SECTION 2

2.2. Hydrogeologic Conceptual Model

The hydrogeologic conceptual model (HCM) provides information on the groundwater flow system of the PID GSA, and it describes the Subbasin's interactions with land use and surface water of the area. The HCM provides descriptions of the geologic setting, geologic structure, boundary conditions, and principal aquifers and aquitards. Additionally, it provides a framework to develop a numerical groundwater flow model of the Subbasin, water budgets, and monitoring networks. This HCM for PID GSA has been developed in accordance with the requirements of California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2, Article 5, Subarticle 2 (§354.14) and in consideration of DWR's Best Management Practices (BMP).

The HCM was developed utilizing information included in the *Tule Subbasin Setting* (Thomas Harder & Co., 2024b) of the Tule Subbasin Coordination Agreement and the ETGSA GSP (Thomas Harder & Co., 2024c), along with additional public and local data sets.

2.2.1. Topography

The terrain throughout the Subbasin is relatively level, with a gentle slope falling from east to west. The low-lying foothills of the Sierra Nevada Mountain Range in the east are the only major topographical feature within the Subbasin. Land surface elevation throughout the Subbasin ranges from approximately 850 ft amsl, along the eastern edge, to approximately 200 ft amsl along the western edge (Thomas Harder & Co., 2024b).

A map of ground surface elevation across PID is presented in **Figure 2-8**. PID is characterized by an increasingly flat topography moving east to west across the GSA. In the eastern portion of PID, adjacent to the foothills of the Sierra Nevada Mountains, land surface elevation is approximately 450 ft amsl. Moving to the west, land surface elevation within the GSA is approximately 370 ft amsl. The PID GSA is approximately 5 miles wide, with an average slope of 1% falling west.

2.2.2. Soils

Soil characteristics are described for the Subbasin in Section 2.1.6 of the *Subbasin Setting*. A map of soils within PID was developed from the USDA's Natural Resources Conservation Service (NRCS, 2025) and is presented in **Figure 2-9**. As part of the NRCS soil surveys, soil map units are defined to express similarities between soils within similar landform and landscape position. The dominant soil types within the GSA include naturally fertile soils like Mollisols and Alfisols. Mollisols are thick, dark, organic rich (mollic epipedon) which typically form under long-term grassland vegetation. These soils are highly fertile and have excellent vertical permeability. Alfisols on the other hand have greater clay content which results in the development of a duripan (i.e. hardpan) which limits vertical permeability. Soils series that dominate PID include Exter, Tagus, Flamen, and Nord loam (NRCS, 2025).

2.2.2.1 Exter Loam

The Exeter Loam is a moderately deep, well-developed soil found on stable alluvial fans and terraces on the eastern San Joaquin Valley. This soil is categorized as Alfisol. It is characterized by a brown, medium-textured loam surface that transitions into a reddish-brown clay loam subsoil with depth. This profile development is a result of long-term weathering of granitic alluvium, leading to a gradual accumulation of clay and iron oxides. At a depth typically between 20 and 40 inches lies a critical feature of this soils which is a silica-cemented duripan (i.e. hardpan). This hardpan is extremely dense and indurated, creating a nearly impenetrable barrier to both root growth and the downward movement of water.

From a hydrogeologic perspective, the Exeter Loam acts as a restrictive layer that significantly influences local water dynamics near PID GSA. Because the saturated hydraulic conductivity drops off sharply at the duripan, the vertical recharge to the Upper Aquifer is negligible in undisturbed areas. This soil requires mechanical ripping to break down the duripan, a process that artificially increases permeability.

2.2.2.2 Tagus Loam

In contrast to the Exeter Loam, the Tagus loam is a very deep, well drained soil that lacks a restrictive duripan, making it a much more favorable profile for vertical water movement. This soil is categorized as a Mollisol. The Tagus series formed from granitic alluvium and is characterized by a thick, dark, organic-rich surface layer. The profile typically consists of a grayish-brown loam that transitions into a light yellowish-brown fin sandy loam or loam with depth. A key feature of this soil is its calcic horizon, where secondary calcium carbonate (lime) has accumulated as filaments or soft masses, usually starting between 10 and 20 inches below the surface.

From a hydrogeologic perspective, this soil is categorized as having moderate permeability throughout its entire depth, which can extend well beyond 60 inches. For this reason, the Tagus Loam is ideal recharge projects because it is very deep and lacks a hardpan.

2.2.2.3 Flamen Loam

The Flamen Loam is a deep, moderately well drained soil found on nearly level stream terraces around PID GSA. It is characterized by a thick, dark mollic epipedon (i.e. a nutrient-rich surface layer) that typically extends 20 to 40 inches deep. This grayish-brown loam surface transitions into a brown or dark brown loam or clay loam subsoil. While it shares many characteristics with the Tagus series due to its dark subsurface, the defining feature of the Flamen Loam is the presence of a silica rich hardpan at a depth between 40 and 60 inches.

From a hydrogeologic perspective, this soil is a middle ground between the restrictive Exeter Loam and the permeable Tagus Loam. With a deeper hardpan at a depth around four feet, the Flamen Loam allows for a greater volume of moisture storage and deeper root zone penetration before reaching a restrictive boundary. This unit may not be as ideal for recharge projects as the Tagus Loam as a restrictive hardpan is present.

2.2.2.4 Nord Loam

The Nord Loam consists of very deep, well-drained soils that are formed in mixed alluvium derived from granitic and sedimentary rocks sources. This soil is categorized as a Mollisol. Typically found on level floodplains and alluvial plains with slopes less than 2%, these soils are widely distributed along the eastern side of the San Joaquin Valley. The profile is characterized by a thick, dark-colored surface layer that is a grayish-brown loam or fine sandy loam. Similar to the Tagus Loam, the Nord Loam completely lacks a hardpan within 60 inches of the surface.

From a hydrogeologic perspective, this soil is ideal for recharge projects. It possesses moderate to high permeability (0.6 to 2 inches per hour).

2.2.3. Geological and Structural Setting

The regional geologic and structural setting describing the entire Subbasin is described in **Chapter 2.2.2** of the *Tule Subbasin Setting* (Thomas Harder & Co., 2024b).

PID is located within California's Great Valley Geologic Province (**Figures 2-1** and **2-2**). A map of the surficial geology is presented in **Figure 2-10**. PID GSA is underlain by alluvium (Q). This unit is Quaternary in age and is made up of unconsolidated to semi-consolidated sand, gravel, and clay, forming alluvial plains, fans, and terraces (Thomas Harder & Co., 2022; 2024b).

Five geologic formations have been identified across the Subbasin and under PID. Descriptions of these geologic formations are provided below and are depicted in **Figures 2-11 and 2-12**.

Unconsolidated Continental Deposits

Sediment consisting of fluvial (i.e. streambed deposits), alluvial, flood plain, and lacustrine (i.e. lakebed) deposits. Within the PID GSA, the deposits are estimated to be up to approximately 1,200 ft (Thomas Harder & Co., 2022; 2024b). Subsurface alluvial sediments consist of highly stratified layers of sand and gravel (relatively high permeability) interbedded with silt and clay (lower permeability). Correlation of individual sand and clay layers that extend laterally across the Subbasin can be unclear due to the interbedded nature of the sediments.

The unconsolidated continental deposits form the primary groundwater reservoir in the Subbasin, and they range in age from recent near-surface stream channels to Upper Pliocene (approximately 2.6 mya) at depth. East of the PID GSA and the Subbasin, Pleistocene sediments (2.6 million to 11,700 years before present) crop out at the land surface along the base of the Sierra Nevada Mountains, forming the dissected uplands (Lofgren and Klausing, 1969). The older continental deposits are semi-consolidated and contain a high percentage of clay; Therefore, they typically do not yield significant water to wells.

The lowermost portion of unconsolidated continental deposits is correlated with the Tulare Formation, which includes the Corcoran Clay confining layer, also referred to as the *E-Clay* (Frink and Kues, 1954), which is located west of the PID GSA area. The Corcoran Clay consists of a Pleistocene diatomaceous fine-grained lacustrine deposit (primarily clay; Faunt, 2009). In the Subbasin, the Corcoran Clay is 150 ft thick at its maximum beneath the Tulare Lake, becomes progressively thinner to the east, and it pinches out on the east side of Highway 99 (Lofgren and Klausing, 1969).

Pliocene Marine Deposits

Consolidated to loosely consolidated marine siltstone with minor interbedded sandstone beds that underlie the continental deposits. The marine siltstone unit ranges in thickness from approximately 250 ft along the eastern region of the PID GSA to greater than 500 ft at its western boundary (Lofgren and Klausing, 1969; Thomas Harder & Co., 2022). The marine siltstone beds dip sharply from the base of the Sierra Nevada Mountains on the east to the central region of the valley in the west. The Pliocene marine strata do not yield significant water to wells due to its relatively low permeability.

Santa Margarita Formation

This formation underlies the Pliocene marine strata and consists of Miocene (approximately 5.3 to 23 million years before present) sand and gravel that is relatively permeable and yields water to wells. Within the PID GSA, the formation is approximately 250 to 650 feet thick, and its depth beneath the GSA ranges from 1,000 feet near State Highway 65 to approximately 2,500 ft beneath the western boundary of the GSA.

Tertiary Sedimentary Deposits

An interbedded assemblage of semi-consolidated to consolidated sandstone, siltstone and claystone of Tertiary age (approximately 2.6 to 66 million years before present) that underlie the Santa Margarita Formation. Some irrigation wells in the southeastern region of the Tule Subbasin produce fresh water sourced by the Olcese Sand Formation within this formation (Ken Schmidt, 2019). Most of the groundwater in the unit is not usable for crop irrigation or municipal supply, except near Highway 65, due to increased salinity to the southwest.

Granitic Crystalline Basement

Basement rock consisting of Mesozoic granitic rocks that compose the Sierra Nevada batholith (Faunt, 2009) and are assumed to be relatively impermeable.

2.2.4. Lateral Basin Boundary

The lateral basin boundaries for the Subbasin, including natural and political boundaries, are described in DWR Bulletin 118 (DWR, 2016). To the north of the Tule is the Kaweah Subbasin, to the west is the Tulare Lake Subbasin, and to the south is the Kern County Subbasin. To the east of the Subbasin is the Sierra Nevada Mountain Range which is outside of the San Joaquin Valley Groundwater Basin (**Figure 2-1**).

For the PID GSA, all boundaries are jurisdictional which include the City of Porterville to the east, LTRID to the west, the Kaweah subbasin to the north, and portions of Tule East and LTRID GSA to the south (**Figure 2-2**).

2.2.5. Bottom of Basin

The bottom of the Tule Subbasin and the PID GSA is defined by the interface between the Tertiary sedimentary deposits and the underlying, relatively impermeable granitic basement rock (Thomas Harder & Co., 2022; 2024a) (**Figures 2-11 and 2-12**). The depth of this interface is approximately 2,000 ft bgs beneath the eastern boundary of the GSA and Highway 65 and increases westward to greater than 2,500 ft (Thomas Harder & Co., 2022, 2024b).

The interface between freshwater and brackish water is thought to occur at depths ranging from less than 1,200 ft bgs in the northeastern region of the Tule Subbasin near the PID GSA area to greater than 2,500 ft bgs near the Tulare/Kern County line (south of the PID GSA). Groundwater quality parameters determine the efficacy of a fresh groundwater basin and determine if it is suitable for municipal, irrigation, or other uses. For example, a measure of the bottom of the basin is determined by an electrical conductivity of 3,000 micromhos per centimeter (µmohs/cm), which is approximately correlative to a total dissolved solids (TDS) concentration of 2,000 milligrams per liter (mg/L) (Thomas Harder & Co., 2024b). Aquifer groundwater quality of the PID GSA is discussed in greater detail in Section 2.3.8 of this GSP.

2.2.6. Principal Aquifers and Aquitards

2.2.6.1 Aquifer Formations

Five aquifer formations have been identified within the subsurface of the Subbasin. These layers include the Upper Aquifer, Corcoran Clay, the Lower Aquifer, Pliocene Marine Deposits, and the Santa Margarita. All but the Corcoran Clay are present with PID GSA (**Figures 2-11 and 2-12**). A summary of the four aquifer/aquitard units that are present in PID, as well as their approximate thicknesses, is described below. Descriptions are based on information presented in (Thomas Harder & Co., 2022; 2024b).

1. **Upper Aquifer** – An unconfined to semi-confined aquifer occurring throughout the entire Subbasin, shallowing from west to east. The Upper Aquifer is generally considered unsaturated near the southern region of the Subbasin, with local areas of groundwater. Within the PID GSA, the Upper Aquifer is located within the upper 150 ft of sediment, increasing to approximately 200 ft near the western boundary.
2. **Lower Aquifer** – Confined beneath the Corcoran Clay, where it is present (west of Highway 99), and conceptualized to be semi-confined in the northeastern portion of the Subbasin. The Lower Aquifer is separated from the underlying Santa Margarita Formation Aquifer by a thick layer of Pliocene Marine Deposits. In the eastern region of the GSA, the Lower Aquifer has an estimated thickness of approximately 500 ft bgs and increases in depth westward to approximately 1,000 ft bgs near the western boundary of the GSA.
3. **Pliocene Marine Deposits** – A layer of marine deposits (confining unit) in the southeastern portion of the Subbasin that separates the Lower Aquifer from the underlying Santa Margarita Aquifer. Due to its low permeability, the Pliocene marine deposits do not yield significant water to wells. The confining marine deposits are between 500 ft to 1,600 ft thick throughout the Subbasin.

4. **Santa Margarita Formation and Olcese Formation** – Tertiary sedimentary deposits occurring at depths greater than 2,000 ft, forming a localized aquifer in the southeastern portion of the Subbasin. The aquifer underlies the Pliocene Marine Deposits and is conceptualized as hydrologically disconnected from the rest of the identified aquifers in the Subbasin. It is relatively permeable and is a major water source for agricultural irrigation.

2.2.6.2 Aquifer Physical Properties

The principal water-bearing aquifers of the Subbasin are formed from permeable sand and gravel layers that are interbedded with low-permeability silt and clay lenses. Shallower saturated sediments are generally unconfined to semi-confined, while confined aquifers in the western region of the basin occur beneath the Corcoran Clay, west of the PID GSA. The ability of aquifer sediments to transmit and store water is based on the aquifer's transmissivity, hydraulic conductivity, and storativity. Aquifer parameters were derived using short-term pump tests and long-term pump tests (24 hours or more at a constant rate).

Transmissivity/Hydraulic Conductivity

Transmissivity is a measure of the ability of groundwater to flow within an aquifer. It is defined as the rate of groundwater flow through a unit width of an aquifer under a unit hydraulic gradient (Fetter, 1994), and it was estimated from short-term pumping test data based on Theis et al. (1963) and the following relationship:

$$T = \frac{S_c \; x \; 2{,}000}{E}$$

Where:

T = Transmissivity (gpd/ft);
S_c = Specific Capacity (gpm/ft);
E = Well Efficiency (assumed to be 0.7)

The transmissivity values at individual wells within the Subbasin were converted into hydraulic conductivity (i.e. aquifer permeability) by dividing by the aquifer thickness using the perforation interval of the well.

Horizontal hydraulic conductivity for the Upper Aquifer ranges from 10-20 ft/day in the southeastern region of the Porterville GSA up to 60-80 ft/day in the northeastern and central regions of the GSA (**Figure 2-13**). Whereas horizontal hydraulic conductivity in the Lower Aquifer range from less than 10 ft/day in the northwest region of the PID GSA to 20-40 ft/day in the eastern region of the GSA (**Figure 2-14**). Higher hydraulic conductivity values in the northern region of the PID GSA indicate that the sediments are more permeable than in the southern region, which derived lower conductivity values.

Additional details on hydraulic conductivity in the region are described in Chapter 2.1.7.2 of the Tule Subbasin Setting.

Specific Yield/Storativity

Specific yield refers to the ratio of the volume of water that sediment will yield by gravity drainage to the volume of the sediment. The majority of the Upper Aquifer is characterized as unconfined; therefore, its storage properties are expressed in terms of specific yield, and its values were assigned based on a USGS texture analysis published in Faunt (2009). Textural descriptions of sediment in terms of coarse-grain percentages were based on drillers' logs generated from boreholes or wells drilled within or immediately outside the Subbasin. Higher percent coarse-grained sediment is directly proportionate to higher specific yields. Across the Subbasin, specific yield values range from 0.001 in the western portions of the subbasin, to as high as 0.25 in the areas where the FKC intersects the White River. Within PID GSA in the Upper Aquifer, specific yield values range from approximately 0.001 to 0.05 in the southeastern region of the GSA near Tule River, and >0.25 in the northwestern region (**Figure 2-15**).

The Lower Aquifer in the Subbasin is confined to semi-confined; therefore, its storage properties are expressed in terms of storativity. Storativity is a measure of the volume of water that an aquifer can release from, or take into, storage per unit of aquifer surface area per unit change in hydraulic head. Storativity is based on long-term pumping tests, during which pumping interference is measured in a monitoring well located a known distance from the pumping well. Pumping interference data for the Tule Subbasin were not available. Therefore, storativity values for the lower alluvial aquifer were originally based on values published in Faunt (2009) and were modified during calibration of the Subbasin's numerical model. Storativity values in the Lower Aquifer under confined conditions range from 8.0e-06 to 3.6e-04, which are indicative of confined aquifer conditions. The storativity values tend to increase from east to west. Within PID, storativity values are estimated to be between 8.0e-06 and 3.6e-04 (**Figure 2-16**).

2.2.7. Geologic Structures that Affect Groundwater Flow

Across the Subbasin, the Corcoran Clay confining unit is the most significant geologic feature that affects groundwater flow. The unit is not within PID, though localized confining beds may be present. Groundwater flow within the PID is described in Section 2.5.1.

No significant faults have been mapped within the PID GSA that would affect groundwater flow. A concealed fault is present in the northeastern corner of the Subbasin (**Figure 2-10**).

2.2.8. Areas of Groundwater Recharge and Discharge

Groundwater recharge occurs primarily through deep percolation of surface water flow and infiltration of applied irrigation water. Deep percolation can occur over relatively permeable surface soils when there is a lack of subsurface impediments. As described in Section 2.2.2, greater recharge is likely to occur in the Tagus and Nord Loams due to their high vertical permeability and lack of duripan. Areas of recharge within the Subbasin are identified for the Subbasin in Chapter 2.1.6 of the *Subbasin Setting*, and generally occur along or within stream channels, unlined canals, in managed recharge basins, and on irrigated agricultural lands. Within PID, areas suitable for recharge occur throughout the central portion of the GSA and in areas along the Tule River.

The Soil Agricultural Groundwater Banking Index (SAGBI) was developed by the University of California Davis and identifies effective areas of recharge based on deep percolation potential, root zone residence time, topography, chemical limitations, and soil surface conditions. The SAGBI is intended to provide a preliminary indicator of potential recharge and where enhanced recharge could be implemented. SAGBI may not represent the complete view of recharge potential and additional geotechnical studies should be conducted prior to the implementation of recharge projects. Classifications of potential recharge in the SAGBI include Very Poor; Poor; Moderately Poor; Moderately Good; Good; and Excellent, in order of increasing recharge potential.

Figure 2-17 contains the SAGBI rating of potential recharge within the PID GSA without consideration for soil modifications, such as deep tillage, that may have occurred historically or could potentially occur. Based on the SAGBI Index, PID generally consists of soils that are “poor” for groundwater recharge. Areas of high recharge potential are in the central portion of the GSA, extending diagonally to the northwest from the east, following the Tule River.

Groundwater discharge within PID occurs through groundwater pumping and baseflow contributions to surface water systems (Tule River). No springs or wetlands are present within PID.