CHINO BASIN WATERMASTER

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NOTICE OF MEETING

Ground-Level Monitoring Committee

9:00 am – Wednesday, October 4, 2023

Held via Zoom Meeting:
https://us06web.zoom.us/j/85972968898?pwd=2BP7HRzfAM66hSgfZFU1SdWUjRjVFn.1
You can also dial in using your phone:
Join by Phone: 1 (669) 444 9171 | Meeting ID: 859 7296 8898 | Passcode: 867398

AGENDA

1. 1D Model Simulation of Subsidence in Northwest MZ—Subsidence Management Alternative #1 (Draft)
2. 2022-23 Annual Report of the Ground Level Monitoring Committee (Draft)

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TECHNICAL MEMORANDUM

DATE: September 26, 2023

Project No.: 941-80-23-25 B.2

TO: Ground-Level Monitoring Committee

CC: Peter Kavounas, *General Manager of the Chino Basin Watermaster*

FROM: West Yost Associates, *Watermaster Engineer*

REVIEWED BY: Andy Malone, PG

SUBJECT: *1D Model Simulation of Subsidence in Northwest MZ-1—Subsidence Management Alternative #1 (DRAFT)*

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BACKGROUND AND OBJECTIVES

The Chino Basin Watermaster's Subsidence Management Plan (SMP)[1] identified several "Areas of Subsidence Concern" across the western portion of Chino Basin where the future occurrence of land subsidence and ground fissuring is a concern. The SMP states that if data from existing monitoring efforts in the "Areas of Subsidence Concern" indicate the potential for adverse impacts due to subsidence, Watermaster will revise the SMP to avoid those adverse impacts.

Figure 1 is a map of the so-called Northwest MZ-1 Area of Subsidence Concern (Northwest MZ-1). Watermaster has monitored vertical ground motion in Northwest MZ-1 via InSAR[2] dating back to 1992. Land subsidence in Northwest MZ-1 was first identified as a concern in 2006 in the MZ-1 Summary Report.[3] Of particular concern is that 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 meetings of the Ground Level Monitoring Committee (GLMC), 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 for Northwest MZ-1.[4] Watermaster increased monitoring efforts in Northwest MZ-1 beginning in 2012 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).[5] 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 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 reports of the GLMC and used to prepare recommendations for future activities.

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[1] Wildermuth Environmental, Inc. 2015. Chino Basin Subsidence Management Plan. Prepared for the Chino Basin Watermaster. July 23, 2015.

[2] Interferometric Synthetic Aperture Radar (InSAR) is a remote sensing technique that is used to monitor vertical ground motion over time.

[3] Wildermuth Environmental, Inc. 2006. MZ-1 Summary Report. Prepared for the MZ-1 Technical Committee. February 2006.

[4] Wildermuth Environmental, Inc. 2017. Initial Hydrologic Conceptual Model and Monitoring and Testing Program for the Northwest MZ-1 Area. Prepared for the Chino Basin Watermaster. December 2017.

[5] Wildermuth Environmental, Inc. 2015. Work Plan to Develop a Subsidence-Management Plan for Northwest MZ-1. Prepared for the Chino Basin Watermaster. July 23, 2015.

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The objective of the *Subsidence Management Plan for Northwest MZ-1* is to provide guidance for the Watermaster and the Parties for how to manage hydraulic heads in Northwest MZ-1 (potentially through the management of pumping, recharge, the use of managed storage, and/or the design and implementation of Storage and Recovery Programs) so that the future occurrence of subsidence is minimized or abated in this area. The development of the *Subsidence Management Plan for Northwest MZ-1* will also include the evaluation of the minimum recharge quantity of supplemental water in MZ-1 as called for in Section 8.4 of the Peace II Agreement.[6]

The Work Plan included tasks to construct, calibrate, and use one-dimensional aquifer-system compaction models in Northwest MZ-1 (1D Models) to:

- Assist in understanding the mechanisms behind the ongoing subsidence in Northwest MZ-1
- Assist in the development of the *Subsidence Management Plan for Northwest MZ-1*.

The Work Plan envisioned the use of the 1D Models to update the Watermaster's three-dimensional groundwater-flow model so it could simulate aquifer-system compaction and then be used to develop the *Subsidence Management Plan for Northwest MZ-1*. However, the GLMC subsequently recommended to use the 1D Models directly to develop the *Subsidence Management Plan for Northwest MZ-1*.

In 2021 and 2022, the Watermaster Engineer constructed and calibrated the 1D Models and published a technical memorandum to document the results.[7] Figure 1 shows the locations of the two 1D Models at the PX and MVWD-28 sites in Northwest MZ-1. Figures 2 and 3 are diagrams that depict a profile view of each 1D Model including: the data used to construct the 1D Models (borehole lithology and geophysics) and the vertical discretization of the 1D Model grid cells into "sand" and "clay" layers.

The next step is to use the 1D Models to project the future rates and magnitudes of land subsidence in Northwest MZ-1 under various "Subsidence Management Alternatives." The first Subsidence Management Alternative (SMA-1) represents the recent plans of the Chino Basin Parties for groundwater management (*e.g.,* pumping, recharge, use of managed storage, etc.) over a defined planning horizon. SMA-1 was reviewed by the GLMC before it was simulated with the 1D Models.

This memorandum describes the results, conclusions, and recommendations from the 1D Model simulations of SMA-1.

The need to develop additional Subsidence Management Alternatives and run 1D Model simulations will be based on the 1D Model results and interpretations described herein. Each new Subsidence Management Alternative will be reviewed by the GLMC before model simulations are conducted.

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[6] See Section 8.4 of the *Final Peace II Documents.pdf (cbwm.org)*

[7] West Yost Associates. 2022. *Construction and Calibration of One-Dimensional Compaction Models in the Northwest MZ-1 Area of the Chino Basin*. Prepared for the Chino Basin Watermaster. December 2022.

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TECHNICAL APPROACH AND METHODS

This section describes the technical approach and methods that were employed to develop and run SMA-1 with the 1D Models to support the ongoing effort to develop a *Subsidence Management Plan for Northwest MZ-1*:

1. **Develop SMA-1 with review and input from the GLMC**. SMA-1 represents the most recently reported plans of the Chino Basin parties for pumping, recharge, and the use of managed storage over the defined planning horizon (2018-2050). The GLMC reviewed and provided input on SMA-1 before it was used in this effort.
2. **Simulate the hydrologic response of the Chino Basin to SMA-1 by aquifer layer**. The existing numerical groundwater-flow model of the Chino Basin (referred to as the Chino Valley Model [CVM]) is used to simulate the hydrologic response of the Chino Basin to SMA-1. The CVM is a five-layer model, so it predicts the hydraulic heads in each model layer under the projected pumping and recharge stresses over the planning horizon.
3. **Simulate the aquifer-system compaction that is predicted to occur in Northwest MZ-1 under SMA-1**. The hydraulic heads of SMA-1, as simulated by the CVM in each model layer, are used as input data for the 1D Models. The output of the 1D Models represents the vertical aquifer-system compaction (and hence, the resulting land subsidence) that is predicted to occur in Northwest MZ-1 under SMA-1. The output is described in terms of the rates, duration, and magnitude of vertical deformation of the aquifer sediments that is predicted to occur at the 1D Model locations over the planning horizon, by CVM layer.
4. **Evaluate model results and develop recommendations**. The Watermaster Engineer and the GLMC evaluate the projected hydraulic heads versus the projected compaction as simulated by the 1D Models, and then can make one or more of the following recommendations:
    a. Recommend "acceptable thresholds" for projected land subsidence that will avoid or mitigate Material Physical Injury (MPI).
    b. Recommend "subsidence management strategies" for Northwest MZ-1. These recommended strategies may come in the form of:
        i. Recommended operating ranges for hydraulic heads by aquifer layer.
        ii. Recommended groundwater management practices, such as pumping, recharge, the use of local storage, and/or the design and implementation of Storage and Recovery programs. Such recommendations can include guidance for the locations and depth intervals for pumping and recharge.
    c. Recommend the minimum recharge quantity of supplemental water in MZ-1.
    d. Recommend additional work, such as: filling data gaps and/or collecting additional hydrogeologic information; developing additional SMAs; performing CVM and 1D Model simulations of the additional SMAs; and making revised recommendations based on the model results (*i.e.,* 4.a. through 4.c. above). Any additional SMAs will be reviewed by the GLMC before taking the next step to simulate the SMA with the CVM and the 1D Models.

5. **Repeat methods to develop the *Subsidence Management Plan for Northwest MZ-1*.** The methods above are repeated until enough information has been generated to develop the *Subsidence Management Plan for Northwest MZ-1*.

SUBSIDENCE MANAGEMENT ALTERNATIVE #1

SMA-1 is equivalent to the planning scenario that was simulated to support the 2020 Safe Yield Recalculation (2020 SYR)[8] using the 2020 CVM. The 2020 SYR was intended to represent and simulate the Parties' projected pumping, recharge, and use of storage through 2050. This scenario spanned from fiscal year (FY) 2018 through 2050 and included the cultural conditions (e.g., land use, water supply plans) that were assumed based on the best-available planning data at the time of the 2020 SYR.[9] An advantage of using 2020 SYR as the planning scenario for SMA-1 is that the CVM modeling is complete and the simulated hydraulic heads by model layer are readily available for use as input data for the 1D Models.

The remainder of this section describes the pumping and recharge assumptions of 2020 SYR (*i.e.,* SMA-1) and the CVM output, which is the simulated hydrologic response of the aquifer system to SMA-1.

Pumping Projections

The projected pumping and use of managed storage was based on planning data collected from the Parties. The Parties provided projections of monthly groundwater pumping and other water supplies, the use of current and projected wells including a prioritization of use, and the future use of their local storage accounts. These projections were used to develop monthly pumping projections by well in the Chino Basin for 2018-2050.

Table 1 shows the projected pumping by well for the three Appropriative Pool parties with wells near Northwest MZ-1 for 2018-2050: Monte Vista Water District (MVWD), City of Pomona (Pomona), and Golden State Water Company (GSWC). Projected pumping of the three parties reaches 18,650 afy in FY 2040 and stays constant through FY 2050.

Managed Recharge Projections

Recharge components in the Chino Basin primarily include (i) subsurface inflow from adjacent groundwater basins and bedrock, (ii) deep infiltration of precipitation and applied water, (iii) streambed infiltration, and (iv) managed aquifer recharge. Managed aquifer recharge includes the recharge of stormwater, recycled water, and imported water in the Chino Basin via spreading basins or Aquifer Storage and Recovery (ASR) wells.

Table 2 shows the projected managed aquifer recharge at the recharge basins located within or directly upgradient of Northwest MZ-1. Projected stormwater recharge was based on the CVM's surface-water model simulations, which included planned improvements developed during and after the 2013 Recharge Master Plan Update that were assumed to be operational in FY 2023. Projected recycled water recharge at spreading basins were estimates provided by the Inland Empire Utilities Agency (IEUA). Projected imported

[8] West Yost Associates. 2020. *2020 Safe Yield Recalculation*. Prepared for the Chino Basin Watermaster. May 2020.

[9] Refer to Section 7.3 of the 2020 SYR report for more detail on the pumping and recharge projections.

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water recharge were estimates based on the requirement to satisfy a portion of the Parties' replenishment obligations when aggregate production exceeds aggregate production rights. Projected managed aquifer recharge in Northwest MZ-1 reaches about 7,000 afy in FY 2040 and stays constant through FY 2050.

Hydrologic Response of the Aquifer System to SMA-1

SMA-1 was simulated for the 2020 SYR from FY 2018 through 2050. Figures 4, 5, and 6 are maps of the Chino Basin that illustrate the changes in hydraulic heads from FY 2018 to FY 2050 in CVM Layers 1, 3, and 5, respectively:

- Figure 4 shows that heads in Layer 1 are projected to decline by up to 25 feet across Northwest MZ-1. Layer 1 represents the shallow, unconfined aquifer in the western portion Chino Basin. At the 1D Model locations, heads in Layer 1 are projected to decline by about 13 to 15 feet.
- Figure 5 shows that heads in Layer 3 are projected to increase by up to 5 feet in the western portion of Northwest MZ-1 and decrease by up to 30 feet in the eastern portion of Northwest MZ-1. Layer 3 represents the intermediate, semi-confined aquifer in the western portion Chino Basin. At the 1D Model locations, heads in Layer 3 are projected to decline by about 5 feet near PX and decline by about 10 feet near MVWD 28.
- Figure 6 shows that heads in Layer 5 are projected to increase across most of Northwest MZ-1. Layer 5 represents the deep, confined aquifer in the western portion Chino Basin. At the 1D Model locations, heads are projected to increase by about 25 feet near PX and increase by about 40 feet near MVWD 28.

Figures 7 and 8 are time-series charts of projected hydraulic heads in CVM model layers 1, 3, and 5 under SMA-1 at the PX and MVWD 28 locations, respectively. The charts span the projection period for SMA-1 (2018-2050), but also show the historical simulation period (1930-2017) to illustrate the lead up to projection period.[10] Note the following changes in hydraulic heads over the historical and projection periods from 1930 to 2050:

- From 1930-1977, heads declined gradually and persistently in Northwest MZ 1 by about 190 feet. Head declines in Layer 5 lagged the head declines in Layers 1 and 3 because there were very few pumping wells with screens across Layer 5 during these times.
- From 1978-2018, heads in Layers 1 and 3 stabilized or increased slightly in response to: implementation of the Judgment which restricted pumping; the wet periods in the late 1970s, early 1980s, and 1990s which enhanced recharge; and the availability of imported water from the State Water Project. However, heads continued to decline in Layer 5 due to the construction of additional deep wells in Northwest MZ-1 with screens across Layer 5 and the associated increases in groundwater extraction from Layer 5.

[10] For the historical period, heads were estimated for the construction and calibration of the 1D Models. For 1930-1977, heads were estimated based on the measured groundwater elevations at wells in the vicinity of the 1D Models. For 1977-2018, heads were estimated from CVM output data at the 1D Model locations by model layer.

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- From 2018-2050 in SMA-1, heads in Layers 1 and 3 at the PX and MVWD-28 locations are projected to decline at a gradual rate starting in 2019 with total declines of up to 17 ft by 2050. These projected declines in heads are generally due to a projected increase in pumping from 2018 through 2050 across the Chino Basin.

- From 2018-2050 in SMA-1, heads in Layer 5 at the PX and MVWD-28 locations increase immediately and significantly at the start of the projection. This immediate increase in heads is due to less projected pumping at several wells in Northwest MZ-1 that are screened across Layer 5. However, by 2030, heads begin to gradually decline through 2050, but remain above their initial 2019 heads.

PROJECTED AQUIFER-SYSTEM COMPACTION AND LAND SUBSIDENCE UNDER SMA-1

The changes in hydraulic heads under SMA-1 by CVM layer were simulated with the 1D Models to project the potential future aquifer-system compaction (*i.e.,* land subsidence) in Northwest MZ-1 from FY 2018 through 2050. For the historical period from FY 1930 through 2017, aquifer-system compaction was simulated during the calibration of the 1D Models.[7] This section describes the results and interpretations of the 1D Model simulations:

- Figures 9 and 10 are time-series charts of the simulated hydraulic heads versus aquifer system compaction by CVM model layer at the PX and MVWD 28 locations, respectively. The charts span the historical simulation period (1930-2017) and the projection period for SMA-1 (2018-2050) to depict the long-term progression of historical and projected aquifer-system compaction. The aquifer-system compaction for CVM layers 2 and 4 (relatively thin aquitard layers) was added to layers 3 and 5, respectively, since layers 2 and 4 are adjacent to and mechanically respond to the head changes in layers 3 and 5.

- Figures 11 and 12 are time-series charts of the simulated hydraulic heads versus aquifer system compaction by CVM model layer at the PX and MVWD 28 locations, respectively, for the projection period for SMA-1 only (2018-2050). These charts provide finer detail of the projected aquifer-system compaction.

The following observations and interpretations are made from inspection of these figures that depict the 1D Model simulation results in Northwest MZ-1:

- From 1930-1977, aquifer-system compaction occurred at its highest rates in response to the persistent declines in heads. Total compaction by 1977 was about six (6) feet at PX and about three (3) feet at MVWD-28. Compaction was greatest in Layers 1, 2, and 3 because shallow pumping dominated during this period.

- From 1978-2017, the rates of aquifer-system compaction in Layers 1, 2, and 3 slowed because of the stabilization of heads after 1978, but delayed drainage of the aquitards in these layers continued. The rates of compaction during this period were highest in Layers 4 and 5 due to the continued declines in heads in Layer 5 caused by increased pumping from Layers 3 and 5. Total compaction from 1930 to 2017 was about nine (9) feet at PX and about 5.5 feet at MVWD-28.

- From 2018-2050 under SMA-1, aquifer system compaction is projected to continue to occur at relatively slow but constant rates. Total compaction during 2018-2050 is projected to be 0.86 ft at PX (about 0.03 ft/yr) and 0.75 ft at MVWD-28 (about 0.02 ft/yr). The highest rates of compaction are projected to occur in Layer 5, even though heads in Layer 5 are projected increase under SMA-1. The persistence of aquifer-system compaction during the projection period is due to the delayed drainage of the aquitard layers, where pore pressures in the clay-rich sediments are continuing to equilibrate with the historical head declines that occurred in the coarse-grained aquifer sediments.

CONCLUSIONS AND RECOMMENDATIONS

The main conclusions and recommendations from this investigation are:

- Under SMA-1, the 1D Model simulations indicate that aquifer-system compaction, and its resulting land subsidence, will continue in Northwest MZ-1 at gradual, constant rates of about 0.02 to 0.03 ft/yr through at least 2050. These rates of projected compaction through 2050 are consistent with the observed current rates of land subsidence in Northwest MZ-1.
- These constant rates of aquifer-system compaction in Northwest MZ-1 are projected to occur even though heads in Layer 5 are assumed to increase by 30-60 ft in SMA-1. This indicates that the compaction is due to the delayed drainage of aquitard layers, where pore pressures in the clay-rich sediments are continuing to equilibrate with head declines that occurred historically within the coarse-grained aquifer sediments.
- The highest rates of compaction are occurring below Layer 1—particularly within in Layers 4 and 5 where hydraulic heads are the lowest. These rates of compaction are projected to continue to occur through 2050.
- Pursuant to the SMP, these persistent rates of compaction should be slowed to tolerable levels or completed abated, if possible. The only way to slow or completely abate the compaction is to increase heads and maintain them at higher elevations—particularly within Layers 3 and 5, where heads are lowest and the rates of compaction are highest.
- The Watermaster should establish a "Northwest MZ-1 Guidance Level" of **630 ft-amsl** for hydraulic heads in Layers 3 and 5 at the PX location. Figure 13 displays this Guidance Level, which approximates the current and projected heads in Layer 1 where the current and projected rates of compaction are the lowest. The Guidance Level is an aspirational Watermaster recommendation that, if achieved, would likely slow the rates of compaction and subsidence to more tolerable levels over time.
- Compliance with the Guidance Level should be measured at the PX-2/3 piezometer. Figure 2 shows that the PX-2/3 piezometer is screened across the uppermost portion of Layer 5 at the PX location, and hence, is generally representative of heads in Layers 3 and 5.
- In addition, achievement of the Guidance Level in Layers 3 and 5 would eliminate the existing downward hydraulic gradients in Northwest MZ-1, which could have the ancillary benefit of inhibiting the downward migration of shallow groundwater contaminants within Northwest MZ-1.

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- The methods to achieve the Guidance Level have not yet been developed, nor has the effectiveness of these methods to comply with the Guidance Level been simulated and evaluated. Hence, the Guidance Level proposed herein should be considered "preliminary" until such work is performed.

- 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.

- 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 upcoming 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 finalization of the Guidance Level and the *Subsidence Management Plan for Northwest MZ-1*.

NEXT STEPS

The GLMC should review this memorandum and come prepared to discuss at the next GLMC meeting scheduled for October 4, 2023 at 10am at Watermaster offices. Written comments and suggestions are due to Andy Malone (amalone@westyost.com) and Edgar Tellez-Foster (etellezfoster@cbwm.org) by November 3, 2023.

Table 1. Projected Pumping at Wells in Northwest MZ-1 for Subsidence Management Alternative #1

Well Name	Well Owner	Well Layers	Historical Pumping FY 2010-18 (afy)	Annual Projected Pumping by Fiscal Year[1] (af)																					
				2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
2	Pomona	1	1,362	0	1,190	1,190	1,190	1,200	1,200	1,200	1,200	1,200	1,210	1,210	1,210	1,210	1,220	1,210	1,220	1,220	1,220	1,220	1,220	1,220	1,220
5B	Pomona	1,3	725	500	850	850	850	850	850	850	850	850	860	860	860	860	860	860	860	860	870	860	860	860	870
6	Pomona	1,3	101	640	900	890	900	900	900	900	900	900	910	910	910	910	910	910	910	910	920	910	910	910	920
10	Pomona	1,3	1,258	1,130	1,000	990	1,000	1,000	1,000	1,000	1,000	1,000	1,010	1,010	1,010	1,010	1,010	1,010	1,010	1,020	1,020	1,020	1,020	1,020	1,020
15	Pomona	1	355	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Pomona	1	353	550	850	850	850	850	850	850	850	850	860	860	860	860	860	860	860	860	870	860	860	860	870
17	Pomona	1,3	235	420	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Pomona	1	649	340	800	800	800	800	800	800	800	800	810	810	810	810	810	810	810	810	810	810	810	810	810
23	Pomona	1,3	864	410	900	890	900	900	900	900	900	900	910	910	910	910	910	910	910	910	920	910	910	910	920
25	Pomona	1,3	1,541	1,540	1,090	1,090	1,100	1,100	1,100	1,100	1,100	1,100	1,110	1,110	1,110	1,110	1,110	1,110	1,120	1,120	1,120	1,120	1,120	1,120	1,120
26	Pomona	1,3	569	270	500	500	500	500	500	500	500	500	500	500	500	500	510	510	510	510	510	510	510	510	510
27	Pomona	1,3	525	1,250	800	800	800	800	800	800	800	800	810	810	810	810	810	810	810	810	810	810	810	810	810
29	Pomona	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	Pomona	1,3	1,296	1,490	1,190	1,190	1,190	1,200	1,200	1,200	1,200	1,200	1,210	1,210	1,210	1,210	1,220	1,210	1,220	1,220	1,220	1,220	1,220	1,220	1,220
35	Pomona	1,3	7	0	500	500	500	500	500	500	500	500	500	500	500	500	510	510	510	510	510	510	510	510	510
36	Pomona	1,3	1,007	730	800	800	800	800	800	800	800	800	810	810	810	810	810	810	810	810	810	810	810	810	810
Margarita #1	GSWC	1	447	530	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370
4	MVWD	1	247	290	190	190	180	180	180	180	180	180	180	180	180	190	190	190	190	190	190	190	190	190	190
5	MVWD	1,3	1,084	1,020	660	650	650	640	640	640	640	640	640	650	650	650	650	650	650	660	660	660	660	660	670
10	MVWD	1,3	165	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	MVWD	1,3,5	1,997	2,480	800	790	790	780	780	770	780	780	780	780	790	790	790	790	800	800	800	800	800	810	810
26	MVWD	1,3,5	1,789	1,330	890	880	880	870	870	860	870	870	870	880	880	880	890	890	890	890	900	900	900	900	910
27	MVWD	1,3,5	384	370	100	100	90	90	80	80	80	80	90	90	90	100	100	100	110	110	110	110	120	120	120
28	MVWD	1,3,5	2,129	1,540	870	860	860	850	850	840	840	850	850	850	860	860	860	860	870	870	870	870	880	880	880
30	MVWD	1,3,5	182	330	100	100	90	90	80	80	80	80	90	90	90	100	100	100	110	110	110	110	120	120	120
31	MVWD	1,3,5	967	370	940	930	920	920	920	910	910	920	920	920	920	930	930	930	940	940	940	940	950	950	950
32	MVWD	1,3,5	495	310	100	100	90	90	80	80	80	80	90	90	90	100	100	100	110	110	110	110	120	120	120
33	MVWD	1,3,5	659	0	940	930	920	920	920	910	910	920	920	920	920	930	930	930	940	940	940	940	950	950	950
34	MVWD	1,3,5	244	0	940	930	920	920	920	910	910	920	920	920	920	930	930	930	940	940	940	940	950	950	950
Subtotal from Layers 1 and 3			*12,790*	*11,110*	*12,590*	*12,550*	*12,580*	*12,590*	*12,590*	*12,590*	*12,590*	*12,590*	*12,700*	*12,710*	*12,710*	*12,720*	*12,760*	*12,740*	*12,770*	*12,790*	*12,830*	*12,790*	*12,790*	*12,790*	*12,840*
Subtotal from Layers 1, 3, and 5			*8,845*	*6,730*	*5,680*	*5,620*	*5,560*	*5,530*	*5,500*	*5,440*	*5,460*	*5,500*	*5,530*	*5,540*	*5,560*	*5,620*	*5,630*	*5,630*	*5,710*	*5,710*	*5,720*	*5,720*	*5,790*	*5,800*	*5,810*
Total			**21,635**	**17,840**	**18,270**	**18,170**	**18,140**	**18,120**	**18,090**	**18,030**	**18,050**	**18,090**	**18,230**	**18,250**	**18,270**	**18,340**	**18,390**	**18,370**	**18,480**	**18,500**	**18,550**	**18,510**	**18,580**	**18,590**	**18,650**

[1] Annual pumping is constant after FY 2040.

Table 2. Projected Managed Recharge Near Northwest MZ-1 for the Baseline Management Alternative

Managed Recharge Type	Historical Recharge FY 2010-18 (afy)	Annual Projected Recharge Volume Near Northwest MZ-1 by Fiscal Year[1,2] (af)																						
		2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Stormwater	1,528	2,520	2,500	2,520	2,620	2,610	2,590	2,610	2,610	2,610	2,590	2,610	2,610	2,610	2,590	2,610	2,610	2,610	2,590	2,610	2,610	2,610	2,580	2,600
Recycled Water	1,177	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650
Imported Water	6,748	0	0	0	0	0	0	0	0	10	150	350	510	320	760	1,200	1,630	2,060	2,380	2,690	3,010	3,330	3,550	2,810
Total	**9,453**	**4,170**	**4,150**	**4,170**	**4,270**	**4,260**	**4,240**	**4,260**	**4,260**	**4,270**	**4,390**	**4,610**	**4,770**	**4,580**	**5,000**	**5,460**	**5,890**	**6,320**	**6,620**	**6,950**	**7,270**	**7,590**	**7,780**	**7,060**

[1] Tabulated recharge includes recharge in College Heights Basins, Upland Basin, Montclair Basins, Brooks Basin, and MVWD ASR wells. No imported water recharge is projected to occur via ASR wells.

[2] Annual managed recharge is constant from FY 2041 through FY 2050.

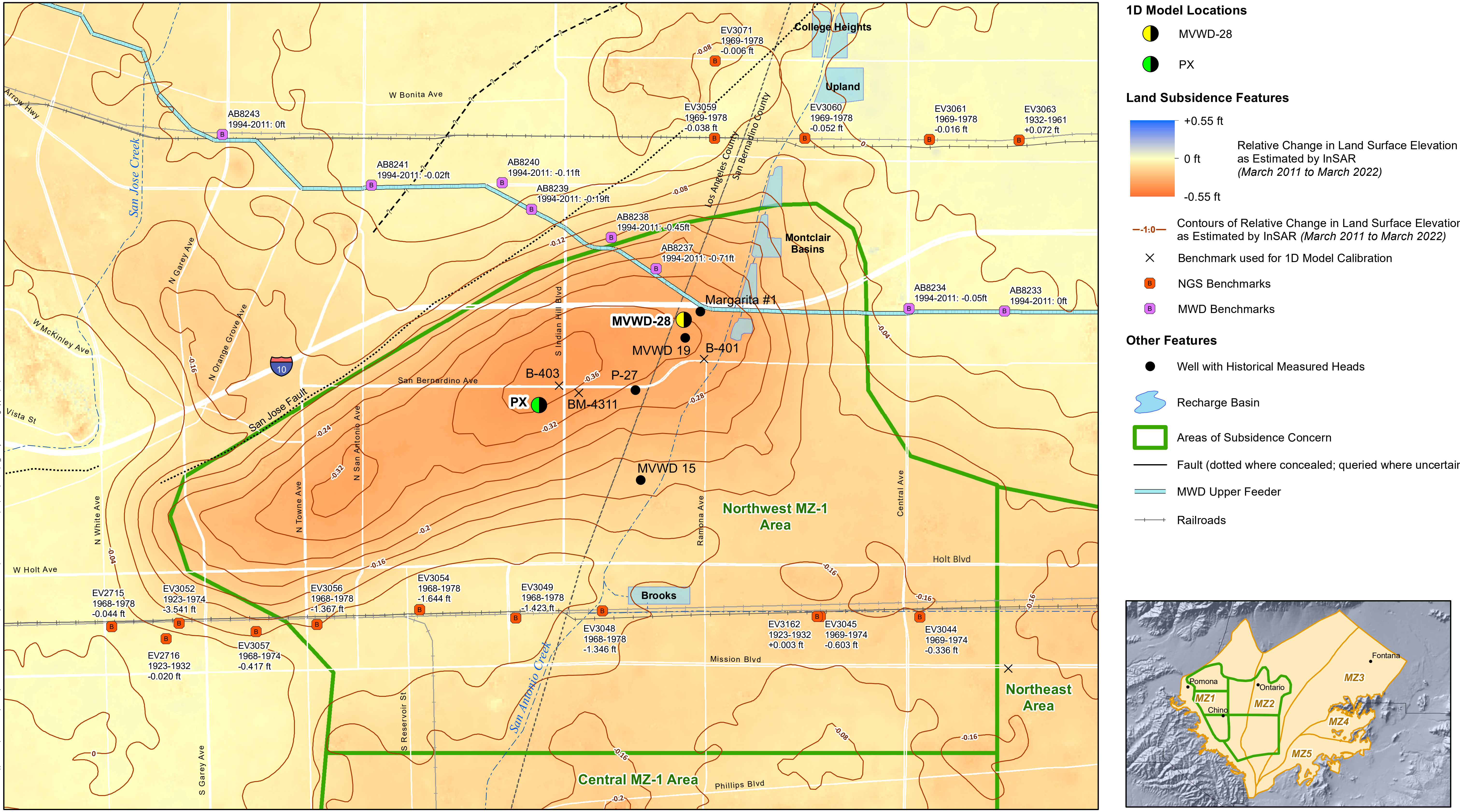

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Figure 1

Locations of PX and MVWD-28 1D Models and Historical Elevation Surveys at Benchmarks

Chino Basin Watermaster

Ground-Level Monitoring Committee

Subsidence Management Plan for Northwest MZ-1

Figure 2. PX Site: CVM Layers, Borehole Lithology, 1D Model Cells, and Resistivity Log

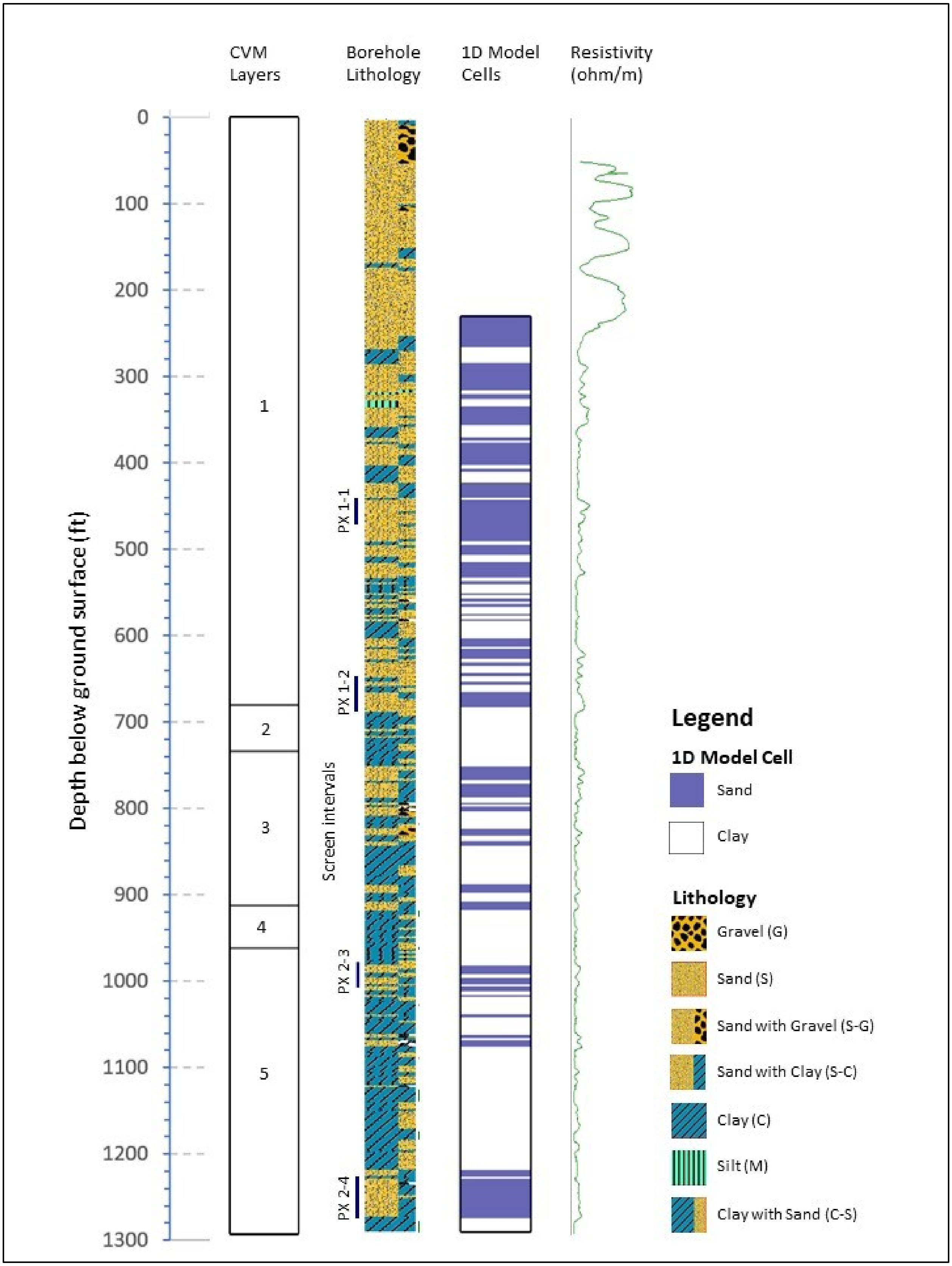
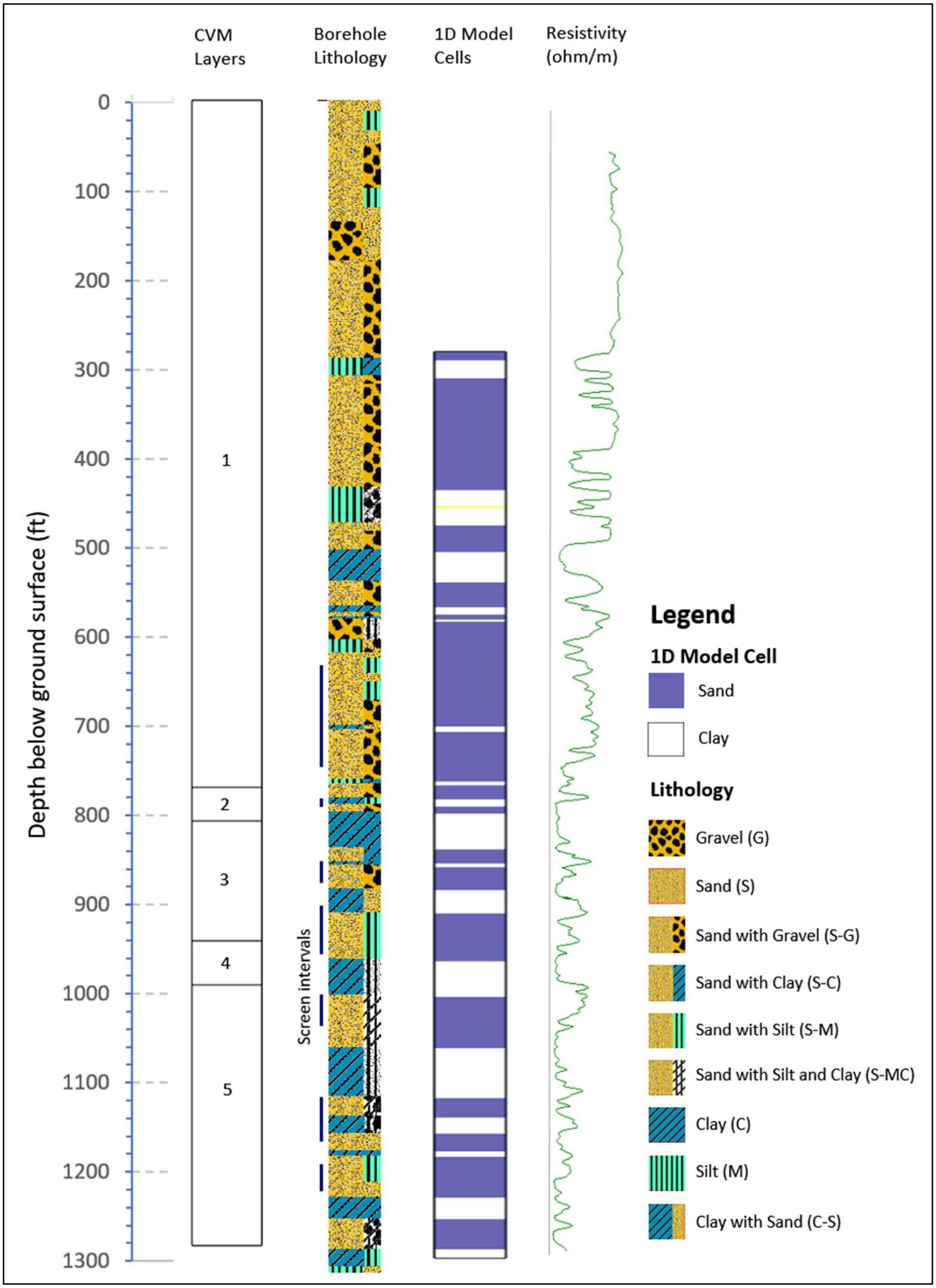
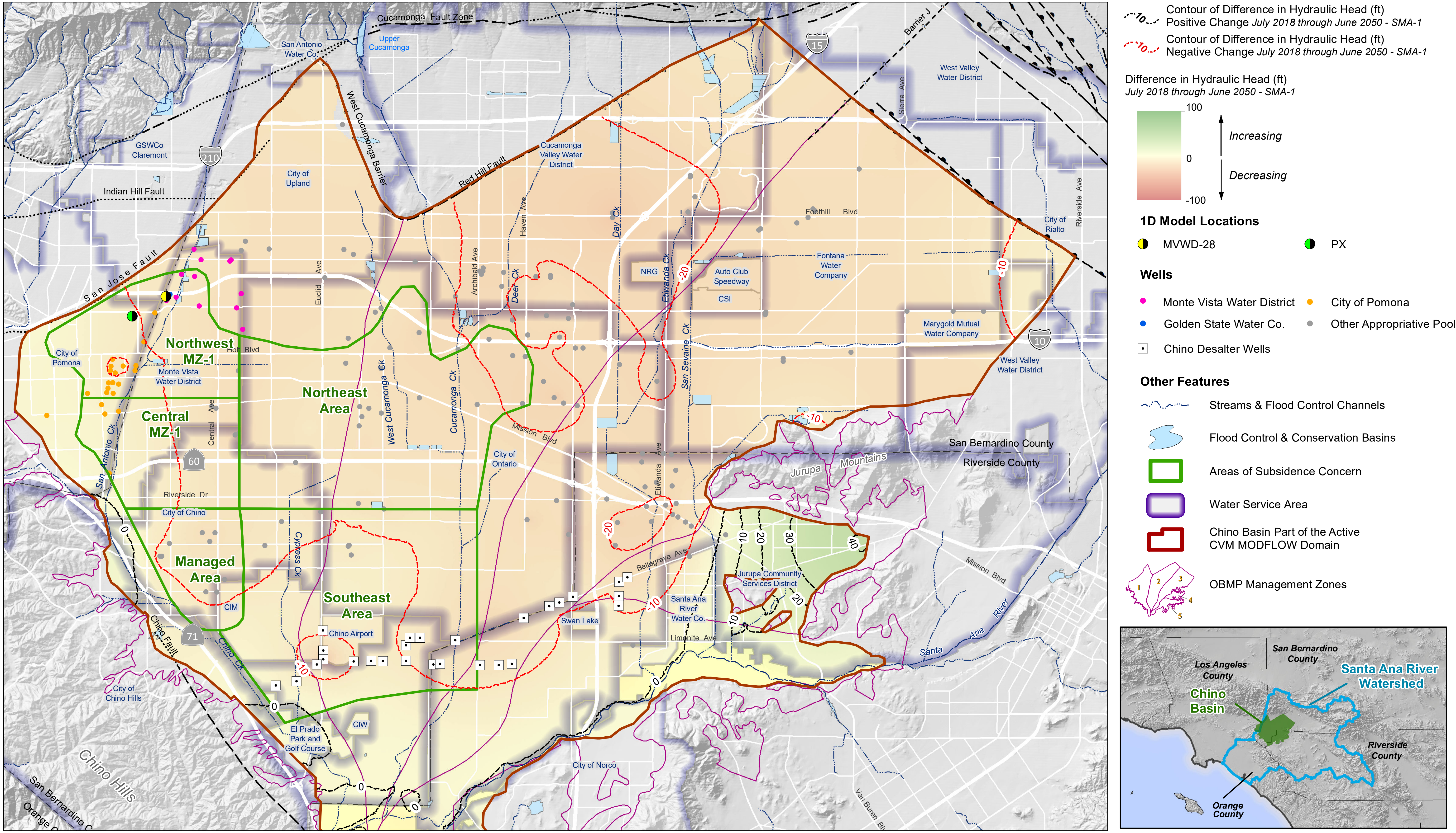


Figure 3. MVWD-28 Site: CVM Layers, Borehole Lithology, 1D Model Cells, and Resistivity Log





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Date: 2/21/2023
File: Figure 2 SYR_2050-2018_L1.mxd

0 1 2 3 4 5 Miles
0 2 4 6 8 Km

Prepared for:

Evaluation of Land Subsidence in Northwest MZ-1 under SMA-1

CHINO BASIN WATERMASTER

Projected Difference in Hydraulic Head for Layer 1
Subsidence Management Alternative #1
July 2018 through June 2050

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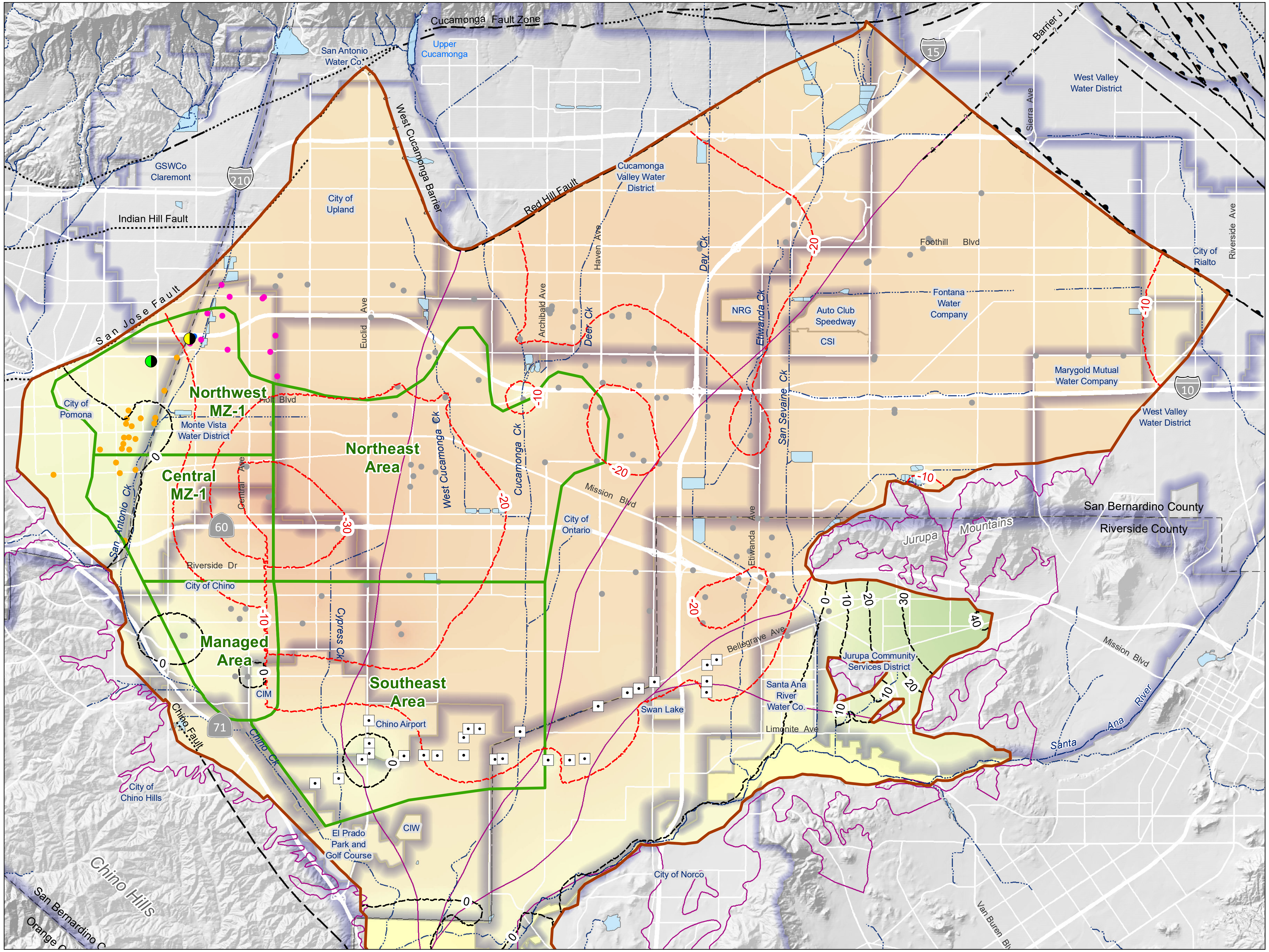
Figure 4



Contour of Difference in Hydraulic Head (ft) Positive Change *July 2018 through June 2050 - SMA-1*

Contour of Difference in Hydraulic Head (ft) Negative Change *July 2018 through June 2050 - SMA-1*

Difference in Hydraulic Head (ft)
July 2018 through June 2050 - SMA-1

100 — *Increasing*
0
-100 — *Decreasing*

1D Model Locations

- MVWD-28
- PX

Wells

- Monte Vista Water District
- City of Pomona
- Golden State Water Co.
- Other Appropriative Pool
- Chino Desalter Wells

Other Features

- Streams & Flood Control Channels
- Flood Control & Conservation Basins
- Areas of Subsidence Concern
- Water Service Area
- Chino Basin Part of the Active CVM MODFLOW Domain
- OBMP Management Zones

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Author: GR
Date: 2/21/2023
File: Figure 3 SYR_2050-2018_L3.mxd

0 1 2 3 4 5 Miles
0 2 4 6 8 Km

Prepared for:

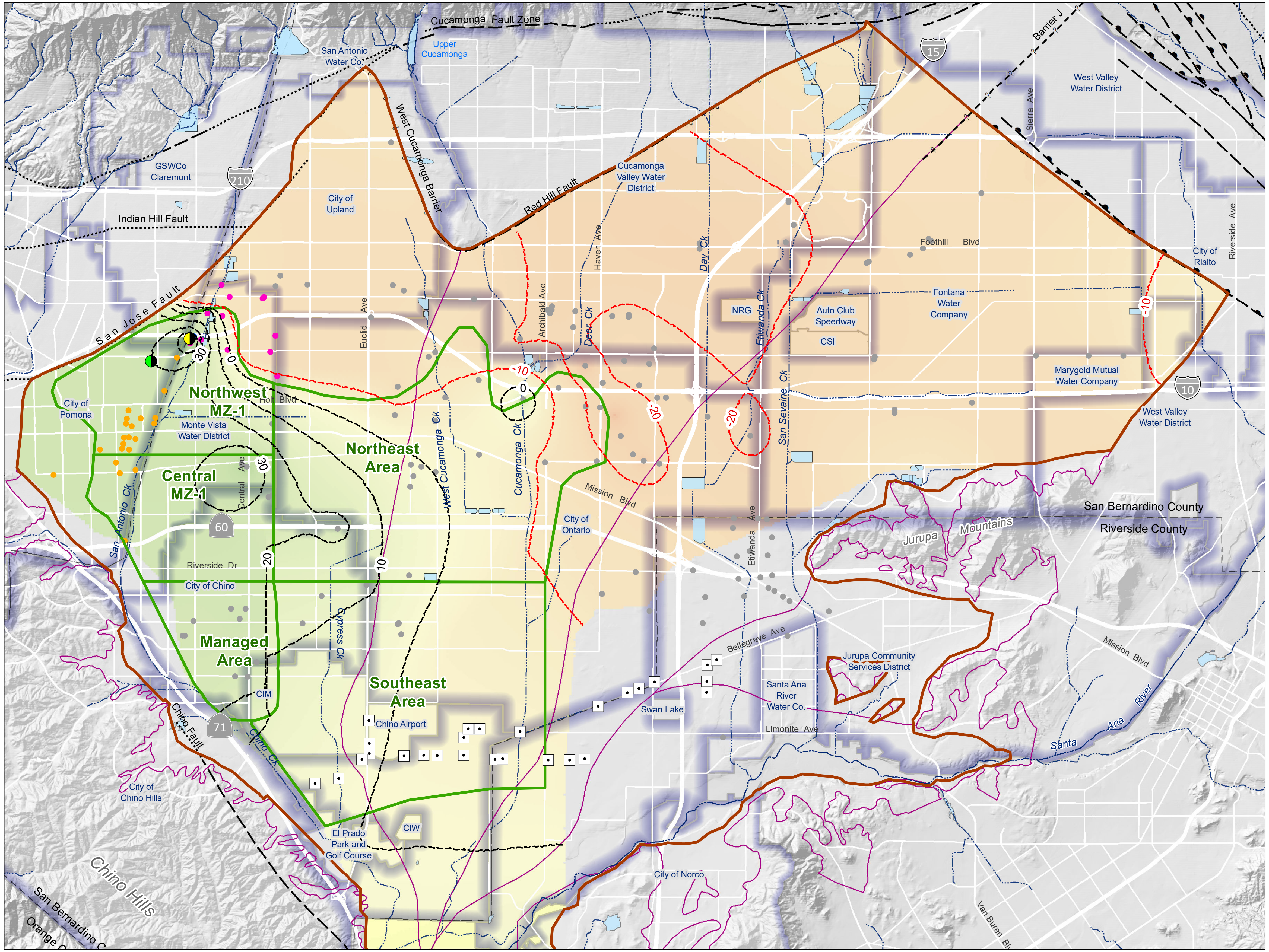
Evaluation of Land Subsidence in Northwest MZ-1 under the SMA-1

CHINO BASIN WATERMASTER

Projected Difference in Hydraulic Head for Layer 3
Subsidence Management Alternative #1
July 2018 through June 2050

Draft

Figure 5



Contour of Difference in Hydraulic Head (ft) Positive Change *July 2018 through June 2050 - SMA-1*

Contour of Difference in Hydraulic Head (ft) Negative Change *July 2018 through June 2050 - SMA-1*

Difference in Hydraulic Head (ft)
July 2018 through June 2050 - SMA-1

100 — *Increasing*
0
-100 — *Decreasing*

1D Model Locations

- MVWD-28
- PX

Wells

- Monte Vista Water District
- City of Pomona
- Golden State Water Co.
- Other Appropriative Pool
- Chino Desalter Wells

Other Features

- Streams & Flood Control Channels
- Flood Control & Conservation Basins
- Areas of Subsidence Concern
- Water Service Area
- Chino Basin Part of the Active CVM MODFLOW Domain
- OBMP Management Zones

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Author: GR
Date: 2/21/2023
File: Figure 4 SYR_2050-2018_L5.mxd

0 1 2 3 4 5 Miles
0 2 4 6 8 Km

Prepared for:

Evaluation of Land Subsidence in Northwest MZ-1 under SMA-1

Chino Basin Watermaster — Partners in Basin Management

Projected Difference in Hydraulic Head for Layer 5
Subsidence Management Alternative #1
July 2018 through June 2050

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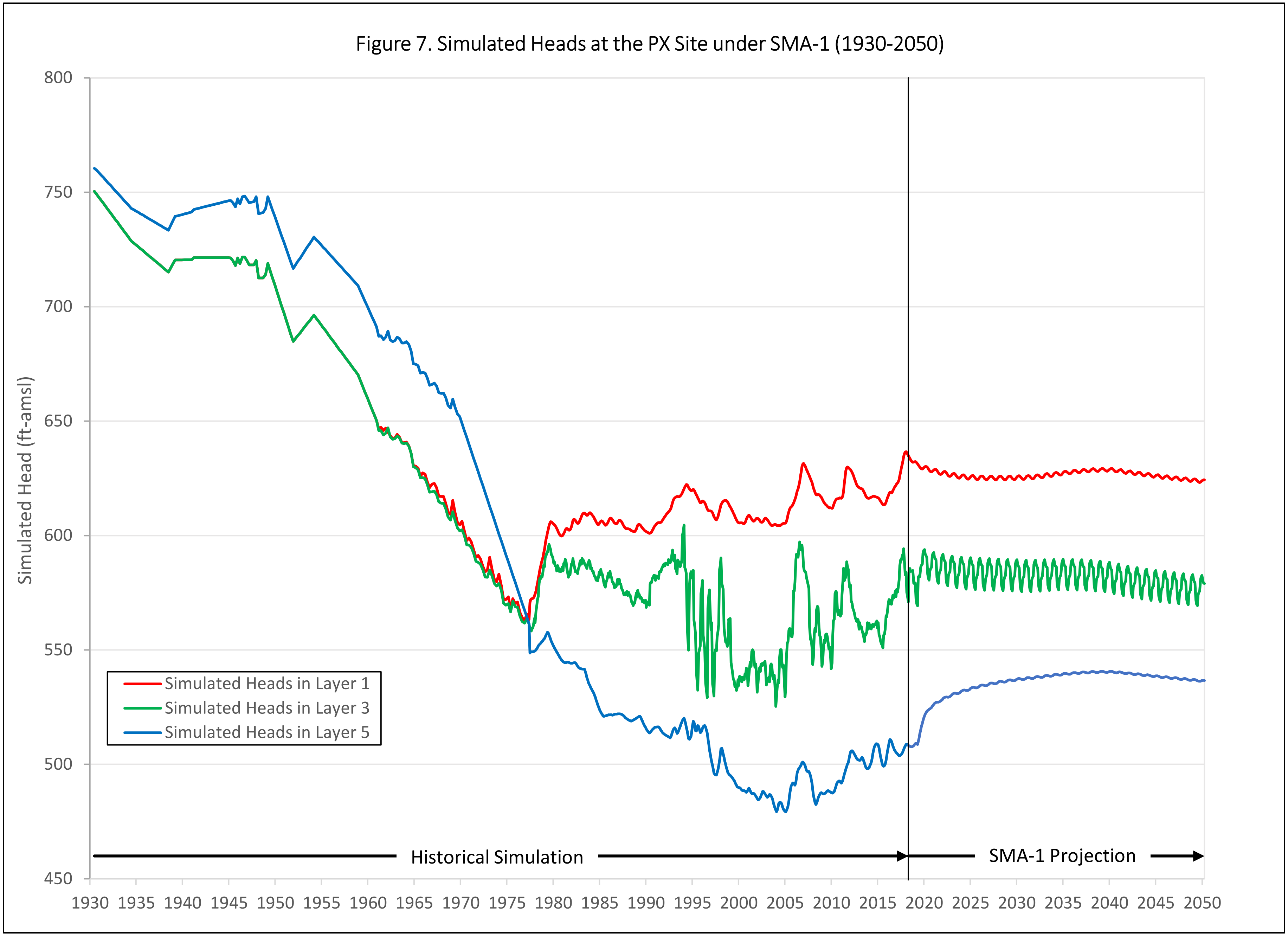
Figure 6



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941-80-23-25

Ground-Level Monitoring Committee
Subsidence Management Alternative #1
Last Revised: 08-30-2023

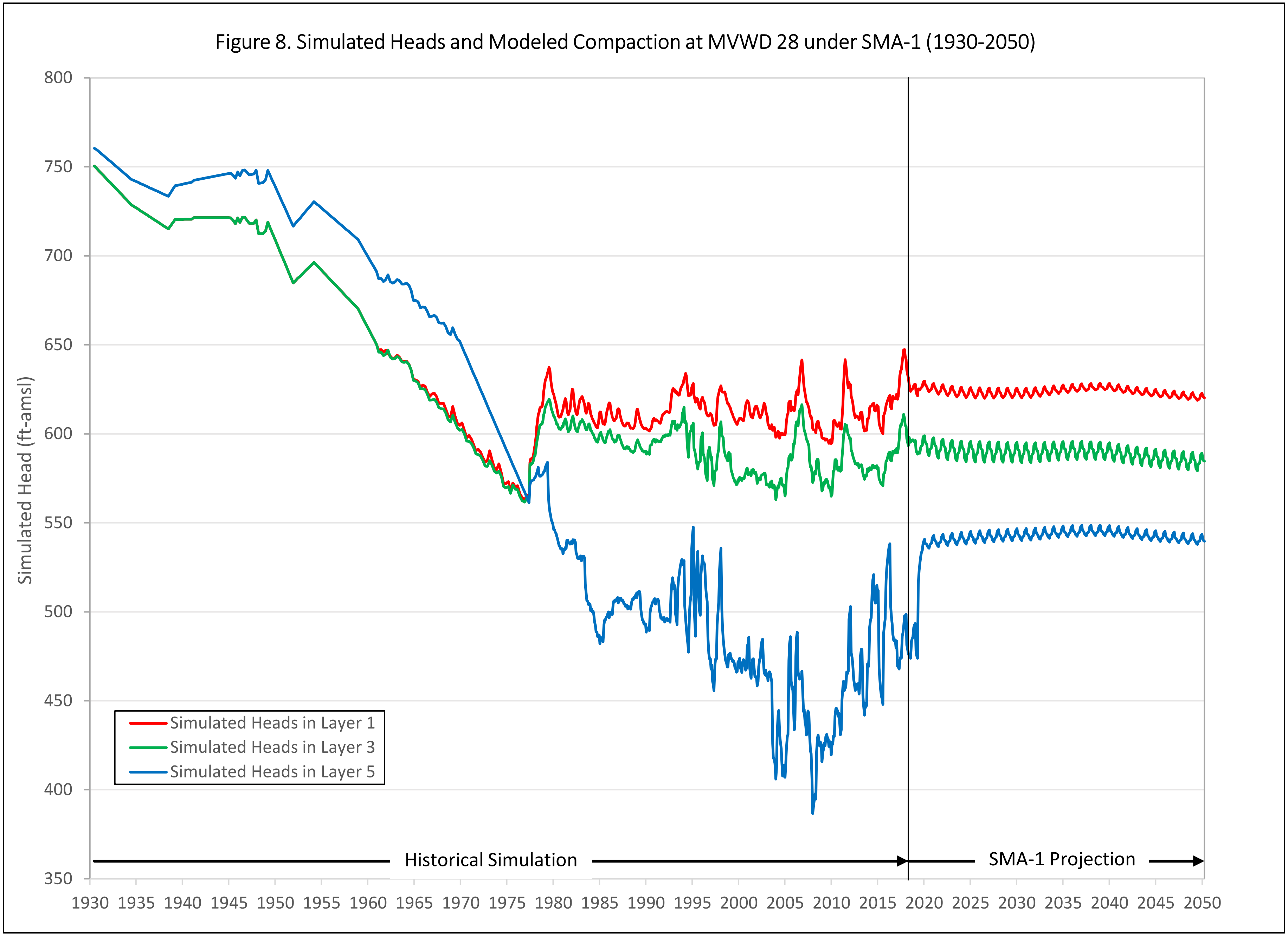


Figure 8. Simulated Heads and Modeled Compaction at MVWD 28 under SMA-1 (1930-2050)
Simulated Head (ft-amsl)
800
750
700
650
600
550
500
450
400
350
1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Simulated Heads in Layer 1
Simulated Heads in Layer 3
Simulated Heads in Layer 5
Historical Simulation
SMA-1 Projection

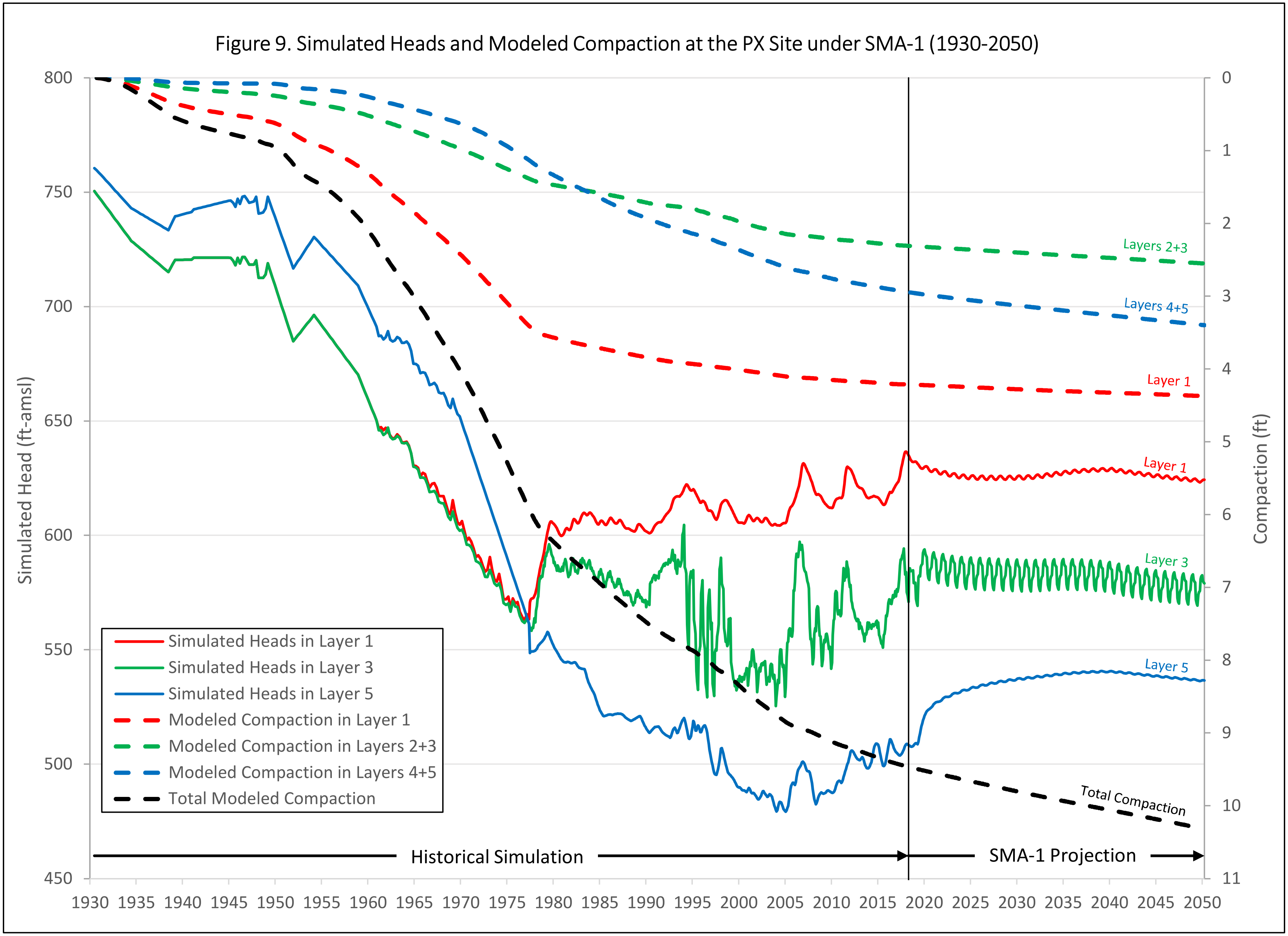


Figure 9. Simulated Heads and Modeled Compaction at the PX Site under SMA-1 (1930-2050)
Simulated Head (ft-amsl)
Compaction (ft)
Layers 2+3
Layers 4+5
Layer 1
Layer 1
Layer 3
Layer 5
Total Compaction
Simulated Heads in Layer 1
Simulated Heads in Layer 3
Simulated Heads in Layer 5
Modeled Compaction in Layer 1
Modeled Compaction in Layers 2+3
Modeled Compaction in Layers 4+5
Total Modeled Compaction
Historical Simulation
SMA-1 Projection
800
750
700
650
600
550
500
450
0
1
2
3
4
5
6
7
8
9
10
11
1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050

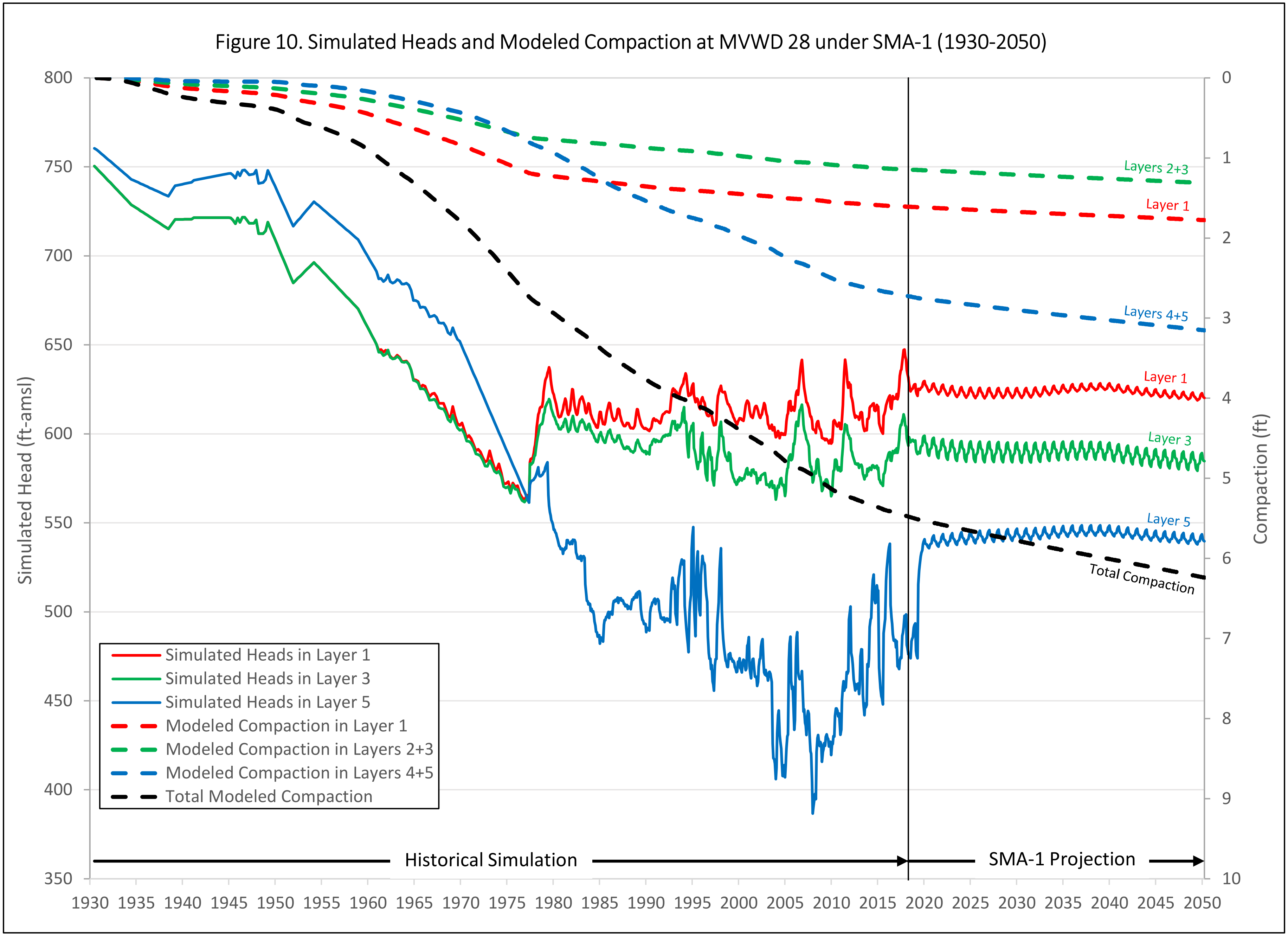
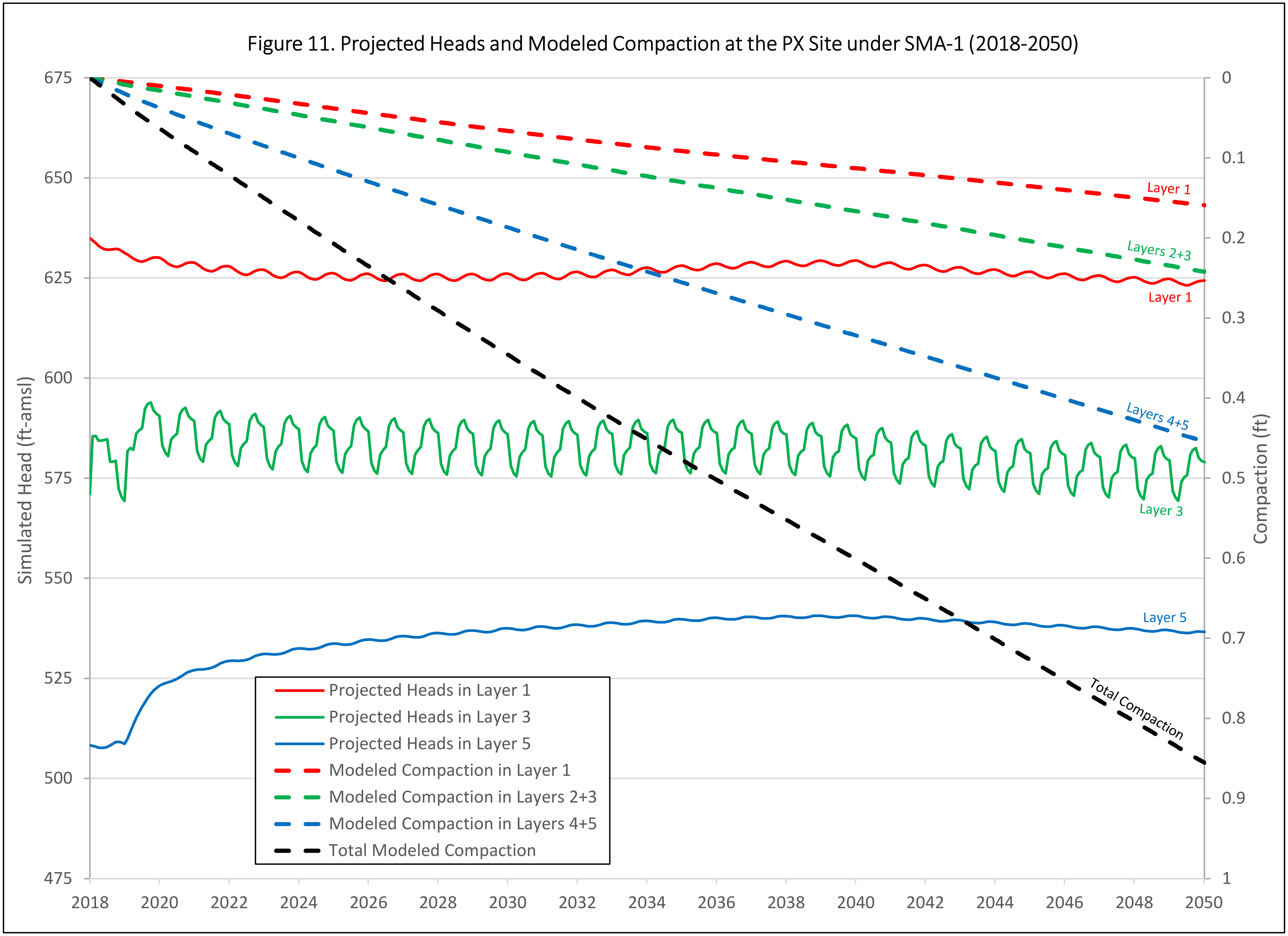


Figure 10. Simulated Heads and Modeled Compaction at MVWD 28 under SMA-1 (1930-2050)
Simulated Head (ft-amsl)
Compaction (ft)
800
750
700
650
600
550
500
450
400
350
0
1
2
3
4
5
6
7
8
9
10
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Layers 2+3
Layer 1
Layers 4+5
Layer 1
Layer 3
Layer 5
Total Compaction
Simulated Heads in Layer 1
Simulated Heads in Layer 3
Simulated Heads in Layer 5
Modeled Compaction in Layer 1
Modeled Compaction in Layers 2+3
Modeled Compaction in Layers 4+5
Total Modeled Compaction
Historical Simulation
SMA-1 Projection



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Ground-Level Monitoring Committee
Subsidence Management Alternative #1
Last Revised: 08-30-2023

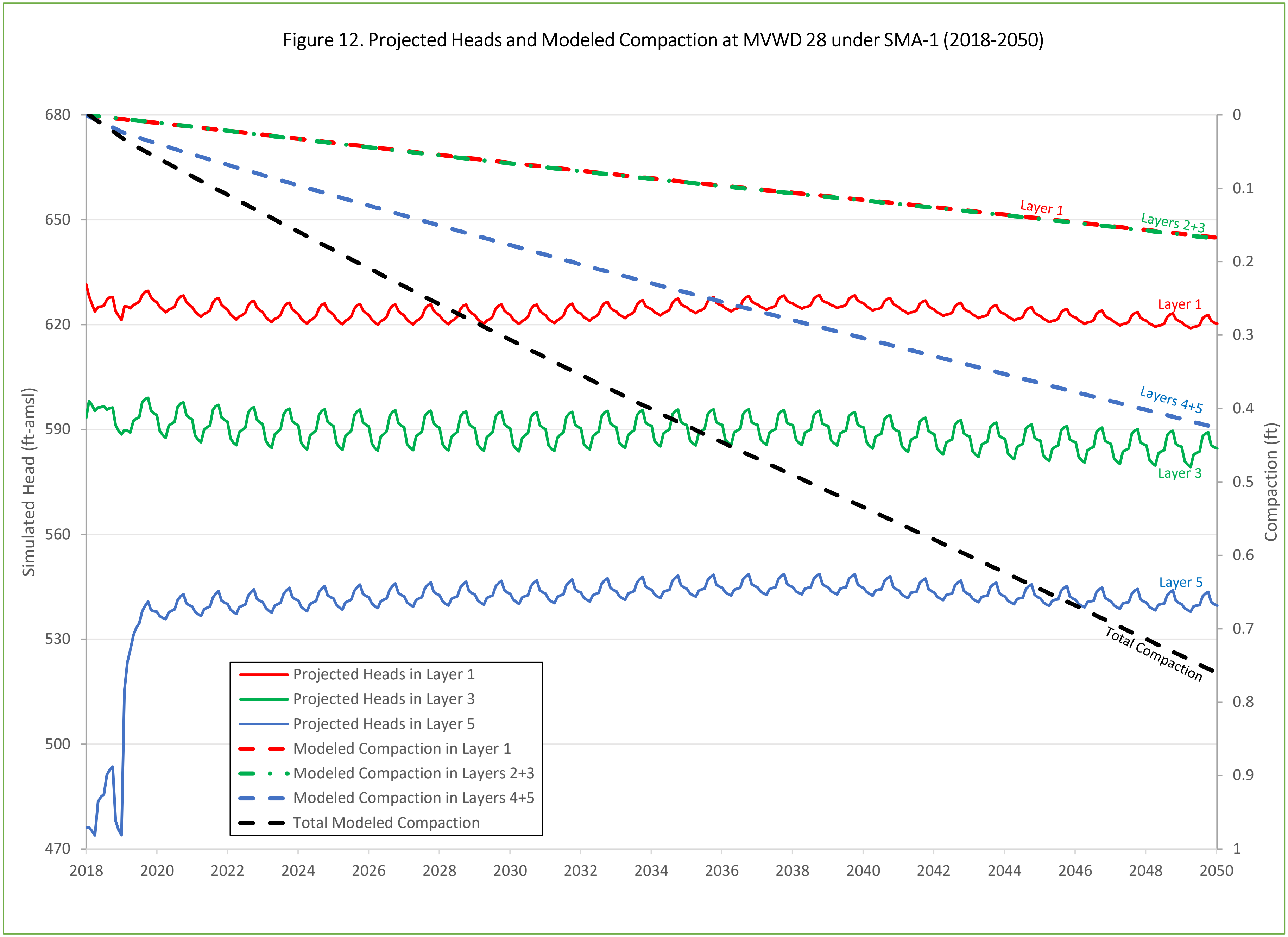

Figure 12. Projected Heads and Modeled Compaction at MVWD 28 under SMA-1 (2018-2050)
Simulated Head (ft-amsl)
Compaction (ft)
680
650
620
590
560
530
500
470
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048
2050
Layer 1
Layers 2+3
Layer 1
Layers 4+5
Layer 3
Layer 5
Total Compaction
Projected Heads in Layer 1
Projected Heads in Layer 3
Projected Heads in Layer 5
Modeled Compaction in Layer 1
Modeled Compaction in Layers 2+3
Modeled Compaction in Layers 4+5
Total Modeled Compaction

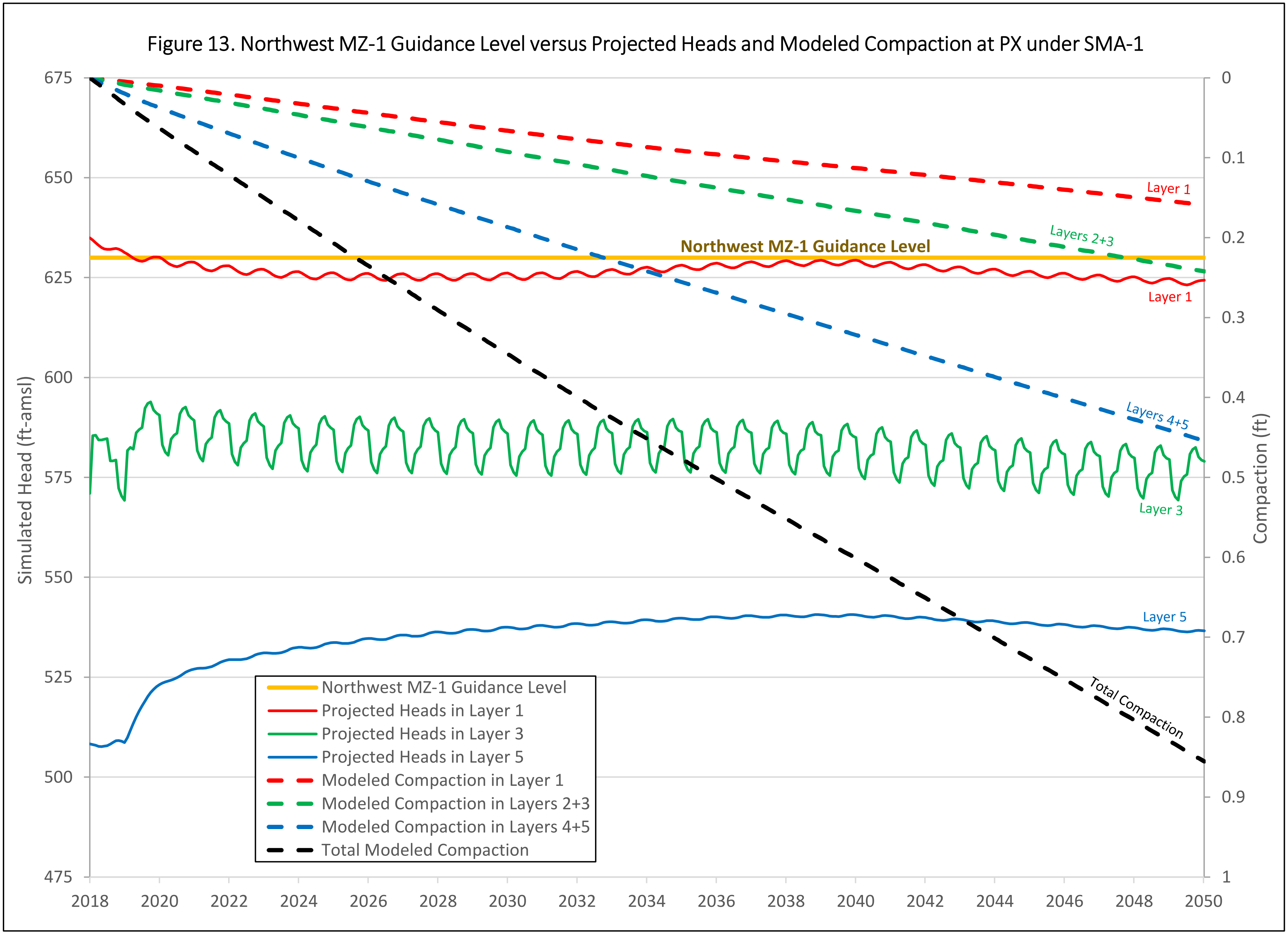
Figure 13. Northwest MZ-1 Guidance Level versus Projected Heads and Modeled Compaction at PX under SMA-1
Simulated Head (ft-amsl)
Compaction (ft)
675
650
625
600
575
550
525
500
475
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048
2050
Northwest MZ-1 Guidance Level
Layer 1
Layers 2+3
Layer 1
Layers 4+5
Layer 3
Layer 5
Total Compaction
Northwest MZ-1 Guidance Level
Projected Heads in Layer 1
Projected Heads in Layer 3
Projected Heads in Layer 5
Modeled Compaction in Layer 1
Modeled Compaction in Layers 2+3
Modeled Compaction in Layers 4+5
Total Modeled Compaction

DRAFT REPORT | SEPTEMBER 2023

DRAFT

2022/23 Annual Report of the Ground-Level Monitoring Committee

PREPARED FOR

Ground-Level Monitoring Committee

Chino Basin Watermaster
Partners in Basin Management

PREPARED BY

West Yost
Water. Engineered.

2022/23 Annual Report of the Ground-Level Monitoring Committee

Prepared for

Ground-Level Monitoring Committee

Project No. 941-80-23-25

Prepared By: Andrea Arevalo | Date

Prepared by: Lauren Salberg | Date

QA/QC Review: Andy Malone, PG | Date

WEST YOST
Water. Engineered.

DRAFT REPORT | SEPTEMBER 2023

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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.

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:

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

- 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	2023 Status	Well Screen 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	City of Chino	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	City of Chino Hills	Abandoned	550-950
CH-7D	600498	City of Chino Hills	Destroyed	320-400; 410-450; 490-810; 850-930
CH-15B	600488	City of Chino Hills	Active	360-440; 480-900
CH-16	600489	City of Chino Hills	Inactive	430-940
CH-17	600499	City of Chino Hills	Inactive	300-460; 500-680
CH-19	600500	City of Chino Hills	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]

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

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.

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.

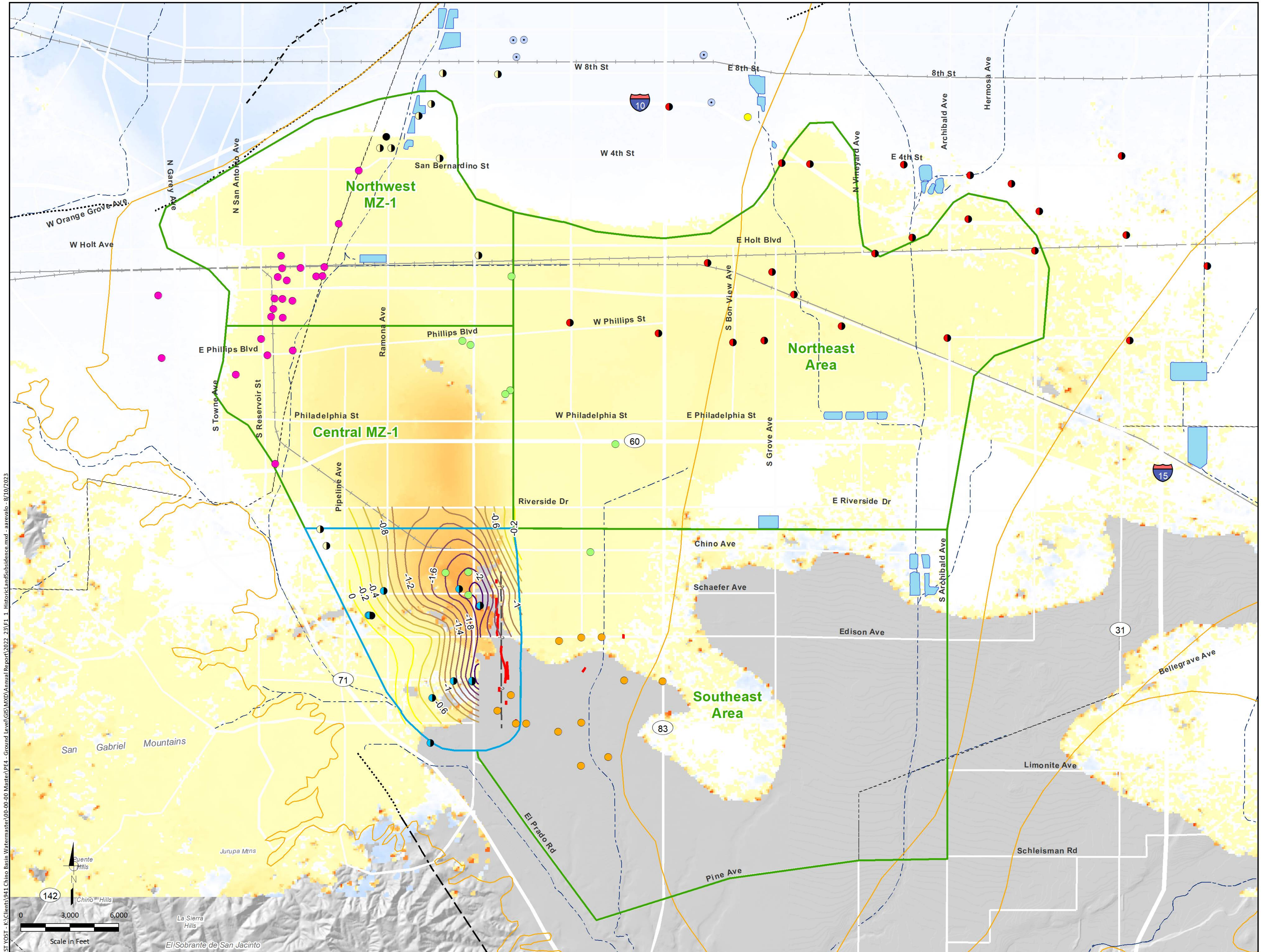
1.1.6 Annual Report of the Ground-Level Monitoring Committee

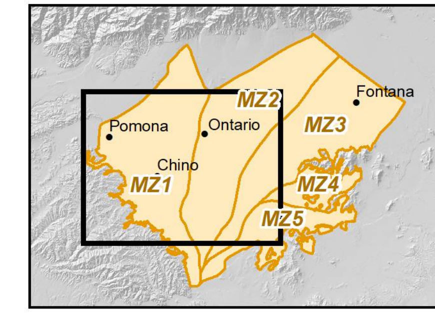
Pursuant to the Subsidence Management Plan, Watermaster prepares an annual report containing the results of ongoing monitoring efforts, interpretations of the data, and recommended adjustments to the Subsidence Management Plan, if any. This Annual Report of the GLMC includes the results and interpretations for the data collected between March 2022 through March 2023, as well as recommendations for Watermaster's GLMP for FY 2023/24.

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 2022 and March 2023.
- **Section 3.0 – Results and Interpretations.** This section discusses and interprets the monitoring data collected between March 2022 and March 2023, 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 2022 and March 2023 and describes recommended activities for the GLMP for FY 2023/24.
- **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.





Contours of Relative Change in Land Surface Elevation as Estimated by Leveling Surveys 1987 to 1999

0.0 ft

-2.2 ft

Relative Change in Land Surface Elevation as Measured by InSAR Oct-1993 to Dec-1995

+1 ft

0

-1 ft

InSAR absent or incoherent

Active Pumping Wells by Owner: 1987 to 1999

- CA Institution for Men
- City of Chino
- City of Chino Hills
- City of Ontario
- City of Pomona
- City of Upland
- Golden State WC
- Monte Vista WD
- San Antonia WC

Managed Areas

- Managed Area
- Areas of Subsidence Concern

Other Features

- Flood Control and Conservation Basins
- Fault (solid where accurately located; dashed where approximately located or inferred; dotted where concealed)

WEST YOST

Figure 1-1

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

Chino Basin Watermaster

Ground-Level Monitoring Committee

2022/23 Annual Report

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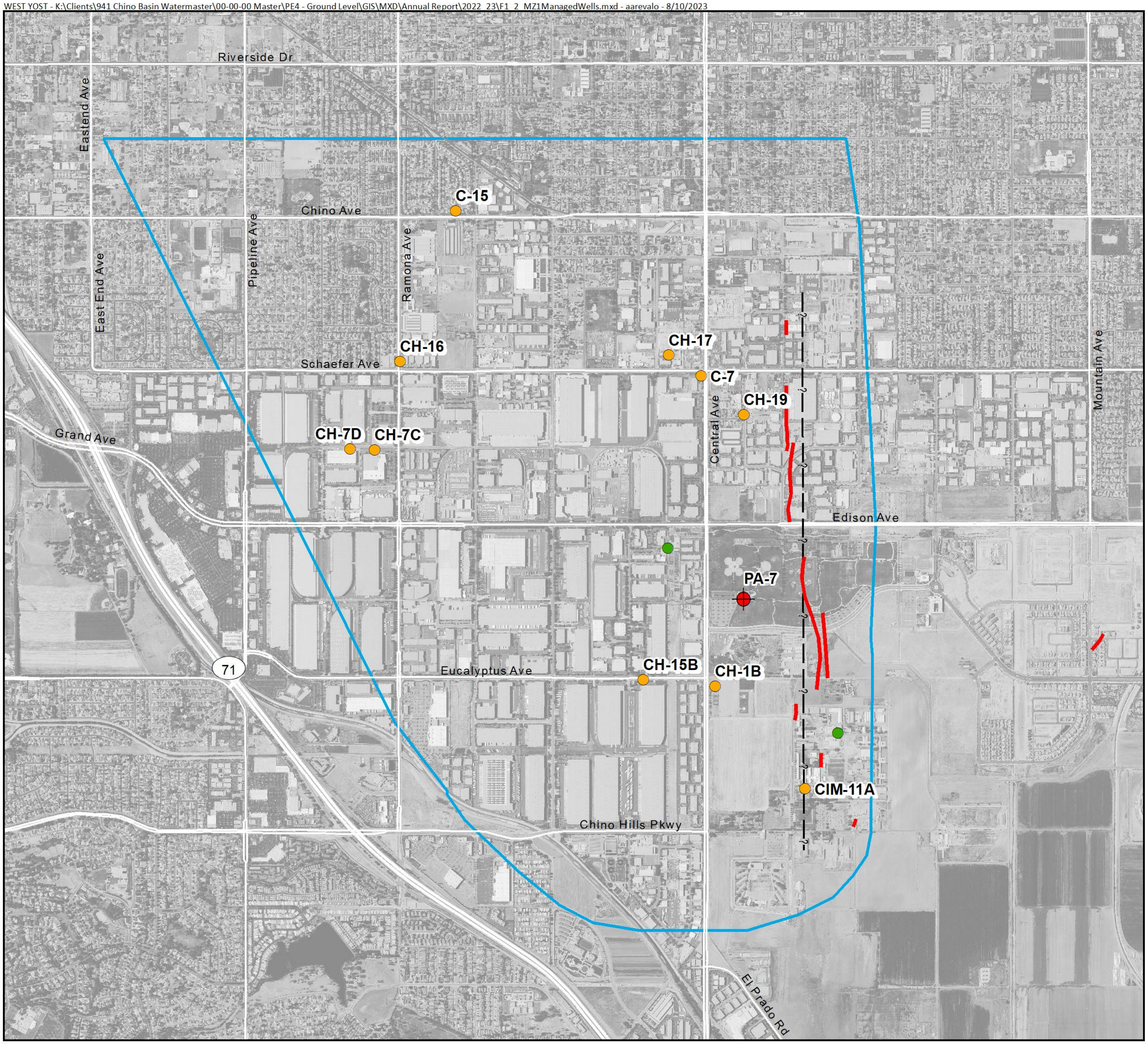

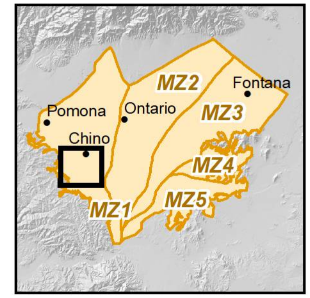

Managed Area

Ayala Park Extensometer Facility

Managed Well

Other Production Well

Ground Fissures

Groundwater Barrier (Riley Barrier) approximate location

N

0 1,500 3,000

Scale in Feet

WEST YOST

Figure 1-2

MZ-1 Managed Area and the Managed Wells

Chino Basin Watermaster

Ground-Level Monitoring Committee

2022/23 Annual Report

2.0 GROUND-LEVEL MONITORING PROGRAM

This section describes the activities performed by Watermaster for the GLMP between March 2022 and March 2023.

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 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 2022 and March 2023 are described below.

2.1.1 Setup and Maintenance of the Monitoring Facilities 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. During the reporting period, the following activities were performed at the Chino Basin extensometer facilities:

- Performed routine monthly maintenance at the Ayala Park, Chino Creek, and Pomona Extensometer (PX) Facilities. Noteworthy activities performed during the reporting period included:
    - Replaced the 12 volt deep-cycle battery for both PX Facility vaults to ensure power to the datalogger and continuous data collection.
    - Replaced the sump pump in the PA vault at Ayala Park to ensure that infiltrating irrigation or storm waters that periodically flood the vault are evacuated.
    - Replaced corroded door at the Ayala Park Extensometer Facility.
    - Repaired two CR1000 dataloggers at the PC vault and Ayala Park Extensometer Facility.
    - Replaced two direct read cables and two transducers at the PC vault.

- The following activities were performed in attempts to improve the accuracy of extensometer data that is being collected at the PX Facility:
    - Installed a dial gauge to manually measure aquifer-system deformation at the PX facility.
    - Adjusted the counterweights and extensometer cable at PX2-3.
    - Updated the software code for the datalogger at the at the PX facility.

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 sub-sections describe Watermaster's monitoring activities between March 2022 and March 2023, as called for in the Subsidence Management Plan and in accordance with the Watermaster-approved scope of work for the GLMP.

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 2022 and March 2023.

Watermaster staff 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. Figure 2-1 shows the locations of the spreading basins.

The Watermaster Engineer collects hydraulic head data once every 15 minutes using transducers at 77 wells located within the Managed Area and the other Areas of Subsidence Concern. Figure 2-2 shows the locations of these wells. Watermaster staff and well owners also manually measure hydraulic heads at other wells in western Chino Basin, typically on a monthly time-step.

2.1.2.2 Monitoring Vertical Aquifer-System Deformation

The Watermaster Engineer collects data on the vertical component of aquifer-system deformation at the Ayala Park, Chino Creek, and Pomona extensometer facilities once every 15 minutes. The Pomona Extensometer facility does not appear to be measuring and recording accurate data for aquifer-system deformation. Adjustments and testing of this monitoring facility are ongoing to improve the accuracy of the measurements.

2.1.2.3 Monitoring Vertical Ground Motion

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

For InSAR, the Watermaster has historically retained General Atomics (formerly Neva Ridge Technologies, Inc.) to acquire and post-process land-surface displacement data from the TerraSAR-X satellite operated by the German Aerospace Center. The width of the TerraSAR-X data frame covers the western half of the

Chino Basin only.[3] Typically each year, seven synthetic aperture radar (SAR) scenes are collected between March to March. The scenes are used to create 12 interferograms[4] to estimate short- and long-term vertical ground motion.[5]

This year, General Atomics informed the Watermaster Engineer that it is discontinuing its InSAR services, and as such, it declined to perform InSAR services for the GLMC for Fiscal Year 2022/23 and beyond.

The GLMC recommended that monitoring of ground motion via InSAR using TerraSAR X data is a critical component of the GLMP; therefore, Watermaster staff and West Yost developed a solution to continue the InSAR time series over the Chino Basin at the same high resolution and high accuracy:

- West Yost hires Sean Yarborough (the General Atomics staff that has performed InSAR monitoring for the Watermaster in the past) as a part-time employee to perform the InSAR services going forward.
- West Yost purchases and sets up all the necessary software and hardware to enable Mr. Yarborough to perform the work.
- West Yost purchases the raw SAR imagery directly from Airbus, the vendor that acquires the TerraSAR-X satellite data from the German Aerospace Center.

This solution is being implemented and is allowing the work to continue in the same high-quality fashion and will be more cost efficient in the long run. However, there have been significant start up efforts, such as establishing the relationships with the satellite vendor (German Space Agency), purchasing and configuring the necessary software/hardware, and collecting, importing, and checking all raw historical data from General Atomics.

Mr. Yarborough is currently preparing the InSAR deliverable for 2022-23; however, for the reasons stated above, the InSAR monitoring data cannot be prepared in time for inclusion in this annual report. Hence, many of the figures that are typically included in the annual report will be deferred to the subsequent annual report for FY 2023-24. That said, in early 2024, the Watermaster Engineer will share the InSAR monitoring results of vertical ground motion for 2022-23 with the GLMC.

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

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

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

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

the date of the most recent benchmark monument survey within the ground-level survey area. The locations of the ground-level survey areas are shown in Figure 2-2.

Table 2-1. 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	June 2023
San Jose Fault Zone Area	June 2023
Southeast Area[(a)]	May 2022
Northeast Area[(a)]	April 2020

(a) The entire benchmark monument survey network for the ground-level survey area was not surveyed in 2023 based on the GLMC scope and budget recommendations for FY 2022/23.

2.1.2.4 Monitoring of Horizontal Ground Motion

Watermaster 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 2022-23.

Table 2-2. 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.

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 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 2022 and March 2023 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.[6] 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.

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.

Task 5. Design and Install the Pomona Extensometer 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.

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's 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

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

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 Pomona Extensometer. 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 GLMC approved 1D model calibrations and deemed them 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 will be performed in FY 2023-24. The task will help 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 will be used to characterize the mechanical response of the aquifer-system to an initial Subsidence Management Alternative (SMA-1). A draft technical memorandum will be prepared that summarizes the evaluation of the SMA-1, particularly, the ability of SMA-1 to raise and hold piezometric levels above the estimated pre-consolidation stresses. The draft memorandum may also include a recommendation for a subsequent Subsidence Management Alternative (SMA-2) if SMA-1 is not successful at raising and holding hydraulic heads above the estimated pre-consolidation stresses. The assumptions of the SMA-1, including the groundwater production and replenishment plans of the Chino Basin parties, will be described and reviewed by the GLMC. A GLMC meeting will be held to review the model results and evaluation of the SMA-1, review the recommended SMA-2, and to receive feedback on the draft technical memorandum.

After the recommended SMA-2 is reviewed by the GLMC, the Watermaster's MODFLOW model will be updated to run SMA-2 and will be used to estimate the hydraulic head response to SMA-2 at the MVWD-28 and PX locations. The projected hydraulic heads generated from the MODFLOW model using SMA-2 will be extracted from the MODFLOW model results at the MVWD-28 and PX locations and will be used as input files for both 1D compaction models. The 1D compaction models will then be run to characterize the mechanical response of the aquifer-system to SMA-2 at both the MVWD-28 and PX locations.

A draft technical memorandum will be prepared that summarizes the evaluation of SMA-2, particularly, the ability of SMA-2 to raise and hold piezometric levels above the estimated pre-consolidation stresses. The draft technical memorandum may also include a recommendation for a subsequent Subsidence-Management Alternative (SMA-3), if SMA-2 is not successful at raising and holding hydraulic heads above the estimated pre-consolidation stresses. The assumptions of the SMA-3, including the groundwater production and replenishment plans of the Chino Basin parties, will be described and reviewed by the GLMC. A GLMC meeting will be held to review the model results and evaluation of the SMA-2, review the recommended SMA-3, and to receive feedback on the technical memorandum. This task is anticipated to be completed in FY 2024/25. If necessary and recommended by the GLMC, additional subsidence management alternative scenarios may be run.

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 GLMC 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.

In 2022-23, efforts were made to collect hydrogeologic data, but without success. Additional efforts to collect hydrogeologic data in this area are occurring in 2023-24.

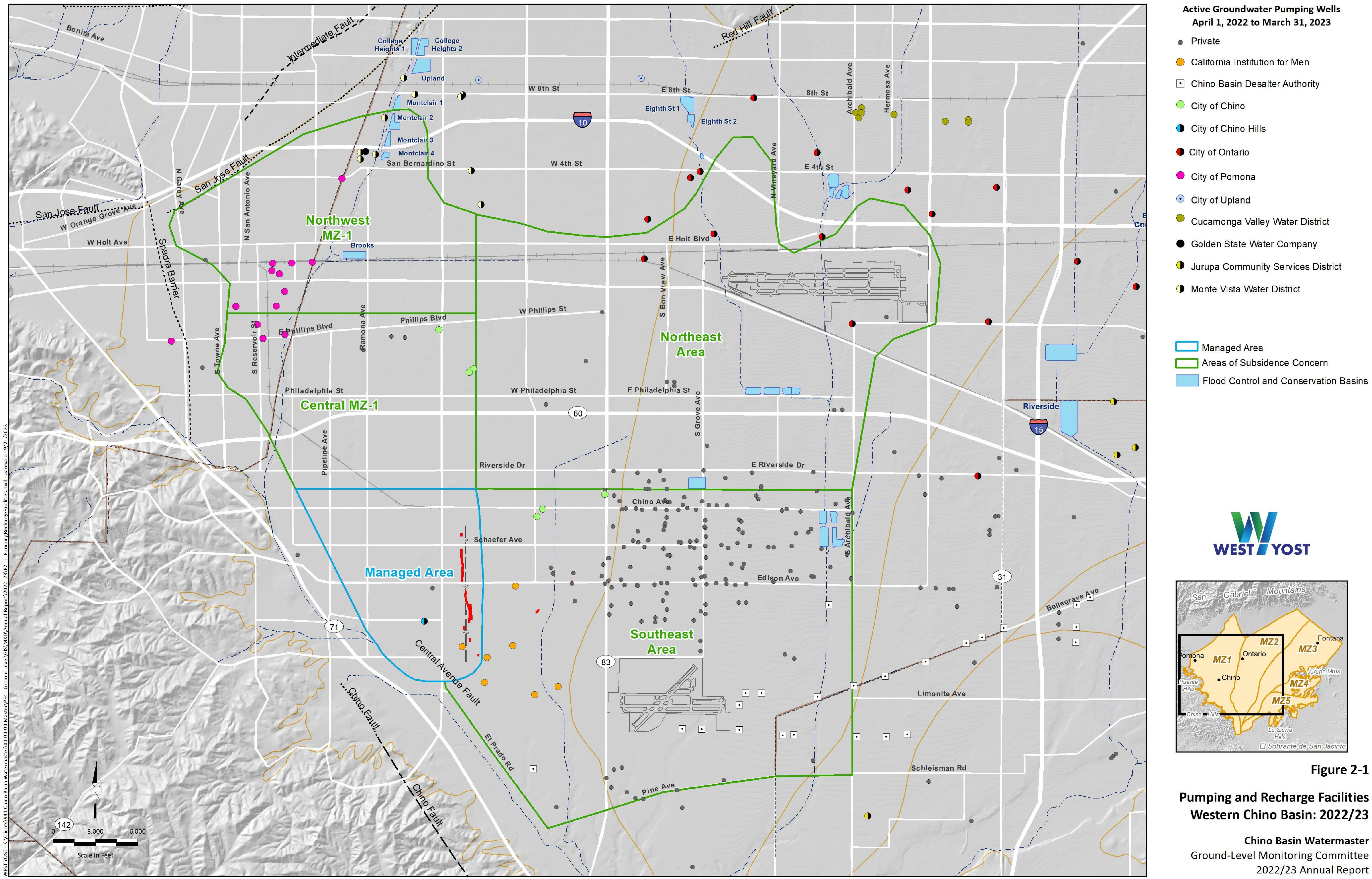
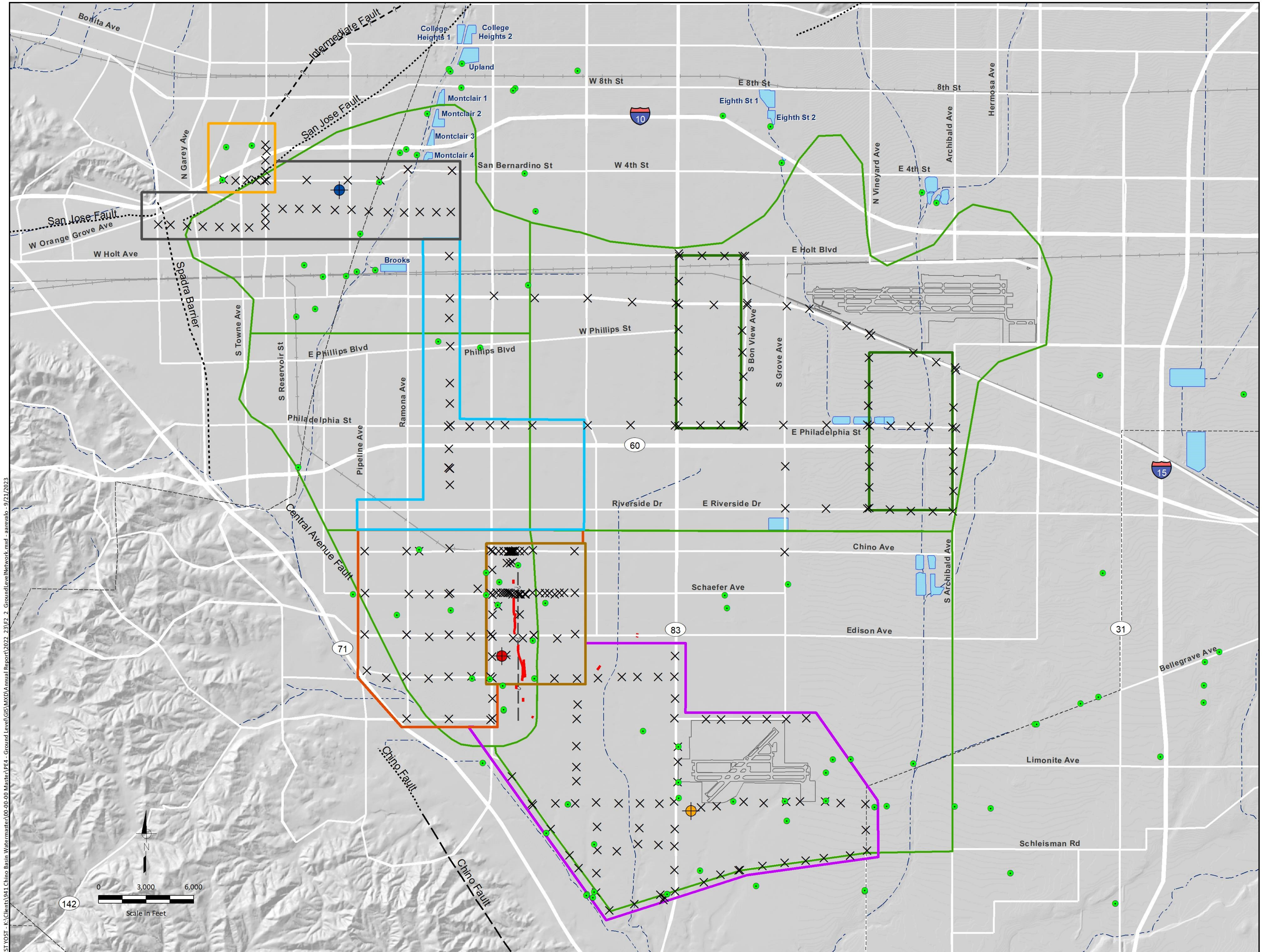


Figure 2-1

Pumping and Recharge Facilities Western Chino Basin: 2022/23

Chino Basin Watermaster

Ground-Level Monitoring Committee
2022/23 Annual Report



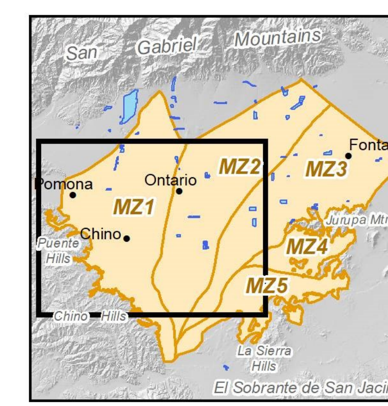


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Figure 2-2

Ground-Level Monitoring Network
Western Chino Basin

Chino Basin Watermaster
Ground-Level Monitoring Committee
2022/23 Annual Report

3.0 RESULTS AND INTERPRETATIONS

This section describes the results and interpretations derived from the GLMP for the Managed Area and the other Areas of Subsidence Concern—particularly for the March 2022 to March 2023 reporting period. As described in Section 2, because of the lack of InSAR data caused by the vendor declining to perform InSAR services, some of the figures and analyses that are typically included in the annual report could not be prepared and will be deferred to the subsequent annual report for FY 2023-24. This annual report includes only the results and interpretations for data analyses that are not dependent upon InSAR.

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 3-1 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 decreases in groundwater pumping were mainly due to poor groundwater quality locally and the availability of alternative water supplies, such as recycled water and treated groundwater from the Chino Basin Desalter Authority.
- 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 11 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 2023. Groundwater pumping in the Managed Area declined from about 5,680 acre-feet (af) in fiscal year 2012 to almost negligible volumes in 2023. A total of about 47 af of groundwater pumping occurred in the Managed Area from July 1, 2022 to March 31, 2023—54 percent of the groundwater pumping was from wells screened across the deep aquifer-system.

Figure 3-2 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 2023. 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 January and 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 2022 represented "full recovery" of hydraulic head at PA-7 as defined in the Subsidence Management Plan.
- Since the first instance of full recovery in 2011, the hydraulic head at PA-7 recovered to 90 ft-btoc or greater in 2012, 2016, 2018, 2019, and 2022 which complies with the recommendation in the Subsidence Management Plan for full recovery within the deep aquifer-system at least once every five years.[7]
- Since 2018, hydraulic heads at PA-10 and PA-7 have increased to relatively high levels as a result of very little to almost zero pumping from the shallow and deep aquifer-systems. On April 1, 2023, heads were at about 51 ft-btoc in PA-10 and about 62 ft-btoc in PA-7.

[7] 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 3-2 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 2023. 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 Deep Extensometer recorded about 0.034 ft of aquifer-system compression, which indicates that this compression was largely permanent compaction that occurred within the depth interval of 30-1,400 ft-bgs.[8]
- From May 3, 2018 to November 28, 2019 (dates of full recovery at PA-7), there was very little pumping in the Managed Area, and the Deep Extensometer recorded about 0.035 ft of aquifer-system expansion, indicating that the entire thickness of the aquifer system (shallow and deep) was experiencing elastic expansion.
- From November 28, 2019 to December 15, 2022 (dates of full recovery at PA-7), the Deep Extensometer recorded insignificant changes, indicating that the vertical deformation of the deep aquifer-system was entirely elastic.

Figure 3-3 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 3, 2006 to May 3, 2018 (dates of full recovery at PA-7), 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. The rate of inelastic compaction appeared to gradually decline over this 12-year period.
- From May 3, 2018 to November 28, 2019 (dates of full recovery at PA-7), the hydraulic heads at PA-7 fluctuated between 65-120 ft-btoc. These were shallower depths to groundwater compared to the earlier period, and the hysteresis loops shifted to the left, indicating that the vertical deformation of the aquifer-system was mainly elastic expansion of the aquifer-system sediments.

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

- From November 28, 2019 to December 15, 2022 (dates of full recovery at PA-7), the hydraulic heads at PA-7 generally remained at or above 90 ft-btoc. By December 15, 2022, the hysteresis loops returned to virtually the same point as November 28, 2019, indicating that the vertical deformation of the aquifer-system was purely elastic.

3.2 Southeast Area

Historically, vertical ground motion has been measured across the Southeast Area via InSAR, traditional ground-level surveys, and the Chino Creek Extensometer Facility (CCX). As described in Section 2, InSAR results are not yet available for 2022-23 and ground-level surveys across the Southeast Area were not conducted in 2023. Hence, the interpretation of the monitoring program results in the Southeast Area are limited to data analysis from the CCX.

Figure 3-4 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 2022. In general, hydraulic heads at the CCX vary seasonally and have gradually increased since 2012, and a small amount of expansion of the aquifer-system has been measured by the CCX extensometers. In early 2023, hydraulic heads increased by more than 10 ft, probably in response to the wet winter of 2022-23 and a decrease in pumping, which caused additional expansion of the aquifer-system sediments as recorded by the CCX extensometers. These observations indicate that vertical deformation of the aquifer-system sediments at this location in the Southeast Area is mainly elastic expansion.

3.3 Other Areas of Subsidence Concern

Historically, vertical ground motion has been measured across Central MZ-1, Northwest MZ-1, and the Northeast Area via InSAR and traditional ground-level surveys. As described in Section 2, InSAR results are not yet available for 2022-23 and ground-level surveys across the Central MZ-1 and Northeast Area were not conducted in 2023. In addition, efforts were made in 2022-23 to collect hydrogeologic data to support the Northeast Area Subsidence Investigation, but without success. Hence, the interpretation of the monitoring program results in these other Areas of Subsidence Concern are deferred until the *2023-24 Annual Report of the GLMC*.

Table 3-1. Groundwater Pumping in the Managed Area -- *Fiscal Year 2012 through 2023*

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

"C" = City of Chino

"CH" = City of Chino Hills

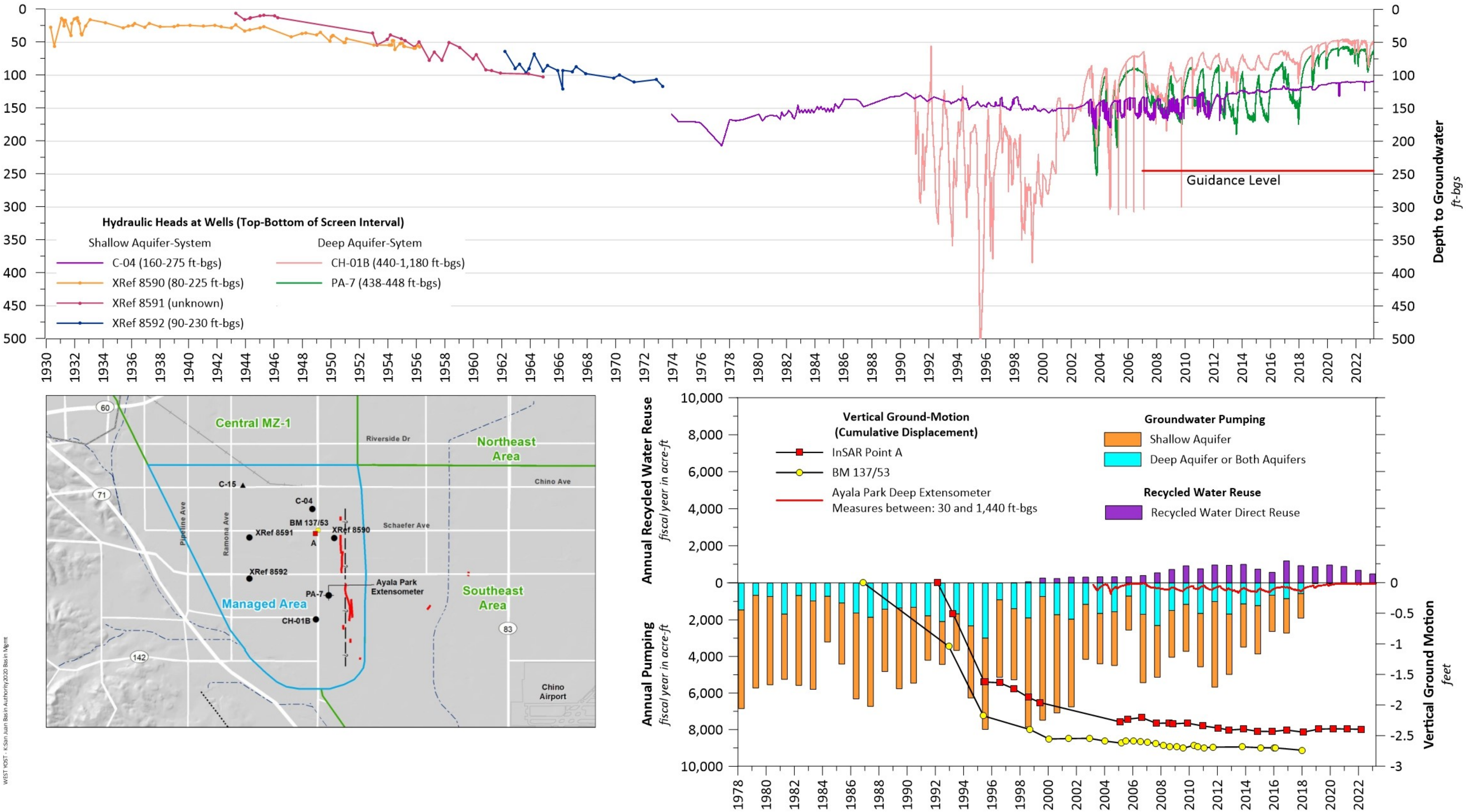
"CIM" = California Institution for Men

"XRef" = Private

(a) Data only available through March 2023.

(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.



Recharge and pumping data through March 31, 2023

For the time-period between July 1, 2022 and March 31, 2023:
Pumping from the shallow aquifer = 53 af
Pumping from the deep aquifer = 2 af

Ground level survey and InSAR data not available in 2023

Figure 3-1

History of Land Subsidence in the Managed Area

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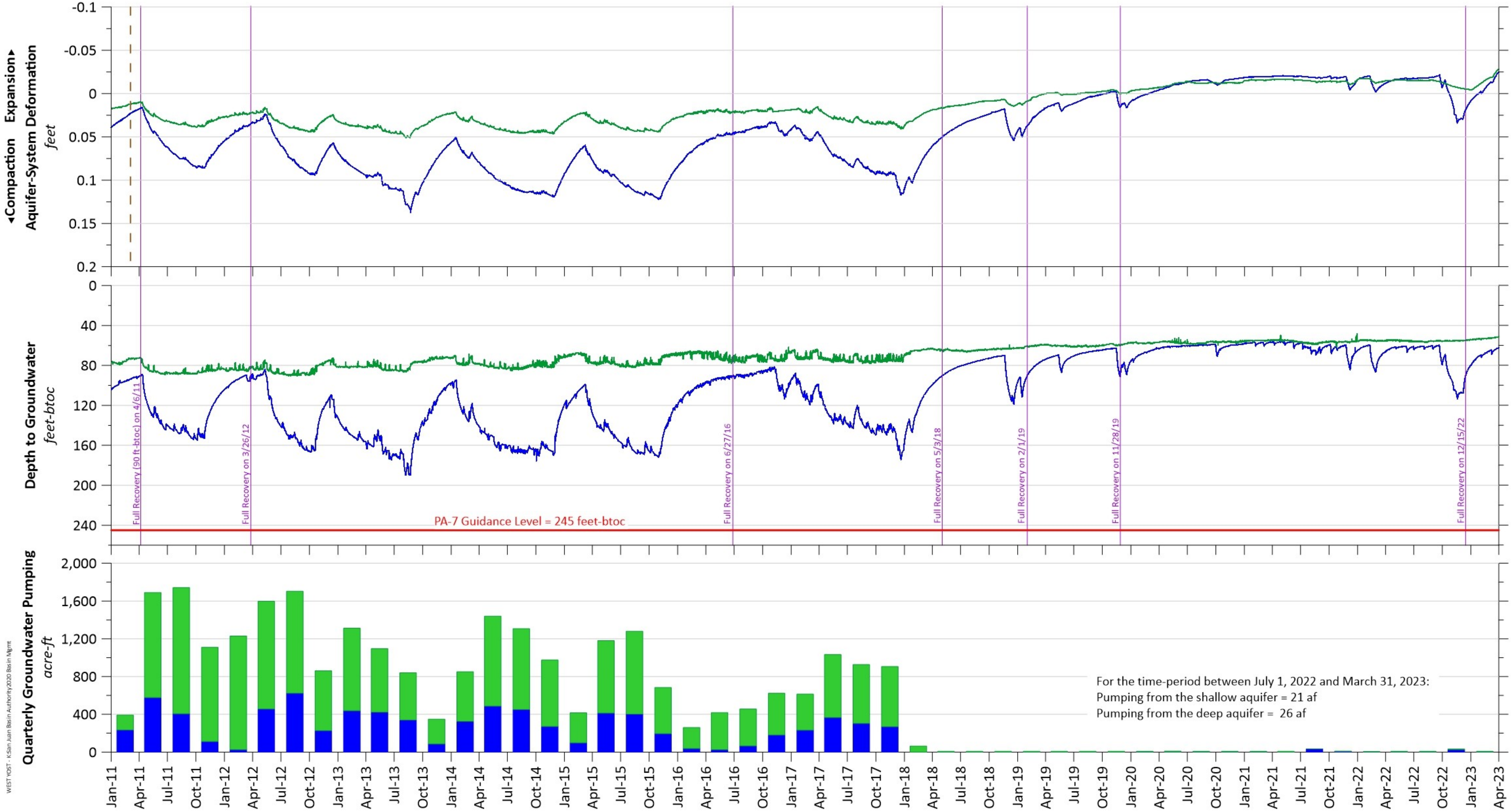

Aquifer-System Deformation at Ayala Park (Extensometer Depth Interval)

Shallow Extensometer (30-550 ft-bgs)

Deep Extensometer

Hydraulic Heads at Ayala Park (Screened Interval)

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

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

Quarterly Groundwater Pumping (see Table 3-1 for groundwater pumping by well)

Shallow Aquifer

Deep Aquifer

Figure 3-2

Stress and Strain within the Managed Area

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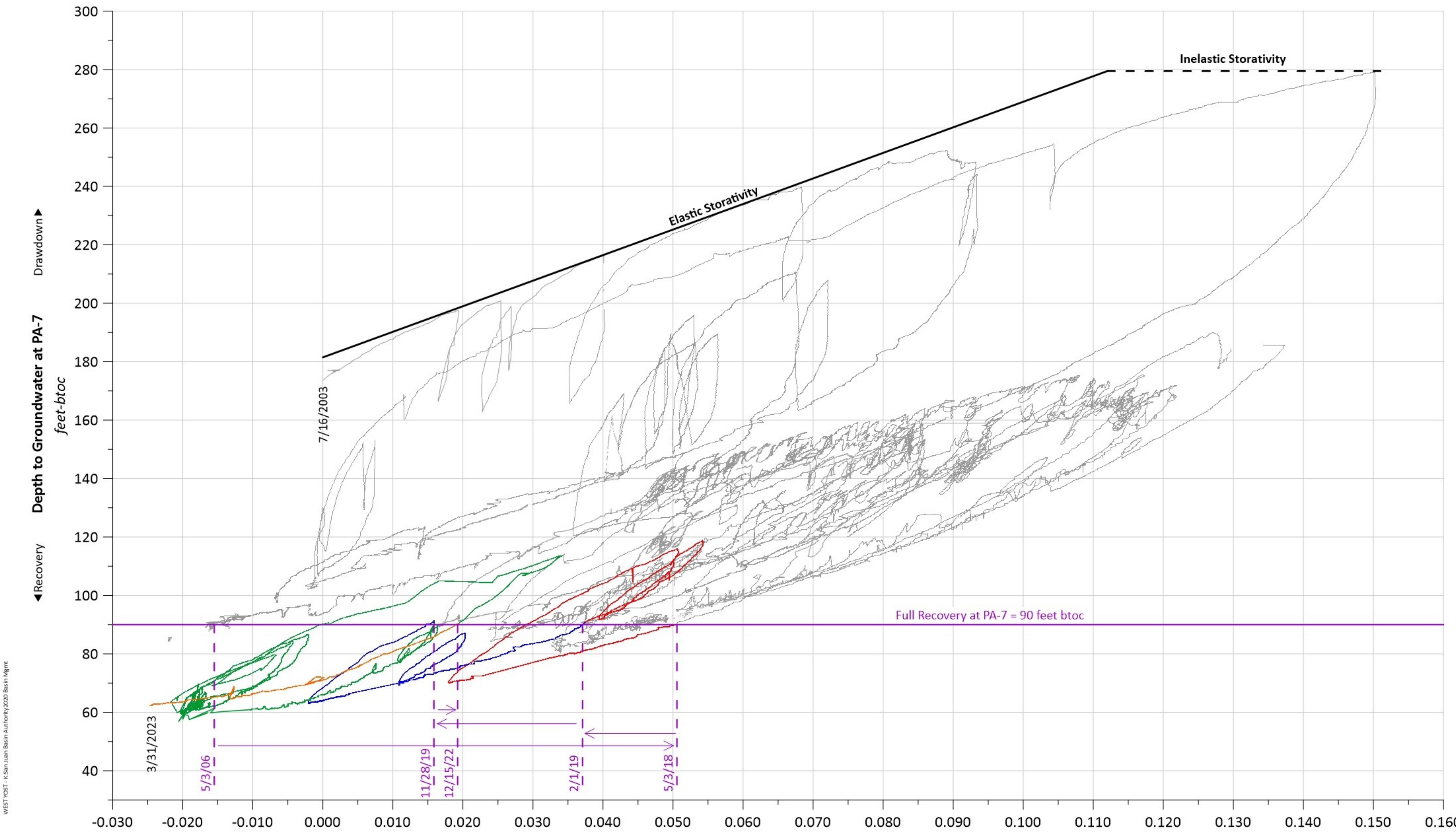

◀ Expansion **Aquifer-System Deformation at the Deep Extensometer** Compaction ▶

feet

Stress - Strain Hysteresis Loops of Drawdown

- Drawdown and recovery between 7/16/03 and 5/3/18
- Drawdown and recovery between 5/3/18 to 2/1/19
- Drawdown and recovery between 2/1/19 and 11/28/19
- Drawdown and recovery between 11/28/19 and 12/15/22
- Drawdown and recovery between 12/15/22 and 3/31/23

*PA-7 well-screen interval: 438-448 ft-bgs

Depth interval of the Deep Extensometer: 30-1,400 feet-bgs

Figure 3-3

Stress-Strain Diagram
Ayala Park Extensometer

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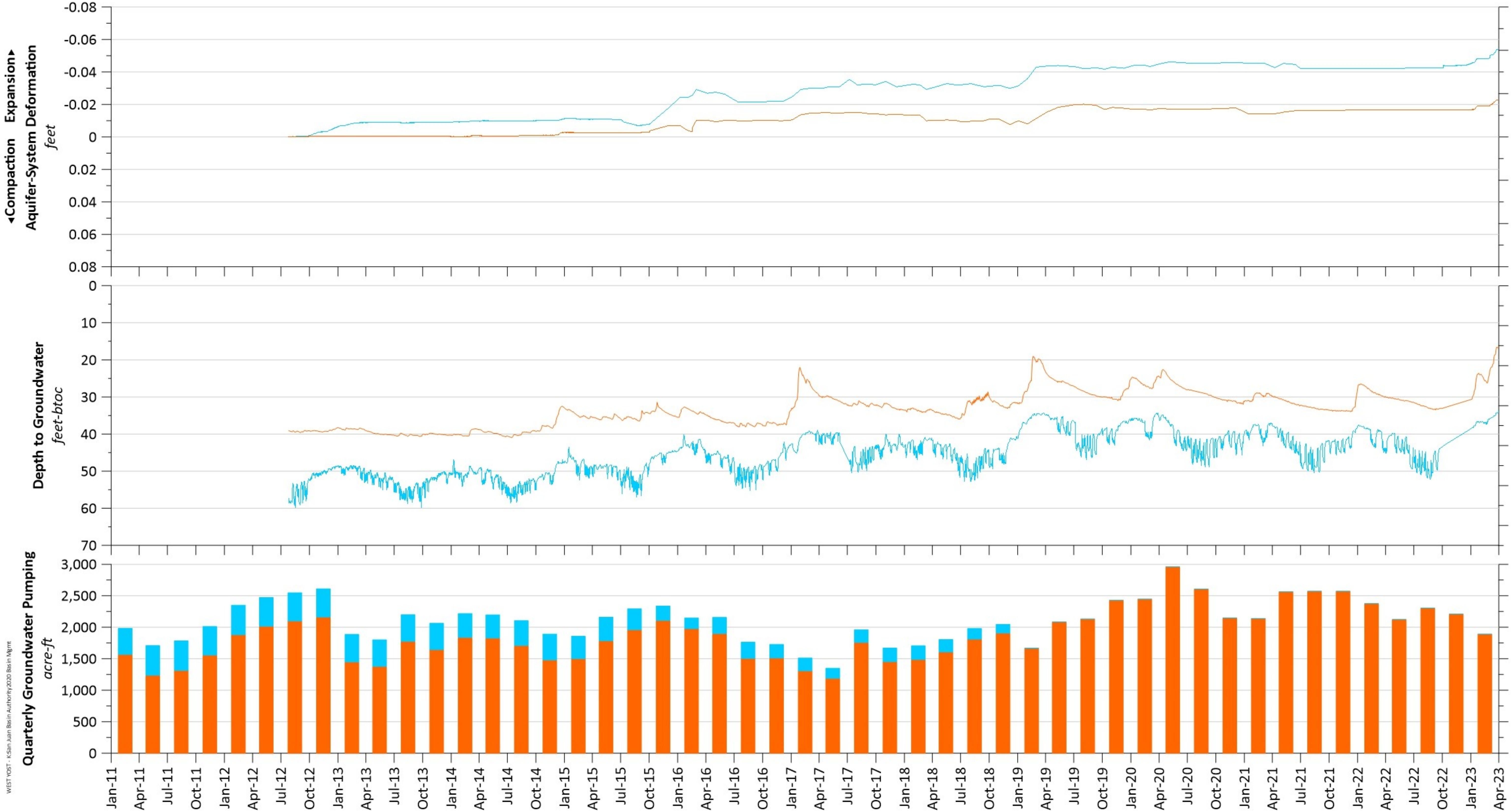

Aquifer-System Deformation (Extensometer Depth Interval)

- CCX-1 with manuals
- CCX-2 (50-610 ft-bgs)
- Preliminary Data

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)

Between April 2022 and March 2023:
There was no CDA pumping from the deep aquifer

Figure 3-4

Stress and Strain within the Southeast Area

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4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions and Recommendations

The major conclusions and recommendations of this *2022/23 Annual Report of the GLMC* are:

- At the Ayala Park Extensometer in the Managed Area, hydraulic heads within the shallow and deep aquifer-systems are near their highest levels since the inception of the GLMP in 2003, and the Ayala Park Extensometers recorded elastic compression and expansion of the aquifer-system during the current reporting period of March 2022 to March 2023. The elevated hydraulic heads were due to the virtual cessation of pumping in the Managed Area since 2018. The reduced pumping is largely due to the presence of water-quality contaminants in groundwater that constrain its use as drinking water and the availability of alternative water supplies. Hydraulic heads in the deep aquifer-system remain well above the Guidance Level, and the Ayala Park Extensometers recorded very little, if any, inelastic compaction of the aquifer-system during the current reporting period.

  RECOMMENDATION: Continue the GLMP in the Managed Area with no changes to the monitoring network or monitoring/reporting protocols.

- At the CCX in the Southeast Area, hydraulic heads within the shallow and deep aquifer-systems are near their highest levels since monitoring began at the CCX in 2012, and the CCX extensometers recorded elastic expansion of the aquifer-system during the current reporting period of March 2022 to March 2023. The recent increases in hydraulic heads were due to the wet winter of 2022-23 and a decrease in pumping in the Southeast Area.

  RECOMMENDATION: Continue the GLMP in the Southeast Area with no changes to the monitoring network or monitoring/reporting protocols.

- 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 land subsidence 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. As described in Section 2, InSAR data were not available for this annual report, so interpretation of the GLMP results in these other Areas of Subsidence Concern are deferred until the *2023-24 Annual Report of the GLMC*.

  RECOMMENDATION: 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. In FY 2023/24, 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. This includes efforts to improve the accuracy of the extensometer data being measured at the PX.

  — Performing and evaluating 1D Model simulations of the potential future aquifer-system compaction (i.e., land subsidence) in Northwest MZ-1 at the PX and MVWD-28 locations. The 1D Model simulation results will be used to develop “Guidance Criteria” for

Northwest MZ-1 (e.g., recommended groundwater-level elevations) that will abate future subsidence in Northwest MZ-1 or reduce it to tolerable levels. The 1D Models should also be used to explore potential methods to achieve the Guidance Criteria, such as voluntary modification of pumping patterns; in-lieu recharge; wet-water recharge via spreading and/or injection; conducting Storage and Recover programs; or a combination of methods.

— The future scenarios for the 1D Model simulations could be developed during Watermaster's upcoming 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, so that the scenarios include various methods to achieve the Guidance Criteria. Then, the 1D Models should be used to evaluate the potential future subsidence in Northwest MZ-1 under these future scenarios, which could support the finalization of the Guidance Criteria and the *Subsidence Management Plan for Northwest MZ-1*.

- For the Northeast Area Subsidence Investigation, efforts were made in 2022-23 to collect hydrogeologic data as recommended in the *2021-22 Annual Report of the GLMC*, but without success. In addition, the InSAR data for 2022-23 are not yet available to confirm the ongoing occurrence of land subsidence in the vicinity of the Whispering Lakes Golf Course.

  RECOMMENDATION: Efforts should continue to collect land subsidence and hydrogeologic data in this area in 2023-24 to further identify the primary cause(s) of the differential subsidence at the Whispering Lakes Subsidence Feature. Data collection should include: InSAR data; well information and data at the nearby Philadelphia Wells; and historical land use data and practices in the vicinity of the Whispering Lakes Golf Course.

4.2 Recommended Scope and Budget for Fiscal Year 2022/23

A scope-of-work for the GLMP for FY 2023/24 was reviewed by the GLMC in April 2023 and approved by Watermaster on May 25, 2023. Appendix A is the technical memorandum prepared by the Watermaster Engineer, titled: *Recommended Scope and Budget of the Ground-Level Monitoring Committee for FY 2023/24*.

In March 2024, the Watermaster Engineer will present the preliminary results of the GLMP through 2023 and a recommended FY 2024/25 scope and budget to the GLMC for consideration and feedback.

4.3 Changes to the Subsidence Management Plan

The Subsidence Management Plan calls for ongoing monitoring, data analysis, annual reporting, and adjustments to the Plan, as warranted by the data. The Subsidence Management Plan states that if data from existing monitoring efforts in the Areas of Subsidence Concern indicate the potential for adverse impacts due to subsidence, Watermaster will revise the Subsidence Management Plan pursuant to the process outlined in Section 4 of the Subsidence Management Plan. The recommendations described above to continue implementation of the *Work Plan to Develop a Subsidence-Management Plan for the Northwest MZ-1 Area* are consistent with the requirements of the OBMP Program Elements 1 and 4 and its implementation plan contained in the Peace Agreement.

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

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Appendix A

Recommended Scope and Budget of the Ground-Level Monitoring Committee for FY 2023/24

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DRAFT TECHNICAL MEMORANDUM

DATE: May 10, 2023 Project No.: 941-80-22-26

TO: Ground-Level Monitoring Committee

FROM: Andy Malone and Garrett Rapp

REVIEWED BY: Andy Malone

SUBJECT: Recommended Scope of Work and Budget of the Ground-Level Monitoring Committee for Fiscal Year 2023/24 **(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 2023/24 in the form of a proposed scope of services and budget.

Members of the GLMC are asked to:

- Review this TM prior to March 2, 2023.
- Attend a meeting of the GLMC at 9:00 am on March 2, 2023 to discuss the proposed scope of services and budget for FY 2023/24.
- Submit comments and suggested revisions on the proposed scope of services and budget for FY 2023/24 to the Watermaster by March 24, 2023.
- Attend a meeting of the GLMC at 9:00 am on March 30, 2023 to discuss comments and revisions to the proposed scope of services and budget for FY 2023/24 (if necessary).

- Submit additional comments and suggested revisions on the proposed scope of services and budget for FY 2023/24 to the Watermaster by April 7, 2023.

The final scope of services and budget that is recommended by the GLMC will be included in the Watermaster's FY 2023/24 budget. The final scope of services, budget, and schedule for FY 2023/24 will be included in Section 4 of the *2022/23 Annual Report of the GLMC*.

RECOMMENDED SCOPE OF SERVICES AND BUDGET – FY 2023/24

A proposed scope of services for the GLMP for FY 2023/24 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. One additional staff member is required at the PX site due to safety concerns.

Non-routine efforts to be performed during FY 2023/24 under this subtask include:

- Monthly adjustments to the PX extensometers to improve the accuracy of the measurements of aquifer-system deformation.
- Repair of the top of the rusted casings at the Ayala Park piezometers.

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 and compilation of hydraulic head and aquifer-system deformation data from the Ayala Park, Chino Creek, and Pomona extensometer facilities.

Task 2.1. Conduct Quarterly Monitoring at Extensometer Facilities

This subtask involves the routine quarterly collection and checking of data from the extensometer facilities. 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 Pomona extensometer facilities will be loaded to HydroDaVE^{SM} (Hydrologic Database and Visual Explanations) and checked.

Table 1. Work Breakdown Structure and Cost Estimates for the Ground-Level Monitoring Program: FY 2023/24

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 *2023/24*	Approved Budget *2022/23*	Net Change *from 2022/23*
												a	*b*	*a - b*
Task 1. Setup and Maintenance of the Monitoring Network				**$39,821**						**$7,968**	**$47,789**	**$47,789**	**$35,470**	**$12,319**
1.1	Maintain Extensometer Facilities													
1.1.1	Routine maintenance of Ayala Park, Chino Creek, and Pomona extensometer facilities		25	$32,509	$649	$250	$300			$1,199	$33,707	$33,707	$22,380	$11,327
1.1.2	Replacement/repair of equipment at extensometer facilities		4	$7,312	$173	$2,500		$2,500		$5,173	$12,485	$12,485	$11,494	$992
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				**$30,552**						**$904**	**$31,456**	**$31,456**	**$30,687**	**$768**
2.1	Conduct Quarterly Monitoring at Extensometers Facilities													
2.1.1	Download data from the Ayala Park Extensometer facility		2	$2,640	$332		$60			$392	$3,032	$3,032	$3,059	-$27
2.1.2	Download data from the Chino Creek Extensometer facility		2	$2,640			$60			$60	$2,700	$2,700	$2,778	-$78
2.1.3	Download data from Pomona Extensometer facility		8	$10,040	$332		$120			$452	$10,492	$10,492	$5,853	$4,639
2.1.4	Process, check, and upload data to database		10	$15,232						$0	$15,232	$15,232	$18,997	-$3,765
Task 3. Basin Wide Ground-Level Monitoring Program (InSAR)				**$6,560**						**$90,000**	**$96,560**	**$96,560**	**$90,472**	**$6,088**
3.1	Acquire TerraSAR-X data and prepare interferograms for 2023/24		1	$2,336				$90,000		$90,000	$92,336	$92,336	$86,892	$5,444
3.2	Check and review InSAR results		2.5	$4,224						$0	$4,224	$4,224	$3,580	$644
Task 4. Perform Ground-Level Surveys				**$7,728**						**$76,552**	**$84,280**	**$84,280**	**$38,241**	**$46,039**
4.1	Conduct Spring-2024 Elevation surveys in Northwest MZ-1		0.5	$1,168				$27,192		$27,192	$28,360	$28,360	$26,259	$2,101
4.2	Conduct Spring-2024 Elevation Survey in the Northeast Area		0	$0				$50,820		$0	$0	$0	$0	$0
4.3	Conduct Spring-2024 Elevation Survey in the Southeast Area		0	$0				$53,812		$0	$0	$0	$0	$0
4.4	Conduct Spring-2024 Elevation and EDM Surveys in the Managed Area/Fissure Zone		0.5	$1,168				$30,080		$30,080	$31,248	$31,248	$0	$31,248
4.5	Replace Destroyed Benchmarks (if needed)		0	$0				$19,280		$19,280	$19,280	$19,280	$5,650	$13,630
4.6	Process, Check, and Update Database		3	$5,392						$0	$5,392	$5,392	$6,332	-$940
Task 5. Data Analysis and Reporting				**$85,412**						**$0**	**$85,412**	**$85,412**	**$87,888**	**-$2,476**
5.1	Prepare Draft 2022/23 Annual Report of the Ground-Level Monitoring Committee		20	$36,136						$0	$36,136	$36,136	$34,124	$2,012
5.2	Prepare Final 2022/23 Annual Report of the Ground-Level Monitoring Committee		8.5	$15,732						$0	$15,732	$15,732	$19,993	-$4,261
5.3	Compile and Analyze Data from the 2023/24 Ground-Level Monitoring Program		14	$23,544						$0	$23,544	$23,544	$21,643	$1,901
5.4	Continue Whispering Lakes Subsidence Investigation		0	$10,000						$0	$10,000	$10,000	$12,129	-$2,129
Task 6. Develop a Subsidence-Management Plan for Northwest MZ-1				**$15,536**						**$0**	**$15,536**	**$15,536**	**$25,203**	**-$9,667**
6.1	Aquifer-System Monitoring													
6.1.1	Collect pumping and piezometric level data from agencies every three months; check and upload data to HDX		8	$10,560						$0	$10,560	$10,560	$12,995	-$2,435
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		3	$4,976						$0	$4,976	$4,976	$12,208	-$7,232
Task 7. Construct and Calibrate Additional 1D Models Across Western Chino Basin				**$192,356**						**$155**	**$192,511**	**$192,511**	**$140,339**	**$52,173**
7.1	Prepare a draft TM summarizing the background, objectives, and methods; distribute to the GLMC		6.5	$12,760						$0	$12,760	$12,760		
7.2	Prepare for and conduct a GLMC meeting to receive feedback and comments on the draft TM	a	2.5	$5,032	$78					$78	$5,110	$5,110		
7.3	Verify and/or recalibrate the 1D Model at Ayala Park Extensometer location		12.5	$22,736						$0	$22,736	$22,736		
7.4	Construct two additional 1D Models in the Southeast Area and Northeast Area		35	$62,368						$0	$62,368	$62,368	$140,339	$52,173
7.5	Calibrate new 1D Models to derive properties of aquifers/aquitards and estimate the pre-consolidation stress(es)		25	$45,472						$0	$45,472	$45,472		
7.6	Prepare a draft TM summarizing the construction/calibration of additional 1D Models; distribute to the GLMC		20	$37,024						$0	$37,024	$37,024		
7.7	Prepare for and conduct a GLMC meeting to receive feedback and comments on the draft TM	a	2.5	$5,032	$78					$78	$5,110	$5,110		
7.8	Incorporate the GLMC comments and prepare a final technical memorandum		1	$1,932						$0	$1,932	$1,932		
Task 8. Meetings and Administration				**$58,866**						**$362**	**$59,228**	**$59,228**	**$54,559**	**$4,669**
8.1	Prepare for and Conduct Four Meetings of the Ground-Level Monitoring Committee	a	18	$32,352	$284					$284	$32,636	$32,636	$29,986	$2,651
8.2	Prepare for and Conduct One As-Requested Ad-Hoc Meeting	a	3	$5,392	$78					$78	$5,470	$5,470	$5,025	$445
8.3	Perform Monthly Project Management		6	$11,592						$0	$11,592	$11,592	$10,740	$852
8.4	Prepare a Recommended Scope and Budget for the GLMC for FY 2023/24		5.25	$9,530						$0	$9,530	$9,530	$8,808	$722
Totals				**$436,831**						**$175,941**		**$612,772**	**$502,860**	**$109,912**

Notes:

a Assumes in-person meetings.

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 2023 to March 2024.

Task 3.1. Acquire TerraSAR-X SAR Data and Prepare Interferograms for 2023/24

In this subtask, five SAR scenes that will be acquired by the TerraSAR-X satellite from March 2023 to March 2024 are purchased from the German Aerospace Center. General Atomics (formerly Neva Ridge Technologies) will use the SAR scenes to prepare 12 interferograms that describe the incremental and cumulative vertical ground motion that occurred from March 2023 to March 2024 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 ($13,000)
- Purchase TerraSAR-X data ($18,000)
- Prepare InSAR results, including GeoTIFFs and GIS raster datasets ($59,000)

Task 3.2. Check and Review InSAR Results

In this subtask, the Watermaster Engineer reviews the InSAR results with General Atomics, performs checks for reasonableness and accuracy of the InSAR estimates of vertical ground motion across the western Chino Basin, and uploads the InSAR results to the GIS database.

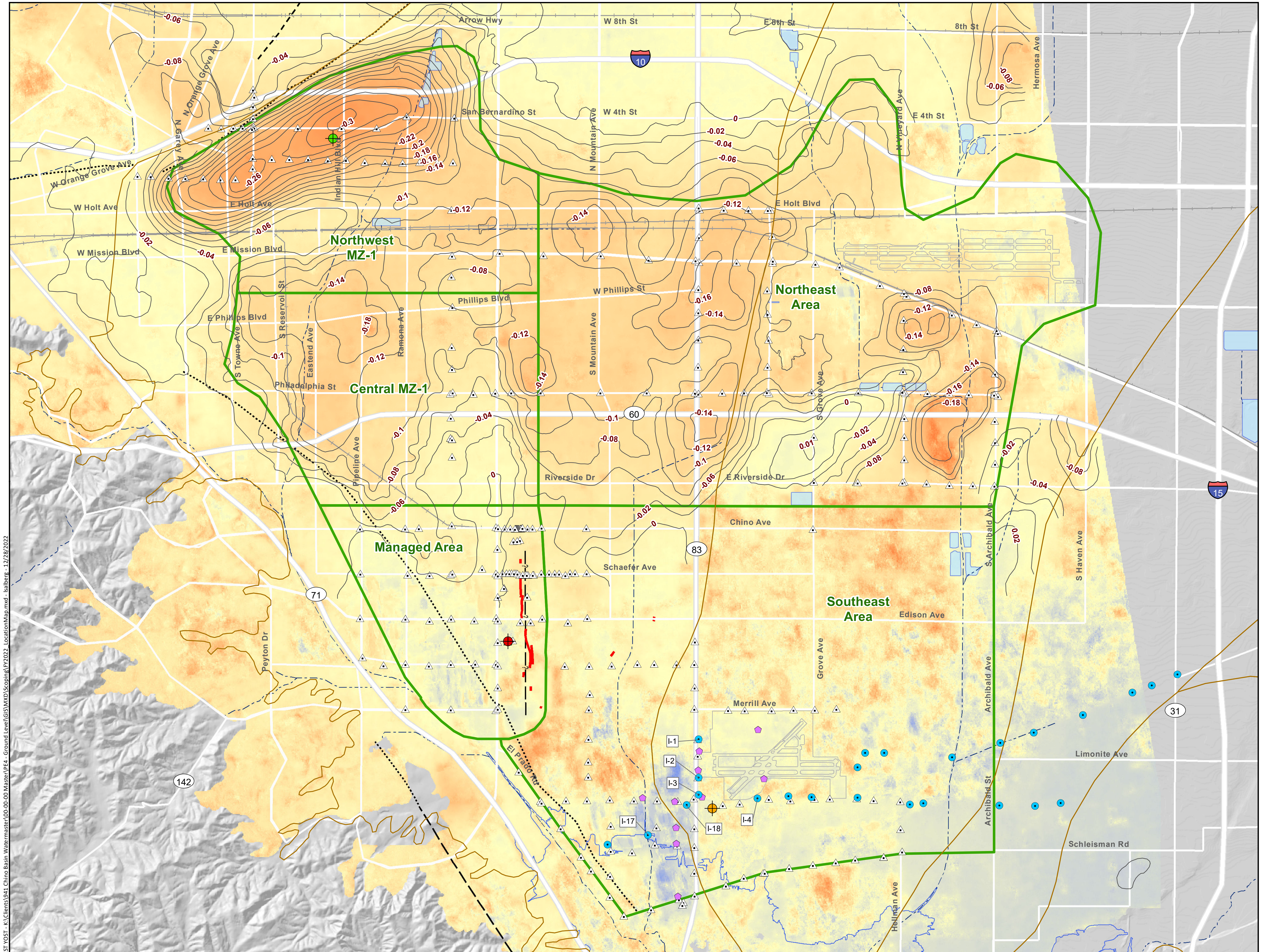
Task 4. Perform Ground-Level Surveys

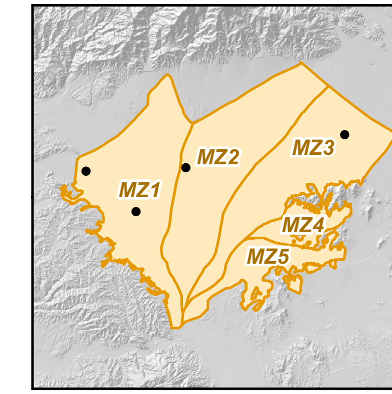
This task involves conducting elevation surveys at benchmark monuments across defined areas of western Chino Basin to estimate the vertical ground motion that occurred since the prior survey. Figure 1 shows the location of the benchmark monuments surveyed across the western Chino Basin. Electronic distance 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.

Table 2. History of Ground-Level Surveys

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

(a) Denotes EDM survey area (measurements of horizontal strain).
(b) The 2023 ground-level surveys are scheduled to begin in early March 2023.





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

-0.20

-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

WEST YOST - K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE4 - Ground Level\GIS\MXD\Scoping\FY2022_LocationMap.mxd - lsalberg - 12/28/2022

The ground-level surveys recommended for FY 2023/24 include the following:

Task 4.1. Conduct Spring-2024 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 2024. The elevation survey will begin at the Pomona Extensometer Facility and includes benchmarks across Northwest MZ-1. The elevation survey will be referenced to a newly established elevation datum at the Pomona Extensometer.

*The vertical elevation survey is recommended in FY 2023/24 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).*

Task 4.4. Conduct Spring-2021 Elevation and EDM Surveys in the Managed Area/Fissure Zone Area

In this subtask, the surveyor conducts elevation and EDM surveys at the established benchmarks in across the Managed Area in Spring 2024. These surveys are recommended because (i) the Managed Area is the primary focus of the Subsidence Management Plan and (ii) the last survey performed in this area was during spring 2018 which, by spring 2024, will be six years between surveys.

Ground-Level Surveys Not Recommended for FY 2023/24

Ground-level surveys are **not** recommended for FY 2023/24 in the other Areas of Subsidence Concern (i.e., 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 2022/23 Annual Report of the Ground-Level Monitoring Committee

Prepare the text, tables, and figures for a draft *2022/23 Annual Report of the GLMC* and submit the report to the GLMC by September 22, 2023 for review and comment.

Task 5.2. Prepare Final 2022/23 Annual Report of the Ground-Level Monitoring Committee

Update the text, tables, and figures based on the comments received from the GLMC and prepare a final *2022/23 Annual Report of the GLMC* by November 3, 2023. 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 2023 Watermaster meetings for approval.

Task 5.3. Compile and Analyze Data from the 2023/24 Ground-Level Monitoring Program

In this subtask, monitoring data generated from the GLMP during 2023/24 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 2024 during the development of a recommended scope of services and budget for FY 2024/25.

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); and

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 2022/23 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 2022/23 along with recommendations for follow-on work.

The GLMC should consider dedicating contingency budget for FY 2023/24 ($10,000) to continue the implementation of the recommendations derived Reconnaissance-Level Investigation and future recommendations based on results of work performed in 2022/23.

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.[1]

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 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 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.

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

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).[2] 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 of the GLMC and used to prepare recommendations for future activities.

Progress to Implement Work Plan thru FY 2022/23

The progress that has been made to implement the Work Plan (through FY 2022/23) is described below:

- An initial hydrogeologic conceptual model of the Northwest MZ-1 Area was developed, and a report was published in 2017.[3] 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[4] was published to document the results of the modeling and 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) 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 recommendations. In December 2022, the GLMC approved 1D Model calibrations and deemed them sufficient for simulation of future land subsidence under prospective plans for pumping and recharge.

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[2] Work Plan to Develop a Subsidence-Management Plan for Northwest MZ-1
[3] https://cbwm.syncedtool.com/shares/folder/PaauzoQapiZ/?folder_id=5150940
[4] https://cbwm.syncedtool.com/shares/folder/PaauzoQapiZ/?folder_id=5150942

- In the first half of 2023, the GLMC is developing an initial "Subsidence Management Alternative" 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 (projected hydraulic heads by CVM layer) will be used as input data for the 1D Model simulations to predict the potential future occurrence of subsidence through 2050. The GLMC will evaluate the predicted hydraulic heads versus the predicted compaction as simulated by the 1D Models, and then make the following determinations and/or recommendations:

    a. Determine the "acceptableness" of the predicted land subsidence.

    b. Recommend "subsidence management strategies" for Northwest MZ-1. These recommended strategies can be considered a preliminary or draft *Subsidence Management Plan for Northwest MZ-1*, and may come in the form of:

        i. Recommended operating ranges for hydraulic heads by aquifer layer.

        ii. Recommended groundwater management practices, such as pumping, recharge, the use of local storage, and/or the design of Storage and Recovery Programs.

    c. Recommend the minimum recharge quantity of supplemental water in MZ-1.

    d. Or, recommend additional work, such as developing additional SMAs, performing CVM and 1D Model simulations of the additional SMAs, and making revised determinations and/or recommendations based on the model results (*i.e.,* a. through c. above). Any additional SMAs must be approved by the GLMC before taking the next step to simulate the SMA with the CVM and the 1D Models.

Based on the expected progress through FY 2022/23, the following work is recommended for FY 2023/24 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[5]; (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.

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

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.

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

The forthcoming 2025 SYR will involve 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 evaluated for MPI and then used to evaluate the current Safe Yield of the Chino Basin. The GLMC should advise in the development of the 2025 SYR scenarios, so that the 1D Models can be used to simulate the land subsidence and support in the evaluation of:

- Potential subsidence-related MPI associated with the Safe Yield estimates.
- The minimum recharge quantity of supplemental water in MZ-1 as required by the Peace II Agreement.

Providing GLMC advice on the projection scenarios should be conducted in conjunction with the 2025 SYR and can be discussed at regularly scheduled GLMC meetings at no additional cost.[6] The model evaluations for MPI and for the minimum recharge quantity of supplemental water in MZ-1 would likely be conducted in FY 2024/25.

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

At the conclusion of FY 2022/23, the GLMC will have used the 1D Models at PX and MVWD-28 to develop recommended "subsidence management strategies" that can be considered the draft *Subsidence Management Plan for Northwest MZ-1*. In this task, additional 1D Models are constructed and calibrated across other Areas of Subsidence Concern in western Chino Basin, so that Watermaster can use all the 1D Models to:

- Evaluate for MPI during the 2025 SYR evaluation.
- Refine the draft *Subsidence Management Plan for Northwest MZ-1*.
- Evaluate for the minimum recharge quantity of supplemental water in MZ-1 as required by the Peace II Agreement.

This task will include the work to:

- Verify and/or recalibrate the 1D Model that was prepared by the GLMC in the Managed Area at the Ayala Park Extensometer.
- Construct and calibrate additional 1D Models in other Areas of Subsidence Concern, such as the Southeast Area around the Chino Desalter well fields and in the Northeast Area (City of Ontario).

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[6] 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.

The deliverables of this task will be the following:

- A draft TM will be prepared to describe the background/objectives of the task and the methods to complete the task. The methods will include a description of the proposed locations for the additional 1D Models and the methods to construct and calibrate the models. A GLMC meeting will be held to review the draft TM and receive GLMC feedback.
- A draft TM will be prepared that summarizes the validation, construction, and calibration of the additional 1D Models. A GLMC meeting will be held to review the draft TM, and a final TM will be prepared based on GLMC feedback.

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:

- July 2023 – Implementation of the GLMP for FY 2023/24
- September 2023 – Review the draft 2022/23 Annual Report of the Ground-Level Monitoring Committee
- Early March 2024 – Review the draft recommended scope and budget for FY 2024/25
- Late March 2024 – Review the final recommended scope and budget for FY 2024/25 (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 2024/25

This subtask includes preparing a draft and final recommended scope of services and budget for FY 2024/25 for the GLMC to support the Watermaster's budgeting process.

Comments and Responses to Comments

The comments received from the GLMC as of March 31, 2023 on the "Recommended Scope of Services and Budget of the Ground-Level Monitoring Committee for Fiscal Year 2023/24 (Draft)" and the Watermaster Engineer's response to comments are documented below.

Comments from the City of Chino (Eric Fordham)

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

Concur with recommended scope and budget.

Response:

n/a

Comment 2 – Task 2. Aquifer System Monitoring and Testing.

Concur with recommended scope and budget.

Response:

n/a

Comment 3 – Task 3.1. Acquire TerraSAR-X SAR Data and Prepare Interferograms for 2023/24

Has General Atomics agreed to continue providing their InSAR services and for how long? What would be the contingency and financial impact should they decide to discontinue their services mid-year?

Response:

General Atomics has decided to terminate its subcontractor agreement with the Watermaster and will no longer provide InSAR services. General Atomics is in the process of transmitting to the Watermaster Engineer all historical SAR data and intermediate/final work products that have been generated for the GLMC since 2011.

The Watermaster Engineer is exploring other options to continue the InSAR time series of estimates of vertical ground motion across the western portion of Chino Basin using the same TerraSAR-X data and data-processing methods. Once a proposal and cost estimate has been prepared, the Watermaster Engineer will bring the proposal to the GLMC for review and comment.

Comment 4 –Task 4. Perform Ground-Level Surveys.

We concur with the recommendations and time frames for conducting the ground-level surveys.

Response:

n/a

Comment 5 –Task 5.4. Conduct Whispering Lakes Subsidence Investigation and the Northeast Area.

Concur with the approach of using a process of elimination to assess potential mechanisms for the observed subsidence. The study efforts and budget should be balanced with the potential for MPI for this relatively limited area.

Response:

We agree with the comment. Any additional recommended work on this task will be included in the draft 2022-23 Annual Report of the GLMC for review and comment by the GLMC.

Comment 6 –Task 6.5. Construct and Calibrate Additional 1D Models Across Western Chino Basin

Prior to constructing additional 1D models, areas where additional land subsidence evaluation could potentially identify the need to mitigate or abate MPI should be screened as to the actual or perceived potential for land subsidence. The need for additional 1D compaction models may not be warranted.

Response:

The additional 1D Models would only be proposed within the “Areas of Subsidence Concern” across the western Chino Basin, which are areas defined in the Chino Basin Subsidence Management Plan. These are areas where subsidence is currently and persistently occurring, or the underlying geology makes these areas susceptible to aquifer-system compaction and permanent land subsidence.

To address this comment, a TM has been added to the scope of work to describe the background and objectives of the task and the methods to complete the task. The methods will include a description of the proposed locations for the additional 1D Models and the methods to construct and calibrate the models. A GLMC meeting will be held to review the draft TM and receive feedback from the GLMC before proceeding with the construction and calibration of the additional 1D Models.

Comment 7 – Meetings and Administration.

Concur with recommended scope and budget.

Response:

n/a

Comment 8 – Table 1

The table should identify any unspent or carry-over budget from the approved 2022/23 budget.

Response:

Currently, it is too early to predict unspent budget from FY 2022/23 that could be carried over to FY 2023/24.

Comments from the State of California (Rick Rees)

Comment 1 – Task 6.5. Construct and Calibrate Additional 1D Models Across Western Chino Basin

We suggest that that Subtask 6.5, "Construct and Calibrate Additional 1D Models Across Western Chino Basin," be broken out as a separate full task because it is not a component of Task 6, "Develop a Subsidence Management Plan for Northwest MZ-1."

Response:

A new Task 7 has been added to the text and Table 1 for the task: "Construct and Calibrate Additional 1D Models Across Western Chino Basin."