CALIFORNIA
Water Boards

Gavin Newsom
Governor

Yana Garcia
Secretary for
Environmental Protection

State Water Resources Control Board

October 17, 2025

Erin Ragazzi
Assistant Deputy Director, Division of Water Rights
State Water Resources Control Board

SUBJECT: Final Response to the Request for External Scientific Peer Review of the Scientific Basis of a Ventura River Watershed Groundwater-Surface Water Model

Dear Erin,

This letter is in response to the attached, revised 11 October 2024 request for external scientific peer review for the subject noted above. The review process is described below. All steps were conducted in confidence. Reviewers' identities were not disclosed.

To begin the process for selecting reviewers, the Program contacted the University of California, Berkeley (University) and requested recommendations for candidates considered qualified to perform the assignment. This service is supported through an Interagency Agreement co-signed by CalEPA and the University. The University was provided with the request letter and attachments. The University interviews each promising candidate.

Each candidate who was both qualified and available for the review period was asked to complete a Conflict of Interest (COI) Disclosure form and submit to the CalEPA Peer Review Program for review, with their Curriculum Vitae. The cover letter for the COI form describes the context for COI concerns that must be taken into consideration when completing the form: "As noted, staff will use this information to evaluate whether a reasonable member of the public would have a serious concern about [the candidate's] ability to provide a neutral and objective review of the work product."

For each candidate judged to be free of conflict, the Program approved that person as reviewer, affirmed by an approval letter to initiate the review. These letters provided access instructions to a secure FTP site where all material to be reviewed was placed. Each reviewer was asked to address each conclusion for which they had previously agreed, as outlined in the initiation letters. Thirty days were provided for the review, unless a reviewer requested additional time. Guidance was provided to ensure confidentiality through the review process.

Reviewers’ names, affiliations, curriculum vitae, initiating letters and reviews are being sent to you now with this letter. This information can be accessed easily through the bookmarks provided in this file.

The review commenced on 23 December 2024, and all initial draft review reports were received by 23 January 2025. Clarification was sought from reviewers after Division of Water Rights (Water Rights) reviewed the reports. Additionally, Water Rights amended their technical report in response to the reviewer’s findings, and a subsequent review was initiated on 7 July 2025. All additional review reports were submitted by 10 August 2025. Upon receipt of the draft review reports, Division of Water Rights staff conducted a sufficiency review of each report and found the reviewers independently and collectively addressed all assumptions, conclusions, and findings under review. The review reports have since been brought into compliance with web accessibility standards. This letter includes those reports and concludes this peer review request.

Approved reviewers:

1. James W. Jawitz, Ph.D.
   Professor, University of Florida
   Department of Soil, Water, and Ecosystem Sciences
   2181 McCarty Hall, PO Box 110290, Gainesville, FL 32611

2. George M. Hornberger, Ph.D.
   University Distinguished Professor Emeritus, Vanderbilt University
   155 Buttrick Hall, Nashville, TN 37240

If you have any questions, please contact the External Scientific Peer Review Program at ORPP-ExternalPeerReview@Waterboards.ca.gov.

Sincerely,

Paola Gonzalez, Senior Environmental Scientist
CalEPA External Scientific Peer Review Program Supervisor
Office of Research, Planning, and Performance
State Water Resources Control Board

Attachments:

(1) Request for External Scientific Peer Review of the Scientific Basis of a Ventura River Watershed GW-SW Model October 11, 2024

(2) Letters to Reviewers Initiating the Review
    i. James W. Jawitz, Ph.D.
    ii. George M. Hornberger, Ph.D.

(3) Guidance to Reviewers, posted at FTP site

(4) Curriculum Vitae
    i. James W. Jawitz, Ph.D.
    ii. George M. Hornberger, Ph.D.

(5) Email from CalEPA External Scientific Peer Review Program to reviewer (Jawitz) requesting subsequent review, including supporting documents

(6) Email from CalEPA External Scientific Peer Review Program to reviewer (Hornberger) requesting clarification, including supporting documents

(7) Web Accessible Reviews
    i. James W. Jawitz, Ph.D.
    ii. George M. Hornberger, Ph.D.
    iii. George M. Hornberger, Ph.D. (addendum for clarification)
    iv. James W. Jawitz, Ph.D. (subsequent review)

cc:

Philip Dutton
Supervising Water Resource Control Engineer, Supply & Demand Section
State Water Resources Control Board

Zachary Zwahlen
Senior Environmental Scientist Supervisor, Instream Flows Unit 1
State Water Resources Control Board

Shahab Araghinejad
Water Resources Control Engineer
State Water Resources Control Board

CALIFORNIA
Water Boards

Gavin Newsom
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SECRETARY FOR
ENVIRONMENTAL PROTECTION

State Water Resources Control Board

TO: Carol Perkins
Manager, CalEPA Scientific Peer Review Program
Office of Research, Planning, and Performance
State Water Resources Control Board

FROM: Erin Ragazzi
Assistant Deputy Director
Division of Water Rights
State Water Resources Control Board

DATE: October 11, 2024

SUBJECT: Request for External Scientific Peer Review of the Scientific Basis of a Ventura River Watershed Groundwater-Surface Water Model

Ventura River Watershed Groundwater-Surface Water Model

This request is regarding a groundwater-surface water hydrology model developed to simulate the Ventura River watershed (VRW), including associated technical report. State Water Resources Control Board (State Water Board) staff request that you initiate the process to identify external scientific peer reviewers for the scientific basis for the planning model and associated technical report, per the requirements of California Health and Safety Code (HSC) section 57004.

The Ventura River Groundwater-Surface Water Model is a planning model that will be used by the State Water Board to evaluate and inform the development and establishment of instream flow requirements for anadromous fish in the Ventura River watershed. Instream flow requirements may be imposed through a rule as defined in Health and Safety Code section 57004, subdivision (a)(1), including by regulation or State Water Board policy for water quality control adopted pursuant to the Porter-Cologne Water Quality Control Act.

Purpose of Review

The State Water Board, under contract with Geosyntec Consultants, Daniel B. Stephens & Associates (DBS&A), and University of California professors, developed the groundwater and surface water model for the Ventura River watershed to help evaluate and develop instream flows for anadromous fish, and in support of the California Water Action Plan, Water Resilience Portfolio, California Salmon Strategy, and litigation related to instream flows and associated water use in the Ventura River watershed. The groundwater-surface water hydrology model and report are titled “Groundwater-Surface

Water Model for the Ventura River Watershed” (VRW GW-SW Model) and “Model Documentation Report of the Groundwater-Surface Water Model for the Ventura River Watershed” (VRW GW-SW Model Report), respectively.

This model is part of coordinated administrative efforts that may include a new regulation or policy for water quality control adopted by the State Water Board to protect or enhance flows in the Ventura River watershed. The VRW GW-SW Model will be used as a planning tool to support development of instream flow requirements for the Ventura River watershed. Specifically, the VRW GW-SW Model will help inform the Board’s establishment of instream flows that consider and balance beneficial uses of water in the Ventura River watershed (e.g., fisheries, municipal, agricultural, etc.). The Board is the agency responsible for making such determinations (See, e.g. Water Code sections 100, 275, and *National Audubon Society v. Superior Court* (1983) 33 Cal.3d 419, 446 noting that “the State has an affirmative duty to take the public trust into account in the planning and allocation of water resources, and to protect public trust uses whenever feasible.”).

The VRW GW-SW Model is not an operations model and will not be used to implement instream flow requirements in real time. Rather, instream flows established with support from the VRW GW-SW Model would be implemented using instream flow gages in the Ventura watershed as compliance points.

Supporting Documents and References

The VRW GW-SW Model[1] and VRW GW-SW Model Report[2] were published on the State Water Board’s California Water Action Plan: Ventura River watershed website[3] on June 21, 2024, and uploaded to a file-transfer-protocol (FTP) website for the peer review process on July 12, 2024. A list of key references cited in the VRW GW-SW Model Report and copies of the references are also available on the FTP website.

In December 2021, the State Water Resources Control Board (State Water Board) published the Draft VRW GW-SW Model and Report to solicit comments on methodology, datasets, and results. A spreadsheet summarizing the comments and technical responses is provided to assist peer reviewers. The Response to Comments spreadsheet, vrw_gsflow_draft_comments.xlsx[4], was published to the State Water Board’s California Water Action Plan: Ventura River watershed website on June 21, 2024.

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[1] URL: https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/cwap_enhancing/docs/ventura_river/vrw_gsflow.zip

[2] URL: https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/cwap_enhancing/docs/ventura_river/vrw_gsflow_report.zip

[3] URL: https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/cwap_enhancing/ventura_river.html

[4] URL: https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/cwap_enhancing/docs/ventura_river/vrw_gsflow_draft_comments.xlsx

Requested Review Period

We request that scientific peer review of the VRW GW-SW Model and VRW GW-SW Report be completed during a 30-day period.

Necessary Areas of Expertise for Reviewers

Surface water and groundwater hydrologists with experience in watershed-scale surface water and groundwater modeling are desired for this peer review. Board staff expect peer reviewers with this expertise will be capable of reviewing the calibration and validation aspects of the VRW GW-SW Model in the VRW GW-SW Model Report.

As noted above, this planning model is intended to inform near-term flow requirements based on the current conditions (baseline scenario), therefore the absence of scenario-specific applications of this model, such as climate change scenarios or assessment of hydrology changes associated with land use and soil characteristics (e.g., fires, conversion of agricultural land to hardscape, etc.) is intentional.

Further, review of the VRW GW-SW Model and VRW GW-SW Model Report will not require peer reviewers with expertise of fishery sciences. As the trustee agency responsible for fish and wildlife in California, the California Department of Fish and Wildlife (CDFW) will use the VRW GW-SW Model in identifying instream flow targets that best protect steelhead at points of interest in the Ventura River and San Antonio Creek. The unimpaired flows provided by the model provide CDFW with water availability in the Ventura River watershed in various hydrologic conditions (wet, moderate, and dry). Input from CDFW on the life cycle needs of anadromous fish would not improve the accuracy and precision of the VRW GW-SW Model's unimpaired flows.

We request at least two (2) peer reviewers with expertise in one or more of the following areas to review the conclusions detailed in Attachment 2. Each expert is anticipated to have sufficient expertise to evaluate the findings assigned to them and labelled "Assigned". Additionally, if the expert has sufficient expertise, they are also requested to evaluate findings that are labelled "If qualified". Please note, that findings labelled "If qualified, please evaluate" are assigned to another peer reviewer as a required finding.

Surface water hydrologist and modeler or with modeling experience, preferably with experience with Precipitation Runoff Modeling System (PRMS), watershed-wide supply and demand analyses, and coupled Groundwater and Surface-water FLOW (GSFLOW) modeling platforms.

As described in Attachment 2, it is requested this expert review the scientific assumptions, references, and findings, in the following sections of the VRW GW-SW Model Report.

- Supply and Demand Analysis (Section 2)
  - Assigned: Findings 1a,b,c,d
- VRW GW-SW Model – Surface Water (Section 3)
  - Assigned: Findings 2a,b

- Geologic Analysis (Appendix C)
  - If qualified, please evaluate: Findings 3a,b,c
- VRW GW-SW Model – Groundwater (Section 4)
  - If qualified, please evaluate: Findings 4a,b,c,d
- VRW GW-SW Model Calibration and Validation (Section 5)
  - Assigned: Findings 5a,b,c,d
- VRW GW-SW Model – Sensitivity Analysis (Section 6)
  - Assigned: Findings 6a,b,c
- VRW GW-SW Model – Unimpaired Flow Scenario (Section 7)
  - Assigned: Findings 7a,b,c

Groundwater hydrogeologist and modeler or with modeling experience, preferably with experience with the modular three-dimensional finite-difference ground-water flow model (MODFLOW) and coupled Groundwater and Surface-water FLOW (GSFLOW) modeling platforms. As described in Attachment 2, it is requested this expert review the scientific assumptions, references, and findings in the following sections of the VRW GW-SW Model Report:

- Supply and Demand Analysis (Section 2)
  - Assigned: Findings 1a,b,c,d
- VRW GW-SW Model – Surface Water (Section 3)
  - If qualified, please evaluate: Findings 2a,b
- Geologic Analysis (Appendix C)
  - Assigned: Findings 3a,b,c
- VRW GW-SW Model – Groundwater (Section 4)
  - Assigned: Findings 4a,b,c,d
- VRW GW-SW Model Calibration and Validation (Section 5)
  - Assigned: Findings 5a,b,c,d
- VRW GW-SW Model Sensitivity Analysis (Section 6)
  - Assigned: Findings 6a,b,c
- VRW GW-SW Model Unimpaired Flow Scenario (Section 7)
  - Assigned: Findings 7a,b,c

List of Attachments

Attachment 1:	Plain English Summary
Attachment 2:	Assumptions, References, and Findings to Review for Ventura River Watershed Groundwater-Surface Water Model and Report
Attachment 3:	Individuals who Participated in the Development of the VRW GW-SW Model
Attachment 4:	References Cited in VRW GW-SW Model and Report
Attachment 5:	Responses to Public and Technical Advisory Committee Comments on Draft Ventura River Groundwater-Surface Water Model and Report (2021)

Attachment 1: Plain English Summary

The State Water Resources Control Board (State Water Board) and Regional Water Quality Control Boards (collectively Water Boards) are responsible for the reasonable protection of water quality and beneficial uses of water as well as ensuring the proper allocation of water and the prevention of the waste and unreasonable use of water. The State Water Board is working on various efforts to establish minimum flows that support threatened and endangered fisheries species with consideration of other uses of water.

Governor Brown Jr.'s 2014 California Water Action Plan identified various actions including the need to "Protect and Restore Important Ecosystems" and directed that:

> The State Water Resources Control Board and the Department of Fish and Wildlife will implement a suite of individual and coordinated administrative efforts to enhance flows statewide in at least five stream systems that support critical habitat for anadromous fish. These actions include developing defensible, cost-effective, and time-sensitive approaches to establish instream flows using sound science and a transparent public process. When developing and implementing this action, the State Water Resources Control Board and the Department of Fish and Wildlife will consider their public trust responsibility and existing statutory authorities such as maintaining fish in good condition.

The Ventura River was identified as one of the five priority streams for this effort. Since 1997, Southern California steelhead (*Oncorhynchus mykiss; s*teelhead), an anadromous fish, have been listed under the federal Endangered Species Act as an endangered species. The listing was most recently renewed in May 2023. In April 2024, the California Department of Fish and Wildlife (CDFW) listed Southern California steelhead as endangered under the California Endangered Species Act.

In response to Governor Newsom's Executive Order N-10-19, the California Water Resilience Portfolio was developed and directs state agencies to "Protect and Enhance Natural Systems". The WRP directs state agencies to, among other actions:

- "Conduct and utilize instream flow analyses to further develop instream flow recommendations for ecologically important streams to protect public trust values."
- "Develop analytical modeling tools that can be used to rapidly assess streamflow depletion tied to groundwater pumping."

Further, Governor Newsom's California Salmon Strategy for a Hotter Drier Future (Salmon Strategy) was published in 2024 and provides ongoing direction related to this work. The Salmon Strategy directs the State Water Board and California Department of Fish and Wildlife to, "by 2026, complete instream flow analysis for all streams identified in the 2014 California Water Action Plan, which includes the Ventura River…" and other watersheds.

In 2014, Santa Barbara Channelkeeper filed a lawsuit against the City of San Buenaventura (City of Ventura) and the State Water Board focused on flows for steelhead. Subsequently, in January 2020, the City of Ventura expanded the litigation to all surface water diverters and groundwater pumpers in the Ventura River watershed. The cross-complaint initiated a basin-wide surface water-groundwater adjudication process; the State Water Board has intervened in the cross-complaint. The State Water Board is participating in an ongoing confidential mediated settlement as a potential means of resolving the pending litigation.

As part of its responsibilities under the California Water Action Plan, California Water Resilience Portfolio, and Salmon Strategy, the State Water Board is working to ensure the reasonable protection of beneficial uses in priority watersheds. The State Water Board and CDFW are working to identify potential actions that may be taken to enhance and establish instream flows for steelhead in the Ventura River watershed. The Ventura River Watershed Groundwater-Surface Water (VRW GW-SW) Model and Report were developed to provide the State Water Board and other parties with a better understanding of water supply, water demand, and instream flow in the Ventura River watershed. The VRW GW-SW Model and VRW GW-SW Model Report are part of the planning process and as such will help inform the development of minimum flow requirements. The VRW GW-SW Model is not designed to be an operations model that would be used to implement instream flow requirements.

Attachment 2: Scientific Assumptions, References and Findings, to Review for Ventura River Watershed Groundwater-Surface Water Model and Report

The VRW GW-SW Model will be used as a planning tool to support development of instream flow requirements for the Ventura River watershed. Specifically, the VRW GW-SW Model will help inform the Board's establishment of instream flows that consider and balance beneficial uses of water in the Ventura River watershed.

We request that you make this determination for each of the following items that may constitute a component of the scientific portion of a regulatory action the State Water Board may take in the Ventura River watershed. A background summary of the Groundwater and Surface-water FLOW (GSFLOW) modeling platform, on which the VRW GW-SW Model was built, is provided below. Specific peer review findings related to items pertaining to the development of the VRW GW-SW Model and VRW GW-SW Report are provided to focus the review of each item. For the peer review findings, explanatory text is provided to describe the related assumptions and/or findings.

Summary of the VRW GW-SW Model

As described in Section 1.4 of the VRW GW-SW Model Report, the overall goal of developing the VRW GW-SW Model is to provide scientifically defensible, cost-effective, time-sensitive, and publicly transparent tools that can be used to support the State Water Board instream flow efforts. The VRW GW-SW Model will be used to meet the following specific project objectives:

- Estimate existing instream flows at multiple points of interest (POI) throughout the entire VRW.
- Evaluate how water use affects the water balance and instream flows;
- Simulate groundwater pumping and GW-SW interactions to understand groundwater effects on instream flows;
- Have a model simulation period long enough to reasonably capture the variability of the full range of water year (WY) types from drought to flood years;
- Simulate unimpaired flow at each POI that would occur with no water diversions, pumping, or storage;
- Simulate the effects of the December 2017-January 2018 Thomas Fire on hydrology, groundwater levels, and instream flows;
- Simulate the effects of climate change, Matilija Dam removal, and other scenarios on hydrology, groundwater levels, and instream flows.

As described in Section 1.5 of the VRW GW-SW Model Report, the United States Geological Survey (USGS) Groundwater and Surface-water FLOW (GSFLOW) software platform was selected as the code for the VRW GW-SW Model because it has the advantages of a high level of credibility and transparency, online training availability, widespread use, and thorough public documentation.

GSFLOW is a coupled groundwater and watershed flow model that integrates the USGS Precipitation-Runoff Modeling System (PRMS) watershed model and USGS Modular Finite-Difference Ground-water Flow model (MODFLOW). GSFLOW was developed by USGS to simulate coupled groundwater-surface water flow in one or more watersheds by simultaneously simulating flow across the land surface, within subsurface saturated and unsaturated materials, and within streams and lakes. As detailed in the GSFLOW documentation (Markstrom et al., 2008), additional model components were developed, and existing components were modified, to facilitate integration of the models.

GSFLOW runs on a daily time step. Methods were developed to route flow among the PRMS hydrologic response units (HRUs) and between the HRUs and the MODFLOW finite-difference cells. An important aspect of the integrated model design is its ability to conserve water mass and to provide comprehensive water budgets for a location of interest. In addition to running integrated simulations, GSFLOW can also be run in PRMS-only or MODFLOW-only modes.

The VRW GW-SW Model is a planning model that will not be used to implement instream flows requirements, but rather will inform the establishment of instream flows that support fisheries and other uses of water in the Ventura River watershed.

The model grid covers the entire Ventura River watershed, with approximately 56,000 land cells, and 1,000 lake cells. CDFW will use the unimpaired flows from the VRW GW-SW Model, in combination with instream flow studies performed by CDFW staff in the Ventura River watershed, to assess needed flow conditions for steelhead at points of interest (POIs) in the watershed. These POIs are in specific reaches of the Ventura River that are at least one mile in length. The 330-foot grid cells of VRW GW-SW Model are accurate enough for the purpose of defining the locations of CDFW POIs and providing the unimpaired flow results at the POIs. More information on the grid size and resolution is presented in sections 4.1 and 4.2 of the VRW GW-SW Model Report.

The temporal resolution of the model was determined in accordance with the needed application of the model. The VRW GW-SW Model is a daily model that simulates flows at a daily time step, which is the appropriate accuracy to inform daily minimum flow requirements needed to support steelhead needs throughout their lifecycle in the Ventura River watershed. The temporal resolution of the model is presented in section 4.2 of the VRW GW-SW Model Report. Please see Table 1 below.

Table 1. Specific sections of the VRW GW-SW Model Report that cover background, goals and objectives, and spatiotemporal resolution of the model.

Section	Subject
1.1	Background
1.4	Goals and Objectives of the Project
4.1	Spatial discretization
4.2	Temporal discretization

Items Pertaining to the Development of VRW GW-SW Model

Peer reviewers are requested to please evaluate the following items pertaining to the VRW GW-SW Model and VRW GW-SW Model Report. Specific sections of the VRW GW-SW Model Report are referenced.

1. Supply and Demand Analysis (Section 2)

Assumptions, References, and/or Findings

As described in Section 2 of the VRW GW-SW Model Report, agricultural and domestic wells in the Ventura River watershed do not typically have reported measurements or estimates of pumping volumes. The exception is in the Ojai Valley Groundwater Basin (Ojai Basin) where quarterly or semi-annual reports are required to be submitted to the Ojai Basin Groundwater Management Agency (OBGMA). In other parts of the Ventura River watershed outside the Ojai Basin, it was necessary to develop estimates of pumping volumes for wells to serve as inputs to the VRW GW-SW Model. This was achieved by performing detailed supply and demand analyses, as described in Section 2.

Section 2 of the VRW GW-SW Model Report first provides an overview of the approach, a summary of the data sources and information used, and descriptions of the methods used to estimate water demands and supplies for the Ventura River watershed. Results and additional details of the analyses are presented as a series of tables (Tables 2.1-2.37) that were cross-checked against other data sources. Finally, a brief description of how results are incorporated into the VRW GW-SW Model is provided.

As described in Section 2.1 of the VRW GW-SW Model Report, the supply and demand analyses balanced estimated water demands with known water supplies, and then used the difference (i.e., deficit in supply) to calculate the unknown pumping volumes. To develop realistic estimates in and around the four groundwater basins, and ideally within smaller subregions in each basin, there is a need to understand spatial differences in the distributions of both supply and demand. Annual water balances were developed for each of the 14 water providers with service areas in the Ventura River watershed. This provided the required spatial resolution and enabled information (e.g., urban water management plans (CMWD, 2010 and 2015) and data particular to those providers were used where available.) The Casitas Municipal Water District (CMWD) distribution area within the Ventura River watershed was divided into five regions to enable additional water balances to be developed at a reasonable spatial scale.

As described in Section 2.6 of the VRW GW-SW Model Report, the water budget analyses incorporate several assumptions to develop estimates for non-measured groundwater pumping throughout the Ventura River watershed. Key assumptions include the spatial distribution of CMWD deliveries throughout the Ventura River watershed, residential per capita water use rates, and crop irrigation rates throughout the watershed, and adjustments of these rates during drought years (as defined in Walters, 2015). The analyses generally used a detailed “bottom up” approach, where assumptions and estimates were made for service areas and sub-regions in the watershed to enable detailed spatial estimates of groundwater pumping volumes.

A key component of the supply and demand analyses was determining the spatial distribution of the CMWD deliveries, and particularly volumes that were used for agriculture, since these have direct implications on the estimates for the non-measured agricultural groundwater pumping. Total volumes for CMWD agricultural deliveries are available through 2015 in CMWD Urban Water Management Plans (CMWD, 2010 and 2015). These could not be used directly, because spatial information on these deliveries was not available. Instead, the results of the current supply and demand analyses were aggregated across the Ventura River watershed and compared to the CMWD delivery data. Results indicate general agreement between the current estimates for CMWD agricultural deliveries and the CMWD delivery data.

Findings

Finding 1a: The methodologies used to address data gaps related to water demand (e.g., surface water supply and groundwater pumping) are sufficiently comprehensive and based upon sound scientific knowledge, methods, and practices.

Finding 1b: The supply and demand analysis used to estimate Lake Casitas deliveries to agricultural groundwater pumpers is based upon sound scientific knowledge, methods, and practices.

Finding 1c: The stated assumptions and limitations of the methods used to address data gaps related to water demand are based on scientifically sound practices and considerations.

Finding 1d: The assumptions and limitations are adequately stated, evaluated, and considered.

2. VRW GW-SW Model – Surface Water (Section 3)

Assumptions, References and/or Findings

As described in Section 3 of the VRW GW-SW Model Report, the surface water model component of GSFLOW uses the USGS PRMS Model (Markstrom et al., 2015). Of the hydrologic systems simulated in GSFLOW, PRMS simulates the hydrologic processes in plant canopy and soil zone. These processes include evaporation, transpiration, runoff, infiltration, and interflow. Section 3 describes the layout and discretization of the PRMS model, the meteorological inputs, the implementation of lakes and reservoirs, diversions from and to streams, transfers to irrigation, and determination of PRMS model parameters.

As described in Section 3.2 of the VRW GW-SW Model Report, meteorological inputs to the PRMS model consist of daily precipitation and daily minimum and maximum temperature. Daily precipitation data from 23 rain gages were processed to fill data gaps. The data gap-filling process for rain gages with missing data involved using data from the nearest available rain gage that was then scaled based upon comparison of the overlapping records between the two rain gages.

The daily precipitation data were interpolated spatially onto each grid cell using a Parameter-elevation Relationships on Independent Slopes Model (PRISM) dataset (PRISM, 2012). The spatial PRISM dataset includes orographic effects and provides additional detail in high-elevation regions of the watershed where there are fewer gages. The PRISM 30-year normal[5] (1981-2010) within Thiessen polygons constructed around rain gage locations were scaled on a daily basis to establish the daily rain depth at each gage location and used as model inputs.

Findings

Finding 2a: The following items related to the PRMS model were developed using sound scientific knowledge, methods, and practices.

- **Layout and discretization of the PRMS model.**
- **Meteorological input data that was compiled and analyzed.**
- **Implementation of lakes and reservoirs, diversions from and to streams, and transfers to irrigation.**
- **Determination and calibration of PRMS model parameters.**

Finding 2b: The methodologies used to address data gaps in meteorological inputs are based on sound scientific knowledge, methods, and practices.

3. Geologic Analysis (Appendix C)

Assumptions, References, and Findings

Appendix C of the VRW GW-SW Model Report summarizes the geologic analysis performed for the Ventura River watershed to support development of the MODFLOW portion of the VRW GW-SW Model and thus the Draft VRW Nitrogen Transport Model. The geologic analysis presented was used, in conjunction with other information as described in the Final Study Plan for the Development of Groundwater-Surface Water and Nutrient Transport Models of the Ventura River Watershed (Geosyntec and DBS&A, 2019), to assign three-dimensional model layer geometry, initial model hydraulic properties (e.g., hydraulic conductivity), and the presence of boundary conditions.

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[5] As stated on the PRISM website (https://prism.oregonstate.edu/), “The normals are baseline datasets describing average monthly and annual conditions over the most recent three full decades. They are our most popular datasets.”

The geologic analysis was performed by mapping the three-dimensional extent of surficial geologic units within the Ventura River watershed, and results were plotted on a series of geologic cross-sections. Alluvial sediment thickness was estimated from review of boring logs, geophysical logs, previous geologic studies, and the location of non-alluvial bedrock outcrops. In the Ojai Basin, previous analysis of geophysical logs from wells located in the Ojai Basin was used to map alluvium thickness (DBS&A, 2011), and this previous mapping was updated based on newly received well logs. The geophysical log analysis also identified the presence of aquifer and semi-confining units in the Ojai Basin.

Bottom-of-alluvium elevation was interpolated throughout the watershed using bedrock elevation data from each location for which lithologic data were present using a combination of manual contouring based on professional judgement and geostatistical (‘kriging’) methods. Previously developed maps of bottom-of-alluvium elevation in the Ventura River watershed developed by Turner (1971) and SGD (1992) were also used to inform the bottom-of-alluvium elevation.

Findings

Finding 3a: The geologic analysis and interpretation of alluvium and semi-confining units was performed using sound scientific knowledge, methods, and practices.

Finding 3b: The interpolation of the bottom-of-alluvium elevation was performed using sound scientific knowledge, methods, and practices.

Finding 3c: The assumptions and limitations are adequately stated, evaluated, and considered.

4. VRW GW-SW Model – Groundwater (Section 4)

Assumptions, References, and Findings

As described in Section 4 of the VRW GW-SW Model Report, the groundwater model component of GSFLOW uses the USGS MODFLOW modeling platform (Markstrom et al, 2015). Of the hydrologic systems simulated in GSFLOW, MODFLOW simulates the hydrologic processes in streams, lakes, and in the subsurface (i.e., below the soil zone simulated by PRMS). Flows are exchanged between PRMS and MODFLOW in many forms (e.g., groundwater recharge from soil zone to the subsurface, interflow from the soil zone to streams and lakes, and groundwater discharge from the subsurface to the soil zone). Section 4 describes the layout and discretization of the MODFLOW model, parameter inputs, boundary conditions, initial conditions, and model implementation.

As described in Section 4.1 of the VRW GW-SW Model Report, the active groundwater model domain extends horizontally throughout the entirety of the Ventura River watershed. The groundwater model represents groundwater flow in the groundwater basins, additional areas of saturated alluvium (e.g., the area underlying San Antonio Creek south of the Ojai Basin), and the bedrock aquifers. Vertically, the full thickness of all groundwater basins is represented, and the bedrock model layer thickness is based on the depth to bedrock data associated with the majority of domestic and agricultural wells screened in bedrock units.

Seven vertical model layers are present in the MODFLOW model, and they are numbered with 1 as the top and 7 as the bottom. The top of Layer 1 represents the bottom of soil zone (simulated by PRMS). Layers 1 through 3 are active throughout the entire Ventura River watershed. Layers 4 through 7 are only active within and underneath the Ojai Basin, which has thicker alluvial deposits compared to the rest of the Ventura River watershed. The layering in the Ojai Basin is generally consistent with the layering of the Ojai Basin Groundwater Management Agency (OBGMA) Model (DBS&A, 2011). However, some layers in the OBGMA Model (which simulated the alluvium with 10 layers) were aggregated into six layers of alluvium for the Ojai Basin portion of the VRW GW-SW Model. Wherever there is alluvium in the VRW GW-SW Model domain, a thick layer of bedrock of at least 200 feet was simulated underneath the alluvium.

As described in Section 4.3 of the VRW GW-SW Model Report, groundwater elevations must be assigned for each model cell at the beginning of the model simulation, and these are referred to as “initial conditions.” No wet/dry mapping data is available for fall 1993. Initial conditions in the groundwater basins were assigned based on interpolation of measured data for fall 1993, which is the beginning of the model calibration/validation time period. Streambed “wet/dry” mapping from fall-winter 2016 was also used to guide the initial conditions interpolation, with the assumption that areas of the streams that are mapped as “wet” would be generally similar in fall 1993. Additionally, “wet” streambed elevations were consistent with groundwater elevations observed from surrounding wells. Stream areas mapped as “wet” were assumed to be in hydraulic connection with groundwater and streambed elevations were therefore assumed to be similar to groundwater elevations.

This simplifying assumption is considered to be reasonable in most parts of the Ventura River watershed but may not be true in all cases. For example, in some instances there may be an unsaturated zone beneath the streambed of a losing stream and therefore no connection. The assumption of hydraulic connection in areas mapped as wet also does not preclude areas not mapped as wet as having a hydraulic connection during the model simulations.

Initial conditions outside the groundwater basins (e.g., within the bedrock units) were assigned based on simulated values as of September 2005 from early VRW GW-SW Model runs, noting that Water Year (WY) 2005 had similar hydrology as WY1993. These initial conditions were updated as needed during the model calibration process to be consistent with simulated September 2005 values for each run.

Initial conditions dictate only the model conditions at the beginning of the simulation. As described in Section 4.3 of the VRW GW-SW Model Report, testing of the VRW GW-SW Model indicated that the assumed initial conditions within the alluvium did not impact model simulations during the calibration period significantly.

Findings

Finding 4a: The parameterization of boundary conditions, alluvial aquifers, aquitards and confining layers, and bedrock aquifers within the groundwater model domain was performed using sound scientific knowledge, methods, and practices.

Finding 4b: The parameterization of semi-confining layers in the Ojai Valley Groundwater Basin is consistent with sound scientific knowledge, methods, and practices.

Finding 4c: The initial conditions for groundwater levels within and outside the Ventura River watershed's four groundwater basins are established using sound scientific knowledge, methods, and practices.

Finding 4d: The assumptions and limitations are adequately stated, evaluated, and considered.

5. VRW GW-SW Model – Calibration and Validation (Section 5)

Assumptions, References, and Findings

As a described in Section 5.1 of the VRW GW-SW Model Report, for the VRW GW-SW Model, a single simulation period was used for calibration and validation ("calibration/validation period") and was further subdivided into a period used for calibration ("calibration period") and a period that was used for validation ("validation period").

The VRW GW-SW Model is a planning tool that will be used to determine unimpaired flow (i.e., water availability) for purposes of establishing flow requirements for fish and other beneficial uses of water. It will not be used to implement instream flow requirements, but rather to inform the establishment of flows.

The VRW GW-SW Model uses two sets of calibration and validation data to assess the model's precision and accuracy. Both calibration and validation datasets include a range of dry to wet water-year types. The calibration and validation of the simulation period (October 1993 – September 2017) is presented in section 5.1 of the model report.

The model errors are discussed using various statistical tests at different time steps (i.e., daily, monthly, seasonal, annual) across the watershed. The results of the model errors analysis are supported by multiple informative figures and tables (see Table 2). The model error analysis results are provided for both calibration and validation data sets. The precision and accuracy of the model results measured by various statistical tests at different time steps are qualitatively categorized (fair to excellent) as recommended by modeling studies in the field of water resources that have used similar statistical tests (section 5.2.1). To measure the acceptability of the model results, the range of various qualitative categories (fair to excellent) for each statistical test is presented for both calibration and validation (or test) datasets. A thorough discussion of model errors is included in section 5.4 of the VRW GW-SW Model Report for surface water results (sections 5.4.1.2, 5.4.1.3, and 5.4.1.4) and groundwater results (section 5.4.2). The model errors are discussed using various statistical tests for different time steps across the watershed. The results of the model errors analysis are supported by multiple informative figures and tables (section 5.4). Furthermore, a spatiotemporal model error analysis is provided in section 5.4.3 of the model report, where wet and dry reaches along the Ventura River and San Antonio Creek for various days of the simulation period are compared with the observed wet and dry maps.

The range of statistical tests comparing simulated and observed data demonstrate that the VRW GW-SW Model results are acceptable (in the range of fair to excellent) as a watershed-wide water budget model to analyze water availability in the Ventura River watershed during various hydroclimatic conditions. This is demonstrated by analysis of the model's precision and accuracy in simulating hydrologic variables across the watershed over a long time-period.

Please see Table 2 below for the sections of the report presenting the error analysis of the model. As presented in section 5.4.1.2 of the model report, the aptness of the model has been categorized as fair to excellent for the range of well-known statistical tests performed as part of the error analysis.

Table 2. Sections of the VRW GW-SW Model report that describe model calibration and uncertainty analysis

Section	Subject	Main Content
5.4.1.1	Surface Water Results Assessment	Graphs demonstrating comparison between simulated and observed data
5.4.1.2	Surface Water Results Assessment	Statistical Metrics for error analysis
5.4.1.3	Surface Water Results Assessment	Error discussion in an annual time scale
5.4.1.4	Surface Water Results Assessment	Simulated and observed lake levels comparison
5.4.2	Groundwater Results Assessment	Graphs and statistical metrics
5.4.3.	Surface and Groundwater Results Assessment	Simulated and observed wet and dry spatiotemporal maps comparison

The GSFLOW calibration/validation period comprises 24 years from WY1994 through WY2017 (October 1, 1993 through September 30, 2017). This period is constrained by limited groundwater pumping datasets prior to the mid-1990s and the assumption of fixed land-use (e.g., cropping types and extents) in the model. Additionally, the Thomas Fire in late 2017/early 2018 altered the watershed's hydrologic characteristics and potentially requires a different set of calibration parameters to correctly model streamflow and recharge. Therefore, using a longer modeling period (i.e., extending prior to WY1994 or after WY2017) was rejected because it would introduce additional uncertainty into many aspects of the model.

The calibration/validation period was divided into a 20-year calibration period (WY1998 through WY2017) and a four-year validation period (WY1994 through WY1997). The calibration and validation periods were altered from those outlined in the Final Study Plan for the Development of Groundwater-Surface Water and Nutrient Transport Models of the Ventura River Watershed (Geosyntec and DBS&A, 2019) to enable both periods to include a representative mix of WY types (i.e., wet years and dry years as defined by Walter, 2015) and to enable the historic multi-year drought (WY2012 through WY2016) to be included in the calibration period.

As described in Section 5.2 of the VRW GW-SW Model Report, calibration of the VRW GW-SW Model consisted of adjustment of specific parameters that govern the surface-water and groundwater portions of the model domain to match simulated groundwater elevation and streamflow values to available real-world measurements. The model calibration approach and parameters that were adjusted for the streamflow and groundwater portions of the model are summarized below. While the streamflow and groundwater model calibration are discussed in separate subsections within Section 5 of the VRW GW-SW Model Report, the final calibrations were performed together in the coupled VRW GW-SW Model.

Section 5.4 of the VRW GW-SW Model Report provides assessments of the final model calibrations to streamflow, groundwater elevations, and wet-dry mapping. The model results indicate good agreement with the measured streamflow during higher flow periods. Notable exceptions are during certain years at some gages where the measured flow rates are anomalously high. Agreement of the model results during low-flow periods (i.e., summer and fall) is generally good, with monthly average flows being well predicted down to approximately 1 cubic foot per second at most locations. Exceptions are noted in years with higher summer flows (e.g., 1995, 1998, 2005, and 2006) where the model underpredicts the summer flows. Model prediction of low flows and how they vary from year to year, including the multi-year drought, are particularly well captured, which was a priority for model development.

The model performs very well in replicating the seasonal drawdowns in Lake Casitas and longer-term drawdowns during the dry years in the early 2000’s, the refill in 2005, and the larger drawdowns in the multi-year drought (WY2012 to WY2016). The trends for Matilija Reservoir are less discernable with the measurements indicating seasonal drawdowns of approximately 8 feet from 2003 through 2010, followed by a more constant elevation after 2011. The model does not fully capture these relatively small changes, which may be a result of difficulties estimating release volumes and the use of a fixed stage-storage relation in the model that does not account for the reservoir filling with sediment over time. As described in Section 3.5.1, changing storage capacity during the modeling period is not implemented into the model. Although this is not consistent with Matilija reservoir storage volume data, the effect in the model is primarily to increase dead storage with anticipated negligible effects on streamflow.

The calibration goals of scaled-root-mean-square-error (RMSE) less than 10 percent and correlation coefficient (R) greater than 0.90 were met during the calibration period for each groundwater basin, the area outside the groundwater basins, and for the model as a whole. During the validation period all statistical measures were met, with the exception of R in the Ojai Valley, which was 0.887 as compared to the goal of 0.90.

Section 5.6 of the VRW GW-SW Model Report describes limitations of the VRW GW-SW Model. The model limitations for the surface water (PRMS) portion of the VRW GW-SW Model, include:

- GSFLOW uses a daily rainfall input and a daily time-step that makes it difficult to resolve the details of individual storm events, including the rate of recession, in the relatively small watershed. This limitation would not appreciably affect dry season low-flow periods.
- The model assumes that land use is fixed in time, including urban development and crop types and extents. This does not account for times in the past where crops may have been fallowed and may have resulted in overestimation of applied water and overestimation of groundwater pumping in some regions during those times.
- The model assumes that the extent of riparian vegetation is fixed in time. This assumption neglects the temporal effects of Arundo eradication efforts, reduction in vegetation following storm events in wet years, and potentially increased evapotranspiration following wet years as vegetation reestablishes. This limitation would primarily affect dry season low-flow periods.
- The model assumes that the channel cross-sections are fixed in time, whereas natural geomorphic processes are constantly occurring. For this reason, the model is better used as a hydrologic tool than a hydraulic one. Reach-specific hydraulic models may use this model’s hydrologic output for different locations and points in time to better predict flow depths, velocities, and shear stresses, such as needed for a fish passage assessment.
- The model assumes a fixed stage-storage relation for Matilija Reservoir. However, the storage relation has changed over time as the reservoir fills with sediment. This may impact the ability to model the releases and downstream flow from the reservoir during low flows.
- Uncertainty from the MODFLOW portion of the simulation will propagate and influence groundwater discharge to surface water estimates.

The model limitations for the groundwater (MODFLOW) portion of the VRW GW-SW Model include:

- Most observation wells are also actively pumped; therefore, observed water levels may be influenced by active pumping and are expected to be lower than the adjacent aquifer.
- Pumping rates are mostly estimated based on a large-scale water balance.
- Well screen intervals (for pumping and observation wells) are often unknown and must be assumed.

- Month-long model stress periods require averaging of boundary flux rates (e.g., model pumping rates), which are assumed constant throughout a month.
- Necessary simplifications in the model layering due to uncertainty in the geologic analysis.
- Homogenous hydraulic properties are assumed within the MODFLOW property zones. 330-ft model grid cells require generalization over fairly broad areas (e.g., assumed equal topographic surface throughout the cell).
- General Head Boundaries (GHB) and Constant Head Boundaries (CHB) are set at the watershed boundary within the Upper Ojai Basin and at the Pacific Ocean, respectively. Predictive simulation results are inherently more uncertain in the vicinity of GHB and CHD (Anderson and Woessner, 1992). The Upper Ojai GHB is likely within the vicinity of a groundwater divide as it is the location of a surface water divide. However, the VRW GW-SW Model simulates groundwater flow into the Ventura River watershed along the boundary. Surface water and groundwater divides are not necessarily at the same location in arid climates, and the divide location is influenced by pumping on both sides of the divide (Fetter, 2001). The location of the groundwater divide between the Ventura River and Santa Clara River watersheds is not well defined and is identified as a current data gap.
- Due to necessary limitations associated with the model grid, the VRW GW-SW Model is not structured to simulate lateral flow to the deep portions of the bedrock units that underlie the alluvial Ojai Basin (Layers 4 through 7).
- Uncertainty from PRMS-portion of the simulation will propagate and influence groundwater recharge estimates.
- Limited aquifer test data are available to constrain the model's assumed hydraulic conductivity and storage values; future data collection may focus on additional aquifer tests.
- Initial conditions were assigned based on several simplifying assumptions (see Section 4.3 of the VRW GW-SW Model Report); however, the impact of initial conditions on model simulations and results are minor based on model testing.
- No groundwater elevation data was identified for the Lower Ventura River Basin during the validation period (WYs 1994-1997).

Findings

Finding 5a: The model calibration and validation periods are consistent with sound scientific knowledge, methods, and practices. For example, the model calibration and validation period is long enough to reasonably capture the variability of the full range of water year types, from very dry years to very wet years.

Finding 5b: The VRW GW-SW Model's calibration and validation sufficiently simulates the historical streamflow, reservoir, and groundwater levels observed during the model simulation period using sound scientific knowledge, methods, and practices.

Finding 5c: The stated assumptions and limitations of the VRW GW-SW Model are explained and/or addressed using sound scientific knowledge, methods, and practices.

Finding 5d: The assumptions and limitations are adequately stated, evaluated, and considered.

6. VRW GW-SW Model – Sensitivity Analysis (Section 6)

To support both model calibration and the uncertainty analysis, a sensitivity analysis was done to measure the effects of changing the model inputs on the outputs (i.e., performance of the model). The details of the calibration and uncertainty analysis are presented in section 6 of the VRW GW-SW Model Report.

Assumptions, References and Findings

As described in Section 6.1 of the VRW GW-SW Model Report, a model sensitivity analysis typically involves repeatedly running a calibrated model with systematic variation of model inputs, followed by graphical and statistical assessments of changes in model outputs. The specifics of the model and the characteristics of the watershed influence which model inputs are varied and the variation magnitude. In addition, the outputs of focus or concern are also important to consider during a sensitivity analysis and will influence which input parameters are varied.

As described in Section 6.1 and summarized in Table 6.1 of the VRW GW-SW Model Report, the soil and surface water inputs, groundwater inputs, and water supply and use assumptions selected for sensitivity analysis were multiplied by factors to increase and decrease the inputs from their original calibrated values. While these inputs generally vary spatially throughout the watershed, the adjustment factors were applied uniformly. Results from past studies guided the magnitude of the adjustment factors, while also maintaining parameter and input values within physically realistic bounds.

Table 6.1 GSFLOW Model Inputs to be Varied in Sensitivity Analysis

Model Input	Description	Multipliers	Notes
soil_moist_max	Maximum available water holding capacity of capillary reservoir from land surface to rooting depth of the major vegetation type of each hydrologic response unit (HRU) [1]	0.8, 1.2	Affects Hortonian surface runoff, evapotranspiration (ET), direct recharge, and flow to gravity reservoir
sat_threshold	Water holding capacity of the gravity and preferential flow reservoirs [1]	0.8, 1.2	Difference between field capacity and total soil saturation for each HRU

Model Input	Description	Multipliers	Notes
slowcoef_sq	Non-linear coefficient in equation to route gravity reservoir storage downslope for each HRU [1]	0.8, 1.2	Controls slow interflow from gravity reservoir. The linear coefficient in the equation had less effect than the non-linear term and is not included in the sensitivity analysis.
jh_coef	Monthly (January to December) air temperature coefficient used in Jensen-Haise potential ET computations [1]	0.8, 1.2	Will directly affect ET and overall water balance
extinction depth	Depth to which ET can occur from groundwater	0.5, 2.0	Only applied to regions with riparian vegetation
ssr2gw_rate	Rate at which water from the soil zone enters the groundwater	0.5, 2.0	Affects both surface water and groundwater
Streambed hydraulic conductivity	Hydraulic conductivity of streambed	0.25, 4.0	Affects groundwater-surface water exchange
Horizontal Hydraulic conductivity	Hydraulic conductivity, broken out for each model layer within each basin and the bedrock areas	0.25, 4.0	Affects rate of groundwater movement
Specific yield	Broken out for each unconfined model layer within each basin and the bedrock areas	0.3, 2 (subject to specific yield not less than 0.02 or greater than 0.3)	Affects the amount of groundwater held in storage
Storage coefficient	Broken out for each model layer within each basin and the bedrock areas	0.1, 10	Affects the amount of groundwater held in storage
Vertical anisotropy	Broken out for each model layer within each basin and the bedrock areas	0.1, 3	Affects rate of vertical groundwater movement

Model Input	Description	Multipliers	Notes
Horizontal-flow barrier conductance	Hydraulic conductivity for faults that intersect alluvial basins	0.1, 10	Affects the rate of groundwater movement across fault zones
General-head boundary (GHB) conductance	GHB where assigned (e.g., at Pacific Ocean, at watershed boundary in Upper Ojai Basin).	0.1, 10	Affects the rate of groundwater flow in cells assigned a GHB condition
Unsaturated-Zone Vertical Hydraulic Conductivity	Saturated vertical hydraulic conductivity of the vadose zone, broken out for each Basin and the bedrock areas	0.1, 10	Affects rate of subsurface water movement above the level of groundwater
Various	Assumptions used in the water supply/use calculations	Vary groundwater pumping volumes up to +/- 20%	Will affect groundwater elevations and low flows

GHB = General-head boundary

[1] PRMS-IV Techniques and Methods 6–B7 (Markstrom et al., 2015)

As described in Section 6.1.2 of the VRW GW-SW Model Report, some PRMS parameters identified in literature as important are not included in the sensitivity analysis. For example, precipitation inputs are included as sensitivity parameters in some studies (e.g., Tian et al., 2015) that have limited meteorological stations. As described in Section 3.2 of the VRW GW-SW Model Report, the Ventura River watershed has more than 20 precipitation measurement stations, and PRISM data were used to augment the observed precipitation data. Therefore, it is expected that resultant precipitation inputs are reliable and are not included in the sensitivity analysis.

Other parameters are not included due to relatively small effects being noted during calibration processes. These include the estimated stream widths and the surface water diversion volumes. The surface runoff parameter, carea_max, the maximum possible fractional area contributing to surface runoff, is varied in some sensitivity studies (e.g., Tian et al., 2015; Markstrom et al., 2016). However, during initial calibration of the VRW GW-SW Model in PRMS-only mode (i.e., not coupled to groundwater) for this study, carea_max showed very small impacts on output variables. Many prior PRMS sensitivity studies used PRMS models that were developed using a lumped parameter approach; whereas, the VRW GW-SW Model is a gridded parameter model. For example, the Regan et al. (2018) PRMS model for the Continental U.S. has approximately 50 HRUs in the Ventura River watershed. As described in Section 3.1 of the VRW GW-SW Model Report, the VRW GW-SW Model has over 100,000 smaller gridded HRUs. Responses of the empirical equations for model parameters assigned on a much finer scale may be different to those assigned in the lumped-parameter approach.

Findings

Findings 6a: The 15 model parameters selected for variation in the sensitivity analysis are evaluated or considered consistently with sound scientific knowledge, methods, and practices.

Finding 6b: The multipliers for each model parameter are varied by a range that is consistent with sound scientific knowledge (i.e., realistic physical conditions), methods, and practices.

Finding 6c: The model parameters are appropriate and sufficiently varied and consistent with sound scientific knowledge, methods, and practices.

7. VRW GW-SW Model – Unimpaired Flow Scenario (Section 7)

Assumptions, References, and Findings

As described in Section 7.1 of the VRW GW-SW Model Report, the purpose of an unimpaired flow scenario is to estimate the total quantity of water available in the watershed that may be put to a reasonable and beneficial use for human and ecosystem needs. The unimpaired flow scenario does not attempt to simulate natural flow.

As described in Section 7.2 of the VRW GW-SW Model Report, the unimpaired flow scenario simulates streamflow and groundwater levels that would occur during the historical modeling period under the following assumptions:

- Evaluation of the same historical time period used for model calibration and validation, WY1994 to WY2017;
- All diversions from surface water are set to zero;
    - Reservoirs are set to zero storage, zero evaporation, and zero leakage. Water flows through existing reservoir locations with no impediment (e.g., no dam);
- All pumping from groundwater is set to zero;
- All other water infrastructure (e.g., levees, channelization, imperviousness, flood bypasses, etc.) functions are consistent with existing conditions:
    - The effects of water infrastructure, excluding dams, on stream routing, infiltration, floodplain connectivity, etc. are retained;
- Land use is consistent with existing conditions:
    - Agricultural, municipal, and industrial land uses are retained;
    - Existing vegetation is retained; and
    - Vegetation types (agriculture, natural, domestic) are retained, but not irrigated. Therefore, vegetation consumes only water available from precipitation and/or shallow groundwater;
- Water discharges to on-site wastewater treatment systems and from wastewater treatment plants are set to zero.

As described in Section 7.4.1 of the VRW GW-SW Model Report, generally higher streamflow is observed in the unimpaired flow scenario compared to the calibration/validation simulation, also known as the existing condition. The amount of difference between the unimpaired flow scenario and the calibration/validation simulation depends strongly upon the location in the Ventura River watershed.

As described in Section 7.4.2 of the VRW GW-SW Model Report, groundwater elevations are generally higher for the unimpaired flow scenario as compared to the calibration/validation (existing condition) simulation. Groundwater elevation fluctuation is also smaller, as some fluctuation is driven by pumping cycles and there is no pumping in the unimpaired scenario. The unimpaired flow scenario typically results in more significant increases in groundwater elevation observed at wells further from the stream network. Additionally, streambed elevation often governs groundwater elevations observed at nearby wells. The amount of groundwater elevation increase is also influenced by the assumed specific yield at the well location (or specific storage in confined aquifers), which influences the amount of groundwater elevation change due to change in groundwater storage. The largest groundwater elevation increases for the unimpaired scenario are observed in the Ojai Basin, and relatively minor increases are observed in the Lower Ventura Basin.

Compared to the calibration/validation simulation, the unimpaired scenario has larger areas of groundwater discharge to surface water and wetlands, particularly for the dry time period. More extensive areas of groundwater elevations greater than surface elevations are shown for the unimpaired flow scenario particularly near the terminus of the Ojai Basin and Upper Ventura River Basin and along portions of Lion Canyon Creek in the Upper Ojai Basin.

As described in Section 7.4.3 of the VRW GW-SW Model Report, wet-dry mapping generated from model results indicate less drying for the unimpaired flow scenario, particularly in the mid-regions (river km 8 to 20) of the Ventura River and the lower reaches (below river km 12) of San Antonio creek.

As described in Section 7.4.4 of the VRW GW-SW Model Report, the unimpaired flow scenario generally has increased discharge to streams, and higher groundwater evapotranspiration.

It should be noted that Ventura River watershed was impacted by Thomas Fire in December 2017. Analysis of Thomas Fire effects on the hydrology of Ventura River watershed is a scenario that will be evaluated in the foreseeable future using the calibrated VRW GW-SW Model (see section 7 of the model report). Thomas Fire scenario development is an ongoing effort, and results will provide a scenario that simulates how hydrologic responses of Ventura River watershed would be different after a widespread wildfire compared to the existing (pre-Thomas Fire) watershed condition. Once the results of the Thomas Fire scenario become available, a combination of the baseline and Thomas Fire scenarios may be used to inform unimpaired flows depending on the fire impacts present in the watershed at that time. However, based on research on the effects of fires in other watersheds (Verkaik et al. 2013, Bixby et al. 2015, Cooper et al. 2015, and Klose et al. 2015), significant effects of fires on a watershed's hydrology are not anticipated to be permanent. Previous studies of wildfire impacts on watersheds show that watershed conditions recover to their pre-fire hydrologic conditions (e.g., peak flow rates, baseflow rates), as modeled in the baseline and unimpaired flow scenarios of the current VRW GW-SW Model. It should be noted that recovery time after a major wildfire varies by the evaluation metric (e.g., peak flow rates, baseflow rates, grass recovery, woody-stemmed species recovery, total suspended solids, and other pollutant concentrations, etc.). The recovery time of the Ventura River watershed following the Thomas Fire is uncertain and will be assessed using the study completed by our consultants once available.

Findings

Finding 7a: The design of the unimpaired flow scenario is appropriate for the purpose of evaluating the total quantity of water available in the Ventura River watershed during various water year types (e.g., wet, dry). The design of the unimpaired flow scenario is consistent with sound scientific knowledge, methods, and practices.

Finding 7b: It is suitable to use the unimpaired flow scenario results to define water year types during the calibration and validation period.

Finding 7c: The model simulation period is sufficient to reasonably capture the variability of the full range of water year types, from very dry years to very wet years, to assess unimpaired flow.

Attachment 3: Individuals who Participated in the Development of the VRW GW-SW Model

In 2017, the State Water Resources Control Board (State Water Board) and LA Regional Water Board contracted with Geosyntec Consultants, DBS&A, and University of California professors to develop the models and reports. Personnel that worked at these organizations on this effort are excluded as potential peer reviewers.

Since 2017, to support development of the VRW GW-SW Model and the State Water Board have used a rigorous public engagement process that has included seven public and Technical Advisory Committee (TAC) comment solicitation periods covering most aspects of model development. The project team has used in-person and virtual public meetings, TAC meetings, site visits, and coordination with individual parties to share information, obtain feedback, and follow-up on specific issues. Members of the TAC were included in the list for exclusion as potential peer reviewers. Members of the public that submitted comments in more than one comment period are also excluded as potential peer reviewers. Additionally, technical staff from local organizations, such as groundwater management agencies, county government, and water districts, who provided technical information or datasets, during or outside of comment periods, are excluded as potential peer reviewers.

The following is complete list of individuals that should be excluded as potential peer reviewers. Parties to the *Santa Barbara Channelkeeper v. City of San Buenaventura* litigation and parties participating in the confidential settlement mediation, some of which are included in the list below, should be excluded as potential peer reviewers

Affiliation (at time of participation)	Name	Role
Aquilogic	Anthony Brown	Technical Commenter, Expert Witness
California Department of Fish and Wildlife (CDFW)	Amber Villalobos	Partner Agency, Technical Commenter
CDFW	Bryan Demucha	Partner Agency, Technical Commenter
CDFW	Diane Haas	Partner Agency, Technical Commenter
CDFW	Karen Lefebre	Partner Agency, Technical Commenter
CDFW	Mary Ngo	Partner Agency, Technical Commenter
CDFW	Mary Larson	Partner Agency, Technical Commenter
CDFW	Kyle Evans	Partner Agency, Technical Commenter
CDFW	Dane St. George	Partner Agency, Technical Commenter
CDFW	Robert Holmes	Partner Agency, Technical Commenter
CDFW	William Cowan	Partner Agency, Technical Commenter
CDFW	Stephen Puccini	Partner Agency, Technical Commenter
CDFW	Steven Slack	Partner Agency, Technical Commenter

Affiliation (at time of participation)	Name	Role
CDFW	Lena Germinario	Partner Agency, Technical Commenter
CDFW	Brionna Drescher	Partner Agency, Technical Commenter
CDFW	Bronwen Stanford	Partner Agency, Technical Commenter
California Office of the Attorney General	Noah Grasner	Partner Agency, Technical Commenter
California Office of the Attorney General	Marc Melnick	Project Team
Cardno Entrix	Claire Archer	Technical Commenter, Expert Witness
Cardno Entrix	Byron Amerson	Technical Commenter
Casitas Municipal Water District	Julia Aranda	Technical Commenter
Casitas Municipal Water District	Neil Cole	Technical Commenter
Casitas Municipal Water District	Kelley Dyer	Technical Commenter
Casitas Municipal Water District	Michael Flood	Technical Commenter
Daniel B. Stephens & Associates	Daniel Acevedo Perez	Project Team
Daniel B. Stephens & Associates	T. Neil Blandford	Project Team
Daniel B. Stephens & Associates	Farag Botros	Project Team
Daniel B. Stephens & Associates	Theresa Castillo	Project Team
Daniel B. Stephens & Associates	Michael Cruikshank	Project Team
Daniel B. Stephens & Associates	Stephen Cullen	Project Team
Daniel B. Stephens & Associates	Ellen Devine	Project Team
Daniel B. Stephens & Associates	Hannah Erbele	Project Team
Daniel B. Stephens & Associates	Robyn Fay	Project Team
Daniel B. Stephens & Associates	Donald Griggs	Project Team
Daniel B. Stephens & Associates	Tracy Hillman	Project Team
Daniel B. Stephens & Associates	Philip Kaiser	Project Team

Affiliation (at time of participation)	Name	Role
Daniel B. Stephens & Associates	James Kelsey	Project Team
Daniel B. Stephens & Associates	Elena King	Project Team
Daniel B. Stephens & Associates	Alan Lewis	Project Team
Daniel B. Stephens & Associates	Lorraine Martinez	Project Team
Daniel B. Stephens & Associates	April Molina-Alvarez	Project Team
Daniel B. Stephens & Associates	W. Tony Morgan	Project Team
Daniel B. Stephens & Associates	Gundar Peterson	Project Team
Daniel B. Stephens & Associates	Christine Pribulick	Project Team
Daniel B. Stephens & Associates	Sarah Reuter	Project Team
Daniel B. Stephens & Associates	Deborah Salvato	Project Team
Daniel B. Stephens & Associates	Gregory Schnaar	Project Team, Expert Witness
Daniel B. Stephens & Associates	Kaelyn Schwartz	Project Team
Daniel B. Stephens & Associates	Michael Thurgood	Project Team
Daniel B. Stephens & Associates	Todd Umstot	Project Team
Daniel B. Stephens & Associates	Shannon Williams	Project Team
Desert Research Institute	Ben Hatchett	Collaborating Party
Dihydrogen Oxide	Brian Epstein	Technical Commenter, Collaborating Party
Hicks Law	Tom Hicks	Technical Commenter
Dudek	Trevor Jones	Technical Commenter
Geosyntec Consultants	Ed Seymour	Project Team
Geosyntec Consultants	Paul Hobson	Project Team
Geosyntec Consultants	Daniel Pankani	Project Team
Geosyntec Consultants	Brandon Steets	Project Team
Geosyntec Consultants	Jan Dagang	Project Team
Geosyntec Consultants	Mark Hanna	Project Team

Affiliation (at time of participation)	Name	Role
Geosyntec Consultants	Avery Blackwell	Project Team
Geosyntec Consultants	Adam Questad	Project Team
Geosyntec Consultants	Scott Mansell	Project Team
Geosyntec Consultants	Sean McKnight	Project Team
Geosyntec Consultants	Lucas Nguyen	Project Team
Geosyntec Consultants	Chad Amada	Project Team
Geosyntec Consultants	Stacey Isaac	Project Team
Geosyntec Consultants	Al Preston	Project Team, Expert Witness
Geosyntec Consultants	Curtis Fang	Project Team
Geosyntec Consultants	Jared Ervin	Project Team
Geosyntec Consultants	Jai Panthail	Project Team
Geosyntec Consultants	Bob Anderson	Project Team
Geosyntec Consultants	Maia Colyar	Project Team
Geosyntec Consultants	Elvis Marti	Project Team
Geosyntec Consultants	Sarah Antonelli	Project Team
Geosyntec Consultants	Najwa Pitois	Project Team
Geosyntec Consultants	Paul Senker	Project Team
Geosyntec Consultants	Ananda Gray-Stewart	Project Team
Geosyntec Consultants	Lauren Godinez	Project Team
Geosyntec Consultants	Tessa Reeder	Project Team
Geosyntec Consultants	Mustafa Ghuneim	Project Team
Geosyntec Consultants	Nami Tanaka	Project Team
Geosyntec Consultants	Yoshi Andersen	Project Team
Geosyntec Consultants	Amy Smith	Project Team
Geosyntec Consultants	David Duong	Project Team
Geosyntec Consultants	Mason King	Project Team
Geosyntec Consultants	Corey Wallace	Project Team
Geosyntec Consultants	Mark Bandurraga	Project Team
Geosyntec Consultants	Zahra Maleki Shahraki	Project Team
Geosyntec Consultants	Samuel Hwang	Project Team
GSI Water Solutions	Comment author unknown	Technical Commenter
Intera	Trey Driscoll	Technical Commenter
IRP Water Resources Consulting	Comment author unknown	Technical Commenter
Kear Groundwater	Jordan Kear	Technical Commenter, Expert Witness

Affiliation (at time of participation)	Name	Role
Los Angeles Regional Water Quality Control Board (Los Angeles Regional Water Board)	Ching-piau Lai	Project Team
Los Angeles Regional Water Board	Deborah Smith	Project Team
Los Angeles Regional Water Board	Jenny Newman	Project Team
Los Angeles Regional Water Board	Alexander Prescott	Project Team
Los Angeles Regional Water Board	Jun Zhu	Project Team
Los Angeles Regional Water Board	Stefanie Hada	Project Team
Los Angeles Regional Water Board	Elisha Wakefield	Project Team
Los Angeles Regional Water Board	Christopher Marquis	Project Team
Los Angeles Regional Water Board	Renee Purdy	Project Team
Lynker Intel	James McCord	Technical Commenter, Expert Witness
National Oceanic Atmospheric Administration	Mark Capelli	Technical Commenter
Numeric Solutions, LLC	Christopher Laber	Technical Commenter
Numeric Solutions, LLC	Shelby Frederickson	Technical Commenter
One-Water Hydrologic, LLC	Unknown	Technical Commenter
Santa Barbara Channel Keeper	Ben Pitterle	Technical Commenter
State Water Resources Control Board (State Water Board)	Kevin DeLano	Project Team
State Water Board (now with CDFW)	Adam Weinberg	Project Team
State Water Board	Robert Solecki	Project Team
State Water Board	Daniel Worth	Project Team
State Water Board	Erin Ragazzi	Project Team
State Water Board	Philip Dutton	Project Team
State Water Board	Valerie Zimmer	Project Team
State Water Board	Rajaa Hassan	Project Team

Affiliation (at time of participation)	Name	Role
State Water Board	Nicole Kuenzi	Project Team
State Water Board	David Coupe	Project Team
State Water Board	Vivian Sieu	Project Team
State Water Board	Marc Van Camp	Project Team
State Water Board	Shahab Araghinejad	Project Team
State Water Board	Erik Ekdahl	Project Team
State Water Board	Ann Marie Ore	Project Team
State Water Board	Zachary Zwahlen	Project Team
State Water Board	Riyana Ayub	Project Team
State Water Board	Rachel Wright	Project Team
State Water Board	Chloe Liu	Project Team
State Water Board	Sarah Sugar	Project Team
State Water Board	Natalie Stork	Project Team
Surfrider	Paul Jenkin	Technical Commenter
UC Davis	Thomas Harter	Project Team
UC Santa Barbara	Arturo Keller	Project Team
UC Santa Barbara	Scott Cooper	Project Team
UC Santa Barbara	Hugo Loaiciga	Technical Commenter
Unaffiliated	Burt Handy	Technical Commenter
United States Geological Survey	Richard Niswonger	Collaborating Party
Upper Ventura River Groundwater Agency	Diana Engle	Technical Commenter
Upper Ventura River Groundwater Agency	Bryan Bondy	Technical Commenter
Upper Ventura River Groundwater Agency	Bruce Kuebler	Technical Commenter
Ventura County Resource Conservation District	Jamie Whiteford	Technical Commenter
Ventura County Farm Bureau	John Krist	Technical Commenter
Ventura County Watershed Protection District	Barbara Council	Collaborating Party
Ventura County Watershed Protection District	Justin Martinez	Collaborating Party
Ventura County Watershed Protection District	Ronald Marotto	Collaborating Party

Affiliation (at time of participation)	Name	Role
Ventura County Watershed Protection District	David Laak	Technical Commenter
Ventura County Watershed Protection District	Yunsheng Su	Technical Commenter
Ventura River Water District	Bert Rapp	Technical Commenter
Ventura Water, City of Ventura	Jennifer Tribo	Technical Commenter
Watershed Progressive	Mark Kenegos	Technical Commenter, Collaborating Party
Watershed Progressive	Regina Hirsch	Technical Commenter, Collaborating Party

Attachment 4: References Cited in the VRW GW-SW Model Report

A list of key references cited in the VRW GW-SW Model Report, and copies of the references, are available on the FTP website. Additionally, a full list of all references is included in Section 8 of the VRW GW-SW Model Report.

Attachment 5: Responses to Public and Technical Advisory Committee Comments on Draft Ventura River Groundwater-Surface Water Model and Report (2021)

In December 2021, the State Water Resources Control Board (State Water Board) published the Draft Ventura River Watershed Groundwater-Surface Water Model and Report (VRW GW-SW Model and Report) to solicit comments on methodology, datasets, and results. The Draft VRW GW-SW Model included model files, simulation results for the calibration and validation simulations (existing conditions) and unimpaired flow scenario simulation results, a data visualization tool for model results, and a user manual. Comments were due April 1, 2022.

To support the approximately 105-day comment period, in February and March 2022, the Water Boards, Geosyntec Consultants, and DBS&A hosted an Overview Webinar and two-part Technical Training webinar.

The Draft VRW GW-SW Model and Report were updated in response to comments. The updates are incorporated in the VRW GW-SW Model and VRW GW-SW Model Report. A spreadsheet summarizing the comments and technical responses is provided to assist peer reviewers. The Responses to Comments spreadsheet, vrw_gsflow_draft_comments.xlsx[6], was published to the State Water Board's California Water Action Plan: Ventura River watershed[7] website on June 21, 2024 and uploaded to the FTP website on July 10, 2024.

Additionally, the VRW GW-SW Model[8] and related information are available on the State Water Board's Ventura River watershed website[9].

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[6] URL: https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/cwap_enhancing/docs/ventura_river/vrw_gsflow_draft_comments.xlsx

[7] URL: https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/cwap_enhancing/ventura_river.html

[8] URL: https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/cwap_enhancing/docs/ventura_river/vrw_gsflow.zip

[9] URL: https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/cwap_enhancing/ventura_river.html

CALIFORNIA
Water Boards

Gavin Newsom
Governor

Yana Garcia
Secretary for
Environmental Protection

State Water Resources Control Board

December 23, 2024

James W. Jawitz, Ph.D.
Professor
Soil, Water, and Ecosystem Sciences Department
University of Florida

Sent via email

SUBJECT: REVIEW COMMENCEMENT REGARDING THE SCIENTIFIC BASIS OF A VENTURA RIVER WATERSHED GROUNDWATER-SURFACE WATER MODEL

Dear Professor Jawitz,

Thank you for accepting the role as an external scientific peer reviewer of subject request. The purpose of this letter is to initiate the external peer review.

Components of the review:

1. Request for External Scientific Peer Review, with the following attachments:
   a. Attachment 1: Plain English Summary.
   b. Attachment 2: Scientific Assumptions, Findings, and Conclusions to Review.
   c. Attachment 3: Individuals who Participated in the Development of the Proposal.
   d. Attachment 4: References Cited.
   e. Attachment 5: Technical Advisory Committee and Public Comments to 2021 Draft Model and Report
2. Proposed rule or related documents (Model Documentation Report).
3. Electronic copies of references cited.
4. *Guidance for Reviewers*.

All components of the review are posted at a secure FTP site:

Site: https://ftp.waterboards.ca.gov

- Username: gbowes-ftp52
- Password: WgbDVM9nBdaMFeQnXc3HFCPR

The findings, assumptions, and conclusions that need review are listed in Attachment 2 of the review request. I ask that you review those findings, assumptions, and conclusions which you previously stated, in communications with me dated 17 December 2024, that you could address with confidence, based on your expertise and experience. These are the following conclusions:

Finding 1.a	Concerning methodologies used to address data gaps related to water demand.
Finding 1.b	Concerning supply and demand analysis to estimate Lake Casitas deliveries to agricultural groundwater pumpers.
Finding 1.c	Concerning assumptions and limitations of methodologies used to address data gaps related to water demand.
Finding 1.d	Concerning assumptions and limitations of supply and demand analysis.
Finding 2.a	Concerning the PRMS model configuration, input data, components, and calibration of model parameters.
Finding 2.b	Concerning methodologies used to address data gaps in meteorological inputs.
Finding 5.a	Concerning model calibration and validation periods.
Finding 5.b	Concerning calibration and validation of historical streamflow, reservoir, and groundwater levels observed.
Finding 5.c	Concerning stated assumptions and limitations of the VRW GW-SW Model.
Finding 5.d	Concerning assumptions and limitations of the model calibration and validation.
Finding 6.a	Concerning 15 model parameters selected for the sensitivity analysis.
Finding 6.b	Concerning range variation of multipliers for each model parameter.
Finding 6.c	Concerning appropriateness and variation of model parameters.
Finding 7.a	Concerning design of the unimpaired flow scenario to evaluate the total quantity of water available.
Finding 7.b	Concerning unimpaired flow scenario results to define water year types.
Finding 7.c	Concerning model simulation period capturing the variability of the full range of water year types.

If you decide to address other assumptions, findings, or conclusions identify the expertise and experience you are relying on to do so. Please refer to *Guidance for Reviewers* for more information about your review and subsequent report, including formatting and web accessibility guidelines.

I will help provide support for any questions you have. To ensure a clear record of our communication, all communications should be in writing (email is preferred). My email address below should prepopulate an email.

Please email your review to me no later than **22 January 2025**. I will forward all reviews and the curricula vitae of all reviewers to the requesting organization. All information may be posted on their website.

The organization requesting the review may require clarification or additional information on a specific subject. If this occurs, I will ask you to supplement your review to address those comments.

Your participation in this review assignment is most appreciated.

Sincerely,

Carol Perkins
Environmental Scientist
Manager, CalEPA External Scientific Peer Review Program
Office of Research, Planning, and Performance
State Water Resources Control Board
1001 “I” Street, 13th Floor Sacramento, California 95814
Carol.Perkins@waterboards.ca.gov

CALIFORNIA
Water Boards

Gavin Newsom
Governor

Yana Garcia
Secretary for
Environmental Protection

State Water Resources Control Board

December 23, 2024

George M. Hornberger, Ph.D.
Distinguished University Professor Emeritus
Vanderbilt University
155 Buttrick Hall, Vanderbilt University
Nashville, TN 37240

Sent via email

SUBJECT: REVIEW COMMENCEMENT REGARDING THE SCIENTIFIC BASIS OF A VENTURA RIVER WATERSHED GROUNDWATER-SURFACE WATER MODEL

Dear Professor Hornberger,

Thank you for accepting the role as an external scientific peer reviewer of subject request. The purpose of this letter is to initiate the external peer review.

Components of the review:

1. Request for External Scientific Peer Review, with the following attachments:
    a. Attachment 1: Plain English Summary.
    b. Attachment 2: Scientific Assumptions, Findings, and Conclusions to Review.
    c. Attachment 3: Individuals who Participated in the Development of the Proposal.
    d. Attachment 4: References Cited.
    e. Attachment 5: Technical Advisory Committee and Public Comments to 2021 Draft Model and Report
2. Proposed rule or related documents (Model Documentation Report).
3. Electronic copies of references cited.
4. *Guidance for Reviewers*.

All components of the review are posted at a secure FTP site:

Site: https://ftp.waterboards.ca.gov

- Username: gbowes-ftp52
- Password: WgbDVM9nBdaMFeQnXc3HFCPR

The findings, assumptions, and conclusions that need review are listed in Attachment 2 of the review request. I ask that you review those findings, assumptions, and conclusions which you previously stated, in communications with me dated 28 November 2024, that you could address with confidence, based on your expertise and experience. These are the following conclusions:

Finding 1.a	Concerning methodologies used to address data gaps related to water demand.
Finding 1.b	Concerning supply and demand analysis to estimate Lake Casitas deliveries to agricultural groundwater pumpers.
Finding 1.c	Concerning assumptions and limitations of methodologies used to address data gaps related to water demand.
Finding 1.d	Concerning assumptions and limitations of supply and demand analysis.
Finding 2.a	Concerning the PRMS model configuration, input data, components, and calibration of model parameters.
Finding 2.b	Concerning methodologies used to address data gaps in meteorological inputs.
Finding 3.a	Concerning geologic analysis and interpretation of alluvium and semi-confining units.
Finding 3.b	Concerning interpolation of the bottom-of-alluvium elevation.
Finding 3.c	Concerning assumptions and limitations of the geologic analysis.
Finding 4.a	Concerning parameterization of boundary conditions, alluvial aquifers, aquitards and confining layers, and bedrock aquifers within the groundwater model domain.
Finding 4.b	Concerning parameterization of semi-confining layers in the Ojai Valley Groundwater Basin.
Finding 4.c	Concerning initial conditions for groundwater levels within and outside the Ventura River watershed's four groundwater basins.
Finding 4.d	Concerning assumptions and limitations of the groundwater component of the model.
Finding 5.a	Concerning model calibration and validation periods.
Finding 5.b	Concerning calibration and validation of historical streamflow, reservoir, and groundwater levels observed.
Finding 5.c	Concerning stated assumptions and limitations of the VRW GW-SW Model.

Finding 5.d	Concerning assumptions and limitations of the model calibration and validation.
Finding 6.a	Concerning 15 model parameters selected for the sensitivity analysis.
Finding 6.b	Concerning range variation of multipliers for each model parameter.
Finding 6.c	Concerning appropriateness and variation of model parameters.
Finding 7.a	Concerning design of the unimpaired flow scenario to evaluate the total quantity of water available.
Finding 7.b	Concerning unimpaired flow scenario results to define water year types.
Finding 7.c	Concerning model simulation period capturing the variability of the full range of water year types.

If you decide to address other assumptions, findings, or conclusions identify the expertise and experience you are relying on to do so. Please refer to *Guidance for Reviewers* for more information about your review and subsequent report, including formatting and web accessibility guidelines.

I will help provide support for any questions you have. To ensure a clear record of our communication, all communications should be in writing (email is preferred). My email address below should prepopulate an email.

Please email your review to me no later than **22 January 2025**. I will forward all reviews and the curricula vitae of all reviewers to the requesting organization. All information may be posted on their website.

The organization requesting the review may require clarification or additional information on a specific subject. If this occurs, I will ask you to supplement your review to address those comments.

Your participation in this review assignment is most appreciated.

Sincerely,

Carol Perkins
Environmental Scientist
Manager, CalEPA External Scientific Peer Review Program
Office of Research, Planning, and Performance
State Water Resources Control Board
1001 “I” Street, 13th Floor Sacramento, California 95814
Carol.Perkins@waterboards.ca.gov

CalEPA Peer Review Program
Guidance for Reviewers

Updated June 2023

Communication with the CalEPA Peer Review Program. To ensure a clear record of our communication, all our communications should be in writing (email is preferred).

Confidentiality. You are required to help maintain the confidentiality of this review process.

- Confidentiality began at the point you were contacted by the University of California, Berkeley (UC).
- You should not inform others about your role as reviewer.
- You will not know the names of other reviewers until all reviews are complete and the requesting organization decides to release reviews.
- You are not allowed to discuss the proposal with employees of the requesting organization or individuals who participated in development of the proposal. The individuals who participated in development are listed in Attachment 3 of the review request. Please let the CalEPA Program know if you have a question, and we will provide the support between you and the requesting organization.

Independence. If you learn what you are reviewing was developed by someone with whom you share a common supervisor or have or had a working relationship, you must let us know so that we can determine whether to seek another peer reviewer. For example, if the CalEPA organization asking for the review contracted with someone in your department or organization to help develop the material you were asked to review, you have a potential conflict of interest.

Your review. The statutory mandate for external scientific peer review (California Health and Safety Code Section 57004) states that the reviewer's responsibility is to determine whether "the scientific portion of the proposed rule is based upon sound scientific knowledge, methods, and practices." Your review should take into account both the scientific basis for the proposed rule and the intended application or implementation of that science in the context of the proposed rule.

Note: you are also invited to identify and address additional subjects that should be considered as part of the scientific basis of the proposed rule, and to consider, whether you conclude the proposed rule, taken as a whole, is based on sound scientific knowledge, methods, and practices.

You may have been asked to review the implementation or application of science that has previously been peer reviewed. In some cases, there is a clear, previously reviewed scientific basis for what you are reviewing but the scientific basis of a new implementation of the science still must be reviewed. For example, the scientific foundation for a drinking water standard may have been reviewed when the drinking water standard was adopted, but you might determine that the same scientific foundation does not support the use of the same standard to protect aquatic life in a river.

You may ask for clarification or for additional specific supporting documents. We will provide what we can to you and all reviewers. Send clarification questions to the CalEPA Program.

Text to include in your review.

- Your name, professional affiliation, and the date.
- The name of the item you are reviewing.
- Begin your review with, “Based on my expertise and experience, I am reviewing the findings, assumptions, or conclusions I agreed I could review with confidence:” and list them by number, as they are referred to in Attachment 2 of the review request.

Formatting your review. To ensure all people can perceive, understand, navigate, and interact with the materials posted on CalEPA websites, files posted on these websites must meet accessibility criteria. Your peer review may be posted on a CalEPA website so you must submit your review in an accessible format. The recommended way to make your file accessible is to use Microsoft Word to write your review and to use only basic text and headings during document creation. Then, run the built-in Word Accessibility Checker and resolve any accessibility issues.

Making your review accessible is your responsibility but staff at the UC may be able to assist you by suggesting changes for your approval.

General accessibility criteria include:

- Text. Text should be black, in Arial, size 12 points or larger.
- Non-text elements. If you use them, equations, graphs, figures, images, charts, or tables must follow accessibility criteria regarding meaningful captions and alternative text.
- Layout. Avoid complex document layouts, such as having text in more than one column, use of text boxes, use of color, and applying different font styles (i.e., bolding, underlining, etc.). It’s best to avoid letterhead, signatures, headers, and footers, aside from page numbers.
- Other requirements. There are also additional accessibility formatting requirements, including meaningful hyperlink text and appropriate use of styles for headings and lists.

The links below provide some information on accessible online content:

- Resources for Creating Accessible Content (created by the California Department of Rehabilitation).
- Video lessons for accessible Word documents (created by Microsoft).
- State, Federal, and Other Related Laws & Regulations on Digital Accessibility (created by the California Department of Rehabilitation).

You may be asked to supplement your review. The organization requesting the review may require clarification or additional information on a specific subject. If this occurs, the CalEPA Program will contact you to revise your review to address those comments.

If you are asked to discuss your comments. After you have submitted your review, you may be approached by third parties, the press, or by colleagues. You are under no obligation to discuss your comments with them and we recommend that you do not. Outside parties are provided an opportunity to address a proposed regulatory action during the public comment period. Discussions outside the provided avenues for comment could seriously impede the established process for vetting the proposal under consideration. Please direct third parties to the CalEPA Program.

JAMES W. JAWITZ

WATER + CLIMATE | HYDROLOGY + HUMANS

☎ 352.294.3141
✉ jawitz@ufl.edu
⌂ www.landscapehydrology.org

Professor | Soil, Water, and Ecosystem Sciences Department | University of Florida

EDUCATION

1999	Ph.D. Environmental Engineering, University of Florida, Gainesville, Florida
1995	M.E. Environmental Engineering, University of Florida
1992	B.S. Environmental Engineering with Honors, University of Florida

PROFESSIONAL APPOINTMENTS

SOIL, WATER, AND ECOSYSTEM SCIENCES DEPARTMENT, UNIVERSITY OF FLORIDA

2001-present	Professor (2011-present) Associate Chair (2012-2018) Graduate Coordinator (2007-2010) Associate Professor (2007-2011); Assistant Professor (2001-2007)

CIVIL AND MATERIALS ENGINEERING, UNIVERSITY OF ILLINOIS AT CHICAGO

2000	Assistant Professor

SCHOOL OF CIVIL ENGINEERING, PURDUE UNIVERSITY

1999	Assistant Professor (Visiting)

PROFESSIONAL HONORS AND AFFILIATIONS

2021-present	UF Director, Memorandum of Understanding between UF and Universidade Federal da Bahia, Salvador, Brazil
2019-present	International Steering Committee, Helmholtz International Research School at the Centre for Environmental Research (UFZ), Leipzig, Germany
2019-2021	US National Academy of Sciences Committee on Independent Scientific Review of Everglades Restoration Progress
2018-present	United Nations Global Water Quality Alliance, chartered by United Nations Environment Assembly 3, Resolution 10
2018	University of Florida Research Foundation Professor (3-year term)
2017	University of Florida Term Professorship (3-year term)
2016	Dresden Senior Fellow, Technische Universität Dresden (Germany)
2015-present	UF Director, Memorandum of Understanding between UF, Purdue University, Helmholtz-Zentrum für Umweltforschung (UFZ), and Technische Universität Dresden (TUD)
2014	University of Florida Water Institute Fellow
2011	University of Florida Research Foundation Professor (3-year term)
2010	Expert witness in highly publicized trial *State of Florida v. Casey Anthony*
2009	Academy of Teaching Excellence, UF College of Agricultural and Life Sciences
2008	Graduate Teacher/Advisor of the Year, UF College of Agricultural and Life Sciences
2006	Alpha Zeta Professor of the Year, UF College of Agricultural and Life Sciences
2005	Teacher/Advisor of the Year, UF Soil and Water Science Department
2002	Professional Engineer, Florida State Board of Professional Engineers License #59369

RESEARCH THEMES

Water and climate
Humans in hydrologic landscapes
Water quality patterns at continental scales
Water resource sustainability

EXTERNAL FUNDING

More than $15M in external grants and contracts from:

National Science Foundation
Department of Defense
Department of Energy
Department of Agriculture
Environmental Protection Agency
National Park Service
US Geological Survey
Florida Department of Environmental Protection
Florida Department of Agriculture and Consumer Services
South Florida Water Management District
St Johns River Water Management District
American Water Works Research Foundation

MENTORING AND TEACHING

>30 PhD and postdoc advisees, placed in industry, consulting, non-profits, and academia, including

University of Waterloo (Canada)
Pukyong University (South Korea)
China Agricultural University (China)
Washington State University
University of Florida
Department of Agriculture
National Park Service
Everglades Foundation

Graduate and undergraduate courses

Landscape Hydrology
Water Resource Sustainability
Cities in Civilization
Contaminant Subsurface Hydrology

International teaching

Technische Universität Dresden, Germany
Florence University of the Arts, Italy
Nanjing University, China
UF in Europe [UF Study Abroad]: Austria, France, Germany, Italy, United Kingdom

PEER-REVIEWED PUBLICATIONS

h-index: 46 i10-index: 115 citations: >7000 link to my Google scholar profile
93 of 128 publications led by graduate students (*) or postdocs (**)

128 Klammler H, Jawitz JW, Cohen MJ, 2024. A simple model of flow reversals in Florida's karst springs, *Water Resources Research*, 60(9): WRCR27440.

127 Wachholz A*, Jawitz JW, Borchardt D, 2024. From Iron Curtain to green belt: Shift from heterotrophic to autotrophic nitrogen retention in the Elbe River over 35 years of passive restoration, *Biogeosciences*, 21 (15), 3537-3550.

126 Shin Y*, Jawitz JW, Cohen MJ, 2024. Energy inputs imprint seasonality and fractal structure on river metabolic regimes, *Limnology and Oceanography Letters*, 9: 634-643.

125 Winter C*, Jawitz JW, Ebeling P, Cohen MJ, and Musolff A, 2024. Divergence between long-term and event-scale nitrate export patterns. *Geophysical Research Letters*, 51(10), e2024GL108437.

124 Yang M**, Lee J, Jang S, Annable MD and Jawitz JW, 2023. Nitrate attenuation potential in karst conduits and aquifer matrix. *Journal of Hydrology*, 624, 129896.

123 Evans B*, Klammler H, Annable MD, and Jawitz JW, 2023. Rainfall-runoff time lags from saltwater interface interactions in Atlantic Coastal Plain basins, *Water*, 15(1):142.

122 Jawitz JW, Klammler H, and Reaver NGF**, 2022. Climatic asynchrony and hydrologic inefficiency explain the global pattern of water availability, *Geophysical Research Letters*, 49(24): e2022GL101214.

121 Wachholz A*, Jawitz JW, Büttner O, Jomaa S, Merz R, Yang S**, and Borchardt D, 2022. Drivers of multi-decadal nitrate regime shifts in a large European catchment, *Environmental Research Letters*, 17: 064039.

120 Büttner O, Jawitz JW, Birk S, Borchardt D, 2022. Why wastewater treatment fails to protect stream ecosystems in Europe, *Water Research*, 118382.

119 Reaver NGF*, Kaplan DA, Klammler H, and Jawitz JW, 2022. Theoretical and empirical evidence against the Budyko catchment trajectory conjecture, *Hydrology and Earth System Sciences*, 26(5): 1507-1525.

118 Bertassello LE**, Jawitz JW, Bertuzzo E, Botter G, Rinaldo A, Aubeneau AF, Hoverman JT, and Rao PSC, 2022. Persistence of amphibian populations in dynamic wetlandscapes, *Landscape Ecology*, 37: 695–711.

117 National Academies of Sciences, Engineering, and Medicine. 2021. *Progress Toward Restoring the Everglades: The Eighth Biennial Review - 2020*. Washington, DC: The National Academies Press. doi: 10.17226/25853.

116 McCurley Pisarello KL* and Jawitz JW, 2021. Coherence of global hydroclimate classification systems, *Hydrology and Earth System Sciences*, 25 (12), 6173-6183.

115 Bertassello LE**, Bertuzzo E, Botter G, Jawitz JW, Aubeneau AF, Hoverman JT, Rinaldo A, and Rao PSC, 2021. Dynamic spatio-temporal patterns of metapopulation occupancy in patchy habitats, *Royal Society Open Science*, 8: 201309.

114 Kumar R, Heße F, Rao PSC, Musolff A, Jawitz JW, Sarrazin F, Samaniego L, Fleckenstein JH, Rakovec O, Thober S and Attinger S, 2020. Strong hydroclimatic controls on vulnerability to subsurface nitrate contamination across Europe. *Nature Communications*, 11(1): 1-10.

113 Klammler H, Quintero CJ*, Jawitz JW, McLaughlin DL and Cohen MJ, 2020. Local storage dynamics of individual wetlands predict wetlandscape discharge. *Water Resources Research*, 56(11): e2020WR027581.

112 Medina M*, Huffaker R, Jawitz JW and Muñoz-Carpena R, 2020. Seasonal dynamics of terrestrially sourced nitrogen influenced Karenia brevis blooms off Florida's southern Gulf Coast. *Harmful Algae*, 98, 101900.

111 Büttner O, Jawitz JW and Borchardt D, 2020. Ecological status of river networks: Stream order-dependent impacts of agricultural and urban pressures across ecoregions. *Environmental Research Letters*, 15(10): 1040b3.

110 Bertassello LE*, Aubeneau AF, Botter G, Jawitz JW and Rao PSC, 2020. Emergent dispersal networks in dynamic wetlandscapes. *Scientific Reports*, 10(1): 1-10.

109 Bertassello LE*, Rao PSC, Jawitz JW, Aubeneau AF, and Botter G, 2020. Wetlandscape hydrologic dynamics driven by shallow groundwater and landscape topography, *Hydrological Process*, 34(6): 1460-1474.

108 Klammler H, Jawitz JW, Annable MD, Yaquian JA*, Hatfield K, and Burger P, 2020. Decadal scale recharge-discharge time lags from aquifer freshwater-saltwater interactions, *Journal of Hydrology*, 582: 124514.

107 Jawitz JW, Desormeaux AM*, Annable MD, Borchardt D, and Dobberfuhl D, 2020. Disaggregating landscape-scale nitrogen attenuation along hydrological flow paths, *Journal of Geophysical Research-Biogeosciences*, 125 (2), e2019JG005229.

106 Krueger EH*, Borchardt D, Jawitz JW, and Rao PSC, 2020. Balancing security, resilience, and sustainability of urban water supply systems in a desirable operating space, *Environmental Research Letters*, 15(3): 035007.

105 Yang S*, Büttner O, Kumar R, Jäger C, Jawitz JW, Rao PSC, and Borchardt D, 2019. Spatial patterns of water quality impairments from point source nutrient loads in Germany's largest national river basin (Weser River), *Science of the Total Environment*, 697: 134145.

104 Bertassello LE*, Jawitz JW, Aubeneau AF, Botter G, and Rao PSC, 2019. Stochastic dynamics of wetlandscapes: Ecohydrological implications of shifts in hydro-climatic forcing and landscape configuration, *Science of The Total Environment*, 694: 133765.

103 Medina M*, Huffaker R, Jawitz JW, and Muñoz-Carpena R, 2019. Nonlinear dynamics in treatment wetlands: Identifying systematic drivers of non-equilibrium outlet concentrations in Everglades STAs, *Water Resources Research*, 55(12): 11101-11120.

102 Yang M**, Yaquian JA*, Annable MD, and Jawitz JW, 2019. Karst conduit contribution to spring discharge and aquifer cross-sectional area, *Journal of Hydrology*, 578: 124037.

101 Krueger EH*, Borchardt D, Jawitz JW, Klammler H, Yang S*, Zischg J* and Rao PSC, 2019. Resilience dynamics of urban water supply security and potential of tipping points, *Earth's Future*, 7(10): 1167-1191.

100 McGrath G, Kaeseberg T*, Reyes Silva JD*, Jawitz JW, Blumensaat F, Borchardt D, Mellander P-E, Paik K, Krebs P, and Rao PSC, 2019. Network topology and rainfall controls on the variability of combined sewer overflows and loads, *Water Resources Research*, 55(11): 9578-9591.

99 Yang S*, Büttner O, Jawitz JW, Kumar R, Rao PSC, and Borchardt D, 2019. Spatial organization of human population and wastewater treatment plants in urbanized river basins, *Water Resources Research*, 55(7): 6138-6152.

98 Arden S* and Jawitz JW, 2019. The evolution of urban water systems: Societal needs, institutional complexities, and resource costs, *Urban Water Journal*, 16:2, 92-102.

97 Shao X*, Fang Y*, Jawitz JW, Yan J, and Cui B, 2019. River network connectivity and fish diversity, *Science of The Total Environment*, 689:21-30.

96 Desormeaux A*, Annable MD, Dobberfuhl D, and Jawitz JW, 2019. In situ measurement of nitrate flux and attenuation using a soil passive flux meter, *Journal of Environmental Quality*, 48:709–716.

95 Jaramillo F, Desormeaux A*, Hedlund J, Jawitz JW, Clerici N, Piemontese L, Rodríguez-Rodriguez JA et al., 2019. Priorities and interactions of sustainable development goals (SDGs) with focus on wetlands, *Water*, 11(3): 619.

94 Westphal K*, Graeber D, Musolff A, Fang Y*, Jawitz JW, and Borchardt D, 2019. Multi-decadal trajectories of phosphorus loading, export, and instream retention along a catchment gradient, *Science of the Total Environment*, 667: 769-779.

93 Yang M**, McCurley KL*, Annable MD, and Jawitz JW, 2019. Diffusion of solutes from depleting sources into and out of finite low-permeability zones, *Journal of Contaminant Hydrology*, 221: 127-134.

92 Fang Y* and Jawitz JW, 2019. The evolution of the human population distance to water in the USA from 1790 to 2010, *Nature Communications*, 10(1), 430

91 Hensley RT**, Cohen MJ, and Jawitz JW, 2018. Channel filtering generates multifractal solute signals, *Geophysical Research Letters*, 45(21): 11722-11731

90 Kaeseberg T*, Kaeseberg M, Zhang J, Jawitz JW, Krebs P, and Rao PSC, 2018. The nexus of inhabitants and impervious surfaces at city scale—wastewater and stormwater travel time distributions and an approach to calibrate diurnal variations. *Urban Water Journal*, 15(6): 576-583

89 Thorslund J*, Cohen MJ, Jawitz JW, Destouni G, Creed IF, Rains MC, Badiou P, and Jarsjö J, 2018. Solute evidence for hydrological connectivity of geographically isolated wetlands, *Land Degradation & Development*, 29(11): 3954-3962

88 Fang Y*, Ceola S, Paik K, McGrath G, Rao PSC, Montanari A, and Jawitz JW, 2018. Globally universal fractal pattern of human settlements in river networks. *Earth's Future*, 6(8): 1134-1145

87 Bertassello LE*, Rao PSC, Jawitz JW, Botter G, Le PV, Kumar P, and Aubeneau AF, 2018. Wetlandscape fractal topography. *Geophysical Research Letters*, 45(14): 6983-6991

86 Kadyampakeni DM*, Morgan KT, Nkedi-Kizza P, Schumann AW, and Jawitz JW, 2018. Modeling water and nutrient movement in sandy soils using HYDRUS-2D. *Journal of Environmental Quality*, 47:1546–1553

85 Fang Y* and Jawitz JW, 2018. Human population distribution in the conterminous United States: High resolution reconstruction 1790-2010, *Scientific Data*, 5: 180067

84 Jaramillo F, Licero L, Guittard A, Åhlen I, Rodríguez-Rodríguez JA, Bolaños J, Manzoni S, Jawitz JW, Wdowinski S, Martínez O, and Espinosa LF, 2018. Effects of hydroclimatic change and rehabilitation activities on salinity and mangroves in the Ciénaga Grande de Santa Marta, Colombia, *Wetlands*, 38(4): 755–767

83 Bertassello LE*, Rao PSC, Park J, Jawitz JW, and Botter G, 2018. Stochastic modeling of wetland-groundwater systems, *Advances in Water Resources*, 112:214-223

82 Creed IF, Lane CR, Serran JN, Alexander L, Basu NB, Calhoun AJK, Cohen MJ, Craft C, D'Amico E, DeKeyser E, Fowler L, Golden HE, Jawitz JW, Kalla P, Kirkman LK, Lang M, Leibowitz SG, Lewis DB, Marton J, McLaughlin DL, Raanan-Kiperwas H, Rains MC, Rains KC, and Smith L, 2017. Enhancing protection for vulnerable waters, *Nature Geoscience*, 10:809–815

81 Thorslund J*, Jarsjö J, Jaramillo F, Jawitz JW, Manzoni S, Basu NB, Chalov SR, Cohen MJ, Creed IF, Goldenberg R, Hylin A, Kalantari Z, Koussis AD, Lyon SW, Mazi K, Mard J, Persson K, Pietro J, and

Destouni G, 2017. Wetlands as large-scale nature-based solutions: Status and challenges for research, engineering and management. *Ecological Engineering*, 108: 489-497

80 Dupas R**, Musolff A**, Jawitz JW, Rao PSC, Jäger CG, Fleckenstein JH, Rode M, and Borchardt D, 2017. Carbon and nutrient export regimes from headwater catchments to downstream reaches, *Biogeosciences*, 14(18): 4391-4407

79 Acharya S**, Kaplan DA, Jawitz JW, and Cohen MJ, 2017. Doing ecohydrology backward: Inferring wetland flow and hydroperiod from landscape patterns, *Water Resources Research*, 53(7): 5742–5755

78 Yang M*, Annable MD, Jawitz JW, 2017. Field-scale forward and back diffusion through low-permeability zones, *Journal of Contaminant Hydrology*, 202, 47-58

77 Musolff A**, Fleckenstein J, Rao PSC, and Jawitz JW, 2017. Emergent archetype patterns of catchment coupled hydrologic and biogeochemical responses, *Geophysical Research Letters*, 44(9): 4143-4151

76 Yang M*, Annable MD, and Jawitz JW, 2017. Forward and back diffusion through argillaceous formations, *Water Resources Research*, 53(5): 4514-4523

75 McCurley KL* and Jawitz JW, 2017. Hyphenated hydrology: Multidisciplinary evolution of water resource science, *Water Resources Research*, 53(4): 2972-2982

74 Okraku TK*, Vacca R, Jawitz JW, and McCarty C, 2017. Identity and publication in non-university settings: Academic co-authorship and collaboration, *Scientometrics*, 111(1): 401-416

73 Casey ST*, Cohen MJ, Acharya S**, Kaplan DA, and Jawitz JW, 2016. Hydrologic controls on aperiodic spatial organization of the ridge–slough patterned landscape, *Hydrology and Earth System Sciences*, 20: 4457-4467

72 Yang M*, Annable MD, and Jawitz JW, 2016. Solute source depletion control of forward and back diffusion through low-permeability zones, *Journal of Contaminant Hydrology*, 193: 54-62

71 Padowski JC*, Carrera L*, and Jawitz JW, 2016. Overcoming urban water insecurity with infrastructure and institutions, *Water Resources Management*, 30 (13): 4913-4926.

70 Paudel R* and Jawitz JW, 2016. Spatially distributed hydrodynamic modeling of phosphorus transport and transformation in a cell-network treatment wetland, *Journal of Hydrologic Engineering*, 22(1), D4016001

69 Cohen MJ, Creed IF, Alexander L, Basu N, Calhoun A, Craft C, D'Amico E, DeKeyser E, Fowler L, Golden HE, Jawitz JW, Kalla P, Kirkman LK, Lane CR, Lang M, Leibowitz SG, Lewis DB, Marton J, McLaughlin DL, Mushet D, Raanan-Kiperwas H, Rains MC, Smith L, Walls S, 2016. Do geographically isolated wetlands influence landscape functions? *Proceedings of the National Academy of Sciences* 113(8): 1978-1986

68 Rains MC, Leibowitz SG, Cohen MJ, Creed IF, Golden HE, Jawitz JW, Kalla P, Lane CR, Lang MW, and McLaughlin DL, 2015. Geographically isolated wetlands are part of the hydrological landscape, *Hydrological Processes*, 30(1): 153-160

67 Yang M*, Jawitz JW, and Lee M, 2015. Uranium and cesium accumulation in bean (Phaseolus vulgaris L. var. vulgaris) and its potential for uranium rhizofiltration, *Journal of Environmental Radioactivity*, 140: 42-49

66 Acharya S**, Kaplan DA, Casey S*, Cohen MJ, and Jawitz JW, 2015. Coupled local facilitation and global hydrologic inhibition drive landscape geometry in a patterned peatland, *Hydrology and Earth System Sciences*, 19: 2133–2144

65 Yang M*, Annable MD, and Jawitz JW, 2015. Back diffusion from thin low permeability zones, *Environmental Science & Technology*, 9 (1): 415–422

64 Annable MD, Jawitz JW, and Davis GB, 2014. GQ13 "Managing groundwater quality to support competing human and ecological needs", *Journal of Contaminant Hydrology*, 169: 1-3

63 Acharya S*, Mylavarapu R, and Jawitz JW, 2014. Evapotranspiration estimation from diurnal water table fluctuations: Implementing drainable and fillable porosity in the White method, *Vadose Zone Journal*, 13(9), doi:10.2136/vzj2014.04.0048

62 Wang F*, Annable MD, Schaefer CE, Ault TD, Cho J, and Jawitz JW, 2014. Enhanced aqueous dissolution of a DNAPL source to characterize the source strength function, *Journal of Contaminant Hydrology*, 169: 75-89

61 Park J*, Botter G, Jawitz JW, and Rao PSC, 2014. Stochastic modeling of hydrologic variability of geographically isolated wetlands: Effects of hydro-climatic forcing and wetland bathymetry, *Advances in Water Resources*, 69: 38-48

60 Yang M*, Annable MD, and Jawitz JW, 2014. Light reflection visualization to determine solute diffusion into clays, *Journal of Contaminant Hydrology*, 161: 1-9

59 McCarty C, Jawitz JW, Hopkins AL*, and Goldman A*, 2013. Predicting author h-index using characteristics of the co-author network, *Scientometrics*, 96(2): 467-483

58 McCarty C and Jawitz JW, 2013. Attitudes about publishing and normal science advancement, *Journal of Informetrics*, 7(4): 850-858

57 Wang F*, Annable MD, and Jawitz JW, 2013. Field-scale prediction of enhanced DNAPL dissolution based on partitioning tracers, *Journal of Contaminant Hydrology*, 152:147–158

56 Hopkins AL*, Jawitz JW, McCarty C, Goldman A*, and Basu NB**, 2013. Disparities in publication patterns by gender, race and ethnicity based on a survey of a random sample of authors, *Scientometrics*, 96: 515-534, doi: 101007/s11192-012-0893-4

55 Gall HE*, Park J*, Harman CJ, Jawitz JW, and Rao PSC, 2013. Landscape filtering of hydrologic and biogeochemical responses in managed catchments, *Landscape Ecology*, 28(4): 651–664

54 Paudel R*, Grace KA, Galloway S, Zamorano M, and Jawitz JW, 2013. Effects of hydraulic resistance by vegetation on stage dynamics of a stormwater treatment wetland, *Journal of Hydrology*, 484: 74–85

53 Padowski JC* and JW Jawitz, 2012. Water availability and vulnerability of 225 large cities in the United States, *Water Resources Research*, 48, W12529, doi: 101029/2012WR012335

52 Kaplan DA**, Paudel R*, Cohen MJ, and Jawitz JW, 2012. Orientation matters: Patch anisotropy controls discharge competence and hydroperiod in a patterned peatland, *Geophysical Research Letters*, 39, 17, doi:101029/2012GL052754

51 Acharya S*, Jawitz JW, and Mylavarapu RS, 2012. Analytical expressions for drainable and fillable porosity of phreatic aquifers under vertical fluxes from evapotranspiration and recharge, *Water Resources Research*, 48, W11526, doi:101029/2012WR012043

50 Paudel R* and Jawitz JW, 2012. Does increased model complexity improve description of phosphorus dynamics in a large treatment wetland? *Ecological Engineering*, 42:283-294

49 Jawitz JW and Mitchell J**, 2011. Temporal inequality of catchment discharge and solute export, *Water Resources Research*, 47, W00J14, doi:101029/2010WR010197

48 McCray JE, Tick GR, Jawitz JW, Brusseau ML, Gierke JS, Falta RW, Knox R, Sabatini D, and Annable MD, 2011. Innovative source-zone remediation studies at Hill and Dover AFB: Lessons learned, *Ground Water*, 49(5): 727-744

47 Bhadha JH*, Jawitz JW, and Min J-H**, 2011. Phosphorus mass balance and internal load in an impacted subtropical isolated wetland, *Water, Air, & Soil Pollution*, 218: 619-632

46 Miller ML*, Bhadha JH*, O'Connor GA, Jawitz JW, and Mitchell J**, 2011. Aluminum water treatment residuals as permeable reactive barrier sorbents to reduce phosphorus losses, *Chemosphere*, 83(7): 978-983

45 Obour AK*, Silveira ML, Vendramini JMB, Jawitz JW, O'Connor GA and LE Sollenberger, 2011. A phosphorus budget for bahiagrass pastures growing on a typical Florida spodosol, *Agronomy Journal*, 103(3): 611-616

44 Obour AK*, Vendramini JMB, Silveira ML, Sollenberger LE, O'Connor GA, and Jawitz JW, 2011. Phosphorus fertilization responses on bahiagrass pastures – Forage production and water quality, *Agronomy Journal*, 103:324–330

43 Obour AK*, Silveira ML, Vendramini JMB, Sollenberger LE, O'Connor GA, and Jawitz JW, 2011. Agronomic and environmental impacts of phosphorus fertilization of low input bahiagrass systems in Florida, *Nutrient Cycling in Agroecosystems*, 89: 281–290

42 Min J-H**, Paudel R*, and Jawitz JW, 2011. Mechanistic biogeochemical model applications for Everglades restoration: A review of case studies and suggestions for future modeling needs, *Critical Reviews in Environmental Science and Technology*, 41: 6, 489 – 516

41 Basu NB**, Destouni G, Jawitz JW, Thompson SE, Loukinova NV, Darracq A, Zanardo S, Yaeger M, Sivapalan M, Rinaldo A, and Rao PSC, 2010. Nutrient loads exported from managed catchments reveal emergent biogeochemical stationarity, *Geophysical Research Letters*, 37(23), L23404, doi:101029/2010GL045168

40 Min J-H**, Perkins DB*, and Jawitz JW, 2010. Wetland-groundwater interactions in subtropical depressional wetlands, *Wetlands*, 30: 997–1006

39 Paudel R*, Min J-H**, and Jawitz JW, 2010. Management scenario evaluation for a large treatment wetland using a spatio-temporal phosphorus transport and cycling model, *Ecological Engineering*, 36(12): 1627-1638

38 Bhadha JH*, Harris WG, and Jawitz JW, 2010. Soil phosphorus release and storage capacity from an impacted subtropical wetland, *Soil Science Society of America Journal*, 74(5): 1816-1825

37 Dunne EJ**, Clark MW, Mitchell J**, Jawitz JW, and Reddy KR, 2010. Soil phosphorus flux from emergent marsh wetlands and surrounding grazed pasture uplands, *Ecological Engineering*, 36(10): 1392–1400

36 Min J-H**, Paudel R*, and Jawitz JW, 2010. Spatially distributed modeling of surface water flow dynamics in the Everglades ridge and slough landscape, *Journal of Hydrology*, 390: 1-12

35 Bhadha JH* and Jawitz JW, 2010. Characterizing deep soils from an impacted subtropical isolated wetland: Implications for phosphorus storage, *Journal of Soils and Sediments*, 10(3): 514–525

34 Reddy KR, and Jawitz JW, 2010. Soil and water quality: Integral components of watershed management, *Journal of Crop Improvement*, 24(1):60-69

33 Chen X** and Jawitz JW, 2009. Convergence of DNAPL source strength functions with site age, *Environmental Science & Technology*, 43(24): 9374-9379, doi: 101021/es902108z

32 Padowski JC* and Jawitz JW, 2009. The future of global water scarcity: Policy and management challenges and opportunities, *The Whitehead Journal of Diplomacy and International Relations*, 10(2): 99-114

31 Padowski JC*, Rothfus EA*, Klammler H**, Jawitz JW, Hatfield K, and Annable MD, 2009. Effect of passive surface water flux meter body shape on water and solute mass flux estimates, *Journal of Hydrologic Engineering*, 14(12): 1334-1342

30 Zhang C*, Yoon H, Werth CJ, Valocchi AJ, Basu NB**, and Jawitz JW, 2008. Evaluation of simplified mass transfer models to simulate the impacts of source zone architecture on nonaqueous phase

liquid dissolution in heterogeneous porous media, *Journal of Contaminant Hydrology*, 102: 49–60

29 Wang H**, Chen X**, and Jawitz JW, 2008. Light transmission visualization methods to quantify nonaqueous phase liquid dissolution dynamics in porous media, *Journal of Contaminant Hydrology*, 102: 29-38

28 Kaye AJ*, Cho J**, Basu NB**, Chen X**, Annable MD, and Jawitz JW, 2008. Laboratory investigation of flux reduction from dense non-aqueous phase liquid (DNAPL) partial source zone remediation by enhanced dissolution, *Journal of Contaminant Hydrology*, 102: 17-28

27 Basu NB**, Fure AD*, and Jawitz JW, 2008. Predicting DNAPL dissolution using a simplified source depletion model parameterized with partitioning tracers, *Water Resources Research*, 44, W07414, doi:101029/2007WR006008

26 Chen X** and Jawitz JW, 2008. Reactive tracer tests to predict dense nonaqueous phase liquid dissolution dynamics in laboratory flow chambers, *Environmental Science & Technology*, 42: 5285-5291

25 Basu NB**, Fure AD*, and Jawitz JW, 2008. Simplified groundwater contaminant source depletion models as mathematical analogs of complex multiphase simulators, *Journal of Contaminant Hydrology*, 97: 87–99

24 Quadri G*, Chen X*, Jawitz JW, Tambone F, Genevini P, Faoro F, Adanai F, 2008. Bio-based surfactant-like molecules from organic wastes: the effect of waste composition and composting process on surfactant properties and on the ability to solubilize tetrachloroethene (PCE), *Environmental Science & Technology*, 42: 2618–2623

23 Basu NB*, Rao PSC, Falta RW, Annable MD, Jawitz JW, and Hatfield K, 2008. Temporal evolution of DNAPL source and contaminant flux architecture: Impacts of source mass depletion, *Journal of Contaminant Hydrology*, 95: 93–109

22 Cho J**, Annable MD, Jawitz JW, and Hatfield K, 2007. Passive flux meter measurement of water and nutrient flux in saturated porous media: Bench-scale laboratory tests, *Journal of Environmental Quality*, 36: 1266-1272

21 Dunne EJ**, Smith J*, Perkins DB*, Clark MW, Jawitz JW and Reddy KR, 2007. Phosphorus storages in historically-isolated wetland ecosystems and surrounding pasture uplands, *Ecological Engineering*, 31(1): 16-28

20 James AI**, and Jawitz JW, 2007. Modeling two-dimensional reactive transport using a Godunov-mixed finite element method, *Journal of Hydrology*, 338: 28-41

19 Perkins DB*, Haws NW*, Jawitz JW, Das BS, and Rao PSC, 2007. Mechanized military training impacts on hydraulic characteristics of ridgetop soils in a forested watershed, *Ecological Indicators*, 7: 589-597

18 Klammler H, Newman MA, Szilágyi E, Padowski JC*, Hatfield K, Jawitz JW, and Annable MD, 2007. Initial test results for a passive surface water fluxmeter to measure cumulative water and solute mass fluxes, *Environmental Science & Technology*, 41: 2485-2490

17 Totten CT*, Annable MD, Jawitz JW, and Delfino JJ, 2007. Fluid and porous media property effects on dense non-aqueous phase liquid migration and contaminant mass flux, *Environmental Science & Technology*, 41(5): 1622-1627

16 Wang H** and Jawitz JW, 2006. Hydraulic analysis of cell-network treatment wetlands, *Journal of Hydrology*, 330: 721-734

15 Fure AD*, Jawitz JW, and Annable MD, 2006. DNAPL source depletion: Linking architecture and flux response, *Journal of Contaminant Hydrology*, 85: 118-140

14 Wang H**, Jawitz JW, White JR, Martinez CJ*, and Sees MD, 2006. Rejuvenating the largest treatment wetland in Florida, *Ecological Engineering*, 26: 132–146

13 Jawitz JW, Fure AD*, Demmy GG, Berglund S, and Rao PSC, 2005. Groundwater contaminant flux reduction resulting from nonaqueous phase liquid mass reduction, *Water Resources Research*, 41, W10408, 15 pp

12 Brooks MC, Annable MD, Rao PSC, Hatfield K, Jawitz JW, Wise WR, Wood AL, Enfield CG, 2004. Controlled release, blind test of DNAPL remediation by ethanol flushing, *Journal of Contaminant Hydrology*, 69(3-4): 281-297

11 Jawitz JW, 2004. Moments of truncated continuous univariate distributions, *Advances in Water Resources*, 27(3): 269-281

10 Jawitz JW, Annable MD, Demmy GG, and Rao PSC, 2003. Estimating non-aqueous phase liquid spatial variability using partitioning tracer higher temporal moments, *Water Resources Research*, 39(7), 1192, doi:101029/2002WR001309

9 Jawitz JW, Dai D, Rao PSC, Annable MD, and Rhue RD, 2003. Rate-limited solubilization of multi-component nonaqueous phase liquids by flushing with cosolvents and surfactants: Modeling data from laboratory and field experiments, *Environmental Science & Technology*, 37(9): 1983-1991

8 Rao PSC, and Jawitz JW, 2003. Comment on "Steady-state mass transfer from single-component dense non-aqueous phase liquids in uniform flow fields" by T C Sale and D B McWhorter, *Water Resources Research*, 39(3), 1068, doi: 101029/2001WR000599

7 Jawitz JW, Annable MD, Clark II CJ, and Puranik S*, 2002. Inline gas chromatographic tracer analysis: An alternative to conventional sampling and laboratory analysis for partitioning tracer tests, *Instrumentation Science & Technology*, 30(4): 427-438

6 Brooks MC, Annable MD, Rao PSC, Hatfield K, Jawitz JW, Wise WR, Wood AL and Enfield CG, 2002. Controlled release, blind tests of DNAPL characterization using partitioning tracers, *Journal of Contaminant Hydrology,* 59: 187-210

5 Jawitz JW, Annable MD, Rao PSC, and Rhue RD, 2001. Evaluation of remediation performance and cost for field-scale single-phase microemulsion (SPME) flushing, *Journal of Environmental Science and Health, Part A–Toxic/Hazardous Substances & Environmental Engineering*, 36(8): 1437-1450

4 Jawitz JW, Sillan RK, Annable MD, Rao PSC and Warner K, 2000. In situ alcohol flushing of a DNAPL source zone at a dry cleaner site, *Environmental Science & Technology*, 34(17): 3722-3729

3 Jawitz JW, Annable MD Rao PSC, and Rhue RD, 1998. Field implementation of a Winsor Type I surfactant/alcohol mixture for in situ solubilization of a complex NAPL as a single-phase microemulsion, *Environmental Science & Technology*, 32(4): 523-530

2 Jawitz JW, Annable MD and Rao PSC, 1998. Miscible fluid displacement stability in unconfined porous media: Two-dimensional flow experiments and simulations, *Journal of Contaminant Hydrology*, 31: 211-230

1 Annable MD, Jawitz JW, Rao PSC, Dai DP, Kim HK and Wood AL, 1998. Field evaluation of interfacial and partitioning tracers for characterization of effective NAPL-water contact areas, *Ground Water*, 36(3): 495-502

EXTERNAL FUNDING

Date	Total Award	Funding Agency	Title	Role	Award to Jawitz lab
2023-2026	$460,000	NSF	*Space-time variability of water quality at continental scales*	PI	$257,000
2023-2026	$375,000	USDA-NRCS	*The carbon dynamics of managed landscapes*	Co-PI	$100,000
2023-2027	$999,900	DOE	*Water and carbon dynamics in landscapes with a shifting terrestrial aquatic interface*	Co-PI	$90,000
2022-2025	$191,000	USDA-NRCS	*Landscape-scale nutrient loading and attenuation in South Florida watersheds*	PI	$173,000
2022-2027	$854,000	SERDP	*Dynamic aquifer-ocean model for coastal DoD facilities: Vulnerability categorization based on geophysical setting and changes in climate and sea level*	PI	$472,000
2021-2024	$605,000	SJRWMD	*Transformation and transport of biosolids-derived phosphorus from fields to receiving waterbodies*	Co-PI	$97,000
2020-2025	$2,200,000	NSF	*Significance of ice-loss to landscapes in the Arctic*	Co-PI	$150,000
2018-2019	$50,000	Fish and Wildlife Foundation of Florida	*Why is flow in Silver Springs declining?*	Co-PI	$5,000
2016-2017	$55,000	SJRWMD	*Nitrogen Transport and Rates of Removal from Land Surface to the Floridan Aquifer System*	PI	$55,000
2015-2018	$48,000	USGS	*Transport in the Upper Floridan Aquifer in the Silver Springs springshed*	PI	$48,000
2014-2017	$3,000,000	SJRWMD	*Springs Protection Initiative: Silver River*	Co-PI	$215,000
2013-2015	$200,000	SJRWMD	*Nutrient Screening Model for Silver Springs*	Co-PI	$82,000
2010-2011	$10,000	National Water Research Institute	*A combined hydrological and managerial approach to evaluating urban water vulnerability*	PI	$10,000
2009-2012	$235,000	SFWMD	*Permeable reactive barriers for passive management of phosphorus in the Lake Okeechobee basin*	PI	$200,000

2008-2013	$1,000,000	SERDP	*Predicting DNAPL source zone and plume response using site-measured characteristics*	Co-PI	$262,000
2008-2009	$100,000	SFWMD	*Comprehensive analysis and evaluation of historical data and information for the Stormwater Treatment Areas*	Co-PI	$50,000
2008	$45,000	SFWMD	*Water quality model calibration with different levels of process complexity*	PI	$45,000
2007-2009	$170000	National Park Service	*Spatially distributed hydroecosystem modeling of Everglades ridge and slough landscapes*	PI	$170,000
2008-2011	$877,000	FDACS	*Phosphorous retention and storage by isolated and constructed wetlands in the Lake Okeechobee basin Phase 2*	Co-PI	$220,000
2007-2010	$356,000	NSF	*Social network analysis of the collaborative interaction of scientists in academic and non-academic settings*	Co-PI	$89,000
2007-2009	$32,000	Choctawhatchee Basin Alliance	*Hydrology of coastal dune lakes*	PI	$32,000
2007-2009	$110,000	American Water Works Research Foundation	*Development of a dynamic decision support system for water supply planning*	PI	$55,000
2007-2009	$159,000	FLDEP	*Reducing nonpoint source loss of nitrate within the Santa Fe Basin*	Co-PI	$25,000
2007-2008	$10,000	USEPA	*A sustainable approach to preserve the Choctawhatchee Coastal Dune Lakes of Florida*	PI	$10,000
2007	$45,000	SFWMD	*Water quality model calibration in a test bed*	PI	$45,000
2007	$50,000	SFWMD	*Implementation of transport and water quality functionality for the SFWMD Regional Simulation Model*	PI	$50,000
2006-2007	$5,000	City of Bonita Springs	*Review of land use and groundwater recharge plan*	PI	$5,000
2006-2007	$52,000	UF Research	*Quantifying scientific impact: Cross-disciplinary trends and attitudes*	Co-PI	$22,000
2004-2006	$470,000	USGS/ SFWMD	*Development of a procedure for using water quality model components with existing hydrologic models*	Co-PI	$111,000
2002-2006	$992,000	SERDP	*Impacts of DNAPL source zone treatment: Experimental and modeling assessment of the benefits of partial source removal*	Co-PI	$260,000

2002-2007	$1,900,000	FDACS	*Phosphorous retention and storage by isolated and constructed wetlands in the Lake Okeechobee basin*	Co-PI	$223,000
2002-2004	$135,000	USDA	*In-situ quantification of surface water and groundwater nutrient fluxes from agricultural watersheds*	PI	$65,000
2001-2002	$95,000	NSF	*In-situ quantification of chlorinated hydrocarbon mass flux and intrinsic remediation using fiber optic biosensors*	PI	$45,000
TOTAL	**$15,885,900**				**$3,738,000**

Nov 2024

CURRICULUM VITAE
George M. Hornberger

Education:

Ph.D.	Hydrology	Stanford University	1970
M.S.C.E.	Hydrology	Drexel University	1967
B.S.C.E.		Drexel University	1965

Employment:

2021 -	University Distinguished Professor Emeritus
2008- 2021	University Distinguished Professor, Craig E. Philip Professor of Engineering, Professor of Civil and Environmental Engineering, Professor of Earth and Environmental Sciences, Director, Vanderbilt Institute for Energy and Environment, Vanderbilt University
1991-2008	Ernest H. Ern Professor of Environmental Sciences University of Virginia
1970-1991	Assistant Professor to Professor University of Virginia

Current Research Interests

My current work is broadly interdisciplinary, focusing on coupled natural-human systems. Water resources are under pressure from many human activities, from climate change to urban development. I and my colleagues and students collect and analyze data to understand how climate, groundwater, surface water, and human abstraction of water interact in complex ways.

Selected Awards and Honors

Fellow, Am. Geophys. Union, 1994; Assn for, Women in Sci., 1996; Geol. Soc. America, 2005
1995 Biennial Medal for Natural Systems, Modelling and Simulation Soc. of Australia
1995 John Wesley Powell Award for Citizen's Achievement (US Geological Survey)
Elected to membership in the National Academy of Engineering, February 1996
1999 Excellence in Geophysical Education Award, American Geophysical Union
Langbein Lecturer, American Geophysical Union, 2002
Virginia Outstanding Scientist, 2007
William Kaula Award, American Geophysical Union, 2010
Harvie Branscomb Distinguished Professor Award, Vanderbilt University, 2017
Elected Fellow, American Academy of Arts and Sciences, 2020
Margaret Cuninggim Women's Center Mentoring Award, Vanderbilt University, 2022

Selected Service on National Committees

Co-chair, National Academies, Committee on Advancing a Systems Approach to Studying the Earth, July 2020-2022.
Chair, Health Effects Institute, Energy Research Committee. 2017-present.
Chair, National Academies, Committee on Future Water Resource Needs for the Nation: Water Science and Research at the U.S. Geological Survey, 2017-2018.
Chair, Geosciences Policy Committee, American Geosciences Institute, 2011-2018.
Chair, National Academies, Water Science and Technology Board, 2013-2017.
Chair, Advisory Committee for the Geosciences Directorate, NSF, 2014- 2016
Chair, Delaware EPSCoR External Advisory Board, 2014-2018.
Chair, National Research Council, Committee on Opportunities and Challenges in Hydrologic Sciences, 2010-2012

Selected Publications Since 2015

Hornberger, G.M. and D. Perrone 2019. ***Water Resources: Science and Society***. Johns Hopkins Press, https://jhupbooks.press.jhu.edu/title/water-resources.

Hornberger, G.M., Hess, D.J., and J. Gilligan 2015. Water Conservation and Hydrological Transitions in Cities. ***Water Resources Research 51***: 4635–4649.

Perrone, D and GM Hornberger 2016. Frontiers of the food-energy-water trilemma: Sri Lanka as a microcosm of tradeoffs. ***Environ. Res. Lett. 11*****:** 014005.

Gunda, T., Hornberger, G.M., and J. M. Gilligan. 2016. Spatiotemporal Patterns of Agricultural Drought in Sri Lanka: 1881-2010. ***Int. J. Climatology 36***: 563–575.

Worland, S.C., Steinschneider, S. and G.M. Hornberger. 2018, Variability in public supply water withdrawals in the U.S. ***Water_Resources_Research 54***: 1868-1889.

Gunda, T, Hess, D, Hornberger, GM and S Worland, 2019. Water Security in Practice: The Quantity-Quality-Society Nexus of Water Security. ***Water Security 6***: 100022.

DeSilva, T., Hornberger, G.M., and H. Baroud 2019. Decision Analysis for the Expansion of the Mahaweli Multi-Purpose Reservoir System in Sri Lanka. ***J. Water Resour. Planning and Mgmt. 145***(9): 05019013.

DeSilva, T.M. and G.M. Hornberger 2019. Assessing Water Management Alternatives in a Multipurpose Reservoir Cascade System in Sri Lanka. ***J. Hydrology – Regional Studies 25***: 100624.

Peters, C. and G.M. Hornberger 2019. A Search for Freshwater in the Saline Aquifer of Coastal Bangladesh. ***Groundwater 57***, doi:10.1111/gwat.12937.

De Silva Manikkuwahandi, T. & G.M. Hornberger. 2021. Deriving Reservoir Cascade Operation Rules for Variable Streamflows by Optimizing Hydropower Generation and Irrigation Water Delivery. ***Journal of Water Resources Planning and Management, 147***(7). https://doi.org/10.1061/(asce)wr.1943-5452.0001372

Ding, K. J., Hornberger, G. M., Hill, E. L., & McDonald, Y. J. (2022). Where You Drink Water: An Assessment of the Tennessee, USA Public Water Supply. ***Water (Switzerland), 14***(16). https://doi.org/10.3390/w14162562

Deslatte, A., Helmke-Long, L., Anderies, J. M., Garcia, M., Hornberger, G. M., & Ann Koebele, E. 2022. Assessing sustainability through the Institutional Grammar of urban water systems. ***Policy Studies Journal, 50***(2): 387–406. https://doi.org/10.1111/psj.12444

Wiechman, AH, Alonso-Vicario, S, Anderies, JM, Garcia, ME, Azizi, K, and GM Hornberger. 2024. Institutional Dynamics Impact the Response of Urban Socio-Hydrologic Systems to Supply Challenges. ***Water Resources Research 60*****:** e2023WR035565. https://doi.org/10.1029/2023WR035565

Alonso-Vicario, S, Hornberger, GM, Mazzoleni, M, and M Garcia. 2024. The importance of climate and anthropogenic influence in precipitation partitioning in the contiguous United States. ***Journal of Hydrology 633***: https://doi.org/10.1016/j.jhydrol.2024.130984

Azizi, K, Hornberger, GM, Baggio, J, Koebele, EA, Anderies, JM, and M. Garcia. 2024. What Conditions Support the Provision of High-Quality and Affordable Urban Drinking Water in the U.S.? ***Journal of Water Resources Planning and Management 150***: https://doi.org/10.1061/JWRMD5.WRENG-6289

Alonso-Vicario, S, Hornberger, GM, Mazzoleni, M, and M Garcia. 2024. Drivers and trends of streamflow droughts in natural and human-impacted basins across the contiguous United States. Submitted to ***Journal of Hydrology.***

From: Fisher, Laura@Waterboards
Sent: Monday, July 7, 2025 5:02 PM
To: Jawitz,James W <jawitz@ufl.edu>
Subject: Additional/Follow-up Peer Review - Ventura GSFLOW Model

Welcome back Professor Jawitz!

Please confirm you are in receipt of this email.

The State Water Resources Control Board appreciates your review of our model report “Model Documentation Report for the Groundwater-Surface Water Model for the Ventura River Watershed” and for providing valuable comments.

Your comments have been carefully considered by the requesting program. Point-by-point responses to your comments are provided in an attachment to this email. Please respond to 1a, 1c, 1b (two parts), 1d, 2a, 2b, 5a, 5b (two parts), 5c, 5d, 6a, 6b, 6c, 7a and 7b (three parts), and 7c.

The revised report (in clean and track changes versions) are posted to the ftp site. Click on the folder **Revised Report and Attachments** (screen shot below).

Please provide your responses by **July 31**. Reach out if you have difficulty with accessing any of the documents.
Generate a web accessible PDF of your review report. If you need assistance, please reach out first to your contact with the UC.
Thank you!

https://ftp.waterboards.ca.gov
Username: gbowes-ftp52
Password: WgbDVM9nBdaMFeQnXc3HFCPR

RESPONSES TO COMMENTS PROVIDED BY PROFESSOR JAWITZ AS PART OF PEER REVIEW OF THE MODEL DOCUMENTATION REPORT FOR GROUNDWATER-SURFACE WATER MODEL FOR THE VENTURA RIVER WATERSHED

MAY 2025

ATTACHMENT: RESPONSES TO COMMENTS PROVIDED BY PROFESSOR JAWITZ AS PART OF PEER REVIEW OF THE MODEL DOCUMENTATION REPORT FOR GROUNDWATER-SURFACE WATER MODEL FOR THE VENTURA RIVER WATERSHED

Below are the comments provided as part of the peer review request and associated responses.

Reviewer's Comments on Findings 1.a and 1.c: "The residential use estimates are based on per capita use data obtained from regional agencies. The regression approach of Figure 2.3 is at first glance a bit strange and seems to be an outcome of lack of clarity on how the reported usage values were determined. It is suggested to be more explicit about how those agencies determined these numbers. In fact, the regression slopes in Figure 2.3 are merely proxies for population estimates. For example, once units are converted, the (inverted) slope of Figure 2.3b translates to 53,457 people. Perhaps this value was used by the local agency, and then this report should elaborate more on the merits of their own method for estimating population vs the agency population numbers.

Table 2.8 reveals that GSWC [Golden State Water Company] per capita use includes ag and golf courses but in other places, the implication seems to be that per capita use represents a population-based residential demand. I suggest review of the text to ensure that these methods are clear and reproducible. Moreover, is should be noted that these per capita uses are very high. The model inputs used in latter years (Figure 2.4) included some adjustments to per capita usage rates, but it is surprising that there seems to be a lack of data about this important input. It would be helpful in the later sections of the report to re-visit the importance of these estimates in the context of the total water budget."

- **Response to Comments 1.a and 1.c**: **"**The regression equations developed in Figure 2.3 were used only to develop estimates for years where there was no data as indicated in Figure 2.4. The gallons per capita per day (gpcd) for Casitas Municipal Water District (CMWD) excluded agricultural deliveries, and therefore primarily represents residential demand. The CMWD Total Annual Deliveries on the x-axis of Figure 2.3b do include agricultural deliveries, and therefore the slope of the line is not indicative of the population. The strong regression is likely a result of weather driving agricultural demand and portions of the residential demand (e.g., use for urban landscaping). The text in Section 2.3.1 has been updated to explain this conclusion and for additional clarity the footnotes in Figure 2.3 and Table 2.3 have been expanded."
    - The gpcd numbers for GSWC and CMWD are notably high, due to warm weather and larger properties in the interior of the watershed (Walter 2015). At the time of model development, there was no actual water use data and no established estimates available for gpcd for the drought. Staff established reasonable estimates with input from a local water purveyor in the area for these years. The per capita use rates were modified during the multi-year drought to account for conservation measures that were implemented. Per capita use was estimated as the five-year average for water year (WY)2009-WY2013 reduced by 20% in WY2014 and WY2015 and by 30% in WY2016 and WY2017. These

reductions were based on guidance in the Meiners Oaks Water District (MOWD) Drought Contingency Plan and storage levels in Lake Casitas.

- The fraction of total pumping that is estimated by the supply and demand analyses is now provided in Section 2.7 and is only 29%. This provides important context since errors or assumptions in the supply and demand analysis manifest in less than one third of the total pumping volume.

Reviewer's Comments on Finding 1.b: "The regressions are weak for predicting irrigation amounts applied to crops (Figure 2.6). For example, the applied amounts in Figure 2.6 vary by a large amount (a factor of 3) and yet the current method provides very little ability to predict that. My suggestion is that annual rainfall is an inappropriate method to use as a predictor variable. Rainfall is highly variable and largely dependent on relatively few large storm events (p.9). Therefore, what matters most is the intra-annual timing of the rainfall, especially in comparison to the potential evapotranspiration at the time. Therefore the analysis of Figure 2.6 would be better served using sums of (P-ET) each at corresponding daily or monthly scales, rather than just sum of rainfall."

- Response to Comments 1.b: It may be possible to improve the regressions by replacing rainfall with some measure of net precipitation or precipitation-evapotranspiration (P-ET). However, the regressions are only used to fill in applied water for six years (1994, 1995, 1996, 1997, 2016 and 2017) of the 24-year modeling period, with 18 years using actual applied water data. The correlation is appropriate for this purpose.

Reviewer's Comments on Finding 1.b (continued): "For groundwater supply wells, it would be helpful to include a summary of the number of wells rather than just the maps. Similarly, agricultural land is reported as 6700 acres but it would be helpful to say what percentage of the total this represents rather than just a map (Figure 2.5)."

- Response to Comments 1.b: The number of municipal, agricultural, and domestic wells has been added in Section 2.1. In addition, the fraction of total pumping that is estimated by the supply and demand analyses is now provided in Section 2.7 and is only 29%. This additional information provides important context since errors or assumptions in the supply and demand analysis manifest in less than one third of the total pumping volume.

  Language was added to Section 1.3 of the model report to note the fraction of the total watershed area (almost 4%) represented by the crops. Additionally, the crop acreage in that section was corrected to reference the crop acreage used in the supply and demand analyses.

Reviewer's Comments on Findings 1.d: "Overall, the modeled supply and demand are well matched. However, note that Figures 2.14 to 2.29 show supply vs demand, but they also show agricultural vs residential. Most of the narrative about these figures is related to the former, but it is recommended to expand the text summarizing the findings from the latter. This would especially help to argue for the relative importance of methods and assumptions used to estimate residential vs agricultural use, as well as the importance of residential vs agricultural conservation efforts.

Drought adjustment factors (p.51) were developed based on observations from Figure 2.17 and applied to Regions 1,2,3, and 5. This approach provides reasonable results."

- Response to Comments 1.d: More discussion of overall demands and supplies was added as a new Section 2.8 in the report, including a new pie chart added to Figure 2.32.

Reviewer's Comments on Findings 2.a and 2.b: "Daily data were available from 23 gages, which is a large number and is helpful for generating a robust model. Moreover, many gages had nearly complete records which is also compelling for supporting confidence in the model development. Data gaps were filled with surrogates that seemed reasonable, but in cases where data are filled it would be better to report correlations between the two stations during the times when both stations have data. For example, at station 308 approximately 50% of the period has overlapping data with station 004A, but what was the correlation between these? (p. 35 of AppB) Presumably the correlation was strong, but again it would be an improvement to report these.

Moreover, it would be an improvement to reflect and report on the rainfall statistics. Thiessen polygons were used but how variable were the rainfall data between these? What would the consequences have been if only one rain gage had been used? This is part of a sensitivity analysis."

- Response to Comments 2.a and 2.b: Appendix B has been updated to include the coefficients of determination (R2) between correlated gages, and the text in Section 3.2 of the report has been updated to note that R2 are provided in Appendix B. Additionally, gages that were not used in the model were removed from Appendix B, including station 308. Of the 23 primary gages used in the model, 17 had complete records, while 6 used correlations to other gages for the portions of the record that were not available. Most correlations had R2 > 0.8, indicating robust correlations. As presented in Appendix B, for most of the gages with incomplete data, the missing data was only a small portion of the total time series, which provides a good degree of certainty about the rainfall data.

  A sensitivity analysis using a single rain gage is not necessary given the large number of gages used, the completeness of record for most of the gages, and the robustness of the correlations used to fill gaps. Given the great amount of data available, including 38 gages that provide high certainty about rainfall inputs, project resources were focused on sensitivity analyses of model parameters as described in Section 6.

Reviewer’s Comments on Finding 5.a: “The total model period is well defended based on data availability (before) and changes in the landscape (after). However, standard ratios of the durations used for calibration/validation tend to be between 70/30 or 80/20. Here, the ratio is 83:17 (20 years and 4 years). Therefore, the fraction of data used for validation used here is relatively low (only 4 years out of 24). The report defends this based on the decision to include the 2012-2016 drought in the calibration period. Reviewers wonder if using only part of the drought would still be sufficient because 4 years is a very short validation period. Another improvement for defending the choices of validation vs calibration is to report statistics (mean and std dev) of annual runoff in both periods. Currently only a figure is shown (Figure 5.1) but this would be improved with statistical analysis to defend the similarity of the two periods.”

- Response to Comment 5a: The use of a four-year validation period was chosen to both maximize and include the unprecedented drought of record within the calibration period. Extending the validation period to 5 years, would have added the “very wet” Water Year 1998 in the validation period, biasing it towards wetter conditions compared to the calibration period (Figure 5.1). The report has been edited to include a new Table 5.1 showing a statistical comparison of rainfall at Ojai Fire Station for the different periods, as well as to a longer 112-year period. The table indicates relatively similar statistics between all periods. Additional discussion has been added in the report text.

Reviewer’s Comments on Finding 5.b: “Overall the approaches are reasonable, however there is not a compelling reason to use different performance metrics for groundwater and surface water. The disparity in methods between sections 5.2.1 and 5.2.2 reads more likely as different teams working on these data sets rather than sound reasons for using different protocols.” Seasonal volume percent errors are useful but could be complemented by seasonal absolute errors (in cubic feet per second). This is pointed out in footnote 1 of Table 5.5, p. 202, but absolute errors are shown only for summer (Table 5.6).

If low flow prediction is truly of primary importance (as suggested at the bottom of p.229), then performance metrics should bring a more clear focus on these periods.”

- Response to Comment 5.b: The error metrics and goodness of fit criteria used for surface water and groundwater modeling of flows and groundwater levels followed standard practices for respective groundwater and surface water modeling per the references cited in the report. There are several key differences between the observed groundwater and surface water data including data frequency, number of stations, impact of seasonality, range in values, and the total number of observations. Our approach is the same as other GSFLOW modeling efforts and associated reports, including those used by the United States Geological Survey (USGS) for the Santa Rosa Plain watershed (Woolfenden and Nishikawa, 2014).

- Response to Comment 5.b: The error metrics and goodness of fit categories for the surface water flow follows those used by USGS for the Santa Rosa Plain watershed (Woolfenden and Nishikawa, 2014). The seasonal volume errors, expressed as a percentage, are a widely used metric in hydrology models, and for calibration are mostly in the “good” to “excellent” range (Table 5.4, new Table 5.5). The main exception is for the summer flows, where the percentage errors are magnified by the very low flows in the denominator. To provide context, the summer flow absolute errors (in cubic feet per second) were also provided (Table 5.5, new Table 5.6). Model performance was also examined in “moderate” and “low” flow years during which fish passage may be more critical. There is little value in adding the absolute errors in other seasons than summer, since the percentage volume errors already indicate good agreement according to the fit metrics.
- We evaluated transforming the flows prior to calculating the Nash-Sutcliffe model efficiency (NSME) to potentially better represent low flows. Specifically, taking the square root and raising to the power of 0.2, both of which may improve calibration of low flows (Thirel et al., 2024), before calculating the NSME was explored. Results indicated no need to change the chosen approach.

<u>Reviewer’s Comments on Finding 5.b (continued)</u>: “Figure 5.30: I found the information in this figure to be very important as a synthesis of the model effort. But the interpretability is constrained because it is not color-blind friendly. A suggestion is to separately report in line graphs the important results of streamflow and change in storage, perhaps as percent of precipitation but perhaps as absolute values. Also, it is recommended to clarify how change in storage is defined. For example, 1998 and 2005 are high-precipitation years and therefore higher streamflow years. But shouldn’t storage increase in those years? It’s hard for me to see from the colors but it looks like storage decreases are indicated? Maybe change in storage is defined as opposite sign (?), but again some clarification is suggested, as well as possibly some revision of figure design.”

- <u>Response to Comment 5.b</u>: Figures 5.30, 5.31, 7.12, and 7.13 have been revised to use a clearer color design scheme. High-contrast colors were assigned to bar charts for data series plotted adjacent to each other. The sign (positive or negative) of change-in-storage were correct but were removed from the plots for clarity. Years with inflow greater than outflow (e.g., 2005) show higher total inflow than total outflow.

<u>Reviewer’s Comments on Findings 5c. and 5.d</u>: “In addition to my comments above, I found the assumption of fixed land to be the most impactful of the limitations listed here. This is perhaps ok for a model developed using two decades of data. Implementation of the model for scenario assessment should include land use changes.”

- Response to Comments 5.c, and 5.d: We agree that it is scientifically defensible to assume fixed land use in the development of the model over the 24-year simulation period. This was a noted limitation in the GSFLOW approach, and while it might be overcome by running the model with different land use in different years sequentially, this would likely require additional scripting and potentially make running the model infeasible due to the computational effort needed to run the model. Instead, land use changes can be evaluated with different model runs as scenarios.

Reviewer's Comments on Findings 6a. 6.b, and 6.c: "My suggestions for the sensitivity analysis are less about which parameters were varied, but rather in the interpretation of the results. The sensitivity analysis interpretation for streamflows was perfunctory, including many plots but very few sentences. Moreover, certain adjusted parameter values were shown to have improved performance compared to the calibrated values. Some discussion is warranted to support why the calibrated values were still maintained. The section on groundwater elevations (6.2.2) includes such discussions.

The current interpretation is mostly limited to 'steepest slopes', but it would be more useful examine which parameter changes led to better performance than the currently calibrated values, and why. Finally, it would be helpful to provide an overview of how what was learned from this was incorporated into the model calibration and scenario design."

- Response to Comments 6a. 6.b. and 6c: Regarding instances where it appears certain surface water calibration metrics were improved in the sensitivity analysis, please refer to the discussion in Section 5.2.1: "The PAEE [percent average estimation error] and AAEE [absolute average estimation error] measure the model bias, or systematic error, but cannot provide a definitive measure of goodness of fit alone. The NSME [Nash-Sutcliffe model efficiency] provides a measure of the mean square error, similar to the normalized root-mean-square error (RMSE) and can be a good indicator of the goodness of fit but can still have substantial estimation bias. Therefore, the combination of the aforementioned statistics, in conjunction with graphical comparisons, is used to represent goodness of fit. The overall model calibration is not necessarily improved because one metric improves for one gage. For example, NSME improves with increased "soil_moist_max" for Gage 604 (Figure 6.1a); however, PAEE deteriorates with the same change for the same gage (Figure 6.1b). NSME improves for Gage 604 with increasing "sat_threshold" (Figure 6.1a), but the same change causes NSME to deteriorate for Gage 608 (Figure 6.3a). Increasing "ss2gw_rate" improves some surface water metrics but deteriorates the groundwater calibration RMSE (Figure 6.5b). The final calibrated model is the simulation that considers statistical and graphical comparisons to surface water and groundwater data that are based on watershed parameter values constrained by the available data. Sensitivity analyses may guide future data collection by highlighting those parameters that impact model results most significantly.

Reviewer's Comments on Findings 7.a, and 7.b: "It would help to include more narrative about the intended use of the results of this scenario. It seems somewhat incongruous to design a scenario where reservoirs are removed, and yet current agricultural land uses (and vegetation types) are retained (even if they are not irrigated). suggest some narrative about the intended use of the results and why remove reservoirs but leave the agricultural land cover."

- Response to comment 7a and 7b: The purpose of developing unimpaired flows in the Ventura River watershed is to calculate the Ventura River watershed flows when flows are not regulated, diverted, or stored in current conditions. This provides the high end of flows that may be available for the protection of fish in the main stem and tributaries of Ventura River. This unimpaired flow is close to natural flows, but it is not the same as natural flows as natural flows considers land use and geomorphological changes in the watershed. The focus of the unimpaired flows scenario in this project is to estimate instream flows under existing conditions by removing everything that regulates water in the watershed (e.g., diversions and storage in Lake Casitas and Matilija reservoir).

Reviewer's Comments on Findings 7.a, and 7.b (continued): **"**The scenario results are compared to the baseline model for four stream gages. For two of the gages the results are unchanged, while for the other two gages the results are only modestly changed. First, I suggest reporting t-test results for Figures 7.5 to 7.8. This will add quantitative authority to statements about which seasons show distinct differences between the scenarios. Second, some narrative explanation is warranted for why certain gages show no difference vs some difference. This is re-visited in section 7.4.3, but it would be better to more directly address seasonality and to more clearly explain which specific changes in the scenario likely affected the observed results."

- Response to Comments 7.a, and 7.b: Additional text was added at the end of Section 7.4.1 to explain the reasons behind the differences at each gage location. Importantly, while the differences at two of the gages (604 and 607*) are "modest" they are not "zero". They are not zero due to removal of upstream surface water diversions and upgradient groundwater pumping that result in an increase in flow that is quantified directly and deterministically by the GSFLOW model. This methodology is consistent with a fundamental understanding of the impact of groundwater pumping on streamflow (e.g., Theis, 1940). For this reason, we do not apply the t-test to Figures 7.4 through 7.8. While a t-test may indicate a lack of statistically significant difference in flow, that does not imply that there is no difference.

Reviewer's Comments on Findings 7.a, and 7.b (continued): **"**Section 7.4.2 about the groundwater results includes more examination of the results and this section should be a guide for revision of section 7.4.1. However, some additional interpretation of the results in section 7.4.2 is still suggested. For example, Figure 7.10 shows 'larger' areas of groundwater discharge to surface waters compared to 5.28. It would help to examine how this result relates to the streamflow differences or non-differences shown in Figures 7.5 to 7.8."

- Response to Comments 7.a, and 7.b: As requested, additional text comparing areas of groundwater discharge to streams and increased streamflow in the unimpaired scenario was added to Section 7.4.2.

Reviewer's Comments on Findings 7.c: "Based on the order of these findings, I was expecting to see a section at the end of the report on this topic, but I did not see any discussion focused on this. The data in Figure 1.4 indicate that rainfall is highly variable. To best defend the statement of Finding 7.c, rainfall statistics from the simulation period should be compared to data from a longer period to show that the "full" observed variability is sufficiently captured. However, the data in Figure 1.4 do indicate that quite a wide range of conditions were indeed captured, which should increase the confidence in the model."

- Response to Comments 7.c: The report has been updated to include a new Table 5.1 showing a statistical comparison of rainfall at Ojai Fire Station for the 24-year simulation period to the longer 112-year period with available precipitation data at this location. The table indicates relatively similar statistics between the periods. Additional text has been added in Section 5.1 of the report

REFERENCES

Theis, C.V. 1940. The source of water derived from wells. Civil Engineering 10(5): 277-280.

Thirel, G., Santos, L., Delaigue, O., and Perrin, C. (2024). "On the use of streamflow transformations for hydrological model calibration." Hydrol. Earth Syst. Sci., 28, 4837-4860. https://doi.org/10.5194/hess-28-4837-2024

Woolfenden, L.R., and T. Nishikawa, eds. 2014. Simulation of groundwater and surface-water resources of the Santa Rosa Plain watershed, Sonoma County, California. U.S. Geological Survey Scientific Investigations Report 2014–5052 258 pp. Prepared in cooperation with California: Sonoma County Water Agency, City of Santa Rosa, City of Sebastopol, City of Rohnert Park, City of Cotati, Town of Windsor, County of Sonoma, and California American Water. URL: http://dx.doi.org/10.3133/sir20145052

From: Perkins, Carol@Waterboards <Carol.Perkins@Waterboards.ca.gov>
Sent: Monday, May 12, 2025 3:55 PM
To: Hornberger, George M <george.m.hornberger@Vanderbilt.Edu>
Cc: Gonzalez, Paola@Waterboards <Paola.Gonzalez@Waterboards.ca.gov>; Perkins, Carol@Waterboards <Carol.Perkins@Waterboards.ca.gov>; WB-ORPP-ExternalPeerReview <ORPP-ExternalPeerReview@Waterboards.ca.gov>
Subject: FW: ESPR [Review Clarification]: DWR Ventura River Watershed GW-SW Model

Dear Dr. Hornberger,

On behalf of DWR staff, I want to extend their sincere gratitude for the thoughtful and insightful feedback provided by you regarding the report, *Model Documentation Report for Groundwater-Surface Water Model for the Ventura River Watershed*.

DWR further notes you were unable to review *Finding 4b.* because references to parameterization of the semi-confining layers of the Ojai Valley Groundwater Basin were not clearly defined in the report.

Please consider the following clarification information DWR provides below to help you address *Finding 4b: The parameterization of semi-confining layers in the Ojai Valley Groundwater Basin is consistent with sound scientific knowledge, methods, and practices* (pp.12-14 of the attached Letter of Request).

For ease of access, I have provided the Letter of Request and the table of contents, and the body of the report (*Model Documentation Report for Groundwater-Surface Water Model for the Ventura River Watershed*) as originally found on the FTP site and the PDF of your draft report (the contents of the zip file are shown in image below).

> Section 4.5 (p. 164 of PDF) of the report is intended to say that shallow semi-confining units in the Ojai Basin were represented as discrete parameter zones (Zones 1 and 2). Deeper semi-confining units in the Ojai Basin were lumped with aquifer units and accounted for by reducing the vertical hydraulic conductivity of the corresponding parameter zones (Zones 4 and 5).
>
> Additionally, Table 5.3 (p. 188 of PDF), rows 1 and 2 represent shallow semi-confining unit parameters, row 3 represents shallow aquifer parameters, and rows 4 and represent deep aquifer and semi-confining units, west and east parameters, respectively.

Project specific FTP site credentials:	*Attached Zip file contents:*
Site: https://ftp.waterboards.ca.gov **Username**: gbowes-ftp52 **Password**: WgbDVM9nBdaMFeQnXc3HFCPR	

Please submit your final, supplemented review report that includes review of *Finding 4b* to the Program by 02 June 2025. Please reach out if more time is needed or you encounter schedule conflicts.

Sincerely,
Carol

Carol Perkins

Environmental Scientist
CalEPA External Scientific Peer Review Program Lead
Office of Research, Planning, and Performance
State Water Resources Control Board
Carol.Perkins@Waterboards.ca.gov

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January 2025

Review of *Model Documentation Report for Groundwater-Surface Water Model for the Ventura River Watershed*

Based on my expertise and experience, I am reviewing the findings, assumptions, or conclusions I agreed I could review with confidence:

- Finding 1.a Concerning methodologies used to address data gaps related to water demand.
- Finding 1.b Concerning supply and demand analysis to estimate Lake Casitas deliveries to agricultural groundwater pumpers.
- Finding 1.c Concerning assumptions and limitations of methodologies used to address data gaps related to water demand.
- Finding 1.d Concerning assumptions and limitations of supply and demand analysis.
- Finding 2.a Concerning the PRMS model configuration, input data, components, and calibration of model parameters.
- Finding 2.b Concerning methodologies used to address data gaps in meteorological inputs.
- Finding 5.a Concerning model calibration and validation periods.
- Finding 5.b Concerning calibration and validation of historical streamflow, reservoir, and groundwater levels observed.
- Finding 5.c Concerning stated assumptions and limitations of the VRW GW-SW Model.
- Finding 5.d Concerning assumptions and limitations of the model calibration and validation.
- Finding 6.a Concerning 15 model parameters selected for the sensitivity analysis.
- Finding 6.b Concerning range variation of multipliers for each model parameter.
- Finding 6.c Concerning appropriateness and variation of model parameters.
- Finding 7.a Concerning design of the unimpaired flow scenario to evaluate the total quantity of water available.
- Finding 7.b Concerning unimpaired flow scenario results to define water year types.
- Finding 7.c Concerning model simulation period capturing the variability of the full range of water year types

My review comments are itemized below on the following pages.

Sincerely,

James W. Jawitz
Professor

Finding 1.a Concerning methodologies used to address data gaps related to water demand. Finding 1.c Concerning assumptions and limitations of methodologies used to address data gaps related to water demand.

- This section of the report is mostly on **pp28-32.**

The residential use estimates are based on per capita use data obtained from regional agencies. The regression approach of Figure 2.3 is at first glance a bit strange and seems to be an outcome of lack of clarity on how the reported usage values were determined. It is suggested to be more explicit about how those agencies determined these numbers. In fact, the regression slopes in Figure 2.3 are merely proxies for population estimates. For example, once units are converted, the (inverted) slope of Figure 2.3b translates to 53,457 people. Perhaps this value was used by the local agency, and then this report should elaborate more on the merits of their own method for estimating population vs the agency population numbers.

Table 2.8 reveals that GSWC per capita use includes ag and golf courses but in other places, the implication seems to be that per capita use represents a population-based residential demand. I suggest review of the text to ensure that these methods are clear and reproducible. Moreover, is should be noted that these per capita uses are very high. The model inputs used in latter years (Figure 2.4) included some adjustments to per capita usage rates, but it is surprising that there seems to be a lack of data about this important input. It would be helpful in the later sections of the report to re-visit the importance of these estimates in the context of the total water budget.

Finding 1.b Concerning supply and demand analysis to estimate Lake Casitas deliveries to agricultural groundwater pumpers. P 31

- This section of the report is mostly on **pp31-38.**

The regressions are weak for predicting irrigation amounts applied to crops (Figure 2.6). For example, the applied amounts in Figure 2.6 vary by a large amount (a factor of 3) and yet the current method provides very little ability to predict that. My suggestion is that annual rainfall is an inappropriate method to use as a predictor variable. Rainfall is highly variable and largely dependent on relatively few large storm events (p.9). Therefore, what matters most is the intra-annual timing of the rainfall, especially in comparison to the potential evapotranspiration at the time. Therefore the analysis of Figure 2.6 would be better served using sums of (P-ET) each at corresponding daily or monthly scales, rather than just sum of rainfall.

For groundwater supply wells, it would be helpful to include a summary of the number of wells rather than just the maps. Similarly, agricultural land is reported as 6700 acres but it would be helpful to say what percentage of the total this represents rather than just a map (Figure 2.5).

Finding 1.d Concerning assumptions and limitations of supply and demand analysis.

- This section of the report is mostly on **pp46-70.**

Overall, the modeled supply and demand are well matched. However, note that Figures 2.14 to 2.29 show supply vs demand, but they also show agricultural vs residential. Most of the narrative about these figures is related to the former, but it is recommended to expand the text summarizing the findings from the latter. This would especially help to argue for the relative importance of methods and assumptions used to estimate residential vs agricultural use, as well as the importance of residential vs agricultural conservation efforts.

Drought adjustment factors (p.51) were developed based on observations from Figure 2.17 and applied to Regions 1,2,3, and 5. This approach provides reasonable results.

Finding 2.a Concerning the PRMS model configuration, input data, components, and calibration of model parameters.

Finding 2.b Concerning methodologies used to address data gaps in meteorological inputs.

- This section of the report is mostly on **pp73-78.**

Daily data were available from 23 gages, which is a large number and is helpful for generating a robust model. Moreover, many gages had nearly complete records which is also compelling for supporting confidence in the model development. Data gaps were filled with surrogates that seemed reasonable, but in cases where data are filled it would be better to report correlations between the two stations during the times when both stations have data. For example, at station 308 approximately 50% of the period has overlapping data with station 004A, but what was the correlation between these? (p. 35 of AppB) Presumably the correlation was strong, but again it would be an improvement to report these.

Moreover, it would be an improvement to reflect and report on the rainfall statistics. Thiessen polygons were used but how variable were the rainfall data between these? What would the consequences have been if only one rain gage had been used? This is part of a sensitivity analysis.

Finding 5.a Concerning model calibration and validation periods.

- This section of the report is mostly on **pp155-156.**

The total model period is well defended based on data availability (before) and changes in the landscape (after). However, standard ratios of the durations used for calibration/validation tend to be between 70/30 or 80/20. Here, the ratio is 83:17 (20 years and 4 years). Therefore, the fraction of data used for validation used here is relatively low (only 4 years out of 24). The report defends this based on the decision to include the 2012-2016 drought in the calibration period. Reviewers wonder if using only part of the drought would still be sufficient because 4 years is a very short validation period. Another improvement for defending the choices of validation vs calibration is to report statistics (mean and std dev) of annual runoff in both periods. Currently only a figure is shown (Figure 5.1) but this would be improved with statistical analysis to defend the similarity of the two periods.

Finding 5.b Concerning calibration and validation of historical streamflow, reservoir, and groundwater levels observed.

- This section of the report is mostly on **pp156-218.**

Overall the approaches are reasonable, however there is not a compelling reason to use different performance metrics for groundwater and surface water. The disparity in methods between sections 5.2.1 and 5.2.2 reads more likely as different teams working on these data sets rather than sound reasons for using different protocols.

Seasonal volume percent errors are useful but could be complemented by seasonal absolute errors (CFS). This is pointed out in footnote 1 of Table 5.5, p. 202, but absolute errors are shown only for summer (Table 5.6).

If low flow prediction is truly of primary importance (as suggested at the bottom of p.229), then performance metrics should bring a more clear focus on these periods.

Figure 5.30: I found the information in this figure to be very important as a synthesis of the model effort. But the interpretability is constrained because it is not color-blind friendly. A suggestion is to separately report in line graphs the important results of streamflow and change in storage, perhaps as percent of precipitation but perhaps as absolute values. Also, it is recommended to clarify how change in storage is defined. For example, 1998 and 2005 are high-precipitation years and therefore higher streamflow years. But shouldn't storage increase in those years? It's hard for me to see from the colors but it looks like storage decreases are indicated? Maybe change in storage is defined as opposite sign (?), but again some clarification is suggested, as well as possibly some revision of figure design.

Finding 5.c Concerning stated assumptions and limitations of the VRW GW-SW Model.
Finding 5.d Concerning assumptions and limitations of the model calibration and validation.

- This section of the report is mostly on **pp226-227.**

In addition to my comments above, I found the assumption of fixed land to be the most impactful of the limitations listed here. This is perhaps ok for a model developed using two decades of data. Implementation of the model for scenario assessment should include land use changes.

Finding 6.a Concerning 15 model parameters selected for the sensitivity analysis.
Finding 6.b Concerning range variation of multipliers for each model parameter.
Finding 6.c Concerning appropriateness and variation of model parameters.

- This section of the report is mostly on **pp229-235.**

My suggestions for the sensitivity analysis are less about which parameters were varied, but rather in the interpretation of the results. The sensitivity analysis interpretation for streamflows was perfunctory, including many plots but very few sentences. Moreover, certain adjusted parameter values were shown to have improved performance compared to the calibrated values. Some discussion is warranted to support why the calibrated values were still maintained. The section on groundwater elevations (6.2.2) includes such discussions.

The current interpretation is mostly limited to 'steepest slopes', but it would be more useful examine which parameter changes led to better performance than the currently calibrated values, and why. Finally, it would be helpful to provide an overview of how what was learned from this was incorporated into the model calibration and scenario design.

Finding 7.a Concerning design of the unimpaired flow scenario to evaluate the total quantity of water available.

Finding 7.b Concerning unimpaired flow scenario results to define water year types.

- This section of the report is mostly on **pp251-269.**

It would help to include more narrative about the intended use of the results of this scenario. It seems somewhat incongruous to design a scenario where reservoirs are removed and yet current agricultural land uses (and vegetation types) are retained (even if they are not irrigated). suggest some narrative about the intended use of the results and why remove reservoirs but leave the agricultural land cover.

The scenario results are compared to the baseline model for four stream gages. For two of the gages the results are unchanged, while for the other two gages the results are only modestly changed. First, I suggest reporting t-test results for Figures 7.5 to 7.8. This will add quantitative authority to statements about which seasons show distinct differences between the scenarios. Second, some narrative explanation is warranted for why certain gages show no difference vs some difference. This is re-visited in section 7.4.3, but it would be better to more directly address seasonality and to more clearly explain which specific changes in the scenario likely affected the observed results.

Section 7.4.2 about the groundwater results includes more examination of the results and this section should be a guide for revision of section 7.4.1. However, some additional interpretation of the results in section 7.4.2 is still suggested. For example, Figure 7.10 shows 'larger' areas of groundwater discharge to surface waters compared to 5.28. It would help to examine how this result relates to the streamflow differences or non-differences shown in Figures 7.5 to 7.8.

Finding 7.c Concerning model simulation period capturing the variability of the full range of water year types.

Based on the order of these findings, I was expecting to see a section at the end of the report on this topic, but I did not see any discussion focused on this. The data in Figure 1.4 indicate that rainfall is highly variable. To best defend the statement of Finding 7.c, rainfall statistics from the simulation period should be compared to data from a longer period to show that the "full" observed variability is sufficiently captured. However, the data in Figure 1.4 do indicate that quite a wide range of conditions were indeed captured, which should increase the confidence in the model.

Review of The Scientific Basis of a Ventura River Watershed Groundwater-Surface Water Model. 23 Jan 2025

George M. Hornberger, University Distinguished Professor Emeritus, Vanderbilt University

Based on my expertise and experience, I am reviewing the findings, assumptions, or conclusions I agreed I could review with confidence:

Finding 1.a Concerning methodologies used to address data gaps related to water demand.
Finding 1.b Concerning supply and demand analysis to estimate Lake Casitas deliveries to agricultural groundwater pumpers.
Finding 1.c Concerning assumptions and limitations of methodologies used to address data gaps related to water demand.
Finding 1.d Concerning assumptions and limitations of supply and demand analysis.
Finding 2.a Concerning the PRMS model configuration, input data, components, and calibration of model parameters.
Finding 2.b Concerning methodologies used to address data gaps in meteorological inputs.
Finding 3.a Concerning geologic analysis and interpretation of alluvium and semi-confining units.
Finding 3.b Concerning interpolation of the bottom-of-alluvium elevation.
Finding 3.c Concerning assumptions and limitations of the geologic analysis.
Finding 4.a Concerning parameterization of boundary conditions, alluvial aquifers, aquitards and confining layers, and bedrock aquifers within the groundwater model domain.
Finding 4.b Concerning parameterization of semi-confining layers in the Ojai Valley Groundwater Basin.
Finding 4.c Concerning initial conditions for groundwater levels within and outside the Ventura River watershed's four groundwater basins.
Finding 4.d Concerning assumptions and limitations of the groundwater component of the model.
Finding 5.a Concerning model calibration and validation periods.
Finding 5.b Concerning calibration and validation of historical streamflow, reservoir, and groundwater levels observed.
Finding 5.c Concerning stated assumptions and limitations of the VRW GW-SW Model.
Finding 5.d Concerning assumptions and limitations of the model calibration and validation.
Finding 6.a Concerning 15 model parameters selected for the sensitivity analysis.
Finding 6.b Concerning range variation of multipliers for each model parameter.
Finding 6.c Concerning appropriateness and variation of model parameters.
Finding 7.a Concerning design of the unimpaired flow scenario to evaluate the total quantity of water available.
Finding 7.b Concerning unimpaired flow scenario results to define water year types.

Finding 7.c Concerning model simulation period capturing the variability of the full range of water year types.

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Overall comment. The report and the supporting material follow the accepted state-of-the practice. The combined groundwater-surface water model is described in detail and all assumptions clearly stated.

Specific questions addressed.

1a. Methodologies used to address data gaps related to water demand.

The residential demands were estimated using appropriate per capita water use amounts. Agreement with available records is good. Agricultural demands are more variable and more difficult to estimate. The approach taken, regressions on annual rainfall, is appropriate, showing a modest decline in agricultural water demand with increasing annual rainfall.

1b. Concerning supply and demand analysis to estimate Lake Casitas deliveries to agricultural groundwater pumpers.

The analyses use available data to the extent possible. The fact that total annual deliveries are given in CMWD reports means that the estimates required are to apportion deliveries to agriculture. The approach taken to distribute deliveries across the pressure zones is sensible.

1c. Concerning assumptions and limitations of methodologies used to address data gaps related to water demand.

Residential demands are based on per capita estimates, which is a standard approach. Although estimates can never be considered perfect, per capita estimates are well constrained. The agricultural demands were based on regressions of available data on water applied to crops annually on annual rainfall (i.e., Fig. 2.6). Regression errors are significant, and this can be considered a limitation, but, in my opinion, they are not likely to have huge effect on overall results.

1d. Concerning assumptions and limitations of supply and demand analysis.

Once again the limitations are obvious in that the observed data are limited. The assumptions made to generate the supply and demand estimates are reasonable. Also, the “cross checks” (Section 2.6) give confidence that gross errors are unlikely.

2a. Concerning the PRMS model configuration, input data, components, and calibration of model parameters.

The PRMS model is well documented. The “configuration” used in the report is appropriate for the study and recognizes the linkage with the groundwater model. Input data are meteorological variables, rainfall and temperature.

Many parameters must be specified for PRMS. The approach described in the report is somewhat "standard." Initial estimates were set using various sources and these were adjusted by calibration, i.e., they "were adjusted iteratively to match modeled streamflow to the measured streamflow for the calibration period." This is standard, the state of the practice.

The metrics used to assist in the manual calibration are based on untransformed flows (section 5.2.1). Typically these measures are influenced most strongly by higher flows. Other metrics may be judged superior when matching low flows is an important objective (e.g., Thirel et al. 2024).

2b. Concerning methodologies used to address data gaps in meteorological inputs.

Data gaps at gage locations were filled using nearby gages (standard procedure). The data were distributed spatially using PRISM, which is widely used.

3a. Concerning geologic analysis and interpretation of alluvium and semi-confining units.

The March 2020 memo summarizes the geological analyses. These are solid in my opinion.

3b. Concerning interpolation of the bottom-of-alluvium elevation.

The March 2020 memo indicates that all available information was used to determine the bedrock elevation. The inferences appear to be reasonable.

3c. Concerning assumptions and limitations of the geologic analysis.

The geological analysis conforms to the state of the practice. Assumptions and limitations are the same as for any construction of three-dimensional geological structure from limited data.

4a. Concerning parameterization of boundary conditions, alluvial aquifers, aquitards and confining layers, and bedrock aquifers within the groundwater model domain.

All of this appears to have been done carefully and thoughtfully.

4b. Concerning parameterization of semi-confining layers in the Ojai Valley Groundwater Basin.

The semi-confining layers were identified from well logs (per the 2020 memo). I could not find any reference to parameterization of the semi-confining layer in the report so I can't comment.

4c. Concerning initial conditions for groundwater levels within and outside the Ventura River watershed's four groundwater basins.

The report states that "*Initial conditions outside the groundwater basins (e.g., within the bedrock units) were assigned based on simulated values as of September 2005 from early VRW GSFLOW Model runs*." I assume that this is sensible but, most importantly, the results do not depend strongly on assumed initial conditions.

4d. Concerning assumptions and limitations of the groundwater component of the model.
Development of the groundwater model is presented clearly so all assumptions are in the open. The limitations are made clear (5.6.2).

5a. Concerning model calibration and validation periods.
The periods were selected "*to enable both periods to include a representative mix of WY types (i.e., wet years and dry years)"* which is a reasonable approach.

5b. Concerning calibration and validation of historical streamflow, reservoir, and groundwater levels observed.
The approach taken to calibration is standard. The procedures are fully described.

5c. Concerning stated assumptions and limitations of the VRW GW-SW Model.
The VRW GW-SW Model, like all physics-based models of watershed hydrology, is quite complex with many parameters to estimate. The report discusses the assumptions made and lists limitations, but the issue of equifinality is not addressed. "*Equifinality means that simulations with different parameter sets (i.e., equal routes) yield similar simulation results (i.e., finality). Equifinality introduces significant uncertainty in selecting optimal parameter sets. Selecting incorrect parameter sets can affect the hydrological model's simulation and prediction capabilities"* (Tang et al. 2024).

5d. Concerning assumptions and limitations of the model calibration and validation.
Calibration and validation are described clearly. Well-established procedures are followed. In terms of limitations, see comment 5c.

6a. Concerning 15 model parameters selected for the sensitivity analysis.
The selection of parameters was based on the experience of the modelling team (second paragraph of section 6). The parameters represent important processes across the model domain and appear to be appropriate.

6b. Concerning range variation of multipliers for each model parameter.
Once again, this was based on the experience of the modelling team. The results indicate that the multipliers gave the sensitivity information desired.

6c. Concerning appropriateness and variation of model parameters.
This appears to be a combination of 6a and 6b. See responses to those items.

7a. Concerning design of the unimpaired flow scenario to evaluate the total quantity of water available.

The definition of unimpaired flow for the VRW GSFLOW Model is clearly described and appears reasonable. The implementation in the model was mostly straightforward except for the removal of lakes and this was handled in a reasonable way.

The uncertainties involved in modelling, including the fact that alternate parameterizations of the model can fit available observations well (see equifinality comment in 5c), mean that predictions and counterfactuals may contain greater uncertainty than the likely impacts being simulated (e.g., Mautner et al. 2024). This is not a criticism of the report but a caution about the degree of confidence to be placed on predictions.

7b. Concerning unimpaired flow scenario results to define water year types.

I do not understand what is requested. The report does not indicate that unimpaired flows were used to define WY types. Rather, the report suggests that WY type (wet vs. dry) was used in selection of the calibration and validation periods. The unimpaired flow analysis covers the full range of “types.”

7c. Concerning model simulation period capturing the variability of the full range of water year types.

Once again, I do not understand what is requested. The report uses the years for which appropriate data were available. In that sense, of course the full range of variability was accommodated. The drought starting in 2012 was, in essence, the drought of record (Griffin and Anchukaitis, 2014). Given that a primary goal is to represent low flows in the model, I would say that the model simulation period captured pertinent “water year types.”

References

Griffin, D & K Anchukaitis, 2014. Quantifying Climate and Catchment Control on Hydrological Drought in the Continental United States. *Geophysical Research Letters 41*: 9017-9023.

Mautner, M et al. 2022. Coupled effects of observation and parameter uncertainty on urban groundwater infrastructure decisions. *Hydrology and Earth System Sciences 26*: 1319-1340

Tang, X, Tang, D & F Zhang 2024. A Framework for Algorithmic Improvement to Mitigate the Effects of Equifinality in the Calibration of High-dimensional Parameters for Hydrological Models. *Water Resources Management 38*: 251-267.

Thirel, G et al. 2024. On the use of streamflow transformations for hydrological model calibration. *Hydrology and Earth System Sciences 28*: 4837–4860.

Addendum for Response to Finding 4b in the Review of The Scientific Basis of a Ventura River Watershed Groundwater-Surface Water Model 06 Jun 2025

George M. Hornberger, University Distinguished Professor Emeritus, Vanderbilt University

Finding 4b: The parameterization of semi-confining layers in the Ojai Valley Groundwater Basin is consistent with sound scientific knowledge, methods, and practices.

Clarification in email of May 12 from ORPP-ExternalPeerReview@Waterboards.ca.gov

"Section 4.5 (p. 164 of PDF) of the report is intended to say that shallow semi-confining units in the Ojai Basin were represented as discrete parameter zones (Zones 1 and 2). Deeper semi-confining units in the Ojai Basin were lumped with aquifer units and accounted for by reducing the vertical hydraulic conductivity of the corresponding parameter zones (Zones 4 and 5)."

Section 4.5 is on page 147 of the copy of the report that I have. The important information is that the semi-confining layers of the Ojai Basin are Zones 4 and 5 in the model.

"Additionally, Table 5.3 (p. 188 of PDF), rows 1 and 2 represent shallow semi-confining unit parameters, row 3 represents shallow aquifer parameters, and rows 4 and represent deep aquifer and semi-confining units, west and east parameters, respectively."

Table 5.3 is on page 171 in the copy of the report that I have. Rows 4 and 5 in the Table indicate a horizontal hydraulic conductivity of 21 and 45 ft/day for zones 4 and 5 respectively and that a very low value (0.001 ft/day) was used for the vertical hydraulic conductivity for Zones 4 and 5.

The parameterization for the horizontal hydraulic conductivities followed a similar path as for other parts of the model. The comparisons with measured data are sensible and are consistent with sound practice.

The value for vertical hydraulic conductivity was chosen to reflect quite limited vertical flows and is not really used in the formal parameterization, i.e., there is no mention of any adjustments being made to the assumed values. In my opinion, this is appropriate in that I expect that the results do not depend strongly on having a precise value. Measurements of vertical hydraulic conductivities are rare (difficult to obtain). Kaehler and Hseih (1994) report values as low as 0.005 ft/day for an aquitard farther south along the California coast, so the order of magnitude is sensible. I do note that the implied anisotropy ratio is quite large.

Kaehler, CA and PA Hseih 1994. Hydraulic Properties of a Fractured Rock Aquifer, Lee Valley, San Diego County, California. USGS Water Supply Paper 2394

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August 2025

Review of <u>revisions</u> to *Model Documentation Report for Groundwater-Surface Water Model for the Ventura River Watershed*

I have carefully reviewed point-by-point responses to my previous comments on the original report, specifically Fingings 1a, 1c, 1b (two parts), 1d, 2a, 2b, 5a, 5b (two parts), 5c, 5d, 6a, 6b, 6c, 7a and 7b (three parts), and 7c.

I reviewed the authors' *Responses to Comments* as well as the revised report.

Overall, the revisions and the responses were comprehensive and very well organized. Nearly all of the responses adequately addressed and/or resolved my comments and suggestions.

However, a few issues remain outstanding. I made specific comments and additional suggestions on the following pages regarding Findings 1a, 1c, 5b, 7a and 7b.

Sincerely,

James W. Jawitz

Professor

Finding 1.a Concerning methodologies used to address data gaps related to water demand.

Finding 1.c Concerning assumptions and limitations of methodologies used to address data gaps related to water demand.

The new text in Section 2.7 clarifies that the pumping estimates affected only 29% of the total pumping volume. This was a valuable addition to the report.

The following three comments relate to measured vs estimated pumping rates.

1. The revised text on p. 24 reports that pumping rates for many wells are measured and therefore wells with unknown pumping rates in which estimates are needed are primarily "outside of the OBGJMA area". Figure 2.1 shows a map of the wells with measured vs estimated pumping. From that figure, it looks like the number of wells requiring estimates is larger than the number of wells with measured pumping rates.

> **Recommendation**: I suggest including in Section 2.1 a clear statement of the total number of wells with measured vs estimated pumping rates.

2. A simple method is described on p. 24 for estimating pumping rates for domestic wells "outside of the OBGMA". But there is a different description on p.28 of how residential demands were estimated. It is not clear which wells this applies to compared to the description on p.24, nor is it clear how these two reported methods are reconciled.

> **Recommendation**: I suggest adding some text to better describe the relationship between these two methods.

3. In part because of the uncertainty of what method is being applied where, the usage of the regressions in Figure 2.3 is not totally clear. Currently p. 29 says "Regressions of per capita use …. with delivery volume were developed… and used to extrapolate to years with no information." But this does not describe exactly what information was being extracted from the regression. Table 2.3 lists gpcd for all years, so my best guess is that the annual deliveries are not known for each year and the regression used these reported gpcd values to estimate the unknown annual deliveries.

> **Recommendation**: My suggestion is to make a more explicit statement such as "The regressions of Figure 2.3 were used to estimate annual deliveries in years with no data based on that year's reported gpcd." (Subject to whether I have interpreted the point of this figure correctly). Finally, if that is correct, then note that it is also standard practice to put the independent variable on the x-axis and the dependent variable on the y-axis. So, if the variable to be estimated is indeed annual deliveries, then standard practice suggests this should be on the y-axis.

Finding 1.d Concerning assumptions and limitations of supply and demand analysis.

The new section 2.8 is a valuable addition to the report. For example it is now clear that one-third of the demand is residential and that CMWD deliveries are approximately equal to groundwater pumping.

Finding 2.a Concerning the PRMS model configuration, input data, components, and calibration of model parameters.

Finding 2.b Concerning methodologies used to address data gaps in meteorological inputs.

The new R2 values in the figures of Appendix B are valuable additions to the report.

Finding 5.a Concerning model calibration and validation periods.

The new Table 5.1 with rainfall statistics is a valuable addition to the report, showing similarity between the modeling period and the full record.

Finding 5.b Concerning calibration and validation of historical streamflow, reservoir, and groundwater levels observed.

Regarding different metrics for groundwater and surface water modeling, this is not a critical issue and is unlikely to affect the important work in this report.

> **Recommendation**: I do not see a need to change this part of the report. The authors are correct that these disciplines were long considered separate enough to develop different standards. However, for future work the authors should recognize that current best practice does not support separate metrics even if relatively obscure regional reports can be found that continue to do this. For example, KGE is widely recognized as the most informative all-around metric for any type of modeling, surpassing NSE in popularity in modern use.

Regarding low-flow importance, I agree that somehow transforming the flows with exponents is a dark path best avoided. However, it is important to maintain a clear focus on the main questions of the work. Based on p. 234, I interpreted low flow periods to be important (from p. 234, “Here, the focus in primarily on low-flow periods”). So, it is concerning when (relative) errors in predicting low flows are concluded (p. 204) as “misleadingly high” as a justification for switching to absolute errors in order to enable concluding that errors are low. The model results are largely very good. The text mostly also says this. But are the errors in low flow periods important? If an important model goal is to predict low flows, then what accuracy is needed in those periods for the model to be considered successful? It seems these questions are somewhat sidestepped by instead focusing on the overall good performance during higher flow periods.

Recommendation: I am not suggesting a new method to transform the flows but rather being specific about the importance of low-flow accuracy during the interpretations in Section 5.4. How accurate is good enough during the low-flow periods?
Recommendation: Figure 5.30 is revised, but check if it is presented twice? (pp. 221 and 226)

Finding 7.a Concerning design of the unimpaired flow scenario to evaluate the total quantity of water available.

Finding 7.b Concerning unimpaired flow scenario results to define water year types.

The additional text on p. 268 is a valuable addition, explaining the role of groundwater in increasing streamflow in the 'unimpaired' scenario at two gages (604 and 605A/605) of the four gages discussed in this section.

However, regarding the other two gages, the data in Figures 7.5 and 7.6 clearly show no difference (overlapping IQRs in the seasonal box plots) between the unimpaired scenario and the calibration/validation period. The authors declined a t-test because it will also show no difference.

Recommendation: Instead of seasonal box plots, consider box plots based on flow quartiles. For example, in Figure 7.2 the unimpaired flow scenario and the baseline results are exactly the same under both high- and low-flow conditions. However, at intermediate flows the unimpaired scenario indeed does have systematically higher flows. The seasonal box plots do not capture this systematic difference because intermediate flows are not restricted to individual seasons. In Figure 7.1 the range of flows where the unimpaired scenario predictions are higher is even narrower (only at the lowest flows), but there appears to be a systematic difference in that interval.
Finally, of the two gages where the unimpaired scenario does not significantly affect streamflow (Figures 7.1 and 7.2), at one of them the model does not describe the measured low flow conditions (Figure 7.2), which occur more than 30% of the time. This discrepancy is far larger than between the calibration and unimpaired scenario and is perhaps worthy of further elaboration. Are the data reliable here at low flows? If so, then why is the behavior so different here compared to the other locations?
In conclusion, because the whole report is leading up to these scenarios, it seems important that the conclusions from the scenarios should be well supported by data analysis.