FINAL REPORT | November 2024

2023/24 Annual Report for the Ground-Level Monitoring Program

PREPARED FOR

Ground-Level Monitoring Committee

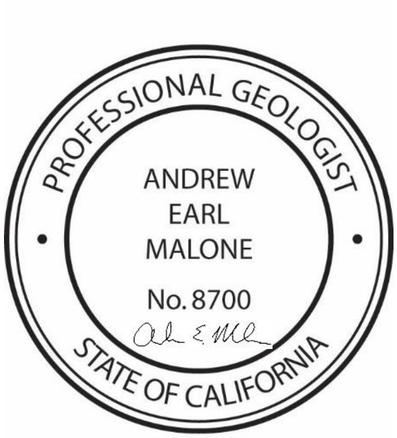
PREPARED BY

2023/24 Annual Report for the Ground-Level Monitoring Program

Prepared for

Ground-Level Monitoring Committee

Project No. 941-80-24-22



11/06/2024

Project Manager, QA/QC Review: Andy Malone, PG — Date

Andrea Arevalo
Charles Martinez
Clay Kelty
Sean Yarborough

11/06/2024

Prepared By: — Date

WEST YOST
Water. Engineered.

FINAL REPORT | November 2024

Table of Contents

Table of Contents

LIST OF TABLES

LIST OF FIGURES

Table of Contents

LIST OF APPENDICES

LIST OF ACRONYMS, ABBREVIATIONS, AND INITIALISMS

af	Acre-feet
Ayala Park	Rubin S. Ayala Park
Ayala Park Extensometer	Extensometer at Ayala Park
BMA	Baseline Management Alternative
CCX	Chino Creek Extensometer Facility
DHX	Daniels Horizontal Extensometer
EDM	Electronic distance measurement
ft	Feet
ft-amsl	Feet above mean sea level
ft-btoc	Feet below top of casing
ft-bgs	Feet below ground surface
ft/yr	Feet per year
FY	Fiscal Year
GLMC	Ground-Level Monitoring Committee
GLMP	Ground-Level Monitoring Program
IMP	Management Zone 1 Interim Monitoring Program
InSAR	Interferometric synthetic aperture radar
ISMA	Initial Subsidence Management Alternative
MVWD	Monte Vista Water District
MZ-1	Chino Basin Optimum Basin Management Plan Management Zone 1
MZ-1 Plan	Management Zone 1 Subsidence Management Plan
OBMP	Optimum Basin Management Plan
PA	Piezometer A (Ayala Park extensometer facility)
PC	Piezometer C (Ayala Park extensometer facility)
PFAS	Per – and polyfluoroalkyl substances
PX	Pomona Extensometer Facility

SAR	Synthetic Aperture Radar
SCADA	Supervisory Control and Data Acquisition
SMA-2	Second Subsidence-Management Alternative
Subsidence Management Plan	2015 Chino Basin Subsidence Management Plan
TCP	1,2,3-trichloropropane
USGS	United States Geological Survey
Watermaster	Chino Basin Watermaster
WEI	Wildermuth Environmental, Inc.
Work Plan	Work Plan to Develop a Subsidence Management Plan for the Northwest MZ-1

1.0 INTRODUCTION

This section describes:

- Background information on the history of land subsidence and ground fissuring in the Chino Basin.
- Information on the formation of the Ground-Level Monitoring Committee (GLMC) and its responsibilities.
- A description of the development and implementation of the Chino Basin Subsidence Management Plan (Subsidence Management Plan).
- The organization of this annual report.

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, over 17,000 square miles in 45 states have experienced land subsidence (United States Geologic Survey [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 the 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 the inelastic deformation (i.e., sinking) of the land surface. The term *inelastic* typically refers to the permanent, non-recoverable 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. A glossary of terms and definitions discussed in this report, as well as other terms related to basic hydrogeology and land subsidence is included in Section 5.0.

1.1.1 Subsidence and Fissuring in the Chino Basin

One of the earliest indications of land subsidence in the Chino Basin was the appearance of ground fissures within the City of Chino. These fissures appeared as early as 1973, but an accelerated occurrence of ground fissuring ensued after 1991 and resulted in damage to existing infrastructure. Figure 1-1 shows the locations of these fissures and the land subsidence that contemporaneously occurred in this area. Several scientific studies of the area 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 Program Phase I Report* (OBMP Phase I Report) identified the pumping-induced decline of hydraulic heads and subsequent aquifer-system compaction as the most likely cause of the land subsidence and ground fissuring observed in the Chino Basin OBMP Management Zone 1 (MZ-1; Wildermuth Environmental Inc. [WEI], 1999). Program Element 4 of the OBMP Implementation Plan, *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 (items 2 and 3 above). This investigation was titled the *MZ-1 Interim Monitoring Program* (WEI, 2003) and is described below.

The OBMP Phase I Report also identified that land subsidence was occurring in other parts of the basin besides in the City of Chino. Program Element 1 of the OBMP Implementation Plan, *Develop and Implement a Comprehensive Monitoring Program*, called for the collection of basin-wide data to characterize land subsidence, including ground-level surveys and remote-sensing (specifically, interferometric synthetic aperture radar [InSAR]), and for the development of an ongoing monitoring program based on the analysis of the collected 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 Interim Management Plan (IMP) under the guidance of the MZ-1 Technical Committee. 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 (MVWD); the Golden State Water Company; and the California Institution for Men.

The IMP consisted of three main monitoring elements to analyze land subsidence: ground-level surveys, InSAR, and aquifer-system monitoring. The ground-level surveys and InSAR analyses were used to characterize vertical ground motion. Aquifer-system monitoring of hydraulic and mechanical changes within the aquifer system was used to characterize the causes of the ground motion.

The monitoring program was implemented in two phases: the Reconnaissance Phase and the Comprehensive Phase. The Reconnaissance Phase consisted of constructing 11 piezometers screened at various depths at Rubin S. Ayala Park (Ayala Park) in the City of Chino and installing pressure-transducers with integrated data loggers (transducers) in nearby pumping and monitoring wells to measure hydraulic head. Following installation of the monitoring network, several months of aquifer-system monitoring and testing were conducted. Testing included aquifer-system stress tests conducted at pumping 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. Figure 1-2 shows the location of the Ayala Park Extensometer. 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 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 summarized the MZ-1 Technical Committee meetings.

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

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 hydraulic head decline that is much greater in magnitude and lateral extent than the hydraulic head decline caused by pumping of the shallow aquifer-system.
- Hydraulic head decline due to pumping from 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 hydraulic heads in the deep aquifer-system at the Ayala Park PA-7 piezometer fell below a depth of about 250 feet (ft).
- 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 resulted in ground fissuring.
- During the development of the IMP, a previously unknown barrier to groundwater flow was identified, shown on Figures 1-1. The barrier was named the “Riley Barrier” after Francis S. Riley, a retired USGS 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 hydraulic head 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 Central MZ-1 had occurred in the past and was continuing to occur. InSAR also suggested that the groundwater barrier (Riley Barrier) extends northward into Central MZ-1 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 Central MZ-1. However, there was not enough historical hydraulic head data in this area to confirm this relationship. The IMP recommended that, if subsidence continued or increased in Central MZ-1, the mechanisms causing land subsidence should be studied in more detail.

The IMP provided enough information for Watermaster to develop Guidance Criteria for the Parties that pump from the southwestern region of MZ-1, that if followed, would minimize the potential for subsidence and fissuring in the investigation area. The methods, results, and conclusions of the IMP, including the Guidance Criteria, were described in detail in the *MZ-1 Summary Report* (WEI, 2006).

The Guidance Criteria consisted of:

- A list of “Managed Wells” subject to the Guidance Criteria. Table 1-1 is a list of the Managed Wells that are subject to the Guidance Criteria. Figure 1-2 is a map that shows the locations of the Managed Wells. These wells have well screens that penetrate the deep aquifer-system.

Table 1-1. Managed Wells Screened in the Deep Aquifer and Subject to the Guidance Criteria[a]				
Well Name	CBWM ID	Owner	2024 Status	Well Screen Depth Interval(s) ft-bgs
CIM-11A[b]	3602461	California Institution for Men	Active[c]	174-187; 240-283; 405-465
C-7	3600461	City of Chino	Abandoned[d]	180-780
C-15	600670		Abandoned	270-400; 626-820
CH-1B	600487	City of Chino Hills	Inactive[e]	440-470; 490-610; 720-900; 940-1,180
CH-7C	600687		Abandoned	550-950
CH-7D	600498		Destroyed	320-400; 410-450; 490-810; 850-930
CH-15B	600488		Active	360-440; 480-900
CH-16	600489		Inactive	430-940
CH-17	600499		Inactive	300-460; 500-680
CH-19	600500		Inactive	300-460; 460-760; 800-1,000

(a) 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.

(b) The original casing was perforated from 135-148, 174-187, 240-283, 405-465, 484-512, and 518-540 feet below ground surface (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.

(c) Active = Well is currently being used for water supply.

(d) Abandoned = Unable to pump the well without major modifications.

(e) Inactive = Well can pump groundwater with little or no modifications.

- The spatial extent of the "Managed Area." Figures 1-1 and 1-2 show the boundary of the Managed Area where the Guidance Criteria apply. Within the boundaries of the Managed Area, both existing (Table 1-1) and newly constructed wells are subject to being classified as Managed Wells. This area was delineated based on the observed and/or predicted effects of pumping on hydraulic heads and aquifer-system deformation. The Managed Well designations were based on the effects measured at the Ayala Park Extensometer during the IMP or well construction and borehole lithology.
- A piezometric "Guidance Level." The Guidance Level is a specified depth to water, as measured in feet below the top of casing (ft-btoc) at the Ayala Park PA-7 piezometer. The initial Guidance Level was established as 245 ft-btoc. It was defined as the threshold hydraulic head 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 can be updated by Watermaster based on the periodic review of monitoring data.
- Criteria for recommending pumping curtailment. If the hydraulic head in PA-7 falls below the Guidance Level, Watermaster recommends that the MZ-1 Parties curtail their pumping from designated Managed Wells as required to maintain hydraulic heads above the Guidance Level.
- Monitoring/reporting of hydraulic heads at PA-7. Watermaster was to provide the MZ-1 Parties with real-time hydraulic head data from PA-7.

- Reporting of pumping operations at Managed Wells. The MZ-1 Parties were requested to maintain and provide Watermaster with accurate records of operations at the Managed Wells, including pumping rates and on-off dates and times. The MZ-1 Parties were requested to promptly notify Watermaster of all operational changes made to maintain the hydraulic head at PA-7 above the Guidance Level.
- Request for ongoing monitoring at other monitoring wells. Watermaster recommended that the MZ-1 Parties allow it to continue to monitor hydraulic heads at the Managed Wells.
- Process for adapting the Guidance Criteria. 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. Changes to the Guidance Criteria could include additions or deletions to the list of Managed Wells, re-delineation of the Managed Area, raising or lowering of the Guidance Level, or additions and/or deletions to the Guidance Criteria, including the need to have periods of hydraulic head recovery.
- Acknowledgement of uncertainty. 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 Subsidence Management Plan* ([MZ-1 Plan]; WEI, 2007), 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 MZ-1 Parties manage their groundwater pumping such that the hydraulic heads at PA-7 remain 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 Area, and Southeast Area. The expanded monitoring efforts outside the Managed Area are consistent with the requirements of the OBMP Program Element 1 and its implementation plan contained in the Peace Agreement.[2]

Potential future efforts listed in the MZ-1 Plan included: (i) more intensive monitoring of horizontal strain across the zone of historical ground fissuring to assist in developing management strategies related to fissuring, (ii) injection feasibility studies within the Managed Area, (iii) additional pumping tests to refine the Guidance Criteria, (iv) computer-simulation modeling of groundwater flow and subsidence, and (v) the development of alternative pumping plans for the MZ-1 Parties affected by the MZ-1 Plan. The MZ-1 Technical Committee (now called the Ground-Level Monitoring Committee or GLMC) discusses these potential future efforts, and if deemed prudent and necessary, they are recommended to Watermaster for implementation in future fiscal years.

[2] Source: http://www.cbwm.org/docs/legaldocs/Peace_Agreement.pdf.

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 land subsidence efforts and obligations, including areas outside of MZ-1. As such, the update included a name change to the 2015 Chino Basin Subsidence Management Plan ([Subsidence Management Plan]; WEI 2015a) and a recommendation to develop a subsidence management plan for Northwest MZ-1.

Watermaster had been monitoring vertical ground motion in Northwest MZ-1 via InSAR during the development of the MZ-1 Plan. 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. Of particular concern, the subsidence across the San Jose Fault in Northwest MZ-1 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 Northwest MZ-1, has been discussed at prior GLMC meetings, and the subsidence has been documented and described as a concern in Watermaster's State of the Basin Reports, the annual reports of the GLMC, and in the *Initial Hydrologic Conceptual Model and Monitoring and Testing Program for the Northwest MZ-1 Area* (WEI, 2017a). Watermaster increased monitoring efforts in Northwest MZ-1 beginning in Fiscal Year (FY) 2012/13 to include ground elevation surveys and electronic distance measurements (EDM) to monitor 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, a cost estimate, and an implementation schedule. The Work Plan was included in the Subsidence Management Plan as Appendix B. Implementation of the Work Plan began in July 2015.

The updated Subsidence Management Plan also addressed the need for hydraulic head "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. And, the Subsidence Management Plan recommends that every fifth year, all deep aquifer-system pumping cease for a continuous period until the hydraulic head at PA-7 reaches "full recovery" of 90 ft-btoc. These periodic cessations of pumping are intended to allow for sufficient hydraulic head recovery at PA-7 to recognize inelastic compaction, if any, at the Ayala Park Extensometer.

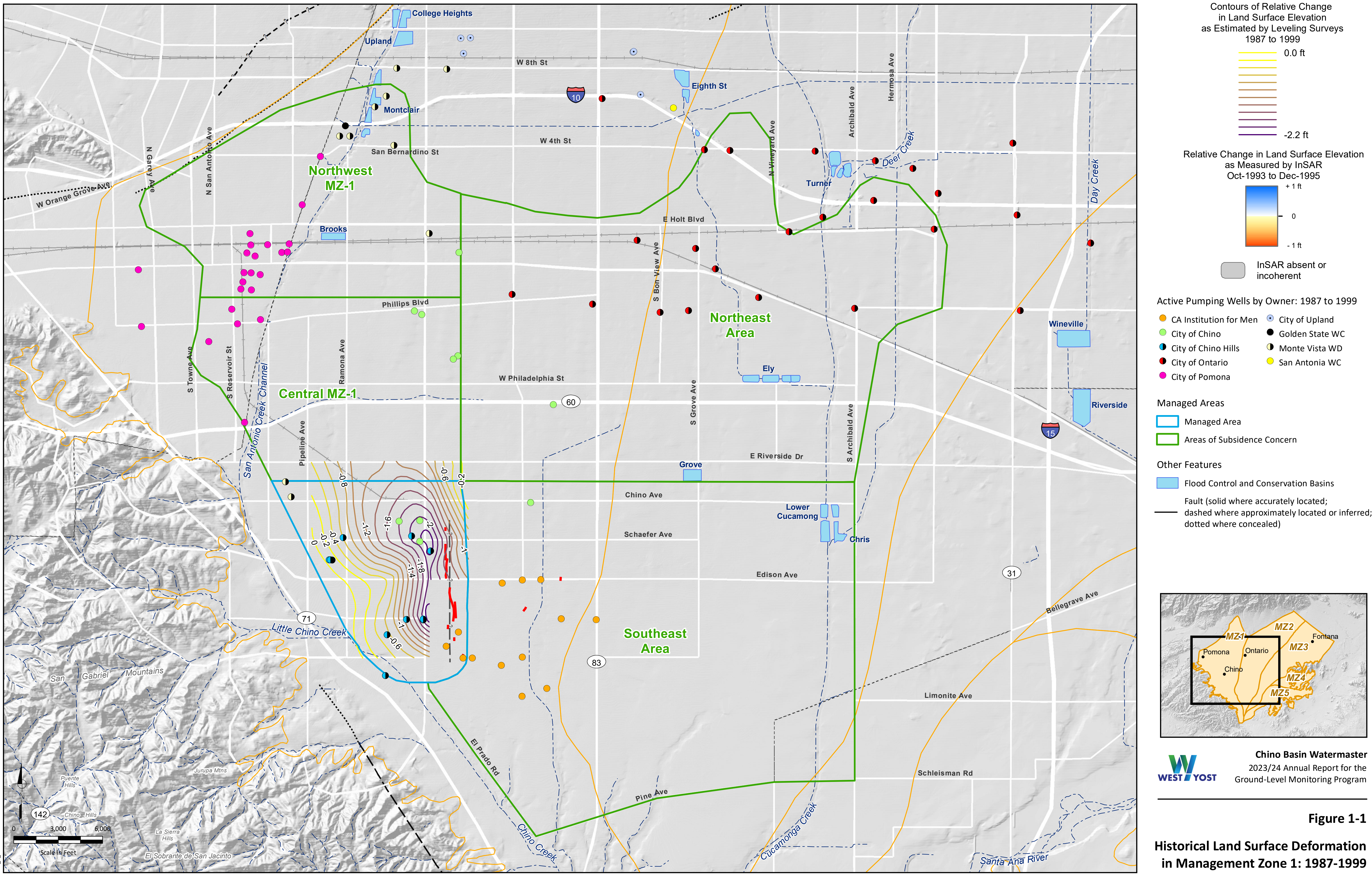
1.1.6 Annual Report for the Ground-Level Monitoring Program

Pursuant to the Subsidence Management Plan, Watermaster prepares an annual report containing the results of ongoing monitoring efforts, interpretations of the data, and recommended adjustments to the Subsidence Management Plan, if any. This Annual Report for the GLMP includes the results and interpretations for the data collected between March 2023 through March 2024, as well as recommendations for Watermaster's GLMP for FY 2024/25.

1.2 Report Organization

This report is organized into the following six sections:

- **Section 1.0 – 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 Subsidence Management Plan, which calls for annual reporting.
- **Section 2.0 – Ground-Level Monitoring Program.** This section describes the monitoring and testing activities performed by Watermaster for its GLMP between March 2023 and March 2024.
- **Section 3.0 – Results and Interpretations.** This section discusses and interprets the monitoring data collected between March 2023 and March 2024, including basin stresses (groundwater pumping and recharge) and responses (changes in hydraulic heads, aquifer-system deformation, and ground motion).
- **Section 4.0 – Conclusions and Recommendations.** This section summarizes the main conclusions derived from the monitoring program between March 2023 and March 2024 and describes recommended activities for the GLMP for FY 2024/25.
- **Section 5.0 – Glossary.** This section is a glossary of the terms and definitions utilized within this report and in discussions at GLMC meetings.
- **Section 6.0 – References.** This section lists the publications and reports cited in this report.

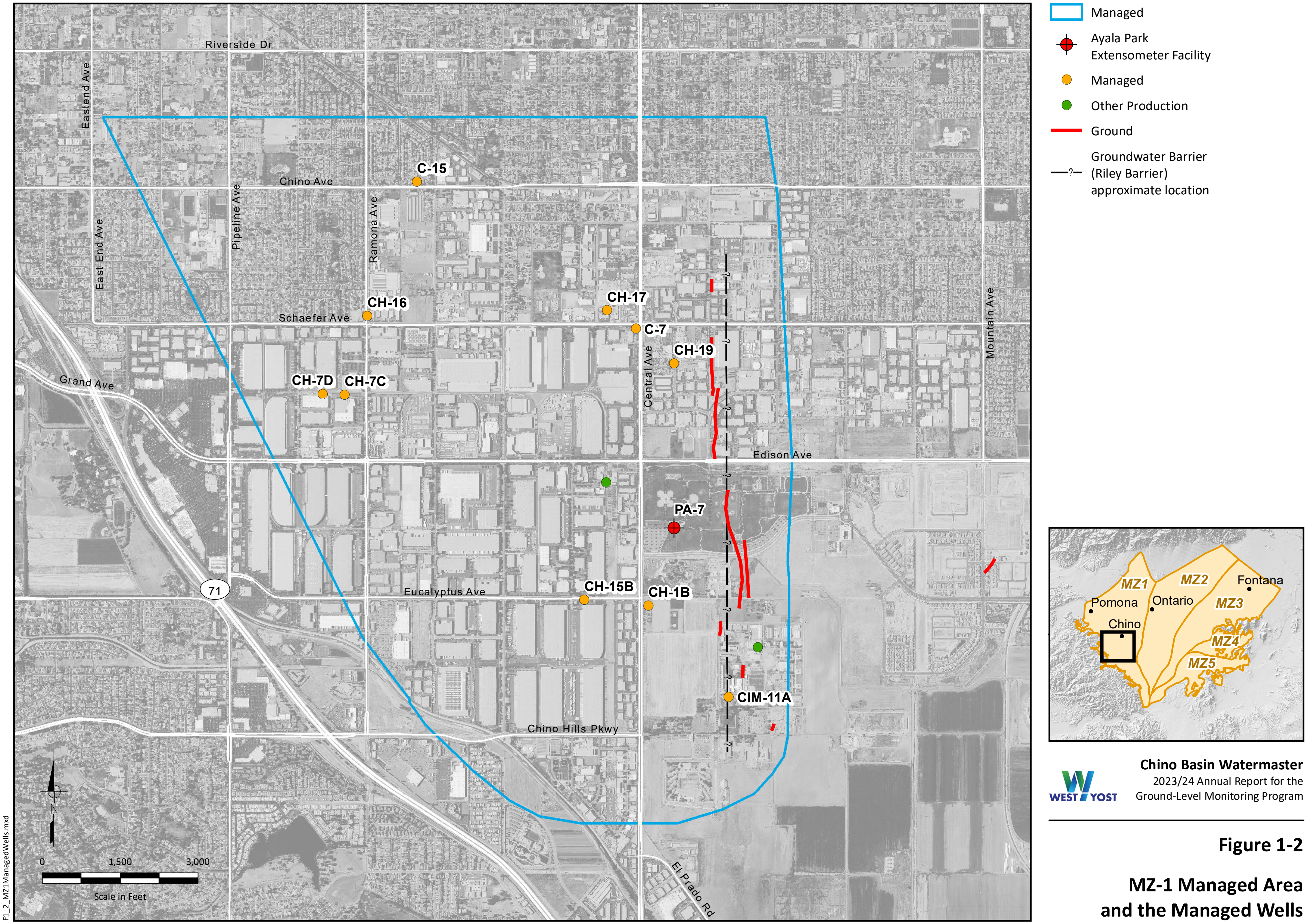


WEST YOST

Chino Basin Watermaster
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 1-1

Historical Land Surface Deformation in Management Zone 1: 1987-1999



Chino Basin Watermaster
2023/24 Annual Report for the Ground-Level Monitoring Program

Figure 1-2

MZ-1 Managed Area and the Managed Wells

2.0 GROUND-LEVEL MONITORING PROGRAM

This section describes the activities performed by Watermaster for the GLMP between March 2023 and March 2024.

Figure 2-1 shows the groundwater pumping 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 a transducer; extensometers that measure vertical aquifer-system deformation; and benchmark monuments that are used to perform periodic ground-elevation and EDM surveys to measure vertical and horizontal deformation of the ground surface.

2.1 Ground-Level Monitoring Program

Watermaster conducts its GLMP in the Managed Area and other Areas of Subsidence Concern pursuant to the Subsidence Management Plan and the recommendations of the GLMC. The GLMP activities performed between March 2023 and March 2024 are described below.

2.1.1 Setup and Maintenance of the Monitoring Network

The Ayala Park, Chino Creek, and Pomona extensometer (PX) facilities are key monitoring facilities for the GLMP. They require monthly or as needed visits for maintenance and calibration to remain in good working order and to ensure the recording of accurate measurements.

2.1.1.1 Pomona Extensometer

During 2023/24, special maintenance and calibration efforts were conducted a the PX facility to improve the accuracy of the extensometer measurements. The background, methods, results, and recommendations associated with these efforts at PX are describe herein.

The PX is an experimental monitoring facility located within the City of Pomona. Its purpose is to monitor depth-specific head changes and the associated vertical compression/expansion of the aquifer-system sediments that can result in land subsidence. At the PX, there are four piezometers completed at progressively deeper elevations; each piezometer is equipped with a pressure transducer to measure hydraulic heads within the pumped aquifer system once every 15 minutes. A cable extensometer is installed within each piezometer to measure the vertical deformation of the overlying sediments relative to the head changes. Each extensometer cable is attached with a steel weight that rests on the bottom of the piezometer and is stretched taught by a counterweight and pully systems at the well head. Aquifer-system deformation is measured with a linear potentiometer as vertical displacement between the cable and the conductor casing (which is anchored to the ground surface) once every 15 minutes. The transducers and linear potentiometers are connected to a Campbell Scientific CR-1000X data logger to record the data. The PX facility is powered by two marine batteries. Figure 2-3 is a schematic diagram of a cable extensometer.

Typical data collected at a properly functioning extensometer facility will display a correlated relationship between head changes and extensometer displacement. For example, as heads decrease, the aquifer-system skeleton (and pore spaces) will contract, causing the land surface (and conductor casing) to sink relative to the extensometer cable. The PX has been measuring logical head changes that are consistent with head changes being measured at nearby wells, but has not been measuring and recording logically correlated extensometer data, which indicates that: (i) the extensometers are malfunctioning, (ii) the monitoring/recording equipment is malfunctioning, or (iii) both are malfunctioning.

Figures 2-4a, 2-4b, 2-4c, and 2-4d are time-series charts of the historical head data versus extensometer data for PX-1, PX-2, PX-3, and PX-4, respectively. In an effort to improve the accuracy of the extensometer data, the Watermaster Engineer has been making incremental adjustments to each extensometer by: (i) adding/subtracting counterweights, (ii) adjusting the position of the cable extensometer within the well casing, and/or (iii) making adjustments to the monitoring/recording equipment. Each adjustment is followed by an extended period of data collection and evaluation.

To date, the PX continues to record data that is not well correlated with the head changes. In addition, some data collected indicates that the monitoring equipment may be malfunctioning. Going forward, the Watermaster Engineer proposes two recommendations to improve the PX for GLMC consideration:

1. Continue to make incremental adjustments to the extensometers followed by extended periods of data collection and evaluation.
2. Reinstall the extensometer cables, counterweights, and monitoring/recording equipment and equip the facility with telemetry to analyze and evaluate the collected data more quickly.

2.1.2 Monitoring Activities

Changes in hydraulic heads are caused by the stresses of groundwater pumping and recharge. Changes in hydraulic head is the mechanism behind aquifer-system deformation, which in turn causes vertical and horizontal ground motion. Because of this cause-and-effect relationship, the Watermaster monitors groundwater pumping, recharge, hydraulic heads, aquifer-system deformation, and vertical and horizontal ground motion across the western portion of the Chino Basin. All data collected as part of the GLMP are compiled, checked, and stored in Watermaster databases.

The following sections describe Watermaster's monitoring activities between March 2023 and March 2024, as called for by the Subsidence Management Plan and in consideration of GLMC recommendations.

2.1.2.1 Monitoring of Pumping, Recharge, and Piezometric Levels

Watermaster staff collects and compiles groundwater pumping data on a quarterly basis from well owners in the Managed Area and Areas of Subsidence Concern. Figure 2-1 shows the well locations where groundwater was pumped between March 2023 and March 2024.

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

Hydraulic heads were measured and recorded once every 15 minutes using transducers maintained by the Watermaster at 77 wells across the Managed Area and Areas of Subsidence Concern. Figure 2-2 shows the locations of these wells. Also, Watermaster staff and well owners typically measure hydraulic heads at other wells in western Chino Basin monthly.

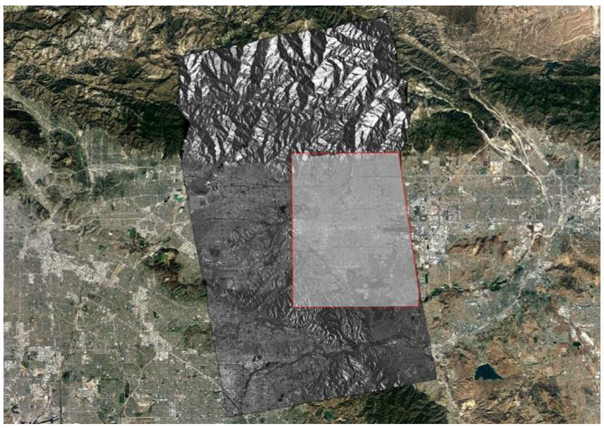
2.1.2.2 Monitoring Vertical Aquifer-System Deformation

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

2.1.2.3 Monitoring Vertical Ground Motion

The Watermaster monitored vertical ground motion via InSAR and traditional leveling techniques.

For InSAR, the Watermaster obtained twelve TerraSAR-X collections through Airbus DS Geo, Inc., covering the western half[3] of the Chino Basin from March 2022 to March 2024. The SAR image collection area is shown in Figure 2-1, with the area of interest highlighted in white with a red outline. While motion estimates are created over the entirety of the image area as a processing by-product, only the highlighted area of interest is analyzed and delivered by the Watermaster, shown in Figure 2-2.



Full SAR Collection Area
Google Earth, Landsat/Copernicus 2020

Delivered Area of Interest
Google Earth, Airbus 2024

Including the final collection from the 2021-2022 monitoring period as a reference, thirteen SAR images were processed[4] to create 25 short- and long-term vertical ground motion estimates[5] over the periods listed in Table 2-1.

[3] The SAR image footprint is fixed in longitude by the satellite orbit and sensor collection parameters. Coverage of the eastern Basin requires separate collection, processing, and analysis. InSAR from 1993 to 2010 indicates minimal vertical motion in the eastern Basin, the GLMC decided in 2012 to acquire and analyze InSAR only in the western Basin as a cost-saving strategy.

[4] Neighboring SAR images are used to create interferograms showing surface deformation between the times of collection of each image. Radar scatterers throughout a pixel generally move up or down together in typical recovery/subsidence scenarios. Unchanging surfaces and objects, for example infrastructure and some types of terrain, produce stable estimates of surface motion over time. Significant change between SAR images causes the surface motion estimate to become noisy or unavailable. Examples of significant change are vegetation growth, urbanization, erosion, flooding, plowing and harvesting, earth-moving, and major construction. The change between SAR images is measured as “coherence,” and any significant loss of coherence is referred to as “decorrelation.” If the coherence of a pixel is calculated as below the general noise level of the interferogram, the pixel will be rejected as “incoherent” for that point in that interferogram. Various kinds of filtering and interpolation are used to preserve ground motion estimates in areas which may be intermittently coherent.

[5] Many factors influence the accuracy of InSAR ground motion estimates, including inaccuracies in satellite ephemerides, atmospheric moisture content, underlying elevation model, filtering and interpolation methods, complex averaging, and projection of results from native SAR resolution to the desired map projection and pixel spacing. On average, InSAR ground motion estimates are accurate to +/- 0.02 ft, based on analysis by Dr. D. Cohen for Wildermuth Environmental, February 2009.

Table 2-1. 2022 to 2024 Vertical Displacement Estimates	
2022 to 2023 Estimates	
March 2022 to May 2022	March 2011 to May 2023
May 2022 to June 2022	March 2022 to June 2022
June 2022 to July 2022	March 2022 to July 2022
July 2022 to September 2022	March 2022 to September 2022
September 2022 to October 2022	March 2022 to October 2022
October 2022 to May 2023[6]	March 2022 to May 2023[6]
2023 to 2024 Estimates	
May 2023 to July 2023	March 2011 to July 2023
July 2023 to September 2023	May 2023 to September 2023
September 2023 to October 2023	May 2023 to October 2023
October 2023 to January 2024	May 2023 to January 2024
January 2024 to February 2024	May 2023 to February 2024
February 2024 to March 2024	May 2023 to March 2024
InSAR Estimate for Comparison to 2014+ Benchmark Survey	
April 2014 to March 2024	

With a transition away from previous seasons' processing arrangement with General Atomics (formerly Neva Ridge Technologies, Inc.) all interferometry beginning March 2011 was reprocessed in-house by the Watermaster,[7] creating a vertical motion estimate independent of previously delivered results.[8] The new estimate was compared frame-by-frame with historic deliveries through March 2022 to verify accuracy, and showed improvements in vertical fidelity in the primary subsidence feature in Northwest MZ-1,[9] decreased

[6] The final collection of the 22-23 monitor would normally be in March. The satellite was tasked with a conflicting collection from November 2022 to April 2023. Airbus was notified of the need for continuing and regular collections over the western Chino Basin, and collections resumed in May 2023.

[7] The basic SAR processing suite (GAMMA) and SAR collection footprint are identical to previous monitoring seasons.

[8] The past processing agreement with General Atomics (previously Neva Ridge Technologies, Inc.) allowed for transferal of the original Airbus data products and some intermediate processing data, but not the scripts used to drive the GAMMA processing software. From 2022 to 2024, the Watermaster developed a new processing framework around the GAMMA software.

[9] InSAR results are subject to the Coastline Paradox. Small spatial filters preserve vertical estimate magnitude and fine spatial detail, but may generate artifacts over less-coherent areas. Broad spatial filters obscure displacement estimates and reduce spatial detail, but must be used to provide temporal continuity over areas with intermittent and spatially variant data quality. The current processing method balances the accuracy of small spatial filters with the necessity of broad spatial filters.

overall spatial noise, decreased time series noise at monitored points,[10] improved feature visibility near the Ontario and Chino airports,[11] and improvements in spatial quadratic phase trend correction.[12]

For the ground-level surveys, Watermaster retained Guida Surveying, Inc. to conduct traditional leveling surveys at selected benchmark monuments in the western part of the Chino Basin. Table 2-2 below shows the date of the most recent benchmark monument survey by ground-level survey area. The locations of the ground-level survey areas are shown in Figure 2-2.

Table 2-2. Benchmark Monuments Surveyed in Ground-Level Survey Areas

Ground-Level Survey Area	Date of Most Recent Survey
Managed Area[(a)]	January 2018
Central Area[a]	January 2018
Northwest Area	May 2022
San Jose Fault Zone Area	May 2022
Southeast Area	May 2022
Northeast Area[a]	April 2020

(a) The entire benchmark monument survey network for the ground-level survey area was not surveyed in 2022 based on the GLMC scope and budget recommendations for FY 2021/22.

2.1.2.4 Monitoring of Horizontal Ground Motion

Watermaster periodically measures horizontal ground motion between benchmarks across areas that are susceptible to ground fissuring via EDMs. The date of the most recent horizontal benchmark survey within the ground-level survey area are shown in Table 2-3. Horizontal benchmark surveys were not performed in 2023/24 and are not planned for 2024/25.

Table 2-3. Horizontal Benchmark Survey

Ground-Level Survey Area	Date of Most Recent Survey
Fissure Zone Area[(a)]	February 2018
San Jose Fault Zone Area[a]	May 2021

(a) EDMs across the Fissure Zone Area and San Jose Fault Zone Area were not conducted in 2022 based on GLMC scope and budget recommendations for FY 2021/22.

---

[10] The residual noise level in previous deliveries forced an overly complex workflow when converting InSAR displacement rasters to ArcGIS contours. The new processing method reduces the standard deviation over small areas while maintaining depth estimates. Though more complex than a spatially variant smoothing operation, it may be described as such.

[11] This improvement, particularly south of ONT around the Whispering Lakes golf course and extending southward toward Ontario Ranch, was made possible by the improvements noted above.

[12] Satellite ephemeris inaccuracies create quadratic phase trends in the processed interferometry. These trends may be thought of as “tilts” or “bends” across the complex data, and are a source of displacement error if left uncorrected. Inaccuracies in the underlying elevation model may also contribute to overall phase trends. Correction requires careful selection of high-quality control points via manual masking and automatic data quality estimation. The improvements were made possible by updates to the GAMMA software, improved computing resources within the Watermaster, detailed analysis of the processed interferometry and displacement results with respect to previous deliveries and ground truth, and substantial analyst time invested by the Watermaster.

2.2 Land-Subsidence Investigations

The Watermaster performs land subsidence investigations pursuant to the Subsidence Management Plan and/or recommendations from the GLMC that are approved in the annual Watermaster budget. The goals of these investigations are to refine the Guidance Criteria (described in Section 1.1.3) or 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 March 2023 and March 2024 that are called for in the Subsidence Management Plan.

2.2.1 Subsidence Management Plan for Northwest MZ-1

In 2015, the GLMC developed the final Work Plan to develop a subsidence-management plan for Northwest MZ-1, which describes a multi-year effort with cost estimates to execute the Work Plan. The Work Plan was included in the Subsidence Management Plan as Appendix B.[13] The background and objectives of the Work Plan are described in Section 1.1.5. The Watermaster began implementation of the Work Plan in July 2015. The Work Plan has evolved over time as new data and information has been collected and evaluated by the GLMC. The following describes the Work Plan tasks and status of each task:

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 summarized the current state of knowledge of the hydrogeology of Northwest MZ-1, the data gaps needed 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 – The Watermaster's Engineer worked with the Watermaster, MVWD, City of Pomona, and SCADA Integrations, Inc. to identify and equip a set of wells with supervisory control and data acquisition (SCADA) monitoring capabilities and/or transducers. Through several field visits and technical meetings with the well owners, a protocol was developed to install monitoring equipment and collect pumping and piezometric data. For the City of Pomona, nine wells were equipped with transducers. For MVWD, seven wells were equipped with transducers, two wells with sonar units, and two wells with air-line units. Hydraulic heads are recorded once every 15 minutes. Nine of the 11 MVWD wells were connected to the MVWD's existing SCADA system. The hydraulic head data from these wells are currently being collected and analyzed as part of the Northwest MZ-1 monitoring and testing program. These data will be used in future efforts to recalibrate the Chino Valley Model (MODFLOW model of Chino Basin) and the 1D Models at PX and MVWD-28.

Task 3. Develop and Evaluate the Baseline Management Alternative (BMA) 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 that described the construction, calibration, and use of a numerical one-dimensional aquifer-system compaction model (1D compaction model) at MVWD-28. The objective of this memo was also to explore the future occurrence of subsidence in Northwest MZ-1 under various basin-operation scenarios of groundwater pumping and artificial recharge and to identify potential subsidence mitigation strategies.

[13] Source: http://www.cbwm.org/pages/reports/engineering/

Task 5. Design and Install the Pomona Extensometer (PX) Facility – The Watermaster's Engineer completed construction of two dual-nested piezometers located in Montvue Park, Pomona, CA in August 2019. Each PX piezometer was equipped with transducers and cable extensometers in June and July 2020 and has been collecting preliminary depth-specific hydraulic head and aquifer-system deformation since December 2020.

The piezometers at the PX facility are providing accurate, depth-specific head data. These data will be used in future efforts to verify or recalibrate the 1D Models at PX. Unfortunately, the extensometers at PX are not recording reasonably accurate data for vertical aquifer-system deformation. The Watermaster Engineer is uncertain of the precise causes for the malfunction at PX extensometers and is proceeding with a stepwise methodology to test and improve the monitoring devices (see Section 2.1).

Task 6. Design and Conduct Aquifer-System Stress Tests (if necessary) – The objective of this task is to perform controlled aquifer-system stress tests at pumping wells in Northwest MZ-1 and to monitor the depth-specific hydraulic head and aquifer-system deformation response at PX. This information, along with hydraulic head data collected as part of Task 2 will be used to help identify the subsidence mechanisms and the pre-consolidation stress(es) in Northwest MZ-1. The Watermaster Engineer has not yet identified specific questions that need to be answered with the controlled aquifer-system stress tests. It is recommended a period of "passive" data collection and assessment of the data over time to determine if a controlled aquifer-system stress test is recommended in the future.

Task 7/8. Update the Hydrogeologic Conceptual Model/Construct and Calibrate Subsidence Modeling Tools – The objectives of these tasks are: (i) to update the hydrogeologic conceptual model of Northwest MZ-1 based on new lithologic information from PX and an improved understanding of hydraulic head data across Northwest MZ-1; (ii) describe the subsidence mechanisms and the pre-consolidation head by aquifer-system layer in Northwest MZ-1; and (iii) develop modeling tools that can be used to explore the future occurrence of subsidence in Northwest MZ-1 under various basin-operation scenarios of groundwater production and artificial recharge and to identify potential subsidence mitigation strategies.

A new 1D compaction model was constructed and calibrated using the hydrogeologic information collected at the PX. The 1D model at MVWD-28 was also updated and recalibrated using current information. This work was reviewed by the GLMC, and additional 1D model calibration refinements and sensitivity analyses were performed based on GLMC recommendations. In December 2022, the Watermaster Engineer, with review and input from the GLMC, deemed 1D model calibrations sufficient for simulation of future land subsidence under prospective plans for pumping and recharge (see Task 9 below).

Task 9. Refine and Evaluate Subsidence-Management Alternatives – This task began in FY 2023-24 and helps answer the question: *What are potential methods to manage the land subsidence in Northwest MZ-1?*

The 1D compaction models at MVWD-28 and PX were used to characterize the mechanical response of the aquifer-system to an initial Subsidence Management Alternative (SMA-1). In 2023, the Watermaster Engineer, with review and input from the GLMC, developed an SMA-1, which is equivalent to the planning scenario that was simulated with the 2020 Chino Valley Model (CVM) to support the 2020 Safe Yield Recalculation (2020 SYR). The 2020 SYR was intended to represent and simulate the Parties' projected pumping, recharge, and use of storage through 2050. The results of the 2020 SYR (*i.e.,* projected hydraulic heads by CVM layer) were used as input data for the 1D Model simulations to predict the potential future occurrence of subsidence through 2050. In February 2024, the Watermaster Engineer published a final TM titled *1D Model Simulation of Subsidence in Northwest MZ-1—Subsidence Management Alternative #1*. The Watermaster Engineer's recommendations from this work were the following:

a) Establish a preliminary "Northwest MZ-1 Guidance Level" of 630 ft-amsl for hydraulic heads in Layers 3 and 5 at the PX location. The preliminary Guidance Level is an aspirational Watermaster recommendation that, if achieved, would likely slow or stop aquitard compaction and land subsidence in Northwest MZ-1.

b) Compliance with the Guidance Level should be measured at the PX-2/3 piezometer, which is generally representative of heads in Layers 3 and 5.

c) The methods to achieve the Guidance Level could include but are not limited to: voluntary modification of pumping patterns; in-lieu recharge; wet-water recharge via spreading and/or injection; or a combination of methods. These methods might necessitate: voluntary modification of water-supply plans of the purveyors in the Chino Basin; modification of Watermaster practices for recharge and replenishment; and/or the implementation of regional-scale storage or conjunctive-use programs.

d) Additional SMAs should be developed and evaluated with the 1D Models to generate the necessary information to finalize the Guidance Level and the *Subsidence Management Plan for Northwest MZ-1*. The additional SMAs could be developed during Watermaster's groundwater modeling efforts associated with the 2025 Safe Yield Reevaluation and the development of the Storage and Recovery Master Plan. The GLMC should participate in the scenario building exercises associated with these Watermaster efforts to develop the SMAs, so that the scenarios include various methods to achieve the Guidance Level. Then, the 1D Models should be used to evaluate the potential future subsidence in Northwest MZ-1 under the SMAs. These model results and evaluations will support the establishment of a Guidance Level in the *Subsidence Management Plan for Northwest MZ-1*. It should be noted that future monitoring and analyses always hold the potential for revisions to the Guidance Level, consistent with the adaptive management approach called for in the Chino Basin Subsidence Management Plan.

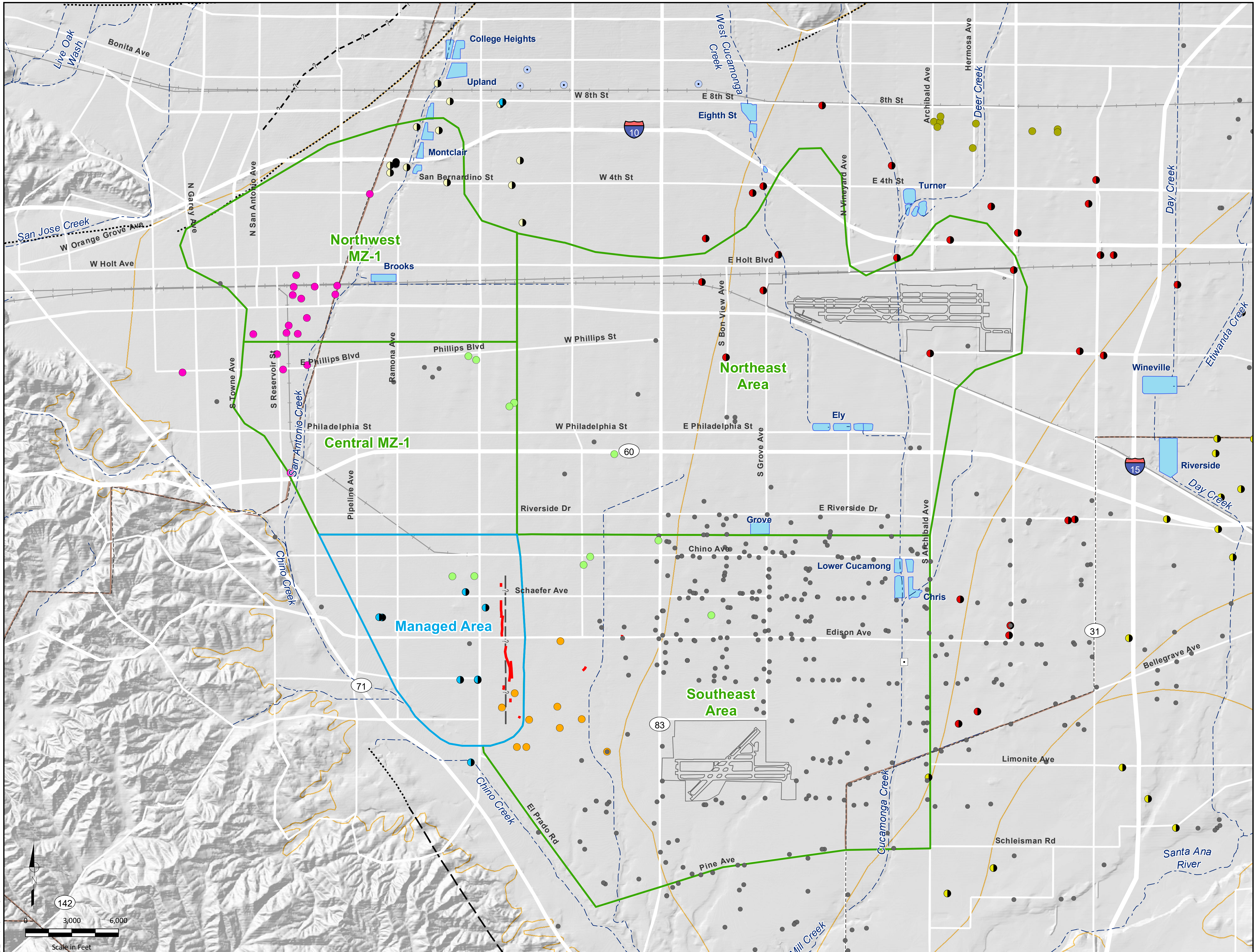
Task 10. Update the Chino Basin Subsidence Management Plan – The objective of this task is to incorporate a preferred subsidence-management alternative for Northwest MZ-1 into the Chino Basin Subsidence Management Plan. The updated Subsidence Management Plan will require review and input by the GLMC and the Watermaster Pools, Advisory Committee, and Board. The Watermaster will apprise the Court of revisions to the Subsidence Management Plan as part of its OBMP implementation status reporting. The updated Chino Basin Subsidence Management Plan is anticipated to be completed by the end of FY 2025/26.

2.2.2 Northeast Area Subsidence Investigation

In the Northeast Area, the long- and short-term InSAR estimates indicate that persistent downward ground motion has occurred in a concentrated area in the vicinity of Whispering Lakes Golf Course, south of the Ontario Airport between Vineyard Avenue and Archibald Avenue. The western and eastern edges of this subsiding area exhibit steep subsidence gradients (i.e., differential subsidence").

In FY 2021/22, the Watermaster conducted a reconnaissance-level subsidence investigation of the Northeast Area focusing on the Whispering Lakes Subsidence Feature. This investigation included collection, review, and analysis of available borehole and lithologic data, pumping and recharge data, hydraulic head measurements, and InSAR estimates of vertical ground motion. Figures and charts were prepared for the *2021-22 Annual Report of the GLMC* to support the data analysis, interpretations, and recommendations for future investigations and monitoring.

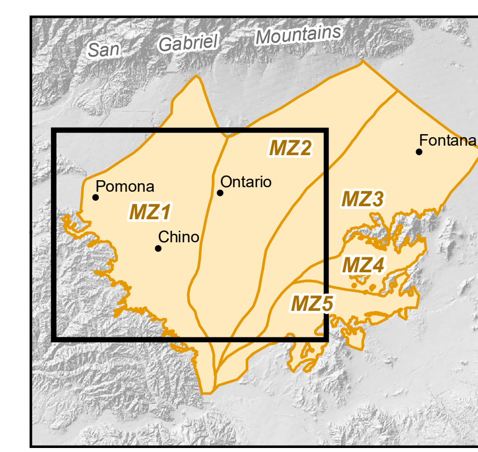
For this annual report, additional monitoring and analysis of groundwater pumping, land use, and land subsidence as measured by InSAR were conducted for the period 2022-24. The results, conclusions, and recommendations of the analysis are reported in Section 3.5.



Active Groundwater Pumping Wells
April 1, 2023 to March 31, 2024

- Private
- California Institution for Men
- Chino Basin Desalter Authority
- City of Chino
- City of Chino HIlls
- City of Ontario
- City of Pomona
- City of Upland
- Cucamonga Valley Water District
- Golden State Water Company
- Jurupa Community Services District
- Monte Vista Water District

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

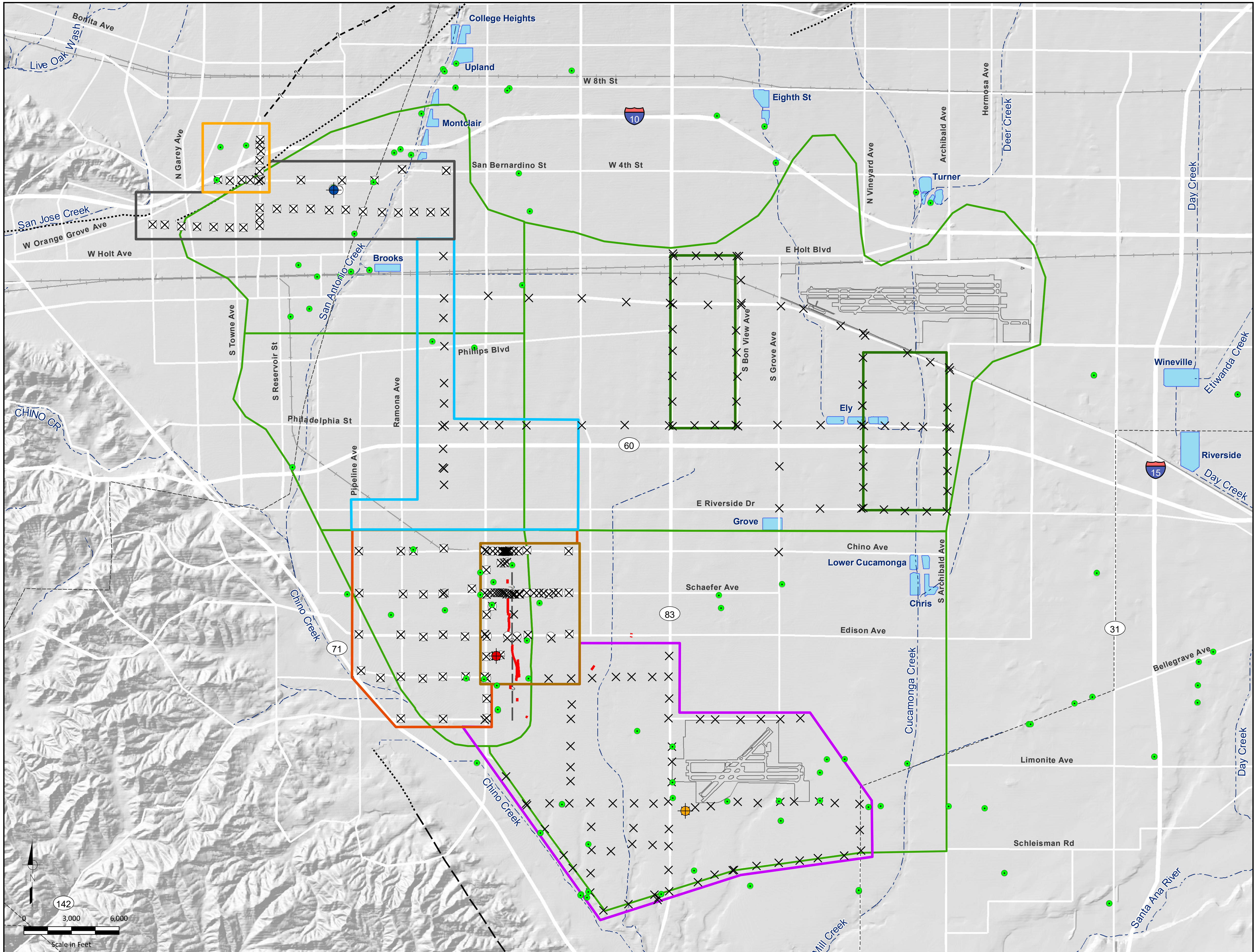


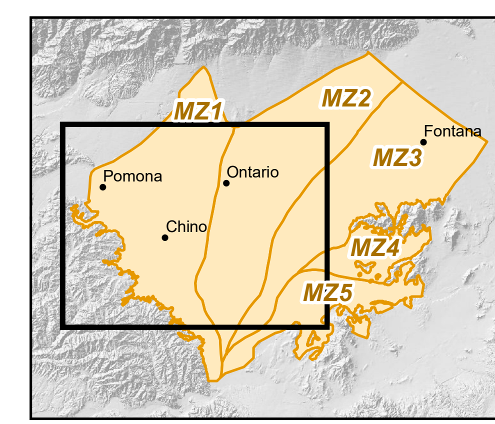
WEST YOST

Chino Basin Watermaster
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 2-1

Pumping and Recharge Facilities
Western Chino Basin: 2023/24



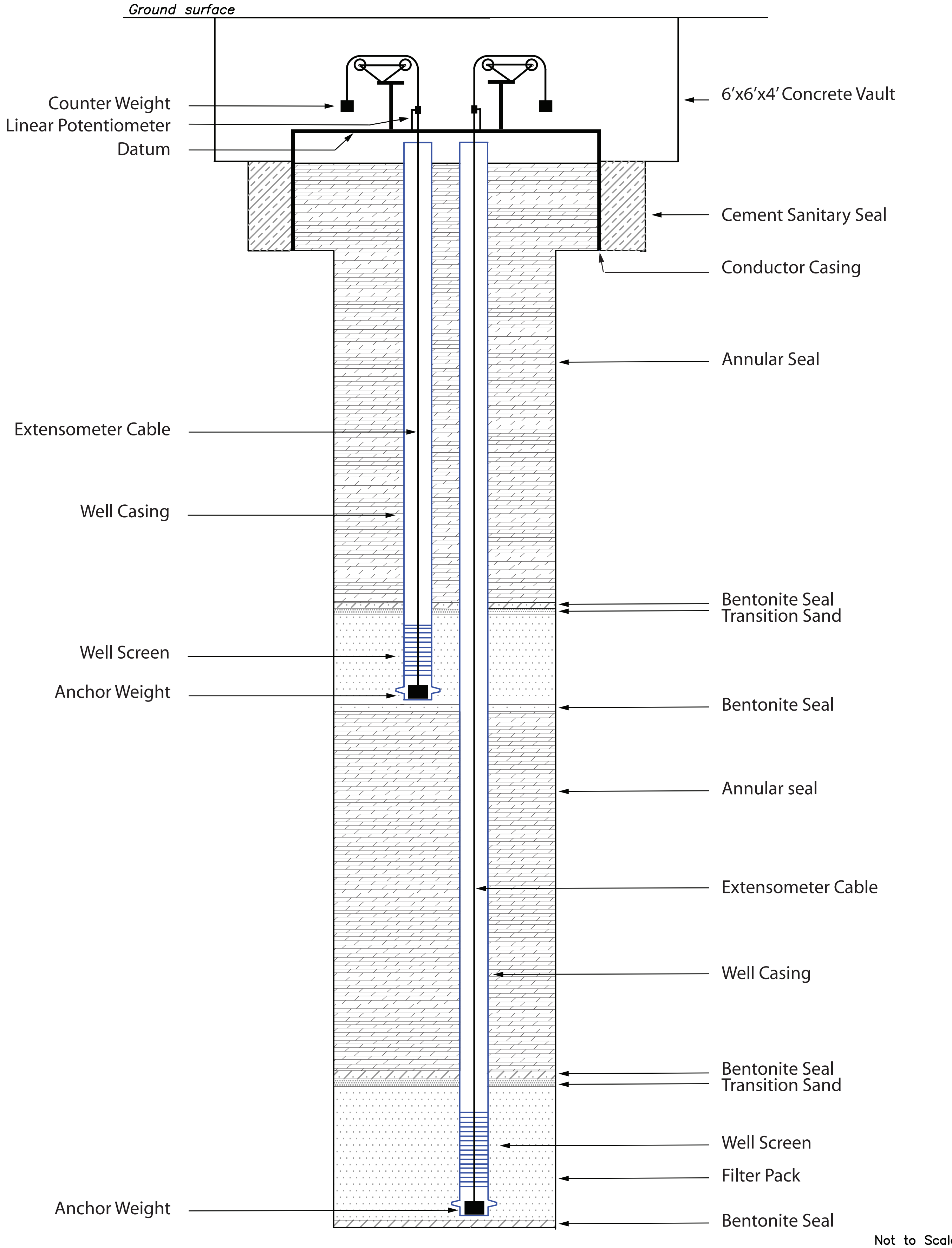


WEST YOST

Chino Basin Watermaster
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 2-2

Ground-Level Monitoring Network Western Chino Basin



Prepared by:

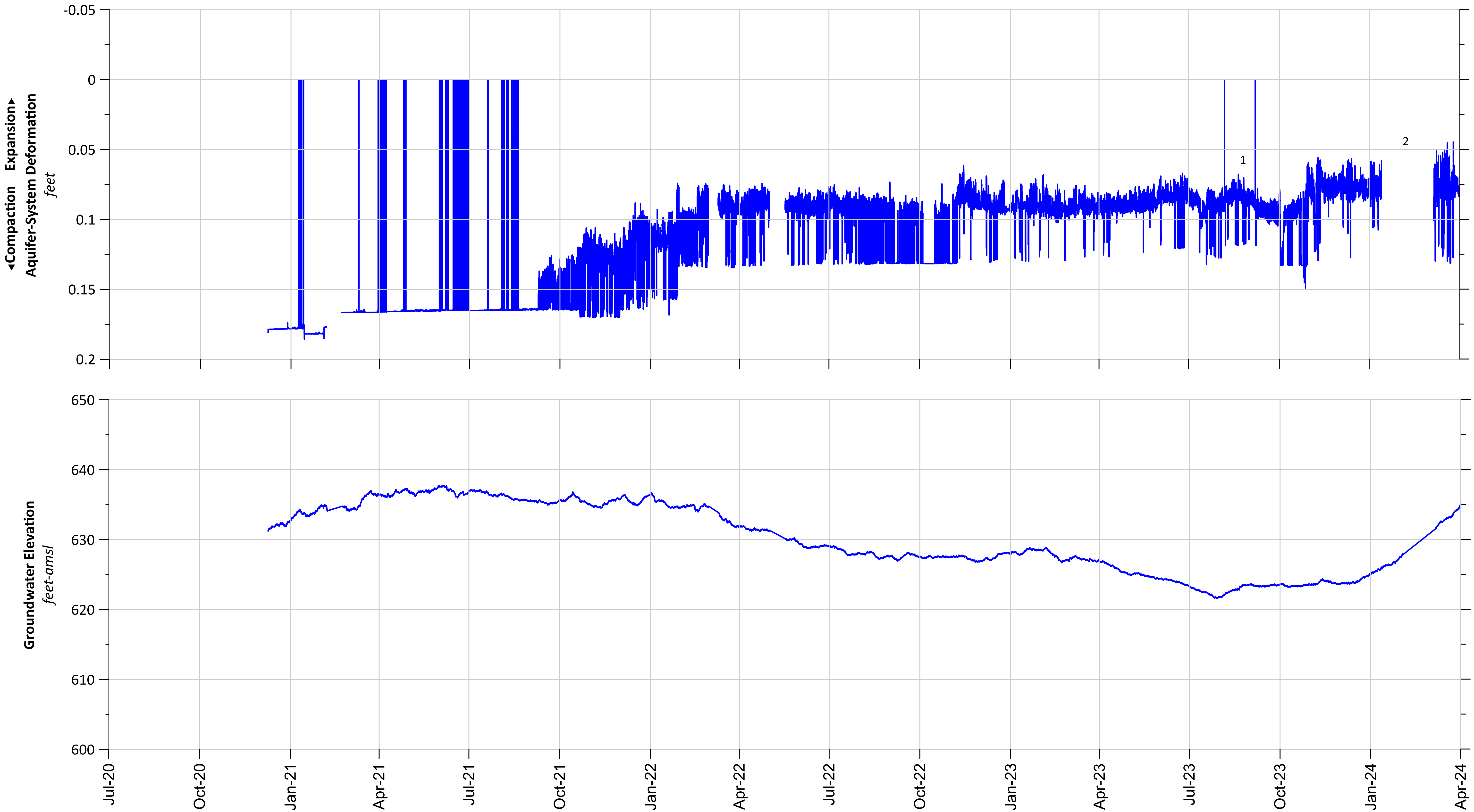
WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: TCR
Date: 20151110
File: Figure 3-2.pdf

Initial Hydrogeologic Conceptual Model,
Monitoring, and Testing Program
for the Northwest MZ-1 Area

Dual-Nested Cable Extensometer
Conceptual Schematic

Figure 2-3



1 Added counterweight sleeve approximately 10 lbs.
2 Battery voltage too low

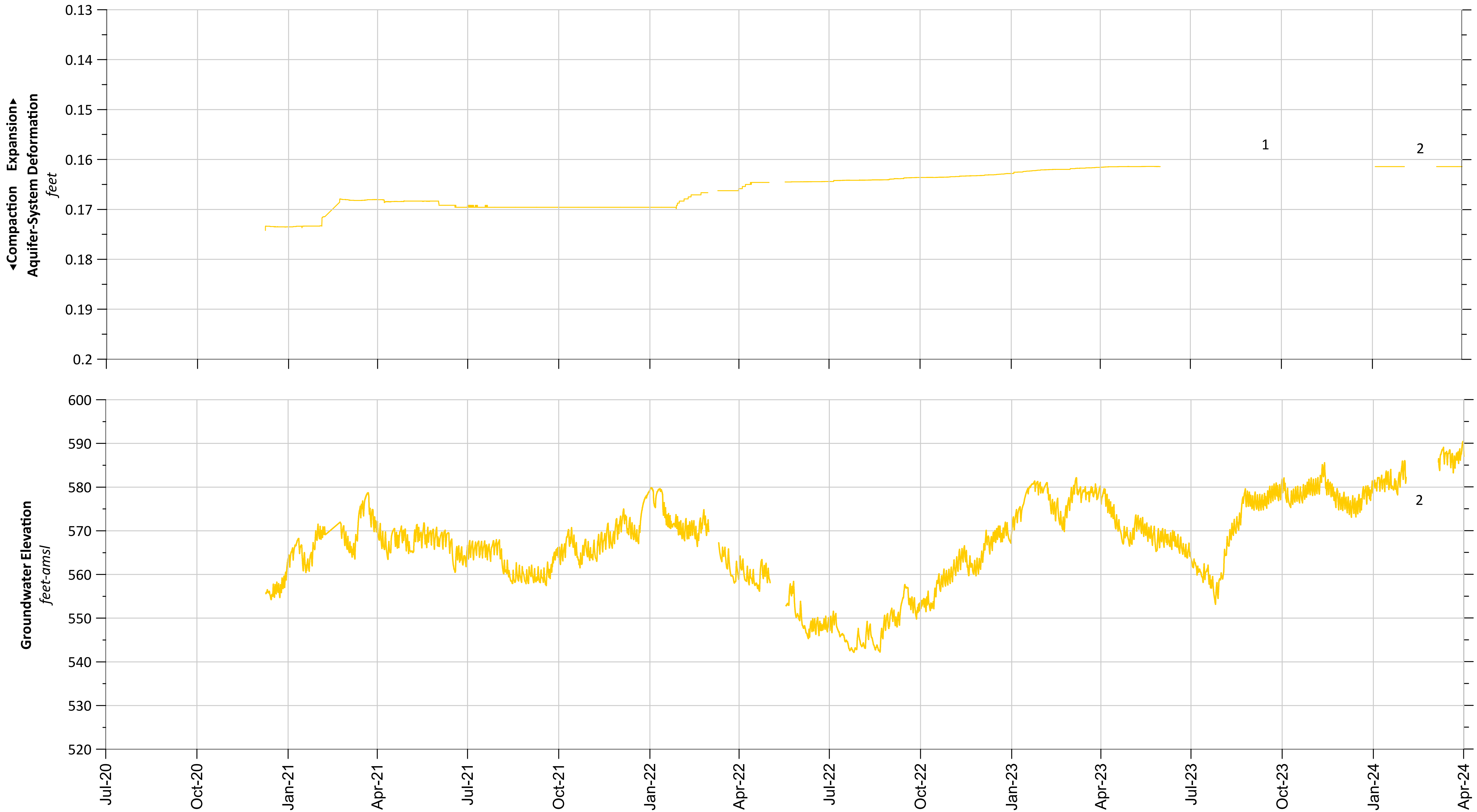
WEST YOST - F2-3a_ManagedAreaStrsStrn.grj

WEST YOST

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 2-4a

Stress and Strain at PX-1
within the Managed Area



1 Removed Linear Potentiometer to test in office
2 Battery source low

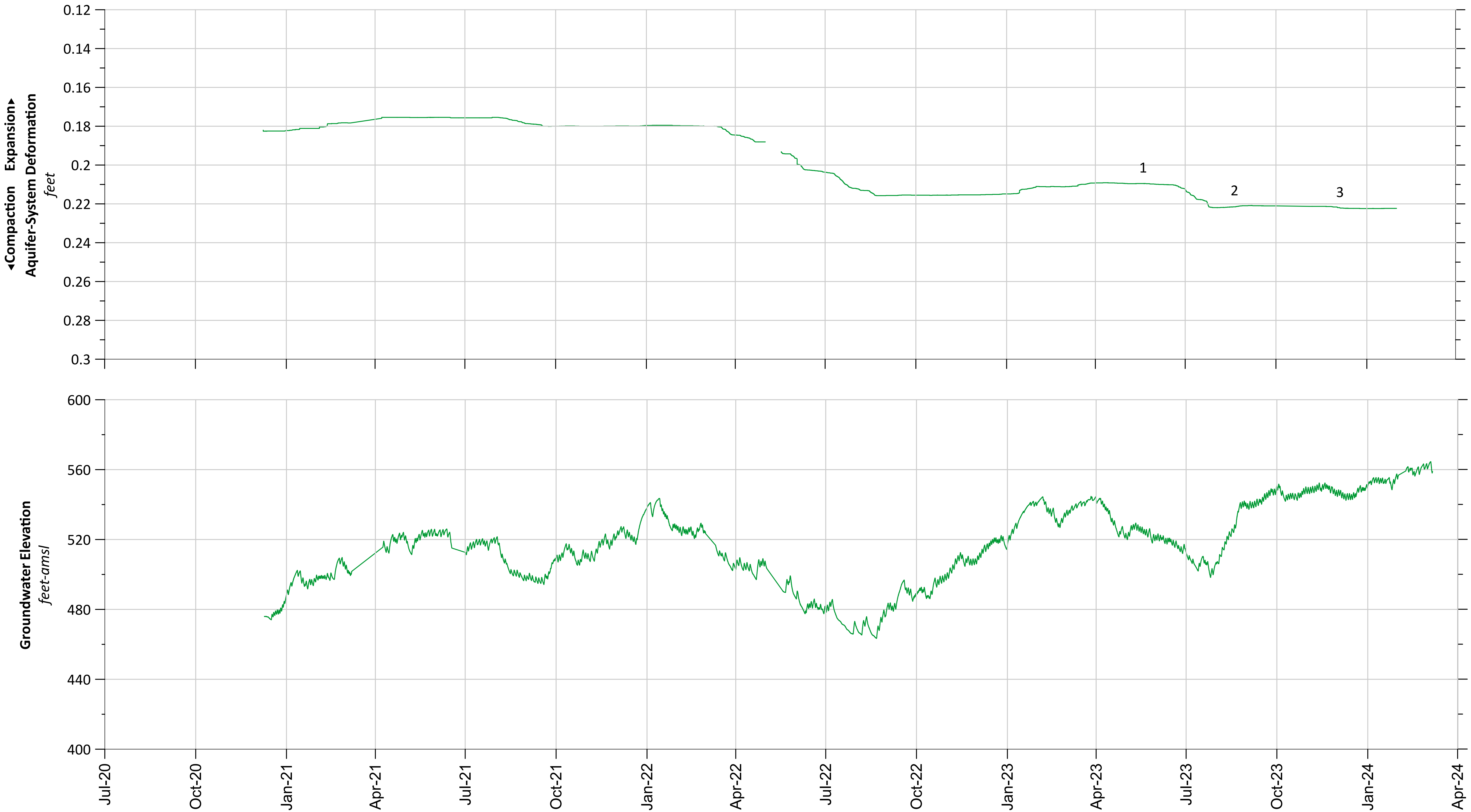
WEST YOST

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 2-4b

Stress and Strain at PX-2 within the Managed Area

WEST YOST - F2-3b_ManagedAreaStrsnStrn.gpj



1 Adjusted linear potentiometer parallel to wire; added counterweight sleeve approximately 10 lbs.
2 Added one weight sleeve approximately 10lbs.
3 Removed one weidght sleeve approximately 10lbs.

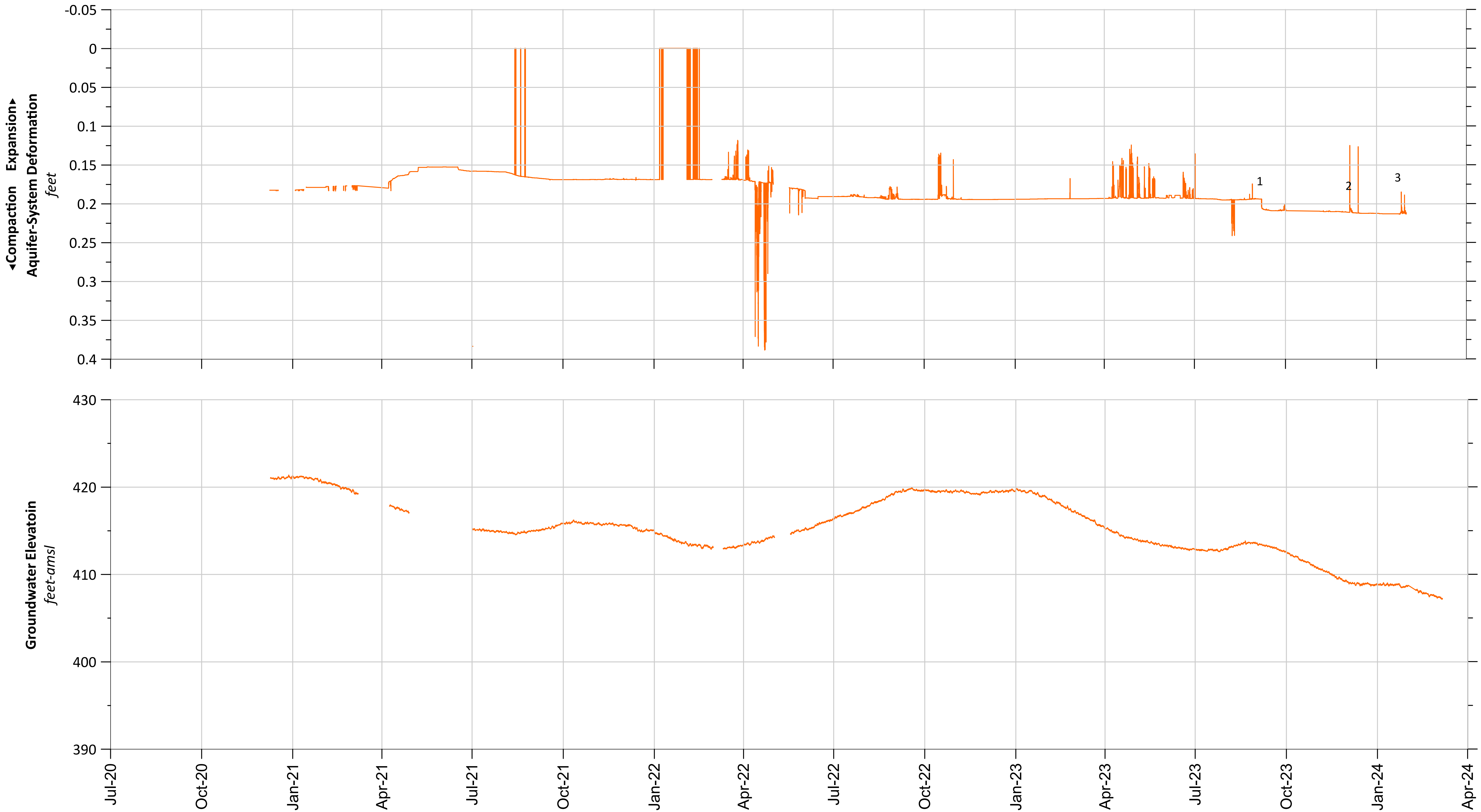
WEST YOST - F2-3c_ManagedAreaStrsStrn

WEST YOST

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 2-4c

Stress and Strain at PX-3 within the Managed Area



WEST YOST - F2-3d_ManagedAreaStrsStrn.grf

1 Adjusted linear potentiometer parallel to wire; added counterweight sleeve approximately 10 lbs.
2 Added one weight sleeve approximately 10lbs.
3 Removed one weidght sleeve approximately 10lbs.

WEST YOST

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 2-4d

Stress and Strain at PX-4
within the Managed Area

3.0 RESULTS AND INTERPRETATIONS

This section describes the results and interpretations derived from the GLMP for the Managed Area and Areas of Subsidence Concern in the Chino Basin for the March 2022 to March 2024 reporting period. Figures 3-1a, 3-1b, and 3-1c are maps that display vertical ground motion as measured by InSAR across the western portion of the Chino Basin between the periods of March 2011 and March 2024, March 2022 and March 2023, and March 2023 and March 2024, respectively. The maps also show the locations and magnitude of pumping and artificial recharge—the stresses to the aquifer-system that can cause ground motion. Data shown on these and subsequent figures are described and interpreted in this section.

3.1 Managed Area

The Managed Area is the primary focus of the Subsidence Management Plan. 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 Subsidence Management Plan.

3.1.1 History of Stress and Strain in the Aquifer-System

Figure 3-2a illustrates the long-term history of groundwater pumping, hydraulic heads, 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 pumping from the area. Recycled water is often used for irrigation purposes and can contribute to groundwater recharge to the shallow aquifer-system as well. General observations and interpretations from this chart are:

- Pumping from the shallow aquifer-system between the 1930s and about 1977 caused hydraulic heads to decline by about 150 ft. From 1978 to 1990, hydraulic heads recovered by about 50 ft.
- Pumping from the confined, deep aquifer-system during the 1990s caused the hydraulic heads to a decline, coinciding 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 pumping decreased, hydraulic heads in the deep aquifer-system recovered, and the rate of land subsidence declined significantly across the Managed Area.
- The direct use of recycled water, which began in 1997, may have contributed to decreased groundwater pumping from the area, which in turn, may have contributed to the observed increases in hydraulic heads in the Managed Area.
- Since 2005, hydraulic heads 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 Subsidence Management Plan 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 13 years of groundwater pumping, changes in hydraulic heads, and vertical ground motion in the Managed Area under the Subsidence Management Plan.

3.1.2.1 Groundwater Pumping and Hydraulic Heads

Table 3-1 summarizes groundwater pumping by well within the Managed Area for fiscal year 2012 through March 2024. Groundwater pumping in the Managed Area has declined from about 5,680 acre-feet (af) in 2012 to almost negligible volumes in 2024. A total of about 24 af of groundwater pumping occurred in the Managed Area from July 1, 2023 to March 31, 2024—97 percent of the groundwater pumping was from wells screened in the shallow aquifer-system.

Figure 3-3 displays the hydraulic stresses and mechanical strains that have occurred within the shallow and deep aquifer-systems in the Managed Area over the period January 2011 through March 2024. The figure includes three time-series charts: quarterly groundwater pumping (hydraulic stress to the aquifer-systems); the resultant head changes (hydraulic responses to pumping); and aquifer-system deformation as measured at the Ayala Park Extensometers (mechanical strain that occurred within the aquifer-system sediments in response to the head changes). The following are observations and interpretations regarding pumping and head changes:

- From 2011 to 2018, there was a seasonal pattern of pumping in the Managed Area – increased pumping during the spring to fall and decreased pumping during the winter. Since 2018, very little pumping has occurred in the Managed Area.
- Hydraulic heads respond differently to the pumping stresses in the shallow and deep aquifer-systems. Pumping from the deep confined aquifer-system causes a hydraulic head decline that is much greater in magnitude than the hydraulic head decline caused by pumping from the shallow aquifer-system despite that more groundwater pumping has occurred from the shallow aquifer-system.
- The hydraulic head at PA-7 (deep aquifer-system) has fluctuated from a low of approximately 190 ft-btoc in August 2013 to a high of about 55 ft-btoc in May 2021 and has not declined below the Guidance Level of 245 ft-btoc.
- The recovery of hydraulic heads in the deep aquifer-system to above 90 ft-btoc in December 2023 represented "full recovery" of hydraulic head at PA-7 as defined in the Subsidence Management Plan.
- Since the first instance of full recovery in 2012, the hydraulic head at PA-7 recovered to 90 ft-btoc or greater in 2016, 2018, 2019, 2022 and 2023 which complies with the recommendation in the Subsidence Management Plan for full recovery within the deep aquifer-system at least once every five years.[14]
- Since 2018, hydraulic heads at PA-10 and PA-7 have increased to relatively high levels because of very little pumping from the shallow and deep aquifer-systems in the Managed Area. On April 1, 2024, heads were at about 49 ft-btoc in PA-10 and about 56 ft-btoc in PA-7.

[14] Page 2-2 in the Subsidence Management Plan, 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."

3.1.2.2 Aquifer-System Deformation

Figure 3-3 also 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 2024. The following are observations and interpretations regarding aquifer-system deformation in response to the pumping and head changes:

- There has been seasonal compression and expansion of the aquifer-system in response to the seasonal decline and recovery of hydraulic heads, which indicates that the vertical deformation of the aquifer-system was mainly elastic during this period.
- However, between April 6, 2011 and May 3, 2018 (dates of full recovery at PA-7 to 90 ft-btoc), the Ayala Park Deep Extensometer recorded about 0.03 ft of aquifer-system compression, which indicates that this compression was permanent compaction that occurred within the depth interval of 30-1,400 ft-bgs.[15]
- From May 3, 2018 to December 8, 2023 (dates of full recovery at PA-7), the Deep Extensometer recorded a multiple cycles of aquifer-system compression and expansion in response to a multiple cycles of decline and recovery of hydraulic heads at PA-7. For much of this period, hydraulic heads at PA-7 remained above 90 ft-btoc (*i.e.,* the full recovery threshold) and the Deep Extensometer recorded about 0.05 ft of expansion, indicating that the vertical deformation of the aquifer-system was mainly elastic.

Figure 3-4 is a stress-strain diagram of hydraulic heads 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 (i.e., elastic versus inelastic deformation). The hysteresis loops on this figure represent cycles of hydraulic head decline-recovery 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 inelastic compaction within the depth interval of the aquifer-system that is penetrated by the Deep Extensometer. Hydraulic head decline (drawdown) is shown as increasing from bottom to top on the y-axis, and aquifer-system compression (compaction) is shown as increasing from left to right on the x-axis. The following are observations and interpretations regarding aquifer-system deformation in response to the head changes:

- From May 2006 to May 2018, the hysteresis loops progressively shifted to the right on this chart, indicating that about 0.065 ft of inelastic compaction occurred during this time-period. However, the rate of inelastic compaction appeared to gradually decline over this 12-year period.
- From May 2018 to December 2023, the hydraulic heads at PA-7 fluctuated between about 60-120 ft-btoc, with hydraulic heads remaining about 90 ft-btoc (*i.e.,* the full recovery threshold) for much of this time. During this period, the hysteresis loops started to overlap one another and then shifted to the left, indicating that the vertical deformation of the aquifer-system was mainly elastic expansion of the aquifer-system sediments.

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

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. Figures 3-1a, 3-1b, and 3-1c and illustrate vertical ground motion[16] as estimated by InSAR for the periods March 2011 to March 2024, March 2022 to March 2023, and March 2023 to March 2024, respectively.

Where coherent, the InSAR estimates of vertical ground motion from 2011 to 2024 shown in Figure 3-1a range from about +0.04 ft to -0.10 ft across the Managed Area. The greatest downward ground motion occurred in the northern portions of the Managed Area. The InSAR estimates of vertical ground motion from 2022 to 2024 shown in Figures 3-1b and 3-1c indicate very little recent vertical ground motion across the Managed Area.

Figure 3-2b is a map that shows the ground-level survey results compared against the InSAR results across the Managed Area from 2011 to 2024. The figure shows a similar spatial pattern of ground motion for both monitoring techniques, but with slightly different magnitudes of ground motion. These differences in magnitudes are most likely related to the different timing of the ground level surveys and the SAR acquisition, differing methods to select the reference elevations, and/or relative errors associated with each monitoring technique.

As described above, Figures 3-1a and 3-2b show that maximum downward ground motion during 2011-2024 occurred in the northern portion of the Managed Area. The City of Chino Well 15 (C-15) is in the northern portion of the Managed Area, is screened across both the shallow and deep aquifers, and has been equipped with a transducer that measures and records hydraulic heads once every 15 minutes. These InSAR and hydraulic head data at the C-15 location provide information on the nature of the aquifer-system deformation that occurred in this area (i.e. elastic versus inelastic deformation). Figure 3-5 is a time-series chart that compares the hydraulic heads at C-15 to vertical ground motion as measured by InSAR at the same location between 2005 and 2024. The main observations from this chart are:

1. The InSAR record at C-15 is measuring seasonal elastic vertical ground motion which is caused by seasonal fluctuations in hydraulic head and the resultant seasonal elastic deformation in the aquifer-system(s). The seasonal fluctuations of hydraulic head at C-15 are coincident with the seasonal fluctuations of vertical ground motion measured by InSAR at the same location.
2. From 2007 to 2018, InSAR indicates a long-term trend of downward ground motion at C-15. However, hydraulic heads at C-15 during this same time-period increased, indicating that about 0.25 ft of subsidence was caused by inelastic compaction of the aquifer-system. The inelastic compaction that occurred during this period of increasing hydraulic head most likely represents the delayed drainage and compaction of aquitards due to historical head declines that occurred prior to 2007.
3. Since 2018, the long-term subsidence trend appears to have stopped, indicating that inelastic compaction of the aquitards has also stopped. This observation is supported by the Deep Extensometer record, which indicates mostly elastic deformation of the aquifer-system since 2018 (see Figure 3-4). The recent cessation of subsidence observed at C-15 is likely a result of increasing hydraulic heads in the aquifers, which has led to equilibration with hydraulic heads in the aquitards and the cessation of aquitard drainage and compaction.

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

4. These monitoring data may be providing information on hydraulic head “thresholds” that could be used as management criteria to protect against the future occurrence of land subsidence. At C-15, when groundwater elevations remain above about 585 ft-above mean sea level (amsl), InSAR indicates that no permanent land subsidence has occurred.

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 (Figures 3-1a, 3-1b, 3-1c) are somewhat 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 pumping, the direct reuse of recycled water, hydraulic heads, and vertical ground motion in the Southeast Area from 1930 to 2024. Vertical ground motion is estimated by InSAR, extensometer data, and ground-level surveys across the southeast Area from 1987 to 2024. The main observations and interpretations from Figure 3-6 are:

- From the 1940s to about 1968, hydraulic heads declined by up to about 75 ft. There is a data gap from about 1968 to 1988; however, it is likely that hydraulic heads 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, hydraulic heads remained relatively stable from 1988 to 2010 and then gradually increased by about 10 to 25 ft from 2010 to 2024 (see wells CH-18A, C-13, CCPA-1, and CCPA-2). In the eastern portion of the Southeast Area, hydraulic heads have been gradually declining by about 22 ft between 2005 and March 2024 (see wells HCMP-1/1 and HCMP-1/2) likely in response to pumping at the Chino Basin Desalter Authority (CDA) wells.
- Figure 3-6 also displays vertical ground motion as estimated by InSAR and ground-level surveys from 1987 to 2024. Both methods indicate relatively minor ground motion over the period and similar, but not exact, spatial patterns and magnitudes of ground motion across the Southeast Area. These differences are likely related to the relative incoherence of the InSAR results, differences in the timing of the ground-level surveys and the SAR acquisition, and/or the relative errors associated with each monitoring technique. From 1987-2024, maximum downward ground motion of about 0.6 ft was estimated by ground-level surveys in the northwestern portion of the area (BM-137/61). From 2011-2024, maximum downward ground motion of about 0.4 ft was estimated by InSAR in the northeastern portion of the area. This gradual downward ground motion most likely represents the delayed drainage and compaction of aquitards due to the historical head declines that occurred prior to the Judgment.
- For the current period March 2022 and March 2024, hydraulic heads remained relatively stable or increased across most of the area, and Figures 3-1b, 3-1c, and 3-6 indicate very little, if any, downward ground motion across most of the Southeast Area.

Figure 3-7 displays the time series of hydraulic heads and vertical aquifer-system deformation recorded at the CCX, which began collecting data in July 2012. Groundwater pumping began at the Chino Creek Well Field in 2014, but appears to have had little, if any, effect on hydraulic heads or aquifer-system deformation at the CCX through March 2024. In general, hydraulic heads at the CCX vary seasonally and have gradually increased since 2012, and a small amount of elastic expansion of the aquifer-system has been measured by the CCX extensometers. In general, the aquifer-system deformation recorded at the CCX is minor and elastic, which is consistent with the estimates of vertical ground motion as measured by InSAR and ground-level surveys (as shown on Figures 3-1a, 3-1b, 3-1c, and 3-6).

3.3 Central MZ-1

Vertical ground motion is measured across Central MZ-1 via InSAR and traditional ground-level surveys. Figures 3-1a, 3-1b, and 3-1c are maps that display vertical ground motion as measured by InSAR across Central MZ-1 during the periods of March 2011 and March 2024, March 2022 and March 2023, and March 2023 and March 2024, respectively. The InSAR results are generally coherent across this area because the overlying land uses are urban and serve as hard and consistent reflectors of radar waves. Ground-level surveys are performed periodically along the eastern portion of the area. Figure 3-8 is a time-series chart that displays and describes the long-term history of pumping, recharge, hydraulic heads, and vertical ground motion in Central MZ-1. The following observations and interpretations are derived from these figures:

- Hydraulic head data are absent in the southern portion of Central MZ-1. In the northern portion of Central MZ-1, hydraulic heads declined by about 200 ft from 1930 to about 1978. From 1978 to 1986, hydraulic heads increased by about 80 ft and remained relatively stable or have slightly increased from 1986 to 2024. Recent hydraulic heads (1986 to 2024) in the northern portion of Central MZ-1 are about 120 ft lower than the hydraulic heads in the 1930s.
- About 1.8 ft of subsidence occurred near Walnut and Monte Vista Avenue from 1988 to 2000, as measured by ground-level surveys at BM 125/49. Since 2000, the rate of subsidence has slowed significantly—about 0.34 ft of subsidence occurred at a gradually declining rate from 2000 to 2024. 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 hydraulic head data in this area to confirm this relationship.
- Figure 3-1a shows that the areas that experienced the greatest magnitude of subsidence from March 2011 to March 2024 are in the western portion of Central MZ-1, where up to about 0.25 ft of downward ground motion has occurred—an average rate of about 0.02 ft/yr. Hydraulic heads remained relatively stable in this area from 2011 to 2024, which indicates that the downward vertical ground motion was, at least in part, permanent subsidence due to delayed aquitard drainage in response to the historical declines in hydraulic heads that occurred from 1930 to 1978.
- The ground motion measured by InSAR in Figure 3-1a also shows that the groundwater barrier (Riley Barrier) may extend from the Managed Area northward into Central MZ-1 to at least Mission Boulevard. This observation is evidenced by a steep subsidence gradient located just east of Central Avenue.
- Figures 3-1b and 3-1c show that between March 2022 and March 2024, vertical ground motion across most of Central MZ-1 was minor.

3.4 Northwest MZ-1

Vertical ground motion is measured across Northwest MZ-1 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, 3-1b, and 3-1c are maps that display vertical ground motion as measured by InSAR across Northwest MZ-1 during the periods of March 2011 and March 2024, March 2022 and March 2023, and March 2023 and March 2024, respectively. Figure 3-9a is a time-series chart that displays and describes the long-term history of pumping, recharge, hydraulic heads, and vertical ground motion in Northwest MZ-1. Figure 3-9b is a map of the most recent data that illustrates vertical ground motion as estimated by InSAR and ground-level surveys across Northwest MZ-1 from April 2014 to March 2024. PX was used as the starting benchmark because it increases the accuracy of the ground-level surveys in this area.

The following observations and interpretations are derived from Figures 3-1a, 3-1b, 3-1c, 3-9a, and 3-9b:

- From about 1930 to 1978, hydraulic heads in Northwest MZ-1 declined by about 200 ft. From 1978 to 1985, hydraulic heads increased by about 100 ft. From 1985 to 2024 hydraulic heads fluctuated but remained relatively stable at elevations well below the levels of 1930.
- A maximum of about 1.4 ft of subsidence occurred in this area from 1992 through March 2024—an average rate of about 0.04 ft/yr—while hydraulic heads remained relatively stable. The persistent subsidence that occurred from 1992 to 2024 cannot be entirely explained by the concurrent changes in hydraulic heads. A plausible explanation for this subsidence is that thick, slow-draining aquitards are permanently compacting in response to the historical declines in hydraulic heads that occurred between 1930 and 1978.
- From March 2011 to March 2024, the InSAR results indicate that the maximum rate of downward ground motion in Northwest MZ-1 slowed to about 0.03 ft/yr. This resulted in a maximum of about 0.4 ft of downward ground motion near the intersection of Indian Hill Boulevard and San Bernardino Avenue.
- Figure 3-9b shows that the ground-level survey results from 2014 to 2024 indicate a similar spatial pattern of downward ground motion as estimated by InSAR but with slightly different magnitudes. Both methods indicate the maximum downward ground motion from December 2013 to March 2024 occurred near the intersection of Indian Hill Boulevard and San Bernardino Avenue. There is a minor difference in the magnitudes of vertical ground motion between InSAR and ground-level survey results, but these differences are most likely related to the different timing of the ground-level surveys and the SAR acquisition and/or relative errors associated with each monitoring technique.
- Figures 3-1c and 3-9a show minor upward ground motion occurred in Northwest MZ1 during 2023-2024, likely in response to reduced pumping and increased recharge in this area.

As described above, Figure 3-1a shows that maximum downward ground motion during 2011-2024 occurred near the intersection of Indian Hill Boulevard and San Bernardino Avenue. The City of Pomona Well 30 (P-30) is located just south of this area. P-30 is a non-pumping well, is screened across the shallow aquifer and upper portion of the deep aquifer and has been equipped with a transducer that measures and records hydraulic heads once every 15 minutes since September 2006. These data can provide information on the nature of the aquifer-system deformation that occurred in this area (i.e., elastic versus inelastic deformation). Figure 3-10 is a time-series chart that compares the hydraulic heads at P-30 to vertical ground motion as estimated by InSAR between 2006 and 2024. The main observations from this chart are:

- The InSAR record at P-30 is measuring seasonal elastic vertical ground motion that is caused by seasonal fluctuations in hydraulic head and the resultant seasonal elastic deformation in the aquifer-system(s). The seasonal fluctuations of hydraulic head at P-30 are coincident with the seasonal fluctuations of vertical ground motion measured by InSAR, but the long-term trend of subsidence remains persistent between 2005 and 2024 despite periods of hydraulic head recovery.
- InSAR indicates a long-term trend of downward ground motion at P-30 from 2005 to 2017. However, hydraulic heads at P-30 during this same period increased, indicating that at least about 0.37 ft of subsidence was caused by inelastic compaction of the aquifer-system. The inelastic compaction that occurred during this period of increasing hydraulic heads most likely represents the delayed drainage and compaction of aquitards due to historical head declines.
- Between mid-2017 and 2024, the long-term subsidence trend appeared to have slowed down, indicating that inelastic compaction of the aquitards had also slowed down. The recent slowing of subsidence observed at P-30 was likely a result of increasing hydraulic heads in the aquifers, which had led to equilibration with hydraulic heads in the aquitards and the slowing of aquitard drainage and compaction.
- Between late 2018 and early 2024, the hydraulic head at P-30 experienced five cycles of head decline and recovery. The head decline and recovery at P-30 appears to be contemporaneous with the downward and upward vertical ground motion measured by InSAR at P-30 during this same period. These observations suggest that in Northwest MZ-1: (i) changes in hydraulic heads, which are controlled by the pumping and recharge stresses in the area, have at least some control on the pattern and rate of subsidence and (ii) these monitoring data may be providing information on hydraulic head “thresholds” that could be used as management criteria to protect against the future occurrence of land subsidence.

3.5 Northeast Area

Vertical ground motion is measured across the Northeast Area via InSAR and ground-level surveys. In December 2017, a new network of benchmarks was installed across the Northeast Area (see Figure 2-2) and surveyed for initial elevations in January 2018. The Northeast Area benchmark network was last surveyed April 2020 and was not surveyed from spring 2022 to spring 2024.

Figures 3-1a, 3-1b, and 3-1c are maps that display vertical ground motion as measured by InSAR across Northeast Area during the periods of March 2011 and March 2024, March 2022 and March 2023, and March 2023 and March 2024, respectively. Figure 3-11 is a time-series chart that displays and describes the long-term history of pumping, recharge, hydraulic heads, and vertical ground motion in the Northeast Area. The following observations and interpretations are derived from these figures:

- From 1930 to 1978, hydraulic heads in the Northeast Area declined by about 125 ft. From 1978 to 1985, hydraulic heads increased by about 25 ft. From 1985 to 2024, hydraulic heads fluctuated but have generally remained relatively stable.
- From 1992 to 2024, about 1.2 ft of subsidence occurred in the Northeast Area near the intersection of Euclid Avenue and Phillips Street (Point D on the inset map on Figure 3-11). From 1992 to 2011, the subsidence occurred at a gradual and persistent rate of about 0.04 ft/yr. From 2011 to 2024, the subsidence rate declined to about 0.02 ft/yr. Hydraulic heads have remained relatively stable in this area from 1992-2024, which indicates that the downward ground motion was, at least in part, permanent subsidence due to delayed aquitard drainage in response to the historical declines in hydraulic heads that occurred from 1930 to 1978. The recent decline in the rate of subsidence at Point D may be due to recent decreases in pumping, recent increases in recharge, recent increases in hydraulic heads, or the gradual equilibration of heads between aquifers and aquitards.

3.5.1 Whispering Lakes Subsidence Feature

Figures 3-1a, 3-1b, and 3-1c also show that downward ground motion has occurred (and continues to occur) in a concentrated area between Vineyard Avenue and Archibald Avenue south of the Ontario International Airport in the vicinity of Whispering Lakes Golf Course in the City of Ontario (referred to herein as the Whispering Lakes Subsidence Feature). The map indicates that a maximum of about 0.6 ft of downward ground motion occurred in this area from March 2011 to March 2024. The Whispering Lakes Subsidence Feature was only recently observed via InSAR due to enhanced processing and interpolation techniques used by General Atomics in post-processing the InSAR data and preparing interferograms (see Section 2).

At the time of the recognition of the Whispering Lakes Subsidence Feature, there was not enough information to describe the history of the subsidence feature or its causes. As an initial step, the Watermaster Engineer performed a desktop investigation utilizing readily available data and information (the "Whispering Lakes Subsidence Investigation"). The specific objectives of the desktop investigation were to:

- Describe the history of the Whispering Lakes Subsidence Feature, including the extent and rate of subsidence.
- Attempt to identify the most plausible mechanism(s) causing the differential subsidence.
- Identify data gaps, if any, that need to be filled to characterize the extent, rate, and mechanisms of the differential subsidence.

The main potential mechanisms for the Whispering Lakes Subsidence Feature that were investigated included:

- Aquitard drainage and compaction
- Shallow soil consolidation due to historical land use and/or land use changes
- Differential tectonic movements

The results, conclusions, and recommendations of the Whispering Lakes Subsidence Investigation were published in the 2021/22 Annual Report of the GLMC.[17]

Since 2022, additional monitoring of vertical ground motion by InSAR was conducted for this annual report. Figure 3-12 is a series of air photo maps overlain with the subsidence contours shown on Figures 3-1a, 3-1b, and 3-1c. Figure 3-12 demonstrates that: (i) land subsidence has continued to occur in this area during 2022-24 and (ii) that the subsidence is spatially coincident with the Whispering Lakes Golf Course.

The Whispering Lakes Subsidence Investigation documented the history of overlying land uses in the vicinity of the Whispering Lakes Subsidence Feature, which included: agricultural, sewage disposal, and recreational (golf courses and parks). These overlying land uses could have involved disturbance, modifications, and additions to the shallow soils, which could have resulted in gradual consolidation of the shallow soils and the downward ground motion. These observations strongly suggest that the golf course and/or its prior land uses are related to the subsidence feature, and that shallow soil consolidation is responsible for the land subsidence. If true, groundwater management will have no effect on the Whispering Lakes Subsidence Feature.

Based on these results and conclusions, the Watermaster Engineer recommends a limited monitoring program going forward that includes:

- Continued monitoring of vertical ground motion by high-resolution InSAR that is currently conducted under the Watermaster's GLMP.
- Continued monitoring of groundwater pumping at wells within the Study Area that is currently conducted on a quarterly time-step by the Watermaster.
- Installing transducers in wells within the Study Area to measure and record hydraulic heads at high temporal frequency.

The results and interpretations from this monitoring should be included in subsequent annual reports, which may improve the understanding of how pumping affects the spatial and depth-specific distribution of hydraulic heads, and could be used to rule out aquitard drainage (and groundwater utilization) as the cause of the subsidence, or not.

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 3-13 is a map that displays the location and magnitude of earthquake epicenters relative to vertical ground motion as estimated by InSAR from March 2011 to March 2024. The main observations and interpretations derived from this figure are:

- The earthquake epicenters on Figure 3-13 do not show a spatial relationship to the differential subsidence that has occurred in Northwest MZ-1. Therefore, tectonic movement along the San Jose Fault Zone, including aseismic creep, is not the likely mechanism for the differential land subsidence that has occurred in Northwest MZ-1.

[17] 2021/22 Annual Report of the GLMC

- Very little seismicity has occurred across the Areas of Subsidence Concern between March 2011 and March 2024. This observation indicates that the vertical ground motion that occurred in these areas is not related to tectonics.
- Most of the seismicity observed between March 2011 and March 2024 occurred in the eastern portion of the Chino Basin. 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).

Table 3-1. Groundwater Pumping in the Managed Area -- *Fiscal Year 2012 through 2024*

Well Name	Aquifer Layer	Fiscal Year, af												Fiscal Year 2024, af				
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Qtr 1	Qtr 2	Qtr 3	Qtr 4[a]	By Layer
C-4	Shallow	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	
C-6		1049	594	0	0	0	0	0	0	0	0	0	0	0	0	0	-	
CH-1A		1137	909	738	861	649	637	369	0	0	0	0	0	0	0	0	-	
CH-7A		530	380	170	286	156	66	0	0	0	0	0	0	0	0	0	-	
CH-7B		712	264	200	616	261	232	350	0	0	0	0	0	0	0	0	-	
CIM-1		724	1,109	1,127	878	911	908	586	0	0	0	0	0	1.56	0	0.01	-	
XRef 8730[b]		3	5	5	4	3	35	29	29	29	30	17	21	7.36	7.36	7.36	-	
	Sub-Totals	**4,679**	**3,260**	**2,240**	**2,644**	**1,980**	**1,879**	**1,334**	**29**	**29**	**30**	**17**	**21**	**9**	**7**	**7**	**-**	**24**
CH-17	Deep[c]	758	1,444	937	1,142	567	624	571	0	0	0	0	0	0	0	0	-	
CH-15B		0	28	105	0	0	0	0	0	0	0	0	25	0	0	0	-	
CIM-11A		243	239	195	92	94	222	0	0	3	3	42	1	0.26	0.20	0.17	-	
	Sub-Totals	**1,001**	**1,711**	**1,237**	**1,234**	**662**	**846**	**571**	**0**	**3**	**3**	**42**	**26**	**0**	**0**	**0**	**-**	**1**
	Totals	**5,680**	**4,971**	**3,477**	**3,878**	**2,642**	**2,725**	**1,905**	**29**	**32**	**33**	**59**	**47**	**9**	**8**	**8**	**-**	**24**

"C" = City of Chino

"CH" = City of Chino Hills

"CIM" = California Institution for Men

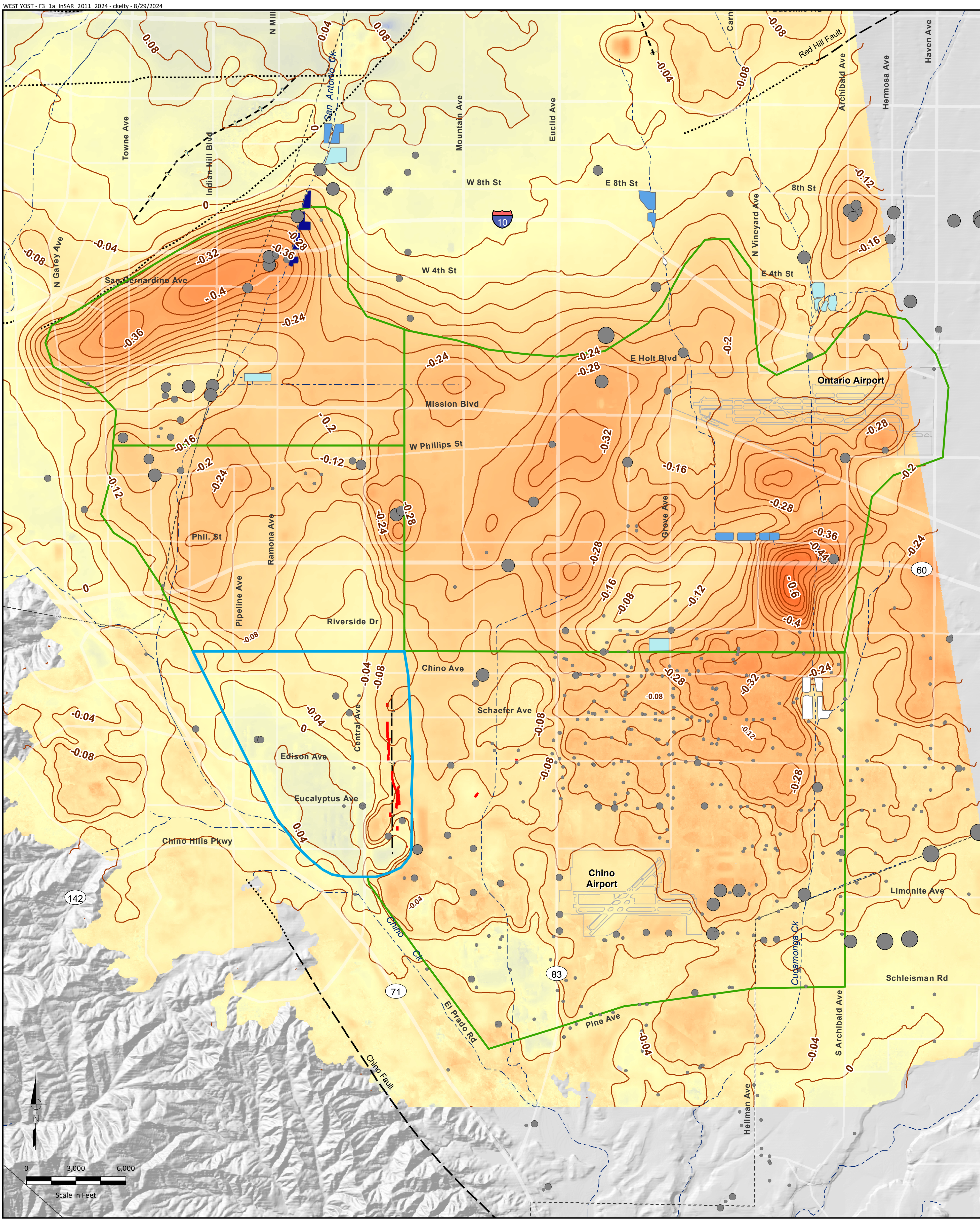
"XRef" = Private

(a) Data only available through March 2024.

(b) Well screen interval is unknown but assumed to be shallow based on typical well construction for other private wells in the vicinity.

(c) These wells have screen intervals that extend into the shallow-aquifer system, so a portion of the production comes from the shallow aquifer-system.

WEST YOST - F3_1a_InSAR_2011_2024 - ckelty - 8/29/2024



Relative Change in Land Surface Elevation as Estimated by InSAR (March 2011 to March 2024)

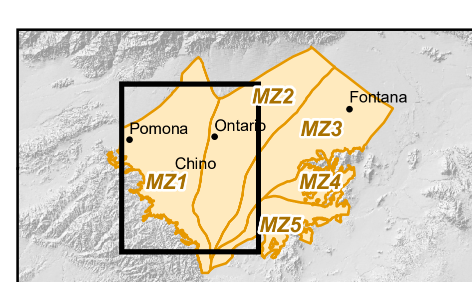
- High : 0.6
- 0 ft
- Low : -0.6
- InSAR absent or incoherent

Average Annual Groundwater Pumping April 1, 2011 to March 31, 2024 (afy)

- 0 - 100
- 101 - 500
- 501 - 1,000
- 1,001 - 2,000
- > 2,000

Average Annual Basin Recharge April 1, 2011 to March 31, 2024 (afy)

- 0
- 1- 1500
- 1500 - 2500
- 2500 - 3500



- Managed Area
- Areas of Subsidence Concern
- Historical Ground Fissures
- Approximate Location of the Riley Barrier
- Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)

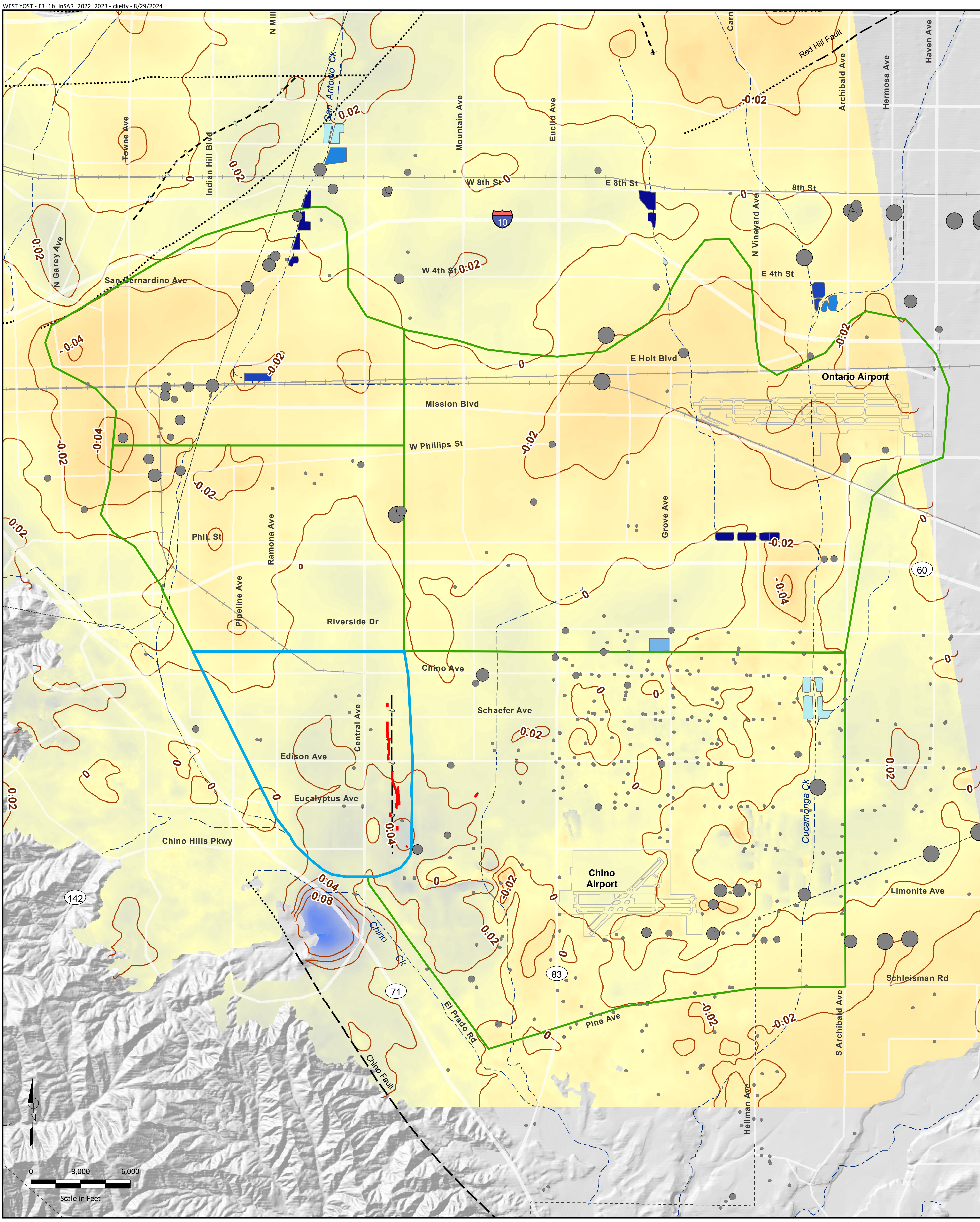
WEST YOST

Chino Basin Watermaster
2023/24 Annual Report for the Ground-Level Monitoring Program

Figure 3-1a

Vertical Ground Motion across the Western Chino Basin: 2011-2024

WEST YOST - F3_1b_InSAR_2022_2023 - ckelty - 8/29/2024



Relative Change in Land Surface Elevation as Estimated by InSAR (March 2022 to May 2023)

+0.2 ft
0 ft
-0.2 ft
InSAR absent or incoherent

Managed Area
Areas of Subsidence Concern

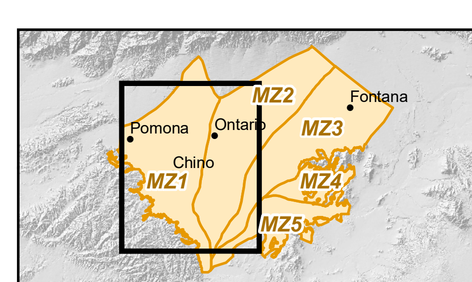
Average Annual Groundwater Pumping April 1, 2022 to March 31, 2023 (afy)

0 - 100
101 - 500
501 - 1,000
1,001 - 2,000
> 2,000

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

Average Annual Basin Recharge April 1, 2022 to March 31, 2023 (afy)

0 - 250
250 - 500
500 - 750
750 - 1,250
> 1,250



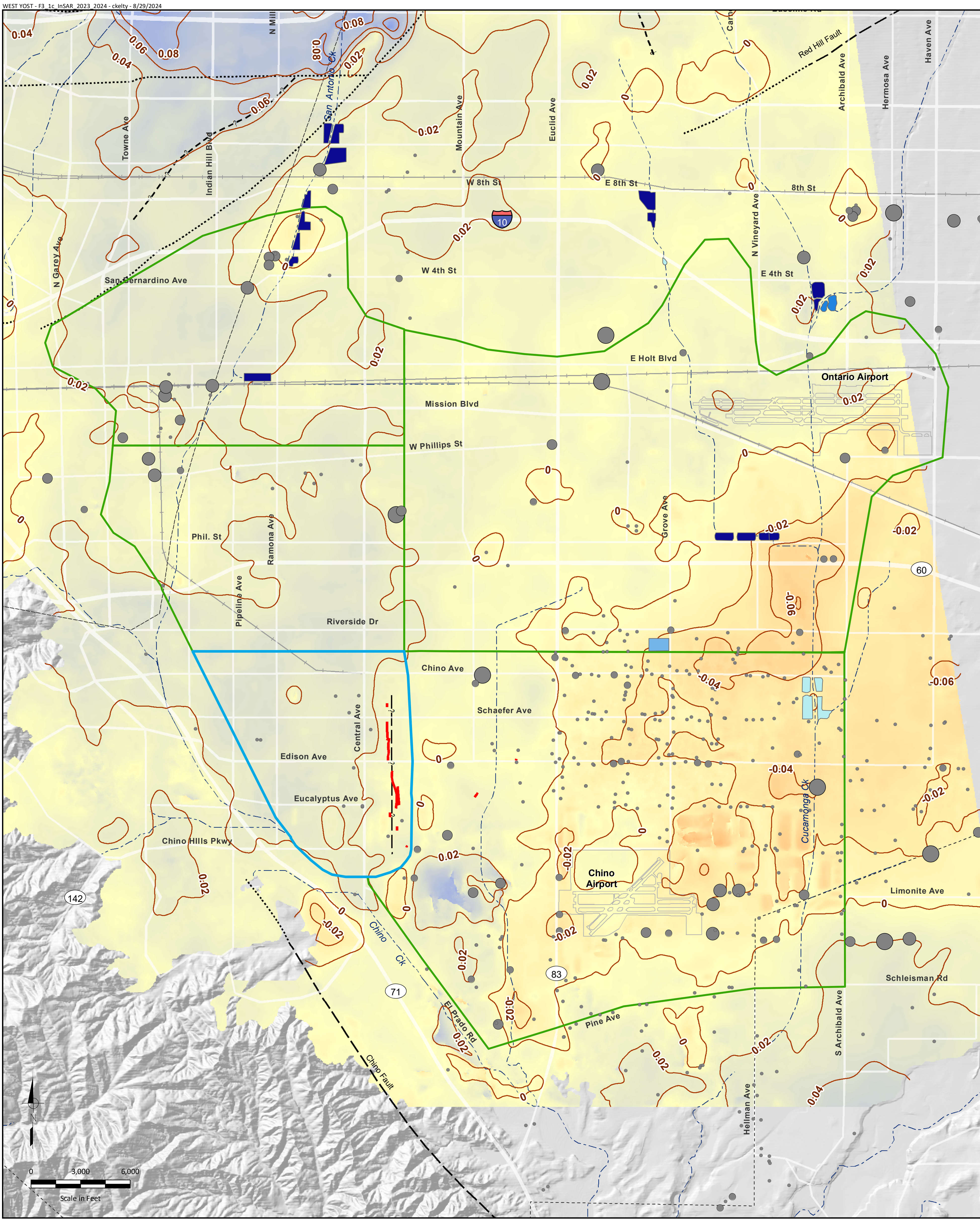
WEST YOST

Chino Basin Watermaster
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 3-1b

Vertical Ground Motion across the Western Chino Basin: 2022-2023

WEST YOST - F3_1c_InSAR_2023_2024 - ckelty - 8/29/2024



Relative Change in Land Surface Elevation as Estimated by InSAR (May 2023 to March 2024)

+0.2 ft

0 ft

-0.2 ft

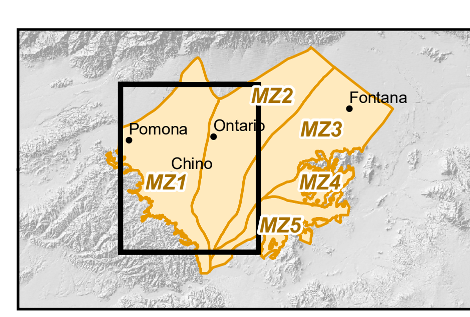
InSAR absent or incoherent

Average Annual Groundwater Pumping April 1, 2023 to March 31, 2024 (afy)

- 0 - 100
- 101 - 500
- 501 - 1,000
- 1,001 - 2,000
- > 2,000

Average Annual Basin Recharge April 1, 2023 to March 31, 2024 (afy)

- 0 - 250
- 250 - 500
- 500 - 750
- 750 - 1,250
- > 1,250



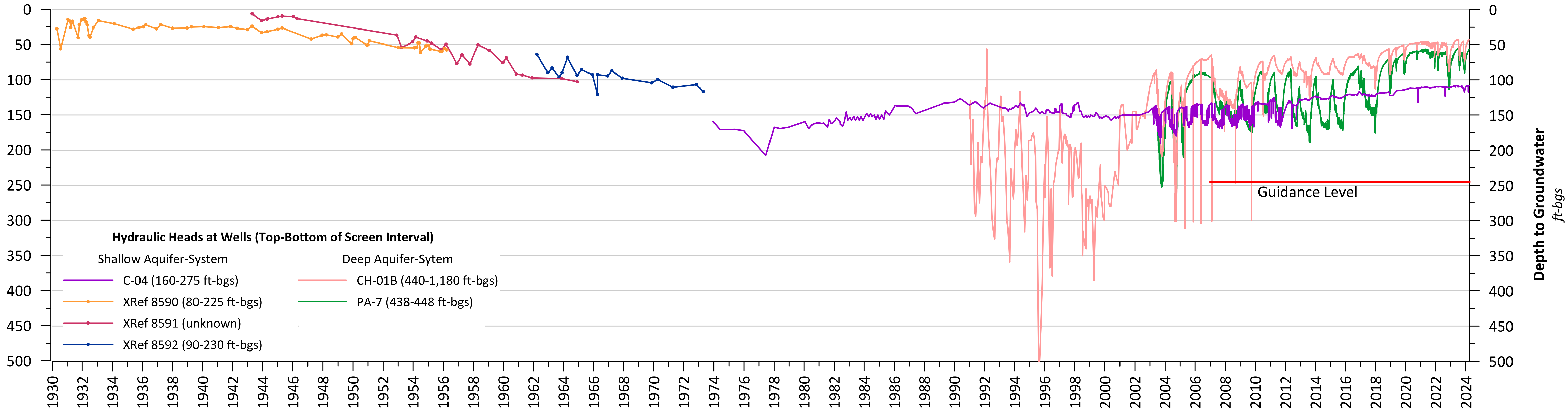
- Managed Area
- Areas of Subsidence Concern
- Historical Ground Fissures
- Approximate Location of the Riley Barrier
- Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)

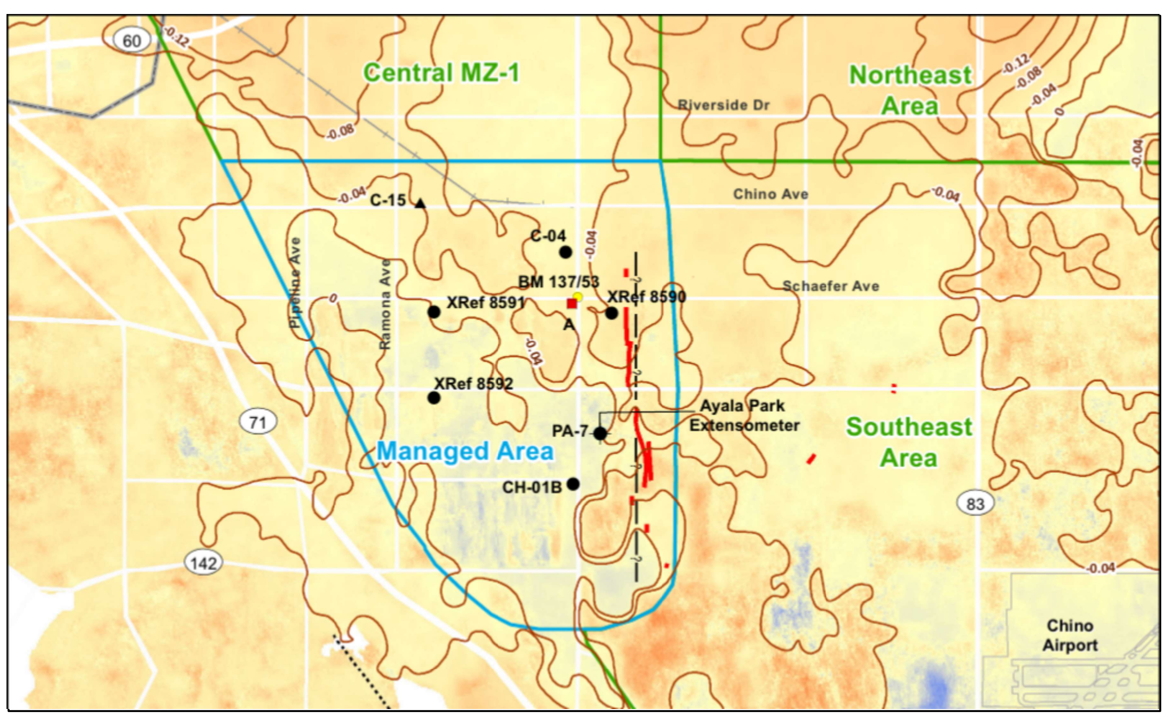
WEST YOST

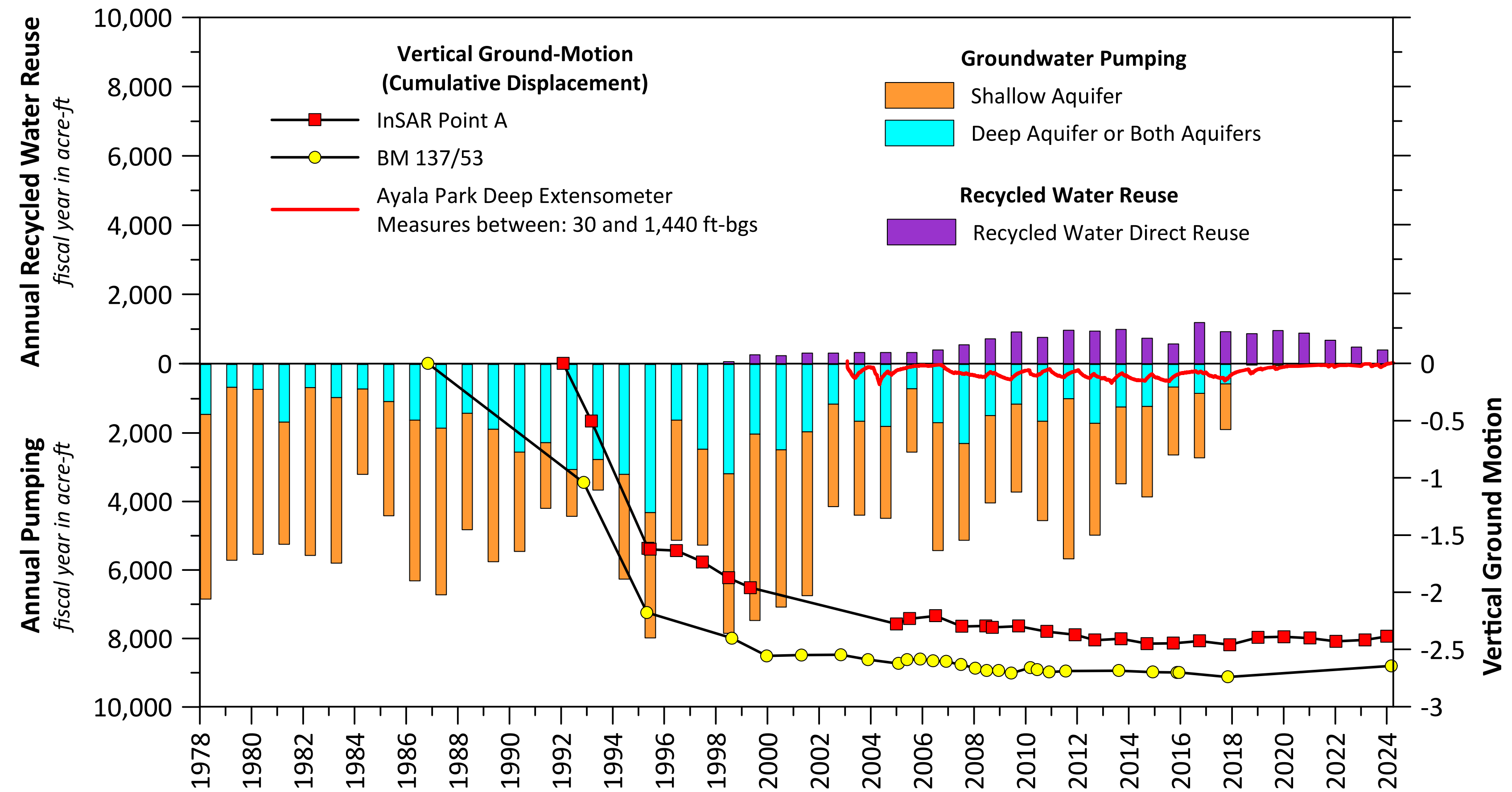
Chino Basin Watermaster
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 3-1c

Vertical Ground Motion across the Western Chino Basin: 2023-2024







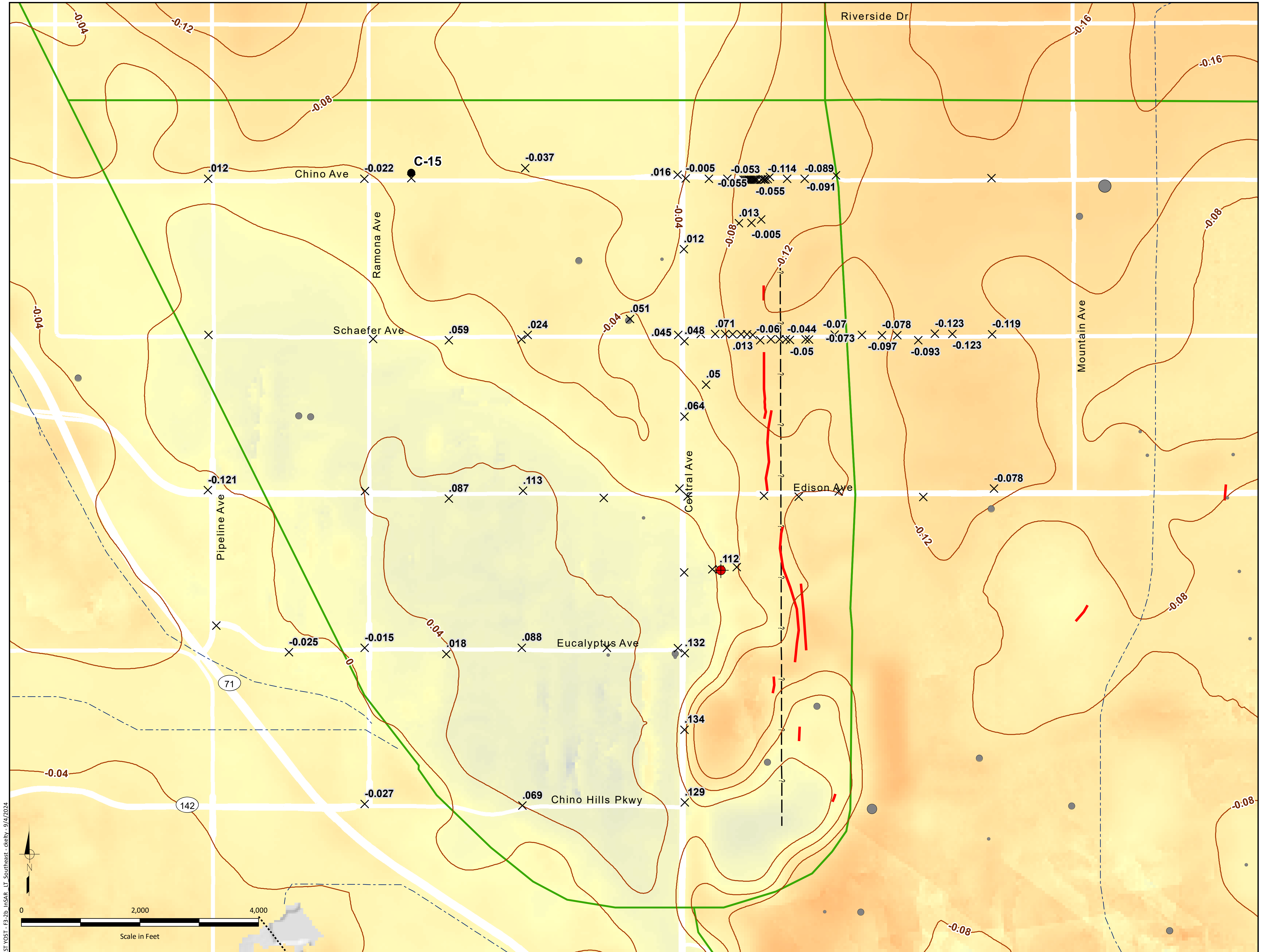
Recharge and pumping data through March 31, 2024

For the time-period between April 1, 2023 and March 31, 2024:
Pumping from the shallow aquifer = 24 af
Pumping from the deep aquifer = 1 af

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 3-2a

History of Land Subsidence in the Managed Area



Relative Change in Land Surface Elevation as Estimated by InSAR (March 2011 to March 2024)

High : 0.6

0

-0.3 ft

Low : -0.6

InSAR absent or incoherent

Ground-Level Survey Benchmark (Measured May 3, 2024) Labeled by Vertical Ground Motion (in feet from November 2011 to May 2024)

Average Annual Groundwater Pumping April 1, 2011 to March 31, 2024 (afy)

- 0 - 100
- 101 - 500
- 501 - 1,000
- 1,001 - 2,000
- > 2,000

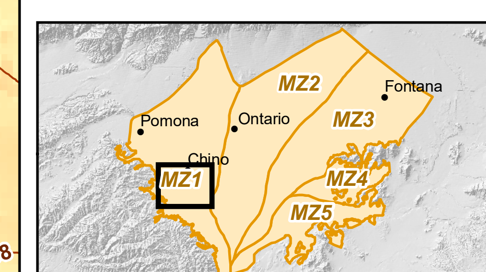
Ayala Park Extensometer

Groundwater Well (C-15)

Areas of Subsidence Concern

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

Historical Ground Fissures



WEST YOST

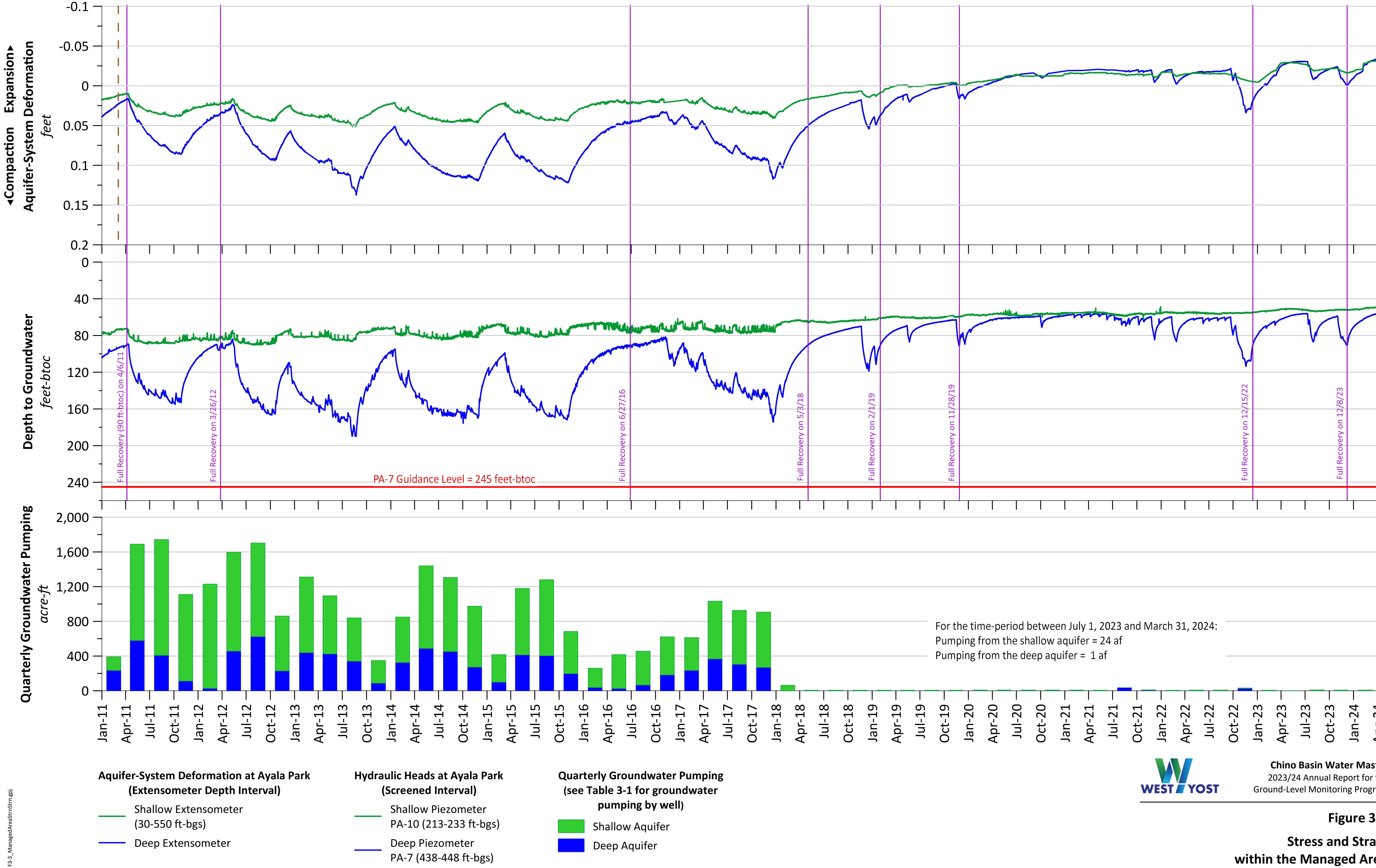
Chino Basin Watermaster

2023/24 Annual Report for the Ground-Level Monitoring Program

Figure 3-2b

Vertical Ground Motion across Southeast MZ-1: 2011-2024

WEST YOST - F3-2b InSAR LT Southeast - ckelty - 9/4/2024

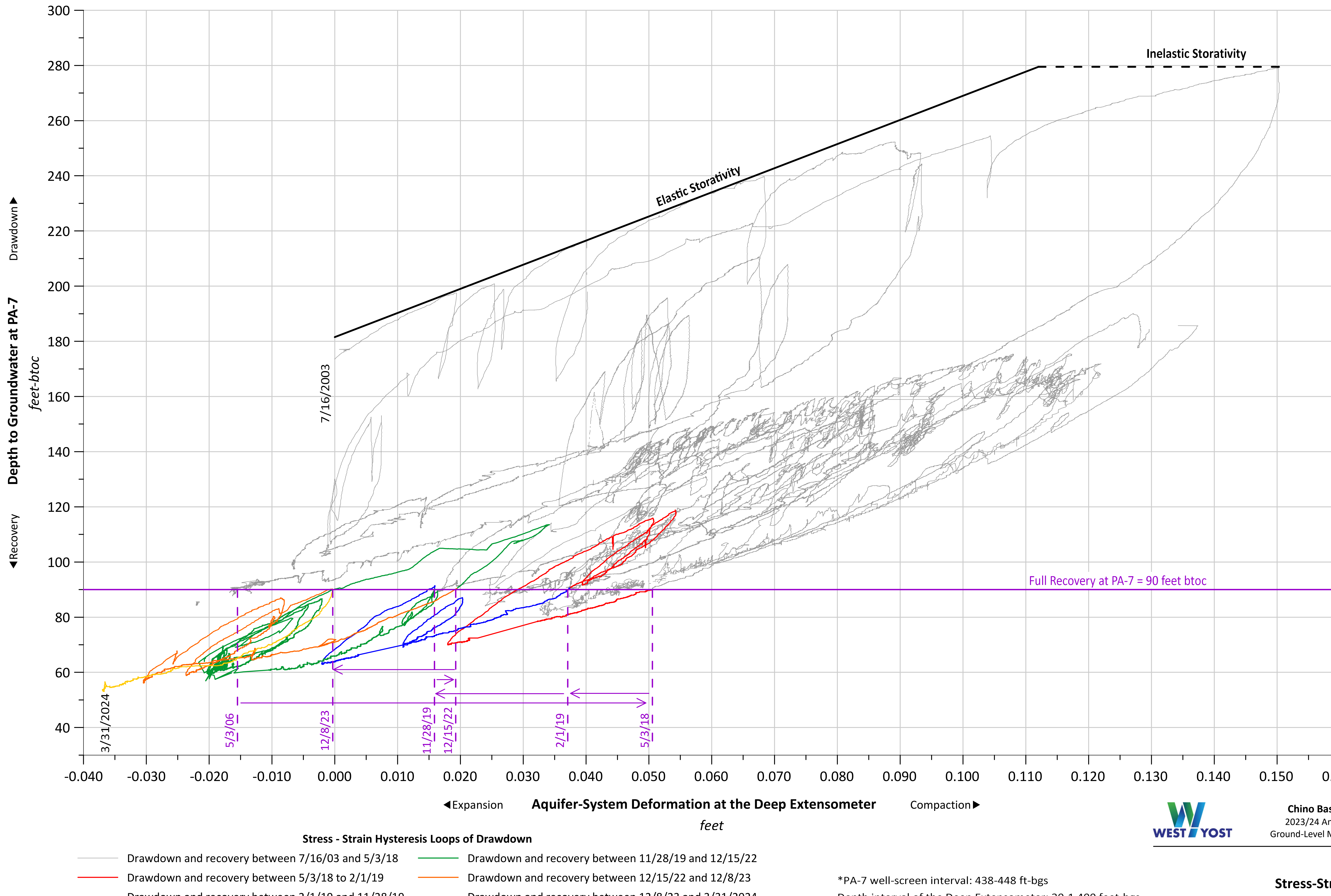


WEST YOST

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 3-3

Stress and Strain within the Managed Area



*PA-7 well-screen interval: 438-448 ft-bgs
Depth interval of the Deep Extensometer: 30-1,400 feet-bgs

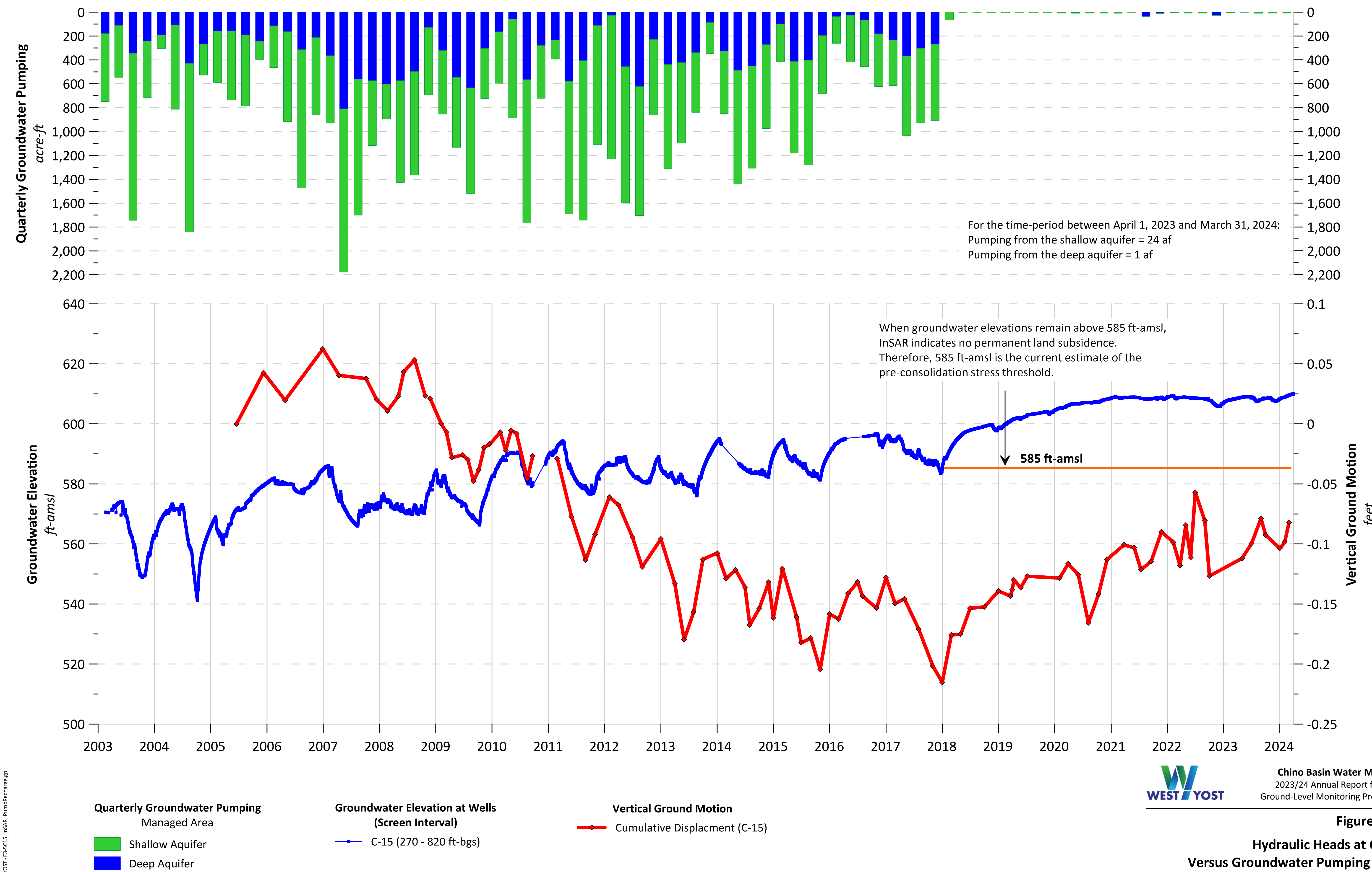
WEST YOST

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 3-4

Stress-Strain Diagram
Ayala Park Extensometer

WEST YOST - F3-4_ManagedAreaHysterisis.grpj

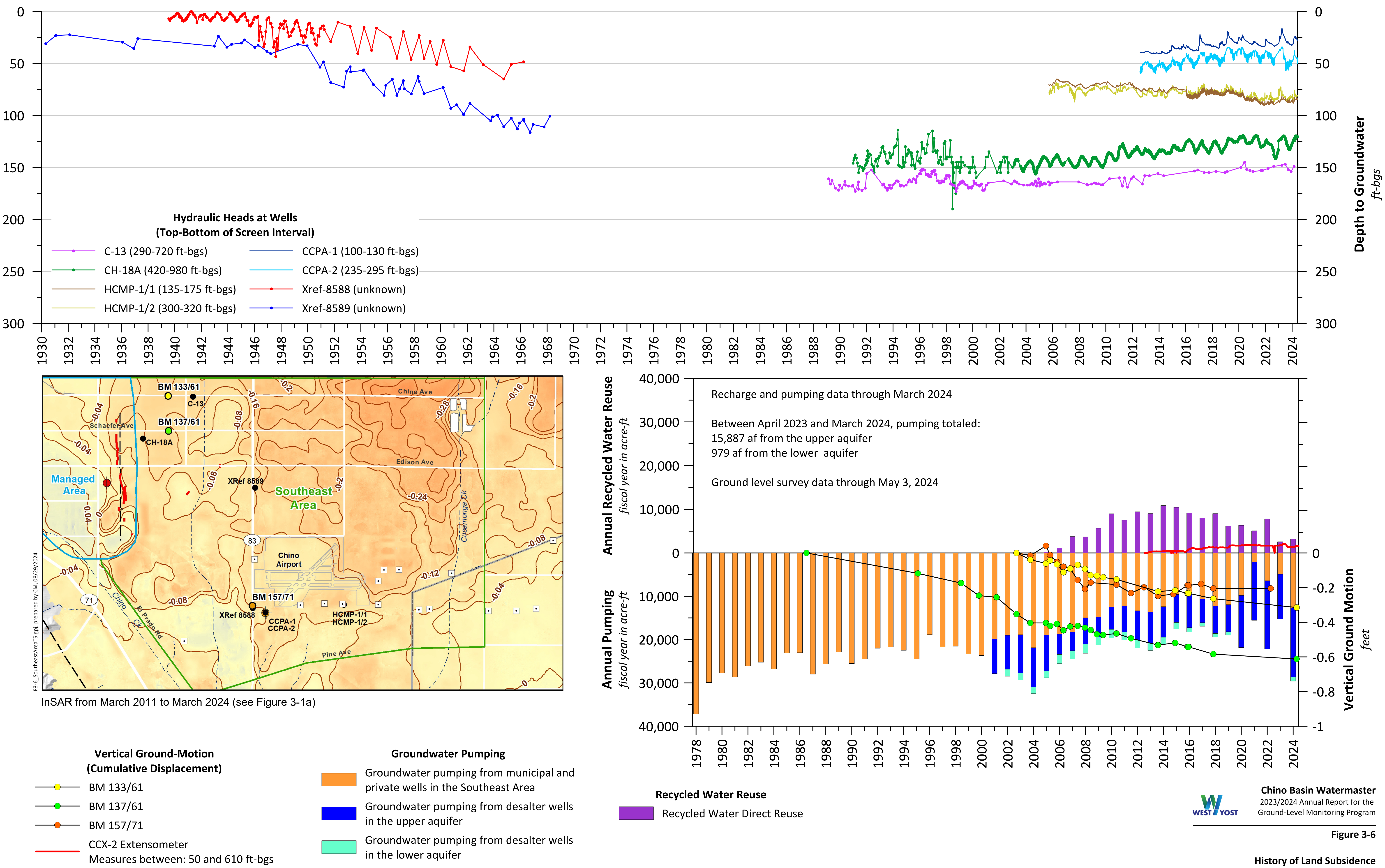


WEST YOST - F3-5C15_InSAR_PumpRecharge.grf

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 3-5

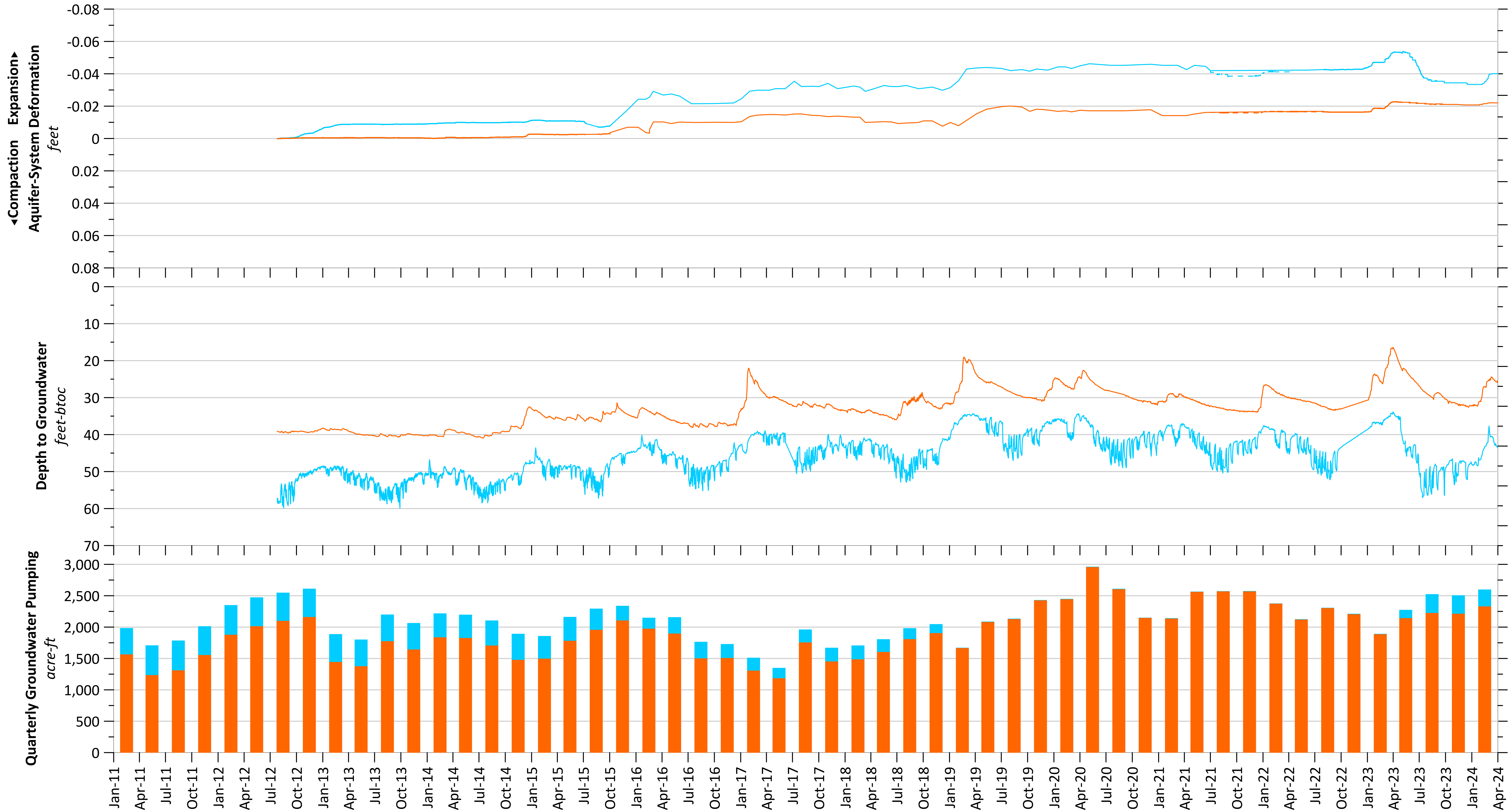
Hydraulic Heads at C-15 Versus Groundwater Pumping and Vertical Ground Motion



Chino Basin Watermaster
2023/2024 Annual Report for the Ground-Level Monitoring Program

Figure 3-6

History of Land Subsidence in the Southeast Area



Aquifer-System Deformation (Extensometer Depth Interval)

- CCX-1 (0-140 ft-bgs)
- CCX-2 (50-610 ft-bgs)

Hydraulic Heads (Screened Interval)

- CCPA-1 (100-130 ft-bgs)
- CCPA-2 (235-295 ft-bgs)

Quarterly Groundwater Pumping

- Shallow Aquifer (CDA-5 to 11; 16, 17, 20 and 21)
- Deep Aquifer (CDA-1 to 4)

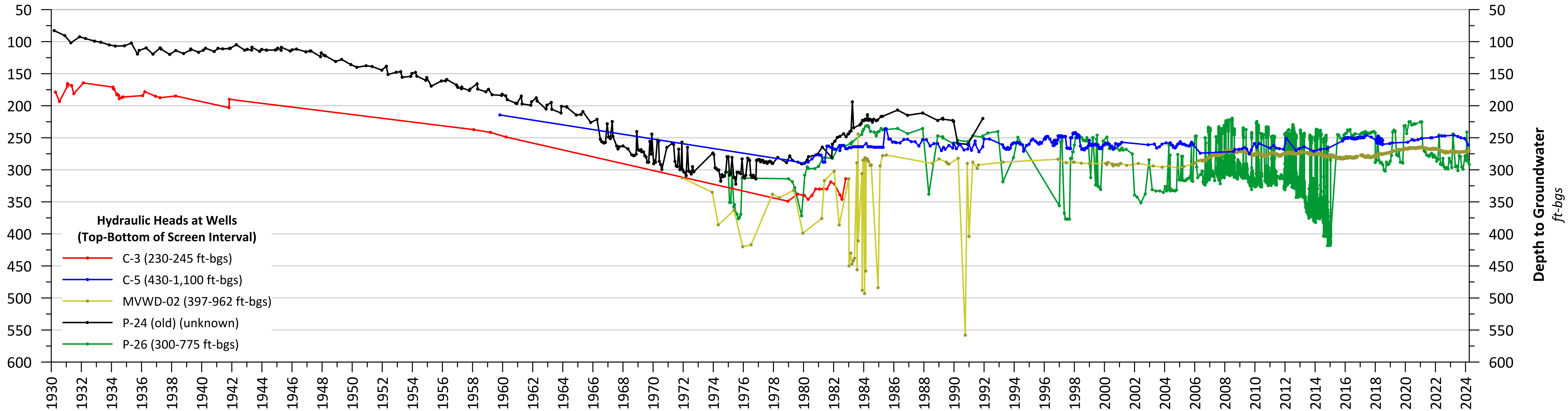
WEST YOST

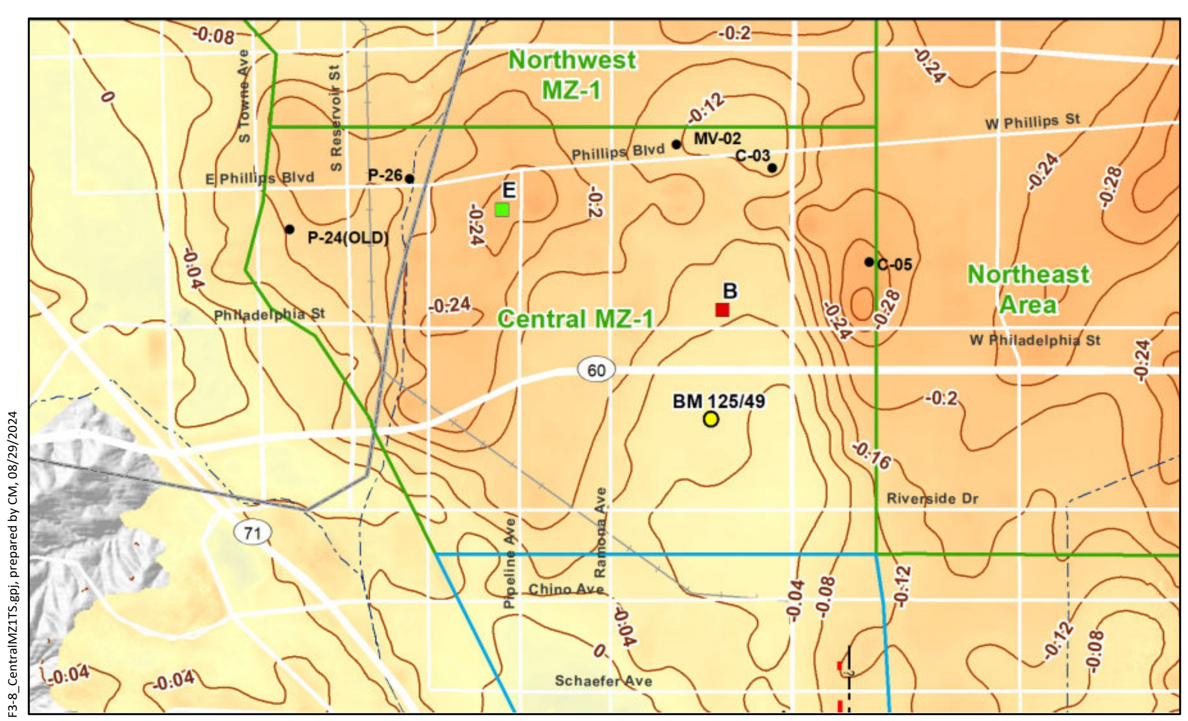
Chino Basin Watermaster
2023/2024 Annual Report for the Ground-Level Monitoring Program

Figure 3-7

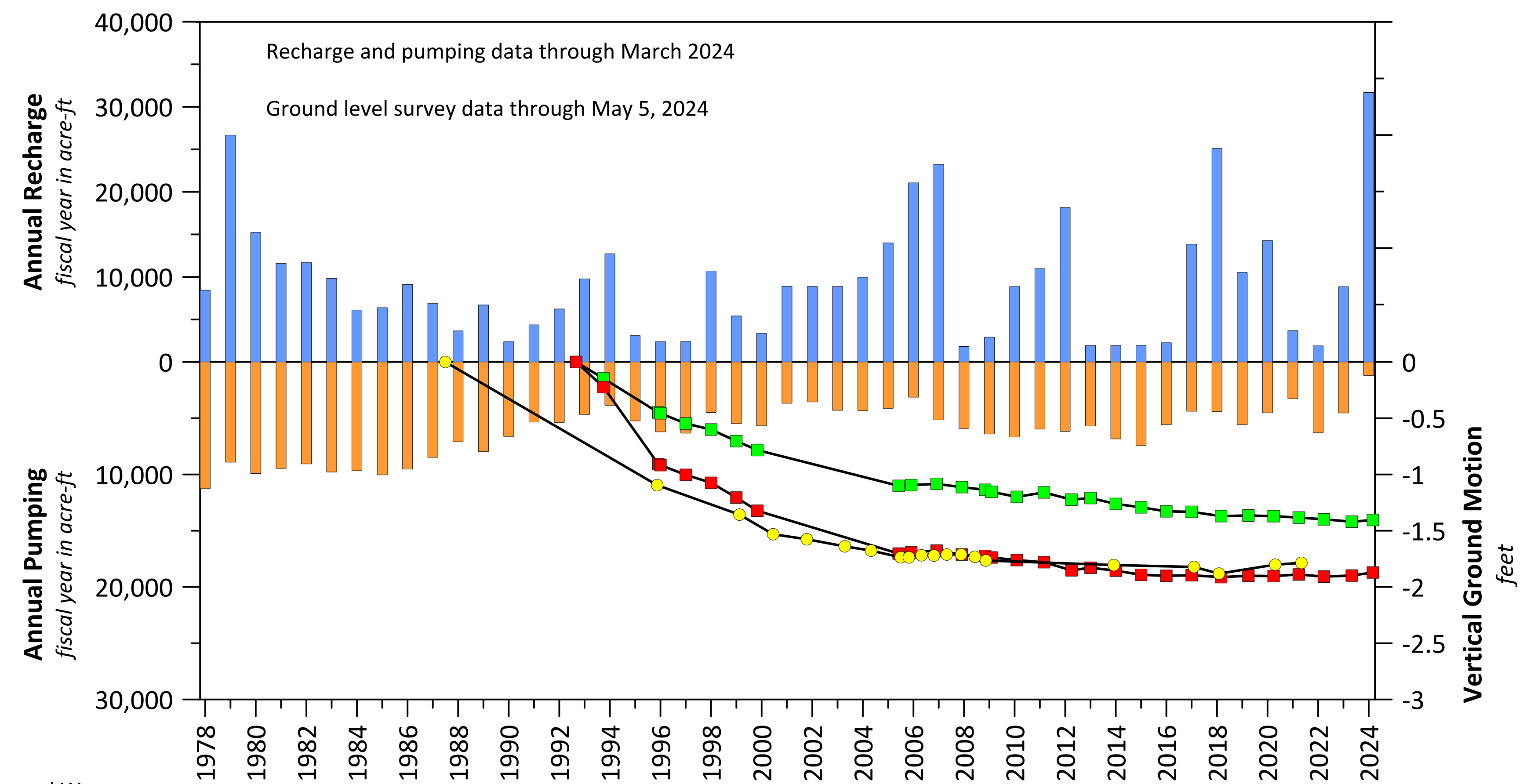
Stress and Strain within the Southeast Area

F3-7_SoutheastAreaStrsStrn.grf, prepared by CM, 08/29/2024





InSAR from March 2011 to March 2024 (see Figure 3-1a)



Vertical Ground-Motion (Cumulative Displacement)

- InSAR Point B
- InSAR Point E
- BM 125/49

Recharge and Pumping

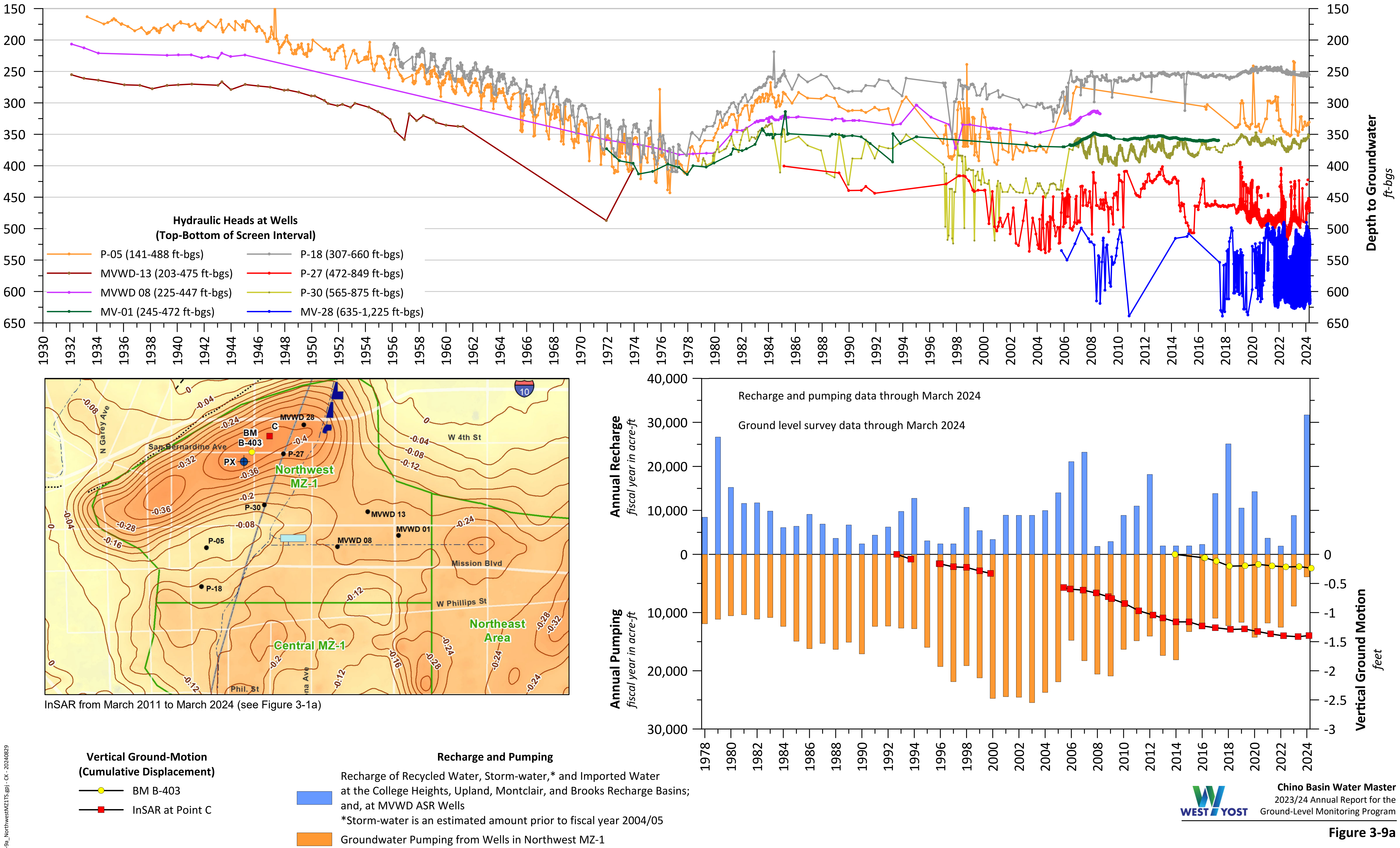
- Recharge of Recycled Water, Storm-water,* and Imported Water at the College Heights, Upland, Montclair, and Brooks Recharge Basins; and, at MVWD ASR Wells
  *Storm-water is an estimated amount prior to fiscal year 2004/05
- Groundwater Pumping from Wells in Central MZ-1

WEST YOST

Chino Basin Watermaster
2023/2024 Annual Report for the
Ground-Level Monitoring Program

Figure 3-8

History of Land Subsidence in Central MZ-1



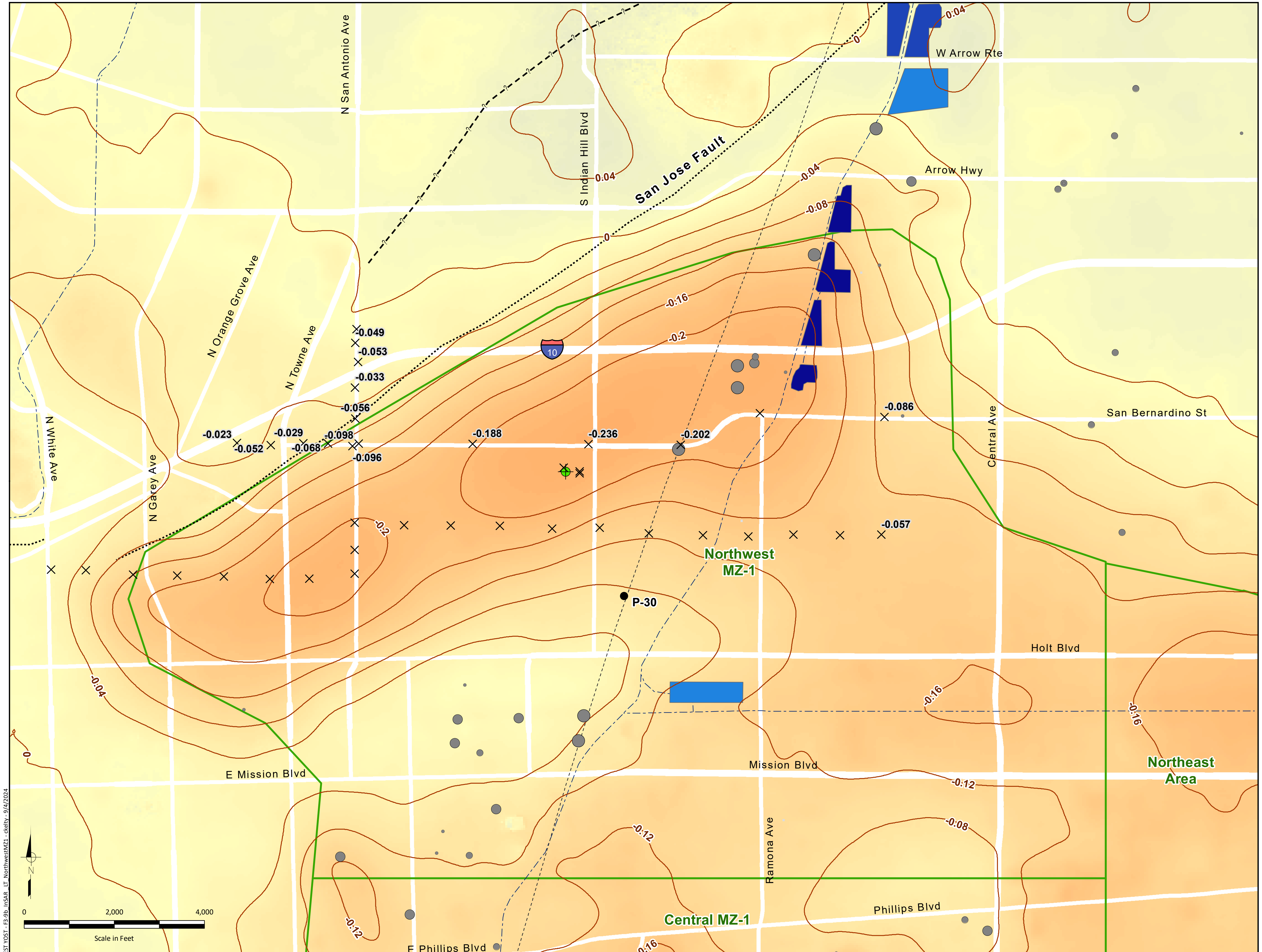
WEST YOST - F3-9a_NorthwestMZ1TS.gpj - CK - 20240829

WEST YOST

Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

Figure 3-9a

History of Land Subsidence in Northwest MZ-1



Relative Change in Land Surface Elevation as Estimated by InSAR (April 2014 to March 2024)

+0.45 ft
0 ft
-0.25 ft
-0.45 ft

InSAR absent or incoherent

Ground-Level Survey Benchmark (Measured May 3, 2024) Labeled by Vertical Ground Motion (in feet from November 2014 to May 2024)

Average Annual Groundwater Pumping April 1, 2014 to March 31, 2024 (afy)

- 0 - 100
- 101 - 500
- 501 - 1,000
- 1,000 - 2,000
- > 2,000

Average Annual Basin Recharge April 1, 2014 to March 31, 2024 (afy)

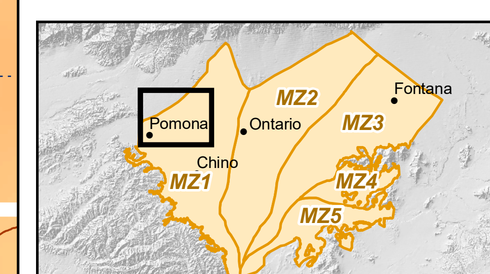
- 0 - 500
- 500 - 1,000
- 1,000 - 1,500
- 1,500 - 2,000
- 2,000 - 2,500
- > 2,500

Pomona Extensometer Facility

Groundwater Well (P-30)

Areas of Subsidence Concern

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



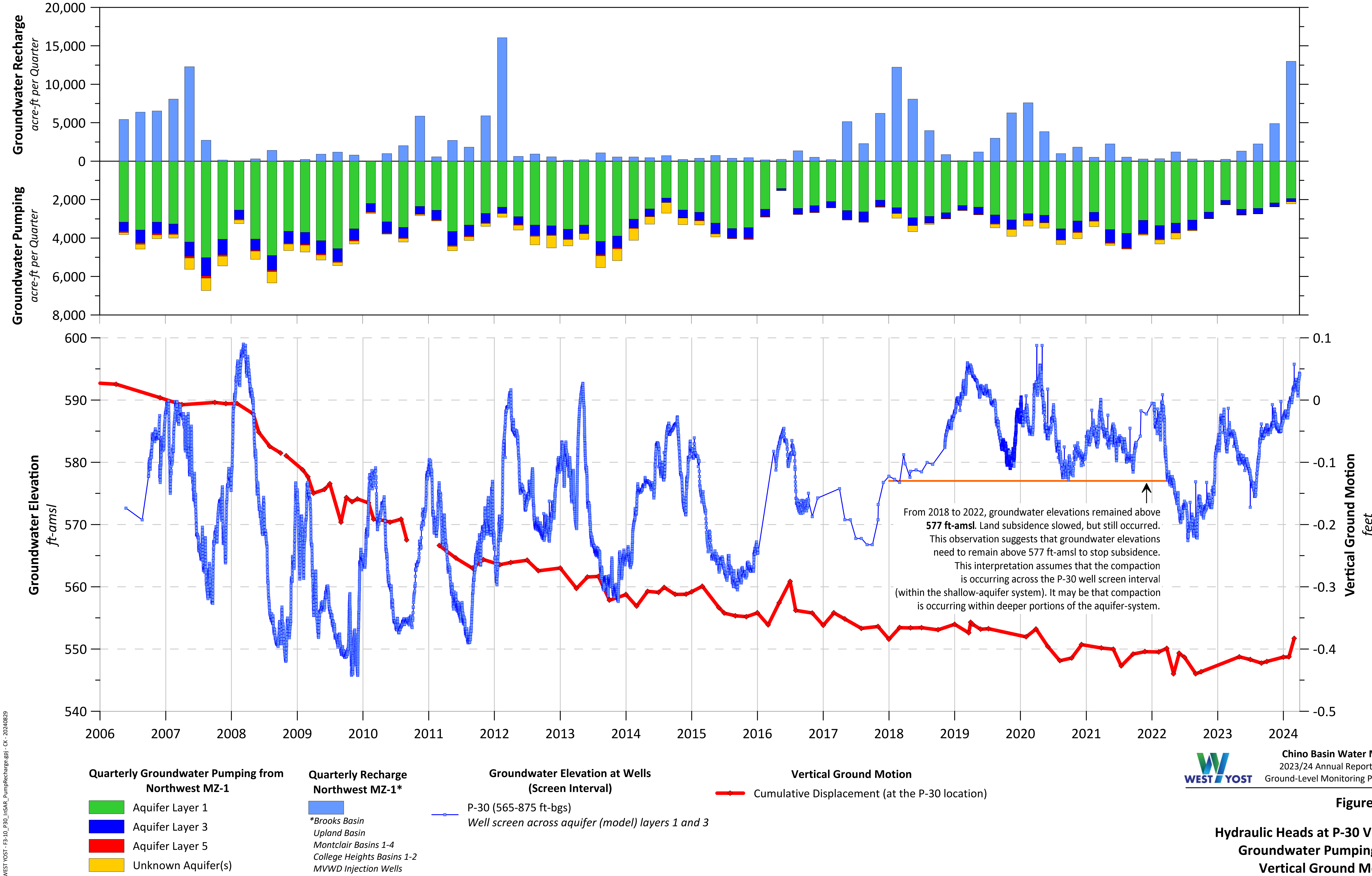
WEST YOST

Chino Basin Watermaster

2023/24 Annual Report for the Ground-Level Monitoring Program

Figure 3-9b

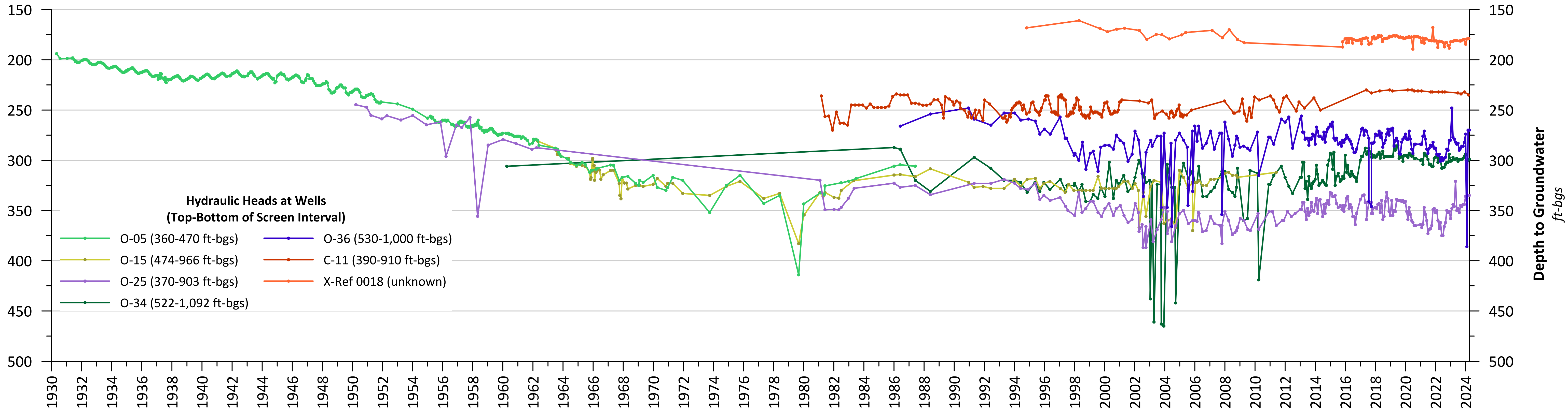
Vertical Ground Motion across Northwest MZ-1: 2014-2024

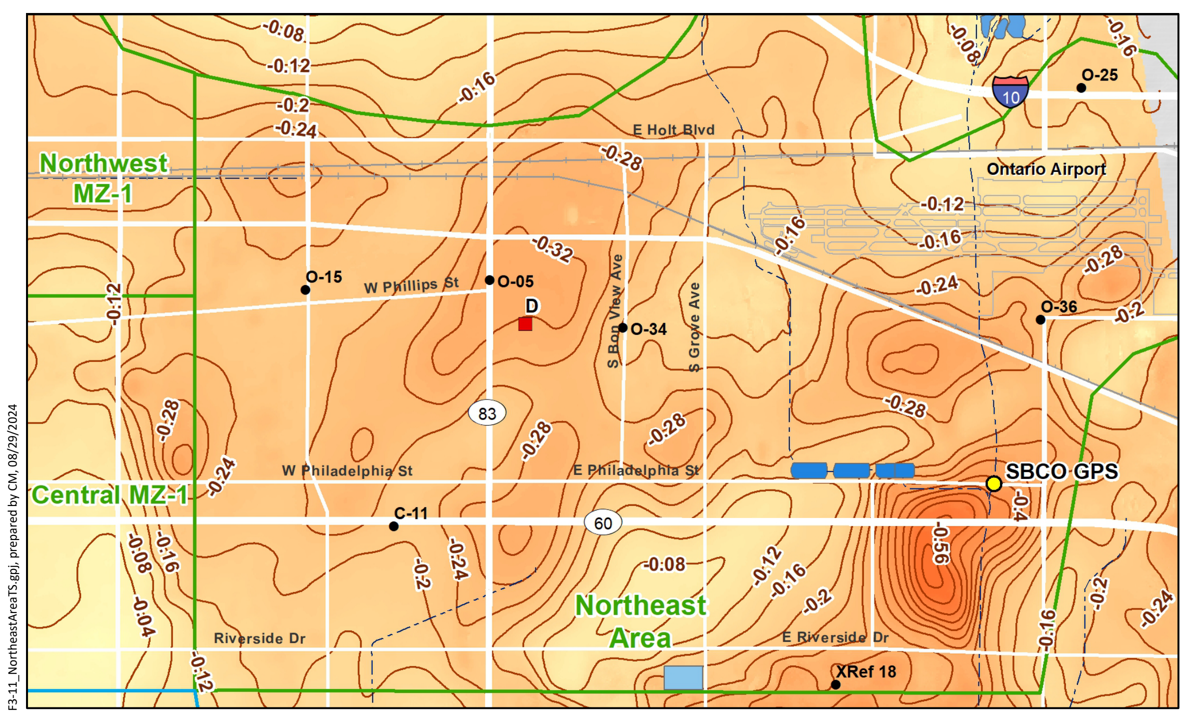


Chino Basin Water Master
2023/24 Annual Report for the
Ground-Level Monitoring Program

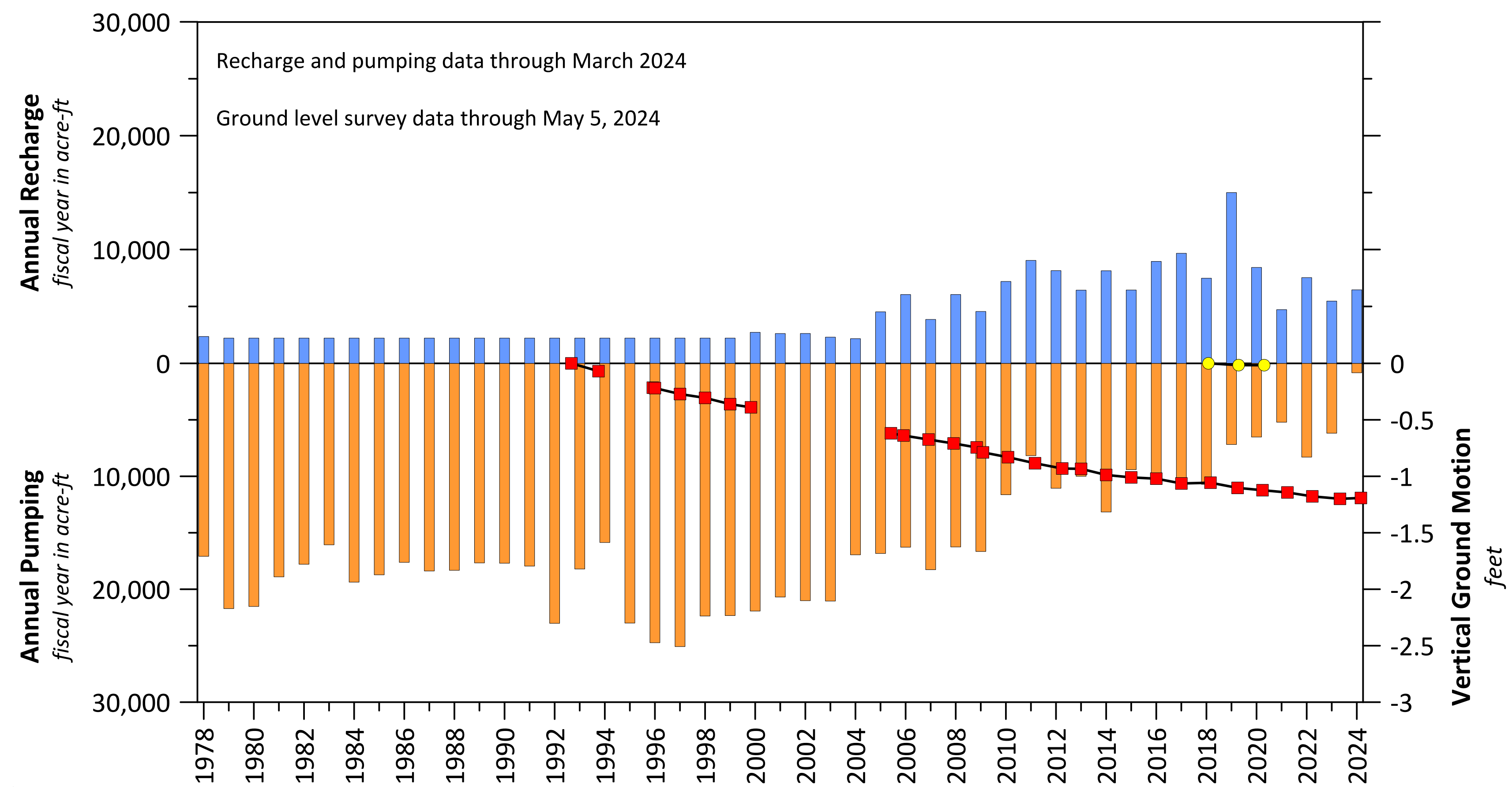
Figure 3-10

Hydraulic Heads at P-30 Versus Groundwater Pumping and Vertical Ground Motion





InSAR from March 2011 to March 2024 (see Figure 3-1a)



Vertical Ground-Motion (Cumulative Displacement)

- BM SBCO GPS
- InSAR at Point D

Recharge and Pumping

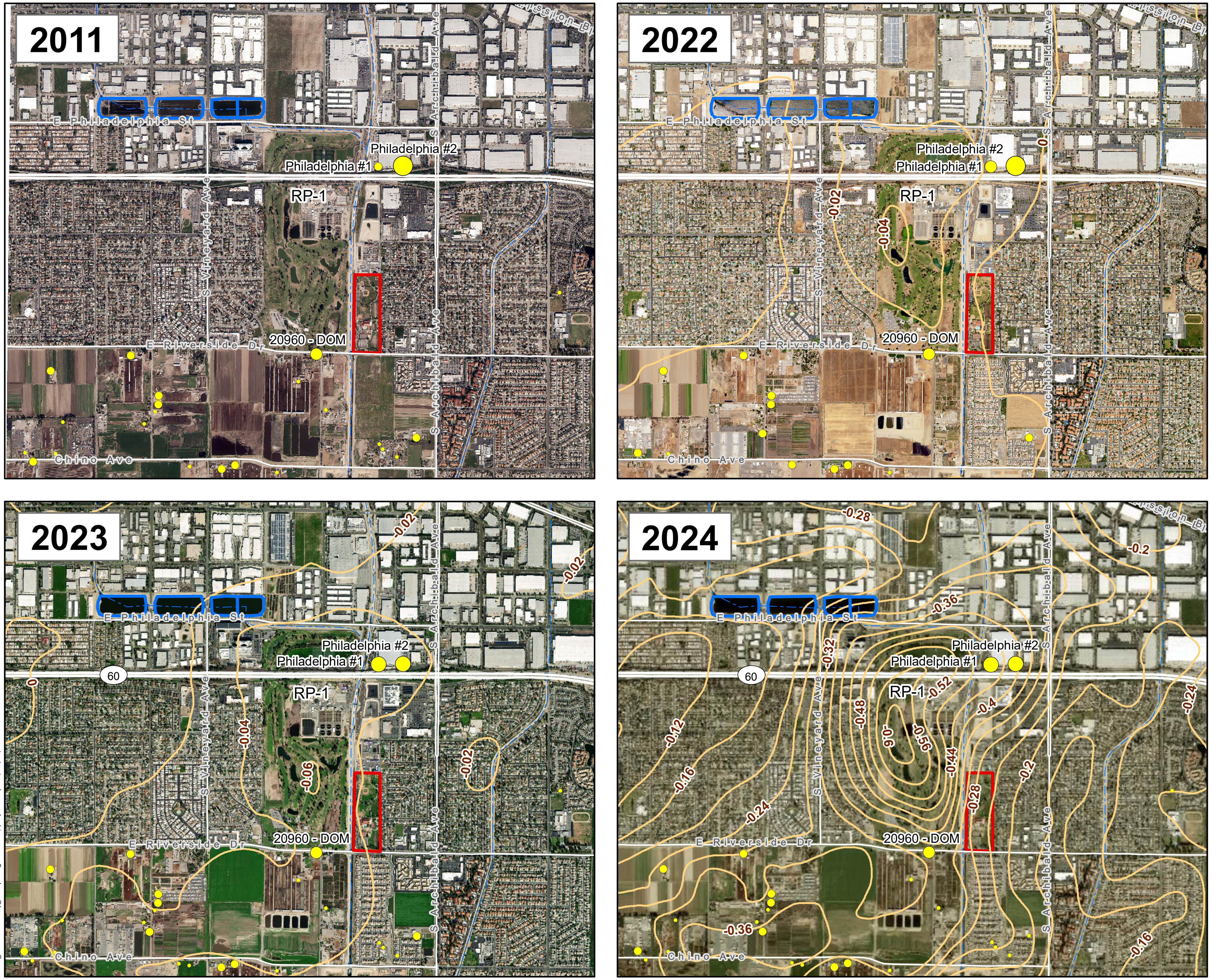
- Recharge of Recycled, Storm-water,* and Imported Water at the Ely, Grove, Turner, 7th Street and 8th Street Recharge Basins
  *Storm-water is an estimated amount prior to fiscal year 2004/05
- Groundwater Pumping from Wells in the Northeast Area

Chino Basin Watermaster
2023/2024 Annual Report for the Ground-Level Monitoring Program

Figure 3-11

History of Land Subsidence in the Northeast Area

InSAR from March 2022 to March 2023



InSAR from March 2023 to March 2024

InSAR from March 2011 to March 2024

F3-12_LandUseHistory_WhisperingLakes.mxd, prepared by CM, 08/29/2024

N

0 0.125 0.25 0.5 0.75 1 Miles

Contours of the Relative Change in Land Surface Elevation as Estimated by InSAR (ft)

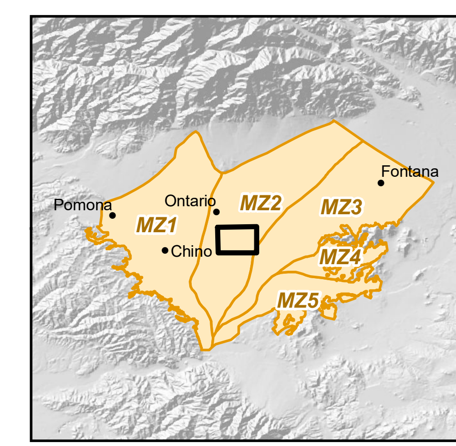
Annual Groundwater Production (af)
(reported by fiscal year)

- < 10
- 10 - 100
- 101 - 250
- 250 - 500
- 500 - 730

*Pumping records unavailable prior 1978 and the Stipulated Judgement
**Pumping for FY 2024 is limited to data from Q1 through Q3

Other Features

- Location of Historic Sewage Disposal Ponds
- Ely Recharge Basins
- Rivers and Streams



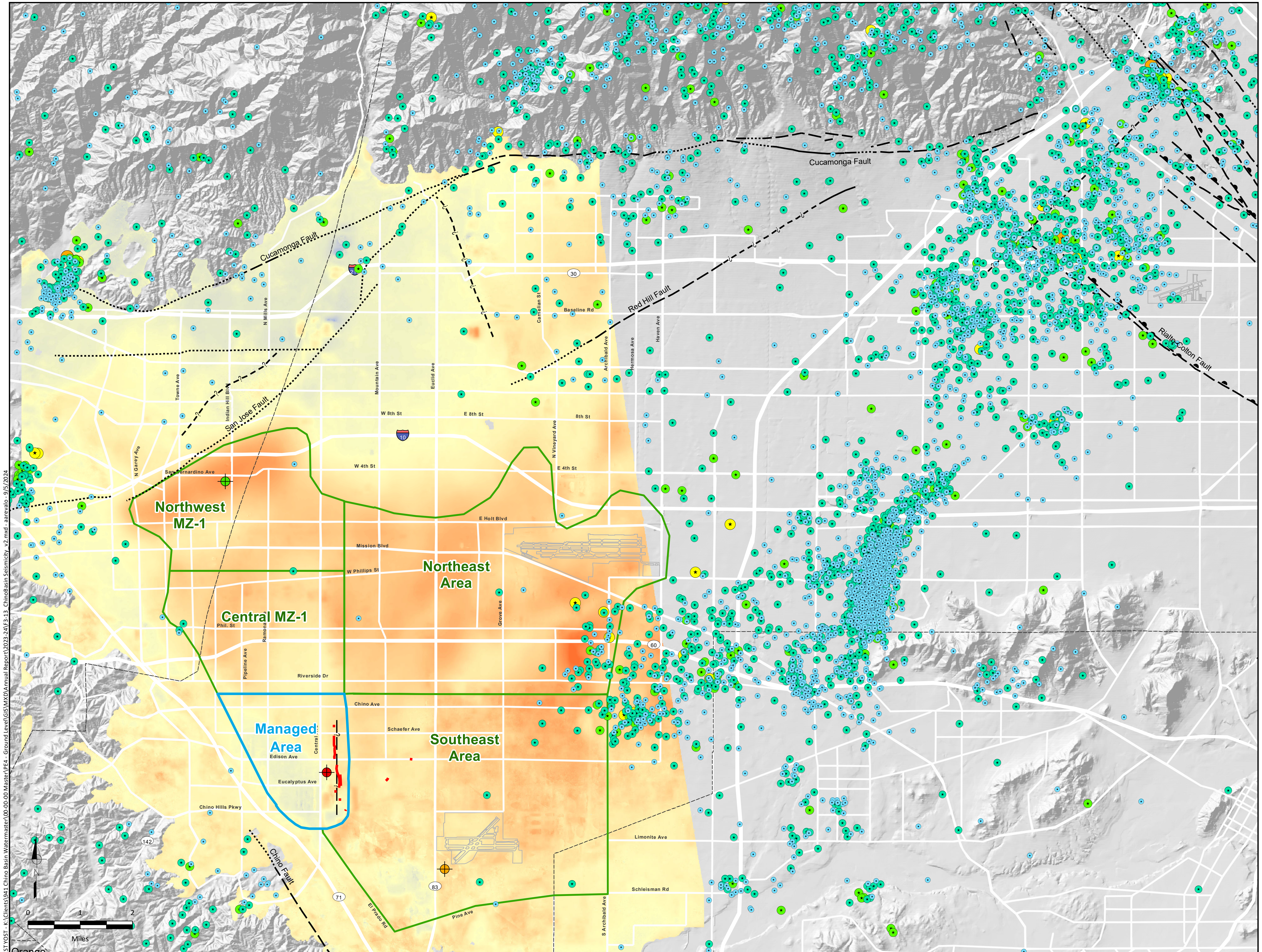
Chino Basin Watermaster

WEST YOST

2023/24 Annual Report for the Ground-Level Monitoring Program

Figure 3-12

Land Use, Pumping, and Vertical Ground Motion at the Whispering Lakes Subsidence Feature



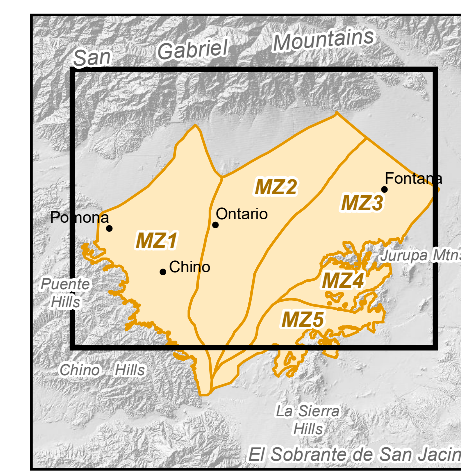
Seismicity in the Chino Basin
March 1, 2011 to March 31, 2024
(Magnitude)

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

Relative Change in Land Surface Elevation as Estimated by InSAR (March 2011 to March 2024)

High : 0.6
0 ft
Low : -0.6

- Pomona Extensometer
- Ayala Park Extensometer
- Chino Creek Extensometer
- Managed Area
- Areas of Subsidence Concern
- Flood Control and Conservation Basins
- Historical Ground Fissures
- Approximate Location of the Riley Barrier
- Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)



WEST YOST

Chino Basin Watermaster
2023/24 Annual Report for the Ground-Level Monitoring Program

Figure 3-13

Seismicity across the Chino Basin: 2011-2024

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions and Recommendations

The major conclusions and recommendations of this 2023/24 Annual Report for the GLMP are:

- At the Ayala Park Extensometer in the Managed Area, hydraulic heads within the shallow and deep aquifer-systems are at or near their highest levels since the inception of the GLMP in 2003, and the Ayala Park Extensometers recorded elastic compaction and expansion of the aquifer-system during the current reporting period of March 2023 to March 2024. The increases in hydraulic head were due to the virtual cessation of pumping in the Managed Area during the reporting period. The reduced pumping is largely due to the presence of water-quality contaminants in groundwater that constrain its use as drinking water. Hydraulic heads in the deep aquifer-system remain well above the Guidance Level, and the Ayala Park Extensometers recorded no inelastic compaction of the aquifer-system during the current reporting period.
- Across most of the other Areas of Subsidence Concern, prior annual reports have noted long-term trends of gradual land subsidence since 1992, even during periods of stable or increasing heads. The long-term trends in downward vertical ground motion have been of particular concern in Northwest MZ-1, where subsidence occurs differentially across the San Jose Fault and differential subsidence poses a threat for ground fissuring. The long-term trends of land subsidence have been attributed to the delayed drainage and compaction of aquitards as they slowly equilibrate with lower heads in the aquifers that were caused by historical pumping. Over the past several years, pumping has decreased across much of the western Chino Basin, partly due to the presence of contaminants in groundwater that constrain its use as drinking water. Also, artificial recharge of imported water in Northwest MZ-1 (Upland, College Heights, Montclair, and Brooks basins) has increased mainly due to a "put" cycle in the Dry-Year Yield Program. The decreases in pumping and increases in recharge have caused heads to stabilize or increase, and InSAR estimates of ground motion across most of the Areas of Subsidence Concern have shown that the long-term trends of land subsidence have slowed. These observations suggest:
    - The reductions in pumping, increases in recharge, and increases in hydraulic head may be causing equilibration of hydraulic heads in the aquitards and aquifers, which is slowing the drainage and compaction of the aquitards.
    - Hydraulic heads may be nearing "threshold levels" that, if achieved and maintained, could abate the future occurrence of permanent land subsidence. These hydraulic head thresholds, and various pumping and recharge strategies to maintain heads above these thresholds, were explored in 2023-24 using a numerical, one-dimensional aquifer-system compaction models in Northwest MZ-1. The past few years of reduced pumping and increased recharge in Northwest MZ-1 functioned as an empirical test of the model simulations and generally confirmed the model results that decreased pumping and increased recharge could elevate hydraulic heads and minimize or abate ongoing subsidence.
- The recent reduction in the rates of land subsidence across the Areas of Subsidence Concern does not mean that the future occurrence of subsidence and ground fissuring is no longer a threat. Future declines in hydraulic heads, which may be caused by increases in pumping or

decreases in recharge, among other causes, may cause aquitard compaction and rates of land subsidence to increase. For example, the pumpers in Northwest MZ-1 could increase pumping in the future, or there could be reduced or infrequent "put" cycles for the Dry-Year Yield Program. The future occurrence of subsidence remains possible in the event of future head declines.

RECOMMENDATION: Watermaster, with input from the GLMC, should continue implementation of the *Work Plan to Develop a Subsidence-Management Plan for the Northwest MZ-1 Area* to develop management strategies to avoid future occurrences of subsidence. This will include:

- Continuing aquifer-system monitoring and data analysis in Northwest MZ-1, including hydraulic head data and aquifer-system deformation data from the PX and hydraulic head data from Pomona and MVWD wells equipped with transducers.
- Using the one-dimensional compaction models at the MVWD-28 and PX locations to estimate the future occurrence of subsidence in Northwest MZ-1 under the planning alternatives that will be simulated as part of the 2025 SYR.
- Developing additional subsidence-management alternatives for evaluation in FY 2025/26 if the 2025 SYR alternatives are unsuccessful at minimizing or abating the future occurrence of subsidence in Northwest MZ-1.

These recommendations are consistent with the requirements of the OBMP Program Elements 1 and 4 and its implementation plan contained in the Peace Agreement.

- Since the inception of the GLMP, Watermaster has employed various methods to monitor ground motion via extensometers, InSAR, and traditional ground-level surveys. Analysis of these data over time has shown that InSAR has become an increasingly reliable and accurate method for monitoring of vertical ground motion across most of the Areas of Subsidence Concern for the following reasons:
  - Improvements in satellite technology over time have increased the spatial resolution, temporal resolution, and accuracy of InSAR. InSAR provides higher spatial and temporal resolution compared to traditional leveling surveys.
  - Sean Yarborough (formerly Neva Ridge Technologies, Inc.), a long-time subconsultant to the Watermaster, has been able to stay abreast of the newest InSAR products and processing techniques which in turn provides InSAR deliverables to the GLMC with high accuracy, resolution, and coherence.
  - Where and when the extensometer, InSAR, and traditional ground-leveling datasets overlap, InSAR shows a similar spatial pattern and magnitude of ground motion. Research performed for the GLMC has shown that the errors inherent in InSAR and traditional ground-level methods are similar.
  - Land-use changes from agricultural to urban uses have added hard, consistent radar wave reflectors to the ground surface over time. InSAR results are now coherent and useful across most of the Areas of Subsidence Concern.

  RECOMMENDATION: The Watermaster should continue to prepare high-quality, high-resolution InSAR deliverables (using data from the TerraSAR-X satellite) to estimate vertical ground motion and reduce the frequency of performing ground-level surveys.

- Section 3.5 described the results and conclusions of the Whispering Lakes Subsidence Investigation and concluded that shallow soil consolidation is the likely cause of the ongoing subsidence in this area.

  RECOMMENDATION: Continue a limited monitoring program to rule out aquitard drainage as a cause, including:

  - Continued monitoring of vertical ground motion by high-resolution InSAR that is currently conducted under the Watermaster's GLMP.
  - Continued monitoring of groundwater pumping at wells within the Study Area that is currently conducted on a quarterly time-step by the Watermaster.
  - Install transducers in wells within the Study Area to measure and record hydraulic heads at high temporal frequency.
  - Analyze and report on the monitoring data in these annual reports.

4.2 Recommended Scope and Budget for Fiscal Year 2024/25

The scope-of-work for the GLMP for FY 2024/25 was recommended by the GLMC in April 2024 and approved by Watermaster in May 2024. Appendix A is the technical memorandum prepared by the GLMC, titled *Recommended Scope and Budget for the Ground-Level Monitoring Program for FY 2024/25*.

In March 2025, Watermaster staff and the Watermaster Engineer will present the preliminary results of the GLMP through 2024 and a recommended FY 2025/26 scope and budget to the GLMC for consideration. As is typically done, the GLMC members can recommend changes to the proposed scope of work for the GLMP.

4.3 Changes to the Subsidence Management Plan

The Subsidence Management Plan calls for ongoing monitoring, data analysis, and annual reporting, and if the monitoring data in the Areas of Subsidence Concern indicate the potential for adverse impacts due to subsidence, Watermaster will revise the Subsidence Management Plan pursuant to the process outlined in Section 4 of the Subsidence Management Plan. Currently, there are no recommended changes to the Subsidence Management Plan.

5.0 GLOSSARY

The following glossary contains the terms and definitions used in this report and generally in the discussions at GLMC meetings.

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 may transmit appreciable water to and from adjacent aquifers and, where sufficiently thick, may constitute an important groundwater storage unit. A really, 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 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 the 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.

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.

Hydraulic 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.

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, 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, representing the portion of the applied stress that becomes effective as intergranular stress.

Stress, Pre-consolidation – The maximum antecedent effective stress to which a deposit has been subjected and can withstand without undergoing additional permanent deformation. Stress changes in the range less than the pre-consolidation stress produce elastic deformations of small magnitude. In fine-grained materials, stress increases beyond the pre-consolidation 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, thus affecting 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 a 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 the portion of the applied stress that becomes effective as intergranular stress.

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

Transducer – 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.

6.0 REFERENCES

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.

Riley, F.S. (1986). *Developments in borehole extensometry,* in Johnson, A.I., Carbognin, L., and Ubertini, L., eds., Proceedings, Land Subsidence – Third International Symposium on Land Subsidence, Venice, Italy, March 1984: International Association of Hydrological Sciences Publication, p. 343-355.

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

Wildermuth Environmental, Inc. (WEI). (2017b). *Task 3 and Task 4 of the Work Plan to Develop a Subsidence Management Plan for the Northwest MZ-1 Area: Development and Evaluation of Baseline and Initial Subsidence-Management Alternatives*. Prepared for the Ground-Level Monitoring Committee of the Chino Basin Watermaster. December 13, 2017.

Appendix A

Recommended Scope and Budget of the Ground-Level Monitoring Committee for FY 2024/25

23692 Birtcher Drive
Lake Forest CA 92630

949.420.3030 phone
530.756.5991 fax
westyost.com

TECHNICAL MEMORANDUM

DATE: April 22, 2024 Project No.: 941-80-22-26

TO: Ground-Level Monitoring Committee

FROM: West Yost Associates

REVIEWED BY: Andy Malone, PG

SUBJECT: Recommended Scope of Work and Budget for the Ground-Level Monitoring Program for Fiscal Year 2024/25 **(FINAL)**

BACKGROUND AND PURPOSE

Pursuant to the Optimum Basin Management Program Implementation Plan and the Peace Agreement, the Chino Basin Watermaster (Watermaster) implements a Subsidence Management Plan (SMP) for the Chino Basin to minimize or stop the occurrence of land subsidence and ground fissuring. The Court approved the SMP and ordered its implementation in November 2007 (2007 SMP). The 2007 SMP was updated in 2015 (2015 SMP) and can be downloaded from the Watermaster website. 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.

The Watermaster Engineer, with the guidance of the Ground-Level Monitoring Committee (GLMC), prepares 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 (FY); and recommendations for adjustments to the SMP, if any.

This Technical Memorandum (TM) describes the Watermaster Engineer's recommended activities for the GLMP for FY 2024/25 in the form of a proposed scope of services and budget.

Members of the GLMC were asked to:

- Review the draft TM prior to March 7, 2024.
- Attend a meeting of the GLMC at 10:00 am on March 7, 2024 to discuss the proposed scope of services and budget for FY 2024/25.
- Submit comments and suggested revisions on the proposed scope of services and budget for FY 2024/25 to the Watermaster by April 4, 2024.

This final scope of services and budget that addresses the comments and suggested revisions of the GLMC will be included in the Watermaster's proposed budget for FY 2024/25. The final scope of services, budget, and schedule for FY 2024/25 will be included in Section 4 of the *2023/24 Annual Report for the GLMP*.

RECOMMENDED SCOPE OF SERVICES AND BUDGET – FY 2024/25

A proposed scope of services for the GLMP for FY 2024/25 is shown in Table 1 as a line-item cost estimate. The proposed scope of services is summarized below.

Task 1. Setup and Maintenance of the Monitoring Network

The Chino Basin extensometer facilities are 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 (PX) facilities to ensure functionality and calibration of the monitoring equipment and data loggers. Two staff members are required for these visits due to safety concerns.

Non-routine efforts to be performed during FY 2024/25 under this subtask include:

- Monthly adjustments to the PX extensometers to improve the accuracy of the measurements of aquifer-system deformation.
- Purchase and install two metal covers for Ayala Park PA vault and PX 2 vault.
- Construct French drains around the PA vault to convey surface-water runoff away from the vault.

Task 1.2. Annual Lease Fees for the Chino Creek Extensometer Site

The County of San Bernardino (County) owns the land the Chino Creek extensometer facility is located on. As such, the Watermaster entered into a lease agreement with the County in 2012 and pays the County and annual rental payment of $1,596.

Task 2. Aquifer-System Monitoring and Testing

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

Task 2.1. Conduct Quarterly Monitoring at Extensometer Facilities

This subtask involves the routine quarterly collection, processing, and checking of data from the three extensometer facilities in the Chino Basin. Quarterly data collection is necessary to ensure that the monitoring equipment is in good working order and to minimize the risk of losing data because of equipment malfunction. For this subtask, the complete extensometer and piezometer records from the Ayala Park, Chino Creek, and PX facilities are loaded to HydroDaVE^{SM} (Hydrologic Database and Visual Explanations), the annual report figures are updated, and all the new data are checked for accuracy. If the data indicated malfunctioning equipment or inaccurate measurements, then any necessary adjustments to the monitoring equipment are made. Two staff members are required for these visits due to safety concerns.

Task 3. Basin-Wide Ground-Level Monitoring Program (InSAR)

This task involves the annual collection and analysis of Synthetic Aperture Radar (SAR) scenes to estimate the vertical ground motion across the western portion of Chino Basin from March 2024 to March 2025.[1]

In this subtask, five SAR scenes that are acquired by the TerraSAR-X satellite from March 2024 to March 2025 are purchased from the German Aerospace Center. West Yost will use the SAR scenes to prepare 12 interferograms (InSAR) that describe the incremental and cumulative vertical ground motion that occurred from March 2024 to March 2025 and since 2011. The associated costs to task, acquire, purchase, and process the InSAR data is as follows:

- Task TerraSAR-X for five SAR acquisitions for the western Chino Basin ($1,000)
- Purchase TerraSAR-X data ($10,000)
- Prepare and check InSAR results, including the interferograms and GIS-generated rasters ($62,000)

In addition, West Yost purchased and maintains the GAMMA software that is necessary to process the SAR data and prepare the InSAR estimates of vertical ground motion. The one-time initial cost for the software was $44,000. Since the Watermaster is the only West Yost client that utilizes InSAR services, the Watermaster is paying for the GAMMA software over a three-year period ($11,000 in FY 2023/24, $22,000 in FY 2024/25, and $11,000 in FY 2025/26). The annual maintenance cost is $6,600. Therefore, in FY 2024/25 the Watermaster's costs for the GAMMA software is: $22,000 + $6,600 = $28,000.

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. Figure 1 shows the location of the benchmark monuments surveyed across the western Chino Basin. Electronic distance measurements (EDM surveys) are also performed periodically between monuments to estimate horizontal ground motion in areas where ground fissuring due to differential land subsidence is a concern. Table 2 documents the areas surveyed over the last six years as part of the GLMP.

[1] West Yost is now performing this task internally instead of subcontracting the work, as was done in the past. This was made possible by West Yost hiring the InSAR subconsultant directly and purchasing/maintaining the necessary hardware and software.

Table 2. History of Ground-Level Surveys

Ground-Level Survey Area	Ground-Level Survey Completed (Y/N)?						
	2018	2019	2020	2021	2022	2023	2024[b]
Managed Area	Y	N	N	N	N	N	Y
Fissure Zone Area[a]	Y	N	N	N	N	N	N
Central Area	N	N	N	N	N	N	N
Northwest Area	Y	Y	Y	Y	Y	Y	Y
San Jose Fault Zone Area[a]	Y	Y	Y	Y	Y	N	N
Southeast Area	Y	N	N	N	Y	N	N
Northeast Area	Y	Y	Y	N	N	N	N

(a) Denotes EDM survey area (measurements of horizontal strain).
(b) The 2024 ground-level surveys are scheduled to begin in March 2024.

The ground-level surveys recommended for FY 2024/25 include the following:

Task 4.1. Conduct Spring-2025 Elevation surveys in Northwest MZ-1

In this subtask, the surveyor conducts elevation and EDM surveys at the established benchmarks in Northwest MZ-1 in Spring 2025. The elevation survey will begin at the Pomona Extensometer Facility and includes benchmarks across Northwest MZ-1. The elevation survey will be referenced to the Ayala Park elevation datum at the Ayala Park Extensometer via a GPS survey performed at both Ayala Park and the Pomona Extensometers.

The vertical elevation survey is recommended in Spring 2025 because of the recent subsidence that has occurred in Northwest MZ-1 and because the survey will support the development of a subsidence management plan in Northwest MZ-1. The EDM survey is ***not*** *recommended to be performed across the San Jose fault zone because past surveys (2013-2021) have demonstrated that the horizontal strain measured between benchmark pairs appears to behave elastically. The EDM surveys should be conducted less frequently than annual (e.g., once every five years).*

Ground-Level Surveys Not Recommended for Spring 2025

Ground-level surveys are **not** recommended for Spring 2025 in the other Areas of Subsidence Concern (*i.e.,* Managed, Central, Southeast, and Northeast Areas). This recommendation is justified because:

- InSAR is proving to be an accurate, more efficient, higher-resolution method to monitor vertical ground motion across the western Chino Basin.
- Hydraulic heads and vertical ground motion in some of these areas are stable or increasing.

Ground-level surveys should be conducted in these areas less frequently than annual (*e.g.,* once every five years).

Task 4.5. Replace Destroyed Benchmarks (if needed)

In this subtask, the surveyor replaces benchmark monuments that have been destroyed since the last survey, if any.

Task 4.6. Process, Check, and Update Database

In this subtask, the Watermaster Engineer receives and catalogs the survey results provided by the surveyor, prepares the data for display as a GIS layer, and performs checks against InSAR and extensometer data for reasonableness and accuracy.

Task 5. Data Analysis and Reporting

Task 5.1. Prepare Draft 2023/24 Annual Report for the Ground-Level Monitoring Program

Prepare the text, tables, and figures for a draft *2023/24 Annual Report for the GLMP* and submit the report to the GLMC by September 20, 2024 for review and comment.

Task 5.2. Prepare Final 2023/24 Annual Report for the Ground-Level Monitoring Program

Update the text, tables, and figures based on the comments received from the GLMC and prepare a final *2023/24 Annual Report for the GLMP* by November 1, 2024. Responses to GLMC comments will be included as an appendix to the final report. The report will be included in the agenda packet for the November 2024 Watermaster meetings for approval.

Task 5.3. Compile and Analyze Data from the 2024/25 Ground-Level Monitoring Program

In this subtask, monitoring data generated from the GLMP during 2024/25 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 2025 during the development of a recommended scope of services and budget for FY 2025/26.

Task 5.4. Conduct Whispering Lakes Subsidence Investigation of the Northeast Area

In the Northeast Area, the long-term and short-term InSAR estimates indicate that persistent downward ground motion has occurred in a concentrated area south of the Ontario International Airport between Vineyard Avenue and Archibald Avenue in the vicinity of Whispering Lakes Golf Course. The western edge of this subsiding area exhibits a steep subsidence gradient or “differential subsidence.”

In FY 2021/22, the Watermaster Engineer conducted a Reconnaissance-Level Investigation that included the review and analysis of readily-available borehole and lithologic data, historical air photos, pumping and recharge data, hydraulic head data, and InSAR estimates of vertical ground motion. Figures and charts were prepared and analyzed to derive interpretations and recommendations for future investigations and monitoring. The investigation and recommendations were included in the FY 2021/22 Annual Report of the GLMC. Plausible mechanisms for this subsidence feature include pumping-induced aquitard drainage and shallow soil consolidation associated with historical land uses. The investigation identified data gaps in available site-specific hydrogeologic data.

Potential next steps presented to the GLMC at its December 13, 2022 meeting included:

- Aquifer-system monitoring (*e.g.,* collecting existing hydrogeologic data; installing transducers at wells in the study area; constructing an aquifer-system monitoring facility within the subsidence feature)

- Further investigation of the historical land use practices in the vicinity of the Whispering Lakes Golf Course (e.g., agricultural disturbance and augmentation of soils; historical sewage disposal and spreading of solids; golf course construction and maintenance activities)
- Perform field studies of shallow soil consolidation (i.e., develop a dataset of site-specific shallow soil compaction that could be compared to the rates of subsidence estimated by InSAR).

The GLMC has recommended a stepwise, process-of-elimination approach to identify the subsidence mechanism(s). The GLMC approved a $10,000 budget for FY 2023/24 to implement the recommendations derived from the Reconnaissance-Level Investigation. This budget is being used to collect and evaluate existing data (e.g., hydrogeologic data, well information, reports, historical land use data) and install transducers at nearby pumping wells. The results of these efforts will be documented in the GLMC Annual Report for 2023/24 along with recommendations for follow-on work.

The GLMC should consider dedicating contingency budget for FY 2024/25 ($10,000) to continue the implementation of the recommendations derived Reconnaissance-Level Investigation and future recommendations based on results of work performed in 2023/24.

Task 6. Develop a Subsidence-Management Plan for Northwest MZ-1

The 2007 SMP called for ongoing monitoring and data analysis of the Managed Area; including annual reporting and adjustments to the SMP, as warranted by the data. The 2007 SMP also called for expanded monitoring of the aquifer-system and land subsidence in other areas of subsidence and ground fissuring concern. Figure 1 shows the location of these so-called Areas of Subsidence Concern: Central MZ-1, Northwest MZ-1, Northeast Area, and Southeast Area. 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]

The 2007 SMP stated that if data from existing monitoring efforts in the Areas of Subsidence Concern indicate the potential for adverse impacts due to subsidence, the Watermaster would revise the SMP to avoid those adverse impacts. The 2014 Annual Report of the GLMC recommended that the 2007 SMP be updated to better describe the Watermaster's land subsidence efforts and obligations, including areas outside of MZ-1. As such, the update included a name change to the 2015 Chino Basin Subsidence Management Plan (2015 SMP) and a recommendation to develop a subsidence management plan for Northwest MZ 1.

The Watermaster had been monitoring vertical ground motion in Northwest MZ-1 via InSAR during the development of the 2007 SMP. 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 2007 SMP. Of particular concern was the occurrence of concentrated differential subsidence across the San Jose Fault in Northwest MZ-1—the same spatial 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 Northwest MZ-1, has been discussed at prior GLMC meetings, and the subsidence has been documented and described as a concern in the Watermaster's State of the Basin Reports, the annual reports of the GLMC, and in the *Initial Hydrologic*

[2] http://www.cbwm.org/docs/legaldocs/Peace_Agreement.pdf.

Conceptual Model and Monitoring and Testing Program for the Northwest MZ-1 Area (WEI, 2017). The Watermaster increased monitoring efforts in Northwest MZ-1 beginning in FY 2012/13 to include ground elevation surveys and electronic distance measurements (EDM) to monitor ground motion and the potential for fissuring.

In 2015, the Watermaster's Engineer developed the *Work Plan to Develop a Subsidence Management Plan for the Northwest MZ-1 Area* (Work Plan; WEI 2015b).[3] The Work Plan is characterized as an ongoing Watermaster effort and includes a description of a multi-year scope-of-work, a cost estimate, and an implementation schedule. The Work Plan was included in the 2015 SMP as Appendix B. Implementation of the Work Plan began in July 2015. On an annual basis, the GLMC analyzes the data and information generated by the implementation of the Work Plan. The results and interpretations generated from the analysis are documented in the annual report for the GLMP and used to prepare recommendations for future activities.

Progress to Implement Work Plan through FY 2023/24

The progress that has been made to implement the Work Plan through FY 2023/24 is described below:

- An initial hydrogeologic conceptual model of the Northwest MZ-1 Area was developed, and a report was published in 2017.[4] This report described the hydrogeology of the area, speculated on the causes of the observed land subsidence, and included a recommended monitoring program.

- A preliminary one-dimensional (1D) compaction model, based on hydrogeologic information from the MVWD-28 well site, was constructed, calibrated and used to explore the future occurrence of subsidence in Northwest MZ-1 under various basin-operation scenarios of groundwater production and artificial recharge and to identify potential subsidence mitigation strategies. A report[5] was published to document the results and interpretations of the modeling, which were: ***the deep aquifer system is most susceptible to future compaction and associated land subsidence, and hence, heads will need to increase in the deep aquifer system to minimize or abate future subsidence in Northwest MZ-1***. The report also included a recommendation to construct the Pomona Extensometer.

- The initial monitoring program was implemented to closely track groundwater-levels, groundwater production, recharge, and ground motion across Northwest MZ-1. This monitoring program included the construction of the Pomona Extensometer to measure and record depth-specific heads and aquifer-system deformation. Implementation of the monitoring program is ongoing.

- A new 1D model was constructed and calibrated using the hydrogeologic information collected at the Pomona Extensometer. The 1D model at MVWD-28 was also updated and recalibrated using current information. The objectives of this exercise were to: (i) describe the subsidence mechanisms and the pre-consolidation head by aquifer-system layer in Northwest MZ-1 and (ii)

---

[3] Work Plan to Develop a Subsidence-Management Plan for Northwest MZ-1
[4] https://www.cbwm.org/docs/engdocs/GLMC/nwmz1/Final_NWMZ1_Task1_Report.pdf
[5] https://www.cbwm.org/docs/engdocs/GLMC/nwmz1/20171220%20Final%20NWMZ1%20Task3-4%20Tech%20Memo.pdf

develop modeling tools that can be used to explore the future occurrence of subsidence in Northwest MZ-1 under various basin-operation scenarios of groundwater production and artificial recharge and to identify potential subsidence mitigation strategies. This work was reviewed by the GLMC, and additional model calibration refinements and sensitivity analyses were performed based on GLMC input. In November 2022, the Watermaster Engineer published a final report[6] on the 1D Model calibrations and sensitivity analyses (with review by the GLMC) and deemed the 1D Models sufficient to simulation future land subsidence under prospective plans for pumping and recharge.

- In 2023, the Watermaster Engineer, with review and input from the GLMC, developed an initial "Subsidence Management Alternative" for Northwest MZ-1 called SMA-1. SMA-1 is equivalent to the planning scenario that was simulated with the 2020 Chino Valley Model (CVM) to support the 2020 Safe Yield Recalculation (2020 SYR). The 2020 SYR was intended to represent and simulate the Parties' projected pumping, recharge, and use of storage through 2050. The results of the 2020 SYR (*i.e.,* projected hydraulic heads by CVM layer) were used as input data for the 1D Model simulations to predict the potential future occurrence of subsidence through 2050. In September 2023, the Watermaster Engineer published a draft TM titled *1D Model Simulation of Subsidence in Northwest MZ-1—Subsidence Management Alternative #1*. The Watermaster's recommendations from this work were the following:

    a. Establish a preliminary "Northwest MZ-1 Guidance Level" of 630 ft-amsl for hydraulic heads in Layers 3 and 5 at the PX location. The preliminary Guidance Level is an aspirational Watermaster recommendation that, if achieved, would likely slow or stop aquitard compaction and land subsidence in Northwest MZ-1.

    b. Compliance with the Guidance Level should be measured at the PX-2/3 piezometer, which is generally representative of heads in Layers 3 and 5.

    c. The methods to achieve the Guidance Level could include but are not limited to: voluntary modification of pumping patterns; in-lieu recharge; wet-water recharge via spreading and/or injection; or a combination of methods. These methods might necessitate: voluntary modification of water-supply plans of the purveyors in the Chino Basin; modification of Watermaster practices for recharge and replenishment; and/or the implementation of regional-scale storage or conjunctive-use programs.

    d. Additional SMAs should be developed and evaluated with the 1D Models to generate the necessary information to finalize the Guidance Level and the *Subsidence Management Plan for Northwest MZ-1*. The additional SMAs could be developed during Watermaster's groundwater modeling efforts associated with the 2025 Safe Yield Reevaluation and the development of the Storage and Recovery Master Plan. The GLMC should participate in the scenario building exercises associated with these Watermaster efforts to develop the SMAs, so that the scenarios include various methods to achieve the Guidance Level. Then, the 1D Models should be used to evaluate the potential future subsidence in Northwest MZ-1 under the SMAs. These model results and evaluations will support the establishment

[6] https://www.cbwm.org/docs/engdocs/GLMC/nwmz1/TM%20-%20941%20-%201D%20Model%20-%20Final.pdf

of a Guidance Level in the *Subsidence Management Plan for Northwest MZ-1*. It should be noted that future monitoring and analyses always hold the potential for revisions to the Guidance Level, consistent with the adaptive management approach called for in the Chino Basin Subsidence Management Plan.

Based on the expected progress through FY 2023/24, the following work is recommended for FY 2024/25 to develop the *Subsidence Management Plan for Northwest MZ-1*:

Task 6.1. Aquifer-System Monitoring

The established monitoring program of piezometric levels and pumping at wells in Northwest MZ-1 will continue through various techniques, including: (i) SCADA-based monitoring by the Monte Vista Water District; (ii) monitoring of piezometric levels via sonar[7]; (iii) monitoring of piezometric levels via pressure transducers at City of Pomona production wells; and (iv) manual measurements of piezometric levels. These data, along with data collected from the PX in Task 2.1, will improve the understanding of the hydrogeology in Northwest MZ-1, will be used to develop the *Subsidence Management Plan for Northwest MZ-1*, and in the future, will be used to adapt the Chino Basin Subsidence Management Plan, as appropriate.

In this subtask, all data is collected, compiled, checked, and analyzed every three months. Charts and data graphics of pumping, piezometric levels, and aquifer-system deformation will be updated to support the data collection and analysis. The PX extensometer data is charted and analyzed monthly in the ongoing effort to improve the reliability and accuracy of the extensometers.

Task 6.5. Provide Advice in the Development of the 2025 SYR Scenarios

The ongoing 2025 SYR involves the development of multiple projection scenarios of future hydrology, pumping, managed recharge, and use of managed storage in the Chino Basin. These projection scenarios will be simulated with an updated CVM. The CVM results will be used to determine a tentative Safe Yield, which will be evaluated for MPI and then used to evaluate the current Safe Yield of the Chino Basin. The evaluation of MPI associated with land subsidence will be performed using the 1D Models in Northwest MZ-1 and in other Areas of Subsidence Concern (see Task 7 below). In FY 2024/25, the GLMC can provide the Watermaster with valuable advice on the following:

- The development of the 2025 SYR scenarios to ensure a plausible range of future conditions are simulated.
- Interpretation of the 1D Model results re: potential subsidence-related MPI associated with the Safe Yield estimates.
- How the model results can be used to evaluate the minimum recharge quantity of supplemental water in MZ-1 as required by the Peace II Agreement.

---

[7] The use of sonar technology to measure piezometric levels in wells in currently being used in Monte Vista Water District wells 28 and 31.

Providing GLMC advice should be conducted in conjunction with the 2025 SYR and can be discussed at regularly scheduled GLMC meetings at no additional cost.[8]

Task 7. Construct and Calibrate Additional 1D Models Across Western Chino Basin

As described above in Task 6, the Watermaster has constructed, calibrated, and used 1D Models at the PX and MVWD-28 locations to evaluate the potential future subsidence in Northwest MZ-1 through 2040. The Watermaster used the information derived from the 1D Models to develop a preliminary "Guidance Level" to avoid future subsidence in Northwest MZ-1.

In Task 7, three additional 1D Models are constructed and calibrated across other Areas of Subsidence Concern in western Chino Basin, so that Watermaster can use all of the 1D Models during the 2025 SYR process to:

- Evaluate for subsidence-related MPI during the 2025 SYR.
- Refine the preliminary "Guidance Level" in Northwest MZ-1 and the Managed Area.
- Evaluate for the minimum recharge quantity of supplemental water in MZ-1 as required by the Peace II Agreement.

In FY 2023/24, the three additional 1D Models are being constructed and calibrated in the following areas: Northeast Area (at Ontario Well 33 location), in the Southeast Area near the CDA well field (at the CCX location), and in the Managed Area (at the Ayala Park Extensometer location).

The deliverables of this task are the following:

- A draft TM to describe the background/objectives of the task and the methods that will be used to complete the task. The methods include a description of the proposed locations for the additional 1D Models and the data that will be used to construct and calibrate the models.
- A draft TM that summarizes the construction and calibration of the additional 1D Models.

This task was budgeted and scheduled for completion in FY 2023/24, but the final work will likely spill over into FY 2024/25. If necessary, unspent budget from FY 2023/24 will be carried over to FY 2024/25 to complete this task. ***No additional budget in FY 2024/25 is necessary to complete this task***.

Task 8. Meetings and Administration

Task 8.1. Prepare for and Conduct Four Meetings of the Ground-Level Monitoring Committee

This subtask includes preparing for and conducting four meetings of the GLMC:

- August 2024 – Review and discuss GLMP for FY 2024/25. Review and discuss the draft TM on Task 7 – *Construction/Calibration of Additional 1D Models*.

[8] This is because most of these discussions will be occurring in the 2025 SYR peer review process with the same technical consultants that participate on the GLMC.

- September 2024 – Review the draft 2023/24 Annual Report for the GLMP
- March 2025 – Review the draft recommended scope and budget for FY 2025/26
- April 2025 – Review the final recommended scope and budget for FY 2025/26 (if needed)

Task 8.2. Prepare for and Conduct One As-Requested Ad-Hoc Meeting

This subtask includes preparing for and conducting one ad-hoc meeting of the GLMC, as requested by the GLMC or Watermaster staff.

Task 8.3. Perform Monthly Project Management

This subtask includes monthly project administration and management, including staffing, financial and schedule reporting to Watermaster and subcontractor coordination.

Task 8.4. Prepare a Recommended Scope and Budget for the GLMC for FY 2025/26

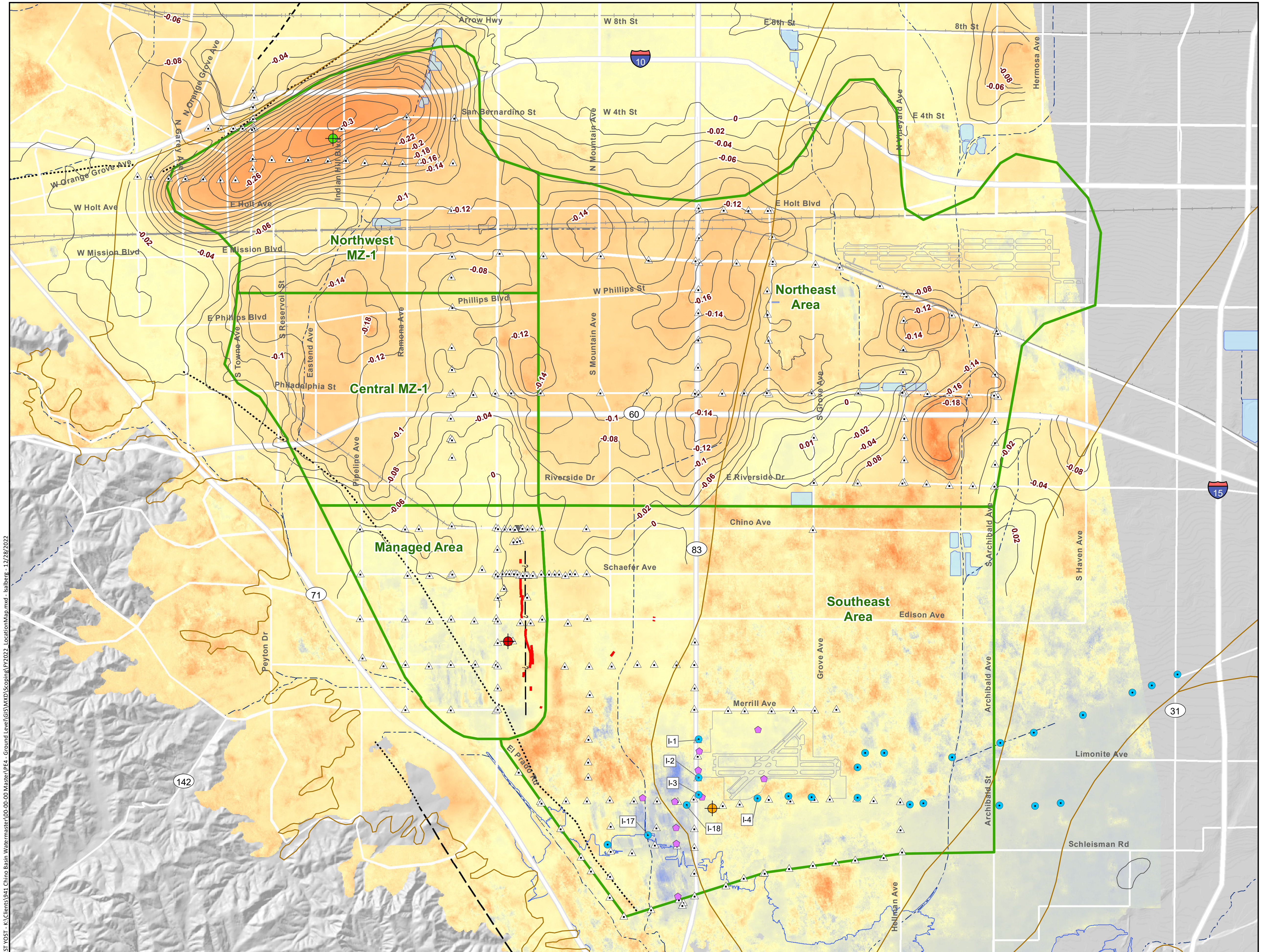
This subtask includes preparing a draft and final recommended scope of services and budget for FY 2025/26 for the GLMP to support the Watermaster's budgeting process.

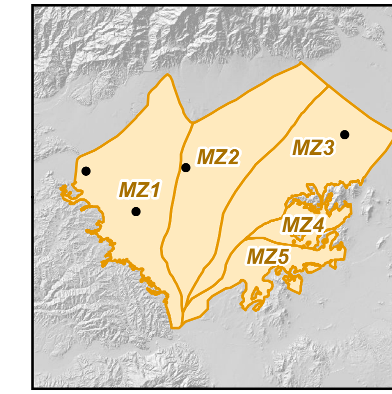
Table 1. Work Breakdown Structure and Cost Estimates for the Ground-Level Monitoring Program: FY 2024/25

Task Description		Notes	Labor (days)		Other Direct Costs						Totals			
			Person Days	Total	Travel	New Equip.	Equip. Rental	Outside Pro	Misc.	Total	Totals by Task	Recommended Budget *2024/25*	Approved Budget *2023/24*	Net Change *from 2023/24*
												a	*b*	*a - b*
Task 1. Setup and Maintenance of the Monitoring Network				**$40,221**						**$8,018**	**$48,239**	**$48,239**	**$47,789**	**$450**
1.1	Maintain Extensometer Facilities													
1.1.1	Routine maintenance of Ayala Park, Chino Creek, and Pomona extensometer facilities		21	$29,437	$649	$250	$350			$1,249	$30,685	$30,685	$33,707	-$3,022
1.1.2	Replacement/repair of equipment at extensometer facilities		6	$10,784	$173	$2,500		$2,500		$5,173	$15,957	$15,957	$12,485	$3,472
1.2	Annual Lease Fees for the Chino Creek extensometer facility		0	$0					$1,596	$1,596	$1,596	$1,596	$1,596	$0
Task 2. MZ-1: Aquifer-System Monitoring and Testing				**$32,724**						**$784**	**$33,508**	**$33,508**	**$31,456**	**$2,052**
2.1	Conduct Quarterly Monitoring at Extensometers Facilities													
2.1.1	Download data from the Ayala Park Extensometer facility		4	$5,436	$332		$40			$372	$5,808	$5,808	$3,032	$2,776
2.1.2	Download data from the Chino Creek Extensometer facility		4	$5,436			$40			$40	$5,476	$5,476	$2,700	$2,776
2.1.3	Download data from Pomona Extensometer facility		4	$5,436	$332		$40			$372	$5,808	$5,808	$10,492	-$4,684
2.1.4	Process, check, and upload data to database		10	$16,416						$0	$16,416	$16,416	$15,232	$1,184
Task 3. Basin Wide Ground-Level Monitoring Program (InSAR)				**$64,880**						**$39,600**	**$104,480**	**$104,480**	**$96,560**	**$7,920**
3.1	Satellite tasking and data selection with AirBus for 2024/25		0.5	$1,144					$1,000	$1,000	$2,144	$2,144	$96,560	$7,920
3.2	Assess SAR baselines for 2024/25 and select/purchase TerraSAR-X frames from Airbus		0.5	$1,144					$10,000	$10,000	$11,144	$11,144		
3.3	Prepare and check interferograms for 2024/25		28	$62,592						$0	$62,592	$62,592		
3.4	GAMMA software for InSAR processing (initial purchase + annual maintenance)		0	$0					$28,600	$28,600	$28,600	$28,600		
Task 4. Perform Ground-Level Surveys				**$7,144**						**$38,600**	**$45,744**	**$45,744**	**$84,280**	**-$38,536**
4.1	Conduct Spring-2024 Elevation surveys in Northwest MZ-1		0.5	$1,288				$28,600		$28,600	$29,888	$29,888	$28,360	$1,528
4.2	Conduct Spring-2024 Elevation Survey in the Northeast Area		0	$0				$53,416		$0	$0	$0	$0	$0
4.3	Conduct Spring-2024 Elevation Survey in the Southeast Area		0	$0				$56,584		$0	$0	$0	$0	$0
4.4	Conduct Spring-2024 Elevation and EDM Surveys in the Managed Area/Fissure Zone		0	$0				$46,800		$0	$0	$0	$31,248	-$31,248
4.5	Replace Destroyed Benchmarks (if needed)		0	$0				$10,000		$10,000	$10,000	$10,000	$19,280	-$9,280
4.6	Process, Check, and Update Database		3	$5,856						$0	$5,856	$5,856	$5,392	$464
Task 5. Data Analysis and Reporting				**$87,084**						**$0**	**$87,084**	**$87,084**	**$85,412**	**$1,672**
5.1	Prepare Draft 2023/24 Annual Report of the Ground-Level Monitoring Committee		19	$36,744						$0	$36,744	$36,744	$36,136	$608
5.2	Prepare Final 2023/24 Annual Report of the Ground-Level Monitoring Committee		8.5	$16,820						$0	$16,820	$16,820	$15,732	$1,088
5.3	Compile and Analyze Data from the 2024/25 Ground-Level Monitoring Program		14	$23,520						$0	$23,520	$23,520	$23,544	-$24
5.4	Continue Whispering Lakes Subsidence Investigation		0	$10,000						$0	$10,000	$10,000	$10,000	$0
Task 6. Develop a Subsidence-Management Plan for Northwest MZ-1				**$16,656**						**$0**	**$16,656**	**$16,656**	**$15,536**	**$1,120**
6.1	Aquifer-System Monitoring													
6.1.1	Collect pumping and piezometric data from agencies every three months; check and upload data to HDX		6	$8,448						$0	$8,448	$8,448	$10,560	-$2,112
6.1.2	Prepare and analyze charts and data graphics of pumping and recharge (Northwest MZ-1), piezometric levels, and aquifer-system deformation from PX		5	$8,208						$0	$8,208	$8,208	$4,976	$3,232
Task 7. Construct and Calibrate Additional 1D Models Across Western Chino Basin				**$0**						**$0**	**$0**	**$0**	**$192,511**	**-$192,511**
7.1	Prepare a draft TM summarizing the background, objectives, and methods; distribute to the GLMC		0	$0						$0	$0	$0	$12,760	-$12,760
7.2	Prepare for and conduct a GLMC meeting to receive feedback and comments on the draft TM		0	$0						$0	$0	$0	$5,110	-$5,110
7.3	Verify and/or recalibrate the 1D Model at Ayala Park Extensometer location		0	$0						$0	$0	$0	$22,736	-$22,736
7.4	Construct two additional 1D Models in the Southeast Area and Northeast Area		0	$0						$0	$0	$0	$62,368	-$62,368
7.5	Calibrate new 1D Models to derive properties of aquifers/aquitards and estimate the pre-consolidation stress(es)		0	$0						$0	$0	$0	$45,472	-$45,472
7.6	Prepare a draft TM summarizing the construction/calibration of additional 1D Models; distribute to the GLMC		0	$0						$0	$0	$0	$37,024	-$37,024
7.7	Prepare for and conduct a GLMC meeting to receive feedback and comments on the draft TM		0	$0						$0	$0	$0	$5,110	-$5,110
7.8	Incorporate the GLMC comments and prepare a final technical memorandum		0	$0						$0	$0	$0	$1,932	-$1,932
Task 8. Meetings and Administration				**$57,562**						**$375**	**$57,937**	**$57,937**	**$59,228**	**-$1,292**
8.1	Prepare for and Conduct Four Meetings of the Ground-Level Monitoring Committee	a	14	$31,744	$291					$291	$32,035	$32,035	$32,636	-$602
8.2	Prepare for and Conduct One As-Requested Ad-Hoc Meeting	a	3	$6,792	$84					$84	$6,876	$6,876	$5,470	$1,406
8.3	Perform Monthly Project Management		3	$7,728						$0	$7,728	$7,728	$11,592	-$3,864
8.4	Prepare a Recommended Scope and Budget for the GLMC for FY 2023/24		5.25	$11,298						$0	$11,298	$11,298	$9,530	$1,768
Totals				**$306,271**						**$87,376**		**$393,647**	**$612,772**	**-$219,125**

Notes:

a Assumes in-person meetings.





N

0 1 2
Miles

Relative Change in Land Surface Altitude as Estimated by InSAR (March 2011 to March 2022)

- + 0.55 ft
- 0 ft
- -0.55 ft
- InSAR absent or incoherent
- Areas of Subsidence Concern
- Pomona Extensometer Facility
- Chino Creek Extensometer Facility
- Ayala Park Extensometer Facility
- Chino Desalter Authority Well
- SB County Proposed Extraction Well
- Ground-Level Survey Benchmark
- Ground Fissures
- Approximate Location of the Riley Barrier

WEST YOST

Figure 1

Ground-Level Monitoring Program Fiscal Year 2022/23

Chino Basin Watermaster
Ground-Level Monitoring Committee

Attachment A – Responses to Comments

The comments received from the GLMC as of April 4, 2024 on the "Recommended Scope of Services and Budget of the Ground-Level Monitoring Committee for Fiscal Year 2024/25 (Draft)" and the Watermaster Engineer's response to comments are documented below.

Comments from the City of Chino (Hye Jin Lee)

Comment 1 – Task 1. Setup and Maintenance of the Monitoring Network.

Task 1.1. The City understands settling of the vault structure located at the Ayala Park Extensometer facility has occurred over time which allows water to enter the vault and potentially flow into the monitoring wells. Watermaster proposes to address this field condition by installing French drains around the vault. The City is concerned the construction of French drains may not be the most suitable means to address the field condition. Any contemplated construction activity at the park must be approved by the City of Chino and coordinated with the City of Chino's Community Services for any planned activities in the area. Prior to taking any steps towards implementing the French drains the Watermaster is advised to contact the City.

Response:

Watermaster staff and engineer will work closely with the City on any modifications at Ayala Park to prevent flooding of the piezometer vault.

Comments from the State of California (Rick Rees)

Comment 1 – Task 3. Basin-Wide Ground-Level Monitoring Program (InSAR)

The InSAR-based monitoring proposed in the 2024/2025 budget is only for the western portion of the Chino Basin. Therefore, it is not "basin-wide" as the task description implies (text and Table 1). The committee has discussed conducting occasional InSAR monitoring of the eastern part of the Chino Basin. This should be considered for the next budget. One option that would reduce cost is to provide InSAR results published by the Department of Water Resources (DWR) to cover the entire basin. Although the DWR InSAR data are not the same level of resolution and not directly comparable with the data that West Yost will process for the western part of the basin, it should be easy to generate true basin-wide InSAR results. This should be continued less frequently than annual (e.g., every five years) to verify that there are no subsidence issues outside of the western part of the Chino Basin where ground levels are well documented every year.

Response:

We concur. The effort to conduct InSAR monitoring of the eastern part of the Chino Basin using InSAR results published by the Department of Water Resources (DWR) will be described and budgeted for the proposed scope and budget for the GLMP for 2025/26.

Comments from Monte Vista Water District (Justin Scott-Coe)

Comment 1 – Task 1.1 Maintain Extensometer Facilities

"Non-routine efforts to be performed during FY 2024/25 under this subtask include… Monthly adjustments to the PX extensometers to improve the accuracy of the measurements of aquifer system deformation."

Watermaster has recognized the importance of the extensometer data in monitoring current conditions and understanding hydrogeologic conditions. As stated in the Technical Memorandum "Construction and Calibration of 1D Compaction Models in Northwest MZ 1 (September 23, 2022), "Continued monitoring and enhanced understanding of hydrogeologic conditions is crucial to minimizing model error and uncertainty, especially the monitoring of the PX in Northwest MZ-1." The District recommends providing a briefing and the currently available extensometer data to the Ground Level Monitoring Committee (GLMC) for review.

Key questions regarding the PX include:

- How is Watermaster assessing the reliability/accuracy of the extensometer data?
- What adjustments have been made and are proposed to be made to the PX in the upcoming year and what is the anticipated result of those changes?
- What does the extensometer data currently indicate regarding ground-level motion in Northwest MZ-1?

Response:

We concur with the recommendation to brief the GLMC re: the currently available extensometer data and answer the questions listed above. This topic will be included on the GLMC meeting agenda for August 1, 2024.

Comment 2 – Basin-Wide Ground-Level Monitoring Program (InSAR)

A significant cost identified under this task is $62,000 for "preparation and checking" of InSAR data. What is the basis for this cost, and are there opportunities for more efficiency by workflow automation in the data processing (e.g. save money over time)?

Response:

The basis for this cost is about 28 days of staff time multiplied by the various daily rates by staff position.

The Watermaster Engineer has recently hired Sean Yarborough to perform this task directly. Mr. Yarborough previously worked for the long-time InSAR subconsultant that worked for the Watermaster. The engineer expects the level of effort for this task to decrease in subsequent years as automated coding of processes are developed and implemented and as junior staff are trained to perform portions of this task.

Comment 3 – Develop a Subsidence-Management Plan for Northwest MZ-1

"…the same pattern of differential subsidence that occurred in the Managed Area during the time of ground fissuring."

The District suggests removing this clause from the sentence or revising to indicate that the differential subsidence conditions in the two areas are not identical. Groundwater levels in Northwest MZ-1 have stabilized since the late 1970s and no ground fissuring has been reported in Northwest MZ-1 to date. Ground fissuring in the Managed Area was reported to occur as early as the early 1970s and accelerated in the early 1990s.

Response:

The phrase has been revised to read "*spatial* pattern of differential subsidence" to distinguish it from rates and magnitudes of subsidence.

Comment 4 – Progress to Implement Work Plan through FY 2023/24

"a. Establish a preliminary 'Northwest MZ-1 Guidance Level' of 630 ft-amsl for hydraulic heads in Layers 3 and 5 at the PX location. The preliminary Guidance Level is an aspirational Watermaster recommendation that, if achieved, would likely slow or stop aquitard compaction and land subsidence in Northwest MZ-1."

The District recommends removing language from this progress summary suggesting that the aspirational Watermaster recommendation would "likely slow or stop aquitard compaction and land subsidence in Northwest MZ-1." It is the District's understanding that modeling to support this statement has neither been conducted nor provided to the GLMC for review; as such, this statement is not supported by relevant technical analyses.

"d. Additional SMAs should be developed and evaluated with the 1D Models… The GLMC should participate in the scenario building exercises associated with these Watermaster efforts to develop the SMAs, so that the scenarios include various methods to achieve the Guidance Level."

Because the "Guidance Level" cited here has not yet been evaluated, scenario-building to meet this or any other proposed guidance level is premature. Any proposed guidance level should be simulated versus a no-action alternative to evaluate the effectiveness of the guidance level at reducing projected land subsidence versus a no-action alternative. The simulation results should then be presented to the GLMC for review prior to initiating any scenario-building to meet the proposed guidance level.

Response:

For (a), the statement suggesting that the aspirational Watermaster recommendation would "likely slow or stop aquitard compaction and land subsidence in Northwest MZ-1" is based on the physics of aquitard drainage—not on modeling. In other words, any increases in hydraulic heads within the deep aquifer system would have the result of slowing or stopping aquitard drainage.

For (d), the ongoing process to re-evaluate the Safe Yield will include a "no action" scenario(s) and will include 1D compaction modeling in Northwest MZ-1 for review by the GLMC.

Comment 5 – Construct and Calibrate Additional 1D Models Across Western Chino Basin

Regarding Additional Expenditure on 1-D Models

The District continues to have concerns regarding the use of 1-D Models as management tools in Northwest MZ-1 and other Areas of Subsidence Concern. Given the size and heterogeneity of the alluvial sediments across the Areas of Subsidence Concern, the limitations and appropriateness of 1-D models should be re-evaluated before additional budget expenditures. (See above comments on Proposed Locations and Data for Construction/Calibration of Additional 1D Models.)

"The Watermaster used the information derived from the 1D Models to develop a preliminary 'Guidance Level' to avoid future subsidence in Northwest MZ-1."

The District's understanding is that the "preliminary 'Guidance Level'" cited here for the deep aquifer was based on water levels in the shallow aquifer and not on "information derived from the 1D Models." If this is the case, this language does not reflect how the preliminary "Guidance Level" was developed. The preliminary "Guidance Level" was not based on an analysis of 1D Models with the guidance level implemented or evaluated compared to a no-action alternative. Whether the currently proposed guidance level will avoid future subsidence is also unknown. The District recommends that this sentence be removed or modified to reflect the approach taken and the uncertainty regarding the effectiveness of the preliminary "Guidance Level."

Response:

As stated in this memorandum, this task was budgeted and scheduled for completion in FY 2023/24. No additional budget in FY 2024/25 is necessary to complete this task.

Appendix B

Response to GLMC Comments

MONTE VISTA WATER DISTRICT (JUSTIN SCOTT-COE)

Comment 1 – Preliminary Guidance Level

The District has previously expressed concerns that the "preliminary guidance level" for groundwater levels of 630 feet above mean sea level (ft-amsl) in Northwest Management Zone 1 (MZ-1) was insufficiently supported by data and modeling when it was issued last year. Land subsidence trends in the interferometric synthetic aperture radar (InSAR) data in Northwest MZ-1 have abated over the latest monitoring period. Given groundwater elevations remain below the "preliminary guidance level" and conditions have stabilized and even rebounded recently, Watermaster should reconsider the issuance of the "preliminary guidance level."

The District also recommends additional discussion in the Report regarding:

1. How the current groundwater levels compare to the "preliminary guidance level"; and
2. How the evaluation of management alternatives would change if subsidence trends continue to stabilize as they have over the last five years.

Given the "No Action" alternative has yielded a cessation of subsidence in the Northwest MZ-1 based on InSAR, the District recommends evaluating an alternative with recent operations (capturing recharge and pumping cycles). Also, the District recommends assessing the feasibility of more frequent, higher volume recharge in the Northwest MZ-1 during the development of subsidence management alternatives.

In relation to recommendations regarding the frequency of ground level surveys, the District recommends that ground level surveys continue at a regular frequency in Northwest MZ-1. The ground level surveys remain an important second data source, given the issues at the Pomona Extensometer (PX) and as a confirmation of InSAR.

Finally, in relation to the predictions of the 1-D models, it will be important to demonstrate that the 1-D models predict the cessation of subsidence in the observed record in Northwest MZ-1 and to evaluate if the 1-D models are overpredicting future subsidence from the delayed drainage and compaction from historical 1930 to 1978 lowering of water levels.

Response:

The Watermaster Engineer considers the "preliminary guidance level" to be "preliminary" and subject to change based on additional data collection, data analysis, and 1D Model evaluations of additional Subsidence Management Alternatives (which will include the newly collected data over the past few years).

The Subsidence Management Alternatives are planned to be developed in a collaborative process with the GLMC and could (and should) include "more frequent, higher volume recharge in the Northwest MZ-1." These efforts are contemplated for FY 2025/26 and should be discussed by GLMC in early 2025 during its efforts to recommend a scope and budget for the GLMP for FY 2025/26.

The suggestion to compare current groundwater elevations at the PX-3 piezometer to the "preliminary guidance level" is reasonable, and such comparisons and evaluations should be included in future annual reports.

The ground-level surveys in Northwest MZ-1 are planned and budgeted for FY 2024/25.

The future 1D Model evaluations of additional Subsidence Management Alternatives will include the newly collected data over the past few years, and therefore, can be used to "validate" the 1D Models or demonstrate that the 1D Models require updates and/or recalibration.

Comment 2 – Section 2.1.1.1: *"The PX has been measuring logical head changes that are consistent with head changes being measured at nearby wells, but has not been measuring and recording logically correlated extensometer data, which indicates that: (i) the extensometers are malfunctioning, (ii) the monitoring/recording equipment is malfunctioning, or (iii) both are malfunctioning."*

Are these the only two possible explanations for the observations at the PX?

Response:

Yes. This interpretation is based on the Watermaster Engineer's past experiences with extensometers in the Chino Basin and elsewhere in California and Arizona.

Comment 3 – Section 2.1.2.4, Footnote 10: *"The residual noise level in previous deliveries forced an overly complex workflow when converting InSAR displacement rasters to ArcGIS contours. The new processing method reduces the standard deviation over small areas while maintaining depth estimates. Though more complex than a spatially variant smoothing operation, it may be described as such."*

Can the new processing methodology be explained more thoroughly? What GIS processes or statistical methods are used? How does the processing methodology affect the data interpretation and compare with the old methodology?

Response:

Yes, the new InSAR processing methodology be explained more thoroughly with comparisons to past InSAR results. However, this would require a significant effort and cost to prepare such documentation. Such documentation was not included in the scope and budget for FY 2024/25. The GLMC could recommend such an effort for the FY 2024/25 scope and budget for the GLMP.

Comment 4 – Section 2.1.2.4, Footnote 12: *"Satellite ephemeris inaccuracies create quadratic phase trends in the processed interferometry. These trends may be thought of as 'tilts' or 'bends' across the complex data, and are a source of displacement error if left uncorrected. Inaccuracies in the underlying elevation model may also contribute to overall phase trends. Correction requires careful selection of high-quality control points via manual masking and automatic data quality estimation."*

Please add some discussion on the magnitude of inaccuracies and manual and automated corrections in processing methodology. Ground-truthing and on-going ground level monitoring surveys are of continued importance. How is data in Northwest MZ-1 affected by these processing techniques and corrections?

Response:

The new InSAR processing methodology be explained more thoroughly with reference to specific areas in the Chino Basin (e.g., Northwest MZ-1), however, this would require a significant effort and cost to prepare such documentation. Such documentation was not included in the scope and budget for FY 2024/25. The GLMC could recommend such an effort for the FY 2024/25 scope and budget for the GLMP.

The InSAR results in Northwest MZ-1 are likely the most accurate in the Chino Basin with the least potential error, mostly due to the virtual complete coverage of the land surface by hard, reflective surfaces that have not changed over time (*e.g.,* an agricultural field being converted into a warehouse). This has been demonstrated by the good match between ground-level survey data and InSAR estimates of vertical ground motion in Northwest MZ-1.

Comment 5 – Section 2.2.1, Subsidence Management Plan for Northwest MZ-1, Task 6: *“The objective of this task is to perform controlled aquifer-system stress tests at pumping wells in Northwest MZ-1 and to monitor the depth-specific hydraulic head and aquifer-system deformation response at PX.”*

The establishment of a reliable data record at the PX and future aquifer testing would be useful in confirming critical aspects of the conceptual model prior to establishing management guidance.

Response:

While it is always true that more data and testing are useful in making interpretations and recommendations, the Watermaster Engineer continues to support the data and modeling that were utilized to recommend a “preliminary guidance level” for Northwest MZ-1 and the proposed process to refine the “preliminary guidance level” in FY 2025/26 (see response to Comment 1).

Comment 6 – Section 2.2.1, Subsidence Management Plan for Northwest MZ-1, Task 9a: *“Establish a preliminary ‘Northwest MZ-1 Guidance Level’ of 630 ft-amsl for hydraulic heads in Layer 3 and 5 at the PX location.”*

The preliminary guidance level was established prematurely without correlation of piezometric heads with aquifer deformation at the extensometer, or modeling in support of the guidance level. What do recent rebounds in land surface in Northwest MZ-1 indicate about the preliminary guidance level, given hydraulic heads in Layers 3 and 5 at the PX location remain at ~ 560 to 580 ft-amsl?

Response:

Please see Section 4.1 of the annual report, which explains the Watermaster Engineer’s interpretations of the recent data/observations, including the recommendations for additional work to refine the “preliminary guidance level” for Northwest MZ-1 in FY 2024/25.

Comment 7 – Section 3.4, Northwest MZ-1, Second/Third Bullets: *“A maximum of about 1.4 ft of subsidence occurred in this area from 1992 through March 2024 – an average rate of about 0.04 ft/yr… … the maximum rate of downward ground motion in Northwest MZ-1 slowed to about – 0.03 ft/yr. This resulted in a maximum of about -0.4 ft of downward ground motion…”*

Can the sign convention be kept consistent in the discussion in these two bullets? In the third bullet, negative downward ground motion would indicate upward displacement, when this does not appear to be the intent.

Response:

The text of the annual report has been revised to address this comment.

Comment 8 – Section 3.4, Northwest MZ-1, Last Bullet: *"These observations suggest that in Northwest MZ-1: (i) changes in hydraulic heads, which are controlled by the pumping and recharge stresses in the area, have at least some control on the pattern and rate of subsidence and (ii) these monitoring data may be providing information on hydraulic head 'thresholds' that could be used as management criteria to protect against the future occurrence of land subsidence."*

What do the observations suggest about the "preliminary guidance level" and potential subsidence management alternatives? Can the subsidence management alternatives include more frequent higher volume recharge in the Northwest MZ-1?

Response:

This section is an analysis of subsidence at the P-30 location and therefore is not directly related to the "preliminary guidance level" which corresponds to the PX location (and specifically, the head at the PX-3 piezometer).

Yes, additional Subsidence Management Alternative could (and should) include greater recharge in Northwest MZ-1.

Comment 9 – Figure 3-10, Inset Note: *"From 2018 to 2022, groundwater elevations have remained above 577 ft-amsl…"*

The discussion in this note includes data from 2018 to 2022. From 2018 to 2024, subsidence trends from InSAR data have stabilized, and groundwater elevations varied across a broader range. Please update the discussion to include the latest data period.

Response:

The note on Figure 3-10 represents the Watermaster Engineer's most defensible interpretation of all available data on the figure (including the data from 2022-24).

Comment 10 – Section 4, Conclusions and Recommendations, Second Bullet: *"The past few years of reduced pumping and increased recharge in Northwest MZ-1 functioned as an empirical test of the model simulations and generally confirmed the model results that decreased pumping and increased recharge could elevate hydraulic heads and minimize or abate ongoing subsidence."*

Please add some discussion on how the current hydraulic heads compare with the "preliminary guidance level." Given the 1-D model predicted ongoing delayed drainage at the current hydraulic heads, and the current conditions/operations result in stabilized conditions, does the 1-D model still serve as a useful management tool for evaluating alternatives? Would a 1-D model of a "No Action" alternative at the current hydraulic heads predict the current stabilized condition?

Response:

Aquitard expansion, compression, and compaction are complex processes that are site-specific and depth-specific and can be influenced by site-specific and depth-specific recharge and pumping activities. For example, the recent increases in groundwater levels and slowing of subsidence are likely due to decreased pumping and increased recharge, which could be causing elastic expansion in some depth intervals of the aquifer system, which in turn, could be masking the delayed drainage of aquitards in other depth intervals of the aquifer system.

Please recall that subsidence management activities in the Chino Basin are an iterative, adaptive process. Ongoing monitoring and the 1D Model efforts work in tandem, and can be used over time to better understand the long-term depth-specific heads, that if maintained, could eliminate aquitard compaction over time.

Comment 11 – Section 4, Conclusions and Recommendations, Third Bullet: *"Developing additional subsidence-management alternatives for evaluation in FY 2025/26 if the 2025 [Safe Yield Reset] alternatives are unsuccessful at minimizing or abating the future occurrence of subsidence in Northwest MZ-1."*

This language and recommendation should be deleted. Safe Yield, by definition, cannot cause an "undesirable result" such as subsidence (Chino Basin Restated Judgement ¶4(x)). The 2022 Updated Safe Yield Reset Methodology allows Watermaster to identify and implement prudent measures necessary to mitigate an "undesirable result," but only after determining that groundwater production at the proposed Safe Yield will cause or threaten to cause an "undesirable result." To our knowledge, such a determination has not been made for projected groundwater production under any 2025 Safe Yield Reset alternative. Therefore, developing additional subsidence-management alternatives would be unnecessary and a waste of public funds.

Response:

The 2025 Safe Yield Reevaluation has not yet been completed, nor has an evaluation of the potential for subsidence under the 2025 Safe Yield Reevaluation. If subsidence is recognized as potential MPI in Northwest MZ-1 in the 2025 Safe Yield Reevaluation, then the 1D Models would become useful tools to explore prudent mitigation measures (*e.g.,* prioritization of recharge in Northwest MZ-1).