Chapter 1 Overview

1.1 Introduction

In 2013, the Stockholm Environment Institute (SEI) contracted with the State Water Resources Control Board (State Water Board) through ICF International to develop a Water Evaluation and Planning system (WEAP) model for use in the update of the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). The State Water Board's water quality control planning process for approving amendments to the Bay-Delta Plan must ensure the reasonable protection of beneficial uses, which requires balancing competing beneficial uses of water, including municipal and industrial (M&I) uses, agricultural uses, fish and wildlife, and other environmental uses. The State Water Board's process will include an analysis of the effects of any changed flow objectives on the environment in the watersheds in which Delta flows originate, in the Delta, and in the areas in which Delta water is used. It will also include an analysis of the economic impacts that could result from changed flow objectives. This report describes the development of the Sacramento Valley Water Allocation Model (SacWAM) model that will be used to support the State Water Board's efforts.

The SacWAM domain is shown in Figure 1-1. The model represents the Sacramento River Hydrologic Region, the Trinity River watershed above the Lewiston gauge (USGS 11525500), and the northern part of the San Joaquin River Hydrologic Region downstream from the gauge at Vernalis (USGS 11303500). The model includes the entire Sacramento-San Joaquin Delta (Delta), and the Delta Eastside streams comprising the Cosumnes, Mokelumne, and Calaveras rivers. SacWAM also includes the Delta-Mendota Canal (DMC), California Aqueduct, and San Luis Reservoir. Flows in the San Joaquin River at Vernalis are specified based on previous modeling efforts developed during the Phase I update of the Bay-Delta Plan. SacWAM represents the water resources within the model domain using a comprehensive approach in which hydrology, water infrastructure, and water management are all contained within the simulation model.

The model was constructed to satisfy specific needs of the State Water Board as it develops an updated Bay-Delta Plan. Model requirements include:

- Period of simulation comprising water years 1922 – 2009.
- A monthly time step.[1]
- Simulation of unimpaired flows in the mountain and foothill watersheds that surround the valley floor.
- Simulation of stream flows at the confluences of tributaries to the Sacramento River.
- Simulation of stream flows at United States Geological Survey (USGS) and California Department of Water Resources (DWR) gauges located on the Sacramento River.
- Simulation of Delta inflow, net Delta outflow, and flows within the south Delta.
- Ability to simulate unimpaired flows.
- Simulation of major water infrastructure and their operations in the upper watersheds.

[1] Crop water demands and rainfall-runoff are determined using a daily time step.

- Simulation of water allocations and diversions on the valley floor.

By necessity, SacWAM simplifies the depiction of stream flows by aggregating surface water diversions, return flows, and groundwater inflows to the stream network. Figure 1-2 and Figure 1-3 show the specific points of interest to the State Water Board where flow is accurately simulated in SacWAM, despite these simplifications.

In the upper watersheds, natural hydrological processes including snow accumulation and melt, rainfall runoff, native vegetation evapotranspiration, and groundwater processes are represented using the Soil Moisture Model of the WEAP software. The Soil Moisture Model was calibrated to unimpaired flows measured or calculated at the edge of the valley floor. All reservoirs with storage of greater than 100,000 acre-feet and all inter-basin transfers exceeding 15,000 acre-feet/year are represented. Typically, these storage and transfer operations are simulated using average monthly historical values of storage and flow. In contrast, foothill reservoir operations including Trinity, Whiskeytown, Shasta, Oroville, and Folsom are simulated to meet flood control, water supply, and environmental water requirements.

Model representation of the valley floor is much more detailed than that for the upper watersheds and includes all major water diversions, canals, weirs, and flood bypasses. Agricultural water demands are represented using 20 crop types and the average irrigated acreage for 1998 – 2007. Crop water use is calculated using a daily dual crop coefficient approach (Allen et al., 1998). Urban water demands, divided into indoor and outdoor water use, are based on historical purveyor data for 2006 – 2010 for major cities and towns and on population data for smaller communities. Wildlife refuges represent permanently and seasonally flooded lands. Associated water demands are calculated in a manner similar to agricultural lands.

Operations of the federal Central Valley Project (CVP) and State Water Project (SWP) significantly affect river and channel flows within much of the model domain. Aspects of the CVP and SWP operations simulated in SacWAM include, but are not limited to:

1. Instream flow requirements (IFRs) on the Trinity, Sacramento, Feather, and American rivers[2]
2. Water Right Decision 1641 (D-1641) Delta flow requirements and Delta export restrictions
3. D-1641 water quality requirements
4. National Marine Fisheries Service (NMFS) Biological Opinions (BiOps)
5. U.S. Fish and Wildlife Service (USFWS) BiOps
6. CVP-SWP Coordinated Operations Agreement (COA)
7. CVP and SWP contract amounts and allocations

Additionally, SacWAM includes regulatory requirements, such as IFRs, that affect local reservoir operations and surface water diversions.

[2] Instream flow requirements modeled include both explicit flow requirements and approximate flows that may be needed to achieve cold water habitat water temperature targets downstream of reservoirs.

Figure 1-1. Sacramento Valley Water Allocation Model Domain

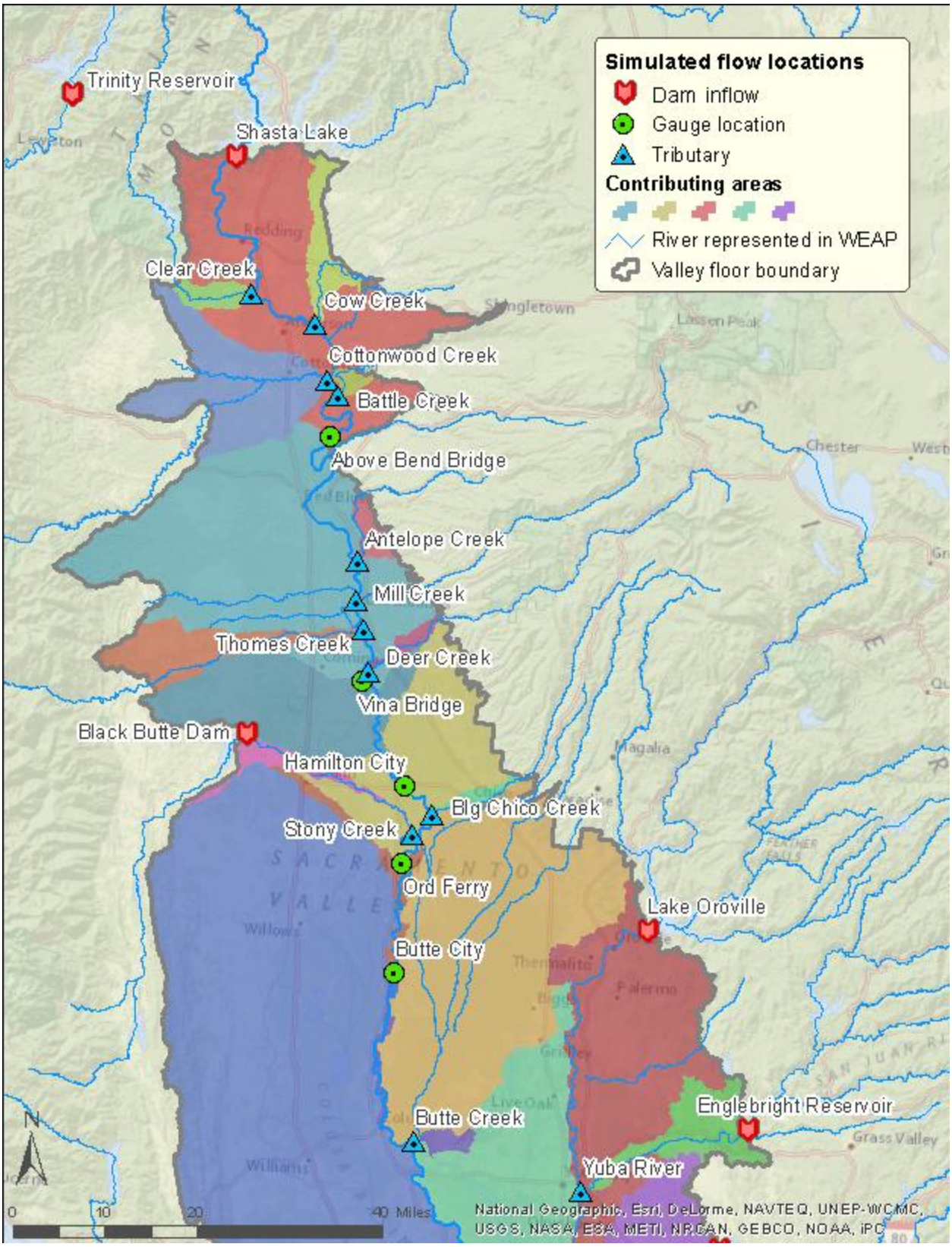

Figure 1-2. Simulated Flow Locations (North)

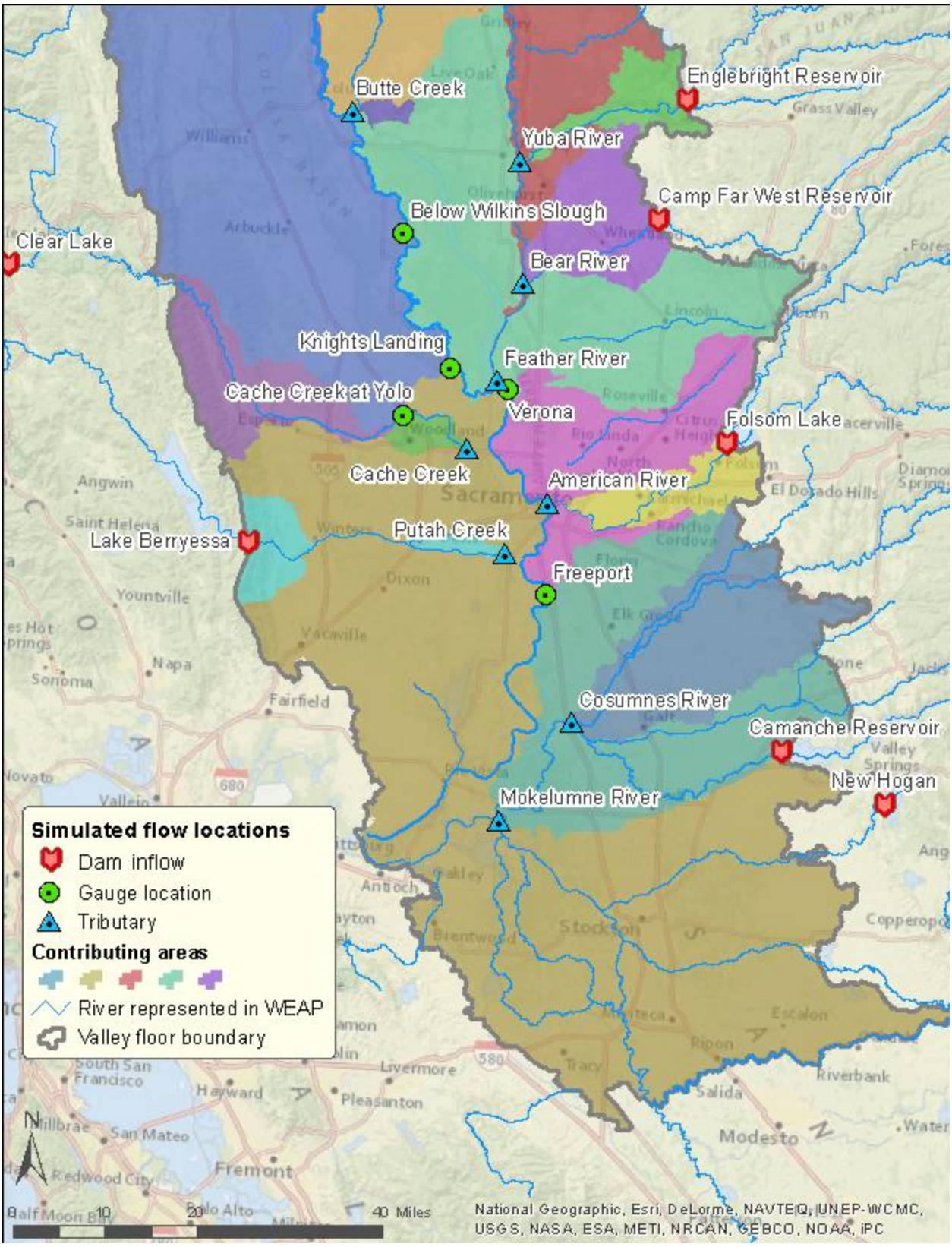

Figure 1-3. Simulated Flow Locations (South)

1.2 Organization and Contents of this Document

This report describes the methods and assumptions used to develop the SacWAM application within the WEAP software that are primarily contained in WEAP's 'Data View'. After the first three introductory chapters, chapter titles correspond to the six major categories found in the Data View in the WEAP software, and chapter subsection titles match the "branch" names used in WEAP. This organizational structure simplifies finding relevant information as a model user navigates through SacWAM. Chapters include information on the representation of the valley floor demands and hydrology, the upper watersheds, and the operations rules for the water management infrastructure. The contents of each chapter are as follows:

Chapter 1, Overview, provides general background on SacWAM and this document.

Chapter 2, Water Evaluation and Planning System, describes the WEAP software used to develop SacWAM.

Chapter 3, Schematic, describes development of the SacWAM schematic, constructed using WEAP's internal water resources objects.

Chapter 4, Demand Sites and Catchments – Delta and Valley Floor, explains the aggregation of water users into demand units, and describes simulation of water demands and water use, and model calibration for the valley floor domain.

Chapter 5, Demand Sites and Catchments – Upper Watersheds, describes the representation of the mountain and foothill watersheds that surround the valley floor, and the calibration of WEAP's internal hydrology model to simulate climate-driven snow accumulation and melt and rainfall-runoff processes.

Chapter 6, Supply and Resources, describes the parameterization of SacWAM's water resources objects using built-in object properties.

Chapter 7, Other Assumptions, describes user-defined state variables whose values are determined at the beginning of each time step and that determine technical coefficients or right-hand side resource constraints in the formulation of linear constraints on model simulation.

Chapter 8, User-Defined Linear Programming Constraints, describes complex operating rules that are formulated using arithmetic expressions rather than constraints that are automatically developed by WEAP from properties of the built-in water resources objects.

Chapter 9, Key Assumptions, lists model settings that control the mode of simulation.

Chapter 10, **Model Calibration**, summarizes the calibration of runoff from catchment objects and stream-groundwater interactions and refers readers to Appendicies A and B for more detailed discussions of the calibration.

Chapter 11, Model Use and Limitations, discusses appropriate use of SacWAM, lists current model limitations, and makes recommendations for using and interpreting model results.

Chapter 12, presents sources cited in this report.

Appendix A, Upper Watershed Hydrology Calibration, discusses the techniques used and results for the calibration of the WEAP catchment objects in the watersheds upstream of the valley rim reservoirs.

Appendix B, Sacramento Valley Floor and Delta Calibration, discusses the calibration of various aspects of the hydrological system on the Sacramento Valley floor. Validation results of CVP and SWP project operations are also presented.

As described above, parameterization of the model is documented in sections of Chapter 4 through Chapter 9 using the same headings found in the WEAP software data tree. For example, if there is a question about the Maximum Flow Volume on a transmission link on the valley floor, a description of how this parameter was derived can be found by navigating through the table of contents to the valley floor parameterization section (Chapter 4) and then following the headings as seen in the WEAP data tree *(Supply and Resources\Transmission links\Linking Rules\Maximum Flow Volume*). Phrases in *italics* in the documentation are model parameters and branches with sub-branches separated by a backslash ("\"). File pathways in the model and documentation directories also use backslashes but are not in italics.

Data and information used to develop SacWAM is contained in a directory structure on a DVD that can be provided upon request from the State Water Board. These data and information include:

- Geographic Information System (GIS) data: used to develop the schematic and define watershed parameters (4 GB)
- Climate data: used to populate WEAP's watershed objects (3 GB)
- Spreadsheets: contain reservoir storage capacity, groundwater, surface streamflow, urban, and agricultural data used to develop the hydrology and water demand parameters (135 MB)
- References: pdf copies of data references, primarily water demand data (2 GB)

These data and information are referenced in the document using three methods. The first method is the inclusion of 'File Location Information' tables found throughout the document. The second method is through standard referencing techniques; supporting documents, journal articles, and reports are cited in the text. Data sources are provided in digital form within the directory structure under 'References' except for data sources that are readily available on the internet (typically government-sponsored data repositories) that are simply referenced by their web page address. The third reference method is for supporting GIS or spreadsheet-based data. This type of data is referenced in the text using an alias in **bold** font. These aliases or referenced names are then listed in tables located throughout the document that also provide the actual name for the file and its location in the directory structure. For example, a GIS shapefile that contains a map of river miles is referred in the text as "**river miles**." In Table 3-13, the alias or referenced name "**river miles**" is associated with the shapefile sac_val_stream_miles.shp located in GIS\Hydrology.

1.3 Accessing WEAP Software

The WEAP software has been under development by SEI for nearly 20 years. The software provides a comprehensive suite of tools for simulating water resources systems including rainfall-runoff hydrology, water resources infrastructure, agricultural, urban, and environmental demands, and the ability to apply complex operations rules and constraints to the water allocation problem. The water allocation problem

is solved using linear programming (LP) defined by user-specified demand priorities, water supply preferences, and user-defined constraints (UDCs). The software is well documented and has a well-developed training tutorial provided on the WEAP21 website. Through an arrangement with DWR, the software is provided for free to all California public agencies. For comprehensive information on the software and downloads please visit www.weap21.org.

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