:

- dredging with existing and new flat-plate fish screens,
- spur dikes/groins on the west bank,
- extended intakes and fish screens downstream and across the river, and
- in-conduit fish screens.

The out-of-river alternatives evaluated included:

- alternative water supplies,
- changed point of diversion,
- collector basin with infiltration galleries,
- multiple production wells, and
- Ranney Collector Wells.

This document provides a summary of the Phase I investigative process and the conclusions and recommendations of the Expert Panel that were developed at the Fourth Workshop (April, 2006) that concluded the Phase I investigation.

1.1. Project Objectives

The primary objective of the M&T/Llano Seco Fish Screen Facility, Short-term/Long-term Project is to resolve the apparent contradiction between protecting ecosystem functions by accommodating natural river meander processes while also protecting the present pumping plant facility in order to provide a fish-screened diversion without threatening the anadromous species and providing water for crops, habitat and waterfowl. The overall project objective was subdivided into specific objectives as follows:

1. Obtain an authoritative and unbiased description of the state of scientific knowledge related to Sacramento River meander and fish screen and pumping plant technologies by convening a multidisciplinary team of experts in the fields of fluvial geomorphology, sediment transport, hydraulic modeling, fish screen and pumping plant technology.
2. Provide an opportunity for stakeholders and scientists to test and refine an understanding of the potential for unintended effects between managing the natural riverine system, fisheries requirements and pumping requirements.
3. Conduct an exhaustive literature search, fill identified data gaps and conduct modeling to provide important data essential to answering specific questions that support a strong research approach in accomplishing the primary project goal.
4. Determine performance measures/indicators that will guide the long-term solution in meeting the primary project goal.
5. Fully document the investigative process of determining, identifying and justifying the long-term solution that will meet the primary goal of the project.

1.2. Project Conceptual Model and Goals

The working goal of the project can be summarized as follows: *To protect threatened and endangered anadromous fish populations and pumping requirements for adjacent agriculture, managed wetlands (federal, state and private), and City of Chico wastewater facility without a significant effect on river meanders.*

In order to evaluate the ability of an alternative to meet the project goals a decision matrix was developed to objectively identify whether a Preferred Alternative that would meet all of the primary screening criteria, (i.e., River Meander, Pumping Requirements and Fisheries/Fish Screen) could be identified (**Figure 3**). However, it was recognized that a Preferred Alternative might not be found, and thus a pathway to a Non-goal Alternative was provided for in the matrix. Non-goal Alternatives are also subjected to Economic and Engineering Feasibility criteria. The decision matrix was designed to provide the Expert Panel with a transparent means of developing an objective and technically based recommendation for the solution of the problems at the M&T Pumps and City of Chico Outfall that would be forwarded to decision-making authorities.

1.3. Project Stakeholders

The stakeholders for this project include those entities that receive water from the M&T pumps; M&T Chico Ranch, Llano Seco Ranch, U.S. Fish and Wildlife Service Sacramento National Refuge Complex, California Department of Fish and Game; the City of Chico because of the river-related problems with its wastewater outfall facility; and the California Department of Parks and Recreation who manage Bidwell State Park to which the bank-attached bar on the east side of the river has accreted.

1.4. Expert Panel and Steering Committee

An Expert Panel composed of multi-disciplinary experts in the fields of fluvial geomorphology, sediment transport and hydraulic modeling was selected by CALFED to guide the investigative project and to ultimately provide recommendations for both short- and long-term solutions to the identified problems. A Steering Committee comprised of stakeholders, CALFED representatives, and engineers with expertise in civil engineering, fish screening and pumping plant technology was also formed. **Table 1** provides a summary of the individuals, and their technical specializations and affiliations that comprised the Expert Panel and Steering Committee.

1.5. Summary of Three Previous Workshops

Three workshops were conducted between 2003 and 2005 to evaluate the problems at the M&T Pumps and City of Chico Outfall and to identify and evaluate a range of in- and out-of-river alternatives for solving the problems. The proceedings of the three workshops are summarized in the following sections.

1.5.1. Workshop 1 (November 12-14, 2003)—Orientation and Information Workshop

The Expert Panel and Steering Committee members conducted a land- and boat-based site visit to the Sacramento River to collectively view the M&T Pumps and the City of Chico Outfall and to evaluate the current conditions and threats posed by the eroding west bank and encroaching gravel bar on the east bank. The locations of the existing bank revetments (hard points) in the reach between Pine Creek and Stony Creek were also inspected during the boat-based

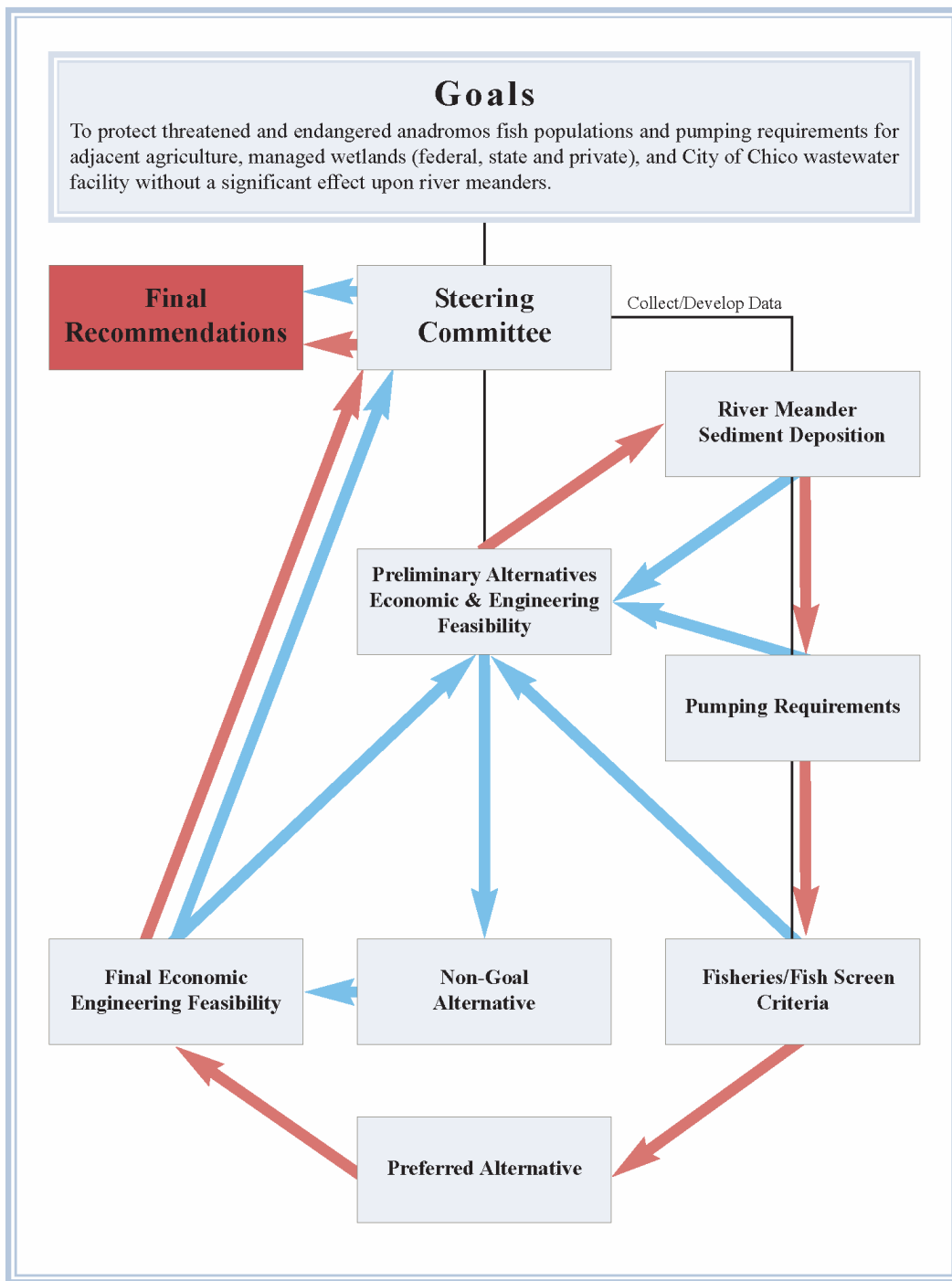


Figure 3. Decision matrix flow chart for identifying a preferred alternative.

Table 1. M&T/Llano Seco Fish Screen Project Expert Panel and Steering Committee Members.		
Individual	Technical Specialization	Affiliation
CBDA Expert Panel		
Yantao Cui, Ph.D.	Hydrology/Geomorphology	Stillwater Sciences
Eric Larsen, Ph.D.	Geology/Meander Modeling	U.C. Davis
Mike Harvey, Ph.D., P.G.	Geomorphology/River Engineering	Mussetter Engineering, Inc.
Bob Mussetter, Ph.D., P.E.	Hydraulic Modeling/Sediment Transport Modeling	Mussetter Engineering, Inc.
Steering Committee Members		
Dennis Dorratcague, P.E.	Fish Screen Technology	MWH Americas
Neil Schild, P.E.	Civil Engineering	MWH Americas
Jim Gaumer, P.E.	Civil Engineering	M&T Chico Ranch
Bruce Ross	Geologist	Cal. Dept. Water Resources
Stacy Cepello	Environmental Science	Cal. Dept. Water Resources
Dan McManus, P.E.	Engineering Geology/Groundwater Hydrology	Cal. Dept. Water Resources
Howard Brown	Fishery Biology	National Marine Fishery Service
Paul Ward	Fishery Biology	Cal. Dept. Fish and Game
Burt Bundy	Manager	Sacramento River Conservation Area Forum
Rebecca Fris	Sacramento Valley Regional Coordinator	California Bay-Delta Authority
Woody Elliott	Resource Ecologist	Cal. Dept. Parks and Recreation
Les Heringer	Ranch Manager	M&T Chico Ranch
Dave Sieperda	Ranch Manager	Llano Seco Ranch
Kelley Moroney	Refuge Manager	US Fish and Wildlife Service
Kevin Foerster	Project Leader	US Fish and Wildlife Service

reconnaissance. Following the site visit, the members met at the Llano Seco Ranch for a 3-day Workshop to begin identifying alternatives that were likely to produce a long-term solution to protect threatened and endangered anadromous fish populations and meet pumping requirements for adjacent agriculture, managed wetlands (federal, state and private), and the City of Chico wastewater facility outfall without a significant effect upon river meandering.

A thorough review was made of the existing studies that document past and current conditions at the pumping plant and fish screen facility. The reviewed studies included: geologic investigations; pumping plant/fish screen construction, pumping capacity and existing conditions analyses; groundwater conditions at, and in the vicinity of, the M&T Pumps; and information on the City of Chico Wastewater Treatment Plant outfall. Potential alternative water supplies were identified and these included local groundwater sources, Ranney Collector Wells, water supply from the Chico Wastewater Treatment plant and increasing the water supply from the Parrott-Phelan Diversion on Butte Creek. Water from the wastewater treatment plant was not acceptable to the wildlife refuges or to the agricultural water users. Increasing the water supply from the Butte Creek diversion would leave insufficient flows for spring-run Chinook salmon in Butte Creek during critical times of the year. Changing the point of diversion to a downstream location or back into the Big Chico Creek diversion area was discussed. Moving the point of

diversion downstream would likely put it below the discharge of the City of Chico Wastewater Treatment Plant outfall which would possibly impact the water quality of the diverted water supply. Moving the point of diversion back to the original Big Chico Creek site would cause adverse biological impacts to the fishery on the Sacramento River. There would also be adverse impacts to the fishery on Big Chico Creek.

As a result of these discussions the Expert Panel and Steering Committee developed the following list of possible alternatives to meet the project goals:

1. Installation of Additional “Tee” Fish Screens across or downstream from the current location,
2. Groundwater extraction from production wells,
3. Groundwater extraction from Ranney Collector Wells, and
4. Installation of rock spur dikes/groins.

The Expert Panel concluded that there was insufficient information available to provide a sound basis for choosing a preferred alternative and recommended further investigations to more fully evaluate the feasibility of the identified alternatives. It was also agreed that a better understanding of the river dynamics and sediment transport and deposition was key to meeting the objectives of the project.

As a result of the Expert Panel’s recommendations, the following investigations were approved:

1. Determine the physical feasibility of extracting 150 cfs of groundwater from the study area.
2. Develop preliminary cost estimates for the installation of an additional “tee” fish screen, groundwater extraction with production wells and groundwater extraction with Ranney Collector Wells.
3. Evaluate the economic and legal aspects of the above-listed alternatives.
4. Evaluate the water supply and water demands.
5. Consider impacts to the City of Chico Wastewater Treatment Plant outfall.
6. Conduct a river meander and sediment-transport analysis for the project site.

1.5.2. Workshop 2 (March 17-19, 2004)—Technical Review and Recommendation Workshop

MWH Americas staff presented the results of their investigations of a groundwater model for a test well and the potential for an alternative supply of water for the stakeholders to the Expert Panel and Steering Committee. Additionally, preliminary cost estimates were presented for the alternatives and legal issues (surface water vs. groundwater rights) and economic (cost of water) issues were discussed by the panel and committee members. Water supply and demand (150 cfs) for the M&T project were discussed. The potential for changing the fish screens and for relaxing fish screen criteria were also discussed.

The results of four investigative studies conducted by the members of the Expert Panel were presented to the Steering Committee and discussed by all of the participants (Harvey et al., 2004). A review of the geologic setting and the geomorphic characteristics and long-term river

behavior in the M&T reach of the Sacramento River concluded that the river was currently located near the eastern boundary of its Holocene meanderbelt and that river sinuosity was at a historic minimum. Therefore, increased sinuosity and concomitant bank erosion and westward migration of the M&T bend should be expected in the future (Harvey). The results of meander modeling indicated that the M&T bend will continue to erode to the west and that the bank-attached bar adjacent to Bidwell State Park will continue to move downstream, thereby further impacting the M&T Pumps and City of Chico Outfall (Larsen). This movement is the natural consequence of river dynamics and could have been anticipated before the M&T Pumps were placed in their current location. A review of river- engineering literature suggested that spur dikes/groins could be used to prevent lateral migration of the river to the west and further downstream migration of the bank-attached bar on the east side of the river. A preliminary design suggested that 8 dikes along a 2,500-foot section of the west bank could be used to prevent further bank erosion and realign the channel so that hydraulic conditions at the intake and outfall facilities would be similar to those in 1997 (Harvey). One-dimensional (HEC-RAS) hydraulic and sediment-transport modeling of the M&T reach demonstrated that replacement of the 189,000 tons of sediment dredged from the bar upstream of the M&T pumps in 2001 could be replaced within a single high flow magnitude year (e.g., 1974), or within about 4 years, on average (Mussetter and Cui).

After reviewing the technical reports, the Expert Panel and Steering Committee listed all of the possible alternatives and then evaluated the likelihood that each alternative would meet fish screen criteria, pumping capacity and river meander goals. Advantages, disadvantages, risks, uncertainties and fatal flaws were identified in the review process. Alternatives evaluated included:

- Collector Basin (Infiltration Gallery)
- Extended Intakes—Down River
- Extended Intakes—Across River
- In-conduit Fish Screen
- Dredging/Modified Screen
- Rock Dikes/Groins
- Multiple Production Wells
- Ranney Collector Wells
- Combination of 1 Ranney Collector Well /Dredging

Table 2 provides a summary of the Expert Panel's alternatives evaluation. Because of significant uncertainties and un-solvable flaws a number of alternatives were rejected. These included:

- Extended intakes down and across the river
- In-conduit fish screens
- Collector basin/infiltration gallery
- Multiple production wells

The alternatives carried forward from the screening process by the Expert Panel included:

- Dredging/modified screen
- Spur dikes/groins
- Ranney Collector Wells

Table 2. Summary of Expert Panel evaluation of alternatives.

Alternative	Criteria					Uncertainties	Flaws
	Fish Screen	Allows Meander	Provides Pumping Capacity	Provides for City Outfall Needs	Other		
Extended Intake - Down the River	Yes	Yes	Maybe	No	Maintains existing facility	River meander City of Chico selection of alternatives Head loss / affects on pump	Project life
Extended Intake - Across the River	Yes	Yes	Maybe	No	Maintains existing facility	Flood flows at the new location Air burst Scour depth River meander	River shift Accessibility
In-conduit Fish Screen	Yes	Yes	Yes	No	Maintains existing facility Pumping costs remain the same Known technology	Pipe extensions--cost/permitting/ long-term maintenance Capacity variables Pumping costs Meet State criteria	Bypass pipe/predation at point of discharge Intake--chase meander
Dredging / Deadend Screen	Yes	Yes	Yes	No	Maintains existing pumping plant Low initial cost (new screens)	How much dredging to maintain capacity Dredging costs Where do the spoils get deposited? Screen costs (flat plate?)	Frequency of dredging Permit process Dredging when endangered species are present Other ownership issues - State Parks As river moves west, channel would need to increase in width and length
Collector Basin/ Infiltration Gallery	Yes	Yes	Yes	No	Low cost for initial construction Compatible with present facility	Permeability of gravels Impact on drawdown Estimated size of basin Site selection River movement Economics Groundwater impacts	Requires loss of farmland Public safety Levee breach liability River meander impacts Maintenance issue - siltation (no backflush ability)
Multiple Production Wells	Yes	Yes	Yes	No	Wider distribution of drought risks	Power availability Pumping costs Water distribution system Groundwater impacts Impacts to farmland Water rights and legal issues	Loss of farmland Higher maintenance costs
Groins/Dikes	Yes	No	Yes	Yes	Maintains current operations Improves current situation Reasonable confidence in utility	Off-site impacts Mitigation costs Mitigation possibilities (trading) Authorities / maintenance	Public safety / navigation Environmental impact to river meander Institutional constraints
Ranney Collectors	Yes	Yes	Yes	No	Minimal environmental impacts Possible use of existing large pumps	Permeability of gravels and water yield (number of wells) Cost for pumping and long-term maintenance Impacts of river meander and aging on yield Capacity / cost Life cycle costs Water rights	Additional pumping expense (\$32/AF v \$8/AF) Highest capital cost idea

After extensive review and discussion of the alternatives, the Expert Panel concluded that there were too many unknowns and uncertainties to make a recommendation to CBDA. The principal uncertainties were the likely future behavior of the river, the hydraulic capacity of the subsurface water-bearing strata and the potential impact of river meandering on groundwater yield. To address these issues the Expert Panel recommended that the following investigations be conducted:

1. Two-dimensional hydraulic modeling of the river to evaluate how sediment is transported through the M&T reach, develop a better understanding of the effects of upstream bank revetments on the flow patterns at the M&T site, and evaluate the necessary length and locations of the spur dikes/groins (Mussetter Engineering, Inc.)
2. Meander modeling of the river from Pine Creek to Stony Creek to evaluate upstream and downstream effects of spur dikes/groins, effects of potential cutoff of Pine Creek bend on M&T reach, and compute the area of floodplain reworked (ecological benefits) under a range of possible scenarios (Larsen).
3. Drilling of a test and monitoring wells to develop the aquifer capacity information required to evaluate the potential for groundwater replacement of current surface-water supplies (MWH Americas).

1.5.3. Workshop 3 (February 16-18, 2005)—Project Alternatives and Feasibility Workshop (meander modeling; 2-D modeling of dikes; groundwater modeling)

The results of the two-dimensional hydraulic and sediment transport modeling (Mussetter Engineering, Inc), meander modeling (Larsen) and groundwater monitoring and analyses (MWH Americas) were presented to the Expert Panel and Steering Committee members. Peer reviews of the reports for these studies were conducted by Dr. Cui.

Additionally, the Director of the City of Chico Public Works Department (Mr. Fritz McKinley) and their consultants (Corrollo Engineers) gave a presentation on the issues associated with the City of Chico's requirements to expand their wastewater discharge from 9 mgd to 12 mgd by 2010. The following provides a summary of the City of Chico's issues, requirements and preferences:

1. City needs to increase the outfall capacity and the size of the diffuser located about 300 feet downstream of the M&T pumps and fish screens, but the growth of the gravel bar and migration of the river to the west will prevent them meeting the required dilution standards.
2. The City would like to maintain the outfall in the same location if possible and would be a willing cost-share partner in a joint project with M&T.
3. The City needs to move forward for an EIS/EIR, and through its consultants has identified six alternatives:
 - a. Dredging of the river, as done in 2001,
 - b. Construction of spur dikes on the west bank of the river,
 - c. Relocation of the gravel bar to the west side of the river,
 - d. Dredging of a pilot channel through Bidwell State Park,
 - e. Develop a moveable diffuser design, and

- f. Relocate the outfall about 1,500 feet downstream of its present location with the expectation that this would meet the design life of the new diffuser (15 to 20 years).
4. City has decided to advance the relocation of the outfall as the preferred alternative to move the EIS/EIR process forward, but would prefer a joint project with M&T that involved construction of spur dikes on the west bank of the river.

1.5.3.1. Aquifer Testing

MWH Americas staff and Mr. Matt Reed of Reynolds, Inc. (designer and supplier of Ranney Collector Wells) provided a presentation on the results of their aquifer test project and the implications with respect to the use of Ranney Collector Wells as a substitute for the existing surface water supply. The results of aquifer testing at M&T Chico Ranch indicated that the shallow groundwater system is a sustainable source of water supply to meet the pumping capacity essential to meet project goals through the use of four Ranney Collector Wells. The Aquifer Test Report provided data to show that a strong connection exists with the Sacramento River (80 percent of the groundwater flow was from the river) which will most likely replenish the shallow aquifer system almost as quickly as groundwater is withdrawn, providing that the river maintains its current location. The Expert Panel concluded that there is significant uncertainty about the operational costs, actual water yields, potential to reduce diversion needs, long-term maintenance and efficiencies, project life and water rights issues associated with this potential preferred alternative. Yearly operational costs were estimated at \$1 million. These costs are quadruple current costs (about \$32/AF compared to existing cost of about \$8/AF) and are significantly beyond the capacity of the farming and wetland operators to support. The additional costs were determined to be unacceptable by the M&T Chico Ranch, Llano Seco Ranch, USFWS Wildlife Refuge and California Department of Fish and Game.

As a result of the Expert Panel review of the data, it was recommended that further investigations were necessary to determine pumping lift and energy costs and site-specific well locations and spacing appropriate to increase project life and reduce energy requirements, assessment of transmissivity of the aquifer, identification and evaluation of critical conditions to compute water costs, evaluation of water efficiencies and alternative water supplies, review of long-term maintenance costs and well-life depreciation, refinement of data to understand well yield from groundwater versus river water, refinement of well construction costs, conveyance systems and water rights legal analysis, and, existing operational Ranney Collector Well data on a range of river types and evaluation of the effects of river migration on water yield.

Answers to these questions were deemed to be critical to the implementation of a Ranney Collector system alternative as a long-term viable solution to provide a reliable off-stream, fish-friendly water supply protected from river meander. It was concluded that successful implementation of this alternative would meet the preliminary project goals and objectives (Figure 3). However, the preliminary investigations identified high capital costs and high operations and maintenance costs. High initial capital costs to construct the Ranney Collector Wells may not be acceptable to the funding agency given that the CALFED Ecosystem Restoration Program has already invested approximately \$7 million (including feasibility studies and construction of the facility) in the M&T Pumps project. Additional studies were recommended to more accurately assess the financial long-term feasibility of this alternative.

1.5.3.2. Two-Dimensional Modeling

Mussetter Engineering, Inc. (Mussetter and Harvey) presented the results of the 2-D hydraulic and sediment transport modeling of the M&T reach of the Sacramento River. Because there

has been a limited history of dike use on the Sacramento River, the modeling effort was conducted to evaluate the basic feasibility of using dikes to prevent bank erosion and to return the river configuration to a condition (1997 conditions) where the hydrodynamic conditions were adequate to meet the pumping and fish screen criteria at the M&T pumps. In order to reduce the cost of the basic feasibility study, existing available river topography was utilized and a basic dike design was developed to test the technical feasibility of this alternative. The results of the 2-D modeling as well as sediment-transport modeling with the hydraulic output from the 2-D model (MEI, 2005), demonstrated that the proposed spur dike configuration that included eight rock dikes should create hydraulic conditions within the reach that would prevent downstream migration of the upstream gravel bar (dredged in 2001) during high flows and prevent build up of sands at the screened intakes during lower flows (4,000 to 14,000 cfs) when the pumps are generally operated. However, the modeling was conducted with 1996 in-river topography that was modified to approximate the bar dredging and the bankline shown on 2003 aerial photography. As a result, the Expert Panel and Steering Committee concluded that modeled conditions may not represent existing conditions at the site, especially since there had been localized retreat of the right bank of up to 50 feet since the 2003 aerial photography was flown.

The Expert Panel, therefore, concluded that in-channel surveys were required to provide existing conditions topography, and the new topography would be used for subsequent hydrodynamic modeling to further evaluate the utility of the proposed spur dike alternative, modifications to the upstream revetment at River Road, and the addition of an additional spur dike at the downstream end of the proposed dike field.

Because the efficacy of the dikes alternative is extremely time-sensitive, it was further recommended by the Expert Panel that placement of a temporary self-launching windrow rock revetment be evaluated along the right bank of the river to slow erosion during the follow up analysis and NEPA/CEQA period required for selection of a preferred alternative that would provide a long-term solution. Maintenance of the existing bank line during the review period would maintain the viability of the spur dike alternative. In the event that the spur dike alternative was selected, the windrow rock would be incorporated into the dikes, and if the alternative was not selected, the rock would be removed from the toe of the bank or the windrow if the rock hadn't launched. A basic design for a windrow revetment would be developed. The design will identify the volume and gradation of rock that will be required and associated costs for emplacement on the top of the right bank. The limits of the windrow revetment will be shown on the most recent aerial photography of the site. Implementation of this action would maintain the viability of the spur dike alternative while further investigations of an off-stream solution are conducted. The windrow revetment design that supports a spur dike option would in addition provide some measure of protection to the City of Chico outfall.

1.5.3.3. Meander Modeling

The results of 50 years of meander modeling of the Pine Creek to Stony Creek reach of the Sacramento River were presented and summarized by Dr. Larsen. A baseline (existing) condition and six scenarios that involved removal of various combinations of existing and hypothesized bank revetments that limit the ability of the river to meander were modeled. Existing revetments are present at Pine Creek, River Road, M&T pumps, Phelan Island and Golden State Island. A hypothesized revetment was modeled at RM 192.4L (Below M&T). Revetment removal scenarios included: Pine Creek, Below M&T, Phelan Island and Golden State Island, individually, and the following combinations Below M&T and Phelan Island and Below M&T, Phelan Island and Golden State Island. For each modeled scenario, the area of existing floodplain reworked was calculated for the 50-year period since this area provides a metric for assessing ecological benefit (riparian forest development). The results of the

analyses indicated that removal of the existing revetment at Pine Creek would provide the greatest ecological benefit by increasing the amount of floodplain reworked by a factor of about 7. Removal of the Below M&T and Phelan Island revetments would increase the amount of land reworked by a factor of about 3, and removal of the Below M&T, Golden State Island and Phelan Island revetments would increase the area reworked by a factor of about 2.

Following discussions by the Expert Panel of the results of the meander modeling it was concluded that further modeling of the reach-scale riverine processes should be conducted to ensure that potential for unintended consequences as a result of implementation of any alternative be reduced as far as possible. The Expert Panel recommended that a river meander migration analysis be performed to simulate upstream and downstream effects of installing the dike field alternative and to evaluate the potential for westward migration of the river if the Ranney Collector well alternative was implemented. The meander migration analysis would be modeled with a variable erosion field providing a 50-year prediction with bank line output mapped at 5-year increments for the following conditions: (1) assuming the placement of Ranney Collector Wells and model river evolution from the current planform, (2) simulate downstream effects of extended bank restraints at River Road and the spur dikes/groins, and (3) simulate downstream effects of removing bank restraints at River Road. Additionally, since dredging for either short- or long-term purposes may be required, and in order to refine an opinion about this alternative, it was recommended by the panel that output from the river meander model be used to estimate the gravel bar location through time. However, the modeling was not done because of concerns by Dr. Larsen that his model may not predict movement of some types of bars.

1.5.3.4. Additional Investigations

As a result of evaluations of risks and uncertainties associated with Ranney Collectors and Spur Dikes/Groins, the Expert Panel recommended that further investigations be conducted to evaluate an annual dredging activities alternative. This alternative was selected to provide assurances that a channel will be maintained to meet present pumping capacity and fish screen requirements when necessary. In order to refine an opinion for this alternative, it was recommended that the river meander model be run to estimate the gravel-bar location through time. In addition, Expert Panel members recommended that discussions begin with key agency representatives (USFWS, NMFS, DF&G) to discuss relaxation of fish screen criteria due to the current stringent sweeping flow velocity requirements at the face of the screens. Relaxing fish screen criteria based on more informed science would provide the basis for salvaging a portion of the initial CALFED investment by finding a solution that maintains the existing pumping facility and installs a redesigned fish screen. Steering Committee members believe that this approach can be supported by data and experience now available through years of operations and maintenance of Sacramento River fish screens currently in use.

A partial or entire excavation of the encroaching gravel bar may be necessary to eliminate a potential threat to the operations and function of the M&T/Llano Seco Fish Screen facility and City of Chico outfall. Ongoing monitoring has been conducted each year to trigger the need to execute this task. As a result of the 2004 diver assessment at the fish screens, the Expert Panel recommended that, due to the sediment deposition that has occurred to date, Ducks Unlimited request CBDA's approval to proceed immediately with the permitting process to implement the gravel bar reduction action. This encroachment has been verified by the modeling completed by the Expert Panel members and evaluated at Workshop No. 3. This action will allow the owners/stakeholders additional time to assure water supply with the existing pumping and fish screen facility while a permanent solution is developed.

1.5.3.5. Summary and Recommendations from Workshop 3

The Expert Panel identified three alternatives and a No-Action alternative for further evaluation. The No-Action alternative was considered to be unacceptable. The panel members concluded that the three alternatives identified would meet the requirements of providing a reliable source of water for the M&T Ranch, Llano Seco Ranch, U.S. Fish and Wildlife Service and California Dept. of Fish and Game Refuges and with varying success meet the other project goals. The three alternatives in order of preference were: (1) Ranney Collector Wells, (2) spur dikes/groins on the west bank of the Sacramento River opposite the existing pumping plant, and (3) dredging of the river to provide both short- and long-term water access to the existing pumps while meeting required fish screen criteria.

After extensive discussion and review, the Expert Panel concluded that a recommendation for a preferred alternative could not be made to CBDA and recommended that comprehensive concurrent investigations be conducted on the three alternatives to assess the feasibility of individual alternatives and combinations of alternatives to meet the goals and objectives for a 40-year project life based on the projected life of the stainless steel fish screens. Because of uncertainty about the operation and maintenance costs, water yields, long-term maintenance and efficiencies, project life expectancy and water rights issues associated with the Ranney Collector System, it was decided that simultaneous further evaluations of the other two alternatives should be conducted to ensure the on-going operation and protection of the fish screen facility in the event that the Ranney Collector alternative failed to meet Economic Feasibility criteria.

In addition, due to the on-going erosion of the west bank, the Expert Panel members recommended an interim action to maintain the viability of the three alternatives. Because the ability to use dikes to rectify the hydraulic conditions at the fish screens and pumps is limited by further erosion of the right bank of the river opposite the pumps, it was further recommended that emplacement of a temporary self-launching windrow rock revetment be evaluated along the right bank of the river to prevent further erosion thereby preserving the existing bank line during the alternative selection and NEPA/CEQA period.

As a result of these recommendations by the Expert Panel, the following actions were implemented to bring the project to the point where a final preferred technical alternative can be recommended from the carried forward alternatives:

1. Conduct four feasibility studies to investigate and prioritize identified risks and uncertainties associated with Ranney Collector Wells, spur dikes, and dredging and fish screen modification.
2. Perform a refined river meander migration analysis to simulate up- and downstream effects of proposed alternatives at 5-year intervals up to 50 years.
3. Present all the investigations to the Expert Panel and Steering Committee in Workshop 4.
4. Immediately begin environmental documentation for gravel-bar extraction.
5. Conduct feasibility study of temporary windrow rock revetment with the goal of preserving the feasibility of the spur-dike option.

2. WORKSHOP 4 (April 24-25, 2006)—Conceptual Model and Project Proposal

2.1. Objectives

The goals of the Fourth Workshop were to:

1. Review and evaluate the results of the four technical studies recommended by the Expert Panel at Workshop 3. These included meander modeling, two-dimensional modeling of the spur dikes, further analysis of Ranney Collector Wells and evaluation of dredging and fish screens,
2. Develop a technical recommendation from the Expert Panel for a Preferred Alternative (PA), and
3. Move the process forward to Phase II that will include pre-construction engineering design and environmental documentation (CEQA, NEPA).

2.2. Technical Reports

2.2.1. Meander Modeling—Dr. Eric Larsen

REPORT: *Future Meander Bend Migration and Floodplain Development Patterns Near River Miles 200 to 191 of the Sacramento River, Phase III Report, March 31, 2006 (Appendix A).*

Dr. Larsen's meander model of the Sacramento River between RM 191 (Stony Creek) and RM 200 (Giannella Bridge) was updated to incorporate the 2004 centerline of the river and was calibrated to river behavior between 1980 and 2004. Scenarios modeled for 50 years into the future (2004-2054) included: existing conditions (n1), 8 spur dikes in place along the west bank of the river (n2), removed bank restraints at River Road with no dikes in place (n3), 8 spur dikes in place on the west bank of the river and existing restraints removed at River Road (n4), and 9 spur dikes in place on the west bank of the river with River Road restraint in place (n5). The area reworked for each scenario, which provides a metric for ecological benefit (riparian forest development), was computed for each scenario.

The results of the modeling showed that the meander migration patterns are not significantly different for the simulations with the spur dikes/groins in place. With the River Road revetment in place (n2) there is no significant change from the existing condition (n1) up- and downstream of the dike field, and thus it can be concluded that the dikes are unlikely to cause adverse up- or downstream effects. With the River Road revetment removed and with the spur dikes in place (n4) there are no significant differences in meander patterns up- and downstream of the dike field from those resulting from removal of the dike field (n3). The model results (n2, n4) also showed that regardless of the scenario modeled with the dikes in place, there is a tendency for continued westward migration of the right bank downstream of the dike field. Modeling of the 9-dike field (n5) indicated that the tendency for continued westward migration of the right bank downstream of the dike field is more limited.

Analysis of the rate of area reworked per year (ha/yr) for the modeled scenario with 8 dikes and the River Road revetment in place (n2) for Bend 3 (upstream of Bidwell State Park), Bend 4 (includes Bidwell State Park and the bank-attached gravel bar), Bend 5 (includes M&T pumps and eroding west bank) and Bend 6 (includes Golden State Island and Phelan Island) indicated that the rates are very similar to existing conditions (n1). At Bends 4 and 5, removal of the River

Road revetment both with (n4) and without (n3) dikes scenarios showed a significant increase in the rate of area reworked, primarily in the area of Bidwell State Park. Addition of an extra dike (n5) appears to reduce the rate of reworking at both Bends 4 and 5, but has no impact on Bends 3 and 6. Comparison of the rates of area reworked at Bends 4, 5 and 6, under scenarios n1 (existing conditions), n2 (8 dikes), and n5 (9 dikes) clearly show that the rates of reworking are 3 to 5 times higher at Bend 6 than they are at Bends 4 and 5 for all scenarios.

Expert Panel members concurred with the results of the meander modeling, but cautioned that the modeling results should be considered in the context of movement patterns on a reach scale (4 meander bends) and has its greatest utility in evaluating system-wide effects. Even though some panel members were concerned about the ability of the model to evaluate the 9-dike scenario, the model results suggest that there will be a tendency for less movement in Bends 4 and 5 with the additional dike.

2.2.2. Two-dimensional Modeling of River Training Works—Drs. Bob Mussetter and Mike Harvey

REPORT: *Two-dimensional Modeling to Evaluate Potential River Training Works at M&T Pumping Plant Sacramento River, RM 192.5 (2005 Topography and Bed Material), April 18, 2005 (Appendix B).*

The objective of the hydraulic and sediment-transport investigation of the Sacramento River between River Mile (RM) 192.5 and RM 194.4 was to determine if spur dikes installed along the west bank of the river upstream of the M&T Pumps (RM 192.75) could recreate hydrodynamic conditions that will permit sustainable operation of the pumps for the next 40 years.

Three specific questions were addressed by the study:

1. Will the spur dikes prevent further erosion of the west bank of the river that has retreated over 330 feet between 1996 and 2006 and accompanying downstream migration of the bank-attached point bar, which are the primary causes of the problems at the M&T Pumps,
2. Will the spur dikes stabilize the bank-attached bar on the east bank that has migrated downstream towards the pump inlets as the west bank has retreated, and
3. Will the spur dikes create sufficiently high velocities and shear stresses in the vicinity of the pumps during the range of flows when pumping generally takes place (4,000 to 14,000 cfs) to prevent sand accumulation around the fish screens and pump inlets?

An existing two-dimensional (2-D) hydrodynamic model (RMA2) (MEI, 2005) was modified to represent the current (December 2005) bathymetry and topography of the site. Models were developed and run for a range of flows from 5,000 to 90,000 cfs for the following scenarios:

1. 2005 channel alignment and geometry for baseline conditions (Scenario 1)
2. An 8-dike configuration with dike height at two-thirds bank height (Scenario 2)
3. A 9-dike configuration with dike height at two-thirds bank height (Scenario 3)
4. An extended 9-dike configuration with the lower three dikes raised to full bank height (Scenario 4)

Incipient motion and sediment-transport analyses were conducted with output from the 2-D models and an average bar sediment gradation with a median (D_{50}) size of 39 mm and a D_{84} size of 60 mm based on three pebble counts that were made on the bank-attached bar in December 2005. A sand size of 1 mm was used in the analysis of deposition potential around the fish screens and pump inlets during low flow periods. Cost estimates for permitting, construction, mitigation and operation and maintenance were developed for the three with-dike scenarios.

The analyses led to the following conclusions:

1. All of the spur dike configurations will prevent further erosion of the west bank within the dike field,
2. All of the spur dike configurations will increase the shear stress on the bank-attached bar and cause it to erode, thereby changing the channel geometry and lowering the sediment transport rate. Once mobilization of the bar sediments has occurred shear stresses downstream of the bar, while not high enough to cause initial mobilization of the gravels, are sufficiently high to maintain sediment transport thereby preventing further downstream migration of the bar itself. Details of the channel adjustment due to the presence of the dikes will need to be quantified with a mobile-boundary physical model.
3. Only the extended and raised 9-dike configuration (Scenario 4) will prevent sand accumulation at the pump inlets during the range of river flows when pumping typically occurs,
4. Construction of the dikes with new rock, with full mitigation required for the 3,200 feet of affected bankline, is estimated to cost \$7.9M, \$8.7M and \$13.4M, for Scenarios 2, 3 and 4, respectively.
5. If mitigation can be offset by removal of an equivalent length of existing bank protection on Golden State Island that is owned by the M&T Chico Ranch, and the recovered rock is incorporated into the spur dikes, estimated costs for Scenarios 2, 3 and 4 decrease to \$5.1M, \$5.5M and \$10.2M, respectively.

Because spur dikes are not commonly used on the Sacramento River, there is little information available to assess their performance for river stabilization or their environmental impacts or benefits. A 5-year Adaptive Management Experiment is proposed to inform future use of these structures where infrastructure protection is required as envisaged in the Senate Bill 1086 process. The likely cost of the experiment is \$345,000. Physical modeling of the dike scenarios is highly recommended to validate the numerical model results at the fish screens and pump inlets. Physical modeling of the dike alternatives could be conducted for approximately \$400,000.

Expert Panel and Steering Committee members reviewed the results of the modeling. Concern was expressed that based on observations of gravel bar migration in other locations of the Sacramento River, the gravel bar on the eastside of the river could continue to migrate downstream even if the spur dikes were constructed. Caution was advised in interpreting the results of the numerical sediment transport modeling at the localized scale of the pumps and fish screens and that addition of the ninth dike and extension of the 3 lower dikes may not be required to solve the local sedimentation problems at the pump inlets and fish screens. Additionally, the extra dike and the extension of the lower three dikes are likely to increase the project costs by about \$4.3 M (Refer to Appendix E – Dr. Yantao Cui Memorandum on M&T/Llano Seco Pumping and Fish Screen Facility Alternatives, Revised May, 3, 2006). The panel members concluded that the questions regarding the results of the numerical modeling,

the issue of continued bar migration, and the final configuration of the dikes could only be investigated with a physical model.

2.2.3. Ranney Collector Wells—Mr. Chris Peterson (MWH Americas)

MWH Americas conducted six tasks that were designed to provide additional information on the Ranney Collector Wells. The Tasks included:

1. Survey Sonoma County Water Agency (SCWA) Supply Operations
2. Survey Results of Collector Well Operators
3. Conference calls with Reynolds Inc, and DWR to discuss potential methods for reducing costs for a Ranney Collector system at the M&T Chico Ranch
4. Refine Well Yield – Groundwater vs River
5. Analysis of Energy Requirements of the Ranney Collector Well Water Supply
6. Identify and Quantify Maintenance Costs

The findings and conclusions from these tasks are provided in **Appendix C**. The following are summaries for the individual tasks.

1. Survey Sonoma County Water Agency Supply Operations

A review of the regional and local hydrogeology at the SCWA and M&T sites shows that the two are drastically different (See report - Appendix A in MWH Americas Report). At SCWA, the alluvial aquifer is tightly bound at approximately 100 feet below ground surface and at the valley edges by nearly impermeable bedrock. The width of the valley is 800 to 4,000 feet. At M&T, the bounding depth is far enough away from the proposed wells to not pose a limitation to well yield. Permeable sediments extend to approximately 3,800 feet below ground surface. The width of the valley also does not pose a limitation on well yield with the nearest bounding bedrock unit outcropping approximately 14 miles to the east. It is recommended that a facility with more similar hydrogeologic conditions be used as a comparison to the proposed M&T site. Such a facility would be the Nearman Water Treatment Plant in Kansas City, Kansas. Here the geologic and river conditions are similar to the M&T site. More information on this site can be found in Appendix B (of the MWH Americas Report), Survey Results of Ranney Collector Well Operators.

Another main difference between the SCWA distribution system and M&T is the mechanics of delivery. SCWA pressurizes their pipes and system to generate 500 feet of head prior to release into their distribution system. M&T requires the lift (no greater than 100 feet) to convey water to an open canal.

2. Survey Results of Ranney Collector Well Operators

Based on geological and hydrogeological information collected in the survey presented in Appendix B, the Nearman Water Treatment Plant program in Kansas City, Kansas is most similar to the proposed Project. The Nearman Water Treatment Plant has two collector wells with 14 laterals each. Each collector well supplies approximately 25 MGD. The alluvial aquifer is semi-confined with cobbles, gravels, sands, silts, and clays. The Missouri River is approximately 100 feet from the well caissons and the caissons are spaced 1,000 feet apart from each other.

Other projects that may have similar characteristics are the following:

- a. City of Cedar Rapids, Iowa
- b. Olathe District, Kansas
- c. City of Lincoln, Nebraska
- d. Humboldt Bay Municipal Water District, California

We can expect the Project collector well system to operate much like these projects if we assume that the data are accurate and conditions at the site are similar.

3. Meeting Minutes from Three Conference Calls

Three conference calls were conducted with Matt Reed (Ranney Division), Dan McManus (Department of Water Resources), and MWH staff. During these calls, the following were discussed:

- various locations for multiple Ranney Collector Wells,
- types of fuel for pumping,
- alternatives of conveying the water to the canal,
- water conservation, and
- operation of the wells.

Discussions concluded that geologic conditions would be favorable to locate one well near the distribution canal on Llano Seco Ranch. This location would change the location of impacts on surrounding groundwater levels. Information regarding energy costs and fuel types were discussed and results are presented in Appendix E (MWH Americas Report). Two alternatives for conveyance of water from the Ranney Collector Wells to the canal at M&T Ranch were discussed; utilization of the existing sump and pipe system from the Ranney Collector Wells, or construction of a conveyance that would connect directly to the canal from the wells. The alternative utilizing the existing system was favored, but would require additional energy costs for lifting from the sump. The favored water conservation alternative is to line the existing canal between Big and Little Chico Creeks to reduce losses from seepage along that section. It was also discussed that the wells may not incur operational costs as high as estimated because the maximum allocation of water supplies may not be necessary 12 months of the year.

4. Refine Well Yield—Groundwater vs. River

Based on the evaluated simulations, it is not expected that river migration will substantially affect yield capacity and operation of one to four Ranney Collector Wells operating at 24.25 MGD each, spaced 1,500 to 2,000 feet between well caissons, and with 200-foot long laterals placed at 95 feet bgs.

5. Energy Requirements of the Ranney Collector Well Water Supply

The proposed M&T Chico Ranch/Rancho Llano Seco Ranney Well Option includes construction of four wells for pumping of water to the existing M&T/Llano Seco Pumping Plant. The issue that this memorandum evaluates is the comparative cost of energy for alternative energy sources and initial planning to reduce the reoccurring costs associated with pumping of the raw water from the Sacramento River to the existing M&T/Llano Seco Pumping Plant. The means and methods used for evaluation involved standard hydraulic

engineering including the Energy Equation of Pipe Flow and Hazen Williams Equation for Friction Head Loss to estimate system losses and total dynamic head for pumping power requirements. The system pumping power requirements were converted into costs per year based on cost per unit energy for the various alternative energy sources. The results of the evaluation showed that natural gas is the most economical source of energy based on the market conditions for energy sources evaluated. The sources evaluated included electricity, diesel fuel, natural gas and gasoline. The conclusions of this Technical Memorandum include a recommendation for using pipe material and sizes most suitable for lowering the energy costs in concert with utilizing natural gas as an economical source of power for the proposed well pumps.

6. Maintenance Costs

The proposed M&T Chico Ranch/Rancho Llano Seco Ranney Collector Well option, if constructed would add pumps, motors, valves and controls as maintenance items that would require consideration related to manpower, schedule and annual budgeting. The issue evaluated in this Technical Memorandum was the annual costs associated with development of this proposed construction option. Experience and standards of the industry were used as the means and methods for the estimate of annual maintenance costs for the M&T Chico Ranch/Rancho Llano Seco Ranney Collector Well option. The results of the evaluation provided an estimate of the anticipated maintenance costs in terms of a conceptual level analysis. The estimate is approximately \$162,125/year for maintenance of the facilities.

The Expert Panel reviewed the additional information provided by MWH Americas on the Ranney Collector system and concurred that the Nearman Water Treatment Plant in Kansas City, Kansas, is a more appropriate analog for the M&T situation than the Sonoma County Water Agency situation. Discussion of costs (Table 7—Appendix E) concluded that yearly O&M costs should be converted to 40-year project life costs. Based on the well yield analysis, the Expert Panel agreed that river migration is unlikely to have adverse effects on water yields from the Ranney Collector Wells, but that Ranney Collector Well pumping is likely to have drawdown effects on deeper production wells in the vicinity. After considerable discussion the Expert Panel concluded that the costs developed by MWH Americas were reasonable for their purposes, and that further refinement would be required in the future if the Ranney Collector Wells alternative was chosen as the Preferred Alternative.

2.2.4. Dredging/Fish Screen Alternatives—Mr. Dennis Dorratcague (MWH Americas)

MWH Americas conducted an evaluation of three dredging and fish screen alternatives for maintaining a reliable water supply at the existing M&T pumps. The results of the investigation are provided in **Appendix D**.

A gravel bar is expanding and threatening to block the M & T Pumps 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. The 250 cfs provides a sweeping flow past the screens (Alternative 1).
- A 150-cfs channel from the river to the intake with no bypass channel back to the river. This has a dead end area at the fish screens (Alternative 2).
- 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 (Alternative 3).

Uniform flow was assumed to determine the size of the dredged 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 the alternatives ranged from \$12, 758,000 (Alternative 1) to \$10, 913,000 (Alternative 3). Alternative 3 appears to be the most attractive alternative; however, excessive sedimentation in the channel from bedload transport across the bar is a problem for river 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 quantitative estimate of the amounts of sediment that must be removed to keep the channel open and to provide a basis for establishing O&M costs. See Appendix D for further discussion of the results, conclusions, and recommendations.

The Expert Panel reviewed and discussed the dredging/fish screens alternative and concurred that Alternative 1 should be analyzed further. Considerable discussion ensued about the uncertainties and risks associated with all the dredging alternatives. Among issues discussed were the considerable uncertainties introduced by continued river meander and bar growth on dredging frequency and volumes. Issues of permitting on both a short-term and longer-term basis were discussed with the observation being made that permitting has historically become more difficult as more species are listed. Removal of debris from the flat plate screens since there would be no bypass flows was considered to be a problem. Concerns were expressed that the reliability of the water supply would be compromised if dredging was not possible at both low and high flows. Panel members concluded that some of the uncertainties could be reduced or eliminated by further numerical modeling, physical modeling and engineering analysis.

2.2.5. Dr. Yantao Cui Review Memorandum

Dr. Cui performed peer reviews of the Meander modeling, 2-D hydrodynamic modeling and sediment transport, and the Dredging/Fish Screen technical studies. His review comments are provided in **Appendix E**.

2.3. Decision Matrix for Alternatives

Following extensive discussion of the pros and cons of the various alternatives, and recognizing that the Senate Bill (SB)1086 Program acknowledged the need to protect existing infrastructure (bridges, buildings, pumping plants, flood management control structures and levees) along the river when other alternatives for allowing river meandering processes to continue had been considered and were found to be infeasible, the Expert Panel members agreed to evaluate the alternatives through the Decision Matrix identified in the Project Conceptual Model (Figure 3). Alternatives evaluated by the panel through this process included three spur dike alternatives, three dredging alternatives, four Ranney Collector Well alternatives and a No-Action alternative.

Criteria for alternative evaluation included:

- Meeting fish screen criteria
- Meeting pumping and water supply requirements
- Meeting river meandering criteria
- Engineering feasibility
- Economic feasibility (Capital and O&M costs)
- Benefits to the City of Chico

Uncertainties, or issues requiring clarification, were identified for each of the alternatives. Additionally, an O&M cost per acre-foot of water was computed for each alternative, except the No-Action alternative, to permit non-capital cost economic comparisons between the alternatives. **Table 3** provides a summary of the evaluation conducted through the decision matrix by the Expert Panel.

2.3.1. No Action and Ranney Collector Well Alternatives

In terms of the primary criteria (Fish Screens, River Meander, Water Supply), only the 3 and 4 Ranney Collector Well alternatives that are capable of delivering 30,000 to 40,000 AF/year meet all the project goals, and thus rank as the preferred alternatives. The alternatives meet the Engineering Feasibility criterion as well. However, the alternatives fail the Economic Feasibility criterion. Capital costs are on the order of \$20 M to \$26.5 M, which exceed the \$12 M non-stakeholder capital limit that was assumed to be available for the project. From a stakeholder perspective, the 3 and 4 Ranney Collector Well alternatives also fail to meet the Economic Feasibility criterion. An additional cost of \$28 to \$27/AF on top of the existing water cost of approximately \$11/AF creates a water cost of about \$38 to \$39/AF, which is beyond the ability of the stakeholders (ranches and refuges) to absorb. The Ranney Collector Wells alternatives provide no benefit to the City of Chico. The 3 and 4 Ranney Collector Wells alternatives were therefore rejected by the Expert Panel.

Since the 3 and 4 Ranney Collector Wells alternatives fail to meet the Economic Feasibility criterion, it was necessary to evaluate non-goal alternatives in the matrix. Ranney Collector Well alternatives that deliver less than 30,000 AF/year (1 and 2 Ranney Collector Wells) fail to meet the Water Supply criterion and fail to meet the Economic criterion for O&M costs (\$41/AF) and were, therefore, rejected by the Expert Panel.

The No-Action alternative fails to meet the Fish Screen, and Water Supply criteria, but does permit continued river meandering. However, no feasible alternative water supply to replace the existing in-river water supply was identified, and thus the alternative was also rejected by the Expert Panel.

2.3.2. Spur Dikes/Groins

Three spur dike/groins non-goal alternatives were evaluated through the matrix. These included 8-, 9-, and 9-extended dike alternatives. All the dike alternatives meet the Fish Screen and Water Supply criteria. Dike alternatives fail to meet the River Meander criterion due to their local prevention of westward migration of the river, but have no significant impacts on upstream or downstream meander processes. All the dike alternatives meet the Engineering Feasibility criterion, but the final configuration of the dike field will be dependent on the results of Phase II physical modeling. All of the dike alternatives meet the Capital Cost Economic criterion (\$7.4 M to \$11.6 M) including the full cost of 1:1 mitigation for the project (assuming full-bank rock protection), but the costs associated with an interim solution bio-remediation project that is required to preserve the dike alternatives prior to project implementation in 2010, are not included in the economic analysis. Costs associated with physical modeling (\$400,000) and an Adaptive Management Experiment (\$345,000) are included in the capital costs. From an O&M costs perspective, the spur dike alternatives increase the existing cost of water (\$11/AF) by between \$0.7 and \$1.7/AF and thus meet the O&M cost Economic criterion. All the spur dike alternatives could provide benefits to the City of Chico in terms of either maintaining the existing location of the wastewater outfall, or by eliminating or postponing the need for a further downriver move of the outfall in the future. Meander modeling indicates that none of the spur dike alternatives are expected to have significant impacts on upstream or downstream meander patterns within the next 50 years.

Removal of approximately 3,000 lineal feet (approximate length of bank affected by the spur dike field) of existing full-bank rock revetment as mitigation for the spur dikes was discussed by the experts and Steering Committee members. Nearby candidate sites for rock removal were identified on M&T Ranch property at Golden State Island (RM 190.5L) and on U.S. Fish and Wildlife Service, Sacramento National Refuge Complex property at Phelan Island (RM 191.5R). An additional candidate site was identified on the upstream limb of the Camp 2 Bend at approximately RM 179R. Meander modeling of Bends 4 and 5 in the M&T reach (Larsen, 2006) showed that under existing conditions there will be little reworking of the floodplain in the next 50 years, and hence little ecological benefit (defined in terms of riparian forest development) on the National Refuge area proposed for the spur dike field. In contrast, the modeling showed that even with the Phelan Island and Golden State Island revetments in place there will be significant floodplain reworking in the next 50 years downstream of the dike locations (Bend 6). Removal of either the Golden State Island or Phelan Island revetments will tend to increase the area of floodplain reworked in the next 50 years (Larsen, 2005) and may provide new bank swallow habitat as well. Removal of any existing rock revetment and incorporation of removed rock into the spur dikes will probably require as yet undefined mitigation for loss of riparian vegetation currently growing in the revetment, as well as cleaning of the rock before it can be incorporated into the dikes.

The Golden State Island and Phelan Island revetments were installed after the 1986 flood in the belief that maintenance of the existing planform of the Sacramento River in the upper reaches of the Butte Basin was critical to maintaining the stage-discharge relations at the M&T and 3B's flood overflow weirs. Subsequent hydraulic modeling of the Butte Basin reach of the Sacramento River following the failure of the County Road 29 levee in 1997 (COE, 1997) demonstrated that the flood overflows are self-regulating and that maintenance of existing river planform within the Butte Basin reach upstream of the head of the Sacramento River Flood Control Project levees (RM 176) is not required.

Table 3. Decision matrix for alternatives reviewed by the Expert Panel.

Alternatives	Fish Screen (Y, N, ?)	Pumping Requirements (Y, N, ?)	River Meander (Y, N, ?)	Engineering Feasibility (Y, N)	Economic Feasibility (x\$1,000) (2006 dollars)		Benefits City of Chico (Y, N)	Uncertainties/Clarifications	O & M Cost (\$ per Ac-ft)
					Capital	O&M			
Spur Dikes (8)	Y	Y	N	Y	\$7,350	\$784	Y	Number and design of dikes depends on results of physical modeling; bio-remediation not included in costs	\$0.65
Spur Dikes (9)	Y	Y	N	Y	\$8,050	\$884	Y	Number and design of dikes depends on results of physical modeling; bio-remediation not included in costs	\$0.74
Spur Dikes (9x)	Y	Y	N	Y	\$11,610	\$2,024	Y	Number and design of dikes depends on results of physical modeling; bio-remediation not included in costs	\$1.69
Dredging (1)	Y	Y ?	Y	Y	\$8,650	\$4,108	N	Permits (costs), state parks, schedule of removal, frequency of removal, access to remove material near screen; screen cost included (\$3,000,000); no mitigation cost included	\$3.42
Dredging (3)	Y ?	Y ?	Y	Y	\$8,650	\$2,263	N	Permits (costs), screen modifications, capacity?schedule of removal, frequency of removal, access to remove material near screen; screen cost included (\$3,000,000); no mitigation cost included	\$1.89
Dredging (GB)	Y?	Y?	Y	Y	\$9,400	\$12,000	N	Permits (costs), Impact of river migration, rate of channel fill, response of other cases, assumes dropping gravel in river; screen cost included (\$3,000,000); no mitigation cost included	\$10.00
Collector Well (1)	Y	N	Y	Y	\$6,637	\$12,120	N	Assumes yield of 10,000AF/y	\$30.30
Collector Well (2)	Y	N	Y	Y	\$13,274	\$24,249	N	Assumes yield of 20,000AF/y	\$30.31
Collector Well (3)	Y	Y ?	Y	Y	\$19,911	\$33,627	N	Assumes yield of 30,000AF/y	\$28.02
Collector Well (4)	Y	Y	Y	Y	\$26,548	\$43,024	N	Assumes yeild of 40,000AF/y	\$26.89
No Action	N	N	Y	Y			N	Where/How would we get replacement water??	

However, before existing revetments can be removed, it will be necessary to model the effects of channel alignment change caused by removal of the revetments on the local hydrodynamics at the M&T and 3B's weirs to ensure that removal of either of the revetments does not increase local flooding. Additional meander modeling (Larsen, 2005, 2006) can be used to predict rates of change and the projected future locations of the channel following removal of the revetments, and the projected change in river planform can be incorporated into a 2-D hydraulic model to evaluate the effects on the stage-discharge rating curves at the weirs.

Based on the matrix evaluation, and taking into account the uncertainty regarding the final configuration of the spur dikes, and the potential for downstream rock removal as mitigation, the Expert Panel recommended that a non-goal spur dike alternative be advanced as a Technical Recommendation.

2.3.3. Dredging Alternatives

Three dredging in-river alternatives that preserve the existing M&T pumping facilities were evaluated through the decision matrix. These included Alternative 1 that involves dredging a 400-cfs inlet channel and a 250-cfs bypass channel and modifying the existing fish screens to flat-plate screens; Alternative 3 that involves dredging a dead-end channel with a flow velocity of less than 0.33 fps with flat-plate fish screens; and Alternative GB that involves continued dredging of the gravel bar and replacement of the existing screens with flat-plate screens. The purpose of the flat-plate fish screens is to permit sediment removal in front of the fish screens which is impossible with the existing cylindrical screens.

Alternative 1 meets the Fish Screen and River Meander criteria, but there is considerable uncertainty as to whether it meets the Water Supply criterion at all times because of the inability to dredge under high flow conditions. The alternative meets the Engineering Feasibility criterion, provided that it is only necessary to dredge under low flow conditions. Access to remove material from near the existing screens will be difficult and addition of the flat-plate screens improves the reliability of supplying the required amount of water. Alternative 1 provides no benefit to the City of Chico, but it does meet both Capital cost and O&M cost criteria. Capital costs are about \$8.6 M, and the alternative increases the existing cost of water (\$11/AF) by about \$3.40/AF. Based on the matrix evaluation, and taking into account the uncertainties regarding permitting, access, and frequency and volume of sand and gravel deposition, the Expert Panel recommended that this dredging alternative be advanced as a Technical Recommendation.

Because of the considerable uncertainties regarding the ability to meet Fish Screen and Water Supply criteria, dredging Alternative 3 was rejected as an alternative by the Expert Panel. Similarly, even though dredging Alternative GB appears to meet all the primary criteria (Fish Screen, River Meander, Water Supply) as well as the Engineering and Capital Cost Economic Feasibility criteria, there is such a high level of uncertainty regarding the impacts of river migration, the effects of point bar dredging on river meandering processes, long-term permitting, gravel disposal and O&M costs that the Expert Panel rejected the alternative.

3. TECHNICAL RECOMMENDATIONS FROM EXPERT PANEL

Based on the results of the decision matrix analysis in Section 2.3 and considerable discussion of the issues identified in Table 3, the Expert Panel unanimously agreed to recommend two in-river technical alternatives for further evaluation and refinement in Phase II of the project (further analysis of preliminary conceptual design, environmental documentation and final engineering). The Recommended Alternatives are:

1. Spur dikes/groins
2. Dredging Alternative 1

Resolution of most, but not all, of the technical uncertainties regarding both alternatives will be achieved with physical modeling, additional numerical modeling and engineering analysis. Completion of the additional analyses will permit a Preferred Alternative and a Contingent Alternative to be selected by the stakeholders. Permitting issues will be addressed by consultation with Regulatory Agencies, and Social and Environmental issues will be resolved through the CEQA/NEPA process.

4. REFERENCES

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