Casitas Municipal Water District

April 1, 2022

Via U.S. Mail and E-Mail
InstreamFlows@waterboards.ca.gov

Ann Marie Ore, Program Manager
State Water Resources Control Board
Division of Water Rights
Water Quality Certification and Public Trust Section
P.O. Box 100
Sacramento, CA 95812-0100

Subject: Comments of Casitas Municipal Water District on the State Water Resources Control Board (SWRCB) Development of Groundwater-Surface Water and Nitrogen Transport Models of the Ventura River Watershed (Ventura River Watershed Modeling Study)

Dear Ms. Ore:

The Casitas Municipal Water District (Casitas) provides drinking water to approximately 65,000 people and 6,000 acres of agriculture within the District's boundaries. This critical service is provided to residents, farms, businesses, and other retail water providers through the storage of water in Lake Casitas as well as from local groundwater wells. For over 15 years, Casitas has implemented a Fisheries Program completing several projects that improve habitat conditions for endangered steelhead trout, including construction of a state-of-the-art fish ladder at Robles Diversion Facility.

Casitas has assembled an expert groundwater modeling team to review the Ventura River Watershed Groundwater-Surface Water model being developed by the SWRCB. Casitas has submitted prior comment letters to the SWRCB dated August 26, 2022 and July 20, 2021. These comment letters remain unaddressed and are available on the Casitas website: https://www.casitaswater.org/your-water/california-instream-flow-studies.

Rather than re-stating all the issues raised in prior comment letters, the attached technical review provides additional review of the model files, model parameters, and other aspects of the model configuration. The review yielded a number of observations and recommendations related to code selection, model construction and package implementation, data integration, and model structural errors.

.

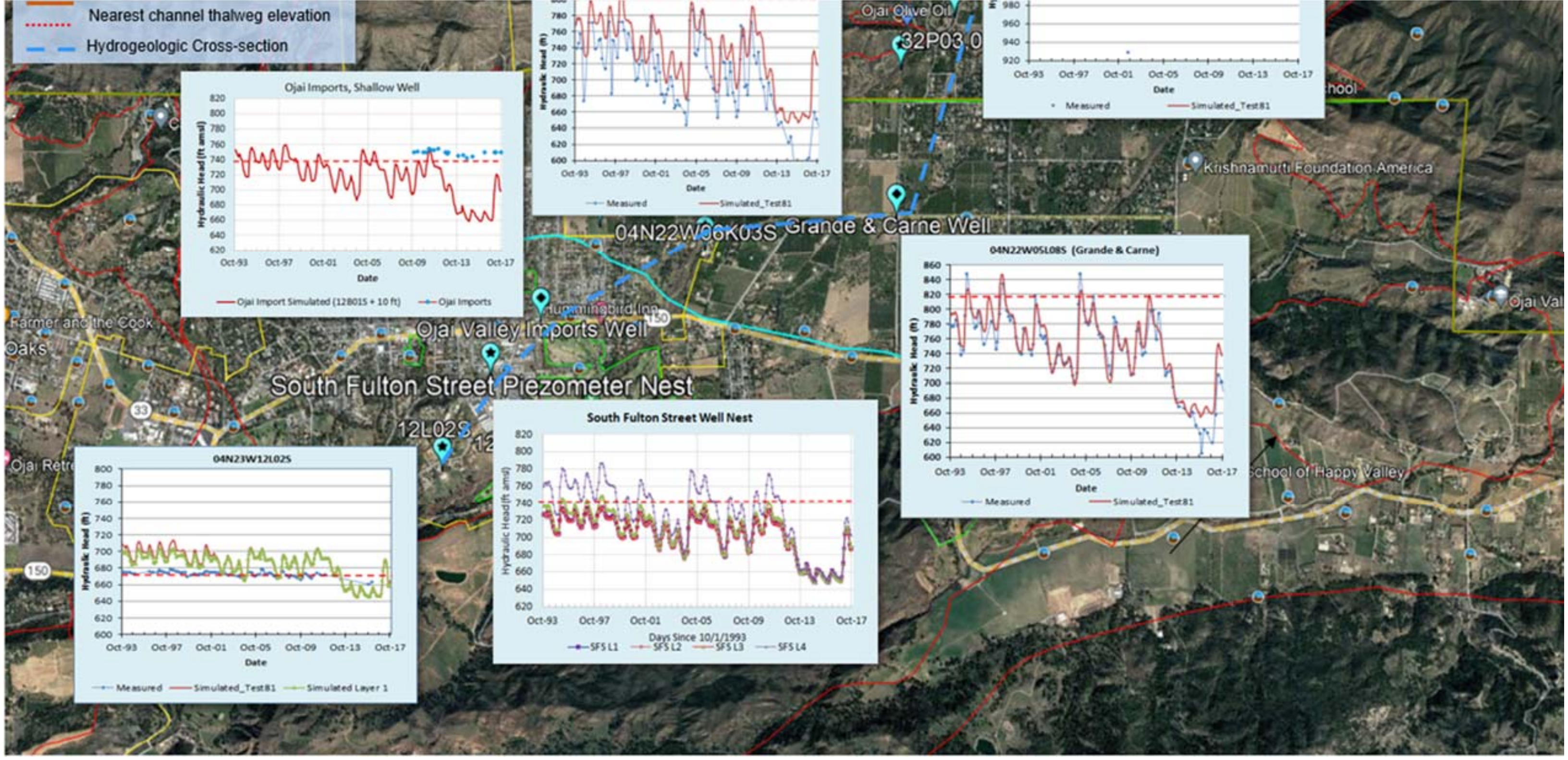
The enclosed technical review reinforces previous findings that the model estimates of surface water – groundwater interactions are inaccurate and unreliable, and provides technical comments that must be addressed before the model is considered useful.

Casitas appreciates the Water Board's consideration of these comments which are intended to help with the model development process and ultimately result in a model that accurately simulates the watershed. If you have any questions or would like additional clarification, please do not hesitate to contact me.

Sincerely,

Michael Flood
Casitas Municipal Water District
General Manager
805.649.2251
mflood@casitaswater.com

Attachment:
Comments on California State Water Resources Control Board's Ventura River Watershed Integrated Hydrologic Model, dated April 1, 2022, prepared for Casitas Municipal Water District, prepared by One-Water Hydrologic, Linker-Intel, and GSI Water Solutions



Prepared for: Casitas Municipal Water District

Comments on California State Water Resources Control Board's Ventura River Watershed Integrated Hydrologic Model

01 April 2022

Prepared by:

One-Water Hydrologic, LLC, San Diego, California
Lynker-Intel LLC, Boulder, Colorado and
GSI Water Solutions Inc., Santa Barbara, California

This page intentionally left blank.

Contents

SECTION 1: INTRODUCTION 1
1.1 Overview 1
1.2 Report Outline 1
SECTION 2: CODE SELECTION, VERSION CONTROL, AND MODFLOW PACKAGE OBSERVATIONS 2
2.1 Code Selection and Use 2
2.2 Issues with Current Version of Model 3
2.3 Specific features used in GSFLOW 3
SECTION 3: MODEL CALIBRATION AND STRUCTURAL ERRORS 6
3.1 Structural Errors In Groundwater Model Development 6
3.2 Structural Errors in VRW Model 6
3.2.1 VRW Model Structural Errors in Upper Ventura River Basin 8
3.2.2 VRW Model Structural Errors in Ojai Basin 11
SECTION 4: SUMMARY OF CONCLUSIONS 18
SECTION 5: REFERENCES 20

Figures and Tables

Figure 1. Spinner log from Casitas well SA-4 5

Figure 2. Scatter plot of observed versus simulated heads for VRW calibration model 95-GHB 7

Figure 3. Scatter plot of simulated versus observed groundwater levels in Upper Ventura River Basin 9

Figure 4. Measured minus simulated groundwater level error versus observed groundwater level for Upper Ventura Basin wells 9

Figure 5. Ventura River flows at Meiners Oaks as observed and simulated by the VRW SW-GW model (reproduced from Figure 2.3.1-12 from Preston and Schnaar, 2021a) 10

Figure 6. Stream channel width versus flow for the Ventura River near Foster Park gage, per direct measurements and as simulated by the VRW SW-GW model 11

Figure 7. Model error residual plotted against observed groundwater level for Ojai Basin 12

Figure 8. Well completion diagram of South Fulton Street nested-well site, with observed groundwater levels compared to VRW model simulated levels 13

Figure 9. Ojai basin boundaries per DWR Bulletin 118, with major surface drainage channels 15

Figure 10. Observed and simulated groundwater levels at wells located along hydrogeologic cross-section of the Ojai Basin (see Fig. 11) 16

Figure 11. Hydrogeologic cross-section from transect illustrated in Fig. 10, showing VRW model layers, and missing confining layer schematically illustrated 17

Abbreviations and Acronyms

AF	acre-feet
AFY	acre-feet per year
cfs	cubic feet per second
CMWD	Casitas Municipal Water District
DBS&A	Daniel B. Stephens and Associates
ET	Evapotranspiration
ft amsl	feet above mean sea level
Geosyntec	Geosyntec Consultants
GSFLOW	Groundwater Surface-water Flow Model
GSI	GSI Water Solutions, Inc.
GW-SW	Groundwater-Surface Water
MF-OWHM2	MODFLOW One-Water Hydrologic Model (Version 2)
MNW	Multi-aquifer Well
MNW2	Multi-aquifer Well Package
MODFLOW-NWT	Newton Formulation for Modflow-2005
PRMS	Precipitation-Runoff Modeling System
SFR2	Streamflow Routing (Package version 2)
Study Plan Review	*Review of the California State Water Resources Control Board's December 2019 Final Study Plan for the Development of Groundwater-Surface Water and Nutrient Transport Models of the Ventura River Watershed (GSI, One-Water, IRP Water, July 2021)*
SWRCB	State Water Resources Control Board
UF	Unimpaired Flow
USGS	United States Geological Survey
VR	Ventura River
VRW	Ventura River Watershed
VRW SW-GW Model	Ventura River Watershed Surface Water – Groundwater Model

SECTION 1: INTRODUCTION

At the request of-Casitas Municipal Water District ("Casitas" or "CMWD"), a team of water resources/hydrogeology experts assembled by GSI Water Solutions, Inc. (GSI), has been closely tracking the development and application of the three-dimensional (3D) integrated hydrologic model and nutrient transport model for the Ventura River watershed. The Ventura River Watershed Groundwater-Surface Water model (VRW GW-SW model) is being developed under the auspices of the State Water Resources Control Board and Los Angeles Regional Water Quality Control Board (collectively referred to below as "Water Boards").

1.1 Overview

The expert hydrogeologic modeling team reviewing the development and application of the VRW-GW-SW model is comprised of specialists from One-Water Hydrologic LLC, Lynker-Intel LLC, and GSI. As part of this model review process, the Casitas expert team has:

- participated in the public review activities of the VRW GW-SW model, including submitting written comments on the model Study Plan in July 2021 (GSI et al., 2021a).
- submitted expert opinion reports on the model in the proceedings of the Ventura River Basin water adjudication[1]
- downloaded model files posted by Water Boards' consultants (GeoSyntec and Daniel B. Stephens and Associates), and reviewed the files and run various versions of the model
- attended the March 2022 online model training hosted by the Water Boards and presented by members of their consultant team.

Rather than re-hashing issues raised in the July 2021 comment memo and Ventura River Basin Adjudication filings, this comment technical memo extends those findings by taking a deep dive into the model files, model parameters, and development and treatment of certain aspects of the hydrogeologic conceptual model (HCM) in the numerical model. This last point associated with the HCM constrains the model in a fashion that actually limits its ability to accurately model the true nature of the surface water – groundwater interaction. This can be referred to as a structural error in the model as described in Section 3 below. It is our opinion that the treatment, or lack thereof, of these issues ultimately renders unreliable the current model estimates of surface water – groundwater interactions.

1.2 Report Outline

Following this introduction, Section 2 presents comments on issues encountered when digging into the model files, running the model, and participating in the March 2022 online training. This section includes comments related to key limitations stemming from the code selection and version control, and observations related to how several of the MODFLOW packages were implemented and parameterized, and identification of limitations associated with the selected and implemented approach. This section also provides comments related to participating in the March 2022 online training, and the use of "tools" provided for running the model and analyzing results.

[1] California Superior Court, County of Los Angeles, Case no. 19STCP01176, Santa Barbara Channel Keepers v. State Water Resources Control Board and City of Buenaventura.

Findings associated with the model calibration results are presented in Section 3, including detailed localized results that indicate that the current version of the model suffers from structural errors that render certain results unreliable. Model structural errors are specifically related to stream-aquifer interactions and poorly simulated low flows in the mainstem of the Ventura River. Finally, Section 4 provides a summary of our observations and recommendations.

SECTION 2: CODE SELECTION, VERSION CONTROL, AND MODFLOW PACKAGE OBSERVATIONS

This section focuses on the aspects of the model related to the code selected, its applicability to the problem at hand, and related issues.

2.1 Code Selection and Use

Overall after attending the workshop, the GSI modeling experts are more convinced than ever that the GSFLOW code is the not the best version of Modflow for this project. The reasons for this conclusion include:

- GSFLOW precludes the flexibility of varying land use and other features over time, factors which are well known to occur (e.g., conversion of rangeland to irrigated ag, conversion of ag land to residential, or removal of invasive species such as Arundo, etc.). A better alternative would have been combining the compiled geologic data, streamflow network, and temporal pumpage data into a MF-OWHM (Boyce et al, 2020) model (such as that developed by Cardno, 2021) combined with either PRMS or BCM may be the best fusion of codes moving forward. This would allow a wider variety of simulation options, faster simulations, and ability to perform formal parameter estimation and sensitivity methods such as PEST. The extremely long simulation times preclude the use of more modern parameter estimation and sensitivity analysis as was the case for the Santa Rosa Plains GSFGLOW model (Woolfenden and Nishikawa, 2014).
- The version of MF-NWT that was embedded and released with the various versions of VRW GSFLOW model was a "corrected" version that was not officially released by the U.S. Geological Survey (USGS). Furthermore, the only executable provided was from 3/3/2021 and no source code or change log was released with this "corrected" version of MF-NWT. Thus, there are considerable issues on how the code was released and the completeness of the USGS GSFLOW/MF-NWT changelog, as not all changes are being documented in their release notes. A newer version of GSFLOW was released on 3/8/2021. We have rerun the version of VRW GSFLOW model with this most recent official release version of the GSFLOW code. The latest public version of GSFLOW (rev 2.2.0 from 3/8/2021) yields a different result than the version supplied by the consultants of the SWRCB.
- The use of daily time steps in the MF-NWT part of the GSFLOW simulation of the VRW model may also be inappropriate because the travel time of most streamflows, and especially low flows, may be on the order of several days or more for many of the levels of streamflow. This has been identified as a problem in other models where decisions or observations related to the surface-water inflow and outflow occur days to a week later such as the Lower Rio Grande (USBR, 2016; Hanson et al. 2020) and Salinas MF-OWHM models.
- While the model developers included a suite of "Custom Tools" for pre-processing and post-processing and reviewing model results, there needs to be a Workflow Flow chart that can graphically summarize the many steps to running the model, as well as data pre-processing and results post-processing. After attending the training it was clear that even for veteran modelers, there are a considerable number of steps involved with the use of GSFLOW and the application to the Ventura River Watershed.

- Many of the "tools" are simply executable codes and would potentially limit any other user from using them for any other scenarios. For this reason, the source code (Fortran or Python) should have been supplied with all of these tools that were not obtained from others (ex SFR build tool from the USGS).

2.2 Issues with Current Version of Model

While the model shows an overall good MODFLOW cumulative mass balance, it failed to converge for two stress periods. If this was a model prepared by the U.S. Geological Survey, that would not be acceptable. The model failed to meet convergence in Stress Period 67/Time Step 12 (Day 2022, year 5.3035) and again at Stress Period 279/Time Step 16 (Day 8478, year 23.211).

In addition, there were numerous warnings about bad minimum and maximum temperature data occur, including 472 warnings of bad solrad_tmin values and 553 warnings of bad solrad_tmax values that required using values from a previous time. There are 16 warnings for UZF cells that were identified as inactive cells but active in the UZF masking file. The extinction depth was set below the model-cell bottom elevation for 715 model cells that had to be reset to 90% of cell thickness by MF-NWT. These issues collectively indicate that no one went back to see if all the features were properly constructed and internally consistent.

2.3 Specific features used in GSFLOW

Selected boundary conditions are potentially deficient or inadequate.

(1) Coastal Constant head of 2.5 ft is not what most modern models are using for representing the ocean equivalent fresh-water head. In addition, the model stopped at the coast whereas most other coastal models extend offshore such as the models of Monterey Bay (Pajaro Valley and Salinas Valley), the Santa Clara-Calleguas models, Santa Barbara, Los Angeles Coastal plain, and San Diego area. Time varying equivalent fresh-water GHBs will be needed to give a more reasonable representation of this boundary, especially for proposed simulation of climate change scenarios that will include climate variability and sea-level rise. For example, this is easily constructed in MF-OWHM GHB that employs Tabfiles and the expression parser to facilitate this for historical and climate-change scenarios.

(2) Evapotranspiration (ET) was not compared against any independent estimates of potential or actual ET estimates using any separate estimation from BCM, Metric, or Open-ET. The overall portion of ET in the model is relatively small compared to many other coastal models and this may be due, in part, to the unrealistic extinction depth of 1 ft used for most of the model domain. This needs to be reviewed and revised as it is inconsistent with the root depths used in other models of the basin (Cardno MF-OWHM model, 2021) or even other estimate methods such as BCM. When combined with the changing capillary fringe, this would more correctly represent the potential range of extinction depths that are likely deeper than 1 foot for large portions of the model.

(3) The streamflow network is simulated within SFR in MF-NWT part of GSFLOW with daily time steps. The streamflow residence travel time for most flows and especially low flows may be several days or more, which makes the use of daily time steps inappropriate. This has been established for other MF-OWHM models such as the Lower Rio Grande and Salinas models that have travel times (temporal delays) of 4-7 days between inflow or reservoir releases and downstream points of diversion or observation. Also the use of the stage-width approximations from the TetraTech (2009) watershed model was not verified against any other estimates or field data. As stated in the TetraTech report (2009), the resulting F-tables that were developed for their HSPF model are subject to considerable uncertainty and are less reliable than those

developed using the HEC models. Based on the comparisons made at the streamflow gaging stations the approximations used for stage-width-flow (ICLAC=4 in SFR2) are not consistent with the field data published by the USGS. (for example, see Fig. 6 presented below). These stream depth-width-flow look up tables used for the stream segments that employ SFR2 ICALC=4 option need to be revised and checked against the USGS field measurements or other sources of data since these estimates have resulted in overestimation of streambed conductance. Finally, diversions were set at maximum diversion rates for the assumed irrigation months, but it is not evident they were all checked to confirm their physical diversion capacity nor if they are consistent with any established water rights.

(4) LAK was found to underestimate the simulated stage in Lake Casitas on average by 1.84 ft (median error 2.19 ft) which represent an average daily volume of error of 4.837 Ac-ft. This underestimation may be related to a combination of underestimation of runoff and/or precipitation, and overestimation of evaporation and/or leakage. Combined with the underestimation of peak diversions at Robles diversion this may suggest that peak flows and related runoff are underestimated. While the more recent bathymetry from 2017 was apparently used for Lake Casitas, any changes in total storage related to sedimentation was not accounted for during the simulation period, which extends back to 1993.

(5) MNW2 representation of wells needs to be rebuilt to use SKIN factors (for each layer) combined with honoring the surface seal (this area is in Ventura County Surface seal zone 1, requiring a minimum seal extending 25 feet below the land surface up to 150 feet for some wells), partial penetration, and a better explanation of location and estimation of pump-depth locations. The features used in the MNW2 package are not consistent with the actual nature of well performance and well construction. The MNW2 should have differentiated between older wells completed with cable-tool methods versus more modern rotary-drilled wells, and small domestic versus larger supply wells, as was done for the RGTIHM model (Hanson et al., 2020).

In addition, the issues with scaling related to mixing of different water types and iron bacteria require the use of the SKIN factor parameter approach with separate SKIN values assigned to each model layer within each well combined with the use of the partial penetration option and proper representation of well surface seals, well diameters, and screened intervals. The application of the MNW2 package in the VRW model further underscores the lack of understanding of the types of wells and the related water quality differences between the shallow and deeper aquifers in subregions like the Ojai Basin. The loss of specific capacity from some wells in Ojai is documented that may also substantiate this along with well casing and screen deterioration (Burke, 2018). This is typical of what has been observed in many other coastal basins such as Salinas, Santa Clara, and Pajaro Valleys, and the nearby Santa Clara-Calleguas (Oxnard Plain subregion). Specific Capacities in the Casitas Ojai Wellfield older wells have declined by 65-95 percent (Burke, 2018, table 2). Also the distribution of wellbore flow exemplified by the spinner log from San Antonio No. 4 well (Fig. 1) demonstrates how the distribution of wellbore inflow largely comes from the upper water-bearing layers which is different from the relatively uniform distribution estimated for this well from the VRW model results. Note that the pump location in Figure 1 is subject to change under current operations.

6. The Model Grid layering does not include the lacustrine clay layer in Ojai Basin as a confining bed / perching layer in the upper model layer. This is a significant structural error in the model, and affects the model estimates of surface water – groundwater interactions in the Ojai Basin, as discussed in Section 3.2.2 below.

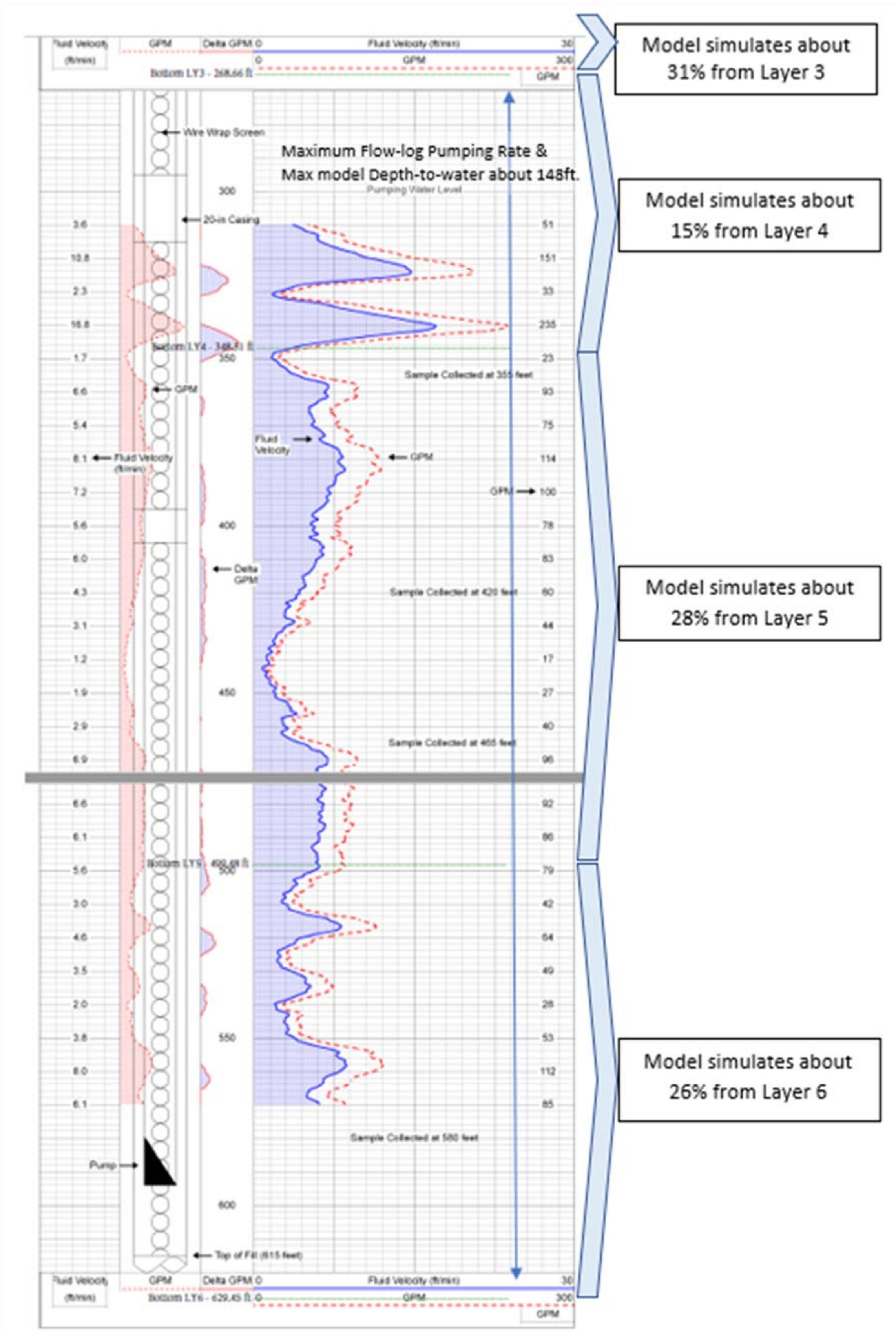


Figure 1. Spinner log from Casitas well SA-4

SECTION 3: MODEL CALIBRATION AND STRUCTURAL ERRORS

After introducing the general concept of structural errors in groundwater model development, this section focuses on certain model results that indicate the current version of the VRW model suffers from structural errors associated with simulation of low streamflows and stream – aquifer interactions.

3.1 Structural Errors In Groundwater Model Development

When developing a numerical model, the first step is synthesizing an HCM of the system that one will be attempting to simulate (ASTM, 2017; Anderson et al., 2015). The HCM provides a qualitative framework for designing a numerical model. It is essentially a descriptive representation of a groundwater system based on what is known about the modeled area, often accompanied by a schematic diagram of the system. Developed by integrating regional and site hydrogeologic and other relevant information, an HCM includes information on system boundaries; hydrostratigraphy; flow directions and sources and sinks; and a field-based estimate of water budget components.

Once the HCM is adopted[2], the numerical model can be constructed. Depending on the questions to be addressed by the numerical model and the HCM, the model domain, gridding, layering, surface boundary conditions (e.g., precipitation, or recharge, etc.), perimeter boundary conditions, internal sources and sinks, and other model features are implemented and parameterized in the numerical model. Following initial construction, the model is calibrated by comparing model simulated hydrologic measures, such as groundwater levels, to observations of the measures at locations across the model domain. Model calibration involves adjusting the values of the model parameters to improve the fit of the simulation to observed "real world" data. It can be undertaken either via trial and error "manual" calibration or using automated methods (ASTM, 2008; Anderson et al., 2015) such as the widely applied PEST (Parameter ESTimation) program (Doherty and Hunt, 2010).

A competent hydrogeologic modeler following the steps above should be able to arrive at a well calibrated model. Well calibrated that is by commonly applied statistical measures (e.g., see ASTM, 2008). But if a data gap exists for certain key aspect of the model, say for example stream-aquifer interaction, or if the representation of that model feature does not comport with all available data, then that "well-calibrated" model may be infected with a framework, or structural, error. In other words, as described by Xu et al. (2017), "*Groundwater model structural error is ubiquitous, due to simplification and/or misrepresentation of real aquifer systems. During model calibration, the basic hydrogeological parameters may be adjusted to compensate for structural error*." One example of model structural error would be if overall groundwater pumping is underestimated, then some other model feature can be adjusted to compensate from the low pumping. Say groundwater recharge can be reduced in this example, so that the model may do a good job of simulating groundwater levels even though the pumping and groundwater recharge are wrong.

In the following subsections, we identify several results in the calibrated model that indicate the current version of the VRW model suffers from structural errors, including simulating stream – aquifer interactions.

3.2 Structural Errors in VRW Model

In the VRW model report, Preston and Schnaar (2021) describe their model calibration procedure, including defining the statistical goodness-of-fit objectives and how well the final calibrated model compared against those objectives. At the conclusion of their section 2.3.2, they state:

[2] Neither the 2019 Study Plan for VRW model development nor model development report (Preston and Schnaar, 2021) explicitly address and develop an HCM, widely recognized as the key first step in developing a numerical model.

> *"Figure 2.2.3-4 presents a "1:1 line chart" that compares the simulated and observed groundwater elevation lines in a scatter plot. Simulated and observed groundwater elevation values that are similar to each other will plot near the line posted on the figure. Consistent with the statistical measures, review of the 1:1 line plot indicates adequate model calibration. In conjunction with meeting the streamflow statistical measures described above, based on these results it was determined that the GSFLOW model is sufficiently calibrated and validated."*

As part of the data and model files provided in the March 2022 online training was an Excel file (GW_calib_Test95_GHB.xlsx) that contained the calibration data and the calibrated groundwater model results. This Excel file contained the simulation vs observation scatter plot presented in their report as Figure 2.2.3-4, and that scatter plot is included here as **Figure 2.**

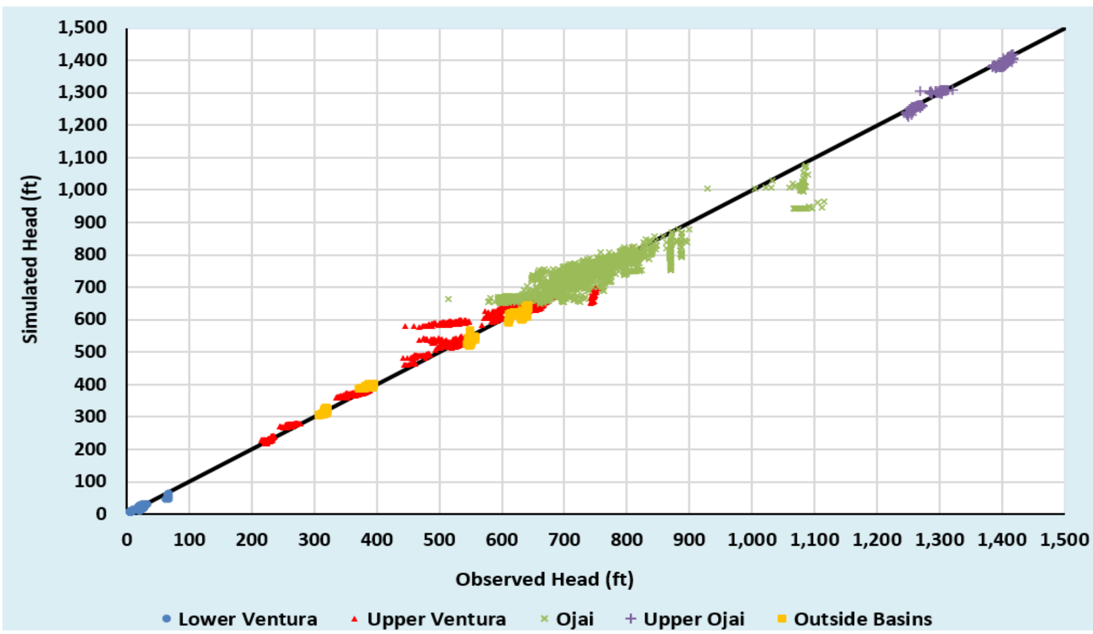


Figure 2. Scatter plot of observed versus simulated heads for VRW calibration model 95-GHB

We agree with Preston and Schnaar's statement that a well calibrated model will exhibit simulated and observed water levels falling near the 1:1 line, and that overall at the plot scale most of the points do fall along a tendency scattered about the 1:1 line. When reviewing the calibration scatter plot in detail, however, it becomes obvious that the simulated groundwater levels at some wells do not comport with the observed water level data. Specifically, in the scatter plot one can see several clusters of points that have a horizontal tendency (red triangles, representing Upper Ventura Basin wells) or a vertical tendency (green crosses, representing Ojai Basin wells); these represent individual wells which are being poorly simulated by the VRW model, indicating potential structural errors in the model. The use of model statistics overlooks the analysis of structural and systematic errors. For example, the use of error statistics of residuals of Measured minus Observed heads help identify the substantial issues of systematic errors in the Ojai Basin not highlighted by the overall model goodness-of-fit statistics, as shown below in Section 3.2.1 (**Fig. 4**).

Thus, as described in the following subsections, we disagree that the chart indicates adequate calibration for one of the intended modeling purposes: simulating interactions and transfers between surface water and connected groundwater.

3.2.1 VRW Model Structural Errors in Upper Ventura River Basin

Figure 3 shows the calibrated model observed vs simulated head scatter plot for only the wells located in the Upper Ventura River Basin. Figure 4 shows a scatter plot of model error (measured minus simulated water level) versus measured water level. A few key observations can be taken from these plots:

1. For observed groundwater levels between 300 feet amsl and 650 feet amsl, the model generally overpredicts groundwater levels (illustrated by preponderance of negative residual values in Fig. 4), this is particularly true for observed groundwater levels between 400 and 650 feet amsl.
2. In this range of observed groundwater levels, the VRW model commonly overpredict groundwater levels by 10 feet or more, and for well 04N23W15D02S the model typically overpredicts groundwater levels by more than 50 feet.
3. Furthermore, for these same wells the VRW model also predicts the simulated groundwater levels (vertical axis) to vary over a very narrow range while the measured groundwater levels (horizontal axis) are observed to vary over a large range, leading to the relatively "flat" tendency of those wells in Fig. 3.
4. These wells with large overprediction errors in the Upper Ventura River Basin are all located along the reach from below the Robles Diversion down to the Ventura River confluence with San Antonio Creek, often referred to as "the intermittent reach." It thus appears the calibrated VRW model greatly overestimates groundwater levels on the intermittent reach.
5. Figure 5 shows the simulated streamflows versus observed streamflows at the Ventura River at Meiners Oaks gage, located on the intermittent reach. Focusing on the middle and bottom charts, one can see that the model significantly overestimates flows in the low flow range at this location. This is consistent with the overpredicted groundwater levels cited above
6. In addition to the overestimated groundwater levels, review of the model SFR channel width specified in the model compared to rating curve data for particular stream gage locations shows that in the flow range between 1 cfs and 50 cfs, the model greatly overpredicts the stream channel width (Figure 6). The combination of these two model biases likely means the model is greatly overpredicting groundwater discharge to the stream channel over the simulation period.
7. The use of the Nash-Sutcliff Statistic that uses the mean value is also potentially misleading because streamflows are log-normally distributed and the mean is skewed towards larger flows. Thus this statistic, as presented, is more of a measure of the models ability to represent larger flow events and does not reflect the skill at median, 75% or 25% flows, median flows for wet versus dry years, nor the low flows proposed for fish passage under different conditions and seasons.
8. No higher-order observations were used to estimate model skill such as vertical-head differences, groundwater-level/surface-water stage differences, streamflow gains and losses between gages, or comparisons with other estimates of climate attributes (Precipitation, AET, and PET) from other estimates such as BCM or Metric or met station data.

In summary, these observations related to model errors in groundwater levels and streamflows in the Upper Ventura River Basin are consistent with each other, and they both indicate a significant structural error in the model. These results also indicate that the stated model objective to simulate low flow conditions on the Ventura River is not met by the current version of the model.

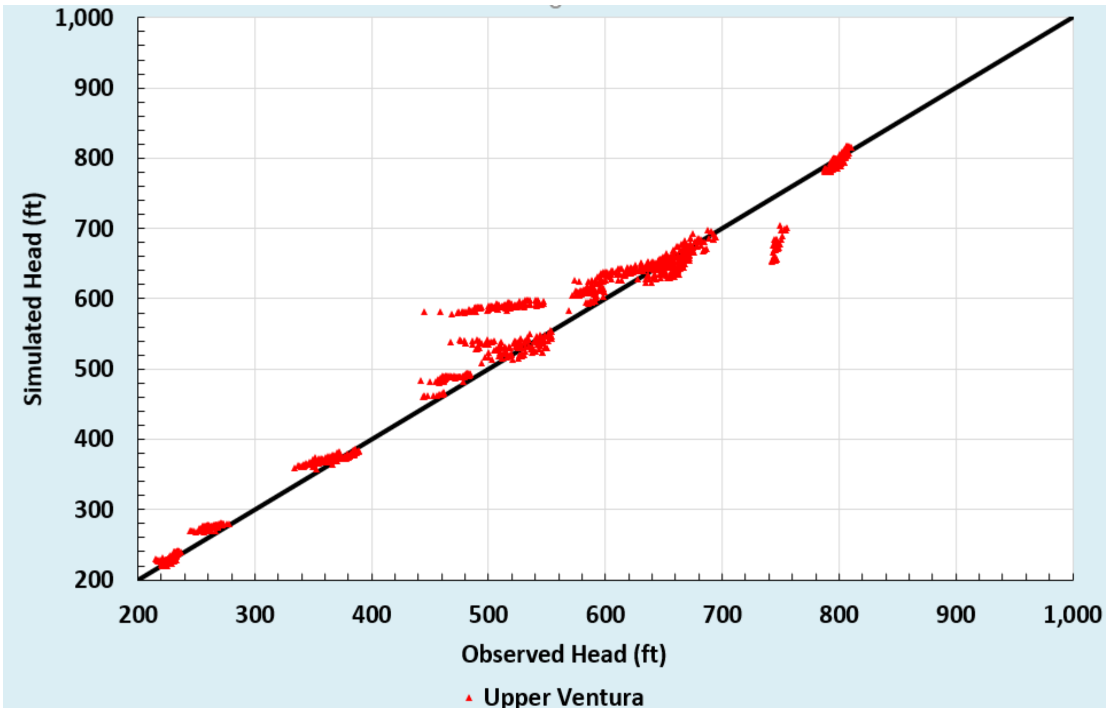


Figure 3. Scatter plot of simulated versus observed groundwater levels in Upper Ventura River Basin

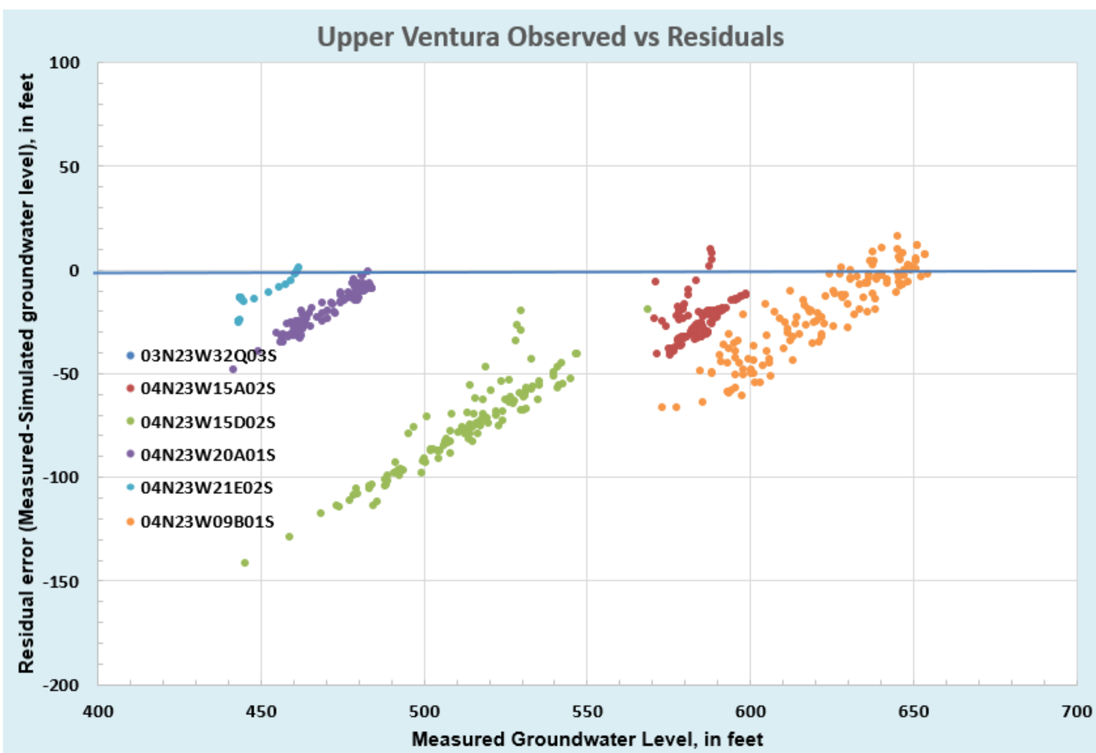


Figure 4. Measured minus simulated groundwater level error versus observed groundwater level for Upper Ventura Basin wells

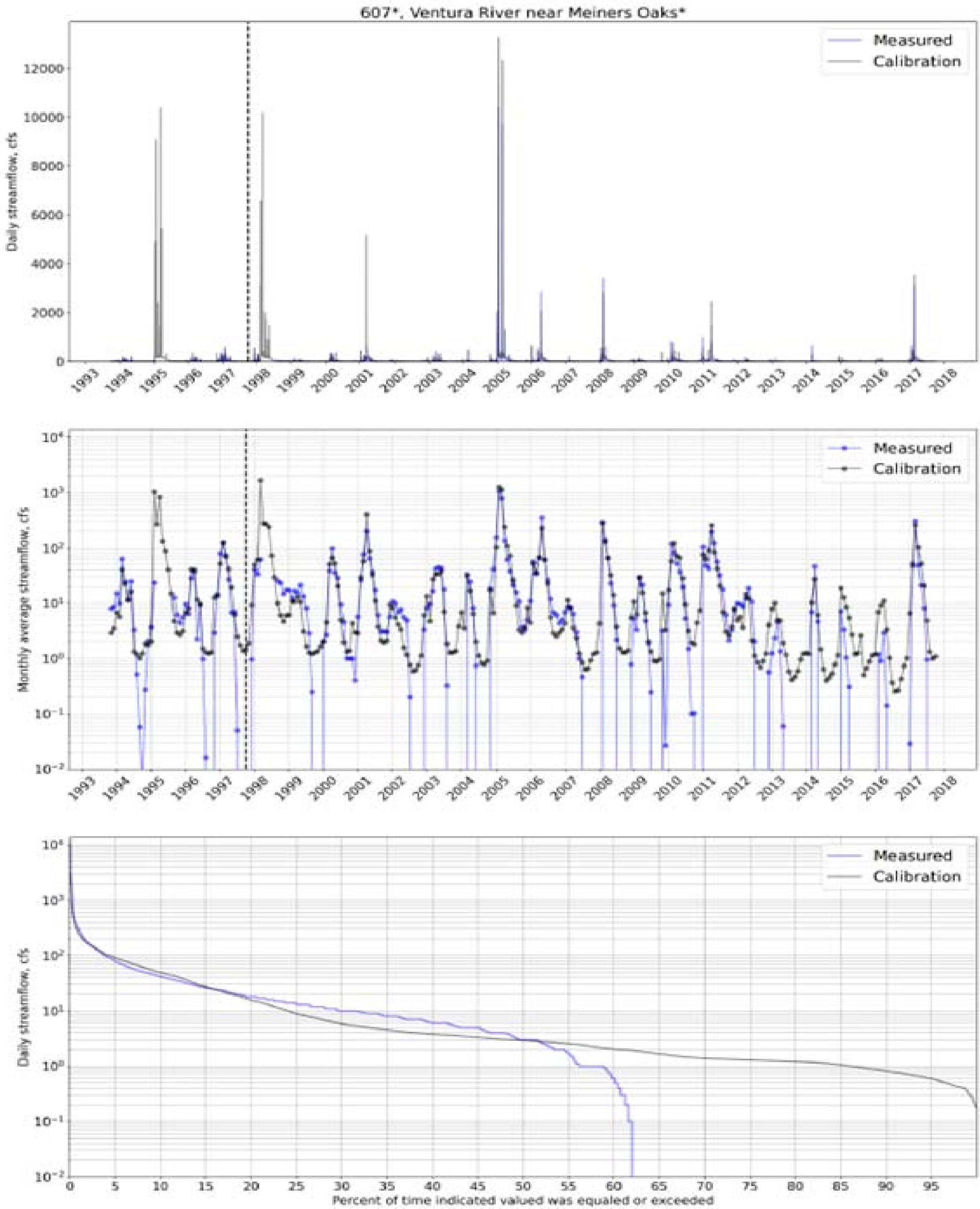


Figure 5. Ventura River flows at Meiners Oaks as observed and simulated by the VRW SW-GW model (reproduced from Figure 2.3.1-12 from Preston and Schnaar, 2021a)

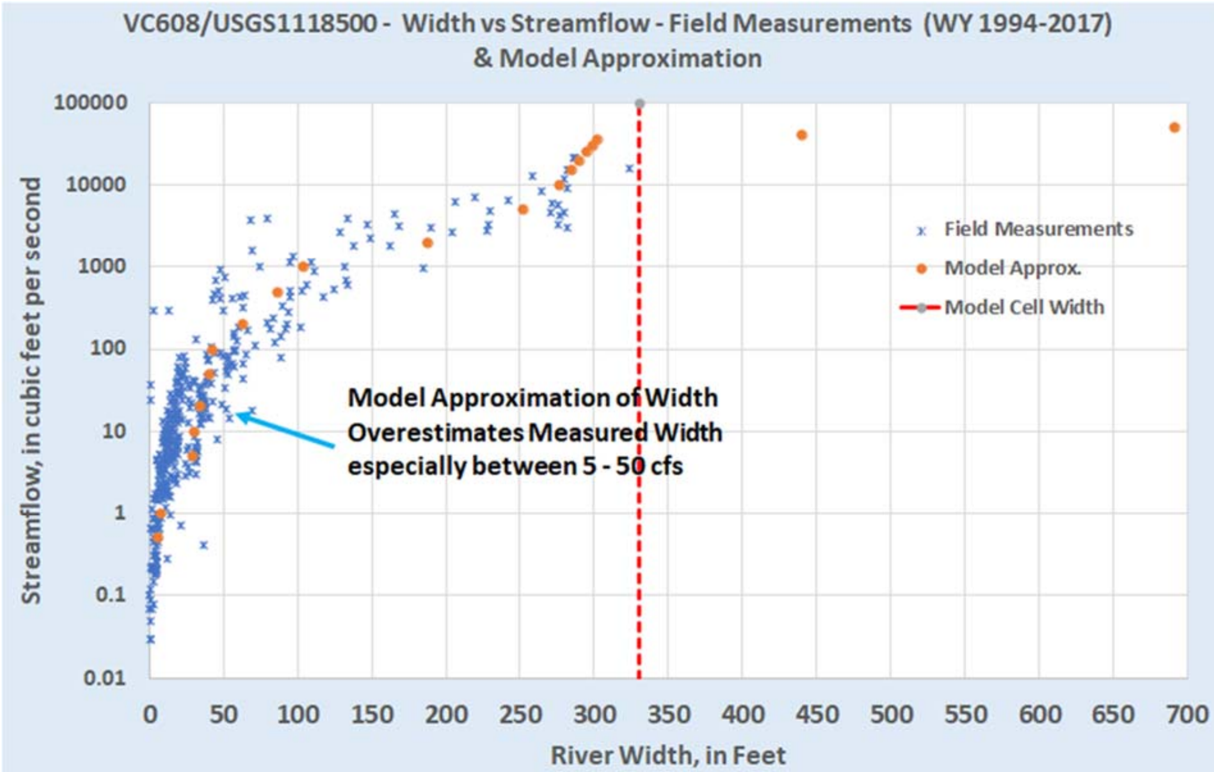


Figure 6. Stream channel width versus flow for the Ventura River near Foster Park gage, per direct measurements and as simulated by the VRW SW-GW model

3.2.2 VRW Model Structural Errors in Ojai Basin

Referring again to the head-calibration scatter plot in Figure 2, those clusters of green crosses with a vertical tendency represent Ojai Basin wells that suggest structural error in the model. Specifically, for these wells, the data shows very little head variability and relatively low fluctuations consistent with unconfined conditions. The simulated heads, on the other hand, exhibit much larger variations, more akin to semi-confined and confined conditions. This divergence between model and observation is further underlined when plotting the head error versus observed head, as shown in Figure 7. Again, a handful of well clusters in the simulated vs observed scatter plot exhibit a vertical tendency. Investigating which wells have this behavior, it was determined that in all cases it was data from shallow wells. This seems to suggest that the VRW model is doing a poor job at simulating shallow wells in the Ojai Basin, specifically wells completed in the shallow perched system.

The current VRW model's inability to correctly simulate the shallow groundwater conditions in the Ojai basin can be demonstrated via a few lines of evidence.

(1) VRW model layering does not include the lacustrine clay layer in Ojai Basin that has been encountered in the southwest thirds of the basin and acts as a confining bed / perching layer over that area. This is a significant structural error in the model and that affects the model estimates of surface water – groundwater interactions in the Ojai Basin.

The presence of this clay layer and its impact on groundwater conditions in the basin is clearly illustrated by the South Fulton Street multi-level well nest installed in 2019 (Kear, 2021). Figure 8 shows the well completion diagram of South Fulton Street (SFS) well nest. The driller's log indicated the clay layer is located between the 30- and 100-foot depth at that location, with perched groundwater above, dry horizons though that interval, and confined groundwater conditions below.

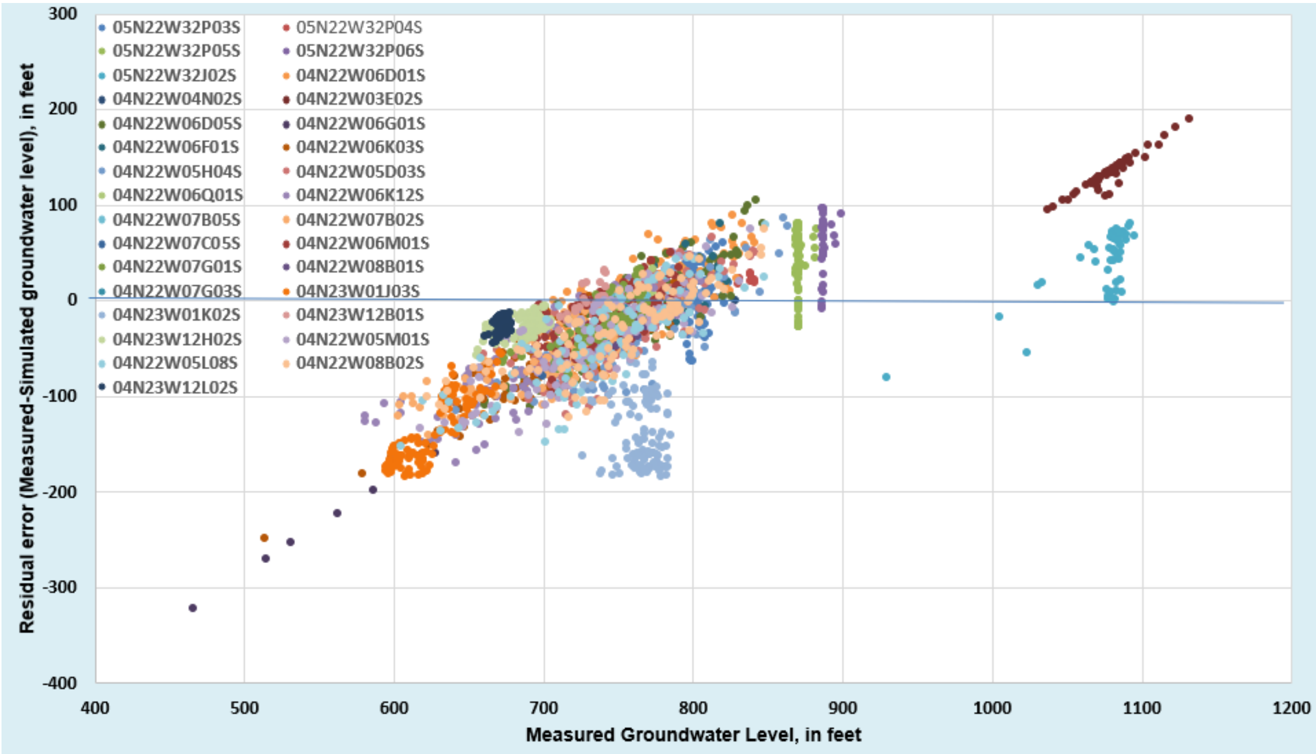


Figure 7. Model error residual plotted against observed groundwater level for Ojai Basin

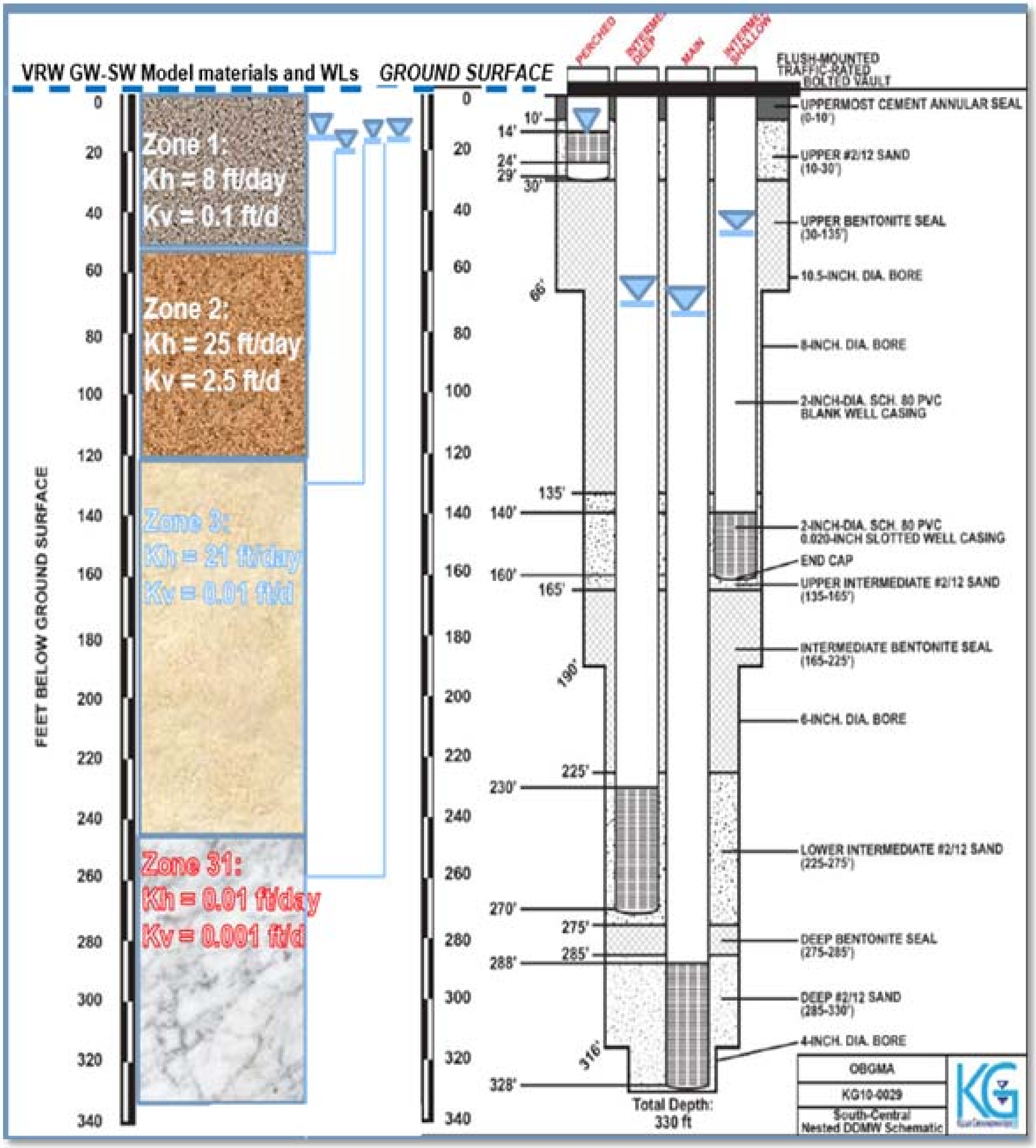


Figure 8. Well completion diagram of South Fulton Street nested-well site, with observed groundwater levels compared to VRW model simulated levels

(2) Figure 8 also shows observed groundwater levels (right side) compared to VRW model simulated levels (left side). The water levels presented are from September 2017 which was a period of relatively low observed water levels due to the multi-year drought period that started in 2012, yet the modeled water levels remained relatively high.

(3) The vertical gradients computed by the model were checked at several locations across the basin and they consistently showed slight values, with head difference rarely more than three feet across model layers. For example, vertical gradients were checked at two locations in the central portion of the Ojai basin:

a. At the SFS well location, and

b. At model cell at (Row 164, Column 234), with the cell centroid located approximately 500 feet northwest of Casitas well SA-4.

(4) In both cases, there is no pumping from these cell in the VRW model over the simulation period, thus vertical head differences between model layers for the simulation period should be considered representative of conditions in the basin if one were to install a well more than 500 feet from a nearby pumping center. Thus the SFS well nest data should be considered representative of these conditions, and the model should mimic this data. For the snapshot in time shown in Figure 7, the data clearly shows a shallow perched layer with heads well above the heads in the confined system below the confining layer show large vertical head differences, that are not exhibited by the model.

(5) In both cases for those cell locations, the model shows very little head gradient over the drier periods, and a larger upward gradient during the wetter periods. For drier times of the simulation period the maximum vertical head difference between model layers ranges between -5 and 5 feet, and 90% of the values are between -1.5 and 1.5 feet. Contrast this to the data at SFS well next that shows vertical head differences across the hydrogeologic profile of more than 20 feet during the current relatively dry period.

The framework error can be further illustrated at a regional scale by comparing model and data along a transect across the basin. Figure 9 shows the Ojai Basin boundaries per DWR Bulletin 118, along with the principal surface water drainages in the basin. Figures 10 and 11 show data from a transect of wells located from the southwest corner of the basin to the north central portion of the basin, roughly paralleling the alignment of the San Antonio Creek channel.

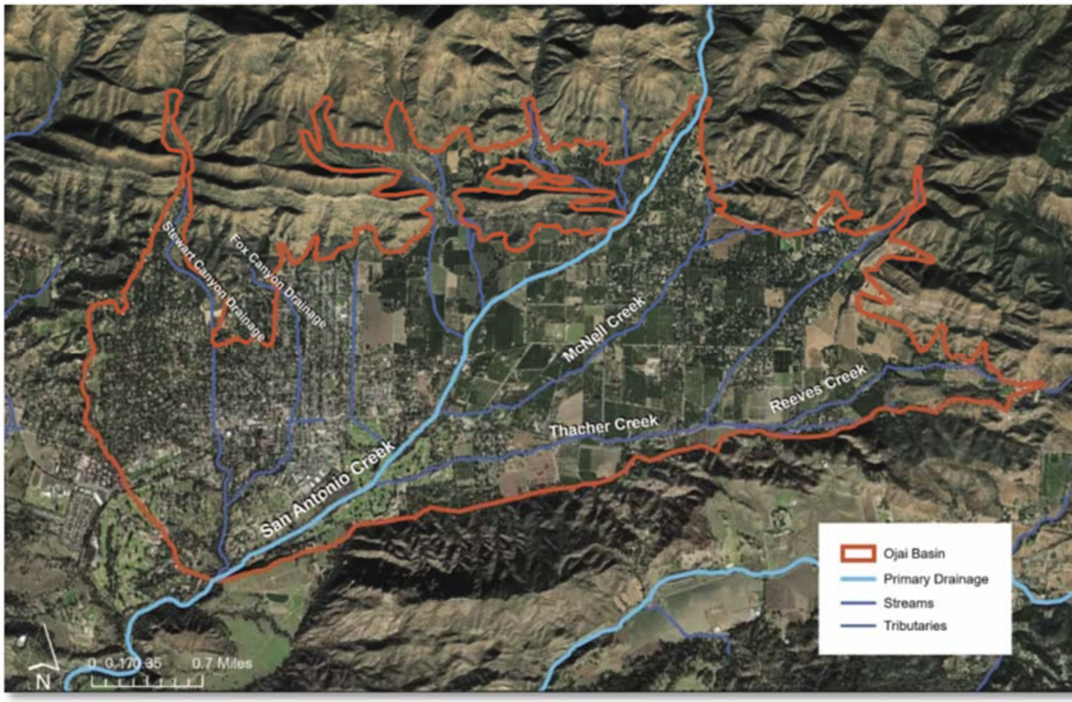


Figure 9. Ojai basin boundaries per DWR Bulletin 118, with major surface drainage channels

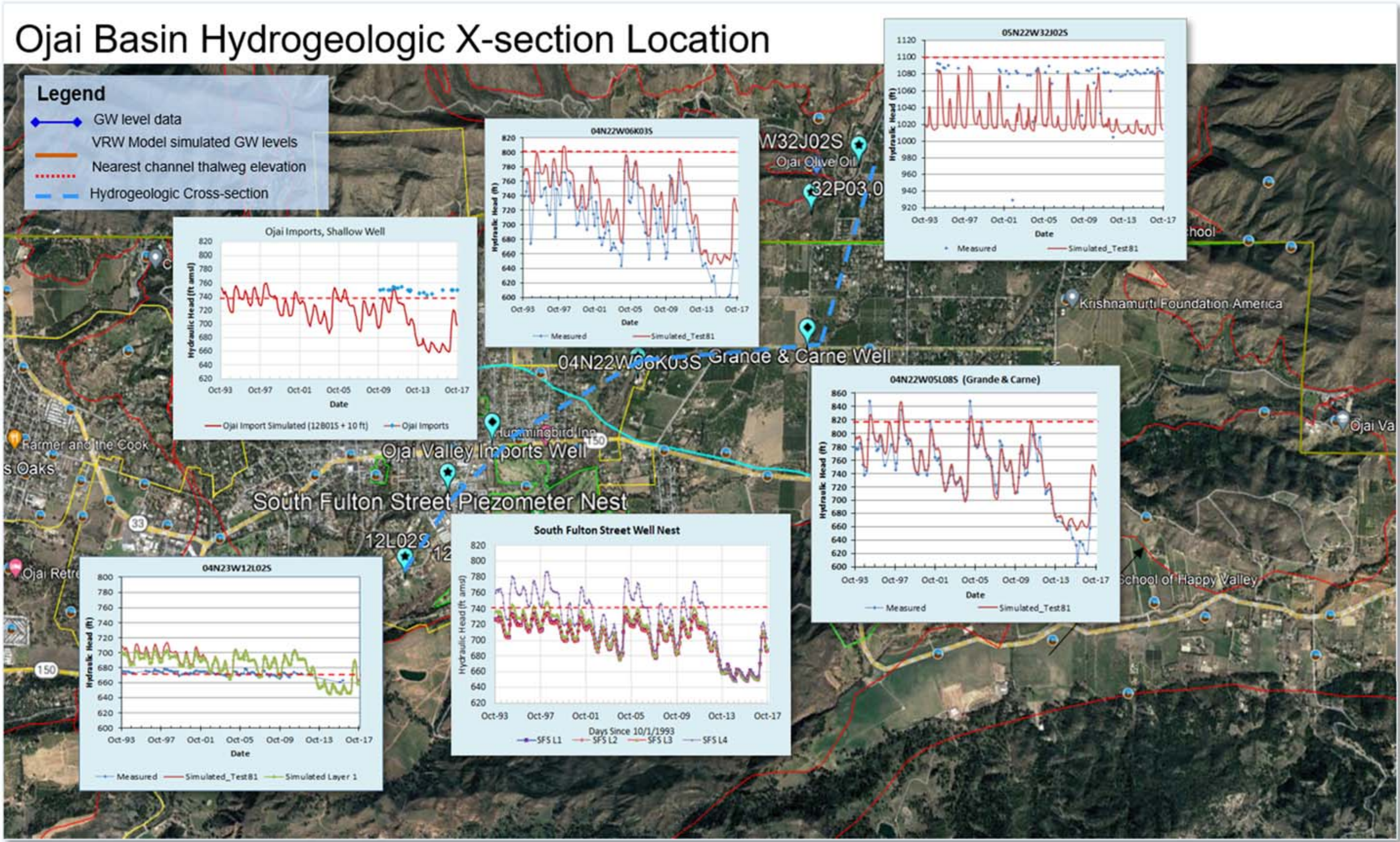


Figure 10. Observed and simulated groundwater levels at wells located along hydrogeologic cross-section of the Ojai Basin (see Fig. 11)

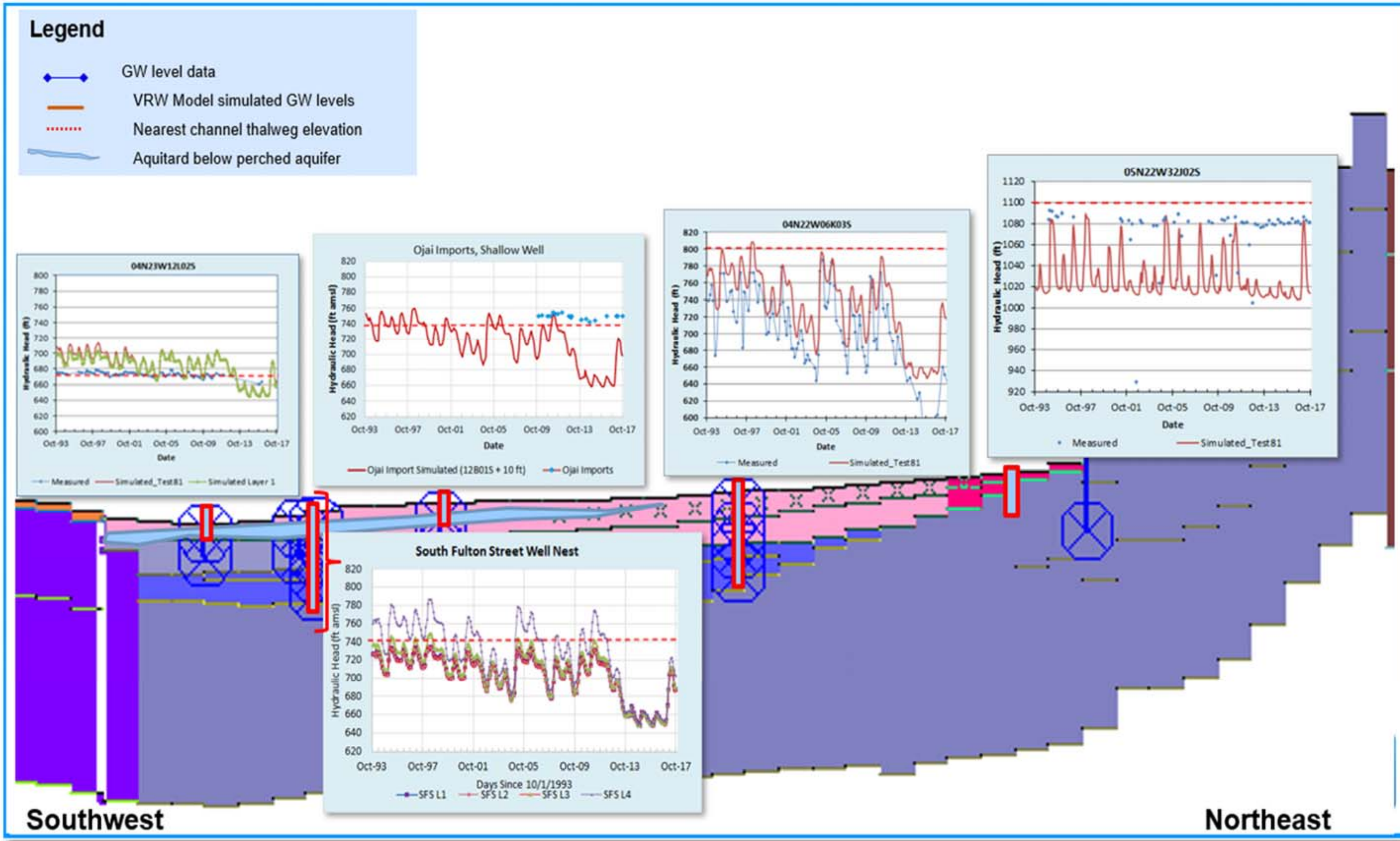


Figure 11. Hydrogeologic cross-section from transect illustrated in Fig. 10, showing VRW model layers, and missing confining layer schematically illustrated

Figures 10 and **11** clearly show the aforementioned behavior of the model poorly simulating the monitoring data from the shallow perched zone, specifically wells 04N23W12L02S, Ojai Imports, and 05N22W32J02S. While only these wells are shown in the cross-section, essentially all shallow wells in the Ojai Basin are similarly poorly simulated.

Shown in the hydrographs in both figures is the thalweg elevation of the nearest stream channel. Also shown schematically in hydrogeologic cross-section (**Fig. 11**) is the approximate location of the perching layer that has been observed across the southwest third of the basin. These two features are important in identifying the model structural error in the Ojai Basin, and how that structural error impacts surface water – groundwater interaction calculations. Comparing the observed and simulated groundwater levels to the nearest stream channel elevation shows that:

- in the north-central upper reaches of the basin, measured groundwater levels generally stay well below the stream channel elevation and exhibit unconfined behavior in the groundwater fluctuations, while the model results incorrectly show confined behavior. Thus, those upper reaches are generally losing surface water to groundwater recharge, via infiltration into the stream channel deposits
- in the central portion of the basin, simulated groundwater levels rise above the nearest stream channel elevation during wet periods, and remain below that level during drier periods, indicating the potential for hydraulic gradients both toward and away from the stream depending on hydrologic conditions
- in the southwest portion of the basin (well 04N23W12L02S) the simulated groundwater levels are usually significantly higher than the nearby stream channel elevation, although the measured groundwater levels rarely rise above the stream channel elevation and exhibit low-fluctuations, unconfined behavior as expected in the shallow zone.

Finally, the data and information previously presented in Section 2.3(5) also points to the groundwater system in the Ojai Basin to be highly stratified, with the extreme well scaling occurring due to mixing of groundwaters of different chemistries encountered at different depths.

All of these data point to a structural error in the model, stemming from not explicitly simulating the perching / confining layer that is obviously an important stratigraphic layer that controls vertical flow and confining heads in the Ojai basin. These errors in the model of the groundwater system lead to strong simulated baseflow discharge to San Antonio Creek in the southwest portion of the Ojai Basin. However, this southwest portion of the basin is precisely where the extensive perching / confining layer has been mapped, and in reality this confining layer effectively prevent upwelling and discharge of deep groundwater to San Antonio Creek. If this model structural error were corrected by explicitly including the confining layer and the shallow perched system as separate layers in the model, then the simulated groundwater discharge to the surface water system in the Ojai Basin would be significantly reduced.

SECTION 4: SUMMARY OF CONCLUSIONS

A detailed review of the VRW SW-GW model undertaken by Casitas' modeling experts has yielded a number of observations related to code selection, model construction and package implementation, data integration, and model structural errors, including:

- Related to model code selection and implementation
  - Use of GSFLOW precludes consideration of temporal changes in land us
  - Alternative approaches to simulating surface processes and coupling with groundwater model would improve model runtimes

- Several issues were noted related to version control of the codes employed in model development, which is poor modeling practice
- Potential daily timestep issues for Ventura River watershed domain
- The Zoom training sessions highlighted the complexity in running the complete set of models and begs that documentation be augmented with flow charts (workflows); in addition, there is lack of flexibility in running scenarios with the provided tools (executables only)
- Capturing output from the Command line window revealed non-convergent timesteps and numerous warnings related to evapotranspiration (ET) parameters , inactive cells, and ET extinction depth
- The fixed coastal head boundary condition can be improved
- No independent check on model computed or input ET values
- No check made related to MODFLOW model timestep size and basin time constants
- The LAK package and Robles diversion treatment may have correlated errors
- MNW treatment of wells completed across multiple layers employs parameters that cannot account for observed well fouling and larger differences between inflows from different aquifers
- The model gridding does not allow for consideration of shallow perched groundwater and shallow confining layers, a hydrogeologic configuration of importance in the Ojai Basin, if not in other portions of the VR watershed as well

- Related to structural errors in the model
    - The model development procedure did not include development of a rigorous Hydrogeologic Conceptual Model as the first step in model development; this may partly explain why the certain structural errors became part of the model
    - Comparing model results to data provides a reasonably good statistical fit overall, but focusing on key portions of the scatter plots reveal potential structural errors in the current model for selected subregions of the watershed
    - In the Upper Ventura River basin (per DWR Bulletin 118) overpredicted groundwater levels in the intermittent reach together with model rating curve biases appear to lead to overestimation of baseflows and of interchanges between the surface water and groundwater systems
    - In the Ojai Basin, numerous lines of independent data indicate that the VRW model's lack of explicit inclusion of the extensive perching / confining layer in the southwest portion of the basin leads to poor fit between model and data in terms of shallow groundwater levels, and significant overpredictions of groundwater discharges to the San Antonio Creek

SECTION 5: REFERENCES

Anderson, M., W. Woessner, and R. Hunt, 2015. Applied Groundwater Modeling: Simulation of Flow and Advective Transport, El Sevier Press, 564 pp.

American Society of Testing and Materials (ASTM), 2008. Standard Guide for Calibrating a Groundwater Flow Model Application, ATSM D5981-96, 6 pp.

American Society of Testing and Materials (ASTM), 2017. Standard Guide for Application of a Groundwater Flow Model to a Site-Specific Problem, ATSM D5447-96, 8 pp.

Boyce, S.E., Hanson, R.T., Ferguson, I., Schmid, W., Henson, W., Reimann, T., Mehl, S.M., and Earll, M.M., 2020, One-Water Hydrologic Flow Model: A MODFLOW based conjunctive-use simulation software: U.S. Geological Survey Techniques and Methods 6–A60, 435 p., https://doi.org/10.3133/tm6a60, (https://pubs.er.usgs.gov/publication/tm6A60).

Burke, M., 2018, Ojai Wellfield Assessment Report Casitas Municipal Water District: Prepared for Water Systems Consulting, Inc., May 2018, 33p.

Doherty, J., and R.J. Hunt, 2010. Approaches to Highly Parameterized Inversion: A Guide to Using PEST for Groundwater-Model Calibration, USGS Scientific Investigations Report 2010-5169, 70 pp.

Gardner, M.A., C.G. Morton, J.L. Huntington, R.G. Niswonger, and W.R. Henson, 2018. Input data processing tools for the integrated hydrologic model GSFLOW, Environmental Modeling & Software, V. 109, pp. 41-53.

Geosyntec and DBS&A. 2019. Final Study Plan for the Development of Groundwater-Surface Water and Nutrient Transport Models of the Ventura River Watershed. Prepared for the California State Water Resources Control Board, Division of Water Rights. Prepared by Geosyntec Consultants (Geosyntec) and Daniel B. Stephens & Associates, Inc. (DBS&A). December 2019, 97p.

GSI et al. (GSI Water Solutions, One Water Hydrologic, IRP Water Resources), 2021a. Review of the California State Water Resources Control Board's December 2019 Final Study Plan for the Development of Groundwater-Surface Water and Nutrient Transport Models of the Ventura River Watershed. Consultant's report from Ground Water Solutions, Inc. (GSI) to Casitas Municipal Water District. July 2021, 107 pp.

GSI et al. (GSI Water Solutions, One Water Hydrologic, Lynker Intel), 2021b. Supplemental Expert Report on the California State Water Resources Control Board's Groundwater-Surface Water Model of the Ventura River Watershed; consultant's report submitted to Rutan and Tucker, LLP, Counsel for Casitas Municipal Water District. December 2021, 31 pp.

Hanson, R.T., Ritchie, A.B., Boyce, S.E., Galanter, A.E., Ferguson, I.A., Flint, L.E., Flint, A., and Henson, W.R., 2020, Rio Grande transboundary integrated hydrologic model and water-availability analysis, New Mexico and Texas, United States, and northern Chihuahua, Mexico: U.S. Geological Survey Scientific Investigations Report 2019–5120, 186 p., https://doi.org/10.3133/sir20195120.

Kear, J. 2021. Opinions of Jordan Kear, PG, CHG, in regard to connectivity of groundwater basins of the Ventura River Watershed, Ventura County, California. Expert Opinion memo submitted to H. Jacobson, Bartkiewicz, Kronick, and Shanahan, counsel for City of Ojai, California, 24 Sept. 2021, 29 pp.

Preston, A. and G. Schnaar, 2021a. Expert Report of Al Preston, PhD, PE and Gregory Schnaar, PhD, PG, prepared by Daniel B. Stephens & Associates and Geosyntec Consultants for the State of California Attorney General's Office, Sept. 24, 2021, 66 pp.

Preston, A. and G. Schnaar, 2021b. Supplemental Expert Report of Al Preston, PhD, PE and Gregory Schnaar, PhD, PG, prepared by Daniel B. Stephens & Associates and Geosyntec Consultants for the State of California Attorney General's Office, Dec. 3, 2021, 69 pp.

Reilly, T.E., and A.W. Harbaugh. 2004. Guidelines for Evaluating Ground-water Flow Models. U.S. Geological Survey Scientific Investigations Report 2004–5038, 30 p. accessed online and downloaded from https://pubs.usgs.gov/sir/2004/5038/PDF/SIR20045038part2.pdf