MONTGOMERY
& ASSOCIATES

Appendix F

Water Budget Tool Selection and Development

TOOL SELECTION

This Study uses the best available tools for the development of the water budget. Chapter 4 provides a summary for the justification for selecting the Salinas Valley SWI Model and the SVIHM for development of the Deep Aquifers water budgets. This section provides additional information on the models used and the calibration for each model.

Description of tools

Three existing models cover overlapping portions of the Deep Aquifers extent:

1. Salinas Valley Integrated Hydrologic Model[1] (SVIHM)
2. Monterey Subbasin Groundwater Flow Model (MBGWFM)
3. Salinas Valley Seawater Intrusion Model (SWI Model)

The SVIHM is currently under development by the United States Geological Survey (USGS). The SVIHM is a numerical groundwater-surface water model that is constructed using version 2 of the MODFLOW-OWHM code (Boyce *et al.*, 2020). This code is a version of the USGS groundwater flow code MODFLOW that estimates agricultural supply and demand through the Farm Process. The model area covers the entire Salinas Valley Groundwater Basin from the Monterey-San Luis Obispo County Line in the south to the Pajaro Basin in the north, including the offshore extent of the major aquifers. The model includes operations of the Nacimiento and San Antonio Reservoirs. The SVIHM is supported by 2 sub models: a geologic model known as the Salinas Valley Geologic Model (SVGM) and a watershed model known as the Hydrologic Simulation Program – Fortran (HSPF). The Deep Aquifers are represented in the SVIHM as the seventh and eighth layer of the 9-layer model. The USGS had only released a provisional version of the SVIHM at the time of the development of this Deep Aquifers Study. Details regarding source data, model construction, and calibration will be summarized in the model documentation once the model is publicly released.

EKI Environment & Water developed the MBGWFM for MCWD. It uses the USGS Newton formulation of the Modular Three-Dimensional Groundwater Modeling platform (MODFLOW-

---

[1] These data (model and/or model results) are preliminary or provisional and are subject to revision. This model and model results are being provided to meet the need for timely best science. The model has not received final approval by the U.S. Geological Survey (USGS). No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the model and related material nor shall the fact of release constitute any such warranty. The model is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the model.

NWT). Since the MBGWFM was not ultimately used for development of Deep Aquifers water budgets, the model will not be described in detail here. Additional details on the design and development of this model are available in the water budget chapter of the Monterey Subbasin Groundwater Sustainability Plan (MCWD and SVBGSA, 2022). The Deep Aquifers are represented in the MBGWFM as a single layer in the bottom active layer of the model.

Montgomery and Associates (M&A) developed the SWI Model. It is a MODFLOW USG-Transport groundwater flow and transport model. USG-Transport is an expanded version of MODFLOW USG, which uses an integrated finite difference framework to simulate heterogeneous, 3D advective-dispersive chemical species flow and transport with equilibrium and non-equilibrium retardation (Panday 2021, Panday *et al.*, 2013). The SWI Model is a density dependent groundwater flow model designed to assess seawater intrusion, primarily in the 180- and 400-Foot Aquifers. This model has the ability to account for the differing densities of freshwater, seawater, and brackish water due to density differences. It builds on existing groundwater models of the region, including the MBGWFM, SVIHM, the North Marina Groundwater Model, and the Seaside Basin Model. The SWI Model simulates groundwater flow and chloride transport using MODFLOW USG Transport V2.2 (Panday 2023). This model covers the Northern and Coastal portions of the Salinas Valley and covers a large portion of the Deep Aquifers. Geologic information from the SVIHM and the MBGWFM was used to inform the layering of the SWI Model. The SWI model contains 11 layers, with the Deep Aquifers represented by model layers 9 and 10.

At present, none of these 3 models can singularly be used to provide a water budget for the full Deep Aquifers. The SVIHM covers the entire Deep Aquifers extent but is poorly calibrated in the Monterey and Seaside areas. The MBGWFM is better calibrated than the other 2 models, but only covers a small portion of the Deep Aquifers. The SWI Model is calibrated in the Deep Aquifers but does not cover the full Deep Aquifers extent in the southern Salinas Valley. Due to the extent and calibration of each model, no single tool can provide dependable water budgets for the Deep Aquifers, and the results of 2 or more models need to be combined to provide an estimate of the water budget. The water budgets presented in Chapter 4 were developed using the SWI Model in conjunction with the SVIHM to cover the Deep Aquifers area outside of the SWI Model extent. This combination of models provides coverage for the entire Deep Aquifers, while minimizing the number of model results that need to be stitched together and using only areas of models that were calibrated.

Some water budget components such as pumping and injection can be directly measured, but most water budget components are either estimated as inputs to the model or simulated by the model. Both estimated and simulated values in the water budgets are underpinned by certain assumptions. These assumptions can lead to uncertainty in the water budget. In each of the above models, selected inputs were developed based on the best available data at the time of model development. While substantial work was completed to reduce the level of uncertainty, uncertainty still exists in model inputs and results. In addition to the model assumptions, additional uncertainty stems from any model's imperfect representation of natural condition and level of calibration.

Calibration Review

To compare the accuracy of each model, observed and simulated water levels from each calibration dataset were extracted and combined into a single calibration dataset. The MBGWFM represents the Deep Aquifers as a single layer. For the SVIHM and SWI Model, which both represent the Deep Aquifers as 2 layers, simulated water levels were averaged for the 2 layers present in each model. Table F-1 lists the scaled root mean square error, or percent error, for the various overlapping areas of the models within the Deep Aquifers. Within the MBGWFM area, the MBGWFM model has the lowest model error and the SVIHM has the highest. Water levels in the Monterey and Seaside Subbasins were not used in the SVIHM calibration. Within the area of the SWI Model east of the MBGWFM boundary, the SWI Model and SVIHM perform similarly. Due to the SVIHM's large model error in the area covered by the MBGWFM and the rest of the Seaside area, the SWI Model performs better overall in the area that it covers.

Table F-1. Percent Error for the Combined Calibration Dataset for Each Model

Model	SWI Model	MBGWFM	SVIHM
Full Basin	12%	-	16%
MBGWFM Deep Aquifers Area	16%	12%	23%
Deep Aquifers Area North and East of MBGWFM	6%	-	6%

The Deep Aquifers was not the focus of the calibration for any of the models considered for this water budget analysis. The calibration for the SWI Model was focused on the 180- and 400-Foot Aquifers where seawater intrusion has been observed. Model error is higher in the Deep Aquifers layers than in other aquifer layers due to limited calibration data available in the majority of the Deep Aquifers and no observed water level elevation data in the portion of the Deep Aquifers calculated by the SVIHM. Additional water level measurements could be used to update the HCM and the models to improve confidence and accuracy of the water budgets in the Deep Aquifers. Despite the limited data for calibration, the SWI Model and the SVIHM are the best available tools to prepare water budgets for the Deep Aquifers.

WATER BUDGET DEVELOPMENT

Time Periods

Water budgets are presented for this historical (2004-2017) and recent periods (2018-2020). These 2 time-periods provide a range of climatic conditions. Selected time periods for the historical and recent water budgets are summarized in Table F-2.

Table F-2. Water Year Types Presented in Water Budget Times Periods

Time Period	Proposed Date Range	Water Year Types Represented in Time Period	Rationale
Historical	Water years 2004 through 2017	Dry: 4 Dry-Normal: 4 Normal: 1 Wet-Normal: 0 Wet: 5	Provides insights on water budget response to a wide range of variations in climate and groundwater use over an extensive period of record. Begins and ends in years with average precipitation.
Recent	Water Year 2018 through 2020	Dry: 1 Dry-Normal: 1 Wet: 1	Best reflection of current land use and water use conditions based on best available data.

The water budget for the Deep Aquifers is calculated using the SWI Model where the SWI Model is active and the SVIHM for the portion of the Deep Aquifers outside the SWI Model extent. For this analysis, water budgets are reported for water year 2004 through 2020, which is the last year the SWI Model runs through. The SVIHM runs through water year 2018, however, simulated groundwater extraction in 2018 does not match reported values in the basin. Consequently, water budgets in 2018 calculated by the SVIHM were excluded and water budget results for water year 2017 were repeated for water year 2018 through 2020. Over the water budget period (2004-2020) both the SWI Model and SVIHM have monthly stress periods. Water budget results were aggregated by water year for each model.

Deep Aquifer Zone Delineation

Water budget results were post-processed using ZoneBudget v 3.01 (Harbaugh, 1990) for the SVIHM and Groundwater Vista's (Rumbaugh, 2023) Hydrostratographic Unit Summary Report for the SWI Model. These tools divide the model results into user-specified zones. Water budgets are then calculated for each zone by aggregating the cell-by-cell water budgets for every node or cell within the zone.

The Deep Aquifers was separated into 3 zones to show spatial variation in the water budgets. The location for the 2 boundaries, between the 3 zones, is based on geology, observed groundwater elevations, and observed water chemistry. As Appendix A describes, the Santa

Margarita formation is present in the Seaside Subbasin and southwestern portion of the Monterey Subbasin and then is not present in the Marina Coast Water District deep wells. In addition, the water chemistry is slightly different between the Northern and Seaside Areas, as shown in Chapter 3. The boundary between the Southeastern Area and the Northern Area is based primarily on the lack of Deep Aquifers data in the Southeastern Area.

The external zones that groundwater flows into and out of the Deep Aquifers are delineated based on groundwater flow direction, geology, as well as geographic location. These zones were developed to match the regions outlined in the HCM. The geology and the connection to the Deep Aquifers for each of these areas is described in more detail in the HCM.

Well Borehole Flow Between Aquifer Layers

In general, outflows exceed inflows for the Southeastern Region, resulting in a loss of groundwater storage in both the historical and recent periods. Groundwater flow is entering from the south and west and exiting the Region into the Gabilan Range Bajada to the east and to the Northern Region of the Deep Aquifers to the north. However, the magnitude of the flow volumes is dependent on the hydraulic parameters within the model, which were not the focus of the calibration for the provisional SVIHM available for this analysis. Future model updates may consider including a sensitivity analysis on hydraulic parameters for the purpose of constraining this flow. A small negligible amount of surficial recharge and stream leakage occurs on the margins of the basin within this Region in portions of the Deep Aquifers that are exposed at the surface within the SVIHM; this is considered an artifact of the model layering and not representative of actual surficial recharge. Given the limited number of known Deep Aquifers wells in this region and the relatively small amount of pumping reported in Table 4-5, the loss of storage could be largely driven by net groundwater outflow to the Eastside Gabilan Bajada area, which could be a result of pumping in that adjacent aquifer. The pumping values in Table 4-5 represent pumping from wells located within the SWI Model boundary. Within the SVIHM, groundwater pumping is included in the SVIHM Net MNW2 term. While a small amount of simulated groundwater is exiting the Deep Aquifers via the MNW2 wells, a significantly larger amount of water is simulated as entering the aquifer via these wells. This occurs as a result of the MODFLOW MNW2 package used for simulating pumping in the SVIHM. This simulated inflow represents groundwater moving through the well bore from 1 aquifer layer to another due to the hydraulic gradient between the well bore and the aquifer layers. Overall, this simulated flow is a net inflow to the Deep Aquifers in the SVIHM. This well flow is further complicated because some of the water is associated with water balance subregions, often referred to as Farms, that are not adjacent to the Southeastern Region. While it is possible that in reality some groundwater is entering the Deep Aquifers via well bores, the magnitude of this flow is likely too high. The MNW well flow is reported as "well bore flow between aquifer layers" in Table 4-5 of the Study.

Combining Water Budget Results from Two Models

As described above, no single model currently available for this analysis is neither calibrated nor has coverage over the entire Deep Aquifers extent. As a result, water budgets from the SWI Model and the SVIHM needed to be combined to prepare water budgets for the entire Deep Aquifers. The Southeastern extent of the SWI Model is located near the middle of the Southeastern Area within the Deep Aquifers. The flows between the 3 models are not consistent across the entire water budget period. Figure F-1 shows the calculated flows across the interface between the SWI Model and the SVIHM along the SWI Model within the Deep Aquifers. The difference between these 2 flow rates is incorporated into the “Error” term presented in the water budgets.

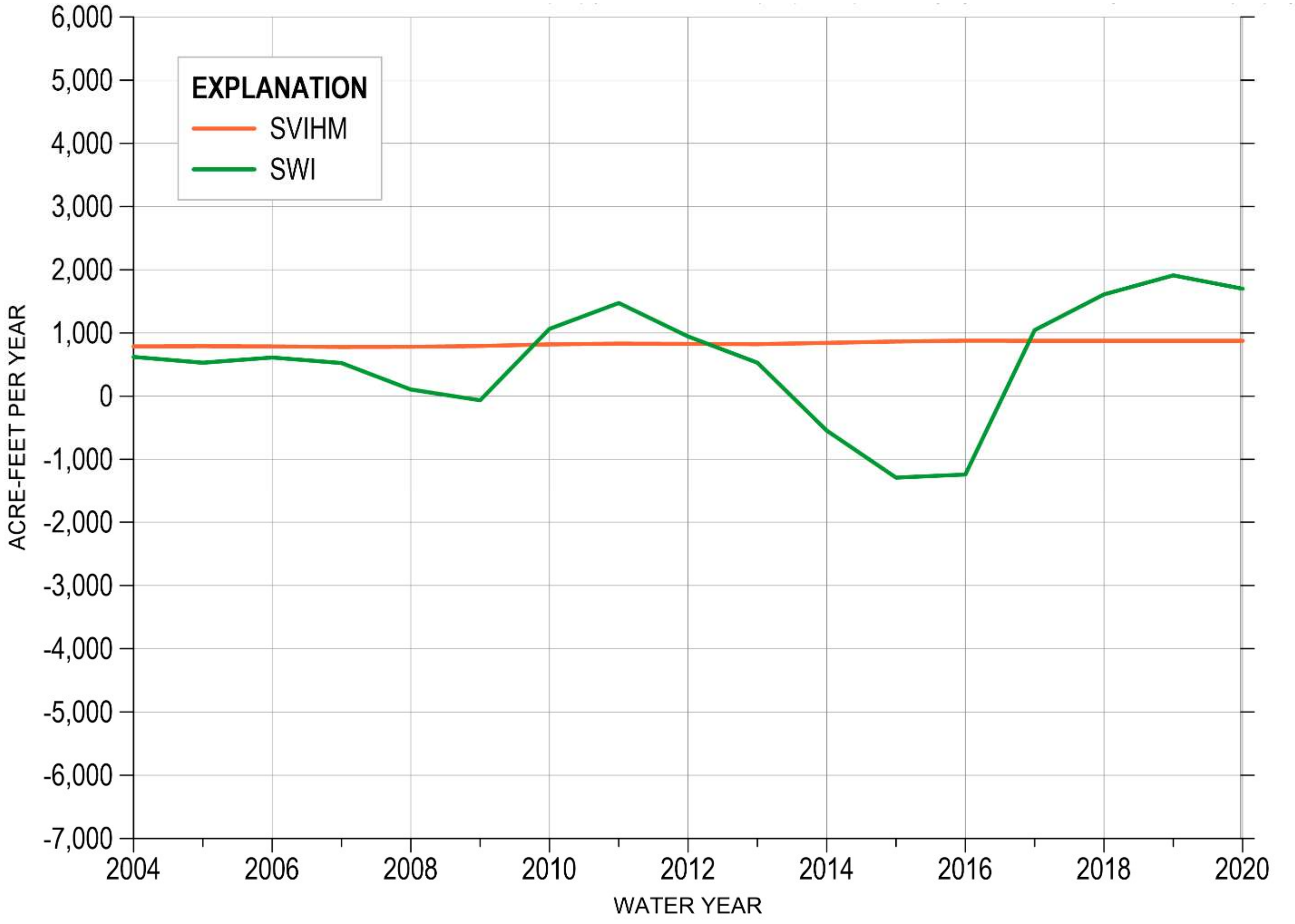

Figure F-1. Net groundwater flow across the SWI Model boundary within the Deep Aquifers

REFERENCES

Harbaugh, A.W., 1990, A computer program for calculating subregional water budgets using results from the U.S. Geological Survey modular three-dimensional ground-water flow model**:** U.S. Geological Survey Open-File Report 90-392, 46 p., https://doi.org/10.3133/ofr90392

MCWD GSA and SVBGSA, 2022, Groundwater Sustainability Plan Monterey Subbasin, Marina Coast Water District Groundwater Sustainability Agency, Salinas Valley Basin Groundwater Sustainability Agency.

Panday, S., 2021; USG-Transport Version 1.9.0: The Block-Centered Transport Process for MODFLOW-USG, GSI Environmental, February 2022 http://www.gsi-net.com/en/software/free-software/USG-Transport.html.

Panday, S., C.D. Langevin, R.G. Niswonger, Motomu Ibaraki, and J.D. Hughes. 2013, MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods, book 6, chap. A45, 66 p.

Rumbaugh, J.O., Rumbaugh, D.B., 2023. Groundwater Vistas, Environmental Simulations, Inc.