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CITY OF SAN BUENAVENTURA

EXEMPT FROM FILING FEES PURSUANT TO GOVERNMENT CODE SECTION 6103

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SUPERIOR COURT OF THE STATE OF CALIFORNIA

COUNTY OF LOS ANGELES

SANTA BARBARA CHANNELKEEPER, a California non-profit corporation,

Petitioner,

v.

STATE WATER RESOURCES CONTROL BOARD, et al,

Respondents.

CITY OF SAN BUENAVENTURA, et al.,

Cross-Complainant,

v.

DUNCAN ABBOTT, an individual, et al.,

Cross-Defendants.

Case No. 19STCP01176

Judge: Hon. William F. Highberger

DECLARATION OF CHRISTOPHER M. PISANO IN SUPPORT OF CITY OF SAN BUENAVENTURA'S OPPOSITION TO EAST OJAI GROUP'S EX PARTE APPLICATION TO CONTINUE TRIAL

[*Filed concurrently with Opposition to Ex Parte Application to Continue Trial; Declaration of Sarah Christopher Foley*]

Date: January 18, 2022
Time: 1:30 p.m.
Dept.: 10

Action Filed: Sept. 19, 2014
Trial Date: February 14, 2022

DECLARATION OF CHRISTOPHER M. PISANO

I, Christopher M. Pisano, declare:

1. I am a partner at the law firm of Best Best & Krieger LLP, the attorneys of record for Respondent and Cross-Complainant City of San Buenaventura ("Ventura"). I am licensed to practice law before all of the courts in the State of California. Unless otherwise stated, I have personal knowledge of the facts set forth herein and if called and sworn as a witness, could and would testify competently thereto.

2. On August 31, 2021, Ventura produced its experts' reports to all parties in the case. This included the report of Ventura's hydrogeologist, Dr. Claire Archer. A true and correct copy of Dr. Archer's report is attached hereto as Exhibit "A." The expert report included numerous exhibits. One such exhibit that was also produced on August 31, 2021 was a separate report that Dr. Archer drafted solely on the preparation of her groundwater and surface water model. A true and correct copy of the model report is attached hereto as Exhibit "B."

3. In December 2021, I was involved in negotiations with counsel for East Ojai Group ("EOG"), City of Ojai and Casitas Municipal Water District regarding a Stipulation and Protective Order for the production of Dr. Archer's model. The Stipulation and Protective Order were based on the standard form on the Los Angeles County Superior Court website, but counsel for the parties carefully negotiated the terms. One of the terms that was negotiated was that there would be a production deadline of December 27, 2021. While these terms were being negotiated, none of these parties complained that December 27th did not give enough time for a review of the model before Dr. Archer's scheduled deposition of January 6th . On December 27th, I produced the model to counsel for these stipulating parties by sending them a link to a secure website.

4. On December 29, 2021, I received an email from EOG's counsel Greg Patterson. In this email Mr. Patterson informed me that he wanted to continue Dr. Archer's deposition because his experts needed three weeks to analyze the model. He also informed me that his expert, Mr. Brown was ill. A true and correct copy of this email is attached hereto as Exhibit "C." I contacted Mr. Patterson later that day or the next day, and I told him that I was fine

continuing Dr. Archer's deposition, and that I was fine taking depositions after the January 14th discovery cut-off date.

5. After the new year, I had multiple conversations with Mr. Patterson regarding the concept of a trial continuance. During these calls I told Mr. Patterson that I would not oppose a short continuance of the trial because I did not want to jam him given the health situation of Mr. Brown. I told Mr. Patterson that I have scheduling issues because I have two trials scheduled for mid-March and late April. I have a trial starting on March 21, 2022 in San Bernardino Superior Court, and I have a trial starting on April 25, 2022 in Riverside County Superior Court. As I told Mr. Patterson, both of those cases are slated to be jury trials, and they may well be continued given the pandemic. But for now they are still on calendar. Still, I tried to work with Mr. Patterson to come up with a reasonable agreed upon continuance, but we could never agree on date that would satisfy all parties.

6. On December 16, 2021, other counsel in the case and I took the deposition of EOG's expert Mr. Brown. A true and correct copy of certain pages of the transcript are attached hereto as Exhibit "D". The deposition did not conclude, and thus a second date will need to be scheduled to complete the deposition. Prior to the deposition counsel for EOG produced documents in response to Ventura's requests for production. These documents included emails that Mr. Brown exchanged with other professionals who work for him, including the person who does his modeling work, and with counsel for EOG. Two such email threads from last September that were produced in advance of Mr. Brown's deposition are attached hereto as Exhibits "E" and "F" respectively.

7. I saw last night that Gregg Garrison filed a declaration for this ex parte application wherein he accuses Ventura and its counsel of having "unclean hands." I note here in response that on December 15, 2021, Mr. Garrison, who is purporting to represent about 20 landowners in the Upper Ojai Basin, submitted an expert report from Jordan Kear regarding the Upper Ojai Basin. After this report was served I asked Mr. Garrison to provide me with dates when Mr. Kear could be available that would be on or prior to the discovery cut-off date of January 14, 2022. On January 3, 2022, having not received a date from Mr. Garrison that would commence the

deposition on or before January 14th, I served a notice of deposition, and set the deposition for January 14th. The notice also included a request for production. Earlier this week Mr. Garrison unilaterally canceled the deposition and gave notice to all parties that the deposition was going to be rescheduled. In additional to not producing his expert, Mr. Garrison likewise did not produce documents responsive to the requests for production three business days before the deposition, as is required by Code of Civil Procedure section 2034.415.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed on January 14, 2022, at Los Angeles, California.

By: ______________________________
Christopher M. Pisano

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EXHIBIT A

EXHIBIT A

Ventura River Watershed/ Groundwater Basin Interconnectivity and Boundary Report

August 31, 2021

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Introduction

I have been retained by Best Best & Krieger (BBK) to provide my opinions in the form of this expert report. I am the primary author of this report and my colleague, Tamara Klug co-authored two sections of this report. My hourly rate is $210 for testimony and $210 for all other work. Ms. Klug's rate for testimony is $324 and for all other work is $216. My CV which contains information of my background, experience and expertise is attached to the report as **Exhibit 142**, Ms. Klug's is attached as **Exhibit 130**. My CV contains a list of all publications I have authored. I have no prior experience testifying as an expert. Ms. Klug's publication and prior testimony experience are provided in her CV.

In formulating my opinions, I reviewed all of the documents listed within the References section of this report, conducted two site visits, one during January 2019 and the other during August 2021, and performed the following analyses: an independent review of existing geologic and hydrogeologic information for each basin, constructed geologic cross sections, analyzed gaged streamflow data, analyzed groundwater levels at monitoring wells, analyzed water deliveries within the Ventura River Watershed, and analyzed groundwater dependent vegetation. I also constructed a groundwater- surface water model and used it to perform predictive simulations related to well pumping and streamflow.

Opinions

My opinions are:

1. The four groundwater basins within the Ventura River Watershed (Watershed) are hydrologically connected to the Ventura River in a substantial and material way, and within each groundwater basin surface water and groundwater are also hydrologically connected in a substantial and material way. Within each basin, and within the watershed as a whole, extractions from either groundwater or surface water materially diminish and could adversely impact the uses of the other such that the water within the Watershed constitutes one common water supply.
2. The National Watershed Boundary Dataset has correctly delineated the boundaries of the Watershed, and those boundaries are shown in Exhibit 1. The groundwater basin boundaries are correctly defined by California Department of Water Resources Bulletin 118.

Scope and Basis for Opinions

There are four groundwater basins located within the Watershed.[1] The Upper Ventura River Basin, Lower Ventura River Basin, Ojai Basin, and Upper Ojai Basin (Basins), are all hydrologically connected to the Ventura River. In each of the basins, groundwater is materially interconnected with surface water and all surface water features in the Basins are either the Ventura River itself or tributaries that eventually feed into the Ventura River. Groundwater withdrawal from any of the Basins has either an indirect or direct material impact on instream flow in the Ventura River.

These opinions of interconnectivity are based on geologic and hydrogeologic data, long-term records of groundwater levels, gaged streamflow, records of water transfers within the Watershed, field studies of groundwater – surface water interaction, surveys of vegetation, and groundwater modeling results.

1.1 THE VENTURA RIVER WATERSHED

The Watershed is located in Ventura and Santa Barbara Counties, CA. The Watershed, with an area of approximately 226 square miles, is a fan-shaped catchment that drains water from land containing uplands at over 6,000 feet in elevation and that extends down to sea level (**Exhibit 1: Watershed Map**). A watershed is defined by the United States Geological Survey (USGS) as the area of land that drains all water to a common body of water or outlet point (USGS, 2021; **Exhibit 2**). The divides between watersheds are defined by terrain, where highs in topography separate one watershed from another and political and jurisdictional boundaries have no effect on delineations. Geographic Information Systems (GIS) that utilize digital elevation models are currently the most accurate spatial data source used to delineate watersheds. The National Watershed Boundary Dataset (WBD) is relied upon by the California State Water Resources Control Board (SWRCB), regional water boards, and other regulatory agencies as the source of the delineation of watersheds within the state. The WDB is a seamless map containing

[1] The Upper Ojai Basin is mostly within the Ventura River Watershed, though a portion lies in the Santa Clara River Watershed.

watershed boundary delineations in the U.S. It is maintained by the USGS and serves as a standardized system for organizing and updating watershed data. In California, the Department of Water Resources (DWR) is an official steward of the WBD, requiring that dataset updates meet federal standards, and requiring a review process before changes are made (USGS and NRCDS, 2013; **Exhibit 3**). The California WBD integrates previous statewide watershed boundary delineations (CalWater) and is updated as topographic data accuracy improves. This watershed boundary dataset is currently used by all state and local agencies to define the Watershed.

It is my opinion that this watershed boundary is the correct delineation of the watershed. The four groundwater basins are within the watershed.

I performed an independent analysis of the Watershed boundaries using the Hydrology toolset in ArcGIS (Esri) to define the Watershed based on recent topographic data, and found that the Watershed delineation matched the WBD delineation exactly **(Exhibit 4: Watershed Delineation Map).** This analysis involved first using a high-resolution digital topographic surface (2018 USGS LiDAR Data) and running a terrain pre-processing analysis to obtain the digital elevation model (DEM). This DEM was used as the basis for several analyses run using the ArcHydro tools: first, I used the flow direction tool to compute the direction that a drop of water would flow from all points within the DEM. The output is a raster, or a grid of values indicating flow direction. I then used this raster to run the flow accumulation tool, which results in another raster output that contains the accumulated number of cells upstream of a cell for each cell in the input grid. The flow accumulation raster is used to create another grid delineating streams in the cells with the highest flow accumulation, then the delineated streams are the input to define catchments, or the area contributing to each stream. I then used the defined catchments output, a spatial dataset made up of interconnected polygons, to perform adjoint catchment processing, a process where for each catchment a polygon representing the upstream area draining to its inlet point is constructed and stored. I then selected the point on the grid where the Ventura River enters the Pacific Ocean and, using the rasters and polygons I created during this process as inputs, used the Watershed delineation tool to create a polygon shape of the Watershed.

The groundwater in the Basins and all surface water in the Watershed originates within the Watershed; no water is delivered from external watersheds. The Upper Ventura River, Lower Ventura River, and the Ojai groundwater basins are entirely within the Watershed, with the exception of a very small area of the Lower Ventura River Basin that drains directly to the Pacific Ocean. The majority of the Upper Ojai Valley basin is also within the Watershed, though a minor portion lies in the neighboring Santa Clara River Watershed. This outlying land area, however, is small compared to the total area of the four groundwater basins. Hydrologically, any water that falls as precipitation within the Watershed travels by gravity to lower elevation, eventually flowing to the Ventura River. Water that infiltrates and recharges the basins within the Watershed also travels generally in the same direction, following the slope of the water table that primarily follows the topography.

In the upper Watershed, outside of the groundwater basins where relief is high and soil thickness is low, there is limited potential for groundwater flow or storage. Most of the precipitation falling in these areas runs off as surface flow to tributary streams that flow towards the groundwater basins. Within the groundwater basins, the decrease in topographic gradients and the increased thickness and permeability of the alluvial sediment encourages infiltration of surface flow to groundwater. Each groundwater basin has a major surface water feature that runs through and drains the basin; either the Ventura River or a creek that eventually joins the Ventura River (**Exhibits 5-8: Individual groundwater basin maps).** The majority of groundwater-surface water interactions take place within the groundwater basins, while surface water flow between tributaries and the Ventura River hydrologically links all of the groundwater basins in the watershed together.

The following section provides the conceptual basis for mechanisms of groundwater- surface water interconnection and the connection between all Basins within the Watershed. The opinions regarding the boundaries and interconnectivity specific to each of the Basins are presented in Sections 1.3 – 1.6.

1.2 Groundwater – Surface Water Interconnection

1.2.1 Mechanisms for groundwater- surface water connection

DWR developed *California's Groundwater* (Bulletin 118) as the State's official publication on the occurrence and nature of groundwater in the state. Bulletin 118 defines groundwater basin boundaries and summarizes groundwater information. A groundwater basin is defined in Bulletin 118 as "an alluvial aquifer or stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and a definable bottom" (DWR, 2016; **Exhibit 9**). The well-defined boundaries of the four groundwater basins within the Watershed are geologic units that do not allow significant groundwater flow or storage (bedrock). Groundwater flows within the Basins from points of recharge to discharge in a direction defined by gravity and hydraulic gradients and at a rate defined by the aquifer material properties. The hydraulic gradient between two points is the slope of the hydraulic head, or the water table, between those two points that causes groundwater to flow. Groundwater is not held statically within the Basins.

Each of the Basins within the Watershed has one primary surface water feature that drains the basin, or in other words, is the single point of natural discharge. The Ventura River drains the Upper Ventura River basin and the Lower Ventura River basin, San Antonio Creek drains the Ojai basin, and Lion Canyon Creek drains the Upper Ojai basin. "Draining" refers to the process where the surface water exiting the basin is a component of the groundwater budget removing water from the groundwater basin. A groundwater budget is an accounting of water movement into and out of a groundwater system.

Groundwater and surface water interact by two main mechanisms: groundwater contributes to surface water flow (gaining stream/river), and surface flow infiltrates and contributes to groundwater (losing stream/river). The losing condition where surface water contributes to groundwater can be further subdivided into "losing connected" or "losing disconnected," depending on the presence and extent of an unsaturated zone beneath the streambed. An unsaturated zone refers to an area where the pore spaces in the aquifer material are partially filled with air and water but are not completely saturated with water. The infiltration rate of surface water into groundwater for a losing, connected stream is inversely related to the water table position, where a lower water table causes a higher infiltration rate. In a losing, disconnected stream, surface water also infiltrates to the groundwater aquifer, but the rate of infiltration is at its maximum and independent of the groundwater table position (Brunner et al., 2011; **Exhibit 10**). The "gaining" and "losing" categorizations of surface water and groundwater interaction are distinctions to separate and generalize the types of connection. In actual systems, communication between the two water bodies occurs on a continuum between these two states, where transitional conditions often occur over short distances along a river or stream. An illustration of these categorizations are shown in **Exhibit 11.**

During the case where a portion of a stream or river is described as "losing disconnected", an unsaturated zone is present between the river bed and the water table. This categorization of interconnection is inaccurately termed "disconnected" because it describes a state where there is communication between the river and aquifer. In the literature, while the majority of studies use this term, some studies refer to this state as "percolating surface water" (Brunner et al., 2011). Throughout the remainder of this report, I will refer to the "losing disconnected" state using the more accurate descriptor "percolating surface water." This type of connection is present at surface water features within the Watershed, particularly during dry months and/or during dry water years when the water table is much lower than the streambed, though the locations and extents of percolating surface water are variable. If surface flow is present in the river or stream, water still infiltrates and recharges the basin, with the hydrogeologic properties of the streambed and aquifer material dictating the rate of infiltration. Additionally, the lateral extent of a reach (upper and lower bounds along the length of a river) of percolating surface water as well as the duration, or persistence of the unsaturated zone beneath the streambed, varies from year to year depending on hydrologic conditions and the amount of groundwater in storage within a groundwater basin. Within all groundwater Basins of the Watershed, losing and gaining conditions exist along the major surface water features. The spatial extent and duration of a given connection type depends on the groundwater levels within the Basins.

1.2.2 The Source of Water to Wells

If pumping groundwater from wells decreases streamflow in a stream or river that flows through the same groundwater Basin where the wells are located, then the stream or river is considered hydraulically connected to groundwater. Groundwater pumping by wells introduces a component to a groundwater Basin's water budget that is not present in the natural system where there is no well pumping. This component causes an adjustment to the long-term dynamic equilibrium of the basin. To reach a new equilibrium, well pumping induces changes in the rate of recharge and/or discharge from the aquifer, including the amount of groundwater discharging to a stream or river or the amount or extent of groundwater recharge from a stream or river (Theis, 1940, **Exhibit 12**; Alley et al., 1999, **Exhibit 13**). The source of water to a pumping well is not solely groundwater held in aquifer storage. Aquifer storage is the reservoir of groundwater held within an aquifer. If this was the only source of water to wells, then we would see groundwater levels in basins where pumping occurs continuing to decline over long time periods, approximately linearly with the rate of extraction. Instead, there is a dynamic equilibrium that is reached where groundwater levels are stable over long time periods, when different water year types are averaged out and the basin is not in a state of overdraft. Some of the water supplying the wells is "captured" from hydraulically connected surface water, a phenomenon termed streamflow depletion (Barlow and Leake, 2012, **Exhibit 14**). A diagram showing how a well causes streamflow depletion is shown in **Exhibit 15.**

Groundwater and surface water are hydraulically interconnected within the four basins of the Watershed and they are connected in a material way. In all four Basins, well pumping either directly or indirectly consumes surface water, leading to streamflow depletion. The direct mechanism for depletion is when a well adjacent to a river or stream pumps water directly from the aquifer where lowered water levels decrease the amount of surface flow. Indirect depletion occurs when pumping wells that are not adjacent to a surface water feature captures water that would otherwise have discharged to the stream or river at a location downstream, where groundwater and surface water are interconnected. Another form of indirect depletion is through well pumping that lowers the water table in the aquifer, resulting in increased infiltration of surface water to groundwater in another location. Groundwater extractions through wells are not isolated occurrences, but impact the groundwater levels of the entire basin where the wells are located. Groundwater is also not statically held within a basin, but rather it moves generally downgradient, following the topography of the base of the alluvium. In each of the four Basins, this direction is toward a surface water feature that discharges from the Basin.

A major component of the groundwater budget of each of the four groundwater Basins in the Watershed is interaction with surface water (Entrix, 2001, **Exhibit 16**; Tetra Tech 2009, **Exhibit 17**; DBS&A 2010, **Exhibit 18**; DBS&A 2011, **Exhibit 19**). Streamflow depletion on the Ventura River, therefore, occurs as a results of well pumping in all four groundwater Basins because each is within the contributing area to the Ventura River, or the Watershed. Each Basin has characteristic hydrogeologic properties that dictate the timing of depletion relative to well pumping, though none of the four Basins are exempt from this response to well pumping.

Bases for Opinions by Groundwater Basin

1.3 UPPER VENTURA RIVER VALLEY GROUNDWATER BASIN

It is my opinion that the boundaries of the Upper Ventura River Valley Groundwater Basin, commonly referred to as the Upper Ventura River Basin (in either case, UVRB) are correctly defined in Bulletin 118, and that the basin is materially connected to the Ventura River. In reaching these opinions for this basin, I did the following: a) independently confirmed the boundaries of the basin as defined by Bulletin 118 using geologic and hydrogeologic studies; b) reviewed existing studies and analyses of the groundwater-surface water connection conducted in the basin; c) analyzed field studies previously conducted in the basin; d) conducted an analysis of gaged streamflow data; e) evaluated long-term records of groundwater levels; f) conducted an analysis of the anthropogenic groundwater and surface water connection; and g) performed groundwater modeling simulations and reviewed the results of groundwater modeling conducted by others. Each of these are discussed in greater detail herein.

The Ventura River flows from north to south throughout the Basin. Groundwater is connected to surface water in the river, and the interconnection depends on the location within the UVRB as well as the season and water year conditions.

1.3.1 Basin Boundaries as defined by Bulletin 118

The UVRB designated by California Department of Water Resources (CA DWR) as the Ventura River Valley Groundwater Basin, Upper Ventura River Subbasin (DWR, 2016a, **Exhibit 20**), is one of the four groundwater Basins within the Watershed. According to Bulletin 118, the basin extends from the confluence of Matilija Creek and North Fork Matilija Creek in the north to the Casitas Vista Road Bridge, below Foster Park, in the south. Bedrock bounds the alluvial groundwater basin on all sides and below, preventing significant groundwater communication with adjacent basins. A portion of the eastern basin boundary is formed by the Arroyo Parida-Santa Ana Fault, where uplifted bedrock units contact the alluvium (**Exhibit 5).** In my opinion, this basin boundary is correctly defined.

1.3.2 Geologic and Hydrogeologic Structure

In support of my opinion that Bulletin 118 correctly defines the basin boundary, I examined the geologic and hydrogeologic structure of the basin to verify that boundaries are correctly defined. My analysis consisted of an independent review of geologic maps and analyses on the presence and extent of alluvium and bedrock, including data that was used by DWR to prepare Bulletin 118. As my review confirmed, the UVRB is an alluvial aquifer composed of mostly sand, silt, gravel and cobbles. The Ventura River flows from north to south, or downvalley, and throughout most of the basin the east-west extent of the aquifer is very narrow on either side of the river. The alluvial aquifer is bounded by bedrock on all sides and below. The bedrock underlying the UVRB is mostly the Sespe Formation, with some portions bounded by the Monterrey Formation, Ojai Conglomerate, and the Rincon Shale (KG, 2016a). Recent geologic mapping indicates that the Ojai Conglomerate is present at the surface within the northeastern portion of the UVRB (UVRGA, 2021a, **Exhibit 25**). The Sespe formation, of Oligocene age, is composed of mostly sandstone with some siltstone and claystone. The Monterey Formation, of Miocene age, is composed of mostly shale with some sandstone and limestone, and the Rincon Shale, also of Miocene age, is composed of shale with some siltstone (DBS&A, 2020, **Exhibit 26**). The hydraulic conductivity, a measure of a material's capability to transmit water, of these consolidated sandstone units is two to four orders of magnitude lower than the unconsolidated deposits that make up the alluvial aquifer, and the conductivity of shale is 5-6 orders of magnitude lower, though presence and degree of fracturing of can influence the conductivity (Heath, 1983, **Exhibit 27**). The conductivity of these bedrock units has not been measured in the vicinity of the UVRB, though groundwater modeling of the neighboring Santa Clara-Calleguas Basin by the USGS concluded that these bedrock formations are non-water bearing (Hanson et al., 2003; **Exhibit 28**). The groundwater budget analysis completed in 2010 for the Upper and Lower Ventura River Basins also found that the flux of groundwater from bedrock to the alluvial aquifers is a minor component of the total budget (DBS&A, 2010, **Exhibit 18**), and the hydrogeologic investigation by Fugro in 2002 (**Exhibit 100**) states that the consolidated shale and sandstone bedrock units have permeability that is so low relative to the recent and Pleistocene alluvium that the contact between these units is considered to be the effective base of the aquifer (Fugro, 2002). This independent review of geologic and hydrogeologic material related to the UVRB confirms that the boundaries of the basin are correctly defined by Bulletin 118.

1.3.3 Existing Studies and Analyses

In support of my opinion of interconnectivity between the UVRB and the Ventura River, I looked at studies or previous analysis that investigated this issue. Those studies all confirm that there is interconnectivity. Groundwater flow direction in the UVRB is down-valley and towards the Ventura River (Entrix, 2001, **Exhibit 16)**. Flow direction is determined by calculating the hydraulic gradient, or the slope of the water table. Groundwater generally moves from points of recharge to points of discharge along this gradient. In the UVRB, groundwater is recharged primarily by stream infiltration with a minor component of direct infiltration of precipitation (DWR 2016a, **Exhibit 20**). The primary discharge point for groundwater is at the southern end of the basin as stream flow in the Ventura River. During dry conditions when aquifer storage is low, groundwater movement is generally downgradient and much of the river infiltrates to groundwater, or no instream flow is present. During and following wet years, high groundwater levels feed surface flow in some locations. The portion of the Ventura River within the UVRB that regularly exhibits gaining conditions is the southern reach, approximately downstream from Santa Ana Boulevard to Foster Park (Entrix, 2001, **Exhibit 16**; UVRGA, 2021a, **Exhibit 25**), though gaining conditions are present near Foster Park during all months of the year of most water years (Hopkins, 2013, **Exhibit 24**). In this area, shallower alluvium and bedrock that is exposed in the active river channel force groundwater to rise closer to the land surface and the majority of downgradient groundwater becomes surface flow (HGC, 2009, **Exhibit 22;** HGC, 2013, **Exhibit 24**).

During periods when groundwater is contributing to surface flow in the Ventura River, or gaining conditions, there is a clear connection between the two entities. During seasons or in locations where losing conditions occur along the river, a connection also exists between groundwater and surface water. River water enters the subsurface through the riverbed by infiltration. The infiltration rate is determined by the riverbed sediment properties, the depth of surface flow in the river/stream, and also by the groundwater levels below the stream. As the water table lowers beneath a stream in the losing condition, the infiltration rate increases. Infiltration rate continues to increase with the lowering of the water table until an unsaturated zone forms beneath the streambed. The unsaturated zone formation results in the maximum losing condition, where the infiltration rate is higher than when the water table is in contact with the streambed. In this situation, the position of the water table does not affect the rate of infiltration.

In the UVRB, there is a portion of the Ventura River that regularly has no surface flow (the "intermittent reach"), that is downstream from a portion of the river where surface water contributes to groundwater. The extent of this reach (section of a river) varies from year to year, but the average extent is from approximately the Robles Diversion to the confluence between the Ventura River and San Antonio Creek downstream. This reach becomes dry because of the widening of the river channel and the high permeability of the riverbed in this part of the basin. During my site visit on August 3, 2021, I observed flow on the Ventura River near where it enters the UVRB from the north at approximately 20 cfs. About a mile downstream, there was no surface flow, and the channel character was dramatically different. The gradient is less steep, the channel becomes wide and braided, allowing rapid infiltration of surface water to groundwater. Photos showing the difference between the two locations on the river taken during my site visit are included as **Exhibit 96.**

During dry periods without instream flow, there is no physical connection between surface water and groundwater, though groundwater pumping in the UVRB adjacent to this disconnected reach still indirectly impacts Ventura River flow. The water table position determines the length of the disconnected reach and the timing of disconnection (Fox and Durnford, 2003, **Exhibit 33**), so as groundwater pumping lowers the water table it influences the timing of the formation of the "dry reach" and its upper and lower bounds in a given year. A lowering of the water table in the vicinity of the dry reach impacts streamflow downstream on the Ventura River at or below the confluence with San Antonio Creek, where conditions are regularly gaining, during the subsequent wet season. This indirect streamflow depletion is evidence for connectivity between groundwater and surface water in the UVRB (UVRGA, 2021a**, Exhibit 25**). The Upper Ventura Groundwater Agency (UVRGA) produced an animation showing the water table in the UVRB rising and falling over the course of several years that illustrates how indirect streamflow depletion functions during some water year types. The animation is included as **Exhibit 92**, and is evidence for the connection between groundwater and surface water in the basin.

1.3.4 Surface Water – Groundwater Interaction Field Studies

In reaching my opinion of interconnectivity, I evaluated existing field studies of groundwater – surface water interaction conducted in the UVRB. A groundwater interaction field study can be conducted in several ways, though a common method is to conduct a pumping test at a well located adjacent to a river or stream. During, before, and after the pumping test, the groundwater levels are monitored at nearby non-pumping well(s) and streamflow is measured upstream and downstream from the pumping well. I looked at four of these studies as part of this review. J. Kear conducted a surface water- groundwater interaction study in 2012 at two of Meiners Oaks Water District's pumping wells in the northern portion of the UVRB. The study involved initiating pumping at the wells and measuring groundwater levels and upstream and downstream river levels continuously before, during and after pumping. The results showed that while the drawdown of river levels in response to pumping was approximately 2 inches, groundwater withdrawal from the wells had an impact on surface water flow. River levels recovered rapidly following the cessation of pumping, providing further evidence that groundwater and surface water are interconnected (KG, 2012, **Exhibit 34**).

Hopkins Consultants conducted several surface water – groundwater interaction studies in the vicinity of Foster Park from 2009-2013 (**Exhibits 22-24**). In each study, the interaction was assessed by taking streamflow measurements and groundwater level measurements in the vicinity of and both upstream and downstream of the City's production wellfield. Measurements were made for a period of approximately three months during the low-flow summer months before and after the City ceased production at one or more of its wells. They found that streamflow responded to pumping, though not as a 1:1 relationship. The magnitude of the response depended on river flow rate and groundwater levels, but in all surveys a response was observed. The recovery of river flow after cessation of pumping was particularly rapid, a response attributed to high riverbed infiltration rates and the high conductivity of surrounding aquifer materials. These studies show how groundwater and surface water are interconnected in the UVRB.

1.3.5 Streamflow Gage Data

In determining interconnectivity within the UVRB, I analyzed gaged streamflow data. The persistence of surface flow in the Ventura River weeks and months following rain events shows that river flow has a groundwater-fed component and does not only consist of surface runoff. I conducted a streamflow gage analysis using average daily flow values at three gages located within the UVRB: USGS gage 11116550 Ventura River at Meiners Oaks (6550), 11117500 San Antonio Creek at Casitas Springs (7500), and 11118500 Ventura River at Casitas Vista Bridge (8500). The locations of these gages are shown in **Exhibit 35**, with two gages measuring flow upstream in the basin (6550 and 7500) and one measuring flow downstream at the point where the Ventura River exits the UVRB (8500). I analyzed daily flow values and selected water years 1960-1965 to encompass a variety of water year types that also coincide with years within the period of record for all gages. Flow values for gages 6550 and 7500 were added together to represent the upstream inflow and were compared to gage 8500, the downstream outflow. The results of this analysis are shown in **Exhibit 36.** Even with consumptive use occurring between the upstream and downstream gaging locations, there are periods lasting several months during some years when downstream flow is greater than upstream flow during the summer and fall when no major precipitation events occured. During April 1960-December 1960, July 1962- January 1963, and June 1963- October 1963, downstream gaged flow (8500) was consistently 2-4 cfs greater than upstream flow. In each of these periods, the last day of recorded rainfall for the water year was weeks to months prior (Apr. 27, 1960; May 16 1962; June 11, 1963). The higher downstream flow relative to upstream during dry seasons is evidence for groundwater contributing to surface water flow, or a measureable baseflow component of the Ventura River.

1.3.6 Groundwater Level Analysis

In determining interconnectivity, I looked at long-term records of groundwater levels at monitoring wells. Manual measurements of groundwater elevation in these wells are taken by DWR and/or other state and federal agencies six times per years and are reported to DWR. These measurements are accessible online through the DWR's Water Data Library (**Exhibit 93**). I compiled data from wells located adjacent to the river that show that the water table is at times sufficiently high for connected river-aquifer conditions. Records of water levels in three wells, state well numbers 04N23W09B001S (09B01), 04N23W16C004S (16C04), 04N23W20A001S (20A01), and 04N23W29F002S (29F02), are displayed in **Exhibits 29-32,** with the land surface elevation at the well and the adjacent riverbed elevation. A map showing the locations of these wells within the UVRB is provided as **Exhibit 147.** Groundwater levels are recorded at these wells approximately every three months. The water levels in well 09B01, located approximately 1,200 feet from the active Ventura River channel, fluctuate ~10-40 feet seasonally, though following wet winters can be less than five feet below the ground surface and are regularly higher than the adjacent riverbed elevation. During these periods, the water table elevation is sufficiently high to intersect the riverbed and contribute to surface flow. **Exhibit 60** shows a diagram of an observed groundwater level that would result in a connection between the aquifer and river or stream. Similarly, at wells 20A01, 16C04, and 29F02, seasonal high water levels are less than five feet below the ground surface and water table elevations are higher than the adjacent riverbed elevation during these periods, indicating a head gradient towards the river and gaining conditions that occur at least during these periods and at these locations.

1.3.7 Vegetation and Groundwater Dependent Ecosystems

In determining interconnectivity, I reviewed existing studies of groundwater dependent ecosystems (GDEs) in the UVRB. There is an existing GDE analysis for this basin that I could rely on, though for basins where there is no final GDE analyses, I relied on a colleague, Tamara Klug, a Principal Botanist employed by Cardno for supporting information on the vegetation. The UVRGA is a Groundwater Sustainability Agency (GSA) formed to develop a Groundwater Sustainability Plan (GSP) as required by the Sustainable Groundwater Management Act (SGMA). SGMA established a statutory mandate for GSAs in medium and high priority basins to develop GSPs that provide a plan for basins to reach long-term sustainability. The UVRB is a medium priority basin and therefore must comply with this requirement. Through SGMA, GSPs must include the identification of groundwater dependent ecosystems (GDEs) and other beneficial uses of groundwater. SGMA implementing regulations define GDEs as "ecological communities of species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (SGMA, 23 CCR § 351(m)). In the UVRB, GDEs include instream aquatic and riparian habitat, as well as any vegetative habitat with terrestrial plant species that are adapted with root systems that can access groundwater in most conditions.

The UVRGA has led two studies that were conducted to identify areas with aquatic and riparian GDEs (Rincon, 2021a, **Exhibit 37**; Rincon, 2021b, **Exhibit 38**). Aquatic GDEs consist of habitat for plants and animals that spend most of their lifecycle within water. Riparian GDEs are ecosystems located in the riparian zone, or the interface between a surface water body and the surrounding terrestrial ecosystem, such as stream or river banks, wetlands, or the area surrounding springs. The riparian GDE assessment investigated potential areas along the Ventura River where plant communities in or adjacent to the riverbed rely on groundwater. Identification of riparian GDEs in the UVRB necessitates areas with interconnected surface water and groundwater. The assessment found two areas with riparian GDEs, one located approximately south of Santa Ana Blvd. to the confluence between the Ventura River and San Antonio Creek, and the other near Foster Park to the southern boundary of the basin. These studies show that there is an interconnection between surface water and groundwater in the UVRB.

1.3.8 Anthropogenic Groundwater – Surface Water Connections

In determining interconnectivity, I conducted an evaluation of how humans have created connections between groundwater and surface water in the Watershed, or the anthropogenic connection. The Watershed has been altered extensively by humans over the last century. The two largest manipulations, the construction of Matilija Dam and Casitas Dam (including the Robles Diversion, shown in an aerial photograph in **Exhibit 149**), were completed to increase water availability at locations within the Watershed without an otherwise reliable source of water and both involved changing the manner that surface water and groundwater are connected within the Watershed. Matilija Dam, originally constructed to store and in part transfer water to the Ojai Basin, is discussed in the Ojai Basin section, below. Lake Casitas, the reservoir formed by installing Casitas Dam on Coyote Creek, is located to the west of the UVRB. Lake Casitas was constructed in 1956. Though the water supply to the lake varies depending on conditions during a water year, the supply is composed partially of inflow from upstream creeks and partially from diversions from the Ventura River at the Robles Diversion. Approximately half of the water in the reservoir is supplied by Ventura River diversions, with the other half supplied by upstream flow from Coyote and Santa Ana Creeks (CMWD, 2004, **Exhibit 39**). Casitas Municipal Water District (CMWD) owns and operates Lake Casitas and distributes water via distribution pipelines to its main conveyance system. This system delivers water to eight municipal water agencies as well as individual agricultural customers within the Watershed, where the water is either the primary supply or back-up supply for customers that also use groundwater wells (CMWD, 2020, **Exhibit 40**). The alteration by humans has had a noticeable impact on flows in the Ventura River and its tributaries as well as the level of groundwater in each of the Basins. I examined these anthropogenic connections to show the human influence on surface water- groundwater interactions.

The delivery of Lake Casitas water to agricultural customers within the UVRB represents an anthropogenic form of interconnection between surface water and groundwater. Lake Casitas water is diverted from the Ventura River, then when applied to crops, some of the water is consumed via evapotranspiration, while some of the irrigated water infiltrates and recharges the groundwater basin. Additionally, Lake Casitas water is supplied to domestic water users, where return-flow occurs both as excess irrigation water not consumed by plants and as infiltration from septic systems. These return flows represent a relatively minor component of the groundwater budget; the draft GSP estimates average total return flows are 480 acre-feet per year, with approximately 50 percent from irrigation return flow, though during dry periods this could be a more significant portion of groundwater recharge. The proportion of applied water for agriculture in excess of crop demand that is irrigation return flow is estimated to be 20 percent (Intera, 2021, **Exhibit 41**). Total CMWD deliveries to the UVRB from 2015-2020 ranged from approximately 1,000 acre-feet to 4,000 acre-feet per year (SWRCB, 2021b, **Exhibit 42**). This analysis of water deliveries and use within the UVRB shows how river water is materially connected to groundwater through a human-made connection.

1.3.9 Groundwater Modeling Results

In determining interconnectivity, I along with two colleagues at Cardno, constructed a groundwater model and performed our own modeling exercise. We constructed a groundwater flow model using MODFLOW, a modular hydrologic model developed by the USGS, to simulate groundwater and surface water flow within the four groundwater Basins of the Watershed (Groundwater Flow Model). The model was constructed under my direction by a team consisting of myself, Jason Early, P. G., and Bryant Mountjoy, both hydrogeologists that specialize in groundwater modeling. Their curriculum vitae are provided in **Exhibits 43 and 44.** Details on the model construction, calibration, and assumptions are provided in the Modeling Report as **Exhibit 45**. We calibrated the model to simulate conditions during water years 2004-2006 with monthly stress periods (stress periods define time intervals where model inputs are kept constant). Results from the calibrated model show that there is a flux from the Ventura River into the aquifer or from the aquifer to the river during all months of the calibration period, though the direction of contribution (gaining or losing conditions) depends on the hydrologic conditions of the simulated month and the location within the UVRB. Not all locations along the river in the UVRB exhibited surface flow during dry months, consistent with observations of flow and wet/dry maps of the intermittent reach of the Ventura River (UVRGA, 2021, **Exhibit 25**).

A scenario was run using the model to test the impacts of pumping wells on instream flow in the Ventura River using the model. In this scenario, all input datasets and parameters were kept the same as in the calibrated model except that all wells in the four Basins (domestic, municipal, and agricultural) were "turned off," or no groundwater was removed via the well object, to simulate conditions in the basin without well pumping. The model-simulated river flows with and without well pumping were compared at three streamflow output locations within the basin (output location map shown in **Exhibit 46**). These locations were selected to determine the potential impacts of pumping at reaches on the Ventura River with different hydrogeologic characteristics. **Exhibit 47** shows the results of the scenarios. At locations A, B and C within the UVRB, simulated Ventura River flow is higher without well pumping in the groundwater basins than with well pumping. These results confirm that the lowering of the groundwater table by well withdrawals decreases streamflow during some months of the year and in parts of the basin, an effect that confirms the connection between groundwater and surface water. The magnitude of simulated streamflow depletion by wells was greater during dry periods and is most evident at the southernmost streamflow output location in the UVRB, Location C, where streamflow depletion was approximately 10 cfs during June through August, 2004.

The UVRGA has also conducted a groundwater modeling exercise using a model developed by its consultant Intera, Inc. to simulate groundwater – surface water interactions within the UVRB (**Exhibit 41**). I also reviewed Intera's modeling results in my analysis of interconnectivity. This model has been used for several scenarios related to the GSP development, including 50-year simulations for future water budget projections and simulations of depletions of interconnected surface water and groundwater. Additionally, model simulations of the effects of well pumping on streamflow were included in the Aquatic GDE assessment. Aquatic GDEs within the UVRB are defined as "instream portions of the Ventura River with interconnected surface water that provide important habitat for aquatic species" (Rincon, 2021a, **Exhibit 37**). Three critical habitat reaches for aquatic GDE's were identified on the Ventura River, then simulated flow over the next 50 years at these reaches was compared with and without UVRB well pumping. Results show that the habitat area within the intermittent reach below the Robles Diversion exhibited minimal streamflow depletion from pumping (~0.2 cfs). This is only a small amount of depletion during most wet-season months and there was no simulated surface flow during the rest of the year. The confluence habitat area, an approximately 1-mile reach from just above the confluence between San Antonio Creek and the Ventura River to below this confluence, exhibited streamflow depletion of up to 4 cfs during dry months of most water year types. The Foster Park habitat area, an approximately 0.5 mile reach of the Ventura River from Foster Park to the southern boundary of the UVRB, exhibited streamflow depletion of up to 8 cfs due to well pumping within the UVRB. Higher depletion values are observed during dry periods, though these results do not fully capture the implementation of the existing pumping protocols at the Foster Park wellfield that go into effect during dry periods and the observed depletions are attributable to all well pumping within the UVRB. The results of these model scenarios are consistent with the results that we found using our groundwater model. Both modeling efforts showed that there is a connection between groundwater and surface water during most seasons and water year types. Both models showed that well pumping in the basin lowers groundwater levels and had either a direct or indirect material impact on the amount of surface flow in the Ventura River.

The SWRCB is developing a groundwater-surface water and nutrient transport model of the Watershed. The results of this modeling effort will be released in September, 2021. I intend to analyze this model and determine how, if it all, the modeling results affect my opinions.

1.3.10 Conclusions

Based on the evaluations above, it is my opinion that the boundaries of the UVRB are correctly defined in Bulletin 118 and that groundwater and surface water are materially connected within the basin.

1.4 LOWER VENTURA RIVER GROUNDWATER BASIN

It is my opinion that the boundaries of the Lower Ventura River Valley Groundwater Basin (LVRB) are correctly defined in Bulletin 118, and that the basin is materially connected to the Ventura River. In reaching these opinions for this basin, I did the following: a) independently confirmed the boundaries of the basin as defined by Bulletin 118 using geologic and hydrogeologic studies; b) reviewed existing studies and analyses conducted in the basin; c) evaluated records of groundwater levels; d) conducted an analysis of the anthropogenic groundwater and surface water connection; and e) performed groundwater modeling simulations. Each of these are discussed in greater detail herein.

1.4.1 Basin Boundaries as defined by Bulletin 118

The Lower Ventura River Basin (LVRB) is an alluvial aquifer that extends from approximately the southern end of Foster Park to the Pacific Ocean (**Exhibit 6**). The boundaries of the basin are defined at its base and sides by the contact between the basin-fill alluvium and bedrock, to the north by the UVRB and to the south by the Pacific Ocean (**Exhibit 48**, Bulletin 118). It is my opinion that the basin boundaries are correctly defined by Bulletin 118. The main surface water features within the basin are the Ventura River and Cañada Larga Creek, a tributary of the Ventura River. In some locations in the basin, river water infiltrates and recharges groundwater, while in other locations and in wet season/water years, groundwater supports surface water flow. Bulletin 118 states that percolation of water from the Ventura River is a major source of recharge to the basin.

1.4.2 Geologic and Hydrogeologic Structure

In determining the basin boundaries, I performed an independent investigation of geologic and hydrogeologic information for the LVRB utilizing data sources beyond those utilized by DWR. The groundwater bearing formations in the LVRB are Quaternary alluvial sediments that range from approximately 60 – 150 feet, and are thickest in the southern portion near the ocean with very thin (<10 ft.) alluvium at the northern boundary of the basin where is abuts the UVRB (DBS&A, 2020, **Exhibit 26**; Fugro West, 2004, **Exhibit 49**). The primary bedrock units that underlie and border the LVRB are the Pico Formation and the Santa Barbara Formation. The Pico Formation, of Pliocene to Pleistocene age, consists of claystone and sandstone, and the Santa Barbara Formation consists of claystone with shale fragments (DBS&A, 2020, **Exhibit 26**). The bedrock formations are fine-grained, consolidated rock that are generally considered as a barrier to groundwater flow, though wells in the Pico formation may yield some groundwater. Generally, however, with hydraulic conductivity several orders of magnitude lower than the alluvial basin fill, movement of groundwater between bedrock and the alluvial sediments of the LVRB is considered to be minimal or insignificant. The direction of groundwater movement through the LVRB is from north to south (Fugro West, 2004). This review of the geology and hydrogeology of the LVRB supports my opinion that Bulletin 118 contains the correct delineation of the basin boundaries.

1.4.3 Groundwater Level Analysis

In determining interconnectivity, I looked at records of groundwater levels within the LVRB and interpreted groundwater flow. Groundwater moves from north to south within the LVRB and the amount that is not consumed by humans or lost to evapotranspiration discharges to the Pacific Ocean. There are two monitoring wells in the LVRB managed by the Ventura County Watershed Protection District (VCWPD) with data available through the DWR Water Data Library, state well numbers 03N23W32Q007S (32Q07) and 03N23W32Q003S (32Q03). These have only been recording water levels since 2013 and have a limited number of published measurements. **Exhibit 94** contains plots of the available groundwater level measurements compared to ground surface elevation and the river elevation adjacent to each well, and **Exhibit 95** is a map showing the locations of these wells. The data from well 32Q003 show that the groundwater levels are within 10 feet of the riverbed at a distance of approximately 200 feet away from the river channel, though during the spring of 2012 were above the riverbed elevation. Well 32Q007 regularly shows groundwater levels higher than the adjacent riverbed elevation. These data show that the water table in the LVRB is sufficiently high to intersect the Ventura River, most likely alternating between losing (connected) and gaining (connected) conditions depending on the season and water year. Most of these measurements were collected during the drought period of 2012-2016, so it is also likely that there is more contribution of groundwater to surface flow during average or wet water years.

I also obtained additional groundwater level data through documents retrieved from GeoTracker, the SWRCB's data portal for remediation sites that have the potential to impact groundwater quality. Two reports for sites adjacent to the Ventura River in the LVRB included either groundwater level monitoring data or depth to groundwater measurements as part of remediation sampling. One of the reports, from a site located approximately 500 feet from the Ventura River, identifies groundwater levels fluctuating from 2.5 feet below ground surface to 15 feet below ground surface. Groundwater flow direction, determined by mapping the water table at the site, was reported as towards the Ventura River (ES, 2006, **Exhibit 50**). The other site, located less than 200 feet from the Ventura River, identified saturated soils at 5 feet below ground surface during soil boring recovery and shallow groundwater during July 2004, a dry water year (AGE, 2004, **Exhibit 51**). The elevation of the riverbed in these locations is below the reported water table position, indicated a state of connection between groundwater and the Ventura River in this location of the LVRB.

1.4.4 Anthropogenic Groundwater – Surface Water Connections

In determining interconnectivity in the LVRB, I evaluated the anthropogenic groundwater- surface water connection. The LVRB receives water from Lake Casitas via CMWD's gravity fed distribution system. The water is delivered to municipal water agencies who mainly distribute the water to agricultural customers, as there are only two active domestic wells in the basin (**Exhibit 90**: Active Wells Map). The delivery amounts vary depending on water year conditions, and the delivered CMWD water is used by some customers as a back-up supply in addition to groundwater wells. During the last five years, deliveries to the LVRB ranged from approximately 1,000 acre-feet per year to 3,000 acre-feet per year (SWRCB, 2021, **Exhibit 42**). When applied to crops, a portion of this surface water is consumed by the plant as evapotranspiration and a portion infiltrates, recharging the groundwater basin. This recharge portion, termed agricultural return flow, has been estimated in neighboring groundwater basins. In the UVRB, return flow is estimated at 20 percent of applied irrigation (Intera, 2021, **Exhibit 41**), and within the Santa Clara River watershed, where soil types, crop types, and climate are similar to the LVRB, the return flow is estimated to be 22 to 25 percent of the applied irrigation water (UWCD, 2018, **Exhibit 52**).

The other anthropogenic surface water – groundwater connection in the LVRB is the input of water to the Ventura River from the Ojai Valley Sanitation District (OVSD). Treated wastewater is discharged to the river at an average rate of 6.44 acre-feet per day from the treatment plant in the northern part of the

LVRB (Walter, 2015, **Exhibit 120**). This additional contribution to surface flow may eventually infiltrate and contribute to groundwater in the basin.

1.4.5 Groundwater Modeling Results

In determining interconnectivity, I performed an independent analysis using the groundwater model that I developed with my colleagues. We used the model to simulate groundwater and surface water interaction in the LVRB. A model scenario was developed that compared flow at one streamflow data output location on the Ventura River with and without well withdrawals to assess the presence or absence of streamflow depletion by well pumping. I compared model simulated flow during the calibration period for the Ventura River in the lower part of the basin before the estuary (**Exhibit 46**, Output Location D) for a scenario where all wells, including wells in the other groundwater basins and agricultural wells, were "turned off" for the three-year simulation versus normal well pumping during the same calibration period. Results of this scenario are shown in **Exhibit 53.** The results show that river flow in the scenario with no well pumping is approximately 6 cfs higher than with well pumping, particularly during dry months and dry water years. These results confirm that there is a material connection between the groundwater basin and surface water flow in the LVRB, and/or that well pumping in other groundwater basins materially impacts river flow in the LVRB.

The SWRCB is developing a groundwater-surface water and nutrient transport model of the Watershed. The results of this modeling effort will be released in September, 2021. I intend to analyze this model and determine how, if it all, the modeling results affect my opinions.

1.4.6 Conclusions

Based on the evaluations above, it is my opinion that the boundaries of the LVRB are correctly defined in Bulletin 118 and that groundwater and surface water are materially connected within the basin.

1.5 OJAI VALLEY GROUNDWATER BASIN

It is my opinion that the boundaries of the Ojai Valley Groundwater Basin (OB) are correctly defined in Bulletin 118, and that the basin is materially connected to the Ventura River via its tributary, San Antonio Creek. In reaching these opinions for this basin, I did the following: a) independently confirmed the boundaries of the basin as defined by Bulletin 118 using existing geologic and hydrogeologic studies; b) reviewed existing studies and analyses on surface water- groundwater connectivity conducted in the basin; c) evaluated long-term records of groundwater levels; d) evaluated stream gage data; e) conducted an analysis of the anthropogenic groundwater and surface water connection; f) surveyed the vegetation and GDEs along San Antonio Creek (also performed Ms. Klug); g) performed groundwater modeling simulations and reviewed the results of groundwater modeling conducted by others; and h) analyzed the connection between all aquifer layers within the OB, including the surficial aquifer layer. Each of these are discussed in greater detail herein.

1.5.1 Basin Boundaries as Defined by Bulletin 118

The OB is located east of the UVRB in the Watershed. The basin is bounded by relatively impermeable bedrock of the Topatopa Mountains to the north and east, the UVRB to the west, the Santa Ana fault and impermeable bedrock of Black Mountain to the south, and the Upper Ojai groundwater basin and San Cayetano fault to the southeast. The Sespe formation and to a lesser extent the Vaqueros Sandstone and the Rincon Shale formations make up the sedimentary bedrock bounding the bottom of the basin (DWR, 2016a, **Exhibit 54**). The OB is designated as a high priority basin under SGMA, a prioritization that is based on eight components relating to well extraction, irrigated acreage, and population within the basin. Bulletin 118 states that the OB is "drained by Thacher and San Antonio Creeks to the Ventura River." These creeks, as well as Reeves Creek, McNell Creek, the Fox Canyon/ Stewart Canyon drainages and other unnamed tributaries combine in the central part of the OB, and then they combine with San Antonio Creek that flows to the southwest where it exits the basin and continues to flow for approximately four miles until it flows into the Ventura River. It is my opinion that the basin boundaries are correctly defined by Bulletin 118.

1.5.2 Geologic and Hydrogeologic Structure

In determining the boundaries of the OB, I independently reviewed the information provided in Bulletin 118 and analyzed available studies and reports on the geologic and hydrogeologic structure of the basin to confirm the basin boundaries. The OB differs from the other basins in the Watershed in that the aquifer is layered and semi-confined. Confinement of an aquifer refers to the presence of geologic units above an aquifer that are less permeable and restrict groundwater movement. The alluvium that makes up the aquifer units in the OB, composed primarily of sand, gravel, and cobbles, is interrupted by fine-grained deposits composed primarily of clay and silt that act as the less-permeable semi-confining units. The basin is also distinct because of the thickness of the alluvial sediment in portions of the basin. The alluvium ranges from less than 20 feet thick in the higher elevation areas to the north and east of downtown Ojai to over 700 feet thick near the central to southern portion of the basin (DBS&A, 2011, **Exhibit 19**; OBGMA, 2021, **Exhibit 56**). Despite the layered structure of the OB, it is one groundwater basin, as defined by Bulletin 118, and the semi-confining units do not separate it into multiple disconnected basins.

The north and east portions of the OB aquifer are unconfined, allowing infiltrating water to reach the deeper aquifer layers and flow laterally to recharge groundwater within the semi-confined aquifer layers. In the southwestern portion of the basin, where groundwater discharges from the basin as near-perennial surface flow in San Antonio Creek, low-permeability clay-rich units create a surficial aquifer layer that has been described by the Ojai Basin Groundwater Management Agency (OBGMA) as a "shallow perched aquifer" (OBGMA, 2021**, Exhibit 56**). A perched aquifer, or perched groundwater, is defined as groundwater separated from an underlying body of groundwater by an unsaturated zone. The lateral extents of the alleged perched zone and a depiction of the aquifer layering that is proposed to result in a perched surficial aquifer are shown in **Exhibit 61**. It is my opinion, and existing geologic and hydrogeologic data suggests, that this layer is not isolated from the rest of the groundwater basin. Additionally, the presence and degree of separation of the alleged perched, or surficial aquifer layer, does not negate the connection between groundwater and surface water in the OB. The basin represents one common water source, and if water is removed from deeper aquifer layers, then less is available for surface water flow. This concept will be discussed in greater detail in a subsequent section.

1.5.3 Existing Studies and Analyses

In determining interconnectivity, I reviewed the existing studies and analyses on groundwater and surface water in the OB. Recharge to the aquifer layers in the OB occurs primarily through infiltration of surface water from San Antonio, Thacher, Reeves, and McNell creeks as well as several other drainages and minor tributaries that enter the basin along its northern and eastern boundaries. Surface water infiltrates rapidly into the uninterrupted alluvium in this portion of the OB and eventually flows in the subsurface to all aquifer layers within the basin. Though portions of these streams and creeks regularly go dry during the late summer and fall, perennial flow is observed in San Antonio Creek where it exits the OB

(OBGMA, 2018, **Exhibit 55**). During my site visit on August 3, 2021, I visited several locations on San Antonio Creek, including where Grand Avenue crosses the creek near the center of the basin, a location on the creek near the discharge point from the basin, and at Camp Comfort, approximately 0.5 miles downstream from the discharge point. Photos from the visit (**Exhibit 99**) show what I observed: no surface flow near the center of the basin, where the creek bed was wider and filled with large-grained alluvial sediment, then at the discharge point flow was present. Surface water flow was low, owing to the persistent drought conditions of this water year, though even during the late summer of a year with the lowest recorded annual precipitation since the 1940s, surface flow is present. This perennial flow is supported by groundwater, and the distance from the basin outflow point to the location upstream where surface flow is first observed increases following wet seasons or wet water years. As San Antonio Creek flows across the OB, it is first characterized by surface flow infiltrating and recharging the basin, then becomes subsurface flow in the alluvium beneath the creek, then transitions again to surface flow as the creek travels from northeast to southwest across the basin (DBS&A, 2006, **Exhibit 21**; OBGMA, 2021, **Exhibit 56**). This demonstrates how San Antonio Creek and groundwater in the OB are one integrated system.

The downstream section of San Antonio Creek that connects the OB to the Ventura River and the UVRB is not considered part of a groundwater basin because the alluvium beneath the creek is thin or absent (0-30 ft.; Entrix, 2001, **Exhibit 16**), providing minimal groundwater storage and/or transfer. Apart from the impacts of well pumping and drought conditions, the near-perennial surface flow in San Antonio Creek provides a linkage between groundwater basins. Groundwater management within the OB impacts flow in the creek that influences both Ventura River surface flow and groundwater levels in the UVRB and LVRB (DBS&A, 2010, **Exhibit 18**).

The direction of groundwater flow in the OB, determined by hydraulic gradients, depends on the conditions of a given water year. During wet years, groundwater flow direction is towards the southwest, where it discharges as surface flow to San Antonio Creek. There is also a component of groundwater flow towards the center of the basin and towards pumping wells, an induced gradient that causes groundwater to move away from the discharge point, with less water contributing to San Antonio Creek that is more pronounced during dry years or under drought conditions (OBGMA, 2021, **Exhibit 56**).

In 2016, the OBGMA submitted an Alternative to the DWR in lieu of a GSP under the SGMA. The submitted alternative is provided in **Exhibit 57 (**KG, 2016c). An Alternative under SGMA must show that the basin has been operated within its “sustainable yield” with no “undesirable results” (Water Code **§** 10733.6(b)(3)). The submitted Alternative identifies San Antonio Creek as a surface water feature interconnected with groundwater in the basin. The Alternative also states that groundwater discharge from the basin to San Antonio Creek is impacted by groundwater levels in the OB. DWR’s assessment of the Alternative found that it failed to show that there will be no undesirable effects related to interconnected surface water through groundwater use and that groundwater discharge rates to San Antonio Creek should be considered when determining the basin’s sustainable yield. The rejection of the Alternative was based in part on the presentation of the OBGMA groundwater modeling report, an appendix to the Alternative, which gave the conclusion that drought conditions cause dramatic decreases in surface flow in San Antonio Creek that are worsened by groundwater pumping. During a 5-year simulated drought period, groundwater continued to contribute to streamflow, though the amount of groundwater discharging to the creek declined to 65% of the smallest rates of discharge over the 39-year modeling period. Both the submitted Alternative and its assessment report recognize the connection between surface water and groundwater within the OB, and affirm the link between groundwater pumping and reductions in surface flow. The assessment of the Alternative by DWR is included as **Exhibit 58.** Because the Alternative was rejected, the OB is now required by SGMA to form a GSA and submit a GSP.

1.5.4 Groundwater Level Analysis

In determining interconnectivity, I analyzed groundwater levels at monitoring wells within the OB that are adjacent to San Antonio Creek. The measurements of groundwater levels at these monitoring wells are collected by state or federal agencies (USGS, DWR) or the VCWPD and are reported to DWR. DWR checks data for accuracy and publishes the data in an online database, the CA Water Data Library (**Exhibit 93**, DWR 2021a). The monitoring wells in the southwestern portion of the OB (i.e. SWN's 04N23W12L002S; 04N22W07G001S) are characterized by a relatively narrow range of seasonal fluctuation in water levels and regularly exhibit high water levels within a few feet of the ground surface. Well 07G001, adjacent to Thacher Creek, a tributary to San Antonio Creek, exhibits flowing artesian conditions during wet periods, where groundwater flows at the land surface. Long-term records from these monitoring wells and a map showing the locations of these wells are shown in **Exhibit 69.** Well W12L002 is located adjacent to San Antonio Creek near the point where the creek drains the basin. Groundwater levels are almost continuously above the elevation of the streambed approximately 600 feet to the south, explaining how this gaining section of the creek is a location where groundwater provides nearly year-round surface flow (DBS&A 2011, **Exhibit 19**; OBGMA, 2018, **Exhibit 55**).

1.5.5 Streamflow Gage Data

In determining interconnectivity, I analyzed streamflow data recorded at continuous gaging stations within the OB. Measured streamflow data is limited within the OB because of the lack of active continuous gaging stations. There are currently three active gages in or near the OB that record daily streamflow on San Antonio Creek, and one event gage on Thacher Creek that only records peak-flow events. Plots of average daily streamflow are shown in **Exhibit 97**, and the locations of the gages on San Antonio Creek are shown in **Exhibit 98**. The record from Gage 616, located on San Antonio Creek at Camp Comfort, approximately 0.5 miles downstream from the discharge point of the OB, shows how in water year 2019 the flow exiting the basin in San Antonio Creek persists for weeks to months following precipitation events. The plot displayed the baseflow recession, or the portion of flow that is sustained following precipitation events, fed to surface water through delayed pathways and groundwater. The plots from the other two gages contrast gage 616 for two reasons: first, San Antonio Creek is a losing stream in the central and northern portion of the OB, with surface flow rapidly infiltrating to groundwater following precipitation events; and second, the available data for gages 649 and 648 is from very dry water years during the drought of 2012-2016. The data from these plots show how the connection between San Antonio Creek and groundwater transitions as the creek flows across the basin from the upper reaches where surface flow contributes to groundwater, to the lower reaches where San Antonio Creek exits the basin and groundwater contributes to surface flow. The data from this streamflow gage analysis supports my opinion that San Antonio Creek is connected to groundwater throughout the OB.

1.5.6 Anthropogenic Groundwater – Surface Water Connections

In determining interconnectivity, I examined records of the anthropogenic connections between groundwater and surface water. An example of how this connection is formed is through the anthropogenic alteration of the water cycle as deliveries of water from Lake Casitas. Lake Casitas, managed and operated by CMWD, is filled partially by diversions from the Ventura River, so the use of this water for irrigation and municipal supply is an indirect usage of river water within the basin. Using water delivered from Lake Casitas to irrigate crops in the OB connects river water to groundwater in the basin, as a portion of the applied irrigation recharges groundwater through deep percolation. The average annual deliveries for water years 1974-2014 were 3,746 acre-feet/year, where groundwater extraction was 4,154 acre-feet/year for the same period (OBGMA, 2021, **Exhibit 56)**. On average, therefore, deliveries make up 47 percent of the OB's water supply. The estimated average return flow from irrigation for the period 1970-2019 is 1,483 acre-feet/year (OBGMA, 2021), representing 17 percent of the total recharge to the basin of 8,889 acre-feet/year. Of that 17 percent, 47 percent is water delivered by CMWD, so, on average, 8 percent of the total recharge to the OB is from CMWD water. The recharge values are averages of water years with varying hydrologic conditions, however, so during dry years when natural recharge is much lower, the percentage of recharge contributed by CMWD-delivered water is larger. This suggests that without the additional water from CMWD, the OB would be in an unsustainable state of groundwater depletion.

Another example of the anthropogenic connection is through the transfer of water from Matilija Reservoir to the OB. The objective for constructing Matilija Dam and forming Matilija Reservoir in 1947 was to provide additional water for domestic and agricultural use in the Watershed, including the OB, before the construction of Casitas Reservoir was used to serve this purpose (DPW, 1946, **Exhibit 71**). A pipeline was constructed concurrently with Matilija Dam that routed water from Matilija Reservoir to the OB that transferred 2,444 acre-feet in 1957 for municipal and irrigation water use as well as spreading (SWRB, 1957, **Exhibit 72**). This amount is approximately two-thirds of the current average annual groundwater extractions in the basin (3,500 acre-feet/yr. for 2015-2018; OBGMA, 2021, **Exhibit 56**). The spreading, or human-induced passive groundwater recharge, was conducted from 1951 to 1963, and water was applied to man-made ponds as well as several natural stream channel sites within the OB. The success of spreading in this area demonstrates the high infiltration capacity of soils and surface water channels in this basin. Both water delivery projects, the original transfer of water from Matilija Reservoir and the subsequent transfer of water from Lake Casitas, establish anthropogenic connections between the Ventura River and the OB.

A third example of anthropogenic groundwater- surface water connection in the OB is the San Antonio Creek Spreading Grounds (SACSG). The SACSG, located on the north edge of the OB, was originally constructed to receive water transferred from Matilija Reservoir. The early SACSG consisted of a series of man-made ponds for passive infiltration of surface water to the groundwater basin. From 1963 to 1985, surface flows from San Antonio Creek were also diverted into this area to recharge the aquifer. Operations ceased following a major wildfire in the Watershed in 1985. In 2010, a water rights application was filed for the San Antonio Creek Spreading Ground Rehabilitation Project (SACSGRP; **Exhibit 91**) so that diversions could resume from San Antonio Creek into an improved spreading facility that included passive recharge wells. The permit to divert water issued by the SWRCB requires a minimum bypass flow that is intended to protect San Antonio Creek downstream from the project and to protect the water rights of those on the Ventura River downstream of the confluence (**Exhibit 141**). The bypass flow requirement stipulates that diversions can occur only if flow exceeds 21 cfs measured at the San Antonio Creek at Grand Avenue gage (VCWPD 649) and 50 cfs measured at the Ventura River near Ventura gage (USGS 11118500). This bypass flow requirement is a recognition of the connection between San Antonio Creek, groundwater in the OB, and the connection between San Antonio Creek and the Ventura River. Protests to the project were filed by several state and federal agencies, including the California Department of Fish and Wildlife (CDFW) and the National Marine Fisheries Service (NMFS). The protests by CDFW were based on concerns that diverting flow from San Antonio Creek would not leave adequate instream flow for fish passage downstream of the project in the lower reaches of San Antonio Creek and in the Ventura River. The protest letter states that "the effects of groundwater pumping on surface flow cannot be discounted," and it refers to the connection between San Antonio Creek to the Ventura River (CDFW, 2011, **Exhibit 73**). The letter documenting NMFS's protest states that "groundwater and surface water are not isolated phenomena occurring apart and distinct from each other, but are interconnected." Additionally, the letter states concerns over instream flow at the San Antonio Creek point of diversion (where San Antonio Creek enters the OB from the north) versus flow at the point of compliance (downstream, near the center of the OB). NMFS stated that based on available data, the rate of infiltration of surface water to groundwater is higher than what was estimated in the project proposal and that the actual loss of surface water to groundwater is estimated at 19-40% through infiltration (NMFS, 2011, **Exhibit 74**). The high rate of surface flow infiltration and deep percolation in the north and east portions of the OB where streams flow over highly permeable alluvial fan head sediments are a major component of recharge in the OB groundwater budget (DBS&A, 2011, **Exhibit 19**). The analysis of these historical documents provides evidence for a material connection between the OB and the Ventura River and its tributaries.

1.5.7 Vegetation and Groundwater Dependent Ecosystems

In determining interconnectivity, I evaluated existing data on groundwater dependent ecosystems in the OB and relied on work conducted by my colleague, Ms. Klug. Ms. Klug's CV is provided as **Exhibit 76.** Ms. Klug conducted field surveys at my direction to identify plant species along San Antonio Creek in the OB. I used the information provided by Ms. Klug to determine that potential GDEs that were identified along San Antonio Creek contain vegetation that depends on shallow groundwater within its root zone. Ms. Klug identified these species on the banks of San Antonio Creek, which is evidence of shallow groundwater present most of the time on the banks of the creek, which would be connected and contribute to surface flow within the creek.

Similar to the UVRB, a consultant for the OBGMA conducted a GDE assessment as part of the GSP process. The GDE assessment for the OB identified areas with potential GDEs, though work is still in progress to confirm GDE presence. The initial step in the GDE identification process is to identify wetland and riparian polygons in the OB from the Natural Communities Commonly Associated with Groundwater (NCCAG) Dataset (DWR, 2020, **Exhibit 75**). This is a spatial dataset compiled from 48 sources mapping vegetation, wetlands, springs and seeps in California that was developed for use with SGMA. The compilation was reviewed by DWR, CDFW, and The Nature Conservancy (TNC) to screen vegetation types that are less likely to be associated with groundwater, retaining only vegetation commonly associated with groundwater. Polygons along San Antonio Creek from approximately upstream of the Soule Park Golf Course to the OB discharge point to the southwest are classified as wetland features commonly associated with groundwater that are seasonally or semi-permanently flooded. The next steps in the OBGMA's GDE analysis were to examine site-specific groundwater level data, lithological data, satellite images and plant health data to determine if the potential GDEs are likely dependent on groundwater. In the draft GSP, there are twelve GDEs identified in the OB as "priority potential GDEs" that are likely impacted by groundwater extraction, the majority of which were located in and surrounding San Antonio Creek at the southwestern part of the basin. As opposed to the GDE assessment conducted by the UVRGA, the OBGMA GDE assessment is ongoing. The work will be finalized with forthcoming data collected by the OBGMA, including field surveys, though the results of the desktop analysis showing strong positive correlation between groundwater levels and vegetation health at locations in the basin along surface water features indicates that these riparian or wetland plants utilize groundwater (OBGMA, 2021, **Exhibit 56**).

I instructed Ms. Klug to conduct a field survey to identify the species present within the polygon identified by the OBGMA as a priority potential GDEs along San Antonio Creek. A map indicating the survey location is included as **Exhibit 77**, with the NCCAG polygons. Ms. Klug identified several species of plants in the San Antonio Creek streambed and along its banks that are classified as riparian or wetland species: mulefat (*Baccharis salicifolia*), red willow (*Salix laevigata*), arroyo willow (*Salix lasiolepis*), giant reed (*Arundo donax*), black cottonwood (*Populus trichocarpa*), and watercress (*Nasturtium officinale*). Photos of these species from the San Antonio Creek field survey are provided in **Exhibit 79**. Riparian and wetland species require surface water and/or groundwater within the rooting zone. Some species are more water dependent than others, either due to different rooting depths or due to drought tolerance. The species identified by Ms. Klug provide information on the persistence of shallow groundwater at this location on San Antonio Creek, which I then used to conclude the status of connection in this area of the OB.

The rooting depths of the species identified by Ms. Klug have been determined in previous studies. Gathering information on rooting depth allowed me to determine if these plants require that groundwater levels be sufficiently high so that the water table must be able to intersect the streambed. The maximum rooting depth of *B. salicifolia* is 1.97 ft. (TNC, 2020, **Exhibit 78**). Black cottonwoods have the majority of their roots within the upper 2 feet of soil (Rood et al., 2011, **Exhibit 144**), and the rooting depths for red willow are in the upper 3 feet of soil (Stover et al., 2018, **Exhibit 145**). Rooting depths have not been reported for arroyo willows, but studies indicate that this species is less drought-tolerant than red willows, more reliant on permanent groundwater and do not tolerate lowering groundwater tables (Williams, 1989, **Exhibit 80;** Warner and Hendrix 1984, **Exhibit 89**). The rooting depths of the species Ms. Klug identified are all shallow, indicating that there must be a consistently high water table that is close enough to the land surface where these plants are located on the stream banks so that it is capable of intersecting the streambed of San Antonio Creek. This intersection between the water table elevation and the streambed elevation shows connectivity between groundwater and surface water. One species that Ms. Klug identified within the San Antonio Creek channel, watercress, is an obligate wetland species. Obligate wetland plants are found in wetlands at least 99 percent of the time. A wetland is defined as an area that is "… inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." (Environmental Laboratory, 1978, **Exhibit 146**). The presence of watercress in San Antonio Creek confirms the perennial presence of surface flow at this location, this basin discharge point, even during the time of the survey, a late summer month during a very dry water year.

The presence of groundwater-dependent vegetation species with shallow root systems suggests that groundwater levels are sufficiently high to intersect the streambed, as the banks of San Antonio Creek are on the order of 5-8 feet high in this portion of the basin. This analysis of vegetation and GDEs provides evidence of the connection between groundwater and surface water on San Antonio Creek in the OB.

1.5.8 Groundwater Modeling Results

In determining interconnectivity, I used the groundwater model to perform analyses of streamflow depletion by well pumping and analyzed the results of previous modeling efforts by others. We used our groundwater model to simulate a scenario comparing modeled streamflow at the basin discharge point on San Antonio Creek with a): all well pumping turned off in the basin; and b): wells pumping the reported amounts during the calibration period. **Exhibit 81** shows the results of simulated streamflow at the streamflow data output location, at the point of basin discharge. These results are primarily useful for observing changes to the water budget when pumping is altered. The results show that when less water is taken out of the basin through well pumping, approximately 10 cfs more groundwater contributes to streamflow during dry months. These results are evidence of the connection between surface water and groundwater in the OB in relation to changes in the overall water budget.

DBS&A had previously developed a MODFLOW groundwater model of the Ojai Basin that includes ten layers representing the different aquifer units and aquitards within the basin (**Exhibit 19**). The modeling results show that under drought conditions, groundwater extraction from the production aquifers contributes to significant decreases of groundwater discharging to San Antonio Creek. This finding agrees with our modeling results using the groundwater flow model and supports the presence of a connection between groundwater and surface water in the basin. Additionally, these results of water budget modeling over the simulation period (1970-2009) show that groundwater discharge to streams comprises 33% of the total basin outflow components of the water budget, compared to 2% for groundwater outflow to bedrock, 4% for evapotranspiration, and 61% to pumping wells. The connection between groundwater and San Antonio Creek is a major component of the water budget, especially of the budgeted outflow of groundwater from the basin, second only to groundwater withdrawals from wells. In a model predictive scenario, when groundwater extractions were increased by 20 percent during the simulation period, the groundwater discharge to streams declined by 584 acre-feet/year, and when extraction was increased by 44 percent, discharge to streams declined by 1,093 acre-feet/year. This shows that groundwater and surface water are interconnected, and if one component decreases, such as groundwater in storage decreased by well extraction, the other (discharge to surface water) must decrease.

The SWRCB is developing a groundwater-surface water and nutrient transport model of the Watershed. The results of this modeling effort will be released in September, 2021. I intend to analyze this model and determine how, if it all, the modeling results affect my opinions.

1.5.9 Connection between all Aquifer Layers

In determining interconnectivity within the OB, I also looked at how all aquifer layers, including the alleged perched layer, are connected in the basin. The fine-grained deposits that separate the aquifer layers in the OB affect groundwater movement but do not prevent connectivity between layers. These aquitards, or geologic units that reduce the rate of water transfer, are composed primarily of clays and are up to ~100 ft. thick in some locations (DBS&A, 2011, **Exhibit 19**; DBS&A, 2020, **Exhibit 26**). The total volume of induced leakage through these units and the contribution of water from these units to pumped wells can be significant because of clay's ability to store water in its pore spaces (Kruseman and de Ridder, 1991, **Exhibit 62**). Induced leakage through aquitards is caused by creating vertical head gradients due to pumping wells that are screened in aquifer layers beneath the aquitard (Konikow and Neuzil, 2007, **Exhibit 63)**. The source of water going into the pumped well is not only water from the aquifer unit where it is screened (wells are typically closed conduits except at a certain depth(s) where well "screens," or perforations in the well casing, allow water to enter the well), but also over time from storage within the clay aquitard and from aquifer layers above the aquitard. This pumping-induced leakage can be thought of as suction across an aquitard that lowers the water table of the surficial aquifer layer above and impacts how much groundwater is available to contribute to interconnected surface water. A diagram showing the mechanism for this leakage is shown in **Exhibit 64**.

Another means for leakage across semi-confining layers is through abandoned or inactive wells in the basin. In the nearby Oxnard Plain groundwater basin within the Santa Clara River watershed, a similar hydrogeologic condition exists where a seasonally perched aquifer overlies the main production aquifer in the basin. Investigations into vertical flow between the semiperched aquifer and the upper aquifer system found that vertical leakage occurs through and around fine-grained units and well bores. Estimated flux through approximately 200 abandoned and/or inactive wells, calculated using intraborehole flow rate tests, could be as high as 4,220 acre-feet per year in the Oxnard Plan subbasin (Hanson et al., 2003, **Exhibit 28**; UWCD, 2018, **Exhibit 52**). Within the OB, at least 15 and possibly as many as 65 wells are abandoned or inactive as of 2015 (VCWPD, 2016, **Exhibit 65**). If these wells penetrate the aquitard beneath the alleged perched zone, vertical flow through these wells could be as high as 1,370 acre-feet per year in the OB. Active wells that are screened through the semi-confining units also likely serve as additional vertical conduits for groundwater movement (Kear, 2005, **Exhibit 59**) and increase the permeability of the clay layers.

Aquifer tests conducted in the OB also indicate that there is leakage across the semi-confining clay units in some locations. A leaky or semi-confined aquifer is one where when a well is pumped that is screened within the confined unit, the source of water to the well is from storage within the aquifer, storage within the aquitards, and from vertically adjacent aquifers (Kruseman and de Ridder, 1991, **Exhibit 62**). Kear (2005, **Exhibit 59**) conducted and analyzed several aquifer tests in the OB and evaluated two previously conducted aquifer tests. Of these tests, one was conducted adjacent to San Antonio Creek at the approximate northern boundary of the alleged perched zone. Analysis of the aquifer test results by type-curve matching indicates that the drawdown observed at the location of pumping was best fit by a solution that contains a leakage term to account for groundwater leaking vertically from the confining unit and overlying aquifer. These results shows that there are locations at the edge of the alleged perched zone, where full confinement would not be expected to completely isolate this zone from the rest of the basin, where the clay aquitard units are not continuous, or allow leakage when water is extracted from aquifer units below. Further, the calculated storativity values, or the volume of water released from storage for a given area of aquifer and decline in hydraulic head, are on the order of 0.001 for this aquifer test location and another test within the surficial aquifer zone. Typical storativity values of confined aquifers range from 0.00001 to 0.001, with higher values indicating lower degrees of confinement (Heath, 1983, **Exhibit 27**). Therefore, groundwater held in the lower aquifer layers of the OB are likely semi-confined, and interacts with other aquifer layers and surface water. Extracting water from wells in the lower aquifer layers of the OB also causes a lowering of the surficial aquifer water table and subsequent depletion of streamflow in San Antonio Creek. The timing of depletion is impacted by the structure of the semi-confining units and rates of leakage through these units (Barlow and Leake, 2012, **Exhibit 14**).

Diagrams that illustrate the stratigraphy in the OB, or cross-sections, provide insight into the vertical association of aquifer units in the OB. Several cross-sections have been developed that bisect the basin at different orientations (Kear, 2005, **Exhibit 59**; DBS&A, 2011, **Exhibit 19**; OBGMA, 2018, **Exhibit 55**). These are developed by correlating geologic information from geophysical logs and/or borehole drilling logs from wells that form an approximate line across a given area. The resulting diagram provides a view of an aquifer as if a straight vertical slice was made through it along a given axis, though these depictions can vary depending on which borehole logs are included and the level of geologic interpretation needed to correlate between discrete data points. In **Exhibit 66,** a cross-section drawn from approximately southwest to northeast across the OB shows a clay unit that is continuous across the basin at the surface, which was developed by Kear (2005). We developed an additional cross-section that bisects the basin in approximately the same location using the stratigraphy identified in Kear's cross section with supplemental data from three well logs. These well drilling logs are publicly available data that is recorded by the well driller. The three additional logs are shown in **Exhibit 67** (DWR, 2021b). When constructing the cross-section, I conservatively interpreted the logs by assuming that any unit described as partially containing clay (i.e. "clay and silt," "sandy clay," or "clay and gravel") is an aquitard. The resulting cross-section shows that, at least at some locations, the clay unit that acts as an aquitard beneath the surficial aquifer layer is not continuous across the basin. It also shows that the clay that crops out at the surface near the northern extent of the surficial aquifer layer is not continuous in the location of the cross section, allowing hydraulic communication between the surficial aquifer layer and deeper aquifer layers.

Geologic maps of the OB delineate a thin strip of Quaternary stream gravels underlying San Antonio Creek as it crosses the basin. One of these maps is included in **Exhibit 68** (Tan and Irvine, 2005). This mapping agrees with reports of the high infiltration rates of water into San Antonio Creek across the central portion of the basin, and the tendency of the middle section of the creek to lose surface water to groundwater during higher flow periods and to go dry during dry periods. The creek channel crosses the northern boundary of the surficial aquifer layer, where there would need to be continuous clay at the surface along this entire boundary to separate the surficial aquifer layer from the deeper aquifer layers. The presence of high permeability stream gravels at the location where San Antonio Creek pierces this supposed boundary shows that in this location, groundwater within the surficial aquifer zone has the opportunity to communicate with other aquifer units in the OB.

Further evidence for the lack of complete separation of aquifer layers in the OB is provided by the aquifer properties assigned in the Ojai Basin Groundwater Model completed by DBS&A in 2011 (**Exhibit 19**). This model simulates the OB as a ten-layer aquifer with alternating aquifer units and semi-confining units. Each unit was assigned a hydraulic conductivity (K) value based on aquifer tests previously conducted in the basin and calibration of the groundwater model simulated heads to observed heads. The calibrated K values of the layers representing the semi-confining units are 0.1 ft./day, compared to 1 ft./day for the layers representing alluvial material that makes up the aquifer layers in the southwestern and central portions of the basin. This difference of only one order of magnitude suggests that these confining units are not impermeable but are only slightly less permeable compared to the alluvial aquifer layers. Because hydraulic conductivity is heterogeneous throughout an actual geologic unit, it is also likely that the relatively similar K values in the calibrated model reflect the presence of different grain sizes within the primarily clay aquitard units.

1.5.10 Conclusions

Based on the evaluations above, it is my opinion that the boundaries of the OB are correctly defined in Bulletin 118, groundwater and surface water are materially connected within the basin, and the basin is connected to the Ventura River through its tributary, San Antonio Creek.

1.6 UPPER OJAI GROUNDWATER BASIN

It is my opinion that the boundaries of the Upper Ojai Valley Groundwater Basin (UOB) are correctly defined by Bulletin 118, and that the basin is materially connected to the Ventura River via its tributary, Lion Canyon Creek. In reaching these opinions for this basin, I did the following: a) independently confirmed the boundaries of the basin as defined by Bulletin 118 using existing geologic and hydrogeologic studies; b) evaluated long-term records of groundwater levels; c) conducted an analysis of the anthropogenic groundwater and surface water connection; d) studied the vegetation in and around Lion Canyon Creek (also performed by Ms. Klug); and e) performed groundwater modeling simulations. Each of these are discussed in greater detail herein.

1.6.1 Basin Boundaries as Defined by Bulletin 118

The UOB is an unconfined alluvial aquifer located south of the Ojai Basin (**Exhibit 8**). It is designated as a low priority basin under SGMA. The basin is bound by the Topatopa Mountains to the east, Sulfur Mountains to the south, and the Santa Ynez Mountain range to the north and west. The UOB is separated from the Ojai Basin by a topographic ridge (Lion Mountain Ridge) and the San Cayetano fault. Groundwater is held within Pleistocene and Holocene-age alluvium that is bounded by Tertiary aged (geologically older) bedrock units. It is my opinion that these boundaries as defined by Bulletin 118 are correct. Lion Canyon Creek, the main surface water feature in the UOB, flows from east to west across the basin. DWR Bulletin 118 states that the basin is "drained westward by Lion Canyon into San Antonio Creek" (DWR, 2003, **Exhibit 82**).

1.6.2 Geologic and Hydrogeologic Structure

In determining the basin boundaries, I evaluated existing geologic and hydrogeologic data related to the basin to independently confirm the basin boundaries as defined by Bulletin 118. The UOB is contained on all sides by relatively impermeable bedrock. It is underlain primarily by the Sespe formation, a sandstone unit of Oligocene age, with Monterey and Pico formations bordering the basin to the south. These bedrocks units, as described previously, have minimal capacity to store and/or transmit groundwater. Fractures within the bedrock in the vicinity of the UOB, however, allow for minor groundwater storage. Lion Canyon Creek flows through the alluvium within the basin, drains the basin at its western edge, and then flows down-canyon across bedrock for approximately two miles until it combines with San Antonio Creek, ~3.75 miles upstream from its confluence with the Ventura River.

There is a topographic high that bisects the eastern part of the UOB, creating a divide for both surface water and groundwater, as stated in Bulletin 118 and as defined by the WBD. The location of the divide in relation to the groundwater basin is shown on the map in **Exhibit 8,** with arrows to indicate the general surface water flow direction in **Exhibit 8b**, and in **Exhibit 83** with the active wells located in the UOB. The groundwater divide, however, is less well-defined. All surface water to the west of this divide is within the Ventura River Watershed and drains to the west from the basin through Lion Canyon Creek, while surface water to the east of this divide drains into Santa Paula Creek and is within the Santa Clara River Watershed. Available data on the alluvium bottom elevations suggest that there is also a ridge in the Monterey Formation that underlies the alluvial aquifer approximately at the location of the surface water divide, causing a separation in the predominant groundwater flow direction. Groundwater contained in the aquifer to the west of this divide generally flows to the west, while groundwater to the east generally flows to the east. The groundwater divide line of demarcation is not a clear line because there is a continuous reservoir of groundwater within the alluvium of the UOB. The alluvium, or unconsolidated sediment that makes up the UOB aquifer, is composed of sand, silt, clay, and gravel (DBS&A, 2020). These materials have high hydraulic conductivity relative to consolidated deposits, allowing groundwater flow within the pore spaces. For this reason, groundwater pumping anywhere within the basin can have a significant impact on the head gradient (the direction of groundwater movement). Groundwater pumping at any well within the UOB can cause a decline in the water table of the entire groundwater basin. Wells that are located outside of the Watershed but within the UOB, therefore, can impact the groundwater in the basin, the interconnected surface flow to Lion Canyon Creek, and flow in the Ventura River.

The geologic structure of the UOB dictates the direction of groundwater movement. The basin slopes downward toward the west, so groundwater moves from point of recharge within the basin generally westward, to points of discharge, or in this case, Lion Canyon Creek. The main recharge sources in the UOB are infiltration from direct precipitation, infiltration of surface water from streams and creeks, and infiltration from agricultural irrigation. Movement of groundwater within the basin, from areas of higher head to lower head, cases the westward trending flow. When groundwater levels are high, discharge occurs at the western end to Lion Canyon Creek. The structure of the basin is the foundation of this groundwater-surface water connection: groundwater does not remain in place like water in a bowl in the UOB because of the slope of the bedrock-alluvium contact. Groundwater cannot "pile up" at one end when levels are high, and must discharge at the surface, in this case, to surface flow in Lion Canyon Creek.

1.6.3 Groundwater Level Analysis

In determining connectivity in the UOB, I analyzed long-term records of groundwater levels that are recorded by monitoring wells within the basin. These wells show that groundwater levels in the basin fluctuate through a range of approximately 20 feet depending on water year type, season, and location within the basin. The long-term records from two of these wells, state well numbers 04N22W09Q002S and 04N22W10K002S located adjacent to Lion Canyon Creek, show that during wet or very wet water years, groundwater levels are regularly within three- five feet of the ground surface (DWR, 2021a, **Exhibit 93**; **Exhibit 84**). This high water table at locations within approximately 200 feet of Lion Canyon Creek or its tributaries indicates that streams exhibited gaining conditions (groundwater contributing to streamflow) during these periods, because water level elevations were higher than the elevation of the streambed (**Exhibit 85).**

1.6.4 Anthropogenic Groundwater – Surface Water Connections

In determining interconnectivity, I looked at the anthropogenic connection between groundwater and surface water in the basin. The UOB receives supplemental water from CMWD. Several storage tanks within the basin are connected to the main distribution system via pipeline, where this water is used as either the main water source or the back-up source to water purveyors. The water supplied by CMWD is primarily sourced from Lake Casitas, which is filled in large part by water diverted from the Ventura River through the Robles Diversion. The CMWD water in the UOB is used by residential and agricultural customers, where water applied as irrigation is either removed through evapotranspiration or infiltrates into the ground as recharge. Between 2015 and 2020, the total CMWD deliveries to the UOB were approximately 50-300 acre-feet/year, with delivery amounts varying depending on water year conditions (SWRCB, 2021b, **Exhibit 42**). Estimated return flow of irrigated water in the UVRB is approximately 20 percent of applied irrigation (Intera, 2021, **Exhibit 41**), so up to 60 acre-feet of water delivered by CMWD could be recharged to the UOB annually.

1.6.5 Vegetation and Groundwater Dependent Ecosystems

In determining interconnectivity, I evaluated the available information on GDEs in the UOB and relied on a field survey conducted by my colleague, Ms. Klug. Similar to her analysis in the OB, Ms. Klug performed a field survey where she identified vegetation types along Lion Canyon Creek. I directed Ms. Klug to survey along Lion Canyon Creek where it flows through the western portion of the basin to provide me with information that could inform my determination of connectivity between surface water and groundwater in the UOB. The location of her survey and the locations of the NCCAG vegetation dataset polygons (TNC, 2020) are shown in **Exhibit 148**. She identified several riparian and wetland species along the banks of the stream and in the streambed (photos are provided in **Exhibit 86**). Where Lion Canyon Creek flows through the western portion of the UOB, the vegetation community present in and adjacent to the streambed is primarily comprised of willows, including arroyo willow (*Salix lasiolepis*) and red willow (*Salix laevigata*). Rooting depths for red willow are in the upper 3 feet of soil (Stover et al., 2018, **Exhibit 145**). Rooting depths have not been reported for arroyo willows, but studies indicate that this species is less drought-tolerant than red willows, more reliant on permanent groundwater and do not tolerate lowering groundwater tables (Williams, 1989, **Exhibit 80;** Warner and Hendrix 1984, **Exhibit 89**). Ms. Klug also identified stinging nettle (*Urtica dioica*) within the streambed. Stinging nettle is rated as a facultative wetland species (USACE, 2018, **Exhibit 143**), and arroyo willows are classified as an obligate wetland indicator species. Obligate wetland species almost always (99% probability) occur in wetlands and requires a high groundwater table, and facultative wetland plant species occur in wetlands between 33 and 66 percent of the time. Based on the definition of a wetland, "…areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (Environmental Laboratory, 1987, **Exhibit 146**), the presence of these species in and surrounding Lion Canyon Creek suggests that groundwater levels are high enough near the creek to support these species. Additionally, this survey was conducted during an extremely dry period when surface flow was not present. It is likely that in average or wet conditions when there is surface flow in Lion Canyon Creek, groundwater levels are also sufficiently high to support this surface flow. This survey and my evaluation of groundwater dependent vegetation confirms that there is a connection between groundwater and surface water in the UOB.

1.6.6 Groundwater Modeling Results

In determining interconnectivity in the UOB, I performed simulations using our groundwater model. The model simulates surface water flow in Lion Canyon Creek and its tributaries. I studied the interaction between Lion Canyon Creek and groundwater in the UOB in the groundwater model by running two model scenarios: a) all model wells are pumping at historical rates, and b) all model wells are "turned off" for the simulation period (calibration period, water years 2004-2006). I then compared the model simulated streamflow at a data output location at the point where Lion Canyon Creek exits the basin (location shown on map in **Exhibit 46**). The resulting streamflow changes, or streamflow depletion attributable to well pumping, are shown in the graph in **Exhibit 90**. The magnitude of streamflow depletion simulated by the model is lower than in the other groundwater basins because there is less groundwater extraction within this basin. **Exhibit 101** shows a map of active wells in the four groundwater basins, and compared to the OB, the UOB has 83 total wells, one of which is a public water supply well, while the OB has 164 active wells, 8 of which are public supply wells. Further, the UOB has 299 irrigated acres versus 1,899 acres in the OB. Another reason why the magnitude of streamflow depletion is lower in the UOB is because flow in Lion Canyon Creek is low compared to the Ventura River and San Antonio Creek. Lion Canyon Creek drains a smaller area than the other surface water features discussed in this report. The proportion of streamflow that is depleted by groundwater pumping in the UOB is significant, however, particularly in dry months (i.e. 1.5 cfs without pumping versus 1 cfs with pumping during August 2004 is a 67% reduction). These results confirm material connectivity between groundwater and surface water in the UOB, because lowered groundwater levels through pumping result in decreased basin outflow through surface water.

The SWRCB is developing a groundwater-surface water and nutrient transport model of the Watershed. The results of this modeling effort will be released in September, 2021. I intend to analyze this model and determine how, if it all, the modeling results affect my opinions.

1.6.7 Conclusions

Based on the evaluations above, it is my opinion that the boundaries of the UOB are correctly defined in Bulletin 118 and that groundwater and surface water are materially connected within the basin and the basin is connected to the Ventura River through its tributary, Lion Canyon Creek.

Submitted by:

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Claire Archer, PhD

August 31, 2021

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EXHIBIT B

EXHIBIT B

Ventura River Watershed Groundwater – Surface Water Model Report

August 30, 2021

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1 Introduction

1.1 Purpose and Scope

The Ventura River Watershed (Watershed), located in southern California, is a region with large demands on its limited water resources. We developed a regional groundwater – surface water flow model to provide a tool to understand the connection between groundwater and surface water within the Upper Ventura River Valley, Lower Ventura River Valley, Ojai Valley, and Upper Ojai Valley Groundwater Basins (the study area, **Figure 1**) as delineated by the California Department of Water Resources (CA DWR) Bulletin 118. This report will discuss the model development and results in relation to this objective.

1.2 Approach

The model will be used to improve understanding of the groundwater system, the interconnectivity between groundwater and surface water, and the inputs and outputs to the water budget. Modeling in relation to other objectives will be described in a separate report(s).

1.3 Description of the Study Area

1.3.1 Topography and Climate

The Watershed is located in Ventura and Santa Barbara Counties, California (**Figure 1).** It encompasses approximately 226 square miles, extending from the high-relief headwaters with elevations above 6,000 feet to sea level at the mouth of the Ventura River at the Pacific Ocean. The Watershed is characterized by steep terrain consisting of mountains and narrow canyons surrounding relatively lower relief alluvial basins that comprise the four groundwater basins. In general, the elevation of the basins decreases from north to south, to outlet points where a surface water feature drains each basin. The Ventura River flows from north to south through the Upper and Lower Ventura Basins and has a relatively steep gradient due to high relief and active tectonic uplift in the Watershed.

The Watershed exhibits a Mediterranean climate, with cool, wet winters and warm, dry summers. The climate of the Watershed is characterized by episodic precipitation, with large variability in total precipitation from year to year as well as within each year. Typically, the majority of precipitation falls between January and April.

1.3.2 Geologic Setting

The Watershed is tectonically active and structurally complex. It is located within the Transverse Ranges of Southern California, where high rates of tectonic uplift create canyons parallel to the ridges. The Ventura River crosses a number of major east-west trending fault and fold systems including the Santa Ynez fault, the Mission Ridge fault system, and the Red Mountain fault (Tan and Jones, 2006, **Exhibit 102**). A portion of the Watershed lies within the Ventura Fold Belt, an area that has experienced uplift rates in the past as high as approximately 1 cm/yr. (Lajoie *et al,* 1979, **Exhibit 103**). More recently, estimates of the dip-slip rate of the Ventura fault are up to 3.1 mm/yr. (Marshall *et al.,* 2013, **Exhibit 104**).

Throughout the Watershed, bedrock is composed almost entirely of sedimentary rock, primarily marine sandstones and shales, ranging in age from the older Upper Cretaceous strata near the headwaters to the younger (Pleistocene) formations near the Pacific Ocean. Bedrock is overlain by Pleistocene and Holocene alluvium in the valleys and floodplains. Generally, this alluvium is thin, ranging from 0 to 100 ft. in thickness, although in the Ojai Valley alluvium can be up to 700 ft. thick. The geology of the study area is shown in **Figure 2**.

1.3.3 Hydrogeologic and Hydrologic Setting

There are four groundwater basins (Basins) within the Watershed designated by the California State Water Resources Control Board in Bulletin 118 (DWR, 2016, **Exhibit 9**), which are the Upper Ventura River Valley, Lower Ventura River Valley, Ojai Valley, and Upper Ojai Valley Groundwater Basins. The

Basins are alluvial fill aquifers that occupy the valley floors, floodplains, and alluvial terraces within the Watershed. These aquifers are bounded by relatively impermeable bedrock on all sides and below, with the exception of the Lower Ventura River groundwater basin which is bounded to the south by the Pacific Ocean. In some locations, faults act as barriers to groundwater flow.

Surface water flows fluctuate substantially within each year and from year to year depending on precipitation amount and timing, as is typical for coastal southern California. Many streams and tributaries to the Ventura River are ephemeral, with surface flow only occurring during wet conditions and/or after storm events. Surface flows infiltrate rapidly to recharge groundwater as these features flow across the Basins. Groundwater and surface water are interconnected within the Basins where surface flows contribute to groundwater, and where groundwater contributes to surface water. The amount and timing of these contributions vary depending on season and water year conditions. The other primary mechanisms for groundwater recharge are through direct precipitation at the valley floors, irrigation return flows, and mountain-front recharge. Discharges from groundwater other than contributions to surface flow include evapotranspiration and well pumping.

1.3.4 Land Use

The primary land use in the Watershed is U.S. National Forest land, followed in order of area by open space, agricultural or rural, and urban or industrial (SCAG, 2019, **Exhibit 105**). The primary agricultural land uses in the Watershed are orchards, row crops, and livestock grazing. Urban areas and developed land in the Watershed are concentrated on the valley floors and floodplains and consist of the City of Ojai, the western portion of the City of Ventura, and the communities of Meiners Oaks, Mira Monte, Oak View, Live Oak Acres, and Casitas Springs.

1.3.5 Water Use

All water for municipal, agricultural, industrial, and domestic use within the Watershed is sourced from the Watershed itself through wells or surface water intakes. Therefore, water supply is limited by the amount of precipitation that falls within the Watershed.

1.3.5.1 Domestic Supply

Domestic water supply in the Watershed is provided by either municipal water companies or private wells. Private wells within the Basins that are used for domestic water supply were identified using the Ventura Watershed Well Inventory database (VCWPD, 2018, **Exhibit 135**).

1.3.5.2 Municipal Supply

There are five major water purveyors in the Watershed: Casitas Municipal Water District (CMWD), Ventura Water (City), Golden State Water Company (now Ojai Water System), Meiners Oaks Water District, and Ventura River Water District. Several minor mutual water companies (MWCs) also exist in the Watershed, including Hermitage MWC, Gridley Road Water Group, North Fork Springs MWC, Old Creek Rd. MWC, Rancho Matilija MWC, Rancho del Cielo MWC, Senior Canyon MWC, Siete Robles MWC, Sisar MWC and Tico MWC. CMWD is the Watershed's largest water purveyor and operates Lake Casitas, a reservoir which receives natural surface water inflow as well as diversions from the Ventura River. CMWD also operates well fields in the Ojai basin and the Upper Ventura River Basin.

1.3.5.3 Irrigation

Water used to irrigate crops within the Basins is sourced from groundwater extracted from wells or as surface water delivered by CMWD. There is one surface water diversion on the Ventura River within the Upper Ventura River Groundwater Basin that is used for crop irrigation. The primary crops grown in the Basins are citrus and avocado groves, with minor olive groves, pastures, walnut groves, and miscellaneous row crops **(Figure 3**). Model Development

We developed two models to simulate groundwater and surface water in the Watershed. The primary model is a groundwater - surface water interaction model developed using the computer code MODFLOW. MODFLOW is an international industry standard for groundwater flow models. It is an open-source computer program that was developed by the U.S. Geological Survey (USGS) and is continually updated, with several versions available that are specific to different modeling applications (Harbaugh *et al.,* 2005, **Exhibit 107**). The MODFLOW model we developed, referred to herein as the groundwater flow model (GFM), simulates groundwater and surface water within the four groundwater basins in the Watershed.

The second model, developed using the Precipitation Runoff Modeling System (PRMS; Markstrom *et al.* 2015, **Exhibit 106**) computer code, simulates the quantity and timing of surface water flow into the four basins from the areas of the Watershed that do not lie within a groundwater basin. PRMS is also developed and maintained by the USGS and is a watershed-scale hydrologic model. We developed the PRMS model in addition to the GFM to account for all of the water within the Watershed, particularly the flows at un-gaged tributary streams into the four groundwater basins, or into the GFM.

2 Model Development

2.1 Model Selection

Within the core MODFLOW program there are several codes that can be selected to model a specific groundwater and/or surface water system. The particular aspects of a groundwater system are simulated by these codes using a combination of independent modular components that represent different parts of the groundwater budget, called "packages"**.** Each MODFLOW code is compatible with a specific set of packages. We selected the code MODFLOW One-Water Hydrologic Flow Model (MODFLOW-OWHM; Hanson *et al*., 2014a, **Exhibit 107**), because it is compatible with all of the packages needed to simulate all the hydrologic elements of the Watershed and its inclusion of the Farm Process (FMP; Schmid and Hanson, 2009, **Exhibit 108**). We utilized FMP, a package that simulates water use and movement through irrigated land, because the majority of agricultural water use in the watershed is unmetered and must be modeled or estimated instead of through direct input. This and the other packages used in the GFM are discussed in greater detail in **Section 2.3.** We used the ModelMuse graphical user interface (GUI) (Winston, 2019, **Exhibit 111**) for this modeling effort. A GUI is a way to input, analyze, and interact with the model data visually.

There are several solver packages available with MODFLOW that are used to solve the groundwater flow equations during a model "run," or execution. These solver packages employ different computational strategies to solve these complex equations, and though all are technically valid ways to solve the equations, some have advantages over others depending on the modeling application. Selection of the solver for a particular model plays a critical role in model convergence and solution robustness. Convergence is when the MODFLOW solver arrives at a solution, and because of the complexity of groundwater flow equations, non-convergence can be common in some settings. We selected the preconditioned conjugate gradient solver with improved nonlinear control (PCGN2; Naff and Banta, 2008, **Exhibit 110**) to solve the three-dimensional, nonlinear groundwater flow equation for the GFM. The GFM solution is nonlinear because parameters of model inputs are dependent on groundwater levels, or dependent on the solution. This solver provides improved convergence options for nonlinear models that include complex boundary conditions (model inputs representing different aspects of the groundwater budget) and models that exhibit cell dewatering, or cells that go dry during a simulation. The default solver settings within ModelMuse were used with the exception of closure criterion, with nonlinear settings of enhanced damping and convergence. The flux-based closure criterion was set to 10,000 ft^3/day and the head (groundwater level) closure criterion was set to 0.1 ft. These closure criteria are the conditions that must be met in order for the model to converge on a final solution.

We activated the cell re-wetting capability for the GFM. This option allows for a cell to go from dry, or inactive, to active within the simulation if designated criteria for the heads (groundwater levels) in neighboring cells are met. We activated it because areas on the edges of the groundwater basins where topography is relatively steep and the aquifer is thin do not store significant groundwater during dry months/ water years. We wanted to ensure that these areas could become re-saturated following dry periods, and cell-rewetting provides this function. The wetting criteria, designated using the wetting threshold and wetting factor, were set to 0.2 and 0.3 ft., respectively.

2.2 Model Discretization

Two aspects of the model must be discretized, or divided into parts: the physical area and the modeled time period. Spatial model discretization is the process of dividing up the model domain (the study area) into a three-dimensional grid, with cells that are discrete elements where all input data is the same. The domain is divided into cells so that the groundwater flow equations can be solved between each three-dimensional cell face. The GFM domain includes the alluvial aquifers of the Upper Ventura, Lower Ventura, Ojai, and Upper Ojai Groundwater Basins as delineated by Bulletin 118 and shown on **Figure 1.** The model grid used to represent the aquifers consists of a series of square model cells. Temporal discretization is the separation of the modeled time period into equal stress periods, or lengths of time when all model inputs are the same. The details of spatial and temporal discretization are discussed below.

2.2.1 Spatial Discretization

The total modeled area (**Figure 4)** is 32.2 mi^2 on a finite-difference grid consisting of a single layer of 385 rows and 315 columns, and a total of 22,419 active model cells. The model has a uniform horizontal discretization of 40,000 ft^2 per cell (200 ft. by 200 ft.) and is oriented parallel to the cardinal directions (i.e., north-south and east-west). The edges of the model area correspond to the designated limits of the alluvial groundwater basins as most-recently delineated by Bulletin 118 (DWR, 2016).

The top of the model is represented by land surface elevation (**Figure 5).** The bottom of the model is represented by the base of alluvial deposits/top of bedrock as presented in several regional hydrogeologic studies. For the Upper Ventura Groundwater Basin, we used the following data sources: Fugro West, Inc. (2002, **Exhibit 100**); Kear (2016a, **Exhibit 112**; 2016b, **Exhibit 113**); Turner (1971, **Exhibit 109**); and Entrix (2001, **Exhibit 16**). We compared the interpolated alluvium-bedrock contact structural contours developed from these data sources to contours presented in DBS&A (2020, **Exhibit 26**) prepared for a four-basin groundwater model concurrently being developed for the California State Water Resources Control Board (SWRCB) and found the contours to be in agreement. In the wider northeastern section of the Upper Ventura Groundwater Basin, we incorporated several additional data points from DBS&A (2020) into the Upper Ventura section of the GFM. For the Lower Ventura, Ojai, and Upper Ojai Groundwater Basins, we used alluvium-bedrock structural contours as presented in DBS&A (2020) and as provided by the SWRCB to set the bottom of the model. Model aquifer bottom contours are presented in **Figure 6,** and the modeled aquifer thickness is presented **in Figure 7.**

2.2.2 Model Calibration Period, Validation Period, and Temporal Discretization

A model calibration period is the period of time where past conditions are simulated by the model, and the model inputs are adjusted until a strong match between model-simulated and observed (i.e., real field-measured) surface water flows and groundwater elevations (heads) is achieved. The model is thereby calibrated to be accurate in recreating real-world hydrologic conditions. We selected a calibration period with the goal of including water years that represent a range of hydrologic conditions and that have adequate surface water gaging, groundwater level monitoring, and water use data. We selected the calibration period of three water years: 2004, 2005, and 2006 (a water year begins on October 1 of the previous year and ends on September 30). The annual precipitation for these water years is shown in **Table 1**, using data from the rainfall station in the Watershed with the longest period of record, Ventura County Watershed Protection District (VCWPD) Station 066 (Ventura Downtown). We included a warm-up year (water year 2003) in the simulation to improve the accuracy of model results during the calibration period by providing a realistic starting point for conditions during water year 2004.

Model validation is the process of simulating a period of time in the past other than the calibration period to determine the model goodness-of-fit for the conditions during the validation period. It is an independent check on the accuracy of the model itself and the model calibration. We selected a model validation period that included a range of water year types and hydrologic conditions that were different from those of the calibration period. We selected water years 2011, 2012 and 2013 because adequate input data was available and because this period had similar land use as the calibration period. We also chose this period because we wanted to assess model performance during a portion of the recent drought period, which began in 2012.

The model was designed to simulate changes in groundwater flow and storage based on temporal changes in inputs and outputs to the groundwater system, so the model was run as a transient simulation. MODFLOW has the options to be run either in steady-state or transient modes. In steady-state, model input values do not change during the simulation. We wanted to simulate how groundwater-surface water interactions change based on different hydrologic, climatic, and anthropogenic conditions, so we used a transient simulation. The modeled period was discretized into stress periods, or periods of time when all model stresses remain constant, of one-month duration each. All model input datasets were determined on a monthly basis to correspond to the monthly stress period.

2.3 Boundary Conditions and Aquifer Hydraulic Properties

2.3.1 Boundary Conditions and Initial Conditions

MODFLOW boundary conditions are locations in the model where water flows into or out of the groundwater system due to external factors. All boundary conditions are applied using different MODFLOW packages. The boundary conditions simulated in the GFM are well withdrawals using the multi-node well (MNW2) package, streamflow and surface flow interaction with groundwater using the streamflow routing (SFR) package, mountain-front recharge, represented using the WEL package, precipitation as part of the FMP, evapotranspiration and irrigation return flow through the FMP, and groundwater interaction with the Pacific Ocean and groundwater flow across the watershed divide in the Upper Ojai Basin using the General Head Boundary (GHB) package. Details of each of these packages are discussed within this section.

Unless a different boundary condition is specified, all edges of the grid are considered no-flow boundaries, or areas where no water enters or exits the model. All external edges and the base of the groundwater basins are no-flow boundaries with the exception of the boundary between the Lower Ventura Basin and the Pacific Ocean and the watershed divide within the Upper Ojai Basin. The locations of the GHBs are shown in in **Figure 8.** The GHB package functions as a cell or set of cells where head (groundwater level) is specified but allowed to vary depending on the head in cells adjacent to the boundary through a conductance term. The conductance term defines how readily head can change across the barrier, and we adjusted this term during calibration.

We simulated the subsurface dam that extends from west to east across part of the floodplain in the Upper Ventura River basin near Foster Park using the Horizontal Flow Barrier (HFB) package. The HFB package is a boundary condition where horizontal hydraulic conductivity can, for a specified area and thickness, differ from the cells in between which the barrier is located. Hydraulic conductivity (referred to as K) is a measure of how easily water can pass through a material. We positioned the subsurface dam in the model based on descriptions and diagrams from Fugro (2002). We assigned a horizontal hydraulic conductivity of 10^{-4} ft./day to the barrier based on literature values for the hydraulic conductivity of concrete. The location of the barrier within the model domain is shown in **Figure 8.**

The initial conditions for the model simulation are defined by the head values, or the starting water levels, during the first stress period (October 2002; beginning of water year 2003). We assigned the initial head value at each cell using an iterative process, as water level observations for this month are only available for a small number of model cells (see **Figure 9**, monitoring well locations). Simple interpolation of these heads would result in a skewed distribution with unrealistic heads in areas without sufficient coverage of water level observation data. Instead, we first set the initial head at two-thirds of the alluvium thickness and ran the model for a period of 12 months and then used the resulting heads as the initial head values for the next simulation. We repeated this iterative process until the heads at cells containing monitoring wells most closely matched the observed values. We used the same process to assign initial heads for the first stress period of the model validation period (October 2009; beginning of water year 2010).

2.3.2 Aquifer Hydraulic Properties

The ability of the aquifers in the GFM to store, transmit, and release water is dictated by their hydraulic properties. These properties depend on the aquifer's geologic material (lithology) and how this material was deposited. The rate that groundwater can move through pore spaces in aquifer material is defined by the hydraulic conductivity (K) of the material that it is flowing through. K values can be assigned for each of the three dimensions of flow (K_x, K_y, K_z). The amount of water that can be released from or accumulate as aquifer storage (groundwater held within the aquifer) when there is a change in head is given by the specific yield (S_y) and specific storage (S_s). Together, these properties govern groundwater movement between the model cells. We simulated internal flow in the GFM using the Layer-Property Flow (LPF) package in MODFLOW. This package allows aquifers to be designated as either confined or convertible and applies hydraulic properties either uniformly or as zones with constant values. We simulated aquifers in the GFM as a single convertible layer because the majority of the aquifers of the four groundwater basins are unconfined (an aquifer whose upper surface is able to rise and fall, or is not confined by a less permeable geologic layer). Zones were delineated for K_x based on aquifer geologic data and for S_y based on generalized geologic data, with one zone per basin except in the Upper Ventura and Ojai basins, where portions of these basins contain deeper, older alluvium deposits that we expected to have lower specific yield values than the younger alluvium (see **Figures 10 and 11**, K and S_y zones).

The shallow alluvial aquifers simulated in the GFM are all unconfined. In the Ojai basin, semi-confined conditions exist in the west, southwest, and central parts of the basin (Kear, 2005, **Exhibit 59**; DBS&A, 2011, **Exhibit 60**). Because of the localized nature of the semi-confined conditions and the intended purpose of this model as a tool for regional simulations, we simulated the Ojai basin as a single convertible layer.

We used literature sources to constrain the values of aquifer hydraulic parameters (K_x, K_z, S_y) and then further refined these parameters during calibration. In addition, we used values from aquifer tests (Fugro West, 2002, **Exhibit 100**; Hopkins, 2007, **Exhibit 118**; Kear, 2005; Turner, 1971, **Exhibit 109**) and previous modeling efforts (DBS&A, 2011) to assign initial hydraulic property values. Test-derived ranges for K of alluvium (unconsolidated sand, silt, and gravel) are between 0.1 and 1,000 ft/day (Freeze and Cherry, 1979; DWR, 2003). Local values estimated from transmissivity values derived from aquifer tests are 62 ft./day in the east Ojai Basin, 5 to 70 ft./day in the central and southeast Ojai Basin (Kear, 2005), and approximately 300 to 2,000 ft./day for the alluvium near Foster Park (Hopkins, 2007). Values from other regional models include the 2011 Ojai Basin groundwater model that used K values of 7 to 45 ft/day and the 2010 Groundwater Budget analysis that estimated a Lower Ventura Basin K of up to approximately 300 ft./day (Fugro, 2004, **Exhibit 49**). There is often significant spatial heterogeneity in alluvial aquifer K values depending on the distribution of fine-grained material and degree of sorting. Additionally, hydraulic parameter estimates based on aquifer test results often do not match calibrated model values. The scale of aquifer tests versus regional groundwater models can cause large differences, as do errors associated with the aquifer tests themselves.

We estimated specific yield values initially using a combination of values from literature and the results of aquifer tests. The upper bound for the Upper and Lower Ventura groundwater basins was informed by values for gravelly to coarse sands, with S_y typically between 0.18 and 0.35 (Johnson, 1966, **Exhibit 114**; DWR, 2003). S_y estimates from aquifer test analyses in the southeastern and central Ojai Basin range from 0.024 to 0.1 (Kear, 2005; Turner, 1971). We adjusted S_y values during model calibration.

The horizontal and vertical anisotropy of an aquifer is the difference in hydraulic conductivity in the x, y, and z directions. The anisotropy determines if there is a preferential direction for groundwater to flow through the aquifer material. Anisotropy is represented by the ratios of K_x/ K_y and K_z/K_r, respectively, where K_r is the horizontal conductivity. We initially assigned a value of 1 for horizontal and vertical anisotropy in the GFM ($K_x=K_y$ and $K_z=K_r$). No measurements of vertical anisotropy exist for the four groundwater basins, so we adjusted this value during calibration.

2.3.3 Surface water outside of the model domain: PRMS Model

We simulated surface water flows through un-gaged tributary streams entering the model domain from the parts of the Watershed outside of the groundwater basins using the USGS Precipitation Runoff Modeling System (PRMS, Markstrom *et al.* 2015, **Exhibit 106**). We modeled runoff for the entire Watershed, excluding the area that drains into gaged streams where actual data is available as model inputs, and excluding the area that drains into Lake Casitas, as this water body does not provide surface flow into the groundwater basins. **Figure 12** shows the sub-watershed where we used PRMS to simulate runoff, or surface flow, into small tributary streams that flow into the model domain. PRMS requires that the modeled area is subdivided into hydrologic response units (HRU), or areas with similar land cover, soil type and slope. We obtained this data for the Watershed from the National Land Cover Database (USGS, 2006, **Exhibit 136**), the State Soil Geographic Database (SSURGO) soil maps (Soil Survey Staff, 2016, **Exhibit 137**), and the National Elevation Dataset (NED) 3DEP LiDAR Data (U.S. Geological Survey, 2020, **Exhibit 138**). The program SWAT (Soil and Water Assessment Tool), configured as ArcSWAT (Neitsch *et al.* 2011, **Exhibit 115**), was used to delineate the HRUs where hydrologic parameters are considered uniform. We input data on elevation, land cover and soil type for the Watershed. We also used ArcSWAT to calculate several parameters that are required inputs to PRMS: the area, aspect, slope, percent impervious area, primary soil and cover type, and we used ArcSWAT to calculate infiltration parameter values based on soil types for each HRU, and delineate the tributary stream network. The tributary locations were verified using GoogleEarth satellite imagery.

PRMS incorporates all major watershed processes (precipitation, solar radiation, canopy interception, impervious runoff, soil zone storage and flow, groundwater reservoir storage and flow, and interflow between subsurface reservoirs) to calculate streamflow and sub-surface flow from a sub-watershed. Additional data inputs to simulate these processes are daily precipitation and air temperature. We acquired these values from 17 meteorological stations within and surrounding the Watershed. We selected stations based on data availability and obtained data from the VCWPD Hydrologic Data Server (VCWPD, 2019, **Exhibit 139**). The model output values are daily flows from each of the sub-Watersheds at the stream outlet point. We averaged the output daily flows over each month to obtain average monthly flow for each stress period to input into the GFM.

The PRMS model also simulates sub-surface flow through the groundwater "reservoir" (the module that accounts for sub-surface flow). We used the output term from the groundwater reservoir, "groundwater sink," representing the flow that enters the groundwater reservoir and no longer interacts with surface flow, to determine mountain-front recharge entering the GFM domain from surrounding bedrock. Simulating mountain-front recharge is discussed in greater detail in Section 2.3.6.

We calibrated PRMS to determine the optimal parameter values governing flow processes where values could not be determined spatially. This calibration process involved selecting a gaged tributary in an area geographically and climatically similar to the upper Watershed, running a PRMS simulation for that area, and adjusting the unknown PRMS parameters until the PRMS simulated tributary flow closely matched the gaged flow. There were no gaged tributary streams within the Watershed that were suitable for this calibration, because gages on Matilija Creek and San Antonio Creek are measuring the streamflow of much larger catchment areas. Additionally, Matilija Creek flow is also influenced by Matilija Dam, and San Antonio Creek flow is influenced by well pumping and development within its catchment. We selected Hopper Creek, located in the adjacent Santa Clara River Watershed, for PRMS calibration (Hopper Creek at Highway 126; Ventura County Watershed Protection District Gage 701; **Figure 13**). This stream has similar soil, slope, and land cover properties to the simulated streams in the Watershed (Hanson *et al.* 2003). We used the Nash-Sutcliffe Model Efficiency (NSE; formula provided **in Table 2**) to assess the progress of the calibration and to determine when a satisfactory match was reached. This metric is the same that was used to evaluate the calibration of streamflow in the MODFLOW-OWHM GFM, and its applicability to the evaluation of model simulated flow is discussed in Section 3.2. The NSE value of 0.98 indicates a robust streamflow calibration (Moriasi *et al.,* 2007, **Exhibit 116**). The calibrated simulated versus observed flows at Hopper Creek are plotted in **Figure 14**.

2.3.4 Streamflow Routing

We used the streamflow-routing package (SFR2; Niswonger and Prudic, 2005, **Exhibit 119**) to simulate the Ventura River and its tributaries within the model domain. This component of the model simulates river and stream flow and groundwater – surface water interaction with the four groundwater basins, while the previous section describes the modeling to simulate tributary streamflow outside of the groundwater basins within the Watershed. We used the PRMS flow values as inputs into SFR2. The package functions by routing surface flows from upstream to downstream through a network of connected segments and calculates stream-aquifer interaction. This interaction depends on the groundwater level in the cell containing the stream, the water level in the river, the hydraulic conductivity of the river or streambed, and the dimensions of the streambed. There are two equations used for calculating the flux of water between the aquifer and the stream:

$$Q = \frac{KwL}{m}(h_s - h_a)$$

Where Q= flow in the stream, K= hydraulic conductivity of the streambed, w= width of the streambed, L= length of the stream segment, m= thickness of streambed, h_s= head in the stream, and h_a= head in the aquifer (Prudic et al., 2004, **Exhibit 117**).

In the GFM, the simulated stream network contains 134 segments (**Figure 15**), where individual segments are defined as the stream length from headwaters to a confluence or between confluences. We determined the location of each stream using GoogleEarth historical satellite imagery (image date: October 2004) to confirm the stream channel locations (additional details of the PRMS stream inflow locations provided in Section 2.3.3). We also used historical satellite imagery from the same period to determine the location and shape of the Ventura River channel.

The entire simulated stream network is connected in the GFM with the exception of two locations: the outflow of San Antonio Creek from the Ojai Basin and the outflow of Lion Creek from the Upper Ojai Basin. These sections were not simulated because they lie outside of the groundwater basins. The locations where gage data was used as stream flow inputs instead of the PRMS output flow values were: San Antonio Creek as it re-enters the Upper Ventura River Groundwater Basin downstream from the confluence of San Antonio and Lion Canyon Creeks and at its confluence with the Ventura River (VCWPD Gage 605), and the sum of flow from Matilija Creek and North Fork Matilija Creek, where these streams combine and become the Ventura River at the northernmost point of the Upper Ventura River Basin (VCWPD Gage 602B and Gage 604). We retrieved daily streamflow data from the VCWPD Hydrodata Server and averaged over each month within the calibration and validation period for model input. Additionally, we input data for the total diversion at the Robles Diversion facility into a SFR2 segment at the facility location. SFR2 has the capability for a stream segment to be designated as a diversion, where a specified flow amount is removed from the stream network at the location of the diversion segment. We obtained data for monthly diversions during the calibration period from CMWD. For all other stream segments within the model domain, SFR2 calculates flows.

The SFR2 package requires data input for each stream segment for each stress period (each month) including: the method for calculating stage, the outflow segment number, flow rate, streambed upper and lower elevation, hydraulic conductivity, thickness, the channel and bank Manning's roughness values, and cross-section geometry. We selected the eight-point channel stage calculation method, where a characteristic geometry is assigned to each segment. We estimated the geometry of each segment using satellite imagery and LiDAR data. We set the thickness of the streambed at 2 ft. We initially estimated hydraulic conductivity, channel and bank roughness (Manning's n) values for the streambed from literature values for similar alluvial streambeds within the neighboring Santa Clara River Watershed where field studies have been conducted to estimate hydraulic conductivity (Hanson *et al.,* 2003), and subsequently adjusted these parameters during model calibration, using the field-derived values as reasonable upper and lower bounds.

2.3.5 Well pumping, Diversions, and Sewage Effluent

We used MNW2 (the multi-node well package) to simulate wells that extract groundwater in the GFM. Active wells that are designated as "agricultural" were instead simulated using the Farm Package (FMP), described in Section 2.3.7. We added all other active wells, designated as municipal, domestic, or agricultural/residential to the model at the location specified in the VCWPD 2018 well inventory database. The locations and classifications of these wells are shown in **Figure 16**. We obtained average monthly extraction data for all wells classified as municipal and industrial from the water provider. Domestic wells are primarily located at single-family residences and extraction data is not regularly reported except in the Ojai Basin. We estimated domestic well extractions using the following method: assuming an average per capita water use of 213 gallons per day (28.5 ft^3 per day; Walters, 2015, **Exhibit 120**), and an average of 3.1 persons per household (U.S. Census Bureau, 2018, **Exhibit 121**), yielding an average of approximately 660 gallons per day (88.2 ft^3/day) per residence. We accounted for seasonality in water use by comparing the actual monthly extraction data for municipal water providers during the calibration period to the average annual use, and then we calculated the percent of the average annual usage for each month and multiplied this percentage by the domestic average annual use to obtain monthly domestic extractions. The minimum monthly domestic water use applied to a domestic well in the GFM was 67.7 ft^3/day during February, and the maximum was 116.1 ft^3/day in August. We assumed that monthly extractions were the same for each year during the calibration period. In the Ojai Basin, groundwater extraction data are reported to the Ojai Basin Groundwater Management Agency (OBGMA). Semi-annual average extraction values are reported to the OBGMA, so we obtained monthly average extraction values by multiplying the semi-annual averages by the same seasonality factor

There are a small number of individual septic systems within the four Basins. We used locations of eight septic systems in the Ojai Basin as specified in the Ojai Basin Groundwater Model (DBS&A, 2011). We obtained the locations of septic systems in the other three basins from the Ventura County Onsite Wastewater Treatment System online record search. We estimated the amount of net recharge from individual systems at 50 gallons per day, or 6.6 ft^3/day, based on literature values for septic system recharge in Southern California (Hantzsche and Finnimore, 1992, **Exhibit 122**). We simulated the septic system input to the groundwater systems using the MNW2.

Treated sewage effluent is discharged to the Ventura River by the Ojai Valley Sanitation District (OVSD) within the Lower Ventura River groundwater basin. The discharge rate is relatively constant with an average discharge of 3.25 cfs (Walter, 2015). The minimum discharge during dry months, provided in the OVSD Master Plan, is 2.3 cfs (MNS Engineers, 2014, **Exhibit 123**), and the monthly dry weather maximum discharge is approximately 4.6 cfs (CA RWQCB, 2018, **Exhibit 124**). We applied the reported average discharge of 3.25 cfs to all stress periods. We added this value as an inflow to the SFR segment corresponding to the treatment plant location. This location is shown in **Figure 15**.

2.3.6 Mountain-front Recharge

The high-relief areas surrounding the four groundwater basins consist of low-permeability bedrock with limited groundwater storage (DWR, 2003). While these areas do not hold large volumes of groundwater because of a thin soil zone and steep land surfaces, there is contribution of groundwater during and after wet months and storm events from these mountainous regions to the alluvial groundwater basins (Wilson and Guan, 2004, **Exhibit 125**). To estimate this contribution, we applied the groundwater reservoir component of the PRMS simulation to the edge of the GFM domain corresponding to the sub-watershed of a tributary entering the model domain.

Water that infiltrates and is routed to subsurface reservoirs in PRMS is distributed into preferential flow, capillary, gravity and groundwater reservoirs sequentially. The groundwater reservoir is either routed to the stream network as baseflow or exits the model domain as the “groundwater sink” component. We used this groundwater sink component to represent the portion of infiltrated precipitation that does not contribute to surface flow. Without a deep storage reservoir in the surrounding bedrock, this groundwater recharge eventually contributes to the alluvial basins at the mountain front. We adjusted the proportion of precipitation that is routed to mountain-front recharge (MFR) during PRMS calibration.

We simulated mountain-front recharge using the WEL package (single node well) as a multi-cell horizontal injection well. The WEL cells were split into reaches which correspond to the sub-watersheds defined in the PRMS model. We positioned the WEL cells at the edge of the active model domain, or at the next nearest cell where the surface slopes transition to less than five percent. The locations of the MFR cells are shown in **Figure 17.** We calculated the monthly MFR input for each stress period by averaging the daily rates output by PRMS over each month during the calibration period.

2.3.7 Farm Process

We used the Farm Package (FMP) to simulate recharge from precipitation, runoff and return flow from crop irrigation, and water leaving the groundwater system through evaporation and transpiration. FMP was created for the purpose of estimating and integrating the components of agricultural water supply and demand on a spatially and temporally variable basis in a groundwater model, but can also simulate all recharge and evapotranspiration (ET) in a groundwater system. We not only input crop data into FMP to simulate irrigation, but also input all vegetation types within the domain to simulate recharge and ET processes.

2.3.7.1 Climate Data

We obtained precipitation and ET data from VCWPD gaging stations (vcwatershed.net/hydrodata/) and the California Irrigation Management Information Systems (cimis.water.ca.gov, **Exhibit 140**), for the calibration period and validation period, respectively. We downloaded daily data and averaged these to obtain monthly values. For consistency, we obtained ET data for the same locations of the Ventura County observation stations. We used ArcGIS to interpolate between observation stations to produce a 1,000 ft. by 1,000 ft. resolution raster of average precipitation and ET values as input for the FMP **(Figure 18).** Interpolation is the process of using points with known values to estimate values at other unknown points.

We checked for data accuracy by comparing the gridded precipitation and ET data to the National Oceanic and Atmospheric Administration (NOAA) historical precipitation data and the CIMIS (the original source of ET data download) data maps.

2.3.7.2 Vegetation Data

We completed the analysis of vegetation data for input into the GFM. In doing so, we merged three datasets to create a vegetation map to cover the extent of the GFM, which we used to assign properties specific to vegetation types to the model. This merged approach to creating the GFM vegetation map allowed for the use of different datasets that we interpret to be more accurate for specific categories of vegetation. The datasets used are: a vegetation map created on behalf of Ventura County Planning Division was used for non-cropland vegetation (David Magney Environmental Consulting, 2008, **Figure 19, Exhibit 129**) and the DWR dataset for agricultural land use for agricultural vegetation (DWR, 2014, **Figure 3, Exhibit 126**). Areas containing *Arundo donax* (giant reed), a common invasive plant in the region, were assigned using a high-resolution dataset created by the California Invasive Plant Council (CAL-IPC, 2008, **Exhibit 127**). Then, we assigned the input parameters to the FMP, including crop coefficients, root depth, fraction of inefficient losses to surface water, and on-farm efficiency on a vegetation-specific basis. Crop coefficients and rooting depths are parameters that define the water requirement and water use by each vegetation type. The fraction of inefficient losses to surface water due to precipitation (FIESWP) and due to irrigation (FIESWI) represent the runoff from excess irrigation water. We adjusted these parameters during calibration. The on-farm efficiency (OFE) is a parameter that represents each crop of vegetation types' proportion of uptake of applied water. This parameter is discussed in greater detail in Section 2.3.7.3.. We adjusted the OFE of irrigated crops during calibration.

Another parameter in FMP used to calculate ET rate is the root pressure. FMP's calculation of ET rate depends on the groundwater head because ET rates vary with root zone saturation. Because the vertical range of root zones is small compared to the range of hydraulic heads simulated, relatively small inaccuracies in head could cause large inaccuracies in ET rates. Because of this, we held the optimal root uptake pressures constant throughout the simulation at an exaggerated range of values intended to allow the optimal ET rate to occur, regardless of simulated head.

2.3.7.3 Irrigation

To determine the proportion of irrigation that recharges groundwater, runs off to surface water, and is consumed by plants, the FMP takes into account numerous farm, climate, soil, vegetation, and hydrogeologic variables. One of these is the Total Farm Delivery Requirement (TFDR) in each Water-Balance Subregion (WBS). A WBS is a group of cells within FMP for which a water budget is computed. In the GFM, each vegetation type is represented by a separate WBS. Some agricultural vegetation types have multiple WBSs for the same vegetation type, grouped by proximity. The TFDR is calculated for each cell within a WBS and is the deficit amount of water required by vegetation after considering uptake from precipitation, groundwater, and inefficient losses. A TFDR of zero means vegetation is able to obtain all water necessary for ET from precipitation and/or groundwater uptake. A positive TFDR means additional water is necessary for optimal vegetation growth, which can be fulfilled by irrigation. The TFDR is also subject to the On-Farm Efficiency (OFE) parameter. A lower OFE results in excess irrigation, which either becomes runoff or aquifer recharge. An OFE of 1, the maximum value, means that irrigation is applied at the exact rate needed, so irrigation does not contribute to runoff or aquifer recharge.

Irrigation in the GFM is applied using Farm Wells. Since actual irrigation well withdrawal records for the model area are incomplete, we assigned theoretical farm wells to agricultural WBSs, with withdrawal rates calculated by FMP as described above. The GFM operates under an "assumed sufficiency" scenario, meaning if farm wells are incapable of meeting the TFDR, the deficit amount of water is supplied by "External Deliveries" of water from another unspecified source. We assumed that this source was the municipal water deliveries supplied by CMWD. Monthly delivery volume or location data were not available from CMWD at the time of model construction, though we obtained historical annual delivery amounts to the Ojai Basin from the Ojai Water System 2010 Urban Water Management Plan (KJC, 2011, **Exhibit 128**) and compared these amounts to the total external deliveries value for the Ojai Basin in the GFM as a model accuracy check, and found the values to be consistent.

2.3.7.4 Soils

FMP provides three default soil types that assign coefficients to MODFLOW-computed equations for ET demand: silt, sandy loam, and silty clay. We used the FMP predetermined coefficients for sandy loam throughout the GFM, which are consistent with soil maps from the U.S. Department of Agriculture Soil Survey Geographic Database (SSURGO; Soil Survey Staff, 2016, **Figure 20**).

3 Model Calibration and Sensitivity Analysis

Model calibration is the process of adjusting model parameters with the goal of achieving a set of parameter values where the resulting model-simulated values are as close as possible to the values observed in the actual system. Calibration is a necessary step in modeling to ensure that the model is capable of accurately recreating and simulating real-world conditions. We calibrated the GFM using trial-and-error methods. Calibration began with the PRMS model, as described previously in Section 2.3.3, and then the GFM model was calibrated via a separate process. We made systematic adjustments to calibrated parameters, altering one parameter at a time incrementally until a close match between simulated and actual conditions was achieved. We determined that the match was strong using variously statistical metrics, described in Section 3.2. Another component of calibration is determining the model's sensitivity to the adjustment of each parameter. Sensitivity refers to the change in model output values for a given change in a single parameter value. The relative sensitivities of the parameters adjusted during calibration are determined in the sensitivity analysis, described in Section 3.3.

3.1 Calibration data

We performed the calibration by aiming to achieve the closest match for two types of data: groundwater levels and streamflow. We used the available streamflow gages and groundwater level monitoring wells within the model domain to obtain observed values for both types of data.

3.1.1 Monitoring Wells

We calibrated the GFM using groundwater level data from 25 monitoring wells within the model domain **(Figure 9).** We obtained historical water levels from these wells from the DWR Water Data Library website (wdl.water.ca.gov, **Exhibit 93**). Water levels are measured and recorded at these sites approximately once every two months. We added this data to the model using the Head Observation package (HOB), a package that stores the measured water level data at the well locations for comparison with simulated water levels.

3.1.2 Stream Gages

The USGS gage 11118500 Ventura River near Ventura, located on the Ventura River below Foster Park, had daily observations of streamflow during the model calibration period. Gaged tributaries in the model domain with streamflow observations during the calibration period include Matilija Creek and North Fork Matilija Creek (VCWPD 603a, 602B, and 604) as well as San Antonio Creek (VCWPD 605), though we used these gages as flow data input for SFR2 so therefore did not utilize these for calibration. We did not include data from the streamflow gage on the Ventura River downstream from the Robles Diversion (607) operated by CMWD in the calibration process because data were not available from this gage before completion of the modeling process. **Figure 9** shows streamflow gages within the Watershed that continuously record data and denotes those that we used in the model, either for calibration or data input.

We obtained average monthly streamflow values at gage 11118500 and compared these to SFR2-simulated flows at the segment corresponding to the Ventura River at Casitas Bridge for model calibration. The comparison of simulated versus gaged flows are shown in **Figure 25.**

3.2 Calibration Process

Our two targets for calibration were: 1) gaged streamflow on the Ventura River at Casitas Bridge; and 2) simulated to observed groundwater heads at each monitoring well.

The model parameters that we adjusted during calibration are given in **Table 3.** These include: horizontal hydraulic conductivity in all zones, specific yield in all zones, streambed conductivity, GHB conductivity, Manning's n values for stream channel and banks, OFE, FIESWI, and FIESWP in the FMP. We constrained initial values within the acceptable ranges described in Section 2.3. We estimated all other model parameter values using methods described in Section 2 and did not adjust during calibration.

We evaluated the progress of model calibration through multiple objective functions, or model performance measures, related to flow and head residuals (the residual equals the observed value minus the simulated value). For groundwater heads, these objective functions were: mean error (ME), mean absolute error (MAE), and normalized root mean squared error (NRMSE). The formulae for these are given in **Table 2**. We assessed streamflow calibration using the Nashe-Sutcliffe model efficiency (NSE). This model performance metric is commonly applied to hydrologic data, and is appropriate for use with long-term continuous data, such as streamflow (Moriasi *et al.,* 2015, **Exhibit 131**)**.** To evaluate the progress of calibration, model performance evaluation criteria are needed that correspond to the objective functions. These criteria are the industry standard for what is considered a satisfactory calibration, and are discussed in Section 3.4 for each objective function.

3.3 Sensitivity Analysis

A sensitivity analysis assesses how the uncertainty in the model output is related to the uncertainty in its input parameters. The most sensitive parameters as those that cause the largest relative change in the mean error (ME) and root mean square error (RMSE) of groundwater heads. Identifying the most sensitive parameters aids in understanding which components have a large effect on model results in contrast to those which have little effect on model simulations. The parameters that have little effect on model simulations may also be considered the most uncertain ones.

All parameters that we adjusted during calibration were used in the sensitivity analysis and are given in **Table 3**. We adjusted the calibrated values using constant multipliers of 1.5 and 0.5 for all parameters except those where the adjustment was limited by the range of realistic values. For these parameters - specific yield, Manning's roughness values, and the OFE values - we used multipliers of 1.2 and 0.8. We changed only one parameter value during each model run of the sensitivity analysis, then we evaluated the relative sensitivity by comparing the RMSE and ME for head during the model calibration period. For parameters with multiple zones (aquifer conductivity and specific yield), we used the average RMSE and ME for all zones for sensitivity comparison. The results of the sensitivity analysis are shown in **Figure 21.**

The most sensitive model parameters are aquifer hydraulic conductivity (K) and specific yield (Sy). The least sensitive parameters are the fraction of inefficient losses to surface water from irrigation (FIESWI) and from precipitation (FIESWP) and on-farm efficiency (OFE) in the FMP, and Manning's roughness coefficients (n values) for stream banks and channels.

3.4 Calibration Results

The results of the model calibration are provided in **Table 4.** The NRMSE was 4.4%, which is within the range of the industry standard of a well calibrated groundwater model of 0% to 10% (Spitz and Moreno, 1996**, Exhibit 132**; Rumbaugh and Rumbaugh, 2005, **Exhibit 133**). A plot of observed versus simulated heads (**Figure 21**) shows that the points fall approximately evenly on either side of a 1:1 line, indicating minimal bias in the simulated heads. A histogram of residuals (**Figure 22**) indicates that most residuals are between -9 and 4 ft., and there is a slight skew towards negative residuals (simulated heads greater than observed). The longer tail towards positive residuals is attributed to a few wells in the Ojai Basin with simulated heads significantly lower than observed during some stress periods.

Hydrographs of simulated and observed heads for individual monitoring wells are shown in **Figure 23a-c**. In general, for most of the model domain, simulated heads matched the seasonal fluctuations observed at the monitoring wells. The simulated water levels at monitoring wells located in the narrower portions of the Upper Ventura River basin exhibited less seasonal fluctuation than observed. This could be an artifact of the model grid discretization, with fewer adjacent cells in these areas. Simulated heads in the Upper Ojai Basin and the Upper Ventura River Basin were generally higher than observed heads. This also may be a result of the discretization of the model domain, where parts of the basins with steeper gradients were effectively smoothed by averaging of land surface elevations within each 200 ft. by 200 ft. model grid cell. This smoothing of the aquifer upper and lower extents created abrupt changes in elevations that led to some cells going dry during the simulation. With some of the aquifer storage capacity effectively removed by dry (inactive) model cells, simulated heads may have been higher than observed to compensate for this reduced storage. These dry cells, however, may be an accurate simulation of conditions in these aquifers during dry periods when there is little groundwater in storage in the steep-gradient areas on the edges of the groundwater basins where alluvium is very thin. Solving for head in areas with dry cells can be problematic in MODFLOW, so although cell re-wetting was allowed during the simulation, we used wetting parameter values that were stringent to improve model convergence.

The model-simulated flow on the Ventura River below Foster Park compared to the gaged flow (USGS gage 11118500; VCWPD station 608) is shown in **Figure 24a. and b.** at two different vertical scales. The NSE of 0.976 indicated a close fit between simulated and observed flow values. The model recreates high flow events well, particularly the peak flows during the 2004 and 2005 winter months, and also closely simulates the recession of peak flow when compared to gaged flow. Low flow months (summer to fall of 2004, 2006) are accurately simulated, though errors of 2 to 3 cfs during the dry year summer to fall (less than 5 cfs of observed flow June to September 2004) are a higher percentage of flow values.

4 Modeling Results

4.1 Simulated Water Budget

We evaluated the model mass balance, or the balance between inflows and outflows, by examining the percent discrepancy for each stress period. A well-developed model should minimize discrepancies in the mass balance so that the model inputs are balanced by the outputs at each stress period. The percent discrepancy is calculated as the difference between total inflows and total outflows to the groundwater model, including changes in storage, divided by total inflow. Discrepancies of approximately ±1% or less are considered to reflect an appropriate mass balance (Anderson and Woessner, 1991, **Exhibit 134**). Overall percent discrepancy for the entire simulation was -0.3%.

We also evaluated how all components of the model water budget changed over the simulated period. **Figure 25** shows the water budget for each stress period during the calibration period. The largest components of the water budget are inflows and outflows from streams and rivers in the model domain. The magnitude of stream-aquifer interaction correlates with precipitation, showing that the model is simulating the expected response to rainfall events. Well pumping becomes a greater proportion of the water budget during dry months, especially during the summer and fall months of water year 2004, a dry year. The smallest components of the simulated water budget are mountain-front recharge (MFR) and flux at the general head boundaries at the distal end of the Lower Ventura Basin at the Pacific Ocean and at the watershed divide in the Upper Ojai Basin.

Changes in groundwater storage, representing the simulated fluctuations of the water table, are shown on **Figure 25** as the net change at each stress period. A negative storage change reflects a rising groundwater table, while a positive net change indicates a lowering water table. The magnitude of the simulated groundwater storage increase during wet months is significant, demonstrating the ability of the groundwater basins to rapidly re-fill following dry periods. The reduction of groundwater storage during dry months is more gradual, though storage declines rapidly following storm periods (e.g., March 2004, March 2005, and May 2006).

4.2 Model Validation

We ran an additional model simulation to independently check the accuracy of our model. We simulated an additional time period to verify that the model can accurately simulate a variety of hydrologic conditions and to confirm that the model's accuracy is not limited to the calibration period. Because of the high variability in climatic conditions in the Watershed, the supply of water from storms can be dissimilar within the same water year classification (e.g., between two wet years) if two years have different storm timing and intensity. The validation period includes one wet year (2011) and two dry years (2012 and 2013). This period contrasted with the calibration period, which included two wet years and one dry year. We selected this validation period because it represents the beginning of the most recent major drought in California.

Our goal during model validation was to compare simulated and observed heads and simulated and observed streamflows and to observe how the model functions with a different set of hydrologic conditions than simulated during the calibration period. To develop the validation simulation, we modified model input datasets for precipitation, reference ET, mountain-front recharge, and streamflow entering the model at each tributary stream (gaged and modeled by PRMS) for each stress period to correspond with the selected model validation period using the same methods described in Section 2.2. We also set the well withdrawals for municipal wells to the monthly average for the validation period. We kept all other data and parameter values the same as the calibration period, assuming land use and population within the study area did not change significantly between 2006 and 2011.

The results of the validation show that the model accurately simulates conditions during different water year types (**Figure 26).** The groundwater head NRMSE of the validation simulation was 5.2%, well below the guidance value of 10% for well-calibrated models. Streamflow was also accurately-simulated during the validation period, with an NSE of 0.88.

5 Model Limitations and Appropriate Use

We constructed the GFM to simulate regional groundwater flow and groundwater-surface water interaction within the four groundwater basins of the Watershed. We did not intend for this model to provide site-specific data or to provide absolute values of heads or flows. The model has limitations related to data availability and model design that should be recognized during the interpretation of model results.

The model range of uncertainty in streamflow is a consideration when interpreting model results or predictive scenarios that involve simulated streamflow values. The average normalized flow residual for the calibration period is 2.8 cfs, representing the general range of uncertainty in simulated flow values. The monthly stress periods also limit the model to output average monthly flow values, which may not accurately capture short term flashy peak flow events or rapid baseflow recession that is characteristic of this system.

Another limitation of the GFM is the lack of temporally and spatially-extensive model input data. Groundwater flow and storage are largely controlled by the shape of the alluvial aquifers, and although the alluvial thickness in the GFM was based on the geologic data available, the process of interpolation introduces uncertainty. The number of head and streamflow observations were also limited by available gage data. Another data gap are the well extraction records for domestic and agricultural wells. Pumping data were only available for the Ojai Basin, so the groundwater extraction component of the water budget in the other basins has a greater level of uncertainty. The extraction data is also limited by the lack of information on water delivery amounts by CMWD to each of the four basins. These deliveries could be a major component of a basin’s water budget, especially during dry months and/or in areas with a high density of agriculture.

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7 Tables

Table 1. Model calibration period and validation period annual precipitation recorded at VCWPD Station 066 (Ventura Downtown). Mean precipitation for the entire period of record (1873-2020) is 15.2 inches, median is 14 inches.

YEAR	TOTAL PRECIPITATION (IN.)
2003	19.85
2004	11.64
2005	35.93
2006	18.11
2010	16.16
2011	19.68
2012	8.86
2013	6.58

Table 2. Statistical metrics used to evaluate model fit.

METRIC	FORMULA
Mean Error	$\mathrm{ME} = \frac{1}{n}\sum_{i=1}^{n}(h_{obs} - h_{sim})$
Mean Absolute Error	$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n} \lvert(h_{obs} - h_{sim}\rvert$
Root Mean Squared Error	$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(h_{obs} - h_{sim})^2}$
Normalized Root Mean Squared Error	$\mathrm{NRMSE} = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(h_{obs} - h_{sim})^2}}{h_{max} - h_{min}}$
Nash-Sutcliffe Efficiency	$\mathrm{NSE} = 1 - \frac{\sum_{i=1}^{n}(h_{obs} - h_{sim})^2}{\sum_{i=1}^{n}(h_{obs} - \overline{h_{obs}})^2}$
Where n = the number of observations; h_{obs} = observed hydraulic head; h_{sim} =simulated hydraulic head; h_{max} = maximum observed head; h_{min} = minimum observed head	

Table 3. Model parameters adjusted during calibration and in the sensitivity analysis. Sensitivity analysis adjustment multipliers are provided.

PARAMETER	NUMBER OF ZONES	MULTIPLIER
Horizontal hydraulic conductivity	6	1.5, 0.5
Streambed conductivity	1	1.5, 0.5
Specific yield	4	1.2, 0.8
Manning's roughness coefficient	2	1.2, 0.8
General head boundary conductance	2	1.5, 0.5
Farm process- Farm Efficiency	1	1.2, 0.8
Farm process- Inefficient losses to surface water	1	1.5, 0.5

Table 4. Results of model calibration

METRIC	RESULT
Mean Error (ME)	-7.5
Mean Absolute Error (MAE)	22.8
Root Mean Squared Error (RMSE)	30.7
Normalized Root Mean Squared Error (NRMS)	4.3%
Nash-Sutcliffe Efficiency (NSE) [1]	0.976
[1]NSE is calculated based on simulated streamflow at the SFR segment corresponding to the USGS 11118500 gage, compared to gaged flow	

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Figure 25 a. and b. Observed versus simulated flow at USGS gage 11118500: Ventura River near Ventura.

Figure 26. Water Budget Plot

Figure 27. Validation Period Observed versus Simulated Streamflow at USGS Gage 11118500

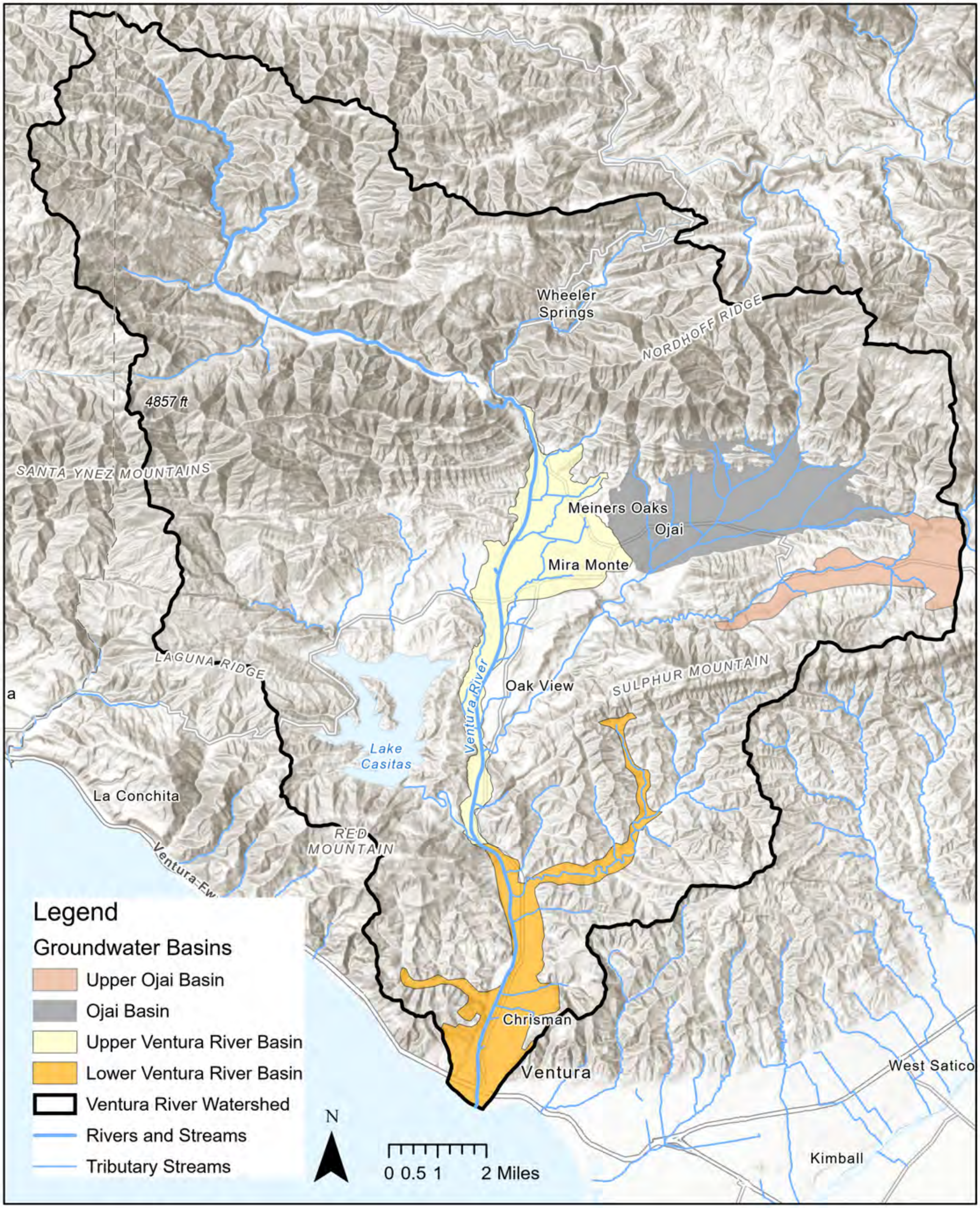


Figure 1. Location of the Groundwater Basins within the Ventura River Watershed

Data Sources: National Watershed Boundary Dataset
California Bulletin 118
USGS National Hydrography Dataset

Figure 2. Geologic Map of Ventura River Watershed

Sources: USGS Geologic Maps of Matilija (Tan & Jones: 2006), Ojai (Tan & Irvine: 2005), Ventura (Tan, Jones, & Clahan: 2005), and Saticoy (Tan, Clahan, & Rosinski: 2004) Quadrangles

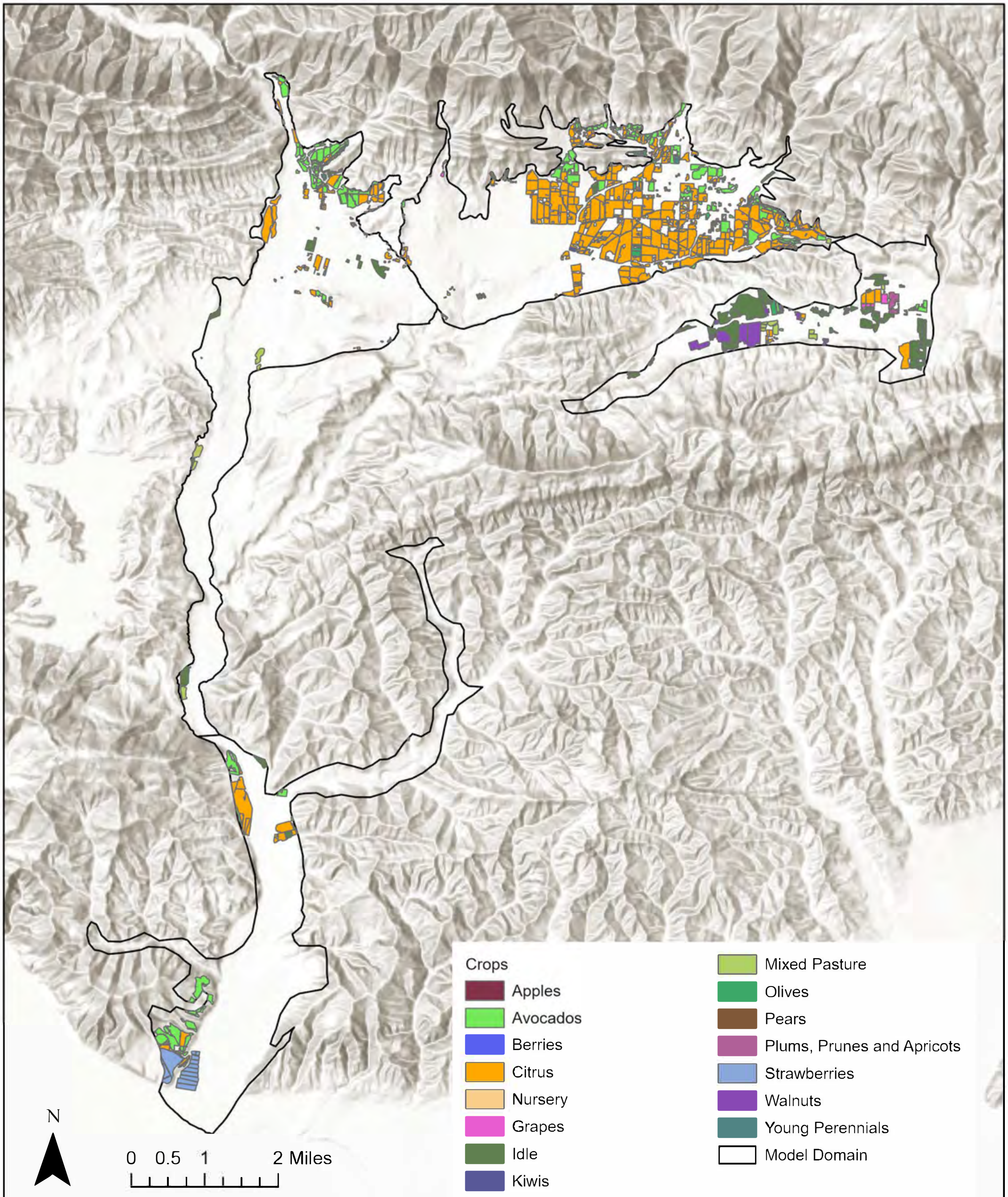


Figure 3. Crops within the Model Domain

Data Sources: CA DWR 2014 Statewide Crop Mapping Dataset

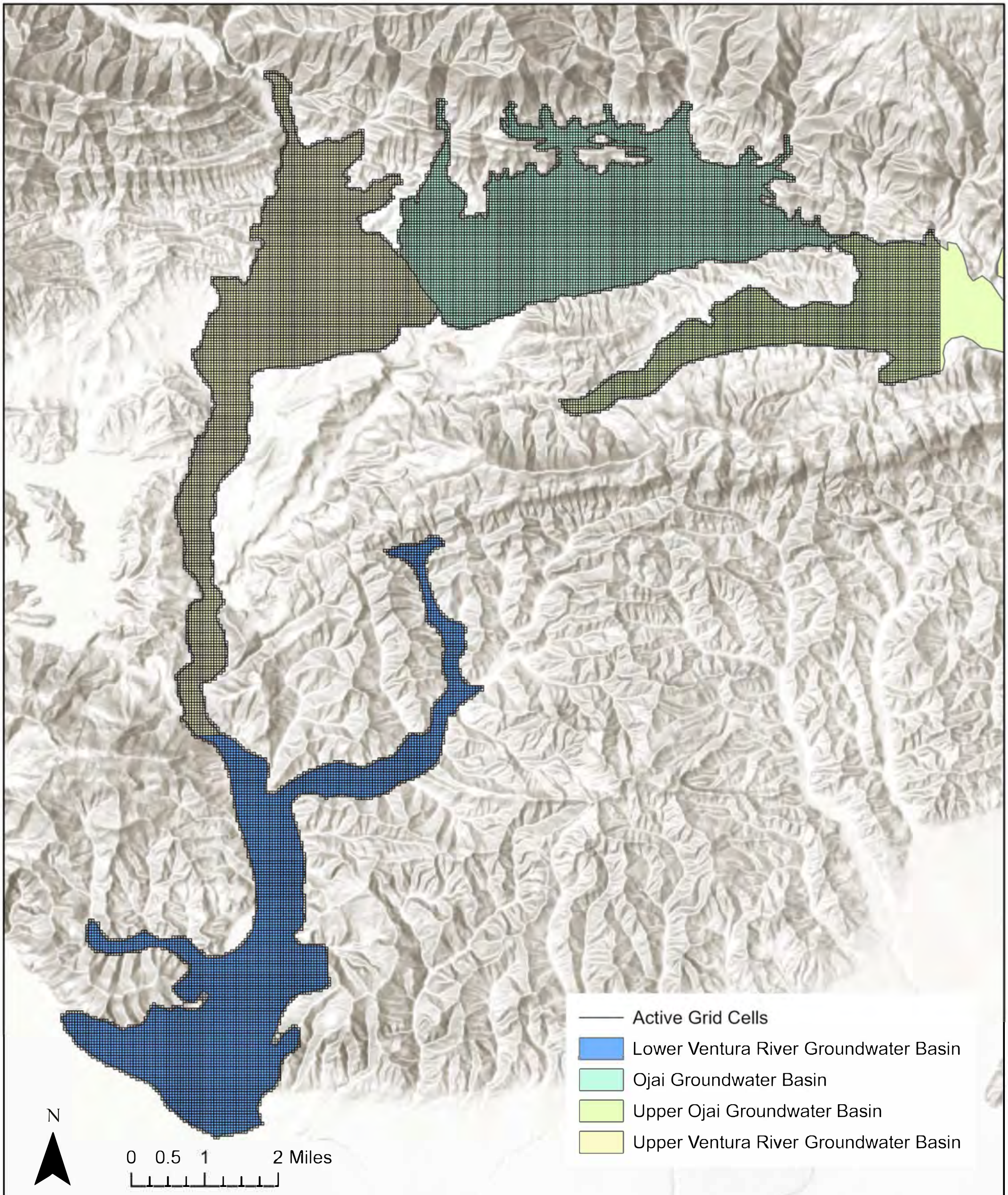


Figure 4. Model Domain and Active Grid Cells

Data Sources: CA DWR Bulletin 118

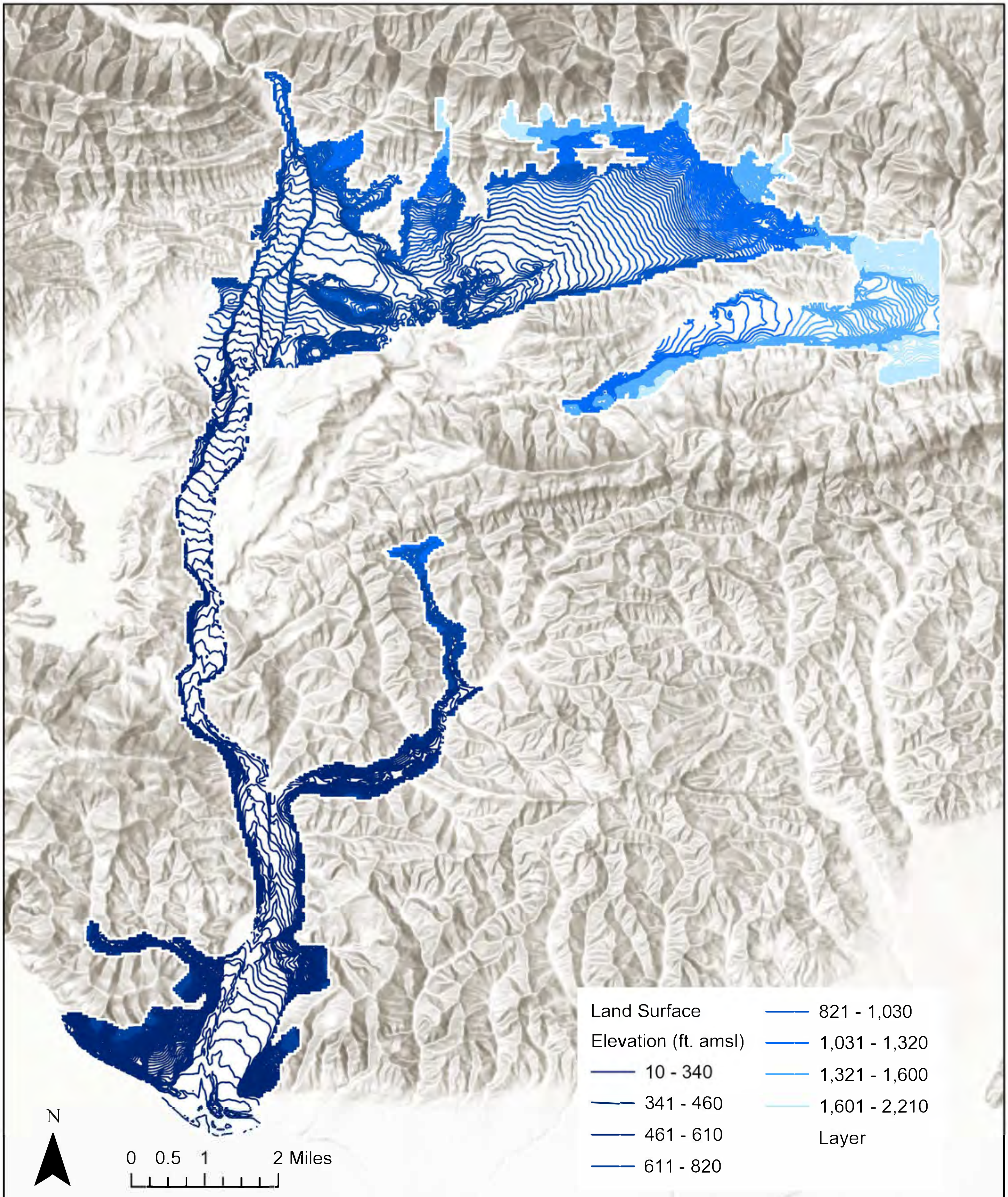


Figure 5. Model Top Elevation Contours

Data Source: USGS 2018 Ventura County LiDAR

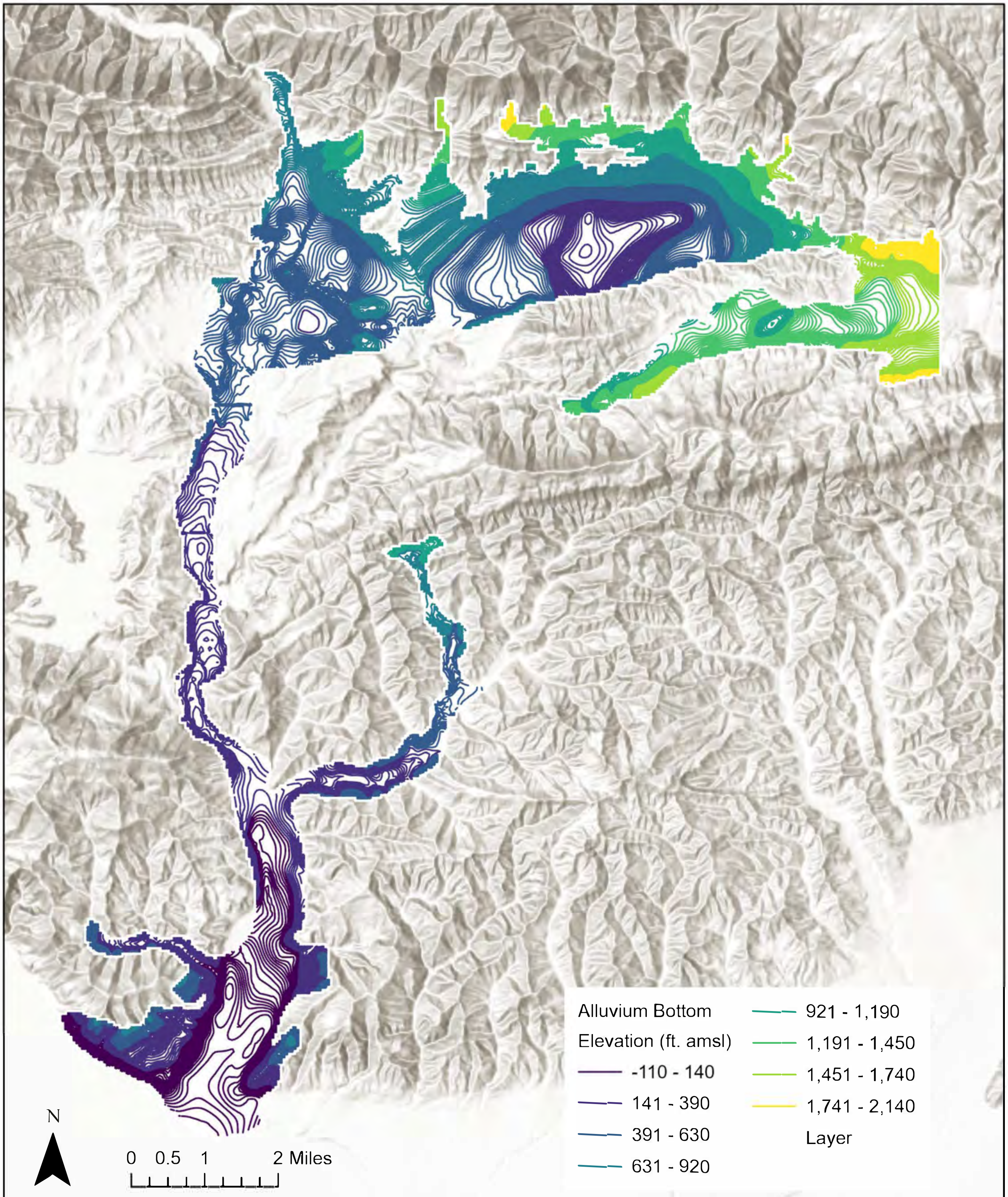


Figure 6. Layer 1 Alluvium Bottom Elevation Contours

Data Sources: Described in Section 2.2.1

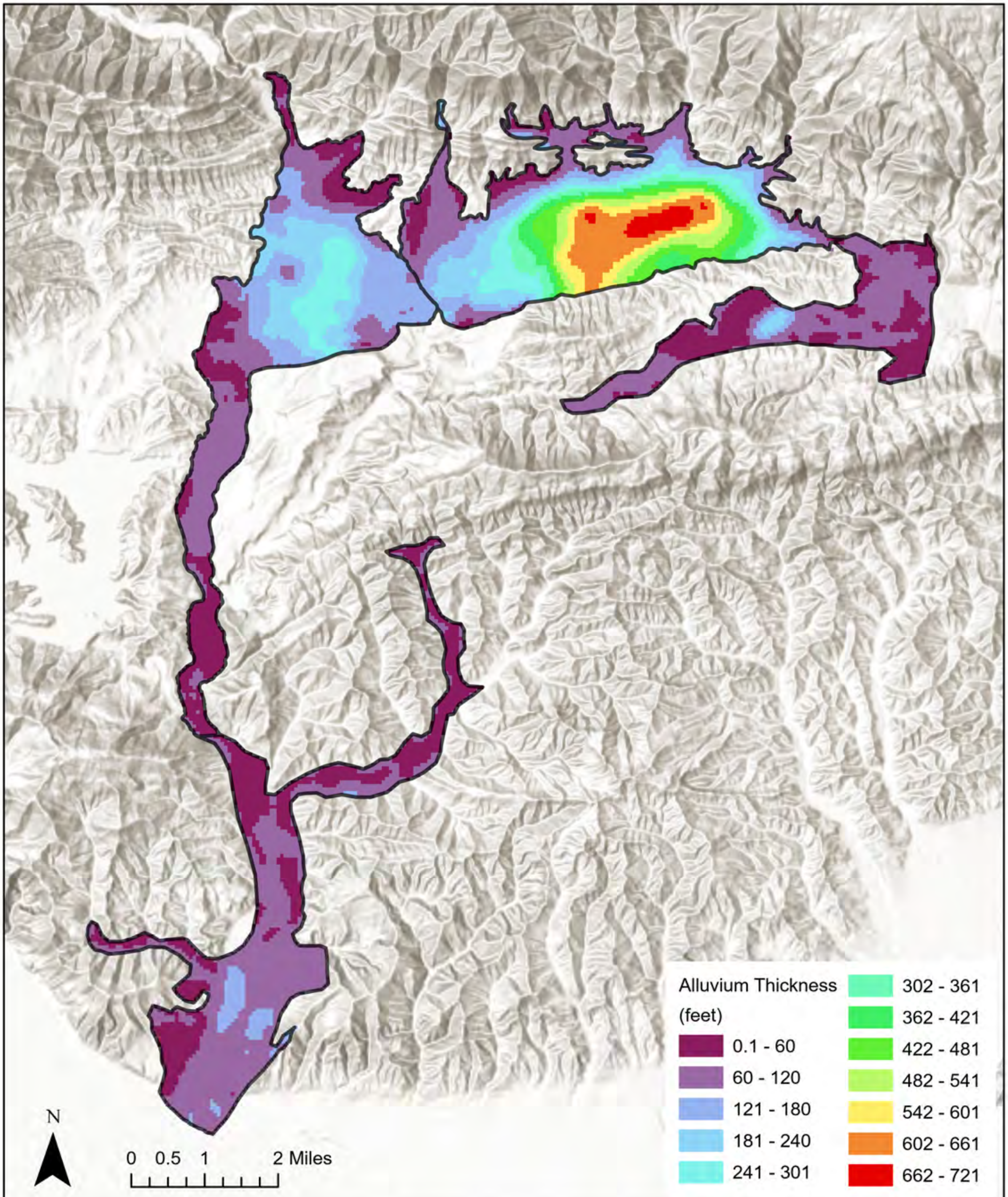


Figure 7. Model Alluvium Thickness

Figure 8. General Head Boundaries (GHB) and Horizontal Flow Barrier (HFB) Locations

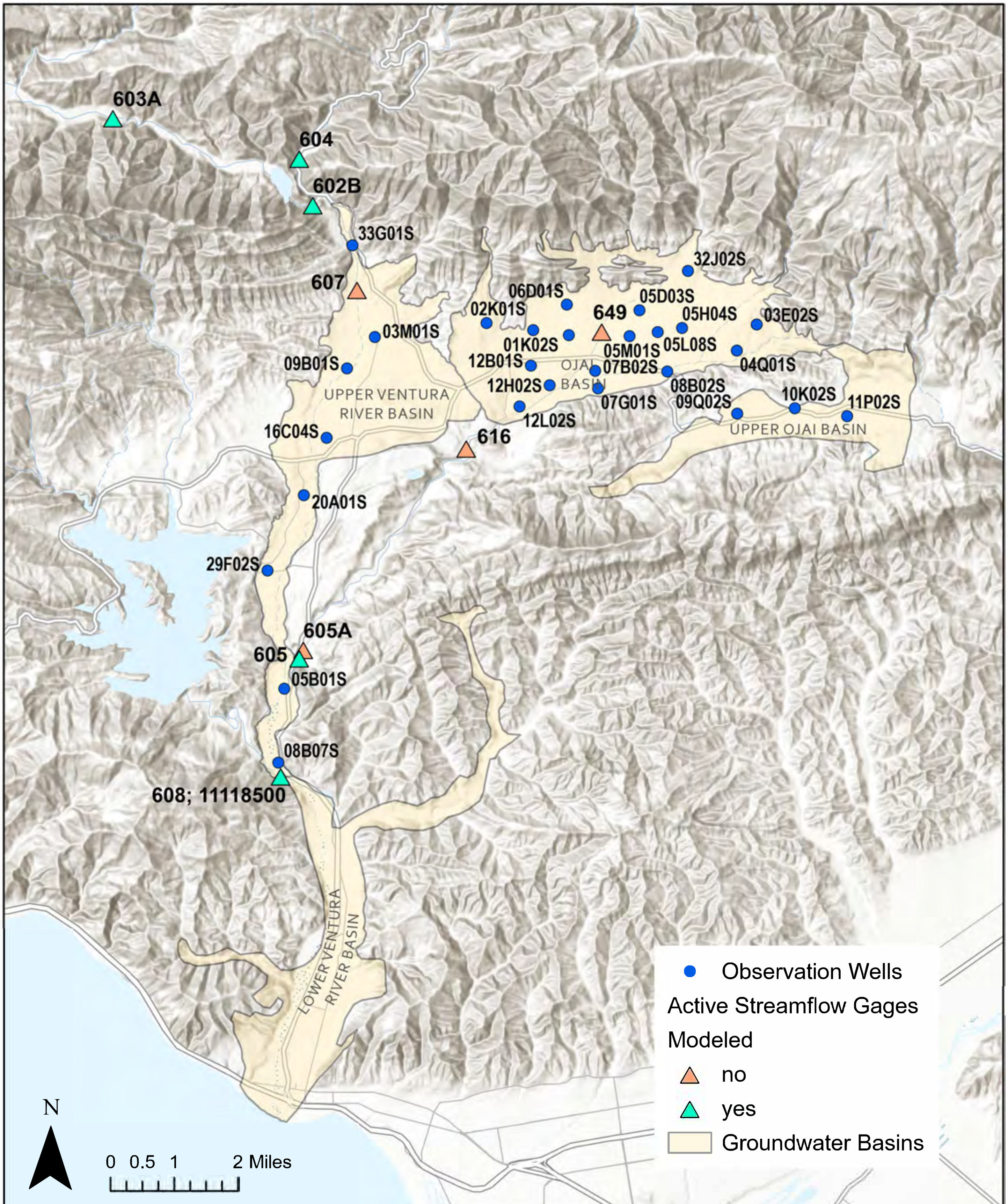


Figure 9. Observation Wells and Streamflow Gages within the Model Domain

Only observation wells with data available during the calibration period are displayed. Streamflow gages are displayed that are both included in the model as SFR input data or calibration points or gages that are not included because data is not available during the calibration period.

Data Sources: CA DWR Water Data Library
USGS Streamflow Gaging
VCWPD Hydrodata Server

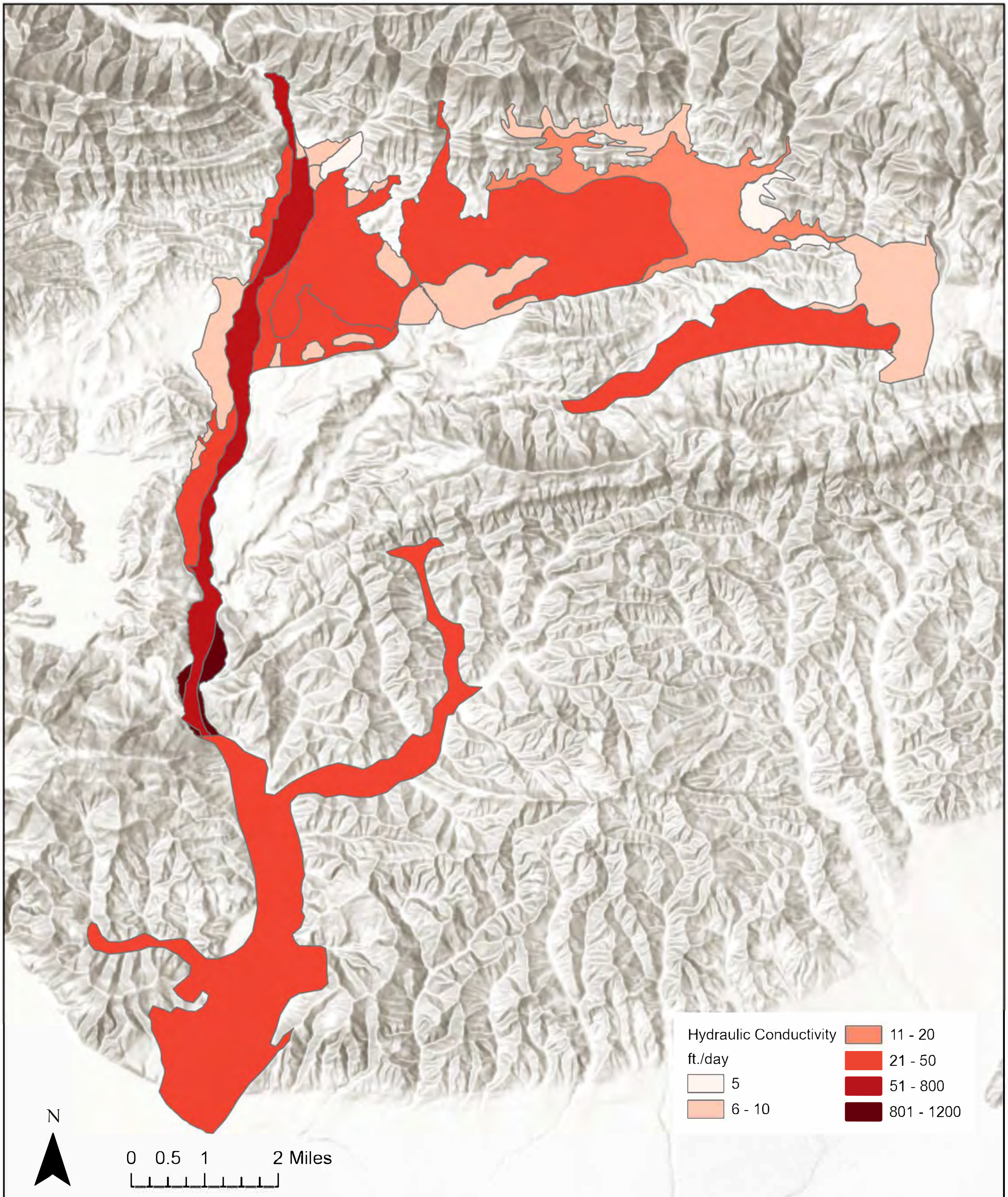


Figure 10. Horizontal Hydraulic Conductivity Zones and Calibrated Values

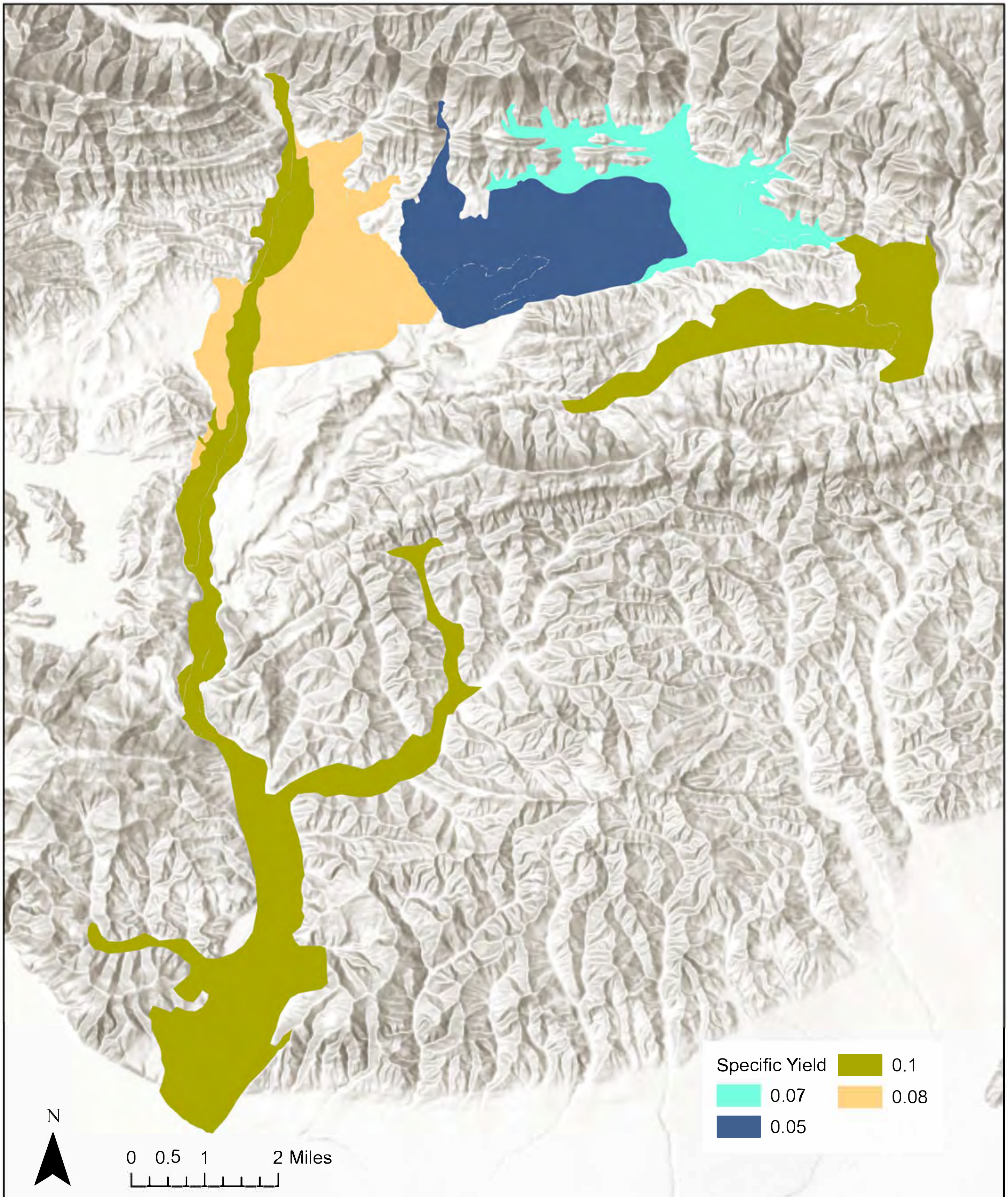


Figure 11. Specific Yield Zones and Calibrated Values

Figure 12. Precipitation Runoff Modeling System (PRMS) Sub-Watershed Extents

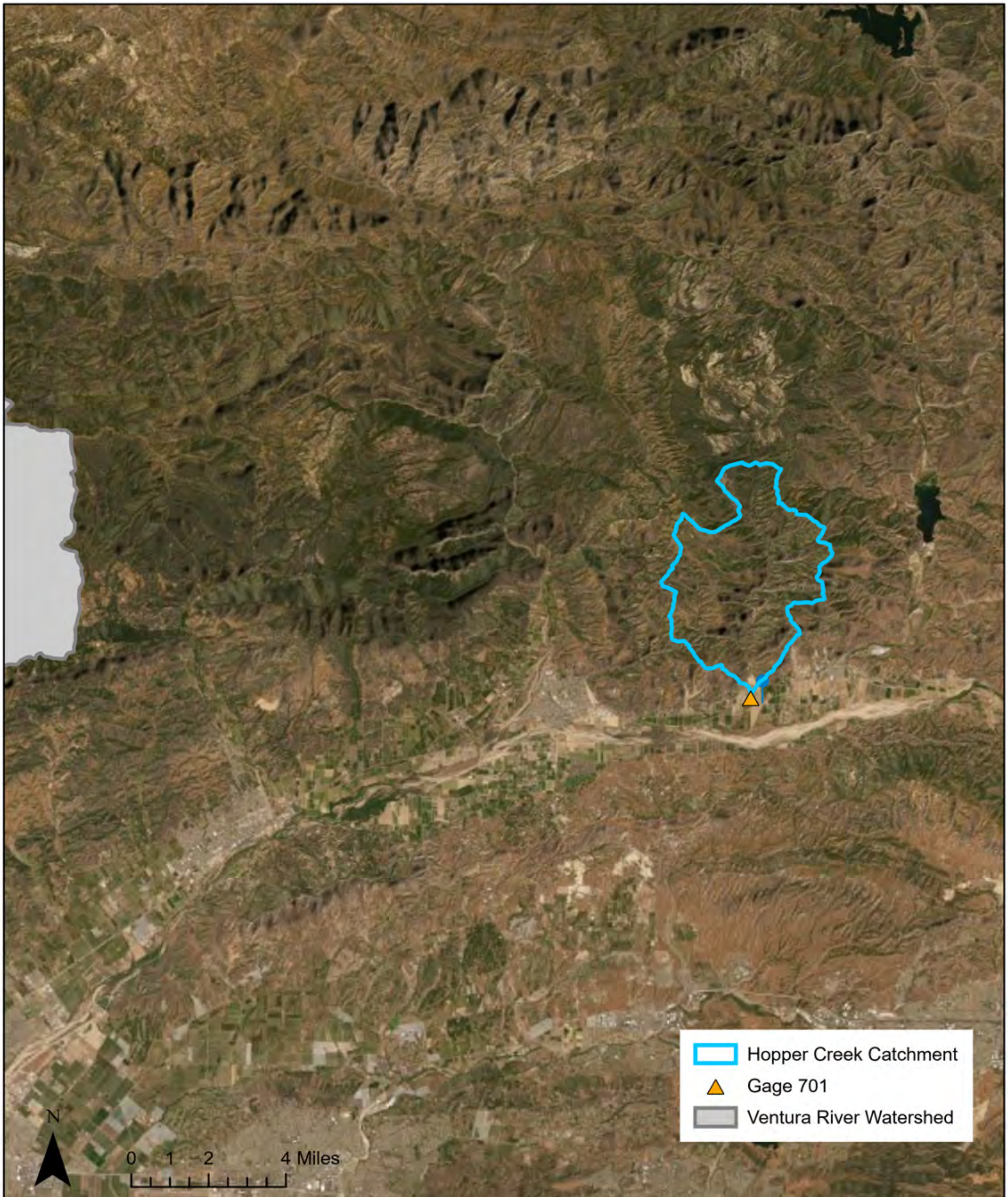


Figure 13. Precipitation Runoff Modeling System (PRMS) Calibration Catchment: VCWPD Gage 701, Hopper Creek at Highway 126 Santa Clara River Watershed

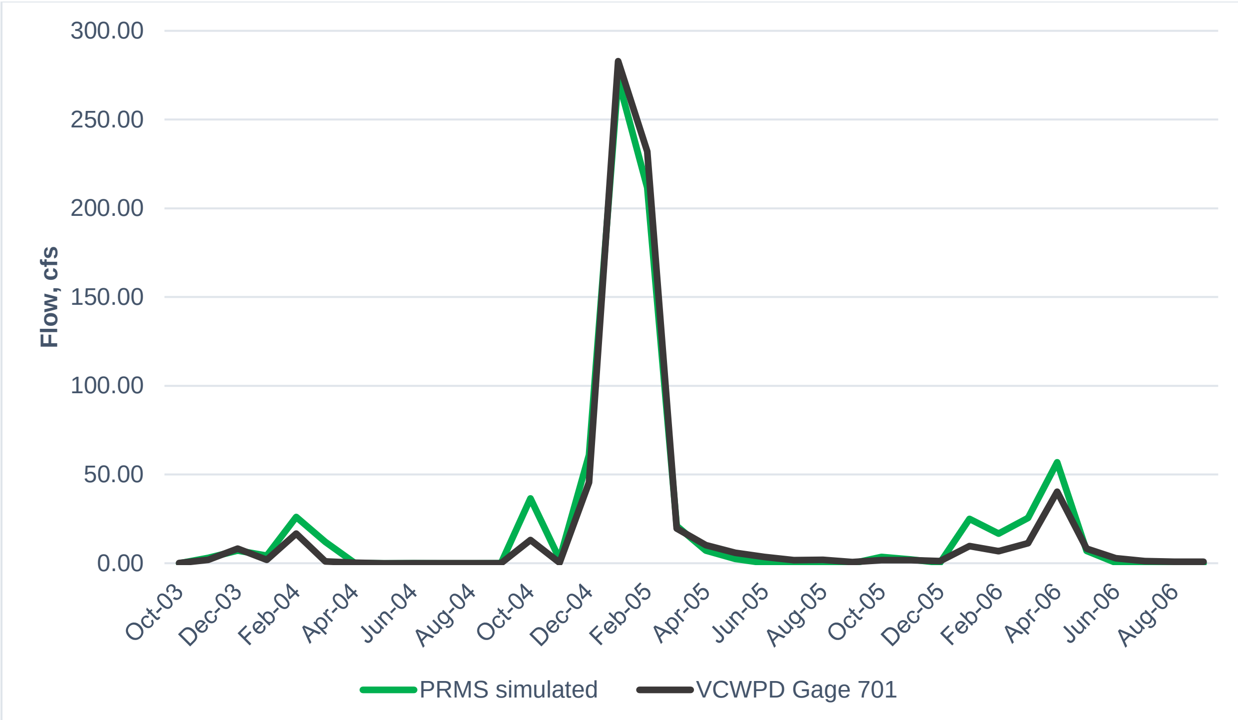


Figure 14. Plot of monthly average streamflow observed at the Ventura County Watershed Protection District (VCWPD) Gage 701, Hopper Creek at Highway 126 versus simulated streamflow by PRMS.

Figure **15**. Streamflow Routing (SFR) Segments and Ojai Valley Sanitation District (OVSD) Treated Sewage Effluent Outfall Location

Data Sources: CA RWQCB NPDES Permit Number CA0053961

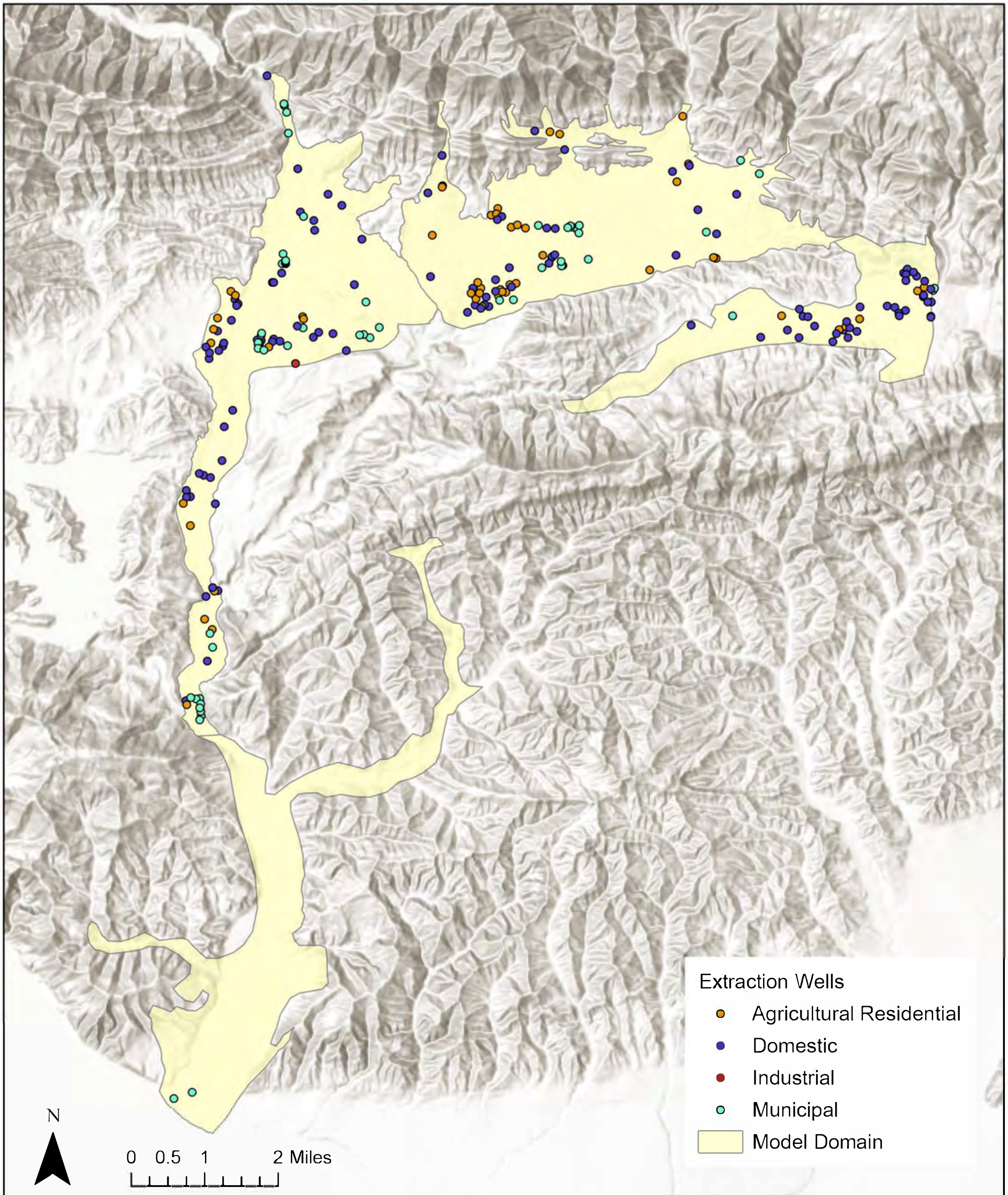


Figure 16. Modeled Extraction Wells and Well Categories

Data Sources: Ventura County Watershed Protection District
(VCWPD) GIS database: 2018 Ventura Watershed Well Inventory

Figure 17. Mountain Front Recharge (MFR) Segments

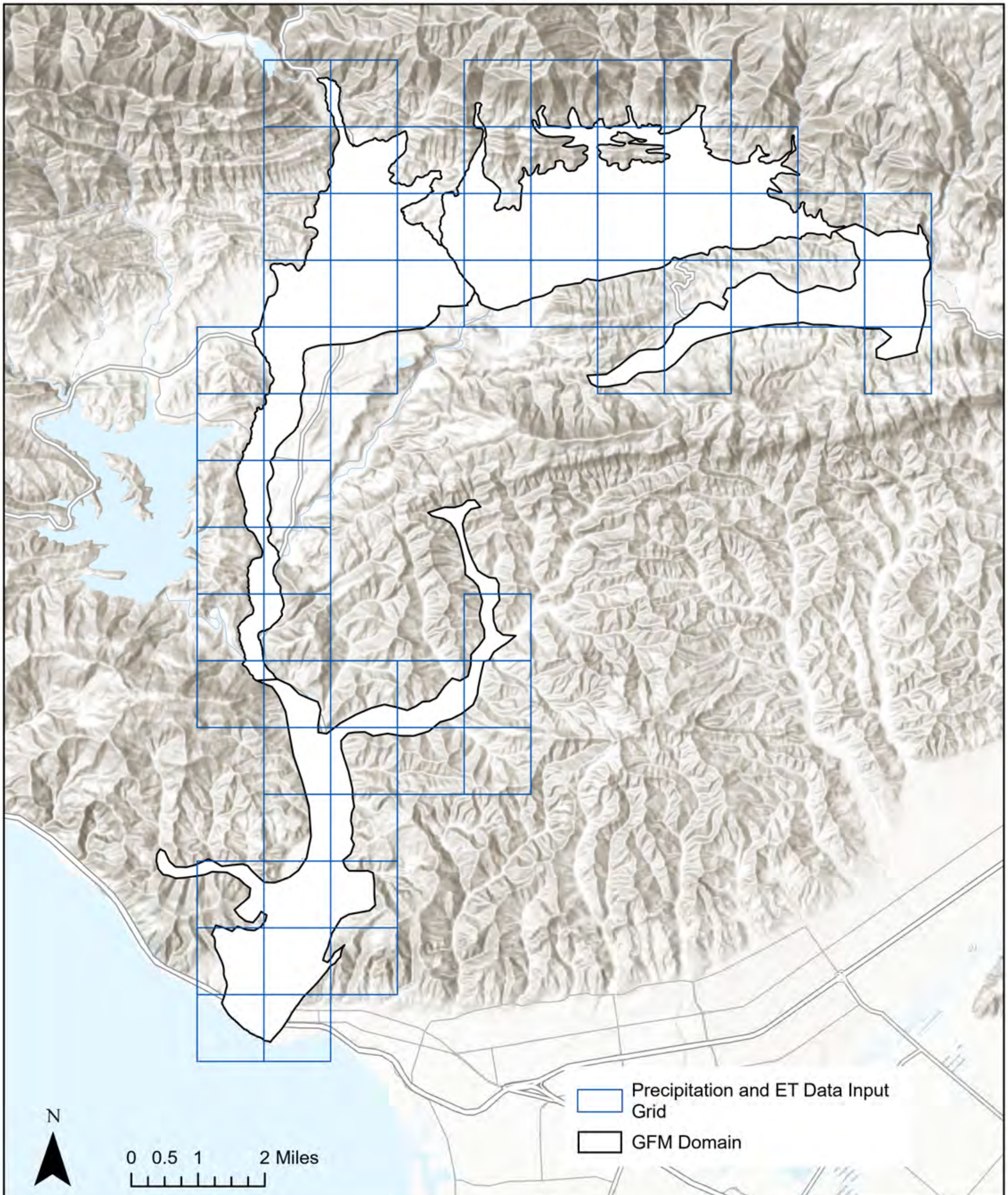


Figure 18. Precipitation and Evapotranspiration Data Input Grid.

Grid size is 1000 ft. by 1000 ft.

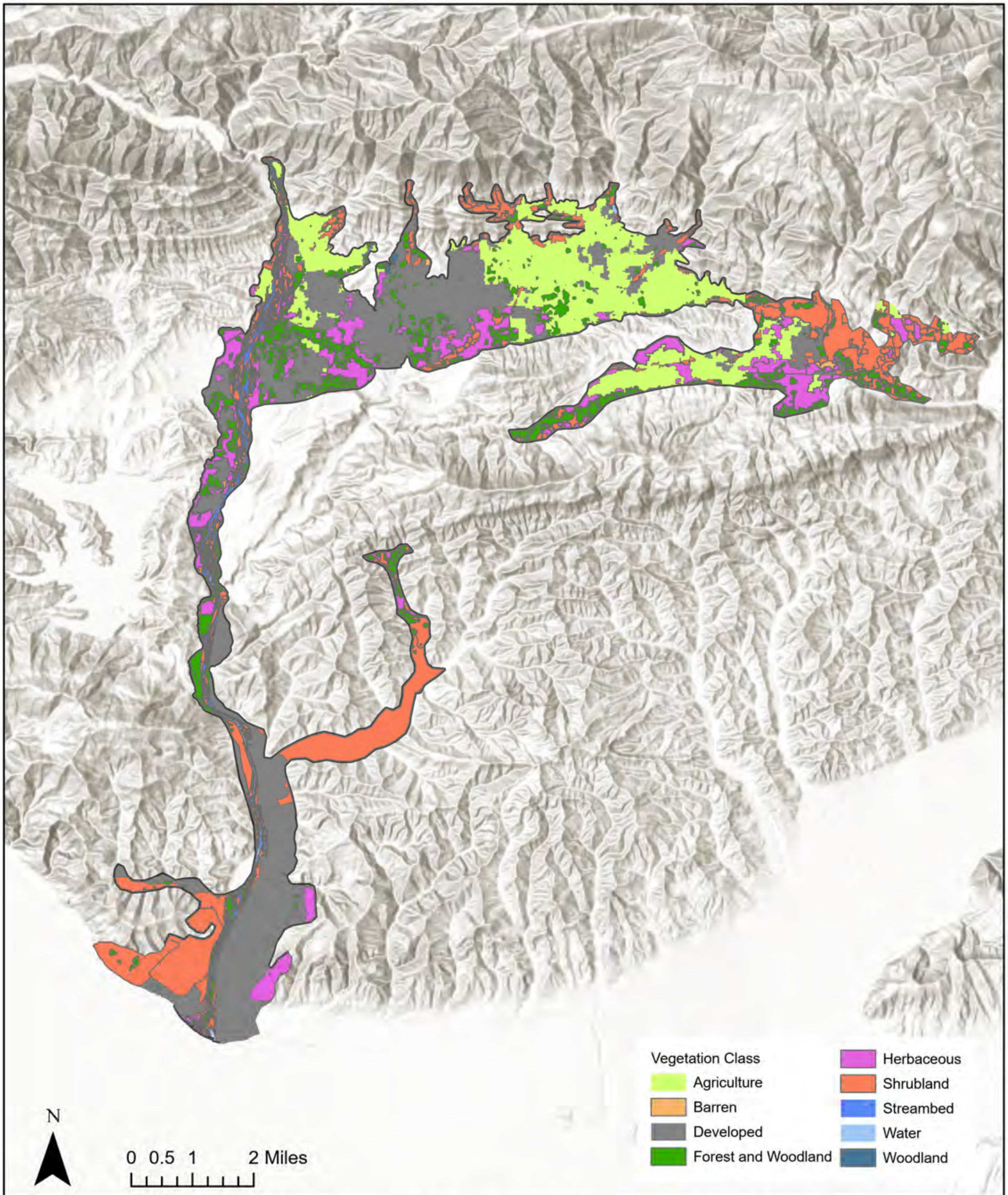


Figure 19. Vegetation Classes within the Model Domain.

Vegetation classes are from the International Vegetation Classification (IVC)
Data Source: Ventura County Vegetation GIS Database, David Magney Environmental Consulting, 2008

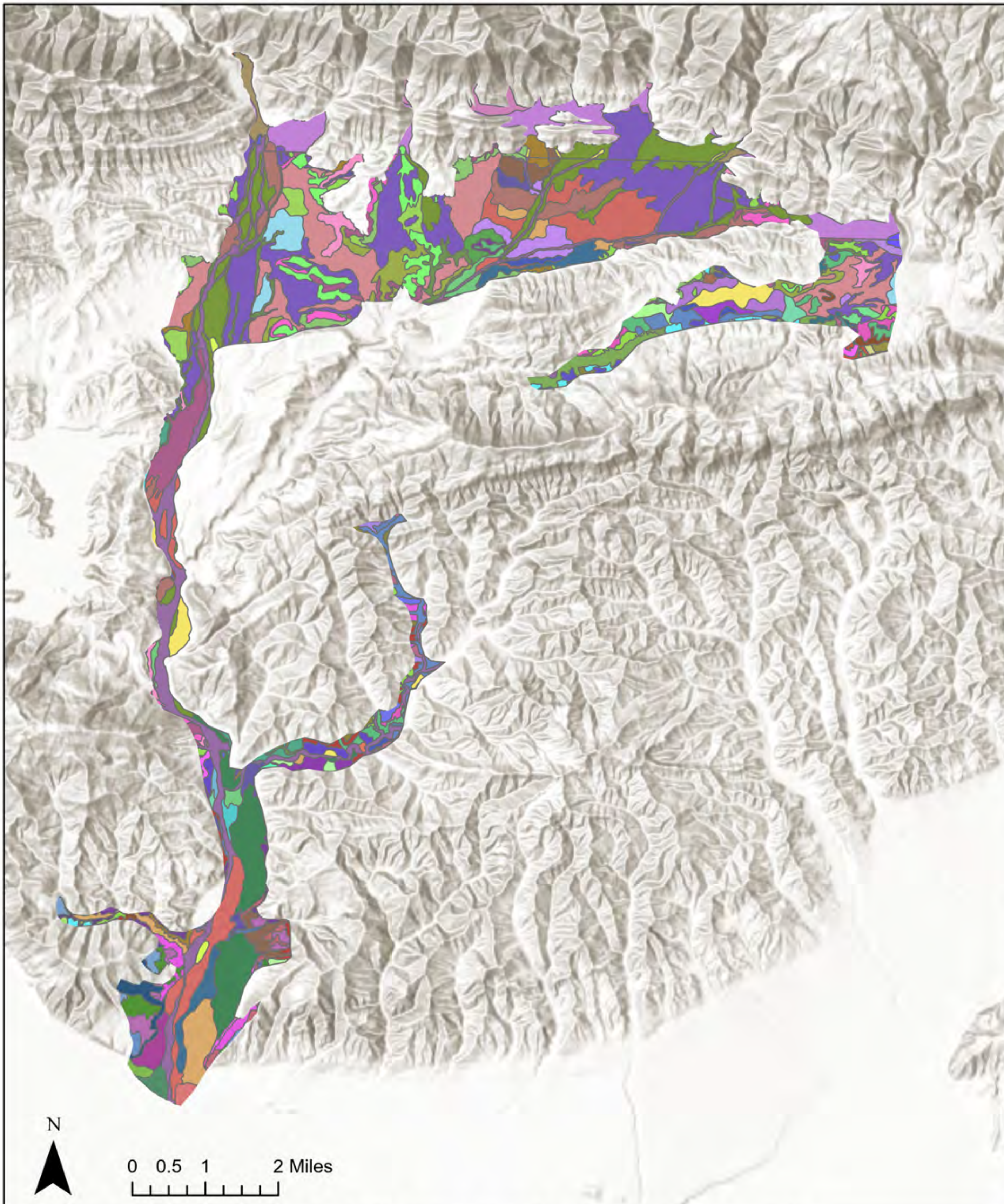


Figure 20. Soil Types within the Model Domain.

Legend is included on Page 2.

Data Source: SSURGO Soils Database, U. S. Department of Agriculture (2016)

Soil Type

- Anacapa gravelly sandy loam, 2 to 9 percent slopes
- Anacapa sandy loam, 2 to 9 percent slopes
- Arnold sand, 9 to 50 percent slopes
- Azule gravelly loam, 5 to 9 percent slopes
- Azule loam, 0 to 5 percent slopes
- Azule loam, 2 to 9 percent slopes, eroded
- Azule loam, 9 to 15 percent slopes
- Badland
- Calleguas shaly loam, 30 to 50 percent slopes
- Calleguas-Arnold complex, 30 to 50 percent slopes, erod ed
- Camarillo loam
- Camarillo loam, sandy substratum
- Camarillo sandy loam
- Castaic-Balcom complex, 30 to 50 percent slopes, eroded
- Coastal beaches
- Cortina stony sandy loam, 2 to 9 percent slopes
- Cropley clay, 0 to 2 percent slopes
- Cropley clay, 2 to 9 percent slopes
- Diablo clay, 15 to 30 percent slopes
- Diablo clay, 30 to 50 percent slopes
- Diablo clay, 9 to 15 percent slopes
- Garretson gravelly loam, 2 to 9 percent slopes
- Garretson loam, 2 to 9 percent slopes
- Garretson silt loam, calcareous variant, 2 to 5 percent slopes
- Gazos silty clay loam, 15 to 30 percent slopes
- Gazos silty clay loam, 30 to 50 percent slopes
- Gazos silty clay loam, 50 to 75 percent slopes
- Gullied land
- Huerhuero very fine sandy loam, 0 to 5 percent slopes
- Huerhuero very fine sandy loam, 5 to 9 percent slopes, eroded
- Huerhuero very fine sandy loam, 9 to 15 percent slopes, eroded
- Inks-Lodo-Agua Dulce families complex, 30 to 80 percent slopes
- Kimball sandy loam, 2 to 9 percent slopes, eroded
- Kimball sandy loam, 9 to 15 percent slopes, eroded
- Landslides
- Linne silty clay loam, 15 to 30 percent slopes, eroded
- Linne silty clay loam, 30 to 50 percent slopes, eroded
- Linne silty clay loam, 9 to 15 percent slopes, eroded
- Lodo rocky loam, 30 to 50 percent slopes
- Lodo-Livermore-Chualar families association, 30 to 60 percent slopes
- Los Osos clay loam, 15 to 30 percent slopes, eroded
- Los Osos clay loam, 30 to 50 percent slopes
- Los Osos clay loam, 9 to 15 percent slopes, eroded
- Malibu loam, 15 to 30 percent slopes, eroded
- Malibu loam, 30 to 50 percent slopes
- Malibu loam, 9 to 15 percent slopes, eroded
- Metz loamy fine sand, 0 to 2 percent slopes
- Metz loamy fine sand, 2 to 9 percent slopes
- Metz loamy sand, 2 to 9 percent slopes
- Millerton-Millsholm families-Rock outcrop complex, 30 to 80 percent slopes
- Millsholm loam, 15 to 50 percent slopes
- Mocho clay loam, 0 to 2 percent slopes
- Mocho clay loam, 2 to 5 percent slopes
- Mocho gravelly loam, 2 to 9 percent slopes
- Mocho loam, 0 to 2 percent slopes
- Mocho loam, 2 to 9 percent slopes
- Nacimiento silty clay loam, 15 to 30 percent slopes, er oded
- Nacimiento silty clay loam, 30 to 50 percent slopes
- Nacimiento silty clay loam, 9 to 15 percent slopes, ero ded
- Ojai stony fine sandy loam, 15 to 30 percent slopes, er oded
- Ojai stony fine sandy loam, 2 to 15 percent slopes, ero ded
- Ojai very fine sandy loam, 0 to 2 percent slopes
- Ojai very fine sandy loam, 2 to 9 percent slopes, erode d
- Ojai very fine sandy loam, 9 to 15 percent slopes, erod ed
- Orthents-Fluvents complex, dry, 0 to 15 percent slopes
- Pits and dumps
- Rincon silty clay loam, 15 to 30 percent slopes, eroded
- Rincon silty clay loam, 2 to 9 percent slopes
- Rincon silty clay loam, 9 to 15 percent slopes, eroded
- Riverwash
- Salinas clay loam, 0 to 2 percent slopes
- Salinas clay loam, 2 to 9 percent slopes
- San Andreas sandy loam, 30 to 50 percent slopes
- San Benito clay loam, 15 to 30 percent slopes, eroded
- San Benito clay loam, 30 to 50 percent slopes, eroded
- San Benito clay loam, 50 to 75 percent slopes
- San Benito clay loam, 9 to 15 percent slopes, eroded
- Sandy alluvial land
- Santa Lucia shaly silty clay loam, 15 to 30 percent slo pes
- Santa Lucia shaly silty clay loam, 30 to 50 percent slo pes
- Saugus sandy loam, 30 to 50 percent slopes, eroded
- Saugus sandy loam, 5 to 30 percent slopes
- Sedimentary rock land
- Sespe clay loam, 15 to 30 percent slopes, eroded
- Sespe clay loam, 30 to 50 percent slopes
- Sespe clay loam, 50 to 75 percent slopes
- Soper gravelly loam, 30 to 50 percent slopes, eroded
- Soper loam, 15 to 30 percent slopes, eroded
- Sorrento clay loam, heavy variant, 2 to 9 percent slope s
- Sorrento clay loam, heavy variant, 9 to 15 percent slop es
- Sorrento loam, 0 to 2 percent slopes
- Sorrento loam, 2 to 9 percent slopes
- Sorrento silty clay loam, 0 to 2 percent slopes
- Sorrento silty clay loam, 2 to 9 percent slopes
- Terrace escarpments
- Tidal flats
- Water
- Xerofluvents-Xerorthents-Riverwash complex, 0 to 15 percent slopes
- Zamora loam, 2 to 9 percent slopes

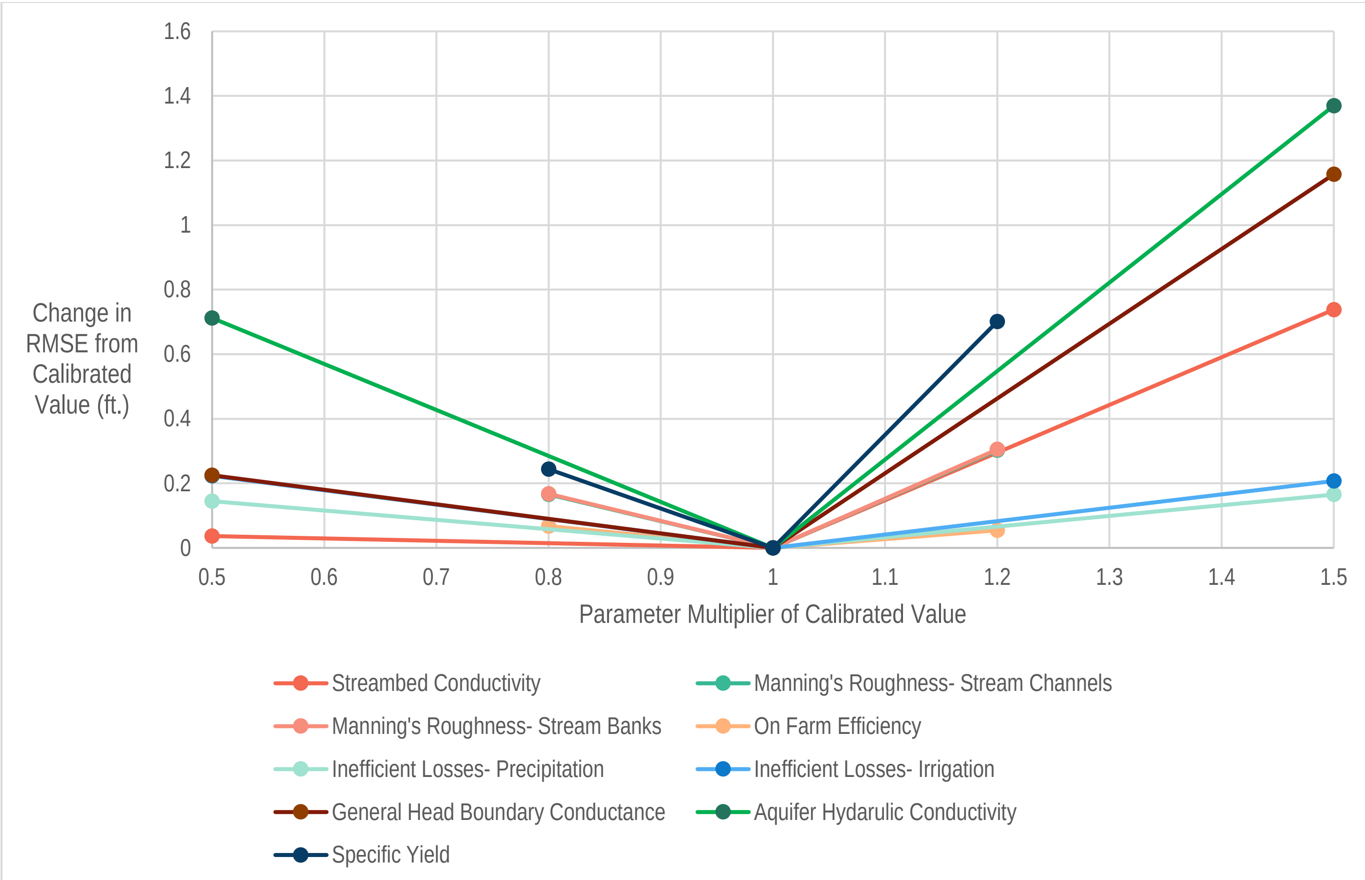


Figure 21. Results of the sensitivity analysis. Calibrated parameters are plotted as the parameter multiplier versus the absolute change in RMSE that resulted from altering the parameter.

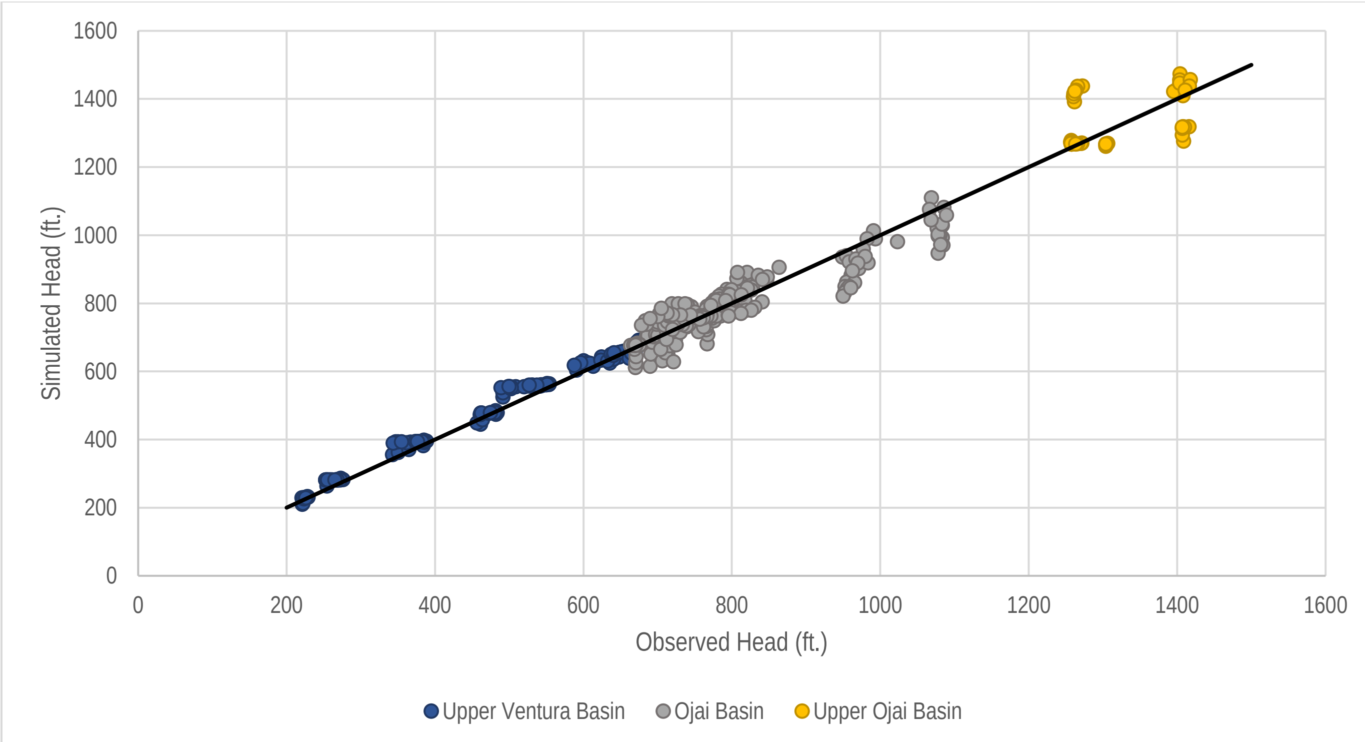


Figure 22. 1:1 plot of observed versus simulated heads during the model calibration period. The black line indicates a 1:1 relationship between heads.

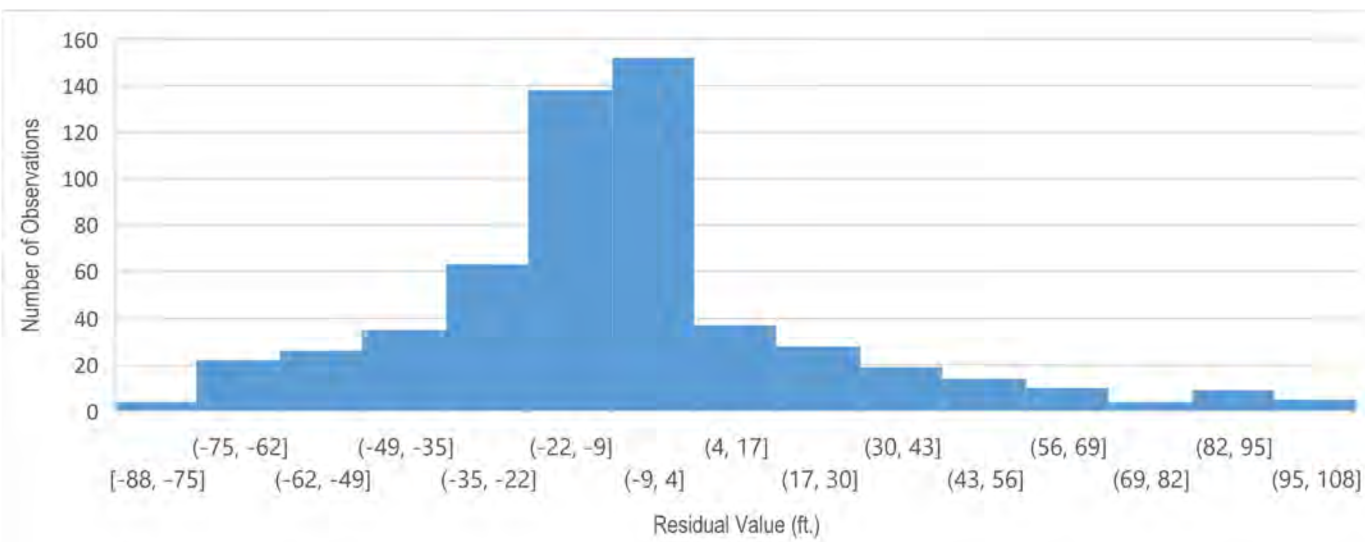


Figure 23. Histogram of all head residuals (observed-simulated) during the model calibration period. Each bar represents the number of observations with residuals in that bin. Residual values for each bin are given on the x-axis, where brackets indicate the upper bound (inclusive) and parentheses indicate the lower bound (exclusive).

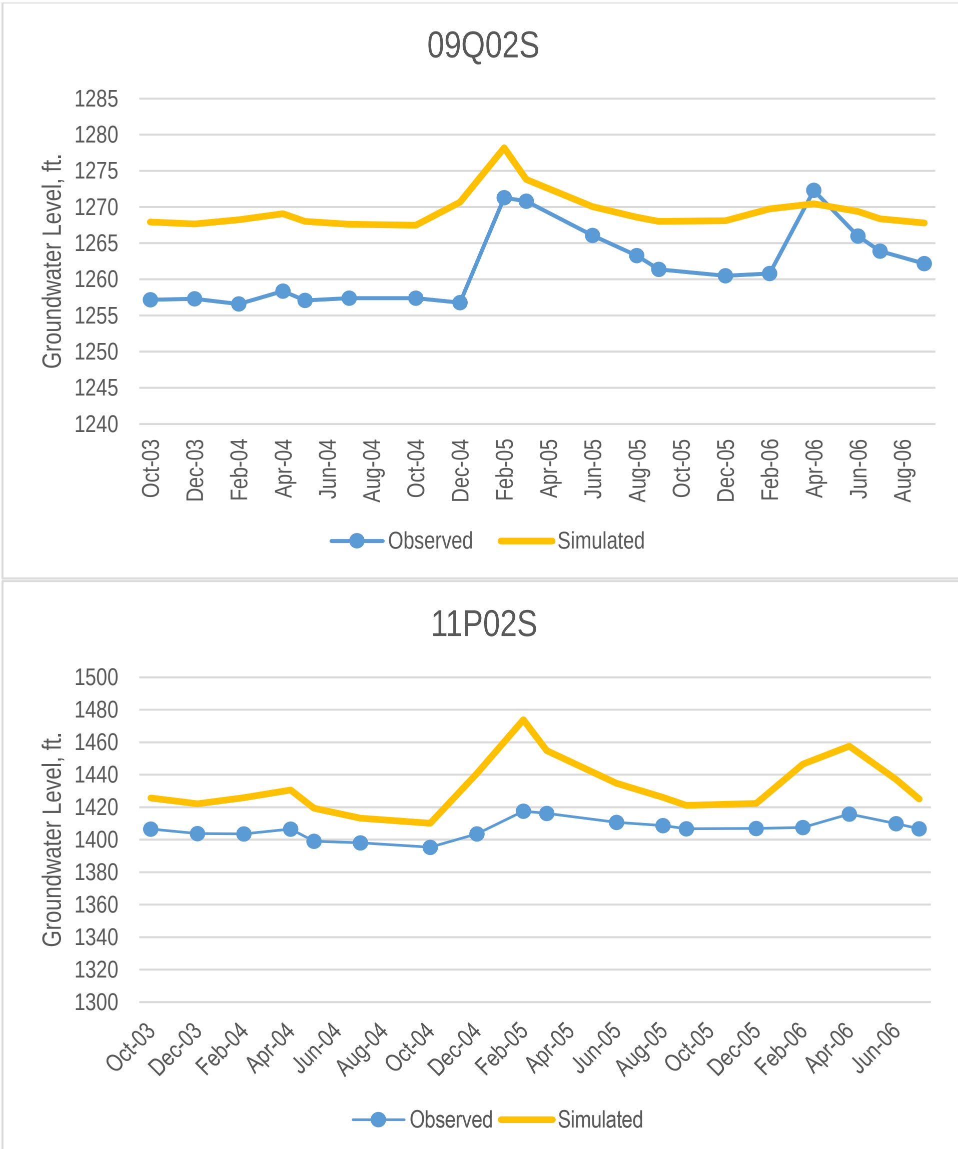
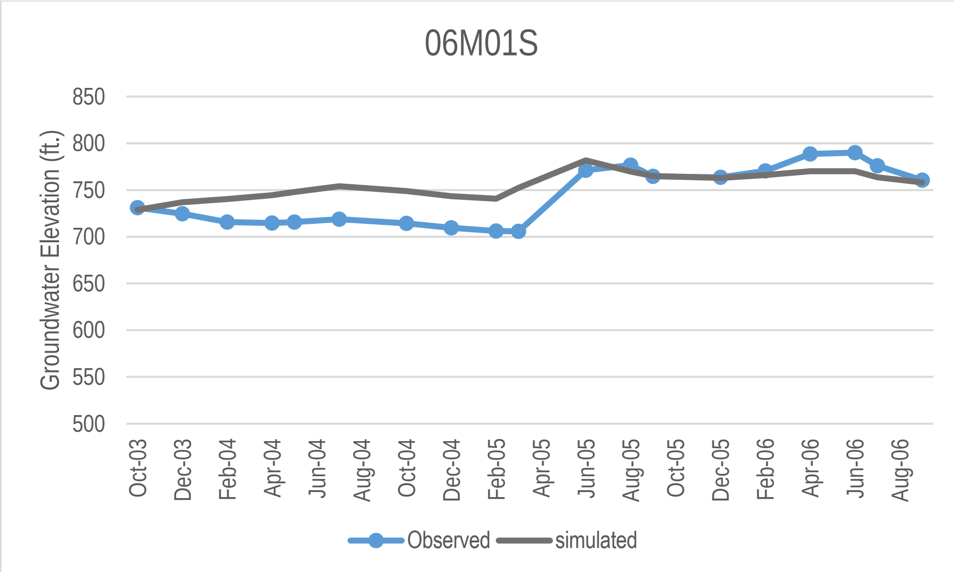
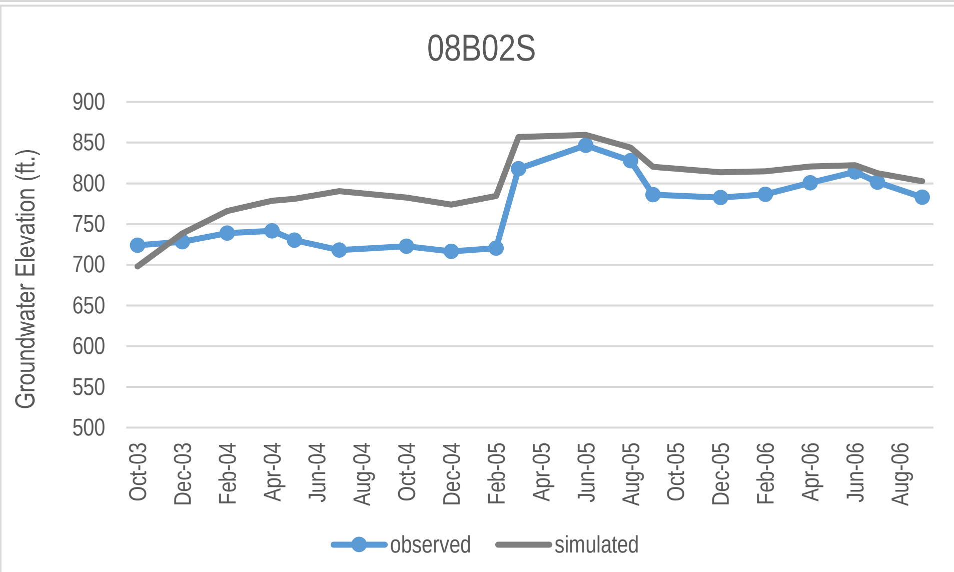
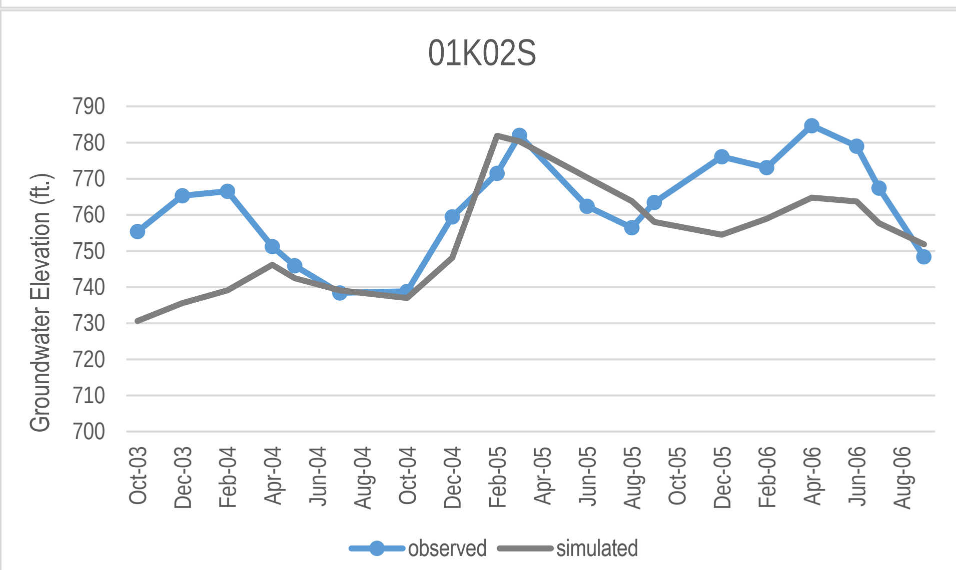
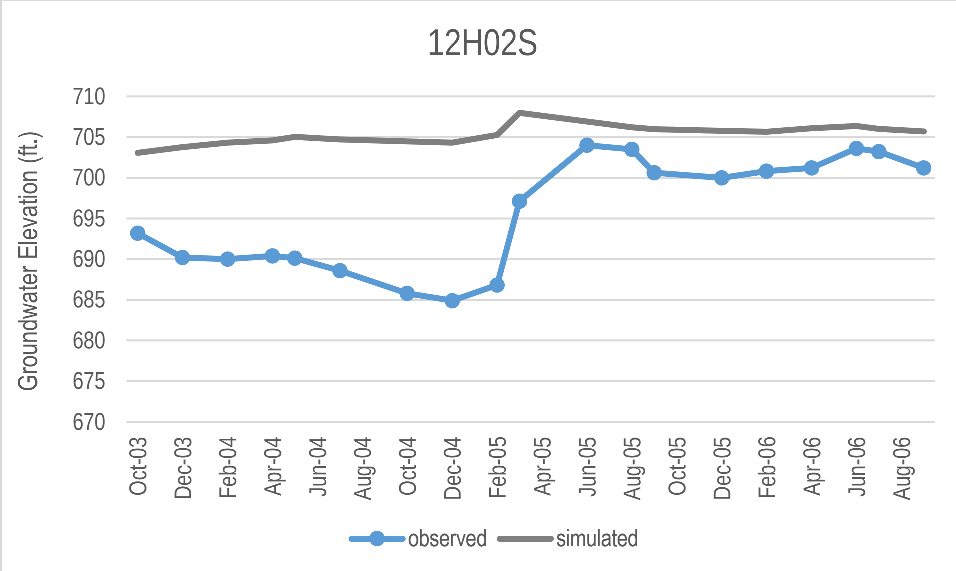


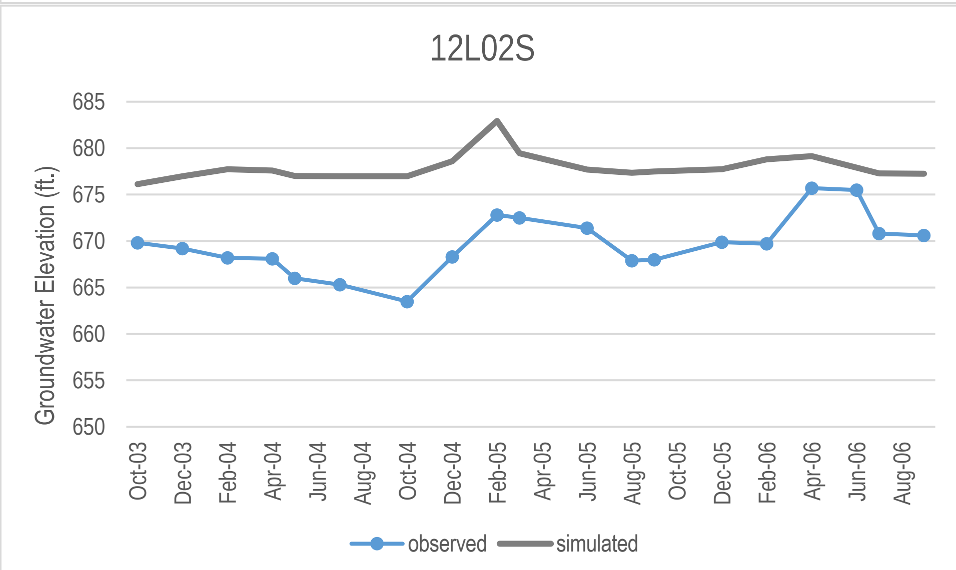
Figure 24a. Individual well hydrographs for observation wells in the Upper Ojai Basin.

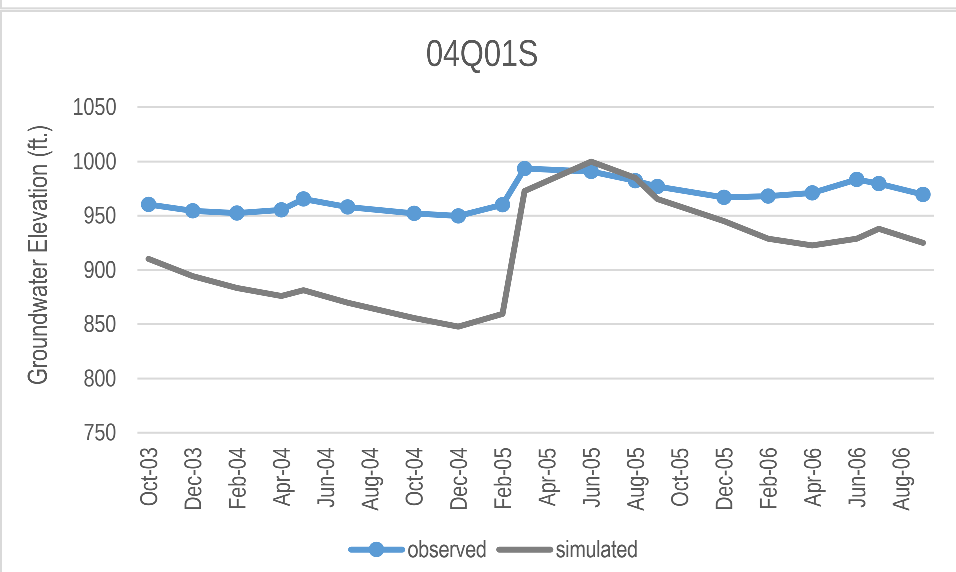

06M01S
Groundwater Elevation (ft.)
850
800
750
700
650
600
550
500
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
Observed
simulated

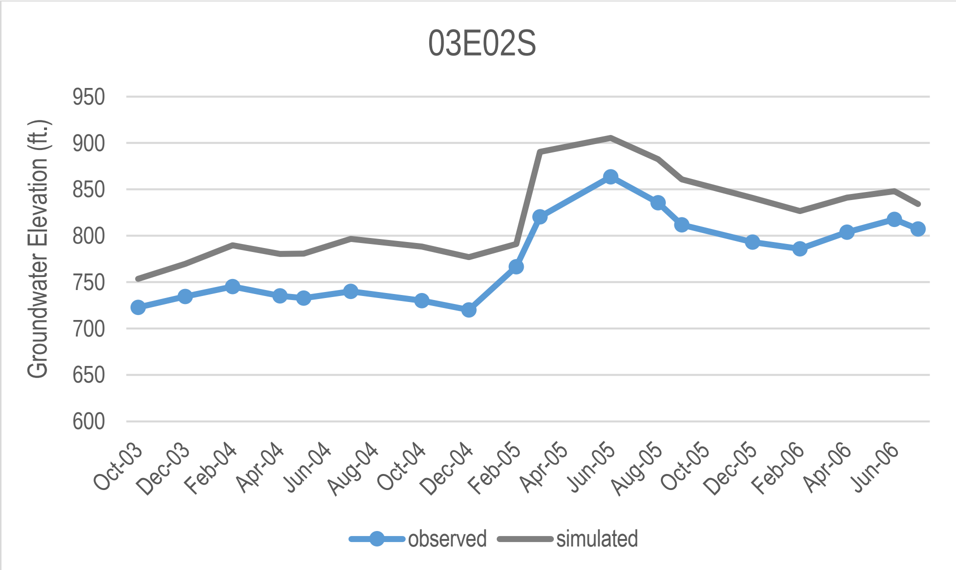

08B02S
Groundwater Elevation (ft.)
900
850
800
750
700
650
600
550
500
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
observed
simulated

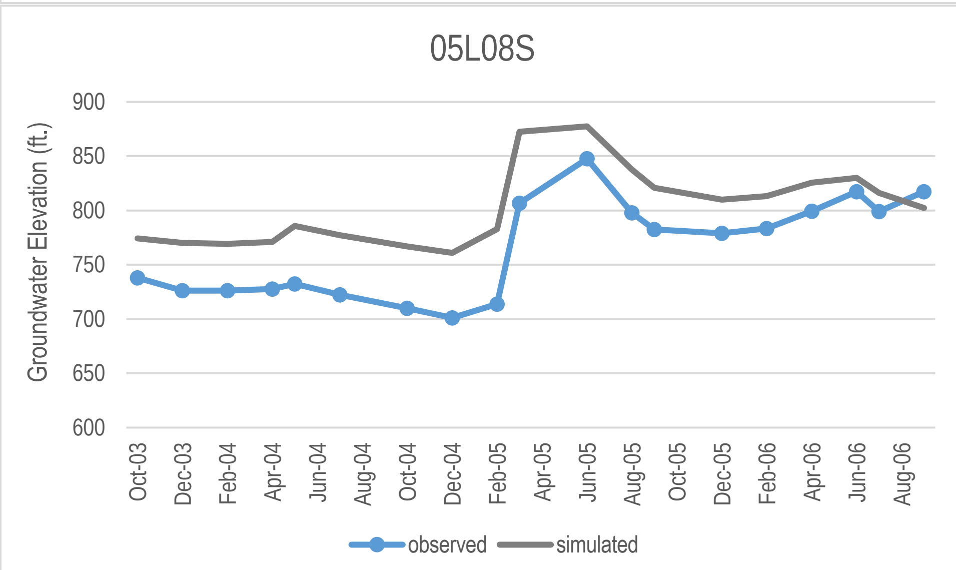

01K02S
Groundwater Elevation (ft.)
790
780
770
760
750
740
730
720
710
700
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
observed
simulated

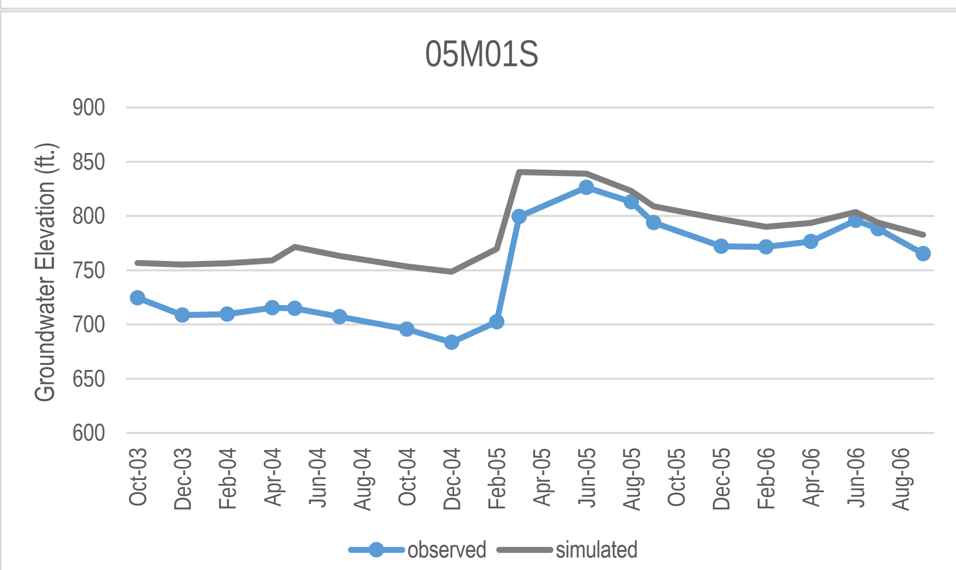

12H02S
Groundwater Elevation (ft.)
710
705
700
695
690
685
680
675
670
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
observed
simulated

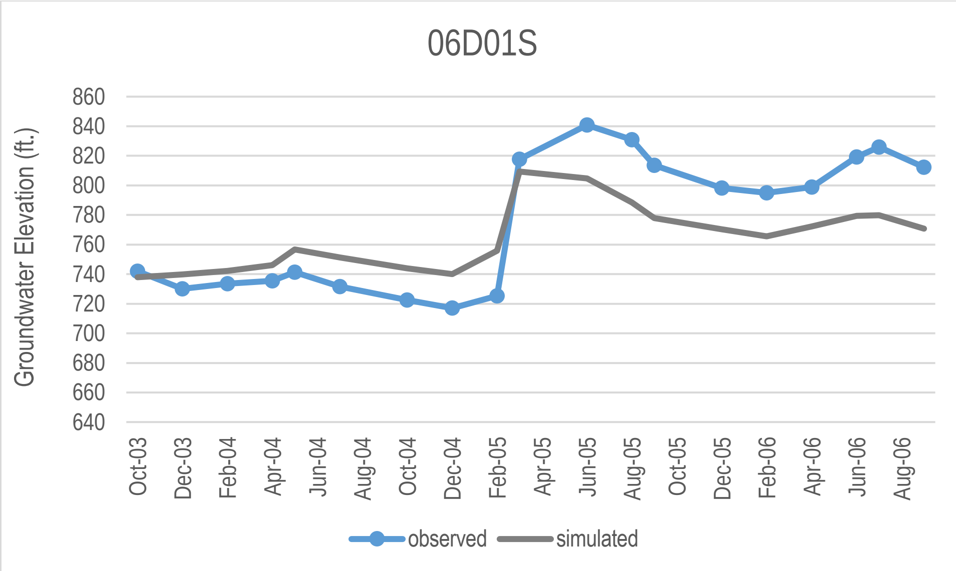

12L02S
Groundwater Elevation (ft.)
685
680
675
670
665
660
655
650
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
observed
simulated

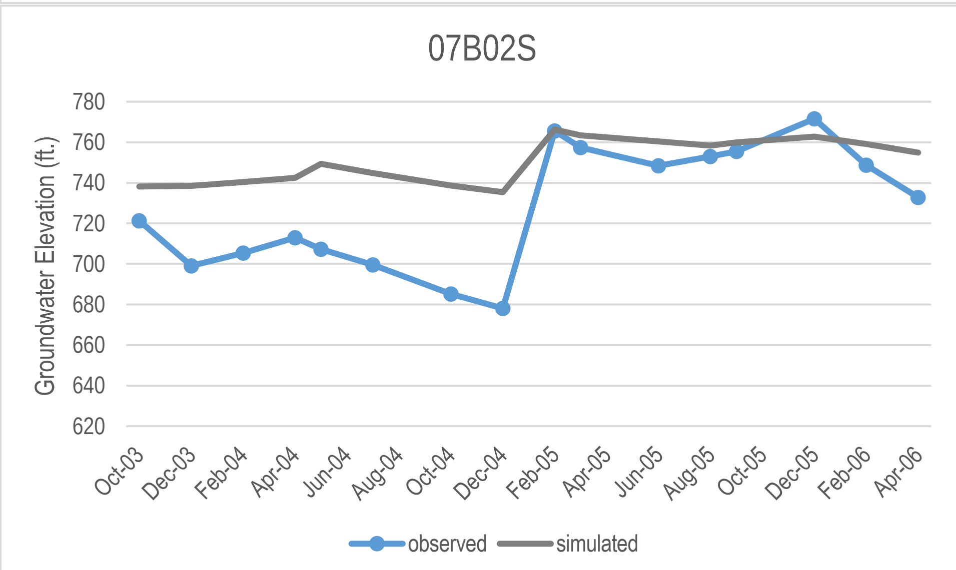

04Q01S
Groundwater Elevation (ft.)
1050
1000
950
900
850
800
750
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
observed
simulated

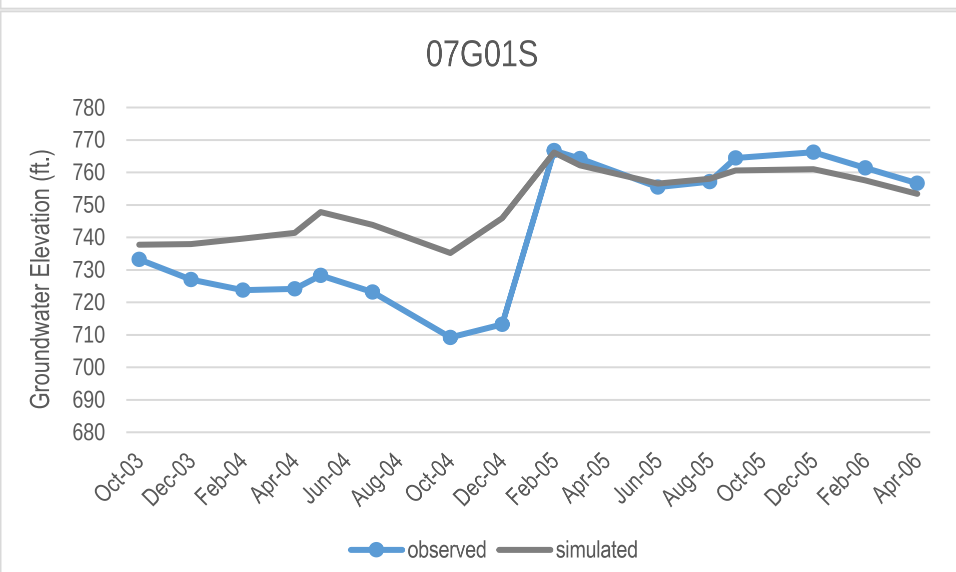

03E02S
Groundwater Elevation (ft.)
950
900
850
800
750
700
650
600
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
observed
simulated

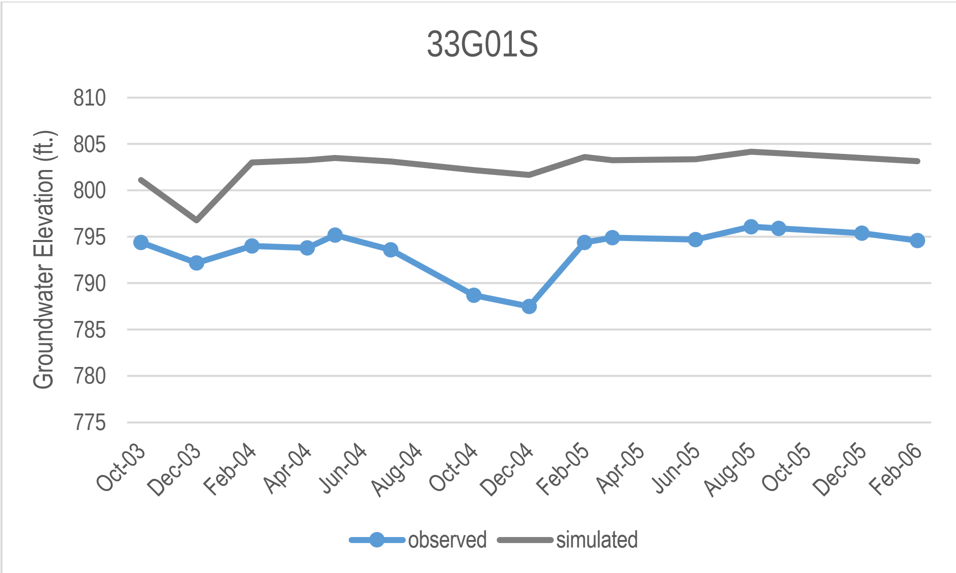

05L08S
Groundwater Elevation (ft.)
900
850
800
750
700
650
600
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
observed
simulated


05M01S
Groundwater Elevation (ft.)
900
850
800
750
700
650
600
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
observed
simulated


06D01S
860
840
820
800
780
760
740
720
700
680
660
640
Groundwater Elevation (ft.)
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
observed
simulated


07B02S
780
760
740
720
700
680
660
640
620
Groundwater Elevation (ft.)
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
observed
simulated


07G01S
780
770
760
750
740
730
720
710
700
690
680
Groundwater Elevation (ft.)
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
observed
simulated



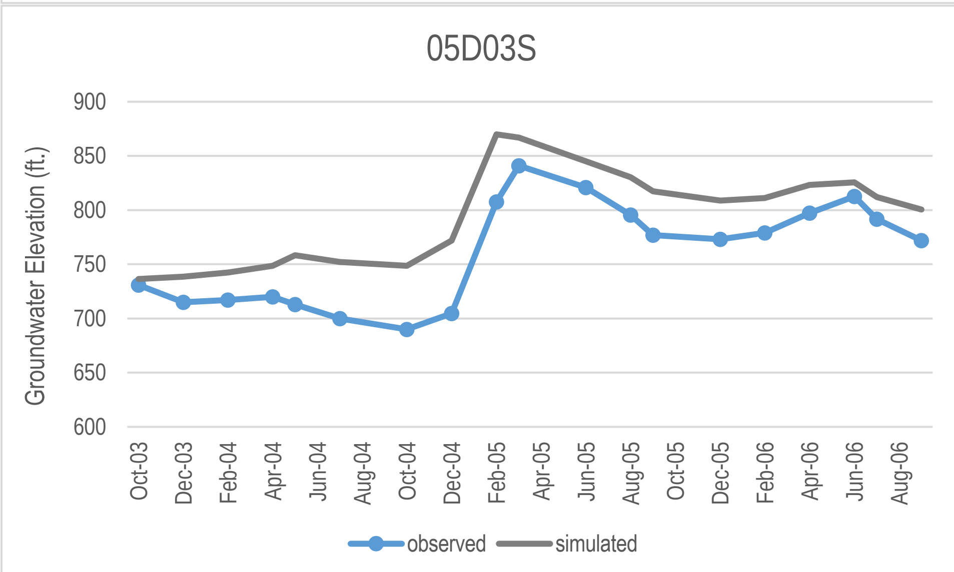
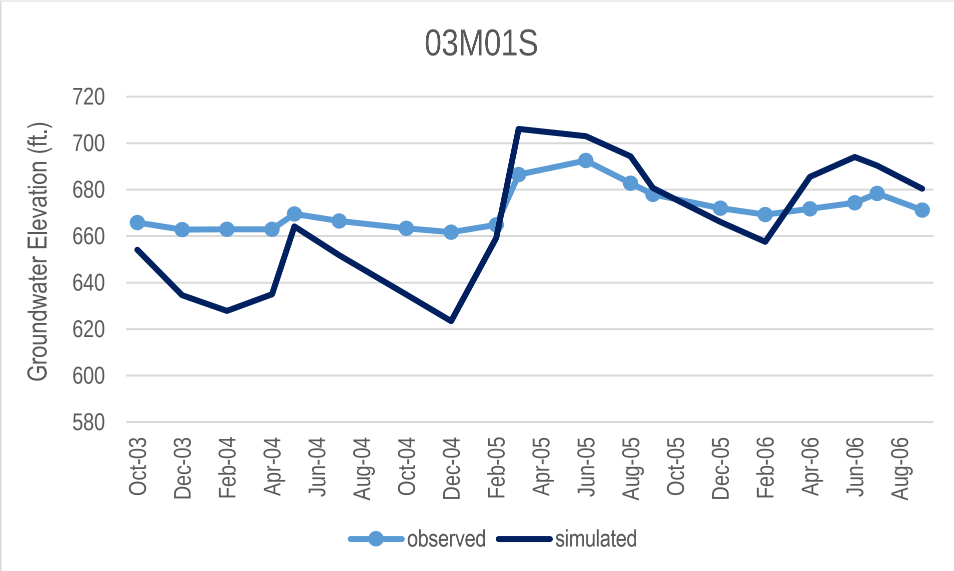
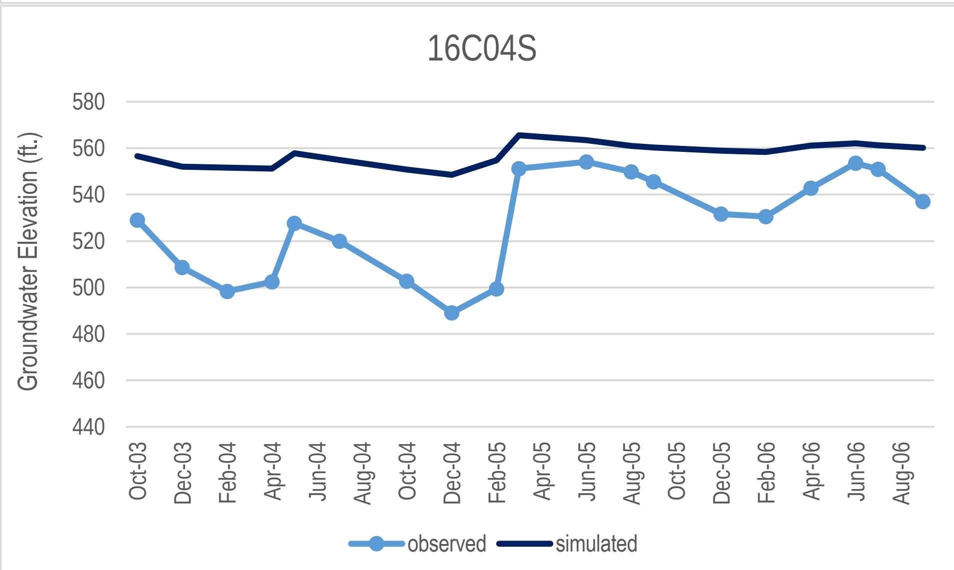
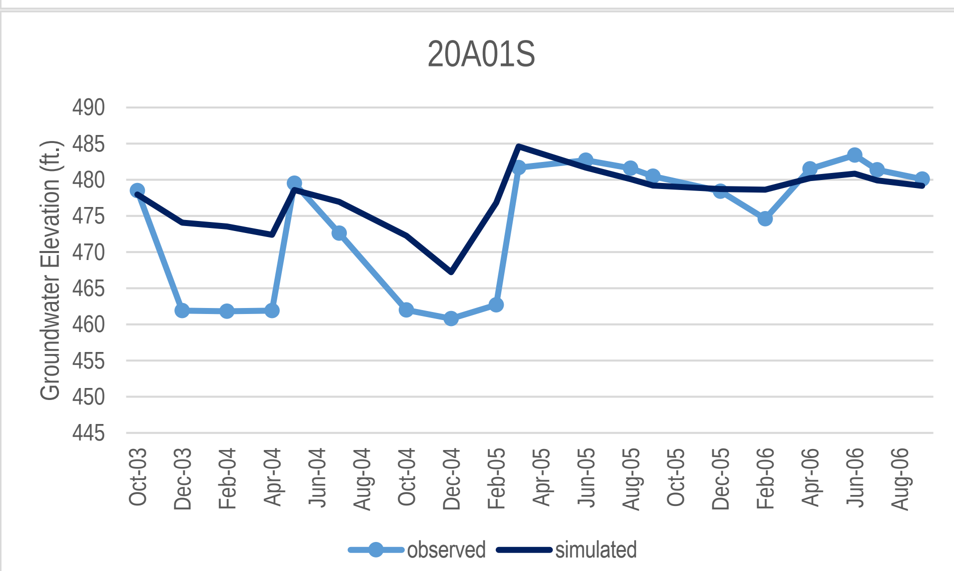
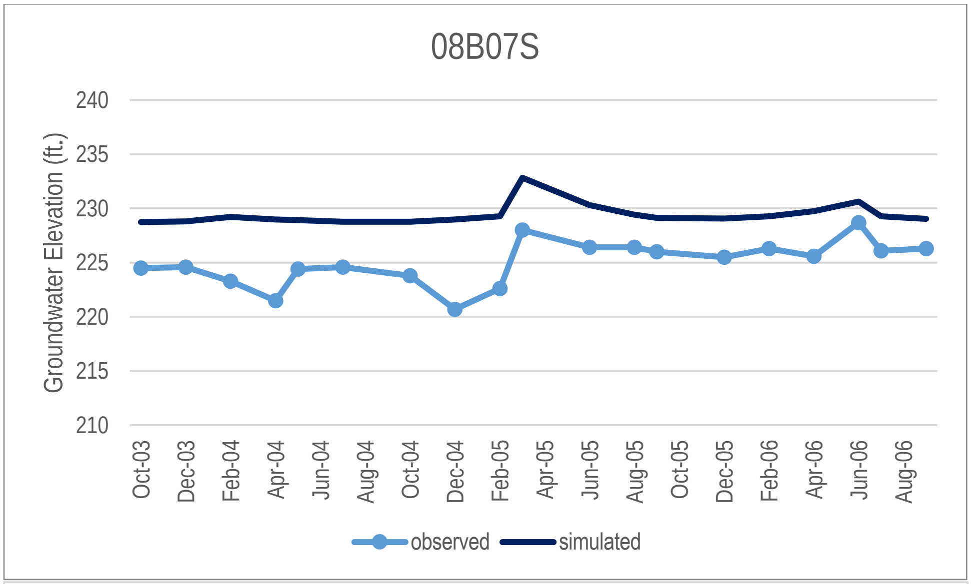


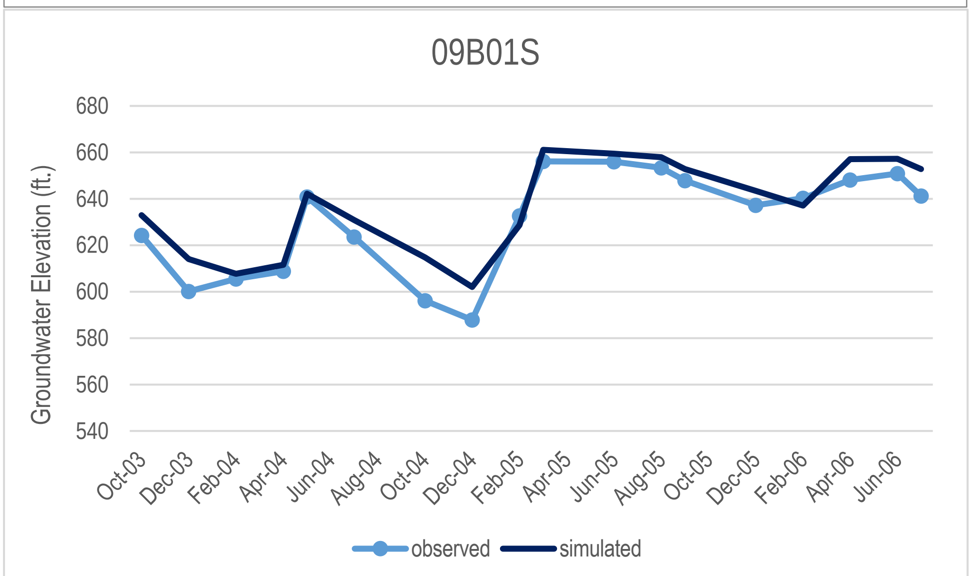
Figure 24b. Individual well hydrographs for observation wells in the Ojai Basin.


03M01S
Groundwater Elevation (ft.)
720
700
680
660
640
620
600
580
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
observed
simulated


16C04S
Groundwater Elevation (ft.)
580
560
540
520
500
480
460
440
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
observed
simulated


20A01S
Groundwater Elevation (ft.)
490
485
480
475
470
465
460
455
450
445
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
observed
simulated





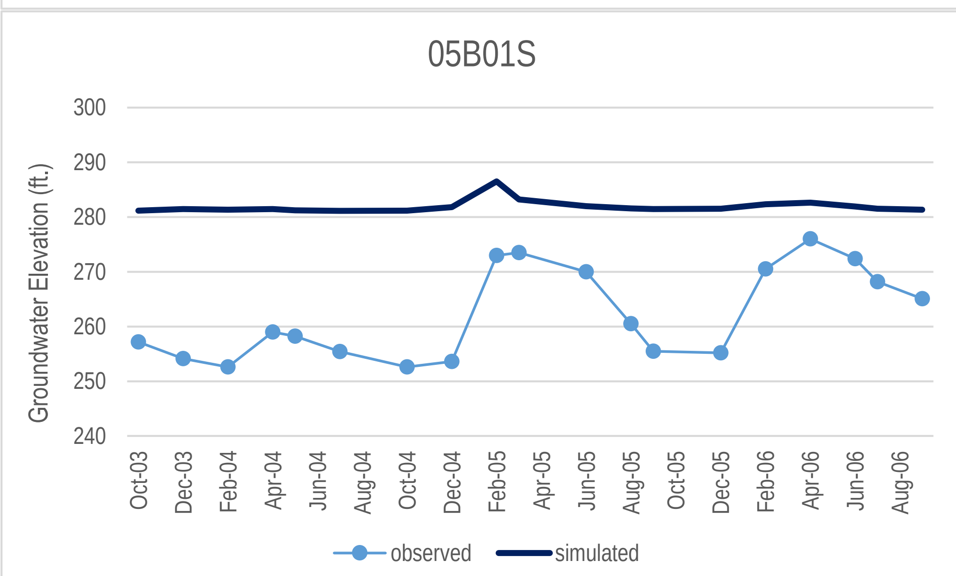


Figure 24c. Individual well hydrographs for observation wells in the Upper Ventura Basin.

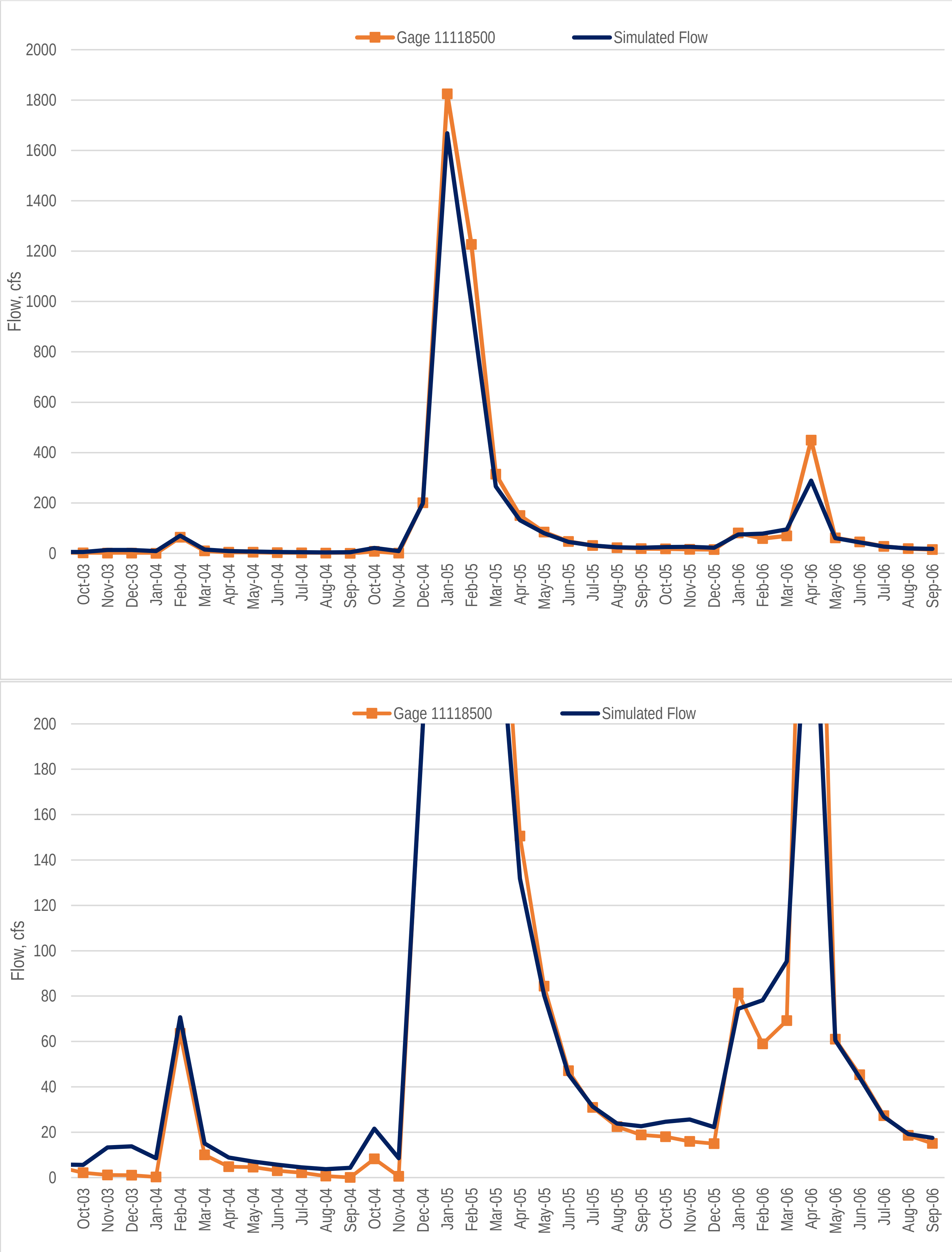


Figure 25a. and b. Average daily flows at USGS gage 11118500 (VCWPD 608) verus model simulated flow at the corresponding SFR segment for each stress period during the calibration period. A shows the full range of flow values, while B shows only flows up to 200 cfs.

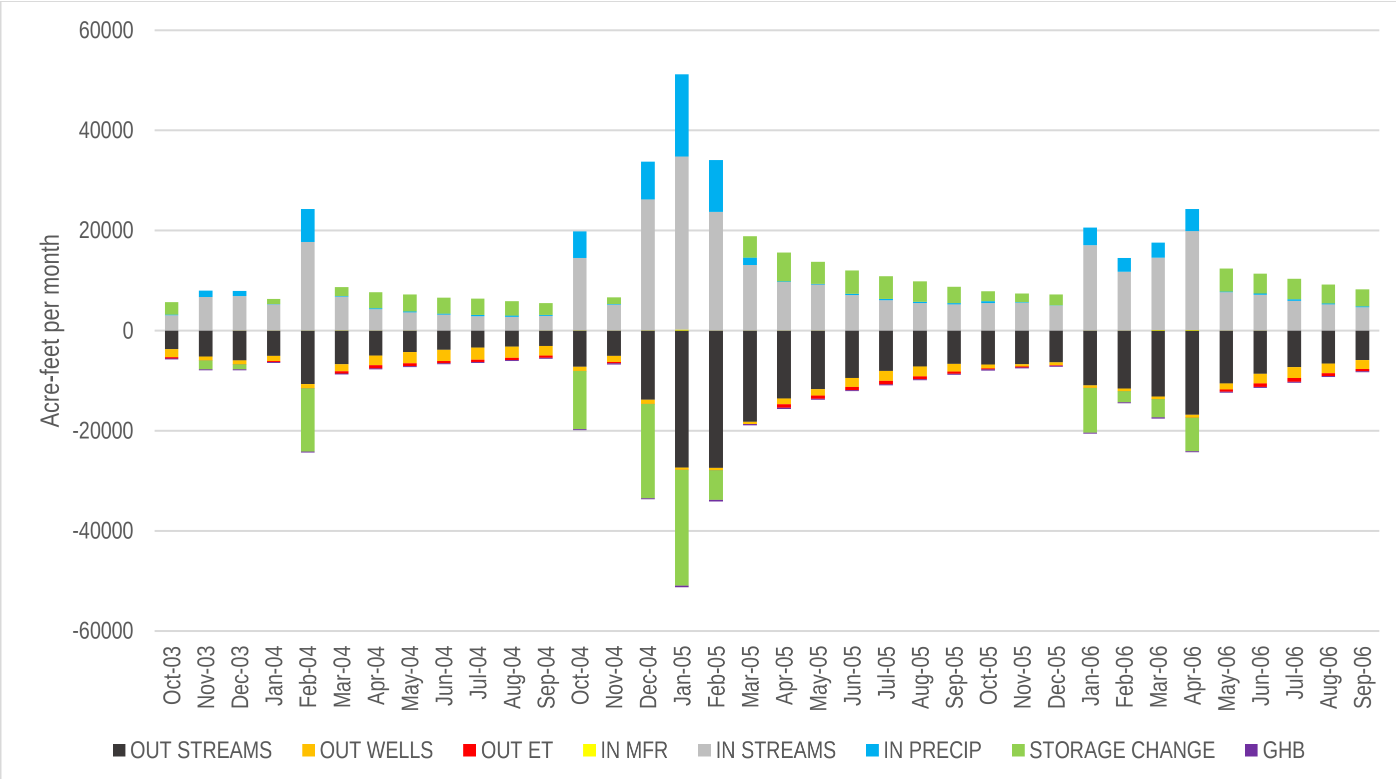


Figure 26. Simulated water budget over the 3 year calibration period. Negative storage change reflect a rising groundwater table; positive storage change indicates a lowering water table. ET= evapotranspiration; MFR= mountain front recharge; GHB= general head boundaries; OUT STREAMS= groundwater contribution to streamflow; IN STREAMS= surface flow contribution to groundwater

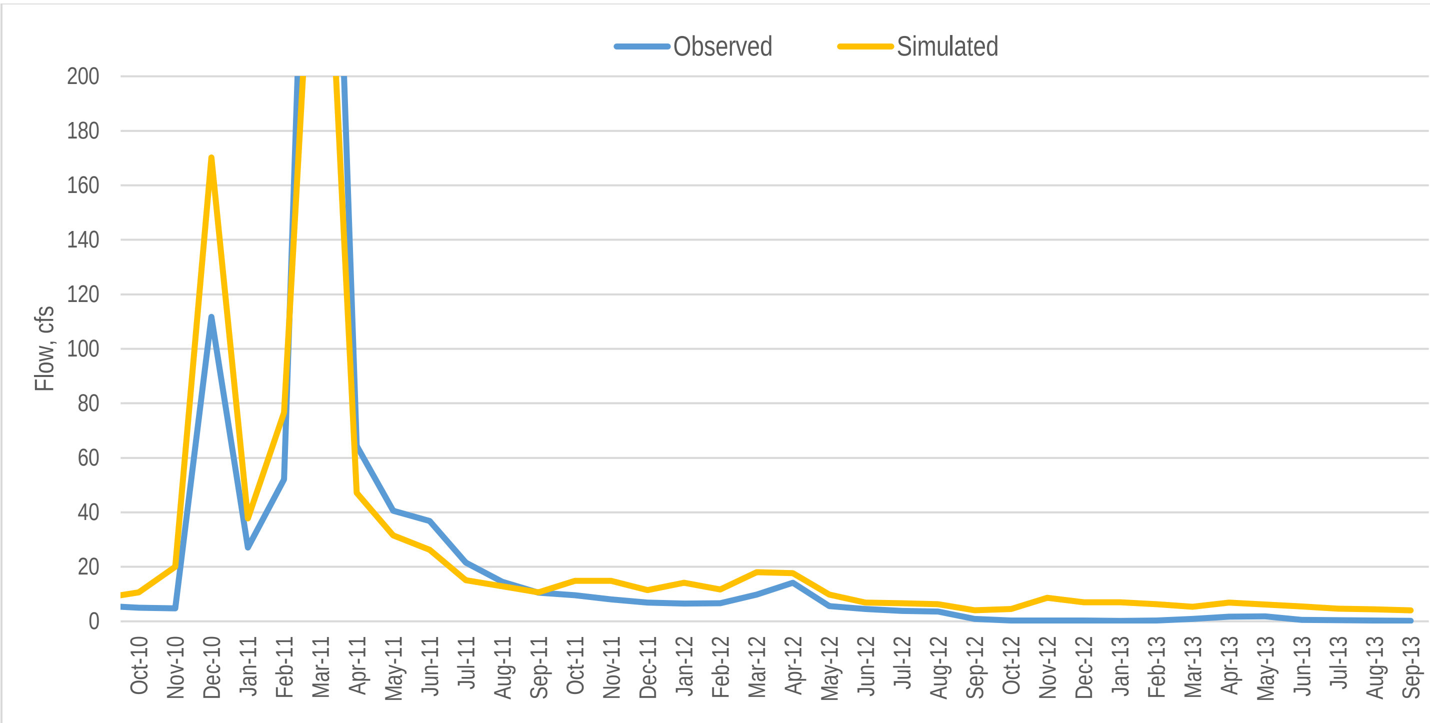


Figure 27. Observed (USGS Gage 11118500) versus simulated monthly streamflow during the model validation period.

EXHIBIT C

EXHIBIT C

From: Patterson, Gregory <G.Patterson@musickpeeler.com>
Sent: Wednesday, December 29, 2021 11:00 AM
To: Christopher Pisano; Shawn Hagerty
Subject: Expert deops

CAUTION - EXTERNAL SENDER.

Chris: can you give me a call to discuss dates. I am told by Aquilogic that it will take about three weeks to review the model, so I would like to discuss setting Archer/Klug on 1/24 -28 or 1/31 or 2/2.

We think we can be ready for the Schnaar depo on the 10th and Preston on the 11th and we can keep Evans on the 12th. I understand that you want to take Kear on the 14th.

Anthony Brown [redacted], so I will need some time to re-schedule his depo. I would prefer that we have one date after Anthony has had time to review the models, so probably looking at the week of 1/24-28.

I am ok if we go over the discovery deadline if necessary.

I am around through Thursday to discuss. I can also be reached over the long week-end at 805-358-8006.

Greg

Gregory J. Patterson
Partner

MusickPeeler

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EXHIBIT D

EXHIBIT D

SUPERIOR COURT OF THE STATE OF CALIFORNIA
FOR THE COUNTY OF LOS ANGELES

SANTA BARBARA CHANNELKEEPER, A CALIFORNIA NON-PROFIT CORPORATION,

PETITIONER,

VS. CASE NO. 19STCP01176

STATE WATER RESOURCES CONTROL BOARD, ET AL.,

RESPONDENTS.

____

CITY OF SAN BUENAVENTURA, ET AL.,

CROSS-COMPLAINANT,

V.

DUNCAN ABBOT, AN INDIVIDUAL, ET AL.,

CROSS-DEFENDANTS.

____

DEPOSITION VIA ZOOM OF ANTHONY BROWN
THURSDAY, DECEMBER 16, 2021

JOB NO. CA 4991890
REPORTED BY KRISTIN VARGAS, CSR NO. 11908, RPR
PAGES 1 - 244

A So that -- those are some of the discussions we have had about watershed appears to be some -- some elements of her report that almost seem to agree with what I have been saying.
Q Okay. Now, anything else that's really vague that jumps to mind that is a kill shot? I mean, should we wear a flat jacket to her deposition?
A I have no idea --
MR. PATTERSON: You don't have to answer that question.
BY MR. PISANO:
Q You know what, it's okay. Mr. Brown, just real quickly. And then I'm going to turn the floor over.
You have, in your shop, I thought I heard earlier -- you have a modeling expert; correct?
A We have -- Bob Abrams is as good as I have seen out there.
Q Okay. And the MODFLOW software that Dr. Archer uses -- that's not anything special, anyone can get their hands on that, right?
A The -- well, MODFLOW itself is publicly available.
Q Right.

A Most people operate MODFLOW within a pre- and post-processor package, such as groundwater vistas or GMS.

Q Right.

A You know, there are -- may be easier to build another model.

Q But if you wanted to build a model -- at least, if Aquilogic wanted to build a model, it could do so; right?

A If the client said we have -- we are providing you the budget to build a model and also, we have the time -- because obviously building a model is not something that you do in a matter of days or weeks. It takes a considerable period of time.

Q So did you build a model in this case due to the constraints of time and money, or was there some other reason?

A Actually, the primary reason is I didn't feel we needed a model to present the arguments that I put forward. I believe the existing data and the existing literature clearly supported the opinions that I offered.

Q Oh, okay. All right. Then I'm going to turn the floor over to Mr. Melnick so that he'll

EXHIBIT E

EXHIBIT E

Alisa Smith

From: tom.parker
Sent: Thursday, September 30, 2021 8:18 AM
To: Bob Abrams
Subject: RE: Scan attached 00000.040

Bob
I should have an update from Rashmi by early next week. I think a high level view would be OK to start with if Anthony is correct in his first look.
Best regards
Tom

From: Bob Abrams <bob.abrams@aquilogic.com>
Sent: 30 September 2021 16:16
To: tom.parker <tom.parker@aquilogic.com>
Subject: RE: Scan attached 00000.040

Hi Tom,
Would you like me to limit my review to a certain number of hours?
On timing, I don't think I can get to it until early next week, although I have had a quick first glance.
Best,
--Bob

Bob Abrams, PHD, PG, CHG
Principal Hydrogeologist
aquilogic
Office: +1.714.770.8040 ext. 132
Mobile: +1.650.743.0594

From: tom.parker <tom.parker@aquilogic.com>
Sent: Thursday, September 30, 2021 12:27 AM
To: Bob Abrams <bob.abrams@aquilogic.com>
Subject: RE: Scan attached 00000.040

Bob
Hope you are well. AB wants me to check September budget before doing too much more so don't go into great detail on your review. As things stand I believe AB may be called in 2nd week in October (preferred), so it might then be a case of we then need to hurry up...
Tom

From: tom.parker <tom.parker@aquilogic.com>
Sent: 28 September 2021 18:25
To: Bob Abrams <bob.abrams@aquilogic.com>
Subject: Fwd: Scan attached 00000.040

Bob
Will catch up tomorrow
Tom

Get Outlook for Android

From: Anthony Brown <anthony.brown@aquilogic.com>
Sent: Tuesday, 28 September 2021, 18:20
To: tom.parker
Subject: FW: Scan attached 00000.040

The State expert report is so far out there, it's hard to think where to start on rebuttal.

- Bizarre model approach not approved by Courts
- Does not consider actual hydro/geo-logic conditions
- Only considers on data set – GW elevation
- Disparity between DBS&A model and this report

Etc, etc.
I have attached two schematics that simplify our position.

Anthony Brown
CEO & Principal Hydrologist
aquilogic
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Mobile: +1.949.939.7160

From: Patterson, Gregory <G.Patterson@musickpeeler.com>
Sent: Monday, September 27, 2021 4:02 PM
To: tom.parker <tom.parker@aquilogic.com>; Anthony Brown <anthony.brown@aquilogic.com>
Cc: Carter, William <W.Carter@musickpeeler.com>
Subject: FW: Scan attached 00000.040

State Board report.

Greg

Gregory J. Patterson
Partner

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From: noreply@musickpeeler.com <noreply@musickpeeler.com>
Sent: Monday, September 27, 2021 4:00 PM
To: Patterson, Gregory <G.Patterson@musickpeeler.com>
Subject: Scan attached 00000.040

Scan attached

EXHIBIT F

EXHIBIT F

Alisa Smith

From: tom.parker
Sent: Tuesday, September 28, 2021 9:26 AM
To: Bob Abrams
Subject: RE: Scan attached 00000.040

Yes please

From: Bob Abrams <bob.abrams@aquilogic.com>
Sent: 28 September 2021 17:26
To: tom.parker <tom.parker@aquilogic.com>
Subject: Re: Scan attached 00000.040

So do you still want me to review?

Sent from my mobile

> On Sep 28, 2021, at 9:19 AM, tom.parker <tom.parker@aquilogic.com> wrote:
>
> fyi
>
> **From:** Anthony Brown <anthony.brown@aquilogic.com>
> **Sent:** 28 September 2021 17:18
> **To:** Patterson, Gregory <G.Patterson@musickpeeler.com>; tom.parker <tom.parker@aquilogic.com>
> **Cc:** Carter, William <W.Carter@musickpeeler.com>
> **Subject:** RE: Scan attached 00000.040
>
> This is pure techno-gobbledygook.
> In summary, "if GW levels are higher than river, then there is connection."
> It does not consider the hydrology, geology, or hydrogeology of the system.
> Thus, if GW levels are higher in Yosemite Valley it is connected to the Ventura River.
> Just because the water level in one bucket is higher than the level in another bucket, doesn't mean they are connected!
> I doubt this modeling approach has ever passed a Daubert/Kelley-Frye test.
> Alas, it will take more effort to rebut and dissect this report (and Archer) than it took to prepare our report.
>
> **Anthony Brown**
> CEO & Principal Hydrologist
> **aquilogic**
> Office: +1.714.770.8040
> Mobile: +1.949.939.7160
>
>
>
> **From:** Patterson, Gregory <G.Patterson@musickpeeler.com>
> **Sent:** Monday, September 27, 2021 4:02 PM

To: tom.parker <tom.parker@aquilogic.com>; Anthony Brown <anthony.brown@aquilogic.com>
Cc: Carter, William <W.Carter@musickpeeler.com>
Subject: FW: Scan attached 00000.040

State Board report.

Greg

<image001.png>

Gregory J. Patterson
Partner

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From: noreply@musickpeeler.com <noreply@musickpeeler.com>
Sent: Monday, September 27, 2021 4:00 PM
To: Patterson, Gregory <G.Patterson@musickpeeler.com>
Subject: Scan attached 00000.040

Scan attached

Vfdqqhg#e|#P fDihh#dqg#frqilup hg#ylux v0iuhh1