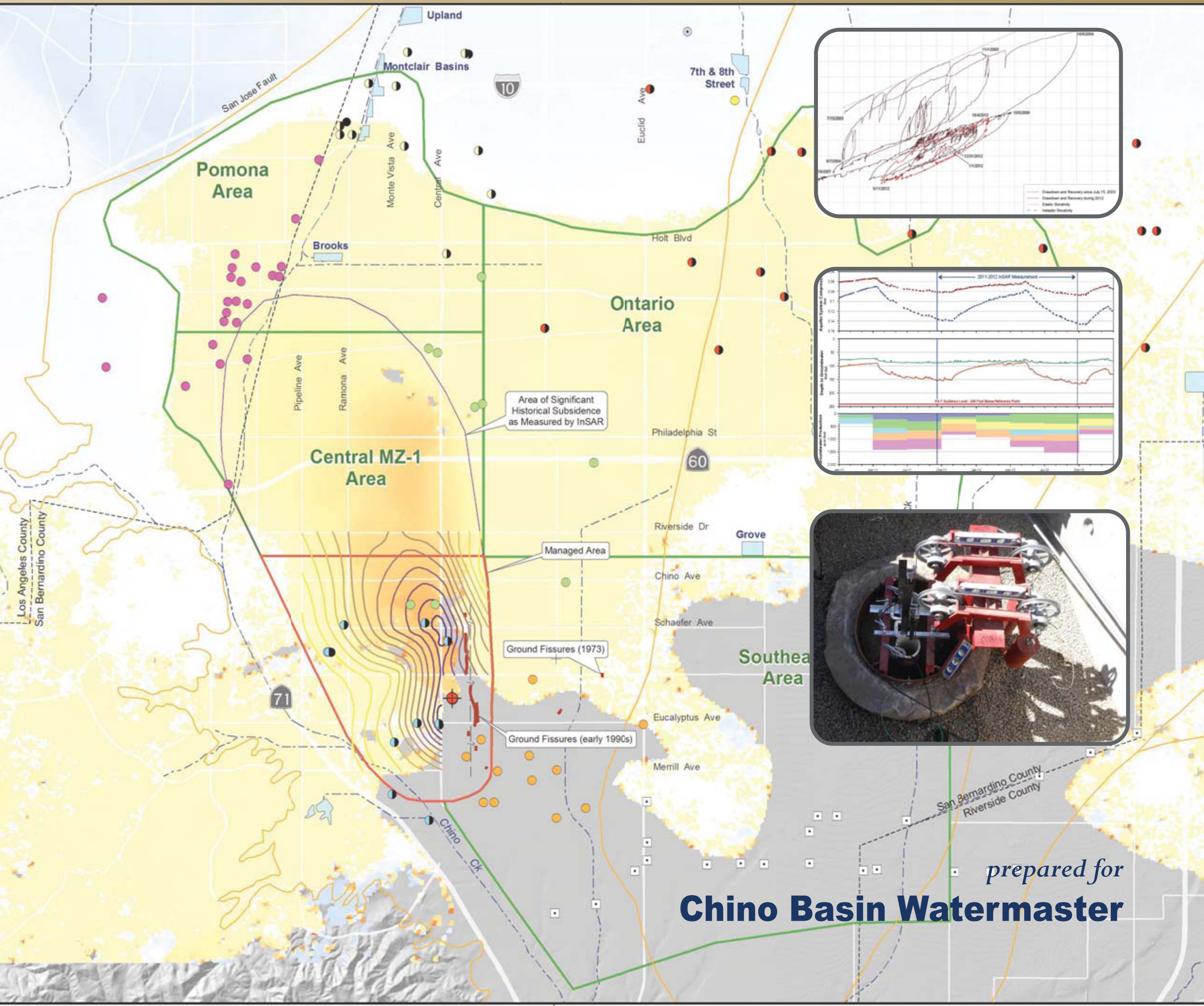
2012 Annual Report of the Land Subsidence Committee



prepared for

Chino Basin Watermaster

December 2013

WILDERMUTH™
ENVIRONMENTAL INC.

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Acronyms, Abbreviations, and Initialisms

acre-ft/yr	acre-feet per year
CCPA	Chino Creek Piezometer A
CCX	Chino Creek Extensometer Facility
CIM	California Institution for Men
DHX	Daniels Horizontal Extensometer
EDM	Electronic Distance Measurement
ft-bgs	feet below ground surface
ft-btoc	feet below top of casing
GSWC	Golden State Water Company
IEUA	Inland Empire Utilities Agency
IMP	Interim Monitoring Program
InSAR	Interferometric Synthetic Aperture Radar
MVWD	Monte Vista Water District
MZ-1	Management Zone 1
OBMP	Optimum Basin Management Plan
PE1	Program Element 1
SAWC	San Antonio Water Company
USGS	United States Geological Survey
WEI	Wildermuth Environmental Inc.

1.1 Background

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. 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).

1.1.1 Subsidence and Fissuring in Chino Basin

One of the earliest indications of land subsidence in Chino Basin was the appearance of ground fissures in the City of Chino. These fissures appeared as early as 1973, but an accelerated occurrence of ground fissuring ensued after 1991 and resulted in damage to existing infrastructure. Figure 1-1 shows the location of the fissures within Management Zone 1 (MZ-1) of the Chino Basin. The scientific studies that followed attributed the fissuring phenomenon to differential land subsidence that was caused by pumping of the underlying aquifer system and the consequent drainage and compaction of aquitard sediments (Fife et al., 1976; Kleinfelder, 1993, 1996; Geomatrix, 1994).

1.1.2 The Optimum Basin Management Program (OBMP)

In 1999, the OBMP Phase I Report (WEI, 1999) identified pumping-induced drawdown and subsequent aquifer-system compaction as the most likely cause of 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 the information necessary to understand the extent, rate, and mechanisms of subsidence and fissuring.
- formulate a management plan to abate future subsidence and fissuring or reduce it to tolerable levels.

In 2000, the Implementation Plan in the Peace Agreement called for an aquifer-system and land subsidence investigation in the southwestern region of MZ-1 to support the development of a management plan for MZ-1 (second and third bullets above). This investigation was titled the MZ-1 Interim Monitoring Program (IMP), which is described below.

The OBMP Phase I Report also noted that land subsidence was occurring in other parts of the Basin besides Chino. Program Element 1 (PE1) of the OBMP and the Implementation Plan, *Develop and Implement a Comprehensive Monitoring Program*, called for the basin-wide analysis of land subsidence via ground-level surveys and InSAR and ongoing monitoring based on the analysis of the subsidence data.

1.1.3 Interim Management Plan and the MZ-1 Summary Report

From 2001 to 2005, Watermaster developed, coordinated, and conducted the IMP under the guidance of the MZ-1 Technical Committee (now called the Land Subsidence Committee). The MZ-1 Technical Committee was composed of representatives from all major MZ-1 producers and their technical consultants, including the Agricultural Pool; the cities of Chino, Chino Hills, Ontario, Pomona, and Upland; Monte Vista Water District; Golden State Water Company; and the State of California, California Institution for Men (CIM).

The main conclusions derived from the IMP were:

1. Groundwater production from the deep, confined, aquifer system in the southwestern region of MZ-1 caused the greatest stress to the aquifer system. In other words, pumping of the deep aquifer system caused groundwater-level drawdown that is much greater in magnitude and lateral extent than drawdown caused by pumping of the shallow aquifer system.[1]
2. Groundwater-level drawdown 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 permanent compaction within the aquifer system was identified during the investigation when water levels fell below a depth of about 250 feet in the PA-7 piezometer at Ayala Park.
3. The then current state of aquifer-system deformation in southern MZ-1 (in the vicinity of Ayala Park) was essentially elastic. Very little permanent compaction was occurring in this area, which was in contrast to the recent past when about 2.2 feet of land subsidence occurred from about 1987 to 1995 and was accompanied by ground fissuring. Figure 1-2 shows the early land subsidence that was measured in the western Chino Basin during this period.
4. During this study, a previously undetected barrier to groundwater flow, called the Riley Barrier, was identified. This barrier is located within the deep aquifer system and is aligned with the historical zone of ground fissuring. Pumping from the deep aquifer system was limited to the area west of the barrier, and the resulting drawdown did not propagate eastward across the barrier. Thus, compaction occurred within the deep system on the west side of the barrier but not on the east side, which caused concentrated differential subsidence across the barrier and created the potential for ground fissuring.
5. InSAR and ground-level-survey data indicated that permanent subsidence in the central region of MZ-1 had occurred in the past and was continuing to occur. The InSAR data also suggested that the groundwater barrier extends northward into central MZ-1. These observations suggested 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.

[1] Production from the deep aquifer system within the Managed Area generally occurs from wells that are screened deeper than 400 feet below the ground surface (ft-bgs). (WEI, 2007)

The methods, results, and conclusions of the IMP are described in detail in the MZ-1 Summary Report (WEI, 2006). The IMP provided enough information for Watermaster to develop Guidance Criteria for the MZ-1 producers in the investigation area that, if followed, would minimize the potential for subsidence and fissuring during the completion of the MZ-1 Subsidence Management Plan (MZ-1 Plan; WEI 2007).

1.1.4 MZ-1 Subsidence Management Plan (MZ-1 Plan)

The Guidance Criteria formed the basis for the MZ-1 Plan, which was developed by the MZ-1 Technical Committee and approved by Watermaster in October 2007. In November 2007, the San Bernardino County Superior Court, which retains continuing jurisdiction over the Chino Basin Adjudication, approved the MZ-1 Plan and ordered its implementation.

The MZ-1 Plan includes a list of the Managed Wells that are subject to the plan. The Managed Wells are listed in Table 1-1. The MZ-1 Plan also includes a map of the so-called Managed Area in southern MZ-1 that is subject to the plan. The Managed Area is shown on Figure 1-1.

To minimize the potential for future subsidence and fissuring in the Managed Area, the MZ-1 Plan established a Guidance Level, which 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 permanent compaction of the aquifer system as recorded by the extensometer, minus five feet. The five foot reduction is meant to be a safety factor to ensure that permanent compaction does not occur in the future. The Guidance Level is subject to change based on the periodic review of monitoring data collected by Watermaster. The initial Guidance Level is 245 feet below the top of the well casing (ft-btoc) in PA-7. The Plan recommended that the Parties manage their groundwater production so that the water level in PA-7 remains above the Guidance Level.

The MZ-1 Plan calls for ongoing monitoring, data analysis, annual reporting, and adjustment to the MZ-1 Plan as warranted by the data. Implementation of the MZ-1 Plan began in 2008. The MZ-1 Plan calls for (1) the continued scope and frequency of monitoring implemented during the IMP within the Managed Area and (2) expanded monitoring of the aquifer system and land subsidence in other areas of the Chino Basin where the IMP indicated concern for future subsidence and ground fissuring. Figure 1-2 shows the location of these so-called Areas of Subsidence Concern: Central MZ-1, the Pomona Area, the Ontario Area, and the Southeast Area. The expanded monitoring efforts outside of the Managed Area are consistent with the requirements of PE1.

Potential future efforts listed in the MZ-1 Plan included: (1) more intensive monitoring of horizontal strain across the zone of historical ground fissuring to assist in developing management strategies related to fissuring, (2) injection feasibility studies within the Managed Area, (3) additional pumping tests to refine the Guidance Criteria, (4) computer-simulation modeling of groundwater flow and subsidence, and (5) development of alternative pumping plans for those Parties affected by the MZ-1 Plan. These potential future efforts are discussed by the Land Subsidence Committee, and if deemed prudent and necessary, are recommended to Watermaster for implementation in future fiscal years.

1.1.5 Annual Report of the Land Subsidence Committee

The MZ-1 Plan states that Watermaster will produce an annual report that includes the results of ongoing monitoring efforts, interpretations of the data, and recommended adjustment to the MZ-1 Plan, if any. This Annual Report of the Land Subsidence Committee includes results and interpretations for data that were collected during calendar year 2012, and includes recommendations for Watermaster's Land-Subsidence Monitoring Program for fiscal year 2013/14.

1.2 Report Organization

This report is organized into the following five sections:

Section 1 – Introduction. This section provides background information on the history of land subsidence and ground fissuring in Chino Basin, the formation of the Land Subsidence Committee and its responsibilities, and the MZ-1 Plan.

Section 2 – Land-Subsidence Monitoring Program (2012). This section describes the monitoring and testing activities that were performed by the Watermaster for its Land-Subsidence Monitoring Program during 2012.

Section 3 – Results and Interpretations. This section discusses and interprets the monitoring data collected during 2012, including the basin stresses of groundwater pumping and recharge and the basin responses including changes in groundwater levels, aquifer-system deformation, and ground motion.

Section 4 – Conclusions and Recommendations. This section summarizes the main conclusions derived from the monitoring program as of December 2012, and describes recommended activities for the program during fiscal year 2013/14 in the form of a proposed scope-of-work, schedule, and budget.

Section 5 – References. This section is a list of the publications cited in this report.

Table 1-1
Managed Wells

CBWM ID	Owner	Well Name	Status	Screened Interval *ft-bgs*
3600461	Chino	C-7	Not Equipped[2]	180-780
600670	Chino	C-15	Not Equipped	270-400, 626-820
600487	Chino Hills	CH-1B	Inactive[1]	440-470, 490-610, 720-900, 940-1180
600687	Chino Hills	CH-7C	Not Equipped	550-950
600498	Chino Hills	CH-7D	Inactive	320-400, 410-450, 490-810, 850-930
600488	Chino Hills	CH-15B	Active[3]	360-440, 480-900
600489	Chino Hills	CH-16	Inactive	430-940
600499	Chino Hills	CH-17	Active	300-460, 500-980
600500	Chino Hills	CH-19	Not Equipped	340-420, 460-760, 800-1000
3602461	CIM	CIM-11A	Active	135-148, 174-187, 240-283, 405-465, 484-512, 518-540

[1] Well can pump groundwater with little or no modifications, but no pumping is planned for the current year.
[2] Unable to pump the well without major modifications, and no pumping is planned for the current year.
[3] Well is currently being used for water supply.

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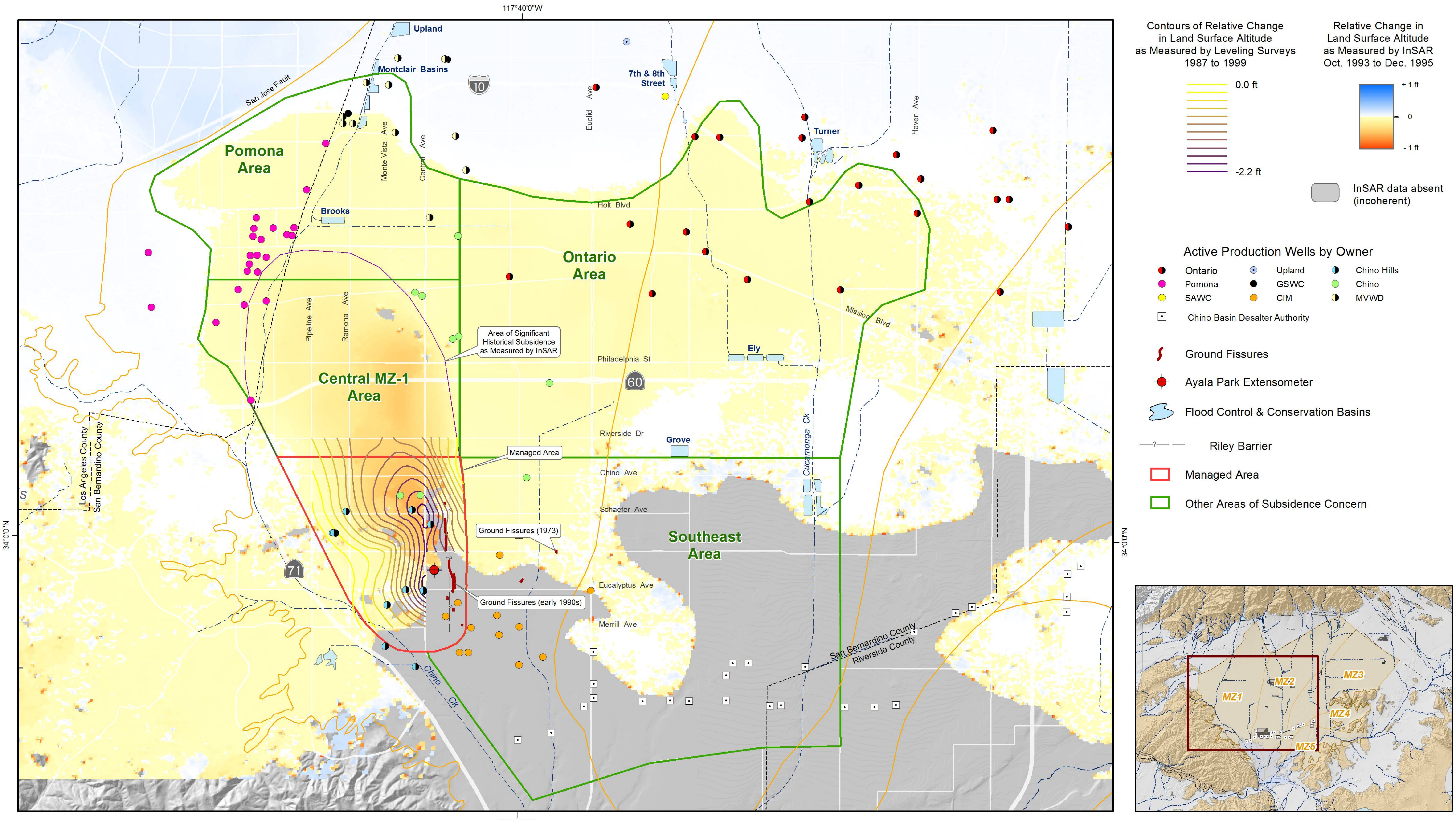
0 0.5 1 Miles

0 0.5 1 1.5 Kilometers

Land Subsidence Committee
2012 Annual Report

MZ-1 Managed Area and Managed Wells

Figure 1-1



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Land Subsidence Committee
2012 Annual Report

Historical Land Surface Deformation in Management Zone 1
Leveling Surveys (1987 to 1999) and InSAR (1993 to 1995)

Figure 1-2

Section 2 – Land-Subsidence Monitoring Program (2012)

This section describes the monitoring and testing activities that were performed by the Watermaster for its Land-Subsidence Monitoring Program during 2012.

2.1 Setup and Maintenance of the Monitoring Network

Watermaster's consulting engineer and/or sub-consultants perform the work to setup and maintain the land-subsidence monitoring network. The equipment and facilities that comprise the monitoring network are shown on Figure 2-1, and include pressure transducers and data loggers to measure and record water levels at wells, extensometers that measure aquifer-system deformation and ground motion, and benchmark monuments that are periodically surveyed to measure ground motion.

2.1.1 Setup of the Chino Creek Extensometer Facility

During 2012, Watermaster installed the Chino Creek Extensometer Facility (CCX) on Chino Airport property in the City of Chino. The CCX is located south of Kimball Avenue and the Chino Airport and east of Euclid Avenue as shown on Figure 2-1. The CCX was installed to measure and record background data and the response of the aquifer system to new groundwater production at the Chino Creek Well Field that is scheduled to commence in 2015. The CCX began recording groundwater levels and vertical aquifer-system deformation in July 2012.

The CCX was constructed within a new dual-nested piezometer—Chino Creek Piezometer-A (CCPA). Figure 2-2 illustrates the borehole lithology, borehole geophysics, and the general well construction information for the CCPA. The shallow piezometer, CCPA-1, was completed within the shallow aquifer system. The deep piezometer, CCPA-2, was completed within the deep aquifer system. The shallow and deep aquifer systems at the CCX are separated by a layer of predominantly fine-grained sediments between about 130 and 230 feet below ground surface. The shallow extensometer, CCX-1, is a cable extensometer that was completed within CCPA-1 to measure vertical aquifer-system deformation across the shallow aquifer system. The deep extensometer, CCX-2, is a cable extensometer that was completed within CCPA-2 to measure vertical aquifer-system deformation across the shallow and deep aquifer systems. Subtraction of the two extensometer records provides aquifer-system deformation data for the deep aquifer system only.

The monitoring equipment to measure and record piezometric levels and aquifer-system compaction were installed and calibrated at the facility during June and July 2012. A benchmark monument was installed at the surface completion of the CCX to facilitate repeated leveling surveys of elevation and to tie the CCX elevation to the Ayala Park elevation datum. Details of the construction and setup of the CCX are described within the CCX installation report which is included as Appendix A to this report.

2.1.2 Maintenance of Monitoring Equipment and Facilities

During 2012, Watermaster's consulting engineer replaced five pressure transducers that were malfunctioning or had failed, and performed maintenance at the extensometer facilities. Maintenance activities included: protection of the PA facility against surface-water intrusion during strong storms; refurbishment and calibration of the pressure transducers in PC-4 and PC-2; maintenance of Watermaster's Ayala Park website; and service of liquid-level equipment and installation of solar panels at the Daniels Horizontal Extensometer.

2.2 Monitoring and Testing during 2012

Watermaster's consulting engineer and/or sub-consultants perform the monitoring and testing programs under the direction of the Land Subsidence Committee. This section describes the monitoring and testing programs, and the implementation of these programs during 2012.

2.2.1 Long-Term Pumping Test in the Managed Area

The MZ-1 Plan states that Watermaster will assist the Parties with "additional testing and monitoring to refine the Guidance Criteria" and to "develop alternative pumping plans" to "produce a reasonable quantity of groundwater from MZ-1." Furthermore, the MZ-1 Plan states that Watermaster will assist the City of Chino Hills in an injection feasibility study to determine if injection is a viable tool for managing subsidence and maximizing the use of existing groundwater production infrastructure (see pages 2-5 and 2-6 of the MZ-1 Plan for reference).

The Land Subsidence Committee developed and is now implementing the Long-Term Pumping Test within the Managed Area in response to these directives in the MZ-1 Plan. The goal of the Long-Term Pumping Test is to develop a strategy for the prudent extraction of groundwater from the Managed Area. In this case, "prudent" is defined as extracting the maximum volume of groundwater without causing damage to the ground surface or the area's infrastructure. Specific questions that the program is designed to answer are:

1. Is the Guidance Level for the Managed Area, as currently defined, appropriate? If no, how should the Guidance Level be updated?

2. Does the Riley Barrier separate the Managed Area from the Southeast Area within the deep aquifer system? If not, should the eastern boundary of the Managed Area be revised?

3. How does subsidence (elastic and inelastic) and rebound that occurs in the Managed Area affect the horizontal strain across the historical zone of ground fissuring and its northward extension into the heavily-urbanized portions of the City of Chino?

4. Is aquifer injection a viable tool for mitigating drawdown and permanent compaction in the deep aquifer system?

5. Is there an "acceptable" rate of land subsidence in the Managed Area? If so, what is the "acceptable" rate?

The Land Subsidence Committee envisioned the following scope and sequence for the Long-Term Pumping Test:

1. Conduct a controlled pumping test of the deep aquifer system in the Managed Area at wells CH-17 and CH-15B (with arsenic treatment). This test should cause drawdown at PA-7 to fall below the Guidance Level. The test will be closely monitored at the

Ayala Park Extensometer and the horizontal monitoring facilities, and will be stopped at the first clear indication of permanent deformation.

2. Stop the pumping test and allow for partial recovery of groundwater levels.

3. Conduct two cycles of injection at CH-16 to see how injection may accelerate recovery of regional drawdown caused by pumping at CH-17 and CH-15B.

4. After injection tests, allow for full recovery of groundwater levels to pre-test conditions (PA-7 = 90 ft-btoc). Check stress-strain diagrams for permanent compaction of the aquifer system and/or horizontal deformation across the fissure zone.

The Long-Term Pumping Test began in spring of 2012 and is scheduled to continue until about July 2014. Ground-level surveys will be conducted when groundwater levels are at maximum drawdown and at maximum recovery. These benchmark elevation surveys will be compared to historical benchmark elevation surveys conducted at maximum recovery. Ground surface deformation will also be measured by InSAR throughout the duration of the test and at maximum drawdown and recovery of groundwater levels.

2.2.2 Monitoring of Piezometric Levels, Production, and Recharge

Changes in piezometric levels are the mechanism behind aquifer-system deformation and land subsidence. During 2012, water levels were measured and recorded once every 15 minutes using pressure transducers at 42 wells in the Managed Area, Central MZ-1, and the Southeast Area.

Production data were collected and compiled from the owners of the Managed Wells for calendar year 2012.

The volumes of recycled and imported water that were artificially recharged at basins in MZ-1 and MZ-2 and the direct use of recycled water within the Managed Area and the Southeast Area were collected from the Inland Empire Utilities Agency (IEUA) for fiscal year 2012.

2.2.3 Monitoring of Aquifer-System Deformation

Watermaster recorded aquifer-system deformation at the Ayala Park Extensometer and at the CCX where the vertical component of aquifer-system deformation is measured once every 15 minutes. Data collection at the CCX began in July 2012.

2.2.4 Monitoring of Vertical Ground-Surface Deformation

Watermaster monitors vertical ground motion via traditional leveling surveys and remote sensing (InSAR) techniques established during the IMP.

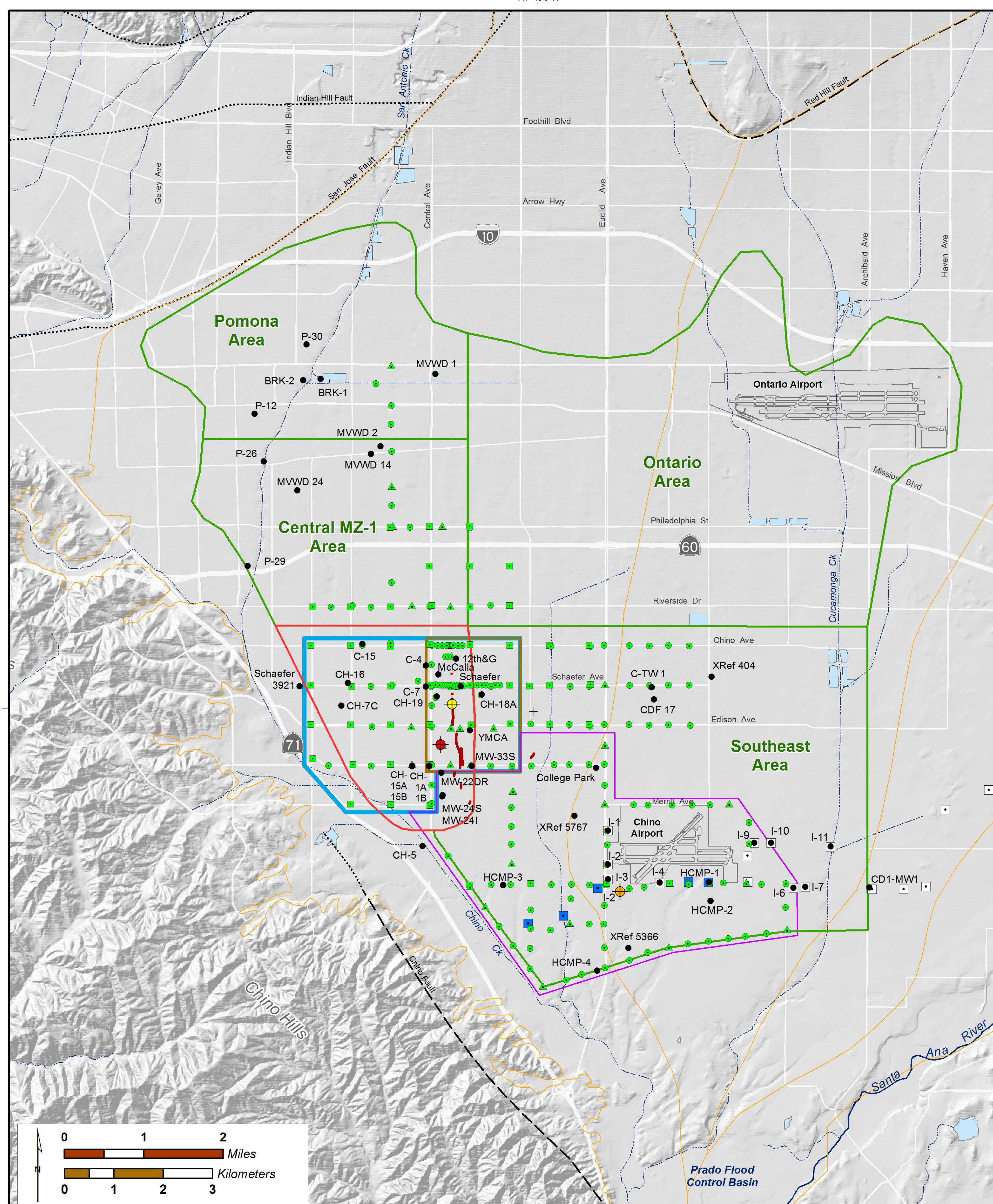
Watermaster retains Parsons Brinkerhoff (Parsons) to conduct the leveling surveys at selected benchmark monuments shown on Figure 2-1. The Land Subsidence Committee decides annually on the benchmarks to be surveyed. During fall 2012, Parsons conducted a leveling survey within the CCWF area. No leveling surveys were conducted in the Managed Area because drawdown did not yet exceed the Guidance Level as planned in the Long-Term Pumping Test.

Watermaster retains Neva Ridge Technologies to acquire InSAR data from the TerraSAR-X satellite operated by the European Space Agency. The width of the TerraSAR-X data frame covers the western half of the Chino Basin only. All historical InSAR data that was collected and analyzed by Watermaster since 1993 indicates that very little vertical ground motion occurs in the eastern half of the Chino Basin. Five InSAR data frames were collected in February 2012, April 2012, July 2012, September 2012, and January 2013, and were used to create seven interferograms to record short-term and long-term vertical ground motion over the following periods:

- November 2011 to February 2012
- November 2011 to April 2012
- November 2011 to July 2012
- November 2011 to September 2012
- November 2011 to January 2013
- September 2011 to September 2012
- February 2012 to January 2013.

2.2.5 Monitoring of Horizontal Ground-Surface Deformation

Watermaster measures horizontal ground motion across the historical zone of ground fissuring via electronic distance measurements between benchmark monuments and at horizontal extensometers that are installed across the fissure zone within the shallow soils. In 2012, data were collected from the Daniels Horizontal Extensometer (DHX) which records extension and compression across the historical fissure zone once every 15 minutes.



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Survey Benchmarks
- Class A Monuments
- Class B Monuments
- City Monuments

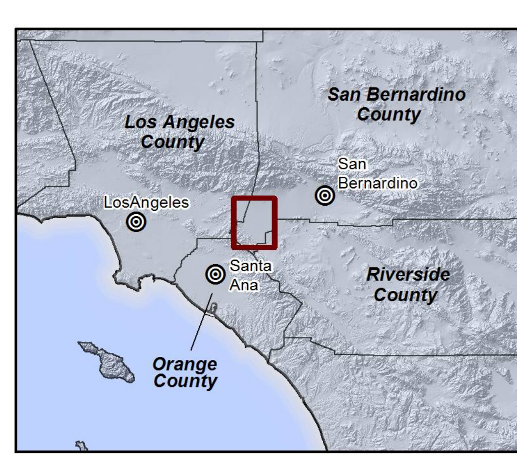
Survey Areas
- Southeast Area Surveys
- Fissure Zone Surveys
- Managed Area Surveys

Wells and Extensometers
- Well Monitored by Pressure Transducer during 2012
- Existing CDA Wells
- Chino Creek Well Field
- Ayala Park Extensometer
- Chino Creek Extensometer
- Daniels Horizontal Extensometer

- Managed Area
- Areas of Subsidence Concern
- Ground Fissures

Faults
- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain

- Chino Basin Management Zones



Land-Subsidence Monitoring Network

2012

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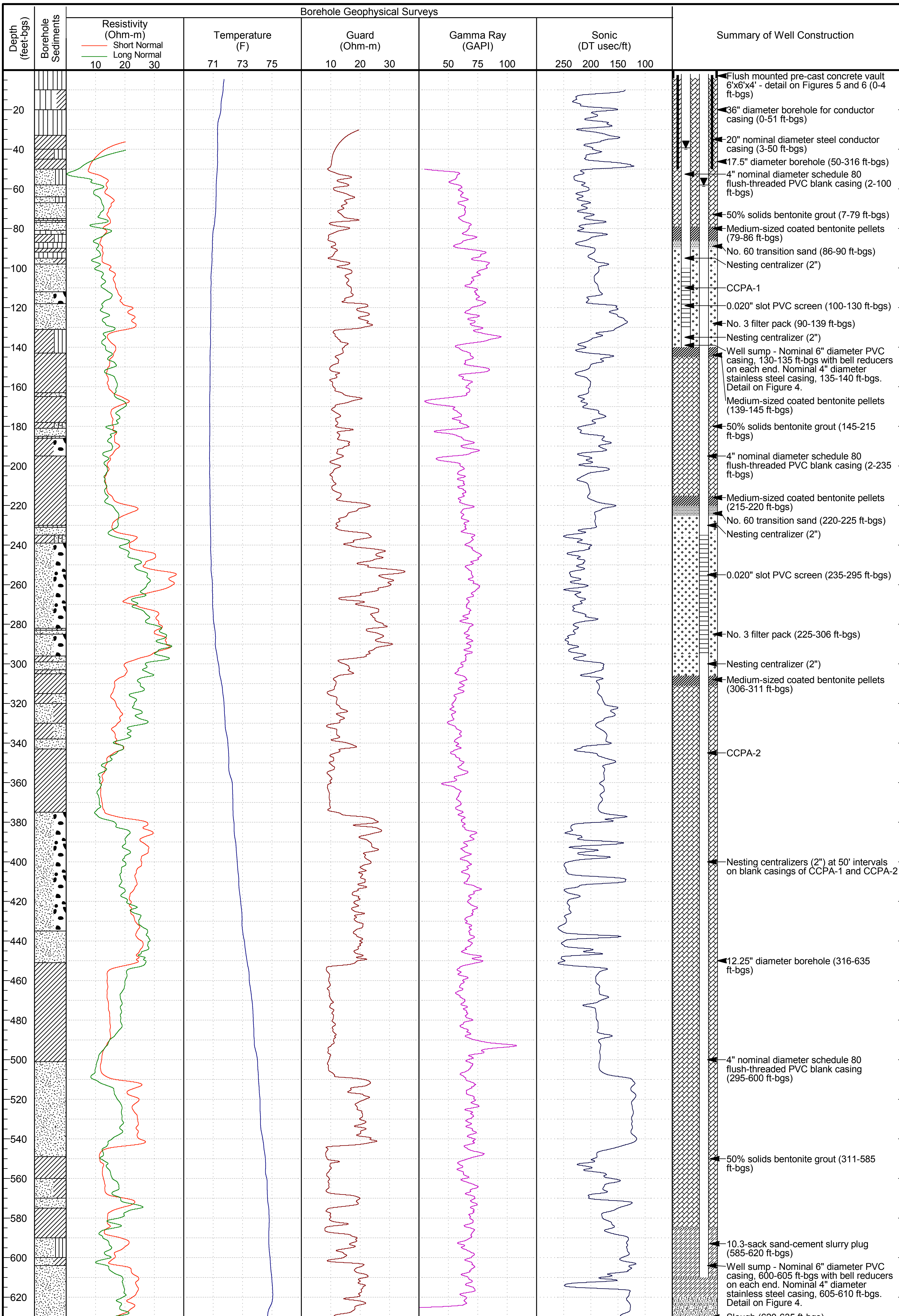
Land Subsidence Committee
2012 Annual Report

Figure 2-1



Facility Name Chino Creek Extensometer Facility (CCX)

Ground Surface Elevation (ft-msl) 588.5

Location Chino Airport, Chino, California

Date Started - Completed 4/24/2012 - 5/25/2012

Silt | Clay with Silt | Silt with Sand | Clay with Sand | Silt with Clay | Sand with Silt | Sand with Clay | Clay with Sand and Silt | Clay | Sand | Sand with Gravel | Clay with Gravel

Static Water Level - May 2012

Borehole and Well Construction Summary
CCPA

Figure 2-2

Report: BOREHOLE DATA SUMMARY-CCPA2; File: CHINO_CK_WELLSUMMARY.GPJ; 9/21/2012

This section describes the results and interpretations of Watermaster's subsidence monitoring efforts during 2012 in the Managed Area, Central MZ-1, the Pomona Area, the Ontario Area, and the Southeast Area.

3.1 Managed Area

The IMP demonstrated that in the Managed Area groundwater production from the deep aquifer is the primary influence on piezometric levels and the subsequent deformation of the aquifer system. The Managed Area is the primary focus of the MZ-1 Plan, so the discussion below describes the results of the monitoring program relative to the Guidance Criteria in the MZ-1 Plan.

3.1.1 Groundwater Production

Table 3-1 summarizes groundwater production by well within the Managed Area for 2012. Approximately 5,400 acre-feet of groundwater was pumped from the Managed Area in 2012—about 75 percent of the production was from wells screened in the shallow aquifer system (4,048 acre-feet) and 25 percent from wells screened in both the shallow and deep aquifer systems (1,328 acre-feet).

Figure 3-1 includes a bar chart of the production data shown in Table 3-1. It illustrates the seasonal pattern of production in the Managed Area. Production increases during the warmer spring/summer months, and decreases during the cooler fall/winter months. Production from the deep aquifer system ceased during the winter.

3.1.2 Groundwater Levels

Figure 3-1 includes a time-series chart of the piezometric levels at the Ayala Park Extensometer facility. These data corroborate the conclusions of the IMP and show that pumping from the deep, confined, aquifer system causes groundwater-level drawdown that is much greater in magnitude than drawdown caused by pumping of the shallow aquifer system, even though more pumping occurs from the shallow aquifer system.

Piezometric levels at the PA-7 piezometer declined by about 82 feet during the summer of 2012 while Chino Hills' Well 17 was pumping. Levels at PA-7 never declined below the Guidance Level of 245 ft-btoc.

3.1.3 Aquifer-System Deformation

Figure 3-1 includes a time-series chart of vertical deformation of the aquifer system as measured at the Ayala Park Extensometer facility. These data illustrate elastic deformation of the aquifer system during drawdown and recovery of piezometric levels during 2011 and 2012. The deep extensometer recorded about 0.06 feet of elastic deformation in 2012.

Figure 3-2 is a stress-strain diagram of piezometric levels measured at PA-7 (stress) versus vertical deformation of the aquifer system measured at the deep extensometer (strain). The overlapping hysteresis loops of this stress-strain diagram since 2009 indicates that little, if any, inelastic compaction of the aquifer system sediments is occurring at Ayala Park.

3.1.4 Vertical Ground Motion

Figure 3-3 is a map of vertical ground motion across the western portion of Chino Basin as measured by InSAR and leveling surveys from fall-2011 to fall-2012. Vertical motion of the ground surface was minimal (+/- 0.01 feet) in the Managed Area during this period, which is consistent with the data from the Ayala Park Extensometer shown on Figure 3-1.

3.1.5 Horizontal Ground Motion

Figure 3-4 is a map of the DHX which measures and records horizontal extension and compression within the shallow soils across the historical fissure zone where it passes north of 12th Street in Chino. The DHX is comprised of nine quartz-tube extensometers that were installed within a trench in an east/west series. The western extensometer is 10-feet long and the other eight extensometers are 20-feet long. The total length of the DHX is about 170 feet. The Q11 extensometer spans the surface rupture of the historical ground fissure.

Figure 3-5 is a time-series chart of horizontal deformation across the length of the DHX from west to east. The DHX began recording on October 5, 2011. The extension/compression data shown on Figure 3-5 were set to zero on May 17, 2012, prior to initiation of pumping at CH-17. Also shown on the chart is the vertical compression of the aquifer system as measured by the deep extensometer at the Ayala Park Extensometer facility, which is a measure of the compression and rebound that is occurring west of the fissure zone.

Figure 3-5 generally shows compression across the fissure zone during rebound of the land surface to the west, and extension during subsidence to the west. This pattern of horizontal strain is consistent with the conceptual model of drawdown and compression west of the fissure zone causing differential subsidence and extensional stresses across the fissure zone (and visa versa). The majority of horizontal extensometers show this same pattern, including Q11, but with differing response time and magnitude of deformation. The response of the DHX to changes at the deep extensometer was almost immediate (i.e. response times of less than an hour).

Figure 3-5 indicates a net horizontal compression of the shallow soils from October 2011 to October 2012, even though subsidence and rebound of the ground surface at Ayala Park was essentially elastic.

3.1.6 Summary

Figure 3-6 provides a comprehensive description and explanation of the history of subsidence in the Managed Area. The most recent data from InSAR, ground-level surveys, and extensometers indicates that minimal vertical ground motion occurred in this area during 2011-2012. The lack of recent subsidence in this area is consistent with the observation that piezometric levels at PA-7 have not declined below the Guidance Level of 245 ft-btoc since about 2005.

3.2 Central MZ-1 Area

Figure 3-7 provides a comprehensive description and explanation of the history of subsidence in the Central MZ-1. The InSAR data on Figure 3-3 indicates that minimal vertical ground motion occurred in this area during the period of fall-2011 to fall-2012. The lack of recent subsidence is consistent with the recent time-series of production, groundwater levels, and subsidence shown on Figure 3-7.

3.3 Pomona Area

Figure 3-8 provides a comprehensive description and explanation of the history of subsidence in the Pomona Area. The InSAR data on Figure 3-3 indicate that a maximum of about 0.04 feet of land subsidence occurred in this area during the period of fall-2011 to fall-2012. This pattern of subsidence is consistent with the historical time-series of subsidence in this area shown on Figure 3-8, but suggests a decrease in the rate of subsidence. Currently, there are not enough aquifer-system data available to definitively explain the causes of the subsidence in this area or the changes in rate of subsidence.

Of particular concern in the Pomona Area is that the historical and ongoing subsidence has been differential across the San Jose Fault. This is the same spatial pattern of subsidence that lead to the episode of ground fissuring in the Managed Area during the 1990s.

3.4 Ontario Area

Figure 3-9 provides a comprehensive description and explanation of the history of subsidence in the Ontario Area. The InSAR data on Figure 3-3 indicate that minimal vertical ground motion occurred in this area during the period of fall-2011 to fall-2012. This indicates a decrease in the recent rate of subsidence. Currently, there are not enough aquifer-system data available to definitively explain the causes of the subsidence in this area or the changes in rate of subsidence.

3.5 Southeast Area

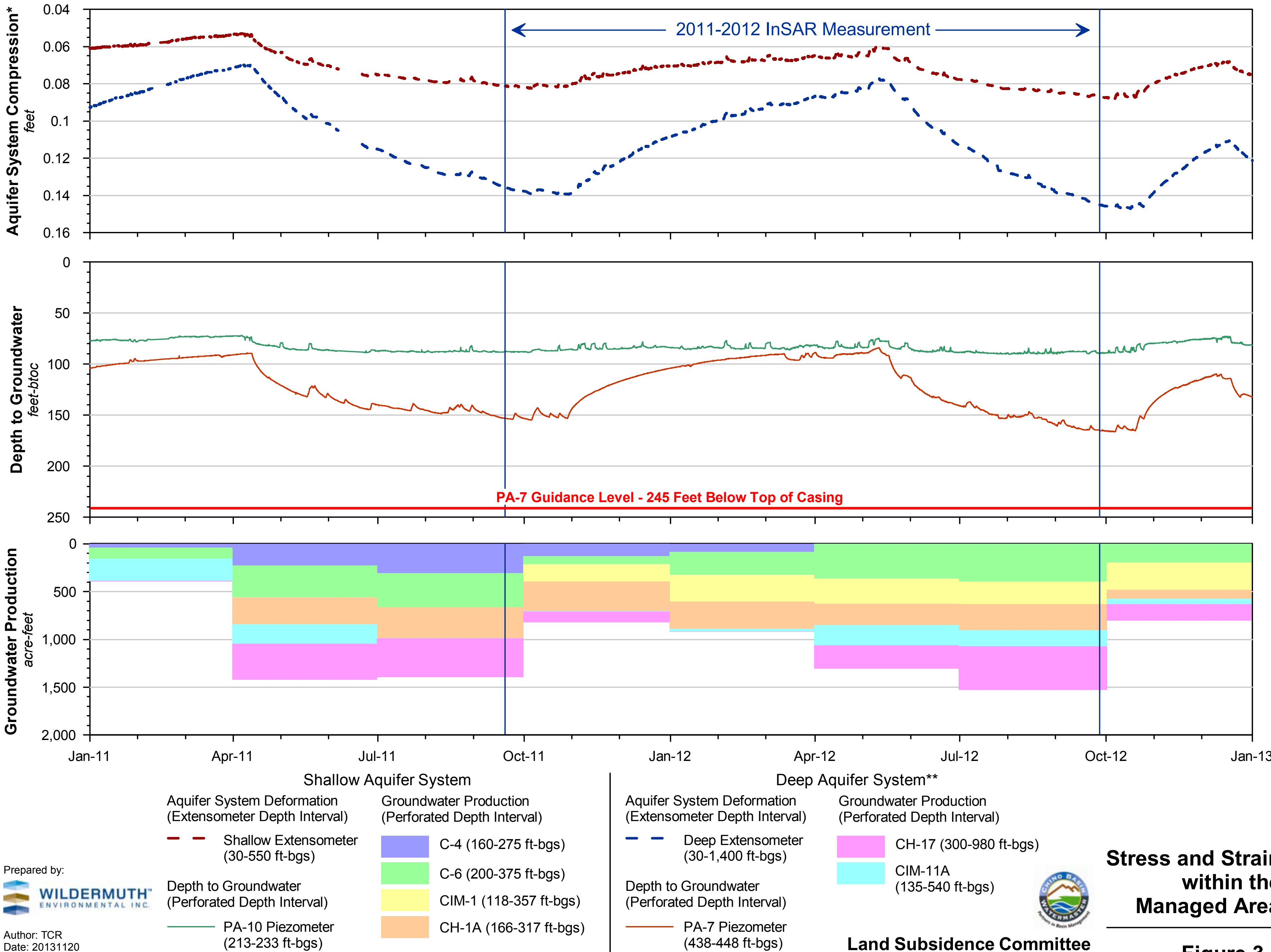
Figure 3-10 provides a comprehensive description and explanation of the history of subsidence in the Southeast Area. The InSAR on Figure 3-3 indicate that minimal vertical ground motion occurred across this area during the period of fall-2011 to fall-2012. The ground-level survey data in the vicinity of the Chino Desalter well field indicates a rebound of the land surface of about 0.05 feet over this same period. Both data sets suggest a decrease in the recent rate of subsidence or cessation of subsidence altogether.

The CCX has been measuring and recording piezometric and aquifer-system deformation data in the vicinity of the Chino Desalter well field since July 2012. Figure 3-11 is a time series chart of these data. In this area, pumping from the Desalter well field has been primarily from the deep aquifer system. In the shallow aquifer system, the data show virtually no change in piezometric levels or aquifer-system deformation. In the deep aquifer system, piezometric levels recovered by about 10 feet from September to December 2012, and the deep CCX-2 extensometer recorded a small, corresponding expansion of the aquifer system.

Table 3-1
Groundwater Production in the Managed Area for 2012
acre-feet

Well Name	Aquifer Layer	2012 Calendar Year					
		Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual Total	Annual Total by Aquifer Layer
C-4	Shallow	85	0	0	0	**85**	**4,048**
C-6		242	367	396	195	**1,201**	
CH-1A		284	222	269	95	**871**	
CH-7A		133	122	112	22	**389**	
CH-7B		180	167	63	28	**438**	
CIM-1		278	261	238	287	**1,064**	
CH-17	Deep[1]	0	241	453	169	**864**	**1,328**
CIM-11A		26	215	169	54	**465**	
Totals		**1,202**	**1,381**	**1,532**	**797**	**4,912**	**5,377**

[1] These deep aquifer wells have perforated inervals that extend into the shallow aquifer system, so a portion of this production comes from the shallow aquifer system.



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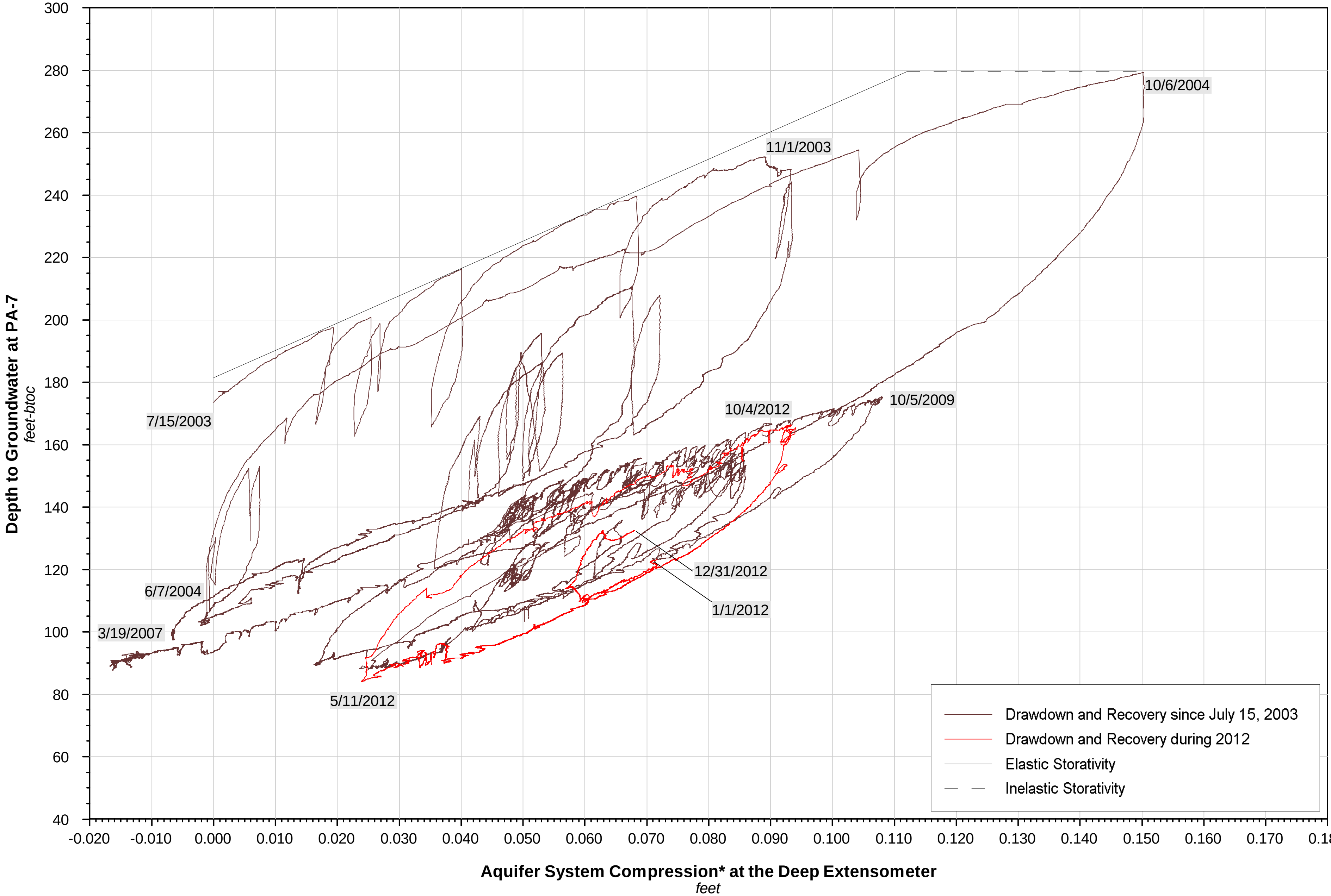
Stress and Strain within the Managed Area

Figure 3-1

*Positive compression values represent compression of soils, negative compression values represent expansion of soils
**These deep aquifer wells have perforated intervals that extend into the shallow aquifer system, so a portion of this production comes from the shallow aquifer system.



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Depth Interval of PA-7 Perforations
= 438-448 ft-bgs

Depth Interval of the Deep Extensometer
= 30-1,400 feet-bgs

*Positive compression values represent compression of soils, negative compression values represent expansion of soils

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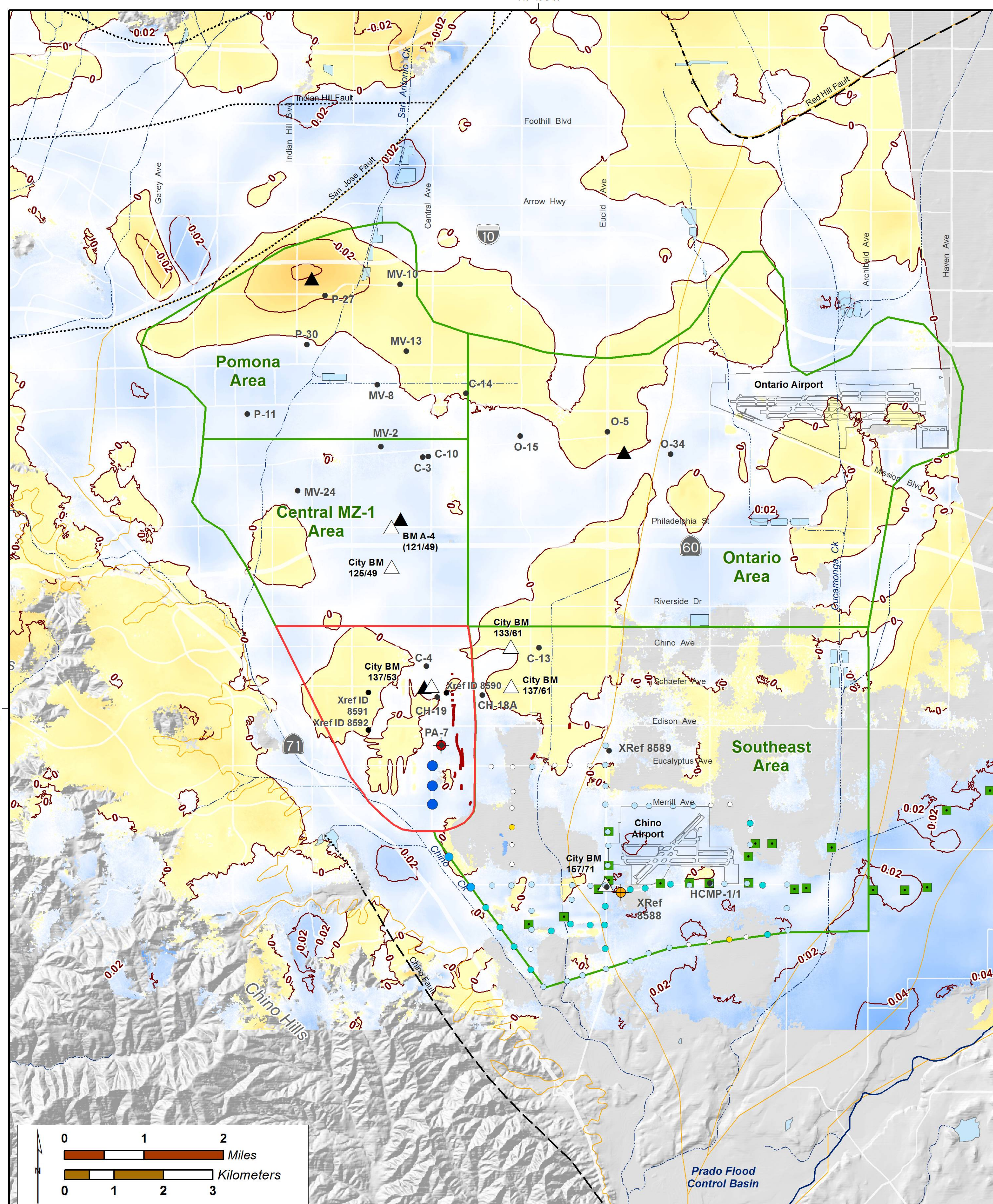
Stress-Strain Diagram
PA-7 Piezometer vs. Deep Extensometer

Figure 3-2



Relative Change in Land Surface Altitudes Measured by Leveling Surveys November 2011 to November 2012 (feet)

- +0.10 - +0.12
- +0.08 - +0.10
- +0.06 - +0.08
- +0.04 - +0.06
- +0.02 - +0.04
- 0.00 - +0.02
- -0.00 - -0.02
- -0.02 - -0.04

+ 0.1 / 0 / - 0.1 / -0.05 Relative Change in Land Surface Altitude as Measured by InSAR September 2011 to September 2012 (feet)

InSAR data absent (incoherent)

Survey Measurement Stations (see Figures 3-6 to 3-10)

InSAR Measurement Point (see Figures 3-6 to 3-10)

Wells and Extensometers

- Wells with Water Level Data (see Figures 3-6 to 3-10)
- Desalter Well
- Ayala Park Extensometer
- Chino Creek Extensometer

Managed Area

Areas of Subsidence Concern

Ground Fissures

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain

1 2 3 4 5 Chino Basin Management Zones

Vertical Ground Motion across Western Chino Basin

2012

Figure 3-3

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Chino Basin Watermaster

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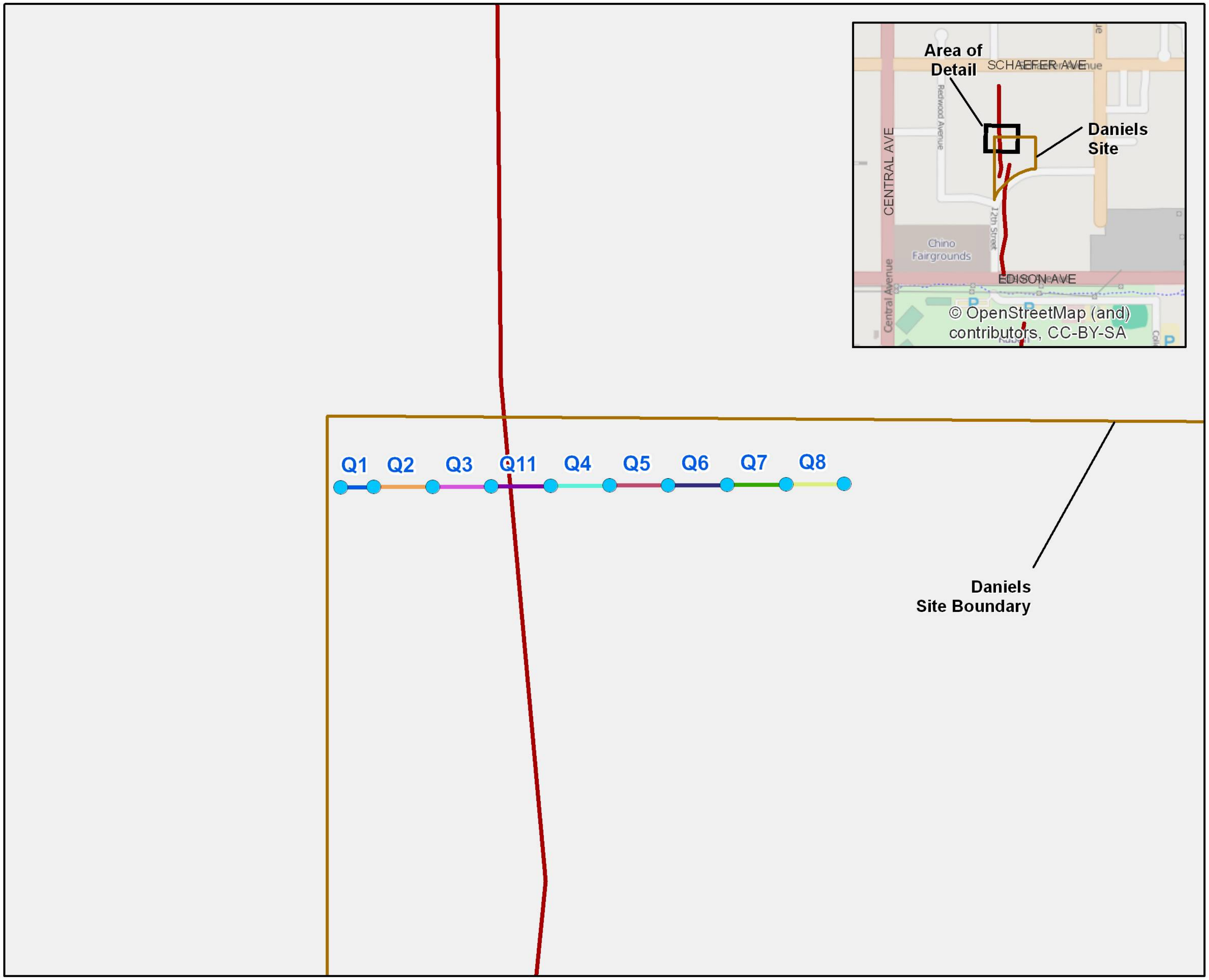
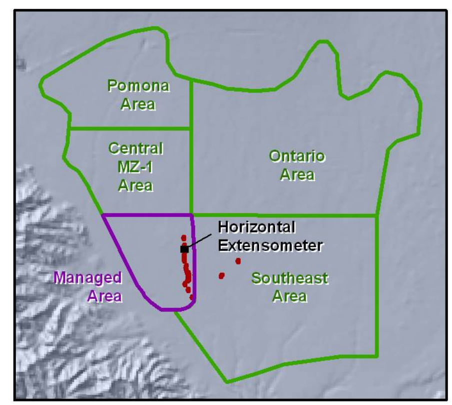


Horizontal Extensometer Benchmark

Quartz Tube Extensometer
color corresponds to recorded deforamtion shown on Figure 3-5

Historical Ground Fissures (1990s)



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0 20 40 60 80 100 Feet
0 10 20 30 Meters

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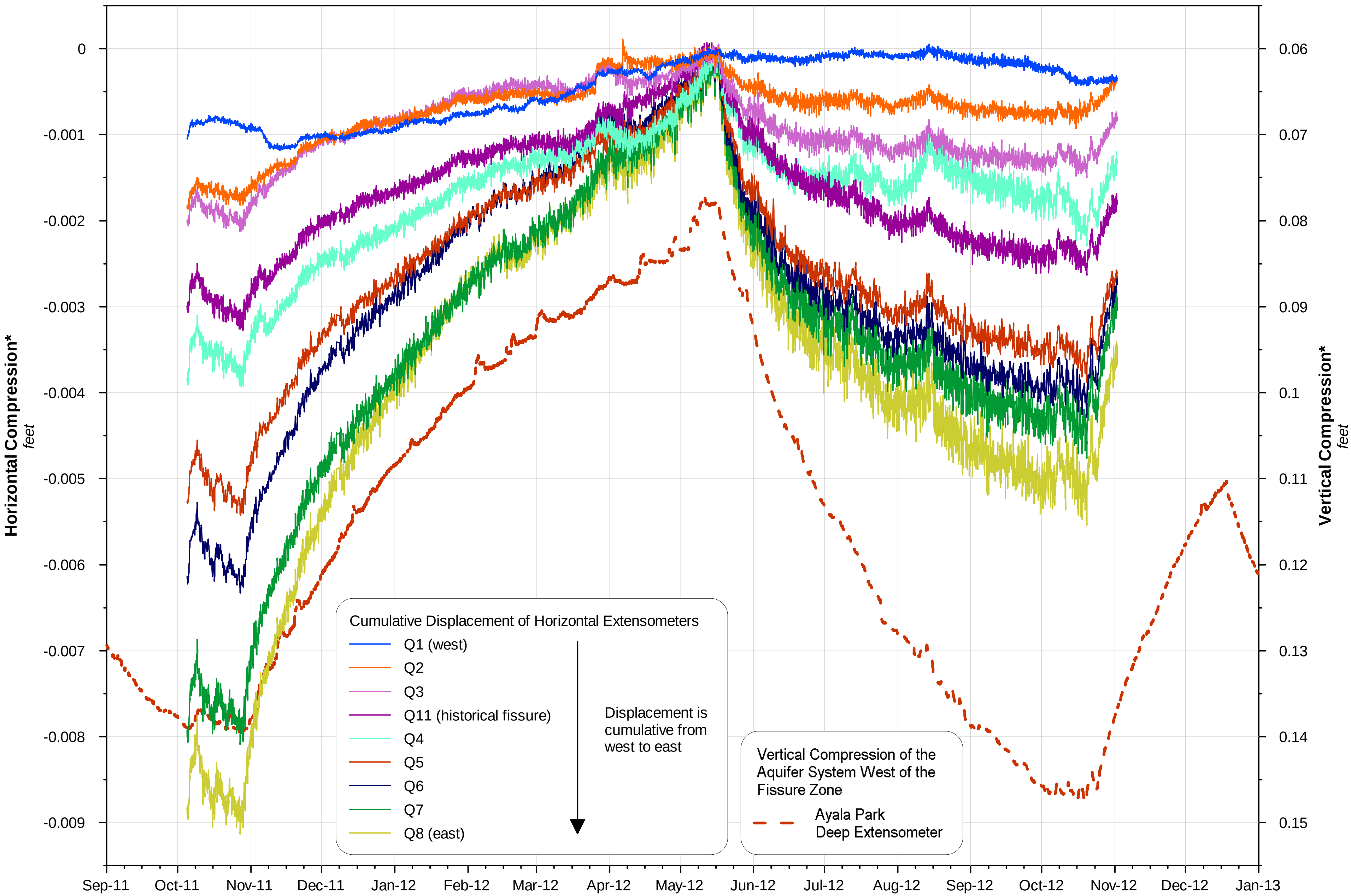
Location of the Daniels Horizontal Extensometer

Figure 3-4



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*Positive compression values represent compression of soils, negative compression values represent expansion of soils.

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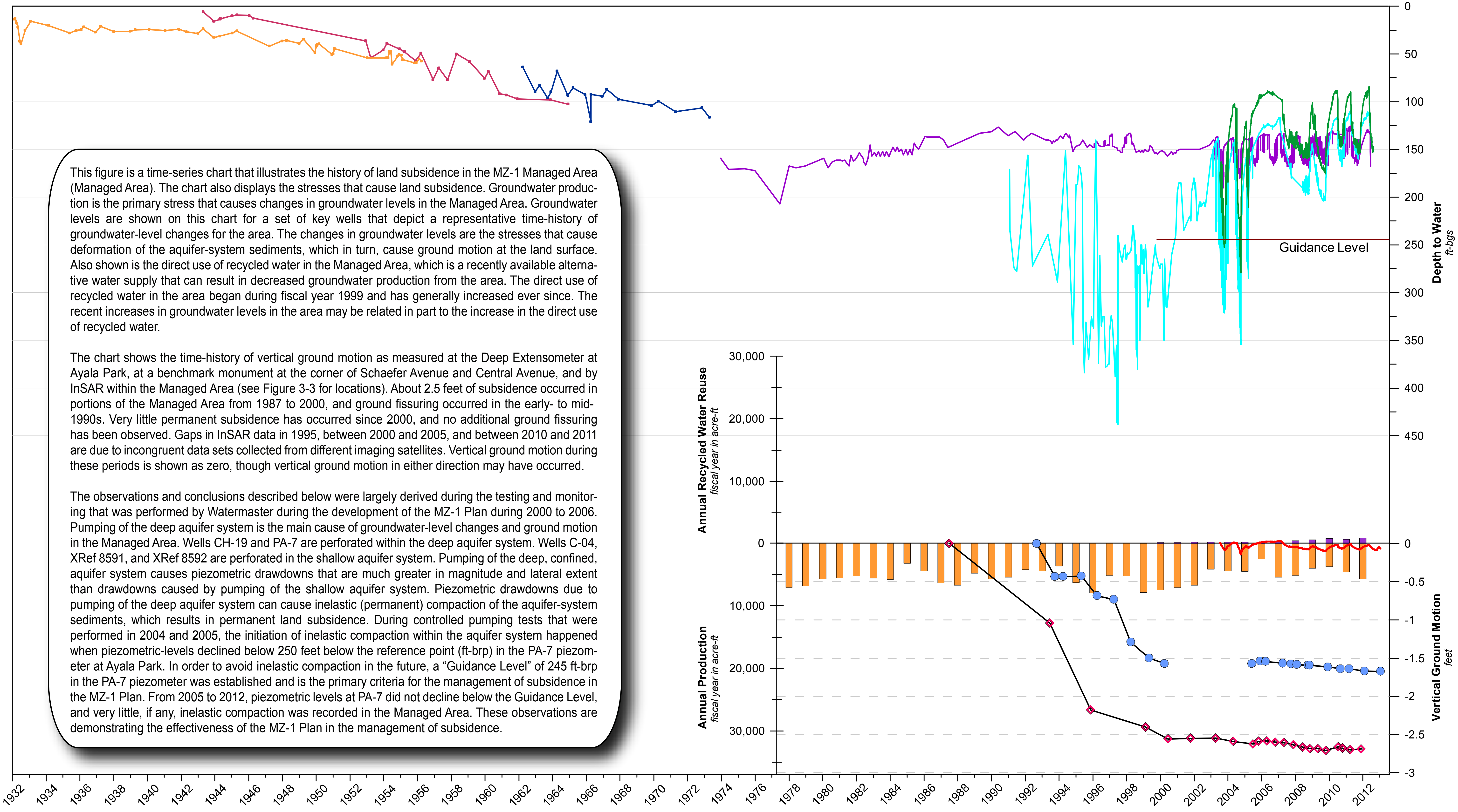
Horizontal Deformation at the Daniels Horizontal Extensometer

Figure 3-5



This figure is a time-series chart that illustrates the history of land subsidence in the MZ-1 Managed Area (Managed Area). The chart also displays the stresses that cause land subsidence. Groundwater production is the primary stress that causes changes in groundwater levels in the Managed Area. Groundwater levels are shown on this chart for a set of key wells that depict a representative time-history of groundwater-level changes for the area. The changes in groundwater levels are the stresses that cause deformation of the aquifer-system sediments, which in turn, cause ground motion at the land surface. Also shown is the direct use of recycled water in the Managed Area, which is a recently available alternative water supply that can result in decreased groundwater production from the area. The direct use of recycled water in the area began during fiscal year 1999 and has generally increased ever since. The recent increases in groundwater levels in the area may be related in part to the increase in the direct use of recycled water.

The chart shows the time-history of vertical ground motion as measured at the Deep Extensometer at Ayala Park, at a benchmark monument at the corner of Schaefer Avenue and Central Avenue, and by InSAR within the Managed Area (see Figure 3-3 for locations). About 2.5 feet of subsidence occurred in portions of the Managed Area from 1987 to 2000, and ground fissuring occurred in the early- to mid-1990s. Very little permanent subsidence has occurred since 2000, and no additional ground fissuring has been observed. Gaps in InSAR data in 1995, between 2000 and 2005, and between 2010 and 2011 are due to incongruent data sets collected from different imaging satellites. Vertical ground motion during these periods is shown as zero, though vertical ground motion in either direction may have occurred.

The observations and conclusions described below were largely derived during the testing and monitoring that was performed by Watermaster during the development of the MZ-1 Plan during 2000 to 2006. Pumping of the deep aquifer system is the main cause of groundwater-level changes and ground motion in the Managed Area. Wells CH-19 and PA-7 are perforated within the deep aquifer system. Wells C-04, XRef 8591, and XRef 8592 are perforated in the shallow aquifer system. Pumping of the deep, confined, aquifer system causes piezometric drawdowns that are much greater in magnitude and lateral extent than drawdowns caused by pumping of the shallow aquifer system. Piezometric 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. During controlled pumping tests that were performed in 2004 and 2005, the initiation of inelastic compaction within the aquifer system happened when piezometric-levels declined below 250 feet below the reference point (ft-brp) in the PA-7 piezometer at Ayala Park. In order to avoid inelastic compaction in the future, a "Guidance Level" of 245 ft-brp in the PA-7 piezometer was established and is the primary criteria for the management of subsidence in the MZ-1 Plan. From 2005 to 2012, piezometric levels at PA-7 did not decline below the Guidance Level, and very little, if any, inelastic compaction was recorded in the Managed Area. These observations are demonstrating the effectiveness of the MZ-1 Plan in the management of subsidence.

Groundwater Levels at Wells (Perforated Interval Depth)		Vertical Ground Motion	Recharge and Production
C-04 (160-275 ft-bgs)	XRef 8591 (no perf data)	BM 137/53 Cumulative Displacement	Recycled Water Reuse Applied in MZ1 Managed Area
CH-19 (340-1000 ft-bgs)	XRef 8592 (90-230 ft-bgs)	Managed Area InSAR	Groundwater Production from Wells in MZ1 Managed Area
PA-7 (438-448 ft-bgs)		Ayala Park Deep Extensometer Measurements Between 30 to 1,400 ft-bgs	
XRef 8590 (80-225 ft-bgs)			

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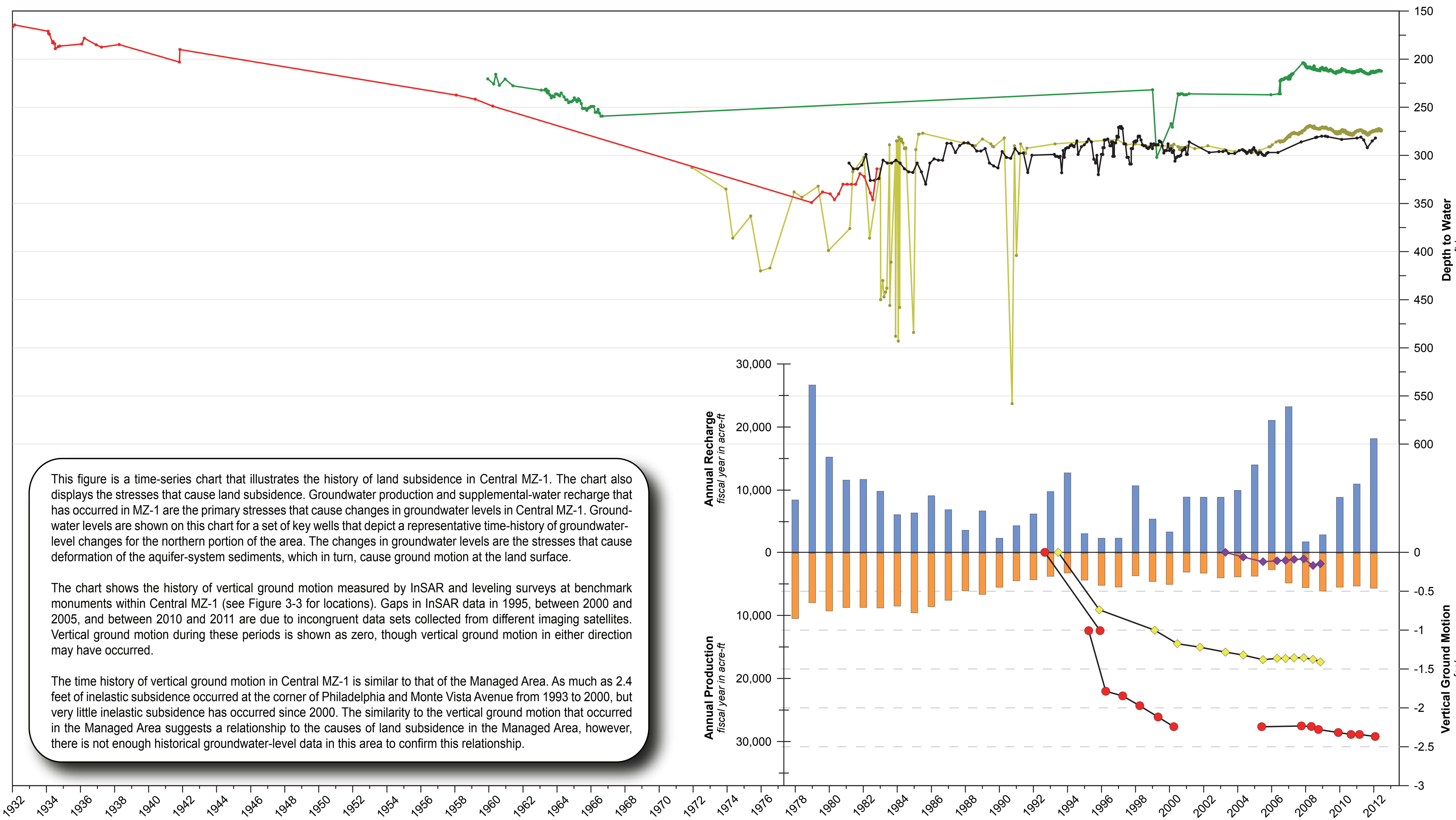
The History of Land Subsidence in the MZ1 Managed Area

Figure 3-6



This figure is a time-series chart that illustrates the history of land subsidence in Central MZ-1. The chart also displays the stresses that cause land subsidence. Groundwater production and supplemental-water recharge that has occurred in MZ-1 are the primary stresses that cause changes in groundwater levels in Central MZ-1. Groundwater levels are shown on this chart for a set of key wells that depict a representative time-history of groundwater-level changes for the northern portion of the area. The changes in groundwater levels are the stresses that cause deformation of the aquifer-system sediments, which in turn, cause ground motion at the land surface.

The chart shows the history of vertical ground motion measured by InSAR and leveling surveys at benchmark monuments within Central MZ-1 (see Figure 3-3 for locations). Gaps in InSAR data in 1995, between 2000 and 2005, and between 2010 and 2011 are due to incongruent data sets collected from different imaging satellites. Vertical ground motion during these periods is shown as zero, though vertical ground motion in either direction may have occurred.

The time history of vertical ground motion in Central MZ-1 is similar to that of the Managed Area. As much as 2.4 feet of inelastic subsidence occurred at the corner of Philadelphia and Monte Vista Avenue from 1993 to 2000, but very little inelastic subsidence has occurred since 2000. The similarity to the vertical ground motion that occurred in the Managed Area suggests a relationship to the causes of land subsidence in the Managed Area, however, there is not enough historical groundwater-level data in this area to confirm this relationship.

Groundwater Levels at Wells
(Perforated Depth Interval)

- C-03 (230-450 ft-bgs)
- MV-24 (244-420 ft-bgs)
- MV-02 (397-962 ft-bgs)
- C-10 (355-1090 ft-bgs)

Vertical Ground Motion

- Central MZ-1 InSAR
- BM A-4
- BM 125/49

Recharge and Production

- Recharge of Recycled Water, Storm Water*, and Imported Water at the College Heights, Upland, Montclair, and Brooks Basins; and at MVWD ASR Wells
*Storm Water is an estimated amount prior to Fiscal Year 04/05
- Groundwater Production from Wells in Central MZ-1 Area

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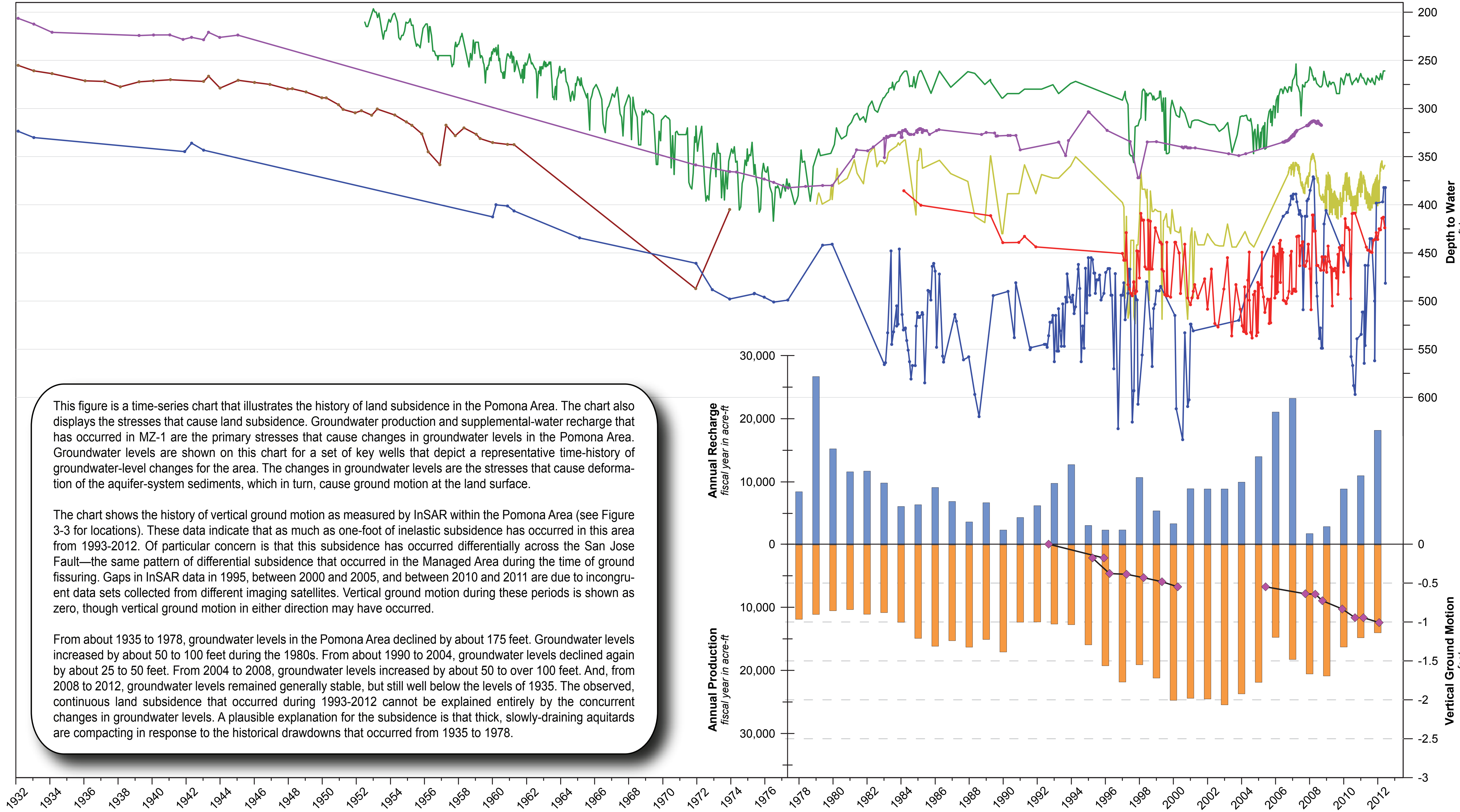
The History of Land Subsidence in Central MZ-1

Figure 3-7



This figure is a time-series chart that illustrates the history of land subsidence in the Pomona Area. The chart also displays the stresses that cause land subsidence. Groundwater production and supplemental-water recharge that has occurred in MZ-1 are the primary stresses that cause changes in groundwater levels in the Pomona Area. Groundwater levels are shown on this chart for a set of key wells that depict a representative time-history of groundwater-level changes for the area. The changes in groundwater levels are the stresses that cause deformation of the aquifer-system sediments, which in turn, cause ground motion at the land surface.

The chart shows the history of vertical ground motion as measured by InSAR within the Pomona Area (see Figure 3-3 for locations). These data indicate that as much as one-foot of inelastic subsidence has occurred in this area from 1993-2012. Of particular concern is that this subsidence has occurred differentially across the San Jose Fault—the same pattern of differential subsidence that occurred in the Managed Area during the time of ground fissuring. Gaps in InSAR data in 1995, between 2000 and 2005, and between 2010 and 2011 are due to incongruent data sets collected from different imaging satellites. Vertical ground motion during these periods is shown as zero, though vertical ground motion in either direction may have occurred.

From about 1935 to 1978, groundwater levels in the Pomona Area declined by about 175 feet. Groundwater levels increased by about 50 to 100 feet during the 1980s. From about 1990 to 2004, groundwater levels declined again by about 25 to 50 feet. From 2004 to 2008, groundwater levels increased by about 50 to over 100 feet. And, from 2008 to 2012, groundwater levels remained generally stable, but still well below the levels of 1935. The observed, continuous land subsidence that occurred during 1993-2012 cannot be explained entirely by the concurrent changes in groundwater levels. A plausible explanation for the subsidence is that thick, slowly-draining aquitards are compacting in response to the historical drawdowns that occurred from 1935 to 1978.

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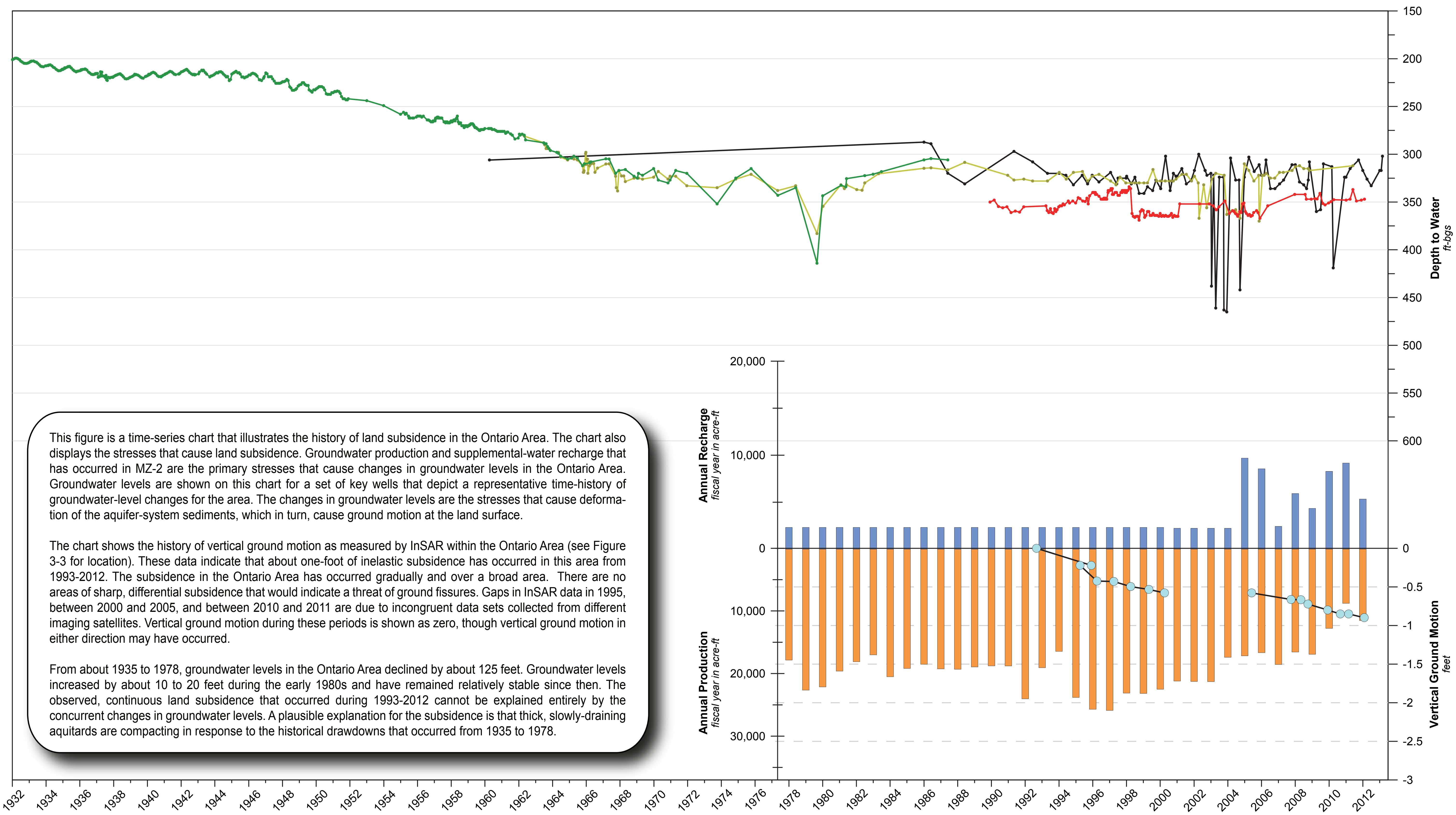
The History of Land Subsidence in the Pomona Area

Figure 3-8



This figure is a time-series chart that illustrates the history of land subsidence in the Ontario Area. The chart also displays the stresses that cause land subsidence. Groundwater production and supplemental-water recharge that has occurred in MZ-2 are the primary stresses that cause changes in groundwater levels in the Ontario Area. Groundwater levels are shown on this chart for a set of key wells that depict a representative time-history of groundwater-level changes for the area. The changes in groundwater levels are the stresses that cause deformation of the aquifer-system sediments, which in turn, cause ground motion at the land surface.

The chart shows the history of vertical ground motion as measured by InSAR within the Ontario Area (see Figure 3-3 for location). These data indicate that about one-foot of inelastic subsidence has occurred in this area from 1993-2012. The subsidence in the Ontario Area has occurred gradually and over a broad area. There are no areas of sharp, differential subsidence that would indicate a threat of ground fissures. Gaps in InSAR data in 1995, between 2000 and 2005, and between 2010 and 2011 are due to incongruent data sets collected from different imaging satellites. Vertical ground motion during these periods is shown as zero, though vertical ground motion in either direction may have occurred.

From about 1935 to 1978, groundwater levels in the Ontario Area declined by about 125 feet. Groundwater levels increased by about 10 to 20 feet during the early 1980s and have remained relatively stable since then. The observed, continuous land subsidence that occurred during 1993-2012 cannot be explained entirely by the concurrent changes in groundwater levels. A plausible explanation for the subsidence is that thick, slowly-draining aquitards are compacting in response to the historical drawdowns that occurred from 1935 to 1978.

Groundwater Levels at Wells
(Perforated Depth Interval)

- C-14 (480-1200 ft-bgs)
- O-05 (360-470 ft-bgs)
- O-15 (474-966 ft-bgs)
- O-34 (522-1092 ft-bgs)

Vertical Ground Motion

- Ontario Area InSAR

Recharge and Production

- Recharge of Recycled, Storm Water*, and Imported Water at Basins in MZ-2 and the 7th and 8th Street Basins
*Storm Water is an estimated amount prior to Fiscal Year 04/05
- Groundwater Production from Wells in the Ontario Area

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The History of Land Subsidence in the Ontario Area

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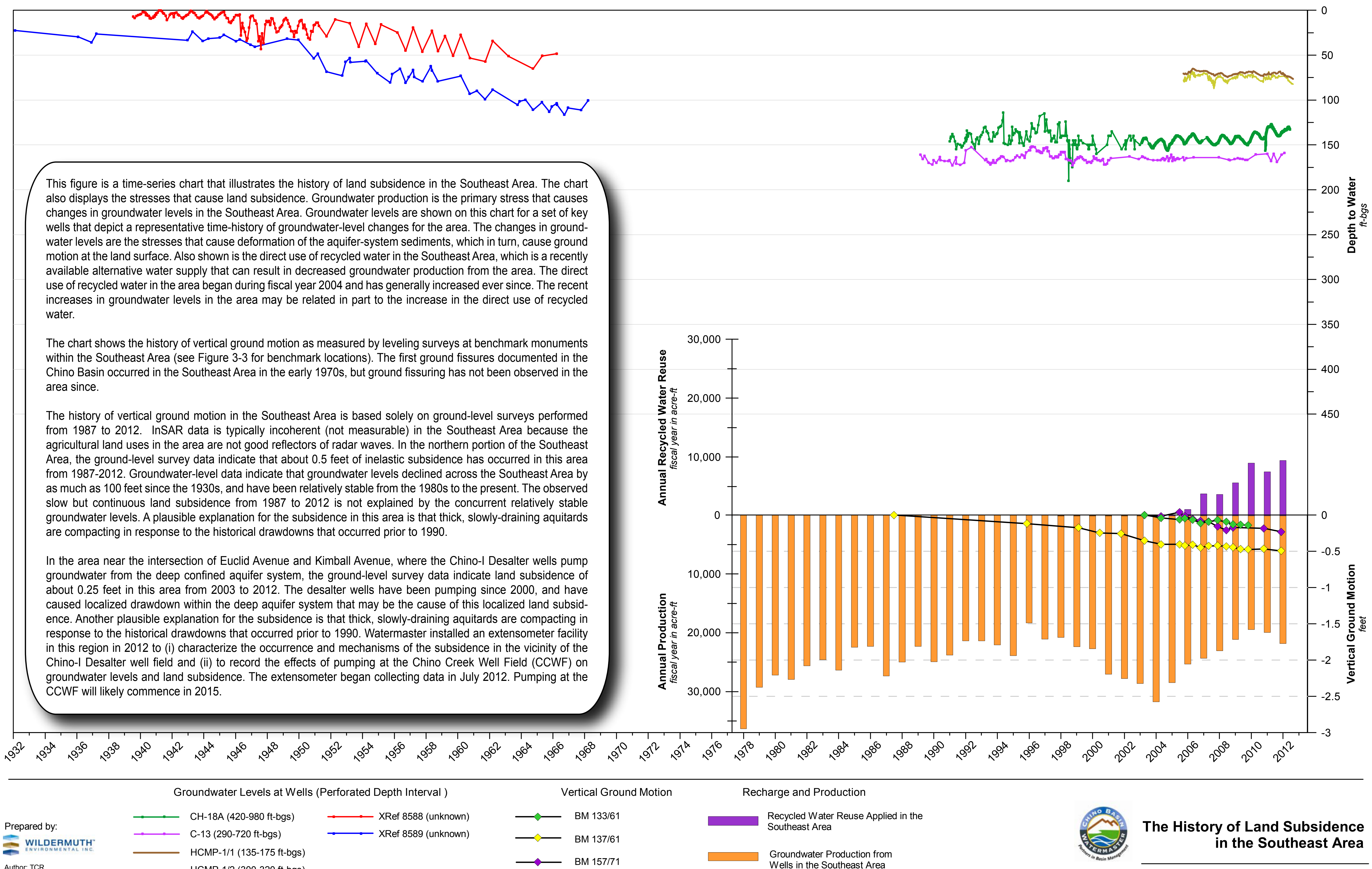
Figure 3-9



This figure is a time-series chart that illustrates the history of land subsidence in the Southeast Area. The chart also displays the stresses that cause land subsidence. Groundwater production is the primary stress that causes changes in groundwater levels in the Southeast Area. Groundwater levels are shown on this chart for a set of key wells that depict a representative time-history of groundwater-level changes for the area. The changes in groundwater levels are the stresses that cause deformation of the aquifer-system sediments, which in turn, cause ground motion at the land surface. Also shown is the direct use of recycled water in the Southeast Area, which is a recently available alternative water supply that can result in decreased groundwater production from the area. The direct use of recycled water in the area began during fiscal year 2004 and has generally increased ever since. The recent increases in groundwater levels in the area may be related in part to the increase in the direct use of recycled water.

The chart shows the history of vertical ground motion as measured by leveling surveys at benchmark monuments within the Southeast Area (see Figure 3-3 for benchmark locations). The first ground fissures documented in the Chino Basin occurred in the Southeast Area in the early 1970s, but ground fissuring has not been observed in the area since.

The history of vertical ground motion in the Southeast Area is based solely on ground-level surveys performed from 1987 to 2012. InSAR data is typically incoherent (not measurable) in the Southeast Area because the agricultural land uses in the area are not good reflectors of radar waves. In the northern portion of the Southeast Area, the ground-level survey data indicate that about 0.5 feet of inelastic subsidence has occurred in this area from 1987-2012. Groundwater-level data indicate that groundwater levels declined across the Southeast Area by as much as 100 feet since the 1930s, and have been relatively stable from the 1980s to the present. The observed slow but continuous land subsidence from 1987 to 2012 is not explained by the concurrent relatively stable groundwater levels. A plausible explanation for the subsidence in this area is that thick, slowly-draining aquitards are compacting in response to the historical drawdowns that occurred prior to 1990.

In the area near the intersection of Euclid Avenue and Kimball Avenue, where the Chino-I Desalter wells pump groundwater from the deep confined aquifer system, the ground-level survey data indicate land subsidence of about 0.25 feet in this area from 2003 to 2012. The desalter wells have been pumping since 2000, and have caused localized drawdown within the deep aquifer system that may be the cause of this localized land subsidence. Another plausible explanation for the subsidence is that thick, slowly-draining aquitards are compacting in response to the historical drawdowns that occurred prior to 1990. Watermaster installed an extensometer facility in this region in 2012 to (i) characterize the occurrence and mechanisms of the subsidence in the vicinity of the Chino-I Desalter well field and (ii) to record the effects of pumping at the Chino Creek Well Field (CCWF) on groundwater levels and land subsidence. The extensometer began collecting data in July 2012. Pumping at the CCWF will likely commence in 2015.

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The History of Land Subsidence in the Southeast Area

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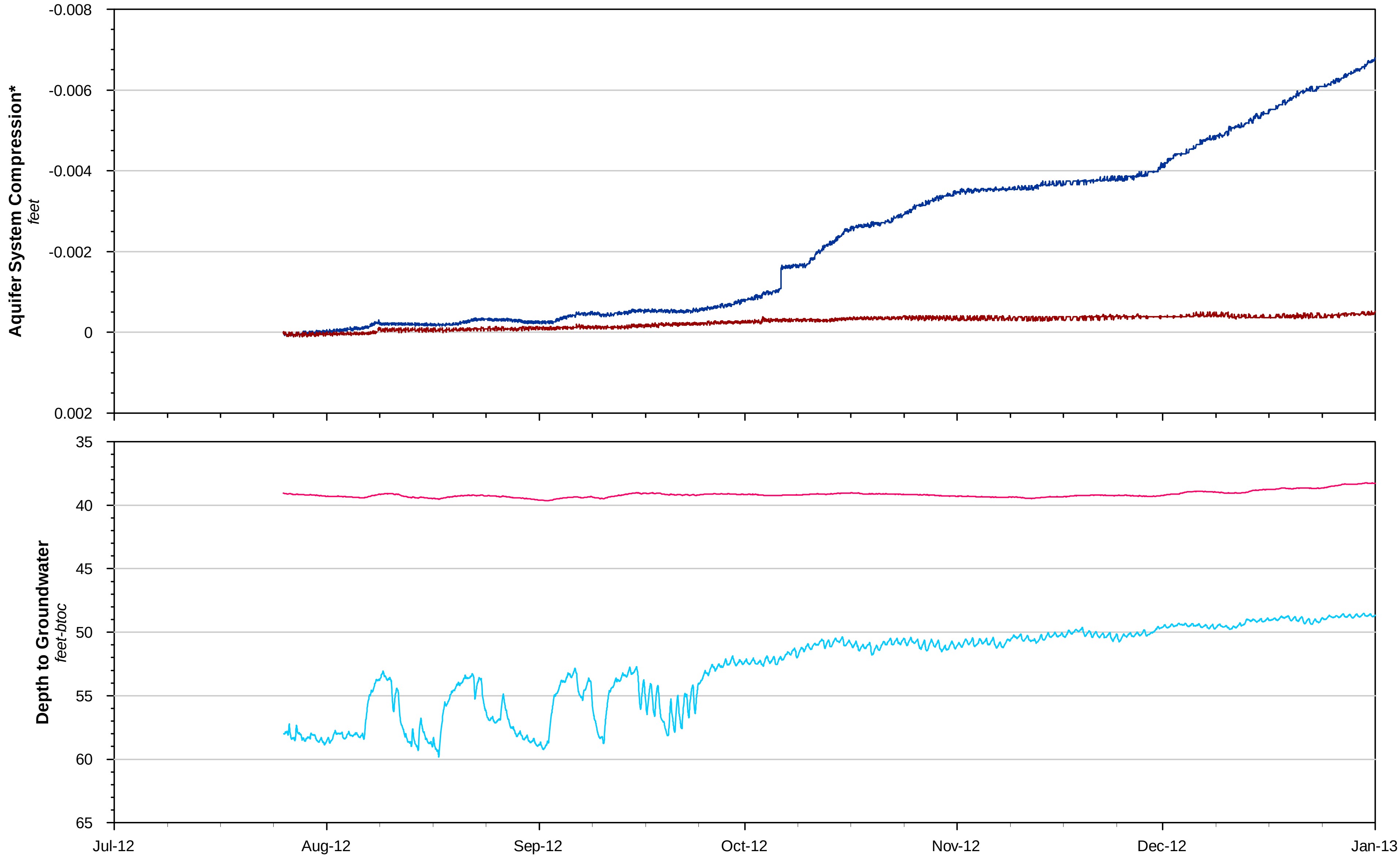
Figure 3-10



Shallow Aquifer System

Aquifer System Deformation
(Extensometer Depth Interval)

CCX-1 Extensometer
(50-140 ft-bgs)

Depth to Groundwater
(Perforated Depth Interval)

CCPA-1 Piezometer
(100-130 ft-bgs)

Deep Aquifer System

Aquifer System Deformation
(Extensometer Depth Interval)

CCX-2 Extensometer
(50-610 ft-bgs)

Depth to Groundwater
(Perforated Depth Interval)

CCPA-2 Piezometer
(235-295 ft-bgs)

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Stress and Strain
Chino Creek Extensometer

Figure 3-11

*Positive compression values represent compression of soils, negative compression values represent expansion of soils

4.1 Conclusions

The following are conclusions based on the data collected and analyzed for the Land-Subsidence Monitoring Program through 2012:

- Pumping of the Managed Wells did not cause drawdown of groundwater levels below the Guidance Level as measured at the PA-7 piezometer, and very little, if any, permanent subsidence was recorded in the Managed Area during 2012. These observations demonstrate the effectiveness of the MZ1 Plan in the management of subsidence.

- During 2012, differential land subsidence continued to occur in the Pomona Area across the San Jose Fault, which is the type of vertical deformation of the land surface that can lead to ground fissuring. A more intensive program of testing and monitoring is needed to better characterize the causes of land subsidence and the threat of ground fissuring in this area.

- The horizontal-strain data collected to date at the DHX demonstrates a logical response to stresses in the Managed Area:

    - horizontal extension across the fissure zone during subsidence of the ground surface in the Managed Area

    - horizontal compression across the fissure zone during rebound of the land surface in the Managed Area

  The data that will be collected and analyzed from the DHX during the Long-Term Pumping Test in the Managed Area is needed to determine if it is capable of producing "management-grade" information in the future.

- Since the installation of the CCX in July 2012, there has been very little fluctuation of groundwater levels or vertical deformation of the aquifer system. There appears to be very little, if any, ongoing subsidence at the CCX.

4.2 Recommendations for Testing and Monitoring – Fiscal Year 2013-14

The scope-of-work for the Land-Subsidence Monitoring Program for fiscal year 2013/14 is shown in Table 4-1 as a work breakdown structure with cost estimates. The Chino Basin Watermaster has approved this scope and budget, which includes:

- Continued regular and as-needed maintenance at the Ayala Park Extensometer, Chino Creek Extensometer, and Daniels Horizontal Extensometer.

- Continued quarterly collection of groundwater-elevation and aquifer-system-deformation data at wells and extensometers within the monitoring network.

- Installation of new benchmark monuments in the Pomona Area and conducting initial elevation and EDM surveys at these benchmarks. Figure 4-1 shows the locations of the new benchmark monuments. The elevation survey will reference the benchmark elevations to the Ayala Park datum. The EDM survey will measure the horizontal distance between the benchmark monuments that cross the San Jose Fault. These surveys will function as a baseline for comparison to future surveys.

- Continued implementation of the Long-Term Pumping Test that began in November 2012. The test is expected to continue through 2013, and into 2014. Figure 4-2 shows piezometric levels at PA-7 recorded through 2012, and the anticipated piezometric levels for the remainder of the Long-Term Pumping Test. An injection test is planned at CH-16 which could correspond with the recovery phase. The injection could accelerate the recovery of groundwater levels and facilitate the evaluation of injection as a tool for subsidence management. Watermaster is assisting the City of Chino Hills in its injection test at CH-16 with subsidence monitoring, administration of a grant from the DWR, and reporting on the results and conclusions of the injection test.

- Conducting elevation and EDM surveys at benchmarks in the Managed Area in fall 2013 and conjunction with maximum drawdown and maximum recovery of groundwater levels during the Long-Term Pumping Test.

- Conducting elevation survey at benchmarks in the Southeast Area in the fall of 2013.

- Collection and post-processing of InSAR data from the TerraSAR-X satellite operated by the European Space Agency. Five InSAR data scenes will be collected for 2013 and used to create interferograms that document the vertical motion of the land subsidence across the western portion of Chino Basin.

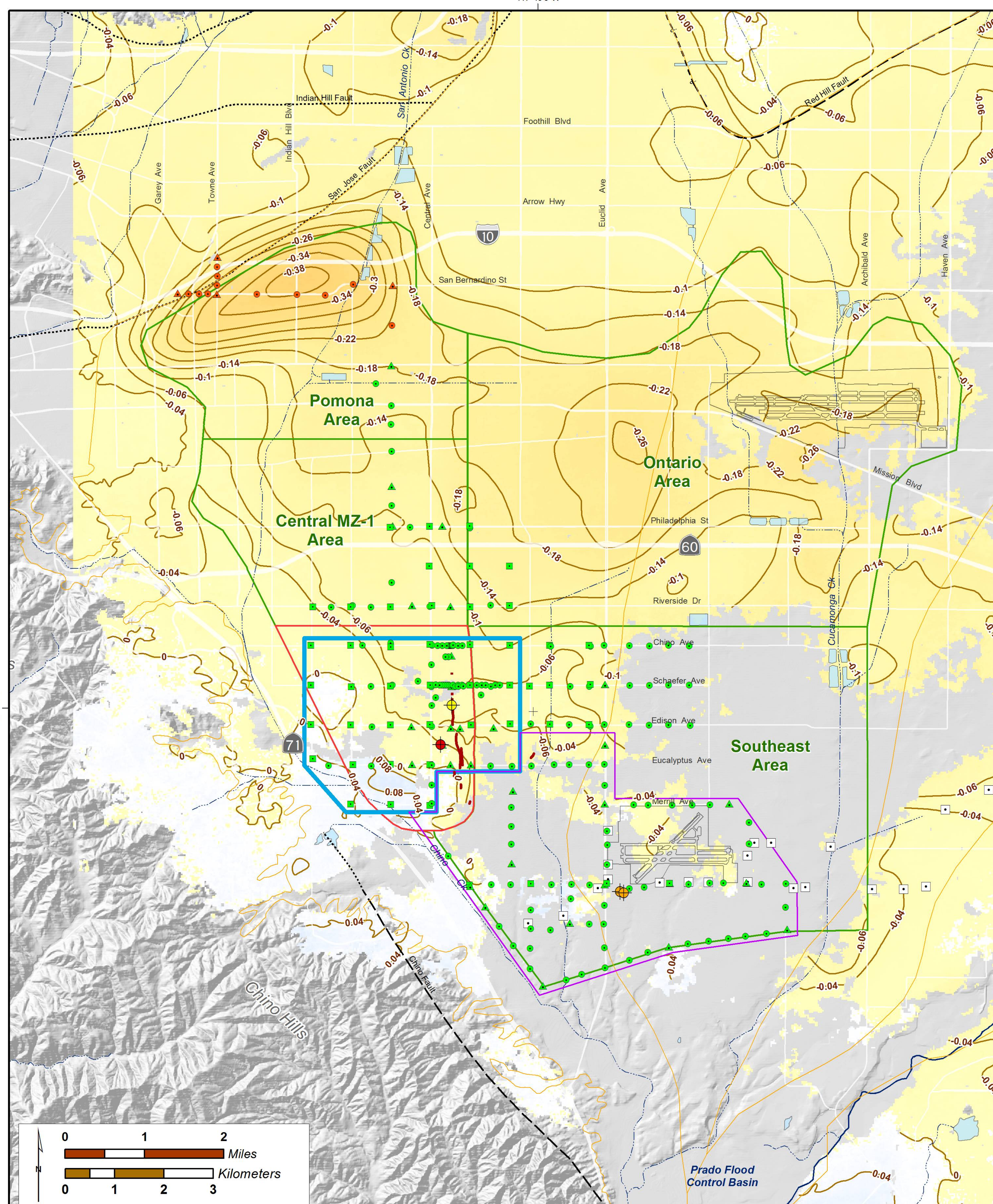
4.3 Recommendations for Changes to the MZ-1 Plan

Currently, there are no recommendations for changes to the MZ-1 Plan.

Table 4-1
Work Breakdown Structure
Land Subsidence Monitoring Program -- Fiscal Year 2013/14

	Task/Subtask/Description	Notes	Labor Cost							Total Labor		Other Direct Costs					Total ODC	Totals		
			Principal II	Principal I	Senior II	Staff	Field Tech	Clerical	Task Repetition Multiplier	Person Days	Cost	Travel	Equip and Expend	Subs	Repro	Misc.		Recommended Tasks *2013-14*	Estimated Future Annual Costs	Potential or Future Tasks
Task 1	**-- Setup/Maintenance of Monitoring Network**																	**$56,214**	**$56,214**	**$89,534**
1.1	Equipment maintenance	(1)																		
	Routine maintenance of Ayala Park/CCWF extensometer facilities				0.125	0.125	0.75		12	12	$9,330	$384	$228				$612	$9,942	$9,942	
	Maintenance at horizontal extensometer site				0.25		1		2	2.5	$1,960	$64	$200	$15,040			$15,304	$17,264	$17,264	
	Replacement/repair of equipment at extensometer facilities	(2)	2		2		2		1	6	$7,380	$32	$10,000	$10,000			$20,032	$27,412	$27,412	
1.2	Annual lease fees for CCWF extensometer site								1	0	$0					$1,596	$1,596	$1,596	$1,596	
1.3	Reset the PA vault at Ayala Park to prevent surface water runoff intrusion	(3)	0.5		10		5		1	15.5	$17,310	$32		$15,000			$15,032			$32,342
1.4	Abandon the PB facility	(3)																		
	Write specification, subcontract, etc.		0.5	2	8	1			1	11.5	$15,748				$200		$200			$15,948
	Coordinate with the City of Chino on schedule and landscaping				1	2			1	3	$3,320				$50		$50			$3,370
	Remove in situ equipment from the wells				0.25	0.5	1		1	1.75	$1,480	$32	$32				$64			$1,544
	Perform well abandonment			1	1		5		1	7	$6,234	$32	$64	$30,000			$30,096			$36,330
Task 2	**-- Aquifer-System Monitoring and Testing**																	**$76,381**	**$9,880**	**$33,540**
2.1	Groundwater-level and extensometer data collection and organization	(1)																		
	Download and check data from the Ayala Park facility		0.125		0.125		0.5		4	3	$2,820	$128					$128	$2,948	$1,520	
	Download and check data from the horizontal extensometer site		0.125		0.125		0.25		4	2	$2,170	$128				$600	$728	$2,898	$1,520	
	Download and check data from the CCWF facility		0.125		0.125		0.25		4	2	$2,170	$128					$128	$2,298	$1,520	
	Process and upload data to database				0.25	1			4	5	$5,320						$0	$5,320	$5,320	
2.2	Conduct Long-Term Pumping Test in the Managed Area	(1)																		
	Coordinate testing with pumpers				1				1	1	$1,320						$0	$1,320		
	Collect field data; process and upload to database				2	4	1		1	7	$7,290						$0	$7,290		
	Prepare, analyze, and distribute stress-strain diagrams to LSC		0.25		0.25				6	3	$4,560				$200		$200	$4,760		
2.3	Conduct Injection Test in Managed Area	(1)																		
	Well rehabilitation and retrofit and injection pilot testing	(4,5)								0	$0			$41,655			$41,655	$41,655		
	Quarterly reports and project administration - LGA Grant	(4)	0.125		0.25	0.125			4	2	$2,680				$200		$200	$2,880		
	Prepare two technical memoranda following each ASR cycle	(4)	1		0.125	0.5			2	3.25	$4,770				$242		$242	$5,012		
	Prepare final report for LGA Grant and final technical report for ASR Pilot Test	(4)	3		16	5		2	1	26	$33,040				$500		$500			$33,540
Task 3	**-- Ground-Level Surveys**																	**$121,880**	**$63,840**	**$15,000**
3.1	Replace destroyed benchmarks	(2)							1	0	$0			$5,400			$5,400	$5,400	$5,400	
3.2	Conduct Fall 2013 ground-level and EDM survey in Managed Area	(1)			0.5				1	0.5	$660			$27,900			$27,900	$28,560	$28,560	
3.3	Conduct Fall 2013 ground-level survey in Central MZ-1 Area	(3)							1	0	$0			$15,000			$15,000			$15,000
3.4	Conduct Fall 2013 ground-level survey in Southeast Area (CCWF)	(3)							1	0	$0			$27,700			$27,700	$27,700	$27,700	
3.5	Install benchmarks in the Pomona Area and perform initial ground-level/EDM Survey	(3)	0.5		1				1	1.5	$2,180			$27,300			$27,300	$29,480		
3.6	Conduct Spring 2014 ground-level and EDM survey in Managed Area	(1)			0.5				1	0.5	$660			$27,900			$27,900	$28,560		
3.7	Process and upload data to database	(1)	0.5		1				1	1.5	$2,180						$0	$2,180	$2,180	
Task 4	**-- BW InSAR**																	**$92,830**	**$92,830**	**$0**
4.1	InSAR data collection	(1)			1				1	1	$1,320			$90,000			$90,000	$91,320	$91,320	
4.2	Process and upload data to database/GIS	(1)	0.25		0.25	0.75			1	1.25	$1,510						$0	$1,510	$1,510	
Task 5	**-- Data Analysis and Reporting**																	**$68,770**	**$68,770**	**$21,280**
5.1	Data analysis in Managed Area	(1)																		
	Production/piezometric/extensometer		1		2	3			1	6	$7,360			$20,230			$20,230	$27,590	$27,590	
	EDM and ground-level survey data		1		4	1			1	6	$8,000						$0	$8,000	$8,000	
	InSAR data				0.5	0.5			1	1	$1,160						$0	$1,160	$1,160	
	Tectonic data					0.5			1	0.5	$500						$0	$500	$500	
	Recycled water reuse data				0.5				1	0.5	$660						$0	$660	$660	
5.2	Prepare MZ-1 Annual Report	(1)																		
	Prepare draft technical memorandum		1		10	6		3	1	20	$23,560				$200		$200	$23,760	$23,760	
	Prepare final technical memorandum		1		2	2		0.5	1	5.5	$6,800				$300		$300	$7,100	$7,100	
5.3	Update MZ-1 Plan (if necessary)	(1)	5		5	5		1	1	16	$21,080				$200		$200			$21,280
Task 6	**-- Meetings and Administration**																	**$27,675**	**$27,675**	**$0**
6.1	Land Subsidence Committee meetings	(1)	1		1				3	6	$9,120	$410			$100		$510	$9,630	$9,630	
6.2	Ad hoc meetings	(1)	1		1				1	2	$3,040	$46			$100		$146	$3,186	$3,186	
6.3	Project Administration	(1)	1.5		6				1	7.5	$10,500						$0	$10,500	$10,500	
6.4	Scope and Budget for FY2014/15	(1)	1		2				1	3	$4,360						$0	$4,360	$4,360	
Totals																		**$443,750**	**$319,209**	**$159,354**

Notes:
(1) Required by MZ-1 Plan and/or Peace Agreement
(2) Contingency budget. Spent only if necessary.
(3) Discretionary task. Performed if recommended by the Land Subsidence Committee
(4) $19,518 is expected to be carried over for labor and ODC for BW-GLMP: Aquifer System Monitoring and Testing for all Recommended Tasks. Total costs are $27,400.
(5) $129,936 is expected to be carried over for Outside Pros for BW-GLMP: Aquifer System Monitoring and Testing - Outside Pro. Total costs are $171,591.



Survey Benchmarks

- Class A Monuments
- Class B Monuments
- City Monuments
- Exisiting Monuments
- Proposed Monuments

Survey Areas

- Southeast Area Surveys
- Managed Area Surveys

+1 / 0 / -1 / -0.5 — Relative Change in Land Surface Altitude as Measured by InSAR June 2005 to September 2010 (feet)

InSAR data absent (incoherent)

Wells and Extensometers

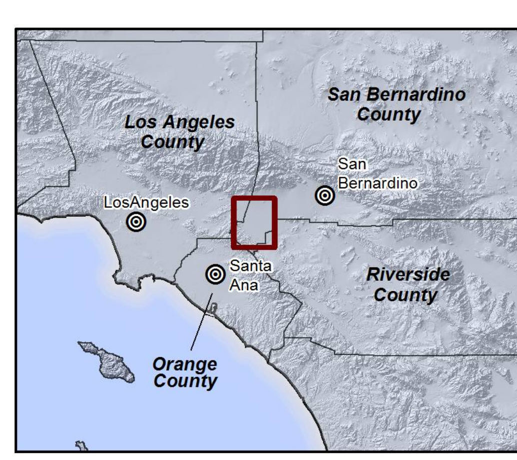
- Desalter Well
- Ayala Park Extensometer
- Chino Creek Extensometer
- Daniels Horizontal Extensometer

- Managed Area
- Areas of Subsidence Concern
- Ground Fissures

Faults

- Location Certain
- Location Approximate
- Approximate Location of Groundwater Barrier
- Location Concealed
- Location Uncertain

Chino Basin Management Zones



Prepared by:
WILDERMUTH ENVIRONMENTAL INC.

Author: TCR
Date: 20130628
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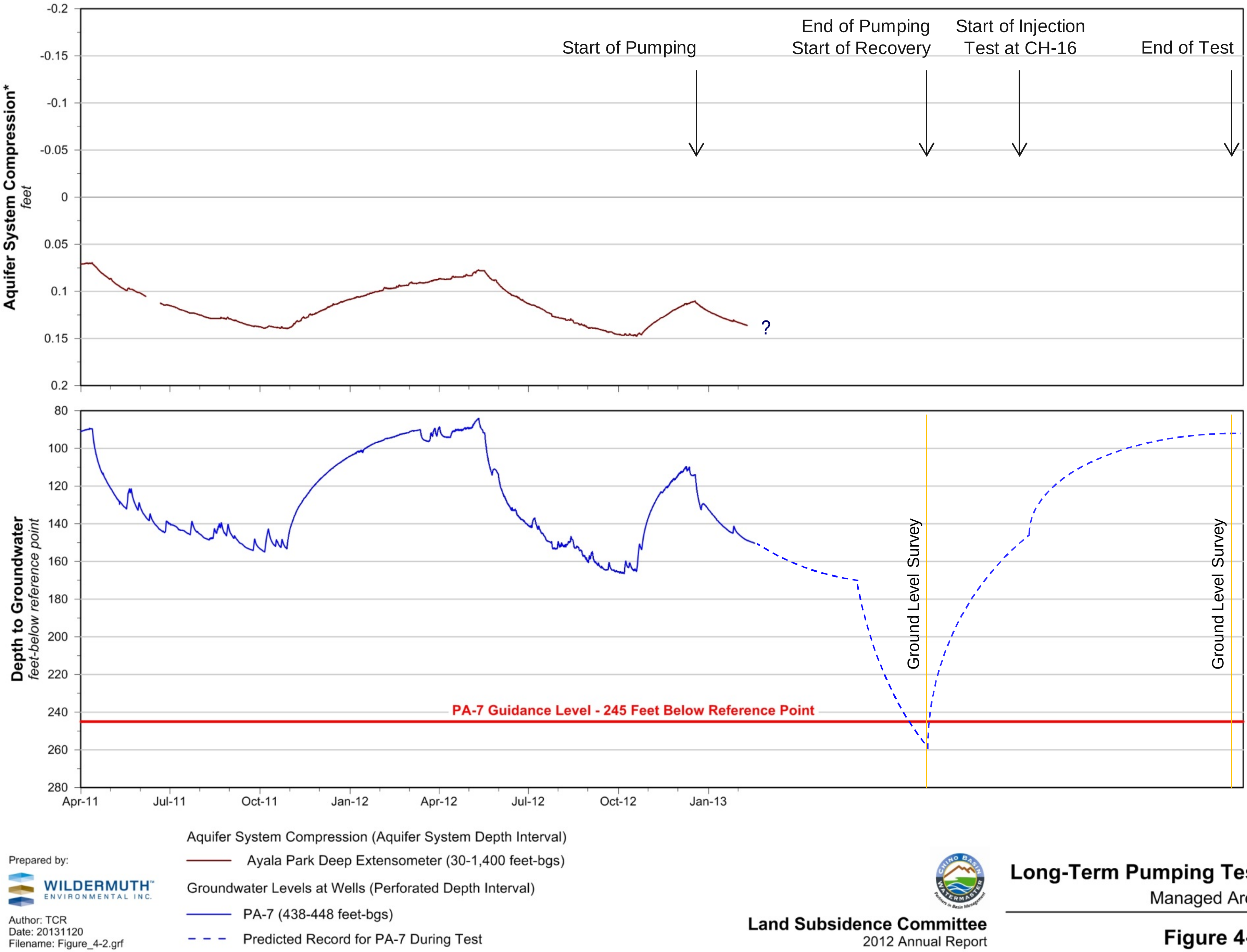
Land Subsidence Committee
2012 Annual Report

Benchmark Locations for Elevation and EDM Surveys

Figure 4-1



*Positive compression values represent compression of soils, negative compression values represent expansion of soils.

Prepared by:

WILDERMUTH™ ENVIRONMENTAL INC.

Author: TCR
Date: 20131120
Filename: Figure_4-2.grf

Land Subsidence Committee
2012 Annual Report

Long-Term Pumping Test
Managed Area

Figure 4-2

The following glossary of terms and definitions are utilized within this report and generally in the discussions at meetings of the Land Subsidence Committee (USGS, 1999).

Aquifer – A saturated, permeable, geologic unit that can transmit significant quantities of groundwater under ordinary hydraulic gradients and is permeable enough to yield economic quantities of water to wells.

Aquifer System – A heterogeneous body of interbedded permeable and poorly permeable geologic units that function as a water-yielding hydraulic unit at a regional scale. The aquifer system may comprise one or more aquifers within which aquitards are interspersed. Confining units may separate the aquifers and impede the vertical exchange of groundwater between aquifers within the aquifer system.

Aquitard – A saturated, but poorly permeable, geologic unit that impedes groundwater movement and does not yield water freely to wells, but which may transmit appreciable water to and from adjacent aquifers and, where sufficiently thick, may constitute an important groundwater storage unit. Areally extensive aquitards may function regionally as confining units within aquifer systems.

Artesian – An adjective referring to confined aquifers. Sometimes the term artesian is used to denote a portion of a confined aquifer where the altitudes of the potentiometric surface are above land surface (flowing wells and artesian wells are synonymous in this usage). But more generally the term indicates that the altitudes of the potentiometric surface are above the altitude of the base of the confining unit (artesian wells and flowing wells are not synonymous in this case).

Compaction – Compaction in the geologic sense refers to the inelastic compression of the aquifer system. Compaction of the aquifer system reflects the rearrangement of the mineral grain pore structure and largely nonrecoverable reduction of the porosity under stresses greater than the preconsolidation stress. Compaction, as used here, is synonymous with the term "virgin consolidation" used by soils engineers. The term refers to both the process and the measured change in thickness. As a practical matter, a very small amount (1 to 5 percent) of the compaction is recoverable as a slight elastic rebound of the compacted material if stresses are reduced.

Compression – A reversible compression of sediments under increasing effective stress; it is recovered by an equal expansion when aquifer-system heads recover to their initial higher values.

Consolidation – In soil mechanics, consolidation is the adjustment of a saturated soil in response to increased load, involving the squeezing of water from the pores and a decrease in void ratio or porosity of the soil. The term "compaction" is sometimes used in preference to consolidation.

Confined Aquifer System – A system capped by a regional aquitard that strongly inhibits the vertical propagation of head changes to or from an overlying aquifer. The heads in a confined aquifer system may be intermittently or consistently different than in the overlying aquifer.

Deformation, Elastic – A fully reversible deformation of a material. In this report, the term "elastic" typically refers the deformation of the aquifer-system sediments or the land surface.

Deformation, Inelastic – A non-reversible deformation of a material. In this report, the term "inelastic" typically refers the permanent deformation of the aquifer-system sediments or the land surface.

Differential Land Subsidence – Markedly different magnitudes of subsidence over a short horizontal distance, which can be the cause ground fissuring.

Drawdown – Decline in aquifer-system head typically due to pumping by a well. Elastic deformation,

Expansion – In this report, expansion refers to expansion of sediments. A reversible expansion of sediments under decreasing effective stress.

Extensometer – A monitoring well housing a free-standing pipe or cable that can measure vertical deformation of the aquifer-system sediments between the bottom of the pipe and the land surface datum.

Ground Fissures – Elongated vertical cracks in the ground surface that can extend several tens of feet in depth.

Head – A measure of the potential for fluid flow. The height of the free surface of a body of water above a given subsurface point.

Hydraulic Conductivity – A measure of the medium's capacity to transmit a particular fluid. The volume of water at the existing kinematic viscosity that will move in a porous medium in unit time under a unit hydraulic gradient through a unit area. In contrast to permeability, it is a function of the properties of the liquid as well as the porous medium.

Hydraulic Gradient – Change in head over a distance along a flow line within an aquifer system.

InSAR (Synthetic Aperture Radar Interferometry) – A remote-sensing method (radar data collected from satellites) that measures ground-surface displacement over time.

Linear Potentiometer – A highly sensitive electronic device that can generate continuous measurements of displacement between two objects. Used to measure movement of the land-surface datum with respect to the top of the extensometer measuring point.

Nested Piezometer – A single borehole containing more than one piezometer.

Overburden – The weight of overlying sediments including their contained water.

Piezometer – A monitoring well that measures groundwater levels at a point, or in a very limited depth interval, within an aquifer-system.

Piezometric (Potentiometric) Surface – An imaginary surface representing the total head of groundwater within a confined aquifer system, and is defined by the level to which the water will rise in wells or piezometers that are screened within the confined aquifer system.

Pore pressure – Water pressure within the pore space of a saturated sediment.

Rebound – Elastic rising of the land surface.

Stress, Effective – The maximum antecedent effective stress to which a deposit has been subjected and which it can withstand without undergoing additional permanent deformation. Stress changes in the range less than the preconsolidation stress produce elastic deformations of small magnitude. In fine-grained materials, stress increases beyond the preconsolidation stress produce much larger deformations that are principally inelastic (nonrecoverable). Synonymous with "virgin stress."

Stress, Preconsolidation – The maximum antecedent effective stress to which a deposit has been subjected and which it can withstand without undergoing additional permanent deformation. Stress changes in the range less than the preconsolidation stress produce elastic deformations of small magnitude. In fine-grained materials, stress increases beyond the preconsolidation stress produce much larger deformations that are principally inelastic (nonrecoverable). Synonymous with "virgin stress."

Stress – Stress (pressure) that is borne by and transmitted through the grain-to-grain contacts of a deposit, and thus affects its porosity and other physical properties. In one-dimensional compression, effective stress is the average grain-to-grain load per unit area in a plane normal to the applied stress. At any given depth, the effective stress is the weight (per unit area) of sediments and moisture above the water table, plus the submerged weight (per unit area) of sediments between the water table and the specified depth, plus or minus the seepage stress (hydrodynamic drag) produced by downward or upward components, respectively, of water movement through the saturated sediments above the specified depth. Effective stress may also be defined as the difference between the geostatic stress and fluid pressure at a given depth in a saturated deposit, and represents that portion of the applied stress which becomes effective as intergranular stress.

Subsidence – Sinking or settlement of the land surface, due to any of several processes.

Transducer, Pressure – An electronic device that can measure groundwater levels by converting water pressure to a recordable electrical signal. Typically, the transducer is connected to a data logger, which records the measurements.

Water Table – The surface of a body of unconfined groundwater at which the pressure is equal to atmospheric pressure, and is defined by the level to which the water will rise in wells or piezometers that are screened within the unconfined aquifer system.

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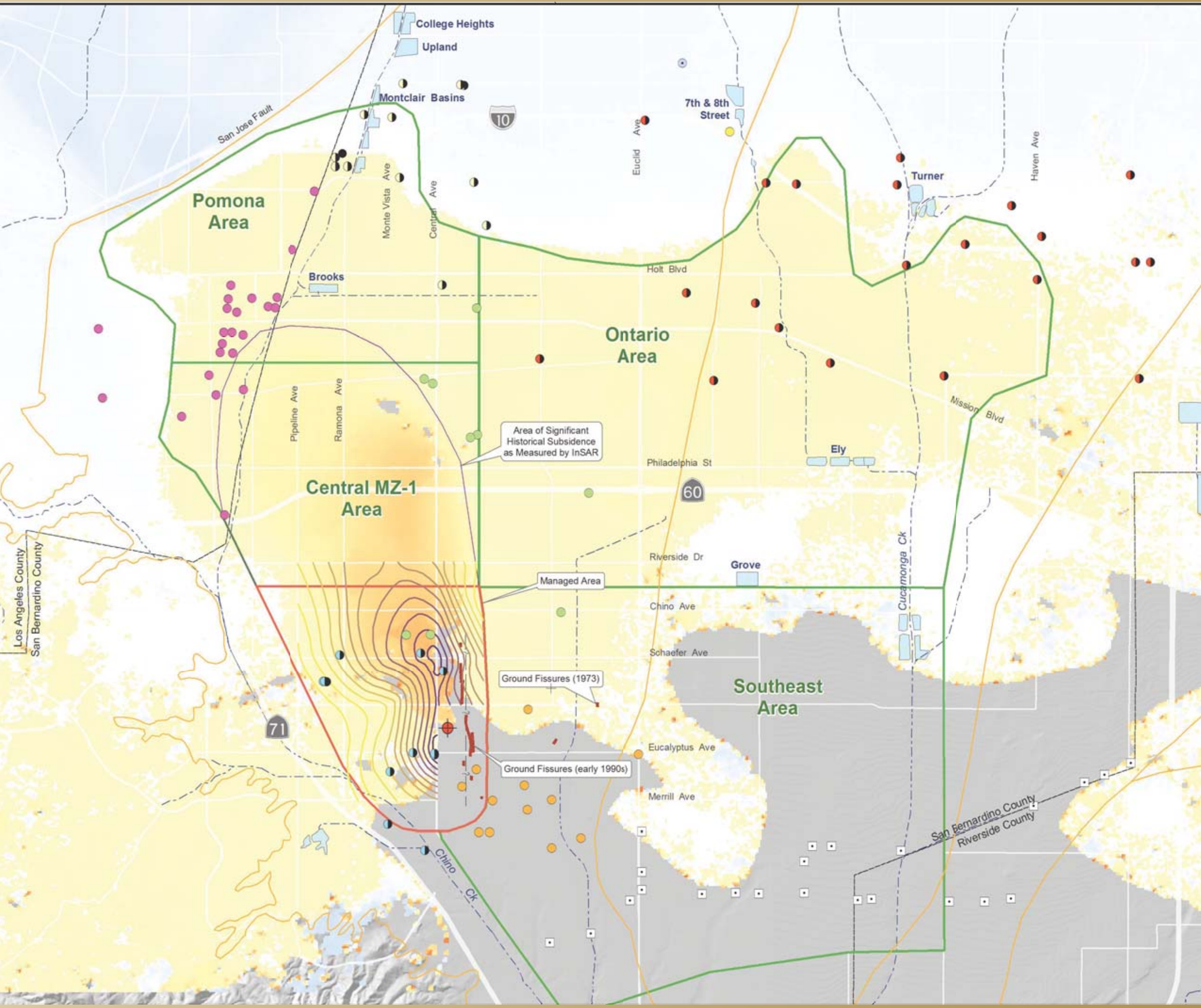
Appendix A

Results of Drilling and Construction of the Chino Creek Extensometer

Appendix B

Monitoring Data through December 2012



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