



CALIFORNIA DEPARTMENT OF WATER RESOURCES
SUSTAINABLE GROUNDWATER
MANAGEMENT PROGRAM

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Resource Guide

DWR-Provided
Climate Change Data and Guidance

for Use During Groundwater
Sustainability Plan Development

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DWR-Provided Climate Change Data and Guidance for Use During Groundwater Sustainability Plan Development

The California Department of Water Resources (DWR) provides multiple resources related to climate change for Groundwater Sustainability Agencies (GSAs) to use during development of Groundwater Sustainability Plans (GSPs). This document gives GSAs and other stakeholders a high-level overview of these climate change resources including datasets provided by DWR, tools for working with the DWR-provided datasets, and guidance for using DWR-provided data and tools in developing GSPs. The datasets and methods can provide technical assistance to GSAs for developing projected water budgets. GSAs may choose not to use the DWR-provided Data, Tools and Guidance to develop projected water budgets. However, DWR recognizes that assessing impacts of climate change is complex and can take considerable time and effort. As a result, the climate change resources are provided to help reduce the level of effort needed for GSAs to account for climate change impacts in their GSPs.

The climate change resources are designed to complement the GSP regulations and best management practices (BMPs). Information pertaining to the use of climate change datasets to develop projected water budgets may be found in Section 354.18(c)(3) of the GSP Regulations, which describe projected water budget assessments. Additional clarification can be found in the water budget and modeling [BMPs](#)¹ which describe the use of climate change data to compute projected water budgets and simulate related actions in groundwater/surface water models. The *Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development* (Guidance Document) is the primary source of technical guidance. The Guidance Document explains the DWR-provided climate change data including how the data were developed, the methods and assumptions used, and how they can be used in the development of a projected water budget.

The information in this document briefly summarizes the DWR-provided climate change resources and serves as a roadmap to point the reader toward additional information with the necessary level of detail. This document is organized as follows:

- Overview – provides overall background on the Sustainable Groundwater Management Act (SGMA) and Regulatory requirements as well as information on the DWR-provided climate change datasets.
- Climate Change Data – summarizes the datasets provided including climate, hydrology, and operations for the different climate change projections.
- Climate Change Data Processing Tools – introduces the web and desktop tools for accessing and using the climate change datasets for projected water budget analysis.
- Climate Change Data Analysis Guidance – summarizes the different types of guidance available including the factsheet, Guidance Document and appendices, and user manual.
- Climate Change Data Analysis Process – provides an overview of the approaches detailed in the climate change Guidance Document.
- Resources – summarizes the different data, tools, guidance, and other resources into a reference table with accessible web-links.

¹ <https://www.water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents>

Overview

Regulatory Background

SGMA requires incorporation of climate change assumptions into the development of projected water budgets, and for the sustainable management of groundwater basins. A select list of SGMA and GSP regulatory requirements are provided below.

SGMA Requirements

- Water Code Section 10727.2, *Required Plan Elements*
- Water Code Section 10733.2, *Department to Adopt Emergency Regulations Concerning Plan Review and Implementation*

DWR GSP Regulations

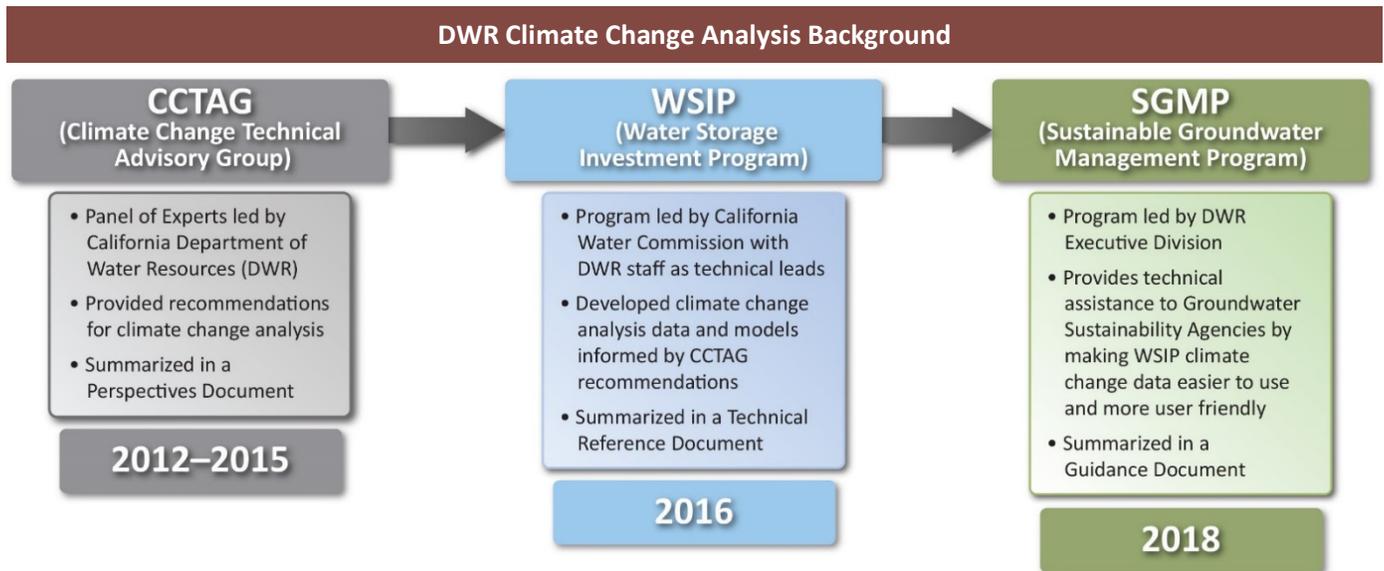
- Section 354.18, *Water Budget*
- Section 354.18(e), *Use of best available information and best available science*

DWR-Provided Information

DWR-provided climate change data are based on the California Water Commission’s Water Storage Investment Program (WSIP) climate change analysis results. The provided climate change data can help GSAs with the following:

- Developing long-term water budgets
- Planning long-term groundwater basin sustainability
- Assessing projects and management actions and performing sensitivity analysis of projected conditions
- Managing resources adaptively

In 2016, the California Water Commission, assisted by DWR as the technical lead, published climate change datasets to be used for WSIP grant application analysis. These WSIP datasets were derived from a selection of 20 global climate projections recommended by the Climate Change Technical Advisory Group (CCTAG). These WSIP datasets were further processed to include data formats useful for the development of GSPs and related technical analysis to implement the SGMA.



While DWR provides these climate change resources to assist GSAs in their projected water budget calculations, the data and methods described in the Guidance Document are optional. Other local analysis and methods can be used, including existing climate change analysis. If the DWR-provided datasets are used, the Guidance Document describes two paths that may be followed to develop a projected water budget. The intent is to provide guidance on a possible method to assist GSAs with including climate change into their projected water budget calculations, especially if no local climate change analysis has been done before. This document provides an overview of DWR-provided data and methods and summarizes additional guidance provided.

Climate Change Data

Datasets provided by DWR were developed based on the WSIP analysis for projected climate conditions centered around 2030 and 2070 (Table 1). The climate projections are provided for these two future climate periods, and include one scenario for 2030 and three scenarios for 2070: a 2030 central tendency, a 2070 central tendency, and two 2070 extreme scenarios (i.e., one drier with extreme warming and one wetter with moderate warming). The climate scenario development process represents a climate period analysis where historical variability from January 1915 through December 2011 is preserved while the magnitude of events may be increased or decreased based on projected changes in precipitation and air temperature from general circulation models (GCMs).

- Climate Data.** The climate data provided include precipitation and reference evapotranspiration as simulated by the VIC model through a downscaling process from global circulation models. Precipitation and reference evapotranspiration (ET) are packaged as monthly change factor ratios that can be used to perturb historical data to represent projected future conditions. Change factor ratios are calculated as the future scenario (2030 or 2070 scenario) divided by 1995 historical temperature detrended scenario.
- Hydrology Data.** The hydrology data provided include projected Central Valley stream inflows as simulated by the VIC model that can be used directly in a water budget by replacing the historical data with the projected data, and additional streamflow data in the area outside of the Central Valley. In addition, for SGMA purposes, unimpaired streamflow change factor datasets were developed through further post-processing of existing data provided via WSIP.
- Water Operations Data.** The water operations data provided include Central Valley reservoir outflows, diversions, State Water Project (SWP)/Central Valley Project (CVP) water deliveries and select streamflow data as simulated by the CalSim II model and produced for all future conditions and scenarios.

Datasets Provided by DWR's Sustainable Groundwater Management Program (SGMP)

- Climatological Data — Gridded change factors for precipitation and reference evapotranspiration
- Central Valley Project Operations Data — Central Valley diversions, deliveries, and modeled flow data (State Water Project [SWP] and Central Valley Project [CVP] Simulation Model [CalSim II] and variable infiltration capacity [VIC] model)

Table 1. Datasets Provided by WSIP and Modified Datasets Provided by SGMP

Data Type	Specific Data	WSIP	SGMP ^a
Climate	Precipitation, reference ET	Individual text files for each VIC model grid cell with associated VIC grid GIS data	VIC model grid GIS data with related table of timeseries data for each grid cell (as change factors)
Hydrology	Central Valley stream inflows	Timeseries data developed as input to the CalSim II model	Point locations provided as GIS data with related timeseries data in .csv format for each location
Hydrology	Statewide unimpaired streamflow change factors ^b	N/A; runoff and baseflow provided in individual text files for each VIC grid	Dataset developed by combining VIC runoff and baseflow for each HUC 8 watershed; provided based on HUC 8 GIS data with related table of timeseries data
Water Operations	Diversion/deliveries and reservoir outflow data	Dataset embedded in CalSim II model runs	Point locations provided as GIS data with related timeseries data in .csv format for each location; delivery data available through lookup table of contracted amounts with CalSim II timeseries outputs in Excel format

Notes:

^aAll data are available through SGMA Data Viewer at <https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer>.

^bStreamflow change factors are for unimpaired flows (i.e., upstream of dams where reservoir operations have not been included).

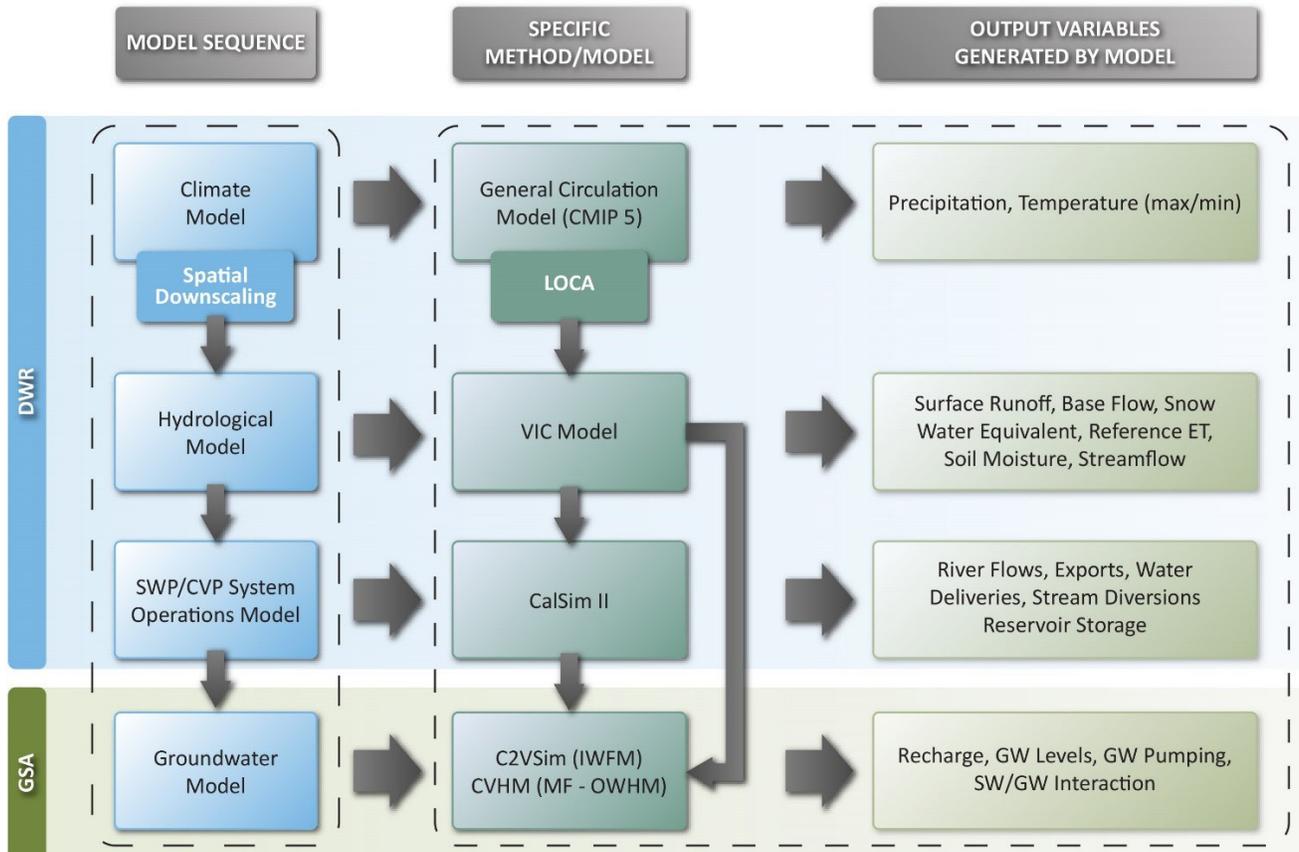
Key:

GIS = geographic information system
 .csv = comma separated values

HUC 8 = Hydrologic Unit Code 8
 N/A = not applicable. developed by SGMP

Climate Change Data

As part of technical assistance, DWR provides climate change datasets that can be readily used by GSAs for projected water budgets. The figure below summarizes the general modeling sequence for evaluating climate change effects on groundwater resources. The center column shows the specific methods and models used if the DWR-provided datasets are used by a GSA in a groundwater model. The data output from each model is shown in the right column. As the figure indicates, DWR provides all but the last step to reduce the level of effort needed for GSAs to incorporate climate change.



DWR: Department of Water Resources; GSA: Groundwater Sustainability Agency; SWP: State Water Project; CVP: Central Valley Project; LOCA: Localized Constructed Analogs; VIC: Variable Infiltration Capacity; CalSim: SWP & CVP Operations Model; C2VSim: California Central Valley Groundwater - Surface Water Simulation Model; IWFM: Integrated Water Flow Model; CVHM: Central Valley Hydrologic Model; MF - OWHM: MODFLOW One Water Hydrologic Flow Model; ET: Evapotranspiration, SW: Surface Water; GW: Groundwater; CMIP 5: Coupled Model Intercomparison Project

- **Appropriate use of climate change datasets**

DWR provides climatological and hydrological data for use in GSP water budget development and modeling. It is the GSA's responsibility to use the data and tools appropriately. Using DWR-provided data and tools does not guarantee that a GSA's projected water budget is acceptable or that the projected water budget meets GSP requirements. GSAs are not required to use DWR-provided climate change data or methods, but GSAs will need to adhere to the requirements in the GSP Regulations. If DWR-provided data are used, GSAs should be careful and use a consistent approach if combining DWR-provided data with other local information. For example, it is not appropriate to mix data produced by a transient climate analysis method with data developed using a climate period analysis method.

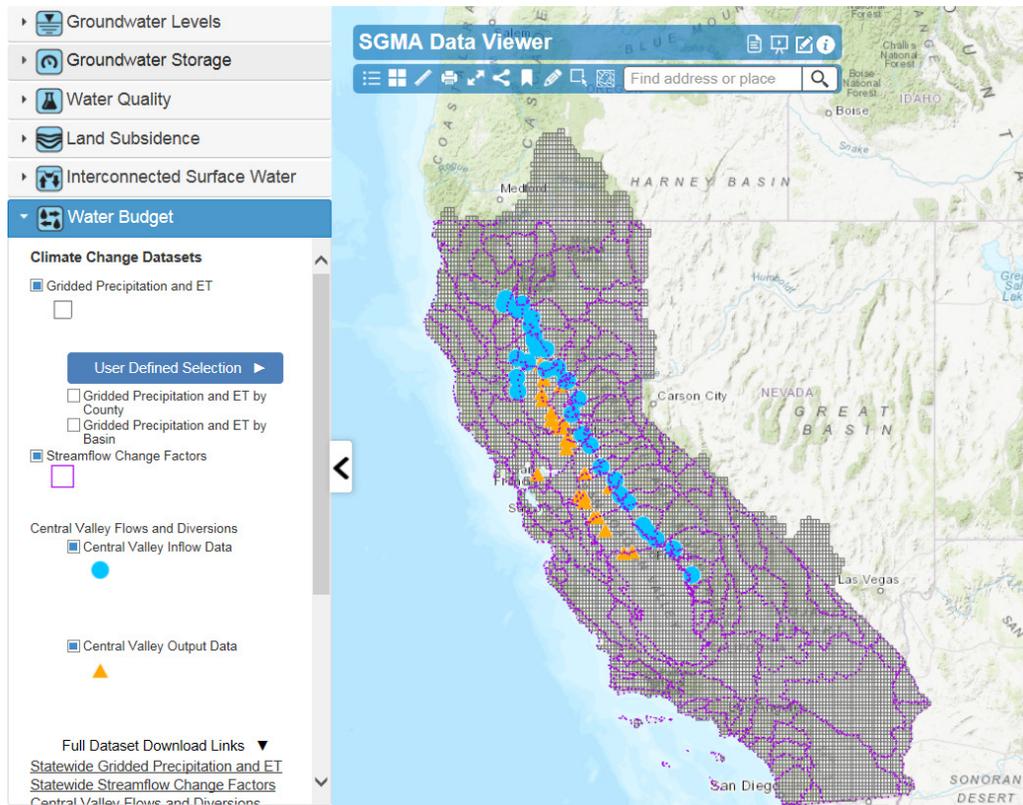
- **Refinement of climate change analysis data and methods in the future**

As climate science further develops, it will be important to use the data that reflect the current understanding and best available science at the time of future GSP updates. For example, Coupled Model Intercomparison Projects (CMIP) are updated every 8 to 10 years to incorporate the latest developments in climate science. DWR will release new data as deemed appropriate at the time of model updates to help GSAs stay current on their climate change analysis.

Climate Change Data Processing Tools

DWR developed and provides the SGMA Data Viewer and desktop tools to help GSAs apply data to their hydrologic models and water budget calculations, as follows:

- **SGMA Data Viewer:** this is an online GIS-based interactive map for downloading relevant spatial and associated time-series (temporal) data in accordance with a user-defined region. Data can be visualized and downloaded for the entire state, or subsets of data can be clipped directly from the statewide dataset by drawing polygons or uploading a boundary shapefile (for example representing a model domain). Datasets are also available by county and basin. The snapshot below shows the [Data Viewer](#) page with the climate change data download options, under the Water Budget section.



- **Desktop tools** are available to help process relevant datasets for future water budget analysis and integrated hydrologic modeling.
 - **Model input file development desktop tools.** These tools help map VIC model gridded precipitation and reference ET data to the correct groundwater model cells (for MODFLOW-based models) or elements (for Integrated Water Flow [IWF]-based models).
 - **Spreadsheet tool for basin average unimpaired streamflow change factor corrections.** This tool modifies monthly change factors to more accurately reflect annual streamflow patterns present in historical data.
 - **Contractor deliveries search table.** These tables summarize water contractor deliveries in a spreadsheet format that reports both the name of contractor and region of delivery.

These and the other tools listed below can be downloaded from DWR's [Data and Tools website](#). These tools can help GSAs analyze projected climate change.

Other Related Tools

- **DWR modeling tools.** Other general modeling tools provided by DWR include the integrated surface-water/groundwater models (IWF and its Central Valley applications, California Central Valley Simulation Model [C2VSim] and Sacramento Valley Groundwater-Surface Water Simulation Model [SVSim]) to facilitate simulation of current and future groundwater conditions.

Climate Change Data Analysis Guidance

In addition to data and tools, DWR provides several guidance documents to help GSAs apply climate change data to their water budgets and for other GSP requirements. Supporting documents (listed below) may help GSAs understand and incorporate climate change into projected water budgets. The main document, the Guidance Document² was developed to help GSAs incorporate DWR-provided climate change and related data into their GSPs.

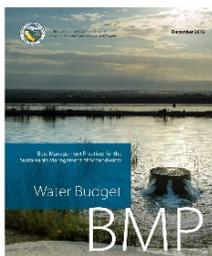
Climate Change-Specific Guidance

- **Factsheet.** The factsheet provides a one-page reference about the climate change data, tools, and guidance being provided by DWR to assist GSAs with climate change analysis in their GSPs.
- **Guidance Document.** The Guidance Document provides GSAs and other stakeholders with information regarding climate change datasets and tools provided by DWR for use in developing GSPs. The focus of the guidance document is the DWR-provided data with information about how the climate change data were developed, including the climate change methods used and key assumptions underlying those methods. The Guidance Document describes how the data can be used to develop projected water budgets. The Guidance Document is the primary reference for understanding the DWR-provided climate change data and is written for a more technical audience. Three appendices provide additional details on climate change data development and background information on California climate.
- **User Manual.** The *Climate Change Data User Manual* provides GSAs with instructions for downloading and incorporating DWR-provided climate change data into water budget calculations and numerical groundwater or integrated hydrologic models.

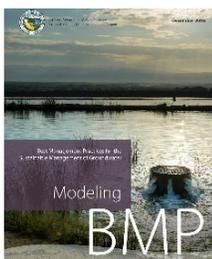
Purpose of Guidance Document

- Provide relevant data and tools for GSAs to incorporate climate change into their GSPs.
- Provide an analysis approach using the provided data and tools that incorporate best available science and best available information to date.

Other Related Guidance



- **Water Budget BMP.** The objective of this BMP is to assist in the use and development of water budgets. Information provided in this BMP provides technical assistance to GSAs and other stakeholders on how to address water budget requirements outlined in the GSP Emergency Regulations. This BMP identifies available resources to support development, implementation, and reporting of water budget information.



- **Modeling BMP.** The objective of this BMP is to assist with the use and development of groundwater and surface water models during GSP development. Information in this BMP provides technical assistance to GSAs and other stakeholders on how to address modeling requirements outlined in the GSP Emergency Regulations. This BMP identifies available resources to support the development of groundwater and surface water models. Specifically, a model can be used to predict water budgets at varying scales under future conditions and climate change, as well as with the inclusion of management scenarios.

² <https://www.water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/Climate-Change-Guidance---SGMA.pdf>

Climate Change Data Analysis Process

Incorporating Climate Change Analysis into Projected Water Budgets

GSP Water Budget Requirements

- For historical conditions
- For current conditions
- For projected conditions over the 50-year planning and implementation horizon

As described in the GSP regulations, the Water Budget BMP, and in the Guidance Document, water budgets are required as part of GSP development for the following conditions:

- Water budget representing a minimum of 10 years of historical conditions
- Water budget representing current conditions
- Water budget representing projected conditions over the planning and implementation horizon using a 50-year hydrologic baseline condition.

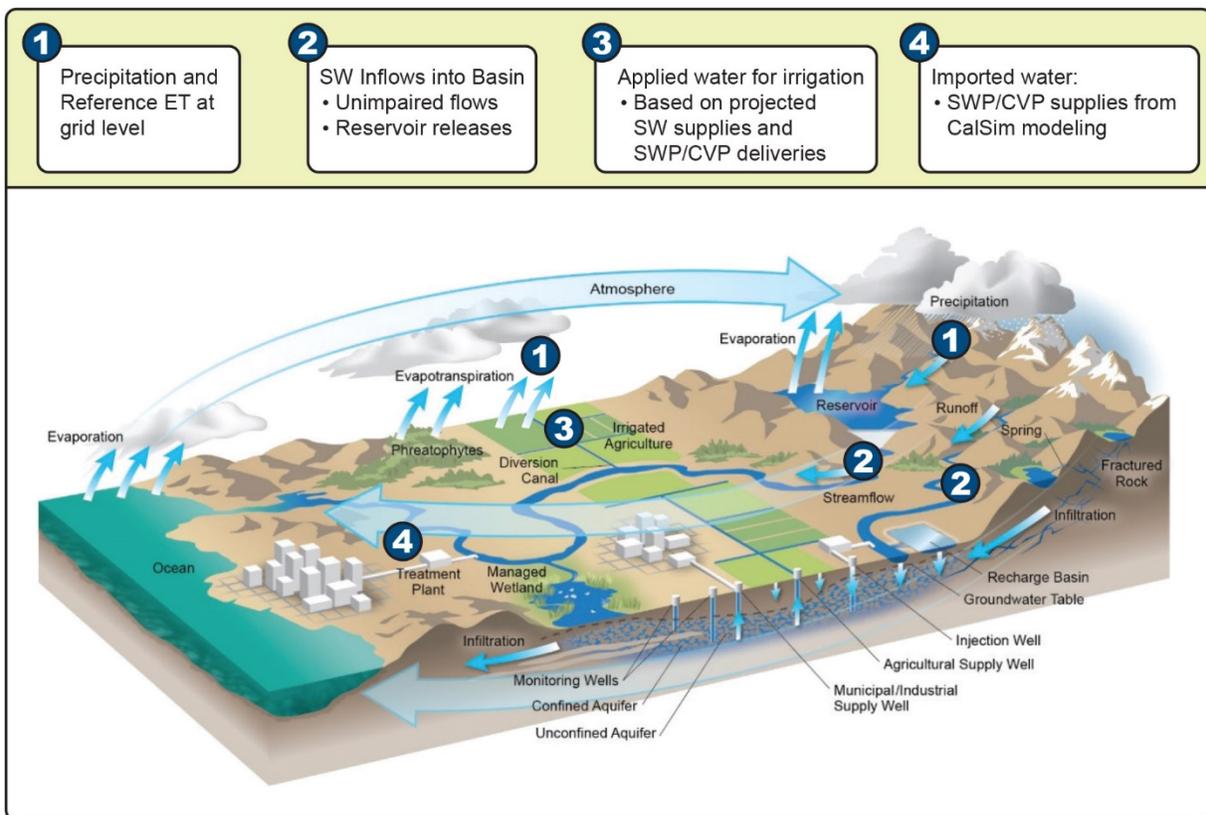
Based on the available climate change data provided by DWR as described in the Guidance Document, the projected water budgets can be developed for two future conditions using a climate period analysis as follows:

- Water budget representing conditions at 2030 with uncertainty (i.e., using 50 years of historical record representative of the range of inter-annual variability as a baseline).
- Water budget representing conditions at 2070 with uncertainty (using the same 50-year period as for 2030).

Projected water budgets will be useful for showing that sustainability will be maintained over the 50-year planning and implementation horizon.

Projected Water Budget Development Without a Numerical Model

The datasets described above can be incorporated into a spreadsheet-type water budget. The figure below illustrates the types of data that would need to be replaced in a historical water budget to develop a projected water budget for 2030 and 2070 conditions, including climate change assumptions, to satisfy SGMA requirements.



Climate Change Data Analysis Process

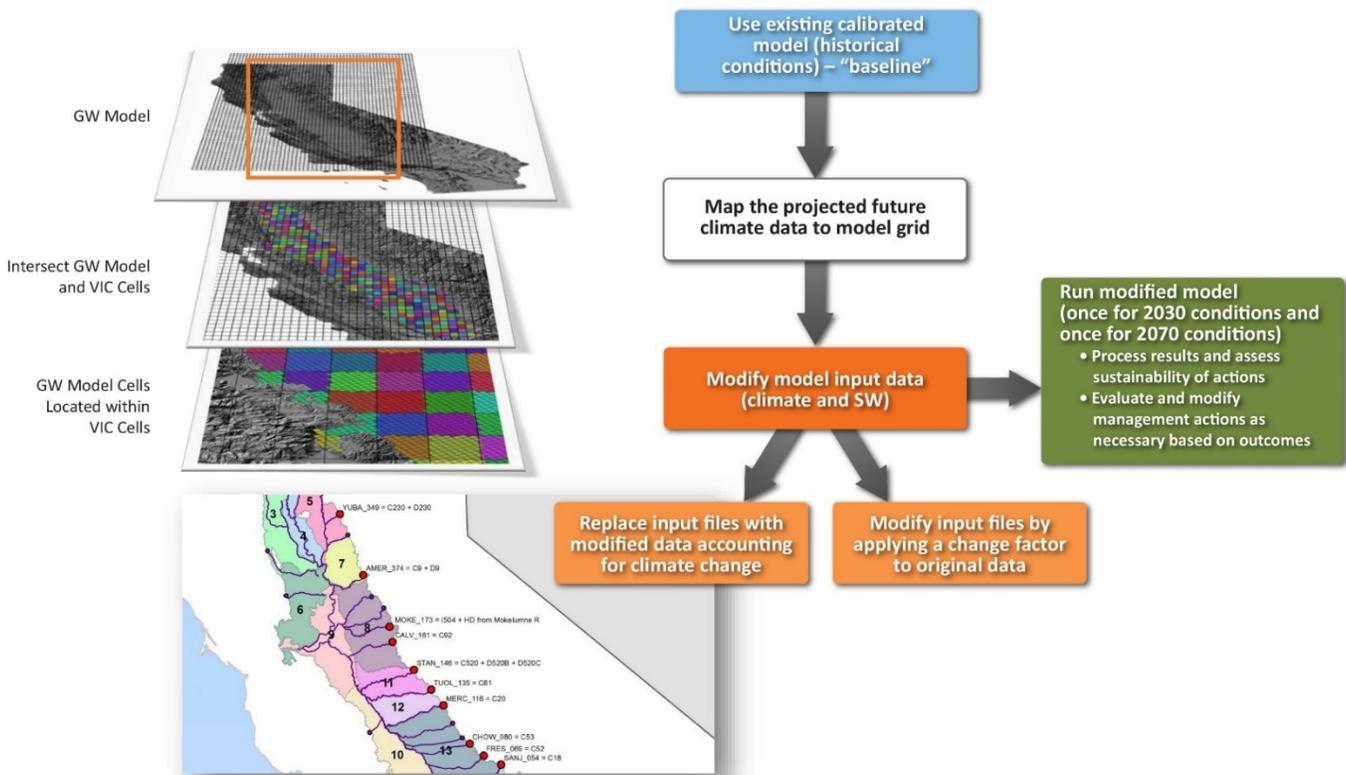
Projected Water Budget Development with a Numerical Model

If a numerical groundwater model or integrated hydrologic model is used for water budget development, the initial step in the climate change analysis is to choose an existing local groundwater model or a DWR-provided groundwater model. Alternatively, if there is not an existing model for the groundwater basin or subbasin, a GSA can choose to develop a new groundwater or integrated hydrologic model. The modeling BMP provides guidance on the model development process as well as information on available model applications.

Once a numerical model is selected or developed, the next step is to modify the model input datasets for projected conditions. Due to uncertainty about future conditions, projected conditions are typically assessed using a baseline condition representative of a range of possible conditions.

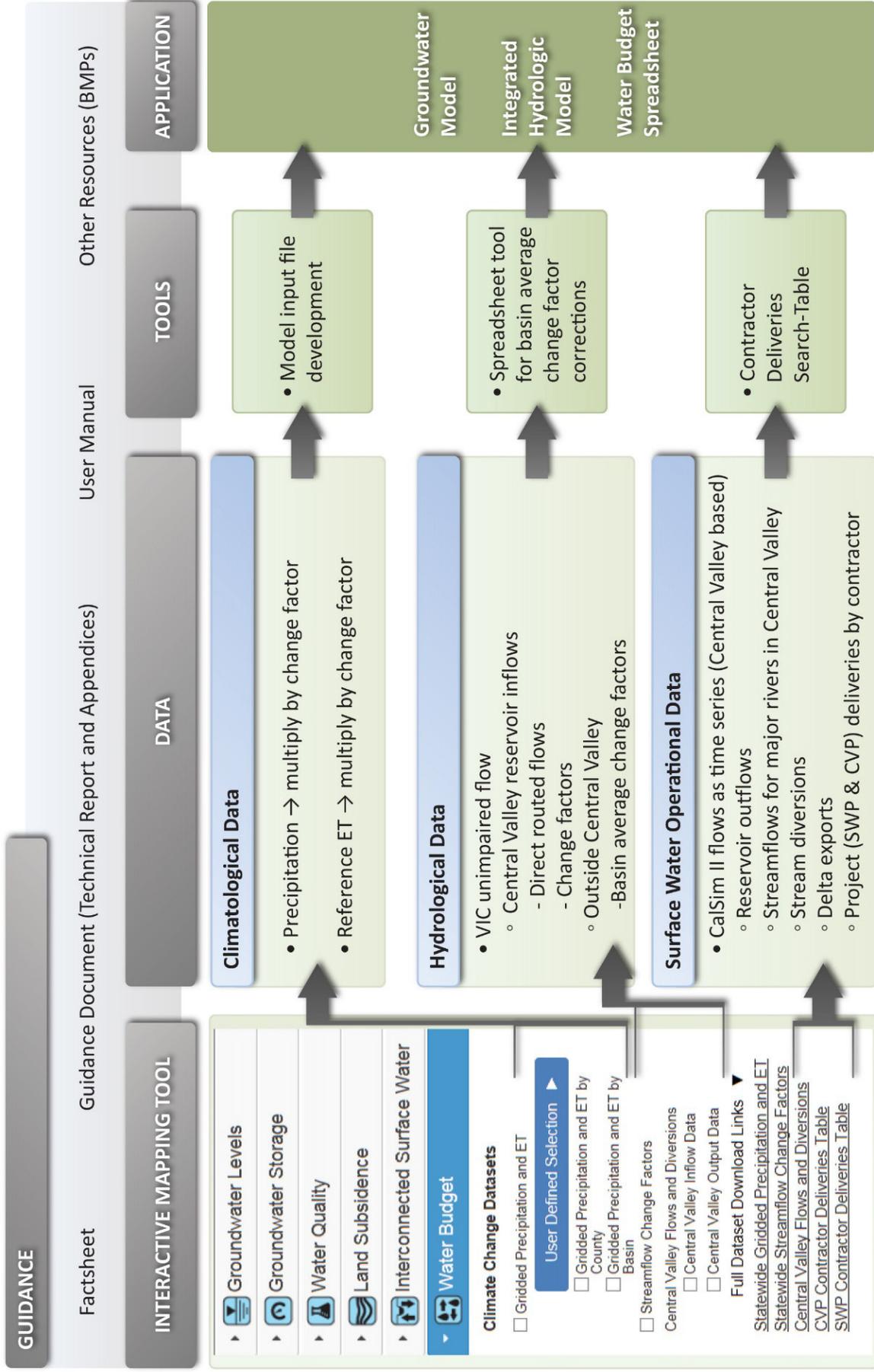
The provided climate change datasets are then used to perturb or replace applicable datasets in the baseline model for projected conditions. For model input datasets such as precipitation and evapotranspiration, all groundwater model grid elements or node locations need to be modified with the change factors from the corresponding VIC model grids. The figure below illustrates the process to incorporate the gridded climate change data (precipitation and ET change factors) into an existing numerical model for future climate change projections to simulate projected water budgets.

Groundwater Model Components to Modify for Future Climate Change-Based Projections



For input datasets such as stream inflow or surface water operations (diversions and deliveries), corresponding locations in the model need to be modified using the provided Central Valley flows and diversions, if applicable. Stream flow change factors corresponding to state-wide watersheds are also provided. In addition, projected water budgets using numerical models may take into account land use and water demand projection approaches for groundwater modeling and consider existing projections from state or local planning agencies, modified as needed to represent a specific study area and future conditions in the planning period.

Summary of Climate Change Data Analysis Process

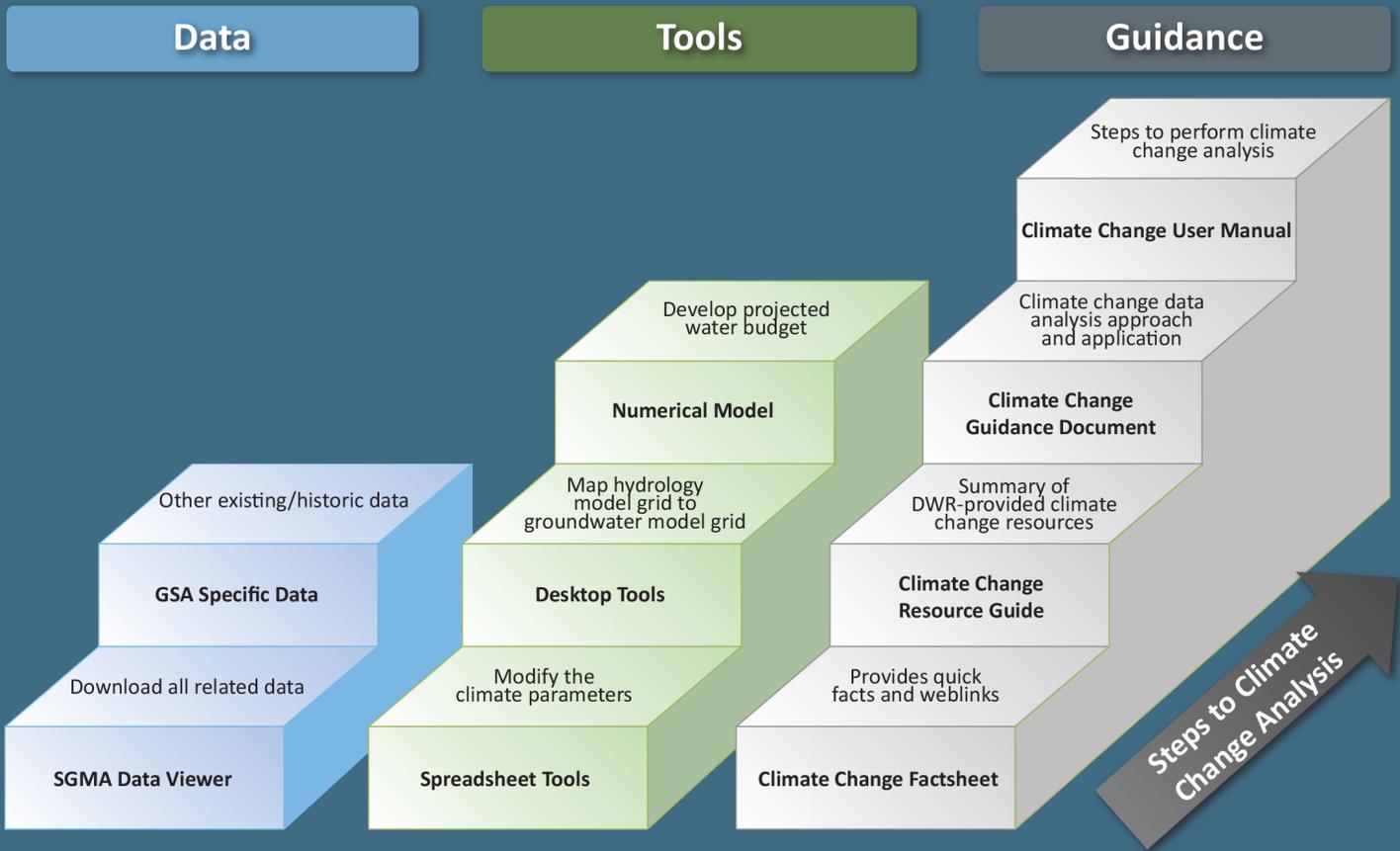


Resources

Table 2 provides an overview of all applicable DWR-provided resources related to climate change analysis under SGMA.

Table 2. Climate Change Data Application Resources

<p>Data</p>	<ul style="list-style-type: none"> • SGMA Data Viewer: This is an interactive, web-based mapping tool for downloading spatial data and associated time-series data. Available at: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer • SGMA Data Viewer Factsheet: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Data-and-Tools/Files/FAQ-and-Fact-Sheets/SGMA-Data-Viewer-Fact-Sheet.pdf
<p>Tools</p>	<ul style="list-style-type: none"> • Second Order Correction Spreadsheet Tool: This tool helps modify monthly change factors to more accurately reflect annual streamflow patterns present in the historical data • Desktop IWFM/MODFLOW Tools: These tools help map VIC model gridded precipitation and reference ET data to the correct groundwater model (for MODFLOW-based models) cells or elements (for IWFM-based models) <p>Tools are available at: https://www.water.ca.gov/Programs/Groundwater-Management/Data-and-Tools</p>
<p>Guidance</p>	<ul style="list-style-type: none"> • Climate Change Factsheet: the factsheet can be found online at https://www.water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Data-and-Tools/Files/FAQ-and-Fact-Sheets/SGMP-Climate-Change-Fact-Sheet.pdf • Guidance for Climate Change Data Use During Sustainability Plan Development: The Guidance Document provides GSAs and other stakeholders with information about DWR-provided climate change datasets for use in GSPs. The document can be found at: https://www.water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/Climate-Change-Guidance---SGMA.pdf <p>Guidance Document Appendices:</p> <ul style="list-style-type: none"> • Appendix A: Methods and Approaches for Climate Change Modeling and Analysis, and California Applications • Appendix B: Reservoir and Local Inflows, CalSim II Output Data, and CVP/SWP Contractor Deliveries • Appendix C: Basin Average Streamflow Change Factor Method <ul style="list-style-type: none"> • Climate Change Data User Manual: This manual provides GSAs with recommendations and instructions for incorporating DWR-provided climate change data into water budget calculations, and numerical groundwater and integrated hydrologic models.
<p>Other Resources</p>	<ul style="list-style-type: none"> • Water Storage Investment Program Technical Reference: WSIP's Technical Reference can be found at https://cwc.ca.gov/Documents/2016/WSIP/WSIP_Data_and_Model_Product_Description_11-1-16.pdf. The Technical Reference supports physical and economic analysis of the public benefits of eligible water storage projects applying for WSIP grant funds. Appendix A includes the development of the climate change data to support this analysis. • DWR-Provided Models: Models such as IWFM, C2VSim, SVSim are general modeling tools provided by DWR, and include the integrated surface-water/groundwater models (i.e., IWFM and its Central Valley applications, C2VSim and SVSim) to facilitate simulation of current and future groundwater conditions. <p>Information on modeling tools is available at: https://water.ca.gov/Programs/Groundwater-Management/Data-and-Tools</p>



DWR Technical Support for Climate Change Analysis During GSP Development

