

## TECHNICAL MEMORANDUM

DATE: March 20, 2023

Project No. 22-1-020

TO: Madera Subbasin GSAs

FROM: LSCE and DE

**SUBJECT: Madera Subbasin Revised GSP - Land Subsidence Draft Workplan**

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### Introduction and Background

Some areas of the Madera Subbasin (Subbasin) have experienced recent land subsidence, as documented in the four revised Groundwater Sustainability Plans (GSP) covering the Subbasin. The Revised Joint GSP covers the largest fraction of the Subbasin and documents recent and historical land subsidence throughout the entire Subbasin. Much of the historical land subsidence in the Subbasin is believed to be caused by declining groundwater levels or piezometric head within the Lower Aquifer, mainly from areas below the Corcoran Clay<sup>1</sup>, and associated release of water from fine-grained sediments, ultimately resulting in compaction of these fine-grained sediments. In other areas of the San Joaquin Valley with long-term historical monitoring of both land subsidence and groundwater levels, land subsidence has been correlated with declining groundwater levels in the Lower Aquifer. Furthermore, considerable lag time between declining groundwater levels and land subsidence has been observed in other areas of the San Joaquin Valley. Within the Subbasin, limited long-term data are available for relating groundwater levels and land subsidence. As a result, there are gaps in the understanding of mechanisms and conditions related to land subsidence in the Subbasin, especially as it relates to how historical groundwater level decline may continue to cause ongoing residual land subsidence in the Subbasin, even as groundwater levels stabilize or rise in the future, as is planned for in the revised GSPs for the Subbasin.

The revised GSPs establish sustainable management criteria (SMC) for land subsidence with consideration of DWR review and input received in the initial GSP consultation letter. However, additional characterization of the relationship between groundwater levels and land subsidence and mechanisms for mitigating future land subsidence are important for confirming the SMC established in the revised GSPs are appropriate. This Workplan is intended to provide additional field data and technical analyses as

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<sup>1</sup> The Corcoran Clay (E-Clay of the Tulare Formation) is a laterally extensive and thick layer of clay present across large areas of the Subbasin and functions as a confining layer hydraulically separating the Upper Aquifer from the Lower Aquifer, where it exists.

input to better characterizing land subsidence for updates to the GSPs to be completed in 2025 (and beyond).

The Workplan outlines future efforts intended to address data gaps identified in the revised GSPs through enhanced monitoring and improving understanding of relationships between groundwater conditions and land subsidence in the Subbasin. The workplan also includes tasks to further evaluate sustainable management criteria (SMC) for land subsidence and support development of a coordinated approach to implementation of projects and management actions (PMAs) presented in the revised GSPs to address land subsidence and achieve sustainable groundwater management, as appropriate.

## Information Summarized in Revised GSP

As summarized in the revised GSPs, historical documentation of land subsidence in the Subbasin indicated limited land subsidence prior to the early 1970s. More recent monitoring using remote sensing information and data collected from benchmark surveys conducted for the San Joaquin River Restoration Program (SJRRP) has shown an increase in land subsidence in parts of the Subbasin since the mid-2000s. Over the period from 2007 through 2021, cumulative vertical displacement ranged from almost zero to more than five feet, with most land subsidence during this period focused in the western part of the Subbasin (see revised GSPs and **Figure 1**). The revised GSPs highlight where greater amounts of historical subsidence have occurred and where more focused monitoring and management of groundwater is planned to track and mitigate impacts to critical infrastructure from future land subsidence.

Although there is historical monitoring of land subsidence in the Subbasin, most of this monitoring has occurred at infrequent temporal intervals and with varying spatial resolution and distribution. Historical monitoring of groundwater levels, especially to support understanding of relationships between groundwater levels and land subsidence, has also been limited in most of the Subbasin. The revised GSPs summarize historical groundwater level and land subsidence monitoring and available data to directly compare groundwater levels and land subsidence. The available data do not indicate clear and consistent relationships between groundwater levels and land subsidence in the Subbasin, largely because of limitations in the temporal and spatial distribution of available historical monitoring data, and also because of the ongoing occurrence of residual land subsidence, which is discussed more below.

Although there are limitations in available data relating groundwater levels and land subsidence in the Subbasin, assessments of long-term and high-quality monitoring data in other parts of the San Joaquin Valley, such as those from nearby sites in the area of Mendota, indicate land subsidence in the San Joaquin Valley has largely been associated with groundwater level declines in the Lower Aquifer. Recognizing there is some amount of unavoidable residual land subsidence that will continue to occur in the Subbasin as a result of historical groundwater level declines, and that the amount of residual land subsidence is something the revised GSPs cannot address or mitigate, the revised GSPs outline an approach to minimize future land subsidence in an effort to avoid adverse impacts.

## Data Gaps Identified in Revised GSPs

As discussed in the revised GSPs, particularly the Revised Joint GSP, key aspects of land subsidence in the Subbasin that are not well understood or quantified relate to:

- Residual land subsidence, specifically differentiating residual land subsidence caused by historical conditions from new land subsidence caused by current conditions, and
- The mechanisms and conditions causing land subsidence in the Subbasin, including the relationship between land subsidence and declining groundwater levels, especially in the Lower Aquifer, within the local context of the Subbasin.

Robust land subsidence monitoring coupled with well-defined groundwater level monitoring will be important for tracking the different mechanisms related to land subsidence.

The revised GSPs note the potential opportunities and benefits related to improving the understanding of relationships between groundwater levels and land subsidence from:

- Continued monitoring of existing benchmarks, including the many land subsidence benchmarks in the Subbasin that are monitored by the United States Bureau of Reclamation (USBR) as part of the SJRRP, and
- Potential establishment of additional land subsidence monitoring sites coupled with depth-specific monitoring of groundwater levels in the Upper Aquifer and also in the Lower Aquifer at key locations.

## Workplan Objectives and Overview

This Workplan outlines a proposed scope of work to compile and review additional data and reports pertaining to land subsidence in the Subbasin, improve understanding of active production wells, establish or construct additional monitoring facilities, and conduct additional technical analyses. The Workplan incorporates consideration of comments and guidance provided by DWR during the initial GSP review and consultation stages. The purpose of this scope of work is to provide sufficient data and analyses to:

- Enhance monitoring and understanding of relationships between land subsidence and groundwater levels at different depths within the western part of the Subbasin;
- Refine mapping of geologic conditions related to land subsidence, including the thickness and extent of the Corcoran Clay and other clay units;
- Improve quantification of groundwater pumping within each of the two principal aquifers (Upper and Lower Aquifer);
- Develop estimates of the amount of expected residual land subsidence caused by historical groundwater conditions that cannot be avoided;
- Assess the adequacy of the PMAs and sustainable management criteria (SMC) included in the revised GSPs to address undesirable results related to land subsidence in the Subbasin; and
- Provide technical analyses to support the development of approaches to managing groundwater pumping and/or enhancing recharge to mitigate additional future land subsidence through implementation of PMAs, including consideration of transitioning of groundwater pumping from the Lower Aquifer to the Upper Aquifer performed in conjunction with enhanced recharge efforts.

## Scope of Work

The scope of work involved in completion of this Workplan includes seven main tasks, including collection and analysis of existing data (beyond data compiled for the Revised Joint GSP) and review of data gaps, installation of new monitoring facilities and collection of additional field data, completion of additional technical analyses, stakeholder outreach, and preparation of an updated assessment of the adequacy of the SMC and PMAs in the revised GSPs to address land subsidence. The scope of work to implement the Workplan is described in more detail below. Implementation of the potential work set-forth herein is predicated on Groundwater Sustainability Agency (GSA) approval and allocation of the necessary funds as may be required (local funding and/or grants).

### ***Task 1: Compile Additional Existing Data and Update Assessment of Available Data***

#### Compile and Synthesize Supplemental Existing Data

In this task, data collected during preparation of the Revised Joint GSP will be supplemented with other newly available data related to groundwater levels and land subsidence in the Subbasin and surrounding areas, with specific focus on the western part of the Subbasin. Available supplemental data that will be incorporated in this assessment may include the following:

- information presented in the GSPs for other subbasins and information presented in the different revised GSPs for the Madera Subbasin;
- new data from specific local landowners or entities previously not available for incorporation into the revised GSPs;
- DWR Well Completion Reports (WCRs) in key areas of the western Subbasin;
- additional data compiled by USBR for the SJRRP for areas in the Subbasin;
- additional data from coupled monitoring of groundwater levels and land subsidence at a site in the Mendota area with an extensometer, continuous GPS station, and dedicated monitoring wells;
- additional data from the United States Geological Survey (USGS) and modeling information for their study of the San Joaquin River; and
- other reports and data, including data or reports published as part of the implementation of the Subsidence Workplan planned for the Chowchilla Subbasin.

The available data will be compiled and reviewed to inform subsequent field work (Task 2) and used as inputs for technical analyses (Task 3). This task can be performed in coordination with similar efforts planned as part of implementation of the Interconnected Surface Water (ISW) Workplan proposed for the Subbasin.

#### AEM Data

Final data from airborne electromagnetic (AEM) surveys conducted in Spring 2022 to support additional characterization of subsurface conditions in the Subbasin and surrounding areas are expected to be available from DWR in 2023. AEM data can provide helpful information on hydrogeologic conditions

through measurements of the resistivity of subsurface materials. These surveys have the potential to improve the understanding of the configuration and composition of different subsurface materials. To the extent that AEM data were collected in the Subbasin, and specifically within the western part of the Subbasin, these data will be evaluated for their potential usefulness in helping to supplement the delineation of stratigraphy, especially within the Lower Aquifer where most of the historical and ongoing compaction is believed to occur. A quality assurance/quality control (QA/QC) analysis of the data will be conducted by comparing AEM hydrostratigraphic interpretations to existing and new field data collected as described in this Workplan and in coordination with efforts related to implementation of the ISW Workplan developed for the Subbasin. Lithologic data from borehole logs along AEM section lines will be compared to evaluate if AEM interpretations are consistent with field data. If AEM data interpretations are found to be consistent and the resolution of stratigraphic interpretations from the AEM data are sufficient, the AEM data will be combined with field borehole lithologic data to develop refined characterization of subsurface geologic materials and stratigraphic configuration, including the depth and thickness of prominent clay layers, including the Corcoran Clay.

### ***Task 2: Complete Additional Field Work***

Enhancements to groundwater level monitoring facilities and activities, specifically within the western Subbasin and in proximity to sites with historical land subsidence monitoring (e.g., SJRRP or other subsidence benchmarks) and planned future land subsidence monitoring, are important for improving the understanding of the relationships between groundwater levels and land subsidence across the Subbasin. Developing continuous groundwater level monitoring at finer temporal scales and at different depths in key areas where land subsidence monitoring is conducted will support understanding of the relationship between groundwater levels at different depths and any associated land subsidence, and will help differentiate residual land subsidence caused by historical groundwater conditions from active land subsidence related to current and future conditions. Instrumentation of suitably-located existing wells and installation of additional dedicated monitoring wells are two approaches that will be pursued to enhance the groundwater level monitoring in key areas for relating with land subsidence. Use of existing wells provides a cost-effective approach to enhancing the groundwater monitoring program and can reduce the need for installation of new monitoring wells, which can be more costly.

### **Identification and Instrumentation of Existing Wells**

This task will include identifying and prioritizing existing wells in key land subsidence monitoring locations, including land subsidence RMS, for instrumentation with automated continuous groundwater level monitoring equipment. Potential use of existing wells to enhance groundwater level monitoring in key areas of interest, especially near SJRRP land subsidence monitoring benchmarks, will be considered as the first step in efforts to improve groundwater monitoring for developing information to inform the assessment of the dynamics between groundwater levels and land subsidence. Use of existing wells for groundwater level monitoring is a cost-effective way to monitor groundwater conditions for the purpose of relating to land subsidence. This task involves working to identify existing wells with suitable well construction characteristics (e.g., well depth, screen interval) in key areas of interest for potential instrumentation and continuous groundwater level monitoring. Existing wells of interest for instrumentation in key areas will target wells completed (screened) within the Lower Aquifer since land

subsidence in the Subbasin is believed to be primarily a result of lowered groundwater levels in the Lower Aquifer. However, wells representing conditions within the Upper Aquifer will also be considered as potential opportunities to evaluate any relationships between groundwater levels in the Upper Aquifer and observed land subsidence. The identification and instrumentation of existing wells will enhance the understanding of relationships between groundwater levels and land subsidence for the purpose of evaluating land subsidence SMC, as defined in the Revised GSP. Furthermore, this work will also support enhancements to the GSP RMS monitoring networks in the Subbasin (if necessary and beneficial) and other ongoing groundwater level monitoring activities used to support GSP annual reporting efforts in the future.

The task involves working with the owners of suitable wells in key monitoring areas to prioritize and implement instrumentation of existing wells with automated pressure transducers for collecting continuous groundwater level data to limit the need for constructing new monitoring wells. As part of this task the feasibility and benefits of instrumenting RMS wells or other sites that are already part of the GSP land subsidence monitoring networks will be considered. It is assumed for purposes of estimating the cost of implementing the Workplan that a total of up to four existing wells (RMS and other) will be identified and selected for instrumentation under this task.

### New Monitoring Facilities

This task will identify and install new monitoring wells and new land subsidence monitoring facilities in key areas of the Subbasin where data gaps exist. Providing robust coupled groundwater level and land subsidence monitoring is important in ensuring land subsidence metrics are appropriate and recognize the expected occurrence of some amount of residual subsidence, even if groundwater levels are stable. The presence of critical surface infrastructure in the western areas of the Subbasin also warrants enhanced monitoring of groundwater conditions in this area. Enhancements to existing land subsidence monitoring in the Subbasin also have the objective of differentiating land subsidence by depth zone, and would also benefit the understanding of relationships between groundwater levels and land subsidence. Current and continuing land subsidence monitoring being conducted by DWR using remote sensing and also as part of the SJRRP benchmark surveying provide broad spatial and temporal coverage of land subsidence, although they do not differentiate the depth where land subsidence is occurring and relationships to groundwater levels. Proposed field efforts related to addressing these objectives are described in more detail below.

### New Monitoring Wells

Monitoring wells are recommended for installation at five locations based on considerations related to locations of critical infrastructure, historical land subsidence, existing SJRRP benchmark survey sites, and existing groundwater level monitoring (especially RMS and dedicated monitoring well locations). These monitoring wells will augment existing groundwater level monitoring for enhanced monitoring of groundwater conditions in key areas of the Subbasin and to support improved understanding of the dynamics between groundwater levels and land subsidence. The five proposed locations are in areas where the greatest amount of historical land subsidence has occurred in the Subbasin. New monitoring wells will be designed to include nested monitoring wells for independent monitoring of conditions in the Upper and Lower Aquifers. The new monitoring wells are anticipated to extend to depths of approximately

700 to 800 feet and consist of three independent casing strings screened at different depths, depending on unique site conditions. Preliminarily identified priority locations for potential new nested wells are shown in **Figure 1** along with key information considered in preliminary site identification. Final site selection will consider the outcome from review of additional data and evaluation of site suitability relating to access for construction and ongoing monitoring.

The monitoring wells are planned to be drilled using the direct rotary drilling method with sediment samples collected every ten feet and downhole geophysical logging completed over the entire depth of the boreholes. A lithologic log of the borehole will be prepared based on samples collected and results from geophysical logging under the supervision and guidance of a Professional Geologist, who will also provide recommendations regarding well construction details such as depth intervals for placement of well screen, filter pack, blank casing, and surface sanitary seal. Preliminarily, the new monitoring wells are planned to be constructed using 2-inch diameter Schedule 40 PVC materials, which will enable installation of automated groundwater level monitoring instrumentation and also provide access for groundwater quality sampling equipment. The new monitoring wells, and any existing wells instrumented as described above, will be surveyed to a consistent elevation datum. Water quality samples will be collected from the new monitoring wells for the purpose of characterizing general geochemical conditions, and they will be outfitted with pressure transducers for ongoing automated collection of groundwater level data.

### *New Land Subsidence Monitoring*

The need and benefit of establishing new land subsidence benchmark monitoring sites for monitoring through periodic elevation surveys or alternatively by establishing sites for ongoing review of land surface elevation changes based on remote sensing InSAR data provided by DWR will be evaluated and implemented as determined appropriate. Any new land subsidence monitoring facilities would be intended to track land subsidence conditions at new monitoring well sites. The planning of any additional subsidence monitoring sites should be coordinated with other land subsidence monitoring efforts occurring in the area, including work being conducted as part of monitoring by the USGS, the California Department of Water Resources (DWR), USBR, and any other interested entities. There may be opportunities to support additional land subsidence monitoring through acquisition of grants or technical support services provided by DWR or through other avenues. The details of potential additional land subsidence monitoring sites should be developed in coordination with any cooperators and with consideration of any new data compiled and evaluated as part of implementation of this Workplan.

## Inventory of Production Wells

### *Desktop Well Inventory*

Documentation of active production wells in the western Subbasin is important for accurately assessing and planning groundwater management activities as they relate to mitigating land subsidence. Achieving groundwater sustainability in the Subbasin, especially in relation to land subsidence, involves ensuring that groundwater extractions do not cause chronic lowering of groundwater levels, especially in the Lower Aquifer. Accurately documenting the locations and construction characteristics of active production wells in the western areas of the Subbasin will provide important information for ensuring appropriate management actions are developed and implemented to address this issue. A desktop evaluation of

available information on active production wells in the western Subbasin will seek to identify likely active production wells and their construction characteristics, especially as they relate to screened interval and zone of production. The desktop well inventory will utilize data from WCRs, well permits, or other sources and will outline appropriate field work activities to refine information developed through the desktop inventory. To the extent possible, this task will coordinate with work being conducted for the ISW Workplan and will build on previous evaluations performed during the initial development and later revision of the GSPs and the domestic well inventory completed as part of a Proposition 68 grant project for the Subbasin along with ongoing mapping of wells conducted by the GSAs.

### Field Survey of Active Production Wells

The desktop inventory of active production wells in the western Subbasin will provide the basis for outlining field work efforts to refine or confirm the information developed from the desktop inventory. The surveying of active production wells in the western Subbasin is anticipated to include targeted efforts through utilizing outreach and field reconnaissance. The field survey will likely focus on areas with higher well densities and/or greater levels of uncertainty relating to existing well status and construction characteristics as informed by evaluation of available data and results from the desktop inventory. The field survey may include focused review of aerial photographs, personal communication with landowners, field visits or other field reconnaissance activities, and other approaches to refine information developed from the desktop inventory.

### ***Task 3: Technical Analyses***

In this task, technical analyses will be conducted to synthesize the available information on dynamics between groundwater levels and land subsidence focused on the western Subbasin by evaluating fluctuations in groundwater levels and land subsidence and by evaluating relationships between groundwater pumping and land subsidence. This task will be completed in coordination with and utilizing new information from compilation of additional available data (Task 1) and field work related to additional monitoring and characterization of groundwater conditions and land subsidence (Task 2). Data from nearby land subsidence monitoring sites near Mendota conducted with a combination of extensometer readings and continuous GPS readings will be incorporated in technical analyses together with interpretations from land subsidence monitoring across the San Joaquin Valley highlighting relationships between inelastic compaction and land subsidence related to lowering of water levels and piezometric head in fine-grained materials within the Lower Aquifer.

Field and monitoring data will be evaluated relative to the relationship between groundwater levels in both the Upper and Lower Aquifers and land subsidence and consideration of ongoing residual land subsidence. Available information suggests that the lack of clear and consistent relationships between groundwater levels and land subsidence may be partly a result of the continued residual land subsidence resulting from historical conditions. Analyses presented in the Revised GSPs based on the limited available historical data suggest that there is limited correlation between shorter-term groundwater level changes and land subsidence, although historical groundwater conditions and the persistence of conditions over longer periods may be the most important drivers related to land subsidence.

Technical analyses will also include conducting refinements to existing available information on the mapped extent and thickness of the Corcoran Clay and other clay layers. This task will involve review of new lithologic information collected through construction of new monitoring wells, including new wells installed at key land subsidence monitoring sites as described in Task 2, and also wells constructed for the ISW Workplan and for other the Subbasin monitoring efforts conducted through Proposition 1 and Proposition 68 grant projects. The ability to incorporate any data developed from the AEM surveys conducted by DWR in the Subbasin will also be considered in these refinements.

#### ***Task 4: Groundwater Modeling (in Conjunction with 5-Year GSP Update)***

Distinguishing between residual land subsidence resulting from historical groundwater conditions and active land subsidence caused by current conditions is a challenging aspect of evaluating appropriate metrics for ensuring sustainable groundwater management. Modeling techniques represent one of the most robust approaches available for evaluating this aspect of groundwater conditions. Key objectives of the modeling to be conducted under this task include 1) estimating the amount, rate, and duration of residual land subsidence likely to occur resulting from historical groundwater conditions, and 2) estimating total anticipated future land subsidence. Additional modeling to be completed as part of Task 7 will assist in evaluating approaches and mechanisms for ensuring groundwater sustainability is achieved in accordance with the Revised GSPs through transitioning of groundwater pumping from the Lower Aquifer to the Upper Aquifer in coordination with projects planned to augment water supplies and enhance recharge. The modeling planned for completion as part of this Workplan is separate from, but will occur in coordination with, other modeling efforts to be completed for the purpose of the first five-year update of the Revised GSPs, which are anticipated to focus on general updates to the numerical groundwater flow model developed to support preparation of the GSP (MCSim) involving extending the historical simulation period, updating hydrology, and updating simulations of PMAs included in the Revised GSPs.

Two potential modeling approaches would help in evaluating historical and projected land subsidence in the Subbasin and differentiation of residual land subsidence from active land subsidence.

The first modeling approach involves using MCSim. At the time the GSP was initially developed, MCSim did not include the ability to simulate subsurface compaction or land subsidence because the Integrated Water Flow Model (IWFM) modeling platform, upon which MCSim is built, did not include this capability. The ability to simulate land subsidence has since been added to IWFM. The modeling task will include implementing the IWFM subsidence module in MCSim and conducting updated model scenarios to evaluate historical and projected future land subsidence. Groundwater modeling scenarios would be conducted with the primary purpose of estimating future land subsidence under varying future conditions, including varying levels of groundwater pumping and under conditions with and without PMAs described in the Revised GSPs.

Updating MCSim with the subsidence module and refined information on active production well distribution developed in previous tasks will improve the accuracy of all model simulations. The MCSim modeling efforts will assist further in understanding the relationship between groundwater levels and land subsidence, both within the Upper Aquifer and Lower Aquifer, continued assessment of mechanisms

to limit future land subsidence and avoid adverse impacts, and evaluation of land subsidence SMC to ensure they are appropriate for defining sustainable groundwater management.

The second modeling approach would consider more simplified, one-dimensional modeling techniques to better quantify residual and active land subsidence in localized areas. Such modeling approaches would support a better understanding of site-specific subsidence mechanisms and projections and could assist in evaluation of the relationship between historic and current groundwater levels and land subsidence, although this modeling method presents limitations with respect to the ability to simulate groundwater conditions at the subbasin scale. One-dimensional modeling would complement the use of MCSim to estimate residual land subsidence; the need for this additional modeling will be evaluated during the course of implementation of the Workplan and evaluation of results from technical analyses and MCSim modeling efforts. However, one-dimensional modeling is included for the purpose of estimating the level of effort to implement this Workplan.

### ***Task 5: Stakeholder Outreach and Interbasin Coordination***

Implementation of the Workplan should involve outreach and coordination with key stakeholders and interested parties. This would include communication with stakeholders associated with critical infrastructure in and around the Subbasin. Outreach efforts should focus on efforts related to the need and benefit from additional groundwater level or land subsidence monitoring and prioritization of efforts to expand monitoring. An additional objective of outreach efforts includes coordination related to the understanding of critical land subsidence thresholds related to damage to infrastructure or other adverse impacts to infrastructure. Furthermore, outreach efforts may also benefit considerations related to the feasibility of potential PMAs to achieve sustainability. Outreach and coordination with adjacent subbasins about land subsidence issues will be a continuing aspect of tracking of groundwater level and land subsidence conditions.

### ***Task 6: Assess the Adequacy of Revised GSP SMC***

An important outcome from efforts conducted as part of this Workplan will be an assessment of the adequacy of current land subsidence SMC and the associated RMS network and need for any revisions to these SMCs as part of updates to the Revised GSPs. The assessment will consider data and analyses developed through implementation of Tasks 1 through 5 of the Workplan and relationships between groundwater levels and land subsidence and the differentiation of residual land subsidence from new active subsidence established through that work. The continued occurrence of residual land subsidence is an important consideration related to how land subsidence SMC are established for the Subbasin, since impacts from residual land subsidence are largely unavoidable. As noted in the Revised GSPs there is some amount of unavoidable residual land subsidence that continues to occur in the Subbasin as a result of historical groundwater conditions. The amount of residual land subsidence is something the Revised GSPs cannot address or prevent, although the Revised GSPs do outline approaches to minimize future land subsidence in an effort to avoid adverse impacts.

The review and assessment of SMC completed under this task will inform decisions on revisions to land subsidence SMC for incorporation in future updates to the Revised GSPs. Future GSP updates will draw upon the most recent data and technical analyses developed through implementation of this Workplan

with consideration for the complexities of the impacts of residual land subsidence resulting from historical conditions that preceded submittal or implementation of the Revised GSPs. The outcomes from assessment of SMC will be summarized in deliverable documents to be prepared as part of Task 8. Some data generated through the completion of the field activities outlined in the Workplan may not be available until after completion of the five-year update of the GSP. As described in the scope of work for Task 8, an initial assessment of the SMC will be conducted to support the five-year update of the GSP to be completed by January 2025. A subsequent deliverable document prepared after completion of all field work will include a summary of all Workplan activities.

### ***Task 7: Technical Support for Development of a Strategy for Managing Groundwater Pumping and Recharge in the Western Subbasin***

An integral aspect of achieving sustainability in the Subbasin involves mitigating future land subsidence to the extent possible, which will require management of groundwater pumping in coordination with enhancing groundwater recharge. Task 7 of the Workplan will involve efforts to refine the understanding of existing groundwater pumping and the vertical and lateral distribution of pumping as the foundation for developing management approaches to mitigate additional land subsidence caused by pumping. These efforts will rely on data from inventorying of existing active wells in the western Subbasin through desktop review and field verification coupled with technical analyses to support groundwater management planning in the Subbasin related to reducing pumping from the Lower Aquifer with the intent to mitigate future land subsidence. Key components of this effort are described below.

#### **Refined Analyses of Pumping Distribution in the Western Subbasin**

Using information assembled through the well inventory tasks in conjunction with data related to groundwater demands derived from groundwater modeling and other water budget analyses, refinements to the assessments of the volumes and spatial distribution (laterally and vertically) of pumping in the western Subbasin will be conducted. The primary objective of this task will be to refine estimates of the amount of groundwater pumping that is occurring in the Lower Aquifer as it relates to the sustainability planning for the Subbasin. The results from this task will inform efforts related to assessing PMAs planned to achieve groundwater sustainability.

#### **Evaluation of Scenarios for PMA Implementation to Mitigate Land Subsidence**

Task 7 will include conducting evaluations of approaches and mechanisms for redistributing pumping in the western Subbasin in a manner that is consistent with sustainability goals and metrics defined in the Revised GSPs, analysis of costs and other considerations relating to the feasibility of different approaches, and assessing the timing needs associated with implementation of potential management actions. These technical analyses will consider the lateral distribution of pumping within the western Subbasin and the vertical distribution between the Upper and Lower Aquifers. A key aspect of these technical analyses will involve consideration of management approaches that recognize the existing or planned groundwater recharge efforts, which focus on enhancing recharge in the Upper Aquifer, to achieve a distribution of groundwater pumping that is consistent with sustainability objectives defined in the Revised GSPs. Numerical groundwater modeling will be used to test PMA implementation scenarios and evaluate the effectiveness of different implementation strategies for mitigating land subsidence.

## Prepare a Technical Summary Document to Inform Policymaking

A technical summary document will be provided at the conclusion of this task for use by the GSAs in developing management strategies to mitigate future subsidence. This document will synthesize technical information developed through completion of the task (and information available from completion of other tasks outlined in the Workplan) relating to how much, where, and when PMAs may be appropriate to achieve necessary reductions of Lower Aquifer pumping and potential mechanisms to achieve these reductions. The goal is to provide the GSAs with a technical basis for their development of policies and a plan related to implementation of PMAs to avoid undesirable results related to land subsidence in the Subbasin. The assessment conducted under this task will consider the importance of developing a strategy that coordinates the management of groundwater pumping in conjunction with enhanced groundwater recharge efforts. The technical summary document for Task 7 will be provided as an interim deliverable intended to support the GSA development of management policies, which may need to be implemented prior to the completion of the entire Workplan.

### ***Task 8: Prepare a Technical Memorandum or Report***

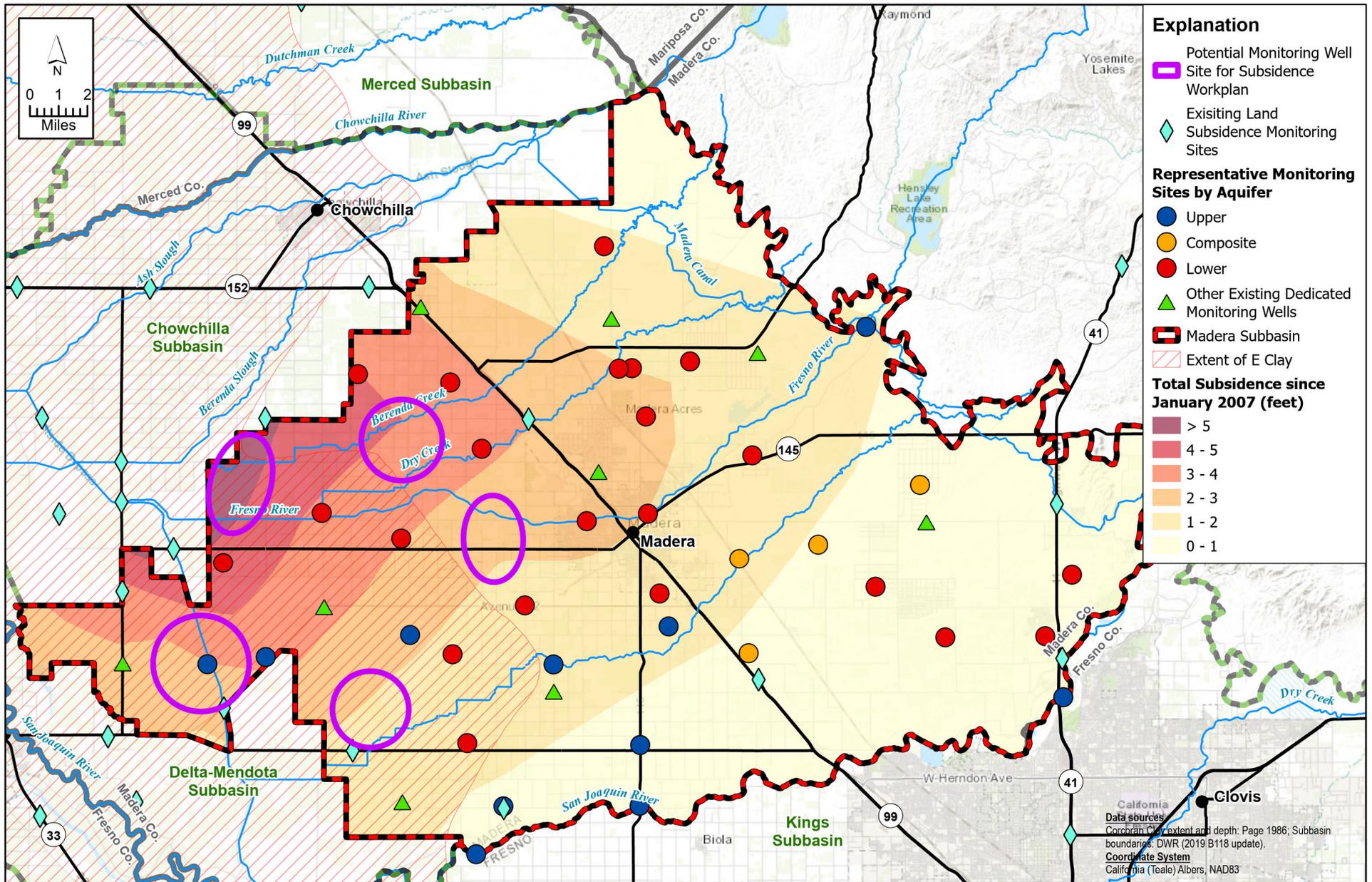
A technical memorandum (TM) or report will be prepared to document all the tasks completed as part of implementation of this Workplan. An interim TM/Report deliverable will be prepared to inform the five-year GSP update efforts occurring prior to January 2025. A Final TM/Report will be prepared and submitted at the time of completion of all field work outlined in the Workplan. For each of the deliverables prepared as part of Task 8, a draft TM/Report will be submitted to the GSAs (and their technical representatives) for review. Comments and suggested edits received from the GSAs will be reviewed and incorporated as appropriate into final versions of the deliverable documents. The deliverable documents will include documentation of all data compiled, field work completed, technical analyses performed, modeling results, and evaluation of the nature of relationships between groundwater levels and land subsidence, and recommended updates to the Revised GSPs' SMC and potential management actions to ensure sustainable groundwater management is maintained in the Subbasin. In addition, the deliverable documents will include a review and summary of any remaining data gaps and recommendations for future monitoring and assessment, as needed.

## Schedule

The overall implementation of this Workplan is envisioned as a longer-term effort to develop important monitoring data and facilities for tracking and understanding groundwater conditions related to land subsidence in the Subbasin. However, several tasks are intended to support shorter-term objectives, including the development of a plan for managing groundwater pumping and recharge to mitigate subsidence. Additional tasks are geared towards completion in time for incorporation into the first five-year update of the Revised GSPs. However, some tasks described in the Workplan will likely extend beyond January 2025, including ongoing data collection. These longer-term tasks include field work involving installation of monitoring facilities, which should be phased with consideration of funding and cooperation from other entities needed to support these efforts. Implementation of the Workplan is planned to start in 2023 with commencement of the additional data review and compilation task. Similarly, field work is also planned to begin in 2023, primarily with well inventory survey efforts and

review of opportunities to instrument existing wells. Planning related to field work including the installation of new dedicated monitoring facilities for groundwater levels and land subsidence should begin in early 2023, although the completion of this work is anticipated to extend over multiple years. As a result, not all of the field work described in this Workplan is anticipated to be completed prior to January 2025 when the first five-year update of the Revised GSPs is to be submitted. A general planned schedule for implementation of the Workplan is outlined below in **Table 1**.

Table 1. Summary of Proposed Schedule for Implementation of the Land Subsidence Workplan		
Task No.	Task Description	Task Completion Timeframe
1	Compile Additional Existing Data and Update Assessment of Available Data	Mid 2023 - Late 2023
2	Complete Additional Field Work	Late 2023 - 2026+ (field work may be phased depending on available funding)
3	Technical Analyses	Mid 2023 - Late 2024
4	Groundwater Modeling (in Conjunction with 5-Year GSP Update)	Early 2024 - Late 2024
5	Stakeholder Outreach and Interbasin Coordination	Mid 2023 - Late 2024+
6	Assess the Adequacy of Revised GSP SMC	Late 2023 - Late 2024
7	Technical Support for Development of a Strategy for Managing Groundwater Pumping and Recharge in the Western Subbasin	Mid 2023 – Mid/Late 2024
8	Prepare a Technical Memorandum or Report	Mid 2024 - Late 2024 for interim deliverable; 2026+ for final deliverable



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**FIGURE 1**



**Potential New Nested Monitoring Well and Land Subsidence Monitoring Sites**

*Madera Subbasin  
Groundwater Sustainability Plan*