Geomatrix

August 28, 2007
Project 7622.007

Mr. Hicham ElTal
Merced Irrigation District
744 West 20th Street
Merced, California 95340

Subject: Evaluation of Potential Impacts of Transfer of up to 25,000 Acre-Feet of Surface Water to the Environmental Water Account

Dear Mr. ElTal:

At your request, Geomatrix Consultants, Inc. (Geomatrix), conducted an evaluation of historical groundwater levels beneath the Merced Irrigation District (MID) and estimated the potential impacts of the proposed one-time transfer of up to 25,000 acre-feet of surface water to the Environmental Water Account (EWA) for the protection and restoration of at-risk fish species listed under the Federal and California Endangered Species Acts. We understand that MID proposes to pump groundwater from its service area equal to the amount of water transferred to EWA, up to 25,000 acre-feet during 2007.

## BACKGROUND

The Merced subbasin is situated near the center of the San Joaquin Valley in the southern portion of the Central Valley of California. The Central Valley, a deep structural trough up to 200 miles long and 70 miles wide, is filled with as much as 32,000 feet of marine and continental sediments deposited during periodic inundation by the Pacific Ocean and by erosion of the surrounding Sierra Nevada and Coast Ranges. Continental deposits that eroded from the surrounding mountains (primarily the Sierra Nevada) formed alluvial wedges that thicken from the valley margins toward the axis of the structural trough. This depositional axis is slightly west of the series of rivers, lakes, sloughs, and marshes, which mark the current and historic axis of surface drainage in the San Joaquin Valley.

The hydrogeological boundaries of the Merced groundwater subbasin include lands south of the Merced River, west of the eastern Merced County boundary, north of the Chowchilla River, and east of the San Joaquin River (Figure 1). The Merced subbasin is underlain by consolidated rocks of the Ione Formation, the Valley Springs Formation, and the Mehrten Formation and unconsolidated sediments consisting of continental deposits, lacustrine and marsh deposits, older alluvium, younger alluvium, and floodbasin deposits. The consolidated rocks generally yield small quantities of groundwater to production wells with the exception of the Mehrten Formation, which is an important aquifer in the eastern portion of the subbasin. The continental deposits and older alluvium are the main water-yielding units in the unconsolidated deposits.

The lacustrine and marsh deposits (which include the Corcoran, or "E- Clay") and the floodbasin deposits yield little groundwater to production wells, and the younger alluvium in most places probably yields only moderate quantities of groundwater to production wells.

Three aquifer systems have been recognized in the Merced subbasin: an unconfined alluvial aquifer, a confined alluvial aquifer, and a consolidated rock aquifer. The unconfined alluvial aquifer occurs in the unconsolidated deposits above and east of the Corcoran Clay, which underlies the western half of the Merced subbasin at depths ranging between about 50 and 200 feet. In the western and southern parts of the basin, in areas where clay lenses occur, semi-confined conditions may exist. The confined alluvial aquifer occurs in the unconsolidated deposits below the Corcoran Clay and extends downward to the base of fresh water. The aquifer in consolidated rocks occurs primarily in the Sierra Nevada foothills under both unconfined and confined conditions.

Natural recharge is primarily from infiltration of precipitation and snowmelt. Annual precipitation ranges from 11 to 13 inches, increasing eastward, and averages about 12.25 inches per year. Groundwater quality beneath the Merced subbasin is generally excellent with a low total dissolved solids content reflecting its Sierra Nevada source. Groundwater beneath the City of Merced and a few industrial areas has been impacted with volatile organic compounds. Small areas of elevated nitrate concentrations also exist throughout the subbasin.

Groundwater levels with the Merced subbasin have been monitored by MID since the 1950s. Long-term hydrographs show that average groundwater elevations have declined from about 140 feet above mean sea level (MSL) in 1959 to about 110 feet MSL in 2006 (Figure 2). Most of this decline occurred during the 1980s. Since 1990, average groundwater levels have stabilized or slightly increased.

Groundwater flow in the Merced subbasin is primarily from northeast to southwest, following the regional dip of basement rocks and sedimentary units from the recharge area in the Sierra Nevada foothills to the discharge area at the San Joaquin River. California Department of Water Resources maps of lines of equal elevation of groundwater in the unconfined aquifer show persistent depressions in the groundwater surface south and southeast of the City of Merced since 1990.

## MID WATER SUPPLY

MID's total annual water supply during the period from 1970 to 2004 has ranged from 342,000 to 743,000 acre-feet per year (AFY) and averaged about 555,000 AFY (Figure 3). During this period, MID groundwater pumping has ranged from 7,700 to 175,000 AFY and averaged about

47,000 AFY. Of the average total water supply of 555,000 AFY, about 508,000 AFY (or about 91 percent) was from surface water supplies and about 47,000 AFY (or about 9 percent) was from pumped groundwater.

MID total system deliveries from 1970 to 2004 ranged from 182,000 to 506,000 AFY (Figure 3) and averaged about 365,000 AFY. During this period, total delivery system losses (comprised of evaporation and delivery system seepage) ranged from 31,000 to 302,000 AFY and averaged about 190,000 AFY. Total system loss was about 34 percent of total MID water supply. A portion of the delivery system losses was returned to the aquifer system through canal leakage and irrigation spreading losses.

Since the mid-1990s, MID has significantly decreased groundwater usage. Between 1970 and 1992, MID pumped an average of approximately 65,000 AFY, comprising about 12 percent of the total water supply. Between 1993 and 2004, MID pumped an average of 13,000 AFY, comprising only 2.3 percent of the total water supply. This reduction in pumping is a result of modernization, automation, and upgrades in the surface water distribution system and fewer dry years during this latter period.

**MID RECHARGE PROGRAMS**

In response to the declining groundwater levels in the 1980s, MID implemented a series of programs in the 1990s to recharge the Merced subbasin aquifer system through in-lieu and direct recharge (Figure 1). "In-lieu recharge" means accomplishing increased storage of groundwater by providing surface water to a user who relies on groundwater as a primary supply in order to accomplish groundwater storage through the direct use of that surface water in lieu of pumping groundwater (California Water Code Section 12879-12879.2). "Direct recharge" means storing water by allowing it to percolate directly to storage in the groundwater basin. The programs include:

- MID installed low-head booster pumps on several canals. This allows for the reassignment of more than 12 deep pumping wells from baseline operations to standby mode for dry years. This has reduced annual pumping from about 24,000 AFY to about 8,000 AFY, resulting in an annual in-lieu recharge of about 16,000 AFY.

- MID implemented a program to provide a high level of service (delivery within 24 hours of demand) to its customer base, reducing supplemental private pumping from an annual average of 42,000 AFY to about 10,000 AFY, resulting in an annual in-lieu recharge of about 32,000 AFY.

- MID implemented a groundwater conservation incentive program, resulting in the shifting of about 3,000 acres of groundwater-irrigated land to surface water irrigation and an annual in-lieu recharge of about 9,000 AFY.

- MID implemented the Highlands Pilot In-Lieu Recharge Project, providing surface water to 450 acres of lands previously irrigated by groundwater only, replacing 12 wells and resulting in an annual in-lieu recharge of about 1,500 AFY.

- MID also implemented a pilot direct recharge project at Cressey Basin, which has the potential to direct-recharge up to 10,000 AFY when surface water is available.

In total, MID has implemented various recharge and conservation projects, which combined provide an annual in-lieu recharge of about 60,000 AFY, which has resulted in the cumulative in-lieu recharge of about 300,000 acre-feet since 2001.

## SCOPE OF ENVIRONMENTAL WATER ACCOUNT TRANSFER

MID proposes a one-time transfer of up to 25,000 acre-feet of surface water from the Merced River to the EWA for augmenting in-stream flows in the Merced and San Joaquin rivers in fall 2007 for migrating Chinook salmon and replacing project water borrowed by EWA for fish protective actions taken in spring 2007 for Delta smelt. MID plans to pump up to 25,000 acre-feet of groundwater from within its service area for irrigation purposes during 2007 in lieu of providing an equivalent amount of surface water from Lake McClure, which will be transferred to EWA in the fall 2007. Pumping of up to 25,000 acre-feet of groundwater will be allocated among 120 water supply wells within the MID service area (Figure 4). The proposed wells are distributed throughout the Merced subbasin with the majority of the wells located in the northwest portion of the district where groundwater is shallowest. The proposed wells are mostly located away from areas of municipal production. MID will use totalizing flow meters to measure groundwater volumes extracted though its wells during the transfer.

MID plans to monitor groundwater elevations on a monthly basis in their network of 200 production and monitoring wells during transfer pumping and subsequently during the post pumping recovery period. Should excessive drawdown be measured at a particular well location during the transfer, pumping may be allocated to an alternative well.

## BASELINE GROUNDWATER MONITORING DATA

MID has been monitoring groundwater levels in as many as 200 production and monitoring wells on an annual basis since 1959 and monthly basis since 1991. These data have been compiled into a database to prepare long-term hydrographs (Figures 5A through 5G) and evaluate groundwater levels beneath the Merced subbasin. Long-term hydrographs show that between 1959 and 2006, average groundwater levels have declined about 28.5 feet (Figure 2). Between 1959 and 1970, average groundwater levels remained relatively stable. Between 1970 and 1991, average groundwater levels declined about 31 feet. Most of this decline occurred between 1983 and 1991 during a period of extended drought. Between 1991 and 1998, average groundwater levels recovered about 8.9 feet. Much of this was due to a decrease in pumping and abundant surface water supplies. Between 1998 and 2006, average groundwater levels declined about 6.4 feet, in part due to increased municipal demand and a few less-than-average precipitation years. However, average groundwater levels in 2006 remain approximately 2.5 feet above the low of 1991.

## POTENTIAL IMPACTS OF EWA TRANSFER

The proposed transfer is less than 50 percent of the 60,000 AFY in-lieu recharge resulting from MID's conservation programs and is only a little more than 50 percent of MID's historical pumping for irrigation supply of about 47,000 AFY. Potential impacts of the transfer include increased drawdown in the regional aquifer, increased surface/groundwater interaction, land subsidence, and migration of poor quality groundwater. These potential impacts are addressed in the following subsections.

### INCREASED DRAWDOWN

The proposed transfer is very similar to a previous EWA transfer conducted in 2001, during which 25,000 acre-feet of groundwater were pumped from the MID service area. As shown on Figure 2, the average groundwater levels declined about 5 feet for a short term (about 6 months) during 2001 as a result of this transfer. However, since 2001, groundwater levels in the Merced subbasin have remained relatively stable or slightly increased, despite 3 years of less than average precipitation from 2002 through 2004. Therefore, based on these historical data trends, the proposed transfer of up to 25,000 acre-feet may potentially result in a short-term average groundwater decline of about 5 feet in the Merced subbasin.

The potential impacts of the proposed transfer on groundwater elevations within the Merced sub-basin were also modeled using MID's existing Merced subbasin numerical groundwater model. This groundwater model was developed by CH2M Hill for the Merced subbasin in 2001 (CH2M Hill, 2001b). The original model was developed using a MicroFEM platform. Geomatrix converted the MID model into Modflow 2000 format (the de-facto standard for groundwater models) to conduct the impact analysis. The model consists of a grid of 40 rows, 51 columns, and 4 layers. Each cell is approximately 1 square mile in area. The model utilizes 30 stress periods of 1 year duration simulating a period between 1970 through 1999.

Geomatrix used the model to simulate baseline groundwater conditions in the MID subbasin. A hind-cast superposition scenario was then simulated by allocating the additional transfer well pumping of 25,000 acre-feet to 113 of the 120 transfer wells. The 1994 model year (model stress period 25) was selected for application of transfer pumping because average basin wide water levels were similar to those observed through the 2006 water year and precipitation totals for 1994 and 2006 were similar. Furthermore, MID groundwater pumping allocations have remained relatively stable between 1993 and 2006 (with the exception of the 2001 exchange extraction). The superposition model assumed that recharge rates in 1994 and 2006 were typical and that recharge and pumping simulated in the hind-cast model between 1994 and 1999 will approximate future recharge and pumping within the basin between 2007 and 2012. Simulated groundwater heads from the superposition model were subtracted from simulated heads in the baseline model, the difference representing drawdown due to simulated transfer pumping within the basin.

The model results indicate that the average drawdown per cell (a 1 square mile area) ranges between 0 and 1.2 feet. The simulated areal extent of drawdown within the subbasin resulting from transfer pumping is depicted on Figure 6. The model results show that the drawdown effects of the transfer pumping dissipate over a period of 5 years (year 2012) to an average of 0 feet to 0.4 feet (Figure 7).

The amount of drawdown simulated by the model is lower than that observed during the 2001 transfer (1.2 versus about 5 feet). That difference is a function of the model resolution and time steps utilized. The 2001 transfer pumping occurred over a 2 month period culminating in an observed average drawdown of about 5 feet measured within 6 months following pumping. This was followed by 3 years of stable or recovering groundwater levels. The groundwater model, however, is an annual model and the proposed 2007 transfer pumping is distributed over a single, 1-year stress period instead of the proposed 2-month period. Although the total amount of groundwater extracted will be the same (25,000 acre-feet), simulating it over a 1-year period and measuring it over a 1-square mile area produces an averaging effect that results in lower average simulated drawdown, but stretches it out over a longer period of time (1 year versus 2 months). In any case, the model corroborates the observations from the 2001 extraction, showing that the removal of the transfer water from the aquifer will have little short-term or long-term effect on groundwater levels.

**INCREASED SURFACE/GROUNDWATER INTERACTION**

Groundwater pumping in the vicinity of a surface water body could potentially alter existing surface/groundwater interactions by inducing more leakage and reducing stream flows and stream water levels. The Merced River is the only water body of significance in the service area.

No wetlands or unregulated streams are present within the proposed pumping area. Groundwater pumping for the transfer will be made available from 120 production wells approved by Reclamation. Based on review of the available groundwater data, in coordination with Reclamation staff, it is unlikely that groundwater pumping from these 120 wells will induce additional leakage from the River. No adverse surface/groundwater interactions were observed during the 2001 transfer of 25,000 acre-feet.

**LAND SUBSIDENCE**

Excessive groundwater extraction from confined or semi-confined aquifers could potentially result in a sufficient decline in water pressure to cause compaction of clays and silts, resulting in land subsidence. The MID service area does not appear to be susceptible to land subsidence. No land subsidence was detected during the 2001 transfer of 25,000 acre-feet. Additionally, no known subsidence has occurred in areas where significant long-term cones of depression have been observed (i.e. southeast of Merced).

**GROUNDWATER QUALITY**

Groundwater quality beneath the MID service area is generally excellent from the foothills to the San Joaquin River. No significant areas of groundwater contamination are present that may be mobilized by the transfer pumping. No known water quality issues arose as a result of the 2001 transfer of 25,000 acre-feet.

## MITIGATION OF POTENTIAL IMPACTS

MID will use its monitoring network of more than 200 production and monitoring wells to evaluate groundwater levels on a monthly basis during and after transfer pumping to monitor potential impacts. This monitoring frequency is more than adequate to detect and monitor potential adverse impacts on the aquifer system resulting from the pumping of up to 25,000 acre-feet. Further, during transfer groundwater pumping, MID staff will address any concerns by landowners appropriately on a case-by-case basis. Should excessive drawdown be measured at a particular well location, transfer pumping may be allocated to an alternative location.

## SUMMARY

Based on the evaluation of the data presented above, the proposed one-time transfer of up to 25,000 acre-feet of groundwater is unlikely to have a significant (greater than 5 feet of average groundwater level decline) or irreversible impact on the Merced subbasin aquifer system.

Please call if you would like additional information or have any questions.

Sincerely yours,
GEOMATRIX CONSULTANTS, INC.

| | |
|---|---|
| Gary L. Kramer, PG<br>Senior Geologist | David M. Bean, PG, CHG<br>Senior Hydrogeologist |

Attachments:

| | |
|---|---|
| Figure 1 | MID Existing and Proposed In-Lieu Recharge Projects |
| Figure 2 | Historical Range and Average Groundwater Elevations |
| Figure 3 | MID Historical Annual Water Supply |
| Figure 4 | Groundwater Supply and Monitoring Wells for 2007 EWA Water Transfer |
| Figures 5A-5G | Long Term Hydrographs for Selected Water Supply Wells |
| Figure 6 | Simulated Extents and Magnitude of Groundwater Drawdown Year 1 |
| Figure 7 | Simulated Extents and Magnitude of Groundwater Drawdown Year 5 |

## REFERENCES

Arkley, R.J., 1962, The geology, geomorphology, and soils of the San Joaquin Valley in the vicinity of the Merced River, California; in Geologic guide to the Merced Canyon and Yosemite Valley: Calif. Div. Mines and Geology Bull. 182, p. 25-31.

Bureau of Reclamation, California Department of Water Resources, California Department of Fish and Game, U.S. Fish and Wildlife Service), National Marine Fisheries Service, 2003, Draft Environmental Impact Statement/Environmental Impact Report, Chapter 6, Groundwater Resources, July.

CH2M Hill, 2001a, Merced Water Supply Plan Update Final Status Report. Prepared for City of Merced, Merced Irrigation District, and University of California, Merced, September 2001.

CH2M Hill, 2001b, Technical Memorandum, Merced ID Proposed Transfer to EWA, Report prepared for Marc Van Camp, September 10.

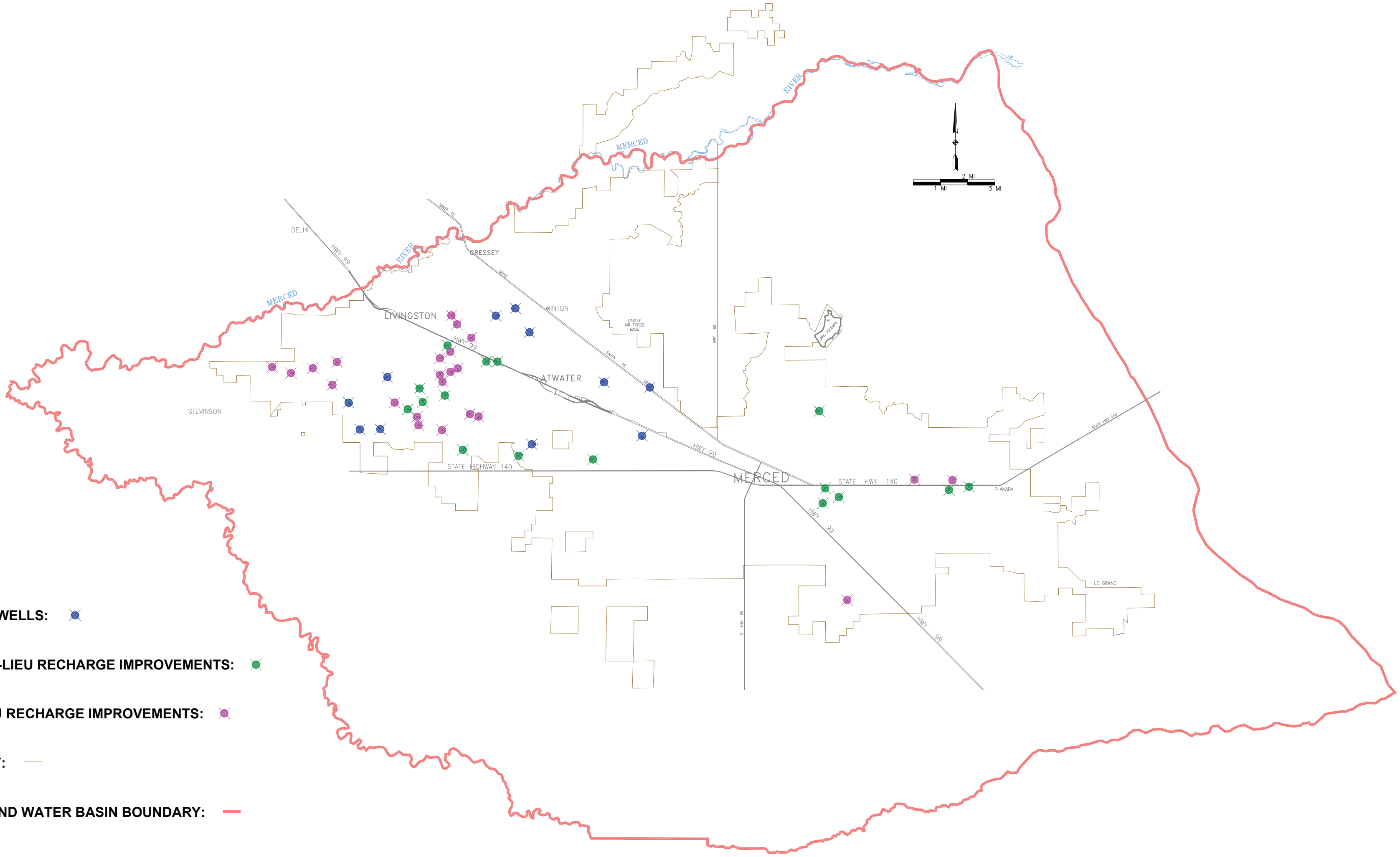
Department of Water Resources, Bulletin 118, 2003 Update.

Marchand, D.E., 1977, The Cenozoic history of the San Joaquin Valley and the adjacent Sierra Nevada as inferred from the geology and soils of the eastern San Joaquin Valley; in Singer, M.J., ed., Soil development, geomorphology, and Cenozoic history of the northeastern San Joaquin Valley and adjacent areas, California: Davis, Univ. Calif. Press, Guidebook for Joint Field Session, Soil Sci. Soc. America and Geol. Soc. America, p. 39-50.

Merced Irrigation District, 2001, Response to Petition for Temporary Transfer from Merced Irrigation District to the CALFED Environmental Water Account, Letter to Edward C. Anton, September 10.

Page, RW, and Balding, CO. 1973, Geology and Quality of Water in the Modesto-Merced Area, San Joaquin Valley, California, with a Brief Section of Hydrology, USGS Water-Resources Investigations 6-73, 85p.

State Water Resources Control Board, 2001, Petition for Temporary Transfer from Merced Irrigation District to the CALFED Environmental Water Account, Letter to Ross Rodgers, August 31.




**LEGEND:**

**HIGH GROUND WELLS:**

**COMPLETED IN-LIEU RECHARGE IMPROVEMENTS:**

**FUTURE IN-LIEU RECHARGE IMPROVEMENTS:**

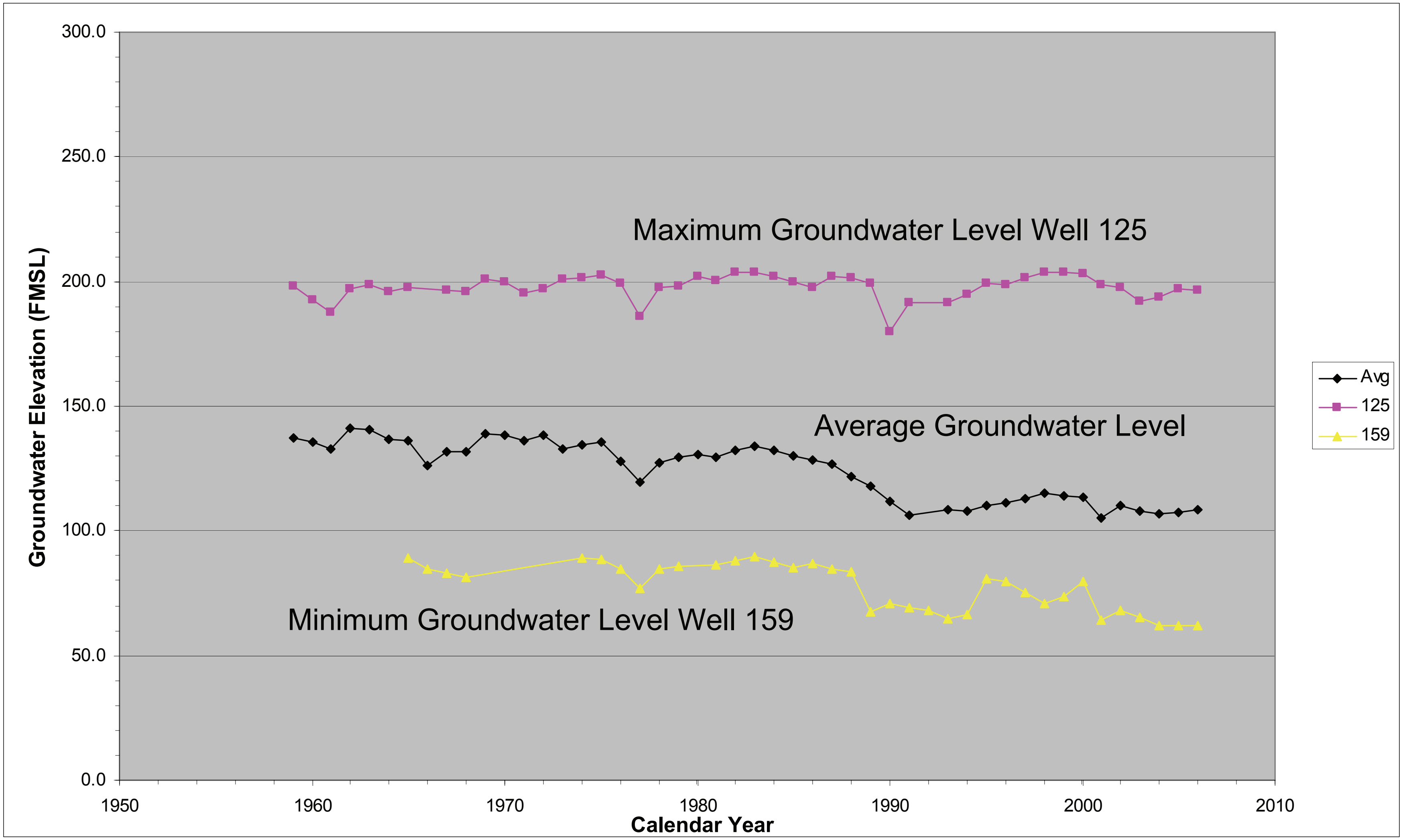
**MID BOUNDARY:**

**MERCED GROUND WATER BASIN BOUNDARY:**

MID EXISTING AND PROPOSED IN-LIEU RECHARGE PROJECTS

EWA Transfer Evaluation
Merced County, California

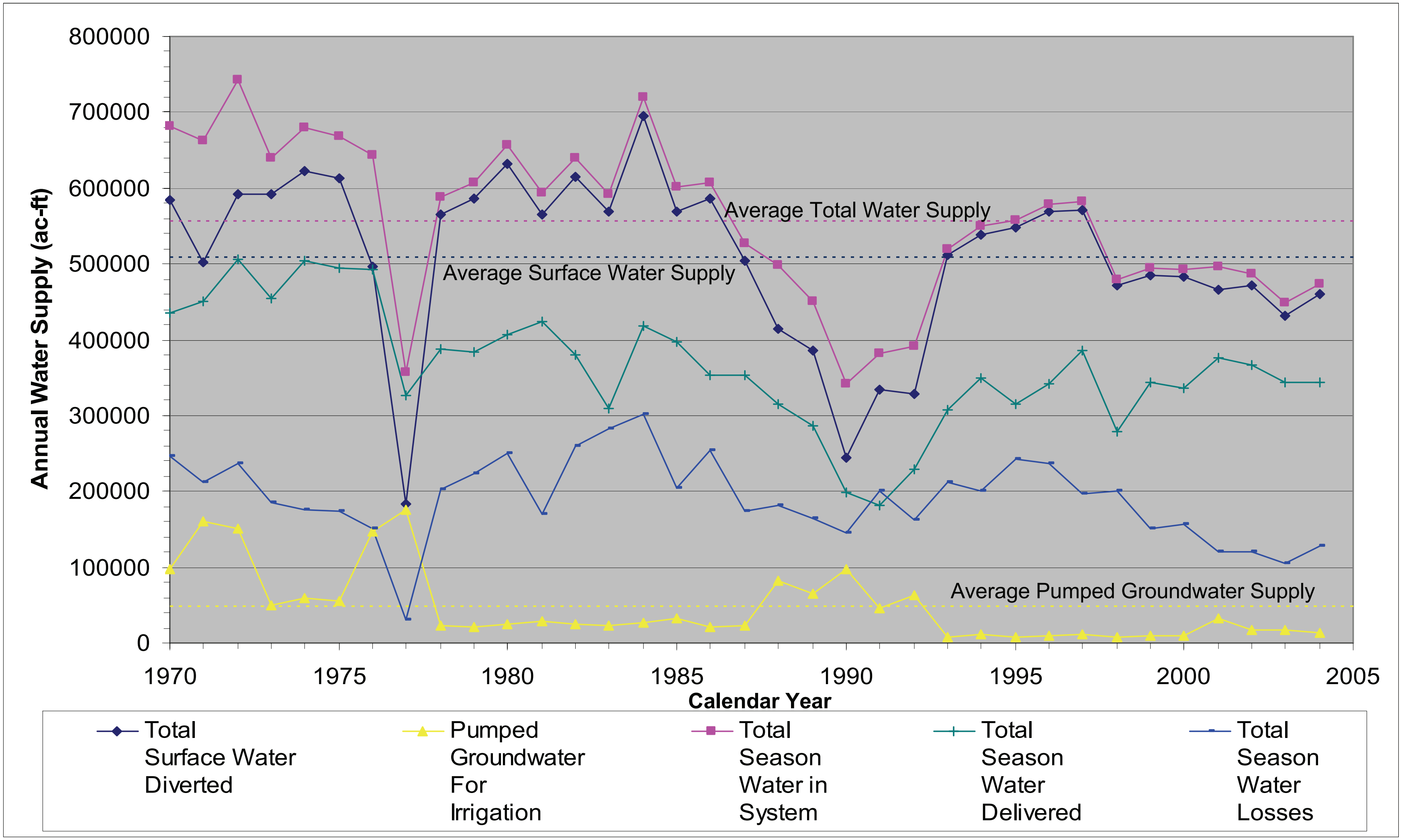
| By: dmb | Date: 06/21/07 | Project No. 7622.007 |
|---|---|---|
| Geomatrix | | Figure 1 |




HISTORICAL RANGE AND AVERAGE
GROUNDWATER ELEVATIONS

EWA Transfer Evaluation
Merced County, California

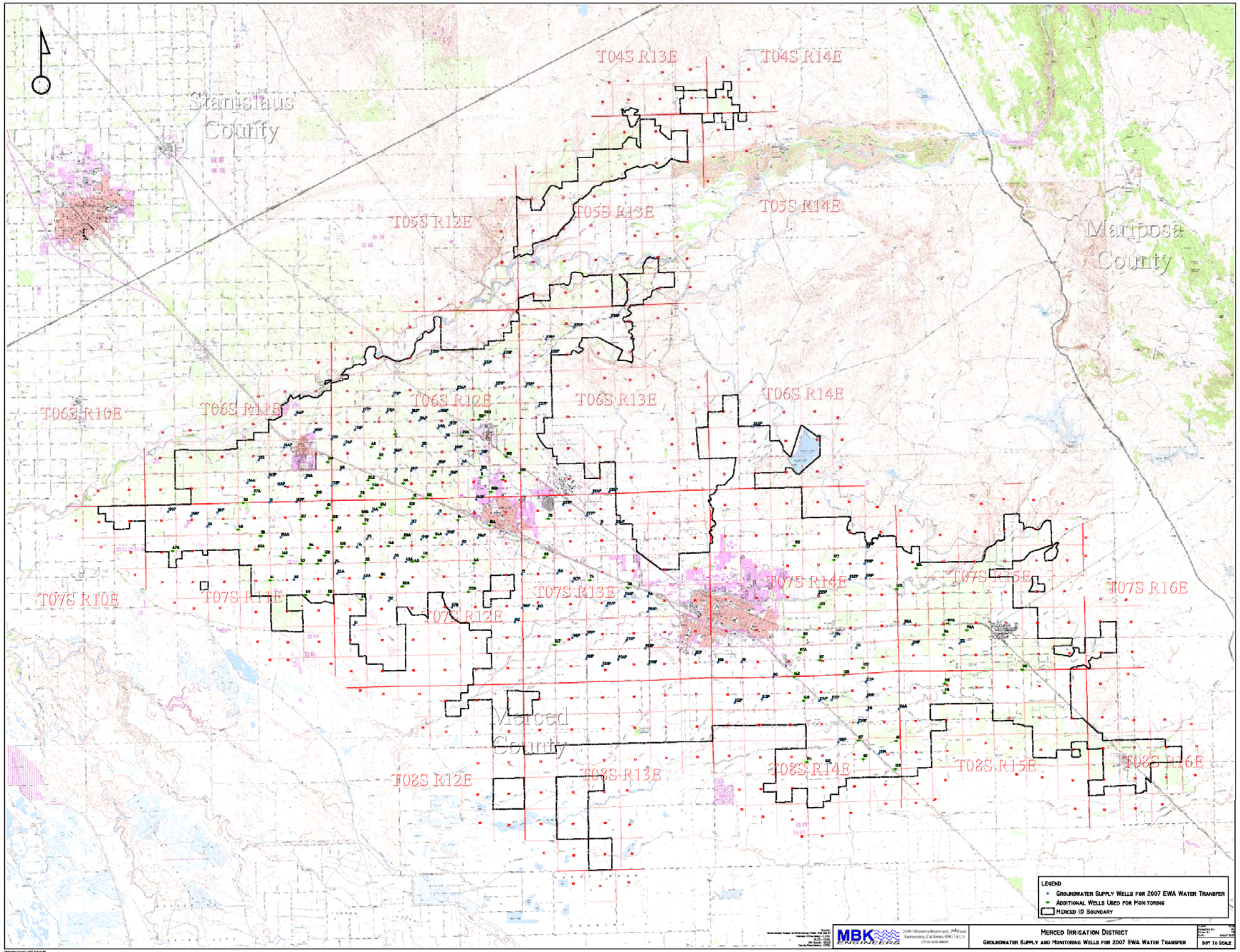
| By: dmb | Date: 06/21/07 | Project No. 7622.007 |
|---|---|---|
| Geomatrix | | Figure 2 |




MID HISTORICAL ANNUAL WATER SUPPLY

EWA Transfer Evaluation
Merced County, California

| By: dmb | Date: 06/21/07 | Project No. 7622.007 |
|---|---|---|
| Geomatrix | | Figure 3 |

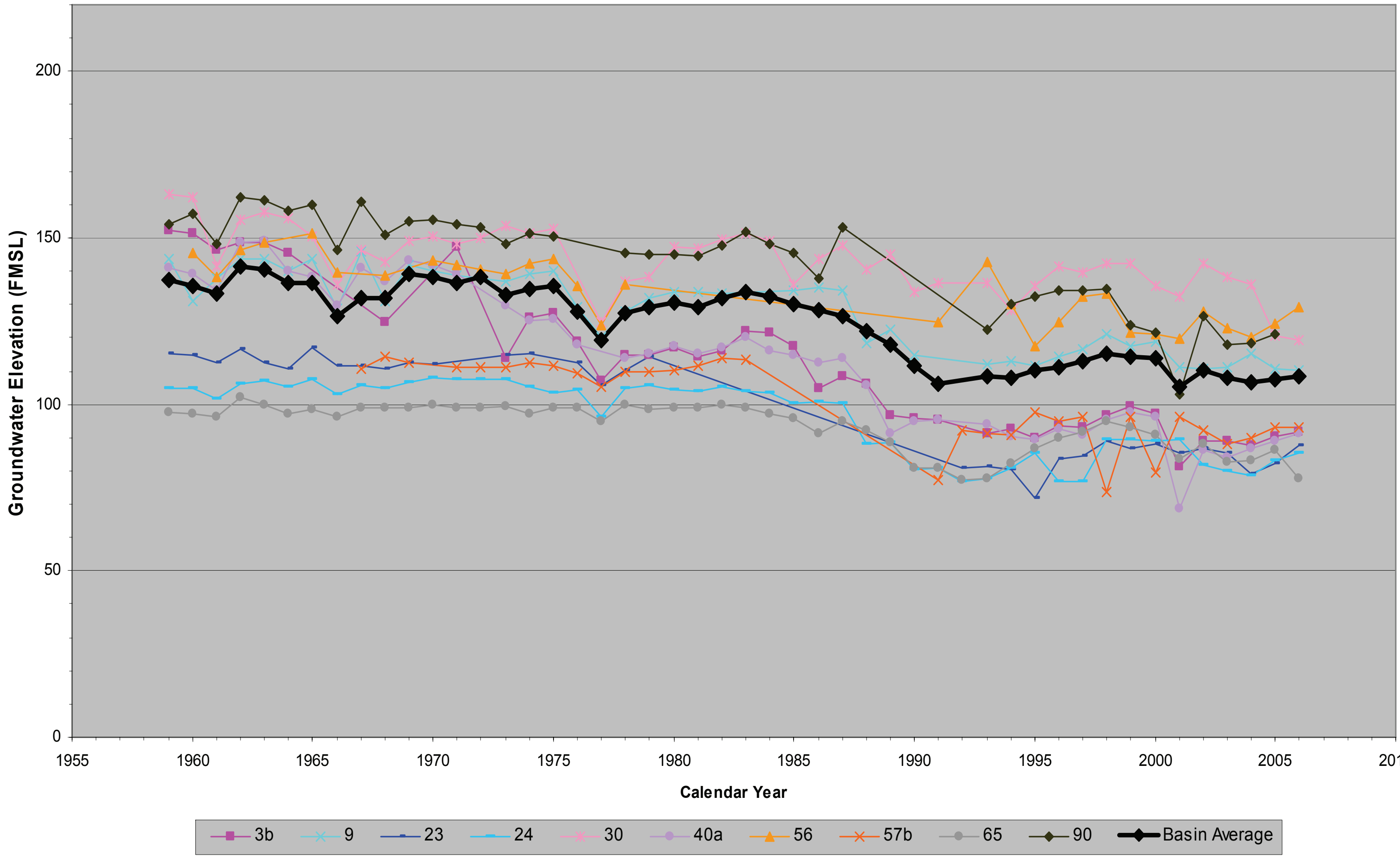



I:\7000s\7622\MID\graphics\MID_wells.ppt

GROUNDWATER SUPPLY AND MONITORING WELLS FOR 2007 EWA WATER TRANSFER

EWA Transfer Evaluation
Merced County, California

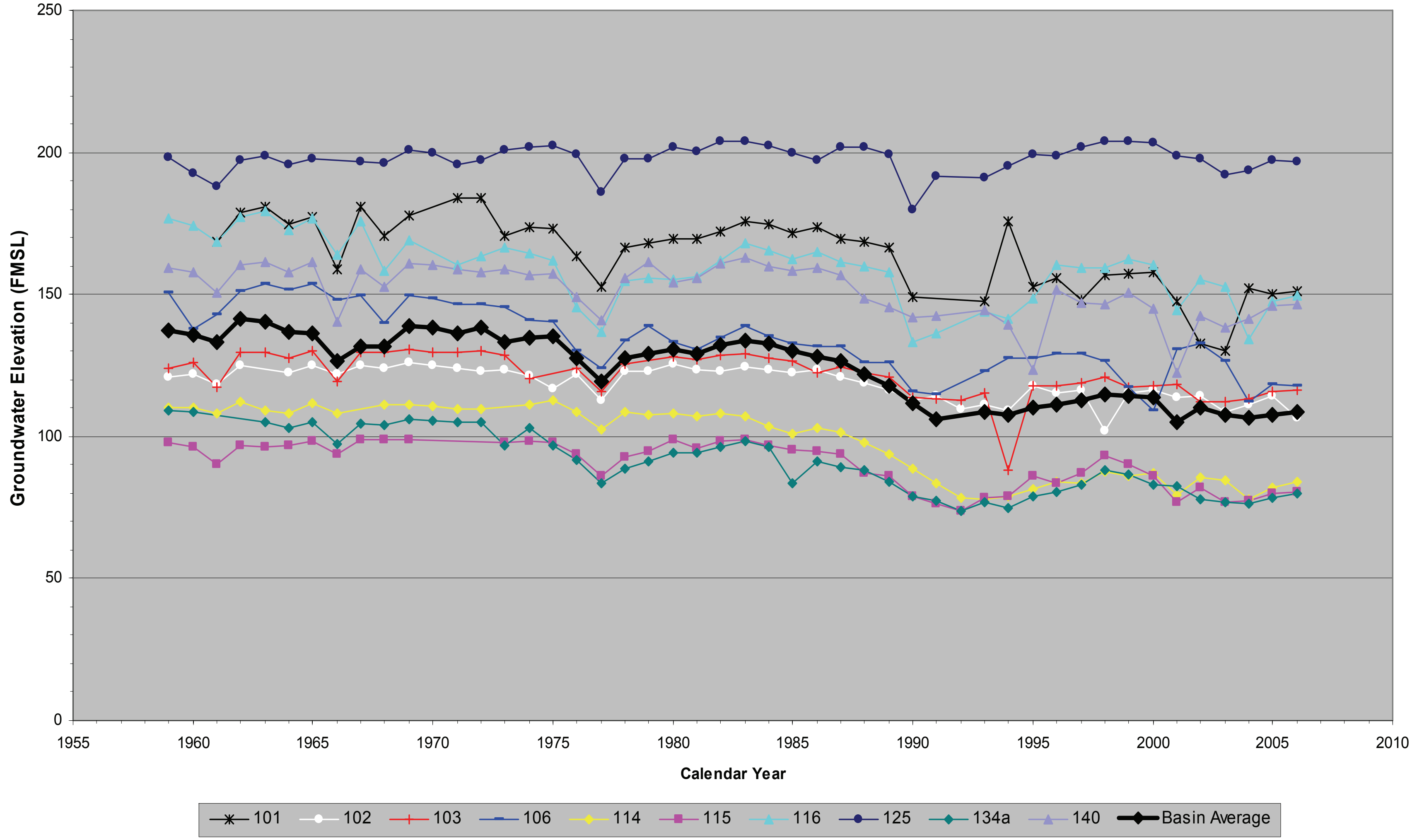
| By: dmb | Date: 07/05/07 | Project No. 7622.007 |
|---|---|---|
| Geomatrix | | Figure 4 |




LONG-TERM HYDROGRAPHS FOR SELECTED WATER SUPPLY WELLS

EWA Transfer Evaluation
Merced County, California

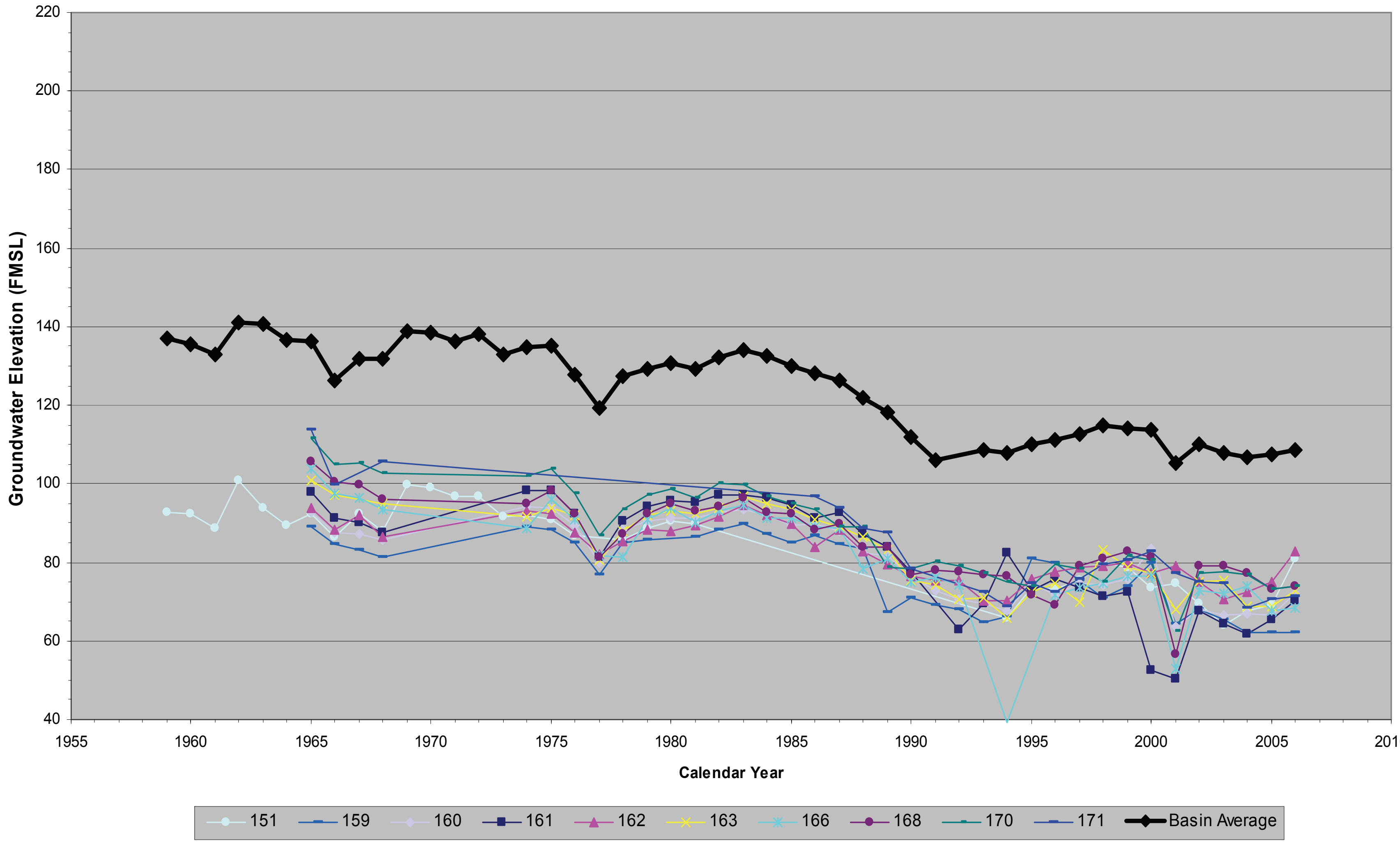
| By: dmb | Date: 06/21/07 | Project No. 7622.007 |
|---|---|---|
| Geomatrix | | Figure **5A** |




LONG-TERM HYDROGRAPHS FOR SELECTED WATER SUPPLY WELLS

EWA Transfer Evaluation
Merced County, California

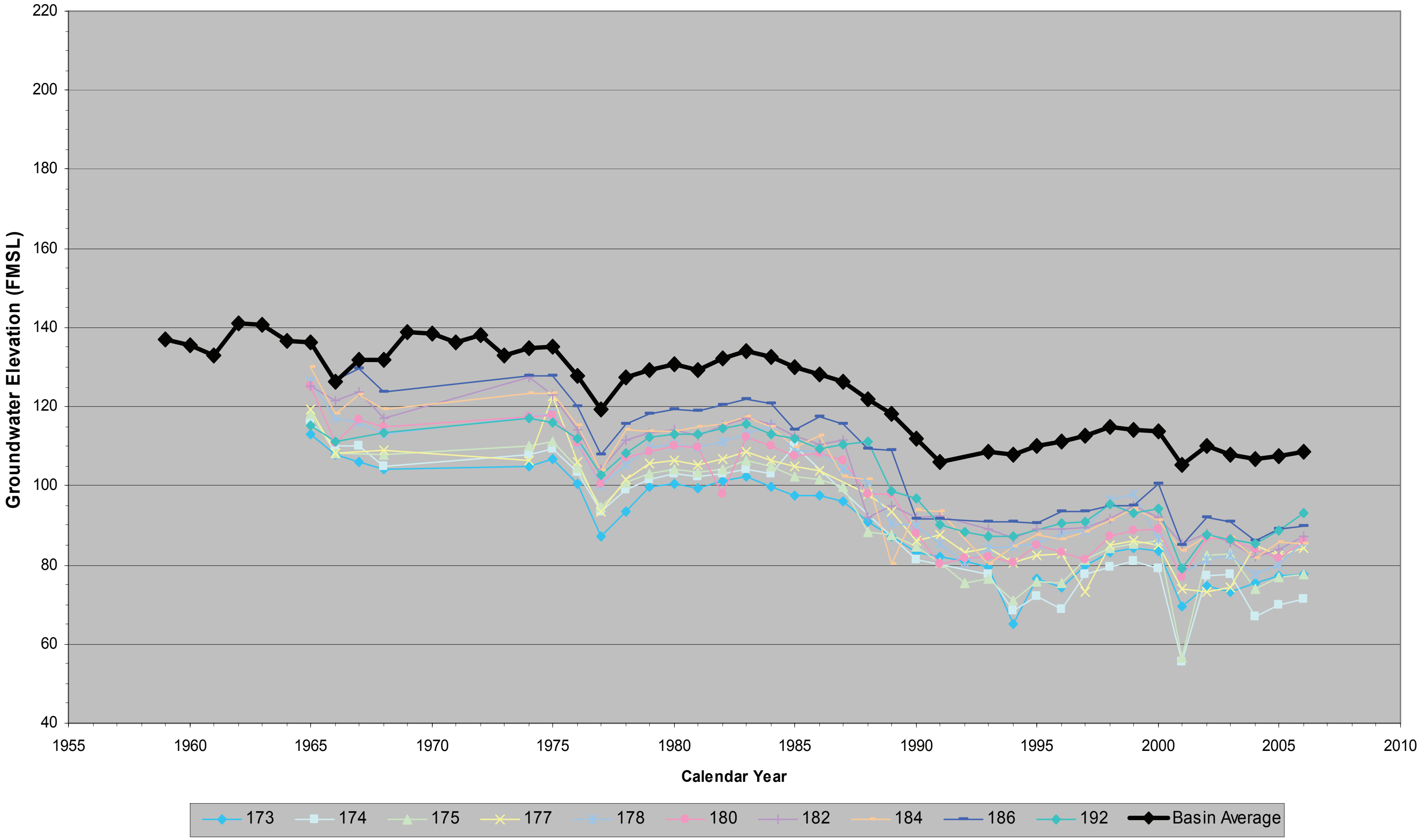
| By: dmb | Date: 06/21/07 | Project No. 7622.007 |
|---|---|---|
| Geomatrix | | Figure **5B** |




LONG-TERM HYDROGRAPHS FOR SELECTED WATER SUPPLY WELLS

EWA Transfer Evaluation
Merced County, California

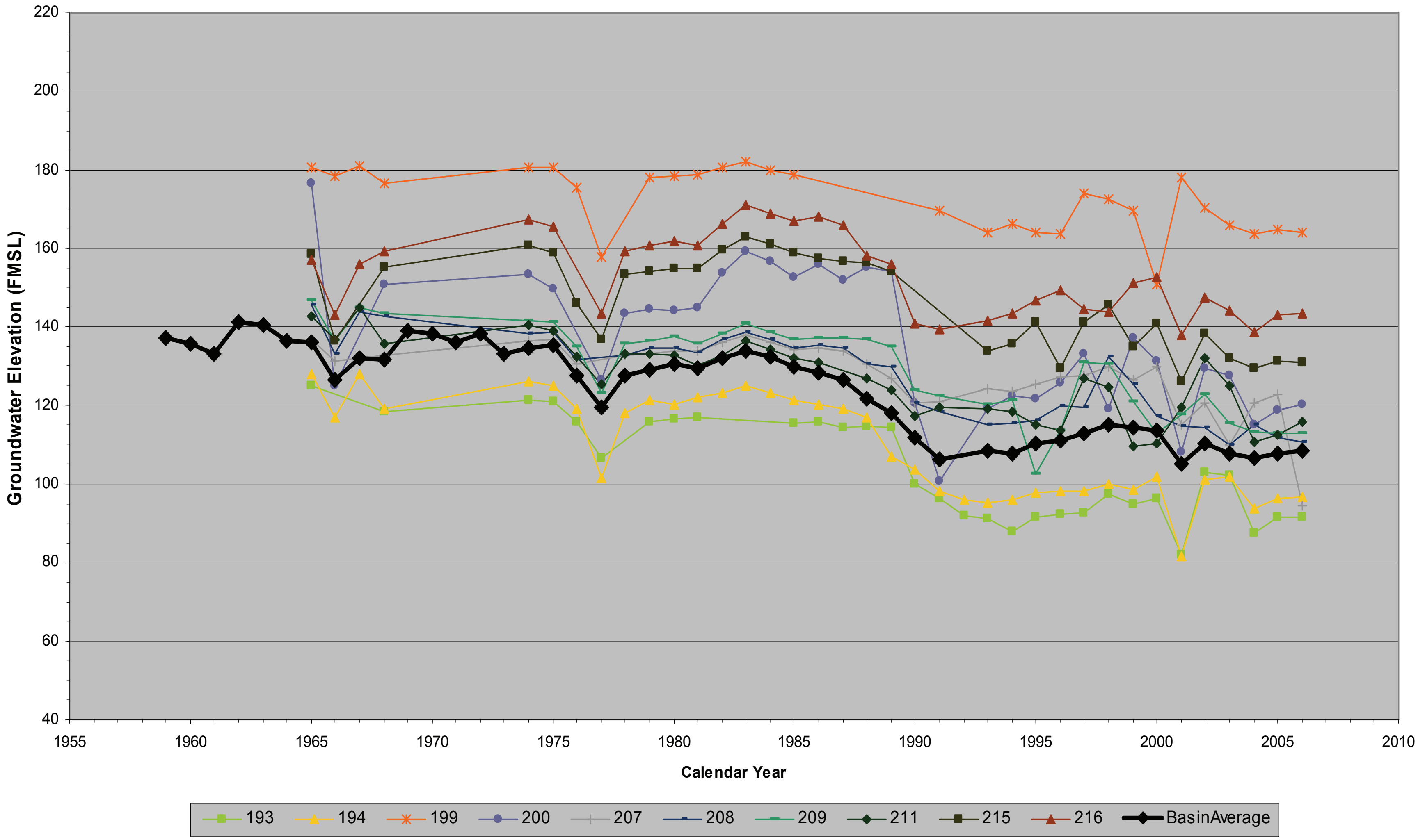
| By: dmb | Date: 06/21/07 | Project No. 7622.007 |
|---|---|---|
| Geomatrix | | Figure 5C |




LONG-TERM HYDROGRAPHS FOR SELECTED WATER SUPPLY WELLS

EWA Transfer Evaluation
Merced County, California

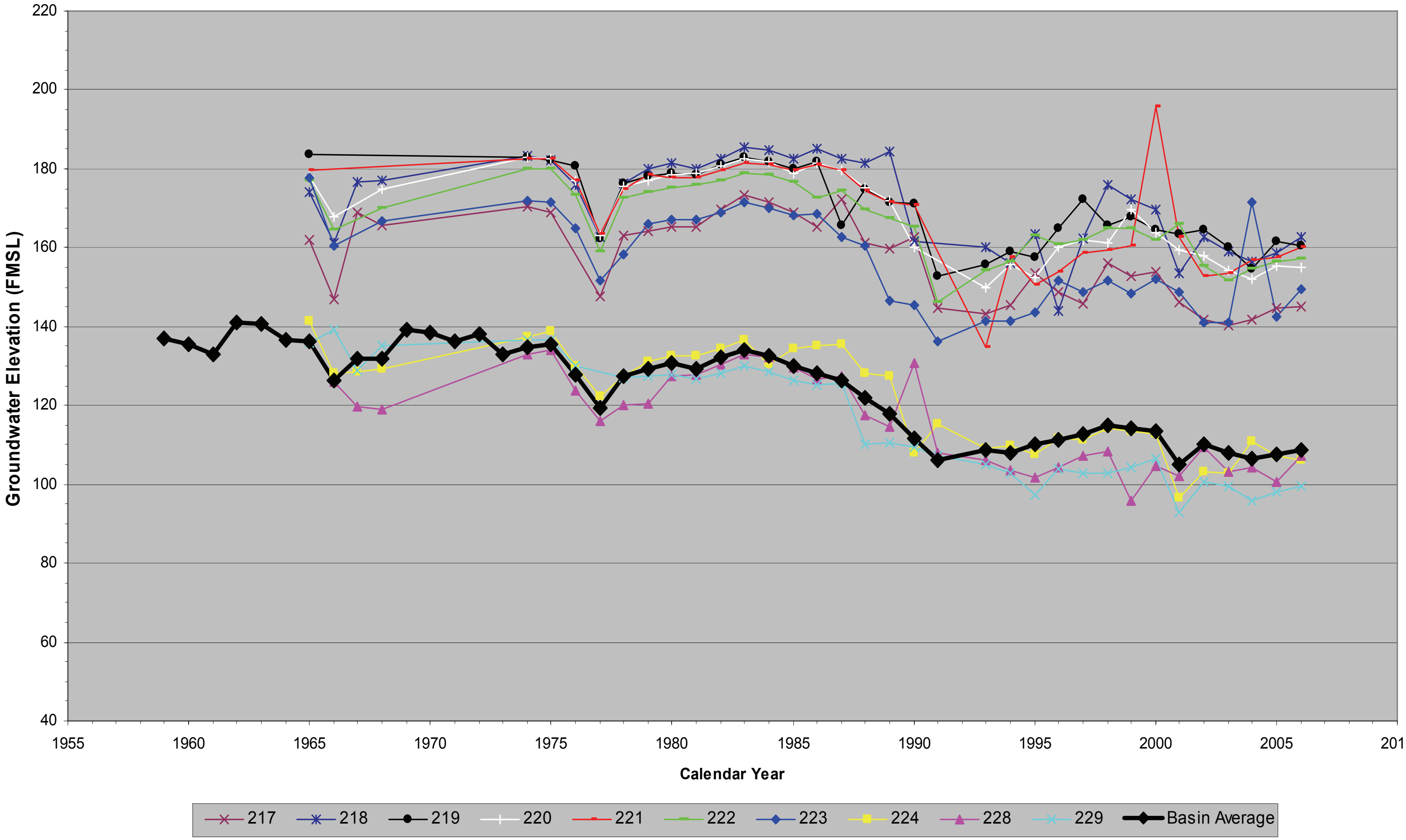
| By: dmb | Date: 06/21/07 | Project No. 7622.007 |
|---|---|---|
| Geomatrix | | Figure **5D** |




LONG-TERM HYDROGRAPHS FOR SELECTED WATER SUPPLY WELLS

EWA Transfer Evaluation
Merced County, California

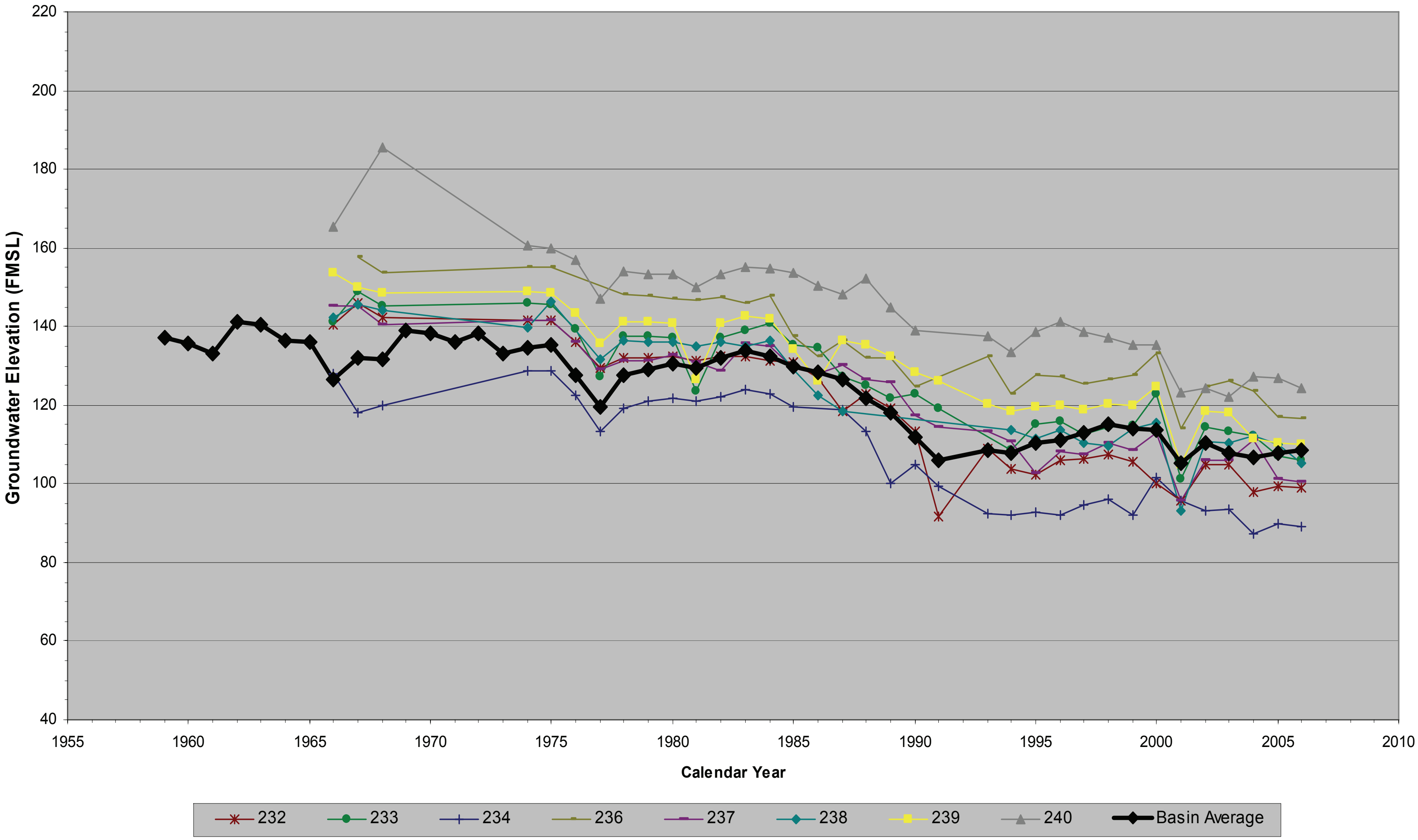
| By: dmb | Date: 06/21/07 | Project No. 7622.007 |
|---|---|---|
| Geomatrix | Figure **5E** | |




LONG-TERM HYDROGRAPHS FOR SELECTED WATER SUPPLY WELLS

EWA Transfer Evaluation
Merced County, California

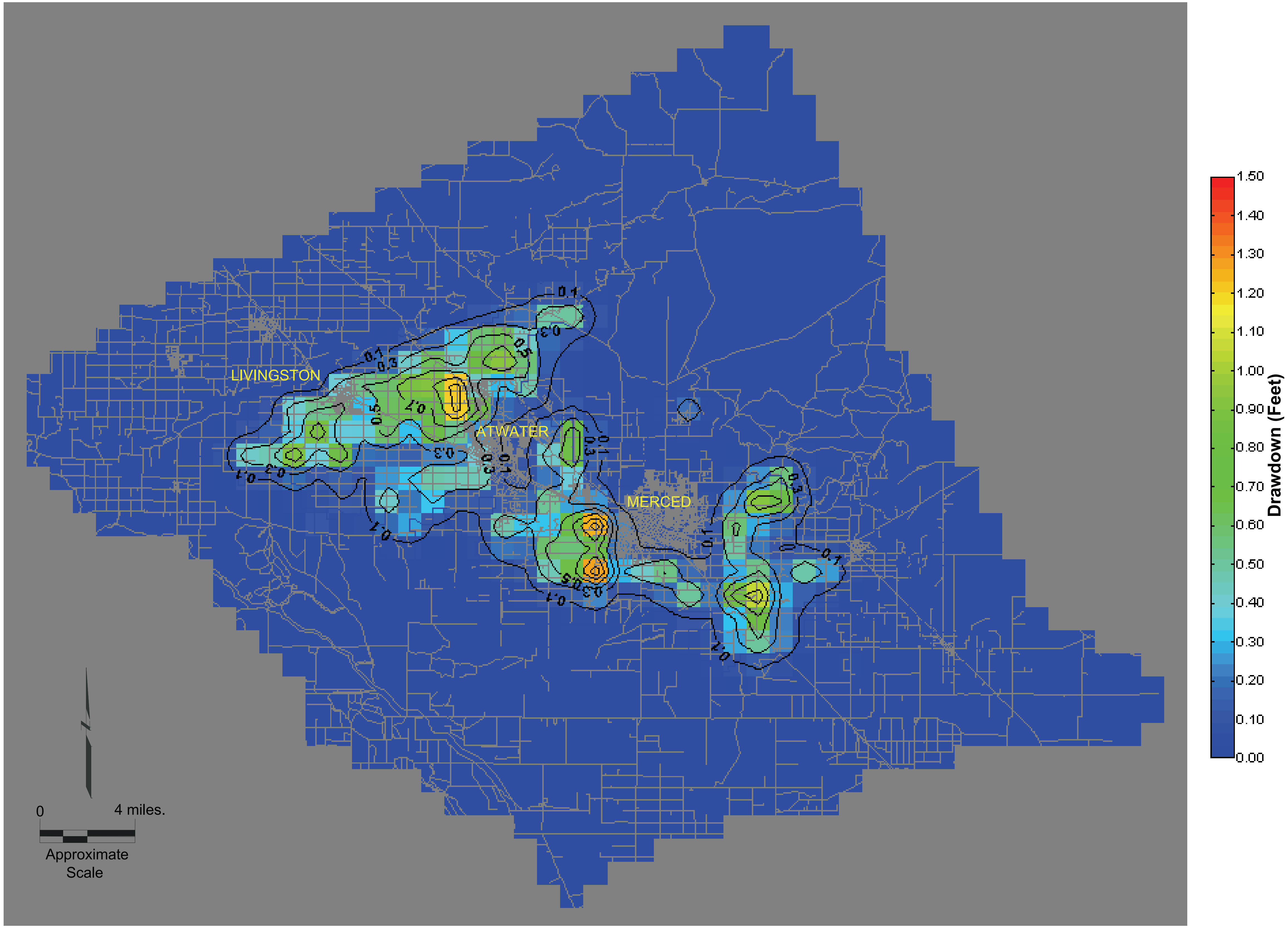
| By: dmb | Date: 06/21/07 | Project No. 7622.007 |
|---|---|---|
| Geomatrix | | Figure 5F |




LONG-TERM HYDROGRAPHS FOR SELECTED WATER SUPPLY WELLS

EWA Transfer Evaluation
Merced County, California

| By: dmb | Date: 06/21/07 | Project No. 7622.007 |
| --- | --- | --- |
| Geomatrix | | Figure 5G |




## EXPLANATION

Merced Subbasin Boundary

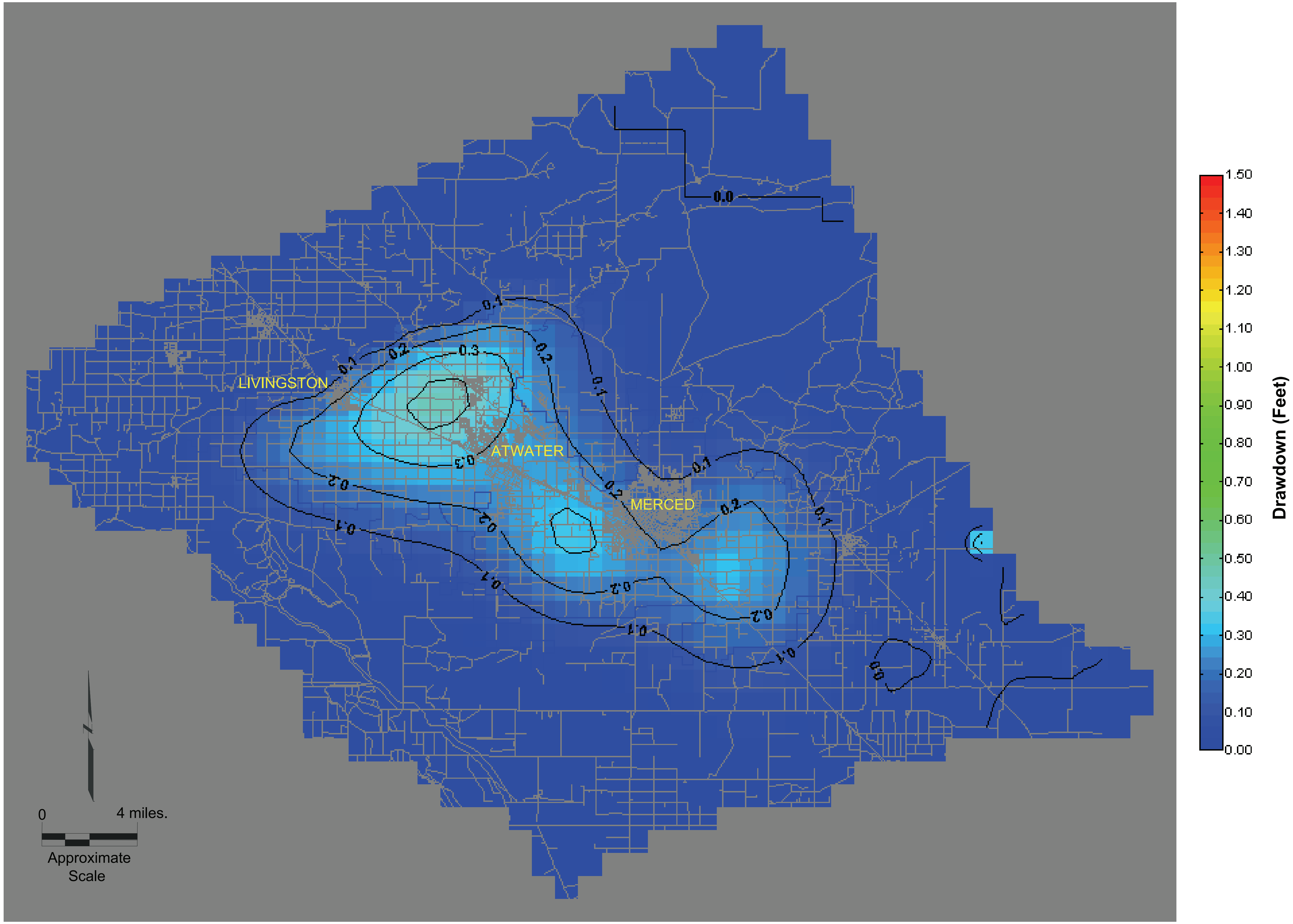
0.5 Lines of Simulated Drawdown, 2007 Proposed EWA Transfer Pumping. (Contour Interval 0.2 Feet)

SIMULATED EXTENTS AND MAGNITUDE OF GROUNDWATER DRAWDOWN YEAR 1

EWA Transfer Evaluation
Merced County, California

| By: GLK | Date: 07/19/2007 | Project No. 7622.007 |
| --- | --- | --- |
| Geomatrix | | Figure 6 |

I:\7000s\7622.007\Graphics\EWA Transfer Figure6_7.ppt




## EXPLANATION

Merced Subasin Boundary

0.2 Lines of Simulated Drawdown, 2007 Proposed EWA Transfer Pumping. (Contour Interval 0.1 Feet)

SIMULATED EXTENTS AND MAGNITUDE OF GROUNDWATER DRAWDOWN YEAR 5

EWA Transfer Evaluation
Merced County, California

| By: GLK | Date: 07/19/2007 | Project No. 7622.007 |
|---|---|---|
| Geomatrix | | Figure 7 |

I:\7000s\7622.007\Graphics\EWA Transfer Figure6_7.ppt