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TECHNICAL MEMORANDUM

DATE: March 26, 2025 **PROJECT #:** 9100.8802

TO: Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA)

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PROJECT: Salinas Valley Hydrogeological Conceptual Model (HCM) Update

SUBJECT: Monterey Subbasin HCM Update: Data, Methods and Findings

INTRODUCTION

The Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA), Marina Coast Water District Groundwater Sustainability Agency (MCWDGSA), and other partner agencies have analyzed new information and filled data gaps identified in the Monterey Subbasin (Subbasin) Groundwater Sustainability Plan (GSP) (MCWDGSA and SVBGSA, 2022). Montgomery & Associates (M&A) and EKI Environment & Water (EKI) used this new information to update the Subbasin's Hydrogeologic Conceptual Model (HCM) to better inform management decisions and prepare for the upcoming 5-year Periodic Evaluation. EKI's efforts primarily focused on the Marina-Ord Area, which corresponds to MCWDGSA's primary management area. To acquire and analyze data, M&A and EKI worked with partner agencies such as Monterey County Water Resources Agency (MCWRA) and California American Water. The updated HCM strengthens and refines the geologic model that forms the basis for the groundwater flow modeling.

The HCM update focused on key areas where new data indicated that an updated understanding was needed. The primary updates to the HCM included the following:

- Updating the location and character of the bedrock surface including offshore geology, and subsequently revising the primary aquifers above the bedrock as needed
- Incorporating the results of the *Deep Aquifers Study* (Study) (M&A, 2024) by refining the extent and depth of the Aquitard that separates the 400-Foot Aquifer from the Deep Aquifers (400/Deep Aquitard)

- Incorporating previous studies with new data to modify the coastal aquitards to refine known extents, gaps, and thin spots
- Based on the updated aquifers and aquitards, refining the relationships with the Seaside Basin and the 180/400-Foot Aquifer Subbasin (180/400 Subbasin) and refining the connection between the Coastal and Corral areas of the Monterey Subbasin

For the purposes of the HCM update, the Coastal Area of the Monterey Subbasin refers to the areas on the northwestern arm of the Laguna Seca Anticline, and the Corral Area refers to the areas on the southeastern arm of the Laguna Seca Anticline. Although these are geologic designations to focus on the hydrogeologic setting, they generally coincide with the Management Area designations defined in the GSP (Figure 1). Therefore, the terms “Coastal Area” and “Marina-Ord Area” are also used interchangeably in this document. This memo summarizes the data used, the analyses and methods employed, and the findings for the updated Monterey Subbasin HCM.

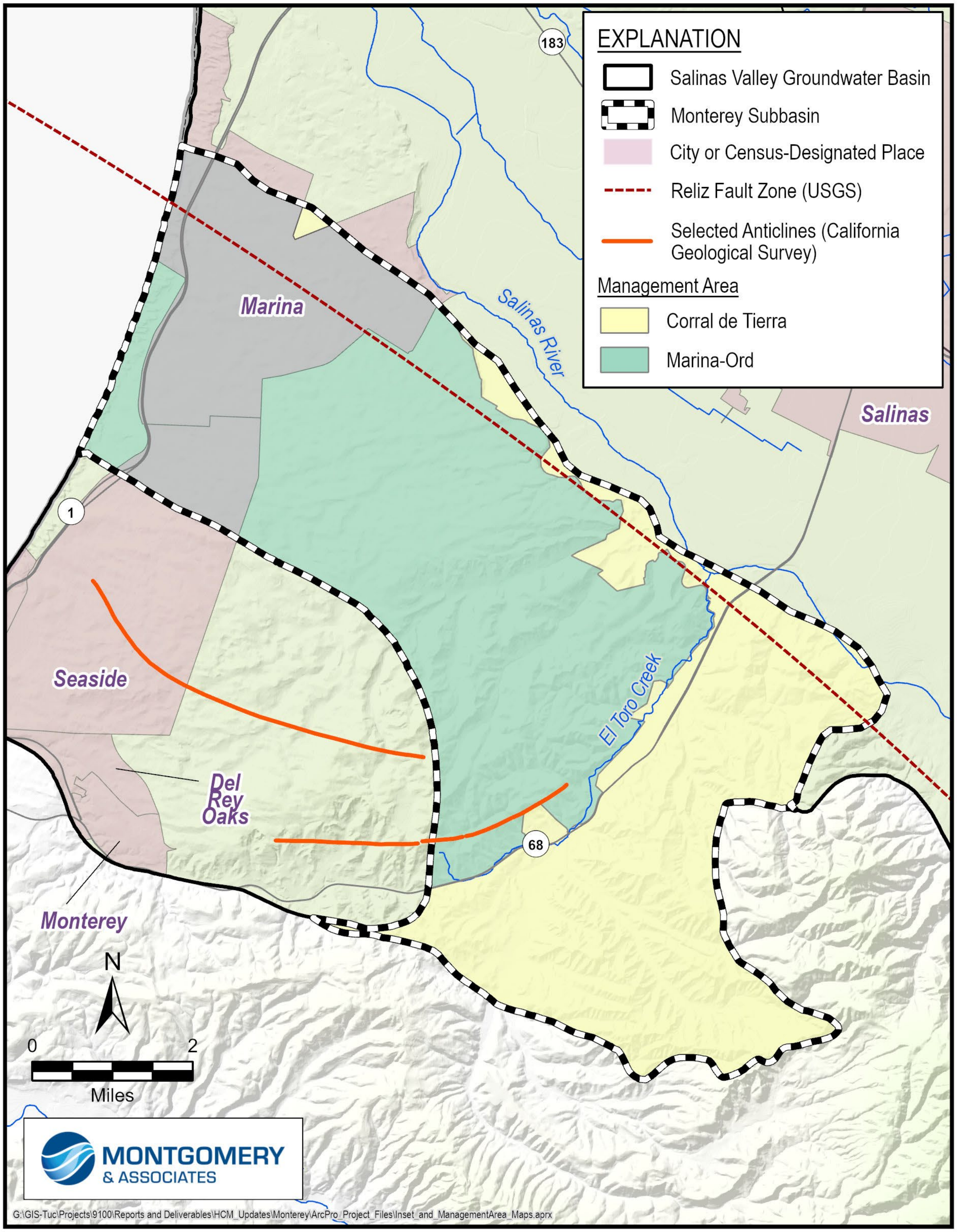

Figure 1. Monterey Subbasin Management Areas and Mapped Anticlines

DATA

The data used to update the HCM include published cross sections and reports, well completion reports (WCRs), numerical groundwater flow model layers, geophysical data, and geologic maps, as detailed in the following subsections.

Published Cross Sections and Reports

The 2022 GSP summarized published cross sections and reports. For this HCM update, the following reports and cross sections were re-reviewed, compared with new data and information, and incorporated into the revised HCM. These included:

- *Hydrogeologic Investigation of Salinas Valley Basin in the Vicinity of Fort Ord and Marina Salinas Valley, California - Final Report* (Harding ESE, 2001)
- *El Toro Groundwater Study Monterey County, California* (GeoSyntec, 2007)
- *Accompanying Documentation Geologic Map and Cross-Sections from El Toro to Salinas Valley* (GeoSyntec, 2010)
- *Deep Aquifer Investigation - Hydrogeologic Data Inventory, Review, Interpretation and Implications* (Feeney and Rosenberg, 2003)
- *Final Report, Hydrostratigraphic Analysis of the Northern Salinas Valley* (Kennedy/Jenks, 2004)
- *Hydrogeologic Report on the Deep Aquifer, Salinas Valley, Monterey County, California* (Thorup, 1976 and 1983)
- *Map Series — Monterey Canyon and Vicinity, California: U.S. Geological Survey Open-File Report 2016–1072* (Dartnell et al, 2016)
- *Deep Aquifers Study* (M&A, 2024a)

Well Completion Reports (WCRs)

WCRs helped refine geologic interpretations and included important information such as driller-observed lithology, screen intervals, and dates of well installation. Some WCRs were more detailed than others with more frequent lithologic descriptions, electric logs (e-logs), and other construction or water level details.

M&A obtained WCRs through the California Department of Water Resources (DWR) Online System for Well Completion Reports (OSWCR) database, the County of Monterey Health Department (MCHD), MCWRA, MCWD, the U.S. Army, other collaborating partner agencies, and private entities. The combination of WCR data helped refine the extents, gaps, and thin spots of the shallower aquitards in the coastal areas of the Monterey Subbasin.

Numerical Groundwater Flow Model Layers

Previous and current groundwater flow models reflect various conceptual understandings of the Subbasin. Models reviewed for the HCM update included:

- The Salinas Valley Geologic Model (Sweetkind, 2023). This document defines the spatial extent, depth, and distribution of geologic materials and textures for the provisional Salinas Valley Integrated Hydrologic Model (SVIHM). It was developed by the USGS, which covers the entire Salinas Valley and includes a geological framework with documentation.
- The Monterey Subbasin Groundwater Flow Model (MBGWFM) (EKI, 2022). This model was developed for MCWD and informed the 2022 Monterey Subbasin GSP. It covers the Monterey Subbasin and an adjacent part of the 180/400 Subbasin southwest of the Salinas River.
- The Seaside Basin Model (HydroMetrics Water Resources, 2009). This model was developed for the Seaside Basin Watermaster and covers the Seaside Basin and adjacent parts of the Monterey Subbasin.
- The Salinas Valley Seawater Intrusion Model (SWI Model) (M&A, 2023; 2024b). This model was developed by M&A for SVBGSA and the County of Monterey in 2023 and covers the coastal area of the Salinas Valley north of Chualar. It was updated based in part on the HCM updates included in this memo in 2024.

These models were primarily used to compare and refine the depths and thicknesses of the hydrostratigraphic layers within the Salinas Valley Groundwater Basin.

Geophysical Data

The following 3 primary types of geophysical data were used in this HCM update:

- Airborne Electromagnetic (AEM) resistivity data. These data were collected by the California Department of Water Resources (DWR) and SVBGSA between 2020 and 2023, and by MCWD in 2017 and 2019. The AEM data provide a broad coverage of general lithologic trends.
- Borehole resistivity data. These geophysical data are collected in boreholes prior to well installation and provided detailed interpretation of localized lithology.

- Seismic data. Seismic data used in this HCM update were from the USGS (Dartnell *et al.*, 2016) and provided stratigraphic information about offshore geology.

The first 2 types of data are electrical resistivity data, which are collected by sending electrical pulses into the subsurface and receiving signals back. The third type of geophysical data, seismic data, is collected from measuring the reflected, refracted, and direct waves from an active wave source, such as an explosion or hammer impact.

AEM Data

AEM surveys measure the resistivity of both solid and liquid materials in the subsurface over large areas. Lower resistivity materials are clays, silts, and/or higher total dissolved solids (TDS) water. Higher resistivity materials are sands and gravels, some types of bedrock, and/or lower TDS water. AEM data are useful for filling gaps between known data points such as wells. This effort focused on reviewing and analyzing the lower resistivities at various target depths where aquitards are expected.

This effort primarily used 3 sets of AEM surveys to fill data gaps, confirm other data, and refine the primary aquifers and aquitards. These data came from the following sources:

- DWR Survey Area 1, 2020 (DWR, 2020)
- DWR Survey Area 8, 2022 (DWR, 2022)
- Deep Aquifers Survey, 2023 (M&A, 2024)

The MCWD 2017 and 2019 AEM surveys of the coastal Salinas Valley area were also used to verify aquitard extents in the Marina-Ord Area where few other data were available (Stanford/Aqua Geo Frameworks, 2017; Aqua Geo Frameworks, 2019).

E-logs/Borehole geophysical logs

Borehole geophysical logs measure the resistivity of materials in the subsurface adjacent to a borehole. Like AEM data, borehole geophysics can help qualitatively differentiate between clays, silts, sands and gravels, high TDS water, and low TDS water. Borehole geophysics data show much more detail than AEM data, but only reflect conditions immediately adjacent to a borehole. Borehole geophysical logs were sourced from other studies or included with WCRs.

Seismic Data

Seismic data are collected from measuring the reflected, refracted, and direct waves from an active wave source such as an explosion or hammer impact. The seismic waves travel through the subsurface, reflect off various lithologic surfaces, and return to the ground surface. Based on the timing of the waves, investigators can determine the locations and general rock types of the subsurface lithology up to a few kilometers below land surface. Seismic survey data from the *Seismic Study in Monterey Bay* (Dartnell *et al.*, 2016) were used to refine the offshore portion of the HCM.

Geologic Maps

Geologic maps provide a visual representation of the rocks, formations, and structures encountered at land surface. The 3 primary maps used for this HCM update were the Rosenberg 2001 Monterey County digital geologic map, the Clark *et al.*, 2002 surface geologic map of the Spreckels quadrangle, and the subsequently revised version of the onshore and offshore geology derived from the Dartnell *et al.*, 2016 Seismic Study in Monterey Bay. These geologic maps supplemented other data during the HCM update by verifying surface expressions of the various lithologic units.

Groundwater Elevations

While groundwater elevation data are not a form of geologic information, they are valuable in identifying where aquitards effectively separate aquifers and where discontinuities may create hydraulic connections, particularly in areas where geologic data are sparse or inconclusive. When aquitards are laterally extensive and effectively confining, significant differences in groundwater elevations can be expected between adjacent aquifers. Conversely, where aquifers are absent or discontinuous, groundwater elevations may equalize, indicating hydraulic connectivity between the aquifers.

In urban areas near the City of Marina, where high-coverage AEM data could not be collected due to infrastructure interference, groundwater elevation data were used in conjunction with WCRs to further support the presence or absence of the aquitards.

Empirical Observation

On April 8, 2024, M&A staff accompanied former Monterey Peninsula Water Management District Water Resources Manager Joe Oliver on a field trip to observe local geologic features in the Subbasin. The field trip went from the Monterey Regional Airport to Laureles Grade Road, down Robley Road to Corral de Tierra Road, to a parking area below Cypress Community Church, north along State Route 68, and then west along Reservation Road. Mr. Oliver spoke at length about the local geology encountered in this Subbasin.

Mr. Oliver pointed out surficial outcrops of the geologic formations that define the bedrock and aquifers in the Subbasin. Field trip stops included discussions of generalities and variance within the formations. The M&A team was able to make hands-on observations of these rocks, which provided critical insight into the Subbasin's subsurface character.

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METHODS

The Subbasin hydrostratigraphy was updated through the following steps:

1. Integrating and reviewing the data using Leapfrog Geo visualization software
2. Prioritizing data based on reliability and availability
3. Selecting the best data to define the new hydrostratigraphic layers
4. Contouring the data to create new hydrostratigraphic layers within Leapfrog Geo software

Geologic Visualization Software

Leapfrog Geo software, developed by Seequent, was the primary 3D visualization software used to relate and analyze the different types of data described above. All data were imported into the software and methodically reviewed and compared to each other.

Data Prioritization

Various data have differing levels of confidence. The list below demonstrates the general hierarchy of confidence in the various data types used in this analysis, starting from highest (1) to lowest (7) confidence.

1. Geologic maps
2. Empirical Observations
3. Published cross sections and reports, unless more recent data were available
4. Borehole logs (well completion reports and e-logs)
5. AEM and seismic data
6. Groundwater Elevations
7. Numerical groundwater flow models

Concurrently using multiple data sources can improve confidence in geologic interpretations. For example, confidence in AEM data can be significantly improved when it is combined and coordinated with geologic maps or borehole logs.

Data are not uniformly distributed throughout the Monterey Subbasin. Wells and associated WCRs are more concentrated in areas with more infrastructure, whereas AEM flightlines generally cover areas with less or no infrastructure. Therefore, hydrogeologic interpretations are more strongly influenced by availability of data in different areas.

Hydrogeologic interpretations initially focused on areas with a higher density of multiple data types to cross validate these data. Developing confidence in any data type allowed analyses using those data to expand horizontally and vertically, and revise the HCM as needed.

The decision-making procedures for updating the HCM generally used the following guidelines. These guidelines do not represent a decision-making hierarchy, rather they are a group of guidelines that interact in various ways based on circumstances in each particular area of focus.

- Newer geologic maps were prioritized over older geologic maps.
- Newer published cross sections were prioritized over older published cross sections, unless there was higher confidence in older cross sections based on the author and how the sections correlated with other data.
- Geologic maps provided anchor locations for the geologic surface contacts, including bedrock contacts, where available.
- Empirical observations provided refined details, insights, and contextualized the geologic formations within the hydrostratigraphic framework.
- The hydrostratigraphy was refined by jointly using AEM data, WCRs, and published cross sections in places where the various data types overlapped. This strengthened confidence in AEM data interpretation.
- Groundwater elevation data supplemented AEM data, WCRs, and published cross sections in determining where aquitards may be present or discontinuous.
- Where AEM data and cross sections did not align, well logs used to develop the cross section were reviewed and used in conjunction with the AEM data.
- AEM data were the primary data source for hydrostratigraphic interpretation in areas with limited borehole data.
- E-logs and published cross sections were used where AEM data were not available and were correlated with the nearest AEM data.
- WCRs were used as verification and interpolation points for key priority areas.
- Areas with no other nearby data relied on the SVIHM geologic model or other groundwater flow model layers to interpolate the hydrostratigraphic layers.

Figure 2 shows an example analysis that encompasses many types of data and shows how they are correlated to provide a more cohesive understanding of the Subbasin's hydrostratigraphy. The cross section on Figure 2 was exported from the Leapfrog software and spans the 180/400 Subbasin, the Monterey Subbasin, and the Seaside Basin. Hydrostratigraphy in the north (left on Figure 2) is based primarily on WCRs, with finer sediments highlighted in blue.

Hydrostratigraphy in the center of Figure 2 is based on AEM data, with finer sediments highlighted in blue. A map of the top of the Monterey Formation (HydroMetrics, 2009) provided structural data in the south, and geologic maps provided locations of surface outcrops of the Monterey Formation, which are highlighted with yellow disks. Published cross sections, e-logs, and surface geology maps are not shown on the figure; however, they were also reviewed for confirmation of other data. Through careful analysis and integration of all data types, a new bedrock surface was developed, shown with a pink mesh and green contour lines on Figure 2. This figure illustrates the data synthesis methodology applied in the Subbasin.

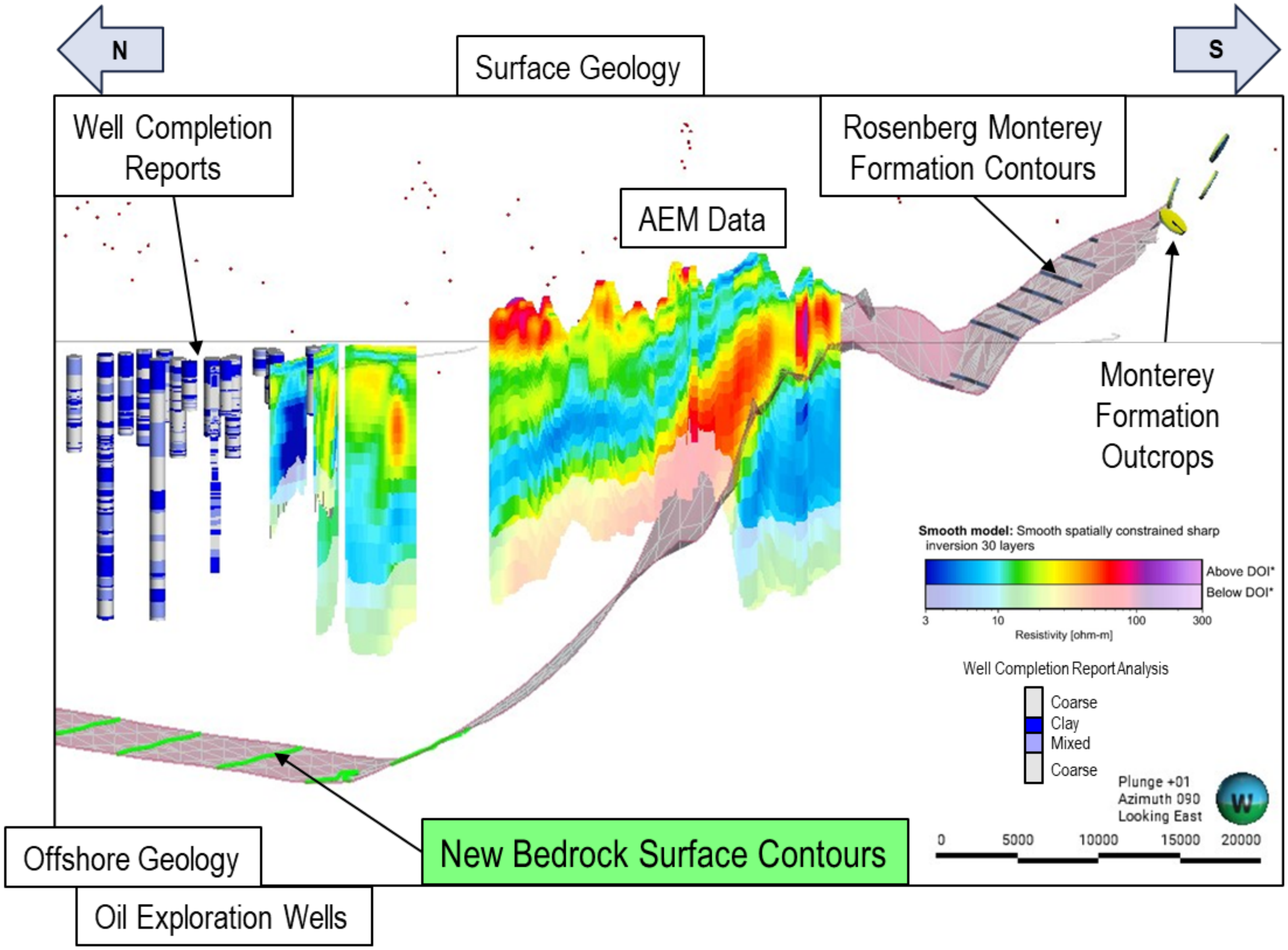

Figure 2. Example of Different Types of Data Juxtaposted in Leapfrog Geo Software

Hydrostratigraphic decision-making was prioritized from deepest to shallowest layers. The bedrock surface was the first priority and was modified using AEM data, oil exploration wells, surface geology maps, the Monterey Shale contours, and the Salinas Valley Geological Framework. After revising the bedrock surface, the Toro Primary Aquifer was assumed to exist above the bedrock in the Corral Area; the location and depth of the aquitard between the 400-Foot Aquifer and Deep Aquifers was revised based on the Deep Aquifers Study in the Marina-Ord Area (M&A, 2024). Following that, the aquitards between the 400-Foot Aquifer and 180-Foot Aquifer and shallow sediments were revised based on additional WCRs, published cross sections, and the AEM data. The respective aquifers were assumed to exist between the aquitards and the bedrock.

RESULTS/FINDINGS

Results of the Subbasin's HCM updates are detailed below.

Bedrock Surface and Offshore Geology

<u>Principal Data Used</u>: Oil exploration wells, AEM data, SVIHM geologic model, seismic data, surface geology maps, and bathymetry

The Monterey Formation and granitic rocks constitute the Subbasin's primary bedrock units. These units define the bottom of what is considered usable aquifer materials. The previous conceptualization of the top of bedrock surface was based on the 1978 Durbin model (Durbin *et al.*, 1978), which relied on geophysical gravity studies. This surface conforms to a traditional bathtub shape for the greater Salinas Basin, generally dipping down toward the Sierra de Salinas and tilting up toward the coast. The Salinas Valley Geological Framework (Sweetkind, 2023) generally follows this same conceptualization.

Coastal Area Onshore Bedrock

This HCM update concluded that the coastal onshore portion of the Monterey Subbasin is consistent with the previous conceptualization, with only minor adjustments along the coastline based on lithology from several deep oil exploration wells.

Coastal Area and Offshore Bedrock and Geology

This HCM update concluded that the top of bedrock elevations deviate from the SVIHM elevations for the offshore area adjacent to the Monterey Subbasin. The revisions are based on oil exploration wells previously mentioned, mapped outcrops of bedrock in Monterey Bay (Dartnell *et al.*, 2016, and Wagner *et al.* 2002), and seismic reflection cross sections (Dartnell *et al.*, 2016). The combination of these data and lack of known significant faulting offsets indicates the top of bedrock surface extends offshore with the same, gently sloping upward trend observed onshore. The top of the bedrock slope flattens farther from the coastline. This interpretation follows the same slightly upward slope shown on the B – B’ geologic cross section in the *Deep Aquifer Investigation - Hydrogeologic Data Inventory, Review, Interpretation and Implications* report (Feeney and Rosenberg, 2003).

M&A updated the offshore hydrostratigraphy above bedrock based on more recent offshore geologic maps and the most recent bathymetry (seafloor topography) data. These updates provide a refined conceptualization of how the aquifers interact with the ocean in Monterey Bay. The primary modifications to the offshore hydrostratigraphy consisted of connecting geologic units to outcrops from the most recent offshore geologic maps, smoothing and revising the offshore hydrostratigraphy, and updating it based on recent bathymetry data (NOAA, 2024). Units that have not been mapped as outcropping offshore were assumed to pinch out between the coastline and Monterey Canyon. This is consistent with similar pinch outs in the SVIHM.

Figure 3 shows a cross section of the revised hydrostratigraphic interpretation that extends offshore. The updated bedrock surface, shown in grey, is a relatively flat-lying layer with no substantial discontinuities between the coastline and Monterey Canyon. Figure 3 also shows the revised hydrostratigraphy above the Monterey Formation, and how only the Purisima and Santa Margarita Formations outcrop along the wall of Monterey Canyon. Included on Figure 3 are drillholes with bedrock contact and the AEM survey flightlines, which were used in the analysis.

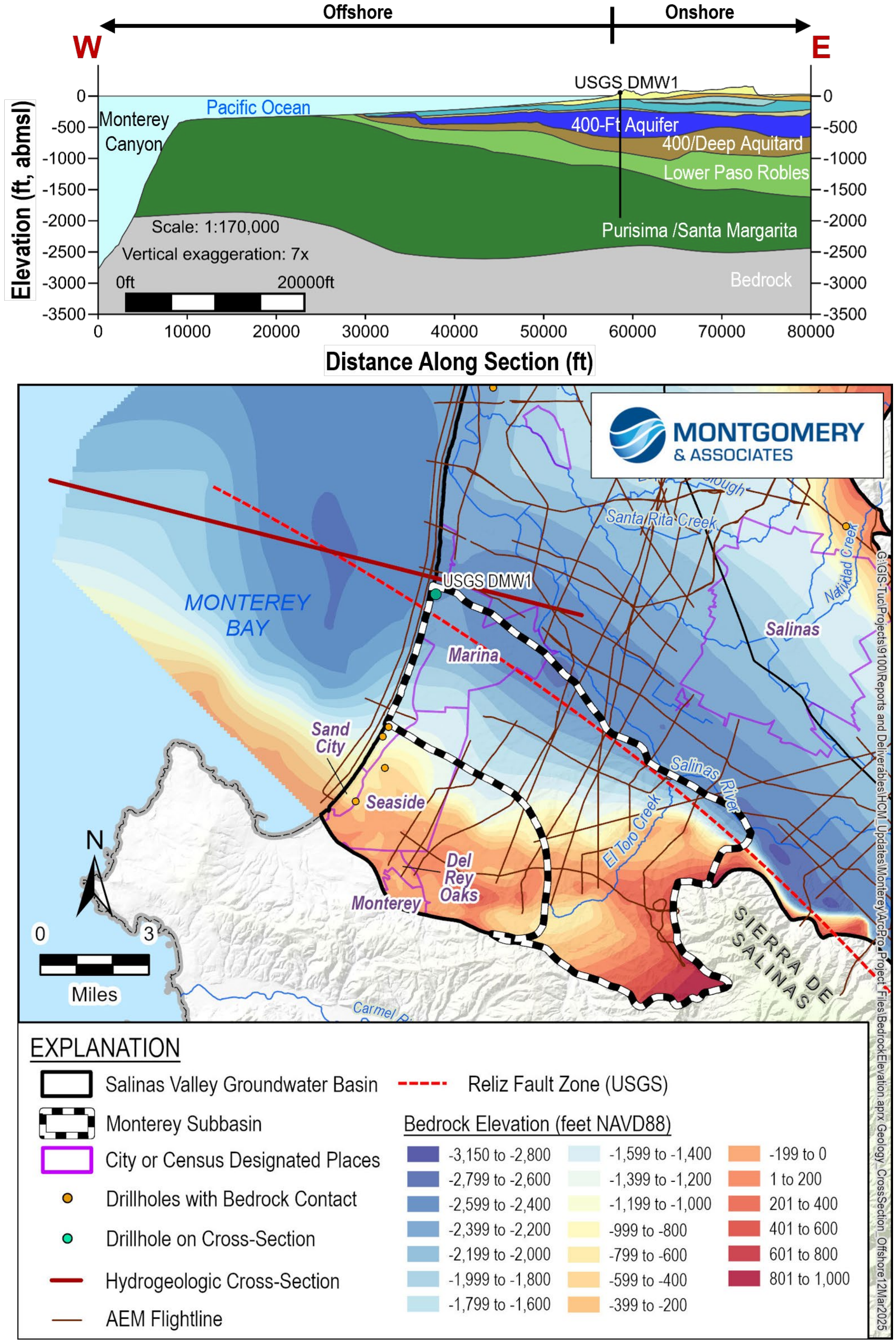

Figure 3. Revised Conceptual Understanding of Offshore Bedrock and Hydrostratigraphy

Corral Area

Previous geologic conceptualizations of the Corral Area identified the Cretaceous granitic and metamorphic rocks as the bedrock units, with the Monterey Shale included as water bearing because some domestic wells completed in the Monterey Shale draw small amounts of water from fractures (GeoSyntec, 2007). The GSP, however, identified the primary water-bearing units as those above the Monterey Shale because the Monterey Shale is generally considered not water-bearing throughout the rest of the Salinas Basin. The best estimate of the top of the Monterey Shale surface came from a 2009 set of contours developed by L. Rosenberg, and was first published by HydroMetrics in their 2009 Seaside Basin Groundwater Model report. These contours show the bedrock dipping from the southeast to the syncline that coincides with Highway 68, rising with the Laguna Seca Anticline and then dipping steeply again to the north, stopping at the Reliz Fault.

This HCM update builds on the interpretation that the Monterey Shale, granitic rocks, and metamorphic rocks all constitute the bedrock, and incorporate additional data to refine the Monterey Shale and the crystalline rock surfaces. The HCM update relied on surface geology maps and AEM data.

Surface geology maps aided in anchoring bedrock outcrops near Highway 68 where there is a surficial outcrop of Monterey Shale. This outcrop indicates a very shallow bedrock in Toro Canyon, and corresponds to mapped shallow groundwater levels near Toro Creek. These data suggest the shallow groundwater near this outcrop is less likely the result of significant stream leakage and more likely the result of the shallow bedrock surface forcing groundwater up.

AEM data provided a strong basis for revising the bedrock surface along the Laguna Seca anticline, as well as north toward the coastal areas. The bedrock surface was revised to be shallower and more undulating than previously understood. The revised bedrock surface also shows distinct bowl-like structures in the Corral de Tierra area. These El Toro Primary Aquifer bowls are shallow, with the main El Toro bowl largely disconnected from the greater Salinas Valley Basin. The secondary bowl is the Highway 68 East bowl, which is shallower but shows some potential hydraulic connectivity with the greater Basin near the boundary with the 180/400-Foot Aquifer Subbasin. A cross section running semi-parallel to El Toro Creek is shown on Figure 4. This cross section shows the 2 bowl structures from the revised bedrock interpretation.

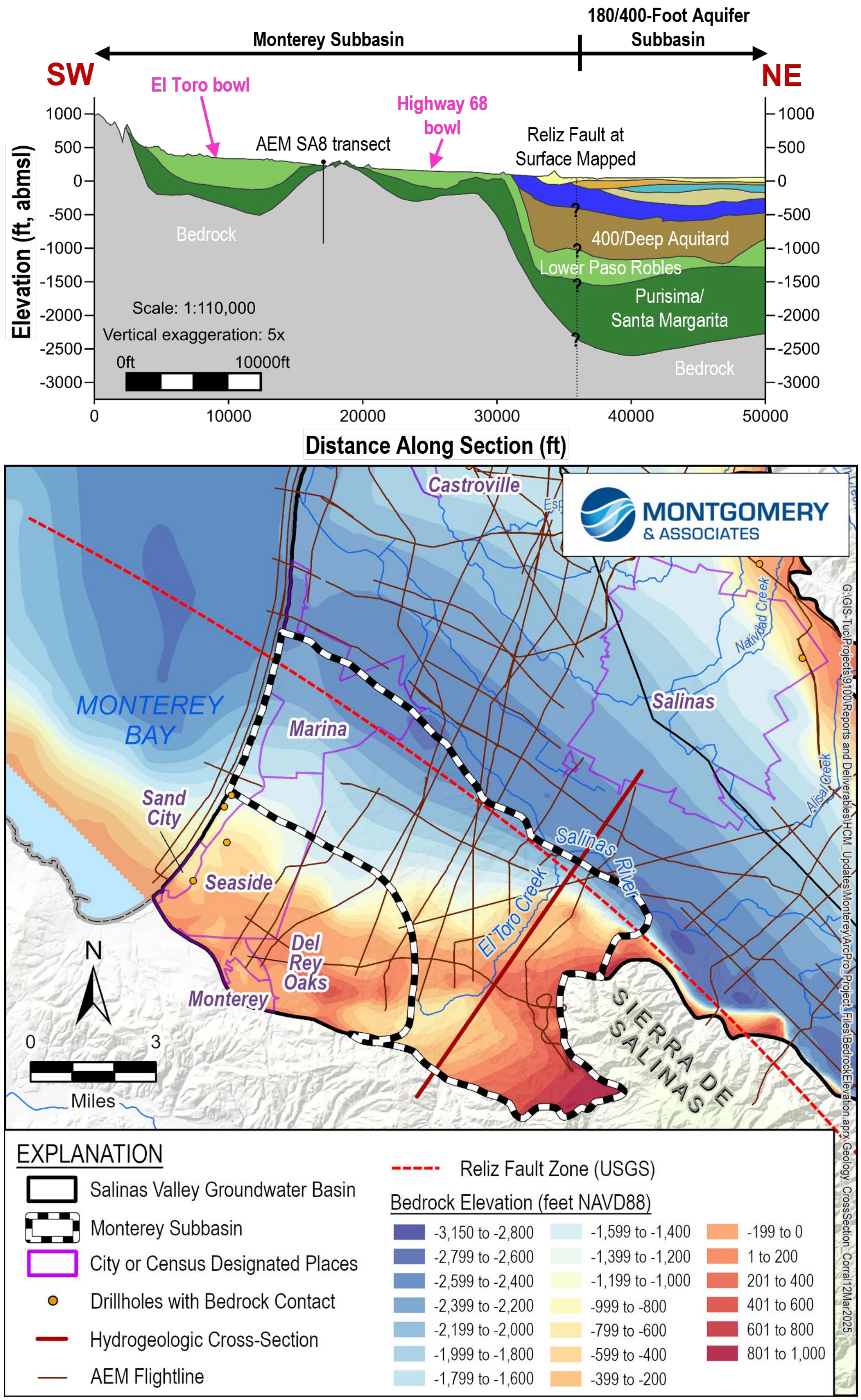

Figure 4. Revised Conceptual Understanding of Bedrock along Highway 68

Coastal 400/Deep Aquitard and Deep Aquifers' Extent

Principal Data Used: Previously published studies, AEM data, WCRs

The Deep Aquifers' extent was revised by incorporating results and data from the *Deep Aquifers Study* (Study) (M&A, 2024). Attachment A to the Study details the data, methods, and extent findings, which are summarized here.

Although the Deep Aquifers were identified as a principal aquifer in the 180/400 and Monterey Subbasins, no cohesive valley-wide description of the Deep Aquifers' depth and extent existed prior to the Study. The previous understanding of the Deep Aquifers focused on the coastal areas of the 180/400 and Monterey Subbasins, where the majority of the deep wells were installed. The *Deep Aquifer Investigation - Hydrogeologic Data Inventory, Review, Interpretation and Implications* (Feeney and Rosenberg, 2003) detailed the geology that constitutes the Deep Aquifers and summarized the known Deep Aquifers wells' screened intervals, extraction, and locations.

The *Hydrogeologic Report on the Deep Aquifer, Salinas Valley, Monterey County, California* (Thorup, 1976) defined the Deep Aquifers as the entirety of the Paso Robles Formation within the Salinas Valley Basin and developed recharge and storage estimates assuming the whole formation was the Deep Aquifers. Other subsequent studies and analyses generally defined the Deep Aquifers based on the presence of the overlying 400-Foot Aquifer or MCWRA-designated Deep Aquifers wells, but notably there was no defined extent.

The updated understanding of the Deep Aquifers presented in the Study focused on the presence of the 400/Deep Aquitard to delineate the Deep Aquifers from the shallower principal aquifers. Accordingly, the Deep Aquifers incorporate all the productive zones below the 400/Deep Aquitard, including the previously named 800-Foot, 900-Foot, 1,100-Foot, and 1,500-Foot Aquifers; and comprise portions of the Paso Robles Formation, Purisima Formation, and Santa Margarita Sandstone. This definition is consistent with the Monterey Subbasin GSP. Although distinct water levels have been measured at different depths of the Deep Aquifers within the Monterey Subbasin, insufficient data exist to subdivide the Deep Aquifers into distinct component horizons.

The Study delineated the lateral extent of the Deep Aquifers throughout the majority of the 180/400 Subbasin and into adjacent and nearby subbasins by tracing the continuous presence of the 400/Deep Aquitard. The extent of the Deep Aquifers into the Monterey Subbasin is shown on Figure 5. This figure includes areas marked as the uncertain extent, where current data are not sufficient to conclusively determine if the Deep Aquifers are present or absent.

The 400/Deep Aquitard was identified and traceable in AEM data and well completion reports from the coastal areas, southward to major geologic structures including the Laguna Seca Anticline. This confirms that the Deep Aquifers exist throughout the coastal Marina-Ord area of the Monterey Subbasin up to the Laguna Seca Anticline, and that the Deep Aquifers are in hydraulic communication with both the Seaside and 180/400-Foot Aquifer Subbasins. The depth of the 400/Deep Aquitard and the Deep Aquifers are refined with AEM data and well completion reports.

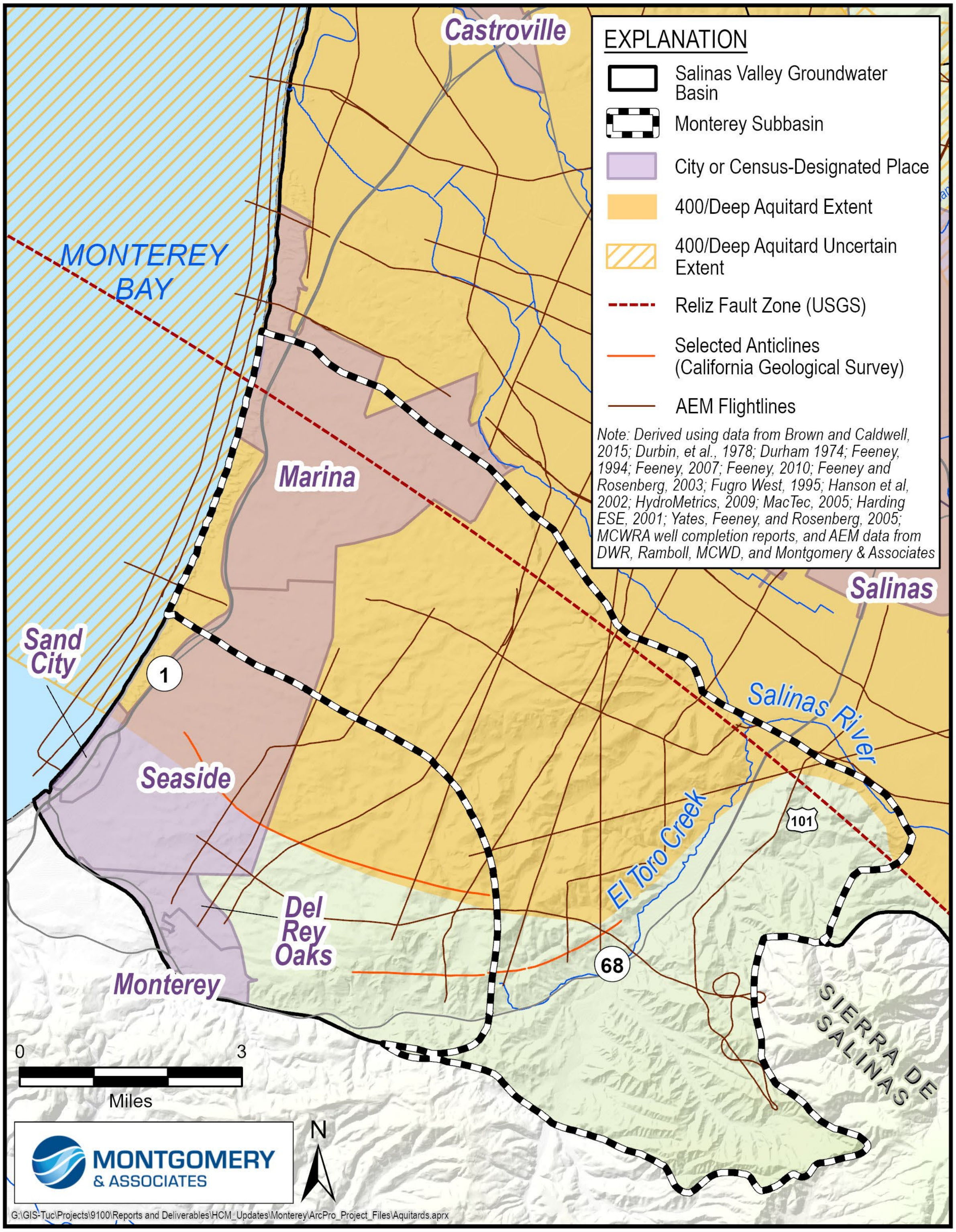

Figure 5. Updated Deep Aquifers Extents, as Determined by the Deep Aquifers Study (M&A, 2024)

Extents and Thicknesses of Coastal Shallow Aquitards

Principal Data Used: WCRs, published cross sections, groundwater elevation data, AEM data, Salinas Valley Geological Framework, MBGWFM

M&A and EKI updated the extents and thicknesses of the coastal aquitards in the Marina-Ord Area. These edits were relatively minor and do not constitute major updates to the Monterey Subbasin HCM.

The MBGWFM provided a starting point for the extents, depths, and thicknesses of aquitards. Where data indicated the aquitards should be refined, more in-depth mapping was completed, such as through analyses of driller-observed lithology supplemented by groundwater elevation data. This effort focused on 3 aquitards: the Salinas Valley Aquitard (SVA), the Intermediate Aquitard between the Upper 180-Foot Aquifer and the Lower 180-Foot Aquifer, and the 180/400-Foot Aquitard.

SVA

The SVA separates shallow sediments and the dune sands from the 180-Foot Aquifer. The lateral extent and thickness of the SVA was refined based on WCRs, AEM data from DWR Survey Area 1 (DWR, 2020), Survey Area 8 (DWR, 2022), the Deep Aquifers Survey (M&A, 2024), published cross sections, and information in the SVIHM and MBGWFM. The revised extent of the SVA is shown on Figure 6.

Consistent with the Monterey Subbasin GSP, the SVA exists near the Fort Ord area. Its extent is primarily based on the extent delineated in the *Final Report, Hydrogeologic Investigation of the Salinas Valley Basin in the Vicinity of Fort Ord and Marina* (Harding ESE, 2001). The extent of the SVA near the coast toward the 180/400 Subbasin was refined using WCRs, and the SVA was defined as pinching out toward the coast near Highway 1.

Figure 7 reproduces a cross section from the *Hydrogeologic Investigation of Salinas Valley Basin in the Vicinity of Fort Ord and Marina Salinas Valley, California* (Harding ESE, 2001) that shows the coastal aquitards in the Subbasin. Although the SVA is not specifically highlighted on this figure, the cross section shows the relatively continuous clay rich horizon that separates the dune sands and A-Aquifer from the 180-Foot Aquifer. Near the Salinas River on the right of the cross section, the SVA is a single, thick layer of clay that overlies the 180-Foot Aquifer. Moving south into the Monterey Subbasin, or to the left on the cross section, the SVA transitions to comprise several layers of clay that together create the hydraulic barrier between the Dune Sands and the 180-Foot Aquifer.

Intermediate Aquitard

Near the coast, the 180-Foot Aquifer in the Monterey Subbasin is separated into the Upper and Lower 180-Foot Aquifer with the Intermediate Aquitard in between. Figure 7 highlights the intermediate aquitard in blue. This figure shows how the Intermediate Aquitard separates the Upper 180-Foot Aquifer from the Lower 180-Foot Aquifer in the Monterey Subbasin. The extent and depth of the Intermediate Aquitard was refined in collaboration with EKI and using AEM data, WCRs, and published cross sections.

180/400 Aquitard

The extent and thickness of the 180/400 Aquitard was refined using data from previous studies including the *Hydrogeologic Investigation of Salinas Valley Basin in the Vicinity of Fort Ord and Marina Salinas Valley, California* (Harding ESE, 2001), the *Final Report, Hydrostratigraphic Analysis of the Northern Salinas Valley* (Kennedy/Jenks, 2004), and *Recommendations to Address the Expansion of Seawater Intrusion in the Salinas Valley Groundwater Basin* (MCWRA, 2017). Additionally, data from WCRs, AEM transects, and groundwater data were used to define the aquitard's gaps and thin spots. The refined extent of the aquitard is shown on Figure 8, with the full extent of the aquitard in green, and the locations of intermittent or aquitard gaps are displayed in light green.

The revised interpretation shows this aquitard as uneven in thickness and intermittently present, especially in the coastal areas of the Monterey and 180/400 Subbasins. Within the Marina-Ord Area, there are notable thin or intermittent zones, which results in hydrologic connections between the 180-Foot and 400-Foot Aquifer. This interpretation was further refined by examining where groundwater elevations in the 180- and 400-Foot Aquifers are similar, as illustrated on Figure 9. Thin or intermittent aquitard locations were furthermore confirmed using AEM data, where applicable. AEM data also demonstrated that the 180/400 Aquitard is more laterally extensive in the southern portion of the Marina-Ord area than previously believed.

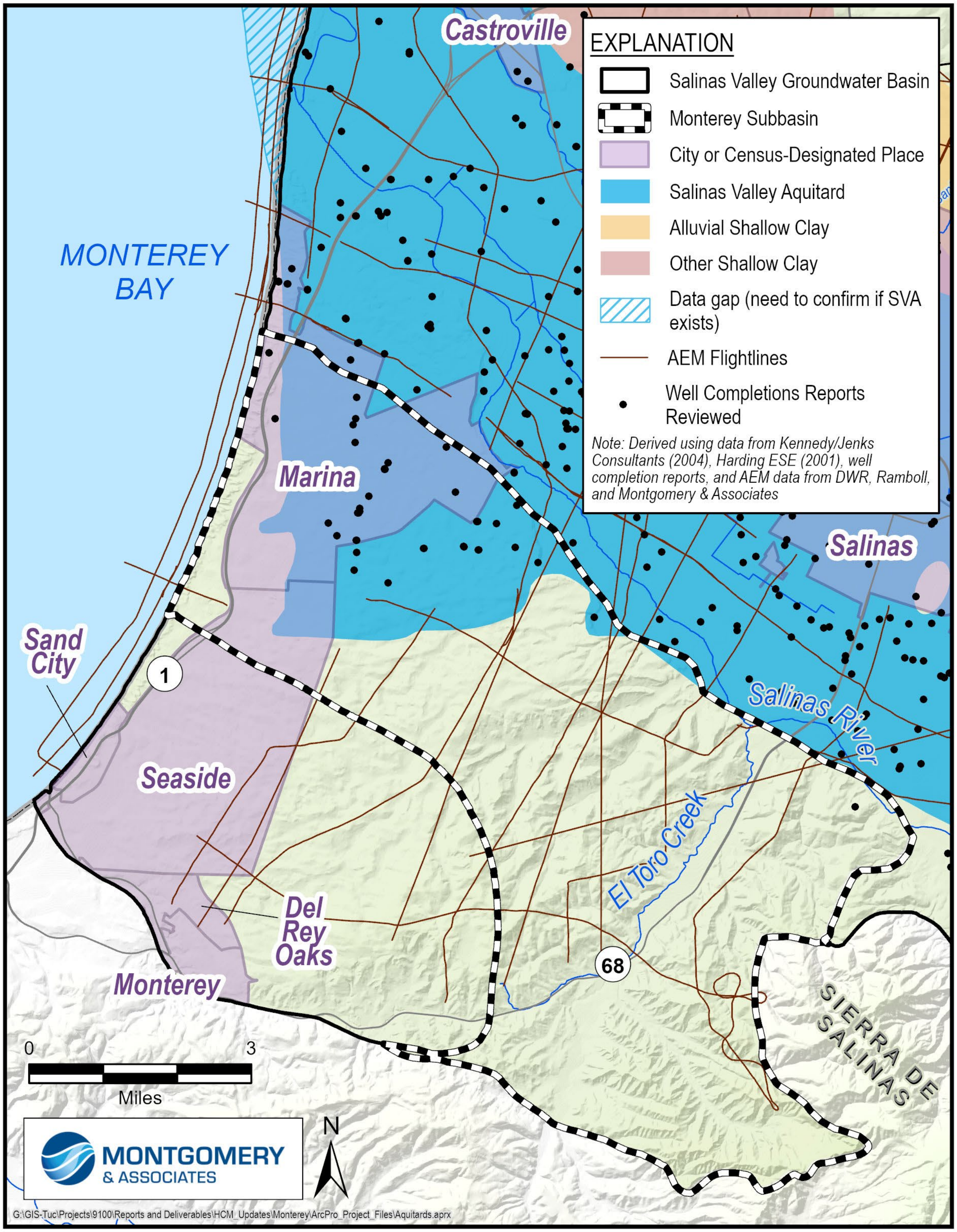

Figure 6. Updated Understanding of the SVA and Shallow Clays with Key Data Sources

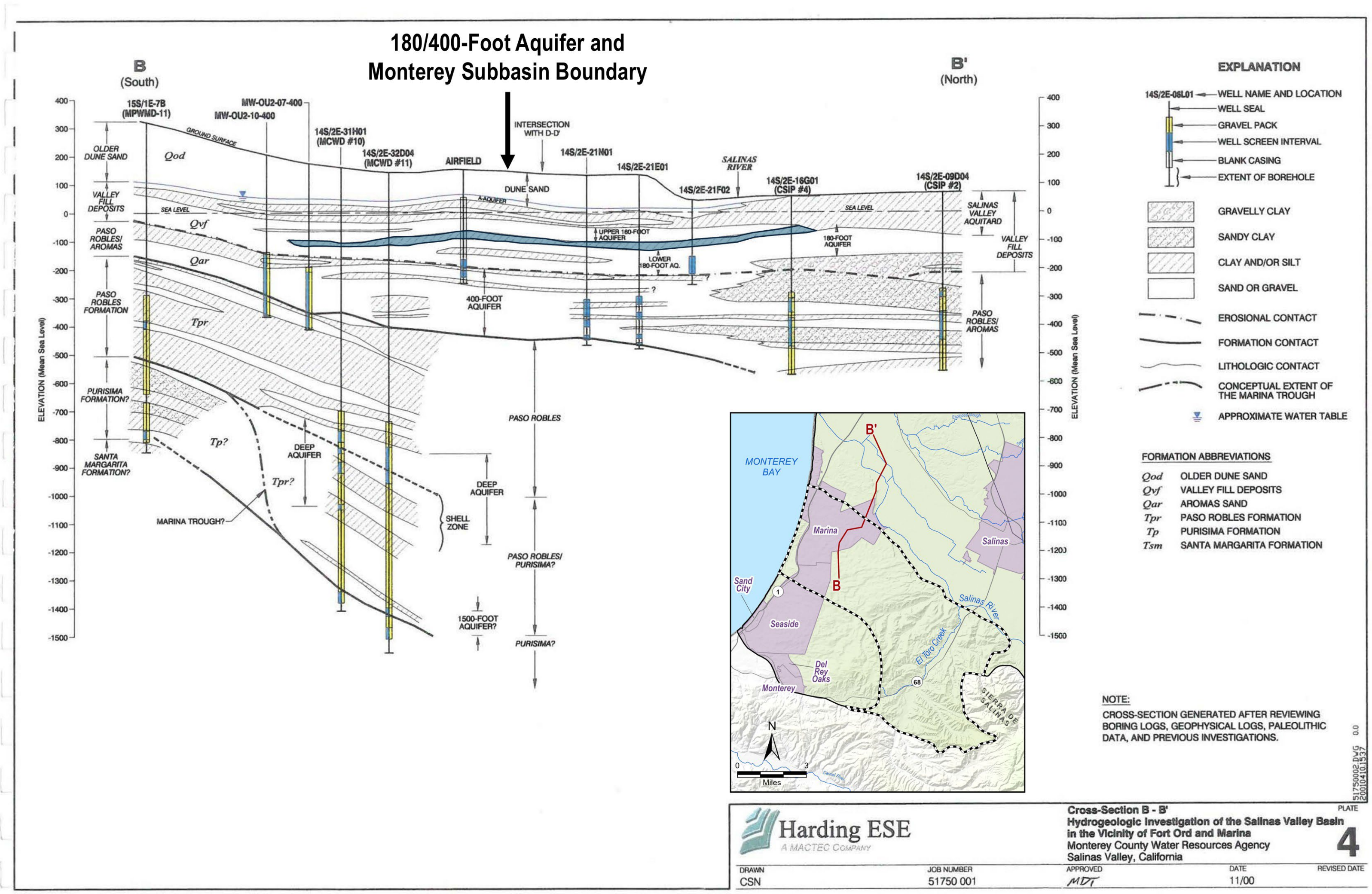

Figure 7. Cross Section of SVA and Intermediate Aquitard (adapted from Harding ESE, 2001)

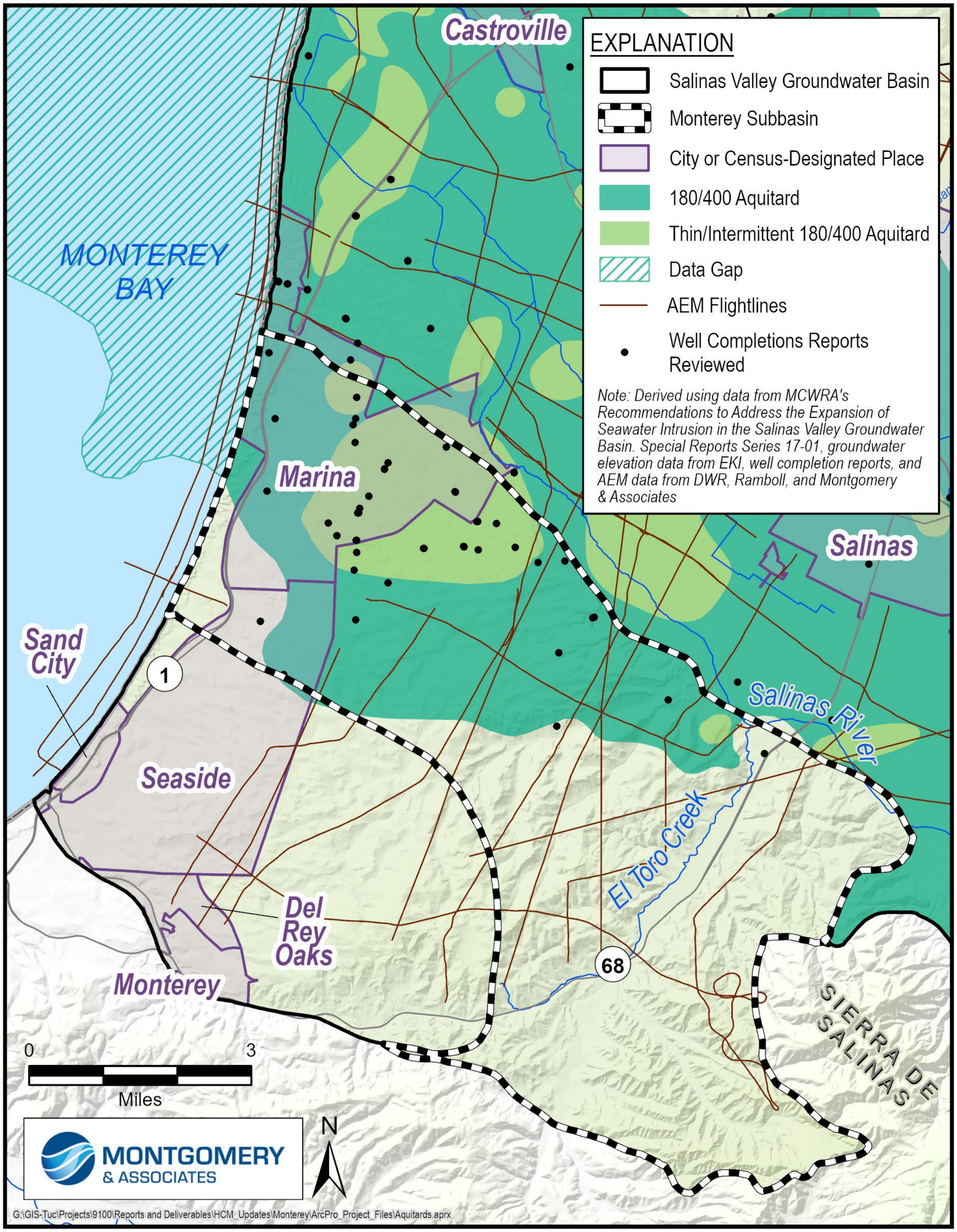

Figure 8. Updated Understanding of the 180/400 Aquitard with noted Thin or Intermittent Zones

Figure 9. Hydrographs with Similar Groundwater Elevation in the 180- and 400-Foot Aquifers in the Marina-Ord Area

Relationships with other Managed Groundwater Areas

Interaction between the Monterey Marina-Ord and Corral Areas

Principal Data Used: AEM data, WCRs, published cross sections, surface geology maps

The relationship between the Corral de Tierra's El Toro Primary Aquifer System and the coastal Marina-Ord aquifers of the Monterey Subbasin has been poorly defined due to a lack of data through the middle of the Subbasin. Previous conceptualizations of the connectivity presumed the El Toro Primary Aquifers System followed the bedrock surface and connected to the principal aquifers in the Marina-Ord Area because of their shared geology. This previous concept supported modeling that simulated strong hydraulic connectivity between the Corral de Tierra and Marina-Ord areas. However, no wells between the Corral de Tierra and Marina-Ord areas provide a basis for this connectivity.

The updated conceptualization, which is primarily founded on the updated, shallower bedrock in the Corral de Tierra area, shows a clearer geologic separation of the 2 regions within the Monterey Subbasin. The Laguna Seca Anticline is well defined by the AEM data. A cross section showing the axis and the arms of the Anticline is shown on Figure 10. The Laguna Seca Anticline forms the north-northwestern rim of the El Toro and Highway 68 East bowls that contain the El Toro Primary Aquifer System discussed in the sections above. This cross section shows how the Paso Robles Formation in the El Toro bowl is hydrogeologically isolated from the same formation in the Marina-Ord area. The hydraulic connectivity between the El Toro bowl and Marina-Ord Area is reduced not only by pinched hydrostratigraphy across the anticline axis, but also by the presence of Toro Canyon, which interrupts potential groundwater flow from higher elevations. When groundwater wells and water table contours are added to the conceptualization, it becomes apparent that the Corral de Tierra and Marina-Ord areas are distinctly separate. However, in the northern portion of the Corral Area, the anticline is not observed, which increases the potential for hydraulic connectivity between the Highway 68 East bowl and the Marina-Ord Area.

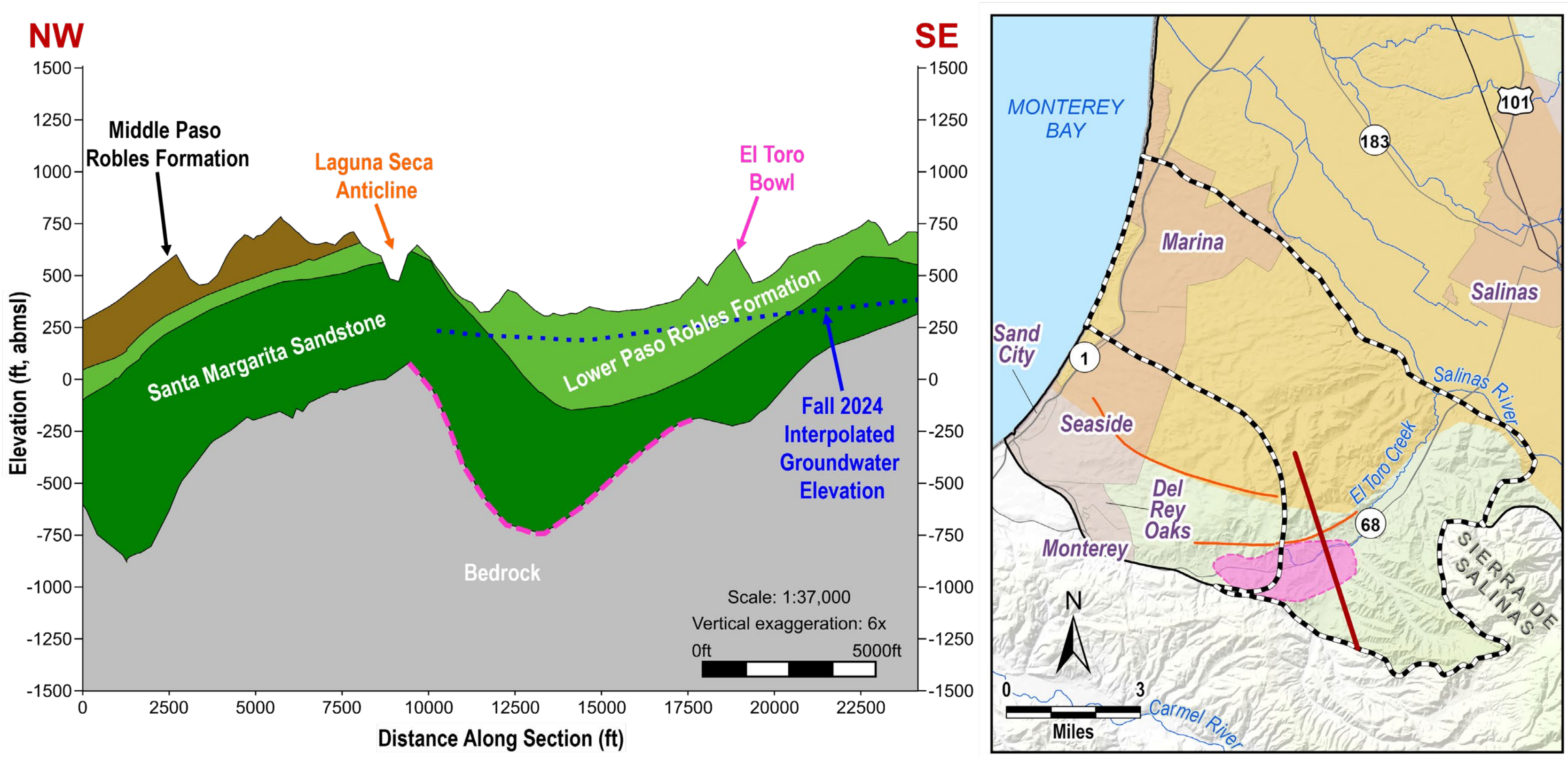

Figure 10. Bedrock Surface Demonstrating Revised Relationship between Corral and Coastal Monterey Subbasin Areas

180/400 Subbasin Boundary

Coastal Area and the 180/400 Subbasin

The relationship between the Coastal area and the 180/400 Subbasin generally remained the same as previous interpretations, with minor modifications from the aquitards' revisions described above.

Corral Area and the 180/400 Subbasin

Principal Data Used: AEM data, published cross sections, surface geology maps

The relationship between the Corral de Tierra El Toro Primary Aquifer System and the 180/400 Subbasin was previously poorly defined due to a lack of data across the subbasins' boundary. Previous conceptualizations of the connectivity presumed the Toro Primary Aquifer System followed the bedrock surface and connected to the principal aquifers in the 180/400 Subbasin because of their shared geology. It was generally thought that water flowed from the El Toro area into the 180/400 Subbasin with little influence from Reliz Fault, similar to what is observed in the coastal areas of the Subbasin. Cross section X_1-Z in the *Geologic Map and Cross-Sections from El Toro to Salinas Valley* (Geosyntec, 2010), as shown in the Monterey Subbasin GSP (MCWDGSA and SVBGSA, 2022), shows uplift of the bedrock that defined the overlying permeable materials connection to the 180/400 Subbasin.

The conceptualization of the boundary between the Corral area and the 180/400 Subbasin was revised to reveal a much more limited hydraulic connection between the 2 areas. AEM data in combination with the geologic map in the Corral de Tierra Area reveal that the bedrock reaches the surface and then dives steeply as it approaches the mapped Reliz Fault as shown on Figure 4, which also shows the bedrock bowls. These data suggest that groundwater flow between the Corral de Tierra area and the 180/400 Subbasin may be somewhat limited. This boundary remains an area of uncertainty due to the geologic complexity, and this conceptual understanding may be updated in the future with more refined data. In addition, results of numerical modeling will be used to verify that measured water level data can be simulated using this updated hydrogeologic conceptual model.

Seaside Basin Boundary

Coastal Monterey and Seaside Basin

The primary aquifers in the Seaside Basin are defined by their geological formations and include the Paso Robles Aquifer, often denoted as "shallow," and the Santa Margarita Aquifer, often denoted as "deep." Historically, it was believed that the 400-Foot Aquifer and the Deep Aquifers in the Monterey Subbasin were generally connected to the Paso Robles and Santa Margarita Aquifers, respectively (MCWDGSA and SVBGSA, 2022).

The revised bedrock surface analysis and the *Deep Aquifers Study* have confirmed the direct hydrostratigraphic connection between the Marina-Ord Area with the Seaside Basin, with no apparent geologic barrier to groundwater flow. The study extended of the Deep Aquifers into the Seaside Basin based on the presence of the continuous 400/Deep Aquitard, which terminates at the axis of the Laguan Seca Anticline. The reassessment of the depth of the 400/Deep Aquitard indicates that many wells screened in the Paso Robles Formation in the southern Marina-Ord Area and Seaside Basin, historically associated with the 400-Foot Aquifer, are screened below the continuous 400/Deep aquitard. This places these wells in the Deep Aquifers, which may affect the assessment of groundwater gradients, aquifer-specific water budgets, and changes in storage. A cross section illustrating how both the 400-Foot and the Deep Aquifers extend from the Monterey Subbasin into the Seaside Basin is shown on Figure 11.

Corral de Tierra Area and Laguna Seca Area

Principal Data Used: AEM data, surface geology maps

The relationship between the Corral de Tierra Area of the Monterey Subbasin and the Laguna Seca area of the Seaside Basin has been poorly understood. There has been historical concern over the groundwater relationships between these areas, and how pumping in one area might impact the adjoining area. No physical boundary to groundwater flow has ever been postulated; this boundary is only one of convenience between the Seaside Basin and the Monterey Subbasin.

The updated conceptualization of this boundary relationship focuses on the geologic setting with the revised bedrock contours providing the basis for the refinement. The revised bedrock surface establishes the isolated El Toro bowl, which is bisected by the jurisdictional boundary between the Seaside Basin and Monterey Subbasin as shown on Figure 12 and Figure 4. The revised bedrock surface establishes the hydrologic connection between these areas and supports the observed related groundwater levels and groundwater pumping. Further, the isolated nature of the El Toro bowl indicates that these 2 hydrologically connected areas might be somewhat separated from other portions of both the Seaside and Monterey Subbasins as discussed above.

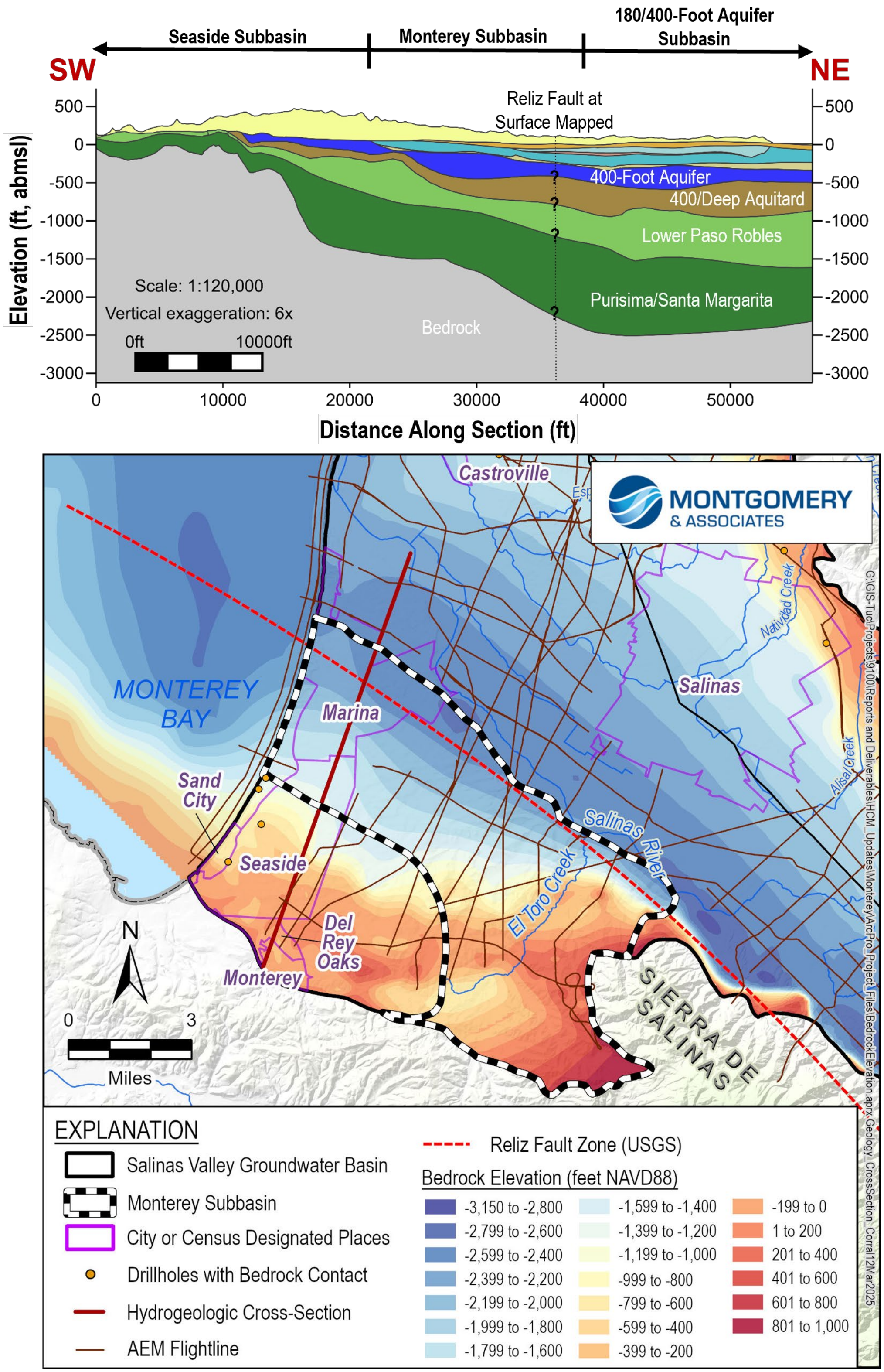

Figure 11. Revised Layers Across the Subbasin Boundary

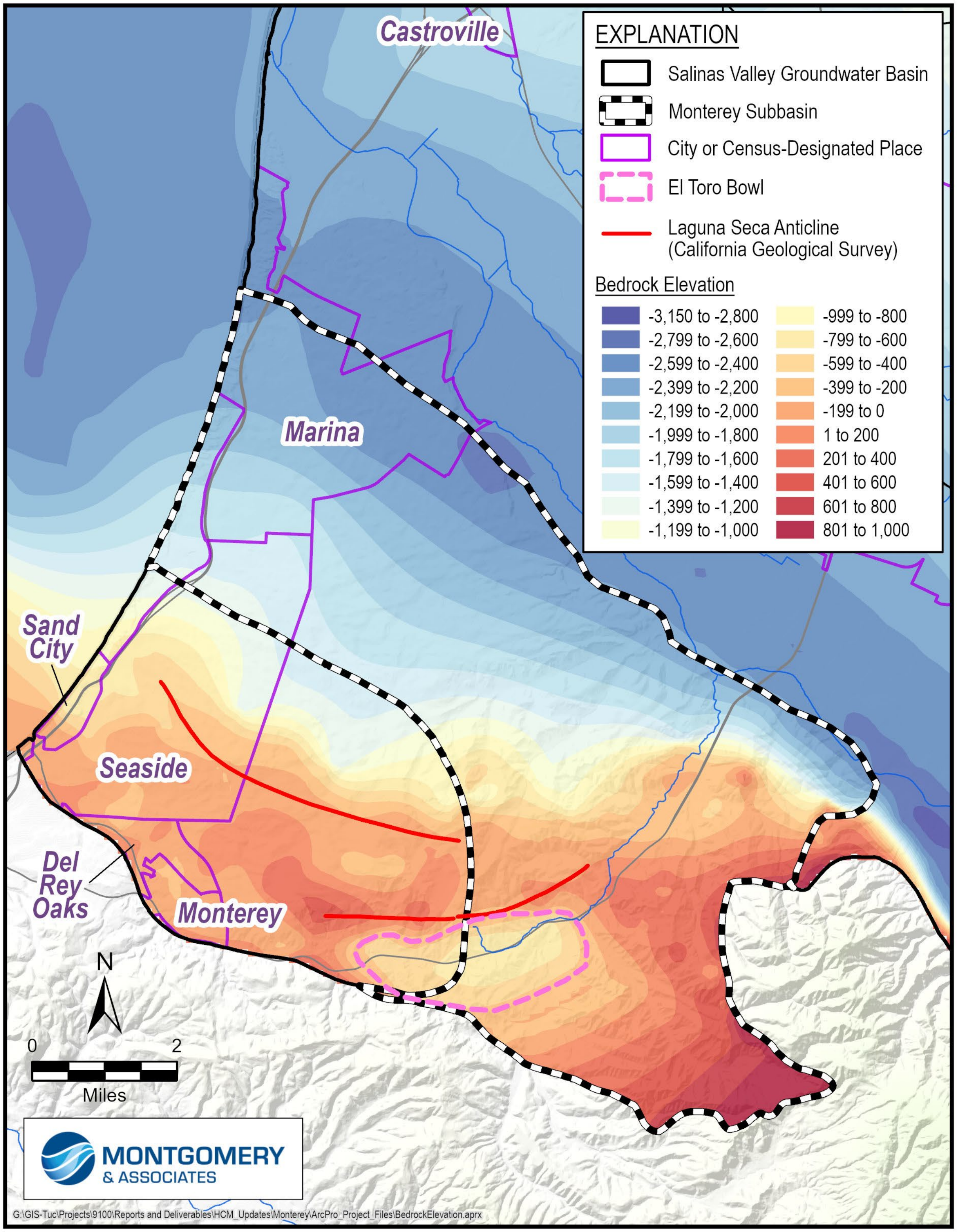

Figure 12. El Toro Bowl and Jurisdictional Boundary with Seaside Basin

CONCLUSIONS

The Monterey Subbasin HCM presented in the GSP was developed using the best available data and information at the time. The SVBGSA, in collaboration with the MCWDGSA, has collected and analyzed significant amounts of new data to refine and update the conceptual model, providing clear HCM refinements for the Monterey Subbasin. These refinements focus on both the Coastal and Corral areas, separated by the axis of the Laguna Seca anticline.

The following bullets summarize the principal updates to the Monterey Subbasin HCM:

- The bedrock surface that delineates the bottom of the productive aquifers has been updated using multiple datasets for a more complete view of the depth and shape of the groundwater basin. In the Coastal Area, the bedrock surface extends to Monterey Canyon where the respective geologic formations crop out. In the Corral Area, the updated bedrock surface indicates the Corral de Tierra Area groundwater occurs primarily in the isolated El Toro bowl and the Highway 68 East bowl.
- The Deep Aquifers are confirmed in the Marina-Ord Area and are defined by the presence of the continuous 400/Deep Aquitard, which extends south terminating at the axis of the Laguna Seca Anticline (M&A, 2024). The depth and extent of the 400/Deep Aquitard was refined by tracing its respective AEM resistivity profile.
- The extents of the coastal aquitards were refined based on additional WCR, cross sectional, AEM, groundwater elevation, and other mapped data without significant changes from the Monterey Subbasin GSP and MBGWFM. Notable thin or intermittent zones were further refined and incorporated into the geologic model.
- The hydrogeologic relationships between the Marina-Ord and Corral areas of the Monterey Subbasin, the Monterey and the 180/400-Foot Aquifer Subbasins, and the Monterey and Seaside Subbasins have been updated based on the revised bedrock surface updates and the results of the *Deep Aquifers Study*.
    - Within the Monterey Subbasin, hydrogeologic connectivity appears to be limited between the El Toro bowl and the coastal Marina-Ord Area, while some degree of potential connectivity between the Highway 68 East bowl and the Marina-Ord Area.
    - Between the Monterey and the 180/400 Subbasins, the Coastal connection in the GSP is confirmed, and there appears to be potential hydrogeologic connectivity between the Corral de Tierra area and the 180/400-Foot Aquifer Subbasin starting at the Highway 68 East bowl.

- Between the Monterey and the Seaside Basins, there is shared hydrogeologic connectivity with the Coastal area. The 400/Deep Aquitard extends into both Subbasins in the coastal areas, demonstrating that the 400-Foot Aquifer and Deep Aquifers exist in both subbasins. There is hydrogeologic connectivity between the Corral area and Laguna Seca area in the El Toro bowl, as defined by the revised bedrock surface.

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