

CHINO BASIN OPTIMUM BASIN MANAGEMENT PROGRAM

Management Zone 1 Interim Monitoring Program

MZ-1 Summary Report



Prepared for
MZ-1 Technical Committee

Prepared by
Wildermuth Environmental, Inc.

February 2006

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ACRONYM AND ABBREVIATIONS LIST

AE	Associated Engineers
CA	California
CBWM	Chino Basin Watermaster
CIM	California Institution for Men
IMP	Interim Monitoring Program
MZ-1	Management Zone 1
OBMP	Optimum Basin Management Program
CH	Chino Hills
InSAR	Synthetic Aperture Radar Interferometry
MSL	mean sea level
PA	Piezometer A at Ayala Park Piezometer/Extensometer Facility
USGS	United States Geological Survey
WEI	Wildermuth Environmental Inc



EXECUTIVE SUMMARY

The Implementation Plan of the Optimum Basin Management Program (OBMP) called for an aquifer-system investigation of suspected pumping-induced land subsidence and ground fissuring that has occurred in the southern region of Management Zone 1 (MZ-1). Watermaster has coordinated and conducted the investigation under the guidance of the MZ-1 Technical Committee, which is composed of representatives from all major MZ-1 producers and their technical consultants. The results of the investigation are being used to develop management tools (models) that will assist in the development of a long-term plan to minimize or abate future land subsidence and ground fissuring.

To date, the main conclusions derived from the investigation are:

1. The current state of aquifer-system deformation in south MZ-1 (in the vicinity of Ayala Park) is essentially elastic. Little, if any, inelastic (permanent) compaction is now occurring in this area, which is in contrast to the past when about 2.2 feet of land subsidence occurred, accompanied by ground fissuring, from about 1987-1995.
2. Groundwater production from the deep, confined aquifer system in this area causes the greatest stress to the aquifer system. In other words, pumping of the deep aquifer system causes water level drawdowns that are much greater in magnitude and lateral extent than drawdowns caused by pumping of the shallow aquifer system.
3. Water level drawdowns due to pumping of the deep aquifer system can cause inelastic (permanent) compaction of the aquifer-system sediments, which results in permanent land subsidence. The initiation of inelastic compaction within the aquifer system was identified during this investigation when water levels fell below a depth of about 250 feet in the PA-7 piezometer at Ayala Park.
4. Through this study, a previously undetected barrier to groundwater flow was identified. The barrier is located within the deep aquifer system and is aligned with the historical zone of ground fissuring. Pumping from the deep aquifer system is limited to the area west of the barrier, and the resulting drawdowns do not propagate eastward across the barrier. Thus, compaction occurs within the deep system on the west side of the barrier, but not on the east side, which causes concentrated differential subsidence across the barrier and creates the potential for ground fissuring.
5. InSAR and ground level survey data indicate that permanent subsidence in the central region of MZ-1 (north of Ayala Park) has occurred in the past and continues to occur today. The InSAR data also indicate that the groundwater barrier extends northward into central MZ-1. These observations suggest that the conditions that very likely caused ground fissuring near Ayala Park in the 1990s are also present in central MZ-1, and should be studied in more detail.

A workshop was held May 25, 2005 to update the Special Referee on progress of the investigation and development of the long-term plan for MZ-1. After the workshop, the Special Referee issued a report to the Court that summarized the workshop and requested that Watermaster:

- produce a MZ-1 Summary Report (this report) that describes the investigation results and conclusions to date
- notify the Court of the schedule for the completion of the long-term plan
- provide “guidance criteria” to the MZ-1 producers in an effort to minimize the potential for future subsidence and fissuring, pending completion of the long-term plan

This report contains the guidance criteria, which consist mainly of setting a “control” water level – 245 feet below the reference point for the PA-7 piezometer at Ayala Park – and recommend that groundwater production from a selected list of wells in MZ-1 not cause water levels to fall below the control level.



This report also outlines the process and schedule for developing a long-term management plan by June 2006. The primary objective of the long-term plan is to prevent additional permanent land subsidence that could initiate additional ground fissuring. A developing secondary objective is to optimize the use of existing groundwater production infrastructure. A key element of the long-term plan will be its *adaptive* nature, as new data are collected and periodically analyzed to evaluate the effectiveness of the long-term plan.

The guidance criteria and the long-term plan discussed above relate to the management of pumping-induced subsidence within the southern region of MZ-1, where associated ground fissuring damaged infrastructure in the early 1990s. However, this investigation has also revealed that the central region of MZ-1 has experienced in the past, and is currently experiencing, measurable land subsidence. This discovery has initiated an additional effort by Watermaster to characterize the subsidence mechanisms in this region through a slightly expanded monitoring effort. The adaptive nature of the long-term plan should accommodate the results that will emerge from the expanded monitoring effort in central MZ-1, so as to minimize the risk of future ground fissuring in this heavily urbanized region of Chino Basin.

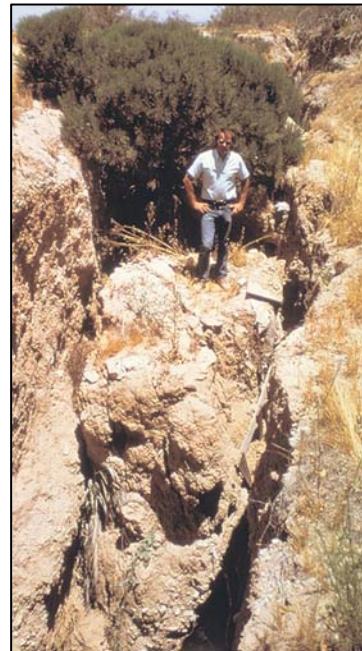
The monitoring and analyses associated with this investigation dovetail nicely with other Watermaster efforts associated with basin re-operation and hydraulic control.



1. BACKGROUND

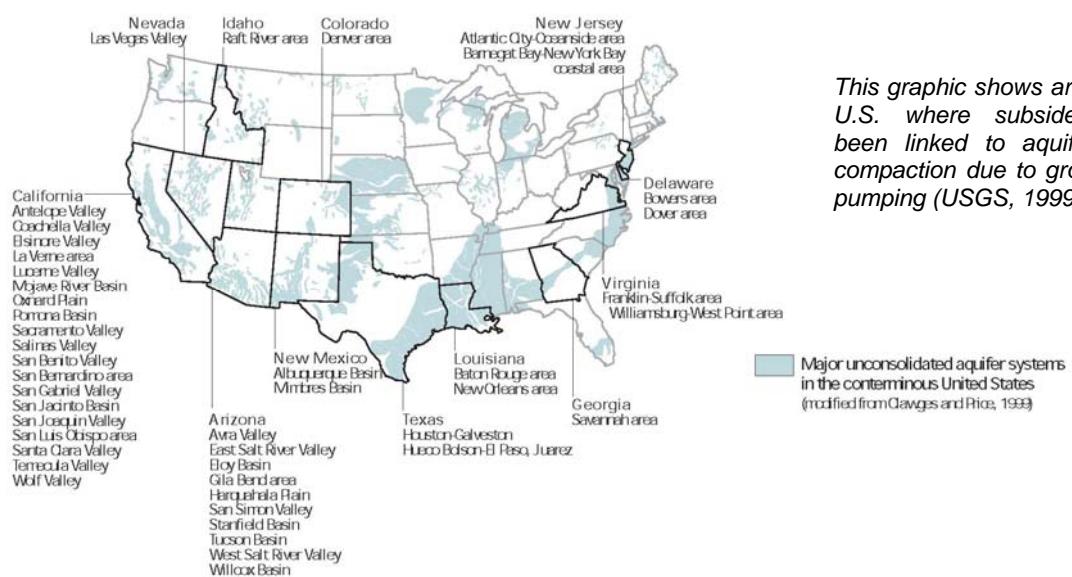
Groundwater Withdrawals and Land Subsidence

Land subsidence is the sinking of the Earth's surface due to the rearrangement of subsurface Earth materials. In the United States alone, over 17,000 square miles in 45 states have experienced land subsidence (USGS, 1999). In many instances, land subsidence is accompanied by adverse impacts at the land surface, such as sinkholes, earth fissures, encroachment of adjacent water bodies, modified drainage patterns, and others. In populated regions, these subsidence-related impacts can result in severe damage to man-made infrastructure and costly remediation measures.



This earth fissure near Mesa, Arizona formed as a result of differential compaction of the aquifer system (USGS, 1999).

Over 80% of all documented cases of land subsidence in the United States have been caused by groundwater extractions from the underlying aquifer system (USGS, 1999). Subsidence due to groundwater extraction is especially well-documented in the arid southwestern United States, where the aquifer systems are typically composed of unconsolidated sediments that are susceptible to permanent compaction when groundwater is extracted. Some infamous examples include the San Joaquin and Santa Clara Valleys in California, the Las Vegas Valley in Nevada, the Houston-Galveston area in Texas, and



This graphic shows areas in the U.S. where subsidence has been linked to aquifer-system compaction due to groundwater pumping (USGS, 1999).

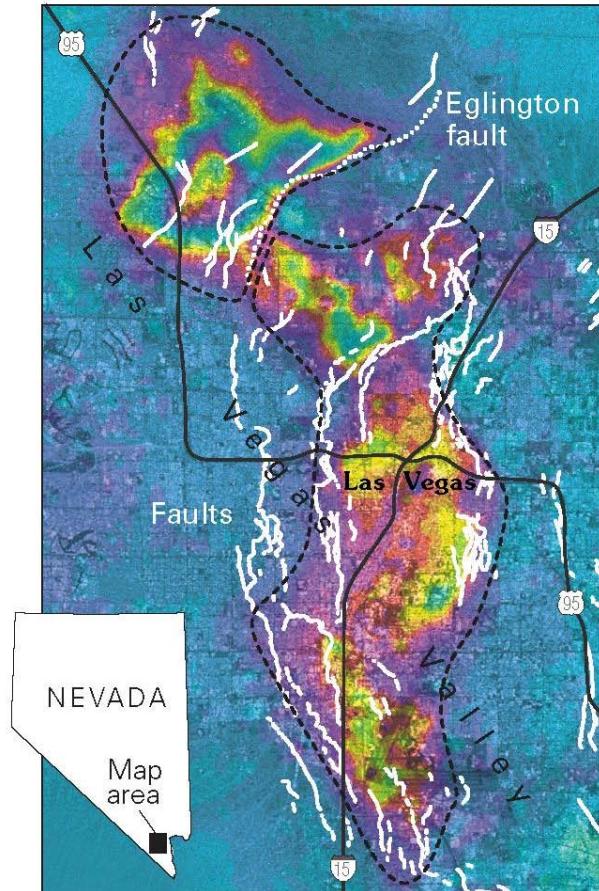
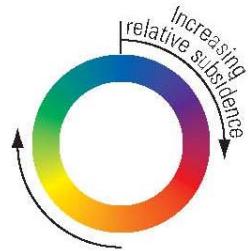


several basins in Arizona. In many of these regions, earth fissuring occurred in areas of differential subsidence (*i.e.* where rates and accumulated magnitudes of subsidence vary over short horizontal distances).

Although drawdown of water levels is the driving force that causes land subsidence due to groundwater pumping, the geology of a groundwater basin also plays an important role in this process. Clay layers within the aquifer-system are relatively compressible materials. Therefore, aquifer-systems that contain thick and/or numerous clay layers are most susceptible to permanent compaction and land subsidence when groundwater is extracted. In addition, faults that act as groundwater barriers can focus and augment drawdown in the aquifer-system when pumping wells are located near these faults. When pumping and drawdown are concentrated on one side of a fault barrier, then differential land subsidence and ground fissuring are a common result (see Las Vegas, as an example).

This map graphic depicts land subsidence in the Las Vegas Valley that occurred from April 1992 to December 1997. The subsidence, attributed to aquifer-system compaction caused by groundwater production, was measured by remote sensing techniques (InSAR). Geologic faults (shown in white) appear to control the location of subsidence, and have been the focal point of earth fissure formation (USGS, 1999).

One color cycle represents about 4 inches of subsidence.



The scientific model that describes the phenomenon of pumping-induced land subsidence is termed the *aquitard-drainage model*. This model has been successfully applied to numerous cases of land subsidence world-wide. It has been incorporated into the industry-standard computer models of groundwater flow and is increasingly recognized as critical to the understanding of aquifer-system hydraulics (flow and storage) and mechanics (deformation). A brief summary of the aquitard-drainage model is below:

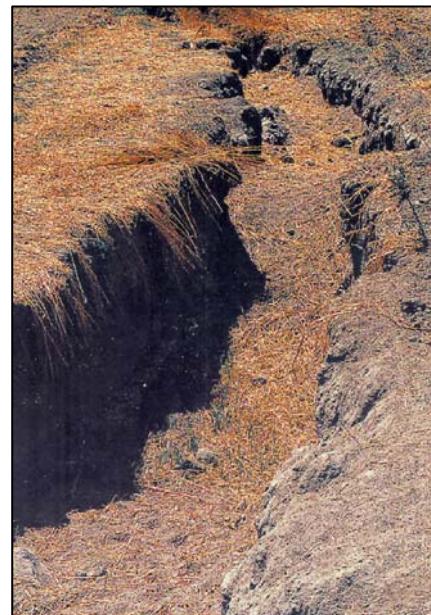


Aquitard-Drainage Model. Simply stated, an aquifer system consists of permeable sand and gravel layers (the aquifers) interbedded with less-permeable silt and clay layers (the aquitards). Pumping wells cause water-level drawdowns in the aquifers which, in turn, cause the aquitards to slowly drain into the aquifers. The draining allows aquitard pore pressures to decay toward equilibrium with the reduced heads in the adjacent aquifers. Since the pressure of the pore water provides some internal support for the sedimentary structure of the aquitards, this loss of internal support causes the aquitards to compress, resulting in a small amount of subsidence at the land surface. When the pumping wells turn off, and water levels recover in the aquifers, groundwater migrates back into the aquitards and they expand, resulting in a small amount of rebound at the land surface. Over a limited range of seasonal water level fluctuations this process can occur in a purely elastic fashion. That is, a recovery of water levels to their original values causes the land surface to rebound to its original elevation. However, when drawdown falls below a certain “threshold” level, elastic compression transitions to a non-recoverable inelastic compaction of the aquitards, resulting in permanent land subsidence. The “threshold” water level, referred to as the *preconsolidation stress*, is taken to be the maximum past stress to which the sedimentary structure had previously equilibrated under the gradually increasing load of accumulating sediments. [Note: The probable value of the virgin preconsolidation stress in the Chino Basin has not been documented, but studies in similar areas suggest that drawdowns in the range of 40 to 100 feet will typically exceed the initial threshold value.]

Drawdowns exceeding a previous threshold water level result in an increase in the value of maximum past stress, and thus the establishment of a deeper threshold, accompanied by an increment of inelastic aquitard compaction. Concomitantly, the compaction results in the one-time irreversible mining of groundwater from the aquitards. The benefits of this process include not only the obvious economic value of the water produced but also the often overlooked fact that, by establishing deeper thresholds, it increases the volume of confined groundwater storage available for cyclical drawdown and replenishment under strictly elastic conditions. The cost, of course, is the resulting deformation of the land surface and its impact on vulnerable infrastructure.

History of Ground Fissuring and Land Subsidence in Chino Basin

Ground Fissuring. One of the earliest indications that land subsidence was occurring in Chino Basin was the appearance of ground fissures in the City of Chino. These fissures appeared as early as 1973 (Fife et al., 1976), but an accelerated occurrence of ground fissuring ensued after 1991. Figure 1-1 shows the location of the fissures within the larger context of Management Zone 1 (MZ-1) and the Chino Basin. Figure 1-2 shows a detailed view of this area.



Surface expression of earth fissure that developed in a field north of CIM in February 1991.

Photo source: Geomatrix Consultants



Subsequent studies of the fissuring attributed the phenomenon to land subsidence (Fife et al., 1976; Kleinfelder, 1993, 1996; Geomatrix, 1994). The evidence to support this cause-and-effect relationship between the subsidence and fissuring is shown in Figure 1-2. In this figure, and as pointed out by Geomatrix (1994), the north-south trend of fissuring is located on the steep eastern limb of the main trough of subsidence that was mapped by ground level surveying (discussed below) – an area where east-west directed extensional stress should be associated with subsidence to the west. These observations and conclusions prompted efforts to quantify the magnitude of historical subsidence and to monitor the rates of on-going subsidence. These efforts included:

- Compilation and analysis of leveling survey data to estimate historical subsidence
- Compilation and analysis of remote sensing data to estimate historical subsidence
- Initiation of monitoring efforts to track on-going subsidence

Through these efforts, the history of land subsidence near the area of ground fissuring was characterized in good detail for the period after 1987, and in lesser detail for the period prior to 1987.

Recent Land Subsidence (Post-1987). Repeated leveling surveys were conducted within the City of Chino from 1987-1999 (Kleinfelder, 1993, 1996, 1999). Figure 1-1 shows the location and extent of the surveys within the larger context of MZ-1 and the Chino Basin. Figure 1-2 shows a close-up view of this area, and subsidence contours of the survey data. These contours delineate a subsidence trough generally aligned north-south with maximum subsidence during the 12-year period of 2.4 feet along Central Avenue between Eucalyptus and Schaefer Avenues (the trough axis). The subsidence trough extends approximately from Pipeline Avenue on the west to Benson Avenue on the east, and from Merrill Avenue on the south to the edge of the survey area on the north (Riverside Drive). The contours suggest that the subsidence trough extends further north of Riverside Drive, but the surveys did not include benchmarks north of Riverside Drive.

Remote sensing studies of subsidence were conducted (Peltzer, 1999a, 1999b) to further analyze subsidence in MZ-1. These studies employed Synthetic Aperture Radar Interferometry (InSAR), which utilizes radar imagery from an Earth-orbiting spacecraft to map ground surface deformation. Figures 1-1 and 1-2 show the results of these InSAR studies that independently confirmed the location and relative magnitude of subsidence in MZ-1 as defined by the leveling surveys, and indicated the occurrence of subsidence north of the area monitored by the leveling surveys (north of Riverside Drive).

The leveling surveys and the InSAR analyses both indicated that subsidence rates have slowed significantly since about 1995. In fact, the leveling surveys indicated that about 90% of the total subsidence measured along Central Avenue from 1987-1999 occurred prior to 1996.

Historical Land Subsidence (Pre-1987). Much less data is available to estimate regional subsidence prior to 1987. Geomatrix (1994) and Geoscience (2002) compared the leveling survey data (post-1987) to elevation data published on USGS 7.5-minute quadrangle maps (1933 and 1967). Geomatrix (1994) estimated as much as 3-4 feet of subsidence from 1967-1993 in some areas shown on Figure 1-2. Geoscience (2002) estimated a maximum of 3.7 feet of subsidence from 1933-1987 at the intersection of Pipeline Avenue and Riverside Drive. These subsidence estimates and their assumptions and limitations are currently being reviewed by Watermaster. If generally accurate, these estimates combined with the post-1987 survey data suggest that as much as 4-5 feet of subsidence has occurred during 1933-1999 in some areas of Chino south of State Highway 60.



Potential Causes of Land Subsidence

The main studies that were commissioned subsequent to the fissuring events in the early 1990s (Kleinfelder, 1993, 1996; Geomatrix, 1994) attributed the subsidence and fissuring phenomenon to the aquitard-drainage model. Watermaster arrived at the same conclusion (WEI, 1999) based on the presence of all requisite elements of the aquitard-drainage model in the southern portion of MZ-1 and other supporting evidence:

- **Presence of aquitards.** Geophysical and lithologic logs from numerous wells in the region indicate that the aquifer-system sediments that underlie the area of subsidence in MZ-1 contain many interbedded aquitard layers, which are susceptible to permanent compaction under reduced piezometric heads. In addition, during the early 1900s, much of the southern part of MZ-1 was an area of flowing-artesian wells (Mendenhall, 1908), indicating the existence of fine-grained confining layers (aquitards) at depth.
- **Reduced pore pressures within the aquifer-system.** The flowing-artesian groundwater conditions in southern MZ-1 also indicate that piezometric heads were at or above the land surface during the early 1900s. Water level histories at numerous relatively shallow wells in the region demonstrate that the piezometric heads (water levels) declined by about 140 feet from about 1940 to 1977, but then recovered by about 40 feet by 1999 (see Figure 1-3).

In addition, the accelerated occurrence of fissuring that commenced in 1991 was preceded by the completion and initial operation of a number of the deep production wells in 1989-1990. These wells are owned by the City of Chino Hills. Water level histories at these wells indicate that drawdowns within the deeper portions of the aquifer system caused by pumping these wells have exceeded 300 feet.

In both the shallow and deep zones of the overall aquifer system, the historical drawdowns were substantially greater than probable maximum value of the virgin threshold of inelastic compaction.

- **Other evidence.** The axis of maximum subsidence along Central Avenue, as delineated by ground level surveys (1987-1999), is aligned with the locations of several deep production wells owned by Chino Hills—suggesting a cause-and-effect relationship.
- **Similarity to other subsidence case studies.** There are numerous examples throughout the western United States where ground fissures have accompanied aquifer-system compaction and land subsidence within alluvial groundwater basins (Holzer, 1984). Geomatrix (1994) studied the ground fissures on CIM property and also reviewed case histories of fissuring throughout the southwestern United States. Their study noted similarities between the physical structure of the CIM fissures and the fissures described in the literature that were associated with areas of subsidence due to groundwater pumping and aquifer-system compaction.

There exist other potential causes of land subsidence that have been documented in other locations worldwide. Most of these causes can be immediately dismissed as explanations for the subsidence observed in Chino Basin, but others can not. Table 1-1 lists all potential causes of land subsidence, and a qualitative description of their applicability to subsidence and fissuring in Chino Basin.

Even though some of these potential subsidence mechanisms cannot be immediately dismissed as contributing to subsidence in Chino Basin, they are not likely. The aquitard-drainage model is based on physical laws of nature—namely, gravity and the compressibility of materials under load. And when the requisite elements of this model are all present (*i.e.* presence of aquitards, piezometric head declines, *etc.*), the question is not whether subsidence occurred, but rather, how much is the inevitable result of the aquitard-drainage mechanism?



By comparison, other potential causes of subsidence were reduced to unlikely and, at the most, minor contributory factors in Chino Basin, and as such, were never directly investigated by Watermaster.

Development of the MZ-1 Interim Monitoring Program

In the Optimum Basin Management Program (OBMP) Phase I Report (WEI, 1999), Watermaster identified the aquitard-drainage model as the most likely cause of the land subsidence and ground fissuring observed in MZ-1. Program Element 4 of the OBMP – *Develop and Implement a Comprehensive Groundwater Management Plan for Management Zone 1* called for the development and implementation of an interim management plan for MZ-1 that would:

- Minimize subsidence and fissuring in the short-term
- Collect information necessary to understand the extent, rate, and mechanisms of subsidence and fissuring
- Formulate a long-term management plan to reduce to tolerable levels or abate future subsidence and fissuring

The main part of the interim management plan was to develop and implement a monitoring and testing program in MZ-1 that would answer certain questions to enable the development of a long-term plan to minimize or abate subsidence and fissuring. These questions included:

1. How much subsidence is currently occurring in MZ-1?
2. How much of the current subsidence is an elastic, reversible process that will restore the land surface to its original elevation if water levels recover to their original values; or, in the alternative phraseology, how much, if any, is irreversible (permanent subsidence)?
3. How much subsidence did historical pumping cause in MZ-1?
4. How much of the historical subsidence was an elastic, reversible process, and how much, if any, was irreversible?
5. These questions give rise to the most critical questions: What was the historical threshold value of head decline at which the deformation of the sedimentary structure would have changed from an elastic compression to inelastic compaction? And additionally, what is that threshold value of head decline today?

In an attempt to minimize subsidence and fissuring in the short-term, the cities of Chino and Chino Hills agreed to jointly reduce groundwater production in MZ-1 by 3,000 acre-feet per year for the duration of the interim management plan. This agreement between the cities was termed the *Forbearance Agreement*.

Formation of the MZ-1 Technical Committee. The MZ-1 Technical Committee was formed to serve as a clearing house for technical information, as well as the source for full professional discussion, input and peer review by its members, for the benefit of Watermaster. The Technical Committee provides comment and assists Watermaster in the development of recommendations for consideration and potential action by Watermaster under the Interim Management Plan. In addition, the Technical Committee provides similar assistance to Watermaster in its effort to develop a long-term plan as provided in Program Element 4. The Technical Committee consists of representatives (and their technical consultants) from those parties to the Judgment that are presently producing groundwater within MZ-1. Each of the following producers is entitled to representation on the Committee: Chino, Chino Hills, Ontario, Upland, Pomona, Monte Vista



Water District, San Antonio Water Company, Southern California Water Company, CIM and the Agricultural Pool. Figure 1-1 shows the locations of wells owned by the producers listed above. The MZ-1 Technical Committee first convened on March 6, 2002, and has continued to meet once every 1-3 months.

Composition of the MZ-1 Interim Monitoring Program. The MZ-1 Technical Committee approved the scope and schedule for the MZ-1 Interim Monitoring Program (IMP) at the January 29, 2003 meeting. The IMP was developed and implemented by Watermaster to collect the information necessary to answer the five questions listed above. The data collected and analyzed as part of this effort are being utilized to develop effective management tools and, ultimately, a long-term management plan that will minimize or completely abate ground fissuring and subsidence in MZ-1.

The IMP is described in detail in the IMP Work Plan dated January 8, 2003 (WEI, 2003), but generally consists of three main elements: benchmark survey, InSAR, and aquifer-system monitoring. The benchmark surveys and the InSAR analyses monitor deformation of the land surface. Aquifer-system monitoring measures the hydraulic and mechanical changes within the aquifer-system that cause the land surface deformation. The methods involved in the implementation of each element are briefly described below:

Methods: Aquifer-System Monitoring. This work involves the measuring of stresses within the aquifer system (water-level changes) that cause land surface deformation as measured by benchmark surveys, InSAR, and the extensometers (described below). The objective is to establish the relationships between water-level changes in the aquifer system (stress) and aquifer-system deformation (strain).

Figure 1-4 shows location of the centerpiece of the aquifer-system monitoring program – the Ayala Park Extensometer – a highly sophisticated monitoring facility consisting of two multi-piezometers and a dual-extensometer. As the aquifer system undergoes various stresses due to groundwater production and recharge, the facility monitors the hydraulic response of the aquifer system at the piezometers and the mechanical response of the aquifer system at the extensometers. The facility is equipped with pressure transducers to measure water levels in the piezometers, linear potentiometers to measure the vertical aquifer-system deformation at the extensometers, and data loggers to record the data at frequent intervals (e.g. 15 minutes).

Piezometer construction and instrumentation was completed in mid-November 2002, at which time collection of piezometric data commenced. Dual-extensometer construction and instrumentation was completed in mid-July 2003, at which time collection of aquifer-system deformation data commenced.

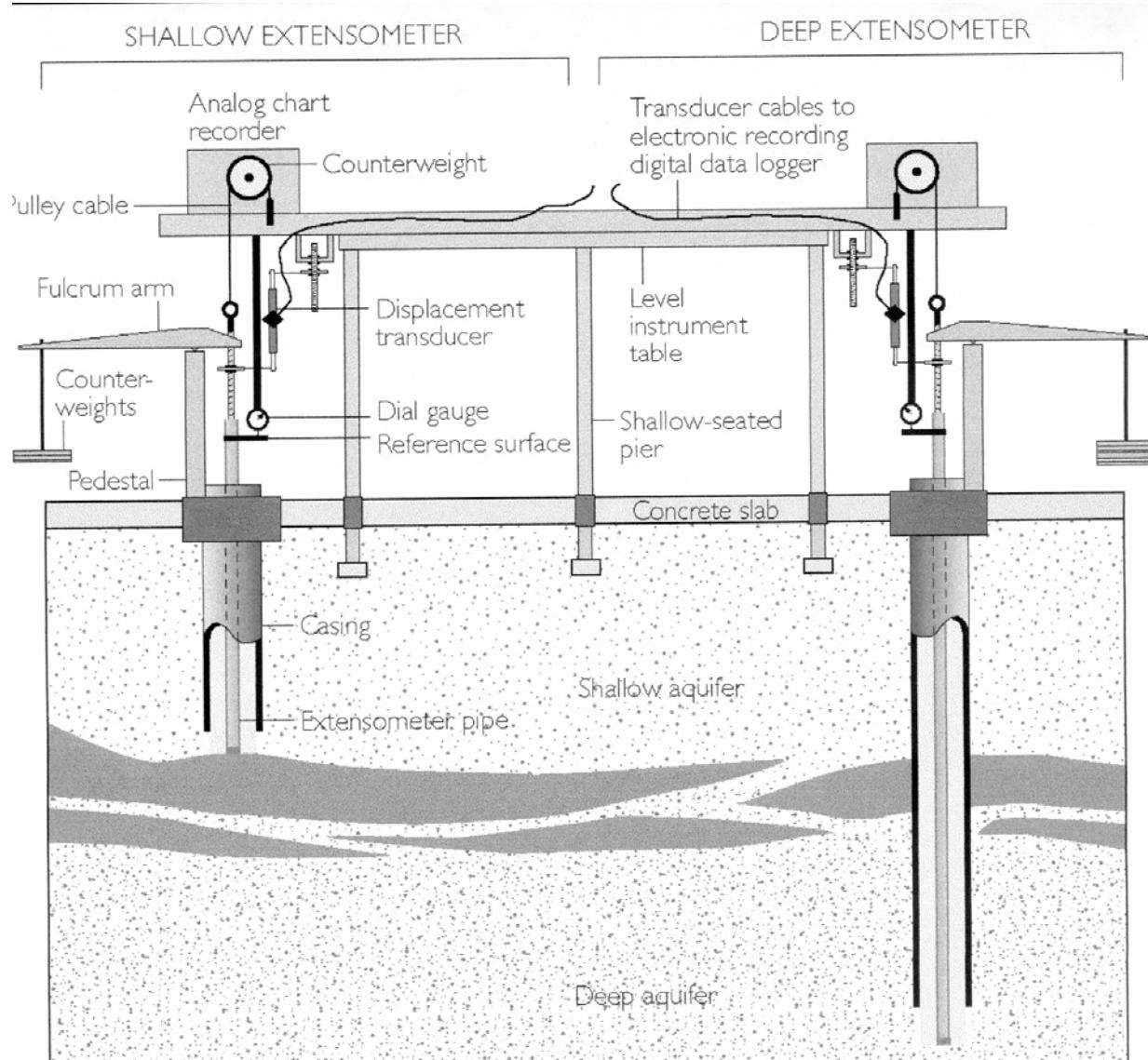
Figure 1-4 also shows the nearby wells owned by CIM and the cities of Chino and Chino Hills that were equipped with pressure transducers and data loggers to record (1) water-level data and (2) the specific timing of pumping cycles at production wells.

The IMP also called for Watermaster, with the assistance of the well owners, to conduct controlled aquifer stress tests (pumping tests) while monitoring water levels and groundwater production at nearby monitoring wells and production wells, as well as aquifer-system compaction and/or expansion at the dual-extensometer. These tests were performed in fall 2003, spring 2004, and fall 2004.

The data collected from this monitoring effort are being used to: (1) quantify and characterize the current state of aquifer-system deformation (i.e. elastic vs. inelastic), (2) determine the threshold value of head decline at which the deformation of the aquifer-system sediments changes from an elastic compression to



inelastic compaction, (3) estimate aquifer-system parameters, such as the conductive and storage parameters of the aquifer and aquitard sediments, (4) reveal the existence of groundwater barrier(s) within the aquifer sediments, and (5) use all the above data as input to predictive computer models of compaction, subsidence, and groundwater flow to support the development of a long-term management plan.



A conceptual graphic of a dual extensometer, very similar to the facility at Ayala Park in Chino. Extensometers measure vertical deformation within an aquifer system. Typically, they are accompanied by piezometers that measure pore water pressure changes that cause deformation within the aquifer system.



Methods: Ground-Level Surveying. This work involves repeated benchmark surveying to measure vertical (and in some cases horizontal) ground surface deformation along selected profiles within Chino Basin – mainly in MZ-1. The benchmark surveys are being used to (1) establish a datum from which to measure land surface deformation during the IMP period, (2) allow determination of historical subsidence at any historical benchmarks that can be recovered, (3) “ground-truth” the InSAR data, and (4) assist in the development and evaluation of the long-term management plan.

A network of stable benchmark monuments was installed to supplement an existing network of benchmarks that was installed for the City of Chino in 1987. Associated Engineers (AE) completed monument installations (see Figure 1-5) and an initial survey of all monument elevations in April 2003. Repeat surveys are planned for April of each year during the IMP period.

The IMP work plan also called for the deep extensometer at Ayala Park (discussed below), which is anchored in sedimentary bedrock at about 1,400 ft bgs, to be used as the “starting benchmark” for all survey loops. To accomplish this, a Class-A benchmark was constructed outside the extensometer building to serve as the practical (i.e. actual) starting benchmark. To link this benchmark to the deep extensometer pipe, each survey event begins by referencing the benchmark to a marked spot on one of the piers that supports the extensometer instrument platform. These piers and the instrument platform represent a stable ground surface datum that is used to measure relative vertical displacement between the ground surface and the deep extensometer pipe (recorded every 15 minutes). The vertical displacement recorded at the deep extensometer between survey events, in addition to any vertical displacement measured between the starting benchmark and the pier, is then used to calculate the elevation at the starting benchmark outside the extensometer building. Then, relative vertical displacement between benchmarks is measured across the entire network to obtain current elevations.

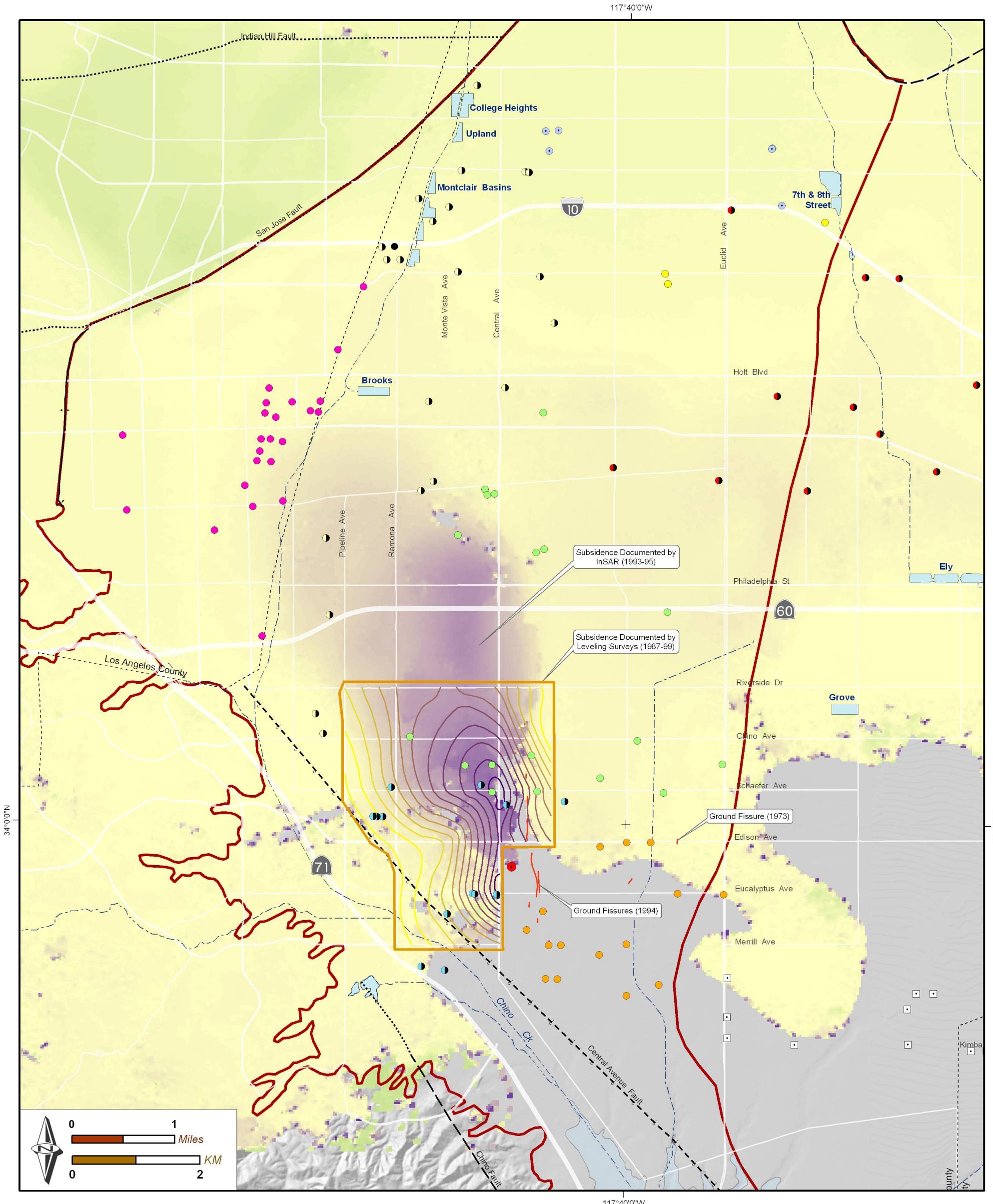
A key element of the MZ-1 benchmark network is the array of closely spaced benchmarks that have been established across the historic fissure zone in the immediate vicinity of the Ayala Park extensometers (Ayala Park Array). At this array, located along Edison and Eucalyptus Avenues, both vertical and horizontal displacements are measured. These horizontal and vertical displacements are defining two-dimensional profiles of land-surface deformation that can be related to the vertical distribution of aquifer-system compaction and expansion that is being recorded continuously at the extensometers. These surveys are being repeated semi-annually during the late spring and early fall periods of highest and lowest water levels in an attempt to monitor fissure movement, if any, that may be associated with elastic and/or inelastic aquifer-system deformation. (Note: the semi-annual survey frequency of the Ayala Park Array monuments is a modification to the IMP work plan, and was agreed upon by the MZ-1 Technical Committee at the September 24, 2003 meeting).

Methods: InSAR Analyses. InSAR is being used to characterize ground surface deformation in Chino Basin. This analysis will be performed for a historical period (1992-2000) and on an on-going basis thereafter. The advantage of InSAR is that it provides an aerially continuous representation of land surface deformation. These data are planned to be used to: (1) characterize the time history of land surface deformation in greater spatial and temporal detail than can be accomplished from the available historical ground-level survey data, (2) calibrate computer simulation models of subsidence and groundwater flow, and (3) assist in the evaluation of the effectiveness of the long-term management plan.



Table 1-1
Applicability of Potential Causes of Subsidence in Chino Basin

Potential Cause of Subsidence	Applicability to Chino Subsidence
Collapse of underground caverns	No caverns or soluble rocks are known to underlie the Chino Basin, and the geologic environment and history of the basin make their existence extremely unlikely.
Consolidation due to surface loading	No substantial surface loading has been applied, other than the construction of Prado Dam and the occasional short-lived accumulation of flood waters behind it. These are well south of the area of significant subsidence.
Consolidation of sediments over geologic time scales	This process is presumably occurring under the gradually increasing load of accumulating alluvial sediments, but at rates much too slow to be readily detectable over a period of decades. Under conditions of subaerial deposition the buildup of surficial sediments far exceeds their compaction at depth.
Desiccation and shrinkage of expansive soils	Swell/shrink properties of soils in the subsiding area have not been investigated. However, most of the area has been subject to agricultural and/or residential irrigation and is unlikely to have experienced serious dessication, despite substantial lowering of the water table.
Settlement of soils due to ground shaking	Significant coseismic settlement of unconsolidated soils typically involves temporary liquefaction manifested in localized slumping and sand boils. These phenomena have not been reported during the seismic events of recent decades.
Drainage of organic soils	High organic soils do not occur in the subsiding area.
Hydrocompaction	Hydrocompaction occurs where thick accumulations of very dry soils are rewetted for the first time since deposition. The very shallow water tables and artesian conditions that historically characterized the area of recent subsidence rule out this phenomenon.
Solution of soluble subsurface deposits like salt	There is no evidence for the existence of soluble rocks underlying the Chino Basin.
Subsurface extraction of hydrocarbons	Not applicable. There are no known oil or gas extraction wells currently in operation in Chino Basin.
Tectonism	While the alluvial basins of California have obviously been subsiding over geologic time relative to their bounding mountain ranges, there is no evidence for a tectonic mechanism that would account for the localized and relatively rapid subsidence observed in the southwestern part of Chino Basin.
Thawing permafrost	Not applicable. Permafrost is soil or rock that remains below 0°C throughout the year, and forms when the ground cools sufficiently in winter to produce a frozen layer that persists throughout the following summer. These conditions do not occur in Chino Basin.
Aquifer-system compaction	Probable cause.



Subsidence Features

-2.2
-2.1 - -2.0
-1.9 - -1.6
-1.5 - -1.4
-1.3 - -1.2
-1.1 - -1.0
-0.9 - -0.8
-0.7 - -0.6
-0.5 - -0.4
-0.3 - 0.0

Relative Change in Land Surface Altitude as Measured by Leveling Surveys 1987 - 1999 (feet)

+ 1.0
0.0
- 1.0

Relative Change in Land Surface Altitude as Measured by InSAR Oct 1993 - Dec 1995 (feet)

Wells in MZ-1 by Owner

- Ontario
- Pomona
- SAWC
- Upland
- SCWC
- CIM
- Chino Hills
- Chino
- MVWD

Other Features

- Ayala Park Extensometer Facility
- Chino Basin Desalter Well (Existing)
- Management Zone 1 Boundary
- No InSAR Data

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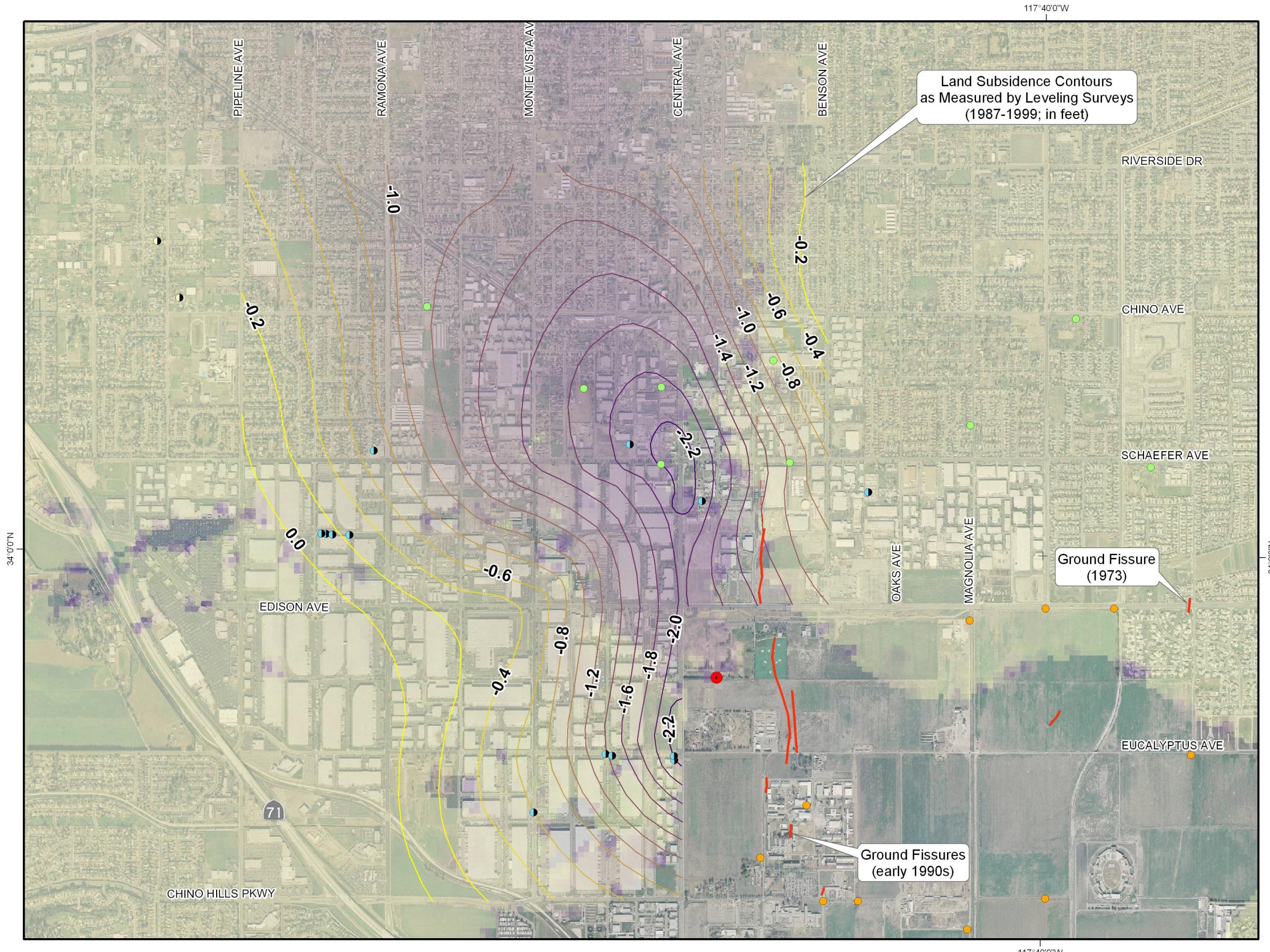
MZ-1 Summary Report
September 2005

Author: AEM
Date: 20050927
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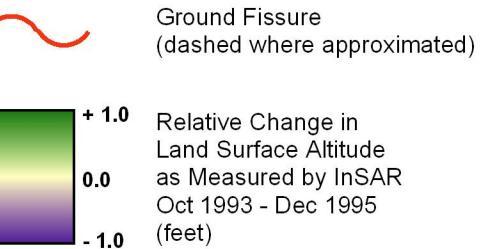


Land Surface Deformation in Management Zone 1
Leveling Surveys and InSAR

Figure 1-1



Subsidence Features



Wells in MZ-1 by Owner



Other Features

Ayala Park Extensometer Facility

Note: Air photo background flown in April 2004.

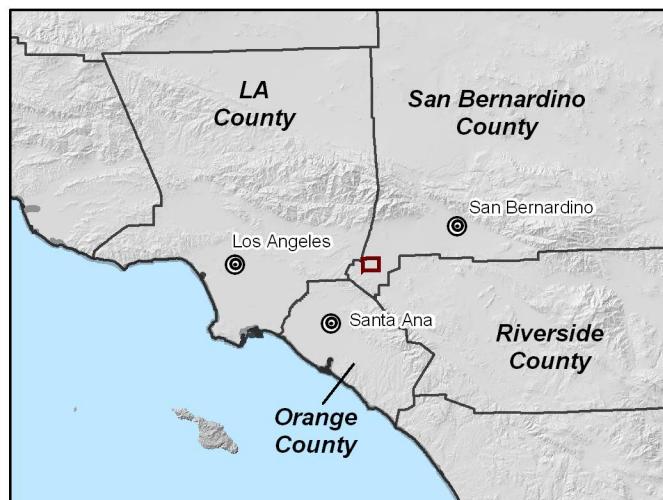
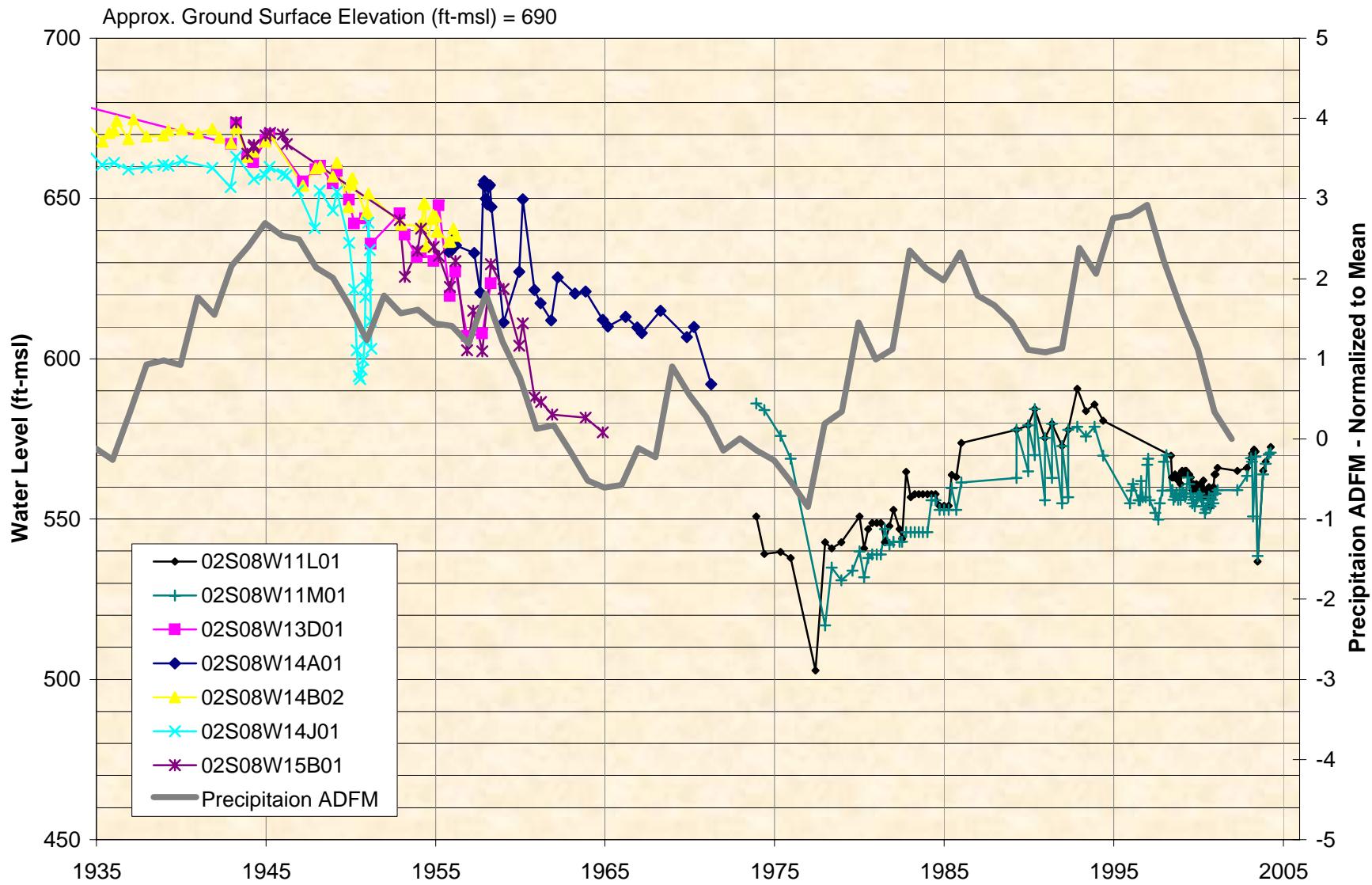
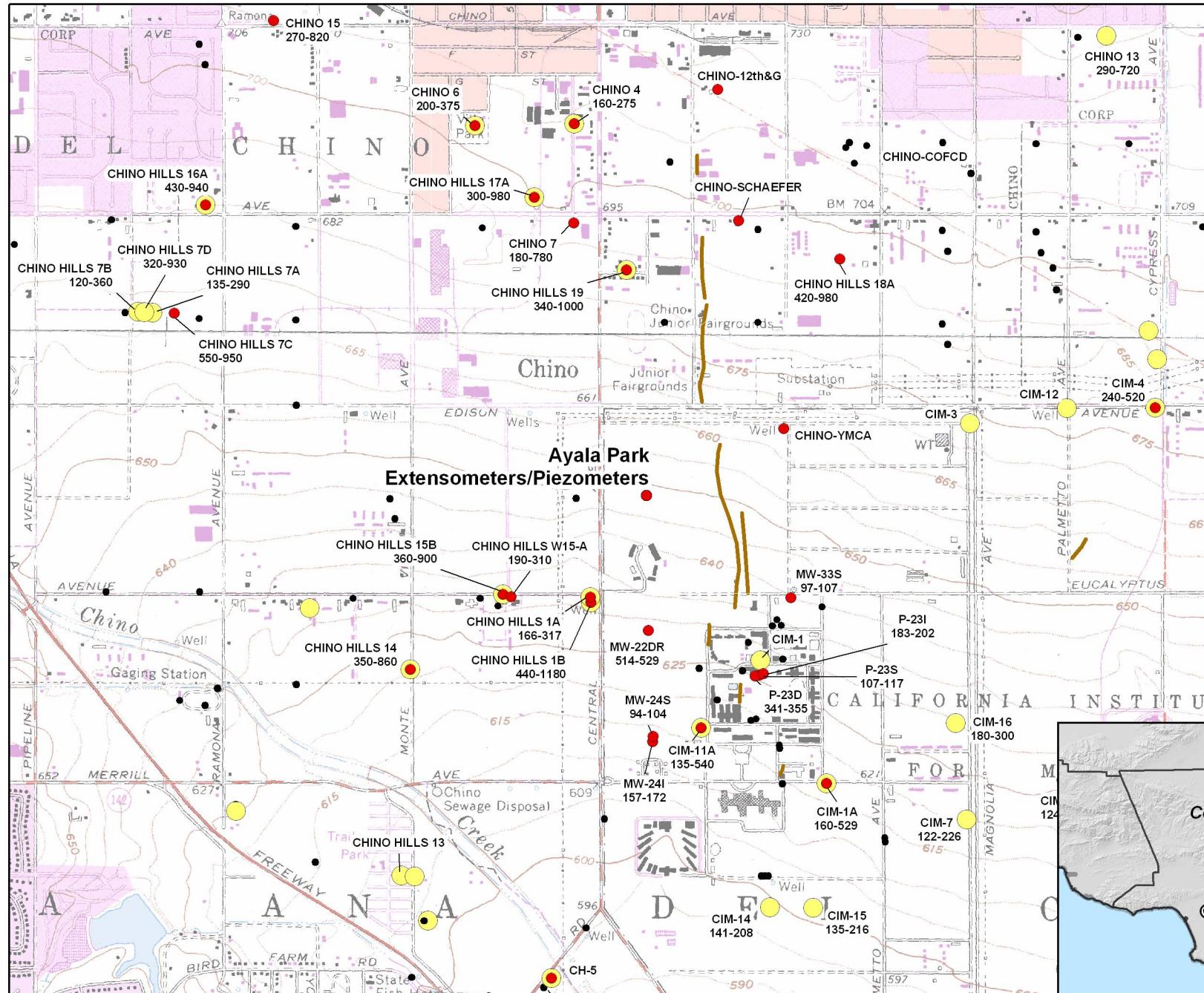


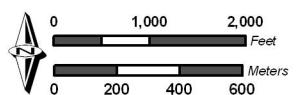
Figure 1-3
Groundwater Level History in Southern MZ-1 (Shallow Wells)





Piezometric Monitoring Network
MZ-1 Interim Monitoring Program

MZ-1 Summary Report
September 2005

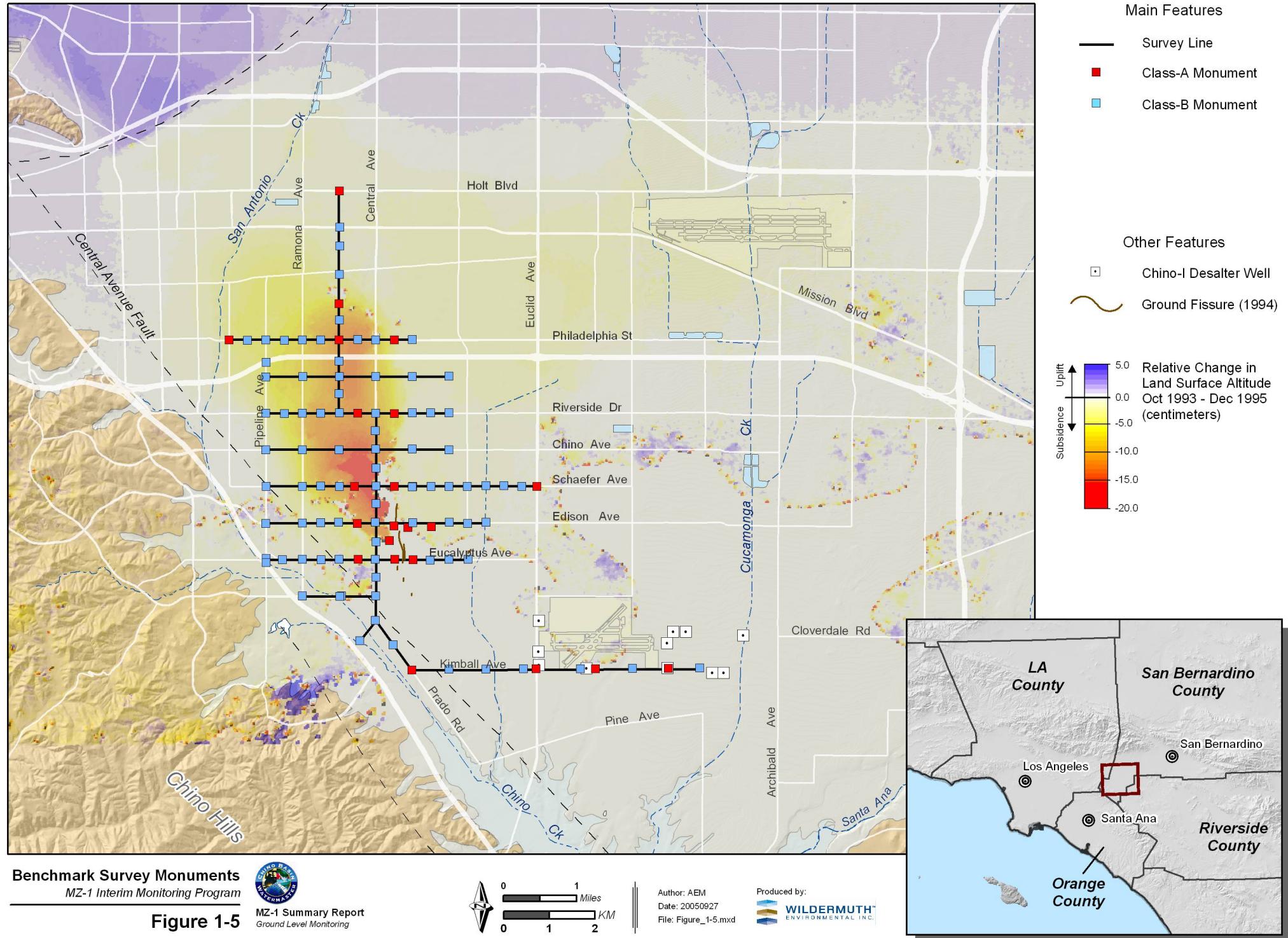


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Date: 20050927
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Figure 1-4





2. MZ-1 INTERIM MONITORING PROGRAM

This section describes the results, interpretations, and major conclusions derived from the Interim Monitoring Program (IMP) as of September 19, 2005.

Results and Interpretations

Aquifer-System Monitoring. The controlled testing and comprehensive monitoring of the aquifer-system (see Section 1) and subsequent data analyses has led to a number of key interpretations:

1. There appear to be two distinct aquifer systems in this area – a shallow, un-confined to semi-confined system from about 100-300 ft-bgs and a deep, confined system from about 400-1,200 ft-bgs.
2. Under current conditions of aquifer utilization in MZ-1, the aquifer-system deformation appears to be essentially elastic. At the Ayala Park Extensometer, about 0.14 feet of elastic land subsidence and rebound were observed during the pumping and recovery seasons of 2004-05. Minor amounts (~0.01 feet) of permanent compaction and associated land subsidence apparently occurred over this same period.
3. The relationships between aquifer-system stress (water level changes) and aquifer-system strain (vertical deformation of the sediment matrix) have been established by comparing piezometer data versus extensometer data. These relationships indicate the nature of the aquifer-system deformation (i.e. elastic vs. inelastic) and provide estimates of aquifer-system parameters for later use in aquifer-system models.
4. A deep aquifer-system pumping test in September 2004 appears to have transitioned the system from elastic to inelastic deformation. This provides a “threshold” water level at Ayala Park, below which further drawdown will result in inelastic compaction. The data derived from this test will assist in the creation of management tools for MZ-1 (e.g. groundwater flow and subsidence models).

A technical discussion related to the above interpretations follows:

Figure 2-1 shows the changes in thickness of the aquifer systems as recorded by the deep and shallow extensometers, completed at depths of 1,400 and 550 ft-bgs. It also shows the water-level fluctuations in two piezometers, PA-10 and PA-7, which are representative of the shallow aquifer system and the upper part of the deep aquifer system, respectively.

During periods of water-level decline in PA-7, both extensometers are recording compaction of the sediments. During periods of recovery in PA-7, both extensometers are generally recording elastic expansion. Note that for the data available, almost all of the compaction during the drawdown season is recovered as expansion during the recovery season.

During the late-spring (2004) pumping of the shallow aquifer system, while the deep system not pumped, the shallow extensometer recorded compression while the deep extensometer recorded an overall expansion. Subtracting the shallow record from the deep confirms that the deeper sediments continued a smooth expansion in response to continuing recovery of heads in the deeper parts of the aquifer system, as represented by the data from PA-7, which is screened from 438-448 ft-bgs. The shallow compression is seen to correlate closely with the drawdown recorded by PA-10, screened from 213-233 ft-bgs.

These observations clearly demonstrate the existence of the deep and shallow aquifer-systems in this region of MZ-1. Nearby pumping at wells that are screened in either the deep or shallow aquifer-systems result in distinct hydraulic and mechanical responses that are recorded at the Ayala Park piezometers and extensometers. These observations also demonstrate the importance, for analytical purposes, of



independently stressing the deep and shallow systems by pumping from only one at a time, so that the observed deformation can be more accurately attributed to production from a specific depth interval.

The relationships between water levels and aquifer-system deformation are further depicted in the stress-strain diagrams shown in Figure 2-2. In this diagram, increasing depth to water (drawdown due to pumping) is the measure of decreasing pore pressure and increasing effective intergranular stress. Increasing compression of the sediments is the resulting strain. When pumping diminishes or ceases, pore pressures recover, intergranular stress is reduced, and the aquifer system expands.

Figure 2-2 shows that the full thickness of sediments responds linearly to extended intervals of continuous drawdown or recovery, but with a large seasonal hysteresis attributable to the time lag involved in the delayed vertical propagation of pore pressure changes from the pumped aquifers into adjacent, poorly permeable aquitards. The parallel slopes of the compression and expansion trends represent the overall elasticity of the sedimentary section. Its inverse is the skeletal storativity, in hydrologic terminology.

Brief intervals of recovery during the drawdown season, and of drawdown during the recovery season, produce steeply sloping, more-or-less tight hysteresis loops. Their much steeper slope represents the (inverse) aggregate compressibility of the permeable pumped aquifers. The longer intervals of recovery and drawdown generate the more open hysteresis loops, as the delayed responses of immediately adjacent portions of the aquitards have time to influence the extensometers.

The parallelism of the seasonal drawdown and recovery stress-strain slopes in Figure 2-2 indicates that seasonal drawdown to 250 ft-bgs at this site is producing essentially elastic, recoverable deformation. However, the slope of the drawdown curve in 2004 begins to deviate from its elastic trend when the seasonal drawdown exceeds 250 ft-bgs indicating a transition to inelastic compaction within draining aquitard interbeds. A minor amount of non-recovered compaction is indicated by the offset of the recovery curve in 2005 to the right (direction of compression). On about September 19, 2005 water levels had recovered to the levels of pre-pumping conditions of 2004 (~105 ft-bgs at PA-7), and the offset of the stress-strain curve to the right (direction of compression) confirmed that about 0.01 ft of permanent compaction occurred during the pumping season of 2004.

The pumping and associate drawdown of water levels in 2004 was part of a controlled aquifer system stress test. The primary objective of this test was to transition the deformation of aquifer-system sediments from elastic compression to inelastic compaction. If successful, it would provide “threshold” piezometric heads at the extensometer location that should not be approached in the future if permanent (inelastic) compaction within the aquifer-system is to be avoided. This would also define a key parameter required for estimating the maximum elastic storage capacity of the confined aquifer-system.

For fear of exacerbating the ground fissuring, one limiting condition of the test that was agreed upon by the participating agencies was that pumping cease when inelastic compaction was identified. Although 0.01 feet of permanent compaction is relatively minor deformation, it is measurable and within the detection limits of the extensometer. The stress-strain diagram in Figure 2-2 indicates that at Ayala Park the aquifer-system transitioned from elastic compression to inelastic compaction when the water level in the PA-7 piezometer at Ayala Park fell below about 250 ft-bgs. The applicability of this limit at increasing distances from the piezometer/extensometer facility is dependent on an approximate replication of the tested pumping conditions (i.e. specific wells pumped, pumping rates, and pumping durations). A different areal distribution of pumping might cause localized inelastic compaction away from Ayala Park without drawing PA-7 below 250 feet or recording inelastic effects at the extensometer.



A different vertical distribution of extraction will stress the aquifer system in a different manner, and may result in a different threshold water level in PA-7.

Other objectives of the pumping test that were successfully accomplished were to (1) estimate key aquifer-system parameters that could be used in later modeling efforts, and (2) confirm and elucidate the existence of a groundwater barrier within the sediments below about 300 ft-bgs

Discovery of Groundwater Barrier. Multiple lines of evidence suggest that a previously unknown groundwater barrier exists within the deep aquifer-system in the same location as the fissure zone.

Controlled aquifer-system stress (pumping) tests in October 2003 and April 2004 provided piezometric response data that revealed a potential groundwater barrier within the sediments below about 300 ft-bgs and aligned north-south with the historic fissure zone. Figure 2-3 is a map that shows the locations of a pumping well perforated in the deep aquifer system (CH-19, 340-1,000 ft-bgs) and other surrounding wells that also are perforated exclusively in the deep system. Figure 2-4 shows the water level responses in these wells during various pumping cycles at CH-19. The groundwater barrier is evidenced by a lack of water level response in CH-18 (east of the fissure zone) due to pumping at CH-19 (west of the fissure zone). Image-well analysis of pumping-test responses also indicates that this barrier approximately coincides with the location of the historic zone of ground fissuring.

Ground level survey data (described in detail below) corroborate the water level data – also indicating the existence of the barrier and its coincident location with the fissure zone. Figure 2-6 shows that during the pumping season of 2003 (April to November) vertical displacement of the land surface (i.e. subsidence) was generally greater on the west side of the fissure zone where water-level drawdown was greatest. Figure 2-7 shows that during the recovery season of 2003-04 (November to April) vertical displacement of the land surface (i.e. rebound) was again greater on the west side of the fissure zone where water level recovery was greatest.

In other words, the groundwater barrier in the deep aquifer-system is aligned with the fissure zone and causes greater water level fluctuations on the west side of the barrier where the pumping is concentrated. These greater water level fluctuations on the west side of the barrier, in turn, cause greater deformation of the aquifer-system matrix which, in turn, causes greater vertical land surface deformation on the west side of the barrier. In addition, the pattern of horizontal displacement of benchmarks over the pumping and recovery seasons, as shown in Figures 2-6 and 2-7, likely reflects, in part, the differential compaction of the aquifer system across the fissure zone.

Similarly, the InSAR data in Figures 1-2 and 2-5 also corroborate the existence of the groundwater barrier by showing maximum subsidence west of the barrier and virtually no subsidence east of the barrier.

This spatial coincidence of the groundwater barrier and the historic fissure zone suggests a cause-and-effect relationship: the barrier causes differential water level declines, which cause differential aquifer-system compaction and a steep gradient of subsidence across the barrier, which can and likely has caused ground fissuring above the barrier.

Monitoring of Ground-Surface Deformation—Ground-Level Surveying. In late April 2004, AE performed the annual survey event across the entire network of benchmark monuments, including the measurements of horizontal displacements at the Ayala Park Array of monuments. The results of the ground level surveys were presented to the MZ-1 Technical Committee at its meeting. Also at this



meeting, the project manager from AE made a presentation to describe survey methodologies, accuracy, results, and challenges.

Figure 2-5 displays the vertical displacement at monuments that occurred from April 2003 to April 2004. Comparing monument elevations over the April-to-April period is meant to reveal the inelastic component of compaction, if any, which may be occurring in the region. The assumption here is that in April 2004 water levels in the region have recovered to the April 2003 levels; thus the measured vertical displacement does not include the elastic component of aquifer system deformation. Water levels measured as part of the IMP (in the vicinity of Ayala Park) support this assumption. Examination of Figure 2-5 shows that the monuments near Ayala Park experienced little to no subsidence over this time period. However, the monuments located in the northern portions of the surveyed area showed small but measurable subsidence of the land surface (on average about 0.04 feet). Maximum subsidence of about 0.08 feet was recorded at monuments located along Philadelphia Street between Pipeline and Ramona Avenues. Water level and groundwater production data have not been collected or analyzed as part of the IMP in these northern portions of the survey area; hence, it is not yet possible to classify the nature of the subsidence in this region (*i.e.* elastic vs. inelastic), since it is not known whether water levels in 2004 had recovered to their 2003 levels.

The color-coded background in Figure 2-5 represents the subsidence that occurred in the area over the October 1993 to December 1995 period as measured by InSAR. The subsidence shown by this InSAR data has been interpreted as primarily permanent subsidence caused by inelastic aquifer-system compaction. If so, the survey data in Figure 2-5 are indicating that the distribution of inelastic compaction in 2003-04 is significantly different than the distribution of inelastic compaction that occurred during the early 1990s. In particular, maximum permanent subsidence of about 1 foot in 1993-95 was measured in the vicinity of Ayala Park by InSAR, whereas in 2003-04 the survey data are indicating minimal permanent subsidence, if any, in this same area.

Figures 2-6 and 2-7 display the vertical and horizontal displacement at monuments of the Ayala Park Array that occurred from April 2003 to November 2003 and November 2003 to April 2004, respectively. The determination of horizontal displacement of monuments was accomplished through the processing of distance and angle measurements between adjacent monuments, and is based on the assumption that the southeastern monument was stable over the period of measurement. The methods used to measure the horizontal displacement of monuments at the Ayala Park Array are currently being refined by AE. These figures show:

- significant horizontal displacement of the ground surface over the course of the pumping and recovery seasons in the vicinity of the historic fissure zone
- the elastic nature of the land surface displacement over the course of the pumping and recovery seasons
- the apparent presence of a groundwater barrier within the deep aquifer system (see Section 5.3.4 below).

Groundwater production and water-level data show that pumping of wells perforated within the deep aquifer system (>300 ft-bgs) causes water-level drawdowns in the deep aquifer system on the order of 150 feet. However, these large drawdowns do not propagate east of the fissure zone. During the pumping season of 2003 (April to November) vertical displacement of the land surface (*i.e.* subsidence) was generally greater on the west side of the fissure zone where water-level drawdown was greatest. During



the recovery season of 2003-04 (November to April) vertical displacement of the land surface (i.e. rebound) was again greater on the west side of the fissure zone where water-level recovery was greatest.

In other words, the groundwater barrier in the deep aquifer system aligned with the fissure zone causes greater water-level fluctuations on the west side of the barrier where the pumping is concentrated. These greater water-level fluctuations west of the barrier cause greater deformation of the aquifer-system matrix which, in turn, causes greater vertical land surface deformation on the west side of the barrier. The InSAR data corroborate the existence of the groundwater barrier by showing maximum subsidence west of the barrier (0.2ft) and virtually no subsidence east of the barrier during the course of one pumping season (April-1993 to September 1993). In addition, the pattern of horizontal displacement of benchmarks over the pumping and recovery seasons likely reflects, in part, the differential compaction of the aquifer system across the fissure zone.

In June 2005, the entire network of monuments was surveyed for vertical displacement and, at the Ayala Park array of monuments, for horizontal displacement. The results of this survey are currently being processed.

Monitoring of Ground Surface Deformation—InSAR. Vexcel Corporation of Boulder, Colorado – a company that specializes in remote sensing and radar technologies – conducted a “proof of concept” study of historical synthetic aperture radar data that was acquired over the MZ-1 area. The objective of this study was to generate cumulative displacement maps over relatively short time steps (April to November 1993). The MZ-1 Technical Group deemed the study successful, and approved follow-up study by Vexcel to perform a comprehensive analysis of all historical synthetic aperture radar data (1992-2003) to characterize in detail the history of subsidence in MZ-1.

The comprehensive analysis was completed during the first quarter of calendar 2005. However, the usable data in this analysis only spanned the 1992-2000 period. Dr. David Cohen of Vexcel presented the InSAR results by to the MZ-1 Technical Committee in March 2005. Figures 2-8 and 2-9 display the summary results of the InSAR analysis of land subsidence for the periods of 1992-1995 and 1996-2000.

The InSAR results were generally consistent with the ground level survey data collected over a similar period with respect to the areal extent and magnitude of historical subsidence. The InSAR data show that:

- the rate of subsidence in the south area of MZ-1 has declined over time, particularly since about 1995.
- currently, the aquifer system is experiencing mainly elastic compression and expansion in the south area of MZ-1.
- the central area of MZ-1 is displaying greater rates of subsidence than the south area (near Ayala Park). This subsidence is probably due to aquifer system compaction, but pumping and water level data that would define this relationship have not yet been collected and analyzed in the central area of MZ-1.
- a steep gradient of subsidence exists across the fissure zone. The steep gradient extends north of the fissure zone to about Francis Street. In addition, the spatially continuous InSAR data show that the gradient of subsidence is steeper across the fissure zone than is shown by surveys of discrete benchmarks, which further supports the potential link between the subsidence and the fissuring. The existence of this steep gradient across the fissure zone also supports/reveals the existence and extent of the groundwater barrier.

Conclusions



There are five major conclusions that have been derived from the IMP to date:

1. The current state of aquifer-system deformation in south MZ-1 (in the vicinity of Ayala Park) is essentially elastic. Little, if any, inelastic (permanent) compaction is now occurring in this area, which is in contrast to the past when about 2.2 feet of land subsidence occurred, accompanied by ground fissuring, from about 1987-1995.
2. Groundwater production from the deep, confined aquifer system in this area causes the greatest stress to the aquifer system. In other words, pumping of the deep aquifer system causes water-level drawdowns that are much greater in magnitude and lateral extent than drawdowns caused by pumping of the shallow aquifer system.
3. Water-level drawdowns due to pumping of the deep aquifer system can cause inelastic (permanent) compaction of the aquifer-system sediments, which results in permanent land subsidence. The initiation of inelastic compaction within the aquifer system was identified during this investigation when water levels fell below a depth of about 250 feet in the PA-7 piezometer at Ayala Park.
4. Through this study, a previously undetected barrier to groundwater flow was identified. The barrier is located within the deep aquifer system and is aligned with the zone of historical ground fissuring. Pumping from the deep aquifer system is limited to the area west of the barrier, and the resulting drawdowns do not propagate eastward across the barrier. Thus, compaction occurs within the deep system on the west side of the barrier, but not on the east side, which causes concentrated differential subsidence across the barrier and creates the potential for ground fissuring.
5. InSAR and ground-level survey data indicate that permanent subsidence in the central parts of MZ-1 (north of Ayala Park) has occurred in the past and continues to occur today. The InSAR data also indicate that the groundwater barrier extends northward into central MZ-1. These observations suggest that the conditions that very likely caused ground fissuring near Ayala Park in the 1990s are also present in central MZ-1, and should be studied in more detail.



Figure 2-1 - Piezometric and Extensometer Data

Ayala Park Piezometer/Extensometer Facility

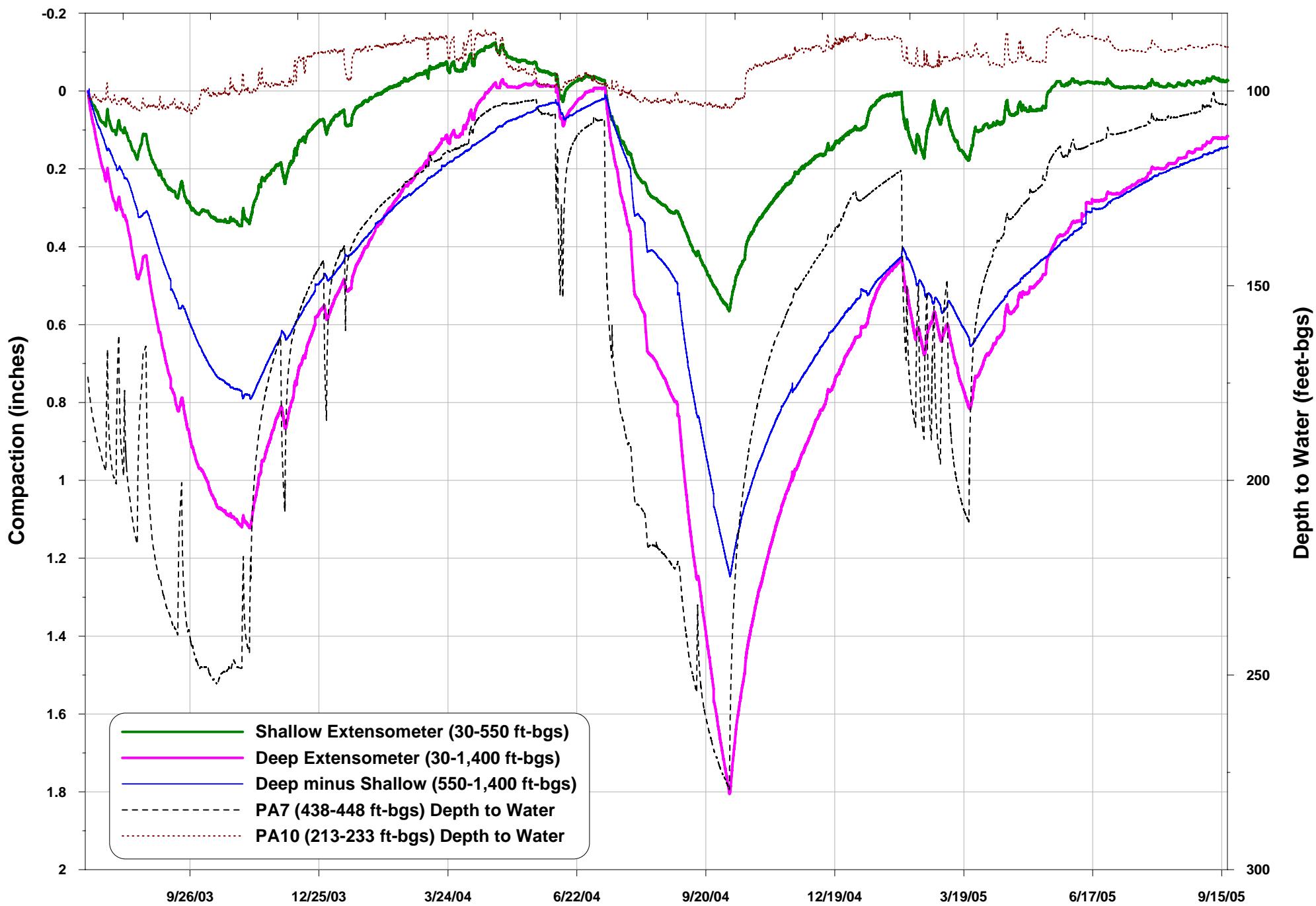
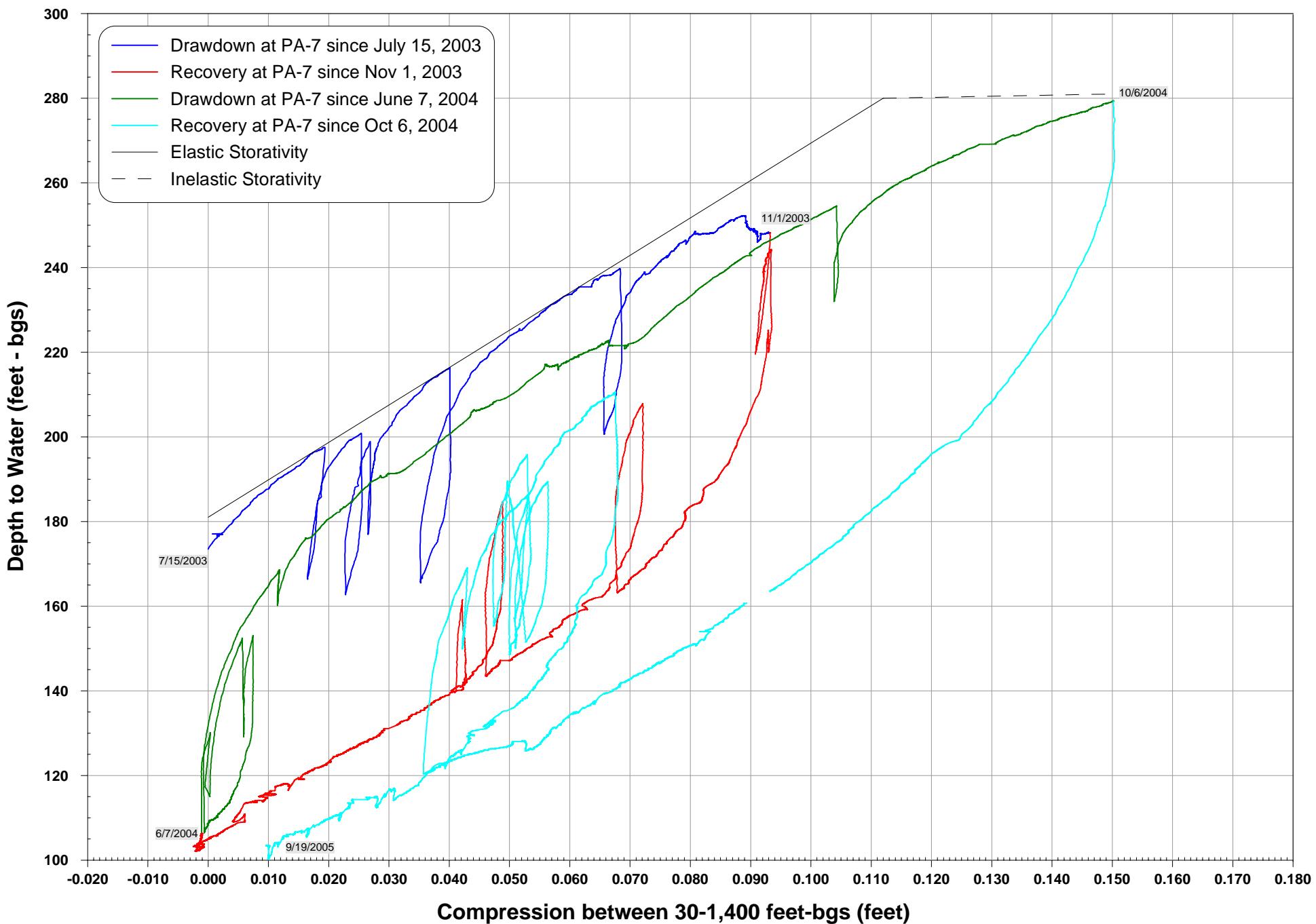


Figure 2-2 -- Stress-Strain Diagram
PA-7 vs. Deep Extensometer



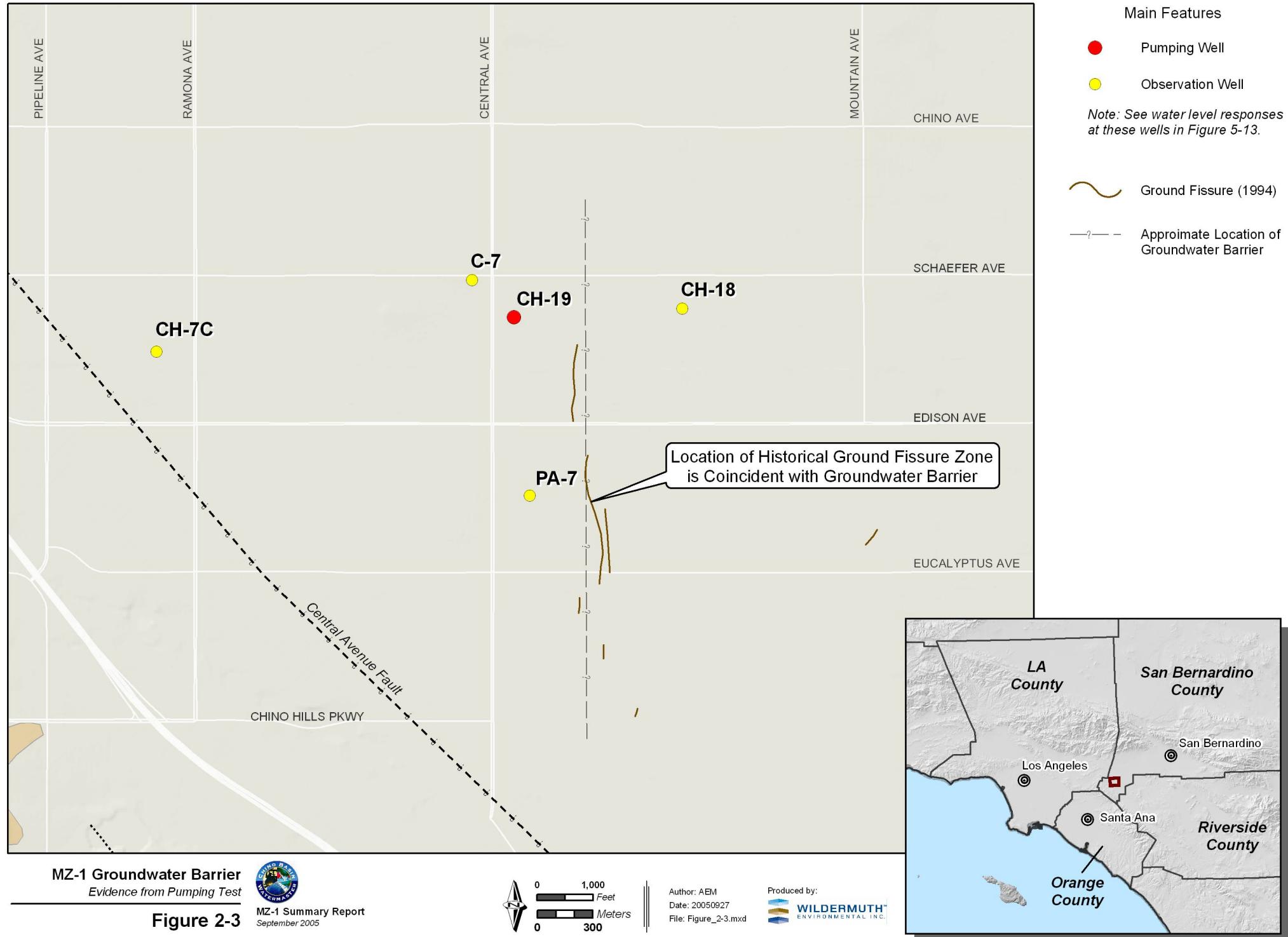
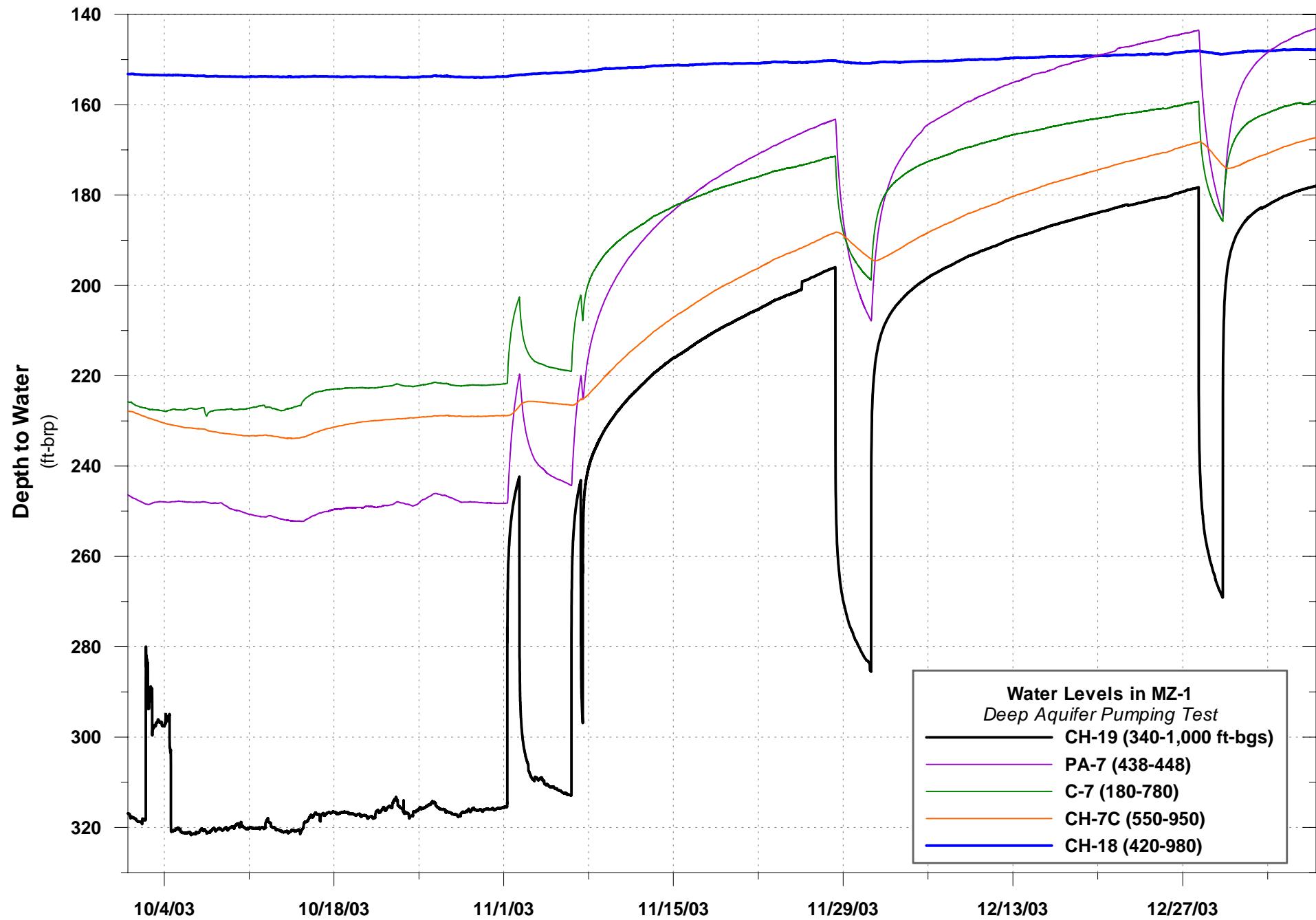
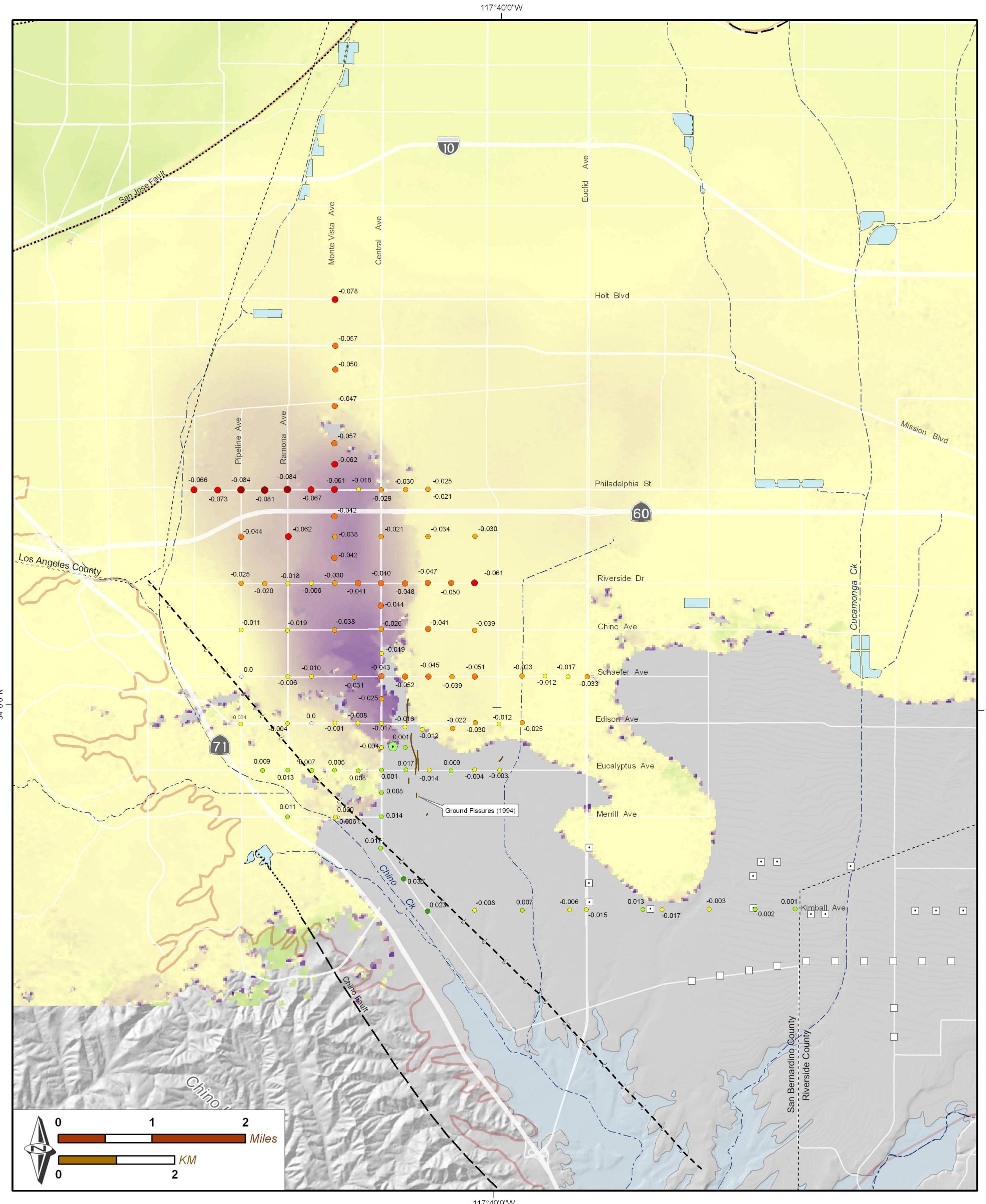


Figure 2-4
Water Level Responses at Nearby Wells to Pumping at CH-19

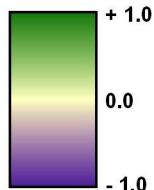




Main Features

- Relative Change in Land Surface Altitude as Measured by Leveling Surveys April 2003 - April 2004 (feet)

 - 0.010 to -0.080
 - 0.079 to -0.060
 - 0.059 to -0.040
 - 0.039 to -0.020
 - 0.019 to -0.001
 - 0.0
 - 0.001 to 0.020



Relative Change in
Land Surface Altitude
as Measured by InSAR
Oct 1993 - Dec 1995
(feet)

Other Features

- Ayala Park Extensometer Facility
 - Chino Basin Desalter Well (Existing)
 - Chino Basin Desalter Well (Planned)
 - Chino Basin Hydrologic Boundary

Faults & Groundwater Divides

- Location Certain - - -? Location Uncertain
- - - Location Approximate - + - Groundwater Divide
..... Location Concealed



Ground Level Survey Results

April 2003 to April 2004

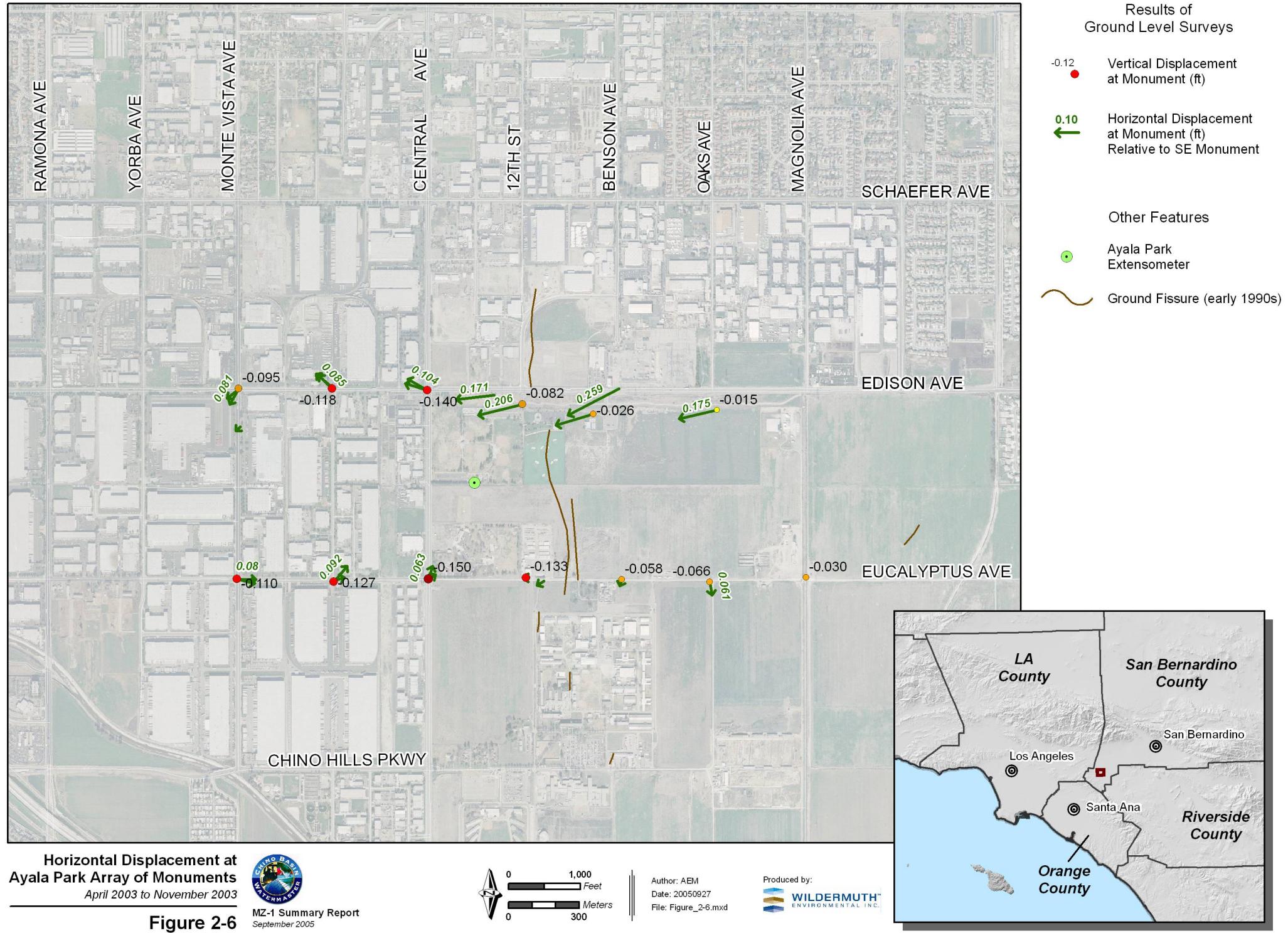


Figure 2-6

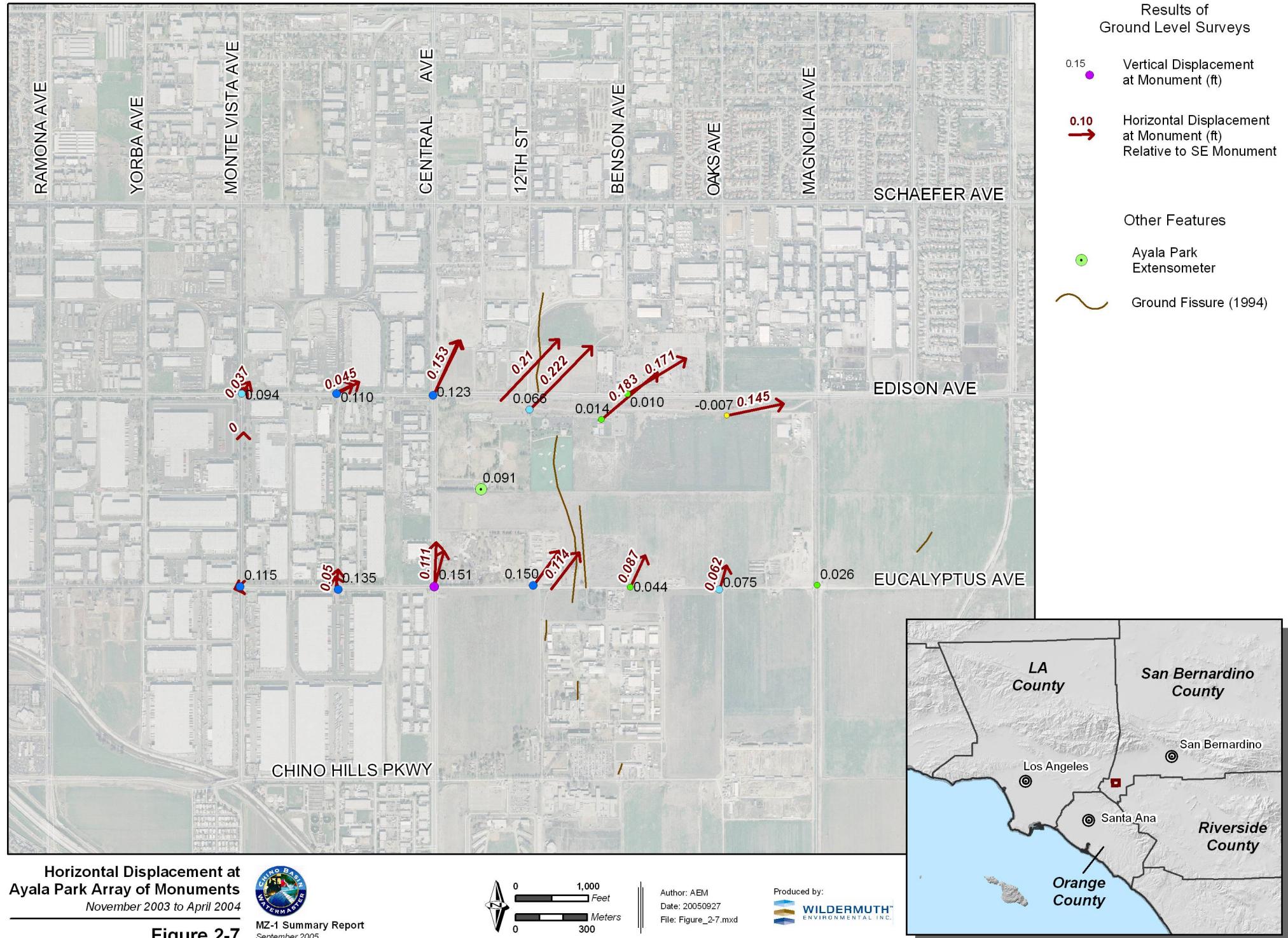
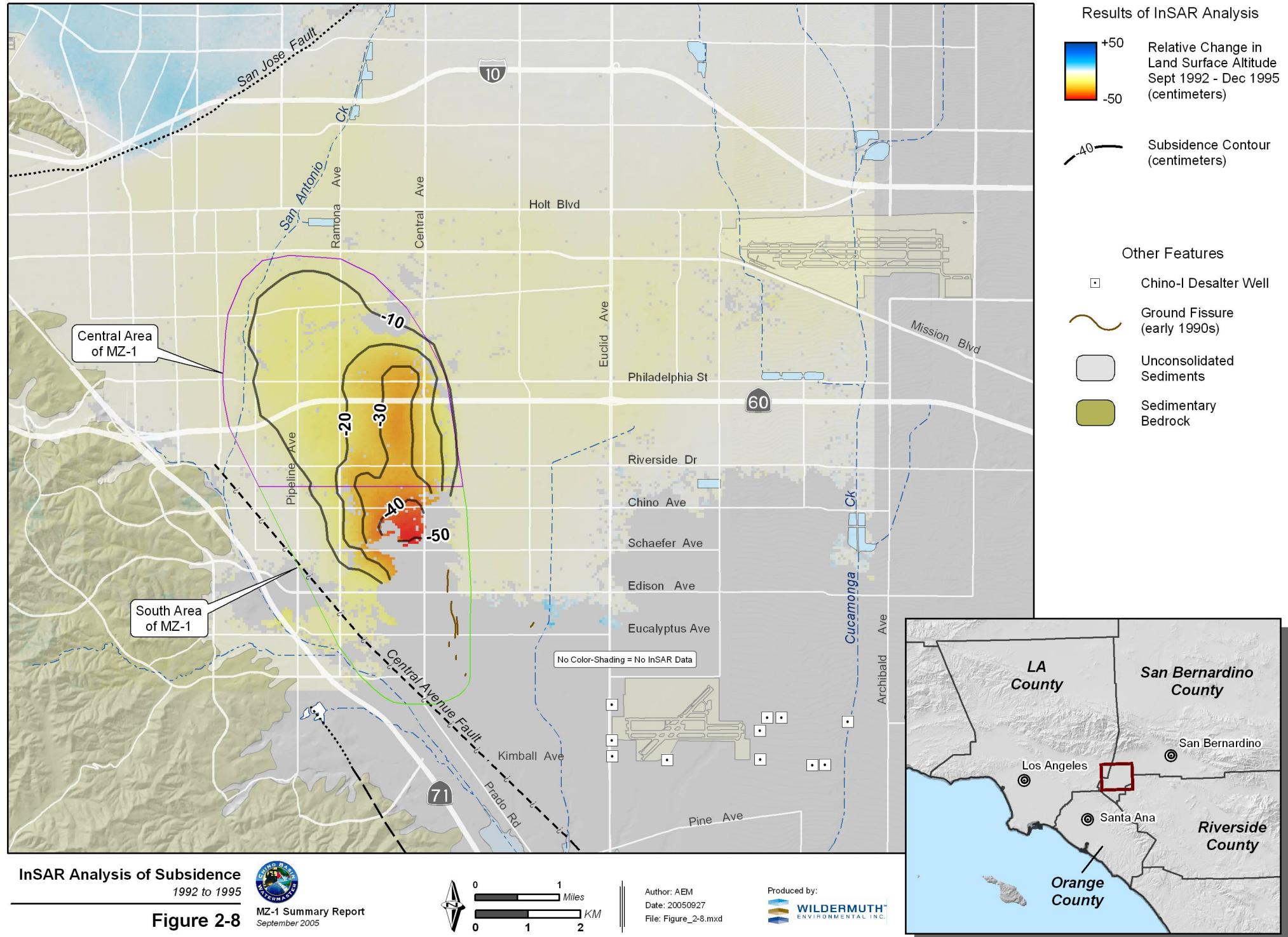
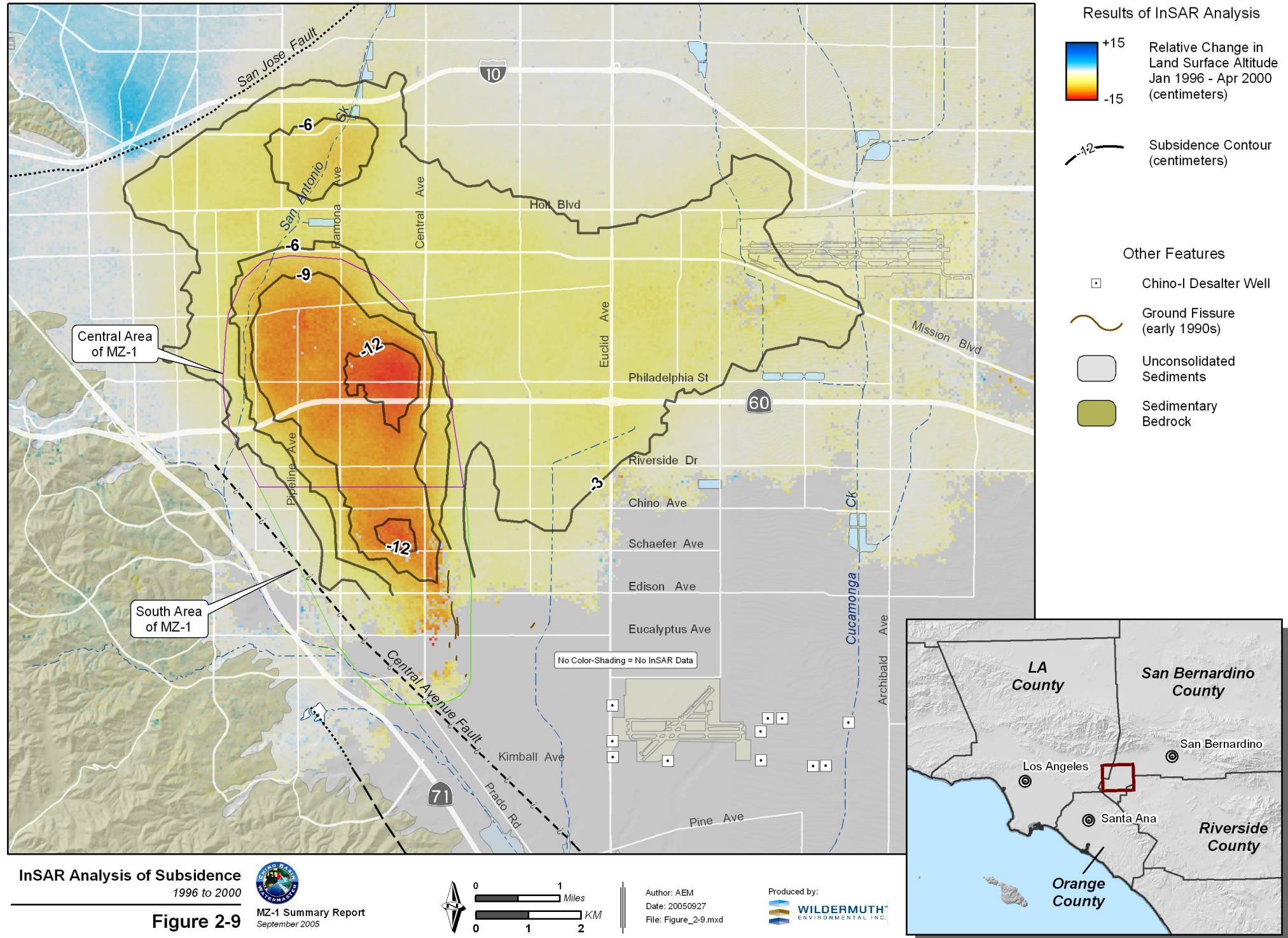


Figure 2-7





3. ONGOING AND RECOMMENDED WORK

This section describes:

- the ongoing work of the IMP, which includes the continued monitoring of the aquifer system and land surface deformation and the development of analytical and numerical models of groundwater flow and aquifer-system deformation.
- the work that is currently being implemented that was not initially part of the IMP, but has been recommended by MZ-1 Technical Committee and/or Watermaster based on data obtained during the IMP period. This work includes the expanded aquifer-system monitoring in the central area of MZ-1, and the monitoring of horizontal ground surface deformation along Schaefer Avenue.

Continued Monitoring

Aquifer-System Monitoring. Aquifer-system monitoring efforts will continue for the duration of the IMP. The MZ-1 Technical Committee will likely recommend that the aquifer-system monitoring efforts continue, albeit at a reduced scope, as part of the long-term management plan. Electronic data from the Ayala Park Extensometer facility and from water level recording transducers in surrounding wells will be collected and entered into the MZ-1 database once every two months. The purpose of this continued monitoring effort is to (1) continually evaluate the effectiveness of the long-term plan, and (2) verify the accuracy of the groundwater flow and subsidence models that are being used as management tools.

InSAR. The MZ-1 Technical Committee is recommending that on-going InSAR monitoring of land surface deformation be conducted on a semi-annual interval (spring and fall data acquisition and interferometric analysis) for the next two years. This analysis will (1) reveal seasonal and annual ground surface displacement across the entire MZ-1 area, and (2) be compared to ground-level survey data collected at the same interval (see Section 5.4.2 below) to help determine a long-term strategy to monitor ground surface deformation.

Ground Level Surveying. The MZ-1 Technical Committee is recommending that the entire network be surveyed twice per year for the next two years (during the spring and fall of each year). The ground level survey data will be compared against the InSAR data (see above) to help determine a long-term strategy to monitor ground surface deformation.

Development of Analytical and Numerical Models

The objectives of aquifer-system modeling in MZ-1 are:

- To evaluate fluid withdrawal as the mechanism of historical land subsidence and fissuring
- To predict the effects of potential basin management practices on groundwater levels and land subsidence and fissuring (forecasting tool)

In other words, if a model can be constructed that simulates past drawdown and associated land subsidence, then the model represents an additional line of evidence that fluid withdrawal was the mechanism of historical land subsidence. In addition, the model can be used to predict future drawdown and associated land subsidence that would result from potential basin management practices.

Three distinct modeling efforts will take place in sequence:

1. *Inverse analytical modeling.* This type of modeling will use groundwater level and production data collected as part of the aquifer-system stress testing (pumping tests) that were conducted in 2003 and



2004. The objectives are to determine the hydraulic and mechanical parameters of the aquifer-system and reveal XY-anisotropy. The results will be used in subsequent numerical modeling efforts.

2. *One-dimensional compaction modeling.* This type of modeling will use groundwater level and aquifer-system deformation data collected at the Ayala Park Piezometer/Extensometer Facility, as well as historical water level and subsidence data collected near Ayala Park. One objective is to determine the aquitard properties in the vicinity of Ayala Park. Areal extrapolation of aquitard properties will be based on geology and InSAR data, and the results will be used in the three-dimensional numerical modeling efforts (see Section 3). Another objective is to predict aquifer-system deformation due to predicted water level changes that may occur at Ayala Park in the future due to nearby pumping.
3. *Three-dimensional groundwater flow and subsidence modeling.* This type of modeling will use groundwater level and production data at all wells in the area and historical land subsidence data from ground level surveys and InSAR. Again, this model will attempt to match historical water level and subsidence data and, if successful, will serve as a forecasting tool for MZ-1 managers.

It is desirable that the calibration period for future groundwater flow and subsidence modeling begins before significant drawdown in MZ-1 (~1940). The comprehensive set of subsidence data in this region begins in 1987. If subsidence data exists prior to 1987, then it needs to be collected, evaluated, and linked to the post-1987 survey data if it is to be used in model calibration. Associated Engineers is currently investigating the quantity and quality of pre-1987 subsidence data in MZ-1, and will deliver a report containing these data in October 2005.

Expanded Monitoring

One of the key discoveries of the IMP has been the groundwater barrier located beneath the historic fissure zone. However, the northern and southern extent of this barrier is unknown. The MZ-1 Technical Committee is contemplating the expansion of the aquifer-system monitoring network to the north and south of its current extent to better characterize the location and effectiveness of the barrier. Further aquifer-system testing (i.e. pumping test) may be necessary as part of this effort.

The horizontal surveys will also be extended to the north over this two year period to include the benchmarks along Schaefer Avenue. The next survey of the entire monument network is planned for October 2005.



4. DEVELOPMENT OF THE LONG-TERM MANAGEMENT PLAN FOR MZ-1

Recall that the objective of the long-term management plan is to minimize or abate permanent land subsidence and ground fissuring in MZ-1. The modeling efforts described above will be critical to the development of the long-term plan, and the continual evaluation of plan in the future.

A workshop was held May 25, 2005 to update the Special Referee on IMP progress and development of the long-term management plan for MZ-1. The OBMP implementation plan called for the development of the long-term plan by June 2005. Because the modeling efforts were just begun in the summer of 2005, the Special Referee was notified before and during the workshop of the impending delay in the development of the long-term plan.

Subsequent to the workshop, the Special Referee issued a report to the Court (Appendix A). In the report, the Special Referee:

- indicated that the IMP progress and current activities are sufficient to warrant a delay in the development of a long-term plan
- indicated that it was incumbent upon Watermaster to request that the Court extend the period for completion of the long-term plan, and that Watermaster file with the Court a motion for an order to set a new schedule for the completion of the long-term plan
- requested that Watermaster produce a MZ-1 Summary Report (this report) that describes the IMP results and conclusions to date, and addresses outstanding issues such as other potential subsidence mechanisms and historical subsidence that pre-dates the 1990s
- requested that Watermaster provide “guidance criteria” to the MZ-1 producers in an effort to minimize the potential for future subsidence and fissuring until the completion of the long-term plan

Guidance Criteria to Minimize Subsidence and Fissuring

In response, Watermaster produced this summary report, and drafted a set of guidance criteria for MZ-1 producers. Again, the purpose of the guidance criteria is to minimize the risk of permanent subsidence and ground fissuring while the long-term plan is being developed. The guidance criteria are listed in Table 4-1 and below:

1. Table 4-2 lists the existing wells (hereafter the Managed Wells) and their owners (hereafter the Parties) that are the subject of these Guidance Criteria.
2. Figure 4-1 shows the area addressed by these Guidance Criteria (hereafter the Area of Subsidence Management). Within the boundaries of this area, both existing and newly-constructed wells are subject to being classified as Managed Wells. This is based upon the observed and/or predicted effects of pumping on groundwater levels and aquifer-system deformation. Initial Managed Well designations for wells that pumped during the IMP were based on effects measured at the Ayala Park Piezometer/Extensometer Facility. Additional Managed Well designations were made based on analysis of well construction and geology.
3. The Guidance Level is a specified depth to water measured in Watermaster’s PA-7 piezometer at Ayala Park. It is defined as the threshold water level at the onset of inelastic compaction of the aquifer system as recorded by the extensometer, minus 5 feet. The 5-foot reduction is meant to be a safety factor to ensure that inelastic compaction does not occur. The Guidance Level is established by Watermaster based on the periodic review of monitoring data collected by Watermaster. The initial Guidance Level is 245 feet below the top of the PA-7 well casing.



4. If the water level in PA-7 falls below the Guidance Level, Watermaster recommends that the Parties curtail their production from designated Managed Wells as required to maintain the water level in PA-7 above the Guidance Level.
5. Watermaster will provide the Parties with real-time water level data from PA-7.
6. The Parties are requested to maintain and provide to Watermaster accurate records of the operation of the Managed Wells, including production rates and on-off dates and times. The Parties are requested to promptly notify Watermaster of all operational changes made to maintain the water level in PA-7 above the Guidance Level.
7. Watermaster recommends that the Parties allow Watermaster to continue monitoring piezometric levels at their wells.
8. Watermaster will evaluate the data collected as part of the MZ-1 Monitoring Program at the conclusion of each fiscal year (June 30) and determine if modifications, additions, and/or deletions to the Guidance Criteria are necessary. These changes to the Guidance Criteria could include (1) additions or deletions to the list of Managed Wells, (2) re-delineation of the Area of Subsidence Management, (3) raising or lowering of the Guidance Level, or (4) additions and/or deletions to the Guidance Criteria (including the need to have periods of water level recovery).
9. Watermaster cautions that some subsidence and fissuring may occur in the future even if these Guidance Criteria are followed. Watermaster makes no warranties that faithful adherence to these Guidance Criteria will eliminate subsidence or fissuring.

Development and Schedule of the Long-Term Plan

In a sense, the guidance criteria listed above are a *first draft* of the long-term plan. Over the next nine months (October 2005 to June 2006), Watermaster will conduct its modeling exercises and coordinate a series of meetings with MZ-1 producers that will likely lead to revisions of the guidance criteria.

Of particular interest to the affected Parties is the sixth criterion (6) listed above, which limits the timing of production from the Managed Wells to July through September of each year. It may be that the Managed Wells can be pumped at reduced rates over periods longer than three months, and still not cause drawdown below 245 feet at the PA-7 piezometer or inelastic compaction within the aquifer system. Watermaster's groundwater flow and subsidence models will help to address these unknowns prior to pumping by predicting:

- the water level response at PA-7 due to various proposed pumping scenarios, and
- the aquifer-system compaction response due to the water level responses.

In June 2006, after the MZ-1 meetings and modeling exercises, Watermaster will release an expanded *second draft* of the guidance criteria, which will be defined as the official long-term plan for MZ-1. A key element of the long-term plan will be the verification of the model predictions and the protective nature of the guidance criteria as related to permanent land subsidence and ongoing fissuring. This verification will be accomplished through continued monitoring and reporting by Watermaster and revision of the guidance criteria when appropriate (see Criterion 11 above). In this sense, the long-term plan will be adaptive.

The guidance criteria and the long-term plan discussed above relate to the management of pumping-induced subsidence within south MZ-1 (the Area of Subsidence Management in the terminology of the



guidance criteria). Recall that central MZ-1 is currently experiencing measurable land subsidence, and is the focus of an expanded effort to monitor piezometric levels and land surface deformation. An adaptive long-term plan will accommodate the results and modified recommendations that will emerge from the expanded monitoring of central MZ-1.

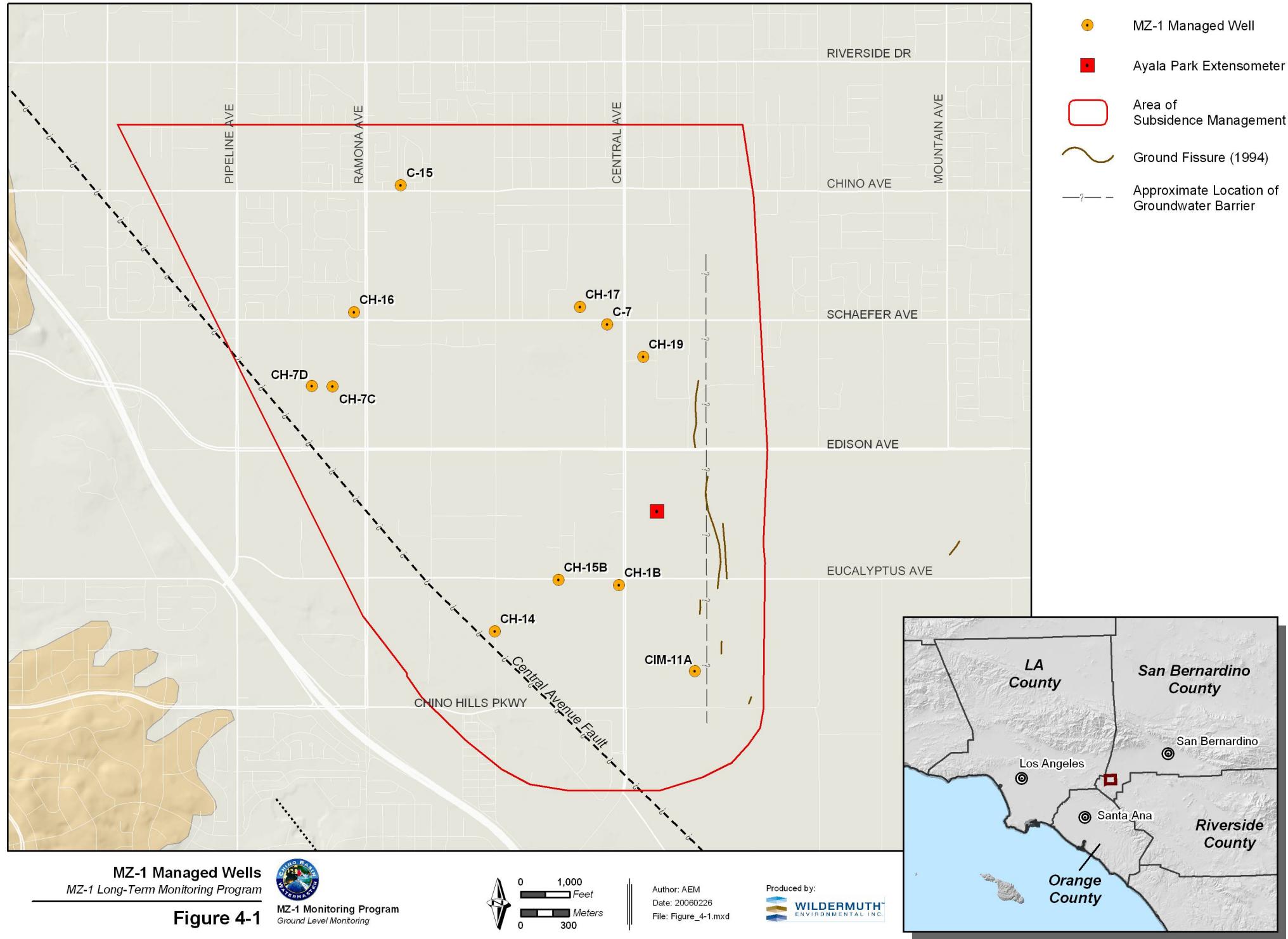


Table 4-1
Guidance Criteria for MZ-1 Producers

1. Table 4-2 lists the existing wells (hereafter the Managed Wells) and their owners (hereafter the Parties) that are the subject of these Guidance Criteria.
2. Figure 4-1 shows the area addressed by these Guidance Criteria (hereafter the Area of Subsidence Management). Within the boundaries of this area, both existing and newly-constructed wells are subject to being classified as Managed Wells. This is based upon the observed and/or predicted effects of pumping on groundwater levels and aquifer-system deformation. Initial Managed Well designations for wells that pumped during the IMP were based on effects measured at the Ayala Park Piezometer/Extensometer Facility. Additional Managed Well designations were made based on analysis of well construction and geology.
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9. Watermaster cautions that some subsidence and fissuring may occur in the future even if these Guidance Criteria are followed. Watermaster makes no warranties that faithful adherence to these Guidance Criteria will eliminate subsidence or fissuring.

Table 4-2
MZ-1 Managed Wells

CBWM_ID	Owner	Well Name	Status	Screened Interval ft-bgs	Capacity gpm
600487	Chino Hills	1B	Inactive	440-470, 490-610, 720-900, 940-1180	up to 1200
600687	Chino Hills	7C	Inactive	550-950	--
600498	Chino Hills	7D	Inactive	320-400, 410-450, 490-810, 850-930	400
600495	Chino Hills	14	Inactive	350-860	300-400
600488	Chino Hills	15B	Active	360-440, 480-900	1500
600489	Chino Hills	16	Inactive	430-940	800
600499	Chino Hills	17	Active	300-460, 500-980	700
600500	Chino Hills	19	Active	340-420, 460-760, 800-1000	1100-1500
3600461	Chino	7	Inactive	180-780	
600670	Chino	15	Inactive	270-400, 626-820	
3602461	CIM	11A	Active	135-148, 174-187, 240-283, 405-465, 484-512, 518-540	500-600



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**APPENDIX A – SPECIAL REFEREE’S REPORT ON PROGRESS MADE ON IMPLEMENTATION OF
THE WATERMASTER INTERIM PLAN FOR MANAGEMENT OF SUBSIDENCE**

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7
8 SPECIAL REFEREE

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10
11 SUPERIOR COURT OF THE STATE OF CALIFORNIA
12 COUNTY OF SAN BERNARDINO, RANCHO CUCAMONGA DIVISION

13
14 CHINO BASIN MUNICIPAL WATER) CASE NO. RCV 51010
15 DISTRICT,)
16 Plaintiff,) Judge: Honorable J. Michael Gunn
17 v.)
18 THE CITY OF CHINO,) Date: TBD
19 Defendants.) Time:
20) Dept:
21 _____)

22
23
24
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26
27
28 SPECIAL REFEREE'S REPORT ON PROGRESS MADE ON
IMPLEMENTATION OF THE WATERMASTER INTERIM PLAN
FOR MANAGEMENT OF SUBSIDENCE

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13 CHINO BASIN MUNICIPAL WATER) CASE NO. RCV 51010
14 DISTRICT,)
15 Plaintiff,) Judge: Honorable J. Michael Gunn
16 v.)
17 THE CITY OF CHINO,) SPECIAL REFEREE'S REPORT ON
18 Defendants.) PROGRESS MADE ON IMPLEMENTATION OF THE WATERMASTER
19) INTERIM PLAN FOR MANAGEMENT OF SUBSIDENCE
20) Date: TBD
21) Time:
22) Dept:
23)
24)
25)
26)
27)
28)

19 I. INTRODUCTION

20 A workshop was held May 25, 2005, as a follow-up to the workshop held August 29, 2002.
21 The second workshop was originally scheduled to be held in 2003, pursuant to Court Order
22 Concerning Watermaster's Interim Plan for Management of Subsidence, dated October 17, 2002
23 ("2002 Order"). The second workshop was postponed until substantial data collection and analysis
24 had been completed.

25 The scope of the workshop was limited to presentation of technical data and analysis
26 completed to date related to the Watermaster Interim Plan for Management of Subsidence ("Interim
27 Plan"). The presentation was made by Mr. Malone of Wildermuth Environmental, Inc., Watermaster
28 Engineering Consultant. Mr. Malone, Mr. Wildermuth, and Mr. Riley addressed questions posed

1 by the Special Referee, technical expert Joe Scalmanini, and several others. Consistent with use of
2 a workshop format, cross-examination was not allowed. A transcript of the workshop has been
3 prepared and will be filed with the Court by Watermaster.

4 **II. 2002 COURT ORDER**

5 In the 2002 Order, Judge Gunn directed Watermaster to:

- 6 (1) Implement the Interim Plan Monitoring Program for subsidence, including all work
7 related to piezometers, extensometers, ground-level monitoring, aquifer testing, and
8 other actions to study, analyze, and interpret subsidence and fissuring in MZ1 and to
determine causes in sufficient detail that they can be managed through a long-term
plan;
- 9 (2) Continue the MZ1 Technical Committee work and have the Technical Committee
10 serve in an advisory capacity to assist Watermaster in developing a long-term
subsidence management plan for MZ1;
- 11 (3) Develop a long-term management plan by fiscal year 2004/2005;
- 12 (4) Submit quarterly reports to the court on all interim and long-term efforts to address
13 MZ1 subsidence and fissuring problems, including documentation of participation,
forbearance, impacts, and other “noteworthy details that pertain to the goal of
14 forbearance to minimize subsidence and fissuring”;
- 15 (5) Schedule a follow-up workshop for July 17, 2003; and
- 16 (6) File reports at least quarterly to apprise the court of any actions pending that could
cause the “jurisdiction issue” to resurface.

17 **III. COMPLIANCE WITH 2002 COURT ORDER**

18 A. **Regular Reports by Watermaster**

19 Watermaster has regularly reported to the court, through its status reports, on the progress
20 of all work related to Management Zone 1 (“MZ1”) subsidence issues. Watermaster has also
21 reported that it is not aware of any pending legal actions which have raised issues concerning the
22 court’s jurisdiction related to subsidence. The City of Chino (“Chino”) has annually asked for
23 continuances of its Paragraph 15 Motion. The process has been that Chino requests continuance
24 after both Chino and the City of Chino Hills (“Chino Hills”) have committed to forbear some
25 pumping. (Our files reflect that Chino requested a continuance to September 1, 2005, but we do not
26 have a copy of a court order approving that continuance.) Watermaster has reported that the MZ1
27 Technical Advisory Committee has been actively meeting.

28 ////

1 **B. Pumping Forbearance Agreements**

2 Annual forbearance agreements have been entered into for the past three years by Chino and
3 Chino Hills. On April 28, 2005, Watermaster approved continuation of the forbearance agreements
4 for a fourth year. The fourth year of forbearance will be fiscal year 2005/2006.

5 **C. Court Order and Deadlines**

6 Two of the deadlines set forth in the 2002 Order have not been met. First, a long-term
7 management plan for MZ1 was to have been completed this fiscal year (by July 1, 2005). Second,
8 a follow-up Special Referee workshop was not held in July 2003, but, instead, was postponed in
9 order that a substantial body of work could be completed to study and assess the MZ1 issues.

10 **IV. INTERIM PLAN WORK**

11 **A. Technical Work Completed to Date**

12 The purpose of the second workshop was to hear a description of the work and study that has
13 been done since the MZ1 Interim Plan was begun, to ascertain whether any conclusions have been
14 reached, and to obtain a description of the activities that are being undertaken now and that remain
15 to be done. Mr. Malone's presentation on the technical work and analysis to date formed the bulk
16 of the workshop. He provided a very detailed description of the monitoring and other technical work
17 that has been undertaken. Ongoing efforts have included installation of piezometers and an
18 extensometer, installation of transducers to monitor water levels in a network of wells, and ground-
19 level and InSAR monitoring for subsidence. Mr. Malone reported several discoveries which he
20 characterized as significant, including discovery of a groundwater barrier at depth in a location
21 approximately coincident with the fissuring that has occurred, and that there are two very distinct
22 aquifer systems. (Reporter's Transcription ("RT") at pp. 44-47)

23 Mr. Malone also indicated that all of the potential causes of the subsidence and fissuring
24 which had been previously suggested had been reviewed, but that the Interim Plan work has focused
25 on the hypothesis that the subsidence and fissuring have been caused by subsurface fluid withdrawal:

26 We reviewed all these [other potential causes of subsidence], but what we zeroed in
27 on was the subsurface withdrawal as our hypothesis. That's what we identified as the
28 most likely cause of the subsidence that we had observed in the City of Chino . . . so
 our hypothesis was that the groundwater production caused land subsidence and
 fissuring in Chino Basin. . . . We also noted that it was likely, or that we were

1 hypothesizing that the production from the confined aquifer system was the main
2 cause of this recent episode of subsidence and fissuring that was measured in the
3 early 1990's. So this is what we designed our monitoring program to test, whether
4 or not this hypothesis was correct.

5 (RT at pp. 32-33) There was no further discussion on the record regarding the nature of the review
6 that was done as to other potential causes of the subsidence and fissuring.

7 A primary focus of the technical work has been to determine at what point subsidence creates
8 inelastic compaction versus subsidence which is elastic and can recover. Mr. Malone described the
9 process to identify:

10 ... the threshold where the deformation process transitions from elastic to inelastic.
11 By doing that, we'd be defining the usable volume of the storage reservoir, under
what range of water levels can we operate where we're not causing inelastic
compaction. And that would be a very key finding to any long-term management
plan that might develop out of this study.

12 (RT at pp. 43-44) The presentation included detailed descriptions of "stress-strain diagrams" which
13 reflect data on the elastic versus inelastic response of the system to pumping. Mr. Malone drew
14 attention to a "key point" that there appears to have been about two one-hundredths of a foot (0.02
15 ft.) of permanent compaction over the 2004 pumping season. (RT at pp. 58-59) He indicated that
16 the "... inelastic threshold was crossed at about 250 feet below ground surface during the latter part
17 of the pumping season." (RT at p. 60) Mr. Malone made it very clear that it is necessary to wait for
18 "fully recovered water levels" before drawing any final conclusions that the system transitions from
19 elastic to inelastic compaction when water levels are somewhere below 250 feet below ground
20 surface. (RT at p. 95)

21 In response to questions as to whether there are sufficient data available now to develop a
22 long-term plan, Mr. Malone responded that:

23 ... When we operate in the forbearance agreement where we pump during the
24 pumping season, but we allow the system to recover during the wintertime months,
25 ... we've demonstrated that we're operating generally in an elastic range. . . And so
to how far we can step out of that same pumping pattern and still operate within the
elastic range, we have not determined that yet. But the models hold the promise of
determining that.

26
27 (RT at p. 93)

28 Mr. Malone explained that the next step in the investigation is to create groundwater models

1 to "... simulate the groundwater production's effects on groundwater levels." (RT at p. 91) The
2 model will: "... help us provide that linkage between groundwater production and groundwater
3 levels that would provide a tool to evaluate any management plan that might come out of this." (RT
4 at p. 107)

5 In response to a question, Mr. Malone indicated that there are not plans to do further testing
6 in the southern part of MZ1:

7 We feel like if the stress-strain diagram goes to where it seems to be going, that
8 we've identified this threshold of preconsolidation stress that is the transition
9 between inelastic and elastic compaction. . . I don't think we have any further
questions that we're trying to answer in this southern part of Management Zone 1.
We're going to be developing the models that will help us provide that linkage
between groundwater production and groundwater levels. . .

10
11 (RT at p. 107)

12 **B. Recommended Additional Technical Work**

13 Mr. Malone recommended that technical work be continued in the southern part of MZ1 and
14 that certain technical work be started in the central MZ1 area to the north. For the southern MZ1
15 area, the recommendation is that monitoring continue (RT at pp. 97-99) and that some of the
16 dedicated piezometers be replaced (RT at pp. 103-104). In addition, numerical models would be
17 developed (a one-dimensional compaction model and a three-dimensional groundwater flow and
18 subsidence model). The three-dimensional model would link:

19 . . . the areal and vertical distribution of pumpage to water level fluctuations and then
20 the ultimate deformation that occurs in the aquifer system. . . We've been working
mostly on this link between water level fluctuation and deformation. The model will,
then, now take us from that to include pumpage, how it affects water level
fluctuations, and then how the water level fluctuations affect deformation.

22 (RT at pp. 99-100)

23 Mr. Malone also discussed expanding the investigation of subsidence, initially via
24 monitoring, to the central region of MZ1, including the installation of water level transducers in
25 existing wells. (RT p. 107) Mr. Malone characterized as speculative the potential need to construct
26 a new monitoring facility or facilities in the central region, including a multi-piezometer and/or
27 extensometer. (RT at p. 102) He clarified that ground-level survey data, InSAR data, and water-
28 level data should be collected in the central MZ1 area before any conclusion would be reached on

1 the need for piezometers or an extensometer. (*Id.*) Expansion of the subsidence investigation into
2 the central region of MZ1 is prompted by the observation of some historical subsidence in the area,
3 confounded to some degree by the lack of any known local pumping in the immediate subsidence
4 area. (RT at pp. 76, 80, 83-84, 87)

5 **C. Long-Term Plan Schedule**

6 There was not extensive discussion at the workshop on either a long-term plan or a schedule
7 for completion of a plan. Mr. Malone indicated that InSAR surveys and ground surveys will be
8 conducted in both fall 2005 and spring 2006. (RT at p. 104) The modeling would be completed in
9 the spring of 2006, with a modeling report to follow that summer. (*Id.*) Mr. Wildermuth responded
10 to a question regarding scheduling by indicating that several more years of studies and model
11 development and analysis would be required, followed by 12 months to reach an agreement on a
12 long-term plan. (RT at p. 109) This timing is consistent with the discussion in the 2002 workshop.
13 At that workshop, in response to the question of how long it would take to start developing a long-
14 term plan given optimal agreement by all parties, Mr. Wildermuth stated that he thought it would
15 take three to five years (2002 Workshop Transcript at page 101.) Mr. Slater also clarified at the 2002
16 workshop that Mr. Wildermuth's three to five years were for the "data development side" and that
17 "the business deal probably follows soon thereon, and one would expect maybe twelve months to
18 wrap that piece up." (2002 Workshop Transcript at p. 103.)

19 **V. RECOMMENDATION OF SPECIAL REFEREE**

20 **A. Preparation of a Summary Report on MZ1 Technical Work**

21 A substantial body of technical work has been completed in the southern MZ1 area.
22 However, conclusions are still preliminary:

23 . . . With our stress-strain diagram . . . we're seeing that these head declines can
24 induce permanent compaction. But again this is a preliminary conclusion because
it is still pending fully recovered water levels. We're waiting for those water levels
25 to be fully recovered to see if any inelastic compaction did occur over the last
pumping season.

26 (RT at p. 95) When sufficient time has elapsed for water levels to have fully recovered, it is our
27 view that a summary report on all of the work presented at the workshop would be extremely helpful.
28 Even though no modeling has been completed, there appear to be sufficient data to conclude that

1 there is a threshold depth to water that, if crossed, will likely lead to new inelastic compaction and
2 subsidence and ground fissuring. That information should be made available to the parties in a
3 summary report as soon as possible. Based on Mr. Malone's presentation, it should be feasible to
4 prepare such a report by the middle of August. When the three-dimensional model is prepared, a
5 modeling report will be written. In the meantime, there are important data and preliminary findings
6 that can be made available very soon that will be of immediate use to the pumpers within MZ1.

7 A further recommendation related to a summary report is that the summary report should also
8 address the other potential causes of subsidence and fissuring that have been suggested in the past.
9 If any of those items cannot be readily addressed, then the summary report should recommend how
10 they will be addressed. While the detailed monitoring and testing has been substantial, they have
11 not apparently addressed whether subsidence and fissuring might have been partially the result of
12 mechanisms other than deep groundwater pumping. The continuing possibility that other
13 mechanisms may also be responsible for subsidence is a potential impediment to development of the
14 long-term plan.

15 As part of this discussion, the summary report should discuss any information related to
16 whether any significant subsidence predated the notable subsidence and fissuring since the early
17 1990's, and should describe the historical surveying investigation commissioned by Watermaster to
18 address that issue. An important outstanding question is whether any pre-1990's subsidence that
19 may have occurred correlates with, or can be attributed to, the large historical changes in
20 groundwater levels that predated the Judgment.

21 **B. Watermaster Issuance of Guidance Criteria.**

22 Near the close of the workshop, there was some discussion of what would be included in a
23 long-term plan, including possibly expanding the study area to include the central MZ1 region. (RT
24 at pp. 123 *et seq.*) The concept of a long-term MZ1 management plan has been part of the
25 Watermaster program since it was first articulated in 1999 in the Optimum Basin Management
26 Program Phase 1 Report. A long-term management plan was to be formulated during the interim
27 plan period, and would be based on investigations, monitoring programs and data assessment. It
28 would be adaptive in nature. The workshop discussion noted that the technical work that has been

1 done and that will be done will form the basis for a long-term plan. Mr. Wildermuth indicated that:

2 ... we haven't felt until very recently, last maybe six or eight months, that we were
3 at a point where we are getting close to coming up with conclusions from which we
4 could build a plan on, pull the parties together and talk about their deal making to
5 implement a plan.

6 (RT at p. 125) As discussed, above, however, development of a long-term plan itself does not appear
7 to be imminent.

8 In response to questions regarding the possibility of phasing the long-term plan, Mr.
9 Wildermuth discussed the option of bifurcating the "... southern and central portion, try to get the
10 southern portion going, and then based on the interests of the stakeholders, do something in the
11 central area." (RT at p. 125) Mr. Wildermuth also suggested that Watermaster's long-term plan
12 could range from being "guidance information" to something more aggressive. (RT at p. 108)

13 The concept of providing guidance criteria is a compelling one. It appears, based on the
14 presentation at the workshop, that Watermaster can very soon alert pumpers in the southern MZ1
15 area that there is a substantial risk that lowering water levels to below approximately 250 to 260 feet
16 below ground surface will result in new inelastic compaction and subsidence. This type of
17 information should formally be made available to the parties as soon as possible, presumably as soon
18 as a summary report on the MZ1 technical work is completed. The guidance criteria would be issued
19 by Watermaster in a timely fashion, to be followed by the long-term plan development which
20 necessarily will require a longer period to complete.

21 **C. Long-Term Plan and Schedule**

22 It is incumbent upon Watermaster now to request that the court extend the period for
23 completion of a long-term plan for MZ1. The overall testimony indicated that several more years
24 of technical and modeling work will be required, followed by approximately a year of negotiations
25 among the parties. The Watermaster should propose a schedule to the court which takes into account
26 the continuation of data collection and modeling work in the main MZ1 area as well as technical
27 work in the central MZ1 area. A date should be established for completion of a long-term plan.

28 Whether the long-term plan is ultimately characterized as a management plan is an issue for
the parties to address. Based on presentation and discussion at the workshop, it is clear that, at the

1 very least, an ongoing monitoring program by Watermaster will be required so that the parties have
2 full and sufficient information available to them to inform their decisions.

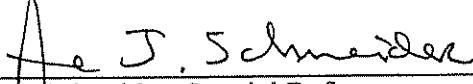
3 **D. Expanded Monitoring in MZ1**

4 The presentation at the workshop, while focused on monitoring and studies in the southern
5 MZ1 area, indicated that some monitoring work can and should be done in the central MZ1 area,
6 including installation of transducers in wells, and ground and InSar ground-level monitoring. More
7 costly and complex efforts involving piezometers and an extensometer would logically be held in
8 abeyance pending assessment of data collected. A phased long-term plan could include provision
9 for central MZ1 monitoring work and studies, with future efforts considered and scheduled on an
10 as-needed basis, while more definitive conclusions are drawn in the southern MZ1 area based on the
11 extensive work already focused in that area. As noted above, the central MZ1 area appears to
12 warrant additional investigation in light of detectable subsidence in spite of no significant pumping
13 stress in the immediate subsidence area. Such additional investigation would also appear important
14 in light of the overall concept of basin reoperation and hydraulic control, which could result in
15 locally lower groundwater levels in parts of the basin.

16 **VI. CONCLUSION**

17 The workshop was very productive. Mr. Malone's presentation was excellent. The
18 Watermaster does not require court approval to direct the preparation of a summary report on the
19 MZ1 technical work or to issue guidance criteria. The Watermaster, however, should file with the
20 court a motion for an order to set a schedule for the completion of a long-term plan.

21 Dated: June 16, 2005

22 
23 _____
Anne J. Schneider, Special Referee
24
25
26
27
28

CHINO BASIN WATERMASTER
Case No. RCV 51010
Chino Basin Municipal Water District v. The City of Chino

PROOF OF SERVICE

I declare that:

I am employed in the County of San Bernardino, California. I am over the age of 18 years and not a party to the within action. My business address is Chino Basin Watermaster, 9641 San Bernardino Road, Rancho Cucamonga, California 91730; telephone (909) 484-3888.

On June 21, 2005 I served the following:

Special Referee's Report on Progress Made on Implementation of the Watermaster Interim Plan for Management of Subsidence

BY MAIL: in said cause, by placing a true copy thereof enclosed with postage thereon fully prepaid, for delivery by United States Postal Service mail at Rancho Cucamonga, California, addresses as follows:

See attached service list:

Mailing List 1

BY PERSONAL SERVICE: I caused such envelope to be delivered by hand to the addressee.

BY FACSIMILE: I transmitted said document by fax transmission from (909) 484-3890 to the fax number(s) indicated. The transmission was reported as complete on the transmission report, which was properly issued by the transmitting fax machine.

BY ELECTRONIC MAIL: I transmitted notice of availability of electronic documents by electronic transmission to the email address indicated. The transmission was reported as complete on the transmission report, which was properly issued by the transmitting electronic mail device.

I declare under penalty of perjury under the laws of the State of California that the above is true and correct.

Executed on June 21, 2005 in Rancho Cucamonga, California.



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