# Technical Memoranda #2

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

## Presented to the Steering Committee

## Workshop #2
## March 17 – 19, 2004

List of Document(s):

- Groundwater Model for Test Well
- Potential Water Supply Alternative - Scenarios 1 through 4
- Preliminary Cost Estimates, legal and economic discussion for Potential Water Supply Alternative – Scenarios 1 through 3
- Riverine Impacts to M&T Chico Ranch Diversion and Chico Wastewater Treatment Plant
- Optional Fish Screen Criteria

Prepared By

MWH

# MEMORANDUM

**To:** **Neil Schild**
**From:** **John Skowronek**
**Date:** **26-Jan-04**
**Subject:** **M&T Chico Ranch,** Groundwater Model for Test Well

## OBJECTIVES

The objective of this memorandum is to determine whether it is physically possible to extract 150 cubic feet per second (cfs) from the study area.

## INTRODUCTION

This memo provides documentation of two modeling scenarios for withdrawing 150 cfs from the east bank of the Sacramento River at the M&T Chico Ranch, as modeled by MWH staff during the week ending 5-Dec-03. **FIGURE 1** is a map showing the M&T Chico Ranch Project Area, with the area of our assessment circled in red.

## APPROACH

The means to model an extraction of 150 cfs from the subsurface of the east bank of the Sacramento River was achieved in this investigation by simulating four hypothetical Ranney wells (for more details on Ranney wells, see **Attachment A**). The two modeling scenarios were designed to show the potential range of drawdown response based on an upper and lower limit of hydraulic conductivity in the extraction zone. Note: hydraulic conductivity is a coefficient of proportionality describing the rate at which water can move through a permeable medium.

The center of each well is located approximately 100 feet perpendicular to the edge of the Sacramento River. Wells are intended to be spaced 1,000 feet from center to center since there is approximately 3,000 linear feet of riverbank in the project area.

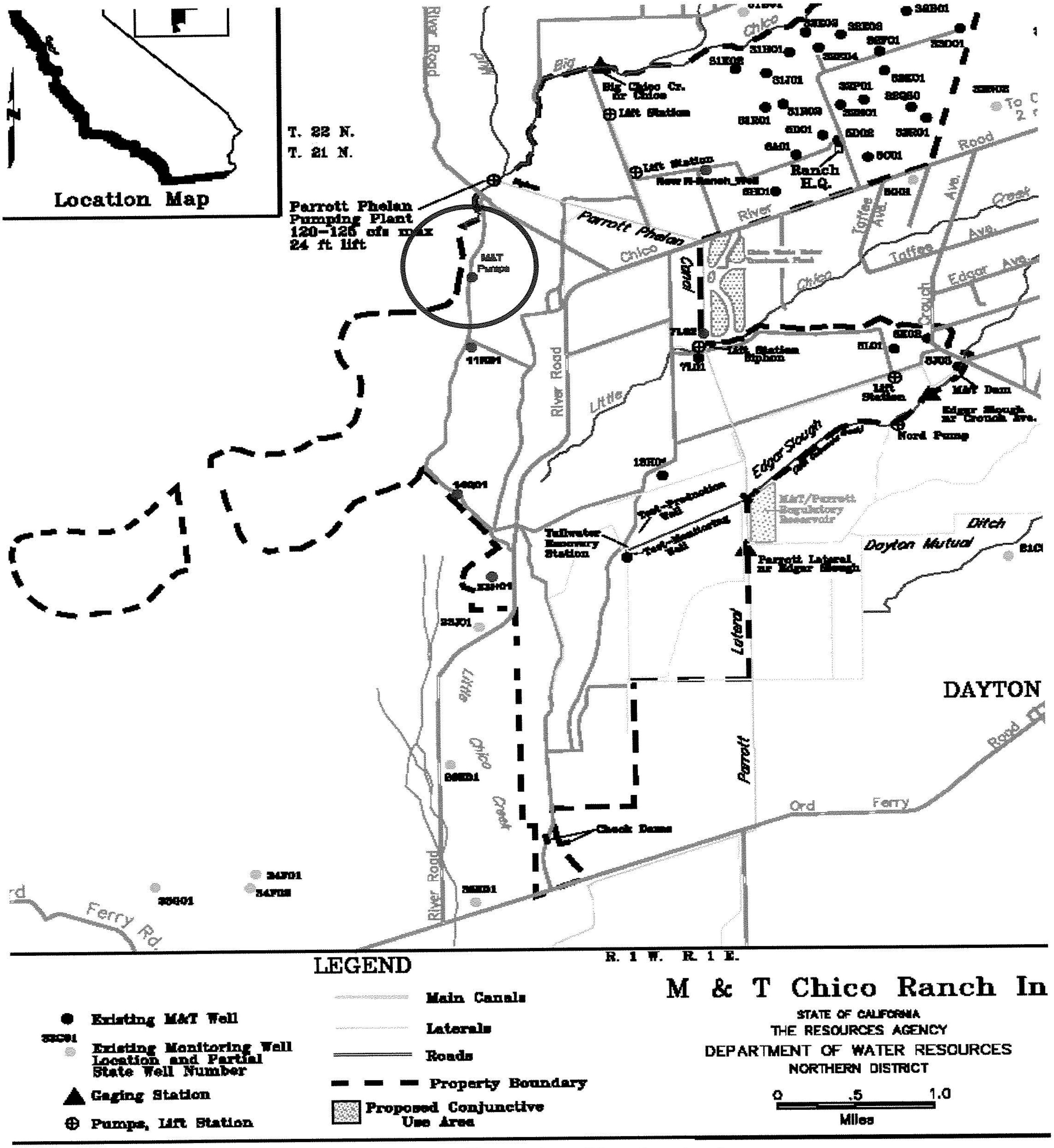
Water Well Driller's Reports from local wells detailing lithology were investigated to understand local subsurface conditions. A general lithologic column for the study area was formulated, based on these logs. Gravel is documented to be present through a consistent sequence in all the logs, and is interpreted to be contiguous between the well sites. This gravel zone is targeted as the extraction zone, or payzone, for our investigation.

## DATA AND MODELING

Three Water Well Driller's Reports from the California Department of Water Resources were the only site-specific data used for this assessment. The reports comprise written observations of the subsurface conditions at the well site as noted by the driller. These reports can be found in **Attachment B** and provide reasonable information to extrapolate a lithologic cross-section north-to-south in the vicinity of the study area. The No. 201892 DWR Water Well Driller's Report is closest in proximity to the study area. From these reports, a generalized lithologic sequence was formulated, as follows in **Table 1**:

**Table 1**

| **Depth Range** (ft) | **Material** | **K Value (ft d$^{-1}$)** |
|---|---|---|
| 0-24 | Top soil/ clay | $10^{-3}$ |
| 24-84 | Gravel (payzone) | $10^{2.5} - 10^{4}$ |
| 84-145 | Hardpan | $10^{-4}$ |



M&T Chico Ranch: Project Area

FIGURE 1

The hydraulic conductivity's for the above materials, or K values, were assigned based on estimates referenced in U.S. Geological Survey Water-Supply Paper 2220. Note that a range of K values was provided for the gravel payzone. The given range of K values provides a best and worst case theoretical modeling scenario for water transmission through a clean, well-sorted gravel.

Sieve analysis data were reviewed by MWH for boreholes tested on M&T Chico Ranch property in 1996. Summary plots of select data prepared by MWH and testing results from AGRA Earth and Environmental (AGRA) are available in **Attachment C**. MWH investigated data collected from test borehole numbers 96-1 and 96-5. Although these were drilled approximately two miles south of the study area, they are the closest of the five AGRA boreholes to the study area. The two AGRA boreholes investigated both penetrate a continuous sequence of gravel 40 to 50 feet thick, at a similar depth as referenced by the driller's reports in Appendix B. This information provides further confirmation to the consistent aerial continuity and thickness of the gravel bed modeled in this investigation.

Further investigation was pursued to derive a K value from the sieve analyses of the local gravel. No reliable and accurate method of determining hydraulic conductivity from grain-size distribution curves is known, although our purpose here is to estimate the order of magnitude of K values for the gravel. **Figure 2**, below, shows a comparison between the gravel bed grain size analysis (average of all sieve analyses from the two boreholes) and an experimental grain size analysis by Patchick (1967).

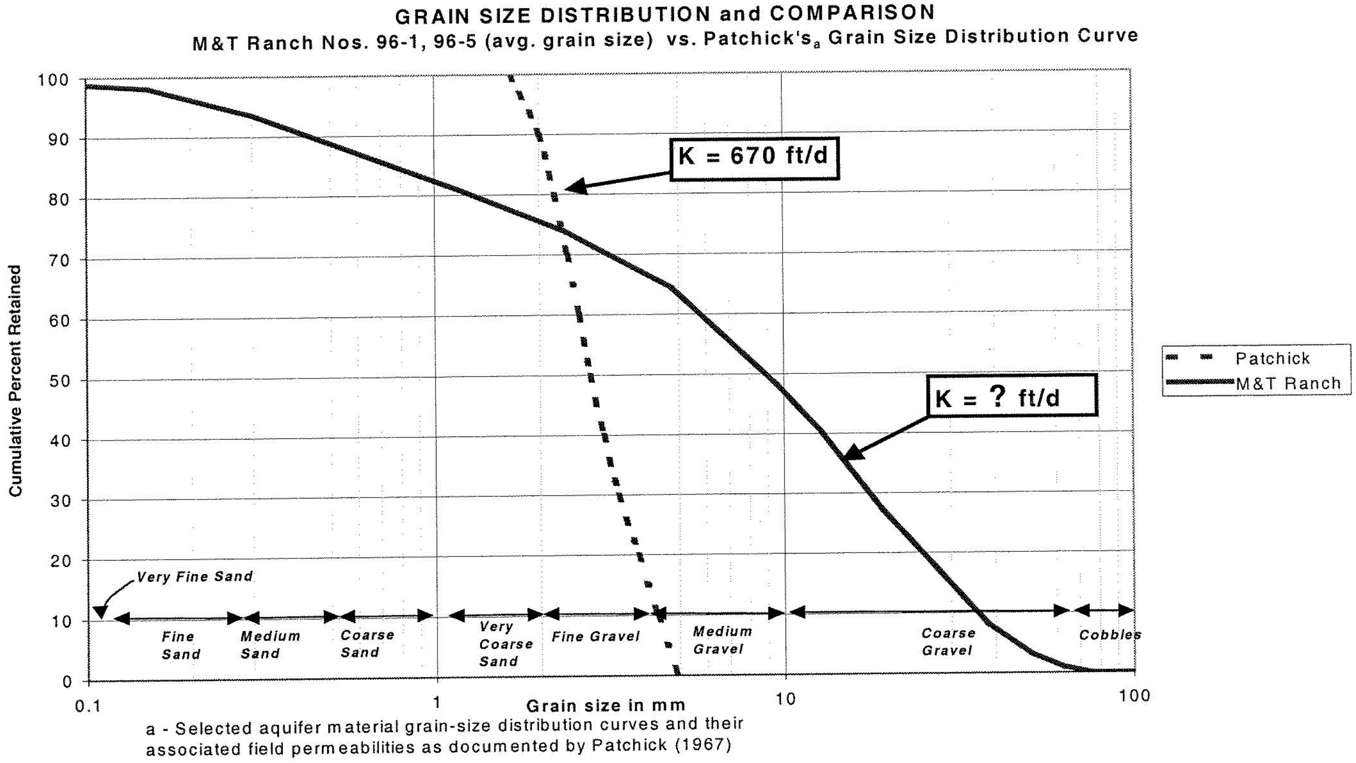


**Figure 2**

Patchick's grain size distribution curve data was used by default for this comparison, since it was the only data found in available literature which correlates a K value to a sand/gravel sample. All others correlate K value to sand exclusively. From this comparison, no 'order of magnitude' K value can be deduced for the gravel. To infer a K value, material tested must have a uniformity coefficient <2 (Walton, 1984). The uniformity coefficient ($C_u$) is the ratio of the grain size diameters retained in two separate sieves which allow 60% and 10%, respectively, of finer material to pass. From the sieve analysis comparisons in Appendix C, uniformity coefficients were derived. The $C_u$ value for the Patchick analysis is approximately 1.5, and the M&T Ranch analyses range from 10 to nearly 60.

It can be seen from Figure 2 above that the M&T Ranch analysis (on average) comprises approximately 20-25% coarse sand and fines which are not present in the Patchick grain size distribution curve. Additionally, 65% of the M&T Ranch analysis is of a coarser grain than that of Patchick analysis. One might conclude that the finer grained material will decrease the comparative K value of the gravel, but conversely, an argument could be made that the presence of 65% coarser material in the M&T Ranch analysis will significantly increase the comparative K value. The difficulty in assigning a K value lies in the high uniformity coefficient of the gravel, and the unknowns concerning how the coarse and fine sands are distributed and packed within the gravel matrix. Considering the high average percentage of coarse gravel (50%) and the possibility of setting the well screens close to the river, it may be possible to remove significant in-situ fines and fine sands from the aquifer between the well screens and the river during well development, thus artificially increasing the K value.

Due to a lack of definitive site-specific data, two K values were modeled to bracket the full range of gravel K values: $K=10^{2.5}$ (300 ft/d) for the smallest gravel, and $K=10^4$ (10,000 ft/d) for the largest gravel. As can be seen from the modeling output, there is a direct relationship between the K value and drawdown effect (see drawdown contours in **Attachment D**). The $K=10^4$ modeled output is 30 times greater than the $K=10^{2.5}$ modeled output, and the drawdown contours of the latter are 30 times greater than those of the former. These theoretical K values provide insight into potential responses of the water table from the given extraction of 150 cfs.

Ranney wells are modeled in this assessment for the following reasons:

- Well screens are situated adjacent to or underneath the river.
- A large percentage of recharge to the well is supplied directly by the river.
- Can be located very close to the river and not be susceptible to flood damage.
- Can produce 10 times the water volume of a conventional well.

Traditional vertical production wells were not modeled in this withdrawal assessment due to the impracticality of installing up to 30 large diameter wells with associated mechanical, electrical and piping equipment for each well in the small study area. Nonetheless, the drawdown effect of 30 production wells located in close proximity to the modeled Ranney well locations is expected to be similar to that modeled for the Ranney wells.

## COSTS

Costs were provided in writing from Ranney, Inc., of Dublin, Ohio, a firm that specializes in design, construction and testing of Ranney wells. The estimated cost per well is $1.85M, accurate to within plus 50%, minus 30% of the actual costs. See the attached Ranney Division Memorandum in **Attachment E**. For installation of four Ranney wells, the cost would be approximately $7.4M, with no permitting, design, or pipeline costs included.

Costs also were discussed with Engineering staff from Sonoma County Water Agency (SCWA) concerning recent Sonoma County Ranney well construction along the Russian River. No written costs were provided, although Remleah Scherzinger, Project Manager from the Agency for Ranney Well Rehabilitation and Maintenance, verbally indicated costs for one well of $2.7M for caisson and access road, and $2.0M for pump house.

Costs of conventional production wells were also discussed with a local, reputable Well Drilling Contractor. No written costs were provided, but a verbal estimate of $50K per well was indicated for well construction, development and outfitting with an electric pump, with no permitting, design, electrical nor pipeline costs included. For a conventional production well option, thirty wells capable of pumping at a rate of 2,000 gallons per minute are required to meet the proposed withdrawal demand. The total cost for these wells would be approximately $1.5M.

Note that the items costed from the SCWA are very broad and inclusive. Ranney Inc.'s proposed cost estimate provides more insight into the actual construction costs of each Ranney well.

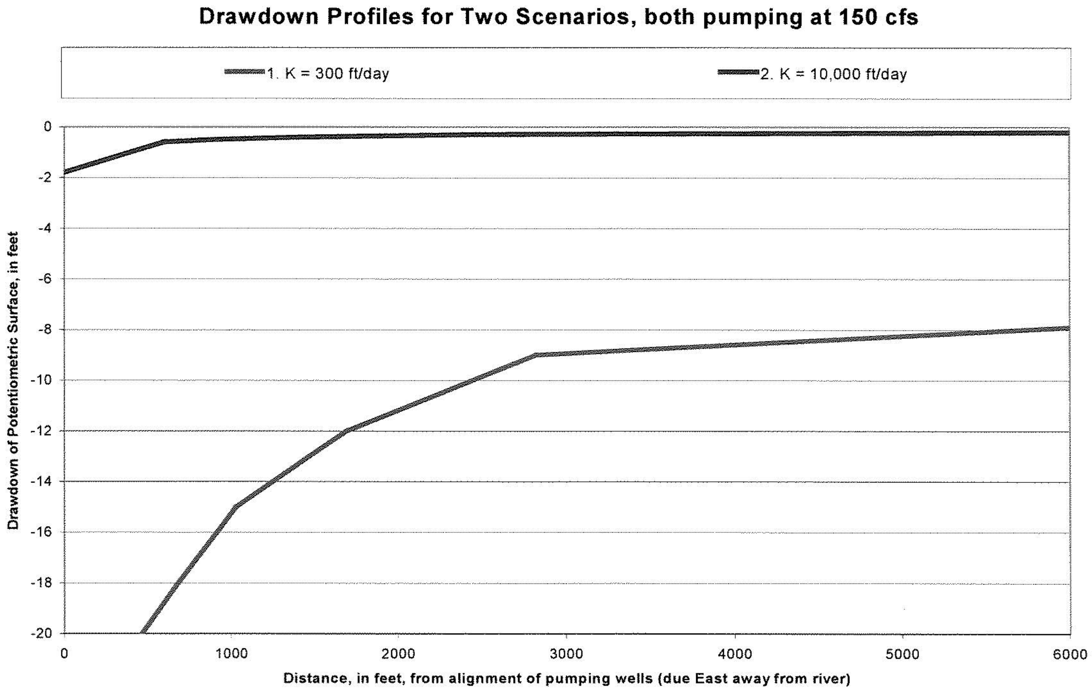
Horizontal wells were not considered because of the relatively deep potential setting depths for a well of this nature, the loose and unconsolidated characteristics of the material to be drilled, and extensive lengths of mudded borehole and screen required to complete a horizontal well.

## DISCUSSION

The following projected drawdowns from withdrawals were determined through the use of MicroFEM. MicroFEM is an integrated large-capacity finite-element computer program for steady-state and transient groundwater aquifer flow modeling under Windows.

Figure 2 shows the variability of a steady-state drawdown response in relation to an upper and lower limit in hydraulic conductivity (K value) in the extraction zone. Both scenarios were executed for a payzone thickness (vertical thickness of producing zone) of 60 feet.

**FIGURE 3**



As can be seen from this graph, there is high variability in the drawdown profiles. Based purely on modeling results, it appears feasible to extract 150 cfs from the aquifer as modeled. In the worst-case scenario using a K value = $10^{2.5}$, the resultant drawdown impact to the existing production wells northeast of the study area is less than 5 feet (see drawdown contours in Attachment D). Knowing the actual K value of the gravel aquifer and how it varies aerially will provide a better insight into the feasibility of a 150 cfs withdrawal.

Unknown conditions can result in significantly greater drawdown than shown here (i.e. impervious river sediments at the river-aquifer interface). Nonetheless, verbal reports from individuals familiar with the indigenous gravel aquifer describe a very transmissive aquifer that draws down minimally when pumped, and collapses during excavation due to saturation with groundwater. See **Attachment F** for notes from DWR concerning surface water - groundwater interconnection.

## RECOMMENDATIONS

The modeling performed for this assessment was based upon theoretical hydraulic conductivity values for the gravel payzone. To better determine the local yield potential, an investigation designed to confirm the physical nature of the water-bearing stratum and quantify the aquifer parameters is suggested. This can be accomplished with an aquifer performance test at a discharge capacity of approximately 2,000-3,000 gallons per minute, which will provide distinct K values in the tested aquifer. The estimated cost for design, construction, construction management and testing of a test production well and a series of monitoring wells is approximately $150,000.

## ATTACHMENTS

**A. Ranney Well Information**

**B. DWR Well Reports**

**C. Grading Analysis and Drill Logs**

**D. Model Output**

**E. Cost Memo**

**F. DWR Notes on M&T Chico Ranch Interconnection of Groundwater – Surface Water**

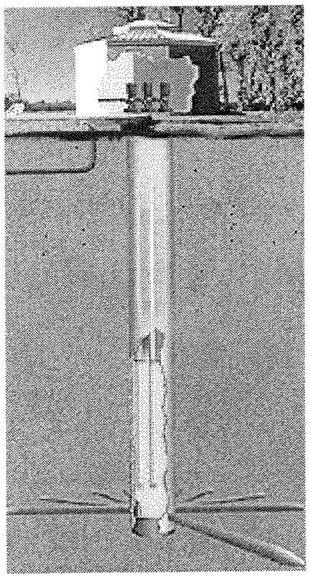
# Attachment A

# Ranney Well Information

## Water Resources

# Ranney Collector Wells

Collector Wells | Surface Water Intakes | Infiltration Galleries



**1-877-4-Ranney**

**(1-877-472-6639)**

Ranney@RanneyMethod.com

How It Works | Construction | Projects
Riverbank Filtration | Inspection & Maintenance | History

## How a Ranney Method® Well Works

A Ranney® Collector Well or Radial Horizontal Collector Well operates hydraulically, similar to a vertical well. The lateral well screens are installed near the bottom of the formation, so more of the saturated thickness of the aquifer can be used. Since these well screens are horizontally positioned, much longer screen lengths can be installed, reducing the velocity of the water entering the screen slots and maximizing well efficiency.

This reduced velocity also minimizes head losses and slows the rate of plugging, extending the intervals between scheduled maintenance. The well pumps are installed in the central caisson, allowing usage of larger and more energy-efficient pumps and motors. This further reduces O & M requirements and costs.

How It Works | Construction | Projects
Riverbank Filtration | Inspection & Maintenance | History

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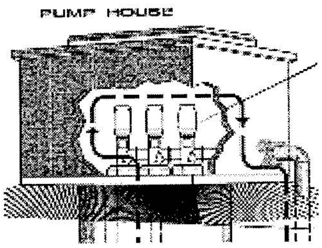
## Well Construction

A reinforced concrete caisson serves as the wet well or pumping station. First, the caisson is constructed using the open-end caisson sinking method. A bottom sealing plug is poured to make the caisson water-tight. Next, a series of lateral well screens are projected horizontally from the caisson into the aquifer formation at one or more elevations. These screens may be placed in a variety of patterns and varying lengths. They can be equipped with an artificial gravel-pack filter, if required.



(Click here for a larger image of the Ranney Collector)

Finally, the caisson is extended above known or anticipated flood elevations. The well is typically completed with a pump house and controls.

How It Works | Construction | Projects
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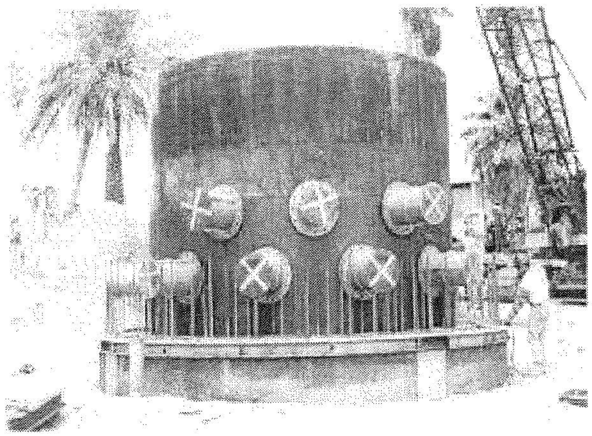
## Recent Collector Projects

The Ranney Division of Reynolds has long had the reputation for designing and building some of the largest water supply wells in the world. In the past eighteen months, we have added to that reputation by completing construction of wells in St. Joseph, Missouri and Lake Havasu City, Arizona. Each of these wells have rated capacities in excess of 15 million gallons per day (10,500 gallons per minute).

- **Lake Havasu City, Arizona**

Lake Havasu City has relied on ground water to meet the drinking water needs of their community. Historically, the quality of that water has been poor, with high concentrations of iron and manganese. As part of major improvements to the drinking water system, a new Ranney Collector Well was constructed and tested. The well was constructed on the shores of Lake Havasu to take advantage of the infiltration of high quality surface water.

The Ranney Well is constructed of a 16 foot inside by 21 foot outside diameter reinforced concrete caisson, 104 feet deep. Over 1750 feet of wire-wrapped stainless steel well screen was installed at the base of the well, in 14 horizontal laterals. After development, the well was test pumped at 17,500 gallons per minute and had 31 feet of measured drawdown.

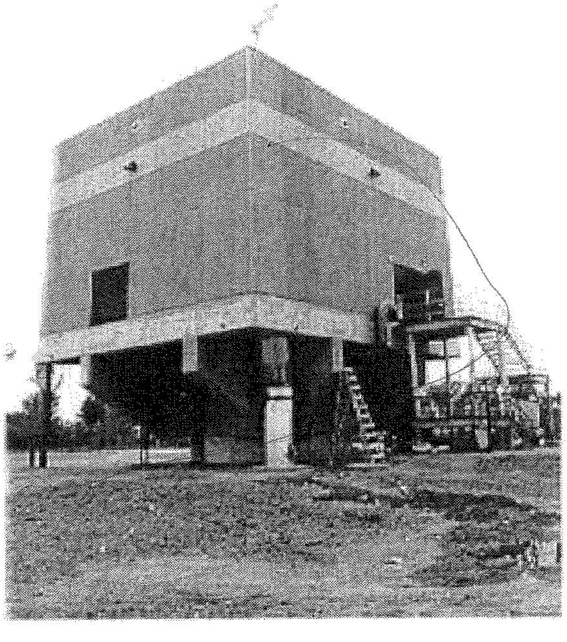


Ranney Well - Lake Havasu City, Arizona

### St. Joseph, Missouri

After the massive flooding on the Missouri and Mississippi Rivers in 1994, the Missouri American Water Company implemented a series of major improvements to their St. Joseph water supply system. Included in those improvments were a series of vertical wells and a Ranney Collector Well.

The Ranney Well is constructed of a 16 foot inside by 20 foot outside diameter reinforced concrete caisson, 118 feet deep. The well has over 1300 feet of wire-wrapped stainless steel well screen, installed in seven horizontal laterals. The well was test pumped at 10,500 gallons per minute and had eleven feet of measured drawdown.



**Ranney Collector Well - St. Joseph, Missouri**

How It Works | Construction | Projects
Riverbank Filtration | Inspection & Maintenance | History

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## Riverbank Filtration

Properly installed Ranney Collector Wells near surface water sources can be operated to induce surface water recharge of ground water. The stream bottom sediments and aquifer materials filter the recharged water. Because of slow infiltration rates and pore size of the aquifer material, turbidity and pathogen removal can be significant. Additionally, organic degradation occurs at the water / sediment interface. The US EPA notes that a Ranney Collector "has the advantage of being the most environmentally sound intake system because it does not have any direct impact on the waterway."

Riverbank filtration can replace / support other water treatment while:

- Reducing treatment residuals by removing particulates / turbidity
- Reducing operation and maintenance costs
- Attenuating rapid changes in water quality & temperature
- Eliminating bacteria and zebra mussels

Siting and Design Considerations:

- Travel Time in Aquifer
- Filtration Capacity of the Suface Water / Aquifer Interface
- Aquifer Composition and Grain Size
- Rate of Infiltration
- Source of Water Quality

Siting and Design Considerations:

- Detailed Hydrogeologic / Geochemical Evaluation
- Assessment of Local Water Quality and Quantity
- Quantification of Infiltration Capacity
- Assessment of Source Water Resources

How It Works | Construction | Projects
Riverbank Filtration | Inspection & Maintenance | History

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## Collector Inspection & Maintenance

- **Collector Inspection**
  Periodic inspection and performance testing is recommended as part of a standard preventative maintenance program for any well system. Our Ranney Horizontal Collector Well inspection services include: underwater video inspection of the entire accessible lateral lengths; underwater photography; individual lateral water quality sampling and monitoring; lateral flow and temperature analysis; well performance testing with pumping rate and water level monitoring; and, long term record keeping program to track well capacity and efficiency.

- **Collector Maintenance**
  Over time, depending on water quality and operational considerations, collector lateral well screens may gradually become encrusted due to bio-fouling, mineral precipitation or migration of fines. Lateral well screen maintenance is typically conducted utilizing up to 10,000 psi high pressure rotating water jet in conjunction with open end sand line and flushing wye. The collector caisson is maintained in a fully dewatered condition to allow the hydrostatic pressure of the aquifer to assist in the development process. If it is necessary to maintain the well in service throughout the maintenance process, we have a proprietary Underwater Lateral Cleaning and Redevelopment System. As appropriate, experience with various well treatment chemistries can be used to optimize well rehabilitation.

- **New Lateral Installation**
  Existing collector wells can be rehabilitated with installation of new laterals. The result is an essentially brand new well, without the cost of related infrastructure replacement. New port assemblies are installed in the caisson wall and new lateral screens are installed. The new laterals can be stainless steel, carbon steel or pvc.

How It Works | Construction | Projects
Riverbank Filtration | Inspection & Maintenance | History

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## History of the Ranney® Well

The concept for the original radial collector well was developed for oil drilling. The inventor, a petroleum engineer named Leo Ranney, first drilled horizontally for oil in the early 1920's in Texas, and then later in Ohio. The theory is that by drilling horizontally into the producing formation, a wider area of the well borehole could be exposed for oil extraction. This technology was applied to recovering water supplies when the bottom fell out of oil prices in the 1930's.

The first Ranney water collector well was installed in London, England in 1933. In 1936, the first Ranney water collector well in the United States was constructed in Canton, Ohio. Since then, hundreds of these wells have been built all over the world.

If you are considering a "Ranney®-type" collector well please contact the Ranney Division.

How It Works | Construction | Projects
Riverbank Filtration | Inspection & Maintenance | History

**1-877-4-Ranney**
**(1-877-472-6639)**
Ranney@RanneyMethod.com

REYNOLDS. INC.
Water Resource Construction

**Ranney Division of Reynolds-Ohio**
6063 Frantz Road
Suite 206
Dublin, OH 43017
614-339-0099 - Main Number
614-339-0098 - Fax Number

Collector Wells | Surface Water Intakes | Infiltration Galleries

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# Attachment B
# DWR Well Reports

①　　21N/1W-~~23~~ 14Q

**ORIGINAL**
**File with DWR**

CONFIDENTIAL LOG
Water Code Sec. 13752

# WATER WELL DRILLERS REPORT

(Sections 7079, 7080, 7081, 7082, Water Code)

## THE RESOURCES AGENCY OF CALIFORNIA
## DEPARTMENT OF WATER RESOURCES

*Do Not Fill In*

№ 18266

State Well No. CONFIDENTIAL LOG
Other Well No. Water Code Sec. 13752

### (1) OWNER:

Name M & T, Incorporated
Address P.O. Box 308,
Chico, California 95926

### (2) LOCATION OF WELL:

County Butte　　Owner's number, if any
Township, Range, and Section Off Ord Ferry Road On
Distance from cities, roads, railroads, etc. River Rd. 3 Miles after
Turning Corner to West From Durham.

### (3) TYPE OF WORK (check):

New Well ☒**　Deepening ☐　Reconditioning ☐　Destroying ☐

*If destruction, describe material and procedure in Item 11.*

### (4) PROPOSED USE (check):

Domestic ☐　Industrial ☐　Municipal ☐
Irrigation ☒*Test Well ☐　Other ☐

### (5) EQUIPMENT:

Rotary ☐
Cable ***☒
Other ☐

### (6) CASING INSTALLED:

STEEL:　OTHER:
SINGLE ☐　DOUBLE ☐

If gravel packed

| From ft. | To ft. | Diam. | Gage or Wall | Diameter of Bore | From ft. | To ft. |
|---|---|---|---|---|---|---|
| 120' | | 16 x 3/16" B/W Plate Casing | | | | |
| 60' | | 14" x 10 Ga. Plain Casing | | | | |
| 40' | | 14" x 10 Ga. Perforated Casing | | | | |

Size of shoe or well ring: =　　Size of gravel:

~~Describe joint~~ Casing Shoes: 1-16"x8"x3/4" & 2-14" x6"x5/8" Liner Shoes

### (7) PERFORATIONS OR SCREEN:

Type of perforation or name of screen

| From ft. | To ft. | Perf. per row | Rows per ft. | Size in. x in. |
|---|---|---|---|---|
| 114' | 154' | | | 1/8" x 1 1/2" |
| | | | | |
| | | | | |
| | | | | |

### (8) CONSTRUCTION:

Was a surface sanitary seal provided? Yes ☐ No ☐ To what depth ft.
Were any strata sealed against pollution? Yes ☐ No ☐ If yes, note depth of strata
From ft. to ft.
From ft. to ft.
Method of sealing

### (9) WATER LEVELS:

Depth at which water was first found, if known 16 1/2 ft.
Standing level before perforating, if known ft.
Standing level after perforating and developing 15 ft.

### (10) WELL TESTS:

Was pump test made? Yes ☐ No ☐ If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
Temperature of water　Was a chemical analysis made? Yes ☐ No ☐
Was electric log made of well? Yes ☐ No ☐ If yes, attach copy

### (11) WELL LOG:

Total depth 0 ft.　Depth of completed well 223 ft.

Formation: *Describe by color, character, size of material, and structure*

| FROM: | TO: | |
|---|---|---|
| 0' | 14' | Top Soil |
| 14' | 28' | Sandy Brown Clay |
| 28' | 46' | Gravel & Sand 4" |
| 46' | 50' | Brown Sandy Clay |
| 50' | 63' | Bravel & Sand 5" |
| 63' | 87' | Brown Shale |
| 87' | 94' | Brown Sandy Shale |
| 94' | 104' | Brown Clay |
| 104' | 108' | Gravel, Sand & Brown Clay |
| 108' | 142' | Brown Shale |
| 142' | 152' | Brown Sandy Shale & Sand |
| 152' | 160' | Gravel & Sand 1" to 1 1/2" |
| 160' | 180' | Sand ( Fine & Sluffing) |
| 180' | 188' | Brown Sandy Shale |
| 188' | 193' | Brown Clay |
| 193' | 198' | Brown Sandy Clay |
| 198' | 210' | Brown Clay |
| 210' | 223' | Sand & Gravel 3" |

LINER CASING

TOP OF LINER SET @ 110 Ft.
BOTTOM OF LINER SET @ 210 Ft.

CONFIDENTIAL LOG
Water Code Sec. 13752

CONFIDENTIAL WELL LOG
Water Code Section 13752.
These data are restricted to governmental agencies for use in making studies.

Work started 6/ 9/ 19 77, Completed 6/17/ 19 77

WELL DRILLER'S STATEMENT:

*This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.*

00316

NAME Frank L. Cornwell & Son
(Person, firm, or corporation) (Typed or printed)

Address 521-3rd St. Marysville, California
95901

[SIGNED] Robt Cornwell
(Well Driller)

License No. 237331　Dated June 23, 197

SKETCH LOCATION OF WELL ON REVERSE SIDE

DWR 188 (REV. 9-65)　　56391-950 10-65 50M TRIP ① △ OSP

5

21N/01W-~~02~~ M
-11K1

**ORIGINAL**
**File with DWR**

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

# WATER WELL DRILLERS REPORT

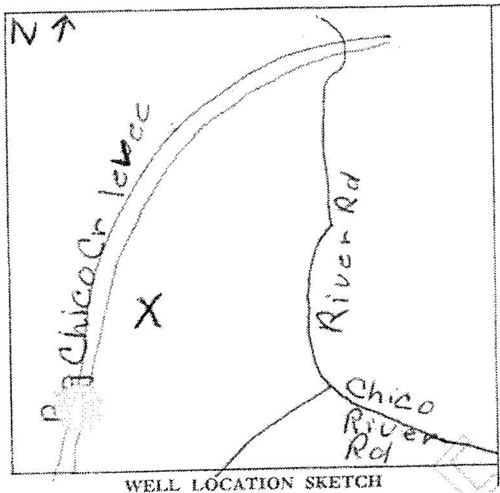
*Do not fill in*
No. 201892

Notice of Intent No.
Local Permit No. or Date

State Well No.
Other Well No.

## (1) OWNER:
Name M & T Ranch
Address [illegible]4 Chico River Road
City Chico Zip 95928

## (2) LOCATION OF WELL (See instructions):
County Butte Owner's Well Number 1
Well address if different from above
Township 21 N Range 1 W Section 11 2
Distance from cities, roads, railroads, fences, etc. 1 mi. west on Big Chico Cr. Turn off of River Rd.



WELL LOCATION SKETCH

## (3) TYPE OF WORK:
New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

## (4) PROPOSED USE:
Domestic ☐
Irrigation ☐
Industrial ☐
Test Well ☐
Stock ☐
Municipal ☐
Other ☐

## (5) EQUIPMENT:
Rotary ☐ Reverse ☐
Cable ☒ Air ☐
Other ☐ Bucket ☐

## (6) GRAVEL PACK:
Yes ☐ No ☐ Size
Diameter of bore
Packed from to ft.

## (7) CASING INSTALLED:
Steel ☐ Plastic ☐ Concrete ☐

## (8) PERFORATIONS:
Type of perforation or size of screen

| From ft. | To ft. | Dia. in. | Gage or Wall | From ft. | To ft. | Slot size |
|---|---|---|---|---|---|---|
| 0 | 12 | 20 | 10 | | | |
| 0 | 33 | 16 | 8 | | | |
| | | 14 | 10 | 125 | 224 | |
| | | 12 | 10 | 220 | 320 | |

## (9) WELL SEAL:
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 20 ft.
Were strata sealed against pollution? Yes ☐ No ☐ Interval ft.
Method of sealing [illegible]

## (10) WATER LEVELS:
Depth of first water, if known 24 ft.
Standing level after well completion 12 ft.

## (11) WELL TESTS:
Was well test made? Yes ☒ No ☐ If yes, by whom? Durham Pump
Type of test Pump ☒ Bailer ☐ Air lift ☐
Depth to water at start of test ft. At end of test ft
Discharge gal/min after hours Water temperature
Chemical analysis made? Yes ☐ No ☐ If yes, by whom?
Was electric log made? Yes ☐ No ☐ If yes, attach copy to this report

## (12) WELL LOG:
Total depth 615 ft. Depth of completed well [illegible] ft.

| from ft. | to ft. | Formation (Describe by color, character, size or material) |
|---|---|---|
| 0 | 24 | Top Soil |
| 24 | 34 | Gravel |
| 34 | 145 | Brown Hardpan |
| 145 | 155 | Cemented Gravel |
| 155 | 165 | Sand & Gravel |
| 165 | 190 | Brown Hardpan |
| 190 | 224 | Gravel |
| 224 | 238 | Yellow Clay |
| 238 | 247 | Gravel |
| 247 | 255 | Yellow Clay |
| 255 | 580 | Brown Hardpan |
| 580 | 585 | Dark Gray Hardpan |
| 585 | | Pink Gray Sand |

NOV 02 1987

Work started 9-11-19 87 Completed 10-[illegible]-19 87

0135

## WELL DRILLER'S STATEMENT:
*This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.*

SIGNED Don Dunlap
(Well Driller)

NAME Dunlap's Well Drilling
(Person, firm, or corporation) (Typed or printed)
Address 13051 Orchard Blossom Ln.
City Chico Zip 95926
License No. 373903 Date of this report 10-22-87

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

**ORIGINAL**
**File with DWR**

RECEIVED
JAN 19 1994
D.W.R.

3

STATE OF CALIFORNIA
# WELL COMPLETION REPORT
*Refer to Instruction Pamphlet*

No. 405700

Page ____ of ____
Owner's Well No. ____
Date Work Began 11-15-93 Ended 12-13-93
Local Permit Agency Butte County Health Department
Permit No. ____ Permit Date ____

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./STATION NO. 21N/01W-19M
LATITUDE ____ LONGITUDE ____
APN/TRS/OTHER ____

## GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DEPTH TO FIRST WATER 18 (Ft.) BELOW SURFACE

| DEPTH FROM SURFACE Ft. | to Ft. | DESCRIPTION *Describe material, grain size, color, etc.* |
|---|---|---|
| 0 | 3 | Top Soil |
| 3 | 42 | Brown Clay |
| 42 | 68 | Gravel |
| 68 | 90 | Brown Clay |
| 90 | 146 | Brown Hardpan |
| 146 | 148 | Sand |
| 148 | 181 | Brown Hardpan |
| 181 | 193 | Clay & Gravel |
| 193 | 224 | Gravel |
| 224 | 243 | Brown Hardpan |
| 243 | 245 | Gravel |
| 245 | 512 | Brown Hardpan |
| 512 | 514 | Lava Sand |
| 514 | 531 | Brown Hardpan |
| 531 | 534 | Lava Sand |
| 534 | 547 | Brown Hardpan |
| 547 | | Sand |

TOTAL DEPTH OF BORING 547 (Feet)
TOTAL DEPTH OF COMPLETED WELL 547 (Feet)

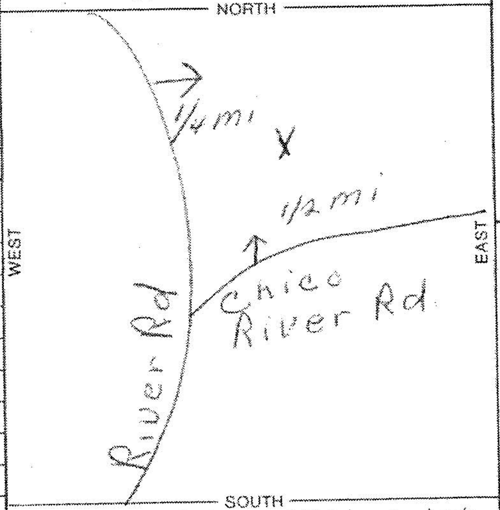
## WELL OWNER

Name M & T Ranch
Mailing Address 3964 Chico River Rd.
Chico Calif. 95928
CITY STATE ZIP

## WELL LOCATION

Address Chico River Rd.
City Chico
County Butte
APN Book ____ Page ____ Parcel ____
or
Township 21 N Range ~~1 E~~ 01W Section 6 01
or
Latitude ____ DEG. MIN. SEC. NORTH Longitude ____ DEG. MIN. SEC. WEST

## LOCATION SKETCH



*Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc.*
*PLEASE BE ACCURATE & COMPLETE.*

## ACTIVITY (✓)

X NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

## PLANNED USE(S) (✓)

___ MONITORING
WATER SUPPLY
___ Domestic
___ Public
X Irrigation
___ Industrial
___ "TEST WELL"
___ CATHODIC PROTECTION
___ OTHER (Specify)

DRILLING METHOD Cable FLUID ____

## WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 18 (Ft.) & DATE MEASURED ____
ESTIMATED YIELD* ____ (GPM) & TEST TYPE ____
TEST LENGTH ____ (Hrs.) TOTAL DRAWDOWN ____ (Ft.)
** May not be representative of a well's long-term yield.*

## CASING(S)

| DEPTH FROM SURFACE Ft. | to Ft. | BORE-HOLE DIA. (Inches) | TYPE (✓) BLANK | SCREEN | CON-DUCTOR | FILL PIPE | MATERIAL/GRADE | INTERNAL DIAMETER (Inches) | GAUGE OR WALL THICKNESS | SLOT SIZE IF ANY (Inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 135 | 16 | | | | | steel | 16 | 188 | 70-130 |
| | | 14 | | | | | steel | 14 | 188 | 170-240 |
| | | | | | | | | every | other | joint |

## ANNULAR MATERIAL

| DEPTH FROM SURFACE Ft. | to Ft. | TYPE CE-MENT (✓) | BEN-TONITE (✓) | FILL (✓) | FILTER PACK (TYPE/SIZE) |
|---|---|---|---|---|---|
| 0 | 20 | | X | | |

## ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ____
*ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.*

## CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

1335

NAME Dunlap's Well Drilling
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

13081 Orchard Blossom Ln. Chico Calif. 95926
ADDRESS CITY STATE ZIP

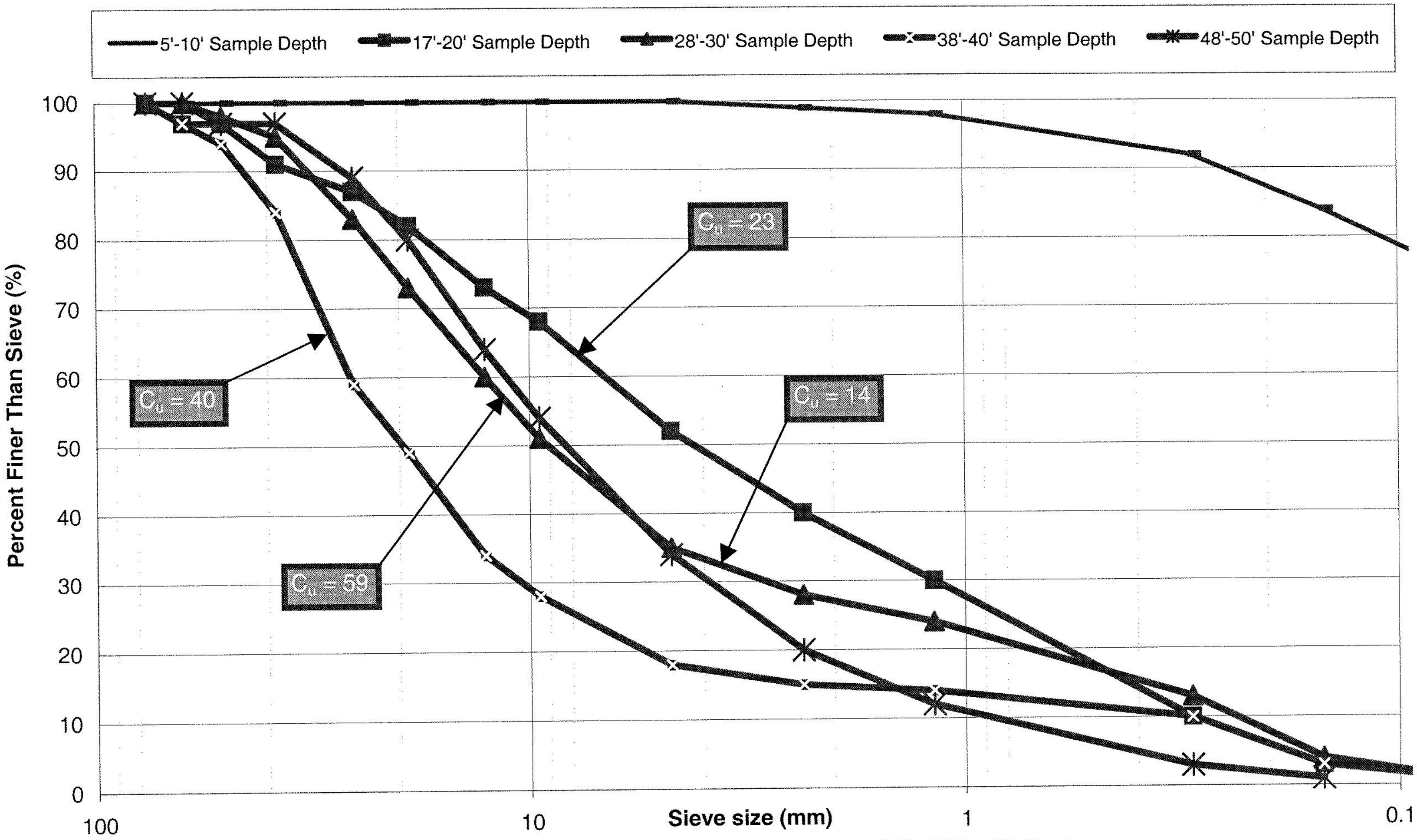
Signed Don Dunlap 12-16-93 378908
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 7-90

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

# Attachment C
# Grading Analysis and Drill Logs

# SIEVE ANALYSIS COMPARISON and UNIFORMITY COEFFICIENTS derived from AGRA Analyses of Borehole 96-1, M&T Ranch

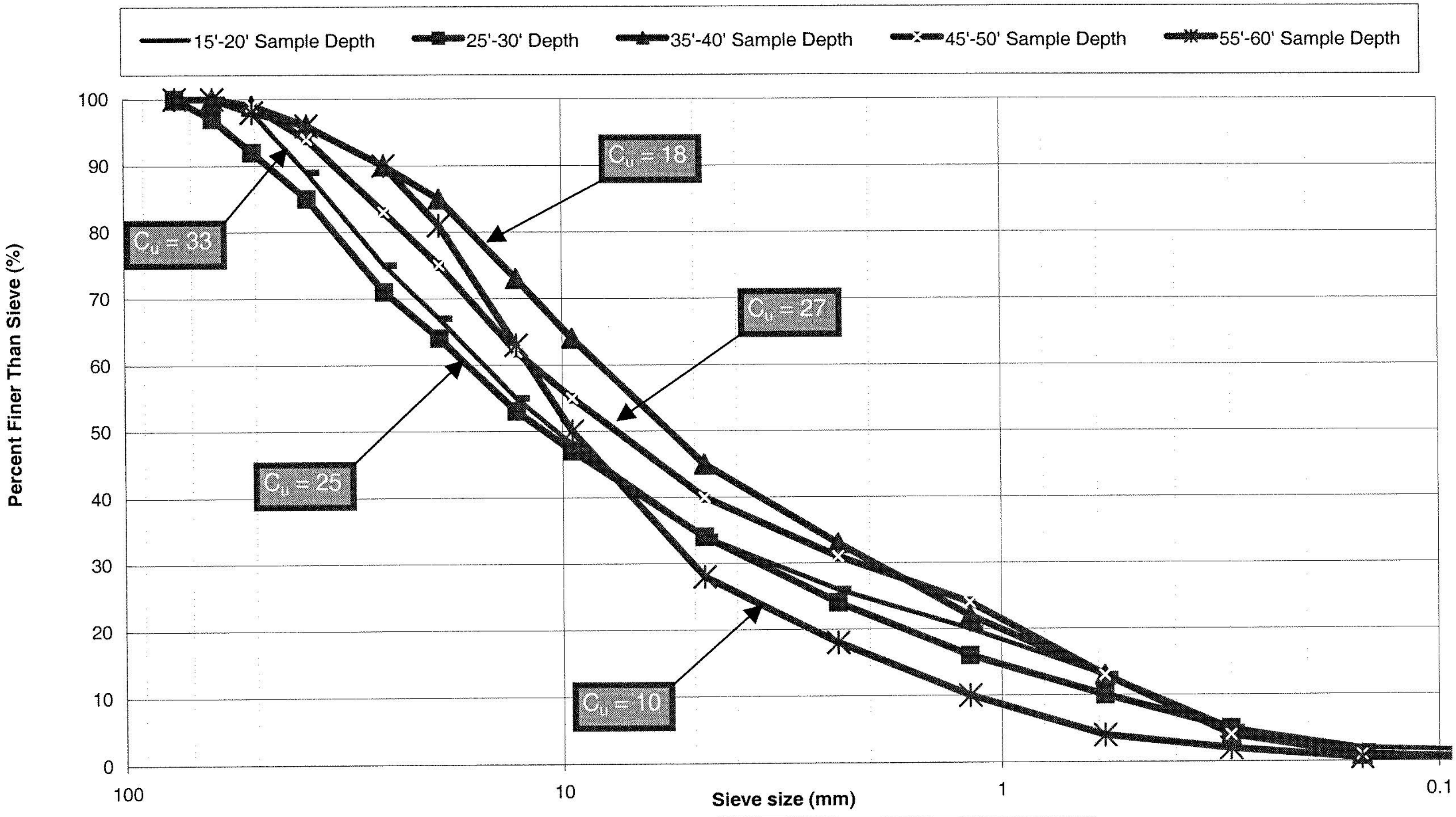


Note: Uniformity coefficient $C_u = D_{60} / D_{10}$

$D_{60}$ = Minimum grain size diameter retained in sieve allowing 60% finer material to pass

$D_{10}$ = Minimum grain size diameter retained in sieve allowing 10% finer material to pass

# SIEVE ANALYSIS COMPARISON and UNIFORMITY COEFFICIENTS
derived from AGRA Analyses of Borehole 96-5, M&T Ranch

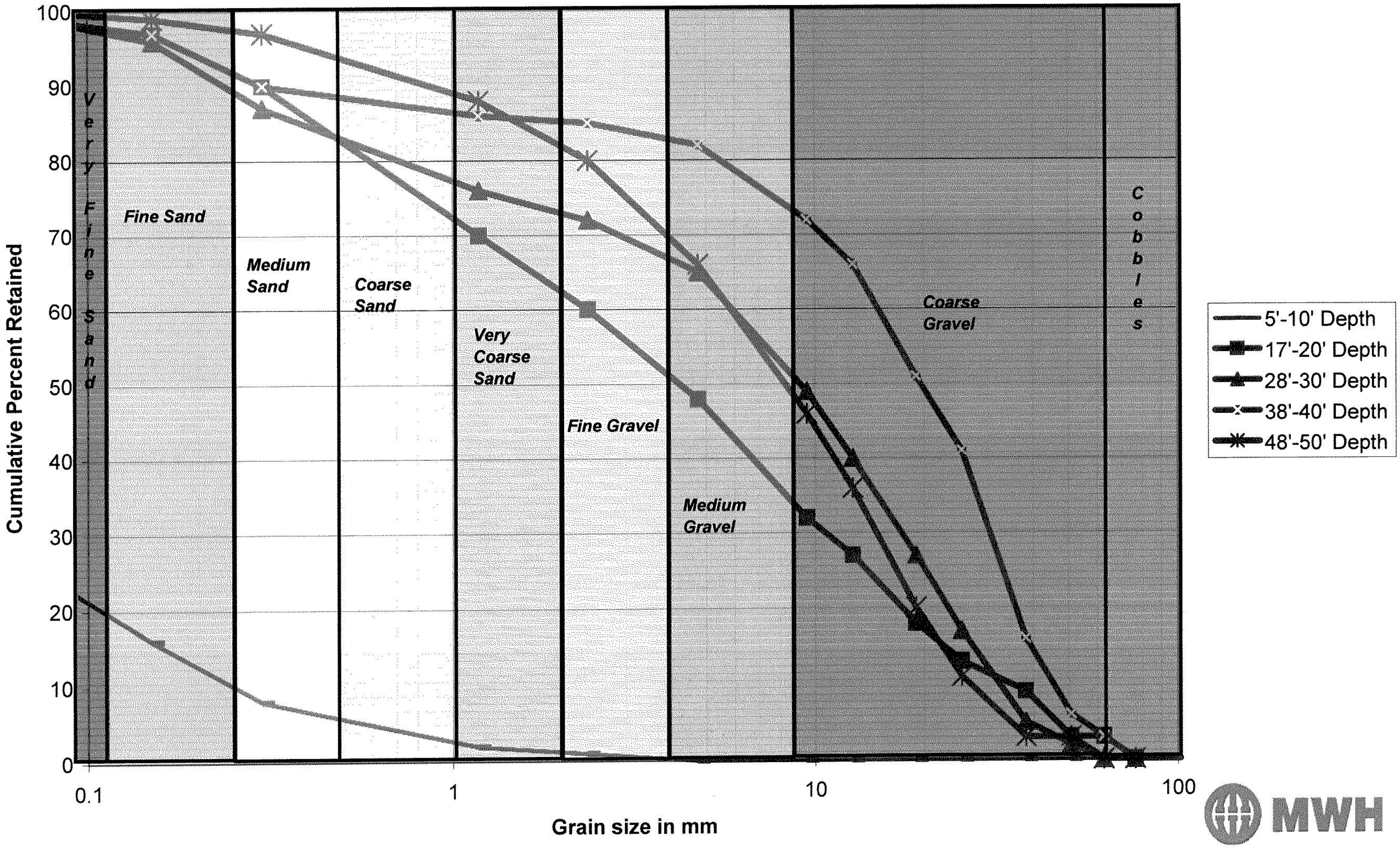


Note: Uniformity coefficient $C_u = D_{60} / D_{10}$

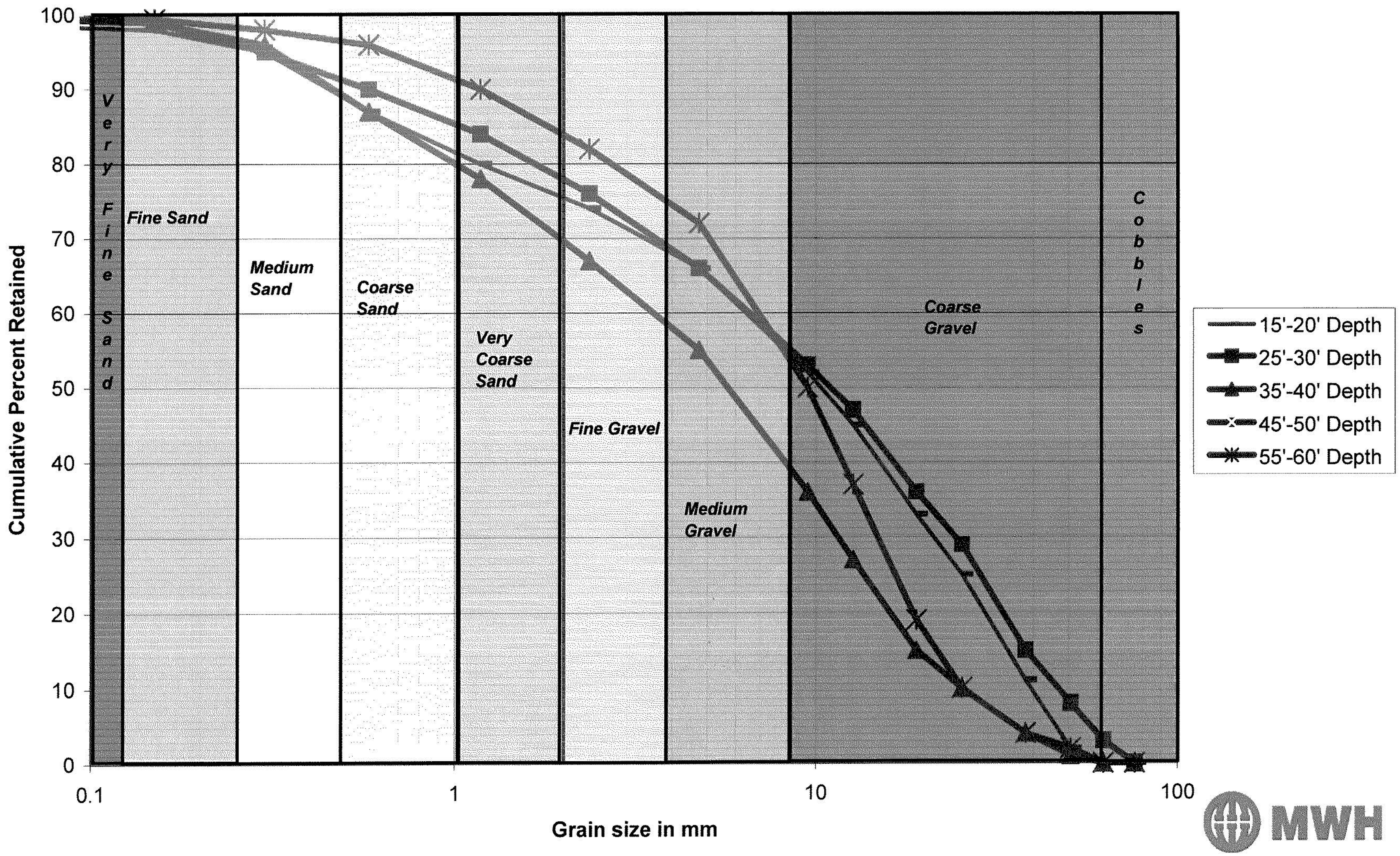
$D_{60}$ = Minimum grain size diameter retained in sieve allowing 60% finer material to pass

$D_{10}$ = Minimum grain size diameter retained in sieve allowing 10% finer material to pass

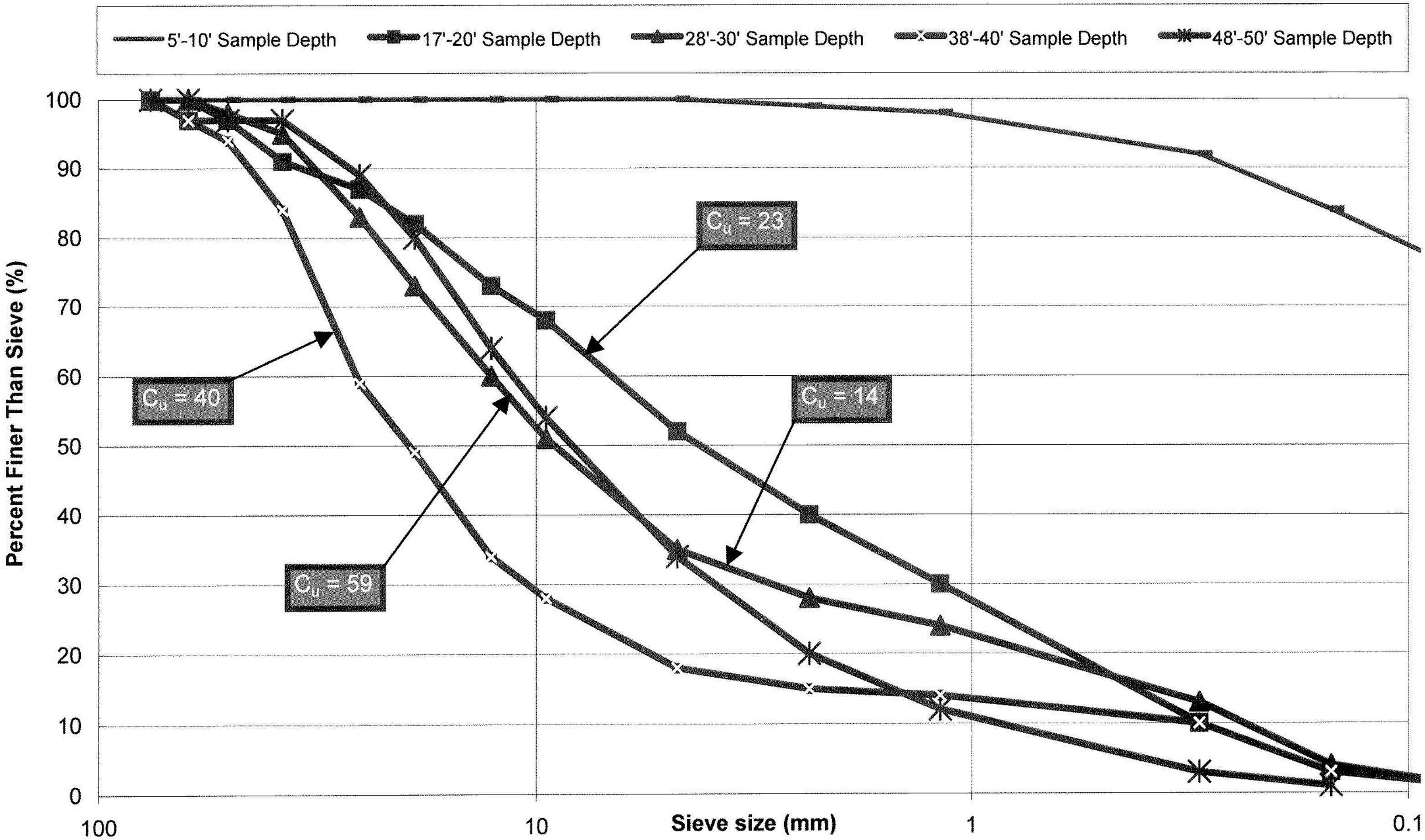
# GRAIN SIZE DISTRIBUTION
## M&T Ranch, Borehole 96-1



# GRAIN SIZE DISTRIBUTION
## M&T Ranch, Borehole 96-5



# SIEVE ANALYSIS COMPARISON and UNIFORMITY COEFFICIENTS derived from AGRA Analyses of Borehole 96-1, M&T Ranch



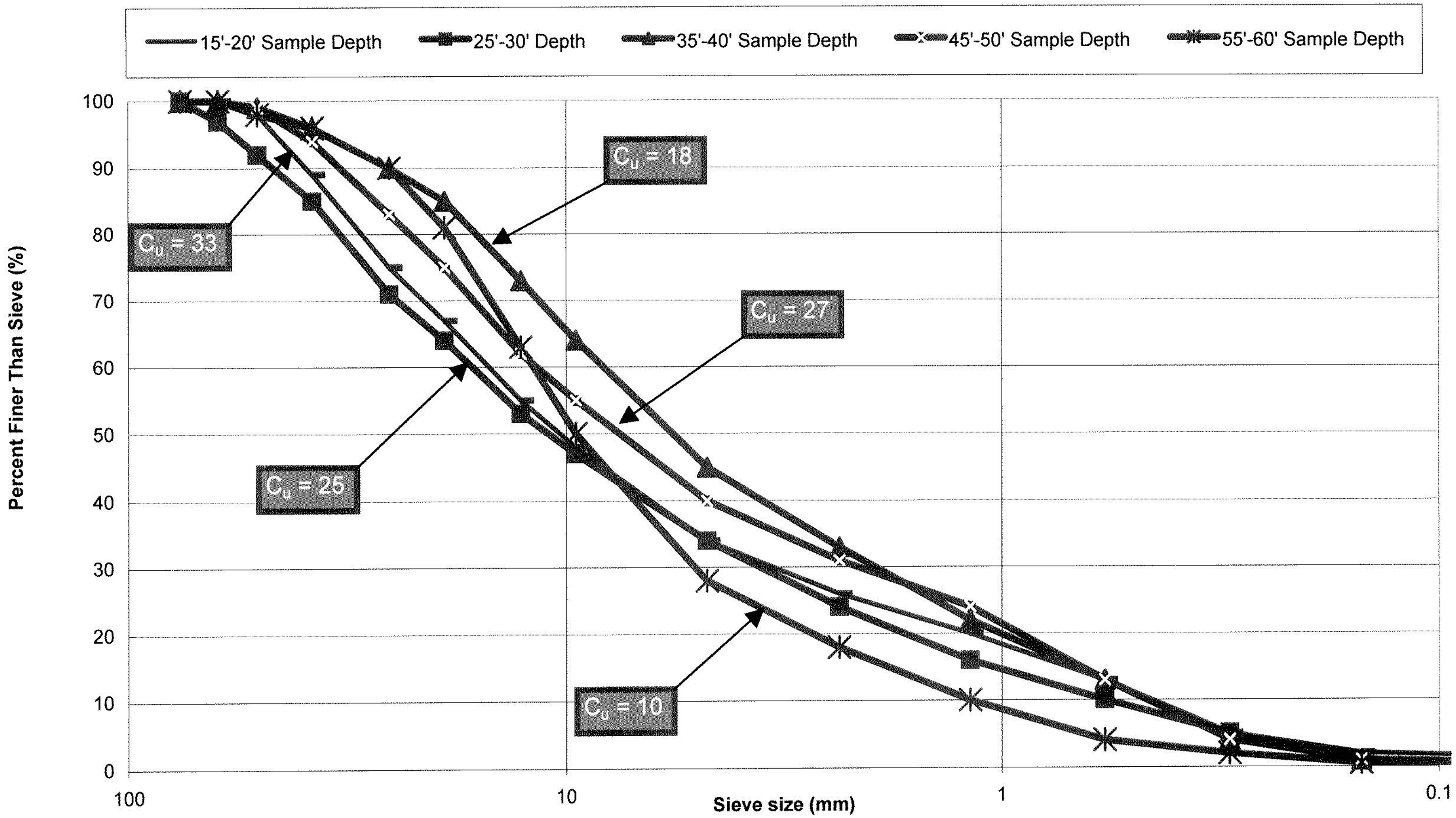
Note: Uniformity coefficient $C_u = D_{60} / D_{10}$

$D_{60}$ = Minimum grain size diameter retained in sieve allowing 60% finer material to pass

$D_{10}$ = Minimum grain size diameter retained in sieve allowing 10% finer material to pass

MWH

# SIEVE ANALYSIS COMPARISON and UNIFORMITY COEFFICIENTS
## derived from AGRA Analyses of Borehole 96-5, M&T Ranch



Note: Uniformity coefficient $C_u = D_{60} / D_{10}$

$D_{60}$ = Minimum grain size diameter retained in sieve allowing 60% finer material to pass

$D_{10}$ = Minimum grain size diameter retained in sieve allowing 10% finer material to pass

**BALDWIN CONTRACTING COMPANY, INC.**

GENERAL ENGINEERING CONTRACTORS

1764 SKYWAY / CHICO, CA 95928 (530) 891-6555 (530) 894-6220 FAX

January 8, 2004

RECEIVED
JAN 26 2004
MWH

Dan McManus
California Department of Water Resources
2440 Main Street
Red Bluff, CA 96080

RE: Drill Log and Grading Analysis, for site on River Road, west of Chico, Butte County

Dear Dan:

Enclosed, for your use, is a drill log and grading analysis, done by AGRA Earth and Environmental, dated April 5, 1996.

The site is on River Road, about 7 miles west of Chico, along Little Chico Creek, east of the Sacramento River.

Very Truly Yours,

Baldwin Contracting Company, Inc.

René A. Vercruyssen

Rene' A. Vercruyssen,

## 3. M&T PROPERTY

The M&T Property is located adjacent to Little Chico Creek and River Road approximately 7 miles southwest of Chico in Butte County and within two miles of the Sacramento River. The site consists of approximately 330 undeveloped acres currently utilized as general farm land and is a small portion of the much larger M&T Chico Farms. No mining has taken place on the property to date but previous subsurface exploration revealed that a potential large quantity of sand and gravel was present. No sampling or quality testing was available from these previous drilling programs. The property consists of mostly flat, low-lying river floodplain with occasional standing water. Chico Creek flows through the property and the water table depth on site is very shallow, probably within 2 to 3 feet of the surface in most locations.

The property being evaluated for aggregate is shown on Figure 2 and is that portion of the property on the western side of the drawing which shows no roads. The eastern portion of the property shown has been leveled into fields with built-up perimeter roads which were used for access during the drilling program.

### 3.1 GENERAL GEOLOGY

The M&T site is part of the present Sacramento River floodplain and the sands and gravels underlying the site consist of channel deposits of the river. Nearby abundant surface meander scars attest to the changing channels of the Sacramento River.

### 3.2 DRILLING PROGRAM

Five holes were drilled on the property at locations as shown on Figure 2. Depths of the drilling ranged from 30 to 70 feet. The logs of the drill holes are presented in Appendix B. Sampling was undertaken on a regular basis and the sample locations (depths) are shown on the logs. As was previous stated, the water table is very shallow and there are several areas of wetlands where standing water appears to be present all the time.

Over 40 previous holes have been drilled on the property in three previous drilling programs. Much of the previous information is rather simplified, however, and no accompanying test data was found. In addition some of the previous drilling did not penetrate the entire depth of the sands and gravels and some of the data was suspect. The five holes in the current drilling program were to confirm the results of the previous drilling, and in addition, to collect samples for testing, especially for determining size distributions. The results of the current drilling program confirmed the accuracy of some of the previous drilling.

The current drilling program had to be confined to existing roadways because of access problems caused by the weather. Rain prior to and during drilling rendered the upper clayey soil on site very soft and it would not support vehicles.

### 3.2.1 Subsurface Description

The results of the drilling program, in combination with some of the previous drilling, indicates the subsurface profile across the site is relatively consistent. A dark colored, fine-grained, relatively soft, clayey surface layer extends to a depth between 3 and 30 feet across the site. Underlying these clays are excellent quality sands and gravels approximately 50 feet thick. Beneath the sands and gravels are older clay deposits.

The sands and gravels are very clean (less than 2% passing a #200 sieve), rounded to subrounded, equidimensional and consist primarily of metamorphic rock, greenstones, quartz, sedimentary rocks, and volcanics. The sands and gravels vary in gradation locally with sandier strata dominating in some areas. Cobbles up to 4 inches are occasionally found.

## 3.3 TEST RESULTS

Testing was undertaken on selected samples principally for gradation analysis to determine fines content and sand-gravel ratios. Additional testing, including sodium sulfate soundness and Los Angeles Rattler, was also undertaken to compare with performance requirements as required by ASTM Standards. This additional testing was undertaken because this is a potential new source of aggregate and no previous test results were available which showed this material met any construction aggregate specifications. The test results are shown in Appendix B. Some of the sieve analyses was conducted by Baldwin Contracting in their own laboratory and those results are so listed.

In general the sands and gravels on site were found to be of excellent quality for use as a construction aggregate. The generally accepted industry standards for aggregate to be used in concrete is ASTM C33 - Standard Specification For Concrete Aggregates. The Los Angeles Rattler Abrasion test and the Sodium Sulfate Soundness test are two of the most definitive tests required in ASTM C33. Results of testing the potential M&T aggregate indicate the Los Angeles Rattler Loss and the Sodium Sulfate Soundness Loss results are some of the lowest of any aggregate in the state. The Los Angeles Rattler showed losses of 16.7 and 18.5%; the maximum allowable loss per ASTM C33 is 50%. The Sodium Sulfate Soundness showed losses between 1.29 and 4.44; the maximum allowable loss per ASTM C33 is 10% for sand and 12% for coarse aggregate. The material, if mined and processed properly, should meet the specifications for a concrete aggregate. It should be noted, however, that no evaluation for potential reactivity was undertaken on the material, but even if it is subsequently shown to be potentially reactive there are mitigating measures that can be taken to counteract reactivity.

The M&T aggregate should also be suitable for use in asphaltic concrete if mined and processed properly. Usually an asphaltic aggregate specification calls for a certain percentage of coarse aggregate to consist of crushed particles. In California this could be as high as 90% and since the M&T aggregate is a river gravel it would require considerable crushing to achieve this. In addition, because the M&T aggregate is so clean, it may require blending with a filler material which would furnish the finer sizes required in an asphaltic concrete gradation specification.

The overall sand to gravel ratio, based on the amount of material passing the #4 sieve size on all samples, is 38 percent sand and 62 percent coarse aggregate. The majority of the material encountered during drilling is classified as gravel. As is evidenced in some of the drill holes there may be areas in the deposit where either sand or gravel predominates. The deposit is not homogeneous in this regard. This may make it necessary during any subsequent mining to blend the material from different locations to obtain a better balance of sand and gravel. In addition, the material is very clean with an average of less than two percent passing the #200 sieve according to the samples collected. There is a possibility, however, that because the material is below the water table and the nature of the sampling method there may have been a small amount of fines washed out of the sample.

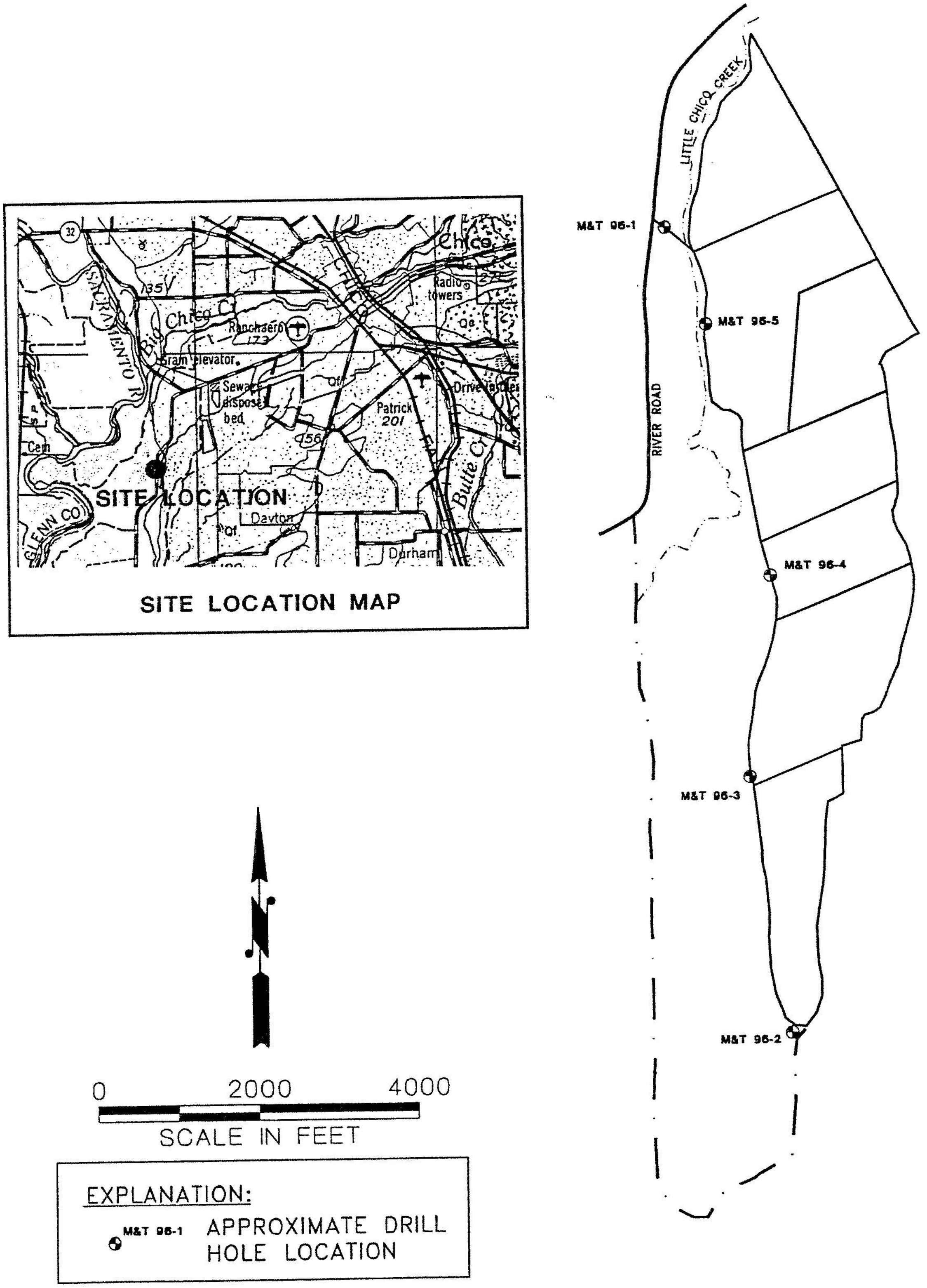
## 3.4 CONCLUSIONS

Based on the drilling and testing program the following conclusions can be reached:

1. The M&T sand and gravel is an excellent potential aggregate source for use in both Portland cement and asphaltic concrete.

2. The sand and gravel unit is very consistent in thickness across the site and averages approximately 50 feet thick. It underlies a fine-grained clayey unit (overburden) ranging from 3 feet to over 20 feet in thickness and averaging approximately 9 feet thick. All aggregate on site is located below the water table.

3. Based on the test results, the percentage of sand in the deposit is approximately 38 percent. Because the deposit may vary in its sand/gravel ratio from place to place it may be necessary to blend the sand and gravel from more than one location on site to assure a specific gradation of material.



**AGRA**
*Earth & Environmental*
737 E. GLENDALE AVENUE
SPARKS, NV. 89431
PHONE: (702) 331-2375

JOB NO. 6-417-8481
DESIGN AGRA
DRAWN TR
DATE 3/12/96
SCALE - - -

FIGURE 2
APPROXIMATE DRILL HOLE LOCATION
M & T PROPERTY
CHICO, CALIFORNIA

D:\T\64178481\FIG-2.DWG

# TABULATION OF TEST RESULTS
## (Testing Completed by AGRA Earth & Environmental, Inc.)

Client: KRC

**Project:** Chico Aggregate Investigation
**Material:** Site Aggregate
**Source:** M&T96 Drill Holes

Job No. 6-417-8481
Page 1 of 3

| HOLE NO. | DEPTH (ft.) | USCS SOIL CLASS | LL | PI | SIEVE ANALYSIS - ACCUM. % PASSING | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4" | 3" | 2½" | 2" | 1½" | 1" | ¾" | ½" | ⅜" | 4 | 8 | 16 | 50 | 100 | 200 |
| M&T96-1 | 5 - 10 | CL | 45 | 27 | | | | | | | | 100 | 100 | 100 | 99 | 98 | 92 | 84 | 75.7 |
| M&T96-1 | 17 - 20 | SP | | | | 100 | 97 | 97 | 91 | 87 | 82 | 73 | 68 | 52 | 40 | 30 | 10 | 3 | 1.9 |
| M&T96-1 | 28 - 30 | GP | | | | | 100 | 98 | 95 | 83 | 73 | 60 | 51 | 35 | 28 | 24 | 13 | 4 | 1.9 |
| M&T96-1 | 38 - 40 | GP | | | | 100 | 97 | 94 | 84 | 59 | 49 | 34 | 28 | 18 | 15 | 14 | 10 | 3 | 1.2 |
| M&T96-1 | 48 - 50 | GP | | | | | 100 | 97 | 97 | 89 | 80 | 64 | 54 | 34 | 20 | 12 | 3 | 1 | 0.9 |
| M&T96-3 | 20 - 25 | GP | | | | | | 100 | 95 | 88 | 83 | 75 | 68 | 47 | 30 | 18 | 3 | 1 | 0.6 |
| M&T96-3 | 35 - 40 | GP | | | | | 100 | 96 | 93 | 86 | 77 | 58 | 47 | 23 | 11 | 7 | 4 | 1 | 0.4 |
| M&T96-3 | 50 - 55 | GP | | | 100 | 95 | 95 | 95 | 91 | 85 | 75 | 59 | 48 | 24 | 12 | 8 | 5 | 1 | 0.5 |

All M&T96-1 Samples Combined from 17' to 50'

**COARSE AGGREGATE**
Durability = 65
Specific Gravity (SSD) = 2.69
Absorption = 0.96%
Los Angeles Rattler (LAR) = 16.7%
Soundness = (see Page 2)

**FINE AGGREGATE**
Durability = 52
Specific Gravity (SSD) = 2.59
Absorption = 1.85%
Soundness = (see Page 2)

All M&T96-3 Samples Combined from 20' to 55'

**COARSE AGGREGATE**
Durability = 87
Specific Gravity (SSD) = 2.68
Absorption = 0.89%
Los Angeles Rattler (LAR) = 18.5%
Soundness = (see Page 2)

**FINE AGGREGATE**
Durability = 65
Specific Gravity (SSD) = 2.63
Absorption = 2.65%
Soundness = (see Page 2)

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Refer to the Site Plan for locations

AGRA
Earth & Environmental

## SODIUM SULFATE SOUNDNESS LOSS: ASTM C-88

| DRILL HOLE | FINE AGGREGATE | | | COARSE AGGREGATE | | |
|---|---|---|---|---|---|---|
| | SIZE | | WEIGHTED % LOSS[1] | SIZE | | WEIGHTED % LOSS[2] |
| M&T 96-1 (Combined sample from 17' to 50') | #4 to #8 | 1.0 | 0.10 | 1" to ¾" | 0.10 | .03 |
| | #8 to #16 | 1.4 | 0.32 | ¾" to ⅜" | 1.68 | .67 |
| | #16 to #30 | 1.8 | 0.43 | ⅜" to #4 | 1.73 | .59 |
| | #30 to #50 | 2.5 | 0.58 | | | |
| | TOTALS | | 1.43 | TOTALS | | 1.29 |
| M&T 96-3 (Combined sample from 20' to 55') | #4 to #8 | 5.0 | 0.50 | 1" to ¾" | 2.47 | .64 |
| | #8 to #16 | 6.2 | 1.43 | ¾" to ⅜" | 3.10 | 1.24 |
| | #16 to #30 | 5.6 | 1.34 | ⅜" to #4 | 2.63 | .89 |
| | #30 to #50 | 5.1 | 1.17 | | | |
| | TOTALS | | 4.44 | TOTALS | | 2.77 |

Notes:

[1] The above weighted % loss is based on the following Hypothetical Gradation from ASTM C33 Sieve Grading For Sand (Center of Grading Band)

[2] The above weighted % loss is based on the following Hypothetical Gradation from ASTM C33 Sieve Grading #57 (Center of Grading Band)

| SIEVE SIZE (Square Openings) | PERCENT PASSING (By Dry Weight) | SIEVE SIZE (Square Openings) | PERCENT PASSING (By Dry Weight) |
|---|---|---|---|
| FINE AGGREGATE[1] | | COARSE AGGREGATE[2] | |
| ⅜ inch | 100 | 1½ inch | 100 |
| #4 | 98 | 1 inch | 97.5 |
| #8 | 90 | ¾ inch | 74.0 |
| #16 | 67 | ½ inch | 42.0 |
| #30 | 43 | ⅜ inch | 34.0 |
| #50 | 20 | No. 4 | 5.0 |
| #100 | 6 | | |
| #200 | 2 | | |

# TABULATION OF TEST RESULTS
## (Testing Completed in Laboratory of Baldwin Contracting Co.)

Client: KRC

**Project:** Chico Aggregate Investigation
**Material:** Site Aggregate
**Source:** M&T96 Drill Holes

Job No. 6-417-8481
Page 3 of 3

| HOLE NO. | DEPTH (ft.) | USCS SOIL CLASS | LL | PI | SIEVE ANALYSIS - ACCUM. % PASSING | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4" | 3" | 2½" | 2" | 1½" | 1" | ¾" | ½" | ⅜" | 4 | 8 | 16 | 30 | 50 | 100 | 200 |
| M&T96-4 | 15 - 20 | SP | | | | 100 | 100 | 100 | 99 | 97 | 94 | 88 | 82 | 66 | 57 | 52 | 46 | 15 | 2 | 0.6 |
| M&T96-4 | 25 - 35 | SP | | | | 100 | 96 | 94 | 91 | 89 | 86 | 80 | 74 | 61 | 49 | 40 | 29 | 9 | 1 | 0.3 |
| M&T96-4 | 35 - 40 | SP | | | | 100 | 96 | 96 | 92 | 88 | 83 | 76 | 71 | 59 | 50 | 43 | 37 | 16 | 1 | 0.3 |
| M&T96-4 | 45 - 50 | GP | | | | 100 | 94 | 93 | 86 | 79 | 69 | 54 | 44 | 26 | 16 | 9 | 5 | 2 | 1 | 0.4 |
| M&T96-4 | 55 - 60 | GP | | | | 100 | 91 | 91 | 85 | 76 | 66 | 51 | 42 | 24 | 12 | 6 | 3 | 1 | 0.2 | 0.1 |
| M&T96-5 | 15 - 20 | GP | | | | 100 | 100 | 98 | 89 | 75 | 67 | 55 | 48 | 34 | 26 | 20 | 13 | 5 | 2 | 1.0 |
| M&T96-5 | 25 - 30 | GP | | | | 100 | 97 | 92 | 85 | 71 | 64 | 53 | 47 | 34 | 24 | 16 | 10 | 5 | 1 | 0.3 |
| M&T96-5 | 35 - 40 | GP | | | | 100 | 100 | 99 | 96 | 90 | 85 | 73 | 64 | 45 | 33 | 22 | 13 | 4 | 1 | 0.3 |
| M&T96-5 | 45 - 50 | GP | | | | 100 | 100 | 99 | 94 | 83 | 75 | 62 | 55 | 40 | 31 | 24 | 13 | 4 | 1 | 0. |
| M&T96-5 | 55 - 60 | GP | | | | | 100 | 98 | 96 | 90 | 81 | 63 | 50 | 28 | 18 | 10 | 4 | 2 | 0.5 | 0.3 |

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Refer to the Site Plan for locations

AGRA
Earth & Environmental

Page 1 of 1

PROJECT KRC - M&T Property

# LOG OF TEST BORING NO. M&T96-1

JOB NO. 6-417-8481 DATE 2/29/96

RIG TYPE Reverse Circulation
BORING TYPE Dual Wall Percussion Hammer
SURFACE ELEV.
DATUM

| Depth in Feet | Continuous Penetration Resistance | Graphical Log | Sample | Sample Type | Blow Counts (SPTs) | Dry Density lbs. per cubic foot | Moisture Content Percent of Dry Weight | Unified Soil Classification | REMARKS | VISUAL CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | GM | | **IMPORTED GRAVEL FOR ROAD** |
| | | | ▽ | SG | | | | CL | | **SANDY CLAY**, with occasional gravel, brown, damp |
| 5 | | | ☒ | D | | | | | | |
| 10 | | | ▽ | SG | | | | | | note: color change to yellow brown at 10' |
| ▽(?) | | | | | | | | | | |
| 15 | | | ▽ | SG | | | | SP | | **GRAVELLY SAND**, with occasional cobbles, saturated, clean |
| | | | ☒ | D | | | | | | |
| 20 | | | | | | | | GP | | **SANDY GRAVEL** |
| 25 | | | | | | | | | | |
| 30 | | | ☒ | D | | | | | | |
| 35 | | | | | | | | | | |
| 40 | | | ☒ | D | | | | | | note: clay lens 2" thick at 40' |
| 45 | | | | | | | | | | note: occasional coarser and finer layers encountered |
| 50 | | | ☒ | D | | | | | | |
| 55 | | | | | | | | | | |
| 60 | | | ☒ | D | | | | CL | | **CLAY**, dense with occasional sand, light brown |
| | | | ▽ | SG | | | | | | |
| 65 | | | | | | | | | | Stopped drill at 65' |
| 70 | | | | | | | | | | |
| 75 | | | | | | | | | | |
| 80 | | | | | | | | | | |
| 85 | | | | | | | | | | |
| 90 | | | | | | | | | | |
| 95 | | | | | | | | | | |
| 100 | | | | | | | | | | |

GROUNDWATER

| | DEPTH | HOUR | DATE |
|---|---|---|---|
| ▽ | < 13.0 | | 2/29/96 |
| ▼ | | | |

SAMPLE TYPE

A - Drill cuttings. B - Block sample.
S - 2" O.D. 1.38" I.D. tube sample.
U - 3" O.D. 2.42" I.D. tube sample.
T - 3" O.D. thin-walled Shelby tube.
SG - Small grab sample. R-Rotary cuttings.
D - Disturbed bulk sample. C - CME sample.

AGRA
Earth & Environmental

Page 1 of 1

# LOG OF TEST BORING NO.M&T96-2

PROJECT KRC - M&T Property

JOB NO. 6-417-8481 DATE 2/29/96

RIG TYPE Reverse Circulation
BORING TYPE Dual Wall Percussion Hammer
SURFACE ELEV.
DATUM

| Depth in Feet | Continuous Penetration Resistance | Graphical Log | Sample | Sample Type | Blow Counts (SPTs) | Dry Density lbs. per cubic foot | Moisture Content Percent of Dry Weight | Unified Soil Classification | REMARKS | VISUAL CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | GM | | **GRAVEL FILL FOR ROADWAY** |
| 5 | | ▨ | | | | | | ~~CL~~ | | **SANDY CLAY,** with occasional gravel, brown, damp |
| 10 | | ▨ | | | | | | | | |
| 15 | | ▨ | | | | | | | | |
| 20 | | ▨ | | | | | | | | |
| 25 | | ▨ | | | | | | | | note: occasional gravel at 28', becoming wetter, must be at top of gravel unit |
| ∇ (?) 30 | | | | | | | | | | Stopped drill at 30'<br>note: water intercepted when permeable gravels were encountered - this is not static ground water level |
| 35 | | | | | | | | | | |
| 40 | | | | | | | | | | |
| 45 | | | | | | | | | | |
| 50 | | | | | | | | | | |
| 55 | | | | | | | | | | |
| 60 | | | | | | | | | | |
| 65 | | | | | | | | | | |
| 70 | | | | | | | | | | |
| 75 | | | | | | | | | | |
| 80 | | | | | | | | | | |
| 85 | | | | | | | | | | |
| 90 | | | | | | | | | | |
| 95 | | | | | | | | | | |
| 100 | | | | | | | | | | |

GROUNDWATER

| | DEPTH | HOUR | DATE |
|---|---|---|---|
| ∇ | < 30.0 | | 2/29/96 |
| ▼ | | | |

SAMPLE TYPE

A - Drill cuttings. B - Block sample.
S - 2" O.D. 1.38" I.D. tube sample.
U - 3" O.D. 2.42" I.D. tube sample.
T - 3" O.D. thin-walled Shelby tube.
SG - Small grab sample. R-Rotary cuttings.
D - Disturbed bulk sample. C - CME sample.

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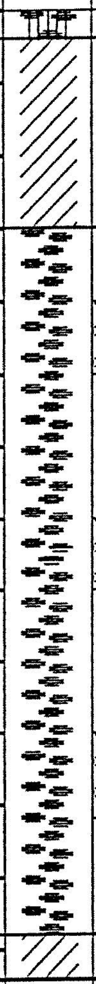
# LOG OF TEST BORING NO.M&T96-3

PROJECT KRC - M&T Property

JOB NO. 6-417-8481 DATE 2/29/96

RIG TYPE Reverse Circulation
BORING TYPE Dual Wall Percussion Hammer
SURFACE ELEV.
DATUM



| Depth in Feet | Continuous Penetration Resistance | Sample | Sample Type | Blow Counts (SPTs) | Dry Density lbs. per cubic foot | Moisture Content Percent of Dry Weight | Unified Soil Classification | REMARKS | VISUAL CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | GM | | **GRAVEL FILL FOR ROAD** |
| | | | | | | | CL | | **SANDY CLAY**, brown, damp |
| ▽(?) 15 | | | | | | | GP | | **SANDY GRAVEL**, with occasional cobbles, saturated<br>note: water encountered when gravel intercepted - not static water level |
| 20 | | ☒ | D | | | | | | |
| 35 | | ☒ | D | | | | | | |
| 50 | | ☒ | D | | | | | | |
| 65 | | | | | | | CL | | **SANDY CLAY**, reddish, dense |
| | | | | | | | | | Stopped drill at 67' |

Depth in Feet: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100

GROUNDWATER

| | DEPTH | HOUR | DATE |
|---|---|---|---|
| ▽ | < 15.0 | | 2/29/96 |
| ▼ | | | |

SAMPLE TYPE

A - Drill cuttings. B - Block sample.
S - 2" O.D. 1.38" I.D. tube sample.
U - 3" O.D. 2.42" I.D. tube sample.
T - 3" O.D. thin-walled Shelby tube.
SG - Small grab sample. R-Rotary cuttings.
D - Disturbed bulk sample. C - CME sample.

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PROJECT KRC - M&T Property

# LOG OF TEST BORING NO. M&T96-4

JOB NO. 6-417-8481 DATE 3/1/96

NOTE: LOGGED BY KRC

RIG TYPE Reverse Circulation
BORING TYPE Dual Wall Percussion Hammer
SURFACE ELEV.
DATUM

| Depth in Feet | Continuous Penetration Resistance | Graphical Log | Sample | Sample Type | Blow Counts (SPTs) | Dry Density lbs. per cubic foot | Moisture Content Percent of Dry Weight | Unified Soil Classification | REMARKS | VISUAL CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | GM | | **GRAVEL FILL FOR ROAD** |
| | | | | | | | | CL | | **SANDY CLAY**, brown, damp |
| 5 | | | | | | | | | | |
| 10 | | | | | | | | SP | | **GRAVELLY SAND**, clean, saturated |
| ∇(?) 15 | | | ☒ | D | | | | | | |
| 20 | | | | | | | | | | |
| 25 | | | ☒ | D | | | | | | |
| 30 | | | | | | | | | | |
| 35 | | | ☒ | D | | | | | | |
| 40 | | | | | | | | | | |
| | | | | | | | | GP | | **SANDY GRAVEL**, trace fines, gravel up to 3" diameter |
| 45 | | | ☒ | D | | | | | | |
| 50 | | | | | | | | | | |
| 55 | | | ☒ | D | | | | | | |
| 60 | | | | | | | | | | |
| | | | | | | | | CL | | **SANDY CLAY**, red |
| 65 | | | | | | | | | | |
| 70 | | | | | | | | | | Stopped drill at 70' |
| 75 | | | | | | | | | | |
| 80 | | | | | | | | | | |
| 85 | | | | | | | | | | |
| 90 | | | | | | | | | | |
| 95 | | | | | | | | | | |
| 100 | | | | | | | | | | |

GROUNDWATER

| | DEPTH | HOUR | DATE |
|---|---|---|---|
| ∇ | < 14.0 | | 3/1/96 |
| ▼ | | | |

SAMPLE TYPE

A - Drill cuttings. B - Block sample.
S - 2" O.D. 1.38" I.D. tube sample.
U - 3" O.D. 2.42" I.D. tube sample.
T - 3" O.D. thin-walled Shelby tube.
SG - Small grab sample. R-Rotary cuttings.
D - Disturbed bulk sample. C - CME sample.

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# LOG OF TEST BORING NO. M&T96-5

PROJECT KRC - M&T Property

NOTE: LOGGED BY KRC

JOB NO. 6-417-8481 DATE 3/1/96

RIG TYPE Reverse Circulation
BORING TYPE Dual Wall Percussion Hammer
SURFACE ELEV.
DATUM

| Depth in Feet | Continuous Penetration Resistance | Graphical Log | Sample | Sample Type | Blow Counts (SPTs) | Dry Density lbs. per cubic foot | Moisture Content Percent of Dry Weight | Unified Soil Classification | REMARKS | VISUAL CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | ▨ | | | | | | CL | | **SANDY CLAY**, brown |
| 5 | | ▨ | | | | | | | | |
| 10 | | ▨ | | | | | | | | |
| ▽(?) 15 | | ░ | ☒ | D | | | | GP | | **SANDY GRAVEL**, clean, trace fines, some sand, some cobbles |
| 20 | | ░ | | | | | | | | |
| 25 | | ░ | ☒ | D | | | | | | |
| 30 | | ░ | | | | | | | | |
| 35 | | ░ | ☒ | D | | | | | | |
| 40 | | ░ | | | | | | | | |
| 45 | | ░ | ☒ | D | | | | | | note: sandier between 35' and 50' |
| 50 | | ░ | | | | | | | | |
| 55 | | ░ | ☒ | D | | | | | | |
| 60 | | ░ | | | | | | | | |
| 65 | | ▨ | | | | | | CL | | **SANDY CLAY**, brown |
| 70 | | | | | | | | | | Stopped drill at 70' |
| 75 | | | | | | | | | | |
| 80 | | | | | | | | | | |
| 85 | | | | | | | | | | |
| 90 | | | | | | | | | | |
| 95 | | | | | | | | | | |
| 100 | | | | | | | | | | |

GROUNDWATER

| | DEPTH | HOUR | DATE |
|---|---|---|---|
| ▽ | < 15.0 | | 3/1/96 |
| ▼ | | | |

SAMPLE TYPE

A - Drill cuttings. B - Block sample.
S - 2" O.D. 1.38" I.D. tube sample.
U - 3" O.D. 2.42" I.D. tube sample.
T - 3" O.D. thin-walled Shelby tube.
SG - Small grab sample. R-Rotary cuttings.
D - Disturbed bulk sample. C - CME sample.

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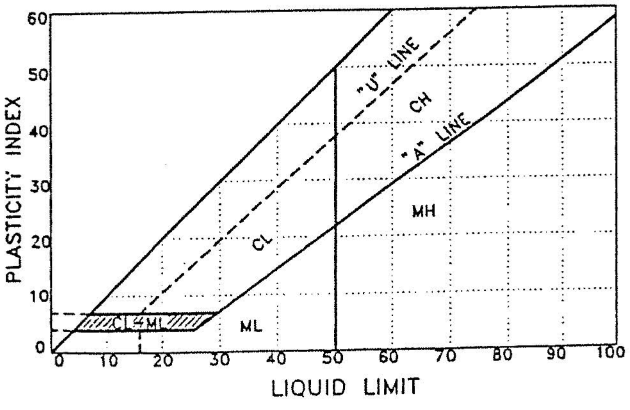
# UNIFIED SOIL CLASSIFICATION SYSTEM

SOILS ARE VISUALLY CLASSIFIED BY THE UNIFIED SOIL CLASSIFICATION SYSTEM ON THE BORING LOGS PRESENTED IN THIS REPORT. GRAIN-SIZE ANALYSIS AND ATTERBERG LIMITS TESTS ARE OFTEN PERFORMED ON THE SELECTED SAMPLES TO AID IN CLASSIFICATION. THE CLASSIFICATION SYSTEM IS BRIEFLY OUTLINED ON THIS CHART. FOR A MORE DETAILED DESCRIPTION OF THE SYSTEM, SEE "THE UNIFIED SOIL CLASSIFICATION SYSTEM" ASTM DESIGNATION: D2487-92.

| MAJOR DIVISIONS | | | | GRAPHIC SYMBOL | GROUP SYMBOL | TYPICAL NAMES |
|---|---|---|---|---|---|---|
| COARSE-GRAINED SOILS (LESS THAN 50% PASSING NO.200 SIEVE) | GRAVELS (50% OR LESS OF COARSE FRACTION PASSING NO.4 SIEVE) | CLEAN GRAVELS (LESS THAN 5% PASSING NO. 200 SIEVE) | | ⁘ | GW | WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, OR SAND-GRAVEL-COBBLE MIXTURES. |
| | | | | ▬ | GP | POORLY GRADED GRAVELS, GRAVEL-SAND-SILT MIXTURES, OR SAND-GRAVEL-COBBLE MIXTURES. |
| | | GRAVELS WITH FINES (MORE THAN 12% PASSING NO. 200 SIEVE) | LIMITS PLOT BELOW "A" LINE & HATCHED ZONE ON PLASTICITY CHART | ▥ | GM | SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES |
| | | | LIMITS PLOT ABOVE "A" LINE & HATCHED ZONE ON PLASTICITY CHART | ▨ | GC | CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES |
| | SANDS (MORE THAN 50% OF COARSE FRACTION PASSING NO.4 SIEVE) | CLEAN SANDS (LESS THAN 5% PASSING NO. 200 SIEVE) | | ⁖ | SW | WELL GRADED SANDS, GRAVELLY SANDS |
| | | | | ⁚ | SP | POORLY GRADED SANDS, GRAVELLY SANDS |
| | | SANDS WITH FINES (MORE THAN 12% PASSING NO. 200 SIEVE) | LIMITS PLOT BELOW "A" LINE & HATCHED ZONE ON PLASTICITY CHART | ▥ | SM | SILTY SANDS, SAND-SILT MIXTURES |
| | | | LIMITS PLOT ABOVE "A" LINE & HATCHED ZONE ON PLASTICITY CHART | ▨ | SC | CLAYEY SANDS, SAND-CLAY MIXTURES |
| FINE-GRAINED SOILS (50% OR MORE PASSING NO.200 SIEVE) | SILTS LIMITS PLOT BELOW "A" LINE & HATCHED ZONE ON PLASTICITY CHART | SILTS OF LOW PLASTICITY (LIQUID LIMIT LESS THAN 50) | | ⁞ | ML | INORGANIC SILTS, CLAYEY SILTS WITH SLIGHT PLASTICITY |
| | | SILTS OF HIGH PLASTICITY (LIQUID LIMIT MORE THAN 50) | | ▮ | MH | INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS, ELASTIC SILTS. |
| | CLAYS LIMITS PLOT ABOVE "A" LINE & HATCHED ZONE ON PLASTICITY CHART | CLAYS OF LOW PLASTICITY (LIQUID LIMIT LESS THAN 50) | | ▨ | CL | INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS |
| | | CLAYS OF HIGH PLASTICITY (LIQUID LIMIT MORE THAN 50) | | ▨ | CH | INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS, SANDY CLAYS OF HIGH PLASITICITY |

NOTE: COARSE GRAINED SOILS WITH BETWEEN 5% & 12% PASSING THE NO.200 SIEVE AND FINE GRAINED SOILS WITH LIMITS PLOTTING IN THE HATCHED ZONE ON THE PLASTICITY CHART TO HAVE DOUBLE SYMBOL.

PLASTICITY CHART



DEFINITIONS OF SOIL FRACTIONS

| SOIL COMPONENT | PARTICLE SIZE RANGE |
|---|---|
| COBBLES | ABOVE 3 IN. |
| GRAVEL | 3 IN. TO NO.4 SIEVE |
| COARSE GRAVEL | 3 IN. TO 3/4 IN. |
| FINE GRAVEL | 3/4 IN. TO NO.4 SIEVE |
| SAND | NO.4 TO NO.200 |
| COARSE | NO.4 TO NO.10 |
| MEDIUM | NO.10 TO NO.40 |
| FINE | NO.40 TO NO.200 |
| FINES (SILT OR CLAY) | BELOW NO.200 SIEVE |

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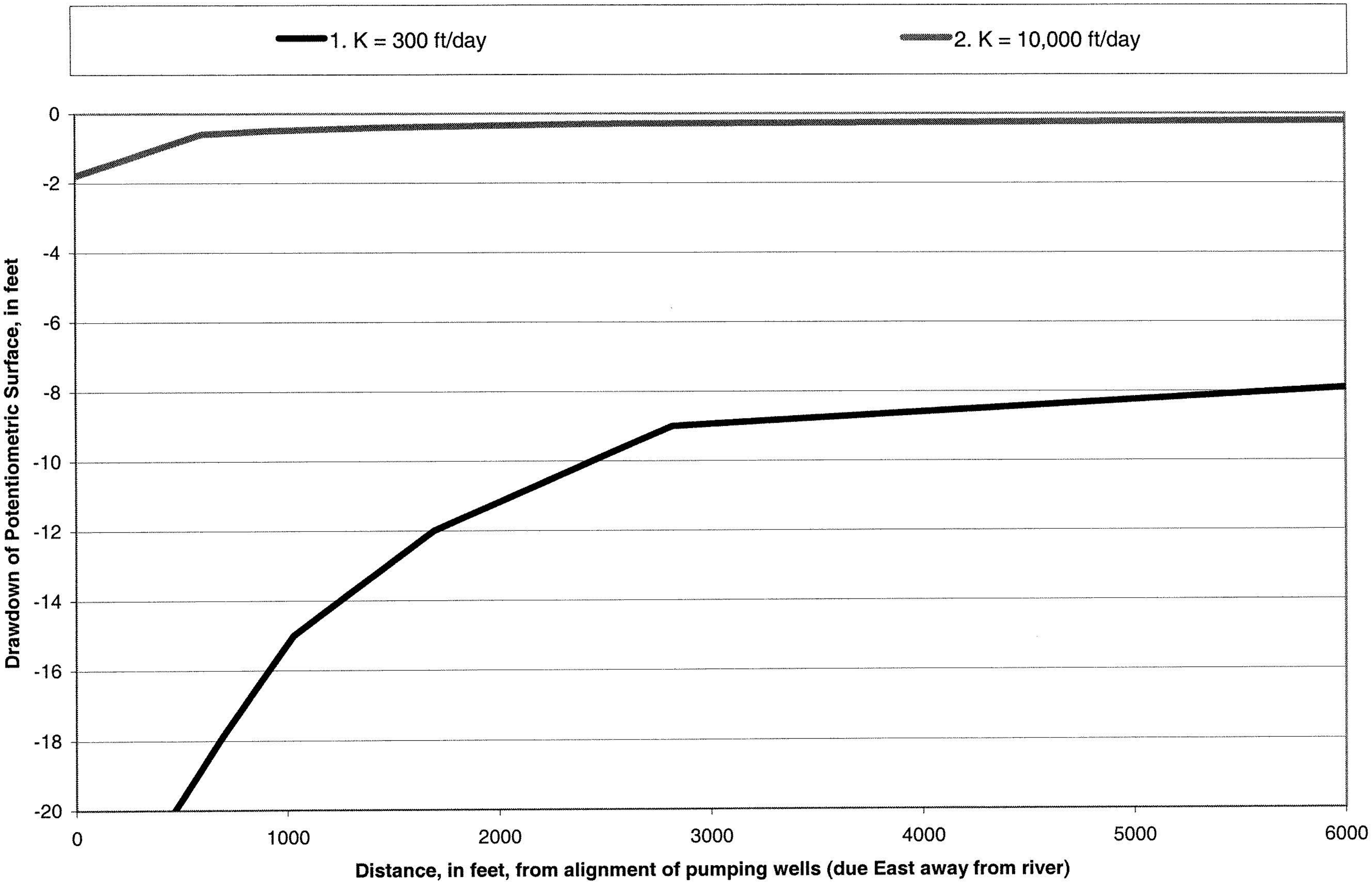
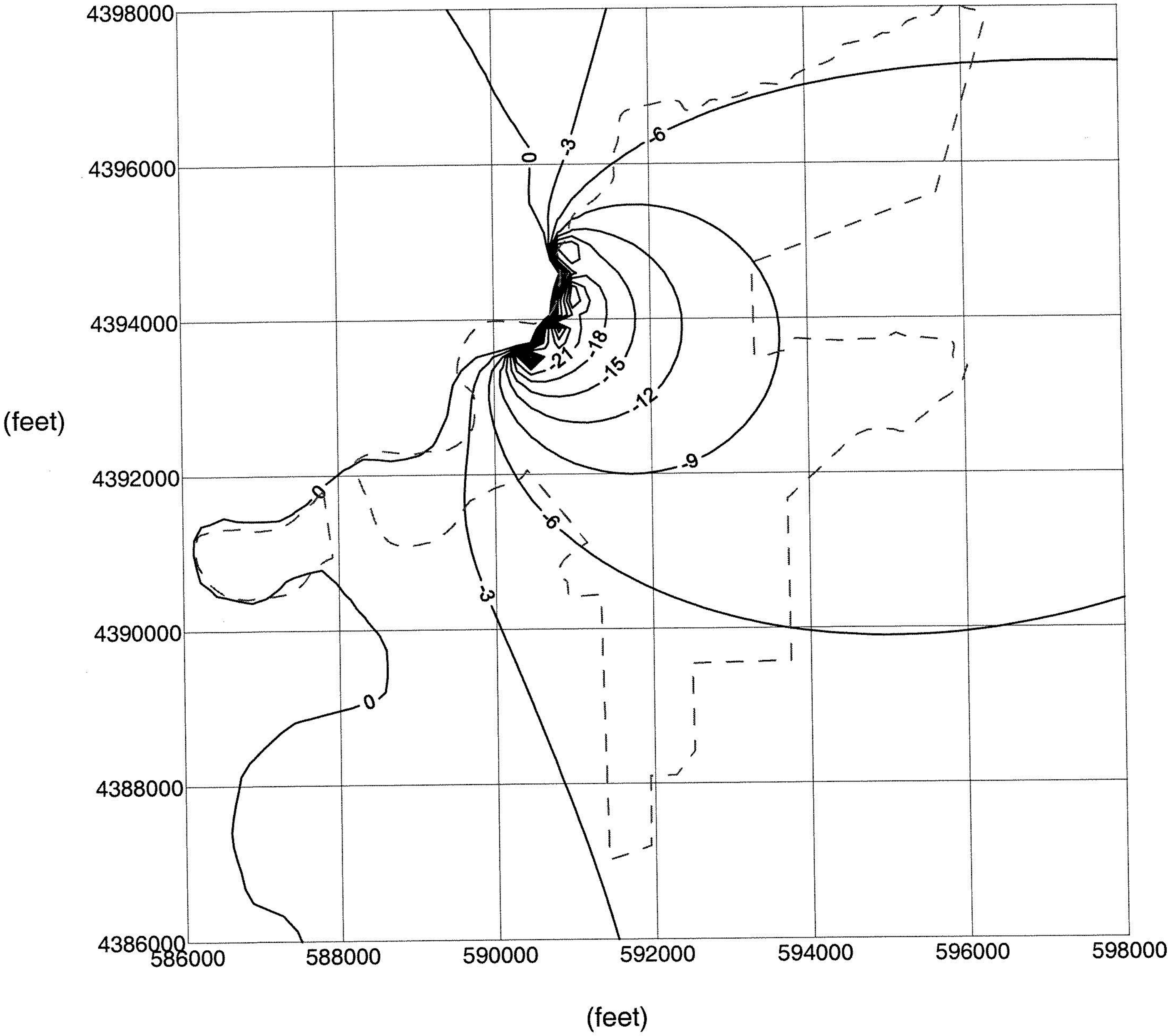
# Attachment D
# Model Output

## Drawdown Profiles for Two Scenarios, both pumping at 150 cfs



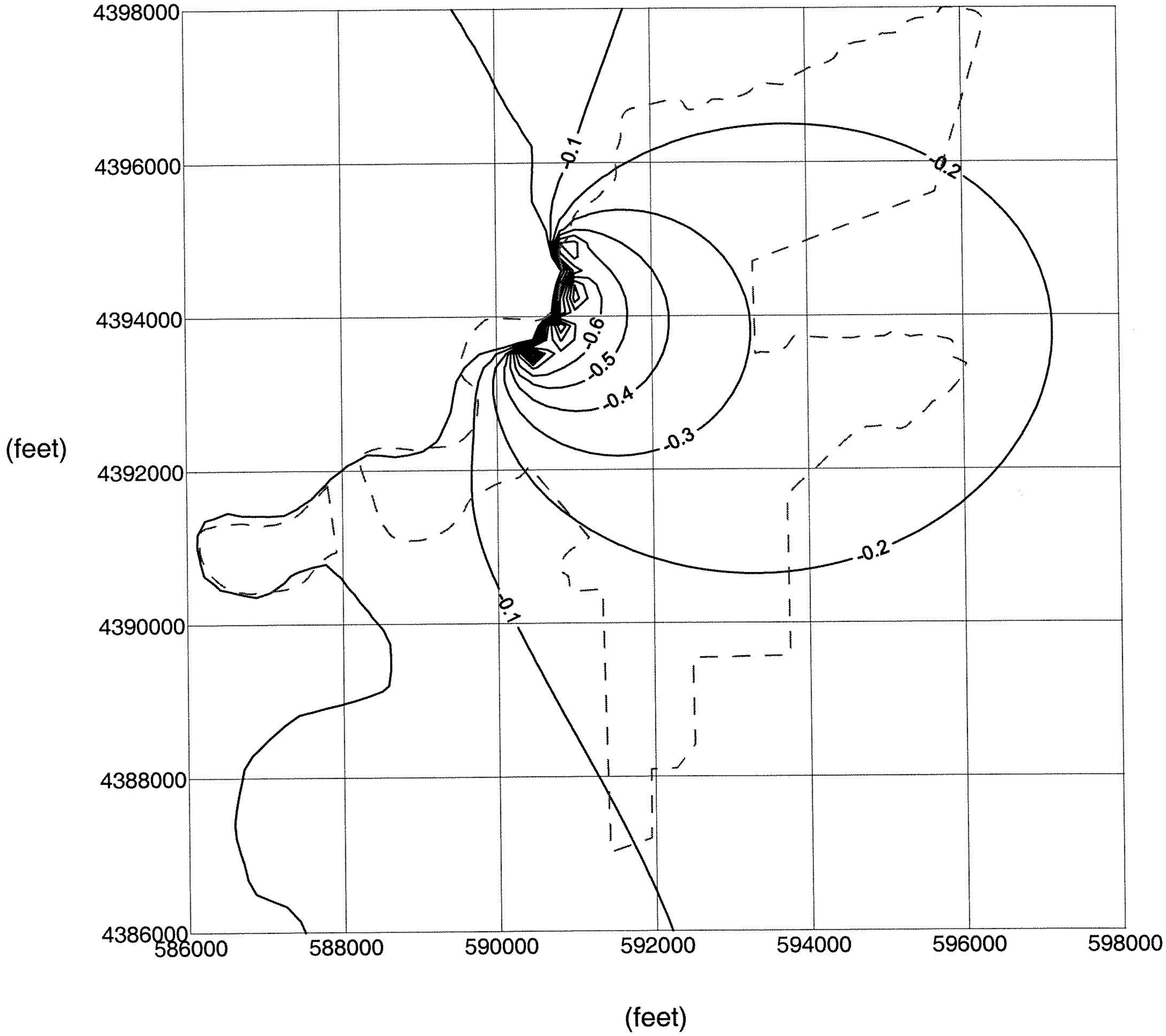
# 150 cfs, 4 Wells Pumping at 37.5 cfs / 24.2 mgd each
# Groundwater Surface Elevation Drawn Down -- k = 10^2.5 (ft/day)

(Draw down in feet)



# 150 cfs, 4 Wells Pumping at 37.5 cfs / 24.2 mgd each
# Groundwater Surface Elevation Draw Down -- k=10^4 (ft/day)

(Draw down in feet)



# Attachment E
# Cost Memo
from
# Ranney, Inc.

**RANNEY DIVISION MEMORANDUM**

**TO:** JOHN SHOWRONEK, MWH

**FROM:** MATTHEW REED

**SUBJECT:** PRELIMINARY COSTS, M&T RANCH

**DATE:** DECEMBER 10, 2003

**CC:** PAUL BURTON

Based upon geologic information provided by MWH, we have developed a conceptual design for a Ranney Collector and a preliminary estimate of cost for that construction. The conceptual design includes a 16 ft inside diameter reinforced steel concrete caisson installed to 90 feet, with bottom plug, and extending 10 feet above grade for flooding considerations; and eight 200 foot long 8-inch diameter wire-wrapped stainless steel laterals with valves, installed at the base of the caisson

For costing purposes, we have assumed two 3500 gpm pumps @ 100 feet TDH and manual controls only, a top slab on the caisson with hand rail and ladder but no pumphouse. We have assumed electrical will be provided to within 50 feet of the collector and the primary transformer will be provided by others. We have included an estimate for the mechanical piping from the pumps to an elbow below grade with all associated valving. We have not assumed any expense associated with permitting, design, or owner oversight/construction management.

Based upon this conceptual design and associated assumptions, we have developed an estimated cost of $1,850,000. We anticipate this estimate is accurate to within plus 50%, minus 30% of the actual costs. If testing demonstrates that more than 10 MGD can be extracted from a single location, the costs would be on the higher end of that range.

# Attachment F
# Interconnection of Groundwater – Surface Water

3-Dec-03 via email from Dan McManus, DWR

# M&T CHICO RANCH
# INTERCONNECTION OF GROUND WATER - SURFACE WATER
## (excerpts from M&T Phase II CU Investigation)

…Currently M & T Chico Ranch has 29 agricultural production wells in operation. Out of the 29 wells, construction data are available for 17. Of these 17 wells, the average depth to the first casing perforation is 120 feet. The average discharge from these wells is 2,200 gallons per minute, with a specific capacity of 70 gpm/ft.

To test the hydrologic continuity between the Sacramento River and nearby M&T Chico Ranch wells, a three-day aquifer test was performed using pumping well T21N/R01W-11K01, and observation well T21N/R01W-14Q01.

The pumping well (11K01) is approximately 400 feet southeast of the Sacramento River. Well 11K01 is 665 feet deep, with 12-inch casing to 320 feet and perforations from 128 to 250 feet. Discharge measured with a pitot tube during the aquifer test, was 3,500 gpm. The static water elevation was 113.5 feet (depth-to-water = 15.8 feet). The surface water elevation of the Sacramento River, nearest to the well was surveyed at 114.1 feet when the stage at the Ord Ferry gage was 97.9 feet.

Results from the aquifer test along the Sacramento River indicate that the pumping well (11K01) encountered a very substantial recharge source within nine minutes of the starting test time. At this point, the ground water level in the pumping well had reached a drawdown elevation of 100.3 feet. Ground water elevation in the pumping well remained fixed at 100.3 feet for the remainder of the test (about 79 hours). Ground water elevations in the well 14Q01 declined a maximum of about 0.5 feet during the test. Further analysis, comparing the specific capacity of 11K01 to other Ranch wells of similar construction, indicates that approximately 2,000 gpm of the 3,500 gpm discharge from 11K01 can be attributed to the subsurface withdrawal of Sacramento River water, with the remaining 1,500 gpm being attributed to withdrawal from aquifer storage.

Aquifer performance tests conducted on 11K01 and other wells on the Ranch indicate a fairly substantial interconnection between surface water systems and the upper 200 feet of the unconfined ground water aquifer in this area. The amount and significance of inner-connectivity depends upon proximity of the pumping well and surface water source. Overall, indications are that water pumped from shallow cased wells within a half mile of a surface water source, is being drawn, in part, from the surface water source.

# TECHNICAL MEMORANDUM

**Subject:** **Potential Water Supply Alternative - Scenarios 1 through 4**

**Workshop #2** **March 17 – 19, 2004**

## PURPOSE

This memo describes four scenarios that could be used to solve or partially solve problems associated with the impacts of Sacramento River meander on the M&T/Llano Seco Pumping Plant and fish screen facility. Also included is a simple analysis of the legal and economics of each scenario examined. Presently, the fish screen installed on the intake of the diversion does not meet fish screen criteria established by the National Oceanic and Atmospheric Agency Fisheries (NOAA Fisheries) (formerly National Marine Fisheries Service) or the California Department of Fish and Game (CDFG). This problem has been caused by significant deposition of alluvial sediment from the meandering streambed of the Sacramento River.

## BACKGROUND

In response to discussions held at the November Steering Committee Workshop, MWH was asked to prepare a Technical Memorandum (TM) that would further develop preliminary costs (see separate TM) for conceptual purposes for each of the scenarios described below. It is important to note that more information will be required for each scenario to accurately assess and evaluate probable outcomes.

## SCENARIO DESCRIPTIONS

### Scenario No. 1 – Install Additional “Tee” Fish Screen Approximately 500 Feet Westerly of the Existing Diversion

For this scenario, an additional diversion intake would be located on the bank opposite the existing diversion. The conveyance would be a 96-inch pipe micro-tunneled under the river below the scour zone. A caisson would be placed on the land-side of the levee near the pumping plant and another caisson would be located on the west bank 700 feet across the river. After the pipe and new caissons were in place, a new intake would be constructed from the west bank caisson into the stream for the water diversion. The new intake would be similar to the existing intake located on the east bank.

Problems with associated with Scenario No. 1 include the following:

- Would the west bank caisson be acceptable to state and federal agencies?
- Would the river meander away from the west bank caisson?

- Would water still flow by gravity to the existing wet well? (Costs would increase if a booster pump were required.)
- Would the fish screens be operable in the future based on possible or projected continued meandering of the river?
- Would the Reclamation Board allow a gate to be installed in the east bank caisson in lieu of a gate on the river-side of the levee?

### Scenario No. 2 – Groundwater Extracted with Production Wells

This scenario consists of drilling and casing 23 new production groundwater wells. A test well would first have to be installed followed by a series of monitoring wells to determine yield and drawdown impacts on the groundwater basin. After these wells were installed, data would indicate the spacing and number of wells required to produce 150 cubic feet per second (cfs).

For this scenario, spacing would be 250 feet, and it has been assumed that yield would be about 3,200 gallons per minute (gpm) (7 cfs). Wells would be installed on the land-side of the levee. Installation of wells would begin about 1,250 feet north of the existing pumping station and end 3,250 feet south of the pump station. Discharge from these wells would be directed into a pipe conveyance system that would connect to the existing 72-inch pipeline to the main canal. Nineteen larger producing wells would be needed, with an additional four wells about 1,000 feet to the east. The wells were assumed to be located near farm access roads.

Well installation concerns include the following:

- This scenario depends on the diversion being credited with the take of water from the river, not from the safe groundwater yield of the area.
- Lowering the water table in this groundwater basin would need to be acceptable to the public, for other wells located within the same groundwater basin now, and in the future.
- The landowners would need to agree to the selected location of the production wells providing the water supply.
- The groundwater policy for Butte County would need to be waived for this scenario to be used.
- A test well would need to be constructed with a series of monitoring wells in the area to determine the impacts of extended pumping on the surrounding groundwater elevations.
- Operation and maintenance costs would increase over costs for the existing operation.
- There would be additional lift from the ground water elevation and pushing the water through the pipe into the wet well or directly into the existing pipe and up into the conveyance.
- Maintenance of the motors and wells would also cause significant increase in costs.

## Scenario No. 3 – Groundwater Extracted from Ranney Wells

Ranney wells would have many of the same problems as production wells. (However, they would take up less area, and thus likely cause less disruption for the landowner.) Groundwater vs. surface water rights and impacts are the same. This option also would require a test well to be drilled to determine the impact of the Ranney wells on groundwater elevations.

Concerns about the Ranney Wells scenario are as follows:

- Yields of water obtainable with various locations of intakes such as laterals upstream and downstream and not our under the river of do the laterals all. Have to be located under the cropland.
- Maintenance costs would be incurred for the horizontal laterals of the main well structure.
- Additional pumps and motors would be required to lift water from the well into the conveyance.
- Construction would be required of conveyance from well to well and the connection to the existing 72-inch pipeline and to the conveyance canal.
- Operation and maintenance costs would increase for this scenario because of additional structures and some unknowns.

## Scenario No. 4 – Installation of Rock Groins Similar to the Cal-Trans Project at Butte City

The Butte City Bridge Project has been closely followed during the M&T/Llano Seco Fish Screen Project. The first stage the Butte City Bridge Project was completing the Environmental Impact Statement (EIR). Next was physical modeling at UC Davis of the river channel for determining the length, spacing, and number of groins required for directing the river channel while protecting the bridge structure. The Sacramento River channel was soon to move to the west side of the area, which would leave the bridge without an approach on the west end. In lieu of extending or reconstructing the bridge, it was decided to use the groins to direct the river channel back towards the left, or east, bank; Cal-Trans engineers designed the groin structures. This project will be advertised for bid in early March 2004, when engineering drawings will be reviewed.

In the meantime, it has been assumed that a similar solution could exist for the M&T/Llano Seco (as identified by the Stillwell Water Sciences report – August 13, 2001). The procedures and costs for M&T/Llano Seco would be roughly the same as those of the Butte City Bridge Project. Environmental costs and modeling costs are known; engineering costs are unknown but Cal Trans is discussing a total project cost of about $7-8 million. The engineers estimate of construction costs is $3.8 million, leaving modeling, environmental, engineering, and mitigation costs at about $3.2 million to $4.2 million.

This scenario will be evaluated in depth if the other scenarios cause impacts unacceptable to landowners and agencies. In addition, a groin on the east bank above the mouth of Big Chico Creek would need to be included in any modeling to determine if that groin would impact the area of concern. The time for implementing such a solution would be at least 3-5 years.

### Conclusion

When additional modeling for the groins or the test wells and monitoring wells have been completed, the best scenario for correcting the problem can be better determined. After direction for further work is given, results of the subsequent investigations should provide sufficient information and detail to address the concerns and engineering unknowns discussed in this review.

## ECONOMIC AND LEGAL ASPECTS OF THE SCENARIOS

Legal discussions in this section of the TM are based on knowledge of the CA State Water Resources Control Board (SWRCB) water rights policies and regulations and not on case law or any interpretation of laws or ordinances.

Economics are based on any increase of operation and maintenance costs compared to the present operation and maintenance of the fish screens and pumping plant. Possible additional capital costs that may be incurred beyond these estimates for construction also are discussed.

### Scenario No. 1 – Install Additional "Tee" Fish Screen Approximately 500 Feet Westerly of the Existing Screen

Legal

Scenario No. 1, "chasing the river," would consist of constructing a new caisson on the opposite bank of the river and then constructing a new intake for diverting the surface water supply. Since this scenario would involve the same water supply and place of use (POU), no change in the legality of the water rights would occur. The California State Water Resources Control Board (SWRCB) would need to be notified of the change in point of diversion, and that the surface water POU would remain the same; no further legal obligation would apply, as this scenario would fully comply with present water rights laws and regulations.

Economics

Economically, costs for operation and maintenance would remain the same with this scenario. Additional costs would be incurred if the intake would have to be relocated again in the future or if the screens had to be removed for some reason. Accessibility to the other bank offers more difficulty from the standpoint of acessability and convenience of observing the operations of the system. Also, a minor amount of additional head would be needed due to drawdown in the wet well to cause the water to flow to the east bank. In addition, this scenario possibly could require additional costs in the future for further meandering of the river channel, which would result in this newly installed new fish screen site being out of compliance with the fish screen criteria.

### Scenario No. 2 – Groundwater Extracted with Production Wells

<u>Legal</u>

Scenario No. 2 consists of installing high production groundwater wells on the land-side of the levee. The majority of the wells would be located just outside the land-side toe of the levee and would likely be considered as a take of water from the flow of the Sacramento River. These wells would fall into the category of taking groundwater in lieu of surface water but still depleting the seepage (groundwater) that likely would have entered the Sacramento River as accretion flows. Therefore, it can be concluded that the groundwater wells are drawing from surface flows of the Sacramento River. This information would need to be furnished to the SWRCB. The water user would have to report the quantities of water used as being diverted from the Sacramento River under water rights.

The M&T Chico Ranch attorney, Mr. Jeff Meith, was of the opinion that Butte County groundwater ordinance Chapter 33 would not apply to this groundwater pumping option. According to Mr. Meith, even though the water supply is removed from the groundwater pool, the basin is close enough to the river that a large portion of the groundwater in this part of the basin is moving into the flow of the river.

<u>Economics</u>

This scenario involves additional costs, including operation costs of pumping the water from the groundwater basin into the conveyance system and up to the main canal. Also, these additional facilities would require some degree of maintenance. Even if the existing pumping plant were taken out of use, operating costs for this type of system would exceed the costs of the present diversion and conveyance.

### Scenario No. 3 – Groundwater Extracted with Ranney Wells

<u>Legal</u>

Legal issues for this scenario are very similar to Scenario No. 2 in that water would be extracted from the groundwater basin in lieu of surface water. The water pumped with this system would be credited as much from surface water of the river as water from the safe yield of the groundwater basin. In this case, also, the water supply from the Ranney wells should be reported to the SWRCB as a diversion under M&T's water rights. The Bureau of Reclamation (USBR) would also account for the water as both base and project water supply, as it applies to the water rights settlement contract currently held by M&T Chico Ranch with the USBR. Similar to Scenario No. 2, this scenario likely would be exempt from the Butte County groundwater policy.

<u>Economics</u>

This scenario, like Scenario No. 2, would have increased costs because water would need to be lifted from groundwater, energy would be needed for pushing the water through the conveyance into the existing pipeline, and operation and maintenance costs would be incurred. In addition, failure or the lateral and caisson systems would be possible.

## Scenario No. 4 - Installation of Rock Groins Similar to the Cal-Trans Project at Butte City

### Legal

Groins have been placed up and down the Sacramento River and in other meandering channels over the years to direct the water and meandering to suit the needs of adjacent lands. With the current preservation of the meandering channel, the number of groins has been reduced, and when the groins were placed to provide desired solutions, there would be mitigation requirements. Regarding legal liabilities, the constructor could be considered the owner. Since the river channel is owned by the state, the owner (builder) could be liable for maintenance, and any disrepair and accidents that occur because of the structure. This also could involve liability on the part of the "owner." So anything that happens because of the structure could be a legal liability to the builder. An official legal opinion relating to liability should be obtained to clarify this issue.

### Economics

After capital costs, operation and maintenance cost likely would not be incurred. However, if a major flood occurred that caused a large amount of debris to collect on or around the groin, there could be expenses to clear the debris away. If a sheetpile wall were constructed in the center of the rock structure, any deterioration of the structure would be highly unlikely. It is also unlikely that deterioration of the structure would cause a change in the function (providing protection to the diversion structure) and therefore repairs would not be required.

## Conclusions

Legally, the simplest scenarios would be the new intake (Scenario No. 1) and the groins (Scenario No. 4). The groundwater scenarios involve surface water rights vs. groundwater rights, which would not be an insurmountable problem but could be a complication.

Economically, costs for the new intake (Scenario No. 1) and groins (Scenario No. 4) are about equal to what is now being spent for operations and maintenance. The groundwater options would involve an increase in costs due to additional conveyance, pumps required to lift the water, and pressure needed to convey the water up to the present point of diversion.

# TECHNICAL MEMORANDUM

**MWH**

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**Subject:** **Preliminary Cost Estimates, legal and economic discussion for Potential Water Supply Alternative – Scenarios 1 through 3**

**Workshop #2** **March 17 – 19, 2004**

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Following are descriptions (including preliminary cost estimates) for construction work that would be necessary for each of the three scenarios currently under consideration for the purpose of maintaining a 150-cfs water supply for M&T Chico Ranch at the Parrott Pumping Plant facility. Under each scenario, the existing pumping plant would remain in operation until the final tie-in work, which could be performed during the irrigation off-season.

## Scenario No. 1 - Install Additional "Tee" Fish Screen Approximately 500 Feet Westerly of the Existing Screen

Under Scenario No. 1, caisson structures would be constructed on both sides of the river, with the east side structure located just outside the levee (adjacent to the existing pump station), and the west side structure located approximately 100 feet westerly of the existing river bank (a potential problem with the west side caisson is the acceptability of constructing the concrete structure at a location that may someday be within the active river channel). The caisson structures would serve two purposes (1) as jacking (east side) and receiving (west side) pits during installation of 700 lineal feet of 96-inch diameter piping (which would be installed below the maximum scour depth) by means of micro tunneling, and (2) for conveyance, as described below.

A sheet pile cofferdam would be installed on the west side of the river for the purpose of constructing a new intake facility, complete with four 54-inch diameter tee fish screens (same as the existing screens, with submergence equal to greater than the existing screens), and the intake would be connected to the caisson structure with 150 lineal feet of 96-inch diameter piping. Four 6-inch diameter air-burst pipelines would be routed from the new intake facility to the existing pump station through the 96-inch diameter piping. Deflection H-piles would be installed upstream of the new intake facility (which may require some sort of above-water marking to identify the hazard to boating), followed by placement of riprap on the three exposed sides of the facility, including the west side river bank.

On the east side of the river, a 96-inch x 96-inch electrically operated slide gate would be installed in the caisson structure, and the structure would be connected to the existing pump structure with 120-inch diameter piping. It should be noted that there would be a significant increase in costs if the slide gate is required to be located on the water side of the levee.

As shown on the attached spreadsheet, the estimated cost to construct Scenario No. 1, including a 20 percent contingency, is $6,391,800. The annual energy cost would not be impacted by this scenario, which for comparison purposes is estimated to be approximately $131,000 (based on 45,000 acre-feet of water lifted 30 feet at $0.09 per kWh).

Scenario No. 2 - Ground Water Extracted with Production Wells

Under Scenario No. 2, the 150 cfs water supply would be maintained through extracting ground water from 23 new production wells, although some test work would be necessary to verify the quantity of wells required, including the allowable spacing. In addition, a study of the potential impact to surrounding ground water wells would be necessary. Construction of the facilities would have both long and short-term impacts on farmed land within the project area. Nineteen wells (7 cfs each) would be located immediately adjacent to the river levee, starting approximately 1,250 feet northerly of the existing pumping plant, and ending approximately 2,750 feet southerly of the plant, with a spacing between wells of 250 feet. Each of the four remaining wells (4.5 cfs each) would be located a minimum of 1,000 feet from the "7 cfs" wells. The wells would be equipped with pumping units, complete with discharge piping, butterfly valve, check valve, and electrical work. The transmission piping necessary to transport well water to the existing pumping facility ranges from 16 to 66 inches in diameter, and the transmission piping would be connected to the existing pump station manifold piping.

As shown on the attached spreadsheet, the estimated cost to construct Scenario No. 2, including a 20 percent contingency, is $5,984,400. The estimated annual energy cost is approximately $330,000 (based on 45,000 acre-feet of water lifted 75 feet at $0.09 per kWh).

Scenario No. 3 - Ground Water Extracted with Ranney Wells

Under Scenario No. 3, the 150 cfs water supply would be maintained through extracting ground water from 4 Ranney wells, although some test work would be necessary to verify the quantity of wells required, including a study of the potential impact to surrounding ground water wells. Construction of the facilities would have both long and short-term impacts on farmed land within the project area. The wells would be located immediately adjacent to the river levee, starting approximately 1,250 feet northerly of the existing pumping plant, and ending approximately 2,750 feet southerly of the plant, with a minimum spacing between wells of 1,000 feet. Each well would be equipped with a 37.5-cfs pumping unit, complete with discharge piping, butterfly valve, check valve, and electrical work. The transmission piping necessary to transport well water to the existing pumping facility ranges from 36 to 60 inches in diameter, and the transmission piping would be connected to the existing pump station manifold piping. Approximately 1 mile of overhead electrical line would be constructed to provide power for the wells.

As shown on the attached spreadsheet, the estimated cost to construct Scenario No. 3, including a 20 percent contingency, is $15,376,200. The estimated annual energy cost is approximately $153,000 (based on 45,000 acre-feet of water lifted 35 feet at $0.09 per kWh).

It should be noted that, under this scenario, there would be a significant change in construction costs if the results of the above-mentioned testing support either decreasing or adding to the quantity of wells. For example, if the supply can be meet with two Ranney wells, the construction costs under this scenario would be approximately $8,400,000. However, if it is determined that six wells are necessary, the approximate cost would be $22,400,000.

M&T Chico Ranch
Preliminary Construction Cost Estimate (1)
Scenario No. 1 - Install Additional Tee Fish Screen

| Description | Quantity | Unit | Unit Cost | Total Cost |
|---|---|---|---|---|
| Caisson bore structures | 2 | ea | $750,000 | $1,500,000 |
| 96-inch dia. pipe (between bore structures) | 700 | lf | $4,000 | $2,800,000 |
| 96-inch x 96-inch electrically operated slide gate | 1 | ea | $75,000 | $75,000 |
| 96-inch dia. pipe (between west bore and new screen facility) | 150 | lf | $960 | $144,000 |
| 120-inch dia. pipe (connection to existing pump structure) | | ls | | $75,000 |
| 6-inch air burst piping | 4,200 | lf | $25 | $105,000 |
| Sheet pile cofferdam (250 lf x 40' long) | 10,000 | $ft^2$ | $25 | $250,000 |
| Cofferdam dewatering | | ls | | $50,000 |
| Structural footing slab and seal concrete | 200 | $yds^3$ | $400 | $80,000 |
| 54-inch dia. tee fish screen with 66-inch dia. manifold piping | | ls | | $175,000 |
| Riprap | 250 | $yds^3$ | $90 | $22,500 |
| Deflection H-piles | | ls | | $50,000 |
| SUBTOTAL | | | | $5,326,500 |
| CONTINGENCY @ 20% | | | | $1,065,300 |
| TOTAL | | | | $6,391,800 (2) |

(1) The estimate of construction costs are at the feasibility level, and therefore very preliminary in nature.
(2) Excludes operations, maintenance and replacement costs.

M&T Chico Ranch

Preliminary Construction Cost Estimate [(1)]

Scenario No. 2 - Ground Water Extracted with Production Wells

| Description | Quantity | Unit | Unit Cost | Total Cost |
|---|---|---|---|---|
| 7.0 cfs production well | 19 | ea | $100,000 | $1,900,000 |
| 4.5 cfs production well | 4 | ea | $60,000 | $240,000 |
| Well site electrical work | 23 | ea | $30,000 | $690,000 |
| Overhead electrical line (1.5 miles) | | ls | | $115,000 |
| Well pump discharge piping with butterfly and check valve | 23 | ea | $30,000 | $690,000 |
| Transmission piping: | | | | |
| 16-inch dia. | 4,000 | lf | $48 | $192,000 |
| 30-inch dia. | 2,500 | lf | $120 | $300,000 |
| 42-inch dia. | 1,250 | lf | $168 | $210,000 |
| 54-inch dia. | 1,250 | lf | $216 | $270,000 |
| 66-inch dia. | 1,250 | lf | $264 | $330,000 |
| Connect to existing facility | | ls | | $50,000 |
| SUBTOTAL | | | | $4,987,000 |
| CONTINGENCY @ 20% | | | | $997,400 |
| TOTAL | | | | $5,984,400 (2) |

(1) The estimate of construction costs are at the feasibility level, and therefore very preliminary in nature.

(2) Excludes operations, maintenance and replacement costs.

# M&T Chico Ranch
## Preliminary Construction Cost Estimate (1)
## Scenario No. 3 - Ground Water Extracted with Ranney Wells

| Description | Quantity | Unit | Unit Cost | Total Cost |
|---|---|---|---|---|
| Ranney well | 4 | ea | $2,800,000 | $11,200,000 |
| Pumping unit (37.5 cfs) | 4 | ea | $75,000 | $300,000 |
| Miscellaneous metalwork | 4 | ea | $8,000 | $32,000 |
| Electrical work | 4 | ea | $75,000 | $300,000 |
| Overhead electrical line (1 mile) | | ls | | $70,000 |
| Pump discharge piping (36-inch dia. x 30-foot long) with butterfly and check valve | 4 | ea | $50,000 | $200,000 |
| Transmission piping: | | | | |
| 36-inch dia. | 1,500 | lf | $126 | $189,000 |
| 48-inch dia. | 1,250 | lf | $168 | $210,000 |
| 60-inch dia. | 1,250 | lf | $210 | $262,500 |
| Connect to existing facility | | ls | | $50,000 |
| SUBTOTAL | | | | $12,813,500 |
| CONTINGENCY @ 20% | | | | $2,562,700 |
| TOTAL | | | | $15,376,200 (2) |

(1) The estimate of construction costs are at the feasibility level, and therefore very preliminary in nature.
(2) Excludes operations, maintenance and replacement costs.

## ECONOMICS AND LEGAL ASPECTS OF THE ALTERNATIVES

The legal discussions here are based on knowledge of the SWRCD water rights policies and regulations. The information is not based on case law or any interpretation of laws or ordinances.

The economics are based on any increase of operation and maintenance costs as compared to the present operation and maintenance of the fish screens and pumping plant. There may be some discussions of possible additional capital costs that may be incurred beyond this review and construction.

### Scenario No. 1 – Install Additional "Tee" Fish Screen approximately 500 feet Westerly of the Existing Screen

#### Legal

Alternative No. 1 of "chasing the river" which consists of constructing a new caisson on the opposite bank of the river and then constructing a new intake for diverting the surface water supply has to be evaluated for both economics and legality. Since this alternative remains with the same water supply and place of use there would be literally no change in the legality of the water rights. The California State Water Resources Control Board (SWRCB) should be notified of the change of point of diversion and that the place of use of the surface water remains the same and that would be the end of the obligation. Everything would be back in full compliance with the present laws and regulations for water rights.

#### Economics

On the economics of this alternative the costs for operation and maintenance would remain the same. Additional costs would be incurred if the intake would have to be relocated again in the future. There would also be additional costs if the screens had to be removed for some reason. Accessibility to the other bank offers more difficulty. There would also be a minor amount of additional head because of drawdown in the wet well to cause the water to flow to the east bank.

This is one alternative that could possibly require additional costs in the future for further meandering of the river channel and leaving the new fish screen site out of compliance with the fish screen criteria.

### Scenario No. 2 – Ground Water Extracted with Production Wells

#### Legal

Alternative No. 2 is scenario of the placement of high production groundwater wells on the land side of the levee. The majority of the wells would be located just outside of the land side toe of the levee and would likely be considered as a take of water from the flow of the Sacramento River. These wells would fall into the category of taking ground water in lieu of surface water but still depleting the seepage (ground water) that would of quite likely entered the Sacramento River as accretion flows. Therefore the conclusion can be drawn that the groundwater wells are drawing from the surface flows of the Sacramento River. The SWRCB would need to be furnished that information. The water user should report the quantities of water used as being diverted from the Sacramento River under the water rights.

In discussions with the attorney, of M&T Chico Ranch, Mr. Jeff Meith, he was of the opinion that the Butte Co. groundwater ordinance Chapter 33 would not apply to this groundwater pumping option. The logic is that the water supply even though it is removed from the groundwater pool, the basin is close enough to the river that a large portion of the groundwater in this portion of the basin is moving into the flow of the river.

### Economics

There are additional costs associated with this alternative. The operation costs of pumping the water from the groundwater basin and then into the conveyance system and up to the main canal. There will also be some maintenance of these additional facilities. Even if the existing pumping plant were taken out of use the operating costs for this type of system would exceed the costs of the present diversion and conveyance.

## Scenario No. 3 – Ground Water Extracted with Ranney Wells

### Legal

The legality of this scenario is very similar to No. 2 in that it is extracting of water from the ground water basin in lieu of the surface water. The depletion is as much surface water as from the safe yield of the ground water basin. In this case also the water supply from the Ranney collectors should be reported to the SWRCB as a diversion under the water rights. The USBR will also account for the water as both base and project water supply as it applies to the water rights settlement contract. This would as explained in scenario No. 2, be exempt from the Butte Co. groundwater policy.

### Economics

This scenario like the production wells would increase the costs because of lifting the water from the groundwater and provide the energy to push through the conveyance into the existing pipeline. There would be related operation and maintenance costs also. There is always the possibility of failure in the lateral and caisson systems.

## Scenario No. 4 - Installation of the Rock Groins Similar to the Cal-Trans Project at Butte City

### Legal

Groins have been placed up and down the Sacramento River as well as other meandering channels over the years to direct the water and meandering to suit the need of adjacent lands. With the current preservation of the meandering channel the number of groins have been reduced and when the groins are placed to provide the desired solutions there are mitigation requirements.

As to legal liabilities the constructor is likely considered the owner since the river channel is owned by the state, the owner (builder) is liable for maintenance and any disrepair and accidents that occur because of the structure may involve liability on the part of the “owner”. This is a statement and is not valid in the courts of law but a legal opinion relating to liability should likely be obtained to clarify the issue.

## Economics

After the capital costs there would not likely be any operation costs and likely not any maintenance cost. If there was a major flood that would cause a lot of debris to collect on or around the groin then there may be some expense to clear the debris from the rock groin. If a sheetpile wall is constructed in the center of the structure it is highly unlikely that there be any deterioration of the rock structure itself. It is also likely that some deterioration of the structure may not cause a change in protection and no change would be required.

## Conclusions

From the legal analysis the simplest alternatives are the new intake and groins. The groundwater scenarios involve the water rights of surface vs. ground water. It isn’t and insurmountable problem but provides confusion of the issue.

The economics of the new intake and groins are about a push in relation to what is now being spent for operations and maintenance. The groundwater options involve the increase of costs because of the additional pumps and conveyance but also the lift of the water and the pressure to convey the water up to the present point of diversion.

# TECHNICAL MEMORANDUM

**MWH**

**Subject:** **Riverine Impacts to M&T Chico Ranch Diversion and Chico Wastewater Treatment Plant**

**Workshop #2** **March 17 – 19, 2004**

## Background

As part of a major effort to reduce the risk of mortality for salmonid species within the Sacramento River Basin, the M&T Chico Ranch diversion pumps, once located on Big Chico Creek, were relocated to the mainstem Sacramento River channel in 1997. This project involved moving the diversion for the Llano Seco Rancho (Llano Seco) and M&T Chico Ranch (M&T) by constructing state-of-the-art fish screens on the pumping facility in the new location on the Sacramento River. At full capacity, the new diversion can supply water at 150 cubic feet per second (cfs) from the Sacramento River to M&T Chico Ranch, Llano Seco Rancho, the Llano Seco Unit of the Sacramento River National Wildlife Refuge, and the Llano Seco Unit of the Upper Butte Basin Wildlife Area. As a year-round pumping facility, the M&T/Llano Seco pumping plant delivers water to 15,000 acres of farmland and refuge land.

The new site is just downstream from the confluence of Big Chico Creek and the Sacramento River on the east bank of the Sacramento River. The City of Chico's wastewater treatment plant (WTP) outfall is also on the east bank, approximately 300 feet downstream from the pumping plant (see **Attachment 1** for location map).

After project completion, geomorphic changes in the Sacramento River channel, in the vicinity of the M&T/Llano Seco diversion pumps, have formed a gravel bar that poses a significant risk to continued pumping and operation of the Chico WTP outfall. The primary threat is to maintaining the fish screen criteria for fish screen operations at the M&T/Llano Seco facility. This encroaching gravel bar, appurtenant to Bidwell State Park, just upstream of the M&T/Llano Seco pumping plant, also potentially threatens the City of Chico WTP outfall. Both facilities are in danger of being severed from the Sacramento River because the pumping plant intake is now in an eddy behind the gravel bar located at the mouth of Big Chico Creek. Subsequently, the intake screens are no longer receiving sufficient sweeping flows consistent with National Marine Fisheries Service and the California Department of Fish and Game (CDFG) fish screen criteria due to the deposition of sediment. Eddy currents are also unable to maintain a clean screen as originally designed. As a result of these changes, there is potential that anadromous fish in the Sacramento River and Big Chico Creek would be adversely impacted by nonfunctioning fish screens. Should the M&T/Llano Seco pumps become inoperable, valuable private, state, and federal wetland refuges and the irrigated agricultural lands would be impacted from a reduction or loss of water supplied by the M&T/Llano Seco pumps.

## M&T Chico Ranch and Llano Seco Rancho Water Supplies and Demands

### Water Supply

Water supplies for these two ranches have varied over the years. M&T Chico Ranch was dependent on a water right (pre-1914) filed with the State Water Resources Control Board (SWRCB) for a pumping plant diversion located on Big Chico Creek and also water rights on the Sacramento River and Butte Creek. The Butte Creek water right was based on natural flow but also on supplemental flows brought into the Butte Creek basin by a Pacific Gas and Electric (PG&E) trans-basin diversion from the adjacent river basin for the purpose of power production. The Sacramento River water diversion is controlled by the CVP Water Rights Settlement Contract No. 14-06-200-940A, signed in 1964. This water rights settlement contract allowed M&T Chico Ranch to divert from the Sacramento River in lieu of water rights with SWRCB. The contract limited the ranch to 17,956 AF during the months of April through October each year. The water right on Butte Creek also has been used as part of the surface water supply. A diversion dam (Parrott-Phelan) located on Butte Creek diverts water into a conveyance canal that was constructed on the right bank of Butte Creek. The conveyance channel leads to a natural drainage channel, known as Edgar Slough. The natural channel enters the M&T Chico Ranch property just south of the Chico WTP.

Llano Seco Rancho water supply is also obtained from a number of sources. The ranch lands are adjacent to the Sacramento River and therefore have a riparian water right to divert Sacramento River water that can be applied to all lands in the holding. A number of pump locations over the years have provided surface water supply from the river. The water rights on Butte Creek are also dedicated to serving lands within Llano Seco. Other areas of the holding have been served through a developed groundwater supply pumped through the conveyance system or through return flows from adjacent fields.

In 1991, an agreement was reached between M&T Chico Ranch and Llano Seco Rancho (owned by Parrott Investment Co. [PIC]) for joint use of diversion points on the Sacramento River and Butte Creek to provide water supplies for the two holdings. A later agreement allowed the two entities to reach an agreement with Reclamation and CDFG to increase diversions from the Sacramento River by 40 cfs in trade for leaving 40 cfs in Butte Creek from October 1 of one year through June 30 of each year following. This would enhance the flows of Butte Creek downstream for environmental purposes such as fish migration and habitat. CDFG would administer the Butte Creek flows to protect them from diversion by other water right holders.

The quantity of water pumped at the point of diversion on Big Chico Creek was 120 cubic feet per second (cfs). Prior to construction of the pumping plant diversion on the

Sacramento River the point of diversion was changed from Big Chico Creek to the relocated pumping plant on the Sacramento River.

The water is diverted for supplying the area farmed by M&T Ranch and also the holding of Llano Seco. In addition to the agricultural operations both ownership's have lands that are dedicated to waterfowl management in addition to the agricultural crops. There are state and national wildlife refuges within Llano Seco that receive a water supply from this diversion on the Sacramento River. All of these uses are dependent on the diversion from the Sacramento River in conjunction with a water right from Butte Creek.

Prior to the construction of the relocated pumping plant CA Dept. of Fish and Game negotiated an agreement with both of the landowners, also the holders of the Butte Creek water right, an agreement involving the US Bureau of Reclamation (CV Project) for exchanging Butte Creek water rights by increasing the diversion from the Sacramento River. This exchange was to take place from October 1 to June 30 each season. The landowners agreed to reduce the diversion from Butte Creek during this period and the water would flow down Butte Creek into the Sutter Bypass and ultimately the Sacramento River. CA Fish and Game agreed to protect the diversion from diversion by junior water right holders.

## Irrigated Acres for Crops and Habitat Management

This section discusses current land use and water use, demand, and supply for M&T Chico Ranch and Llano Seco Rancho. This information is provided in this TM to show the areas served and the water requirements that are needed to maintain the current level of economy for the area. The area served reaches out to improve the way of life for the agricultural community as well as the sportsman and environmental restoration of the major water projects.

M&T Chico Ranch has 6,719 irrigated acres, as shown in Bureau of Reclamation (Reclamation) Central Valley Project (CVP) Water Rights Settlement Contract No. 14-06-200-940A. M&T Chico Ranch Manager, Mr. Les Heringer, Jr., furnished data for acres farmed and irrigated for this Technical Memorandum (TM): the cropping pattern at M&T Chico Ranch for 2003 was 158 acres of dry beans, 1,654 acres of rice, 117 acres of sunflowers, 2,061 acres of almond trees, 708 acres of prunes and 1,222 acres of walnuts, for a total of 5,912 acres. The remainder of ranch land is managed habitat (sloughs) or is left fallow for other reasons. In addition, 225 acres of wetlands are being maintained, for a total of approximately 800 noncultivated acres; the ranch manages the water for these noncrop lands.

Llano Seco Rancho's land holding is 11,337.2 acres. Llano Seco Rancho Manager Mr. Dave Sieperda, provided 2003 cropping pattern information for this TM. In 2003, Llano Seco Rancho used 645.8 acres for various irrigated row crops and 200 acres for rice. Another 616 acres was used for irrigated pastureland for a total of 1,461.8 acres of currently irrigated croplands managed by Llano Seco staff. In addition, 2,399.8 acres of cropland are entitled to receive riparian water from the Sacramento River but aren't presently being irrigated. The remainder of ranch land, 3,475.6 acres, is managed for habitat and uses about 75 percent of the amount of water that would be required to produce crops.

Within the Llano Seco holding, another 2,479 acres are under the management or easement of the United States Fish and Wildlife Service (USFWS); 177.5 of these acres are listed as irrigated pasture. Water used for the remaining 2,301.5 acres is about 75 percent of the water supply level would be needed for producing crops.

Finally, CDFG manages 1,521 acres of Llano Seco lands for waterfowl management. Again, water used for this acreage is about 75 percent of the water supply used for crop production.

## Water Demands

M&T Chico Ranch. Water demands for M&T Chico Ranch lands are probably slightly less than for Llano Seco Rancho because M&T experiences fewer conveyance losses and has somewhat higher irrigation efficiencies. Conveyance losses and irrigation efficiencies are assumed, for purposes of this TM, to be about 20 percent and 80 percent, respectively. Lower conveyance losses result from shorter distances from diversion to fields and irrigation efficiencies are based on irrigation methods.

Also, some row crops at M&T have less consumptive use than at Llano Seco Rancho. Consumptive water use would be about 40 inches for tree and row crops, and with reduced conveyance losses and greater irrigation efficiencies, the demand per acre would be about 4.8 acre-feet (AF)/acre. Demand for total irrigated acreage would be 28,400 AF.

Demand for habitat would be about 3.0 AF/acre; M&T's 800 acres of habitat would require 2,400 AF. Water deliveries for habitat and land management would have an added 30 percent for conveyance losses added but would be considered 100 percent efficient for consumptive use.

Therefore, present water diversion demands for M&T include 28,400 AF for M&T irrigated land and 2,400 AF for habitat management, for a total demand of 26,800 AF in an average year.

Llano Seco Rancho. For Llano Seco Rancho, irrigated acreage consumes 42 inches of water during the growing season. If irrigation practices are 65 to 70 per cent efficient and conveyance is 70 per cent efficient, water requirements at the diversion points would be 5.9 AF/acre for irrigated crop lands. This calculates to a demand of 9,700 AF for croplands.

Habitat lands consume about 31 inches of water to maintain water levels and produce food for waterfowl. Habitat requirements would be 3.4 AF /acre, for a total habitat demand of 24,800 AF for the waterfowl and habitat lands managed by Llano Seco, USFWS, and CDFG.

Therefore, present water diversion demands for Llano Seco Rancho include 9,700 AF for croplands and 24,800 AF for habitat, for a total demand 34,500 AF, excluding the additional area that could come under irrigation in the future. Potential demand for these currently uncultivated 2,399.8 acres of cropland would increase delivery requirement by 14,200 AF for a total future demand of 48,700 AF.

The canal and channel are used as the conveyance for this part of the surface water supply.

## Chico Wastewater Treatment Plant

The City of Chico Wastewater Treatment Plant (WWTP) is located on River Road on the east side of the M&T Chico Ranch boundary. The Chico WWTP outfall has been in place since the WWTP was constructed in 1972. This outfall consists of a 42-inch pipeline that outlets into a diffuser system (7-inch to 12-inch risers) on the east bank of the Sacramento River. The outfall is located about 300 feet downstream of the point of diversion for the M&T/Llano Seco ranches.

The Chico WWTP diffuser also is being impacted (isolated) by the formation of the gravel bar in the Sacramento River, similar to impacts on the diversion intake for M&T/Llano Seco ranches. Downstream flow in the area of the diffuser is being reduced, which in turn reduces the mixing and dilution of the WWTP effluent.

Expansions of the Chico WWTP in the last 5 years have required that some additional diffusers be added at the end of the pipeline. After high flows in 1986, the diffuser structure became detached from the outlet pipe making the diffuser ineffective. In the low water years of 1991 and 1992 apparently it was discovered that the diffuser had become detached and a repair had to be made. The repair was to remove a section of the outlet pipe and move the diffuser structure back into position. This moved the diffuser closer to the east bank reducing the exposure to the extreme higher flows in the river.

Currently, additional expansion of the Chico WWTP is being studied. Problems caused by the gravel deposit are of concern for this expansion effort. If the current condition continues in the river, other arrangements must be made for mixing river water and WWTP effluent.

## Previous Investigations

Past evaluations of the river channels and levees were made to select the current pumping site on the Sacramento River. Historical maps and aerial photographs compiled by California Department of Water Resources (DWR) indicate that, since 1896, the river has not meandered east of its current location at the pumping plant, which is located on a geologic control. Because the bank is relatively stable, it was chosen as the site for the new pumping plant. At this location, however, the Sacramento River has historically migrated to the west. As recently as 1935, the west bank was approximately 1,000 feet west of its current location. Between 1995 and 2001, the Sacramento River shifted 500 feet to the west (an average of 83 feet/year). As the river migrated in this direction, flow velocities at the pump intake and outfall were reduced and sediment deposition increased. In addition, aerial photographs indicate that the mouth of Big Chico Creek has shifted both upstream and downstream from its current location over recent decades.

Concurrent with the lateral migration of the Sacramento River channel, a gravel bar at the apex of the meander has enlarged and migrated downstream toward the pump facility. Between 1995 and 1999, the gravel bar migrated over 1,100 feet downstream. Between 1999 and 2001, the gravel bar moved an additional 600 feet downstream. Diving surveys in May 2001 showed that the riverbed aggraded approximately 5 feet relative to past surveys at the City of Chico diffuser, and two of the seven diffuser nozzles were buried by sediment (Sierra View Divers, 2001). A similar survey conducted in May 2001 at the M&T/Llano Seco pumps revealed that the channel bed was encroaching on the bottoms of the fish screens. These surveys noted that sediment deposition reduced the clearance under the intake from 6 feet to 2 to 3 feet. The date of the previous survey was not given in the report, but the divers estimated that the screens would stop functioning normally within 2 years if the current rate of deposition continues (Sierra View Divers, 2001). (**Attachment 2** illustrates the migration of the bed from 1997 to 2001.)

The Sacramento River Conservation Area (SRCA) Program (SB 1086) reviewed this problem and, with funding from CALFED, commissioned Stillwater Sciences to identify near-term and long-term alternatives to maintain operation of the pumps and outfall. (See **Attachment 3**) Stillwater Sciences examined historical maps and aerial photographs from 1923 through 1999. These maps indicate that river migration historically occurred upstream of the pumping plant. As with DWR's research, Stillwater Sciences found that the Sacramento River has historically migrated to the west at this location. As recently as 1935 the east bank was approximately 1,000 feet west of its current location. As noted earlier, the river shifted 500 feet toward the west bank between 1995 and 2001.

The gravel bar was not visible in the 1964 aerial photographs, but was visible in the 1979 photo about halfway between its present location and the revetment at River Road. Although the bar is at the mouth of Big Chico Creek, Stillwater Sciences concluded that it is composed primarily of Sacramento River sediment. Although some of the material may be coming from bank erosion in the immediate vicinity, Stillwater Sciences staff believes most of the material is likely being transported from further upstream. The report concludes:

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

Stillwater Sciences identified five possible alternatives to maintain operation of the pumps and outfall:

Alternative 1 - Dredge (excavate) sediment from the bar upstream of the pump intake and City of Chico outfall

Alternative 2 - Cut a channel across the bar to redirect flow in the Sacramento River

Alternative 3 - Dredge the bar and armor the west bank across from the pump intake and City of Chico outfall

Alternative 4 - Excavate/dredge sediment from the bar and install spur dikes on the west

Alternative 5 - Redesign or replace the pumping plant

Stillwater Sciences concludes that Alternatives 4 and 5 are the most likely to succeed in the long term.

In November 2001 a total of 144,000 cubic yards of material were excavated and removed from the bar. Divers examined the fish screens again in April 2002. The level of gravel was found to be 2 to 4 feet below the screens (Sierra View Divers, 2002). In the opinion of the divers, excavation of the gravel bar had temporarily slowed encroachment of the gravel into the screen structure.

## Long-Term Planning Study

A long-term planning study was proposed and included in an application for CALFED funding. The plan was approved as a Directed Action in October 2002. The revised application was completed early in 2003 and is included as **Attachment 4**.

In summary, this plan will consist of gathering existing data, convening a Steering Committee comprising stakeholders and recognized experts, researching existing conditions in the river, understanding fluvial geomorphology, monitoring the gravel bar, gathering data from surveyors, hydrologists, bio-engineers and geo-technical engineers, and preparing a river model to assist in determining an appropriate long-term solution. The approach associated with the long-term planning study is explained in detail below.

1. Gather existing studies and reports on the Sacramento River's fluvial geomorphology to obtain a general understanding of the river and its processes. Determine what information that was used to place the pumps in the current location and compare these data to compiled data and existing conditions. Review and analyze proposed alternatives presented by Stillwater Sciences in its report entitled, "Final Draft of M&T Ranch and Llano Seco Wildlife Refuge Pump Intake." Conduct an exhaustive literature search pertaining to research and development of innovative fish-friendly water diversion technologies/engineering that are designed to operate in or around a dynamic river system (see Performance

Measure No. 5). The performance measures pointed out are from the Cal Fed (now California Bay Delta Agency) application filed to obtain funding to correct the river channel situation included is this document as Attachment No. 4 on page 26 of 40.

2. Convene a Steering Committee comprising stakeholders, recognized experts, and CALFED representatives to review and evaluate existing data, identify data gaps, and identify alternatives to be examined and developed to reach a long-term solution. This process will be facilitated by Ducks Unlimited, Inc. (see Performance Measure No. 1).

3. Ayres Associates and MWH will work closely with the Steering Committee to determine the methods of maintaining an effective, fish-friendly diversion while maintaining a river meander and responding to the concerns of those affected by the project. Performance and model development meetings will be held with the Steering Committee to develop a river model and to receive input for a long-term planning study. Stakeholders include M&T Chico Ranch, Llano Seco Ranch, City of Chico, Bidwell State Park, USFWS, CDFG, DWR, National Marine Fisheries Service, landowners Walter Stiles, Jr., and Val Shaw, M.D., and the Sacramento River Conservation Area. This process will likely be iterative with various sets of promising project elements combined, simulated, and brought back for consideration (see Performance Measure No. 5).

4. As a short-term protection measure, perform gravel bar monitoring to document the current size and outer boundaries of the existing gravel bar. Divers will inspect the gravel bar annually and collect necessary data on the southern migration of the gravel bar. A general monitoring plan will be detailed and initiated to supplement existing data and augment ongoing monitoring. A physical monitoring plan will be developed to establish a firm understanding of existing conditions and enable informative assessments of pre- and post-project performance with respect to natural processes in the Sacramento River (see Performance Measure No. 3).

5. Collect various data such as hydraulic and geotechnical information to compile a list of design criteria to be used in developing a river model and in the final design of the preferred alternative (see Performance Measure No. 5).

6. Develop a river model to analyze the hydraulic effects of implementing various alternatives. Ayers Associate will prepare the model (see Performance Measure No. 6).

7. Using the river model, develop conceptual designs of selected alternatives to determine a cost-efficient and feasible alternative that will be recommended as the long-term solution to the sediment deposition at the M&T/Llano Seco pumping plant while maintaining and protecting native habitat (see Performance Measure No. 8).

8. Conduct a Biological Assessment to determine environmental effects on the natural habitat within the Sacramento River (see Performance Measure No. 7).

9. Prepare the Long-Term Planning Study. The study will explain the problem, list the alternatives, justify the preferred alternative, and summarize the benefits associated with implementing the preferred alternative. The Long-Term Planning Study will be reviewed by the Steering Committee, City of Chico Public Works, and CALFED Technical Committees (see Performance Measures No. 9 and No. 10).

# TECHNICAL MEMORANDUM

**MWH**

**Subject: Optional Fish Screen Criteria**

**Workshop #2 March 17 – 19, 2004**

During 1996 the M&T pumping station was moved from Big Chico Creek to the present location on the Sacramento River immediately downstream of the mouth of Big Chico Creek near River Mile 193. The relocation was done for two reasons. At maximum capacity the previous pump station consumed the entire flow of Big Chico Creek and drew water approximately 0.75 miles up the channel of Big Chico Creek from the Sacramento River. This condition often existed during periods of adult salmon and steelhead migration, thus eliminating access to Big Chico Creek. Secondly, the previous pumping station had never been fitted with a juvenile fish screen and was potentially entraining juveniles exiting Big Chico Creek as well those from the Upper Sacramento River and tributaries.

The relocated pumping station was designed with a capacity of 150 cfs and fitted with four cylindrical tee-screens, each 15 feet long and 54 inches in diameter, covered with stainless steel wedge-wire screen material. The screens were designed to comply with criteria established by the California Department of Fish and Game (February 1993) and the National Marine Fisheries Service (1995) as follows:

| | |
|---|---|
| **Approach Velocity** | CDFG – 0.33 fps<br>NMFS – 0.40 fps |
| **Sweeping Velocity** | CDFG – “at least two times the allowable approach velocity”<br>NMFS – “greater than the approach velocity” |
| **Screen Slot** | CDFG – 0.094 inches (3/32” or 2.39 mm)<br>NMFS – 1.75 mm (0.0689 inches) slot |
| **Open Area** | CDFG – Minimum 50% open area<br>NMFS – Minimum 27 % open area |

The M&T diversion falls under California Fish and Game Code Section 5900 et seq. Specifically Section 5900 (b) defines those diversion structures which potentially require a fish screen to include pipes, millraces, ditches, flumes, siphons, tunnels, canals, and any other conduits of diversion used for the purpose of taking or receiving water from any river, creek, stream or lake. Section 6020 provides for juvenile fish screens on any diversion with a capacity of 250 cfs or less. Specifically, such diversions will be assigned a lower priority until those diversions over 250 cfs have been screened unless such a diversion is located within the essential habitat of a State listed species, or within the Critical Habitat of federally listed species. Additionally, Section 5901 regulates devices or structures which impede, or tend to prevent or impede, the passing of fish up and down stream.

Federal fish screen requirements applicable to the M&T pumps are administered by the National Marine Fisheries Service under authority of the Endangered Species Act, the Federal Power Act, and the Fish and Wildlife Coordination Act.
The M&T pumps in both the present and previous location are and were within the federally designated critical habitat of the Sacramento River winter-run Chinook salmon (Federal Register June 16, 1993), and within the critical habitat designation for the Central Valley spring-run Chinook and steelhead, which is currently under review based upon the April 30, 2002 NMFS consent decree. Thus both state and federal fish screen requirements for salmonids are applicable at the M&T site. Due to the recent shift in the channel of the Sacramento River the screens were not in compliance with the sweeping velocity criteria for much of the time. In addition, sedimentation was potentially diminishing screen surface area affecting compliance with approach velocity criteria. The river shift was eliminating connectivity of Big Chico Creek with the Sacramento River at the highest pumping volumes. Removal of the upstream gravel bar temporarily restored the function of the screens to the original design criteria. However, continued movement of the river to the west will once again diminish or eliminate compliance with applicable state and federal requirements.

Various alternatives for addressing river channel movement are being considered, each with the potential to require modification to the existing structure or to require new and innovative approaches to providing both juvenile and adult fish passage. California State fish screen policy allows variances to existing screen criteria to accommodate new technology or to address species-specific or site-specific circumstances. Such variances require review and concurrence by the appropriate Regional Manager, and concurrence from both the Deputy Directors of the Habitat Conservation Division and the Wildlife and Inland Fisheries Division. Evaluation and monitoring may be required to demonstrate that any variance does not result in reduced levels of protection. Federal fish screen criteria allow variances where site constraints or extenuating circumstances warrant waiver or modification of one or more of the criteria and are considered on a project-by-project basis.

Potential modifications to the existing structure to restore or maintain compliance include moving the screens, increasing screen area, and installing in-conduit screens.

## Moving the Screens

This alternative involves removing the four-cylinder manifold and screens and extending the intake pipe out into the river to a location with suitable depth. There the screen manifold would be installed over the pipe and anchored to the bottom. A protective rack similar to the existing one would also have to be built. Moving the screens downstream is not an option since the intake would interfere with the City of Chico sewage plant outfall and the intake might draw in the effluent from the plant. This alternative is also susceptible to further river channel migration, which could move the channel away from the intake. River training work is necessary to insure a long-term water supply with this alternative.

## Increasing Screen Area

In CDFG screening criteria provision is made for installing fish screens where no sweeping flow exists such as a reservoir or lake. Such an installation requires a reduced approach velocity to the screens of 0.0625 feet per second. This is about 20% of the 0.33 feet per second required with sweeping velocity. A variance from the 0.0625 feet per second would be possible under the provisions mentioned above. NOAA Fisheries has considered wavers to the approach velocity requirements in areas of lower sweeping flow. The approach velocity would be below 0.20 feet per second at a diversion rate of 150 cfs. If waivers were granted the array of cylindrical screen already in place would have to be doubled. Even if twice the screen area were installed, the screens still could be partially occluded by the migrating gravel bar.

## In-Conduit Screens

Screens could be placed in the intake conduit leading from the existing cylindrical screens to the pump station. In this alternative the existing screens would be removed, and the intake pipe would be extended out into the river to a stable channel. One of two types of screens could be built between the pump station and levee. These are:

1. Vertical plate fish screens – These screens would be built by removing a length of pipe and install the screen structure. The screens consist of vertical flat plate screens in a "V" platform with screens on one or both sides of the "V" in an open channel. A bypass pipe would be installed from the screens back to the river to return fish to the river. The screens would be fitted with a cleaning system of brushes or a backwash system. This system creates its own sweeping flow by virtue of its shape. A bypass pump would have to be installed to obtain the head necessary to return fish to the river. With this additional head the bypass could return the fish a great distance downstream. The bypass flow would be about 15 to 25 cfs.
2. Modular Inclined Screens – These screens are placed at an angle in a pressurized rectangular conduit. The upstream edge of the rectangular screen is on the floor with the screen sloping up in the downstream direction. The fish are guided along the screens until finding a bypass at the top of the screens. This bypass flow would also have to be pumped to return the fish to the river. This screen does not meet screening the criteria of NOAA Fisheries and CDFG, since its approach velocity is about 1 foot per second. It has been tested and shown to have good fish survival although it is not fully approved by either agency. A waiver would be required to build this fish screen. To build this screen the pipe between the levee and pump station would be removed and a concrete conduit to house the screen would be installed. Transitions upstream and downstream of the screen conduit would also be installed.

   Both of these screens require pumping fish back to the river. "Fish friendly" pumping has been tested and found to pass fish safely, and has been installed in areas where endangered species are migrating. Early test results using marked fish are good. This alternative has the drawback that a suitable location in the river must be found for the pipe intake. In addition, this alternative is not desirable since the fish have to pass through a pipe from the pipe intake in the river to the screens and then return through another pipe back to the river.

All alternatives calling for modification of the screens require that the intake be located in an area of river where a stable channel can be found or trained to remain.