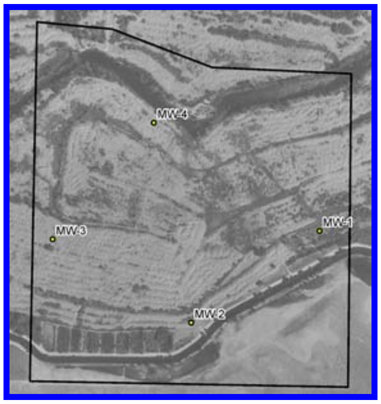
Merced River Corridor Restoration Plan
Phase IV: Dredger Tailings Reach



Technical Memorandum #11
Merced River Ranch Groundwater Study

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I INTRODUCTION

The Merced River Ranch groundwater study was undertaken as a component of the Merced River Corridor Restoration Plan - Phase IV Project (CALFED ERP-02-P12-D), which is intended to evaluate strategies for channel and floodplain restoration within the context of the contemporary flow regime. The Phase IV Project focuses on restoration planning activities on the Merced River Ranch (MRR), located at the uppermost end of the Merced River Dredger Tailings Reach (Figure 1). The Dredger Tailings Reach (DTR) has been severely impacted by historic gold dredger mining and alteration of the natural hydrograph by upstream dams. The reach is also the primary spawning area in the Merced River for fall-run Chinook salmon (*Oncorhynchus tshawytscha*), an important management species for the California Department of Fish and Game (CDFG), and potentially steelhead (*O. mykiss*), which is listed as threatened under the Federal Endangered Species Act.

This technical memorandum reports the results of the first five months of the groundwater study, which was conducted to better understand the potential risks of floodplain and in-channel restoration on groundwater dynamics at the MRR. The study was initiated in July 2006 and groundwater elevation monitoring is currently ongoing.

1.1 Study Area

The Merced River is a tributary to the San Joaquin River in the southern portion of California's Central Valley (Figure 1a). The river, which drains an approximately 3,305-km^2 (1,276-mi^2) watershed, originates in Yosemite National Park and flows southwest through the Sierra Nevada range before joining the San Joaquin River 140 km (87 mi) south of the City of Sacramento. Elevations in the watershed range from 3,960 m (13,000 ft) at its crest to 15 m (49 ft) at the confluence with the San Joaquin River. The DTR of the Merced River extends from Crocker-Huffman Dam (river mile [RM] 52) to approximately 1.9 km (1.2 mi) downstream of the Snelling Road Bridge (RM 45.2), a reach of approximately 11.6 km (7.2 mi) (Figure 1b and c). The 129 ha (318 ac) MRR is located in the upstream portion of the DTR (RM 51 to 50) and was purchased by CDFG in 1998 as a source of coarse sediment for future river restoration projects and as a floodplain restoration site.

The physiography of the DTR consists of river channel and floodplain and dissected uplands (Page and Balding 1973). The floodplain and channel deposits are made up of alluvium, which consists primarily of sands, gravels, and cobbles derived chiefly from the granites of the nearby Sierra Nevada (Page and Balding 1973). The thickness of the channel and flood plain deposits typically range from 6–15 m (20–50 ft) (Page and Balding 1973). Underlying the channel and floodplain deposits, and forming the bluffs on both sides of the river floodplain, is the Tertiary Mehrten Formation. The Mehrten Formation consists primarily of sandstone, breccia, tuff, siltstone and claystone (Page and Balding 1973). The Merced River has dissected the Mehrten Formation as much as 46 m (150 ft) in some locations. In the DTR, the Mehrten Formation typically ranges from 6–61 m (20–200 ft) thick.

The hydrology of the Merced River has been altered by water supply requirements and flood control operations, which together have reduced flood frequency, reduced peak flow magnitude, altered seasonal flow patterns, and reduced the temporal variability of flows. These changes in hydrologic conditions have altered the frequency, duration, and magnitude of floodplain inundation, and reduced the frequency of sediment transport and bed mobilization, but, in conjunction with a lack of sediment supply, have caused bed scour and armoring in the remaining flood events (Stillwater Sciences 2001).

Since 1926, sediment supply from the upper 81 percent of the watershed has been intercepted at the original Exchequer Dam and then the New Exchequer Dam. This interception has eliminated the vast majority of the river’s historical sediment supply, thus depriving the river of a basic element necessary to maintain geomorphic equilibrium.

In addition to the effects of flow regulation and loss of sediment supply from the upper watershed, this reach has been extensively modified by gold dredging. In the early-to-mid twentieth century, gold dredges excavated the river channel, floodplain, and valley floor. The dredges had earthmoving capacities of 1.4–3.4 million cubic yards/year and excavated the channel and floodplain deposits to bedrock, usually at a depth of 6–11 m (20–36 ft) (Page and Balding 1973, Clark 1998). After recovering the gold, the dredgers redeposited the remaining tailings in long rows, often roughly parallel to the river channel, on the floodplain. Although they were originally thought to consist of fine sand and gravel overlain by cobbles and boulders (Goldman 1964) extending to the original dredging depths, recent surveys indicate that the tailings piles exhibit little stratification (URS 2004a). As a result of gold dredging, the channel has been depleted of coarse sediment, the adjacent floodplain has been raised and covered with dredger tailings piles, and soil and fine sediment have been washed downstream. An estimated 3.22 million cubic yards (2.46 million m^3) of dredger tailings currently cover approximately 305 acres (1,236,000 m^2) of the riparian corridor of the DTR (URS 2004a).

1.2 Restoration Planning

The Phase IV Project, and therefore MRR groundwater study, stem from the larger Merced River Corridor Restoration Plan (MRCRP). Funded by the CALFED Ecosystem Restoration Program, the intent of the MRCRP was to provide a technically sound, publicly supported, and implementable plan to improve ecological function in the Merced River corridor from Crocker-Huffman Dam (RM 52) to the confluence with the San Joaquin River (RM 0). Crocker-Huffman Dam is the downstream-most dam on the Merced River and the upstream limit of anadromous fish access. The MRCRP (Stillwater Sciences 2002) identifies restoration objectives and provides management recommendations based on current scientific understanding of the Merced River with input from the Merced River Stakeholders (MRS), Merced River Technical Advisory Committee (MRTAC), and the broader public. Since a broad spectrum of interests, represented by the MRS, MRTAC, and public, provided input to the restoration objectives, they address not only geomorphic and ecological restoration in the river, but also the concerns of local citizens, landowners, and other stakeholders.

To guide reach-scale restoration efforts and address various anthropogenic impacts to the DTR, the MRCRP identified the following objectives for the DTR (Stillwater Sciences 2002):

- balance sediment supply and transport capacity to allow the accumulation and retention of channel bed material suitable for spawning and to prevent riparian vegetation encroachment;
- restore floodplain functions to improve the establishment of riparian vegetation and the quality of riparian habitat;
- increase in-channel habitat complexity to improve aquatic habitat for native aquatic species; and
- scale low-flow and bankfull channel geometry to current flow conditions.

The Phase IV Project begins to address the MRCRP objectives through the design of pilot floodplain and channel restoration experiments. The Phase IV project includes conducting: 1) DTR- and MRR-scale studies of current conditions to provide the basis for (Stillwater Sciences 2004a, b and c; URS 2004a and b; Stillwater Sciences 2006a; URS 2006a, b, c) and to inform the design of restoration actions (Stillwater Sciences 2006b and c, URS 2006d and e) and 2) experiments to test actions that will initiate the restoration of natural ecosystem function at the MRR to the extent feasible (Stillwater Sciences 2007). The project will provide transferable scientific information to reduce uncertainty in future restoration design on the Merced and potentially in other rivers in the Central Valley. For example, removal of the tailings from the floodplain has the potential to yield multiple restoration opportunities and ecosystem benefits, but the detailed impacts of such restoration activities are largely unknown. The Phase IV Project studies, of which this groundwater study is one, are designed to increase the collective scientific understanding of the potential for dredger tailings removal and re-use (*e.g.*, as material to use as fill during channel reconstruction or for gravel augmentation), and is intended to improve restoration effectiveness and reduce project uncertainty when implementing restoration actions in the future.

1.3 Study Background and Goals

While not intentionally manipulated during restoration, groundwater dynamics can be altered by restoration activities and strongly influences the performance of restoration actions. In reviewing other Central Valley floodplain restoration projects and developing the 30 percent conceptual restoration design for the MRR (Stillwater Sciences 2005) it became apparent that an improved understanding of groundwater was needed to better predict the effects of floodplain restoration on groundwater conditions as well as the effects of groundwater on the success of revegetation and wetland management activities. Preliminary groundwater data collected at two monitoring wells as part of the revegetation experiment (these wells are further referred to as block wells because of their location at experimental block areas) indicated that groundwater is not influenced by river flow conditions and is perched 2–3 m (8–10 ft) above the average river stage (Stillwater Sciences 2007). This, as well as year-round inundation of swale ponds between tailings piles and the fact that Merced Irrigation District’s (Merced ID) unlined Main Canal bounds the southern end of the MRR, has lead agency representatives, local landowners, and virtually every visitor to the MRR to question where groundwater at the MRR is coming from, how patterns vary across the site, and why the groundwater table is so much higher than the river stage. Further complicating groundwater dynamics is the lack of stratigraphy in the tailing piles/floodplain substrate, which makes groundwater movement and patterns even more difficult to predict.

The objectives of the groundwater study were developed with the long-term intention of decreasing the uncertainty of the effects of channel and floodplain restoration on groundwater. The objectives of the study were to: 1) evaluate how groundwater patterns may vary across the site, 2) identify potential sources of groundwater, and 3) evaluate groundwater elevations relative to the stage of the Merced River.

2 METHODS

2.1 Groundwater Monitoring Well Installation

Four monitoring wells (MW-1, MW-2, MW-3, and MW-4) were installed to assess seasonal variations of groundwater patterns across the MRR, potential groundwater sources, and groundwater elevations relative to the Merced River stage. The locations of the four monitoring wells were chosen to maximize the area of coverage across the MRR and were installed close to MRR or hydrologic boundaries (Figure 2). The approximate locations of the wells were obtained using a hand-held GPS unit.

Due to the difficulties associated with drilling in the tailing piles, a track-mounted sonic drilling rig was used for well installation. Sonic drilling technology utilizes resonant energy waves on a rotating drill bit to advance the well casing through the subsurface. An outer casing (6 in) was advanced, along with the inner casing (3 in), to collect continuous soil core samples. Soil cores were retrieved in 5-ft long plastic sleeves for lithologic logging, in accordance with the Unified Soil Classification System (ASTM 1996). Core recovery in sandy zones was sometimes poor. Because the outer casing remains in place during well installation, geophysical surveys could not be performed.

Monitoring wells MW-1 and MW-2 were installed on June 28, 2006; MW-3 and MW-4 were installed on July 7, 2006. MW-1 and MW-2 were installed to depths of approximately 20 and 27 ft below ground surface (bgs), respectively. MW-3 and MW-4 were installed to depths of approximately 16 ft bgs. Well depths were determined by the contact with the underlying Mehrten Formation. The wells were screened in the 10 ft of alluvium directly above the Mehrten contact. On November 3, 2006, the top of all four wells was surveyed to determine each well’s elevation above mean sea level. Detailed well installation information is presented in Table 1 and well construction diagrams are included in Appendix A.

Table 1. Well installation details.

Well ID[1]	Date Installed	Depth (ft bgs)	Diameter (in)	Screened Interval (ft bgs)	Well Seal (ft bgs)	Elevation of Top of Well (ft NGVD 29)
MW-1	06/28/06	25	2/0.02	10.57-20.04	2	298.53
MW-2	06/28/06	37	2/0.02	16.72-26.22	2	304.51
MW-3	07/07/06	37	2/0.02	6.59-16.06	2	301.00
MW-4	07/07/06	36	2/0.02	5.87-15.37	2	288.74

[1] Monitoring well locations are shown in Figure 2.

2.2 Groundwater Monitoring

Continuously recording pressure transducers (Solinst Levelogger) were installed in each of the monitoring wells on July 19, 2006 to monitor groundwater levels. Several manual groundwater level measurements were taken prior to and following pressure transducer installation to calibrate each pressure transducer. A barometer was installed at MW-4 to monitor ambient air pressure.

The dataloggers (pressure transducers and barometer) were programmed to take measurements every 20 minutes and were first downloaded on November 3, 2006. Pressure transducer readings were corrected barometric pressure, elevation, and depth of submergence.

Potentiometric surface maps were prepared by interpolating the manual groundwater level data collected from the four monitoring wells in July, September, and November 2006. Data from block wells were not utilized in preparing the potentiomentirc surface maps because the block well construction and completion intervals are dissimilar to the monitoring wells, and the data may not be comparable.

2.3 Groundwater Quality Sampling

Groundwater samples from the four monitoring wells and surface water samples from the Main Canal were collected in July and November 2006. The wells were bailed until at least three casing volumes were removed and the water produced was relatively clear and free of sediments. All samples were sent to BSK Analytical Laboratories for analysis of general cations, anions, alkalinity, pH, total dissolved solids, and electrical conductivity.

3 RESULTS AND DISCUSSION

3.1 Groundwater Monitoring Well Installation

The locations of the four groundwater monitoring wells are presented in Figure 2. Monitoring well MW-2 is located near the Main Canal and is likely representative of canal stage. Monitoring well MW-4 is located near the Merced River and is similar to river stage.

Soil cores reveal that the shallow sediments beneath the site consist primarily of dredger tailings composed of highly heterogeneous mixture of interbedded silty sand, fine to coarse sand, gravel, and cobbles. The ground surface typically consists of a cobble or gravel layer several feet thick. This is underlain by a mixture of poorly graded sand with silt and gravel, and occasional cobble. The water table was encountered between 8 and 13 ft bgs. Core recovery below the water table was sometimes poor as the loose soil core was flushed out of the core barrel by the water. In three of the soil cores, a hard stiff lean clay was encountered at a depth of 17 to 18 ft bgs (there was no recovery across this interval in MW-2). This appears to be Mehrten Formation. The relatively uniform depth of occurrence may reflect the maximum depth of dredging at the MRR. Soil core logs are presented in Appendix B.

3.2 Groundwater Monitoring

Groundwater levels from the four monitoring wells, the two block wells installed for the revegetation experiment, and Merced River stage are presented in Figure 3. Manual water level measurements are summarized in Table 2 and plotted in Figure 3 for reference. The manual groundwater measurements follow well development and the datalogger measurements are relatively consistent (Figure 3). Most of the monitoring wells and block wells show little variation in groundwater elevation during the monitoring period (Figure 3). The data show that the Merced River stage is typically 5 to 6 ft lower than the groundwater beneath the MRR, and that the water levels in MW-4, located closest to the river, appear to vary in parallel with river stage (Figure 3). Water level in MW-2, located nearest the Merced ID Main Canal, also show a gradual long-term rise of about 0.5 ft during the monitoring period (Figure 3).

Table 2. Manual groundwater level measurements.

Well ID[1]	Date	Reference Point Elevation (feet MSL)[2]	Depth to Water (feet btoc)[3]	Groundwater Elevation (feet MSL)[4]
MW-1	06/28/06	298.53	8.00 [5]	290.53
	07/06/06		8.65 [6]	289.88
	07/10/06		8.61	289.92
	09/12/06		8.57	289.96
	11/03/06		8.81	289.72
	11/21/06		8.92	289.61
MW-2	06/28/06	304.51	8.00 [5]	296.51
	07/06/06		14.00 [6]	290.51
	07/10/06		13.95	290.56
	09/12/06		14.32	290.19
	11/03/06		14.87	289.64
	11/21/06		15.66	288.85
MW-3	07/07/06	301.00	14.55 [5]	286.45
	07/13/06		17.23	283.77
	09/12/06		17.88	283.12
	11/03/06		17.72	283.28
	11/21/06		17.47	283.53
MW-4	07/07/06	288.74	9.00 [5]	279.74
	07/13/06		7.00	281.74
	09/12/06		6.07	282.67
	11/03/06		6.00	282.74
	11/21/06		6.19	282.55

[1] Approximate monitoring well locations are shown on Figure 2.

[2] Elevation of top of casing in feet above mean sea level (MSL), surveyed on November 3, 2006.

[3] Depth to water measured in feet below top of casing (btoc) on the indicated date.

[4] Calculated elevation of top of groundwater in feet MSL.

[5] Approximate depth to water collected during well installation.

[6] Approximate depth to water prior to well development.

Potentiometric surface maps of groundwater elevations indicate that groundwater flow is approximately perpendicular from the Merced ID Main Canal toward the Merced River, and that the Merced ID Main Canal is a losing reach and the Merced River is a gaining reach (Figures 4, 5, and 6). Groundwater appears to flow through the sand and gravel dredger tailings along the top of a fine-grained (clay) material of the Mehrten Formation and discharges where the river has cut down through the dredger tailings and the Mehrten Formation. During the monitoring period, the Main Canal appears to have acted as a near steady-state source of groundwater and the Merced River as a near constant sink, resulting in a relatively consistent hydraulic gradient of 0.00286 to 0.00376 (approximately 15 to 20 ft per mile)across the MRR (Figures 4, 5, and 6).

3.3 Groundwater Quality Sampling

Analytical results of the water quality sampling are summarized in Table 3 and presented in Appendix C. The water quality data show that the groundwater beneath the site is primarily a calcium-bicarbonate type water as shown on a Piper diagram (Figure 7). Overall the groundwater water quality is excellent with low total dissolved solids (TDS) ranging between 32 and 160 mg/L. The observed changes in water quality across the MRR and over time are relatively subtle, and are only apparent because of the very low TDS of the water. The groundwater and surface water quality data plot in a relatively small area of the Piper diagram, indicating similar quality (Figure 7).

The water samples from the Main Canal and MW-4, which is located closest to the Merced River, are very close in quality (Table 3, Figure 7). This is not unexpected, given that the Merced River is the source of water in the Main Canal, and is diverted into the canal approximately one mile upstream of MW-4. This suggests that the aquifer in the vicinity of MW-4 is in communication with the Merced River. The groundwater quality in MW-2 and MW-3 is nearly identical and also similar to the water from the Main Canal, although with slightly higher TDS (Table 3, Figure 7). The water samples from MW-1 have slightly higher calcium and bicarbonate concentrations compared to the rest of the MRR monitoring wells (Table 3, Figure 7).

During the monitoring period, there was a slight drift in water quality at the MRR (Figure 7). The water quality in MW-2 and MW-3 remained very similar, but both showed a slight decrease in sodium and chloride. The water quality in the Main Canal and MW-4 also showed a drop in sodium and chloride (Figure 7). The November sample from MW-4 was, however, closer in quality to MW-2 and MW-3, suggesting less communication with the Merced River. There was little change in water quality in MW-1, suggesting that groundwater in the vicinity of this well may not be in full communication with the rest of the MRR.

Subtle changes in water quality beneath the site over time suggest that the primary source of groundwater beneath the Ranch is the Main Canal and that groundwater discharges to the Merced River.

Table 3. Groundwater and Main Canal surface water analyte levels.

Analyte	Method[1]	Units	Canal Water		MW-1		MW-2		MW-3		MW-4	
			07/10/06	11/21/06	07/10/06	11/21/06	07/10/06	11/21/06	07/13/06	11/21/06	07/13/06	11/21/06
Bicarbonate (as CaCO3)	SM 2320 B	mg/L	16	12	120	110	36	33	83	94	33	27
Carbonate (as CaCO3)	SM 2320 B	mg/L	<1[2]	<1	<1	<1	<1	<1	<1	<1	<1	<1
Alkalinity, Total	SM 2320 B	mg/L	16	12	120	110	36	33	83	94	33	27
Calcium	EPA 200.7	mg/L	3.6	2.7	32	26	8.4	7.4	17	19	6.5	5.7
Chloride	EPA 300.0	mg/L	1.0	<1	3.0	1.9	4.0	1.3	9.0	3.5	2.0	1.1
Hydroxide (as CaCO3)	SM 2320 B	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Iron, Dissolved	EPA 200.7	mg/L	0.67	<0.05	14	20	5.5	<0.05	<0.05	0.64	<0.05	<0.05
Magnesium	EPA 200.7	mg/L	1.2	0.9	8.8	7.2	4.8	3.4	10	12	2.3	2.0
Manganese, Dissolved	EPA 200.7	mg/L	0.044	<0.01	4.0	3.7	0.33	0.026	0.15	0.18	0.17	<0.01
Nitrate (NO3-N)	EPA 300.0	mg/L	<0.23	<0.23	<0.23	<0.23	0.68	0.33	<0.2	<0.2	<0.2	<0.2
pH	SM 4500-H+ B	units	7.5	7.3	7.6	7.1	7.4	7.4	7.5	7.6	7.4	7.3
Potassium, Dissolved	EPA 200.7	mg/L	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sodium, Dissolved	EPA 200.7	mg/L	1.8	1.4	4.4	3.3	5.3	2.7	12	7.2	3.5	1.7
Specific Conductance	EPA 2510 B	µmhos/cm	32	28	260	210	94	78	200	210	65	52
Sulfate	EPA 300.0	mg/L	<2	<2	<2	<2	4.0	2.5	8.0	7.0	<2	<2
Total Dissolved Solids	SM 2540 C	mg/L	23	22	160	140	160	66	150	150	69	32

[1] SM = standard method; EPA = U.S. Environmental Protection Agency.

[2] Constituents that are not detected are denoted as being less than (<) the practical quantifiable limit.

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5 FIGURES

Appendix A

GROUNDWATER MONITORING WELL CONSTRUCTION DIAGRAMS

Appendix B

GROUNDWATER MONITORING WELL BORING LOGS

Appendix C

GROUNDWATER QUALITY LABORATORY ANALYTICAL RESULTS