2017/18 Annual Report of the Ground-Level Monitoring Committee

FINAL REPORT
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Prepared for:
Ground-Level Monitoring Committee

Prepared by:

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Acronyms, Abbreviations, and Initialisms

af	Acre-ft
CCX	Chino Creek Extensometer Facility
DHX	Daniels Horizontal Extensometer
EDM	Electronic Distance Measurement
ft	Feet
ft-btoc	Feet below top of casing
GLMC	Ground-Level Monitoring Committee
GLMP	Ground-Level Monitoring Program
IMP	Interim Monitoring Program
InSAR	Interferometric Synthetic Aperture Radar
MZ-1	Chino Basin OBMP Management Zone 1
OBMP	Optimum Basin Management Plan
SAR	Synthetic Aperture Radar
SMP	Chino Basin Subsidence Management Plan
mi^2	Square miles
Watermaster	Chino Basin Watermaster
Work Plan	Work Plan to Develop a Subsidence Management Plan for the Northwest MZ-1 Area

1.1 Background

In general, land subsidence is the sinking or settlement of the Earth's surface due to the rearrangement of subsurface materials. In the United States alone, over 17,000 mi^2 in 45 states have experienced land subsidence (USGS, 1999). In many instances, land subsidence is accompanied by adverse impacts at the ground 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 percent of all documented cases of land subsidence in the United States have been caused by groundwater extractions from the underlying aquifer-system (USGS, 1999).

For purposes of clarification in this document, subsidence refers to permanent (i.e. non-recoverable) sinking of the land surface. The term inelastic (i.e. non-recoverable) typically refers to permanent deformation of the land surface or the aquifer-system. The term elastic typically refers to fully reversible deformation of the land surface or the aquifer-system.

1.1.1 Subsidence and Fissuring in Chino Basin

One of the earliest indications of land subsidence in the Chino Basin was the appearance of ground fissures within Management Zone 1 (MZ-1) 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. Figures 1-1 and 1-2 show the locations of these fissures. Scientific studies of the area have attributed the fissuring phenomenon to differential land subsidence 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; GEOSCIENCE, 2002).

1.1.2 The Optimum Basin Management Program

In 1999, the Optimum Basin Management Plan (OBMP) Phase I Report (WEI, 1999) identified the pumping-induced decline of piezometric levels and subsequent aquifer-system compaction 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 the information necessary to understand the extent, rate, and mechanisms of subsidence and fissuring.
- Abate future subsidence and fissuring or reduce it to tolerable levels.

The OBMP 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; WEI, 2003) and is described below.

The OBMP Phase I Report also noted that land subsidence was occurring in other parts of the Basin besides the City of Chino. Program Element 1 of the OBMP Implementation Plan, *Develop and Implement a Comprehensive Monitoring Program*, called for a basin-wide analysis of land subsidence via ground-level surveys and remote-sensing (specifically, interferometric synthetic aperture radar or InSAR) and for 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, the Chino Basin Watermaster (Watermaster) developed, coordinated, and conducted the IMP under the guidance of the MZ-1 Technical Committee (now called the Ground-Level Monitoring Committee or GLMC). The MZ-1 Technical Committee was comprised 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; the Monte Vista Water District; the Golden State Water Company; and the California Institution for Men.

The IMP consisted of three main monitoring elements: ground-level surveys, InSAR, and aquifer-system monitoring. The ground-level surveys and InSAR analyses were used to monitor deformation of the ground surface. Aquifer-system monitoring measured the hydraulic and mechanical changes within the aquifer-system that cause ground-surface deformation. Groundwater production and piezometric level data were collected from wells surrounding the areas of observed subsidence and ground fissuring.

The monitoring program was implemented in two phases: the Reconnaissance Phase and the Comprehensive Phase. The Reconnaissance Phase consisted of constructing multi-depth piezometers (11 piezometers screened at various depths) at Rubin S. Ayala Park (Ayala Park) in Chino and installing pressure transducers in nearby production wells and monitoring wells to measure piezometric levels. Following the installation of the monitoring network, several months of aquifer-system monitoring and testing were conducted. Testing included aquifer-system stress tests conducted at production wells in the area.

The Comprehensive Phase consisted of constructing a dual-borehole pipe extensometer at Ayala Park (Ayala Park Extensometer) near the area of historical fissuring. Following installation of the Ayala Park Extensometer, two aquifer-system stress tests were conducted followed by passive aquifer-system monitoring.

During implementation of the IMP, Watermaster's Engineer made the data available to the MZ-1 Technical Committee and prepared quarterly progress reports for submission to the MZ-1 Technical Committee, the Watermaster Pools and Board, and the Court.[1] The progress reports contained data and analyses from the IMP and a summary of the content of any Technical Committee meetings.

The main conclusions derived from the IMP were:

- Groundwater pumping from the deep and confined aquifer-system in the southwestern region of MZ-1 causes the greatest stress to the aquifer-system. In other words, pumping of the deep aquifer-system causes a piezometric level decline

[1] San Bernardino County Superior Court, which retains continuing jurisdiction over the Chino Basin Judgment.

that is much greater in magnitude and lateral extent than the piezometric level decline caused by pumping the shallow aquifer-system.

- Piezometric level decline due to pumping of the deep aquifer-system can cause inelastic compaction of the aquifer-system sediments, which results in land subsidence. The initiation of inelastic compaction within the aquifer-system was identified during the investigation when piezometric levels in the deep aquifer-system fell below a depth of about 250 ft in Watermaster's PA-7 piezometer at Ayala Park.
- The state of aquifer-system deformation in southern MZ-1 was essentially elastic during the Reconnaissance Phase of the IMP. Very little inelastic compaction was occurring in this area, which contrasted with the recent past when about 2.2 ft of land subsidence occurred from about 1987 to 1995 and was accompanied by ground fissuring. Figure 1-1 shows the land subsidence that was measured in the western Chino Basin and the wells that pumped during that period.
- During the development of the IMP, a previously unknown barrier to groundwater flow was identified, and its location is shown in Figures 1-1 and 1-2. The barrier was named the "Riley Barrier" after Francis S. Riley, a retired United States Geological Survey geologist who first detected the barrier during the IMP. 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 piezometric level decline did not propagate eastward across the barrier. Thus, compaction occurred within the deep aquifer-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.
- The InSAR and ground-level surveys indicated that subsidence in the central region of MZ-1 had occurred in the past and was continuing to occur. InSAR also suggested that the groundwater barrier extends northward into the Central MZ-1 Area, as shown in Figure 1-1. These observations suggested that the conditions that very likely caused ground fissuring near Ayala Park in the 1990s were also present in the Central MZ-1 Area. However, there was not enough historical piezometric level data in this area to confirm this relationship. The IMP recommended that, if subsidence continued or increased, the mechanisms causing the land subsidence should be studied in more detail.

The methods, results, and conclusions of the IMP were described in detail in *MZ-1 Summary Report* (WEI, 2006). The IMP provided enough information for Watermaster to develop Guidance Criteria for 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).

The Guidance Criteria were:

1. A list of existing wells, shown in Table 1-1, with screens completed into the deep aquifer-system (hereafter the Managed Wells) and their owners (hereafter the Parties) that are the subject of these Guidance Criteria.

2. A defined spatial area, shown in Figures 1-1 and 1-2, where the Guidance Criteria applies (hereafter the Managed Area). Within the boundaries of the Managed Area, both existing and newly constructed wells are subject to being classified as Managed Wells. This area was based on the observed and/or predicted effects of pumping on piezometric 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 Extensometer. Future Managed Well designations were to be based on analyses of well construction and borehole lithology.
3. The Guidance Level was a specified depth to water measured in Watermaster's PA-7 piezometer at the Ayala Park. It was defined as the threshold piezometric level at the onset of inelastic compaction of the aquifer-system as recorded by the extensometer minus five feet. The five-foot reduction was meant to be a safety factor to ensure that inelastic compaction does not occur. The Guidance Level is to be established by Watermaster based on the periodic review of monitoring data collected by Watermaster. The initial Guidance Level was established as 245 feet below the top of the PA-7 well casing.
4. If the piezometric level in PA-7 falls below the Guidance Level, Watermaster recommends that the Parties curtail their pumping from designated Managed Wells as required.
5. Watermaster was to provide the Parties with real-time piezometric level data from PA-7.
6. The Parties were requested to maintain and provide Watermaster with accurate records of operations at Managed Wells, including pumping rates and on-off dates and times. The Parties were requested to promptly notify Watermaster of all operational changes made to maintain the piezometric level in PA-7 above the Guidance Level.
7. Watermaster recommends that the Parties allow it to continue monitoring piezometric levels at their wells.
8. Watermaster and Watermaster's Engineer were to evaluate the data collected as part of the MZ-1 Monitoring Program (now called the Ground-Level Monitoring Program or GLMP) after each fiscal year and determine if modifications, additions, and/or deletions to the Guidance Criteria were necessary. These changes to the Guidance Criteria could include: 1) additions or deletions to the list of Managed Wells, 2) re-delineation of the Managed Area, 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 piezometric level recovery.
9. Watermaster cautioned that some subsidence and fissuring could occur in the future, even if the Guidance Criteria were followed. Watermaster made no warranties that faithful adherence to the Guidance Criteria would eliminate subsidence or fissuring.

1.1.4 MZ-1 Subsidence Management Plan

The Guidance Criteria formed the basis for the MZ-1 Plan, which was developed by the MZ-1 Technical Committee and approved by the Watermaster Board in October 2007. In November 2007, the Court approved the MZ-1 Plan and ordered its implementation.

To minimize the potential for future subsidence and fissuring in the Managed Area, the MZ-1 Plan codified the Guidance Level and recommended that the Parties manage their groundwater production such that the piezometric level in PA-7 remains above the Guidance Level.

The MZ-1 Plan called for ongoing monitoring, data analysis, annual reporting, and adjustments to the MZ-1 Plan, as warranted by the data. Implementation of the MZ-1 Plan began in 2008. The MZ-1 Plan called for the continued scope and frequency of monitoring implemented during the IMP within the Managed Area and 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 1-1 shows the location of these so-called Areas of Subsidence Concern: Central MZ-1, Northwest MZ-1, Northeast, and Southeast Areas. The expanded monitoring efforts outside of the Managed Area are consistent with the requirements of OBMP Program Element 1 and its implementation plan contained in the Peace Agreement.[2]

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) the development of alternative pumping plans for those Parties affected by the MZ-1 Plan. The GLMC discusses these potential future efforts, and if deemed prudent and necessary, they are recommended to Watermaster for implementation in future fiscal years.

1.1.5 2015 Chino Basin Subsidence Management Plan

The MZ-1 Plan stated that if data from existing monitoring efforts in the Areas of Subsidence Concern indicate the potential for adverse impacts due to subsidence, Watermaster would revise it to avoid those adverse impacts. The 2014 Annual Report of the GLMC recommended that the MZ-1 Plan be updated to better describe Watermaster's efforts and obligations about land subsidence, including areas outside of MZ-1. As such, the update included a name change to the 2015 Chino Basin Subsidence Management Plan (SMP; WEI 2015a) and a recommendation to develop a subsidence management plan for the Northwest MZ-1 Area. Land subsidence in Northwest MZ-1 was first identified as a concern in 2006 in the MZ-1 Summary Report and again in 2007 in the MZ-1 Plan. Since then, Watermaster has been monitoring vertical ground motion in this area via InSAR and piezometric levels with pressure transducers at selected wells.

Of particular concern, the subsidence in the Northwest MZ-1 Area across the San Jose Fault has occurred in a pattern of concentrated differential subsidence—the same pattern of differential subsidence that occurred in the Managed Area during the time of ground fissuring. Ground fissuring is the main subsidence-related threat to infrastructure. The issue of differential subsidence, and the potential for ground fissuring in the Northwest MZ-1 Area, has been discussed at prior GLMC meetings, and the subsidence has been documented and described as a concern in past State of the Basin Reports (WEI, 2013), annual reports of the GLMC, and in the *Initial Hydrologic Conceptual Model and Monitoring and Testing Program for the Northwest MZ-1 Area* (WEI, 2017). Watermaster increased monitoring efforts in the Northwest MZ-1 Area beginning

[2] In July 2000, the Parties to the Judgement signed the Peace Agreement. The Peace Agreement outlined the Parties' intent to implement the OBMP as well as other related responsibilities for Watermaster and the Parties.

in winter 2012-2013 to include ground elevation surveys and electronic distance measurements (EDMs) to monitor the ground motion and the potential for fissuring.

In 2015, Watermaster's Engineer developed the *Work Plan to Develop a Subsidence Management Plan for the Northwest MZ-1 Area* (Work Plan; WEI 2015b). The Work Plan is characterized as an ongoing Watermaster effort and includes a description of a multi-year scope-of-work, cost estimate, and a schedule. The Work Plan was included in the SMP as Appendix B. Implementation of the Work Plan began in July 2015.

The updated SMP also addressed the need for piezometric level "recovery periods" in the Managed Area by recommending that all deep aquifer-system pumping cease for a continuous six-month period between October 1 and March 31 of each year within the Managed Area. Every fifth year, Watermaster recommends that all deep aquifer-system pumping cease for a continuous period until piezometric level recovery reaches 90 ft-btoc at PA-7. These cessations of pumping are intended to allow for sufficient pyiezometric level recovery at PA-7 to recognize inelastic compaction, if any, at the Ayala Park Extensometer and at other locations where piezometric level and ground-level data are being collected.

1.1.6 Annual Report of the Ground-Level Monitoring Committee

The SMP states that Watermaster will produce an annual report, containing the results of ongoing monitoring efforts, interpretations of the data, and recommended adjustments to the SMP, if any. This annual report of the GLMC includes results and interpretations for the data collected between January 2017 through March 2018 as well as recommendations for Watermaster's GLMP for FY 2018/19.

1.2 Report Organization

This report is organized into the following six sections:

Section 1 – Introduction. This section provides background information on the history of land subsidence and ground fissuring in Chino Basin, information on the formation of the GLMC and its responsibilities, and a description of the development and implementation of the SMP, which calls for annual reporting.

Section 2 – Ground-Level Monitoring Program. This section describes the monitoring and testing activities that were performed by Watermaster for its GLMP between January 2017 and March 2018.

Section 3 – Results and Interpretations. This section discusses and interprets the monitoring data collected between January 2017 and March 2018, including basin stresses (i.e. groundwater production and recharge) and responses, which include changes in piezometric levels, aquifer-system deformation, and ground motion.

Section 4 – Conclusions and Recommendations. This section summarizes the main conclusions derived from the monitoring program between January 2017 and March 2018 and describes recommended activities for the GLMP for FY 2018/19.

Section 5 – Glossary. This section is a glossary of the terms and definitions utilized within this report and in discussions at GLMC meetings.

Section 6 – References. This section lists the publications cited in this report.

Table 1-1
Managed Wells Screened in the Deep Aquifer and Subject to the Guidance Criteria*

Well Name	CBWM ID	Owner	2017 Status	Well Screen Interval(s) *ft-bgs*
CIM-11A**	3602461	California Institution for Men	Active	174-187; 240-283; 405-465
C-7	3600461	City of Chino	Abandoned	180-780
C-15	600670	City of Chino	Inactive	270-400; 626-820
CH-1B	600487	City of Chino Hills	Inactive	440-470; 490-610; 720-900; 940-1,180
CH-7C	600687	City of Chino Hills	Abandoned	550-950
CH-7D	600498	City of Chino Hills	Destroyed	320-400; 410-450; 490-810; 850-930
CH-15B	600488	City of Chino Hills	Inactive	360-440; 480-900
CH-16	600489	City of Chino Hills	Inactive	430-940
CH-17	600499	City of Chino Hills	Active	300-460; 500-680
CH-19	600500	City of Chino Hills	Abandoned	300-460; 460-760; 800-1,000

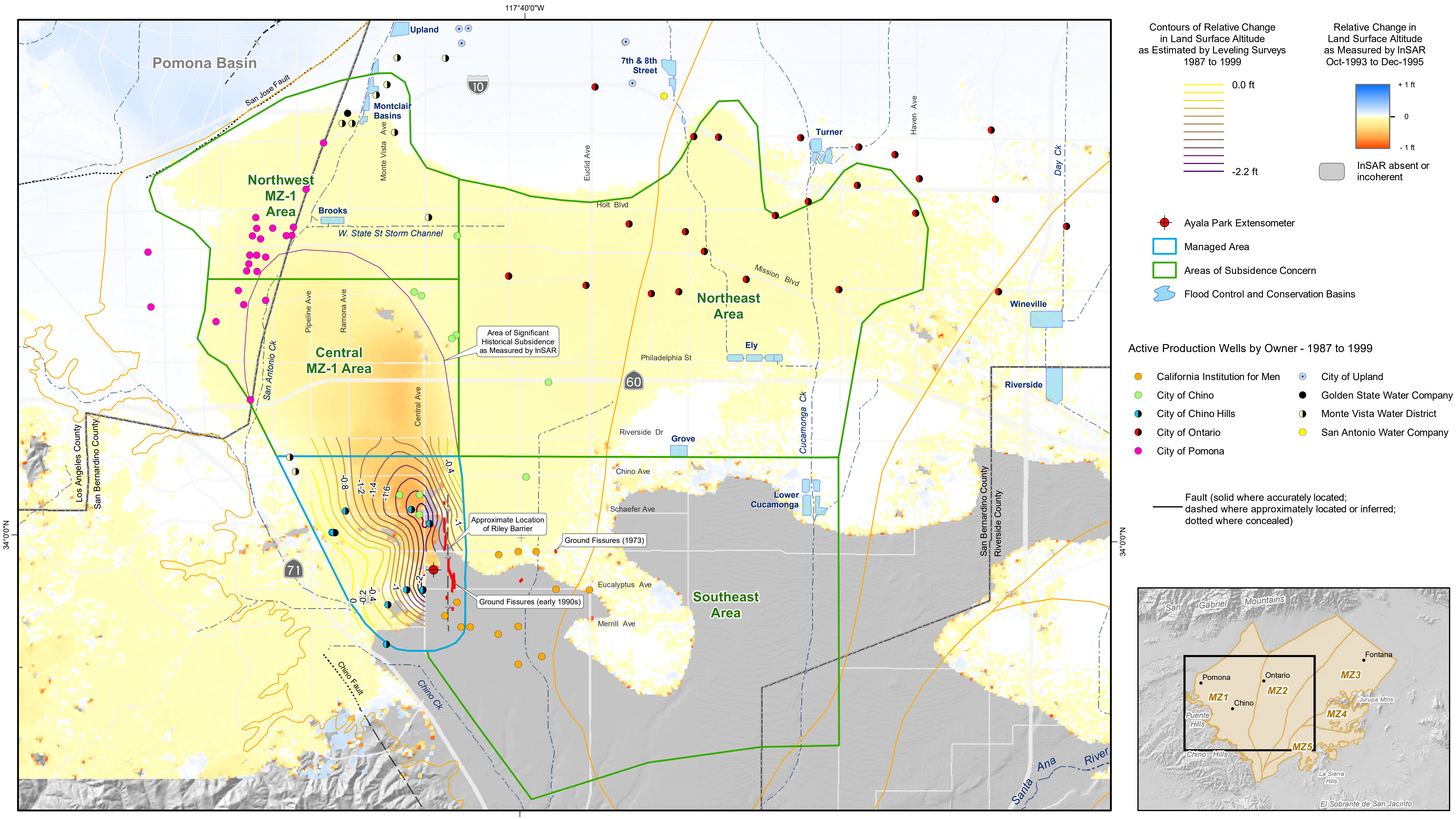
*The MZ-1 Subsidence Management Plan identified the Managed Wells that are subject to the Guidance Criteria for the Managed Area that, if followed, would minimize the potential for subsidence and fissuring.

**The original casing was perforated from 135-148, 174-187, 240-283, 405-465, 484-512, and 518-540 ft-bgs. This casing collapsed below 471 ft-bgs in 2011. A liner was installed to 470 ft-bgs with a screen interval from 155 to 470 ft-bgs.

Active = Well is currently being used for water supply

Inactive = Well can pump groundwater with little or no modifications

Abandoned = Unable to pump the well without major modifications



WEI
Wildermuth Environmental, Inc.

Author: NWS
Date: 8/30/2018
Document Name: Figure_1-1_20180622

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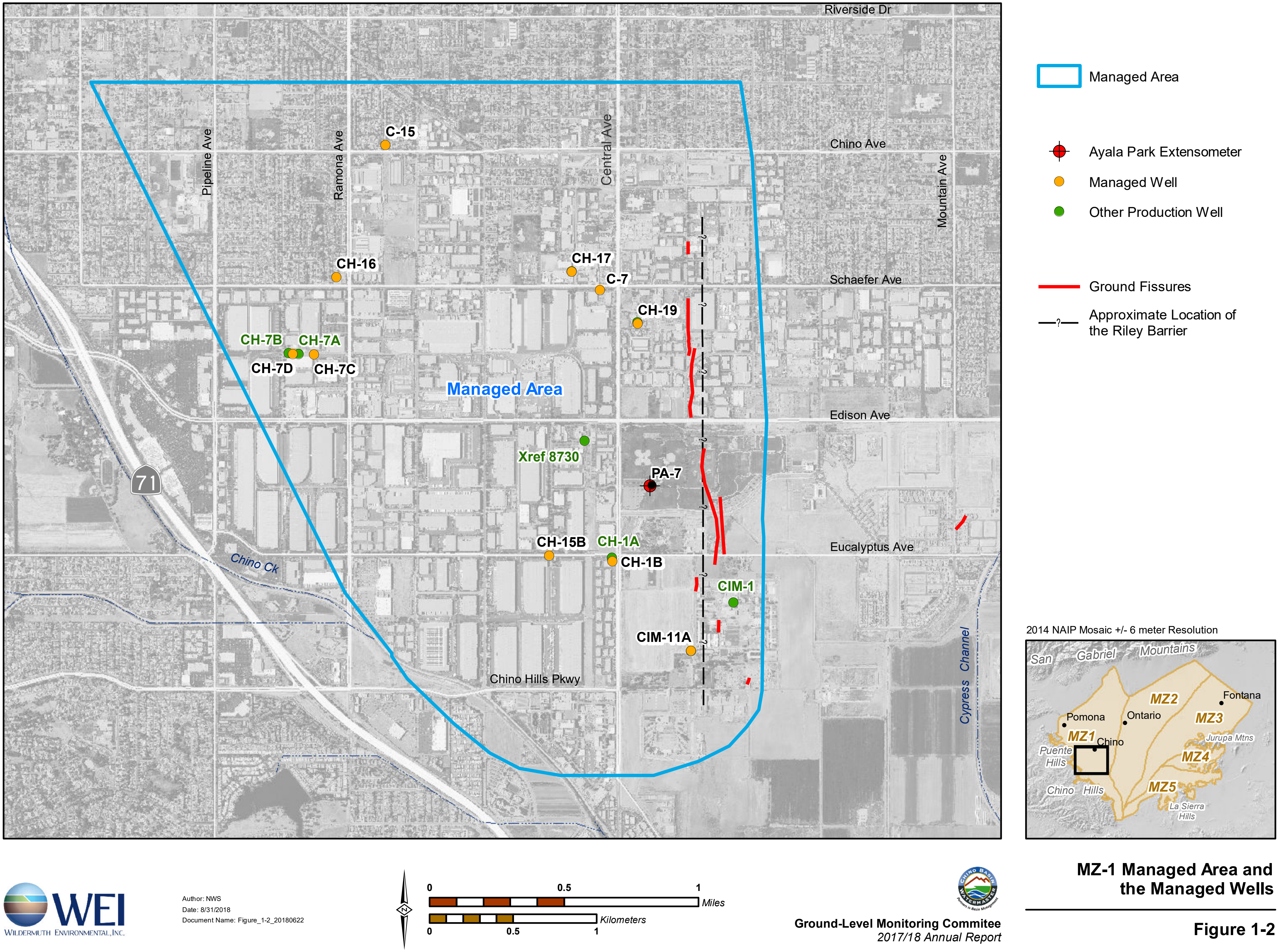
Historical Land Surface Deformation in Management Zone 1
1987-1999

Figure 1-1



WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: NWS
Date: 8/31/2018
Document Name: Figure_1-2_20180622

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MZ-1 Managed Area and the Managed Wells

Figure 1-2

Section 2 – Ground-Level Monitoring Program

This section describes the activities performed by Watermaster for the GLMP between January 2017 and March 2018.

Figures 2-1 and 2-2 are reference figures for this section. Figure 2-1 shows the groundwater production and recharge facilities in the western Chino Basin that impart pumping and recharge stresses to the aquifer-system. Figure 2-2 shows the locations of the monitoring facilities in Watermaster's ground-level monitoring network, including wells equipped with pressure transducers that measure piezometric levels, extensometers that measure vertical aquifer-system deformation, and benchmark monuments that are used to perform ground elevation and EDM surveys to measure vertical and horizontal deformation of the ground surface.

2.1 Ongoing Ground-Level Monitoring Program

Watermaster conducts its GLMP in the Managed Area and other Areas of Subsidence Concern pursuant to the SMP and the recommendations of the GLMC. The GLMP activities performed between January 2017 and March 2018 are described below.

2.1.1 Setup and Maintenance of the Monitoring Facilities Network

- Performed routine maintenance at the Ayala Park and Chino Creek Extensometer Facilities. Additional maintenance activities included:
    - Troubleshot the internet connection at the Ayala Park Extensometer to maintain electronic data delivery to Watermaster's Ayala Park website.[3]
    - Troubleshot the CR1000 Datalogger and Ayala Park computer at the Ayala Park Extensometer Facility to ensure data is being continuously recorded. Outside technical support reconfigured the datalogger and computer settings in March 2017 after the datalogger failed in January 2017.
    - Replaced the 12 volt deep-cycle batteries at the Ayala Park and Chino Creek Extensometer Facilities to ensure power to the datalogger and continuous data collection.
    - Installed backup piezometric level transducers from January to March 2017 when the datalogger and/or computer system was down for maintenance to minimize data loss.
    - Troubleshot the backup and dedicated piezometric level transducers and associated installation hardware when the equipment failed or malfunctioned.

2.1.2 Monitoring Activities during 2017/18

Changes in piezometric levels are caused by the stresses of groundwater production and recharge. Changes in piezometric levels are the mechanism behind aquifer-system deformation,

[3] http://ayala.wildermuthenvironmental.com:8888/AyalaPark/default.aspx

which in turn causes vertical and horizontal ground motion. Because of these cause-and-effect relationships, Watermaster monitors groundwater production, recharge, piezometric levels, aquifer-system deformation, and vertical and horizontal ground motion across the western portion of the Chino Basin. The following sub-sections (2.1.2.1 through 2.1.2.4) were Watermaster's monitoring activities between January 2017 and March 2018, as called for by the SMP and in accordance with the recommendations of the GLMC.

2.1.2.1 Monitoring of Production, Recharge, and Piezometric Levels

Watermaster collects and compiles groundwater production data on a quarterly time-step from well owners in the Managed Area and the Areas of Subsidence Concern. The locations of wells that produced groundwater between January 2017 and March 2018 are shown in Figure 2-1.

Watermaster collects data on the volumes of imported water, storm-water, and recycled water that are artificially recharged at spreading basins, and the volumes of recycled water used for direct use within the Chino Basin from the Inland Empire Utilities Agency.

Piezometric levels were measured and recorded once every 15 minutes using pressure transducers maintained by Watermaster at approximately 70 wells in the Managed Area, Central MZ-1, Northwest MZ-1, Southeast, and the Northeast areas. Figure 2-2 shows the locations of these wells. Also, Watermaster staff and well owners typically measure piezometric levels at other wells in western Chino Basin monthly.

2.1.2.2 Monitoring of Vertical Aquifer-System Deformation

Watermaster measured and recorded the vertical component of aquifer-system deformation at the Ayala Park and the Chino Creek Extensometer Facilities once every 15 minutes.

2.1.2.3 Monitoring of Vertical Ground Motion

Watermaster monitored vertical ground motion via ground-level surveys using InSAR and traditional leveling techniques.

For InSAR, Watermaster retained Neva Ridge Technologies, Inc. to acquire and post-process land-surface displacement data from the TerraSAR-X satellite operated by the German Aerospace Center. The width of the TerraSAR-X data frame covers the western half of the Chino Basin only.[4] Six synthetic aperture radar (SAR) scenes were collected between January

[4] All historical InSAR data that were collected and analyzed by Watermaster from 1993 to 2010 indicate that very little vertical ground motion occurred in the eastern half of the Chino Basin. In 2012, the GLMC decided to acquire and analyze InSAR only in the western portion of the Chino Basin as a cost-saving strategy.

2017 and March 2018. The scenes were used to create twelve interferograms[5] to estimate short-term and long-term vertical ground motion[6] over the following periods:

January 2017 to March 2017
January 2017 to May 2017
January 2017 to August 2017
January 2017 to November 2017
January 2017 to January 2018
January 2017 to March 2018
March 2017 to May 2017
May 2017 to August 2017
August 2017 to November 2017
November 2017 to January 2018
January 2018 to March 2018
March 2011 to March 2018

Watermaster retained WSP USA to conduct traditional leveling surveys at selected benchmark monuments in the western part of the Chino Basin. The table below shows the number of benchmark monuments that were surveyed within each ground-level survey area. The locations of the ground-level survey areas are shown in Figure 2-2.

Ground-Level Survey Area	Date of Most Recent Survey	Number of Benchmarks Surveyed
Managed Area*	Jan-2018	28
Southeast Area	Jan-2018	77
Central MZ-1 Area	Jan-2018	14
Northwest MZ-1 Area	Jan-2018	69
Northeast Area**	Jan-2018	25

*The entire benchmark monument survey network for the Managed Area was not surveyed in 2018 based on the GLMC scope and budget recommendations for FY 2017/18. Only benchmark monuments included in survey lines to other Areas of subsidence concern were surveyed.
*The Northeast Area benchmarks were set in December 2017 and re-surveyed in January 2018.

2.1.2.4 Monitoring of Horizontal Ground Motion

Watermaster measured horizontal ground motion between benchmark locations across areas that are susceptible to ground fissuring via EDMs. EDMs were performed between the benchmark monuments shown in Figure 2-2. The number of benchmark monuments surveyed are shown in the table below.

[5] Two or more SAR scenes are used to generate grids of surface deformation (interferograms) over a given period. Typically, surfaces within a pixel will move up or down together as would be expected in uplift/subsidence scenarios. However, surfaces within the area of a pixel can move randomly and cause decorrelation in the radar signal. Examples of random motion within a pixel area are vegetation growing, urbanization, erosion of the ground surface, harvesting crops, plowing fields, and others. The magnitude of this decorrelation in the signal is measured mathematically and called incoherence. Based on the magnitude of decorrelation in an area, pixels will be rejected as "incoherent."

[6] Several factors can influence the accuracy of ground-motion results as estimated by InSAR, such as satellite orbital uncertainties and atmospheric interference. On average, accuracy of ground-motion results as estimated by InSAR are +/- 0.02 ft.

Ground-Level Survey Area	Date of Most Recent Survey	Number of Benchmarks Surveyed
Fissure Zone Area*	Jan-2018	66
San Jose Fault Zone Area	Jan-2018	10

*EDMs across the Fissure Zone Area were not conducted in 2018 based on the GLMC scope and budget recommendations for FY 2017/18. Vertical survey measurements of the Fissure Zone Area were surveyed as part of the Managed Area survey for FY 2017/18.

2.2 Land-Subsidence Investigations

Watermaster performs land subsidence investigations pursuant to the SMP, the recommendations of the GLMC, and approval of scope-of-work and budget by the Watermaster Pools, Advisory Committee, and Board. Investigations can include aquifer-stress tests (e.g. pumping and injection) and the simultaneous monitoring of piezometric levels, aquifer-system deformation, and deformation of the ground surface. The goals of these investigations are to refine the Guidance Criteria and assist in the development of subsidence management plans to minimize or abate land subsidence and maximize the prudent extraction of groundwater.

This section describes the land subsidence investigations conducted between January 2017 and March 2018 that are called for by the SMP.

2.2.1 Long-Term Pumping Test in the Managed Area

The GLMC developed the Long-Term Pumping Test in the Managed Area in response to the directives in the SMP. 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 possible without causing damage to the ground surface or the area’s infrastructure. Specific questions that the test is designed to answer are:

1. Is the Guidance Level for the Managed Area, as currently defined, appropriate? If not, 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 the recoverable and inelastic aquifer-system deformation 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 the decline of piezometric levels and preventing inelastic compaction in the deep aquifer-system?

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

Figure 1-2 shows the locations of the wells included in the Long-Term Pumping Test. The GLMC 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. This test should cause the piezometric level at PA-7 to fall below the Guidance Level and may cause a small amount of subsidence.[7] The test will be closely monitored at the Ayala Park Extensometer and will be stopped at the first indication of inelastic compaction. Piezometric levels recorded at 15 minute intervals at PA-7 will be updated every three hours on Watermaster's website. When the piezometric levels decline to within 20 ft of the Guidance Level, data from the Ayala Park Extensometer will be downloaded and used to prepare a stress-strain diagram. The stress-strain diagram will be distributed promptly to the GLMC by e-mail. Watermaster staff and the Watermaster Engineer will remain in close telephonic contact with staff at the City of Chino, the City of Chino Hills, and the California Institution for Men to review and interpret the stress-strain diagram, to plan for the preparation of the next stress-strain diagram, or to decide to stop the test when appropriate.

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

3. Conduct two cycles of injection at CH-16 to see how injection accelerates the recovery of the regional piezometric levels that were lowered by pumping at CH-17 and CH-15B.[8] After the injection tests, allow for full recovery of piezometric levels at PA-7 to pre-test conditions.

4. Conduct ground-level surveys, InSAR monitoring, and EDM surveys to measure vertical and horizontal ground motion across the Managed Area before, during, and after the test. Collect piezometric and aquifer-system deformation data at the Ayala Park Extensometer once every 15 minutes throughout the test.

5. Check stress-strain diagrams from the Ayala Park Extensometer for inelastic compaction of the aquifer-system in the Managed Area. Analyze ground-level survey, InSAR, and EDM data for inelastic horizontal and vertical ground deformation within the Managed Area.

Through March 2018, the following activities were performed related to the Long-Term Pumping Test:

[7] The aquifer-system stress testing in 2004-05 resulted in about 0.01 feet of non-recoverable compaction and associated land subsidence (WEI, 2006). The Long-Term Pumping Test may cause a similar small amount of subsidence. This small amount of subsidence is far less than the >2 ft of subsidence that occurred from 1987 to 1995 when ground fissures opened in the City of Chino and is much less than the +/- 0.1 ft of elastic vertical ground motion that occurs seasonally in this area.

[8] The City of Chino Hills is conducting an injection feasibility study at CH-16 as part of the Long-Term Pumping Test. The study will help determine if aquifer injection is a viable tool to manage subsidence within the Managed Area while maximizing the use of existing infrastructure (i.e. wells). The study includes the conversion CH-16 to an aquifer storage and recovery well and pilot testing well. Watermaster assisted the City of Chino Hills in applying for and acquiring a Local Groundwater Assistance grant from the DWR to partially fund the study. Watermaster also assisted with a cost-share contribution of $368,000 to execute the study. As of the end of 2016, Chino Hills completed modifications to well CH-16 to convert it to an ASR well and completed connections to a potable water supply pipeline.

- The Long-Term Pumping Test was not completed. The City of Chino Hills reported CH-17 to be inactive as of June 2018 due to TCP (1,2,3-Trichloropropane) contamination. Groundwater was produced from CH-17 in the first two quarters of FY 2017/18. Production from CH-17 did not cause piezometric levels to decline below the Guidance Level at the PA-7 piezometer (245 ft-btoc). The maximum depth-to-groundwater at the PA-7 piezometer was about 175 ft-btoc before pumping ceased at CH-17 in December 2017.

- The City of Chino Hills is in the process of re-lining CH-15B due to failed casing. No production occurred at CH-15B between January 2017 and March 2018.

- The City of Chino Hills is still in the process of acquiring a permit from the Department of Drinking Water to perform injection at CH-16.

2.2.2 Analysis of EDM Measurements across Fissure Zone and the San Jose Fault Zone

The SMP calls for Watermaster to monitor for horizontal ground motion across areas that are susceptible to ground fissuring. Historically, this monitoring has occurred via EDMs and with the Daniels Horizontal Extensometer (DHX). The GLMC annually recommends the scope and frequency of EDM surveys. The DHX was decommissioned and removed in 2015 because the site was developed. As reported in the WEI (2016) Annual Report of the GLMC, an in-depth review of horizontal strain that had occurred over time and measured from EDM data across the Fissure Zone was performed to assess if the EDM data can be used in-lieu of the horizontal extensometer data collected at the DHX. Based on the review of the EDM data between closely spaced benchmark monuments in the Fissure Zone Area, the EDM method appears to be a suitable monitoring technique to detect the occurrence of tensile strain within shallow soils and the potential threat of ground fissuring. Additionally, the 2016 Annual Report recommended that if permanent subsidence is absent in the Managed Area, the GLMC should consider performing EDM surveys across the Fissure Zone at a frequency longer than annual, and to perform EDM surveys in coordination with the Long-Term Pumping Test in the Managed Area. In 2018, an EDM survey across the Fissure Zone in the Managed Area was not conducted based on the GLMC scope and budget recommendations for FY 2017/18.

Like the benchmark network in the Fissure Zone in the Managed Area, a series of closely spaced benchmarks have been installed across the San Jose Fault Zone in the Northwest MZ-1 Area. These benchmark monuments have been installed across the San Jose Fault along San Bernardino and San Antonio Avenues to measure horizontal strain across the fault zone. EDM surveys have been performed across the San Jose Fault Zone in the Northwest MZ-1 Area each year since 2014.

2.2.3 Develop a Subsidence Management Plan for Northwest MZ-1

In 2015, Watermaster's Engineer developed the Work Plan, which includes a description of a multi-year effort with cost estimates and a schedule to develop a subsidence management plan for the Northwest MZ-1 Area. The Work Plan was included in the SMP as Appendix B. The background and objectives of the Work Plan are described in Section 1.1.5 herein. Watermaster began implementation of the Work Plan in July 2015. The following work was completed in FY 2017/18:

Task 1 Describe Initial Hydrogeologic Conceptual Model and Monitoring and Testing Program – A final report was submitted to the GLMC and Watermaster in December 2017 that summarizes the current state of knowledge of the hydrogeology of the Northwest MZ-1 Area, the data gaps that need to be filled to fully describe the occurrence and mechanisms of aquifer-system deformation and the pre-consolidation stress, and a strategy to fill the data gaps.

Task 2 Implement the Initial Monitoring and Testing Program – As of March 2018, Watermaster's Engineer worked with Watermaster, the Monte Vista Water District, the City of Pomona, and SCADA Integrations to identify a set of wells capable of being equipped with SCADA monitoring capabilities and/or high frequency piezometric level transducers. Through several field visits and technical meetings with the parties mentioned, a protocol was developed to install monitoring equipment that will collect production and piezometric level data effectively. Monitoring equipment is currently being purchased and installed. The data collected will be incorporated into the Northwest MZ-1 Area monitoring and testing program.

Task 3 Develop and Evaluate the Baseline Management Alternative and Task 4 Develop and Evaluate the Initial Subsidence-Management Alternative – A final technical memorandum was submitted to the GLMC and Watermaster in December 2017, describing the construction, calibration, and use of a numerical one-dimensional aquifer-system compaction model in the Northwest MZ-1 Area – an area that has experienced gradual and persistent subsidence for decades. The objective of this memo is to explore the future occurrence of subsidence in the Northwest MZ-1 Area under various basin-operation scenarios of groundwater production and artificial recharge and to identify potential subsidence mitigation strategies.

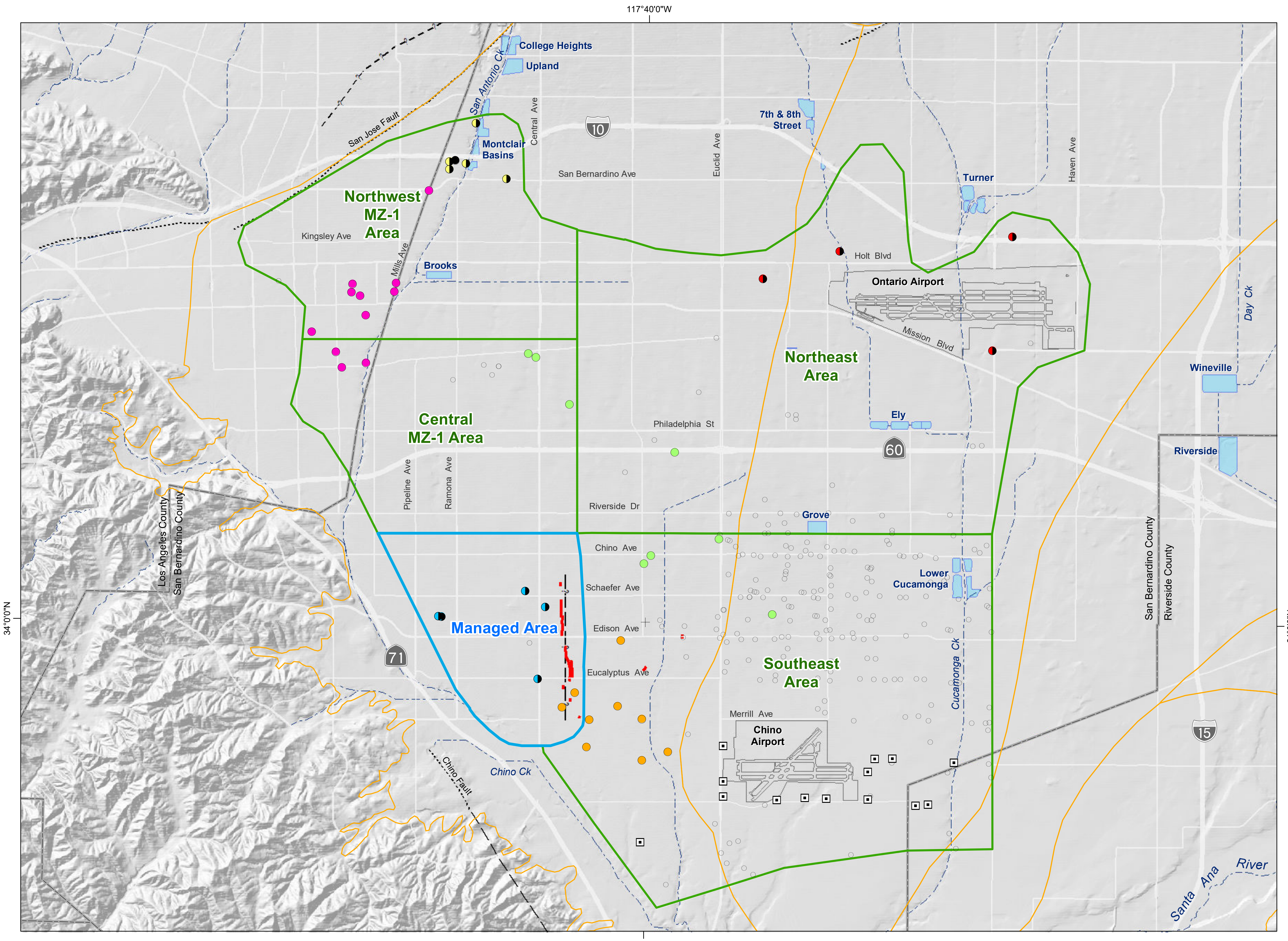
Task 5 Design and Install the Pomona Extensometer Facility – Watermaster's Engineer, Watermaster, and the City of Pomona have worked in conjunction to finalize the technical specifications for the Pomona Extensometer facility, prepare the California Environmental Quality Act documentation, prepare permits and right of way agreements, and prepare the bid documents.

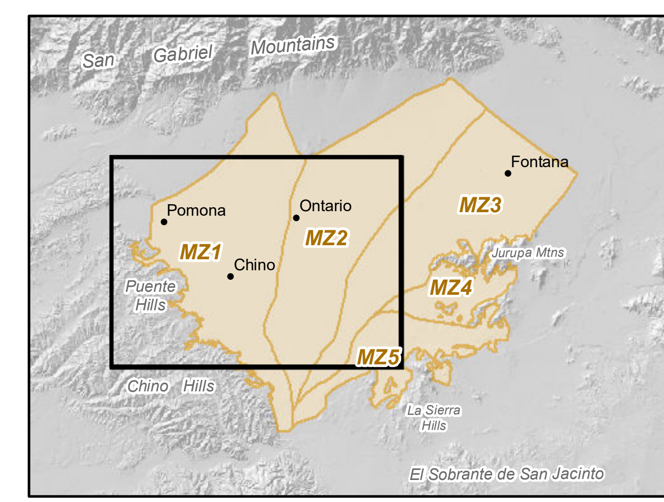
Active Groundwater Production Wells Within the Managed Area and Areas of Subsidence Concern 2017/18

- Private
- California Institution for Men
- Chino Basin Desalter Authority
- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- Golden State Water Company
- Monte Vista Water District

- Managed Area
- Areas of Subsidence Concern
- Flood Control and Conservation Basins

- Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)
- Ground Fissures
- Approximate Location of the Riley Barrier





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Author: NWS
Date: 8/31/2018
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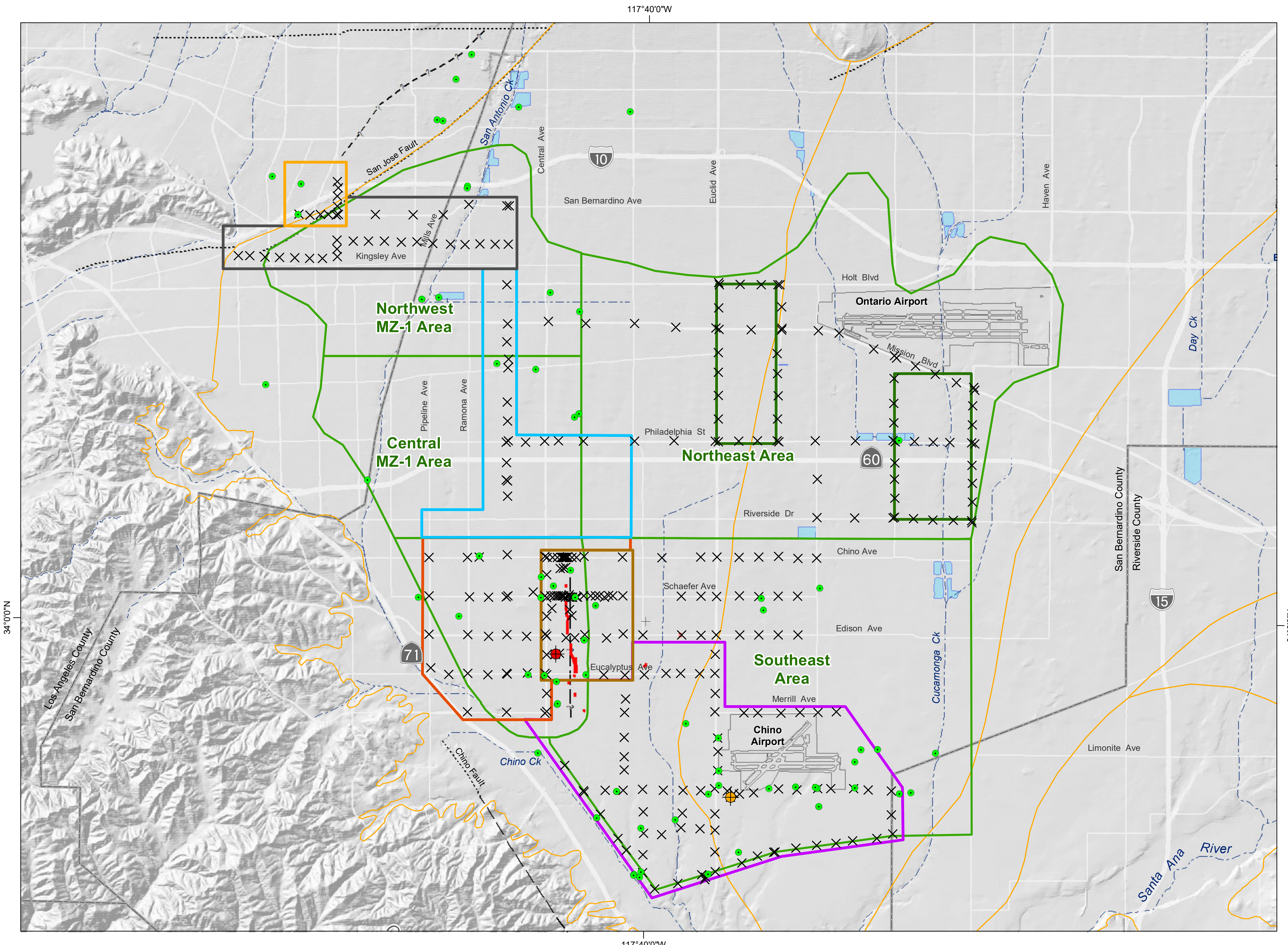
Ground-Level Monitoring Committee
2017/18 Annual Report

Pumping and Recharge Facilities
Western Chino Basin: 2017/18

Figure 2-1



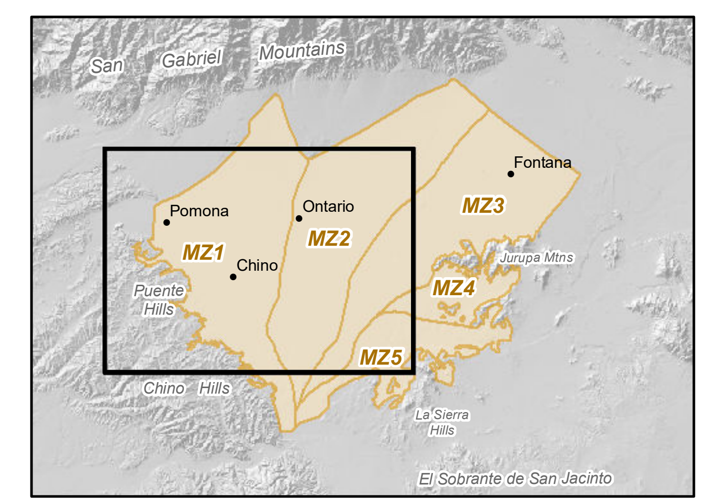
Ground-Level Monitoring Network Facilities

- Ayala Park Extensometer
- Chino Creek Extensometer
- Well Equipped with Transducer (2017/18)
- Ground-Level Survey Benchmark

Ground-Level Survey Areas

- Managed Area
- Fissure Zone Area
- Central Area
- Northwest Area
- San Jose Fault Zone Area
- Southeast Area
- Northeast Area

- Areas of Subsidence Concern
- Flood Control and Conservation Basins
- Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)
- Ground Fissures
- Approximate Location of the Riley Barrier



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Author: NWS
Date: 9/10/2018
Document Name: Figure_2-2_20180401

Ground-Level Monitoring Committee
2017/18 Annual Report

Ground-Level Monitoring Network
Western Chino Basin: 2017/18

Figure 2-2

Section 3 – Results and Interpretations

This section describes the results and interpretations derived from the GLMP for the Managed Area and all other Areas of Subsidence Concern in the Chino Basin between January 2017 and March 2018. Figures 3-1a and 3-1b display vertical ground motion as measured by InSAR across the western portion of the Chino Basin over the period between March 2011 and March 2018 and between March 2017 and March 2018, respectively. Included on the figures are the locations of the specific monitoring sites and facilities referred to in this section. The data shown in the figures are described and interpreted in this section.

3.1 MZ-1 Managed Area

The Managed Area is the primary focus of the SMP. The discussion below describes the results and interpretations of the monitoring program in the Managed Area, and where appropriate, relative to the Guidance Criteria in the SMP.

3.1.1 History of Stress and Strain in the Aquifer-System

Figure 3-2 is a chart that illustrates the long-term history of groundwater production, piezometric levels, and vertical ground motion in the Managed Area. Also shown is the volume of the direct use of recycled water in the Managed Area, which is an alternative water supply that can result in decreased groundwater production from the area. Recycled water is often used for irrigation purposes and can contribute to groundwater recharge as well. The main observations and interpretations from this chart are:

- Pumping from the shallow aquifer-system between the 1930s and about 1977 caused the water table to decline by about 150 ft. From 1978 to 1990, the water table recovered by about 50 ft.

- Pumping from the confined deep aquifer-system during the 1990s caused a decline of piezometric levels that coincided with high rates of land subsidence. About 2.5 ft of subsidence occurred from 1987 to 1999, and ground fissures opened within the City of Chino in the early 1990s.

- Since the early 2000s, groundwater production decreased, piezometric levels in the deep aquifer-system recovered, and the rate of land subsidence declined significantly across the Managed Area.

- The direct use of recycled water, beginning during FY 1998/99 and continuing through March 2018, may have also contributed to the observed increases in the water table in the Managed Area.

- Since 2005, piezometric levels at PA-7 have not declined below the Guidance Level, and very little inelastic compaction was recorded in the Managed Area. These observations demonstrate the effectiveness of the SMP in the management of land subsidence in the Managed Area.

3.1.2 Recent Stress and Strain in the Aquifer-System

This section discusses the last seven years of groundwater production, piezometric levels, and vertical ground motion in the Managed Area under the SMP.

3.1.2.1 Groundwater Production and Piezometric Levels

Table 3-1 summarizes groundwater production by well within the Managed Area for fiscal years 2012 through 2018. A total of about 1,900 af of groundwater production occurred in the Managed Area during between July 2017 and March 2018 —70 percent of the groundwater production was from wells screened in the shallow aquifer-system and 30 percent was from wells screened in both the shallow and deep aquifer-systems. Groundwater production in the Managed Area has declined over the past five years from about 5,680 af in FY 2011/12 to about 1,900 af between July 2017 and March 2018.

Figure 3-3 is a time-series chart that displays stress and strain in the shallow and deep aquifer-systems in the Managed Area. The chart includes: quarterly groundwater production, the resultant piezometric change (stress), and aquifer-system deformation (strain) for the period January 2011 through March 2018. The chart illustrates a seasonal pattern of production in the Managed Area—increased production during the spring and summer and decreased production during the fall and winter.

Figure 3-3 displays the time-series of piezometric levels at two piezometers at Ayala Park, PA-7 (deep aquifer-system) and PA-10 (shallow aquifer-system), illustrating the deep and shallow piezometric level responses to seasonal groundwater production. These data are consistent with the conclusions of the IMP and show that pumping from the deep confined aquifer-system causes a piezometric level decline that is much greater in magnitude than the piezometric level decline caused by pumping from the shallow aquifer-system—even though more groundwater production occurs from the shallow aquifer-system. The chart shows that piezometric levels at PA-7 have fluctuated from a low of approximately 190 ft-btoc in August 2013 to a high of about 80 ft-btoc in November 2016 and have not declined below the Guidance Level of 245 ft-btoc. The recovery of piezometric levels at PA-7 to above 90 ft-btoc in 2016 represented a "full recovery" of piezometric levels at PA-7 as defined in the SMP. This is the first instance of full recovery since 2012, which complies with the recommendation in the SMP for full piezometric recovery within the deep aquifer-system at least once every five years.[9]

From November 2016 to March 2018, piezometric levels within the shallow aquifer-system, as measured at PA-10, fluctuated within a relatively narrow range of 60 to 80 ft-btoc.

From November 2016 to March 2018, piezometric levels within the deep aquifer-system, as measured at PA-7, experienced a cycle of decline and recovery: piezometric levels began to decline in November 2016 from a high of about 80 ft-btoc; by March 2017, piezometric levels were at about 110 ft-btoc and continued to decline to a low of about 175 ft-btoc by December 2017; and piezometric levels then recovered to about 100 ft-btoc by the end of March 2018.

[9] Page 2-2 in the SMP, Section 2.1.1.3—Recovery Periods: "Every fifth year, Watermaster recommends that all deep aquifer-system pumping cease for a continuous period until water-level recovery reaches 90 ft-btoc at PA-7. The cessation of pumping is intended to allow for sufficient water level recovery at PA-7 to recognize inelastic compaction, if any, at the Ayala Park Extensometer and at other locations where groundwater-level and ground-level data are being collected."

Figure 3-3 illustrates that the length of the period of piezometric decline in the deep aquifer-system was about 13 months, which, since 2011, is about three to seven months longer than prior periods of seasonal piezometric decline.

3.1.2.2 Aquifer-System Deformation

Figure 3-3 includes a time-series chart of vertical deformation of the aquifer-system as measured at the Ayala Park Extensometers for the period January 2011 through March 2018. These data show that the seasonal vertical compression and expansion of the aquifer-system is responding to the seasonal decline and recovery of piezometric levels and indicate that the vertical deformation of the aquifer-system was mainly elastic during this period. However, between April 6, 2011 and June 27, 2016 (dates of full recovery of piezometric levels at PA-7 to 90 ft-btoc), the Deep Extensometer recorded about 0.029 ft of compression within the aquifer-system, which indicates that this compression is permanent compaction that occurred within the depth interval of 30-1,400 ft-bgs.[10]

From November 2016 to March 2018, Figure 3-3 displays the compression and expansion of the aquifer-system at the Deep Extensometer in response to the decline and recovery of piezometric levels at PA-7 (described in the prior section). By the end of March 2018, the Deep Extensometer recorded about 0.02 ft of compression since November 2016. That piezometric levels at PA-7 are about 20 ft lower in March 2018 compared to November 2016 indicates that the 0.02 ft of compression is mostly elastic deformation of the aquifer-system.

Figure 3-4 is a stress-strain diagram of piezometric levels measured at PA-7 (stress) versus vertical deformation of the aquifer-system sediments as measured at the Deep Extensometer (strain). This diagram provides additional information on the nature of the aquifer-system deformation that occurred during the November 2016 to March 2018 period (i.e. elastic versus inelastic deformation). The hysteresis loops on this figure represent piezometric level decline-recovery cycles and the resultant compression-expansion of the aquifer-system sediments. The diagram can be interpreted to understand the timing and magnitude of the occurrence of compaction within the depth interval of the aquifer-system that is penetrated by the Deep Extensometer. Piezometric level decline is shown as increasing from bottom to top on the y-axis, and aquifer-system compression is shown as increasing from left to right on the x-axis. From April 2011 to January 2014, the hysteresis loops progressively shift to the right on this chart, indicating that about 0.029 ft of inelastic compaction occurred during this time-period. Beginning in 2014 through March 2018, the hysteresis loops start to overlap one another, indicating that the seasonal vertical deformation observed in the deep aquifer-system sediments have deformed almost entirely elastically. Figure 3-4 shows the most recent decline-recovery cycle from the November 2016 to March 2018 in red. By the end of the record in March 2018, the hysteresis loop shows a slight shift to the right compared to the prior hysteresis loop of about 0.004 ft of compression. There are two potential interpretations of this shift:

1. The 0.004 ft of compression is permanent compaction of the aquifer-system, which may be due to the relatively long 13-month period of decline in piezometric levels.

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[10] The analysis of full recovery and inelastic compaction at Ayala Park was included in the 2016 Annual Report (WEI, 2017).

2. The 0.004 ft of compression is elastic (at least in part), and the aquifer-system will expand in a delayed fashion during a future period of full recovery of piezometric levels.

3.1.2.3 Vertical Ground Motion

Vertical ground motion is measured across the Managed Area via InSAR, traditional ground-level surveys, and the Deep Extensometer. For FY 2017/18, the entire Managed Area benchmark monument network was not surveyed per the GLMC's scope and budget recommendations except for benchmarks that are part of survey lines to other Areas of Subsidence Concern. Figures 3-5a and 3-5b illustrate vertical ground motion[11] as estimated by InSAR for the period from March 2011 to March 2018 and from March 2017 to March 2018, respectively.

Where coherent, the InSAR estimates shown in Figure 3-5a indicate the occurrence of about zero to -0.15 ft of vertical ground motion across the Managed Area from 2011 to 2018. The greatest downward ground motion occurred in the northern and central portions of the Managed Area near well CH-17—the main active deep production well in the Managed Area. The principal areas of InSAR incoherence in the Managed Area are located south of Schaefer Avenue.

The InSAR estimates shown on Figure 3-5a are consistent with the Deep Extensometer record at Ayala Park from March 2011 to March 2018. Over this period, the Deep Extensometer recorded about -0.04 ft of aquifer-system deformation compared to about -0.03 ft of vertical ground motion estimated by InSAR at the Deep Extensometer location. The discussion in the prior section on aquifer-system deformation, as measured and interpreted from the data recorded at the Ayala Park Extensometer, concluded that about -0.03 ft of inelastic compaction occurred beneath Ayala Park during 2011-2014. Therefore, it is likely that the downward vertical ground motion, as estimated by InSAR across the Managed Area in Figure 3-5a, is at least in part a result of inelastic compaction of the aquifer-system and represents permanent land subsidence that occurred over this period.

The InSAR estimates shown in Figure 3-5b indicate the occurrence of about zero to -0.03 ft of vertical ground motion across the Managed Area from March 2017 to March 2018. The greatest downward ground motion occurred in the northern portions of the Managed Area.

The InSAR estimates shown in Figure 3-5b are consistent with the Deep Extensometer record at Ayala Park from March 2017 to March 2018. Over this one-year period, the Deep Extensometer recorded about -0.01 ft of aquifer-system deformation compared to about -0.01 ft of vertical ground motion estimated by InSAR at the Deep Extensometer location. The discussion in the prior section on aquifer-system deformation, as measured and interpreted from the data recorded at the Ayala Park Extensometer, concluded that aquifer-system deformation at Ayala Park was primarily elastic from March 2017 to March 2018 but that a portion of the recorded compression could be inelastic compaction. Therefore, it is possible that a portion of the downward vertical ground motion shown in Figure 3-5b across the Managed Areas is a

[11] Upward vertical ground motion is indicated by positive values; downward vertical ground motion is indicated by negative values.

result of inelastic compaction of the aquifer system and represents permanent land subsidence that occurred over this one-year period.

The downward vertical ground motion as estimated by InSAR in the northern portion of the Managed Area (see Figures 3-1a and 3-1b) appears to be related to the vertical ground motion the Central MZ-1 Area. The next annual report should include an analysis of pair observations of piezometric levels at well C-15 and vertical ground motion as estimated by InSAR to characterize the nature of the vertical ground motion in the northern portion of the Managed Area (i.e. elastic vs. inelastic).

3.1.2.4 Horizontal Ground Motion

Since 2003, EDM surveys have been performed periodically since 2003 in the Managed Area between the benchmark monuments located along Eucalyptus, Edison, Schaefer, and Chino Avenues to monitor for horizontal ground motion across the historical Fissure Zone. EDM surveys were not conducted in 2018 per the GLMC's scope and budget recommendations for FY 2017/18.

3.2 Southeast Area

Vertical ground motion is measured across the Southeast Area via InSAR, traditional ground-level surveys, and the Chino Creek Extensometer Facility (CCX). The InSAR results are generally incoherent across much of this area because the overlying agricultural land uses are not hard, consistent reflectors of radar waves. Where InSAR results are incoherent, the history of subsidence is best characterized by ground-level surveys and the CCX.

Figure 3-6 is a time-series chart that displays and describes the history of groundwater production, direct reuse of recycled water, piezometric levels, and vertical ground motion in the Southeast Area from 1930 to 2018. Figures 3-7a and 3-7b illustrate vertical ground motion as estimated by InSAR across the Southeast Area during 2011-2018 and 2017-2018, respectively. The main observations and interpretations from these figures are:

- From the 1940s to about 1968, piezometric levels declined by up to about 75 ft. There is a data gap from about 1968 to 1988; however, it is likely that piezometric levels continued to decline from 1968 to 1978 (as was the case in most portions of the Chino Basin during this period). In the western portion of the Southeast Area, piezometric levels remained relatively stable from 1988 to 2010 and then gradually increased by about 10 to 20 ft from 2010 to 2018 (see wells CH-18A, C-13, CCPA-1, CCPA-2). In the eastern portion of the Southeast Area, piezometric levels gradually declined by about 10 to 15 ft from 2005-2018 (see wells HCMP-1/1 and HCMP-1/2).

- In general, the occurrence of subsidence has been relatively minor across the Southeast Area, and some areas have recently experienced upward vertical ground motion.

- The magnitude and history of land subsidence differs in different portions of the Southeast Area:
    - In the northwest portion of the Southeast Area, a total of 0.58 ft of subsidence occurred at BM 137/61 from 1987 to 2018, and 0.26 ft of subsidence occurred at BM 133/61 from 2003 to 2018. Both benchmarks have subsided at a similar

rate of 0.02 ft/yr. However, piezometric levels remained relatively stable or increased during this period, which indicates that the downward ground motion is, at least in part, permanent subsidence due to delayed aquitard drainage in response to the historical declines in piezometric levels that occurred from the 1940s to about 1978.

- In the southern portion of the Southeast Area near the CCX, a total of 0.2 ft of subsidence occurred at BM 157/71 from 2003 to 2009 (about 0.03 ft/yr). However, from 2009-2018, the subsidence has virtually ceased.

- In the eastern portion of the Southeast Area, piezometric levels have declined by 10 to 15 ft from 2011-2018, and up to -0.073 ft of vertical ground motion occurred. There is not enough data in this area to determine if a portion of the downward ground motion is permanent land subsidence.

- Generally, the InSAR and ground-level survey results do not always corroborate each other in the spatial pattern and/or magnitude of vertical ground motion where both data-sets overlap. Both monitoring techniques should continue to be used to estimate vertical ground motion across the Southeast Area.

- Figure 3-7b shows an isolated area of downward vertical ground motion located southwest of the intersection of Highway 71 and Soquel Canyon Parkway. The area of downward ground motion is a new feature visible in the InSAR maps for the time-period March 2017 to March 2018. The exact mechanism(s) of the downward ground motion is not known at this time, but there are two potential causes:

    1. *New earthwork construction activities*. The area of downward ground motion spatially corresponds to the area of recent earthwork construction activities. Historical aerial imagery of the area via Google Earth Pro shows open-space land from May 1994 to February 2016. Sometime between February 2016 and October 2016, earthwork construction activities began. The earthwork construction activities are visible in the historical imagery between October 2016 and February 2018.

    2. *Groundwater extraction activities related to new earthwork construction activities*. The Watermaster's database indicates at least one inactive well is located within the area downward ground motion. It is possible that the well was equipped with a pump to supply construction water for the earthwork construction activities, and that groundwater extraction from the well caused the downward ground motion shown on Figure 3-7b.

It is plausible that either one or a combination of the two scenarios described above caused the downward ground motion. In 2018-19, Watermaster staff will investigate with the land owners, and monitoring of this area via InSAR will be conducted in subsequent years.

Figure 3-8 displays the time series of piezometric levels and vertical aquifer-system deformation recorded at the CCX, which began collecting data in July 2012. Groundwater production began at the Chino Creek Well Field in 2014, but appears to have had little, if any, effect on piezometric levels or aquifer-system deformation at the CCX through March 2018. In general, piezometric levels at the CCX have changed very little and show recovering levels since 2012. A small amount of expansion of the aquifer-system has been measured by the CCX extensometers, coincident with piezometric recovery beginning in 2012. From March 2017 to March 2018, piezometric levels in both the shallow and deep piezometers declined slightly—most likely in response to the increase in pumping from both aquifers—and a small amount of compression of the aquifer-system sediments was measured by the CCX extensometers. These observations illustrate the piezometric levels have experienced very little change since 2012 and that the aquifer-system deformation has been elastic.

3.3 Central MZ-1 Area

Vertical ground-motion is measured across the Central MZ-1 Area via InSAR and traditional ground-level surveys. Figures 3-1a and 3-1b illustrate vertical ground motion as estimated by InSAR across Central MZ-1 for 2011-2018 and 2017-2018, respectively. The InSAR results are generally coherent across this area because the overlying land uses are urban and serve as hard, consistent reflectors of radar waves. Ground-level surveys are performed periodically along the eastern portion of the area.

Figure 3-9 is a time-series chart that displays and describes the long-term history of production, recharge, piezometric levels, and vertical ground motion in Central MZ-1. The following observations and interpretations are derived from Figure 3-9 and Figures 3-1a and 3-1b:

- Piezometric data are absent in the southern portion of Central MZ-1. In the northern portion of Central MZ-1, piezometric levels declined by about 200 ft from 1930 to about 1978. From 1978 to 1986, piezometric levels increased by about 80 ft and remained relatively stable from 1986 to 2018. Recent piezometric levels (1986 to 2018) in the northern portion of Central MZ-1 are about 120 ft lower than the piezometric levels of 1930.

- About 1.2 ft of subsidence occurred near Walnut and Monte Vista Avenue from 1993 to 2000, as measured by ground-level surveys at BM 125/49 (about 0.17 ft/yr). Since 2000, the rate of subsidence slowed significantly: about 0.3 ft of subsidence occurred at a gradually declining rate from 2000 to 2018 (about 0.017 ft/yr). This time history and magnitude of vertical ground motion along the eastern side of Central MZ-1 is like the time history and magnitude of vertical ground motion in the Managed Area, which suggests a relationship to the causes of land subsidence in the Managed Area; however, there is not enough historical piezometric level data in this area to confirm this relationship.

- Figures 3-1a and 3-1b show that the areas that experienced the greatest magnitude of subsidence from 2011-2018 are located along the western portion of Central MZ-1 where up to -0.16 ft of vertical ground motion has occurred (about -0.02 ft/yr). Piezometric levels remained relatively stable in this area from 2011 to 2018, which indicates that the downward ground motion is, at least in part, permanent subsidence due to delayed aquitard drainage in response to the historical declines in piezometric levels that occurred from 1930 to 1978.

3.4 Northwest MZ-1 Area

3.4.1 Vertical Ground Motion

Vertical ground motion is measured across the Northwest MZ-1 Area via InSAR and ground-level surveys. The InSAR results are generally coherent across this area because the overlying land uses are urban and serve as hard, consistent reflectors of radar waves. Ground-level surveys have been performed annually in the early spring across the area to complement and check the InSAR estimates of vertical ground motion.

Figures 3-1a illustrates vertical ground motion as estimated by InSAR across Northwest MZ-1 during 2011-2018. Figure 3-10 is a time-series chart that displays and describes the long-term history of production, recharge, piezometric levels, and vertical ground motion in Northwest MZ-1. Figures 3-11a and 3-11b are maps of the most recent data and illustrate vertical ground motion as estimated by InSAR and ground-level surveys across Northwest MZ-1 from January 2014 to March 2018 and from March 2017 to March 2018, respectively. The following observations and interpretations are derived from these figures:

- From about 1930 to 1978, piezometric levels in the Northwest MZ-1 Area declined by about 200 ft. From 1978 to 1985, piezometric levels increased by about 100 ft. From 1985 to 2018 piezometric levels fluctuated but have remained relatively stable. Piezometric levels in 2018 are at least 100 ft lower than the piezometric levels in the 1930s.

- A maximum of about 1.3 ft of subsidence occurred in this area from 1992 through March 2018—an average rate of about -0.05 ft/yr—while piezometric levels have fluctuated but have remained relatively stable. The persistent subsidence that occurred from 1992 to 2018 cannot be entirely explained by the concurrent changes in piezometric levels. A plausible explanation for the subsidence is that thick, slow-draining aquitards are permanently compacting in response to the historical declines in piezometric levels that occurred between 1930 and 1978.

- More recently, subsidence continues to occur in this area at a persistent rate of about -0.04 ft/yr. The InSAR results indicate a maximum of about -0.27 ft of vertical ground motion occurred in Northwest MZ-1 from 2011 to 2018 near the intersection of Indian Hill Boulevard and San Bernardino Avenue. A maximum of about -0.04 ft of vertical ground motion occurred from March 2017 to March 2018 at the same location.

- The ground-level survey results indicate a similar spatial pattern of downward ground motion as was estimated by InSAR; however, ground-level surveys indicate a higher magnitude of downward vertical ground motion compared to the InSAR results. For example, Figure 3-11a shows that both methods indicate that maximum downward ground motion from January 2014 to March 2018 occurred near the intersection Indian Hill Boulevard and San Bernardino Avenue. That said, the InSAR results indicate a maximum of about -0.13 ft of vertical ground motion while ground-level surveys indicate about -0.20 ft of vertical ground motion. This discrepancy is likely related to the differences in timing of the ground-level surveys and the SAR acquisition and/or relative errors associated with each monitoring technique.[12]

3.4.2 Horizontal Ground Motion

Figure 3-1a shows a steep gradient of subsidence across the San Jose Fault in Northwest MZ-1—the same pattern of "differential subsidence" that occurred in the Managed Area during the time of ground fissuring. Differential subsidence can cause an accumulation of horizontal strain in the shallow sediments and the potential for ground fissuring.[13]

To identify potential areas of accumulation of tensile horizontal strain in the shallow soils in this area, annual EDM surveys between closely spaced benchmark monuments that cross the San Jose Fault have been performed annually since December 2013. Figure 3-12 displays the time series of east/west-oriented and north/south-oriented strain between the pairs of closely-spaced benchmarks (see the inset map on Figure 3-12) between 2013 and 2018. For reference, the top left chart on Figure 3-12 shows the downward ground motion in Northwest MZ-1 as estimated by InSAR at Point C on Figure 3-11a. The horizontal strain between most pairs of benchmarks appears to behave elastically—alternating between compressive and tensile deformation between EDM surveys. Tensile strain has been calculated between one pair of benchmarks (B-409 to B-408); however, this magnitude of strain is within the range of elastic strain observed between other pairs of benchmarks. It is premature to draw conclusions at this point. The GLMC should recommend the continuance of annual elevation and EDM surveys across the San Jose Fault Zone during the development of the *Subsidence Management Plan for the Northwest MZ-1 Area*.

3.5 Northeast Area

Prior to 2017, vertical ground motion was estimated across the Northeast Area via InSAR only. In December 2017, a new network of benchmark monuments was installed across the Northeast Area (see Figure 2-2) and surveyed for initial elevations in January 2018. The ground-level surveys will complement and verify the vertical ground motion estimates derived by InSAR.

Figures 3-1a and 3-1b illustrate vertical ground motion as measured by InSAR across the Northeast Area from March 2011 to March 2018 and from March 2017 to March 2018, respectively. Figure 3-13 is a time-series chart that displays and describes the long-term history of production, recharge, piezometric levels, and vertical ground motion in the Northeast Area. The following observations and interpretations are derived from these figures:

---

[12] The general accuracy associated with both monitoring techniques is about +/- 0.02 ft. In addition, the farther away the surveyed benchmarks are from the starting benchmark (i.e. the Ayala Park Extensometer), the larger the potential error and uncertainty in the absolute position of the benchmark (Jim Elliot, personal communication, July 11, 2018). The future Pomona Extensometer (see location on Figure 3-11a) is planned to be used as the starting benchmark for future ground-level surveys in Northwest MZ-1, which will increase the accuracy of future ground-level surveys.

[13] Ground fissuring is the main subsidence-related threat to overlying infrastructure. Watermaster, consistent with the recommendation of the GLMC, has determined that the SMP needs to be updated to include a *Subsidence Management Plan for the Northwest MZ-1 Area* with the long-term objective to minimize or abate the occurrence of the differential land subsidence. Development of this subsidence management plan is an ongoing, multi-year effort of the Watermaster.

- From about 1930 to 1978, piezometric levels in the Northeast Area declined by about 125 ft. From 1978 to about 1985, piezometric levels increased by about 25 ft. From 1985 to 2018 piezometric levels fluctuated but remained relatively stable. However, from 2011 to 2018, piezometric levels in several wells across the area gradually increased by about 5 to 10 ft. In 2018, piezometric levels across the area are about 100 ft lower than the piezometric levels in the 1930s.

- About one foot of subsidence occurred in the Northeast Area near the intersection of Euclid Avenue and Phillips Street ("Point D" on Figure 3-1a) from 1992 to 2018. From 1992 to 2011, the subsidence occurred at a gradual and persistent rate of about 0.04 ft/yr. From 2011 to 2018, the rate has declined to about -0.025 ft/yr. Piezometric levels remained relatively stable in this area from 1992-2018, which indicates that the downward ground motion is, at least in part, permanent subsidence due to delayed aquitard drainage in response to the historical declines in piezometric levels that occurred from 1930 to 1978. The recent decline in the rate of subsidence may be due to recent increases in piezometric levels.

- The InSAR estimates in Figures 3-1a and 3-1b also indicate that downward ground motion has occurred in an area between Vineyard Avenue and Archibald Avenue south of the Ontario International Airport, where a maximum of about -0.16 ft of vertical ground motion occurred from March 2011 to March 2018. Figures 3-1a and 3-1b displays earthquake epicenters over this period, which may indicate an alternative mechanism for the subsidence observed in this portion of the Northeast Area. Section 3.6 below discusses the potential relationship between the seismic activity and land subsidence for the Northeast Area.

3.6 Seismicity

Tectonic displacement of the land surface on either side of geologic faults can be horizontal, vertical, or a combination of both. During a large earthquake, the land surface can deform suddenly (Weischet, 1963; Myers and Hamilton, 1964; Plafker, 1965). Aseismic creep is a process where smaller, more frequent earthquakes cause the land surface to deform more gradually (Harris, 2017). Figure 3-1a and Figure 3-1b display the location and magnitude of earthquake epicenters relative to vertical ground motion from March 2011 to March 2018 and from March 2017 to March 2018, respectively. The following section discusses the possibility of seismic activity as a cause for the historical subsidence in the Northwest MZ-1 and Northeast Areas.

Tectonic movement along the San Jose Fault, including aseismic creep, is a plausible mechanism for the occurrence of the differential land subsidence that has occurred in the Northwest MZ-1 Area. However, the earthquake epicenters shown in Figure 3-1a and Figure 3-1b do not show a spatial relationship to the differential subsidence in Northwest MZ-1. Without direct measurement of aquifer-system deformation, as will be provided by the Pomona Extensometer, tectonic deformation cannot be ruled-out as a mechanism for the observed subsidence in Northwest MZ-1.

Between March 2011 and March 2018 and March 2017 and March 2018, several earthquake epicenters, varying in magnitude (local magnitude) from zero to four, were observed in the

Northeast Area east of Cucamonga Creek and south of Mission Blvd (Figures 3-1a and 3-1b). Figure 3-14 shows that the seismicity observed along the eastern edge of the Northeast Area extends northeast towards the San Jacinto Fault. The observed seismicity may reflect deep-seated convergence between the Perris Block that underlies the Chino Basin and the San Gabriel Mountains south of the Cucamonga Fault Zone (Morton and Yerkes, 1974; Morton et al., 1982; Morton and Matti, 1987).

Currently, there is not enough data and information to determine whether tectonic movement, aquifer-system deformation, or both are the mechanisms of the observed subsidence in the eastern portion of the Northeast Area. Additional monitoring and investigation is necessary to assist in the determination. The GLMC should explore options and potentially develop recommendations for additional monitoring and investigation, including the installation of an extensometer monitoring facility in the Northeast Area, GPS monitoring, and/or a comprehensive study of InSAR and GPS results across the northeast portion of the Chino Basin versus seismicity.

4.1 Conclusions and Recommendations

The main conclusions and recommendations of this annual report are:

- From November 2016 to March 2018, the deep aquifer-system within the Managed Area experienced a cycle of piezometric decline and recovery. The decline in piezometric levels did not exceed the Guidance Level as measured at the PA-7 piezometer at the Ayala Park Extensometer; however, the length of the period of piezometric decline was about 13 months, which, since 2011, is about three to seven months longer than the prior periods of seasonal piezometric decline.

- The aquifer-system deformation that accompanied the most recent cycle of piezometric decline and recovery was mostly elastic; however, a small portion of the deformation (about 0.004 ft) may be inelastic compaction. There are two potential outcomes:

    - The 0.004 ft of compression is permanent compaction of the aquifer-system, which may be due to the relatively long 13-month period of decline in piezometric levels.

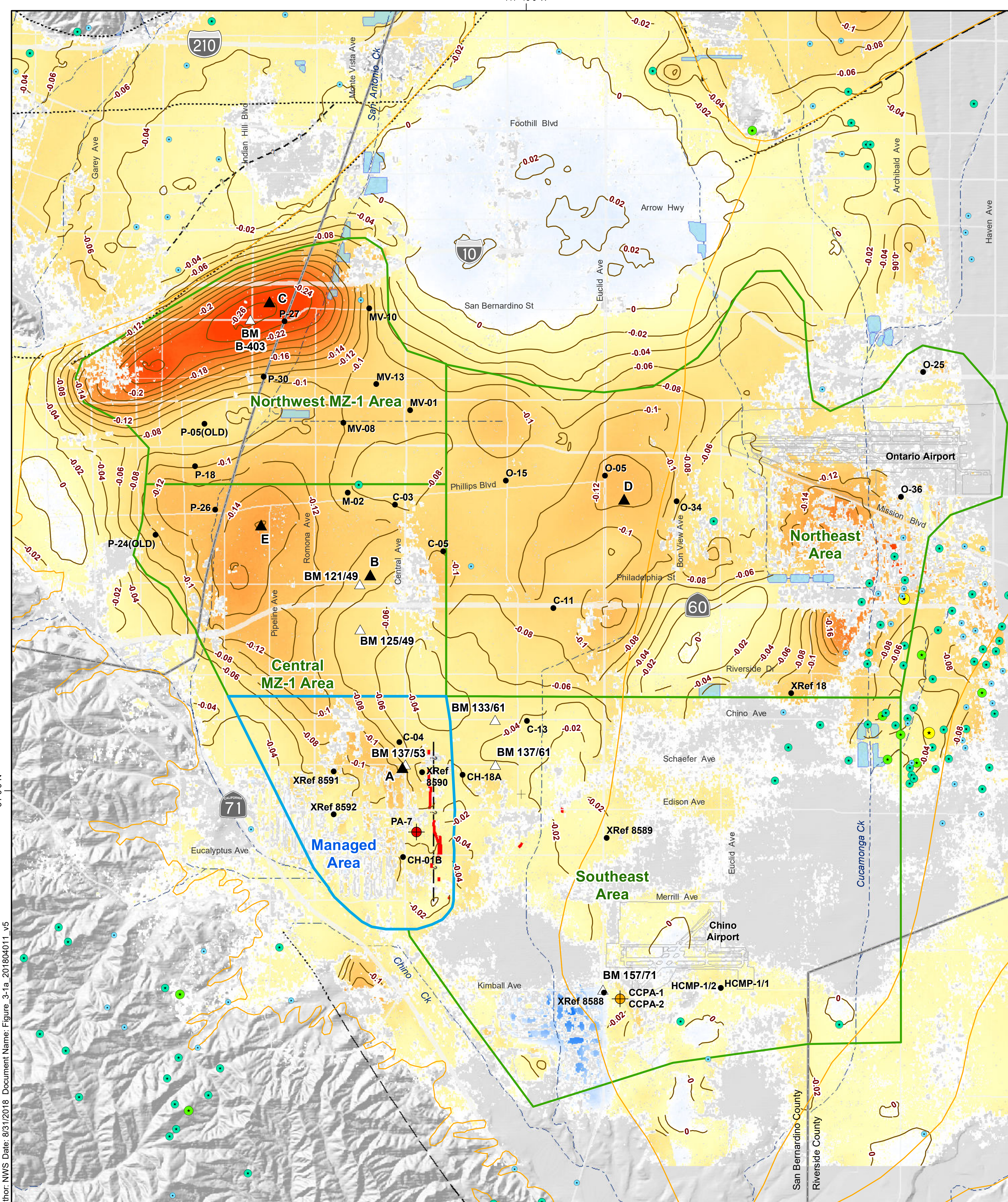
    - The 0.004 ft of compression is elastic (at least in part), and the aquifer-system will expand in a delayed fashion during a future period of full recovery of piezometric levels.

- In the northern portion of the Managed Area, analysis of the InSAR results indicates more than 0.1 ft of downward ground motion from 2011 to 2018. The vertical ground motion in this northern portion of the Managed Area appears to be related to the ground motion Central MZ-1. The next annual report should include an analysis of pair observations of piezometric levels and vertical ground motion to characterize the nature of the vertical ground motion (i.e. elastic vs. inelastic) in the northern portion of the Managed Area.

- In the Southeast Area, the vertical ground motion has been relatively minor since 2011. In fact, in areas near the Chino Creek Desalter Well Field and the CCX, piezometric levels have been relatively stable or increasing, and vertical ground motion has been upward. Based on these observations, ground-level surveys were not recommended for FY 2018/19 in the Southeast Area.

- In other portions of the Southeast Area that have experienced downward ground motion since 2011, piezometric levels remained relatively stable, which suggests that the downward ground motion is, at least in part, permanent subsidence due to delayed aquitard drainage in response to the historical declines in piezometric levels that occurred from the 1940s to about 1978.

- Generally, the InSAR and ground-level survey results in the Southeast Area do not always corroborate each other in the spatial pattern and/or magnitude of vertical ground



Relative Change in Land Surface Altitude as Estimated by InSAR (March 2011 to March 2018)

+ 0.25 ft

0 ft

-0.20

- 0.25 ft

InSAR absent or incoherent

Ayala Park Extensometer

Chino Creek Extensometer

Ground Fissures

Approximate Location of the Riley Barrier

Earthquake Epicenters March 2011 to March 2018 (Local Magnitude)

0 - 1

1 - 2

2 - 3

3 - 4

4 - 5

5 - 6

Wells with Long-Term Time Series of Depth to Groundwater

Location of InSAR with Time Series of Ground Surface Elevation

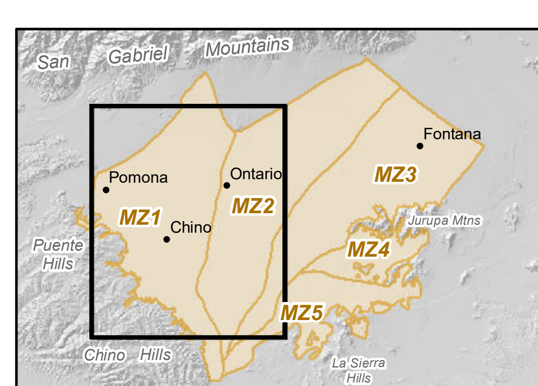
Location of Benchmark with Time Series of Ground Surface Elevation

Managed Area

Areas of Subsidence Concern

Flood Control and Conservation Basins

Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)



0 1 2 Miles

0 1 2 Kilometers

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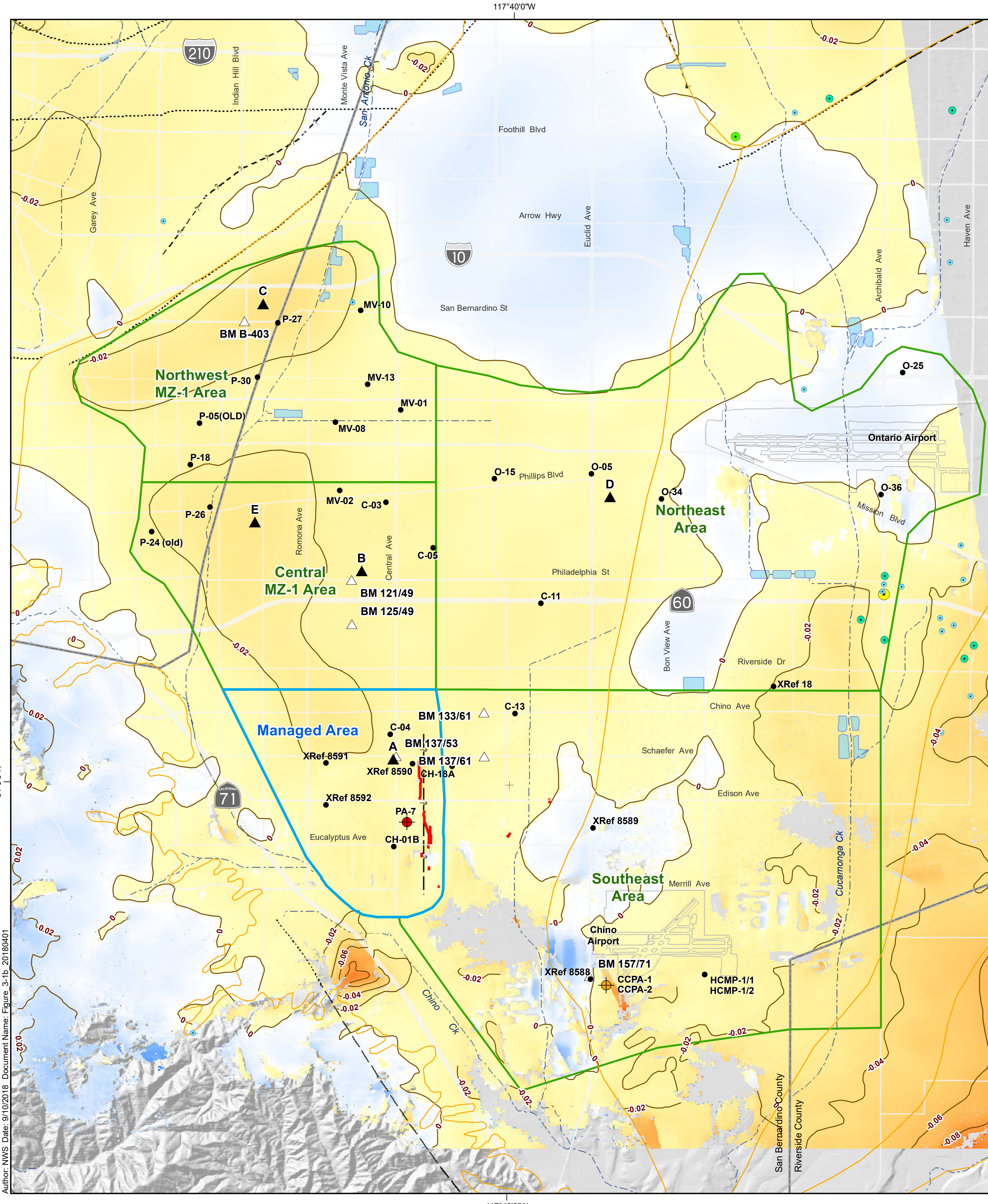
Vertical Ground Motion Across the Western Chino Basin
2011 - 2018

Figure 3-1a

Author: NWS Date: 8/31/2018 Document Name: Figure_3-1a_20180411_v5



Relative Change in Land Surface Altitude as Estimated by InSAR (March 2017 to March 2018)

+ 0.12 ft

0 ft

-0.06

- 0.12 ft

InSAR absent or incoherent

Ayala Park Extensometer

Chino Creek Extensometer

Ground Fissures

Approximate Location of the Riley Barrier

Earthquake Epicenters March 2017 to March 2018 (Local Magnitude)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6

Wells with Long-Term Time Series of Depth to Groundwater

Location of InSAR with Time Series of Ground Surface Elevation

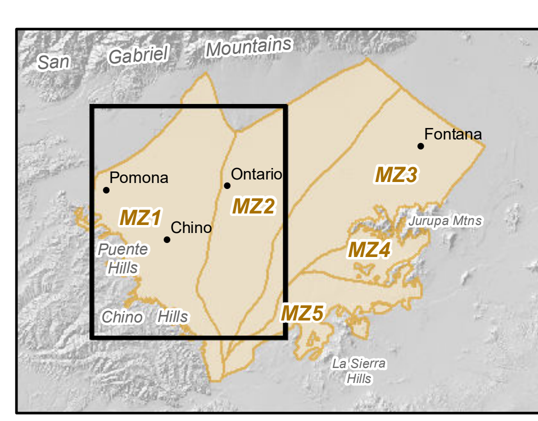
Location of Benchmark with Time Series of Ground Surface Elevation

Managed Area

Areas of Subsidence Concern

Flood Control and Conservation Basins

Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)



0 1 2 Miles

0 1 2 Kilometers

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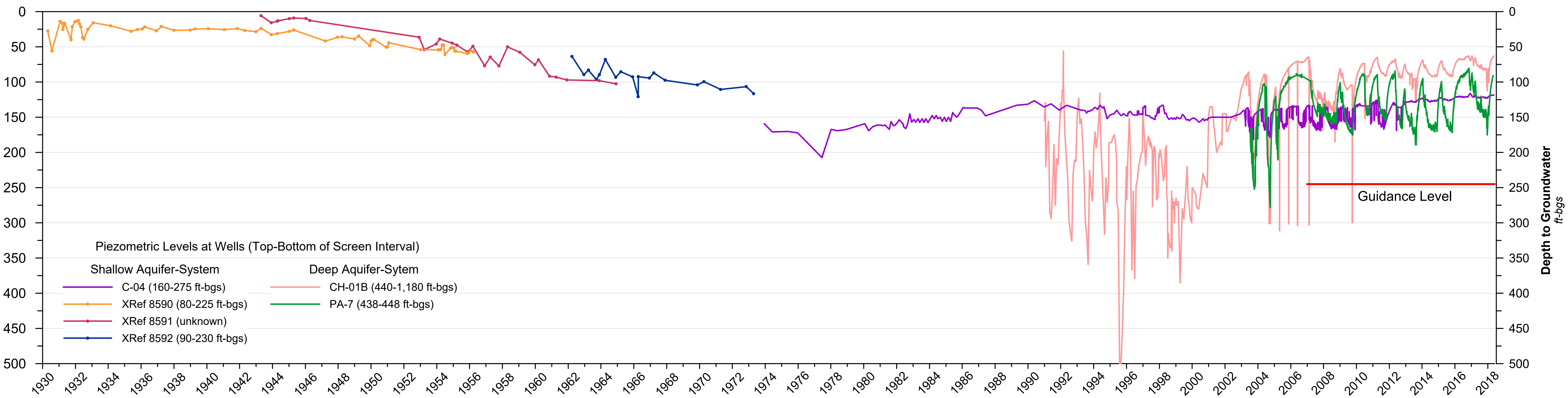
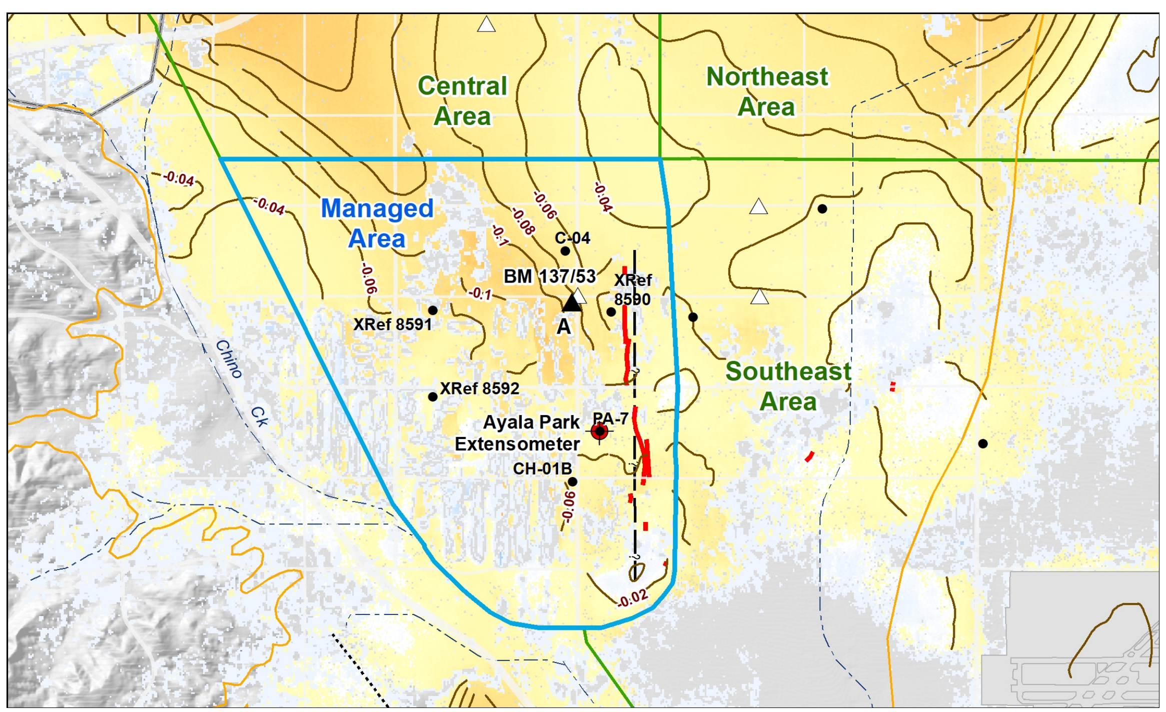
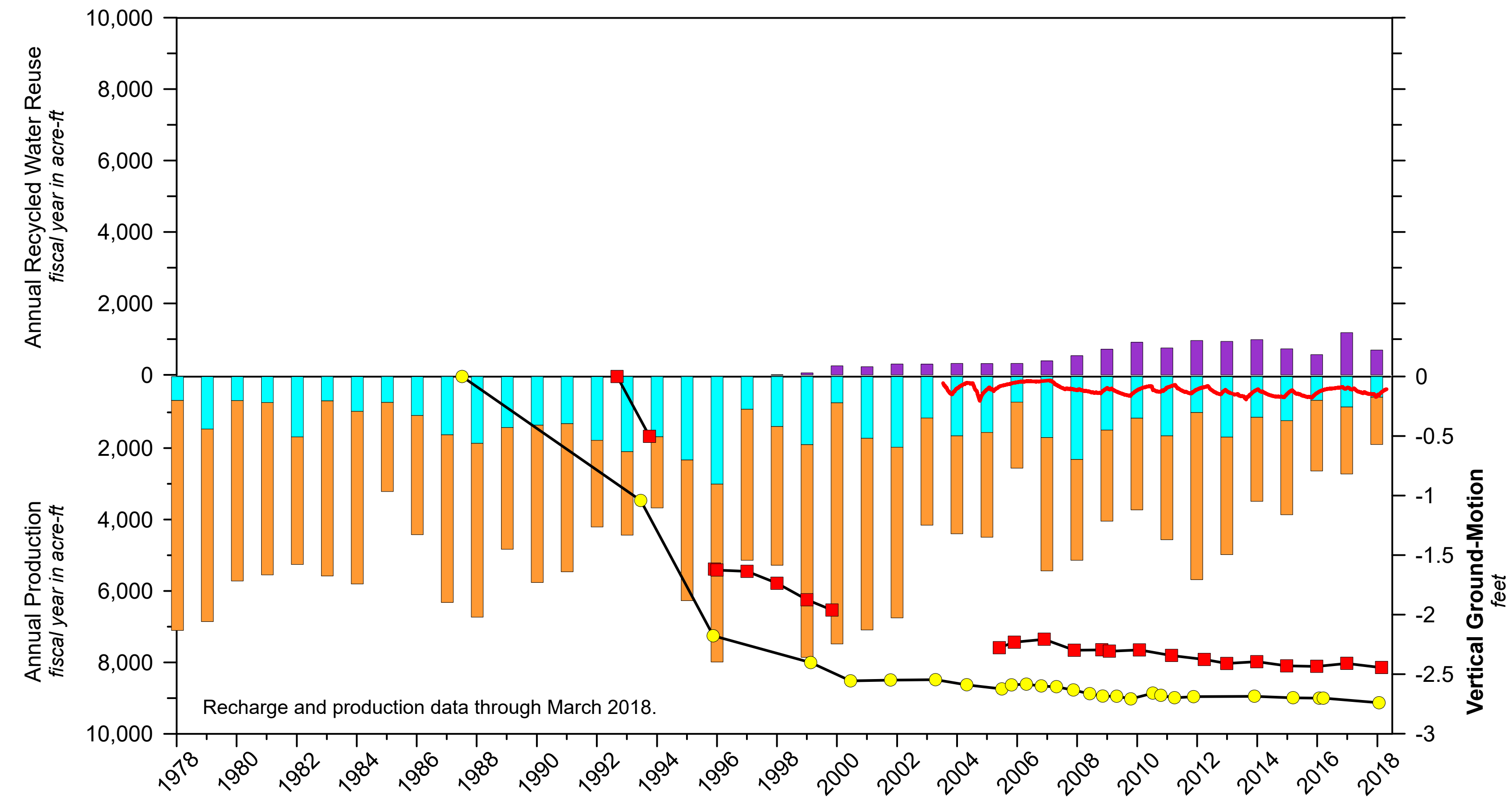
Vertical Ground Motion across the Western Chino Basin
2017/18

Figure 3-1b





See Figure 3-1a for map item descriptions.



Vertical Ground-Motion (Cumulative Displacement)

InSAR Point A (see inset)

BM 137/53

Ayala Park Deep Extensometer Measures between: 30 and 1,440 ft-bgs

Recylced Water Reuse and Production

Recycled Water Direct Reuse

Groundwater Production

Shallow Aquifer or Unknown Aquifer

Deep Aquifer or Both Aquifers

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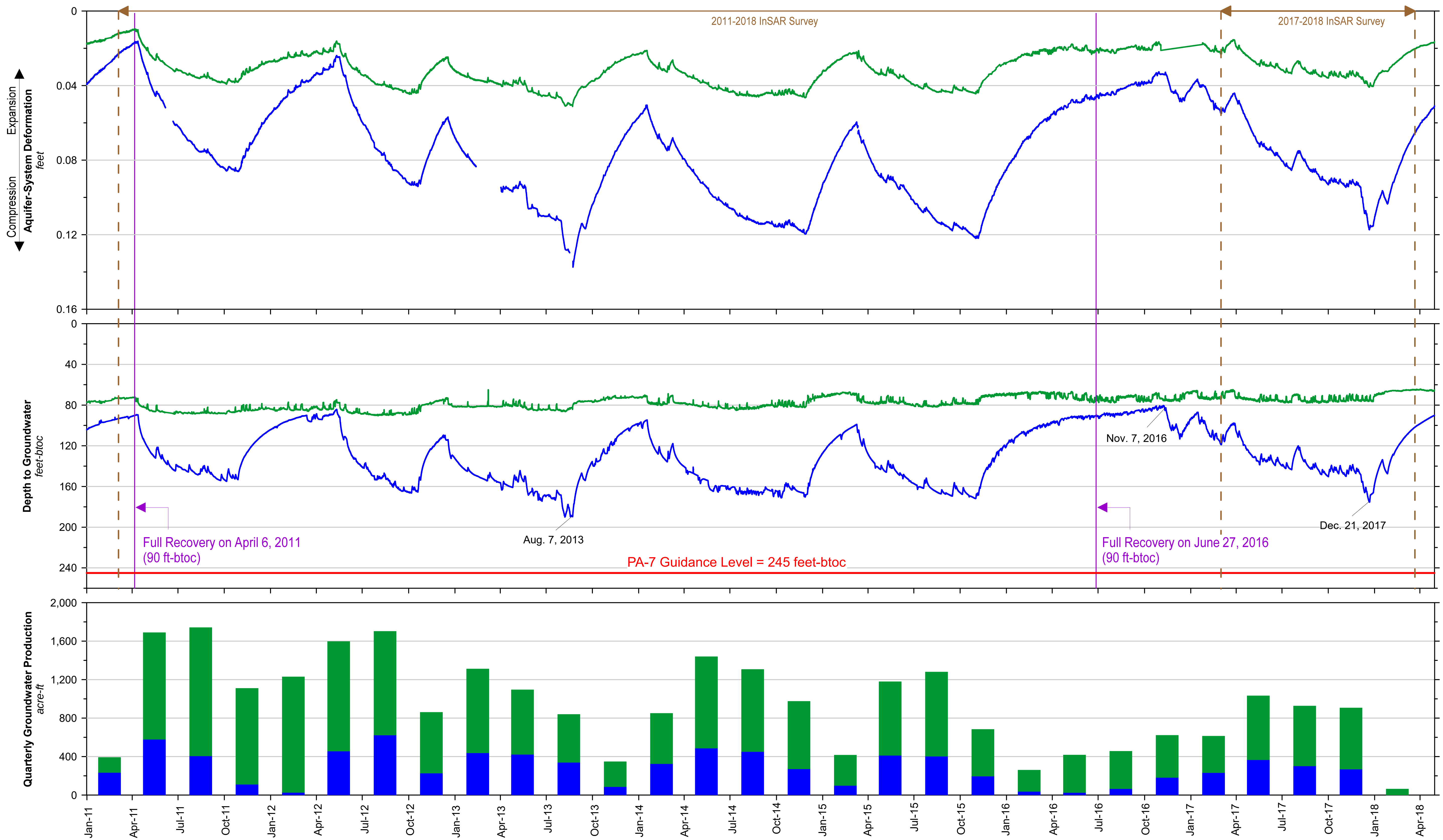
The History of Land Subsidence in the Managed Area

Figure 3-2



Aquifer-System Deformation at Ayala Park
(Extensometer Depth Interval)

Shallow Extensometer
(30-550 ft-bgs)

Deep Extensometer
(30-1,400 ft-bgs)

Piezometric Levels at Ayala Park
(Perforated Depth Interval)

Shallow Piezometer
PA-10 (213-233 ft-bgs)

Deep Piezometer
PA-7 (438-448 ft-bgs)

Groundwater Production
(see Table 3-1 for groundwater production by well)

Shallow Aquifer

Deep Aquifer

*Production data only available through March 2018

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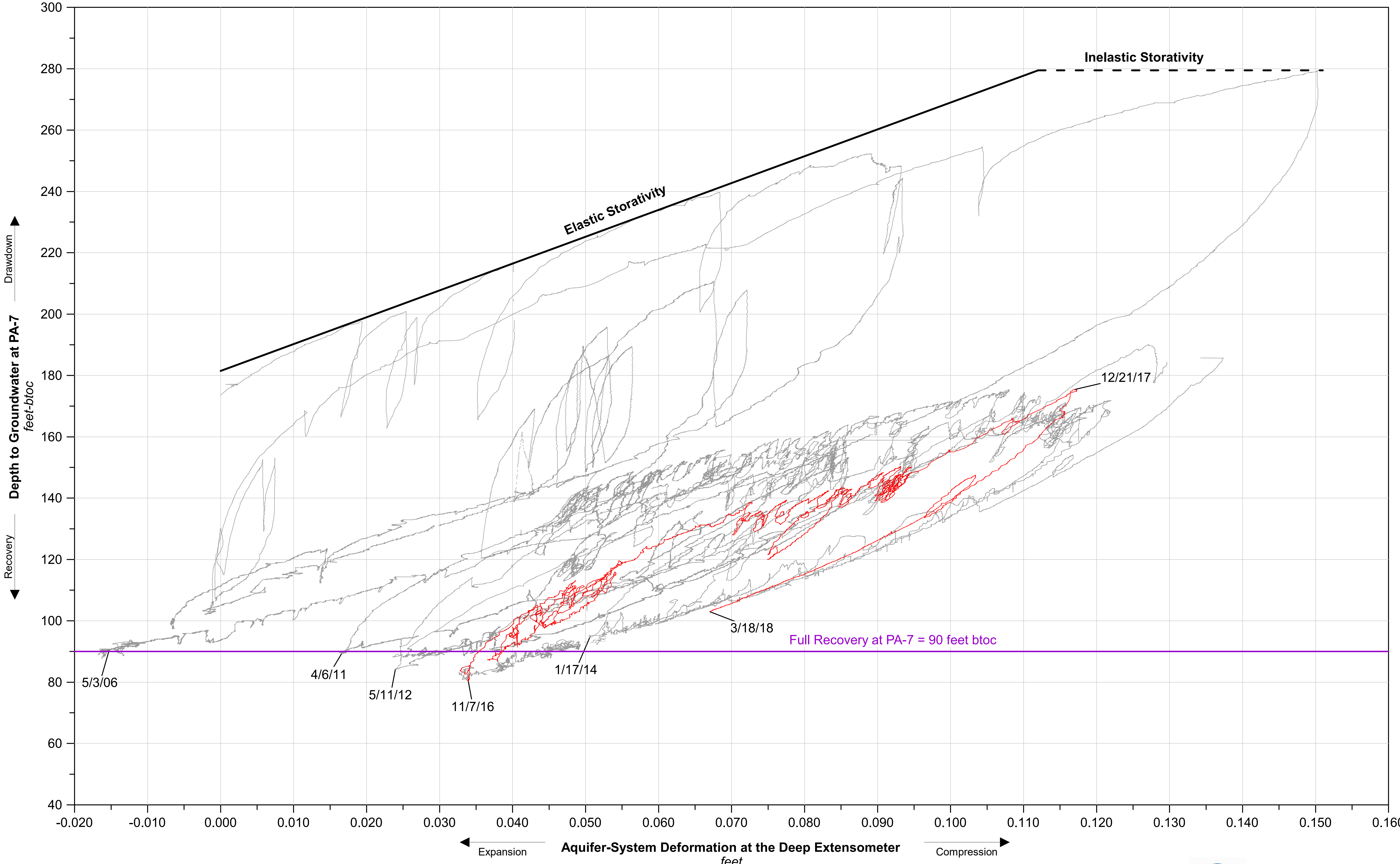
Stress and Strain within the Managed Area

Figure 3-3



Stress - Strain Hysteresis Loops
of Drawdown and Recovery Cycles

Drawdown and Recovery Between July 2003 and November 2016
Drawdown and Recovery Between November 2016 and March 2018

*PA-7 Well-Screen Interval: 438-448 ft-bgs
Depth Interval of the Deep Extensometer: 30-1,400 feet-bgs

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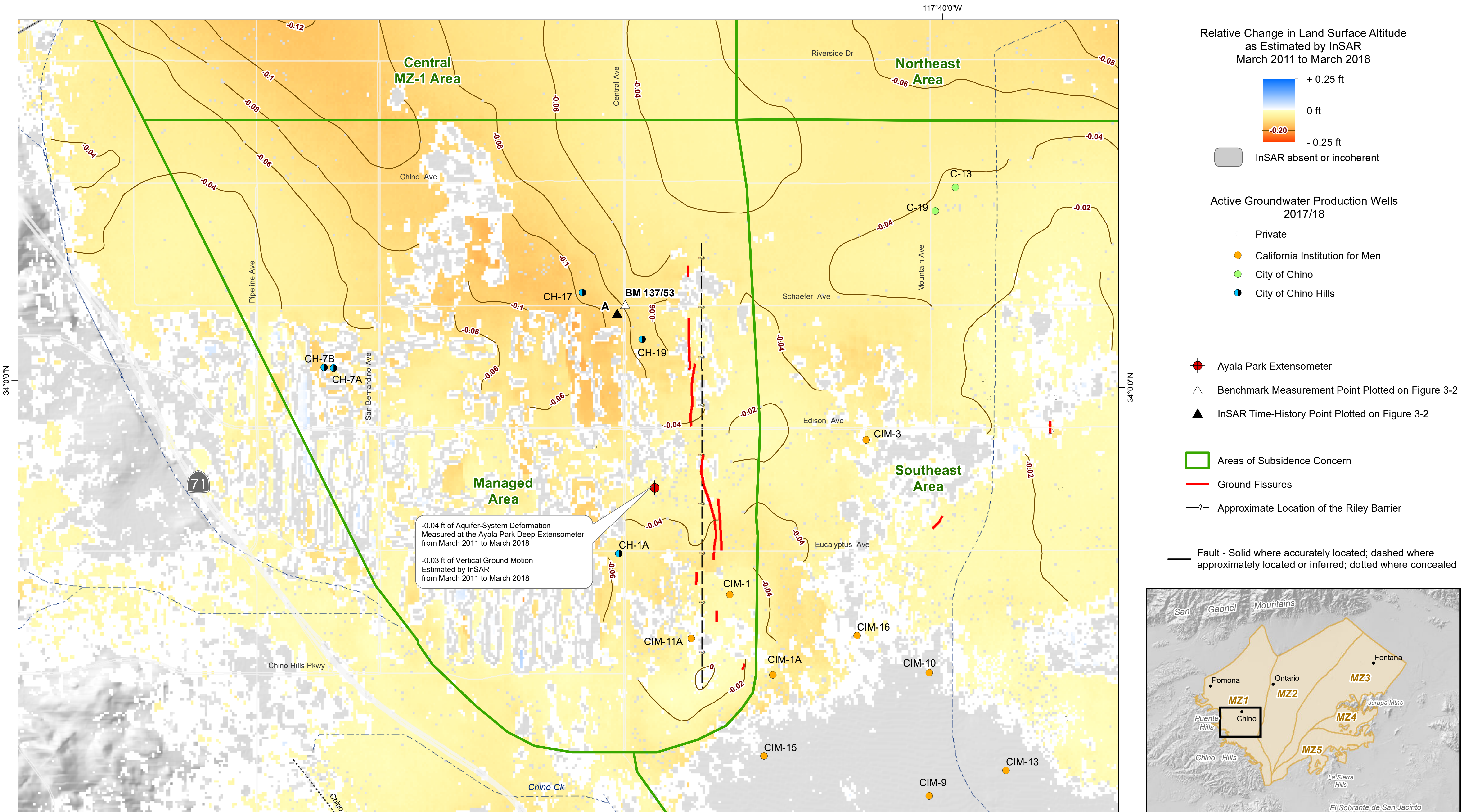
Stress-Strain Diagram
Ayala Park Extensometer

Figure 3-4



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Author: NWS
Date: 9/10/2018
Document Name: Figure_3-5a_20180711

0 0.5 1 Miles
0 0.5 1 Kilometers

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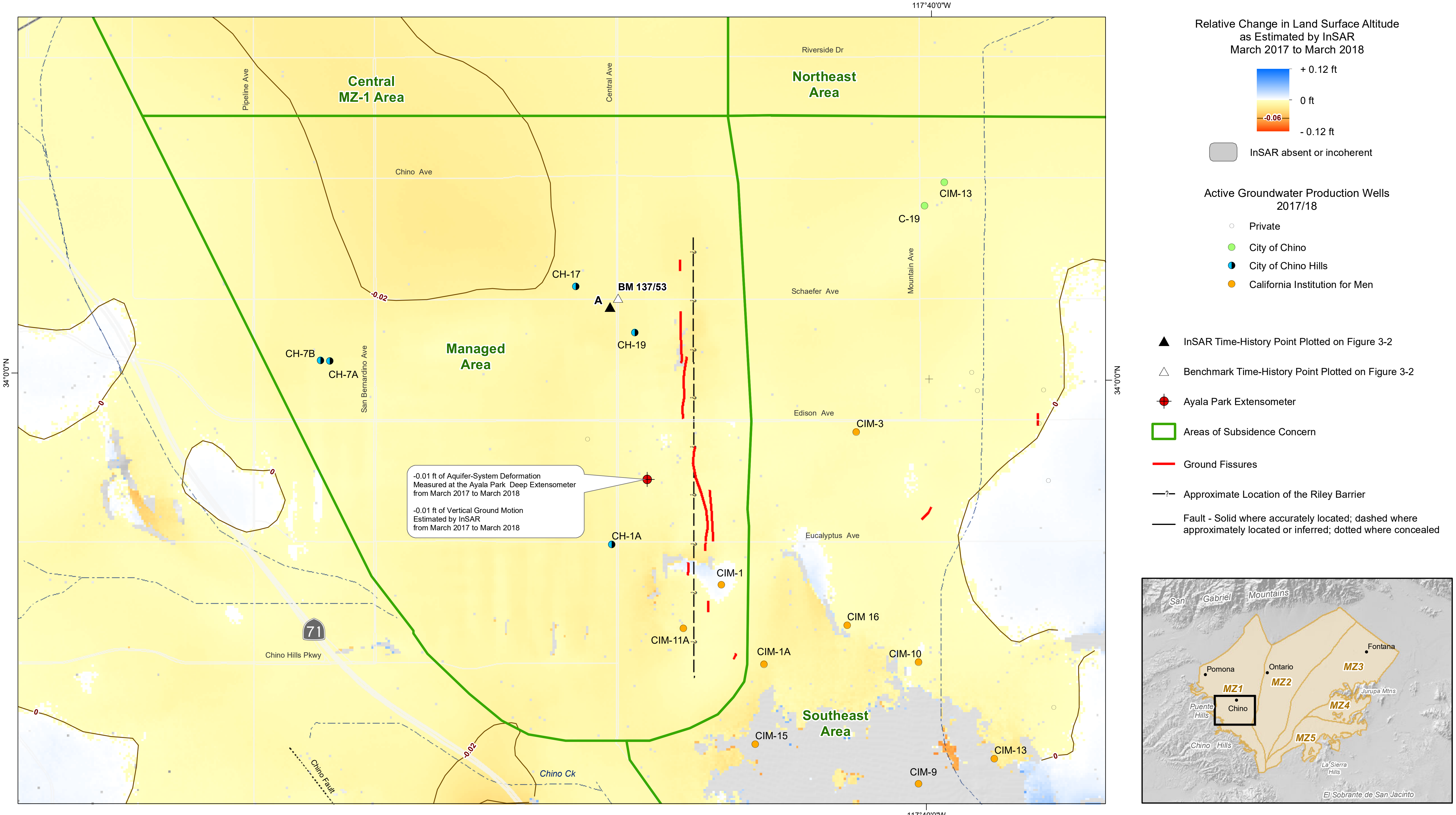
Vertical Ground Motion across the Managed Area
2011 - 2018

Figure 3-5a



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Author: NWS
Date: 9/10/2018
Document Name: Figure_3-5b_20180401

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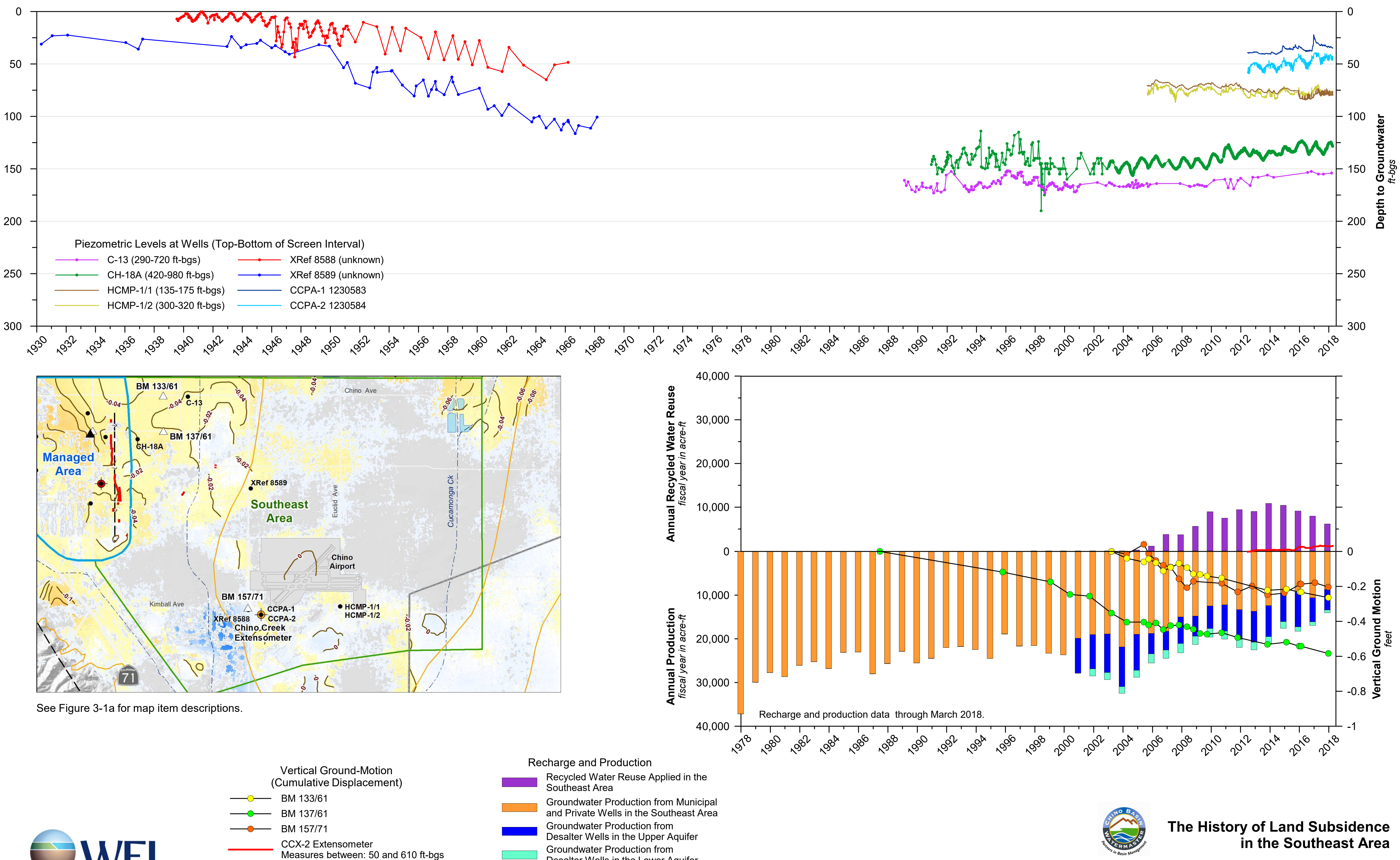
Vertical Ground Motion across the Managed Area
2017/18

Figure 3-5b



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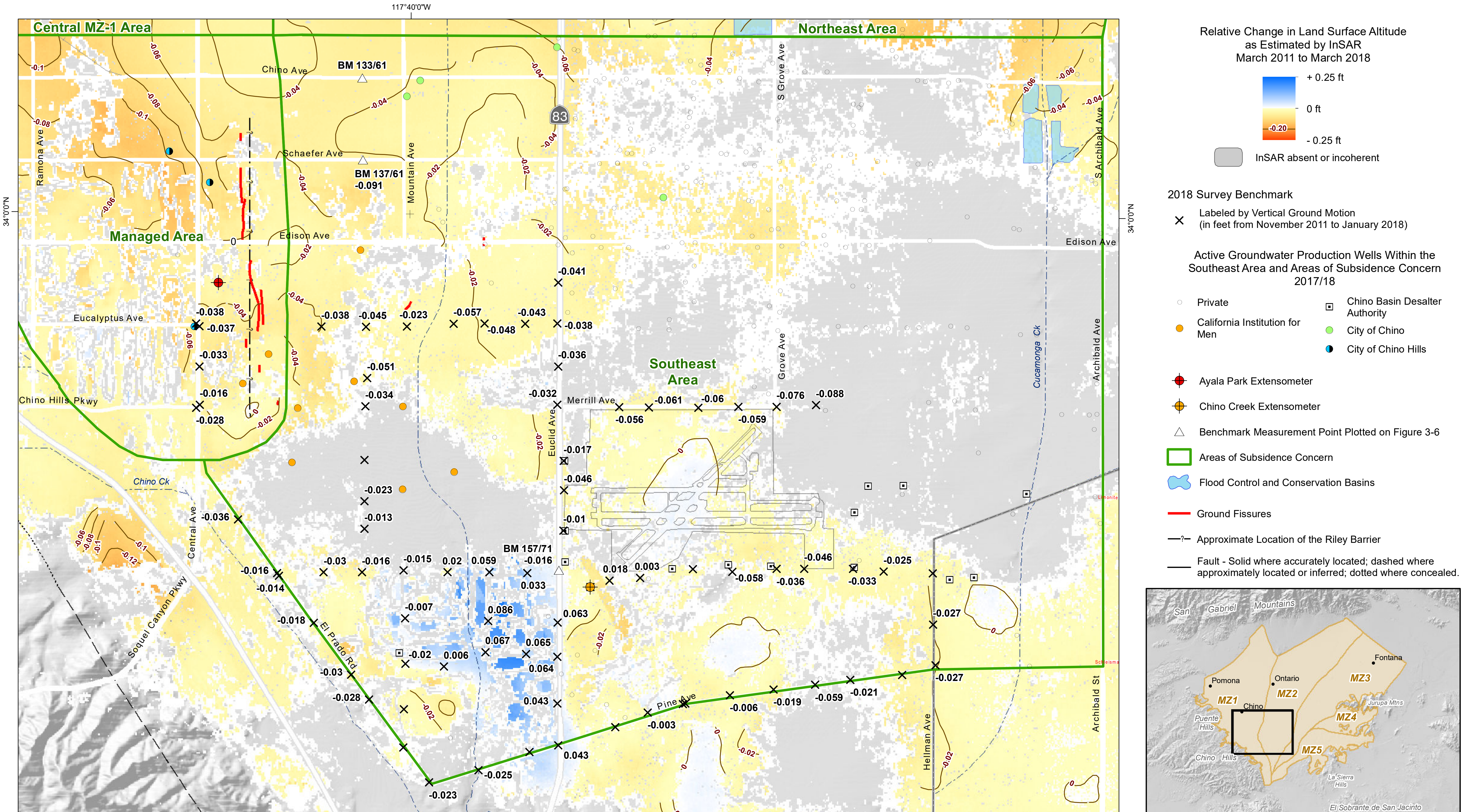
The History of Land Subsidence in the Southeast Area

Figure 3-6



Author: NWS
Date: 10/30/2018
Document Name: Figure_3-7a_20180711

0 0.5 1 Miles
0 0.5 1 Kilometers

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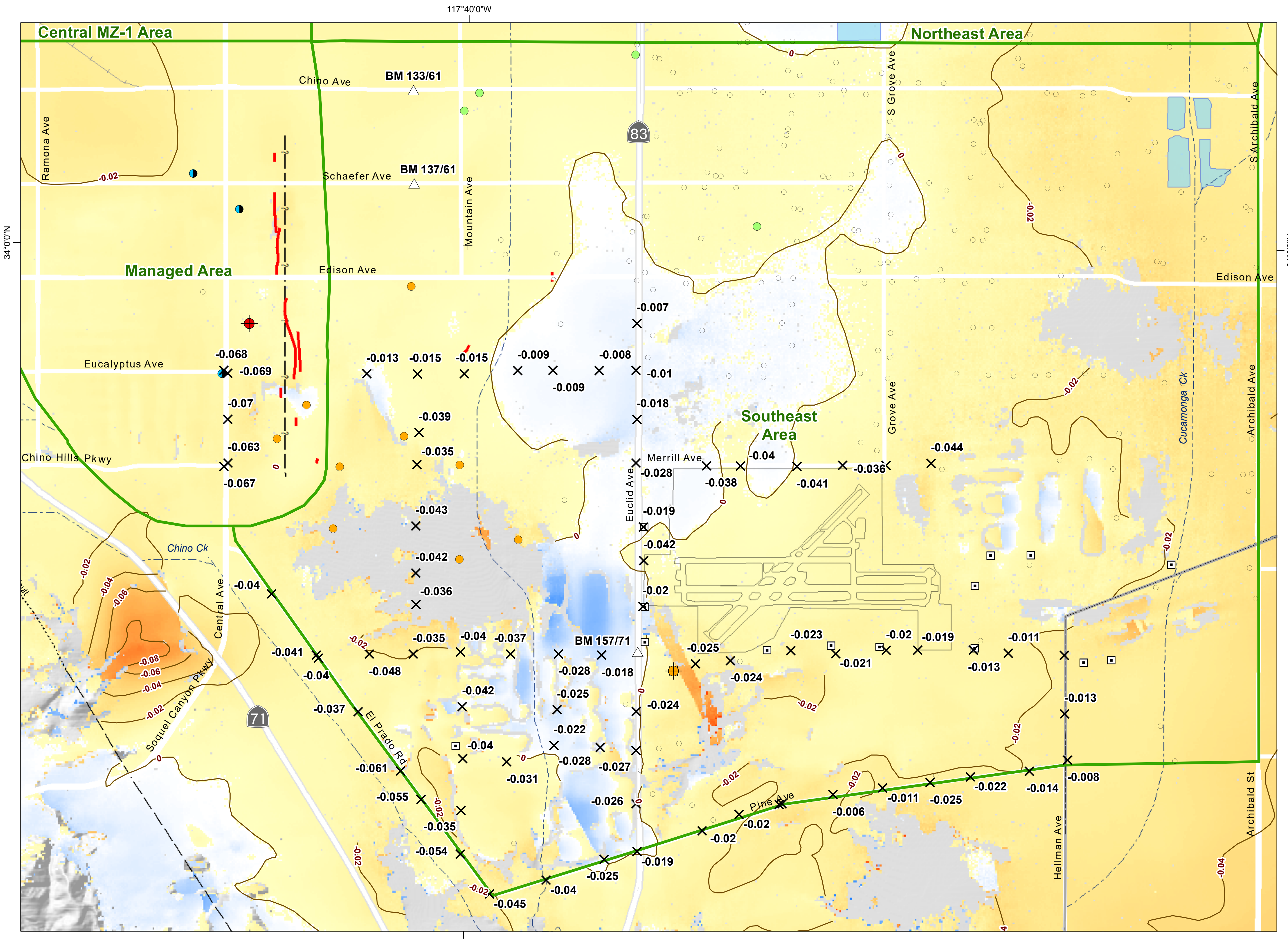
Vertical Ground Motion across the Southeast Area
2011 - 2018

Figure 3-7a



Relative Change in Land Surface Altitude as Estimated by InSAR March 2017 to March 2018

+ 0.12 ft

0 ft

-0.06

- 0.12 ft

InSAR absent or incoherent

2018 Survey Benchmark

Labeled by Vertical Ground Motion (in feet from February 2017 to January 2018)

Active Groundwater Production Wells Within the Southeast Area and Areas of Subsidence Concern 2017/18

- Private
- City of Chino
- California Institution for Men
- City of Chino Hills
- Chino Basin Desalter Authority

Ayala Park Extensometer

Chino Creek Extensometer

Benchmark Measurement Point Plotted on Figure 3-6

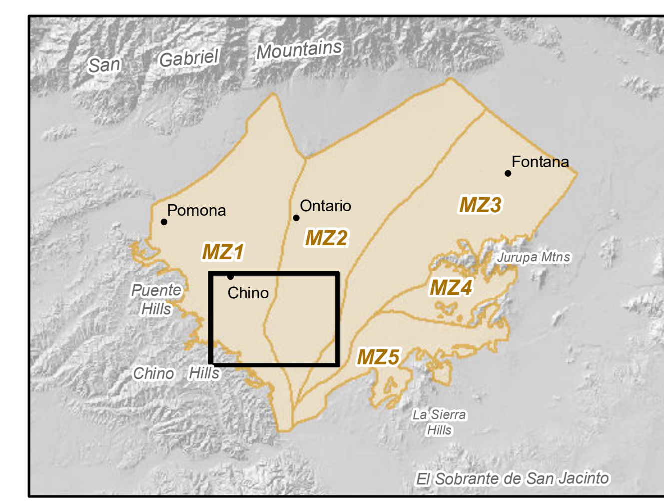
Areas of Subsidence Concern

Flood Control and Conservation Basins

Ground Fissures

Approximate Location of the Riley Barrier

Fault - Solid where accurately located; dashed where approximately located or inferred; dotted where concealed.



0 0.5 1 Miles

0 0.5 1 Kilometers

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Author: NWS
Date: 10/30/2018
Document Name: Figure_3-7b_20181018

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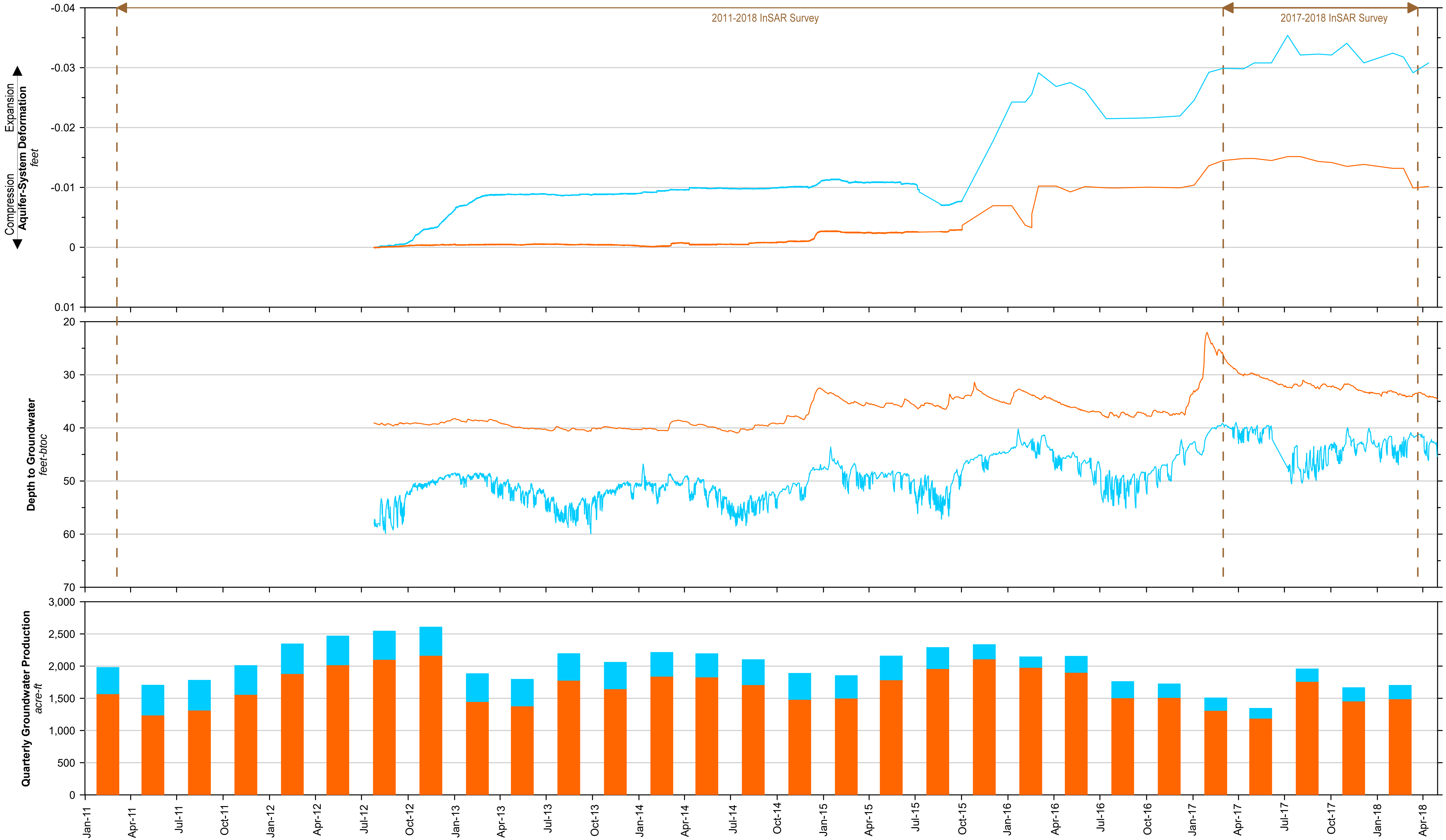
Vertical Ground Motion across the Southeast Area
2017/18

Figure 3-7b



Aquifer-System Deformation
(Extensometer Depth Interval)

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

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

Piezometric Levels
(Perforated Depth Interval)

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

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

CDA Groundwater Production

Shallow Aquifer[1]

Deep Aquifer[2]

1 = CDA-5 through 11, 16, 17, 20 and 21
2 = CDA-1 through 4

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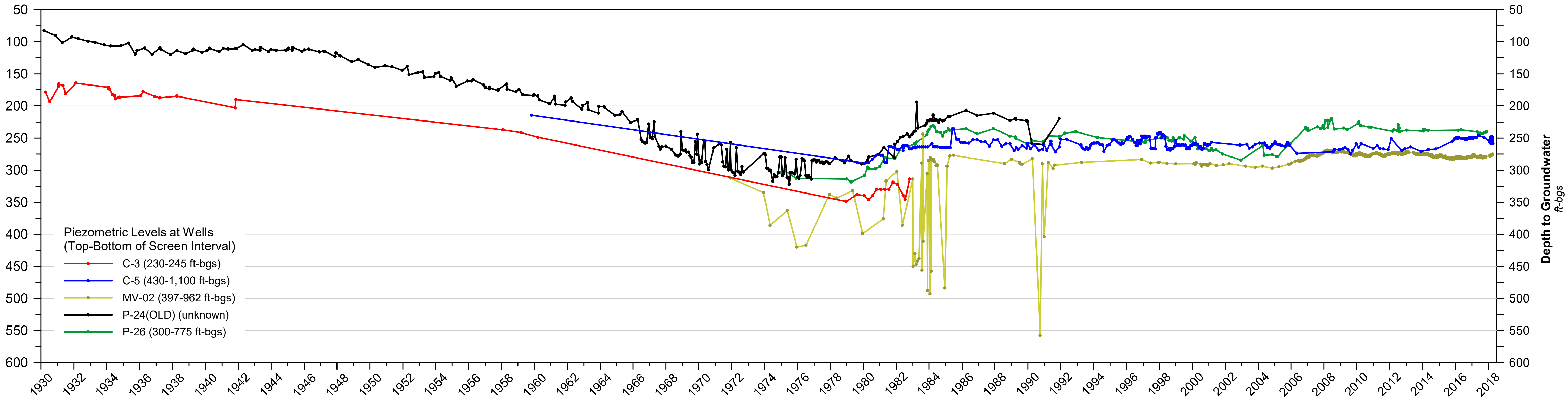
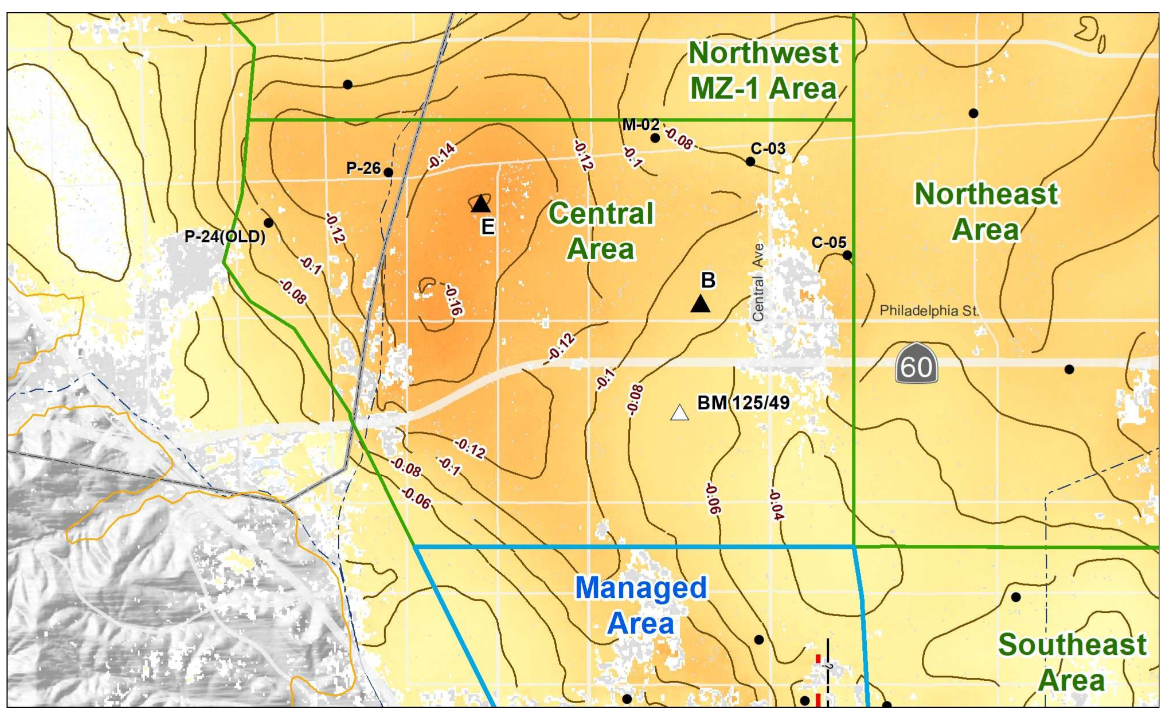
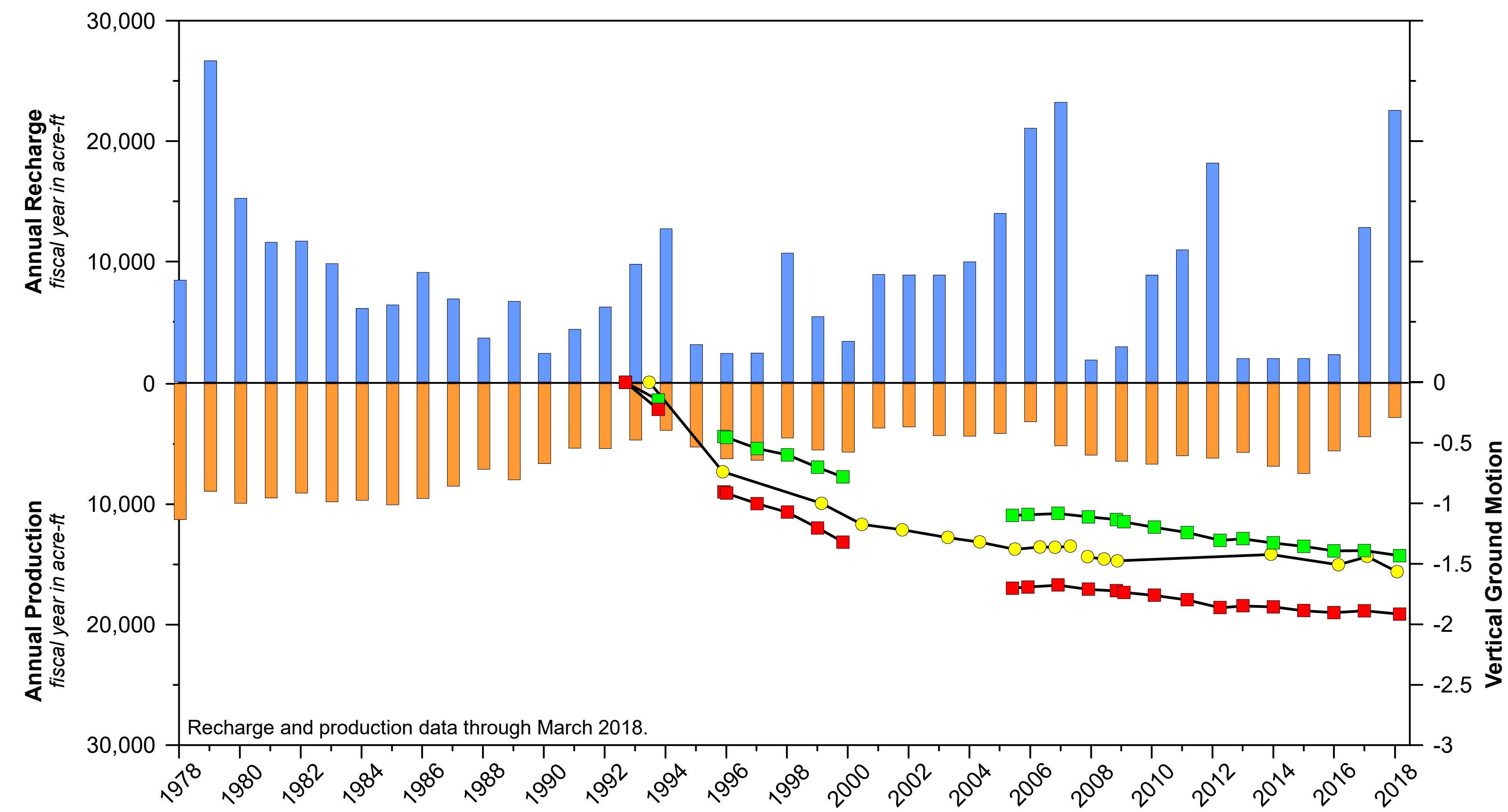
Stress and Strain within the Southeast Area

Figure 3-8





See Figure 3-1a for map item descriptions.



Vertical Ground Motion
(Cumulative Displacement)

- InSAR Point B (see inset)
- InSAR Point E (see inset)
- BM 125/49

Recharge and Production

- Recharge of Recycled Water, Storm-water,* and Imported Water at the College Heights, Upland, Montclair, and Brooks Recharge Basins; and, at MVWD ASR Wells
  *Storm-water is an estimated amount prior to fiscal year 2004/05
- Groundwater Production from Wells in Central MZ-1 Area

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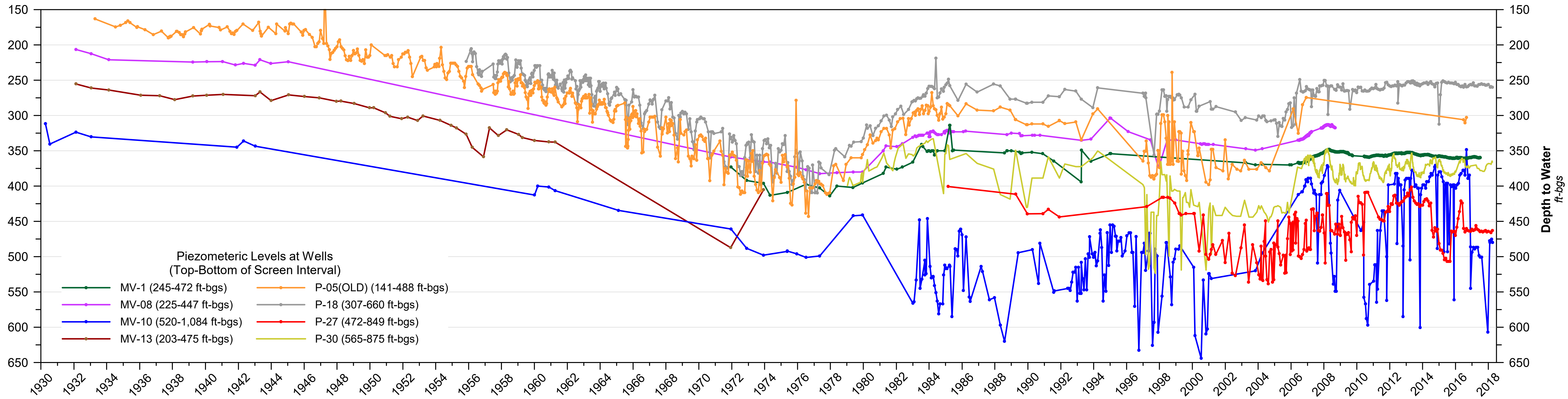
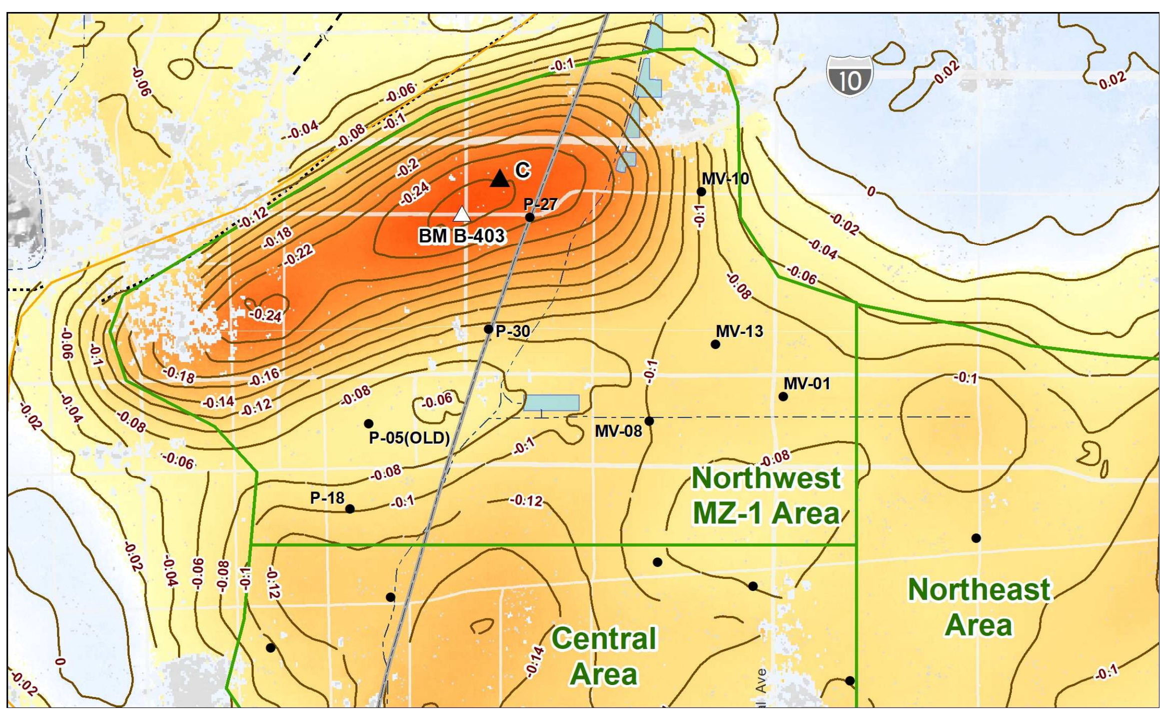
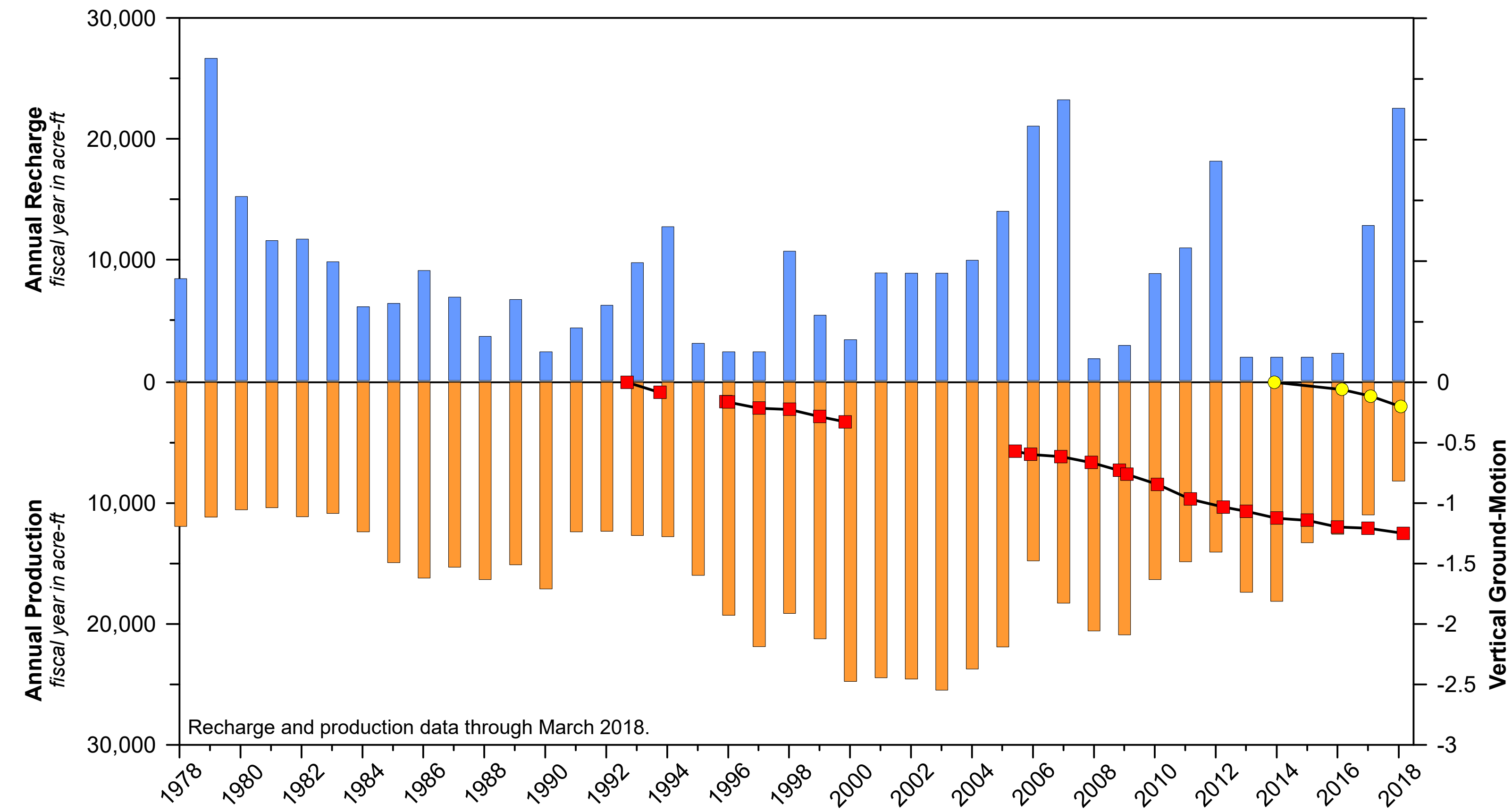
The History of Land Subsidence in the Central MZ-1 Area

Figure 3-9





See Figure 3-1a for map item descriptions.



Vertical Ground-Motion
(Cumulative Displacement)

InSAR Point C (see inset)

BM B-403

Recharge and Production

Recharge of Recycled Water, Storm-water,* and Imported Water at the College Heights, Upland, Montclair, and Brooks Recharge Basins; and, at MVWD ASR Wells
*Storm-water is an estimated amount prior to fiscal year 2004/05

Groundwater Production from Wells in the Northwest MZ-1 Area

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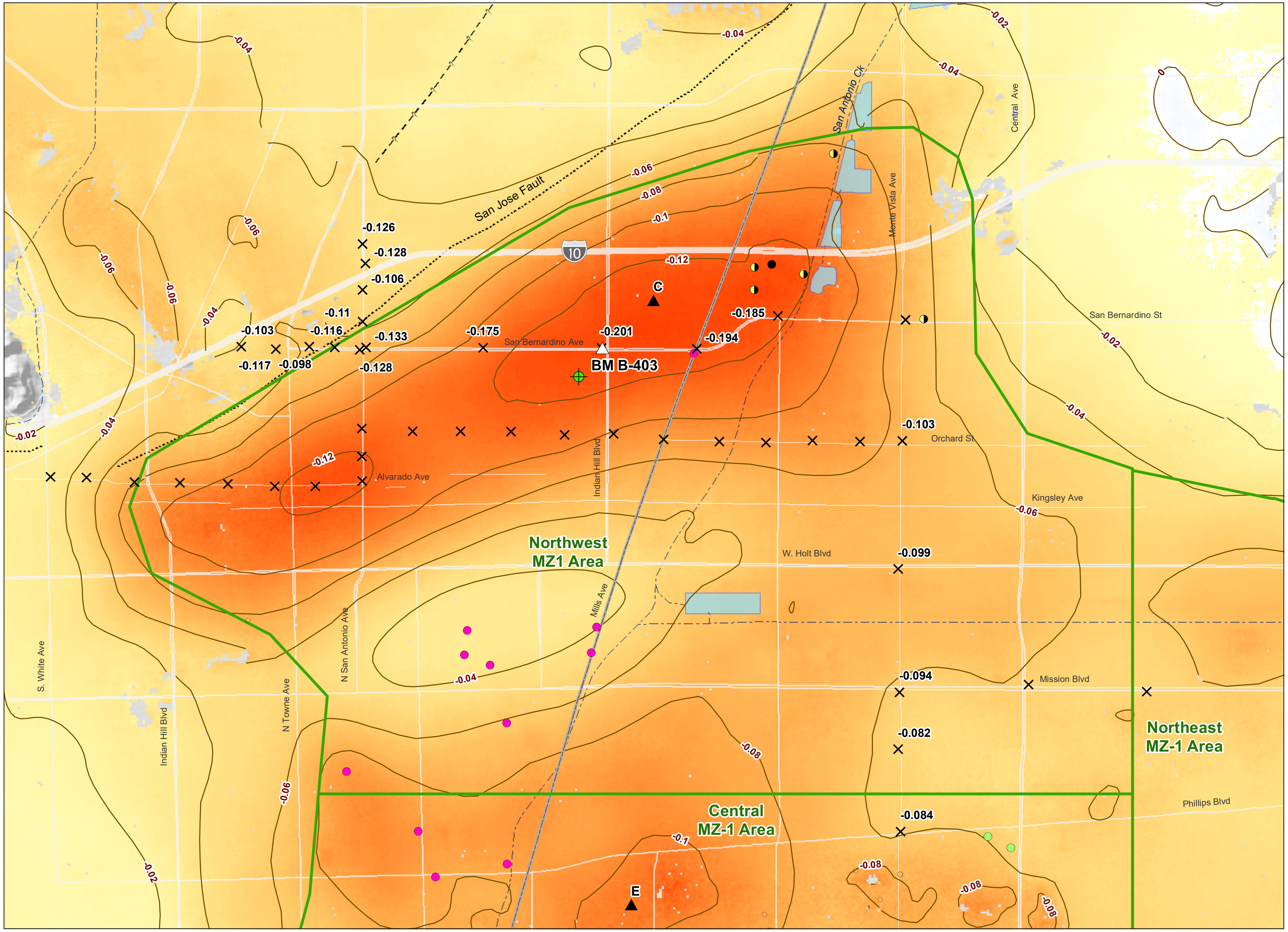
The History of Land Subsidence in the Northwest MZ-1 Area

Figure 3-10



Relative Change in Land Surface Altitude
as Estimated by InSAR
January 2014 to March 2018

+ 0.13 ft
0 ft
-0.07
- 0.13 ft

InSAR absent or incoherent

2018 Survey Benchmark

Labeled by Vertical Ground Motion (in feet from December 2013 to January 2018)

Active Groundwater Production Wells Within the Northwest Area and Areas of Subsidence Concern 2017/18

- Private
- City of Chino
- City of Pomona
- Golden State Water Company
- Monte Vista Water District

Planned Location of the Pomona Extensometer Facility

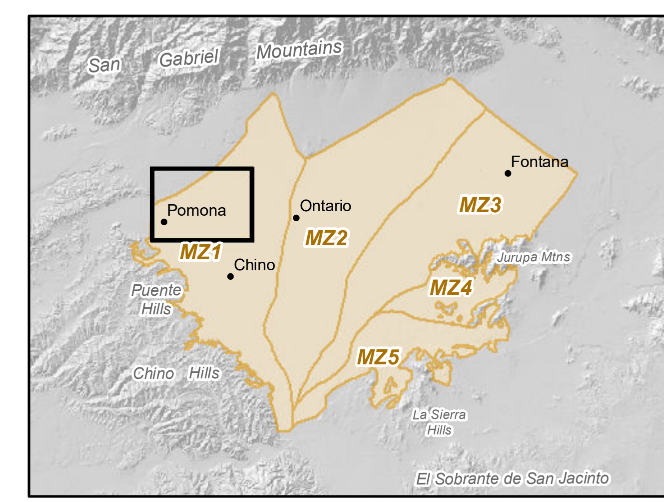
Benchmark Time-History Point Plotted on Figure 3-10

InSAR Time-History Point Plotted on Figure 3-10

Areas of Subsidence Concern

Flood Control and Conservation Basins

Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)



0 0.5 1 Miles
0 0.5 1 Kilometers

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Author: NWS
Date: 9/10/2018
Document Name: Figure_3-11a_20180830

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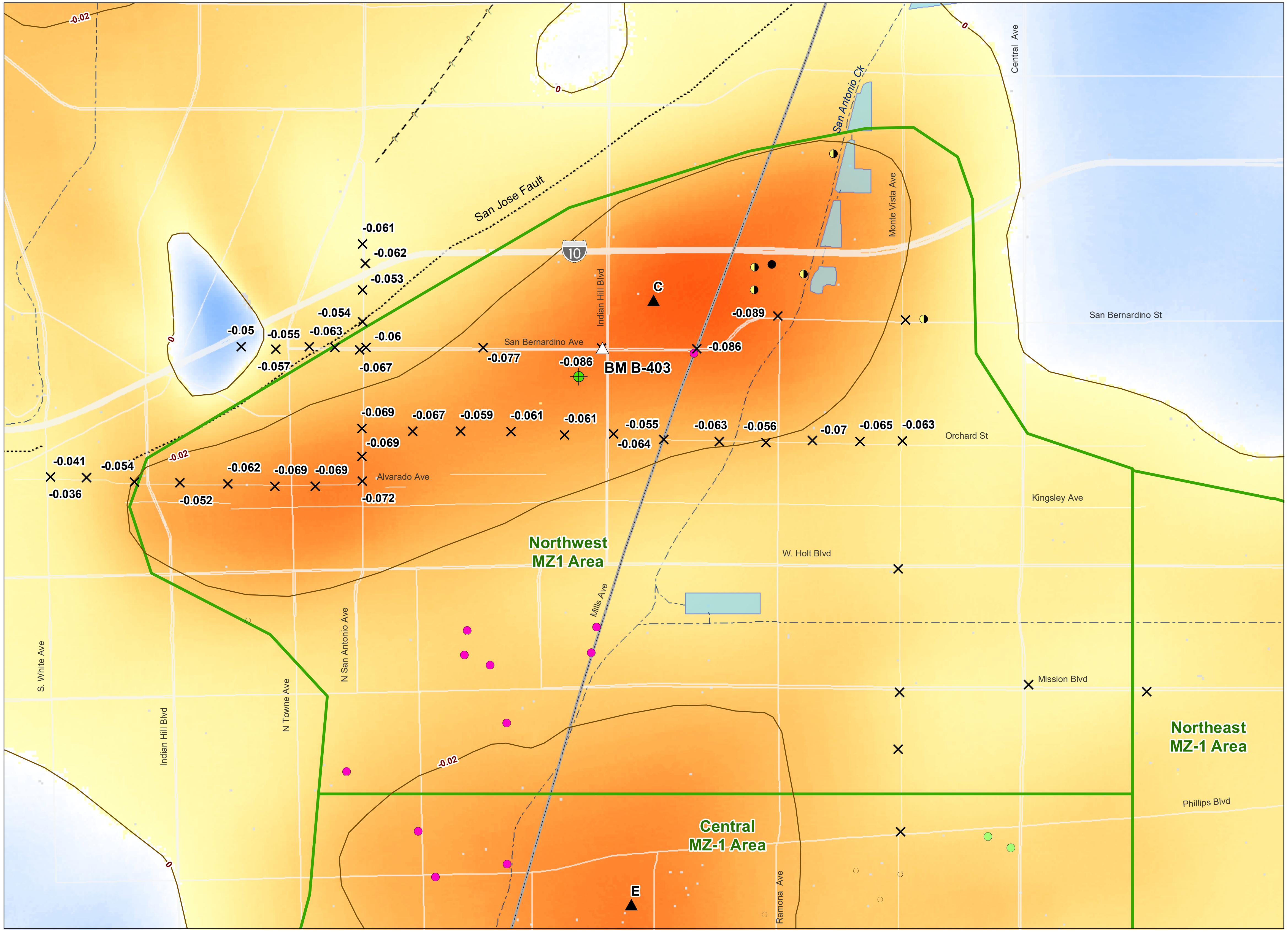
Vertical Ground Motion across the Northwest MZ-1 Area
2014 - 2018

Figure 3-11a



Relative Change in Land Surface Altitude
as Estimated by InSAR
March 2017 to March 2018

+ 0.04 ft
0 ft
-0.02
- 0.04 ft

InSAR absent or incoherent

2018 Survey Benchmark

Labeled by Vertical Ground Motion
(in feet from February 2017 to January 2018)

Active Groundwater Production Wells Within the
Northwest Area and Areas of Subsidence Concern
2017/18

Private
City of Chino
City of Pomona
Golden State Water Company
Monte Vista Water District

Planned Location of the Pomona Extensometer Facility

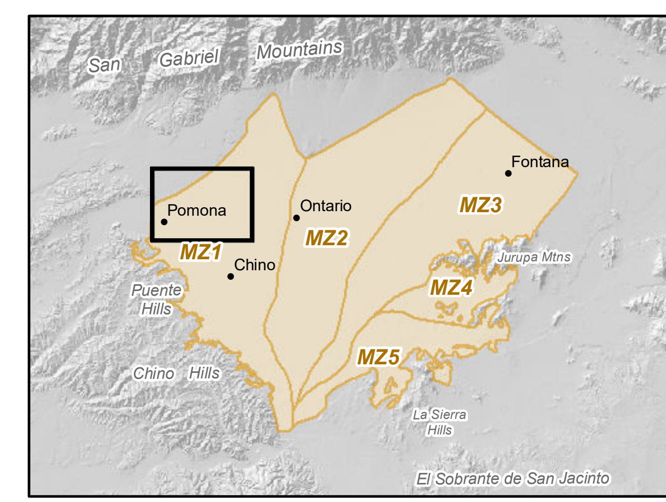
Benchmark Time-History Point Plotted on Figure 3-10

InSAR Time-History Point Plotted on Figure 3-10

Areas of Subsidence Concern

Flood Control and Conservation Basins

Fault (solid where accurately located; dashed where
approximately located or inferred; dotted where concealed)



WILDERMUTH ENVIRONMENTAL, INC.

Author: NWS
Date: 9/10/2018
Document Name: Figure_3-11b_20180830

0 0.5 1 Miles
0 0.5 1 Kilometers

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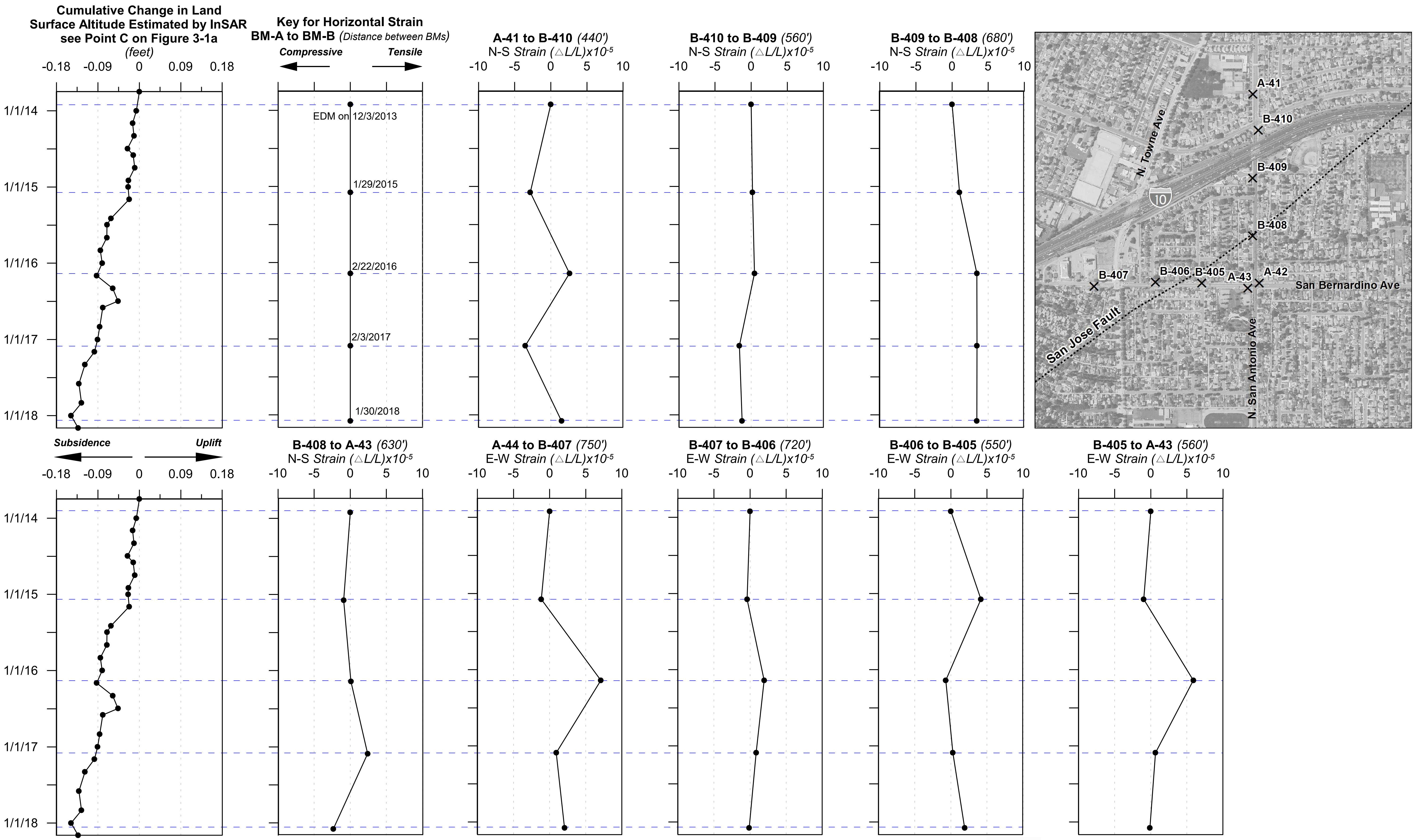
Vertical Ground Motion across the Northwest MZ-1 Area
2017/18

Figure 3-11b



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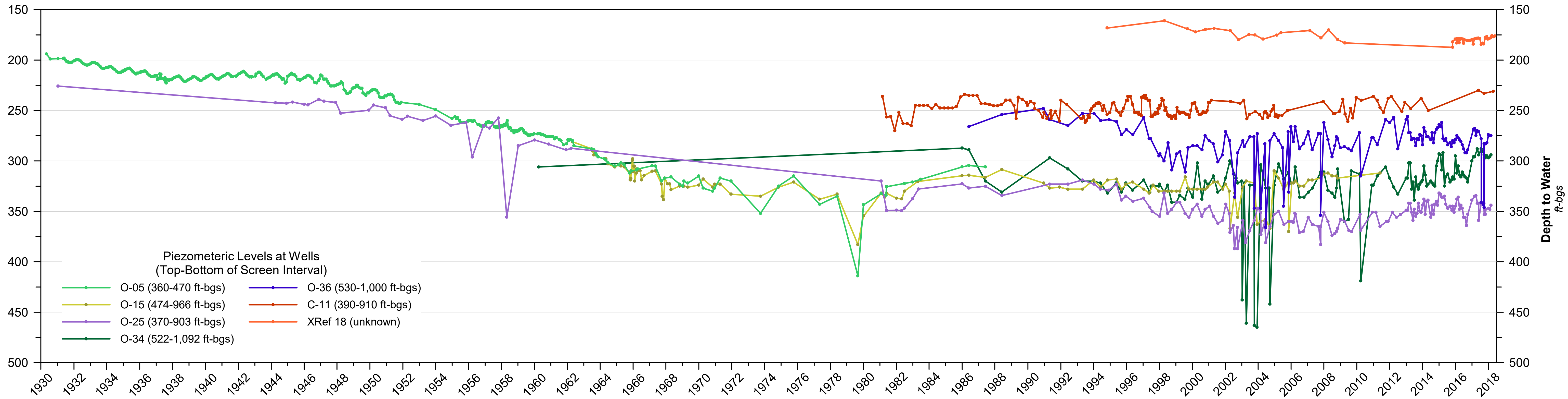
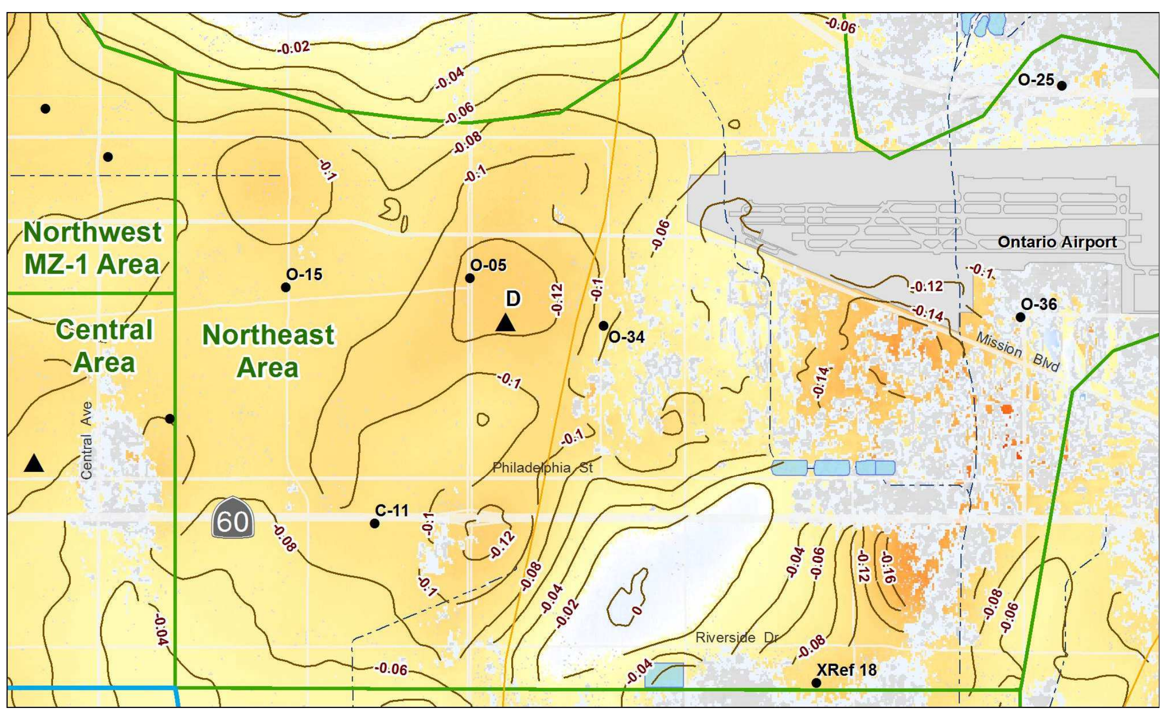
Chino Basin Watermaster

Ground-Level Monitoring Committee
2017/18 Annual Report

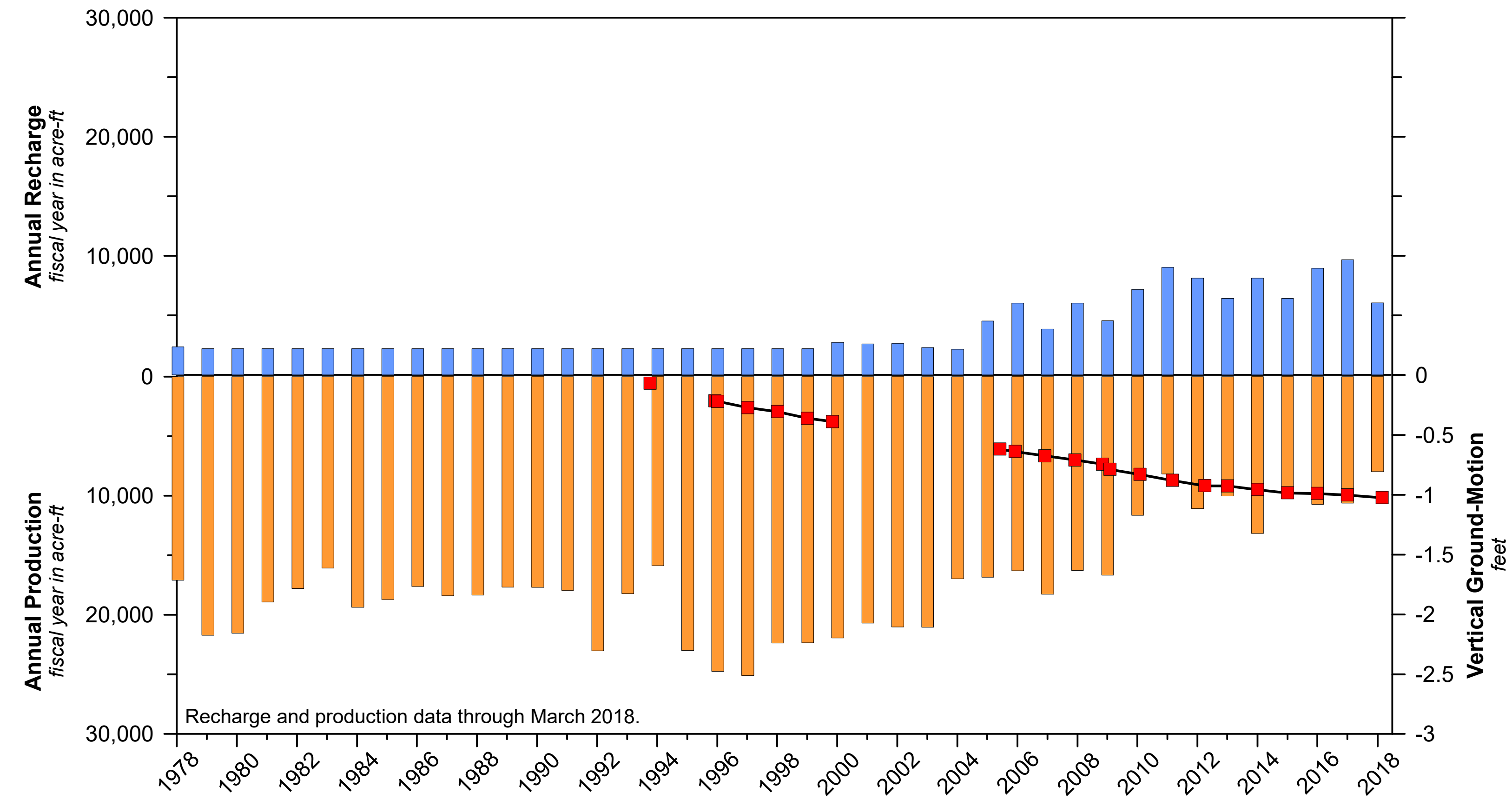
Horizontal Strain across the San Jose Fault as Calculated from Electronic Distance Measurements
2013 - 2018

Figure 3-12





See Figure 3-1a for map item descriptions.



Vertical Ground-Motion
(Cumulative Displacement)

InSAR Point D (see inset)

Recharge and Production

Recharge of Recycled, Storm-water,* and Imported Water
at the Ely, Grove, Turner, 7th Street and 8th Street Recharge Basins
*Storm-water is an estimated amount prior to fiscal year 2004/05

Groundwater Production from
Wells in the Northeast Area

WEI
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Ground-Level Monitoring Committee
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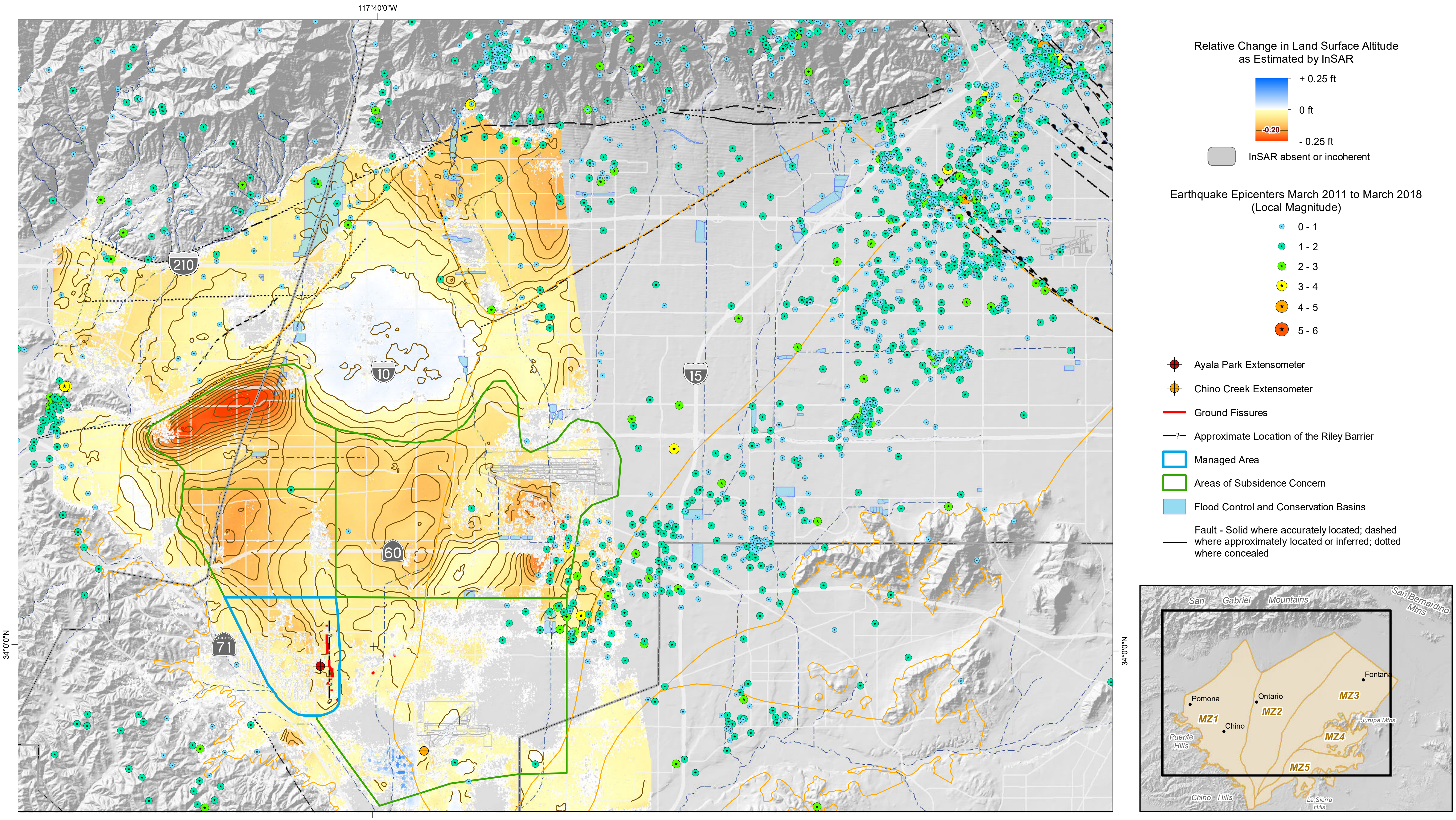
The History of Land Subsidence in the Northeast Area

Figure 3-13



WEI
Wildermuth Environmental, Inc.

Author: NWS
Date: 8/31/2018
Document Name: Figure_3-14_EQ_ZoomOut

Ground-Level Monitoring Committee
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Seismicity Across the Chino Basin
2011 - 2018

Figure 3-14

motion where both datasets overlap. Therefore, both monitoring techniques should continue to be used to estimate vertical ground motion across the Southeast Area.

- In Central MZ-1, maximum downward ground motion was about -0.16 ft from 2011 to 2018 (about -0.02 ft/yr), which is likely, at least in part, permanent subsidence. The time history and magnitude of vertical ground motion in Central MZ-1 appears like the time history and magnitude of vertical ground motion in the Managed Area, which suggests a common causal relationship; however, there is not enough piezometric data in Central MZ-1 to confirm this relationship. The GLMC should consider the value of additional monitoring in Central MZ-1 to better understand the occurrence and mechanisms of the recent subsidence.

- In Northwest MZ-1, subsidence continues to occur at a persistent rate of about 0.04 ft/yr, which is likely permanent subsidence that occurs as differential subsidence across the San Jose Fault and poses a risk for future ground fissuring. The GLMC should continue implementation of the *Work Plan to Develop a Subsidence-Management Plan for the Northwest MZ-1 Area*. In FY 2018/19, this will include installation of the Pomona Extensometer and implementation of the monitoring program, which includes: piezometric measurements at wells with transducers, estimating vertical ground motion via InSAR, elevation surveys at benchmarks, and EDM surveys at benchmarks across the San Jose Fault.

- In the Northeast Area, about one-foot of gradual and persistent land subsidence has occurred from 1992 to 2018. However, in 2011 the rate of subsidence declined from about 0.04 ft/yr to 0.025 ft/yr, which is likely due to the recent increases in piezometric levels across the area.

- A portion of the Northeast Area (south of the Ontario International Airport) is experiencing subsidence and is located adjacent to areas of concentrated micro-seismicity. The GLMC should consider the value of additional monitoring and investigation to explore the relationship between the seismicity and the subsidence.

4.2 Recommended Scope and Budget for Fiscal Year 2018/19

The scope-of-work for the GLMP for FY 2018/19 was recommended by the GLMC in March 2018 and approved by Watermaster on May 24, 2018. Appendix A is the technical memorandum prepared by the GLMC titled *Recommended Scope and Budget of the Ground-Level Monitoring Committee for FY 2018/19*.

In March 2019, Watermaster staff and engineer will present the preliminary results of the GLMP through 2018 and a recommended scope and budget for the GLMC for FY 2019-20 for consideration of the GLMC. During this process, the GLMC recommends changes to the then-current scope of work for the GLMP.

4.3 Changes to the Subsidence Management Plan

The SMP states that if data from existing monitoring efforts in the Areas of Subsidence Concern indicate the potential for adverse impacts due to subsidence, Watermaster will revise the SMP pursuant to the process outlined in Section 4 of the SMP. Currently, there are no recommended changes to the SMP.

The following glossary contains terms and definitions that are used in this report and generally in the discussions at GLMC meetings (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 of the aquifer-system reflects the rearrangement of the mineral grain pore structure and largely non-recoverable reduction of the porosity under stresses greater than the pre-consolidation 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. For the purposes of this report, the term "compaction" is used in preference to consolidation when referring to subsidence due to groundwater extraction.

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 to the reversible (recoverable) 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 to the permanent (non-recoverable) 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 of ground fissuring.

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

Expansion – In this report, expansion refers to the 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, or piezometric level, 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 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.

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 (non-recoverable). 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 – Permanent or non-recoverable sinking or settlement of the land surface due to any of several processes.

Transducer, Pressure – An electronic device that can measure piezometric 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.

Fife, D.L., Rodgers, D.A., Chase, G.W., Chapman, R.H., and E.C. Sprotte. (1976). *Geologic Hazards in Southwestern San Bernardino County, California*: California Division of Mines and Geology Special Report 113, 40 p.

Geomatrix Consultants, Inc. (1994). *Final Report Ground Fissuring Study, California Department of Corrections, California Institution for Men, Chino, California*. Project No. 2360. San Francisco, CA.

GEOSCIENCE, Support Services, Inc. (2002). *Preliminary Geohydrologic Analysis of Subsidence in the Western Portion of the Chino Basin*. Prepared for the City of Chino Hills. August 29, 2002.

Harris, R. A. (2017), *Large earthquakes and creeping faults*, Rev. Geophys., 55, 169-198, doi:10.1002/2016RG000539.

Kleinfelder, Inc. (1993). *Geotechnical Investigation, Regional Subsidence and Related Ground Fissuring, City of Chino, California*. Project No. 58-3101-01. Diamond Bar, CA.

Kleinfelder, Inc. (1996). *Chino Basin Subsidence and Fissuring Study, Chino, California*. Project No. 58-5264-02. Diamond Bar, CA.

Morton, D.M., and Yerkes, R.F. (1974). *Spectacular scarps of the frontal fault system, eastern San Gabriel Mountains.* Geological Society of America Abstracts with Programs, v. 6, no. 3, p. 223-224.

Morton, D.M., Matti, J.C., and Tinsley, J.C. (1982). *Quaternary history of the Cucamonga fault zone, southern California.* Geological Society of America Abstracts with Programs, v. 14, no. 4, p. 218.

Morton, D.M., and Matti, J.C. (1987). *The Cucamonga fault zone: Geologic setting and Quaternary history, in Morton, D.M., and Yerkes R.F., eds., Recent reverse faulting in the Transverse Ranges, California.* U.S. Geological Survey Professional Paper 1339, p. 179-203.

Myers, W.B. and Hamiliton, W. (1964). *Deformation Accompanying the Hebgen Lake Earthquake of August 17. 1959.* U.S. Geological Survey Professional Paper 435-1, p. 55-98.

Plafker, G.G. (1965). *Tectonic Deformation Associated with the 1964 Alaska Earthquake of March 27, 1964*. Science, v. 148, no. 3678, p. 1675-1687.

United States Geological Survey (USGS). (1999). *Land subsidence in the United States* (Devin Galloway, David R. Jones, S.E). Ingebritsen. USGS Circular 1182. 175 p.

Weischet, W. (1963). *Further Observations of Geologic and Geomorphic Changes Resulting from the Catastrophic Earthquakes of May 1960, in Chile* (translated by R. Von Huene). Seismology Society America Bulletin, v. 53, no. 6, p. 1237-1257.

Wildermuth Environmental, Inc. (WEI). (1999). *Optimum Basin Management Program. Phase I Report*. Prepared for the Chino Basin Watermaster. August 19, 1999.

Wildermuth Environmental, Inc. (WEI). (2003). *Management Zone 1 (MZ-1) Interim Monitoring Program*. Prepared for the Chino Basin Watermaster. January 2003.

Wildermuth Environmental, Inc. (WEI). (2006). *Optimum Basin Management Program. Management Zone 1 Interim Monitoring Program. MZ-1 Summary Report*. Prepared for the Chino Basin Watermaster. February 2006.

Wildermuth Environmental, Inc. (WEI). (2007). *Chino Basin Optimum Basin Management Program. Management Zone 1 Subsidence Management Plan*. Prepared for the Chino Basin Watermaster. October 2007.

Wildermuth Environmental, Inc. (WEI). (2013). *2012 State of the Basin Atlas*. Prepared for the Chino Basin Watermaster. June 2013.

Wildermuth Environmental, Inc. (WEI). (2015a). *Chino Basin Subsidence Management Plan*. Prepared for the Chino Basin Watermaster. July 23, 2015.

Wildermuth Environmental, Inc. (WEI). (2015b). *Work Plan to Develop a Subsidence-Management Plan for the Northwest MZ-1 Area*. Prepared for the Chino Basin Watermaster. July 23, 2015.

Wildermuth Environmental, Inc. (WEI). (2016). *2016 Annual Report of the Ground-Level Monitoring Committee*. Prepared for the Chino Basin Watermaster. September 2017.

Wildermuth Environmental, Inc. (WEI). (2017). *Initial Hydrologic Conceptual Model and Monitoring and Testing Program for the Northwest MZ-1 Area*. Prepared for the Chino Basin Watermaster. December 2017.

Appendix A

Recommended Scope and Budget of the Ground-Level Monitoring Committee for FY 2018/19

WILDERMUTH ENVIRONMENTAL, INC.

Technical Memorandum

To:	**Ground-Level Monitoring Committee**
From:	**Watermaster Engineer – Wildermuth Environmental Inc. (WEI)**
Date:	**March 22, 2018**
Subject:	**Recommended Scope and Budget of the Ground-Level Monitoring Committee for FY 2018/19 (Final)**

Background and Purpose

Pursuant to the Optimum Basin Management Program (OBMP) Implementation Plan and the Peace Agreement, the Chino Basin Watermaster (Watermaster) implements a Subsidence Management Plan (SMP) for the Chino Basin to minimize or abate the occurrence of land subsidence and ground fissuring. The SMP outlines a program of monitoring, data analysis, and annual reporting. A key element of the SMP is its adaptive nature—Watermaster can adjust the SMP as warranted by the data.[1]

The Watermaster Engineer, under the supervision of the Ground-Level Monitoring Committee (GLMC), prepares the annual reports which include the results of the monitoring program, interpretations of the data, recommendations for the Ground-Level Monitoring Program (GLMP) for the following fiscal year, and recommendations for adjustments to the SMP, if any.

This memorandum describes the Watermaster Engineer's recommended activities for the GLMP for FY 2017/18 in the form of a proposed scope-of-work and budget.

Members of the GLMC are asked to:

1. Review this memorandum by March 1, 2018.
2. Attend a meeting of the GLMC at 9:00 am on March 1, 2018 at Watermaster to discuss the proposed scope-of-work and budget for FY 2018/19.
3. Submit comments and suggested revisions on the proposed scope-of-work and budget for FY 2018/19 to the Watermaster by March 15, 2018.
4. Attend a meeting of the GLMC at 9:00 am on March 29, 2018 at Watermaster to discuss comments and revisions to the proposed scope-of-work and budget for FY 2018/19.

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[1] The Court approved the SMP and ordered its implementation in November 2007. The SMP was updated in 2015, and can be downloaded or viewed at this link.

The final scope-of-work and budget that is recommended by the GLMC will run through Watermaster's budgeting process for revisions, if needed, and approval. The final scope-of-work, budget, and schedule for FY 2018/19 will be included in Section 4 of the *2017/18 Annual Report of the Ground-Level Monitoring Committee*.

Recommended Scope of Work and Budget – FY 2018/19

A proposed scope-of-work for the GLMP for FY 2018/19 is shown in Table 1 as a line-item cost estimate. The proposed scope-of-work is summarized below:

Task 1—Setup and Maintenance of the Monitoring Network

The extensometers are the key monitoring facilities for the GLMP. They require regular and as-needed maintenance and calibration to remain in good working order and to ensure the recording of accurate measurements.

Task 1.1—Maintain Extensometer Facilities. This subtask includes performing monthly visits to the Ayala Park, Chino Creek, and Pomona Extensometer facilities to ensure functionality and calibration of the monitoring equipment and data loggers.

Task 1.2—Annual Lease Fees for CCX Extensometer Site.

Task 1.3—Identify a Site and Install a Horizontal Extensometer in the Managed Area. This sub-task involves siting a new horizontal extensometer in the Managed Area to replace the Daniels Horizontal Extensometer, performing CEQA, and procuring permits and easements. Pursuant to the recommendation in the *2016 Annual Report of the GLMC,* the installation of a new horizontal extensometer is not recommended at this time.

Task 2—Aquifer-System Monitoring and Testing

This task involves the collection and compilation of hydraulic head and aquifer-system deformation data from the Ayala Park, Chino Creek, and Pomona Extensometer facilities.

Task 2.1—Conduct Quarterly Data Collection from Extensometers; Data Checking and Management. This subtask involves the routine quarterly collection and checking of data from the extensometer facilities. Quarterly data collection is necessary (i) to ensure that the monitoring equipment is in good working order and (ii) to minimize the risk of losing data because of equipment malfunction. For 2018/19, this task now includes collection and compilation of data from the newly-installed Pomona Extensometer facility.

Task 2.2—Conduct Long-Term Pumping Test in the Managed Area. This sub-task involves the work to implement the Long-Term Pumping Test in the Managed Area to test the appropriateness of the current Guidance Level. The work includes: (i) coordination with the City of Chino Hills on the start and duration of the pumping test; (ii) downloading and checking data from the Ayala Park Extensometer, and uploading the data to the database; (iii) preparing stress-strain diagrams of the PA-7 piezometer and deep extensometer data, and distributing the diagrams to the GLMC; and (iv) terminating the test once the stress-strain diagrams indicate the first occurrence of permanent compaction. The results of the test will be documented in the 2018/19 Annual Report of the GLMC, which is prepared in FY 2019/20. *This sub-task only necessary if the City of Chino Hills indicates that it wants to proceed with the test in FY 2018/19*.

Task 2.3—Conduct Pilot Injection Test in the Managed Area. This sub-task involves the work to implement a Pilot Injection Test in the Managed Area at City of Chino Hills well CH-16 to test the effectiveness of injection as a tool to manage hydraulic head and land subsidence in the Managed Area. The work involved in this task includes coordinating the injection test with the City of Chino Hills, and collecting and compiling the injection/production data at CH-16 (*e.g.* timing of injection, injection rates, water levels at CH-16, etc.). The results of the test will be documented in the 2018/19 Annual Report of the GLMC, which is prepared in FY 2019/20. *This sub-task only necessary if the City of Chino Hills indicates that it wants to proceed with the test in FY 2018/19*.

Task 3—Basin-Wide Ground-Level Monitoring Program

This task involves the annual collection and analysis of Synthetic Aperture Radar (SAR) scenes to estimate the vertical ground motion that occurred across the western portion of Chino Basin from March 2018 to March 2019.

Task 3.1—Acquire SAR Data from German Aerospace Center and Prepare Interferograms for 2018/19. In this sub-task, six SAR scenes that were acquired by the TerraSAR-X satellite from March 2018 to March 2019 are purchased from the German Aerospace Center. Neva Ridge Technologies of Boulder, CO uses the SAR scenes to prepare 12 interferograms that describe the incremental and cumulative vertical ground motion that occurred from March 2018 to March 2019 and since 2011.

Task 3.2—Convert Interferograms to GIS Layers; Check and Upload to GIS Database. In this sub-task, the Watermaster Engineer converts the interferograms into GIS layers and performs checks for reasonableness and accuracy.

Task 4—Perform Ground-Level Surveys

This task involves conducting elevation surveys at benchmark monuments across defined areas of western Chino Basin to estimate the vertical ground motion that occurred since the prior survey. Electronic distance measurements (EDM surveys) are performed between benchmark monuments to estimate horizontal ground motion in areas where ground fissuring due to differential land subsidence is a concern. The surveys for consideration in FY 2018/19 include:

Task 4.1—Conduct Spring-2019 Elevation and EDM surveys in the Northwest MZ-1 Area. In this subtask, the surveyor conducts elevation and EDM surveys at the established benchmarks in Northwest MZ-1 in early 2019. The elevation survey begins at the new Pomona Extensometer Facility, and includes benchmarks across Northwest MZ-1 shown on Figure 1. The elevation survey will be referenced to a newly-established elevation datum at the Pomona Extensometer. The EDM survey is performed across the San Jose Array of benchmark monuments shown on Figure 1. These surveys are recommended in FY 2018/19 because of the ongoing subsidence that is occurring in Northwest MZ-1, and will support the development of a subsidence management plan in Northwest MZ-1.

Task 4.2—Conduct Spring-2019 Elevation Survey in the Northeast Area. In this subtask, the surveyor conducts an elevation survey at the established benchmarks in the Northeast Area in early 2019. The elevation survey begins at the Ayala Park Extensometer or at the new Pomona Extensometer Facility, and includes benchmarks across the Northeast Area shown on Figure 1. The starting point for the elevation survey will be recommended by the surveyor. Elevation surveys in the Northeast Area were recommended by the GLMC as part of the FY 2017/18 budget because InSAR indicated up to 0.14 feet of subsidence between Euclid and Bon View Avenues since 2011, and because InSAR is largely incoherent south and southwest of the Ontario Airport. Because Spring-2018 was the initial elevation survey in this area, and because this area is experiencing ongoing subsidence, an elevation survey is recommended for Spring 2019.

Task 4.3—Conduct Spring-2019 Elevation Survey in the Southeast Area. In this subtask, the surveyor conducts an elevation survey at the established benchmarks in the Southeast Area in early 2019. The elevation survey begins at the Ayala Park Extensometer and includes benchmarks across the Southeast Area shown on Figure 1. The elevation survey data is referenced to the Ayala Park elevation datum. *This survey is not recommended for FY 2018/19 because over the past several years hydraulic heads have been relatively stable, and recent ground motion as measured by InSAR, ground-level surveys, and the Chino Creek Extensometer, has been minor in the Southeast Area.*

Task 4.4—Install Closely-Spaced Benchmarks along Edison and Eucalyptus (for Long-Term Pumping Test). In this sub-task, closely-spaced benchmarks are installed by the surveyor across the historic fissure zone in the Managed Area along Edison and Eucalyptus Avenues to facilitate future the EDM surveys. This task was a recommendation in the 2016 Annual Report of the GLMC, if the Long-Term Pumping Test is conducted in the future to test the Guidance Level. *Implementation of this task in 2018/19 is not recommended unless the Long-Term Pumping Test is planned for execution in the near future.*

Task 4.5—Conduct Two Elevation and EDM Surveys in the Managed Area (for Long-Term Pumping Test). In this sub-task, two elevation and EDM surveys are conducted at benchmarks across the Managed Area as part of the Long-Term Pumping Test. The elevation survey begins at the Ayala Park Extensometer and includes benchmarks across the Managed Area shown on Figure 1. The elevation survey data is referenced to the Ayala Park elevation datum. The EDM surveys are performed between closely-spaced benchmarks located across the historic fissure zone along Chino, Schaefer, Edison, and Eucalyptus Avenues. *These surveys are only recommended if the Long-Term Pumping Test is executed in the Managed Area. Otherwise, these surveys are not recommended because little to no permanent subsidence is occurring in the Managed Area.*

If the Long-Term Pumping Test is planned for 2018/19, then the elevation/EDM survey scheduled for spring-2018 should be re-scheduled for the time of "full recovery" of hydraulic head in the Managed Area, which should occur in late Spring or Summer 2018. The two elevation/EDM surveys in this sub-task should occur at the times of maximum drawdown and full recovery of hydraulic head associated with the Long-Term Pumping Test.

Task 4.6—Replace Destroyed Benchmarks (if needed). In this sub-task, the surveyor replaces benchmark monuments that have been destroyed since the last survey, if any.

Task 4.7—Process, Check, and Update Database. In this sub-task, the Watermaster Engineer receives and catalogs the survey results provided by the surveyor, converts the data into GIS layers, and performs checks for reasonableness and accuracy.

Task 4.7—Select New Surveyor and Support Transition. The long-time surveyor for the GLMP (Jim Elliott of WSP USA) has informed the Watermaster that WSP USA is eliminating its field surveying division, and that the Spring-2018 surveys will be the last conducted by WSP USA. A new surveyor needs to be selected for FY 2018/19. This effort will require: (i) locating, selecting, and contracting with the new surveyor and (ii) working with the new surveyor to educate them on the objectives of the GLMP, the documentation of historical ground-level surveys, the location of all existing benchmarks, the surveying methods, the protocols for data processing, and the data deliverables. Jim Elliot has agreed to assist with the transition, as well as helping to review the 2019 ground-level survey data completed by the new surveyor.

Task 5—Data Analysis and Reporting

Task 5.1—Prepare Draft 2017/18 Annual Report of the Ground-Level Monitoring Committee. Prepare the text, tables, and figures for a draft *2017/18 Annual Report of the GLMC* and submit it to the GLMC by September 18, 2018 for review and comment.

Task 5.2—Prepare Final 2017/18 Annual Report of the Ground-Level Monitoring Committee. Update the text, tables, and figures based on the comments received from the GLMC, and prepare a final *2017/18 Annual Report of the GLMC* by November 1, 2018. Responses to comments will be included as an appendix to the final report. The report will be included in the agenda packet for the November Watermaster meetings for approval.

Task 5.3—Compile and Analyze Data from the 2018/19 Ground-Level Monitoring Program. In this task, monitoring data generated from the Ground-Level Monitoring Program during 2018/19 is checked, mapped, charted, and analyzed as the first step in the preparation of the subsequent annual report. Some of the maps, charts, and tables are shared with the GLMC at its meetings in early 2019 during the development of a recommended scope and budget for 2019/20.

Task 6—Develop a Subsidence-Management Plan for the Northwest MZ-1 Area

The development of the subsidence management plan for the Northwest MZ-1 Area is a multi-year effort. The conceptual framework for this effort is described in the *Work Plan to Develop a Subsidence-Management Plan for the Northwest MZ-1 Area*.[2] Several tasks outlined in the Work Plan are recommended for implementation in FY 2018/19:

Task 6.1—Implement the Monitoring Program and Conduct Passive Monitoring. The monitoring of water levels and production at wells in Northwest MZ-1 will continue to be implemented through various techniques, including: (i) the SCADA-based monitoring by Monte Vista Water District and the City of Pomona; (ii) monitoring of water levels via sonar[3]; (iii) monitoring of water levels via pressure transducers; (iv) manual measurements of water levels; and (iv) monitoring of water levels and aquifer-system deformation at the newly-installed Pomona Extensometer facility. This subtask includes one-year of passive monitoring. Analysis of these data will improve the understanding of

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[2] http://www.cbwm.org/docs/engdocs/Land%20Subsidence/20150724%20-%20Chino%20Basin%20Subsidence%20Management%20Plan%202015/FINAL_CBSMP_Appendix_B.pdf

[3] The use of sonar technology to measure piezometric levels in wells in currently being tested in both the City of Pomona (P-27) and Monte Vista Water District (MVWD-28) wells.

the hydrogeology in Northwest MZ-1 and provide the basis for designing controlled pumping tests in the future, if deemed necessary by the GLMC.

- **Task 6.2—Install the Pomona Extensometer Facility**. By June 30, 2018, the Pomona Extensometer facility is expected to be constructed. No additional budget is recommended for this subtask in FY 2018/19.
- **Task 6.3—Install and Test Monitoring Equipment at the Pomona Extensometer**. During the first quarter of FY 2018/19, all monitoring equipment at the PX will be installed and tested, including: pressure transducers, cable extensometers, data loggers, and telemetry. Data collection will commence as described in Task 2. This sub-task was expected to have been completed in FY 2017/18. The budget will be carried over to FY 2018/19.
- **Task 6.4—Prepare Completion Report for the Pomona Extensometer Facility**. A completion report will be prepared to document drilling, well construction, equipping, testing, and well head completion for the Pomona Extensometer Facility by the end of the 2018. This sub-task was expected to have been completed in FY 2017/18. The budget will be carried over to FY 2018/19.

Task 7—Meetings and Administration

Task 7.1—Prepare for and Conduct Four Meetings of the Ground-Level Monitoring Committee. This sub-task includes preparing for and conducting four meetings of the GLMC:

- July 26, 2018 – Implementation meeting for the GLMP for FY 2018/19.
- September 27, 2018 – Review the draft *2017/18 Annual Report of the Ground-Level Monitoring Committee.*
- March 2018 – Review the draft recommended scope and budget for FY 2019/20.
- April 2018 – Review the final recommended scope and budget for FY 2019/20.

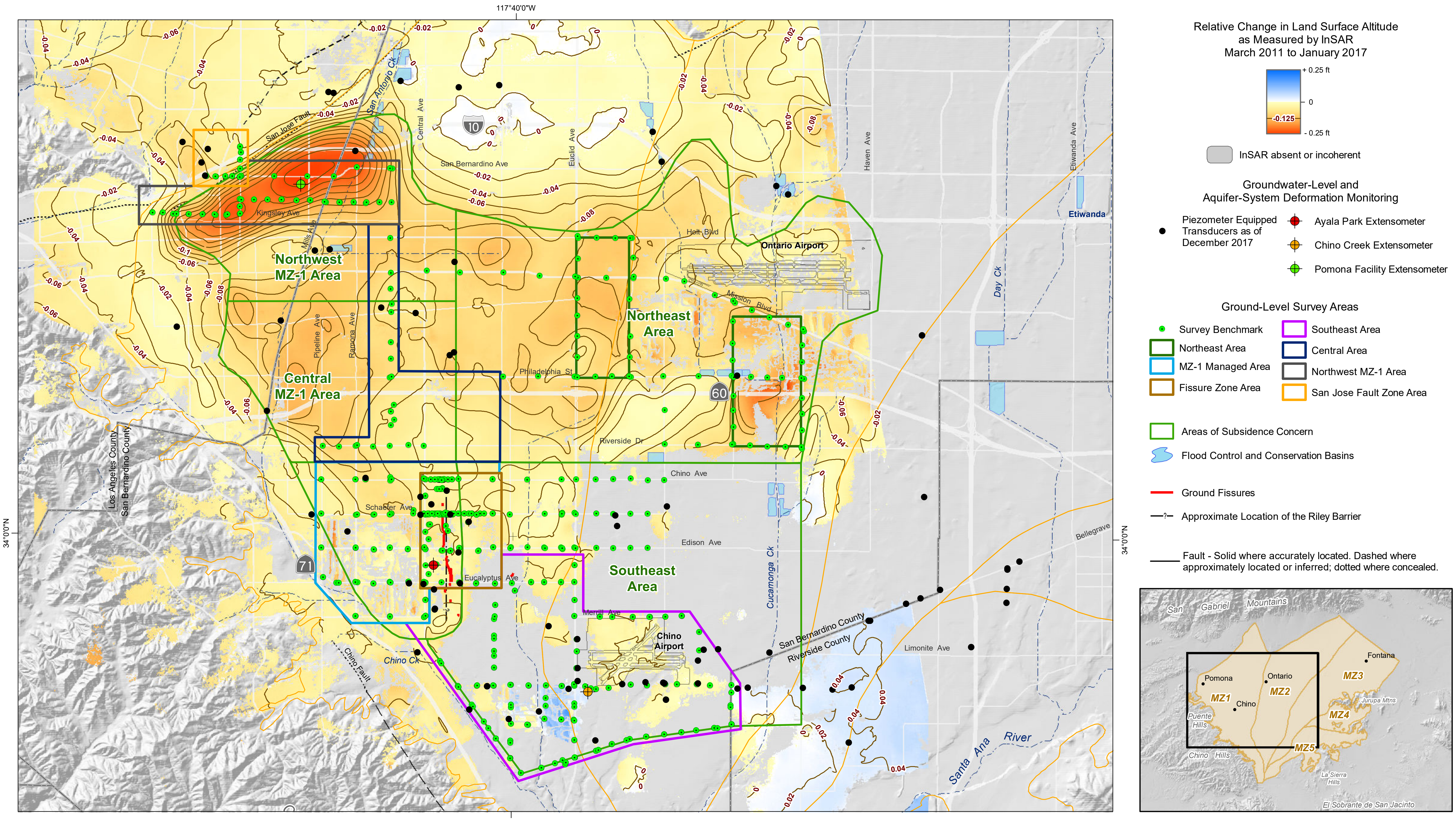
Task 7.2—Prepare for and Conduct One As-Requested Ad-Hoc Meetings. This sub-task includes preparing for and conducting one ad-hoc meeting of the GLMC, as requested by the GLMC or Watermaster staff.

Task 7.3—Perform Monthly Project Management. This sub-task includes monthly project administration and management, including: staffing, financial and schedule reporting to Watermaster, and sub-contractor coordination.

Task 7.4—Prepare a Recommended Scope and Budget for the GLMC for FY 2019/20. This sub-task includes preparing a draft and final recommended scope and budget for FY 2019/20 for the GLMC to support the Watermaster's budgeting process.

Table 1
Work Breakdown Structure and Cost Estimates
Ground-Level Monitoring Program: FY 2018/19

Task Description	Labor: Person Days	Labor: Total	Other Direct Costs: Travel	New Equip.	Equip. Rental	Outside Pro	Lab	Repro	Misc.	Total	Totals: Totals by Task	Recommended Budget 2018-19	Budget 2017-18	Net Change 2017-18 to 2018-19	Potential Carry-Over 2018-19	Budget with Carry-Over 2018-19
												a	*b*	*a - b*	*c*	*a - c*
Task 1 -- Setup and Maintenance of the Monitoring Network		**$26,816**								**$8,537**	**$35,353**	**$35,353**	**$66,274**	**-$30,921**	**$0**	**$35,353**
1.1 Maintain Extensometer Facilities																
Routine maintenance of Ayala Park, Chino Creek, and Pomona extensometer facilities	16	$21,120	$1,139	$250	$152					$1,541	$22,661	$22,661	$12,443	$10,218	$0	$22,661
Replacement/repair of equipment at extensometer facilities	4	$5,696	$362	$3,000	$38	$2,000				$5,400	$11,096	$11,096	$10,727	$369	$0	$11,096
1.2 Annual Lease Fees for CCX Extensometer Site									$1,596	$1,596	$1,596	$1,596	$1,596	$0	$0	$1,596
1.3 Identify a Site and Install a Horizontal Extensometer in the Managed Area													$0			
Coordinate with the City of Chino	0	$0	$0							$0	$0	$0	$10,954	-$10,954	$0	$0
Prepare for and attend a meeting of the GLMC to discuss and approve potential sites	0	$0	$0							$0	$0	$0	$3,582	-$3,582	$0	$0
Perform CEQA for the potential new sites and procure permits and easements	0	$0				$0				$0	$0	$0	$26,972	-$26,972	$0	$0
Task 2 -- MZ-1: Aquifer-System Monitoring and Testing		**$48,304**								**$5,303**	**$53,607**	**$33,150**	**$22,774**	**$10,375**	**$0**	**$33,150**
2.1 Conduct Quarterly Data Collection from Extensometers; Data Checking and Management																
Download data from the Ayala Park Extensometer facility	2	$2,432	$275		$76					$351	$2,783	$2,783	$2,339	$444	$0	$2,783
Download data from the Chino Creek Extensometer facility	2	$2,432	$42		$76					$118	$2,550	$2,550	$1,139	$1,411	$0	$2,550
Download data from Pomona Extensometer facility	4	$4,864	$269		$76					$345	$5,209	$5,209	$1,336	$3,873	$0	$5,209
Process, check, and upload data to database	11	$14,944								$0	$14,944	$14,944	$17,960	-$3,016	$0	$14,944
2.2 Conduct Long-Term Pumping Test in the Managed Area																
Coordinate testing with pumpers	1	$1,632								$0	$1,632	$0	$0	$0	$0	$0
Equip CH-15B and CH-17 with high-frequency water-level monitoring devices	3	$4,064	$138	$2,000	$38					$2,176	$6,240	$0	$0	$0	$0	$0
Collect data; process, check, and upload to database	2	$2,432								$0	$2,432	$0	$0	$0	$0	$0
Prepare, analyze, and distribute stress-strain diagrams to GLMC; terminate test	4	$7,168								$0	$7,168	$0	$0	$0	$0	$0
Adjust extensometer hardware, as necessary	2	$2,848	$138							$138	$2,986	$0	$0	$0	$0	$0
2.3 Conduct Pilot Injection Test in the Managed Area																
Coordinate testing with pumpers	1	$1,424								$0	$1,424	$1,424	$0	$1,424	$0	$1,424
Equip CH-15B and CH-17 with high-frequency water-level monitoring devices	3	$4,064	$138	$2,000	$38					$2,176	$6,240	$6,240	$0	$6,240	$0	$6,240
Task 3 -- Basin Wide: InSAR		**$5,064**								**$85,000**	**$90,064**	**$90,064**	**$89,292**	**$772**	**$0**	**$90,064**
3.1 Acquire SAR Data from German Aerospace Center and Prepare Interferograms for 2018/19	1	$1,632				$85,000				$85,000	$86,632	$86,632	$86,608	$24	$0	$86,632
3.2 Convert Interferograms to GIS Layers; Check and Upload to GIS Database	2.5	$3,432								$0	$3,432	$3,432	$2,684	$748	$0	$3,432
Task 4 -- Ground-Level Surveys		**$17,722**								**$190,600**	**$208,322**	**$84,046**	**$127,058**	**-$43,012**	**$0**	**$84,046**
4.1 Conduct Spring-2019 Elevation and EDM surveys in the Northwest MZ-1 Area	0.5	$816				$23,000				$23,000	$23,816	$23,816	$22,507	$1,309	$0	$23,816
4.2 Conduct Spring-2019 Elevation Survey in the Northeast Area	0.5	$816				$32,500				$32,500	$33,316	$33,316	$57,818	-$24,502	$0	$33,316
4.3 Conduct Spring-2019 Elevation Survey in the Southeast Area	0.5	$816				$30,000				$30,000	$30,816	$0	$29,871	-$29,871	$0	$0
4.4 Install Closely-Spaced Benchmarks along Edison and Eucalyptus (for Long-Term Pumping Test)	1.75	$2,728				$12,200				$12,200	$14,928	$0	$0	$0	$0	$0
4.5 Conduct Two Elevation and EDM Surveys in the Managed Area/Fissure Zone Area (for Long-Term Pumping Test)	1	$1,632				$76,900				$76,900	$78,532	$0	$0	$0	$0	$0
4.6 Replace Destroyed Benchmarks (if needed)	0	$0				$6,000				$6,000	$6,000	$6,000	$5,963	$37	$0	$6,000
4.7 Process, Check, and Update Database	4.25	$5,768								$0	$5,768	$5,768	$10,900	-$5,132	$0	$5,768
4.8 Select New Surveyor and Support Transition																
Identify and Selecting a New Surveyor	1	$1,810				$2,500				$2,500	$4,310	$4,310	$0	$4,310	$0	$4,310
Support the Transition of Work from Prior Surveyor to New Surveyor	2.25	$3,336				$7,500				$7,500	$10,836	$10,836	$0	$10,836	$0	$10,836
Task 5 -- Data Analysis and Reports		**$60,476**								**$10,000**	**$70,476**	**$70,476**	**$79,644**	**-$9,168**	**$0**	**$70,476**
5.1 Prepare Draft 2017/18 Annual Report of the Ground-Level Monitoring Committee	23	$33,384								$0	$33,384	$33,384	$32,920	$464	$0	$33,384
5.2 Prepare Final 2017/18 Annual Report of the Ground-Level Monitoring Committee	5.5	$8,148								$0	$8,148	$8,148	$8,036	$112	$0	$8,148
5.3 Compile and Analyze Data from the 2018/19 Ground-Level Monitoring Program																
Production/recharge/piezometric/extensometer	4	$5,280				$10,000				$10,000	$15,280	$15,280	$25,208	-$9,928	$0	$15,280
Ground-level survey and Northwest MZ-1 Area EDM data	4	$5,648								$0	$5,648	$5,648	$5,572	$76	$0	$5,648
InSAR data	4	$5,280								$0	$5,280	$5,280	$5,208	$72	$0	$5,280
Tectonic data	0.25	$304								$0	$304	$304	$300	$4	$0	$304
Recycled water reuse data	2	$2,432								$0	$2,432	$2,432	$2,400	$32	$0	$2,432
Task 6 -- Work Plan to Develop a Subsidence-Management Plan for the Northwest MZ-1 Area		**$118,320**								**$54,818**	**$173,138**	**$173,138**	**$1,582,576**	**-$1,409,438**	**$136,732**	**$36,406**
6.1 Implement the Monitoring Program and Conduct Passive Monitoring	19	$24,672	$472		$76	$10,000				$10,548	$35,220	$35,220	$84,918	-$49,698	$0	$35,220
6.2 Install the Pomona Extensometer Facility	0	$0	$0			$0				$0	$0	$0	$1,360,926	-$1,360,926	$0	$0
6.3 Install and Test Monitoring Equipment at the Pomona Extensometer	48	$63,132	$1,920	$18,300		$24,000				$44,220	$107,352	$107,352	$106,532	$820	$106,532	$820
6.4 Prepare Completion Report for the Pomona Extensometer Facility	20	$30,516						$50		$50	$30,566	$30,566	$30,200	$366	$30,200	$366
Task 7 -- Meetings and Administration		**$44,016**								**$418**	**$44,434**	**$44,434**	**$43,646**	**$788**	**$0**	**$44,434**
7.1 Prepare for and Conduct Four Meetings of the Ground-Level Monitoring Committee	12	$20,864	$334							$334	$21,198	$21,198	$20,770	$428	$0	$21,198
7.2 Prepare for and Conduct One As-Requested Ad-Hoc Meetings	3	$5,216	$84							$84	$5,300	$5,300	$5,192	$107	$0	$5,300
7.3 Perform Monthly Project Management	7.5	$12,720								$0	$12,720	$12,720	$12,540	$180	$0	$12,720
7.4 Prepare a Recommended Scope and Budget for the GLMC for FY 2019/20	3	$5,216								$0	$5,216	$5,216	$5,144	$72	$0	$5,216
Totals											**$675,393**	**$530,660**	**$2,011,265**	**-$1,480,605**	**$136,732**	**$393,928**



Prepared by:

WEI
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Author: MAB
Date: 2/7/2018
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CHINO BASIN WATERMASTER
Partners in Basin Management

Ground-Level Monitoring Committee
Ground-Level Monitoring Program

Ground-Level Monitoring Program
Fiscal Year 2018-19

Figure 1

Appendix B

Comments and Responses

Appendix B - Response to GLMC Comments

2017/18 Annual Report of the GLMC

Monte Vista Water District by Van Jew

Comment 1 – InSAR

InSAR is a heavily relied upon component of the Committee's work and it seems to measure such small increments (e.g. "0.02 ft/year"). Given this, let's add a paragraph in the report discussing the margin of error of InSAR so as to provide the reader a better understanding of the so many numbers he/she is reading.

Response:

A footnote has been added to Section 2.1.2.3: "Several factors can influence the accuracy of ground-motion results as estimated by InSAR, such as satellite orbital uncertainties and atmospheric interference. On average, accuracy of ground-motion results as estimated by InSAR are +/- 0.02 ft."

Comment 2 – Section 4.3

Didn't we at the 9/27/18 workshop say that some of the monitoring/surveying can be cut back?? If so, shouldn't this be put into Section 4.3??.

Response:

There was discussion at the GLMC meeting on September 27, 2018 on reducing the frequency of leveling surveys, particularly in areas where the InSAR results are coherent, such as Northwest MZ-1. However, Ron Craig suggested that the GLMC should consider such a reduction in monitoring after the Pomona Extensometer is installed and the initial survey that utilizes the Pomona Extensometer as the starting datum is completed.

A paragraph has been added to Section 4.2: "In March 2019, Watermaster staff and engineer will present the preliminary results of the GLMP through 2018 and a recommended scope and budget for the GLMC for FY 2019-20 for consideration of the GLMC. During this process, the GLMC recommends changes to the then-current scope of work for the GLMP."

State of California Department of Justice by Carol A.Z. Boyd

Comment 1 – Figures 3-1b and 3-7b

In our opinion, the final version of the report should address the ground-level depression northwest of the intersection of the 71 Freeway and Central Avenue/Soquel Canyon Parkway, occurring during 2017/2018 and depicted in Figures 3-1b and 3-7b. During the September 27 Committee meeting, there was a general discussion that the area was not considered an issue because no known pumping occurs there and it is in the general vicinity of relatively recent earth work construction/grading activities. While the site is outside the managed area and other areas of concern, it is the most prominent ground-level related feature of Figure 3-7b and has relevance to potential future interpretations of ground-level features, that is, large development activities may result in short term ground-level anomalies.

Response:

Text has been added to Section 3.2: "Figure 3-7b shows an isolated area of downward vertical ground motion located southwest of the intersection of Highway 71 and Soquel Canyon Parkway. The area of downward ground motion is a new feature visible in the InSAR maps for the time-period March 2017 to March 2018. The exact mechanism(s) of the downward ground motion is not known at this time, but there are two potential causes:

1. *New earthwork construction activities*. The area of downward ground motion spatially corresponds to the area of recent earthwork construction activities. Historical aerial imagery of the area via Google Earth Pro shows open-space land from May 1994 to February 2016. Sometime between February 2016 and October 2016, earthwork construction activities began. The earthwork construction activities are visible in the historical imagery between October 2016 and February 2018.
2. *Groundwater extraction activities related to new earthwork construction activities*. The Watermaster's database indicates at least one inactive well is located within the area of downward ground motion. It is possible that the well was equipped with a pump to supply construction water for the earthwork construction activities, and that groundwater extraction from the well caused the downward ground motion shown on Figure 3-7b.

It is plausible that either one or a combination of the two scenarios described above caused the downward ground motion. In 2018-19, Watermaster staff will investigate with the land owners, and monitoring of this area via InSAR will be conducted in subsequent years."