Mound Basin Groundwater Sustainability Plan

Draft Text – Section 3.1, 3.2

MoundBasin
GROUNDWATER SUSTAINABILITY AGENCY

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ACRONYMS AND ABBREVIATIONS

AF	acre-feet
Alta MWC	Alta Mutual Water Company
Basin	Mound Basin
bgs	below ground surface
CALVEG	Classification and Assessment with Landsat of Visible Ecological Groupings
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
DDW	Division of Drinking Water, State Water Resources Control Board
DTSC	Department of Toxic Substances Control, California
DWR	Department of Water Resources, California
FCGMA	Fox Canyon Groundwater Management Area
FICO	Farmers Irrigation Company
ft	foot or feet
ft/d	feet per day
GPS	Ground Positioning System
GSP	Groundwater Sustainability Plan
HCM	hydrogeologic conceptual model
Hopkins	Hopkins Groundwater Consultants, Inc.
HSU	hydrostratigraphic unit
iGDE	Indicator of a potential groundwater dependent ecosystem
InSAR	interferometric synthetic aperture radar
LAS	Lower Aquifer System
M&I	municipal and industrial
MBGSA	Mound Basin Groundwater Sustainability Agency
MCL	maximum contaminant level
MCLR	maximum contaminant level range
mg/L	milligrams per liter
mm	millimeter *or* millimeters
msl	above mean sea level
NC	Natural Communities as defined by USDA
NCCAG	Natural Communities Commonly Associated with Groundwater
NRCS	Natural Resources Conservation Service
RWQCB-LA	Regional Water Quality Control Board—Los Angeles Region
SGMA	Sustainable Groundwater Management Act
SSP&A	S.S. Papadopulos & Associates, Inc.
SWRCB	State Water Resources Control Board

TDEM	time domain electromagnetic
TDS	total dissolved solids
TNC	The Nature Conservancy
UAS	Upper Aquifer System
United	United Water Conservation District
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UST	underground storage tank
VCWPD	Ventura County Watershed Protection District
Ventura Water	City of Ventura water utility
WQO	water quality objective
WWTP	Waste Water Treatment Plant
yr	year

3.0 Basin Setting [Article 5, SubArticle 2]

§354.12 Introduction to Basin Setting. *This Subarticle describes the information about the physical setting and characteristics of the basin and current conditions of the basin that shall be part of each Plan, including the identification of data gaps and levels of uncertainty, which comprise the basin setting that serves as the basis for defining and assessing reasonable sustainable management criteria and projects and management actions. Information provided pursuant to this Subarticle shall be prepared by or under the direction of a professional geologist or professional engineer.*

This section describes the information about the characteristics and current conditions of Mound Basin (the Basin) that provide the basis for defining and assessing reasonable sustainable management criteria, projects, and management actions. As required under Section 10733.2 of the California Water Code, this section was prepared by a professional geologist and includes sub-sections that describe the hydrogeologic conceptual model (HCM), current and historical groundwater conditions, a water balance, and management areas within Mound Basin based on best available data and information available for Mound Basin at the time of preparation of this Groundwater Sustainability Plan (GSP).

Most of the information presented in this section is derived from the following sources, which synthesize and summarize and add to historical scientific studies and information:

- "Hydrogeologic Assessment of Mound Basin—United Water Conservation District Open-File Report 2012-01" (United, 2012);
- "Ventura Regional Groundwater Flow Model and Updated Hydrogeologic Conceptual Model: Oxnard Plain, Oxnard Forebay, Pleasant Valley, West Las Posas, and Mound Groundwater Basins—Open-File Report 2018-02" (United, 2018); and
- "Preliminary Hydrogeological Study—Mound Basin Groundwater Conditions and Perennial Yield Study" (Hopkins, 2020).

In addition to the above-listed studies, well construction, groundwater elevation, and groundwater quality data collected by United Water Conservation District (United), Ventura County Watershed Protection District (VCWPD), and others were relied upon and have been compiled into the Mound Basin Groundwater Sustainability Agency (MBGSA) Data Management System.

All reported model values in this document will be checked to confirm they are consistent with values in the final model.

3.1 Hydrogeologic Conceptual Model [§354.14]

§354.14 Hydrogeological Conceptual Model.
(a) Each Plan shall include a descriptive hydrogeologic conceptual model of the basin based on technical studies and qualified maps that characterize the physical components and interaction of the surface water and groundwater systems in the basin.

Section 3.1 provides a descriptive HCM of the Basin based on technical studies and qualified maps that characterize the physical components and interaction of the surface-water and groundwater systems in Mound Basin, to the extent such characterization is possible based on existing best available data and information.

3.1.1 Regional Hydrology

Topography, surface-water bodies, and imported water sources and points of delivery in Mound Basin are described below.

3.1.1.1 Topography [§354.14(d)(1)]

§354.14 Hydrogeological Conceptual Model.
(d) Physical characteristics of the basin shall be represented on one or more maps that depict the following:
(1) Topographic information derived from the U.S. Geological Survey or another reliable source.

Topography of Mound Basin is shown on Figure 3.1-01. The topography of Mound Basin consists largely of gently south-sloping coastal plain, coastal and alluvial terraces, and alluvial fans. The Santa Clara River floodplain and estuary occupies the southwest corner of the basin, and moderately sloping hills rising to 1,000 feet above mean sea level (ft msl) are present along the northern margin of the basin. Several small, intermittent streams originate in the canyons above the Basin and trend south and southwest within the Basin, forming incised drainage features labeled “barrancas” (Spanish for “gullies”) on United States Geological Survey (USGS) topographic maps of the region. The barrancas typically have a vertical relief in the range of 10 to 30 ft.

3.1.1.2 Surface Water Bodies [§354.14(d)(5)]

§354.14 Hydrogeological Conceptual Model.
(d) Physical characteristics of the basin shall be represented on one or more maps that depict the following:
(5) Surface water bodies that are significant to the management of the basin.

Surface-water bodies significant to the management of the Mound Basin include the Santa Clara River, its estuary, and the Pacific Ocean (Figure 3.1-01). In addition, three barrancas (Sanjon, Arundell, and Harmon) tributary to the Santa Clara River in Mound Basin are shown on Figure 3.1-01. The barrancas typically only flow in response to precipitation events, but are considered further in this GSP where they coincide with potential groundwater dependent ecosystems. No springs or seeps are shown on USGS topographic maps within or adjacent to the boundaries of Mound Basin.

3.1.1.3 Imported Water [§354.14(d)(6)]

§354.14 Hydrogeological Conceptual Model.
(d) Physical characteristics of the basin shall be represented on one or more maps that depict the following:
(6) The source and point of delivery for imported water supplies.

Sources and approximate points of delivery of imported water supplies used in Mound Basin are shown on Figure 3.1-01. Three water purveyors import water into Mound Basin: Alta Mutual Water Company (Alta MWC), Farmers Irrigation Company (FICO), and the City of Ventura (Ventura Water), as follows:

- Alta MWC conveys approximately 200 acre-feet per year (AF/yr) of groundwater pumped from its wells located in the Santa Paula and Oxnard Basins to farms in the eastern Mound Basin (Alta MWC, personal communication, 2020).
- FICO conveys approximately 1,000 AF/yr of groundwater pumped from its Santa Paula Basin wells to farms in the eastern Mound Basin (United, 2017a).
- Ventura Water imports water for municipal supply from several sources outside of Mound Basin, as follows (quantities of water reported below are averages for the period from 2015 to 2020 [Ventura Water, 2020]):
  - Ventura Water pumps approximately 2,700 AF/yr of groundwater from its Saticoy wells in the Santa Paula Basin and supplies that water to portions of the city overlying both the Mound and Santa Paula Basins. Ventura Water has stated that the specific quantity of imported water from this source distributed to each basin is variable and cannot be precisely determined. However, estimating based on the area occupied by the City of Ventura in Santa Paula Basin and typical water use per acre for developed land in the region, it appears that most of the groundwater pumped from Santa Paula Basin by Ventura Water may be used within Santa Paula Basin, and the quantity of groundwater imported by the City of Ventura to Mound Basin is a relatively small portion of the 2,700 AF/yr total pumped.
  - Ventura Water pumps approximately 3,500 AF/yr of groundwater from its "Golf Course" well field in the Oxnard Basin for blending and distribution throughout its service area.
  - Ventura Water obtains approximately 5,000 AF/yr of surface water from the Ventura River watershed (sources include water from Casitas Municipal Water District and Ventura Water's facilities at Foster Park) for blending and distribution throughout its service area.

3.1.2 Regional Geology [§354.14(b)(1) and (d)(2)]

§354.14 Hydrogeological Conceptual Model.

(b) *The hydrogeologic conceptual model shall be summarized in a written description that includes the following:*

(1) The regional geologic and structural setting of the basin including the immediate surrounding area, as necessary for geologic consistency.

(d) *Physical characteristics of the basin shall be represented on one or more maps that depict the following:*

(2) Surficial geology derived from a qualified map including the locations of cross-sections required by this Section.

This sub-section describes the regional geologic and structural setting of Mound Basin. The groundwater basins of the Santa Clara River Valley, including Mound Basin, are within the Transverse Ranges geomorphic province of California, characterized by mountain ranges and valleys (basins) that are oriented east-west rather than the typical northwest-southeast trend common in the adjacent Peninsular and Coastal Ranges geomorphic provinces. Structurally, Mound Basin occurs within an elongate, complex syncline referred to as the Ventura structural basin, which trends east to west (Yeats et al., 1981). The province is tectonically active today as a result of transpressional stress related to right-lateral movement along the San Andreas Fault, where the North American tectonic plate contacts the Pacific plate. This transpressional stress occurring in the Transverse Ranges results in ongoing uplift of the adjacent mountains while the basins continue to flex downward (deepen).

The Ventura structural basin is filled with sediments that were deposited in both marine and terrestrial settings (Yeats et al., 1981). Near the coast, sediments were deposited on a wide delta complex that formed at the terminus of the Santa Clara River. The total stratigraphic thickness of these marine and terrestrial deposits in the Ventura structural basin reportedly exceeds 55,000 ft (Sylvester and Brown, 1988). Surface exposures of the major rock units and structural features in the vicinity of Mound Basin are shown in a simplified manner on Figure 3.1-02 and are discussed below. A geologic map that shows more details of the shallow surficial sediments (including landslides, stream terraces, alluvium in active stream channels, artificial fill, alluvial fans, and other near-surface deposits) prepared by the California Geological Survey (Gutierrez et al., 2008) is provided on Figure 3.1-03.

Geologic units (strata) in Mound Basin that may contain freshwater aquifers or aquitards are classified from youngest (top) to oldest (bottom as follows):

- Recent (active) stream-channel deposits along the present course of the Santa Clara River and its tributaries;
- Holocene -age alluvial fan deposits, which cover most of the Mound Basin;
- Stream-terrace deposits adjacent to the Santa Clara River;
- Undifferentiated older alluvium of Pleistocene age; and
- Semi-consolidated sand, gravel, and clay deposits of the San Pedro Formation (also referred to as the Saugus Formation and/or Las Posas Formation by some researchers, most recently by Gutierrez and others, 2008), of late Pleistocene age.

Stratigraphic relationships are shown conceptually on Figure 3.1-04. The classification approach shown on Figure 3.1-04 is based largely on hydrogeologic characteristics (United, 2018). Other researchers have divided these deposits in other, equally valid ways, based on geomorphological or other characteristics (e.g., Mukae and Turner, 1975; Dibblee, 1992; Hanson et al., 2003; Hopkins, 2020). For example, Hopkins Groundwater Consultants, Inc. (Hopkins), mapped the subsurface geologic formations through Mound Basin based upon 10 cross-sections. Cross-sections showing the subsurface geometry of these units are shown on Figures 3.1-05 through 3.1-08.

Older (and typically deeper) strata than those listed above typically are poorly permeable or contain water that is too brackish or saline for municipal or agricultural uses. These strata include (following the descriptions of Burton et al., 2011):

- Sandstone, siltstone, and shale of the Santa Barbara Formation (Yerkes, 1987), of early Pleistocene age. This unit was mapped as the “Mudpit Claystone Member of the Pico formation” by Dibblee (1988, 1992), but several more recent investigations, including those by Burton et al. (2011), the USGS (Hanson et al., 2003), and United (2012, 2018), refer to this unit as the Santa Barbara Formation.

- Marine siltstones, sandstones, and conglomerates of the Pico Formation, of Pliocene or early-Pleistocene age.
- Marine shales of the Sisquoc and the Monterey Formation, both of Miocene age, which underlie the Pico Formation at depth.

Within the Ventura structural basin, the trend of many (but not all) geologic structures is east-northeast to west-southwest, consistent with regional structural trends (Figure 3.1-02). The Country Club, Oak Ridge, and McGrath (sometimes referred to as Montalvo) Faults have previously been identified as significantly limiting or diverting groundwater flow (John F. Mann Jr. and Associates, 1959; Mukae and Turner 1975; Weber et al., 1976). In general, the older (deeper) geologic units show greater displacement across these faults than the younger (shallower) units. Therefore, groundwater flow in the deeper aquifers can typically be expected to be more disrupted across faults than groundwater flow in shallow aquifers.

Similar to faults in the Ventura structural basin, the axes of major folds (anticlines and synclines) in the sedimentary strata tend to be oriented approximately east-northeast to west-southwest (Figure 3.1-02). The axis of the Ventura-Santa Clara River syncline trends through Mound Basin in an east-west direction, plunging gradually to the west. The Montalvo-South Mountain-Oak Ridge anticline is approximately parallel to the Ventura-Santa Clara River syncline and is located near the southern boundary of Mound Basin (Geotechnical Consultants, 1972). Some workers also place a parallel fault at the location of the Montalvo-South Mountain-Oak Ridge anticline (John F. Mann Jr. and Associates, 1959; Fugro West, 1996). Folding in the Ventura structural basin is ongoing, with older strata (including those that comprise deep aquifers) being more deformed than younger strata (including shallow aquifers). The limbs of these folds are gently dipping within most of the freshwater-bearing strata in Mound Basin and adjacent Oxnard Basin (United, 2018). Therefore, it is unlikely that the folds themselves have a notable direct impact on groundwater flow. However, changes in strata thickness (which affects transmissivity), outcrop area (which affects where recharge occurs), and other hydraulic properties of strata can potentially be indirectly influenced by fold geometry.

3.1.3 Soil Characteristics [§354.14 (d)(3)]

§354.14 Hydrogeological Conceptual Model.

(b

(d) *Physical characteristics of the basin shall be represented on one or more maps that depict the following:*

(3) Soil characteristics as described by the appropriate Natural Resources Conservation Service soil survey or other applicable studies.

The hydrologic characteristics of soils in Mound Basin were downloaded from the Natural Resources Conservation Service (NRCS) online database (NRCS, 2020). Relevant soil information available from the NRCS for groundwater sustainability planning purposes includes soil infiltration capacity, which is shown on Figure 3.1-09. Most of the soils in Mound Basin are reported to have low to very low infiltration rates (Groups C and D, respectively). However, moderate-infiltration-rate soils are reportedly present in an approximately 1-mile-wide band oriented east-to-west along the axis of the basin (Figure 3.1-09). Smaller areas of high-infiltration-rate soils are reportedly present near the Santa Clara River, Harmon Barranca, and in some of the canyons in the foothills in the north part of Mound Basin.

Some clay-rich soils within the Holocene and Pleistocene alluvial deposits present in Mound Basin may be of sufficiently low vertical permeability to allow the formation of thin, discontinuous lenses or layers of shallow, "perched" groundwater above the primary saturated zone of the shallow alluvial aquifer (described in the next sub-section of this GSP). Municipal and agricultural return flows contribute substantial quantities of infiltrating water at land surface in Mound Basin, supplementing natural recharge of precipitation (discussed in more detail in Sections 3.1.4.2 and 3.3). When the rate of infiltration exceeds the ability of silt and clay lenses and layers to allow the water to pass through them, small saturated zones can develop in the soil. Groundwater in perched zones typically moves laterally to better-draining soils, where it can then resume its downward infiltration, or it may migrate laterally to nearby depressions in the topography, where it seeps out at land surface, evaporates, or is transpired by vegetation.

3.1.4 Principal Aquifers and Aquitards [§354.14(b)(4)(A)]

§354.14 Hydrogeological Conceptual Model.
(b) *The hydrogeologic conceptual model shall be summarized in a written description that includes the following:*
(4) Principal aquifers and aquitards, including the following information:
(A) Formation names, if defined.

Strata with distinct hydrogeologic characteristics are referred to as hydrostratigraphic units (HSUs). Aquifers have traditionally been defined as those HSUs that are capable of yielding appreciable quantities of groundwater to wells or springs. The Sustainable Groundwater Management Act (SGMA) defines "principal aquifers" as "aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems." Aquitards, on the other hand, are poorly permeable HSUs that impede groundwater movement (typically in the vertical direction) and generally do not yield appreciable quantities of groundwater to wells or springs.

The aquifers in Mound Basin consist of layers and lenses of relatively coarse-grained, permeable sediments (primarily sand and gravel) deposited within unconsolidated alluvium and the underlying, semi-consolidated San Pedro Formation (Figure 3.1-04). Aquitards present between the aquifers in Mound Basin consist of layers of poorly permeable fine-grained sediments (primarily silt and clay, Figure 3.1-04).

In Mound Basin, distinct HSUs were identified by United (2018) during their recent update of the hydrostratigraphic conceptual model for the region. United (2018) observed that electrical-log "signatures" of the Mugu, Hueneme, and Fox Canyon Aquifers (and the aquitards between these aquifers) observed in wells in the Oxnard Basin are often recognizable north of the McGrath Fault (Figure 3.1-02). The HSUs are generally grouped into three major "aquifer systems" by United as follows (from shallow to deep): the shallow alluvial aquifer, the Upper Aquifer System (UAS), and the Lower Aquifer System (LAS). Figure 3.1-04 shows the names and relationships between HSUs in Mound Basin, together with their corresponding geologic formations and ages. Details regarding the aquifers and aquitards within each aquifer system are provided below.

3.1.4.1 Physical Properties of Aquifers and Aquitards

3.1.4.1.1 Basin Boundary (Vertical and Lateral Extent of Basin) [§354.14(b)(2),(b)(3),(b)(4)(B), and (c)]

§ 354.14 Hydrogeological Conceptual Model.
(b) *The hydrogeologic conceptual model shall be summarized in a written description that includes the following:*
(2) Lateral basin boundaries, including major geologic features that significantly affect groundwater flow.
(3) The definable bottom of the basin.
(c) The hydrogeologic conceptual model shall be represented graphically by at least two scaled cross-sections that display the information required by this section and are sufficient to depict major stratigraphic and structural features in the basin.

The lateral boundaries of Mound Basin determined by the California Department of Water Resources (DWR, 2019) are defined as follows:

- **East:** The eastern boundary is defined by the western jurisdictional boundary of the Santa Paula Basin stipulated judgment (adjudication), as approved by DWR (2019) pursuant to a formal Basin Boundary Modification. This jurisdictional boundary is approximately aligned with the Country Club Fault system (Figure 3.1-02). The Country Club Fault system offsets the aquifers (see cross-section A-A', Figure 3.1-05) and impedes groundwater flow from the Santa Paula Basin into the Mound Basin.
- **Northwest:** The northwestern boundary is defined by the hydraulic divide between Mound Basin, Lower Ventura River Sub-basin (Figure 3.1-01).
- **West:** The western boundary is the Pacific Ocean shoreline. However, it should be noted that the UAS and LAS in Mound Basin extend approximately 10 miles offshore under the Pacific Ocean west of the shoreline, where they are mapped as cropping out on the continental shelf, as shown on Figure 3.1-10. The submarine outcrops may be covered with fine-grained marine sediments, such as silt and clay (Greene et al., 1978) that would tend to impede interaction of seawater with fresh water from the aquifers. Although DWR has delineated the western boundary of Mound Basin at the shoreline, the offshore portions of the principal aquifers of Mound Basin are in all likelihood capable of storing and transmitting significant quantities of fresh groundwater that has migrated westward from inland recharge areas. Because the DWR (2019) does not include this offshore area within the boundaries of Mound Basin, it is not included in calculations of area of Mound Basin or volumes of groundwater in storage in each aquifer (this statement will be confirmed once the water budget is finished). However, it must be emphasized that fresh groundwater can flow within the aquifers of Mound Basin either to or from the offshore areas without impediment, and groundwater flowing eastward (landward) across this boundary should not be assumed to consist of seawater.
- **North:** The northern boundary is defined by the contact of the San Pedro Formation (the deepest freshwater-bearing formation in the Basin) with the underlying Santa Barbara Formation (Figure 3.1-02; the Santa Barbara Formation is mapped as the "Mudpit Claystone Member of the Pico formation" by Dibblee [1988, 1992]). The northern boundary of Mound

Basin is at the northern edge of cross-section B-B', where the Fox Canyon Aquifer basal aquitard is in contact with the Santa Barbara Formation (Figure 3.1-06).

- **South:** The southern boundary is defined by the northern jurisdictional boundary of the Fox Canyon Groundwater Management Area (FCGMA), which also serves as boundary between the Mound and Oxnard basins, as approved by DWR (2019) pursuant to a formal Basin Boundary Modification. This jurisdictional boundary is approximately aligned with the axis of the Montalvo-South Mountain-Oak Ridge anticline and the McGrath Fault (Figure 3.1-02), which were understood at the time of formation of the FCGMA (early 1980s) to be the approximate northern limit of the Oxnard Basin.

The "bottom" of the basin is defined by the effective base of fresh water as described by Mukae and Turner (1975), which they mapped as the base of the San Pedro Formation. The lowermost strata of the San Pedro Formation have also been referred to as the Las Posas Sand (Dibblee, 1988, 1992). In Mound Basin, the San Pedro Formation overlies poorly permeable siltstone and shale of the Santa Barbara Formation (where present) and the Pico Formation (note: some investigators, including Dibblee [1988, 1992]) include portions of the Santa Barbara Formation in the Pico Formation). The depth to these units varies from as little as 0 ft below ground surface (bgs) along the northern basin boundary to approximately 2,400 ft bgs along the axis of the Ventura-Santa Clara River syncline, as shown on cross-sections A-A' through D-D' (Figures 3.1-05 through 3.1-08).

3.1.4.1.2 Groundwater Flow Barriers [§354.14(b)(4)(C) and (c)]

§354.14 Hydrogeological Conceptual Model.
(b) *The hydrogeologic conceptual model shall be summarized in a written description that includes the following:*
(4) *Principal aquifers and aquitards, including the following information:*
(C) Structural properties of the basin that restrict groundwater flow within the principal aquifers, including information regarding stratigraphic changes, truncation of units, or other features.

Geologic structures in Mound Basin affect groundwater flow within the aquifers to varying degrees. The most common example is where upward or downward apparent displacement (throw) of aquifer materials across a fault plane disrupts an aquifer's lateral continuity. Such an offset can impede groundwater flow through the aquifer along the fault plane. In Mound Basin, faulting has caused greater displacement (and correspondingly greater potential to impede groundwater flow) in the aquifers of the LAS, which are older (and thus have undergone more faulting and folding) than the aquifers of the UAS. The following sub-sections describe the primary structures that are believed to impact groundwater flow.

Country Club Fault

The trace of the Country Club Fault forms a northwest-trending arc approximately corresponding with the eastern boundary of Mound Basin adjacent to Santa Paula Basin (Figure 3.1-02). It is a steeply dipping (almost vertical) reverse fault with some left-lateral displacement (Turner, 1975). United's (2012, 2018) inspection of electrical logs for oil wells in the area indicate a displacement of 1,600 to 1,800 ft, with the southwest wall displaced upward relative to the northeast wall (Figure 3.1-05), consistent with the offset reported by previous investigators (Fugro West, 1996; Geotechnical Consultants, 1972). Review of electrical logs for wells in the area suggests that only a portion of the low permeability Santa Barbara

Formation has been uplifted against the San Pedro Formation (which contains the Hueneme and Fox Canyon Aquifers). With aquifers of the San Pedro Formation present on both sides of the Country Club Fault above the displaced Santa Barbara Formation, the Country Club Fault is not considered to be a complete barrier to groundwater flow. The fault is not believed to extend upward through the undifferentiated younger alluvium (Geotechnical Consultants, 1972). Consistent with the above geologic information, previous investigators, including USGS (Hanson et al., 2003) and United (2018), have noted a consistently steeper hydraulic gradient along the fault at the boundary between Mound Basin and Santa Paula Basin, compared with more gentle hydraulic gradients elsewhere within these basins. Such a steepening of hydraulic gradients is common along faults that impede groundwater flow. To calibrate its groundwater flow model for this area, United (2018) applied a conductance of 0.00001 square ft per day to the Country Club Fault, indicating it is a significant impedance to groundwater flow.

Oak Ridge and McGrath Faults

The Oak Ridge and McGrath Faults trend east-northeast to west-southwest in the southern Mound Basin (Figure 3.1-02). As noted by Yerkes et al. (1987), these faults are buried and known only from subsurface data in this area. Yerkes et al. (1987) describe two pressure ridges in Mound Basin as isolated, elongate northwest-trending structural uplifts. These ridges are described as compressional features and are compatible with left-lateral slip along the adjacent Oak Ridge Fault. Their existence suggests a significant strike-slip component along the Oak Ridge Fault as well as a reverse fault uplift on the south side.

Based on review of electrical logs, United (2012) determined that vertical displacement of approximately 700 ft of vertical displacement occurs along the McGrath Fault, with the up-thrown side on the south. This offset has juxtaposed the low-permeability Santa Barbara Formation against the lower section of the San Pedro Formation (Figures 3.1-06). Another notable feature is the significant difference in San Pedro Formation thickness across the McGrath Fault shown on cross-section B-B' (Figure 3.1-06). The younger deposits overlying the San Pedro Formation (Mugu Aquifer and shallow alluvial aquifer), do not appear to have been offset to the same degree as the LAS by either the McGrath or Oak Ridge Faults (Figures 3.1-06 and 3.1-07). Calibration of groundwater flow models for the area (Hanson et al., 2003; United, 2018) required incorporating the Oak Ridge and McGrath Faults as horizontal flow barriers, consistent with the concept that these faults restrict flow to some degree. In its regional groundwater flow model, United (2018) found that assigning a conductance to these faults of 0.0001 square ft per day resulted in an acceptable calibration.

Ventura, Pitas Point, and Foothill Faults

The Ventura and Foothill Faults trend east to west in the northern part of Mound Basin (Figure 3.1-02). The Pitas Point Fault is the westerly, offshore (mostly) extension of the Ventura Fault (Greene et al., 1978). The Ventura and Pitas Point Faults are reverse faults that dip to the north at a high angle; upward movement of the north side of the fault likely contributed to formation of the foothills in the north part of Mound Basin (Yerkes at al., 1987). The Foothill Fault is included in a USGS database of Quaternary faults (Burton et al., 2011), and an inferred fault is shown in approximately the same location by Yerkes et al. (1987). It is also shown on the geologic map included in the Hopkins (2020) report for Mound Basin. United (2012) hypothesized that the Foothill Fault is a reverse fault that dips to the north, similar to the Ventura and Pitas Point Faults.

As a result of vertical offset of the San Pedro Formation along the Ventura, Pitas Point, and Foothill Faults ranging from tens to hundreds of feet (Figures 3.1-06 and 3.1-07), it is inferred that these faults impede groundwater flow in the aquifers to some degree because, as shown on cross-section B-B' (Figure 3.1-06) the faulting disrupts the lateral continuity of the aquifers and juxtaposes different HSUs across the fault plane. However, no groundwater monitoring wells are located north and south of these faults to detect groundwater elevation changes across them that would allow estimation of conductance across the faults. Neither the USGS (Hanson et al., 2003) nor United (2018) modeled these faults as horizontal flow barriers due to lack of data to support calibration of the barrier effect of these faults.

3.1.4.1.3 Hydraulic Properties [§354.14(b)(4)(B)]

§354.14 Hydrogeological Conceptual Model.

(b) *The hydrogeologic conceptual model shall be summarized in a written description that includes the following:*

(4) *Principal aquifers and aquitards, including the following information:*

(B) Physical properties of aquifers and aquitards, including the vertical and lateral extent, hydraulic conductivity, and storativity, which may be based on existing technical studies or other best available information.

This sub-section provides a written description of the physical properties of the aquifers and aquitards within Mound Basin, including estimates of their lateral extent, thickness, hydraulic conductivity, and storativity. The lateral and vertical extents of the aquifers and aquitards are depicted on cross-sections A-A', through D-D' (Figures 3.1-05 through 3.1-08). At the time of writing of this GSP, no aquifer test results for hydraulic conductivity or storativity were found in available references. However, well information collected over the past several decades by United (now included in the MBGSA's Data Management System) from well completion reports includes 10 specific-capacity measurements obtained at water-supply and monitoring wells in Mound Basin, which were considered when United (2018) calibrated its numerical groundwater flow model of the region.

For basin-wide estimates hydraulic conductivity and storativity for each aquifer in Mound Basin, this GSP relies on United's calibrated flow model for the region (United, 2018), which is considered the best available information concerning aquifer and aquitard properties. These estimates are summarized in Table 3.1-01. However, it is recognized that on a local scale, hydraulic conductivity can vary by orders of magnitude over short distances, and there may be areas in Mound Basin where hydraulic conductivity is higher or lower than the values shown on Table 3.1-01.

Shallow Alluvial Aquifer

The shallow alluvial aquifer in Mound Basin consists of Holocene alluvial fan deposits (USGS, 2003a, 2003b, 2004) deposited by streams emanating from mountain canyons to the north. These deposits are composed of moderately to poorly sorted interbedded sandy clay with some gravel (USGS, 2003a, 2003b, 2004). The shallow alluvial aquifer is present in most areas of Mound Basin, except on the hillsides along the northern flank of the basin (United, 2018). The alluvial fan deposits that comprise the shallow alluvial aquifer are also absent along the Santa Clara River, where stream terrace deposits and active wash deposits are present instead (Figure 3.1-03). The stream terrace deposits include point bar and overbank deposits that consist of poorly sorted, clayey sand and sandy clay with gravel (USGS 2003a). The hydrostratigraphic conceptual model indicates thickness of the shallow alluvial aquifer ranges from less than 50 ft along the margins of Mound Basin to more than 100 ft in the central portion of the Basin (Figures 3.1-05 through 3.1-08) (United, 2018). The shallow alluvial aquifer is unconfined across Mound Basin (United, 2012, 2018).

Since 1979, when reporting of groundwater extraction from wells was mandated within United's service area, no pumping has been reported from the shallow alluvial aquifer for water supply in Mound Basin (pumping data for water-supply wells are included in the Mound Basin Data Management System), likely due to insufficient saturated thickness and/or poor water quality. Because it is not used for water supply, the shallow alluvial aquifer is not considered a "principal aquifer" at this time for the purpose of groundwater sustainability planning.

Based on calibration of its regional groundwater flow model, United (2018) estimated the horizontal hydraulic conductivity of the shallow alluvial aquifer to be 200 ft/d in Mound Basin, and the vertical hydraulic conductivity to be 20 ft/d. The specific yield of the shallow alluvial aquifer in the groundwater flow model is 15 percent (United, 2018). These values do not necessarily apply to the localized stream terrace deposits along the Santa Clara River. The presence of tile drains on agricultural lands situated on the stream terrace deposits (Figure 3.1-10) suggests that the stream terrace deposits are poorly permeable and, therefore, are not considered to be an aquifer, but may contain perched groundwater zones.

Upper Aquifer System

The UAS in Mound Basin consists of fine-grained Pleistocene deposits (which behaves as an aquitard) and the Mugu Aquifer. Each of these HSUs is described in more detail below.

Fine-Grained Pleistocene Deposits. United (2018) reports the presence of fine-grained Pleistocene deposits in Mound Basin, consisting primarily of a thick sequence of clays and silts, with sparse interbeds or lenses of sand and gravel. These deposits are stratigraphically equivalent to the Oxnard Aquifer of the Oxnard Basin, but do not yield significant quantities of groundwater in Mound Basin. This HSU has been logged to depths of 350 to 600 ft (typically 100 to 400 ft thick) in a number of wells in Mound basin (Figures 3.1-05 through 3.1-08). Along the Oxnard Basin boundary these deposits abut or interfinger with the Oxnard Aquifer. Because of its fine-grained nature, this HSU generally is poorly permeable and is rarely targeted for groundwater production; therefore, few data are available regarding its hydraulic parameters. It is possible that sand and gravel layers or lenses in this HSU could contain modest volumes of fresh groundwater.

Based on calibration of its regional groundwater flow model, United (2018) estimated the horizontal hydraulic conductivity of the fine-grained Pleistocene deposits to be 0.1 ft/d, typical of an aquitard rather than an aquifer, and vertical hydraulic conductivity to be 0.01 ft/d. The specific yield and storage coefficient for this unit were estimated by United (2018) to be approximately 5 percent and 0.001 (dimensionless), respectively. This HSU acts as a confining unit for the Mugu Aquifer in Mound Basin, except along the northern margin of the basin where the San Pedro Formation (which includes the Hueneme and Fox Canyon Aquifers) is exposed at land surface and, therefore, is unconfined.

Mugu Aquifer. The Mugu Aquifer consists of marine and non-marine sands and gravels with interbedded silt and clay that lie below the fine-grained Pleistocene deposits and unconformably overlie the San Pedro Formation (Figures 3.1-05 through 3.1-08). Thickness of the Mugu Aquifer in Mound Basin is variable, ranging from approximately 100 to 425 ft, based on borehole geophysical logs reviewed by United (2018). The Mugu Aquifer is generally thickest along the northeast-southwest axis of the basin, and thins to the north, where it pinches out south of the northern basin boundary. The Mugu Aquifer also thins (to approximately 200 ft) in the south toward the boundary with the Oxnard Basin. Several water-supply wells in Mound Basin are screened in the Mugu Aquifer, as it is generally the first aquifer encountered when drilling that yields significant quantities of acceptable-quality groundwater.

Based on calibration of its regional groundwater flow model, United (2018) estimated the horizontal hydraulic conductivity of the Mugu Aquifer to be 100 ft/d in Mound Basin, and vertical hydraulic conductivity to be 10 ft/d. The specific yield and storage coefficient used in the model (United, 2018) were approximately 15 percent where unconfined (along the northern basin margin) and 0.001 (dimensionless) where confined (throughout most of the basin), respectively.

As described in more detail in Section 3.1.4.4, the Mugu Aquifer stores, transmits, and yields significant or economic quantities of groundwater to wells; therefore, it is considered a "principal aquifer" of Mound Basin.

Lower Aquifer System

The LAS in Mound Basin includes the Hueneme and Fox Canyon Aquifers, as well as the aquitards present between each aquifer. These aquifers and aquitards consist of relatively coarse- and fine-grained strata, respectively, of the San Pedro Formation, which is Pleistocene in age. The LAS, being older than the UAS, has undergone more faulting and folding. It has also been eroded, creating an unconformity that separates the UAS from the LAS (Turner, 1975). Except near the northern margin of Mound Basin, the LAS is overlain unconformably by the UAS. The San Pedro Formation crops out in the foothills near the northern boundary of the basin, attaining a maximum thickness of 2,300 ft in this region (Geotechnical Consultants, 1972). In this area, the aquifers of the San Pedro Formation are not overlain by confining units, and, therefore, are unconfined. The aquifers of the LAS are isolated from each other vertically by relatively low-permeability silt and clay layers called the "Hueneme-Fox Canyon Aquitard." The base of the LAS is considered to be the base of fresh water (Mukae and Turner, 1975). Beneath the LAS lie older sedimentary rocks that are generally considered to contain brackish to saline water or to be poorly transmissive (Mukae and Turner, 1975) and are not used for water supply in Mound Basin. More details regarding each aquifer and aquitard comprising the LAS is provided below.

Mugu-Hueneme Aquitard. The upper portion of the LAS in Mound Basin (immediately below the Mugu Formation) consists of poorly permeable sediments with relatively high silt and clay content. This unit is referred to by United (2018) as the Mugu-Hueneme aquitard. Electrical logs for oil and water wells in the region show that this aquitard is present throughout most of Mound Basin between the Mugu and Hueneme Aquifers, except along the northern margin of the basin where this unit has been uplifted by the Ventura-Pitas Point Fault and eroded away. Thickness of this aquitard ranges from approximately 100 ft at the northern margins of the basin to 200 ft near the center of the basin (Figures 3.1-05 through 3.1-08).

Based on calibration of its regional groundwater flow model, United (2018) estimated the horizontal hydraulic conductivity of the Mugu-Hueneme aquitard to be approximately 1 ft/d in Mound Basin, and vertical hydraulic conductivity to be 0.1 ft/d. The specific yield for the Mugu-Hueneme aquitard in Mound

Basin in the model is 5 percent where unconfined (along the northern basin margin), and the storage coefficient is 0.0005 (dimensionless) where confined (throughout most of the basin).

Hueneme Aquifer. A series of interbedded, water-bearing sands in the upper approximately two-thirds of the San Pedro Formation comprise the Hueneme Aquifer (United, 2018). Structural complexities have resulted in thinning of these beds in the southern part of Mound Basin (south of the Oak Ridge and McGrath Faults), compared to the central axis of Mound Basin (Figures 3.1-06 and 3.1-07). In the central and northern parts of the basin, resistivity-log signatures indicate some lithologic differences in this unit compared its lithology in the Oxnard Basin; specifically, some of the coarse-grained strata of the Hueneme Aquifer thin or become increasingly lenticular in the northward direction (United, 2012). However, thick (up to 1,000 ft) sections of the Hueneme Aquifer (or time-equivalent strata) do occur in Mound Basin, as oil-well electrical logs interpreted by United (2012) indicate variable amounts of coarse grained (permeable) materials. Borehole geophysical (resistivity) logs reviewed by United (2018) indicate the Hueneme Aquifer is generally thickest (typically 1,000 ft) along the northeast-southwest axis of the basin, becoming thinner (200 to 600 ft) along the northern and southern basin boundaries. Most of the water-supply wells in Mound Basin are screened primarily or entirely in the Hueneme Aquifer.

Based on calibration of its regional groundwater flow model, United (2018) estimated the horizontal hydraulic conductivity of the Hueneme Aquifer to be 20 ft/d throughout Mound Basin, and vertical hydraulic conductivity to be 2 ft/d. The specific yield for the Hueneme Aquifer in Mound Basin in the model is 10 percent where unconfined (along the northern basin margin), and the storage coefficient is 0.002 (dimensionless) where confined (throughout most of the basin).

As described in more detail in Section 3.1.4.4, the Hueneme Aquifer stores, transmits, and yields significant or economic quantities of groundwater to wells; therefore, it is considered a “principal aquifer” of Mound Basin.

Hueneme-Fox Canyon Aquitard. Below the Hueneme Aquifer, laterally extensive deposits of silt and clay of the San Pedro Formation up to approximately 100 ft thick (Figures 3.1-05 through 3.1-08), with interbeds of sand and gravel, form an aquitard between the Hueneme and Fox Canyon Aquifers throughout Mound Basin. This HSU is referred to by United (2018) as the Hueneme-Fox Canyon aquitard.

Based on calibration of its regional groundwater flow model, United (2018) estimated the horizontal hydraulic conductivity of the Hueneme-Fox Canyon Aquitard to be 1 ft/d in most of Mound Basin, and vertical hydraulic conductivity to be 0.1 ft/d. The specific yield for the Mugu-Hueneme Aquitard in Mound Basin in the model is 5 percent where unconfined (along the northern basin margin), and the storage coefficient estimated to be 0.0005 (dimensionless) where confined (throughout most of the basin).

Fox Canyon Aquifer. Lower portions of the San Pedro Formation consist principally of sand and gravel zones with variable thicknesses of interstratified clay and silt (United, 2018). In a northerly direction across Mound Basin, these coarser grained water-bearing strata are somewhat lenticular and generally become thinner (John F. Mann Jr. and Associates, 1959; Geotechnical Consultants, 1972), similar to the Hueneme Aquifer. The sand and gravel zone located at or near the base of the San Pedro Formation is known as the Fox Canyon Aquifer in the Oxnard Basin, and United (2012, 2018) extends that nomenclature for this HSU to Mound Basin as well. Electrical log data and outcrops near the base of the San Pedro Formation in the foothills on the north side of Mound Basin do not indicate the same aquifer thickness or sediment coarseness as observed at the location in Fox Canyon on the south flank of South Mountain, 11 miles southeast of Mound Basin (Geotechnical Consultants, 1972; United, 2012). However, the distinct borehole resistivity log signature of the Fox Canyon Aquifer is discernible across Mound Basin and adjacent areas (United, 2012). The Fox Canyon Aquifer commonly occurs at depths greater than 1,000 ft in Mound Basin and is not targeted for groundwater supply (United, 2012), with the exception of two active water-supply wells that are screened partly in the Fox Canyon Aquifer and partly in the overlying Hueneme Aquifer (Table 3.1-02).

Borehole resistivity logs reviewed by United (2018) indicate that the Fox Canyon Aquifer in Mound Basin is typically 400 to 600 ft thick (Figures 3.1-05 through 3.1-08). However, as discussed above, the coarser-grained layers that comprise the main water-producing zones of the Fox Canyon Aquifer thin and become more lenticular in a northerly direction across Mound Basin, as shown on the resistivity logs on Figures 3.1-06 and 3.1-07. In the Oxnard Basin, John F. Mann Jr. and Associates (1959) further divided the Fox Canyon Aquifer into a "main" (sometimes called "upper") member and a "basal" member (at the base of the San Pedro Formation), separated by a 50-ft-thick aquitard consisting primarily of fine-grained sediments. United (2018) incorporated this subdivision of the Fox Canyon Aquifer into the area of their regional groundwater flow model that represents the Oxnard Basin. However, United (2018) did not observe indications of a distinct basal member of the Fox Canyon Aquifer in Mound Basin from review of electrical logs. No water supply wells in Mound Basin are screened to the depth needed to reach the base of the Fox Canyon Aquifer; therefore, the hydraulic characteristics of this unit are uncertain.

Based on calibration of its regional groundwater flow model, United (2018) estimated the horizontal hydraulic conductivity of the main Fox Canyon Aquifer to be 10 ft/d in most of Mound Basin, and vertical hydraulic conductivity to be 1 ft/d. The specific yield for the main Fox Canyon Aquifer in Mound Basin in the model is 10 percent where unconfined (along the northern basin margin), and the storage coefficient is 0.002 (dimensionless) where confined (throughout most of the basin).

Based on calibration of its regional groundwater flow model, United (2018) estimated the horizontal hydraulic conductivity of the San Pedro Formation below the main Fox Canyon Aquifer in Mound Basin (referred to as the Fox Canyon main-basal aquitard) to be 1 ft/d in Mound Basin and vertical hydraulic conductivity to be 0.1 ft/d. The specific yield for these strata in the model is 5 percent where unconfined (along the northern basin margin), and the storage coefficient is 0.0005 (dimensionless) where confined (throughout most of the basin).

The "basal Fox Canyon Aquifer" in the adjacent Oxnard Basin, was assigned equivalent hydraulic conductivity and storage values to the overlying aquitard within the Mound Basin area in United's groundwater flow model (2018). Specifically, the horizontal hydraulic conductivity was assigned a value of 1 ft/d in Mound Basin, and vertical hydraulic conductivity was assigned a value of 0. 1 ft/d. The specific yield for these strata was assigned a value of 5 percent where unconfined (along the northern basin margin) by United (2018), and storage coefficient was assigned a value of 0.0005 (dimensionless) where confined (throughout most of the basin).

Owing to the lack of wells screened in the Fox Canyon Aquifer, it does not meet the SGMA definition of a principal aquifer because it does not currently (and has not, historically) "store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems" in Mound

Basin. If future water-supply wells are screened in the Fox Canyon Aquifer, then this designation should be reconsidered as part of the required periodic GSP update process.

3.1.4.2 Groundwater Recharge and Discharge Areas [§354.14(d)(4)]

> **§354.14 Hydrogeological Conceptual Model.**
> *(d) Physical characteristics of the basin shall be represented on one or more maps that depict the following:*
> ***(4) Delineation of existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas, including significant active springs, seeps, and wetlands within or adjacent to the basin.***

Multiple sources of groundwater recharge (water that enters an underlying groundwater system from land surface) occur in Mound Basin (United, 2018), including:

- Infiltration of precipitation—Most infiltration of precipitation recharges the shallow alluvial aquifer, although some infiltration of precipitation occurs in outcrops of the Hueneme and Fox Canyon Aquifers, in the foothills in the northern part of Mound Basin.
- Mountain-front recharge—For this report, the term "mountain-front recharge" refers to infiltration of runoff from the foothills north of Mound Basin, where many of the small drainages in Mound Basin have watersheds that extend northward beyond the basin boundary. Both United (2018) and the USGS (Hanson and others, 2003) computed monthly runoff in each of these small catchment areas based on rainfall, and incorporated infiltration of this runoff into aquifers as a recharge component in their regional numerical models. Infiltration of this runoff is assumed to occur within a short distance (2,000 ft) south of the basin boundary, where the Hueneme and Fox Canyon Aquifers are exposed at land surface. In Mound Basin, infiltration of this runoff recharges the Hueneme and Fox Canyon Aquifers.
- Municipal and industrial (M&I) return flows—This term refers to water applied for landscape irrigation, leaked water from water-supply and wastewater pipelines, and stormwater that is collected in detention basins or other facilities and allowed to infiltrate into the ground. Most of these return flows recharge the shallow alluvial aquifer, but some may contribute to recharge of the Hueneme Aquifer and Fox Canyon Aquifer in the foothills in the north part of Mound Basin, where residential development exists on the hillsides.
- Agricultural return flows— This term refers to water applied for agricultural irrigation (in addition to rainfall) that infiltrates deeper than the root zone of crops. Some "excess" irrigation of farmland is required to leach salts from shallow soil, and some irrigation inefficiencies occur due to the variability in irrigation application and soil infiltration capacity. These infiltrating return flows may be intercepted by perched zones in near-surface soil horizons or continue downward to the uppermost aquifer, which in most of Mound Basin is the shallow alluvial aquifer. However, some return flows in the foothills in the north part of Mound Basin may contribute to recharge of the Hueneme Aquifer and Fox Canyon Aquifer, where avocado and other orchards are present in areas where these aquifers are present at or near land surface.
- Stream-channel recharge—This term refers to infiltration of surface-water flows in "losing" reaches of major streams (excluding areas of mountain-front recharge as described above). The quantity of recharge occurring in the narrow channels of the barrancas in Mound Basin, most of which only flow briefly following storm events, is so small as to be considered by United

(2018) to be indistinguishable from areal recharge of agricultural and M&I return flows. The Santa Clara River is the only major stream in Mound Basin, and the reach of the Santa Clara River in Mound Basin is considered to usually be the site of groundwater discharge, rather than recharge (Stillwater Sciences, 2011; United, 2018). However, the lower Santa Clara River in the area of its estuary is reported to fluctuate from gaining to losing cycles as water levels rise and fall in response to breaching of the barrier sand at the mouth of the river (Stillwater Sciences, 2011). When the elevation of surface water in the estuary rises (following closure of the barrier bar), some of the rising water infiltrates (recharges) the shallow deposits adjacent to the river. Then, typically in the following winter or spring, a large storm will produce sufficient flows in the river that it will breach the barrier bar and cause rapid decline of surface-water levels in the estuary, causing groundwater in the adjacent shallow deposits to discharge back into the river over a sustained period.

Areas where these sources of recharge occur in Mound Basin are shown on Figure 3.1-11, and further discussion of the nature and quantities of these sources of recharge are discussed in Section 3.3. In addition to the types of recharge (from land surface) listed above, subsurface inflow of groundwater also occurs in Mound Basin as a result of groundwater underflow from adjacent basins (United, 2018), as discussed in Section 3.3.

Within Mound Basin, groundwater discharge occurs along the lower, gaining reach of the Santa Clara River (area 11 on Figure 3.1-11), and via tile drains installed under farm land adjacent to the river, as noted on Figure 3.1-11. Groundwater discharge may also occur at Area 10 on Figure 3.1-11, as discussed in more detail in Section 3.2.6. These areas of groundwater discharge in Mound Basin are shown on Figure 3.1-11, and their quantities are discussed in Section 3.3. As noted in Section 3.1.1.2, no springs or seeps are shown on USGS topographic maps within or adjacent to the boundaries of Mound Basin. In addition to the types of discharge listed above, extraction of groundwater also occurs in Mound Basin at water-supply wells, as discussed in Section 3.1.4.4.

3.1.4.3 Groundwater Quality [§354.14(b)(4)(D)]

§354.14 Hydrogeological Conceptual Model.
(b) *The hydrogeologic conceptual model shall be summarized in a written description that includes the following:*
(4) *Principal aquifers and aquitards, including the following information:*
(D) General water quality of the principal aquifers, which may be based on information derived from existing technical studies or regulatory programs.

Available groundwater-quality data and existing technical studies were reviewed to understand the age, major-ion chemistry, and spatial and temporal trends in key groundwater-quality indicator constituents, such as total dissolved solids (TDS), sulfate, chloride, and nitrate, in the principal aquifers of Mound Basin.

Groundwater-quality data are available from wells screened in three HSUs in Mound Basin: the fine-grained Pleistocene deposits, Mugu Aquifer, and Hueneme Aquifer. Maps of recent (2017) concentrations of the key indicator constituents and time-series graphs of historical concentrations detected at selected wells are shown on Figures 3.1-12 through 3.1-25. Water quality data for 2017 were selected for these maps because 2017 was the most recent year when a relatively large number of Mound Basin wells was sampled; fewer wells were sampled in 2018 by VCWPD due to staffing issues) The major-ion chemistry of the HSUs is shown using stiff diagrams on Figures 3.1-21 through Figure 3.1-23. Comparison of the stiff diagrams reveals that groundwater in the fine-grained Pleistocene deposits has a very different chemistry than groundwater in the principal aquifers (Mugu and Hueneme Aquifers). Groundwater in the fine-grained Pleistocene deposits is 3 to 5 times more mineralized and has a different major-ion signature than groundwater in the Mugu and Hueneme Aquifers. The degree of mineralization and major-ion chemistry in the Mugu and Hueneme Aquifer are similar, with Hueneme Aquifer groundwater generally being slightly more mineralized. One exception is the shallow dedicated monitoring well at Community Park (CWP-510), which is screened in the upper Hueneme Aquifer and has major-ion chemistry that bears similarities to the fine-grained Pleistocene deposits (Figure 3.1-23) The dramatic difference between groundwater chemistry in the fine-grained Pleistocene deposits versus the Mugu and Hueneme Aquifers is explained by different geochemical processes operative in the shallow HSUs versus the deeper, principal aquifers. S.S. Papadopulos & Associates, Inc. (SSP&A, 2020) concluded that groundwater in the principal aquifers appears to be similar in composition to regional groundwater in other local basins; however, in contrast, shallow groundwater is additionally influenced by reactions with local aquifer minerals, principally gypsum and perhaps other evaporites that do not appear to be present in the principal aquifers.

SSP&A (2020) further concluded that there is no significant evidence for interactions between groundwater in the principal aquifers and shallow groundwater (CWP-510 is included here) or deeper, mineralized water. SSP&A (2020) also concluded that groundwater at the sample locations in the basin is at least 1,000 years old. These conclusions together suggest that vertical movement of water percolating from land surface is not a major source of recharge to the principal aquifers, except where they are exposed at land surface in the northern portion of the basin.

Groundwater quality in each of the principal aquifers, as discussed further below, is relatively stable at many Mound Basin wells having long-term groundwater-quality records, consistent with the conclusion by previous investigators that natural causes are the primary source of elevated concentrations of dissolved constituents in groundwater.

The Basin Plan of the Regional Water Quality Control Board, Los Angeles region (RWQCB-LA) establishes groundwater-quality "objectives" (WQOs) as "the allowable limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area" (RWQCB-LA, 2019). The WQOs for Mound Basin are shown in Table 3.1-03.

Mugu Aquifer

Maximum TDS, sulfate, chloride, and nitrate concentrations detected in 2017 at five wells screened in the Mugu Aquifer (including wells with screens that extend above or below the Mugu Aquifer) were reported to or obtained by United (Figures 3.1-12 through 3.1-15). Four of these five wells are located along the west-southwest to east-northeast axis of the basin, and one is located in the southeast quadrant of the basin. Also shown on Figures 3.1-12 through 3.1-15 are water-quality data at wells in adjacent areas of the Oxnard and Santa Paula Basin, as they may provide some insight to groundwater quality along the southern and eastern margins of Mound Basin. Figures 3.1-20 through 3.1-22 show concentrations of TDS, sulfate, and chloride over time at selected wells with historical data available in Mound Basin. These graphs indicate that concentrations of common dissolved constituents at each well have not undergone large fluctuations, nor have there been readily discernible increasing or decreasing concentration trends at most of the wells. It is noted that well 02N22W07P01S has anomalously high nitrate concentrations, suggesting influence of shallow groundwater through a possibly compromised well seal or well casing. Thus, the elevated concentrations of TDS, sulfate, and chloride reported for this well are not necessarily considered representative of the Mugu Aquifer groundwater quality.

The maximum TDS concentrations detected in 2017 at wells screened in the Mugu Aquifer in Mound Basin ranged from 880 to 3,040 milligrams per liter (mg/L) (Figure 3.1-12). The single highest TDS concentration was detected at agricultural water-supply well 02N22W07P01S, near the intersection of U.S. Highway 101 and State Highway 126, in the central portion of Mound Basin. As stated above, the TDS concentrations detected at this well is not considered representative of Mugu Aquifer groundwater quality. After excluding the unrepresentative result, the range of maximum TDS concentrations measured in the remaining four wells is 880 to 1,140 mg/L (Figure 3.1-12). For comparison and as shown in Table 3.1-03, the RWQCB-LA WQO for TDS in confined aquifers of the lower Santa Clara River basins (including Mound Basin) is 1,200 mg/L (RWQCB-LA, 1994). The California Division of Drinking Water (DDW) lists a "recommended secondary" maximum contaminant level range (MCLR) for TDS in public water supplies of 500 mg/L.

The maximum sulfate concentrations detected in 2017 at wells screened in the Mugu Aquifer in Mound Basin ranged from 312 to 1,550 mg/L (Figure 3.1-13). Similar to TDS, the single highest sulfate concentration was detected at agricultural water-supply well 02N22W07P01S, in the central portion of the Basin. As stated above, the sulfate result from this well is not considered representative of Mugu Aquifer groundwater quality. After excluding the unrepresentative result, the range of maximum sulfate concentrations measured in the remaining four wells is 312 to 698 mg/L (Figure 3.1-13). The RWQCB-LA's applicable WQO for sulfate (Table 3.1-03) in Mound Basin is 600 mg/L (RWQCB-LA, 1994). The DDW-recommended secondary MCLR for sulfate in public water supplies is 250 mg/L. DDW also lists an "upper secondary" MCLR for sulfate in public water supplies of 500 mg/L.

The maximum chloride concentrations detected in wells screened in the Mugu Aquifer in Mound Basin ranged from 45 to 138 mg/L (Figure 3.1-14). Similar to TDS and sulfate, the single highest chloride concentration was detected at agricultural water-supply well 02N22W07P01S, in the central portion of the basin. As stated above, the chloride result from this well is not considered representative of Mugu Aquifer groundwater quality. After excluding the unrepresentative result, the range of maximum chloride concentrations measured in the remaining four wells is 45 to 76 mg/L (Figure 3.1-14), which is in Marina Park near the coastline. The RWQCB-LA's applicable WQO for chloride (Table 3.1-03) in Mound Basin is 150 mg/L (RWQCB-LA, 1994). DDW's recommended secondary MCLR for chloride in public water supplies is 250 mg/L and DDW's upper MCLR for chloride in public water supplies is 500 mg/L.

The maximum nitrate as (as nitrate [NO_3]) concentrations detected in 2017 at wells screened in the Mugu Aquifer in Mound Basin ranged from less than the detection limit (0.4 mg/L) to 64.6 mg/L (Figure 3.1-15). Nitrate concentrations are occasionally reported by laboratories in equivalent weight as nitrogen; in this GSP, nitrate results reported as nitrogen have been recalculated to equivalent concentrations as NO_3, unless otherwise noted. Similar to the other common dissolved constituents noted above, the single highest nitrate concentration in the Mugu Aquifer in 2017 was detected at agricultural water-supply well 02N22W07P01S, in the central portion of the basin. It is noted that the nitrate concentration in well 02N22W07P01S is anomalously high compared to other Mugu Aquifer wells in the Basin, suggesting influence of shallow groundwater through a possibly compromised well seal or well casing. Nitrate concentrations were below the detection limit at three of the four remaining wells in the Mugu Aquifer and 8.4 mg/L at the fourth well (Figure 3.1-15). The RWQCB-LA's applicable WQO for nitrate (as NO_3) in Mound Basin is 45 mg/L (RWQCB-LA, 1994). Similarly, DDW lists a "primary" maximum contaminant level (MCL) for nitrate in public water supplies of 45 mg/L (as NO_3).

Figures 3.1-20 through 3.1-22 show times series of measured historical TDS, chloride, and sulfate in wells screened in the Mugu aquifer. At Well 02N23W14K01S, TDS exceeded WQOs for the Basin from the early 1930s to 1957. However, for the rest of historical records from the mid-1960s through the early 1980s, TDS concentration at Well 02N23W14K01S remained below WQOs, with the exception of two samples. Sulfate concentrations measured at the same well have been below WQOs from the early 1930s through the last sample taken in the early 1980s, with the exception of one sample that appears to be an outlier and, thus, should not be considered. Chloride concentrations measured at the same well have been below the WQO from the early 1930s through the last sample taken in the early 1980s, with the exception of one sample that also appears to be an outlier and, thus, should not be considered. TDS, chloride, and sulfate concentrations at other wells (Figure 3.1-21 and 3.1-22) have been at or below the WQO throughout the available period of record from 1995 through 2020, with the exception of a few samples of TDS. TDS, sulfate, and chloride concentrations have been below the RWQCB-LA WQOs for the entire period of record at the Marina Park and Camino Real Park Mugu monitoring wells (02N23W15J02 and 02N22W07M02, respectively) (Figures 3.1-21 and 3.1-22).

Measured historical boron concentration slightly exceeded the Basin WQO in October of 2013 at only one well (02N22W07P01S). The average boron concentration measured at Well 02N22W07P01S over the available period of record of 2000 to 2017 was 0.71 mg/L. The one-time exceedance was likely due to the major drought that occurred in 2013. All the samples taken after October 2013 at the same well had concentrations less than the Basin WQO and did not show any specific trend. Therefore, the October 2013 sample appears to be an outlier and should not be considered.

Hueneme Aquifer

Maximum TDS, sulfate, chloride, and nitrate concentrations detected in 2017 at nine wells screened in the Hueneme Aquifer (including wells with screens that extend above or below the Hueneme Aquifer) were reported to or obtained by United (Figures 3.1-16 through 3.1-19). Five of these nine wells are located along the west-southwest to east-northeast axis of the basin, and four are located in the southeast quadrant of the basin. As noted above, Figures 3.1-20 through 3.1-25 show concentrations of TDS, sulfate, and chloride over time at selected wells with historical data available in Mound Basin. It is noted that wells 02N23W13K03S, 02N22W08G01S, and 02N22W09L04S exhibit anomalously high concentrations of TDS, sulfate, chloride, and nitrate, suggesting influence of shallow groundwater through a possibly compromised well seal or well casing. Thus, the elevated concentrations of TDS, sulfate, and chloride reported for these wells should not be considered representative of Hueneme Aquifer groundwater quality.

The maximum TDS concentrations detected in 2017 at wells screened in the Hueneme Aquifer in Mound Basin ranged from 1,060 to 6,390 mg/L (Figure 3.1-16). The highest TDS concentration was detected at monitoring well 02N22W09L04S, in the southeast quadrant of the Basin. As stated above, the TDS result from this well and two others are not considered representative of Hueneme Aquifer groundwater quality.

After excluding the unrepresentative results, the range of maximum TDS concentrations measured in the remaining six wells is 1,060 to 1,548 mg/L (Figure 3.1-16). Three of the six representative wells have TDS concentrations below the RWQCB-LA WQO and three are above.

The maximum sulfate concentrations detected in 2017 at wells screened in the Hueneme Aquifer in Mound Basin ranged from 412 to 3,620 mg/L (Figure 3.1-17). Similar to TDS in the Hueneme Aquifer, the single highest sulfate concentration was detected at monitoring well 02N22W09L04S, in the southeast quadrant of the basin. As stated above, the sulfate result from this well and two others are not considered representative of Hueneme Aquifer groundwater quality. After excluding the unrepresentative results, the range of maximum sulfate concentrations measured in the remaining six wells is 412 to 705 mg/L (Figure 3.1-16). Four of the six representative wells have sulfate concentrations below the RWQCB-LA WQO and two are above.

The maximum chloride concentrations detected in 2017 at wells screened in the Hueneme Aquifer in Mound Basin ranged from 68 to 181 mg/L (Figure 3.1-18). Similar to TDS and sulfate in the Hueneme Aquifer, the single highest chloride concentration was detected at monitoring well 02N22W09L04S, in the southeast quadrant of the basin. As stated above, the chloride result from this well and two others are not considered representative of Hueneme Aquifer groundwater quality. After excluding the unrepresentative results, the range of maximum chloride concentrations measured in the remaining six wells is 68 to 93 mg/L (Figure 3.1-18). All six representative wells have chloride concentrations below the RWQCB-LA WQO.

The maximum nitrate concentrations detected in 2017 at wells screened in the Hueneme Aquifer in Mound Basin ranged from less than the laboratory detection limit (0.4 mg/L) to 136 mg/L (Figure 3.1-19). Similar to the other common dissolved constituents detected in the Hueneme Aquifer, the single highest nitrate concentration in the Hueneme Aquifer was detected at monitoring well 02N22W09L04S, in the southeast quadrant of the basin. It is noted that the nitrate concentrations in this well (together with 02N23W13K03S and 02N22W08G01S) are anomalously high compared to other Hueneme Aquifer wells in Mound Basin, suggesting influence of shallow groundwater through a possibly compromised well seal or well casing. Nitrate concentrations were below the detection limit at five wells in the Hueneme Aquifer in Mound Basin (Figure 3.1-19).

Municipal water supply well 02N22W08F01S (Victoria 2) is one of the few wells in Mound Basin where increasing trends are clearly discernible in past (1995 to 2006) TDS and sulfate concentrations (Figure 3.1-24). This well has three screened intervals (580 to 640; 900 to 940; and 1,060 to 1,180 ft bgs) in the Hueneme Aquifer. As groundwater production increased from this well in the 1990s, TDS concentrations increased from approximately 1,000 mg/L to approximately 1,500 mg/L by 2006. Concentrations have since stabilized and have not increased further. The cause of the groundwater-quality changes at this well is currently unknown. It is noted that all other wells screened in the Hueneme Aquifer with historical water-quality data exhibit generally stable trends for all constituents (Figures 3.1-21 through 3.1-23, and 3.1-25).

Measured historical boron concentration has exceeded the Basin WQO at six wells. The maximum measured Boron concentration at these wells ranged from 1.05 to 1.30 with the exception of one well (02N23W24G01S) which only had reported data during the 1950's. The reported concentrations at Well 02N23W24G01S show that boron was 7.0 mg/L in October 1953, whereas the rest of the reported concentrations at the same well were below 0.59 mg/L. The 7.0 mg/L reported for October 1953 appears to be an outlier and thus should not be considered. Boron concentration at four of the five remaining wells show boron concentrations below the Basin WQO for the entire period of records with the exception of one or two samples. For the sixth well (02N22W07M03S), the nine reported samples were above the basin WQO. However, these samples do not show any particular trend.

3.1.4.4 Primary Beneficial Uses [§354.14(b)(4)(E)]

> **§354.14 Hydrogeological Conceptual Model.**
> ***(b)*** *The hydrogeologic conceptual model shall be summarized in a written description that includes the following:*
> ***(4)*** *Principal aquifers and aquitards, including the following information:*
> ***(E) Identification of the primary use or uses of each aquifer, such as domestic, irrigation, or municipal water supply.***

The primary uses of each principal aquifer in Mound Basin are reflected in the pumping records that are reported to United (and included in the MBGSA Data Management System). The recent (as of 2019) pumping records for groundwater in Mound Basin reported to United include agricultural water supply (at 22 wells) and M&I water supply (at 4 wells). In 2019, 2,873 AF (45 percent of the total of 6,319 AF of groundwater pumped from Mound Basin) was used for agriculture, and 3,446 AF (55 percent of the total) was used for M&I purposes. The locations of all 26 water-supply wells active in Mound Basin in 2019, and relative volumes of groundwater extracted by each well, are shown on Figure 3.1-26. The quantities of groundwater pumped for agricultural and M&I uses from the principal aquifers underlying Mound Basin during the past 40 years (1980 through 2019) are shown on Figures 3.1-27 through 3.1-29. None of the wells active in 2019 were reportedly used for domestic supply, likely due to the availability of potable water from Ventura Water and the significant expense required to drill a domestic water-supply well to the depth required to reach a principal aquifer in Mound Basin. The following sub-sections provide more detail regarding the primary uses of groundwater extracted from each principal aquifer in Mound Basin.

Mugu Aquifer Pumping

Five active wells are screened solely in the Mugu Aquifer; the water pumped from them is all used for agricultural purposes (Table 3.1-02). In 2019, a total of 1,071 AF was pumped from these wells, approximately 17 percent of the total quantity of groundwater (6,319 AF) pumped from Mound Basin that year.

Hueneme Aquifer Pumping

Eleven active wells are screened solely in the Hueneme Aquifer (Table 3.1-02). In 2019, four of these wells supplied 3,446 AF of groundwater for M&I use, which represents all M&I pumping from Mound Basin in 2019 and 55 percent of the total pumping from Mound Basin. The remaining wells supplied 850 AF of groundwater for agricultural use, which is approximately 13 percent of the total pumped from Mound Basin in 2019.

Pumping from Wells Screened Across Multiple Aquifers

Five active water-supply wells are screened in both the Mugu and Hueneme Aquifers. All water pumped from these wells is used for agricultural purposes (Table 3.1-02). In 2019, a total of 289 AF was pumped from these wells, approximately 5 percent of the total pumped from Mound Basin that year.

Two active water-supply wells are screened in both the Hueneme and Fox Canyon Aquifers; the water pumped from these wells is used for agricultural purposes (Table 3.1-02). In 2019, a total of 191 AF was pumped from this well, about 3 percent of the total quantity of groundwater pumped from Mound Basin that year. Due to the generally higher hydraulic conductivity and transmissivity of the Hueneme Aquifer in Mound Basin compared to the Fox Canyon Aquifer, most of the groundwater extracted from these wells likely was derived from the Hueneme Aquifer.

Pumping from Wells with Unknown Screened Intervals

The depth of the screened intervals for three active water-supply wells in Mound Basin has not been reported. The water pumped from these wells is used for agricultural purposes (Table 3.1-02). In 2019, a total of 472 AF was pumped from these wells, approximately 7 percent of the total pumped from Mound Basin that year.

Other Beneficial Uses

In addition to groundwater production from the principal aquifers, discharge of small quantities of groundwater from the shallow alluvial aquifer to the lower reach of the Santa Clara River and possibly one other area in Mound Basin may contribute to groundwater dependent ecosystems. This potential beneficial groundwater use is further described in Section 3.2.6.

3.1.5 Data Gaps and Uncertainty [§354.14(b)(5)]

§354.14 Hydrogeological Conceptual Model.

(b) *The hydrogeologic conceptual model shall be summarized in a written description that includes the following:*

(5) Identification of data gaps and uncertainty within the hydrogeologic conceptual model.

The discussion of data gaps and uncertainty within the HCM of Mound Basin is provided below, organized according to the HCM elements listed in the GSP Emergency Regulations.

Topography [§354.14(d)(1)]

No data gaps or significant uncertainties were identified.

Surface Water Bodies [§354.14(d)(5)]

No data gaps or significant uncertainties were identified.

Imported Water [§354.14(d)(6)]

No data gaps or significant uncertainties were identified.

Regional Geology and Structural Setting [§354.14(b)(1), (d)(2)]

No data gaps or significant uncertainties were identified.

Soil Characteristics [§354.14(d)(3)]

No data gaps or significant uncertainties were identified.

Vertical and Lateral Extent of Mound Basin [§354.14(b)(2),(b)(3), (c)]

The precise location, orientation, and hydraulic impact of the Basin-bounding McGrath Fault (south boundary) and Country Club Fault (east boundary) are not known precisely because they do not offset surficial units within the Basin. However, the south and east boundaries are jurisdictional and, thus, do not depend on precise knowledge of the fault locations. Going forward, MBGSA will work with the adjacent basin institutions (Santa Paula Basin Technical Advisory Committee and FCGMA), as well as United, to improve the understanding of the location and hydraulic barrier effects of the Basin-bounding faults, when opportunities arise.

With regard to the western Basin boundary, it is defined as the Pacific Ocean shoreline, of which the location is known with certainty. From a purely hydraulic perspective, the western Basin boundary is more appropriately considered to be the location where the principal aquifers are exposed to seawater. The principal aquifers of Mound Basin are believed to extend up to approximately 10 miles offshore under the Pacific Ocean west of the shoreline, to the location where they are mapped as cropping out on the continental shelf edge, as shown on Figure 3.1-10. However, it is unknown if the aquitards that separate the principal aquifers from the seafloor have been eroded away or otherwise compromised by faulting or folding between the shoreline and the continental shelf edge. This is a very significant uncertainty in the HCM that directly impacts management relative to the seawater intrusion sustainability indicator.

The vertical extent (definable bottom) of the Basin is known only from a relatively small number of oil well logs. This is because few wells tap the deepest freshwater aquifer and none fully penetrate it. The uncertainty in the vertical extent of the Basin is not considered a significant data gap or uncertainty in the HCM because there is little, if any, groundwater extracted from the deepest freshwater aquifer.

Groundwater Flow Barriers [§354.14(b)(4)(C) and (c)]

The prior discussion of uncertainty concerning the location, orientation, and hydraulic impact of the basin-bounding faults (McGrath and Country Club Faults) also applies to this part of the HCM.

In addition, the hydraulic impact of Pitas Point, Ventura, and Foothill Faults, located in the northern portion of the Basin, are uncertain. These faults have uplifted the principal aquifers in the northern portion of the Basin, exposing them at land surface. Given the significant offset of the principal aquifers and the juxtaposition of different HSUs across the fault plane, it can be inferred that these faults likely impede groundwater flow in the principal aquifers to some degree. There are no groundwater monitoring wells located north and immediately south of these faults to detect groundwater elevation change across the faults. Neither the USGS (Hanson et al., 2003) nor United (2018) regional groundwater flow models incorporated these faults as horizontal flow barriers because of this lack of data. This is considered a significant uncertainty in the HCM because MBGSA's knowledge of groundwater flow directions is largely derived from United's groundwater model, which currently assumes no impedance of flow from the principal aquifer outcrops north of these faults. If these faults impede flow, the groundwater flow directions and water budget for Mound Basin derived from the groundwater flow model might be significantly different. MBGSA will work with United to test alternative model calibrations that consider varying degrees of potential barrier effects of these faults to evaluate uncertainty in groundwater flow directions and water budget and the resulting impact on Basin management decisions.

Formation Names and Hydraulic Properties [§354.14(b)(4)(A), (b)(4)(B)]

The lateral and vertical extents of the basin HSUs are well established, except for the bottom of the deepest freshwater aquifer, as discussed above.

As noted in Section 3.1.4, no aquifer tests have been reported in the literature. The best available information for aquifer and aquitard hydraulic properties in Mound Basin is from the calibrated regional groundwater flow model (United, 2018). Use of model-derived hydraulic properties values is considered appropriate and, therefore, the lack of aquifer tests results is not considered a significant data gap or uncertainty at this time. Going forward, MBGSA will work with well owners in the Basin to conduct aquifer tests when such opportunities arise, such as when new or replacement wells are constructed.

Groundwater Recharge and Discharge Areas [§354.14(d)(4)]

No data gaps or significant uncertainties were identified; however, as described above, the degree of hydraulic connectivity of the principal aquifer outcrops in the northern part of Mound Basin with the remainder of the basin (south of the Ventura, Pitas Point, and Foothills Faults) is uncertain.

Water Quality [§354.14(b)(4)(D)]

Groundwater in the principal aquifers in the northern and western portions of Mound Basin has not been sampled in recent years (and in some areas, it has never been sampled) for water-quality analysis. No wells currently are known to exist that can be used to obtain samples in these areas. However, there is no groundwater production in these portions of the basins, so this is not considered to be a significant data gap or uncertainty in the HCM.

Primary Beneficial Uses [§354.14(b)(4)(E)]

No data gaps or significant uncertainties were identified.

3.2 Groundwater Conditions [§354.16]

This sub-section provides a description of current and historical groundwater conditions in the principal aquifers of the Mound Basin, based on best available information. Groundwater conditions during the past 10 years, and particularly from 2015 to present, are the primary focus of this sub-section, although historical data are also discussed where such data provide relevant information about long-term trends in groundwater conditions. Additional details regarding historical groundwater conditions in Mound Basin and vicinity in the first half of the 20th century are provided by Mukae and Turner (1975) and John F. Mann Jr. and Associates (1959). In addition, Hanson et al. (2003) estimated groundwater levels and movement throughout the region from the 1890s to the early 1990s, based on data synthesis and modeling. United and other local agencies have been collecting groundwater elevation and groundwater-quality data from wells in Mound and adjacent basins since the 1920s. United maintains a comprehensive, up-to-date database of groundwater elevations in Mound Basin, incorporating selected data from the VCWPD and other sources that supplement the data collected by United. Therefore, the source of most of the data used relied upon in this sub-section is United's database, supplemented with additional data from the City of San Buenaventura, the County of Ventura, and other agencies as appropriate. All of the above-described data have been incorporated into the MBGSA Data Management System.

3.2.1 Groundwater Elevations [§354.16(a)]

Maps of groundwater elevation data, combined with hydrographs showing changes in groundwater elevations over time, can help illustrate groundwater occurrence and movement in an aquifer system. Groundwater elevation data are available for nearly 60 wells located within Mound Basin. However, not all of these wells are being monitored at present. The distribution of wells is heavily skewed towards the southern half of the basin, with relatively few wells existing in the northern half of the basin (north of Highway 126). As noted in Section 3.1, faults near the southern and eastern boundaries of the basin affect groundwater movement. Therefore, groundwater level data from adjacent areas of the Oxnard and Santa Paula Basins are also presented in this section to help define lateral gradients along the eastern and southern boundaries of Mound Basin.

3.2.1.1 Groundwater Elevation Contours [§354.16(a)(1)]

§354.16 Groundwater Conditions. *Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:*

(a) Groundwater elevation data demonstrating flow directions, lateral and vertical gradients, and regional pumping patterns, including:

(1) Groundwater elevation contour maps depicting the groundwater table or potentiometric surface associated with the current seasonal high and seasonal low for each principal aquifer within the basin.

The contouring of groundwater levels in Mound Basin is complicated by the sparse data, particularly in the northern portion of the basin. Groundwater-level measurements obtained from wells screened in the Mugu and Hueneme Aquifers (the principal aquifers in Mound Basin) during 2012 and 2020 are shown on Figures 3.2-01 through 3.2-08. Year 2012 was the most recent year when groundwater levels in Mound Basin were representative of average conditions, while year 2020 represents more recent conditions, which continue to be influenced by overall drought conditions that started in 2012 and the associated reduction in groundwater recharge. The groundwater elevations posted on Figures 3.2-01 through 3.2-08 are seasonal high and seasonal low groundwater levels, which typically occur during the spring and fall, respectively, of each year. Data shown were generally collected in March or April (for spring highs) and September or October (for fall lows). Due to the limited distribution of wells where groundwater elevations can be measured, groundwater elevations simulated by United using the Ventura Regional Groundwater Flow Model (United, 2018) for the Mugu and Hueneme Aquifers in 2012 and 2020 were contoured to illustrate groundwater flow directions and horizontal groundwater gradients throughout Mound Basin, and are shown on Figures 3.2-01 through 3.2-08.

As discussed in the HCM (Section 3.1), Mound Basin is structurally complex. The main groundwater flow pattern is flow from east-northeast to the west-southwest, along the axis of the Mound Basin, towards the Pacific Ocean (United, 2012). Available information indicates that Mound Basin receives groundwater underflow from both the Santa Paula Basin to the east and the Oxnard Forebay/ Oxnard Plain to the south (United, 2018). Generalized conceptual groundwater flow paths in the principal aquifers of Mound Basin are depicted on Figure 3.2-09.

Figures 3.2-01 and 3.2-02 show modeled groundwater elevation contours in the Mugu Aquifer during spring and fall of 2012, together with spring-high and fall-low groundwater level measurements reported for wells screened in the Mugu Aquifer. Overall, the pattern of groundwater contours in the Basin during spring and fall are similar, with groundwater levels about 10 ft lower in the fall than spring. The groundwater flow direction in the Mugu Aquifer is consistent with the typical flow pattern, from the eastern side of the Basin to the west-southwest toward the Pacific Ocean, with a gradient of approximately 0.002 ft/ft. Groundwater flows from areas of high groundwater elevation to areas of low groundwater elevation. The highest contoured groundwater elevation in the Mugu Aquifer during 2012, 135 ft msl, occurred in the easternmost portion of the Basin. The lowest contoured groundwater elevations in the Mugu Aquifer in 2012, 20 ft msl and 10 ft msl (spring and fall, respectively), occurred during spring and fall in the central portion of Mound Basin.

Figures 3.2-03 and 3.2-04 show modeled groundwater elevation contours in the Hueneme Aquifer during spring and fall of 2012, together with spring-high and fall-low groundwater levels measured at wells screened in the Hueneme Aquifer. The groundwater flow direction in the Hueneme Aquifer during the spring was consistent with the typical flow pattern, from the eastern side of the Basin to the west-southwest toward the Pacific Ocean with a gradient of approximately 0.001 ft/ft. However, during the fall of 2012, groundwater flow was to the south toward the boundary with the Oxnard Basin with a gradient of approximately 0.002 ft/ft. Groundwater levels in the Basin are more than 10 ft lower in the fall than spring. The highest contoured groundwater elevation in the Hueneme Aquifer during spring 2012, 115 ft msl, again occurred in the easternmost portion of the Basin. The lowest contoured groundwater elevation in the Hueneme Aquifer during spring 2012, 15 ft msl, occurred in the central portion of Mound Basin. The lowest contoured groundwater elevation in the Hueneme Aquifer in fall 2012, 5 ft msl, occurred at the southern boundary with Oxnard Basin.

The following text and figures will be developed after United has expanded the temporal range of its groundwater flow model to include 2019 and 2020, expected to be completed by fall 2020.

Figures 3.2-05 and 3.2-06 present modeled groundwater elevation contours in the Mugu Aquifer during spring and fall of 2019/2020.

Figures 3.2-07 and 3.2-08 present modeled groundwater elevation contours in the Hueneme Aquifer during spring and fall of 2019/2020.

3.2.1.2 Groundwater Elevation Hydrographs [§354.16(a)(2)]

§354.16 Groundwater Conditions. *Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:*

(a) *Groundwater elevation data demonstrating flow directions, lateral and vertical gradients, and regional pumping patterns, including:*

(2) Hydrographs depicting long-term groundwater elevations, historical highs and lows, and hydraulic gradients between principal aquifers.

Groundwater elevations in Mound Basin fluctuate in response to seasonal, annual, and longer-term changes in rainfall, which influences several water-balance components in Mound Basin (as discussed in Section 3.3). Changes in groundwater levels can vary both by location and by aquifer within Mound Basin, although the general patterns of decline and recovery are similar throughout the Basin within the principal aquifers. The cumulative departure from the average precipitation is used to identify historical wet and dry periods to aid in interpretation of groundwater level trends over time. The cumulative departure from average precipitation is calculated by accumulating the annual differences between annual precipitation and the long-term average annual precipitation. Precipitation records from rain gauge station 222 (at "Ventura, Thille Ranch") and station 222A (at the Ventura County Government Center) were used to calculate the cumulative departure curves, which are shown on the graphs included in Figures 3.2-10 through 3.2-13. These stations were selected because of their central location and long period of record (1926 to present). During this period, the calculated average annual precipitation in the central Mound Basin is 15.56 inches. For the discussion of groundwater elevation hydrographs below, wells have been grouped geographically within Mound Basin (south, north, central, east, west) with locations shown on Figures 3.2-10 to 3.2-13. In general, extended periods of low groundwater levels were recorded between the late 1920s and early 1930s, late 1940s and early 1950s, mid-1980s, early 1990s, and 2012 to 2018. These time periods are coincident with multi-year droughts, as shown in the declining limb of the curve showing cumulative departure from average precipitation, plotted on Figures 3.2-10 to 3.2-13. Groundwater elevations in both principal aquifers briefly declined below sea level during the historical droughts, but recovered during the subsequent wet periods.

Measured groundwater levels in southern Mound Basin have varied over about a 120-ft range over the period of record, ranging from about 60 ft below sea level to around 60 ft msl. Groundwater levels generally follow the trend of the cumulative departure curve (Figure 3.2-10). Groundwater elevations at wells located south of the Oak Ridge Fault are similar to groundwater elevations measured at wells in the adjacent Oxnard Basin, to the south (Figure 3.2-10). Wells located in the southeast Mound Basin closest to the Forebay area of the Oxnard Basin (e.g., well 02N22W16K01S) exhibit the greatest annual variability in groundwater elevations, as a response to the large volumes of artificial recharge and pumping that occur in the Forebay area, although the range of recorded groundwater levels in Mound Basin is smaller than the range in the Forebay area (United, 2017b).

Groundwater level records are known to exist for only one well in the northern portion of Mound Basin, 02N23W01P01S, with a total depth 300 ft (Figure 3.2-11). No information about the screened interval of this well is available, only total depth was provided by the Ventura County Watershed Protection District. Groundwater level records for this well are available solely for the mid-1970s; at that time, groundwater levels at this well were about 100 ft higher than in wells located in the central portion of the basin.

Measured groundwater levels in central Mound Basin have varied about a 120-ft range over the period of record, ranging from about 40 ft below sea level to around 80 ft msl (Figure 3.2-11). Groundwater levels generally follow the cumulative departure curve (Figure 3.2-11). The high groundwater levels shown for monitoring well 02N22W07M03S reflect groundwater levels in the fine-grained Pleistocene deposits.

Measured groundwater levels in eastern Mound Basin have varied over about a 100-ft range during the period of record, ranging from about 40 ft below sea level to around 60 ft msl. Water-level trends again generally follow the cumulative departure curve (Figure 3.2-12). Groundwater elevations in some principal aquifer wells in the eastern Mound Basin are approximately 80 to more than 100 ft lower than similarly screened wells in western Santa Paula Basin (Figures 3.2-01 through 3.2-08). This differential in groundwater elevations produces a large hydraulic gradient across the basin boundary between Santa Paula Basin and Mound Basin (DBSA, 2017; United, 2018). However, groundwater elevations at other wells in this area are similar to western Santa Paula Basin groundwater levels (Figure 3.2-12). These differences are likely related to the complex structural geology in the eastern Mound Basin area that is associated with the intersection of the Country Club and Oak Ridge faults. The time domain electromagnetic (TDEM) surface geophysical survey conducted by United (2020), documented changes in resistivity of the sediments across the Mound-Santa Paula and adjacent Forebay basin boundaries. Anomalous zones of high and low resistivity (indicating sands/gravels and silts/clays, respectively) were observed in eastern Mound Basin, consistent with structural complexities related to faulting in this area (United, 2020).

Measured groundwater levels in western Mound Basin have varied over about a 60-ft range over the period of record, ranging from about 20 ft below sea level to around 40 ft msl. Again, these groundwater levels generally follow the cumulative departure curve (Figure 3.2-13). Near the coast, few wells existed prior to the 1990s. In 1995, United and the City of Ventura jointly funded installation of three monitoring wells at Marina Park near the north side of Ventura Harbor to assess groundwater conditions at the coast. Artesian conditions (aquifer with sufficient water pressure to cause the groundwater level in a cased well to rise above land surface) are common in the shallowest of these wells, 02N23W15J03S, which is screened in the fine-grained Pleistocene deposits (170 to 240 ft bgs), as shown on Figure 3.2-13. Artesian heads of 30 ft above land surface are commonly recorded at this well. Coincident with overall drought conditions since 2012, groundwater levels in most wells in the western Mound Basin have been below sea level since approximately 2014, but heads in the monitoring well screened in the fine-grained Pleistocene deposits have remained artesian. The deeper wells at Marina Park (well 02N23W15J02, screened from 480 to 660 ft bgs in the Mugu Aquifer and 02N23W15J01S (screened from 970 to 1070 ft bgs in the Hueneme Aquifer) commonly displayed weak artesian conditions before the recent drought began in 2012. In the agricultural area east of Ventura Harbor, groundwater levels commonly are below sea level during dry periods (Figure 3.2-13). For example, groundwater elevations of 25 ft below sea level were recorded in 1991 and 14 ft below sea level in 2004; since 2014 groundwater levels have declined up to 20 ft below sea level.

Vertical groundwater gradients between principal aquifers in Mound Basin are measured using groundwater level data collected at two of the three monitoring well clusters in Mound Basin. One cluster-well site is at Marina Park (wells 02N23W15J01S, 02N23W15J02S, 02N23W15J03S), located at the coast north of the Ventura Harbor (Figure 3.2-14). Another site is at Camino Real Park (wells 02N22W07M01S, 02N22W07M02S, 02N22W07M03S), located 2 miles inland near the intersection of U.S. Highway 101 and State Highway 126 (Figure 3.2-15). The last site (wells 02N22W09L03, 02N22W 09L04) is farther east at the Community Water Park on Kimball Rd, but both wells in this cluster are interpreted to be screened within the Hueneme Aquifer. The sites at Marina Park and Camino Real Park have three monitoring wells, one screened in each of the following HSUs: fine-grained Pleistocene deposits, Mugu Aquifer, and Hueneme Aquifer. Hydrographs for these monitoring wells are shown on Figures 3.2-14 through 3.2-16. Groundwater levels in the shallowest wells, screened in the fine-grained Pleistocene deposits, are shown with a green line; groundwater levels in the middle depth wells, screened in the Mugu Aquifer, are shown with an orange line; and groundwater levels in the deepest wells, screened in the Hueneme Aquifer, are shown with a blue line. Since the monitoring wells at the Community Water Park are both screened in the Hueneme Aquifer, the groundwater level for the deeper screened well is shown in a darker blue than the groundwater level record for the shallower well. Table 3.2-01 provides the calculated vertical gradients at the three monitoring well sites. This includes the vertical gradient from the fine-grained Pleistocene deposits to the underlying Mugu Aquifer and the Mugu Aquifer to the underlying Hueneme Aquifer at Marina Park and Camino Real Park. The vertical gradient is also calculated from upper to deeper strata of the Hueneme Aquifer at the Community Water Park, near Kimball Road. Vertical gradients were calculated using the available data record, from 1995 through 2019 at Marina Park and Camino Real Park and from 2008 through 2019 at the Community Water Park, near Kimball Road. A positive vertical gradient value represents downward flow, and a negative vertical gradient value represents an upward flow.

Near the coast, groundwater levels in the well screened in the fine-grained Pleistocene deposits at Marina Park are significantly higher than those in the deeper wells (Figure 3.2-14), indicating that this aquitard is in poor hydraulic communication with the underlying principal aquifers of Mound Basin. The vertical gradient from the fine-grained Pleistocene deposits to the underlying Mugu Aquifer ranged from 0.009 to 0.120 ft/ft and averaged 0.075 ft/ft. Groundwater levels in the well screened in the Mugu Aquifer are generally higher than the deepest well, which is screened in the Hueneme Aquifer, indicating a downward vertical gradient. Since the recent drought began in 2012, groundwater levels for the wells screened in the Mugu and Hueneme Aquifers are similar (Figure 3.2-14). The vertical gradient from the Mugu Aquifer to the underlying Hueneme Aquifer ranged from -0.020 to 0.033 ft/ft and averaged 0.008 ft/ft.

Farther inland at Camino Real Park, groundwater levels in the well screened in the fine-grained Pleistocene deposits are significantly higher than the deeper wells (Figure 3.2-15), again indicating limited hydraulic communication with deeper aquifers. The vertical gradient from the fine-grained Pleistocene deposits to the underlying Mugu Aquifer ranged from 0.219 to 0.325 ft/ft and averaged 0.276 ft/ft. Prior to 2010, groundwater levels in the well screened in the Mugu Aquifer at this location were generally higher than those in the deepest well, indicating a downward vertical gradient. After 2010, groundwater levels in the deepest well, screened in the Hueneme Aquifer, were usually similar to or occasionally higher than the groundwater level in the well screened in the Mugu Aquifer, indicating neutral to slightly upward vertical gradient. The vertical gradient from the Mugu Aquifer to the underlying Hueneme Aquifer ranged from -0.028 to 0.043 ft/ft and averaged 0.008 ft/ft.

The monitoring well site furthest inland at the Community Water Park at Kimball Road show that groundwater levels in the shallower well are usually higher than the deeper well, indicating a downward vertical gradient (Figures 3.2-16). The vertical gradient from the shallow to deeper depth in the Hueneme

Aquifer ranged from -0.018 to 0.070 ft/ft and averaged 0.038 ft/ft. Both wells in this cluster are interpreted to be screened within the Hueneme Aquifer. The electric log at this location indicates the Hueneme Aquifer consists of a series of coarse-grained zones separated by fine-grained zones of varying thickness. The electric log shows fine-grained zones between the monitoring well screen intervals, including a 30-ft-thick clay unit. The water-quality data from the upper well at this location show anomalous major-ion chemistry, and groundwater levels recover very slowly after sampling events, sometimes taking several months to return to a similar groundwater level as before the sampling event. Thus, the vertical gradients reported at this location may not be representative of vertical gradients throughout the Hueneme Aquifer.

3.2.2 Change in Storage [§354.16(b)]

§354.16 Groundwater Conditions. *Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:*

(b) A graph depicting estimates of the change in groundwater in storage, based on data, demonstrating the annual and cumulative change in the volume of groundwater in storage between seasonal high groundwater conditions, including the annual groundwater use and water year type.

To be written when updated version of United's Groundwater Flow Model is calibrated and can be used to compute changes in storage in Mound Basin.

3.2.3 Seawater Intrusion [§354.16(c)]

§354.16 Groundwater Conditions. *Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:*

(c) Seawater intrusion conditions in the basin, including maps and cross-sections of the seawater intrusion front for each principal aquifer.

SGMA defines seawater intrusion as "the advancement of seawater into a groundwater supply that results in degradation of water quality in the basin, and includes seawater from any source." The primary cause for seawater intrusion in coastal aquifers is development of a landward hydraulic gradient in areas where groundwater pumping has caused groundwater elevations to decline below the hydraulic head necessary to prevent landward movement of seawater. If groundwater elevations inland of the coast fall below this protective elevation, and assuming there is a pathway for seawater to enter one of the principal aquifers, then landward migration of seawater from the ocean into freshwater aquifers can occur. This process is referred to herein as "lateral seawater intrusion." The principal aquifers of the adjacent Oxnard Basin are highly vulnerable to lateral seawater intrusion due to the existence of two deep submarine canyons just offshore from Port Hueneme and Point Mugu where erosion during periods of lower sea level (ice age) exposed the aquifers to seawater in the canyon walls at a very close distance to the shoreline (Figure 3.1-10). However, no such submarine canyons exist offshore of Mound Basin, greatly reducing the likelihood that seawater can find a near-shore path for intrusion into the principal aquifers (Mugu and Hueneme Aquifers) (Figure 3.1-10). Instead, the Mound Basin principal aquifers may only be exposed to seawater where they crop out on the continental shelf edge, approximately 10 miles offshore (Figure 3.1-10).

Previous investigators (John F. Mann Jr. and Associates, 1959; Geotechnical Consultants, 1972; Fugro West, 1996) did not find evidence of lateral seawater intrusion into the principal aquifers of the Mound Basin. Geotechnical Consultants (1972) conducted the most detailed review to that point and determined that "to date, there is no evidence that seawater intrusion has occurred historically or that it is occurring presently in Mound Basin." Their report notes that a landward hydraulic gradient existed in the area of Pierpont Bay from 1957 to 1961 as a result of pumping from municipal water-supply wells in the Pierpont Bay area. Those wells have since been decommissioned. The landward gradient was a concern as a potential source of seawater intrusion at that time, and chloride concentrations increased at the former Pierpont Bay wells in the same general timeframe. However, Geotechnical Consultants (1972) proposed that downward movement of poor-quality groundwater from shallower aquifer zones via "improper well seals and/or over-extended gravel envelopes" was the cause for the increasing chloride concentrations detected at the Pierpont Bay wells, rather than seawater intrusion. Monitoring data at the Marina Park cluster of monitoring wells, located near Pierpont Bay, have shown no signs of seawater intrusion in the principal aquifers (Figure 3.1-21).

Consistent with the findings of Geotechnical Consultants (1972) nearly 50 years ago, recent water-quality data for wells near the coast do not show evidence of lateral seawater intrusion into the aquifers of Mound Basin. The maximum recorded chloride concentrations from the 2017 calendar year are shown on Figures 3.2-14 and 3.2-18 (data for 2017 are shown because data are available for most wells in Mound Basin; fewer wells were sampled in 2018 by VCWPD due to staffing issues). Most coastal well samples contained chloride concentrations below 100 mg/L; however, four wells located farther inland (Figure 3.2-18) had chloride concentrations at or above 100 mg/L, a target water-quality threshold for many agricultural operations. These chloride concentrations are not believed to be associated with seawater intrusion, as they are farther inland than coastal monitoring wells that did not show indications of seawater intrusion. The shallowest well in the Marina Park coastal monitoring well cluster, 02N23W15J03S (Figure 3.1-21), is screened from 170 to 240 ft bgs in the fine-grained Pleistocene deposits and has the poorest water quality in the area. In this well, TDS concentrations are above 3,000 mg/L and chloride values average nearly 100 mg/L. However, strong artesian heads (well above sea level) are consistently measured in this well (Figure 3.2-14). The high artesian heads in this well indicate offshore groundwater gradients in this vicinity. Groundwater quality in the principal aquifers at the Marina Park monitoring well cluster have not shown any evidence of seawater instruction (Figure 3.1-21). Groundwater levels in the principal aquifers at this location have been typically above sea level, except briefly in 2004 and since 2014, suggesting that offshore groundwater flow has occurred more frequently than onshore flow (Figure 3.2-14). Well 02N23W14K01S, located approximately 0.75 miles inland of the Marina Park monitoring well cluster (Figure 3.1-20), has produced groundwater of good quality for the period of record (1933 to 1981). Concentrations for most analytes are fairly stable, with TDS concentrations averaging less than 1,200 mg/L (Figure 3.1-20). This agricultural well is screened in the Mugu Aquifer from 475 to 915 ft bgs. One outlier of elevated chloride (376 mg/L) was detected in 1962; otherwise, water-quality data from this coastal production well show no evidence of saltwater intrusion. In summary, available data do not indicate that seawater is or has been present in the onshore portions of the principal aquifers to date. There are no available data concerning the presence or absence of seawater in the offshore portions of the aquifers.

Due to the lack of evidence of seawater intrusion in onshore portions of the Basin and lack of data concerning the location of any offshore seawater intrusion front in the principal aquifers, the maps and cross-sections of the seawater intrusion front required pursuant to §354.16(c) cannot be prepared.

3.2.3 Groundwater Quality Impacts [§354.16(d)]

§354.16 Groundwater Conditions. *Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:*

(d) Groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes

This section describes groundwater-quality issues that may affect the supply and beneficial uses of groundwater.

Groundwater Contamination Sites and Plumes

Information available on the State Water Resources Control Board (SWRCB) GeoTracker mapping site (SWRCB, 2020) and the Department of Toxic Substances Control (DTSC) mapping website (DTSC, 2020) were reviewed for locations of known groundwater contamination sites and plumes. Sixteen sites out of approximately 200 leaking underground storage tank (UST) sites and other soil or groundwater cleanup sites are identified as open cases in Mound Basin on GeoTracker. None of the DTSC sites were noted as having groundwater contamination. A map showing the locations of the open Geotracker cases is presented in Figure 3.2-17. Based on review of the open UST cases, none are reported to have impacted groundwater quality in the principal aquifers (Mugu and Hueneme Aquifers). The uppermost principal aquifer in the developed portion of Mound Basin is the Mugu Aquifer, which is vertically separated from the known waste sites by the fine-grained Pleistocene deposits aquitard (generally 350 to 585 ft thick in Mound Basin) and the shallow alluvial aquifer (typically 50 to 100 ft thick). Releases from most UST sites in southwestern Ventura County, which typically involve fuel spills, do not commonly impact groundwater below the water table of the shallowest aquifer. No contamination sites were identified where the deeper aquifers crops out at land surface in the hillside area along the northern margin of Mound Basin (this is in an area of mostly undeveloped land, approximately 1 mile from the nearest currently active water-supply well). Based on the review of open cases, the principal aquifers in Mound Basin do not appear to have been impacted by contamination sites and plumes.

Nitrate concentrations in excess of the drinking water MCL of 45 mg/L (as nitrate) were detected at three agricultural water-supply wells that are screened in principal aquifers (Mugu and Hueneme Aquifers) in Mound Basin in 2017 (the most recent year with abundant water-quality data), as follows:

- 02N22W07P01S—Nitrate was detected at a concentration of 64.6 mg/L at this well screened in the Mugu Aquifer near the center of Mound Basin (Figure 3.1-15);
- 02N23W13K03S—Nitrate was detected at a concentration of 61.4 mg/L at this well screened in the Hueneme Aquifer in the southwest part Mound Basin (Figure 3.1-19);
- 02N22W09L04S—Nitrate was detected at a concentration of 136 mg/L at this well screened in the Hueneme Aquifer in the southeast part Mound Basin (Figure 3.1-19).

It should be noted that none of these wells are used for municipal or industrial water supply, and that wells 02N22W07P01S, 02N23W13K03S, and 02N22W09L04 also exhibit anomalously high concentrations of TDS, sulfate, and chloride, suggesting influence of shallow groundwater through a possibly compromised well seal or well casing (as discussed in Section 3.1.4.3), rather than presence of nitrate "plumes" in the Mugu and Hueneme Aquifers in Mound Basin. It is further noted that other wells in the Basin do not exhibit elevated nitrate concentrations, further reinforcing the conclusion that nitrate is not a widespread issue in the Mound Basin principal aquifers.

As discussed in Section 3.1.4.3, the common ion chemistry of the groundwater in the Mugu and Hueneme principal aquifers is not ideal, but is beneficially used by municipal and agricultural users across the Basin. Common ions with RWQCB-LA WQOs include sulfate, boron, and chloride. TDS also has a WQO. In general, TDS, sulfate, boron, and chloride concentrations are lower in the Mugu Aquifer and meet the WQOs with few exceptions. In general, TDS, sulfate, boron, and chloride concentrations are higher in the Hueneme Aquifer and meet the WQOs at more locations than not. Dissolved constituents are derived from natural sources, and pumping does not appear to be correlated with common ion chemistry concentrations. Elevated TDS and sulfate concentrations relative to drinking water secondary MCLRs are mitigated by blending with other water sources by the City of Ventura. The City of Ventura is pursuing its Water Pure Project (fully advanced treated recycled water) and an interconnection to facilitate delivery of its State Water Project entitlement, both of which may provide further opportunities to blend water produced from its Mound Basin wells.

Groundwater Quality Trends at Clustered Monitoring Wells

Three monitoring wells (02N23W15J01S, 02N23W15J02S, and 02N23W15J03S), jointly funded by United and the City of Ventura, were installed in 1995 in a cluster near the coast at Marina Park, on the north side of Ventura Harbor. Groundwater quality in these three wells has been fairly stable since the wells were installed, as indicated by the chemical hydrographs shown on Figure 3.1-21. The shallowest well at this location, well 02N23W15J03S, is screened in the fine-grained Pleistocene deposits from 170 to 240 ft bgs and has the poorest groundwater quality, with TDS typically above the WQO exceeding 3,000 mg/L; however, there is no groundwater production from this unit in the Basin. The deepest well, screened in the Hueneme Aquifer from 970 to 1,070 ft bgs, routinely records TDS concentrations near 1,300 mg/L, slightly above the WQO, and sulfate concentrations of approximately 500 mg/L, below the WQO. Well 02N23W15J02S, screened in the Mugu Aquifer between 480 and 660 ft bgs, records lower TDS and sulfate concentrations, with TDS around 900 mg/L and sulfate around 400 mg/L, both below WQOs. Chloride concentrations at all three of these wells typically are approximately 100 mg/L, which is less than the RWQCB-LA WQO and lower than chloride concentrations detected at many of the wells located farther inland in Mound Basin, indicating that none of the monitored zones at this location are impacted by seawater intrusion. Additionally, results from a geochemical investigation by SSP&A (2020) suggest that groundwater from the shallow well is not impacted by seawater intrusion, noting that samples were more depleted in bromide, boron, and iodide compared to typical groundwater that has mixed with saline water.

A cluster of three monitoring wells (02N22W07M01S, 02N22W07M02S, and 02N22W07M03S) was also installed by United and the City of Ventura at Camino Real Park in the central portion of the Basin. These wells are the site of the only groundwater-quality samples collected from north of Highway 126 in Mound Basin. As with the Marina Park wells, solute concentrations are slightly higher in the Hueneme Aquifer (well 02N22W07M01S, with a screen depth of 1,200 to 1,280 ft bgs) than in the Mugu Aquifer (well 02N22W07M02S, with a screen depth of 710 to 780 ft bgs). In the deeper screened interval, TDS concentrations of 1,100 mg/L are commonly recorded, which is below the WQO for the basin. TDS is generally less than 1,000 mg/L in the well screened in the Mugu Aquifer (Figure 3.1-22), which is less than the RWQCB-LA WQO. Sulfate accounts for about half of the TDS of the groundwater, as is typical for other wells in the basin. Well 02N22W07M03S, which is the shallowest of the three wells at the Camino Real Park site (screened from 210 to 280 ft bgs in the fine-grained Pleistocene deposits), has the poorest water quality in the cluster. TDS in this well sometimes exceeds 5,000 mg/L. Chloride and nitrate are also found at high concentrations in this well. However, there is no groundwater production from this unit in the Basin. The recent geochemical investigation by SSP&A (2020) found that the primary dissolved anion in samples collected from the shallow well was sulfate, which if derived from local aquifer minerals and evaporates, implies a potential similar evaporitic origin for chloride.

Two monitoring wells (2N22W09L04S and 2N22W09L03S) were installed in Mound Basin near Kimball and Telegraph Roads in 2008 as part of a siting study for a potential new production well for the City of Ventura (Hopkins, 2008). These two wells are in the southeast quadrant of Mound Basin near the boundary between Mound and Santa Paula Basins. Groundwater-quality data are available for these wells since 2011. Groundwater quality has consistently been very poor in the shallower well (2N22W09L04S, which is screened in the upper strata of the Hueneme Aquifer, from 480 to 510 ft bgs). Groundwater samples from this well routinely contain TDS concentrations over 6,000 mg/L and sulfate concentrations over 3,500 mg/L. Nitrate and chloride concentrations are also high. Such concentrations exceed the WQOs for the basin. Groundwater samples from the deeper well (screened in deeper strata of the Hueneme Aquifer, from 890 to 950 ft bgs) contain dissolved constituent concentrations that are more typical of Hueneme Aquifer elsewhere (Figures 3.1-16 through 3.1-19).

3.2.4 Land Subsidence [§354.16(e)]

§354.16 Groundwater Conditions. *Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:*

(e) The extent, cumulative total, and annual rate of land subsidence, including maps depicting total subsidence, utilizing data available from the Department, as specified in Section 353.2, or the best available information.

A review of available reports during preparation of this GSP did not indicate any documented groundwater-related subsidence. DWR (2014) prepared a summary of recent, historical, and future subsidence potential for groundwater basins, described in detail in DWR Bulletin 118 (DWR, 2016). The stated intent of the document was to provide screening-level information with respect to subsidence. Mound Basin was listed as having a "low" overall estimated potential for future subsidence.

DWR provides subsidence data on their "SGMA Data Viewer" Web-based geographic information system (GIS) viewer (DWR, 2020) to support development of GSPs. The DWR data includes land subsidence estimates for Mound Basin based on interferometric synthetic aperture radar (InSAR) measurements for the period from June 13, 2015, through September 19, 2019 (TRE Altamira, Inc., 2020). This subsidence dataset is provided by DWR as a raster image depicting the range of estimated average vertical displacement values in 100-ft by 100-ft grid cells throughout Mound Basin and adjacent groundwater basins. This subsidence dataset was downloaded, mapped and reviewed (as presented in Figure 3.2-18). The data accuracy report for the InSAR data (Towill, 2020) states that "InSAR data accurately models change in ground elevation to an accuracy tested to be 16mm at 95% confidence." Areas falling below the reported accuracy are shown in gray on Figure 3.2-18. Areas depicted in color on Figure 3.2-18 indicate measureable subsidence above the accuracy tolerance. Although a sizeable area of the Basin shows measured subsidence that exceeds the accuracy tolerance of the InSAR data, there are several considerations that should be accounted for when evaluating the data.

As shown on Figure 3.2-18, the highest subsidence rate reported in the InSAR raster data set are concentrated in the southwestern area of the Basin. This InSAR raster data set was apparently derived by interpolating the data points shown on the same figure as black squares. As shown on the figure, there is relatively sparse coverage by the InSAR data points used to derive a full coverage of raster data within this area. In addition, it appears that deriving this high subsidence rate area was highly influenced by interpolating data points that represent a hot spot located outside the Basin. Such a hot spot represents a landfill that is located in the Oxnard Basin. It also appears that values in the southwestern portion of the Mound Basin were estimated by interpolating data points from outside the Basin across the McGrath Fault, which appears to have resulted in erroneous estimates of subsidence in the southwestern portion of the Mound Basin.

Another important consideration is the fact that the InSAR results do not differentiate between subsidence caused by groundwater withdrawal and other potential causes, such as tectonic activity. The Mound Basin is located in a high tectonic activity area characterized by north-south compression. In fact, the Mound Basin is a synclinal basin, caused by ongoing downwarping associated with this compression. The west-east axis of the basin follows along the Ventura-Santa Clara River Syncline (a downwarp or downward fold) that plunges (deepens) to the west. Additionally, the Mound Basin is bounded by faults to the north (Ventura-Pitas Point Fault) and south (McGrath Fault), along which the majority of the Basin is being downdropped (Figures 3.1-02 3.1-06). Thus, it is to be expected that tectonic activity may be causing the observed subsidence. In fact, inspection of the InSAR data (Figure 3.2-18) reveals that the limits of measurable subsidence are constrained by the Ventura-Pitas Point Fault on the north and narrow to the west, consistent with a west plunging synclinal structure. Unfortunately, the lack of InSAR data points to the south and interpolation artifacts associated with the Oxnard Basin landfill prevent further evaluation of tectonic origins of subsidence along the southern Mound Basin boundary.

In addition to the InSAR results, data from a continuous Ground Positioning System (GPS), VNCO, which is maintained by a non-profit university consortium, were reviewed (Figure 3.2-18) (UNAVCO, 2020). The VNCO site is the only continuous GPS location in the Basin. The VNCO GPS site indicates a steady decline in ground position during the period of record, which began in 2000. Comparison with groundwater-level data shows that the rate of ground position decline does not vary with groundwater levels, suggesting that the subsidence is unrelated to groundwater levels or pumping (Figure 3.2-18). This comparison further suggests that the measure subsidence in the basin is of tectonic origin.

In summary, available data suggest that the Mound Basin south of the Ventura-Pitas Point Fault is subsiding at steady rate of approximately 5 millimeters (mm) per year due to tectonic activity. Further investigation may be warranted to confirm these conclusions and more conclusively rule groundwater levels as a causal factor in the observed subsidence.

3.2.5 Interconnected Surface Water Systems [§354.16(f)]

§354.16 Groundwater Conditions. *Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:*

(f) Identification of interconnected surface water systems within the basin and an estimate of the quantity and timing of depletions of those systems, utilizing data available from the Department, as specified in Section 353.2, or the best available information.

Available data do not suggest depletion of interconnected surface water systems within Mound Basin caused by groundwater use. The following paragraphs describe available information regarding groundwater-surface water interaction that support this conclusion.

Santa Clara River

The lowest approximate 1-mile reach of the Santa Clara River from its mouth (at the Pacific Ocean), including its estuary and adjacent areas of riparian vegetation, is within Mound Basin. The Santa Clara River flows perennially during most years along some or all of the 5-mile reach upstream from its mouth to approximately one-quarter mile northeast of the U.S. Highway 101 bridge between the cities of Ventura and Oxnard (Figure 3.1-11) at the southwest limit of the Forebay area of the Oxnard Basin. Baseflow in the perennial reach has been estimated at approximately 2 cubic feet per second (cfs), which is equivalent to an annual discharge of 1,500 AF/yr (Stillwater Sciences, 2017). However, total annual flow (including storm flows) in the Santa Clara River, like most streams in southern California, is highly variable, and can exceed 400,000 AF/yr during particularly wet years. Figure 3.2-19 shows records for three stream gauges located along the Santa Clara River near Mound Basin; all three guages are located in the adjacent Oxnard Basin (gauge locations are shown on Figure 3.1-01). No permanent stream gauges have ever existed on the Santa Clara River within Mound Basin. Thus, any change in baseflow downstream of the gauge 723, including within Mound Basin is not known. It should be noted that gauge 723 is poorly calibrated to low flows in the river (Stillwater Sciences, 2017).

There are multiple inferred sources of baseflow in the perennial reach of the Santa Clara River. These sources include discharge from the stream terrace deposits of the Mound Basin, discharge from the semi-perched aquifer in Oxnard Basin, agricultural tile drain systems present in both basins, perched groundwater above the regional water table, and urban runoff via storm drains. The contributions of these different sources have not been documented in literature.

Data are not available to characterize the interconnection of Santa Clara River surface water and groundwater. Although the frequent perennial baseflow conditions imply that surface and groundwater is interconnected, it is not known specifically which groundwater in which units are connected and where. Of importance for this GSP, it is unknown whether the water table of the shallow alluvial aquifer in Mound Basin extends beneath the stream terrace deposits and intersects surface water in the Santa Clara River channel within the limits of Mound Basin. It is possible that the principal interconnection with the Santa Clara River in Mound Basin could be limited to perched groundwater in the stream terrace deposits. As discussed in Section 3.1.4.1.3, the presence of tile drains on agricultural lands situated on the stream terrace deposits (Figure 3.1-10) suggests that the stream terrace deposits are poorly permeable and, therefore, are not considered to be an aquifer, despite the occurrence of perched water in these deposits. Perched water within the stream terrace deposits, fed by percolating rainfall and agricultural return flows, may be the primary groundwater that is interconnected with Santa Clara River baseflow within Mound

Basin. Regardless of the questions and uncertainty surrounding interconnection of shallow aquifer and/or stream terrace groundwater with the Santa Clara River baseflow, it can be concluded that there is no depletion of interconnected surface water in this area because neither unit has any known groundwater extractions within Mound Basin. Furthermore, SSP&A (2020) concluded that there is no significant evidence for interactions between groundwater in the principal aquifers and shallow groundwater, which is consistent with the several hundred feet of fine-grained materials that lie between the shallow aquifer and the principal aquifers near the Santa Clara River (Figure 3.1-08). This will be further confirmed with data obtained from a future monitoring well planned for the construction at the Ventura Wastewater Treatment Plant (WWTP). Based on the foregoing, pumping from the principal aquifers in Mound Basin is not believed to deplete surface water in the Santa Clara River.

Barrancas

Surface water flow in the various barrancas crossing Mound Basin in response to precipitation events may be briefly interconnected with the shallow alluvial aquifer or perched groundwater, but this cannot be verified with available data. Regardless of the questions and uncertainty surrounding interconnection of shallow aquifer with surface water flows in the barrancas, it can be concluded that there is no depletion of interconnected surface water because the shallow aquifer does not have any known groundwater extractions within the Mound Basin. Furthermore, SSP&A (2020) concluded that there is no significant evidence for interactions between groundwater in the principal aquifers and shallow groundwater, which is consistent with several hundred feet of fine-grained materials that lie between the shallow aquifer and the principal aquifers throughout most of the basin. Additionally, there is no pumping north of the Pitas Point-Ventura-Foothill Faults in the northern portion of the Basin where the principal aquifers are exposed and underlie the barrancas. Based on the foregoing, pumping in the principal aquifers is not believed to deplete surface water in the barrancas.

3.2.6 Groundwater Dependent Ecosystems [§354.16(g)]

§354.16 Groundwater Conditions. *Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:*

(g) Identification of groundwater dependent ecosystems within the basin, utilizing data available from the Department, as specified in Section 353.2, or the best available information.

This section describes the current best available information concerning potential groundwater dependent ecosystems in Mound Basin. This understanding is primarily informed by regional information sources including (1) the DWR statewide database of indicators of groundwater dependent ecosystems (iGDEs) and supporting documentation and (2) descriptions of vegetation alliances from the United States Department of Agriculture (USDA) Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG), which generally correspond with the Natural Communities Commonly Associated with Groundwater (NCCAG) classifications discussed below.

The Natural Communities (NC) dataset is a compilation of 48 publicly available state and federal agency datasets that map vegetation, wetlands, springs, and seeps in California. A working group comprised of DWR, the California Department of Fish and Wildlife (CDFW), and The Nature Conservancy (TNC) reviewed the compiled dataset and conducted a screening process to exclude vegetation and wetland types less likely to be associated with groundwater and retain types commonly associated with groundwater, based on criteria described in Klausmeyer et al. (2018) and available online from the California Natural Resources Agency (2020). Because there is uncertainty in the knowledge of when and how plants and animals depend on groundwater, the spatial database identifies ecosystems that potentially rely on groundwater and , therefore, are referred to as “indicators of groundwater dependent ecosystems (iGDEs)” (TNC, 2020). TNC suggests using the iGDEs as a starting point for the identification and analysis of GDEs under SGMA, including specifically steps to validate the groundwater dependency of iGDEs with local information (TNC, 2020). Determining whether an iGDE is actually a GDE requires local detailed data about the land use, groundwater levels, surface water hydrology, and geology. Per TNC guidance (TNC, 2019), it is suggested that this statewide database be refined using local information to ensure that the map accurately reflects local conditions. Once a connection from the iGDE to groundwater is determined/ground-truthed, the basin’s GDE map can be finalized (TNC, 2019).

The iGDEs are categorized into the following two NCCAG classifications:

- Wetland features commonly associated with the surface expression of groundwater under natural, unmodified conditions. Note, the wetlands class also includes wetlands within the channel of rivers which may also be referred to as aquatic habitat in other publications.
- Vegetation types commonly associated with the sub-surface presence of groundwater (phreatophytes) (CNRA, 2020).

Figure 3.1-11 shows areas of iGDEs mapped in Mound Basin. A map of each numbered iGDE area is presented in Appendix A, indicating the NCCAG class or classes mapped. Each iGDE was screened in general accordance with TNC recommendations to evaluate groundwater dependency (TNC, 2018). The screening results are presented in Appendix A.

As presented in Appendix A, iGDE areas 1 through 10 have been screened out and are not considered GDEs.

Given the possible, but likely limited, connection between Mound Basin shallow groundwater and the Area 11 iGDEs, Area 11 is retained as a GDE pursuant to TNC’s “precautionary principle” (TNC, 2018). However, it is noted that is no known shallow groundwater extraction within Mound Basin. Furthermore, SSP&A (2020) concluded that there is no significant evidence for interactions between groundwater in the principal aquifers and shallow groundwater, which is consistent with the several hundred feet of fine-grained materials that lie between the shallow aquifer and the principal aquifers in Area 11 (Figure 3.1-08). Based on the foregoing, pumping from the principal aquifers in Mound Basin is not believed to significantly impact Area 11 iGDEs. This will be further confirmed with data obtained from a future monitoring well planned for the construction at the Ventura WWTP. Given the lack of potential for significant impacts to the GDEs by principal aquifer pumping, Area 11 will not be considered further in the development of sustainable management criteria for the principal aquifers. However, the GSP will include a management action to monitor well permit applications for proposed uses of shallow groundwater in the vicinity of Area 11. If any shallow wells are proposed, MBGSA will require the applicant to evaluate impacts to the Area 11 GDEs pursuant to the California Environmental Quality Act prior to issuing a permit. Proposed uses that would have a significant impact to Area 11 GDEs would be required to mitigate those impacts as a condition of MBGSA permit approval.

3.5 References

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