FINAL REPORT

Bowman Subbasin

Sustainable Groundwater Management Act

Groundwater Sustainability Plan (Chapter 2C Water Budget)

January 2022

Prepared For:

Tehama County Flood Control and Water Conservation District

Prepared By:

Luhdorff & Scalmanini, Consulting Engineers

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS & ABBREVIATIONS

ACID	Anderson-Cottonwood Irrigation District
af	Acre-feet
AN	Above normal Sacramento Valley water year type
AWMP	Agricultural Water Management Plan
BMP	Best Management Practice
BN	Below normal Sacramento Valley water year type
C	Critical (dry) Sacramento Valley water year type
CCR	California Code of Regulations
CVP	Central Valley Project
D	Dry Sacramento Valley water year type
DWR	Department of Water Resources
ET	Evapotranspiration
GMP	Groundwater Management Plan
GSP	Groundwater Sustainability Plan
GWS	Groundwater System
Maf	Million acre-feet
SWS	Surface Water System
taf	Thousand acre-feet
Tehama IHM	Tehama Integrated Hydrologic Model
UWMP	Urban Water Management Plan
W	Wet Sacramento Valley water year type
WMP	Water Management Plan

2 SUBBASIN PLAN AREA AND BASIN SETTING (REG. § 354.8)

2.1 Description of Plan Area

2.2 Basin Setting

2.3 Water Budget (Reg. § 354.18)

An integral component of the GSP is the quantification of the water budget, which is an accounting of water movement and storage between the different systems of the hydrologic cycle (**Figure 2-55**). The Subbasin water budget includes an accounting of all inflows and outflows to the Subbasin. The difference between the volume of inflow and outflow to the Subbasin is equal to the change in storage as illustrated in **Equation 2-1**.

Inflows – Outflows = Change in Storage

Equation 2-1. Water Budget Equation

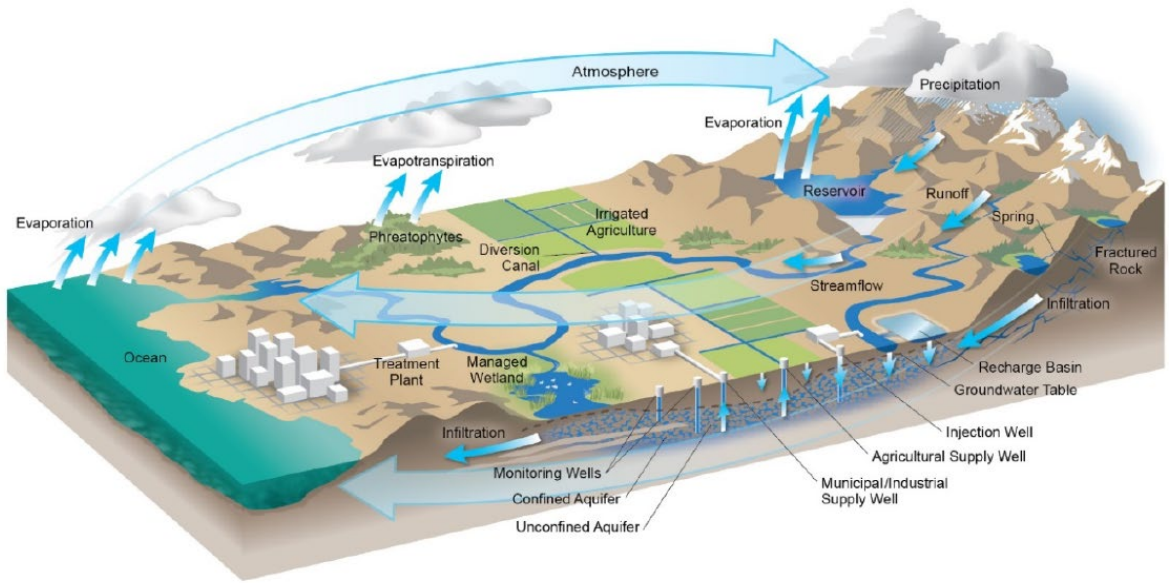
DWR has published guidance and Best Management Practice (BMP) documents related to the development of GSPs, including Water Budget BMPs (DWR, 2016a). The Water Budget BMPs recommend a water budget accounting structure, or conceptual model, which distinguishes the subbasin surface water system (SWS) and groundwater system (GWS). The SWS represents the land surface down to the bottom of plant root zone[1], within the lateral boundaries of the Subbasin. The GWS extends from the bottom of the root zone to the definable bottom of the Subbasin, within the lateral boundaries of the Subbasin. The complete Subbasin water budget is a product of the interconnected SWS and GWS water budgets. The lateral and vertical boundaries of the Subbasin are described in **Section 2.2** of the GSP.

Consistent with these BMPs, this section presents the methodology and results for the historical, current, and projected water budgets of the Bowman Subbasin. The water budgets were developed through application of the Tehama Integrated Hydrologic Model (Tehama IHM), a numerical groundwater flow model developed for the Subbasin area that characterizes surface water and groundwater movement and storage across the entire Subbasin, including extending into areas extending outside of the Subbasin. The Tehama IHM is an integrated groundwater and surface water model developed for the purpose of conducting sustainability analyses within Tehama County, including for the Bowman Subbasin. The model utilized foundational elements of DWR's SVSim regional model for the Sacramento Valley (DWR, 2021) and was refined locally for improved application in the Subbasin area. Key model refinements made during development of the Tehama IHM include, but are not limited to, extending of the simulation period through water year 2019, refinement of land use conditions based on recent land use mapping information, review and modification to land use crop coefficients based on local remote sensing energy balance data, refinement of surface water supplies and diversions, and enhancements to the sediment textural model used for aquifer parameter. After conducting refinements, the Tehama IHM was calibrated using local groundwater level and streamflow data. The Tehama IHM has a historical simulation period

[1] The root zone is defined as "the upper portion of the soil where water extraction by plant roots occurs." The depth to the bottom of the root zone varies by crop, but typically ranges from 2-7 feet (ASCE, 2016).

spanning from water year 1985 through 2019, although the calibration period is 1990-2019. Detailed documentation associated with the development of the Tehama IHM is included in **Appendix 2-J.**

This section presents the historical, current, and projected water budget results for the Bowman Subbasin. Water budget results for the SWS and GWS are presented individually and as part of a complete water budget for the Subbasin. This section describes the different water budget components and the results of water budget estimates derived from the Tehama IHM. The section includes discussion of the estimated uncertainties associated with the water budget analysis, data sources, and results with additional details related to these topics also described in the model documentation included as **Appendix 2-J**. The water budget results presented in this section are rounded to two significant digits consistent with the typical uncertainty associated with the methods and sources used in the analysis. Water budget component results may not sum to the totals presented because of rounding.



2.3.1 Water Budget Conceptual Model

A water budget is defined as a complete accounting of all water flowing into and out of a defined volume[2] over a specified period of time. When the water budget is computed for a subbasin, the water budget facilitates assessment of the total volume of groundwater and surface water entering and leaving the subbasin over time, along with the change in volume of water stored within the subbasin.

[2] Where 'volume' refers to a space with length, width and depth properties, which for purposes of the GSP means the defined aquifer and associated surface water system.

2.3.1.1 Water Budget Structure

For accounting purposes, the Subbasin's water budget is divided into the surface water system (SWS) and groundwater system (GWS), described above. These systems are referred to as *accounting centers*. Flows between accounting centers and storage within each accounting center are water budget *components*. A schematic of the general water budget accounting structure is provided in **Figure 2-56**.

The conceptual model (or structure) for the Subbasin water budget is presented in **Figure 2-57**, including presentation of terms used in the following section to describe individual aspects of the water budget. The required components for each accounting center are listed in **Table 2-11**, along with the corresponding section of the GSP Regulations (California Code of Regulations Title 23[3] (23 CCR) §354). Separate but related water budgets were prepared for each accounting center that together represent the overall water budget for the Subbasin.

This section discusses the inflows and outflows from each of the SWS and GWS parts of the Subbasin. The water budgets are calculated using the Tehama IHM, which integrates flows between the SWS and GWS. The GWS water budget incorporates all inflows and outflows from the SWS into an accounting of the net effect of the hydrology and water use on groundwater storage in the Subbasin.

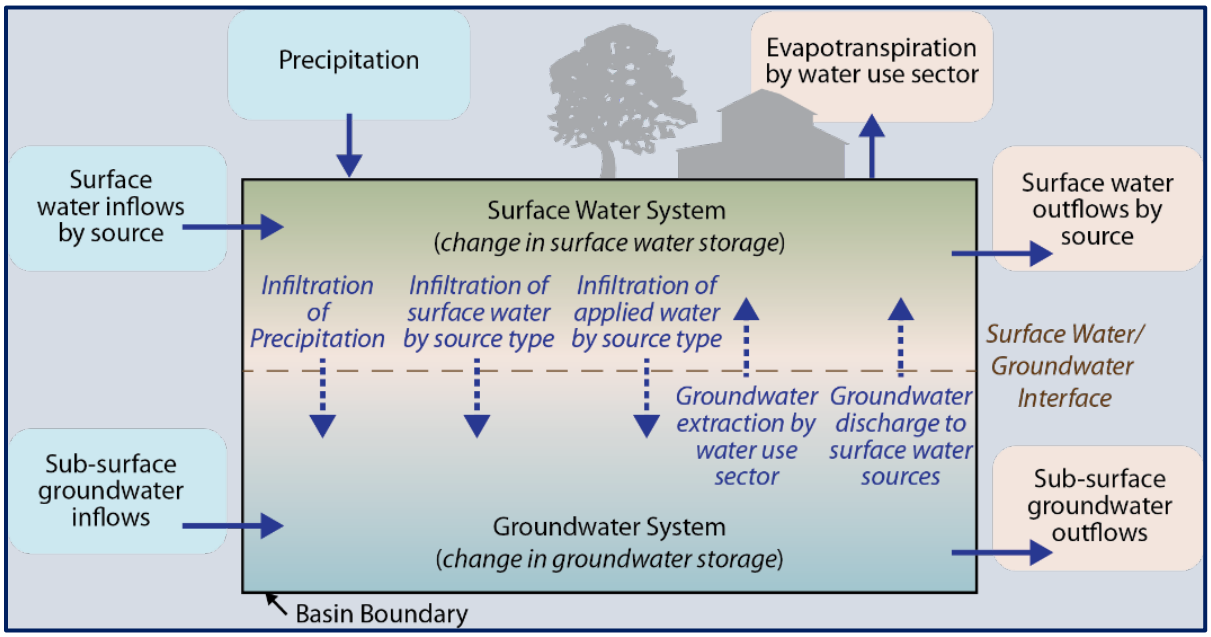
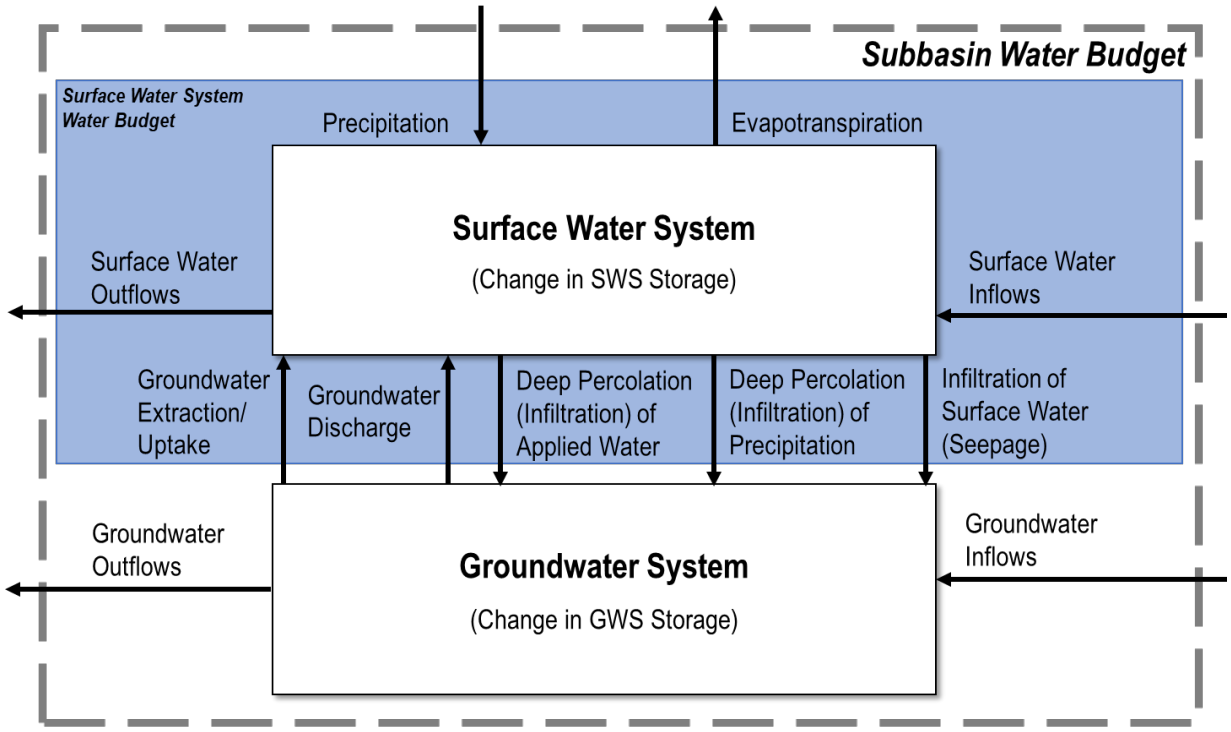


Figure 2-56. Water Budget Accounting Structure (Source: DWR, 2016a)

[3] California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2 Groundwater Sustainability Plans, Article 5 Plan Contents



Net Recharge from the SWS =
(Deep Percolation of Applied Water + Deep Percolation of Precipitation + Infiltration of Surface Water) – Groundwater Extraction/Uptake

Figure 2-57. Subbasin Water Budget Conceptual Model

Table 2-11. Water Budget Components by Accounting Center and Associated GSP Regulations

Accounting Center	Water Budget Component (flow direction)	GSP REGULATION SECTION[1]
Basin	Surface Water Inflow[2] (+)	§354.18(b)(1)
	Precipitation (+)	Implied
	Subsurface Groundwater Inflow (+)	§354.18(b)(2)
	Evapotranspiration[3] (-)	§354.18(b)(3)
	Surface Water Outflow[2] (-)	§354.18(b)(1)
	Subsurface Groundwater Outflow (-)	§354.18(b)(3)
	Change in Storage	§354.18(b)(4)
Surface Water System	Surface Water Inflow[2] (+)	§354.18(b)(1)
	Precipitation (+)	Implied
	Groundwater Extraction (+)	§354.18(b)(3)
	Groundwater Discharge (+)	§354.18(b)(3)
	Evapotranspiration[3] (-)	§354.18(b)(3)
	Surface Water Outflow[2] (-)	§354.18(b)(1)
	Infiltration of Applied Water[4,5] (-)	§354.18(b)(2)
	Infiltration of Precipitation[4] (-)	§354.18(b)(2)
	Infiltration of Surface Water[6] (-)	§354.18(b)(2)
	Change in SWS Storage[7]	§354.18(a)
Groundwater System	Subsurface Groundwater Inflow (+)	§354.18(b)(2)
	Infiltration of Applied Water[4,5] (+)	§354.18(b)(2)
	Infiltration of Precipitation[4] (+)	§354.18(b)(2)
	Infiltration of Surface Water[6] (+)	§354.18(b)(2)
	Subsurface Groundwater Outflow (-)	§354.18(b)(3)
	Groundwater Extraction (-)	§354.18(b)(3)
	Groundwater Discharge (-)	§354.18(b)(3)
	Change in GWS Storage	§354.18(b)(4)

1. California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2 Groundwater Sustainability Plans, Article 5 Plan Contents
2. By water source type.
3. Evapotranspiration includes total evapotranspiration and evaporation, by water use sector. Total evapotranspiration includes the combined evaporation from the soil and transpiration from plants, resulting from both applied water and precipitation. In this context, evaporation is the direct evaporation from open water surfaces.
4. Synonymous with deep percolation.
5. Includes infiltration of applied surface water, groundwater, and reused water
6. Synonymous with seepage. Includes infiltration of lakes, streams, canals, drains, and springs.
7. Change in storage of root zone soil moisture, not groundwater.

2.3.2 Water Budget Analysis Periods

Per 23 CCR §354.18, each GSP must quantify the historical, current, and projected water budget conditions for the Subbasin.

2.3.2.1 Historical and Current Water Budget Periods

The historical water budget for the Subbasin must quantify all required water budget components starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the water budget (23 CCR § 354.18(c)(2)(B)). The historical water budget period effectively represents long-term average historical hydrologic conditions. The current water budget must include the most recent hydrology, water supply, water demand, and land use information (23 CCR § 354.18(c)(1)). The historical water budget enables evaluation of the effects of historical hydrologic conditions and water demands on the water budget and groundwater conditions within the Subbasin over a period representative of long-term hydrologic conditions. The current water budget presents information on the effects of recent hydrologic and water demand conditions on the groundwater system.

The historical and current water budget periods were selected to evaluate conditions over discrete representative periods considering the following criteria: Sacramento Valley water year type; long-term mean annual water supply; inclusion of both wet and dry periods, antecedent dry conditions, adequate data availability; and inclusion of current hydrologic, cultural, and water management conditions in the Subbasin. Water years, as opposed to calendar years, are used as the time unit for defining analysis, following the DWR standard water year period (October 1 through September 30). Unless otherwise noted, all years referenced in this section are water years.

Based on these criteria, the following periods were identified for presentation of historical and current water budgets:

- **Historical Water Budget Period**: Water years 1990-2018 (29 years) using historical hydrologic, climate, water supply, and land use data.
- **Current Water Budget Periods**: Consideration of five different recent water year periods (listed below) using the historical hydrologic, climate, water supply, and land use data over each period.
    - Recent 10 years (2009-2018)
    - Recent 5 years (2014-2018)
    - Recent 3 years (2016-2018)
    - Recent 1 year (2018)
    - Recent 1 year (2019)

For the historical water budget, the period from 1990-2018 was selected to represent long-term average historical hydrologic conditions following evaluation of precipitation records and DWR Sacramento Valley water year type classification (**Table 2-12**). Further information and discussion of the historical water budget period, including discussion of historical hydrology and the base period selection process, are presented in **Section 2.2** of this GSP. Discussion of the historical water budget water results is included in **Section 2.3.5**

Table2-12. Sacramento Valley Water Year Type Classification during the Historical Water Budget Period (1990-2018)

SACRAMENTO VALLEY WATER YEAR TYPE	ABBREVIATION	NUMBER OF YEARS, 1990-2018	PERCENT TOTAL YEARS, 1990-2018
Wet	W	8	28%
Above Normal	AN	4	14%
Below Normal	BN	5	17%
Dry	D	5	17%
Critical	C	7	24%
Total		29	100%

For consideration in estimating the current water budget, the results for several recent periods were presented, including recent 1-year, 3-year, 5-year, and 10-year periods. These various periods result in widely varied inflows and outflows, much of which is attributed to varied precipitation and water supplies in individual years (see results in **Section 2.3.6**). Although the model simulations were run for the 1990-2072 period, results for 2019 are only shown in the current water budget comparison table for the purpose of considering variability in water budget over different recent time periods. The water budget for year 2019 is not explicitly included in the historical, current, or projected water budgets for the Subbasin although it was simulated in the model to span the years between historical (1990-2018) and projected (2022-2072) water budget periods. Details of model inputs are presented in **Appendix 2-J**. Because of the year-to-year variability in water budget results, the current water budget summarizes results from the various recent periods considered to provide an appropriate and reasonable representation of the current water budget based on recent conditions.

2.3.2.2 Projected 50-Year Hydrology and Water Budget Period (§354.18c3)

The projected water budget is intended to evaluate the effects of anticipated future conditions of hydrology, water supply availability, and water demand over a 50-year GSP planning period on the Subbasin water budget and groundwater conditions. The projected water budget incorporates consideration of potential climate change and water supply availability scenarios and evaluation of the need for and benefit of any projects and management actions to be implemented in the Subbasin to maintain or achieve sustainability. The 50-year projected water budget uses hydrologic conditions representative of the most recent 50 years of hydrology in the Subbasin, with adjustments applied in scenarios for evaluating the water budget under climate change and/or altered water supply and demand conditions.

To evaluate projected water budgets, fifty years of future hydrology inputs to the Tehama IHM were developed through consideration of the historical hydrology from 1968 to 2018. Because of the availability of higher quality data and characterization of conditions in the Subbasin during more recent years spanning the historical base period (1990-2018), the projected water budget analyses used surrogate years from the historical period to construct a future hydrology and water budget period representative and consistent with hydrologic conditions over a historical 50-years period from 1968 to 2018. Surrogate years from the historical period were assigned to represent 50 years of future hydrology based on 1) the Sacramento Valley water year index from DWR for each year, 2) mimicking variability (wet and dry) in the historical precipitation conditions in the Subbasin and replicating precipitation consistent with the annual average historical precipitation, and (3) replicating regional streamflow conditions based on flows in the Sacramento River. The frequency of water year types used in the projected hydrology is representative of the 50 years of hydrology for the period 1969-2019 and includes approximately equal proportions of water years with above normal (wet and above normal; 48%) and below normal (below normal, dry, critical; 52%) hydrologic conditions (**Table 2-13**).

The approach and inputs used in development of the projected water budget are described in greater detail in the Tehama IHM documentation included as **Appendix 2-J**.

Table 2-13. Sacramento Valley Water Year Type Classification Over the Projected Water Budget Period (2022-2072)

SACRAMENTO VALLEY WATER YEAR TYPE	ABBREVIATION	NUMBER OF YEARS, 2022-2072	PERCENT TOTAL YEARS, 2022-2072
Wet	W	18	35%
Above Normal	AN	7	14%
Below Normal	BN	7	14%
Dry	D	9	18%
Critical	C	10	20%
Total		51	100%

2.3.3 Surface Water System (SWS) Water Budget Description

Water budgets for the SWS were developed to characterize historical and current conditions in the Subbasin relating to the individual inflows and outflows and overall SWS water budget. The general approach used in the SWS water budget calculations is described in **Section 2.3.3.1**. **Section 2.3.5** presents the results of the historical SWS water budgets within the boundary of the Subbasin and **Section 2.3.6** presents results for current SWS water budget analyses. The analyses and results relating to the projected water budget are presented in **Section 2.3.7** through **2.3.9**. Additional detailed discussion of the procedures and results of the SWS water budgets is included in documentation of the Tehama IHM development and results presented in **Appendix 2-J.**

2.3.3.1 General SWS Water Budget Components and Calculations

SWS inflows and outflows were quantified on a monthly basis, including accounting for any changes in SWS storage, such as changes in water stored in the root zone (**Equation 2-2**).

Total SWS Inflows – Total SWS Outflows = Change in SWS Storage (monthly)

Equation 2-2. Equation for Bowman Subbasin SWS Water Budget Analysis

As shown in **Figure 2-56** and **Table 2-11**, inflows to the SWS include surface water inflows (in various rivers, streams, and canals), precipitation, groundwater extraction (pumping and groundwater uptake), and groundwater discharge to surface water sources (from areas of high groundwater levels). Outflows include evapotranspiration (ET), surface water outflows (in various rivers, streams, and canals), infiltration of applied water (deep percolation from irrigation), infiltration of precipitation (deep percolation from precipitation), and infiltration of surface water (seepage).

The ET outflow component includes the following: ET of applied water (ET from soil and crop surfaces, of water that is derived from applied surface water, groundwater, and reused water); ET of precipitation (ET from soil and crop surfaces, of water that is derived from precipitation); and evaporation from rivers, streams, canals, reservoirs, and other water bodies. 'ET of applied water' differs from 'applied water' in that applied water is the volume of water that is directly applied to the land surface by irrigators (from all water sources), whereas ET of applied water is the volume of that applied water that is consumptively used by crops, vegetation, and soil surfaces.

Change in SWS storage is also depicted in **Figure 2-57** and **Table 2-11**. This represents the change in root zone soil moisture throughout the year. This is different from change in groundwater storage.

Net recharge from the SWS is defined as the total groundwater recharge (total infiltration from all sources) minus groundwater outflows to the surface water system, including both groundwater extraction and groundwater uptake by crops and vegetation.[4] Groundwater discharge to the SWS is not included in the net recharge term but is summarized separately as an exchange between the SWS and GWS. Net recharge from the SWS is a useful metric that equates only the impacts of the SWS on recharge and extraction from the GWS, providing valuable insight to the combined effects of land surface processes on the underlying GWS.

However, it should be recognized that net recharge from the SWS does not account for the complete GWS water budget, including subsurface groundwater flows. Thus, net recharge from the SWS is not meant to evaluate overdraft, but rather is most useful for evaluating how management of the surface layer impacts the GWS in the Subbasin. Net recharge from the SWS does not precisely express the effective availability of recharge in upgradient areas, which would be unable to utilize recharge that occurs in the downgradient

[4] Groundwater discharge to surface water is not included in the calculation of net recharge from the SWS, as groundwater discharge is more dependent on shallow groundwater and soil characteristics along waterways and is much less dependent on the management of the surface layer. Net recharge from the SWS is intended to describe the impacts of the SWS on the GWS, but groundwater discharge is more reflective of the GWS effects on the SWS.

areas of the Subbasins. More information about the net exchanges of surface water and groundwater in the Subbasin is provided below in the describing of components of the GWS water budget.

2.3.3.2 Detailed SWS Water Budget Accounting Centers and Components

To estimate the water budget components required by the GSP Regulations (**Table 2-11**), the SWS water budget accounting center is subdivided into detailed accounting centers representing the Land Surface System, the Canal System, and the Rivers, Streams, and Small Watersheds System (waterways conveying natural flow and surface water supplies into the Subbasin).

The Land Surface System represents inflows and outflows from irrigated and non-irrigated land. The Canals System represents flows through the canals and conveyance systems of diverters with access to surface water. The Rivers, Streams, and Small Watershed Systems represent inflows and outflows through waterways that convey natural flow, upgradient runoff, and drainage.

The Land Surface System is further subdivided into water use sectors, defined in the GSP Regulations as "categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation" (23 CCR Section 351(al)). Principal water use sectors in the Subbasin include Agricultural (irrigated crop land and idle agricultural land), Native Vegetation (native and riparian vegetation), and Urban (urban, residential, industrial, and semi-agricultural[5]).

2.3.3.2.1 *SWS Inflows*

2.3.3.2.1.1 Surface Water Inflow by Water Source Type

Per the GSP Regulations, surface inflows must be reported by water source type. According to the Regulations (23 CCR § 351(ak)):

> *"Water source type" represents the source from which water is derived to meet the applied beneficial uses, including groundwater, recycled water, reused water, and surface water sources identified as Central Valley Project, the State Water Project, the Colorado River Project, local supplies, and local imported supplies.*

Major surface water inflows to the Bowman Subbasin are summarized below according to water source type. Additionally, runoff of precipitation from upgradient areas adjacent to the Subbasin represents a potential source of SWS inflow.

Local Supplies

Local supply inflows to the Bowman Subbasin predominantly include runoff from upgradient small watersheds adjacent to the Subbasin and surface inflows along Cottonwood Creek. A portion of the local supplies are diverted by local water rights users for beneficial use within the Subbasin. There are about 140

[5] As defined in the DWR crop mapping metadata, semi-agricultural land includes farmsteads and miscellaneous land use incidental to agriculture (small roads, ditches, etc.) (DWR, 2016b).

riparian diverters in the Subbasin with active water rights. These water rights users divert water primarily from Cottonwood Creek and its tributaries, but there are a few diversions along the Sacramento River.

Central Valley Project

Central Valley Project (CVP) inflows to the Bowman Subbasin primarily include surface water diverted from the Sacramento River by the Anderson-Cottonwood Irrigation District (ACID). ACID holds the third oldest water rights on the Sacramento River and has a total Settlement Contract of more than 100,000 AF per year. While the majority of the ACID service area overlies the Anderson Subbasin, a portion of ACID's CVP supplies are delivered to parcels that overlie the Bowman Subbasin. Surface water is also diverted by small CVP contractors to irrigated land along the Sacramento River.

2.3.3.2.1.2 Precipitation

Precipitation falling on the landscape within the Subbasin is an inflow to the SWS. Precipitation inflows are accounted for by the land use (water use sector) on which they occur.

2.3.3.2.1.3 Groundwater Extraction and Uptake

Groundwater extraction is an inflow to the SWS (an outflow from the GWS). Groundwater extraction is accounted for by agricultural and urban (urban, residential, semi-agricultural, industrial) water use sectors. Urban groundwater pumping includes domestic well pumping. Groundwater uptake is water taken up by plant roots directly from the GWS.

2.3.3.2.1.4 Groundwater Discharge to Surface Water

Groundwater discharging to surface water features can occur where groundwater is very shallow and where groundwater levels are higher than the stage in surface water bodies. Groundwater discharge to surface water represents an inflow to the SWS (an outflow from the GWS).

2.3.3.2.2 SWS Outflows

2.3.3.2.2.1 Evapotranspiration

Evapotranspiration (ET) is accounted for by water use sector (urban, agriculture, native) and according to the source water (applied water or precipitation). ET from land includes from applied water and precipitation sources. Evaporation also occurs from rivers, streams, canals, and drains throughout the Subbasin.

2.3.3.2.2.2 Infiltration

Infiltration (deep percolation) is water that infiltrates below the root zone and recharges the GWS. Infiltration can occur from applied water (e.g., irrigation) or precipitation occurring on the landscape within the Subbasin. Alternatively, infiltration of surface water (stream seepage) can occur from surface water that seeps through the bottom of surface water features and recharges the GWS.

2.3.3.2.2.3 Surface Water Outflow

In the Bowman Subbasin, surface water outflows consist entirely of local supplies that traverse the Subbasin, or that drain from lands within the Subbasin or runoff into the Subbasin from upland areas outside the Subbasin. As described above, substantial local supply volumes enter the Bowman Subbasin along Sacramento River and tributary waterways, although much of this water passes through the Subbasin.

2.3.3.3 SWS Water Budget Overview

Water budget components are defined for each detailed accounting center in **Table 2-14 through Table 2-16**. Within the Land Surface System accounting center, water budget components are also defined for each water use sector. These detailed water budget accounting centers and components are quantified based on the best available data and science, including information from water management plans (WMPs), groundwater management plans (GMPs), agricultural water management plans (AWMPs), urban water management plans (UWMPs), and other sources.

Each detailed accounting center was computed for the Subbasin. The Subbasin boundary SWS water budget components are identified in **Table 2-17**. The water budget includes the crop demands, available water supplies, and other characteristics specific to the Subbasin, including diversions, evaporation, and infiltration of surface water within the Subbasin.

Table 2-14. Land Surface System Water Budget Components

DETAILED ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
	Deliveries	Inflow	Deliveries of surface water supply for use within the Subbasin.
	Groundwater Extraction	Inflow	Groundwater pumping to meet water demands, and groundwater uptake by crops and vegetation.
	Precipitation	Inflow	Direct precipitation on the land surface.
	Reuse	Inflow	Reuse of percolated water from the unsaturated zone[1].
	ET of Applied Water	Outflow	Consumptive use of applied irrigation water.
	ET of Groundwater Uptake	Outflow	Consumptive use of shallow groundwater uptake.
	ET of Precipitation	Outflow	Consumptive use of infiltrated precipitation.
	Net Return Flow	Outflow	Net runoff of applied irrigation water, accounting for reuse[2].
	Runoff of Precipitation	Outflow	Direct runoff of precipitation.
	Infiltration of Applied Water	Outflow	Deep percolation of applied water below the root zone.
	Infiltration of Precipitation	Outflow	Deep percolation of precipitation below the root zone.

[1] "The unsaturated zone is below the land surface system and represents the portion of the basin that receives percolated water from the root zone and either transmits it as deep percolation to the GWS or to reuse within the land surface system, or both." (DWR, 2016a).

[2] Includes tailwater and pond drainage for ponded crops.

Table 2-15. Canal System Water Budget Components

DETAILED ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Canal System	Diversions	Inflow	Diversions of surface water supply from waterways, a portion of which is delivered and used within the Subbasin.
	Deliveries	Outflow	Deliveries of surface water supply for use within the Subbasin.
	Infiltration of Surface Water (Seepage)	Outflow	Seepage from canals to the GWS.
	Evaporation	Outflow	Direct evaporation from canal water surfaces.
	Spillage	Outflow	Spillage from canals used for conveyance.

Table 2-16. Rivers, Streams, and Small Watersheds System Water Budget Components

DETAILED ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Rivers, Streams, and Small Watersheds System	Stream Inflows	Inflow	Surface water inflows at the upstream boundary of waterways that traverse the Subbasin; includes natural flow and spillage, drainage, and runoff from canals and land surfaces upgradient of the Subbasin.
	Small Watershed Inflows	Inflow	Surface water inflows of drainage from upgradient small watersheds.
	Groundwater Discharge	Inflow	Discharge from shallow groundwater into rivers and streams.
	Spillage	Inflow	Spillage from canals used for conveyance.
	Stream Outflows	Outflow	Surface water outflows at the downstream boundary of waterways that traverse the Subbasin; includes natural flow and spillage, drainage, and runoff from canals and land surfaces.
	Small Watershed Outflows	Outflow	Surface water outflows of drainage from upgradient small watersheds at the downgradient boundary of the Subbasin.
	Diversions	Outflow	Diversions of surface water supply from waterways, a portion of which is delivered and used within the Subbasin.
	Infiltration of Surface Water (Seepage)	Outflow	Seepage from rivers, streams, and small watershed inflows to the GWS.
	Evaporation	Outflow	Direct evaporation from river and stream water surfaces.

Table 2-17. Subbasin Boundary Surface Water System Water Budget Components

DETAILED ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Rivers, Streams, and Small Watersheds System	Stream Inflows	Inflow	Surface water inflows at the upstream boundary of waterways that traverse the Subbasin; includes natural flow and spillage, drainage, and runoff from canals and land surfaces upgradient of the Subbasin.
	Small Watershed Inflows	Inflow	Surface water inflows of drainage from upgradient small watersheds.
	Groundwater Discharge	Inflow	Discharge from shallow groundwater into rivers and streams.
Canal System	Diversions *(in select cases)*	Inflow	Diversions of surface water supply from waterways *at a point outside or along the boundary of the Subbasin*, a portion of which is delivered and used within the Subbasin
Land Surface System *Water Use Sectors: Agricultural, Native Vegetation, Urban*	Groundwater Extraction	Inflow	Groundwater pumping to meet water demands, and groundwater uptake by crops and vegetation.
	Precipitation	Inflow	Direct precipitation on the land surface.
	ET of Applied Water	Outflow	Consumptive use of applied irrigation water.
	ET of Groundwater Uptake	Outflow	Consumptive use of shallow groundwater uptake.
	ET of Precipitation	Outflow	Consumptive use of infiltrated precipitation.
	Runoff of Applied Water	Outflow	Direct runoff of applied irrigation water[2].
	Runoff of Precipitation	Outflow	Direct runoff of precipitation.
	Infiltration of Applied Water	Outflow	Deep percolation of applied water below the root zone.
	Infiltration of Precipitation	Outflow	Deep percolation of precipitation below the root zone.
	Change in SWS Storage	Storage	Change in root zone soil moisture throughout the year; (not change in groundwater storage)
Canal System; and Rivers, Streams, and Small Watersheds System	Infiltration of Surface Water (Seepage)	Outflow	Seepage from canals, streams, and small watershed inflows to the GWS.
	Evaporation	Outflow	Direct evaporation from canals, rivers, and streams.
Canal System	Spillage	Outflow	Spillage from canals used for interior conveyance.
Rivers, Streams, and Small Watersheds System	Stream Outflows	Outflow	Surface water outflows at the downstream boundary of waterways that traverse the Subbasin; includes natural flow and spillage, drainage, and runoff from canals and land surfaces.
	Small Watershed Outflows	Outflow	Surface water outflows of drainage from upgradient small watersheds at the downgradient boundary of the Subbasin.

2.3.4 Groundwater System (GWS) Water Budget Description

Water budgets for the GWS were developed to characterize historical and current conditions in the Subbasin utilizing the Tehama IHM for different historical and current time periods described above. **Sections 2.3.5** and **2.3.6** present the results of the historical and current GWS water budgets within the lateral and vertical boundaries of the Subbasin. Discussion of the general approach used in developing model scenarios to evaluate projected GWS water budgets for the Subbasin with the Tehama IHM and the results from these projected water budget analyses are included in **Sections 2.3.7** through **2.3.9**. More detail related to the procedures and results of the GWS water budgets are also included in documentation of the Tehama IHM development presented in **Appendix 2-J.**

2.3.4.1 GWS Water Budget Components and Calculations

Inflows and outflows of the GWS were quantified on a monthly basis, including accounting for any changes in GWS storage (**Equation 2-3**).

Total GWS Inflows – Total GWS Outflows = Change in GWS Storage (monthly)

Equation 2-3. Equation for Bowman Subbasin GWS Water Budget Analysis

As shown in **Figure 2-56** and **Table 2-18**, inflows to the GWS include some of the outflow components from the SWS including infiltration (deep percolation) of precipitation and applied water and infiltration (seepage) of surface water. Additional GWS inflows include lateral subsurface groundwater inflows from adjacent subbasins and from adjacent upland or foothill areas outside the Subbasin (small watersheds). GWS outflows include exchanges with the SWS including groundwater discharge to surface waterways, groundwater extraction through pumping, and root water uptake by plants occurring directly from shallow groundwater. Lateral subsurface groundwater flows to adjacent subbasins represent additional GWS outflows. Water budget components representing exchanges between the GWS and the SWS are also included in discussions and presentations of the SWS conceptual water budget and results.

2.3.4.1.1 *Lateral Subsurface Flows*

Subsurface groundwater flows to and from the Bowman Subbasin occur between the Anderson Subbasin to the north, the Red Bluff Subbasin to the south, and the South Battle Creek Subbasin to the east. Additional subsurface groundwater inflows occur from the upland (small watershed) areas adjoining the Bowman Subbasin.

2.3.4.1.2 *Deep Percolation From the SWS*

Deep percolation from the SWS includes infiltration of water below the root zone (deep percolation) from precipitation and applied water. These two water budget components represent inflows to the GWS and are also included in the SWS water budget as outflows from the SWS.

2.3.4.1.3 *Net Stream Seepage/Groundwater Discharge to Surface Water*

The flow of water between the GWS and SWS through seepage of water from streams and canals and groundwater discharging into streams is discussed as part of the SWS water budget. These components are combined in the GWS water budget as a net volume of stream seepage. Positive total net seepage values represent a net inflow of water from the SWS to the GWS via stream and canal seepage indicating that the overall volume of stream seepage is greater than the volume of any groundwater discharging into surface waterways. Negative net seepage values represent a net outflow of groundwater from the GWS to the SWS through groundwater discharge to surface water. When net seepage is negative, it means that more groundwater is discharging into the surface waterways than is seeping from surface waterways into the GWS.

2.3.4.1.4 *Groundwater Extraction and Uptake*

Groundwater extractions and groundwater uptake are exchanges that occur between the GWS and the SWS and represent an outflow from the GWS. Groundwater extraction from the GWS occurs through groundwater pumping to meet water demands for urban and agricultural needs whereas groundwater uptake occurs through uptake of water by plants directly from the GWS.

2.3.4.2 GWS Water Budget Overview

Change in GWS storage as represented by change in groundwater storage is also depicted in **Figure 2-56** and **Table 2-18**. The change in groundwater storage represents the total change in the volume of water in storage in the groundwater system as a result of exchanges between the GWS and the SWS and the balance of all inflows and outflows of the GWS. The change in groundwater storage is directly related to changes in water levels in the groundwater system, both of which are sustainability indicators to be considered during development of a sustainable yield for the Subbasin. Each of the detailed components of the Subbasin boundary GWS water budget are identified in **Table 2-18** and were computed for the Subbasin to develop a complete GWS water budget. The HCM discussed in **Section 2.2** identifies two principal aquifers within the GWS: an Upper Aquifer and Lower Aquifer. Vertical groundwater flow does occur between these aquifers and change in storage of the entire GWS and also within each principal aquifer zone are considerations for sustainable groundwater management.

.

Table 2-18. Subbasin Boundary Groundwater System Water Budget Components

ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Groundwater System	Lateral Subsurface Groundwater Flows Between Adjacent Subbasins	Inflow	Lateral subsurface groundwater inflow from adjacent subbasin.
	Lateral Subsurface Groundwater Flows Between Adjacent Upland or Foothill Areas	Inflow	Lateral subsurface groundwater inflow from adjacent upland or foothill areas.
	Infiltration of Surface Water (Seepage)	Inflow	Seepage from canal, streams, and small watershed inflows from the SWS.
	Infiltration (Deep Percolation) of Applied Water	Inflow	Deep percolation of applied water below the root zone from the SWS.
	Infiltration (Deep Percolation) of Precipitation	Inflow	Deep percolation of precipitation below the root zone from the SWS.
	Lateral Subsurface Groundwater Flows Between Adjacent Subbasins	Outflow	Lateral subsurface groundwater outflow to adjacent subbasin.
	Groundwater Extraction	Outflow	Groundwater pumping to meet water demands, and groundwater uptake by crops and vegetation.
	Groundwater Discharge	Outflow	Discharge from shallow groundwater into rivers and streams.
	Vertical Subsurface Groundwater Flows within the GWS	Storage	Vertical subsurface groundwater flows between the Upper and Lower Aquifers within the GWS
	Change in GWS Storage	Storage	Change in volume of water stored within the groundwater system, representative of total accrual or depletion of groundwater storage.

2.3.5 Historical Water Budget

The following section summarizes the analyses and results relating to the historical SWS water budget for the Subbasin. Detailed descriptions and presentation of results for each of the individual water budget components, and the processes and data sources used in their development are included in **Appendices 2-J and 2-K**.

2.3.5.1 Land Use

Characterizing historical land use is foundational for accurately quantifying how and where water is beneficially used. Land use areas are also used to distinguish the water use sector in which water is consumed, as required by the GSP Regulations. **Figure 2-58** and **Table 2-19** summarize the annual land use areas over the historical period (1990-2018) in the Bowman Subbasin by water use sector, as defined by the GSP Regulations (23 CCR § 351(al)). In the Bowman Subbasin, water use sectors include agricultural, urban, and native vegetation land uses. The urban water use sector covers all urban, residential, industrial, and semi-agricultural[6] land uses. See Plan Area section 2.1.1.2, Land Use.

Agricultural, urban, and native vegetation land uses covered an average of 5,800 acres, 1,500 acres, and 115,100 acres, respectively, between 1990 and 2018. Since 1990, approximately 1,200 acres of native vegetation in the Bowman Subbasin has been converted to agricultural and urban land uses.

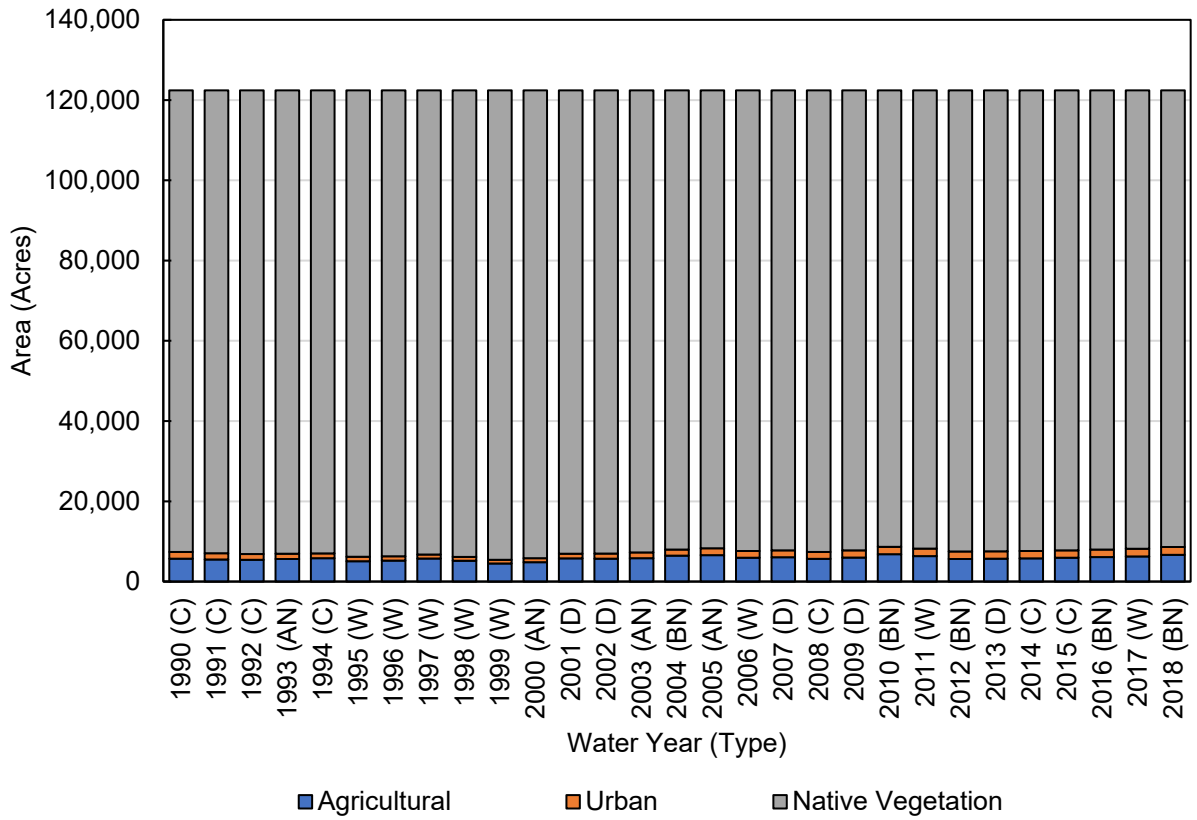


Figure 2-58. Bowman Subbasin Land Use Areas, by Water Use Sector

[6] As defined in the DWR crop mapping metadata, semi-agricultural land use subclasses include farmsteads, livestock feed lot operations, dairies, poultry farms, and miscellaneous semi-agricultural land use incidental to agriculture (small roads, ditches, non-planted areas of cropped fields (DWR, 2016b).

Table 2-19. Bowman Subbasin Land Use Areas, by Water Use Sector

WATER YEAR (TYPE)	AGRICULTURAL	URBAN[1]	NATIVE VEGETATION	TOTAL
1990 (C)	5,713	1,670	115,042	122,425
1991 (C)	5,506	1,559	115,360	122,425
1992 (C)	5,430	1,432	115,563	122,425
1993 (AN)	5,613	1,324	115,488	122,425
1994 (C)	5,821	1,208	115,396	122,425
1995 (W)	5,070	1,111	116,245	122,425
1996 (W)	5,219	1,095	116,110	122,425
1997 (W)	5,728	1,033	115,664	122,425
1998 (W)	5,178	973	116,274	122,425
1999 (W)	4,523	923	116,979	122,425
2000 (AN)	4,817	1,019	116,589	122,425
2001 (D)	5,775	1,167	115,482	122,425
2002 (D)	5,692	1,293	115,440	122,425
2003 (AN)	5,828	1,418	115,179	122,425
2004 (BN)	6,448	1,523	114,453	122,425
2005 (AN)	6,601	1,683	114,141	122,425
2006 (W)	5,936	1,683	114,805	122,425
2007 (D)	6,054	1,719	114,652	122,425
2008 (C)	5,671	1,711	115,043	122,425
2009 (D)	6,004	1,757	114,663	122,425
2010 (BN)	6,813	1,825	113,787	122,425
2011 (W)	6,357	1,842	114,226	122,425
2012 (BN)	5,626	1,869	114,930	122,425
2013 (D)	5,701	1,858	114,866	122,425
2014 (C)	5,798	1,839	114,788	122,425
2015 (C)	5,935	1,852	114,638	122,425
2016 (BN)	6,108	1,860	114,457	122,425
2017 (W)	6,263	1,917	114,245	122,425
2018 (BN)	6,663	1,947	113,815	122,425
Average (1990-2018)	5,789	1,521	115,115	122,425

[1] Area includes land classified as urban, residential, industrial, and semi-agricultural.

Agricultural land uses are further detailed in **Figure 2-59** and Table **2-20**. Historically, irrigated pasture has been the predominant agricultural land use in the Bowman Subbasin. Other irrigated crops include mainly alfalfa, grain, and various orchard crops, especially walnuts, almonds, and prunes. Flood irrigation is typically used to support pasture, alfalfa, and grain crops in the Bowman Subbasin.

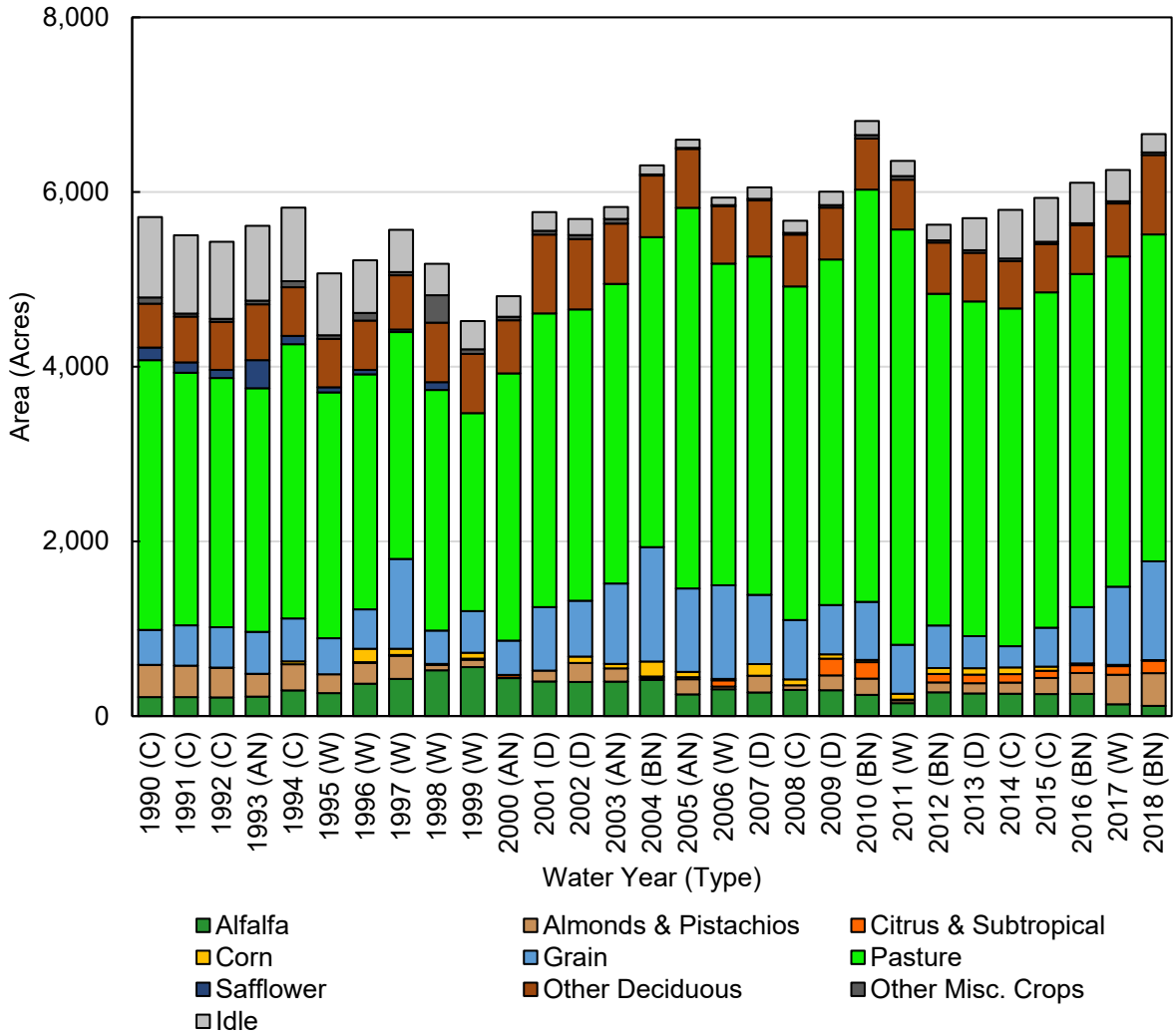


Figure 2-59. Bowman Subbasin Agricultural Land Use Areas

Table 2-20. Bowman Subbasin Agricultural Land Use Areas (acres)

WATER YEAR (TYPE)	ALFALFA	ALMONDS & PISTACHIOS	CITRUS & SUBTROPICAL	CORN	GRAIN	PASTURE	PONDED (RICE)	SAFFLOWER	OTHER DECIDUOUS[1]	OTHER MISC. CROPS[2]	IDLE	TOTAL
1990 (C)	217	369	0	0	400	3,090	0	144	503	71	919	5,713
1991 (C)	217	361	0	0	463	2,890	0	119	523	35	898	5,506
1992 (C)	214	341	0	0	461	2,853	0	95	549	36	881	5,430
1993 (AN)	223	261	0	0	479	2,790	0	322	639	42	856	5,613
1994 (C)	294	300	0	33	491	3,139	0	96	556	71	841	5,821
1995 (W)	262	217	0	0	413	2,814	1	59	552	43	708	5,070
1996 (W)	371	237	9	154	450	2,692	0	51	564	86	604	5,219
1997 (W)	426	264	9	72	1,028	2,597	161	29	621	37	483	5,728
1998 (W)	525	61	2	9	382	2,754	0	90	682	314	360	5,178
1999 (W)	561	84	13	67	478	2,267	0	0	677	54	323	4,523
2000 (AN)	434	5	32	0	393	3,060	10	0	608	40	234	4,817
2001 (D)	397	124	0	0	727	3,363	5	0	901	44	214	5,775
2002 (D)	390	219	0	73	638	3,337	0	0	804	46	185	5,692
2003 (AN)	394	152	0	51	920	3,428	0	2	691	53	137	5,828
2004 (BN)	412	25	16	172	1,310	3,549	144	0	704	14	103	6,448
2005 (AN)	248	173	25	59	955	4,359	2	0	674	14	92	6,601
2006 (W)	307	30	73	15	1,073	3,682	0	0	656	16	85	5,936
2007 (D)	271	191	0	134	793	3,875	0	0	640	19	132	6,054
2008 (C)	300	52	0	68	680	3,819	0	0	593	20	139	5,671
2009 (D)	296	170	192	49	563	3,958	0	0	593	30	153	6,004
2010 (BN)	243	186	188	25	666	4,718	0	0	585	41	161	6,813
2011 (W)	148	32	8	69	561	4,754	0	0	570	42	174	6,357
2012 (BN)	272	112	97	69	487	3,798	0	0	585	27	179	5,626
2013 (D)	259	117	100	72	368	3,832	1	0	558	29	367	5,701
2014 (C)	256	127	97	78	242	3,867	1	0	540	32	557	5,798
2015 (C)	253	183	82	49	445	3,841	2	0	553	27	502	5,935
2016 (BN)	254	239	89	21	644	3,813	1	0	558	24	464	6,108
2017 (W)	135	337	98	15	895	3,782	12	0	605	26	357	6,263
2018 (BN)	117	374	144	6	1,132	3,741	0	0	911	28	211	6,663
Average (1990-2018)	300	184	44	47	639	3,464	12	35	627	47	390	5,789

[1] Includes primarily walnuts and prunes.
[2] Area includes land classified as cotton, cucurbits, dry beans, onions & garlic, potatoes, sugar beets, tomatoes, vineyards, other field crops, and other truck crops.

2.3.5.2 Historical Surface Water System Water Budget Summary

Annual inflows, outflows, and change in SWS root zone storage during the historical water budget period (1990-2018) are summarized in **Figure 2-60** and **Table 2-21**. Inflows in **Figure 2-60** are shown as positive values, while outflows and change in SWS root zone storage are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the SWS water budget.

Of particular note in the historical SWS water budget results are the volume of precipitation that makes up a large part of the Subbasin SWS inflows averaging about 290 taf per year over the historical period. By comparison, other SWS inflows in the Subbasin are relatively smaller. Surface water inflows average about 81 taf per year. Groundwater extraction and uptake represents a relatively small SWS inflow averaging about 9.1 taf per year, and groundwater discharge to surface water is negligible over the historical water budget period.

Among the outflows from the Subbasin SWS, ET of precipitation makes up a large fraction of the total Subbasin SWS outflows averaging about 160 taf per year over the historical period. The surface water outflows total about 110 taf per year on average, a value that corresponds with the large volumes of precipitation and surface water inflow (a total of about 370 taf per year). By comparison, other SWS outflows in the Subbasin are relatively smaller, with values for deep percolation of precipitation about 44 taf per year and infiltration (seepage) of surface water about 43 taf per year on average. ET of applied water, and deep percolation of applied water are about 11, 8.6, and 10.5 taf per year on average, respectively. The outflows of ET of groundwater uptake and evaporation from surface water average about 3.0 and 0.7 taf per year, respectively.

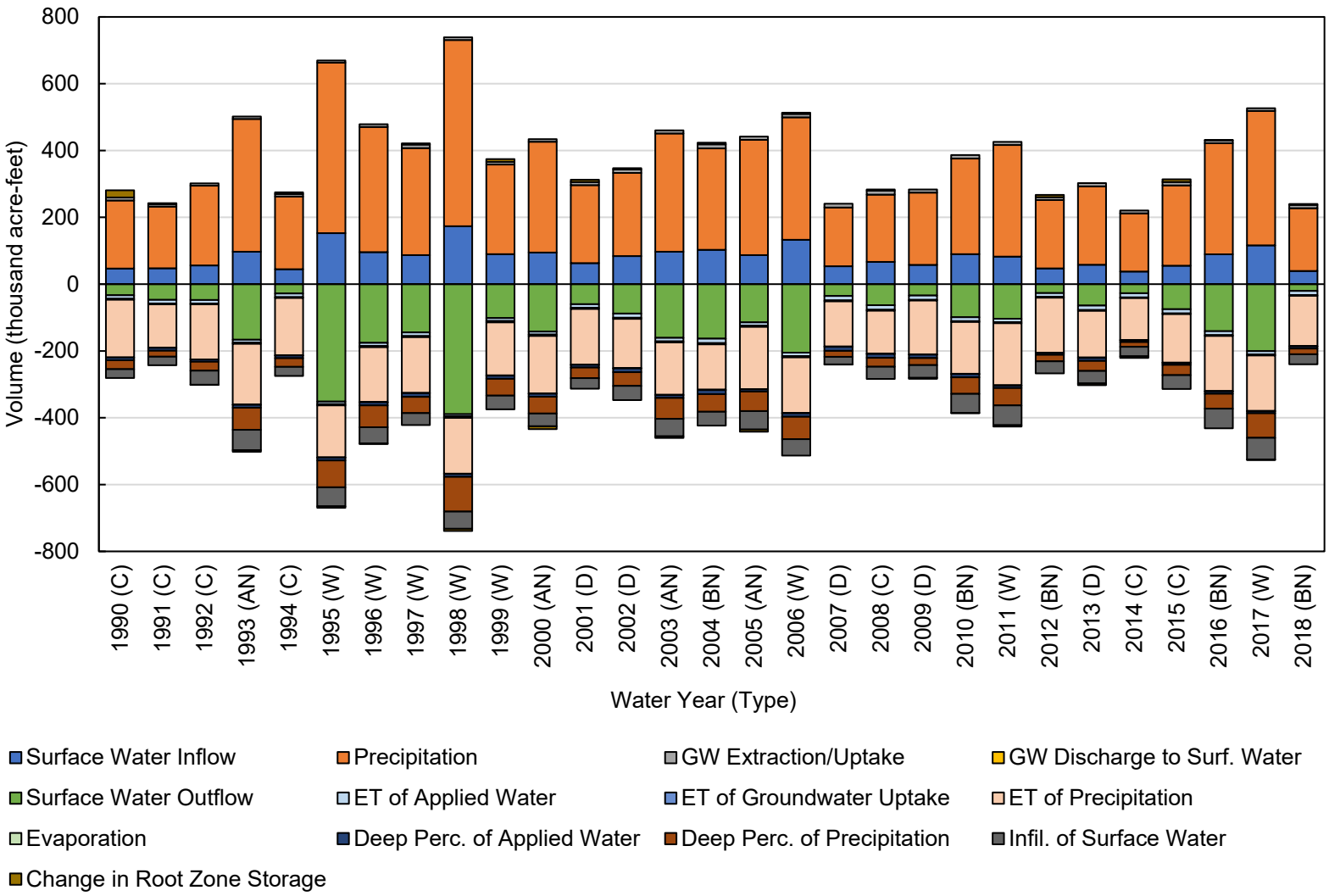


Figure 2-60. Bowman Subbasin Surface Water System Historical Water Budget, 1990-2018

Table 2-21. Bowman Subbasin Surface Water System Historical Water Budget, 1990-2018 (acre-feet)

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND-WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	
1990 (C)	47,000	200,000	8,600	0	33,000	11,000	3,000	170,000	330	7,900	27,000	26,000	-22,000
1991 (C)	48,000	180,000	7,300	0	47,000	11,000	2,300	130,000	330	8,400	18,000	26,000	-3,200
1992 (C)	56,000	240,000	7,100	0	47,000	11,000	2,200	160,000	330	6,800	27,000	42,000	620
1993 (AN)	97,000	400,000	7,200	0	170,000	9,200	3,100	180,000	330	8,700	66,000	61,000	5,100
1994 (C)	45,000	220,000	7,600	0	28,000	11,000	2,400	170,000	320	8,400	26,000	27,000	-5,100
1995 (W)	150,000	510,000	6,700	0	350,000	8,000	3,300	160,000	390	8,400	80,000	57,000	4,600
1996 (W)	96,000	370,000	8,200	0	180,000	9,200	3,600	160,000	490	9,000	66,000	48,000	2,100
1997 (W)	87,000	320,000	10,000	0	140,000	11,000	3,500	170,000	600	11,000	49,000	35,000	-3,900
1998 (W)	170,000	560,000	8,000	0	390,000	6,900	4,400	170,000	500	8,900	100,000	52,000	6,500
1999 (W)	90,000	270,000	7,700	0	100,000	8,800	4,300	160,000	740	9,500	50,000	41,000	-8,800
2000 (AN)	95,000	330,000	7,800	0	140,000	8,800	4,100	170,000	710	9,200	50,000	38,000	8,600
2001 (D)	63,000	230,000	9,300	0	60,000	11,000	3,300	170,000	760	7,900	32,000	31,000	-7,100
2002 (D)	84,000	250,000	11,000	0	88,000	13,000	3,400	150,000	850	11,000	41,000	43,000	-3,700
2003 (AN)	97,000	350,000	9,000	0	160,000	10,000	3,500	160,000	780	8,500	63,000	52,000	4,600
2004 (BN)	100,000	300,000	12,000	0	160,000	13,000	3,700	140,000	970	12,000	53,000	41,000	-4,600
2005 (AN)	87,000	340,000	9,800	0	110,000	9,900	3,600	190,000	780	6,300	58,000	55,000	6,700
2006 (W)	130,000	370,000	9,800	0	200,000	10,000	4,100	170,000	830	10,000	67,000	49,000	-3,700
2007 (D)	54,000	180,000	11,000	0	35,000	13,000	3,100	130,000	970	12,000	18,000	23,000	170
2008 (C)	66,000	200,000	12,000	0	63,000	14,000	2,900	130,000	960	11,000	27,000	36,000	-4,000

WATER YEAR (TYPE)		INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
		SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND-WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	
2009 (D)		58,000	220,000	9,300	0	34,000	13,000	2,400	160,000	950	10,000	21,000	38,000	2,600
2010 (BN)		90,000	290,000	10,000	0	99,000	12,000	2,700	150,000	890	9,800	49,000	57,000	1,300
2011 (W)		83,000	330,000	9,400	0	100,000	10,000	3,200	190,000	760	7,000	52,000	59,000	4,000
2012 (BN)		47,000	200,000	8,300	0	27,000	11,000	2,300	160,000	820	6,100	19,000	36,000	-7,000
2013 (D)		58,000	230,000	10,000	0	64,000	14,000	2,300	140,000	960	9,200	30,000	37,000	5,600
2014 (C)		38,000	170,000	8,700	0	27,000	13,000	1,700	130,000	820	5,400	14,000	28,000	4,800
2015 (C)		55,000	240,000	11,000	0	75,000	13,000	1,700	150,000	770	5,900	31,000	42,000	-7,900
2016 (BN)		89,000	330,000	8,900	0	140,000	12,000	2,300	170,000	830	6,900	44,000	59,000	-710
2017 (W)		120,000	400,000	8,200	0	200,000	10,000	2,800	170,000	760	6,000	73,000	65,000	1,700
2018 (BN)		39,000	190,000	9,700	0	20,000	13,000	1,900	150,000	820	6,300	17,000	30,000	-3,000
Average (1990-2018)		81,000	290,000	9,100	0	110,000	11,000	3,000	160,000	700	8,600	44,000	43,000	-870
1990-2018	W	120,000	390,000	8,600	0	210,000	9,300	3,700	170,000	630	8,800	68,000	51,000	300
	AN	94,000	360,000	8,500	0	150,000	9,600	3,500	170,000	650	8,200	59,000	52,000	6,300
	BN	74,000	260,000	9,900	0	90,000	12,000	2,600	150,000	870	8,300	37,000	45,000	-2,800
	D	63,000	220,000	10,000	0	56,000	13,000	2,900	150,000	900	10,000	28,000	34,000	-480
	C	51,000	210,000	8,800	0	46,000	12,000	2,300	150,000	550	7,700	24,000	32,000	-5,200

2.3.5.3 Historical Groundwater Budget Summary

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Figure 2-61** and **Table 2-22**. Deep percolation represents the largest inflow averaging nearly 53 taf per year while net seepage represents an inflow of about 43 taf per year. Net subsurface flows (combined subsurface flows with adjacent subbasins and upland areas) represent the largest net outflow totaling about -88 taf per year of outflow from the Bowman Subbasin on average. Groundwater pumping (on average -6.1 taf per year) and groundwater (root water) uptake directly from shallow groundwater (on average -3.0 taf per year) represent smaller outflows from the GWS. Overall, the water budget results for the 29-year historical period indicate a cumulative change in groundwater storage of about -50 taf, which equals an average annual change in groundwater storage of only about -1.7 taf per year. These changes in storage estimates equate to total decreases in storage in the Subbasin of about 0.41 acre-feet per acre over the 29 years and an annual decrease of less than 0.01 acre-feet per acre across the entire Subbasin (approximately 122,425 acres). **Figure 2-61** provides a conceptual illustration of the historical water budget. **Figure 2-62** highlights the cumulative change in groundwater storage that has occurred over the 1990-2018 period, with a notable decline in storage over the generally dry period since the mid-2000s. The decrease of groundwater storage during relatively dry years is not an indication of overdraft, but likely due to removal of temporary surplus of groundwater. Temporary surplus removal is the extraction of a volume of aquifer storage to enable the capture of recharge and reduction in subsurface outflow from the subbasin without impacting beneficial users of groundwater creating unreasonable results. In contrast, overdraft is defined as “the condition of a groundwater basin or subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions. Overdraft can be characterized by groundwater levels that decline over a period of years and never fully recover, even in wet years. If overdraft continues for a number of years, significant adverse impacts may occur, including increased extraction costs, costs of well deepening or replacement, land subsidence, water quality degradation, and environmental impacts” (DWR, 2003).

Additional details on the historical GWS water budget results are presented in **Appendix 2-K**.

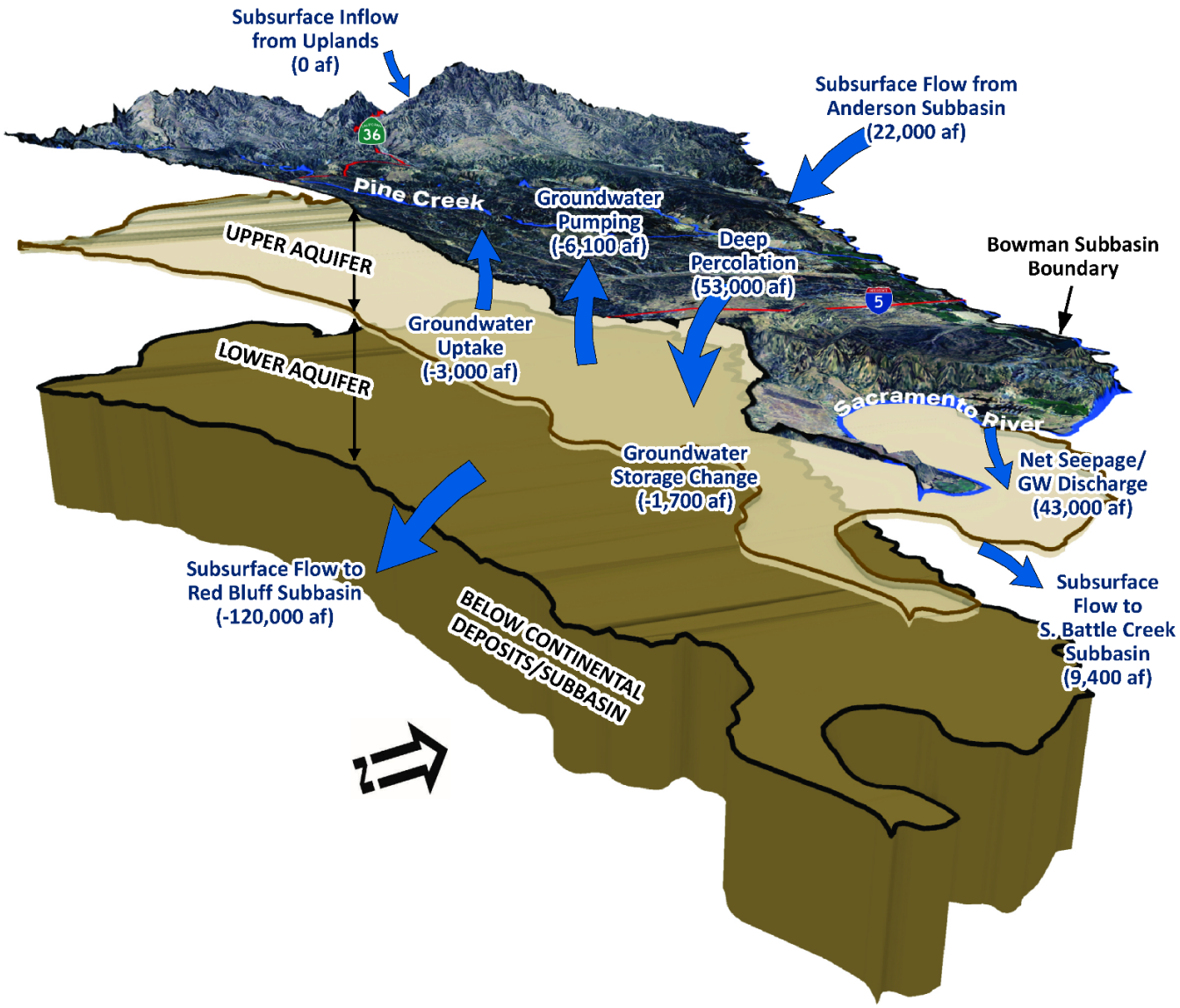


Figure 2-61. Diagram of the Bowman Subbasin Historical Average Annual Water Budget (1990-2018)

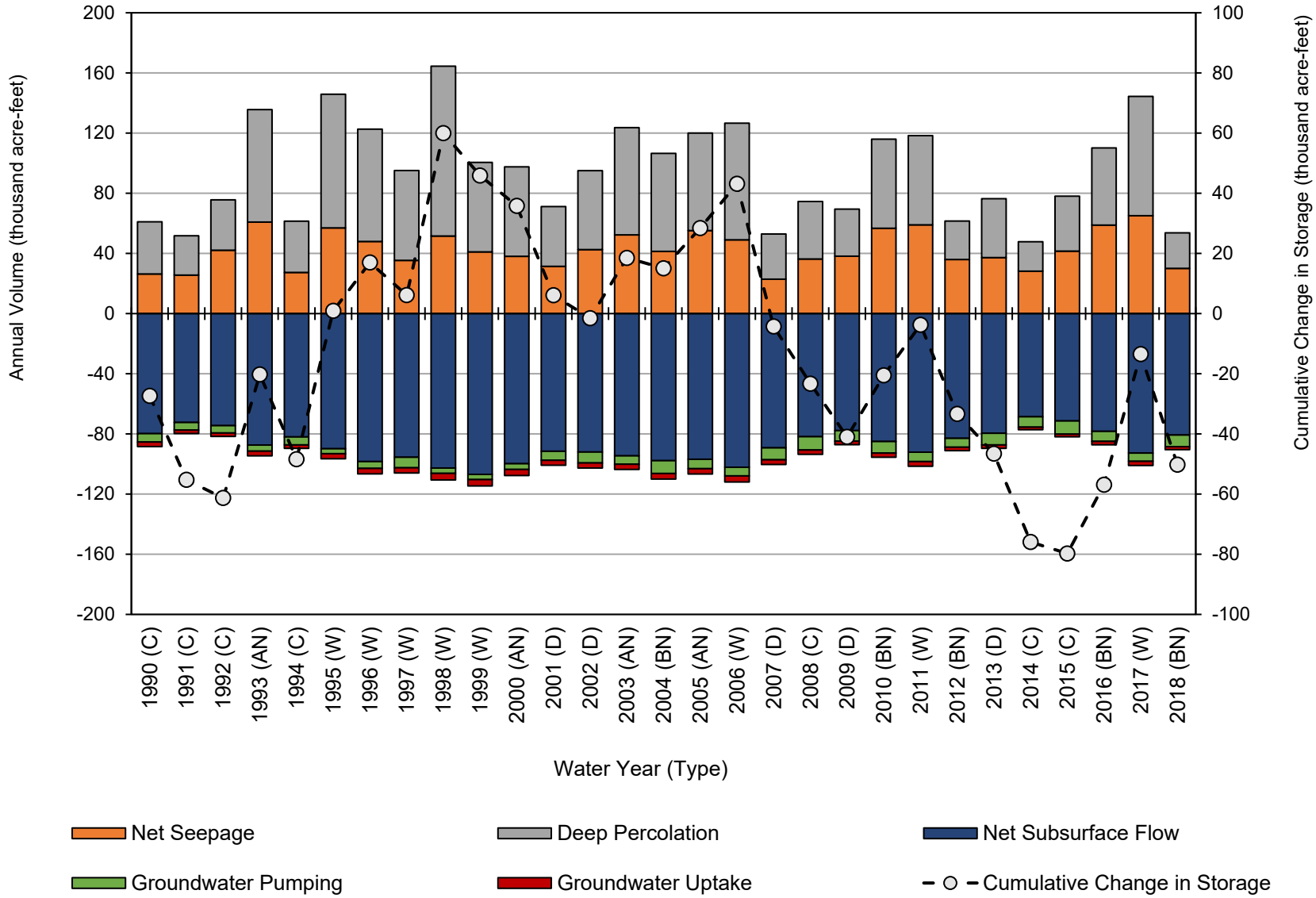


Figure 2-62. Bowman Subbasin Historical Water Budget Summary

Table 2-22. Bowman Subbasin Historical Water Budget Summary (acre-feet)

WATER YEAR (TYPE)		NET SEEPAGE	DEEP PERCOLATION	NET SUBSURFACE FLOWS	GROUND-WATER PUMPING	GROUND-WATER UPTAKE	ANNUAL GROUNDWATER STORAGE CHANGE	CUMULATIVE GROUNDWATER STORAGE CHANGE
1990 (C)		26,000	35,000	-80,000	-5,600	-3,000	-27,000	-27,000
1991 (C)		26,000	26,000	-72,000	-5,100	-2,300	-28,000	-55,000
1992 (C)		42,000	33,000	-75,000	-4,900	-2,200	-6,000	-61,000
1993 (AN)		61,000	75,000	-87,000	-4,100	-3,100	41,000	-20,000
1994 (C)		27,000	34,000	-82,000	-5,300	-2,300	-28,000	-48,000
1995 (W)		57,000	89,000	-90,000	-3,300	-3,300	49,000	910
1996 (W)		48,000	75,000	-98,000	-4,500	-3,600	16,000	17,000
1997 (W)		35,000	60,000	-96,000	-7,000	-3,500	-11,000	6,100
1998 (W)		52,000	110,000	-100,000	-3,600	-4,400	54,000	60,000
1999 (W)		41,000	59,000	-110,000	-3,400	-4,300	-14,000	46,000
2000 (AN)		38,000	59,000	-100,000	-3,800	-4,000	-10,000	36,000
2001 (D)		31,000	40,000	-92,000	-5,900	-3,300	-30,000	6,100
2002 (D)		43,000	53,000	-92,000	-7,200	-3,400	-7,600	-1,500
2003 (AN)		52,000	71,000	-95,000	-5,500	-3,500	20,000	19,000
2004 (BN)		41,000	65,000	-98,000	-8,500	-3,700	-3,500	15,000
2005 (AN)		55,000	65,000	-97,000	-6,300	-3,600	13,000	28,000
2006 (W)		49,000	78,000	-100,000	-5,700	-4,000	15,000	43,000
2007 (D)		23,000	30,000	-89,000	-8,000	-3,100	-47,000	-4,300
2008 (C)		36,000	38,000	-82,000	-8,900	-2,900	-19,000	-23,000
2009 (D)		38,000	31,000	-78,000	-6,900	-2,400	-18,000	-41,000
2010 (BN)		57,000	59,000	-85,000	-7,700	-2,700	21,000	-20,000
2011 (W)		59,000	59,000	-92,000	-6,200	-3,200	17,000	-3,700
2012 (BN)		36,000	26,000	-83,000	-6,000	-2,300	-30,000	-33,000
2013 (D)		37,000	39,000	-80,000	-7,700	-2,300	-13,000	-47,000
2014 (C)		28,000	20,000	-69,000	-6,900	-1,700	-29,000	-76,000
2015 (C)		42,000	37,000	-71,000	-8,800	-1,700	-3,800	-80,000
2016 (BN)		59,000	51,000	-78,000	-6,700	-2,300	23,000	-57,000
2017 (W)		65,000	79,000	-93,000	-5,400	-2,800	43,000	-13,000
2018 (BN)		30,000	24,000	-81,000	-7,800	-1,900	-37,000	-50,000
Average (1990-2018)		43,000	53,000	-88,000	-6,100	-3,000	-1,700	
1990-2018	W	51,000	76,000	-98,000	-4,900	-3,700	21,000	
	AN	56,000	70,000	-93,000	-5,300	-3,400	25,000	
	BN	47,000	46,000	-84,000	-7,200	-2,500	-590	
	D	34,000	39,000	-86,000	-7,200	-2,900	-23,000	
	C	32,000	32,000	-76,000	-6,500	-2,300	-20,000	

Note: positive values indicate inflows/increasing storage, negative values indicate outflows/decreasing storage.

2.3.6 Current Water Budget

As described above in **Section 2.3.2**, several recent water budget periods have been considered for use in representing the current water budget. Because the hydrology and land use conditions can vary year to year, estimating the current water budget can be challenging. To evaluate the current water budget, water budget results from the historical model run were summarized for five different recent time periods to evaluate variability and trends. The five different recent water budget periods evaluated include the following:

- Most recent 10 years (2009-2018)
- Most recent 5 year (2014-2018)
- Most recent 3 years (2016-2018)
- Recent single year 2018
- Recent single year 2019

Comparison of these recent water budget periods provides a representation of how water use varies with precipitation and water supply conditions from year to year. Based on these comparisons and consideration of the hydrologic conditions over these recent periods, the recent three-year period from 2016 through 2018 is believed to provide a reasonable representation of the recent water budget conditions. For reporting a current water budget in the GSP, the average water budget for the three-year period between 2016 and 2018 is considered to be representative of the current water budget and representative of current hydrologic and land use conditions. This period incorporates recent land use conditions and spans three years (two below normal years and one wet year) that collectively have precipitation and hydrology similar to the long-term average. Although the 2016 through 2018 period provides a summary of the water budget for recent years that appear to be reasonably representative of recent typical conditions, it is not necessarily representative of any longer-term average conditions. Understanding the recent water budget years is helpful in anticipating longer-term conditions under a scenario where current land uses are maintained in the Subbasin (see **section 2.3.7**). The results from comparisons of the recent water budget periods evaluated are presented below, including the results and discussion of the selected current water budget period of 2016-2018.

2.3.6.1 Surface Water System Water Budget Summary

The comparison of the different recent SWS water budget periods provides a representation of how individual SWS water budget components vary from year to year depending on water demands, precipitation, and water supply conditions. The SWS water budget results for these different recent time periods are presented in **Table 2-23**. The single year SWS water budget results highlight the high variability between these two years, which included a below normal year in 2018 and a wet year in 2019. The water budget inflows and outflows from the SWS vary by about 300 taf between these two single years. Most of the variability in the total SWS inflows and outflows is a result of variability in precipitation, surface water inflow and surface water outflow. When comparing the average annual water budget results for recent multi-year periods, the variability is considerably reduced with a maximum difference in both inflows and outflows of about 60 taf per year between the three different recent multi-year periods evaluated.

The selected current water budget period of 2016-2018 (highlighted blue in **Table 2-23**) has total SWS inflows and outflows of about 400 taf per year with the largest SWS inflows being precipitation (310 taf per year) and the largest SWS outflow being the ET of Precipitation (160 taf per year). Current SWS water budget inflows also include 82 taf per year of surface water inflow and 9.0 taf per year of groundwater extraction and uptake. Groundwater discharge to surface water is negligible. Other SWS outflows in the current SWS water budget include 120 taf per year surface water outflow, 51 taf of infiltration (seepage) of surface water, 45 taf per year deep percolation of precipitation, 12 taf per year ET of applied water, 6.4 taf per year of deep percolation of applied water, and additional smaller outflows for ET of groundwater uptake, and evaporation from surface water.

Table 2-23. Comparison of Recent SWS Water Budget Periods (acre-feet).

FLOW PATH		RECENT WATER BUDGET PERIOD				
		RECENT 10 YEARS (2009-2018)	RECENT 5 YEARS (2014-2018)	RECENT 3 YEARS (2016-2018)	RECENT 1 YEAR 2018	RECENT 1 YEAR 2019
Inflow	Surface Water Inflow	67,000	68,000	82,000	39,000	100,000
	Precipitation	260,000	270,000	310,000	190,000	420,000
	Groundwater Extraction/Uptake	9,300	9,200	9,000	9,700	8,900
	Groundwater Discharge to Surface Water	0	0	0	0	0
	Total Inflows	***340,000***	***340,000***	***400,000***	***240,000***	***540,000***
Outflow	Surface Water Outflow	79,000	93,000	120,000	20,000	210,000
	ET of Applied Water	12,000	12,000	12,000	13,000	10,000
	ET of Groundwater Uptake	2,300	2,100	2,300	1,900	2,900
	ET of Precipitation	160,000	150,000	160,000	150,000	180,000
	Evaporation	840	800	800	820	740
	Deep Percolation of Applied Water	7,300	6,100	6,400	6,300	7,100
	Deep Percolation of Precipitation	35,000	36,000	45,000	17,000	65,000
	Infiltration of Surface Water (Seepage)	45,000	45,000	51,000	30,000	60,000
	Change in Root Zone Storage	140	-1,000	-670	-3,000	6,600
	Total Outflows	***340,000***	***340,000***	***400,000***	***240,000***	***540,000***

2.3.6.2 Groundwater System Water Budget Summary

Comparing the different recent water budget periods provides a representation of how the overall GWS water budget components vary from year to year depending on conditions including inflows/outflows between the SWS and subsurface flows. The GWS water budget results for these different recent time periods are presented in **Table 2-24**. As with the results for the current SWS water budget summaries, the single year results for the GWS water budget highlight the high variability between the two individual years of 2018 and 2019, which included a below normal year (2018) and a wet year (2019). Although some of the individual water budget components are relatively stable between the two different recent water budget years, the total change in groundwater storage varied by about 73 taf ranging from a decrease in storage of about -37 taf in 2018 (a below normal year) to an increase in storage of nearly 36 taf in 2019 (a wet year). There is considerably less variability in most of the different water budget components when comparing between the three different recent multi-year periods, although the net seepage and net subsurface flows do show relatively higher differences between the three recent periods. Average annual change in storage varies between -2.7 and -0.7 taf per year for the recent 10-year and 5-year periods, respectively, and indicates an average increase in storage of about 9.8 taf per year for the recent three-year period. This difference is likely attributable to the drought years consisting of dry and critical years that occurred between 2013 and 2015, which are included in the recent five- and ten-year periods, but not included in the most recent three-year period from 2016 to 2018.

The selected current water budget period of 2016-2018 (highlighted blue in **Table 2-24**) has total net seepage of about 51 taf per year, indicating net contribution of surface water to the GWS through exchanges occurring in surface waterways. Deep percolation also averages about 51 taf per year. Net subsurface flows total about -84 taf per year on average over the current water budget period occurring as outflow. Groundwater pumping is an outflow from the GWS and averages about -7.8 taf per year during the current water budget period while groundwater uptake represents an additional GWS outflow of about -1.9 taf per year.

Table 2-24. Comparison of Recent GWS Water Budget Periods (acre-feet)

GWS WATER BUDGET COMPONENT	RECENT WATER BUDGET PERIODS				
	RECENT 10 YEARS (2009-2018)	RECENT 5 YEARS (2014-2018)	RECENT 3 YEARS (2016-2018)	RECENT 1 YEAR 2018	RECENT 1 YEAR 2019
Net Seepage	45,000	45,000	51,000	30,000	60,000
Deep Percolation	42,000	42,000	51,000	24,000	72,000
Net Subsurface Flows	-81,000	-78,000	-84,000	-81,000	-87,000
Groundwater Pumping	-7,000	-7,100	-6,600	-7,800	-6,000
Groundwater Uptake	-2,300	-2,100	-2,300	-1,900	-2,900
Annual Groundwater Storage Change	***-2,700***	***-700***	***9,800***	***-37,000***	***36,000***

Note: positive values indicate inflows/increasing storage, negative values indicate outflows/decreasing storage.

2.3.7 Projected Water Budgets

To evaluate projected water budgets in the future, projected model runs were developed using Tehama IHM. The projected model runs are intended to evaluate the effects of anticipated future conditions of hydrology, water supply availability, and water demand on the Bowman Subbasin water budget and groundwater conditions over a 50-year GSP planning period. The projected model runs also incorporate consideration of potential climate change and water supply availability scenarios and evaluation of the need for and benefit of any projects and management actions to be implemented in the Subbasin to maintain or achieve sustainability. The projected model runs use hydrologic conditions representative of the most recent 50 years of hydrology in the Subbasin, with adjustments applied in scenarios for evaluating the water budget under climate change and/or altered water supply and demand conditions. A number of projected future scenarios were simulated in Tehama IHM to compare possible outcomes, including different projected land uses and potential climate change impacts. Additional information about the development of the projected model scenarios is provided in **Appendix 2-J**.

2.3.7.1 Projected (Current Land Use) Water Budget

This section presents the results of the Projected (Current Land Use) scenario. The Current Land Use scenario assumes constant land use conditions based on 2018 conditions.

2.3.7.1.1 *Projected (Current Land Use) Surface Water System Water Budget Summary*

Annual inflows, outflows, and change in SWS root zone storage during the projected (current land use) water budget period (2022-2072) are summarized in **Figure 2-63** and **Table 2-25.** Inflows in **Figure 2-63** are shown as positive values, while outflows are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the SWS water budget.

Of particular note in the projected (current land use) SWS water budget results is the volume of precipitation that makes up the largest part of the Subbasin SWS inflows averaging about 300 taf per year over the projected period. By comparison, other SWS inflows in the Subbasin are relatively smaller. Surface water inflows average about 83 taf per year. Groundwater extraction and uptake represents a relatively small SWS inflow averaging about 9.1 taf per year, and groundwater discharge to surface water is negligible over the projected (current land use) water budget period.

Among the outflows from the Subbasin SWS, ET of precipitation makes up a large fraction of the total Subbasin SWS outflows averaging about 160 taf per year over the projected (current land use) period. The surface water outflows total about 120 taf per year on average, a value that corresponds with the large volumes of precipitation and surface water inflow (a total of about 380 taf per year). By comparison, other SWS outflows in the Subbasin are relatively smaller, with values for each deep percolation of precipitation and infiltration (seepage) of surface water totaling about 43 taf per year on average. ET of applied water, and deep percolation of applied water are about 11 and 7.3 taf per year on average, respectively. The outflows of ET of groundwater uptake and evaporation from surface water average about 2.9 and 0.85 taf per year, respectively.

Detailed results for the projected (current land use) SWS water budget are presented in **Appendix 2-K**.

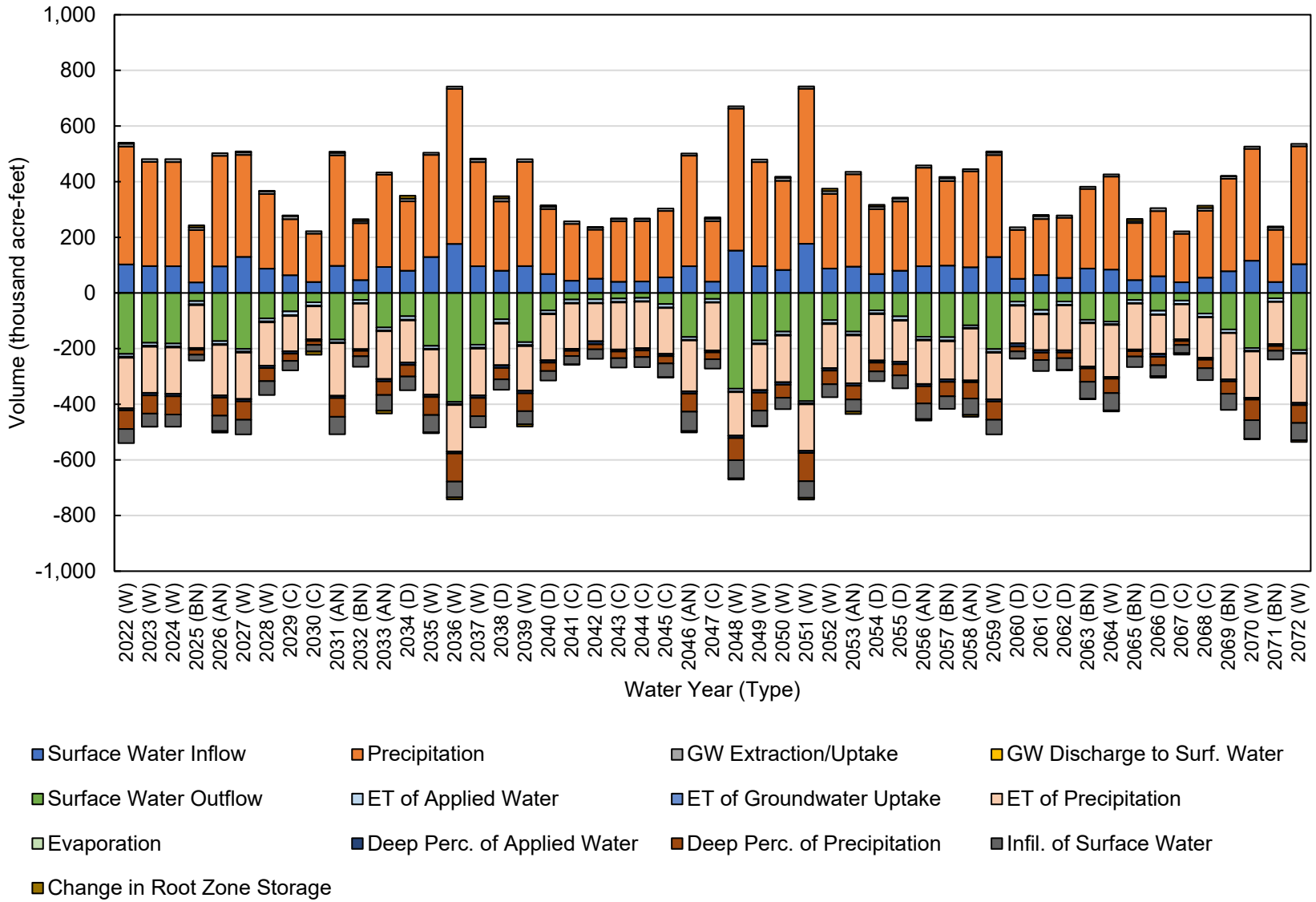


Figure 2-63. Bowman Subbasin Surface Water System Projected (Current Land Use) Water Budget, 2022-2072

Table 2-25. Bowman Subbasin Surface Water System Projected (Current Land Use) Water Budget, 2022-2072 (acre-feet)

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND-WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION[1]	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	
2022 (W)	100,000	420,000	10,000	0	220,000	9,900	3,900	180,000	730	6,600	67,000	51,000	-3,500
2023 (W)	96,000	370,000	10,000	0	180,000	10,000	3,900	170,000	810	8,300	65,000	47,000	640
2024 (W)	96,000	370,000	10,000	0	180,000	10,000	4,000	170,000	810	8,300	65,000	44,000	0
2025 (BN)	38,000	190,000	9,700	0	29,000	12,000	2,900	150,000	800	5,800	18,000	21,000	-7,300
2026 (AN)	96,000	400,000	9,100	0	170,000	10,000	3,500	180,000	860	7,000	65,000	55,000	5,800
2027 (W)	130,000	370,000	8,800	0	200,000	9,800	3,800	170,000	790	7,600	66,000	53,000	-3,500
2028 (W)	87,000	270,000	9,600	0	92,000	11,000	3,700	160,000	940	7,700	47,000	50,000	-1,700
2029 (C)	64,000	200,000	11,000	0	66,000	13,000	3,000	130,000	1,000	7,800	26,000	34,000	-2,200
2030 (C)	39,000	170,000	8,700	0	33,000	13,000	2,000	120,000	830	5,200	14,000	24,000	12,000
2031 (AN)	98,000	400,000	8,800	0	170,000	9,900	3,000	190,000	850	7,800	67,000	63,000	-4,300
2032 (BN)	46,000	200,000	7,800	0	25,000	11,000	2,200	160,000	820	5,200	19,000	38,000	-6,400
2033 (AN)	93,000	330,000	8,000	0	120,000	10,000	2,900	170,000	850	8,000	49,000	56,000	10,000
2034 (D)	80,000	250,000	10,000	0	84,000	12,000	2,800	150,000	960	8,300	42,000	49,000	-10,000
2035 (W)	130,000	370,000	8,300	0	190,000	10,000	3,200	160,000	790	7,500	64,000	62,000	3,200
2036 (W)	180,000	560,000	8,400	0	390,000	7,100	3,900	170,000	650	6,300	100,000	57,000	7,300
2037 (W)	96,000	370,000	10,000	0	190,000	10,000	3,900	170,000	810	8,300	66,000	40,000	-2,300
2038 (D)	80,000	250,000	11,000	0	95,000	12,000	3,500	150,000	960	8,500	41,000	38,000	-8,200
2039 (W)	96,000	370,000	9,700	0	180,000	11,000	3,500	160,000	810	8,500	64,000	47,000	8,200
2040 (D)	68,000	230,000	8,900	0	63,000	11,000	3,000	170,000	890	7,400	30,000	34,000	-4,600
2041 (C)	44,000	200,000	9,500	0	24,000	12,000	2,500	160,000	920	6,400	19,000	30,000	540

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND-WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION[1]	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	
2042 (D)	52,000	180,000	8,900	0	23,000	13,000	2,100	140,000	950	11,000	18,000	34,000	-510
2043 (C)	40,000	220,000	8,600	0	20,000	12,000	1,900	170,000	830	6,300	24,000	34,000	-2,200
2044 (C)	41,000	220,000	8,500	0	18,000	12,000	1,800	170,000	830	6,700	24,000	36,000	-10
2045 (C)	56,000	240,000	8,700	0	40,000	12,000	1,800	170,000	870	6,700	26,000	50,000	270
2046 (AN)	96,000	400,000	8,100	0	160,000	10,000	2,500	180,000	860	7,200	65,000	70,000	4,900
2047 (C)	41,000	220,000	8,600	0	22,000	12,000	1,900	170,000	830	6,200	24,000	34,000	-5,100
2048 (W)	150,000	510,000	8,200	0	340,000	9,400	2,900	160,000	760	8,100	79,000	65,000	4,500
2049 (W)	96,000	370,000	9,300	0	170,000	10,000	3,000	170,000	800	8,200	65,000	54,000	2,100
2050 (W)	83,000	320,000	11,000	0	140,000	12,000	2,900	170,000	930	8,000	47,000	41,000	-4,000
2051 (W)	180,000	560,000	8,300	0	390,000	7,300	3,800	170,000	650	6,600	100,000	60,000	6,400
2052 (W)	88,000	270,000	9,800	0	97,000	11,000	3,800	160,000	950	7,700	49,000	47,000	-8,900
2053 (AN)	95,000	330,000	8,800	0	140,000	10,000	3,600	170,000	860	8,200	49,000	43,000	8,800
2054 (D)	68,000	230,000	8,900	0	63,000	11,000	3,000	170,000	890	7,200	31,000	35,000	-6,700
2055 (D)	80,000	250,000	10,000	0	84,000	13,000	3,000	150,000	960	8,400	40,000	47,000	-3,700
2056 (AN)	96,000	350,000	8,200	0	160,000	10,000	3,100	160,000	820	7,300	62,000	56,000	4,700
2057 (BN)	99,000	300,000	9,800	0	160,000	12,000	3,300	140,000	970	8,800	52,000	45,000	-4,600
2058 (AN)	92,000	340,000	8,000	0	120,000	8,900	3,200	190,000	770	5,700	58,000	59,000	7,000
2059 (W)	130,000	370,000	8,700	0	200,000	9,900	3,600	170,000	800	7,400	66,000	53,000	-3,900
2060 (D)	51,000	180,000	9,400	0	31,000	12,000	2,700	130,000	950	10,000	18,000	25,000	430
2061 (C)	64,000	200,000	11,000	0	61,000	14,000	2,500	130,000	990	8,000	26,000	40,000	-4,400
2062 (D)	54,000	220,000	8,100	0	31,000	12,000	2,100	160,000	940	7,100	20,000	42,000	2,700

WATER YEAR (TYPE)		INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
		SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND-WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION[1]	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	
2063 (BN)		88,000	290,000	7,700	0	97,000	9,800	2,500	160,000	860	6,800	48,000	61,000	1,800
2064 (W)		84,000	330,000	7,900	0	100,000	9,000	2,900	190,000	750	5,900	52,000	62,000	3,900
2065 (BN)		46,000	200,000	7,800	0	25,000	11,000	2,100	160,000	820	5,300	19,000	38,000	-7,300
2066 (D)		60,000	230,000	10,000	0	64,000	13,000	2,200	140,000	960	9,500	30,000	39,000	5,800
2067 (C)		38,000	170,000	8,800	0	27,000	12,000	1,700	130,000	830	4,900	14,000	30,000	4,900
2068 (C)		55,000	240,000	10,000	0	74,000	12,000	1,700	150,000	770	5,700	31,000	43,000	-8,000
2069 (BN)		78,000	330,000	8,900	0	130,000	12,000	2,100	170,000	830	6,800	44,000	58,000	-720
2070 (W)		120,000	400,000	8,100	0	200,000	9,700	2,700	170,000	750	5,800	73,000	67,000	1,700
2071 (BN)		39,000	190,000	8,800	0	19,000	12,000	1,900	150,000	800	6,400	17,000	31,000	-3,100
2072 (W)		100,000	420,000	8,900	0	210,000	10,000	2,800	180,000	740	7,000	65,000	62,000	6,700
Average (2022-2072)		83,000	300,000	9,100	0	120,000	11,000	2,900	160,000	850	7,300	46,000	46,000	-70
2022-2072	W	110,000	390,000	9,200	0	200,000	9,900	3,500	170,000	790	7,400	67,000	53,000	940
	AN	95,000	370,000	8,400	0	150,000	9,900	3,100	180,000	840	7,300	59,000	58,000	5,300
	BN	62,000	240,000	8,700	0	69,000	11,000	2,400	160,000	840	6,400	31,000	42,000	-4,000
	D	66,000	220,000	9,500	0	60,000	12,000	2,700	150,000	940	8,600	30,000	38,000	-2,800
	C	48,000	210,000	9,300	0	39,000	12,000	2,100	150,000	870	6,400	23,000	35,000	-460

1 Diversions for some years were estimated based on average monthly data, resulting in a generally constant evaporation volume for some years.

2.3.7.2 Projected (Current Land Use) Groundwater System Water Budget Summary

Summarized results for major components of the projected (current land use) water budget as they relate to the GWS are presented in **Figure 2-64** and **Table 2-26**. Deep percolation represents the largest inflow averaging nearly 53 taf per year while net seepage represents an inflow of about 46 taf per year. Net subsurface flows (combined subsurface flows with adjacent subbasins and upland areas) represent the largest net outflow totaling about -90 taf per year of outflow from the Bowman Subbasin on average. Groundwater pumping (on average -6.2 taf per year) and groundwater (root water) uptake directly from shallow groundwater (on average -2.9 taf per year) represent smaller outflows from the GWS.

Overall, the water budget results for the projected period indicate a cumulative change in groundwater storage of about -11 taf, which equals an average annual change in groundwater storage of about -0.2 taf per year. These changes in storage estimates equate to decreases in storage in the Subbasin of about 0.1 acre-feet per acre over the 51 years across the entire Subbasin (approximately 122,425 acres). **Figure 2-64** provides a conceptual illustration of the projected (current land use) water budget. **Figure 2-65** highlights the cumulative change in groundwater storage that would occur during anticipated multi-year wet and dry periods within the projected period.

Detailed results for the projected (current land use) GWS water budget are presented in **Appendix 2-K**.

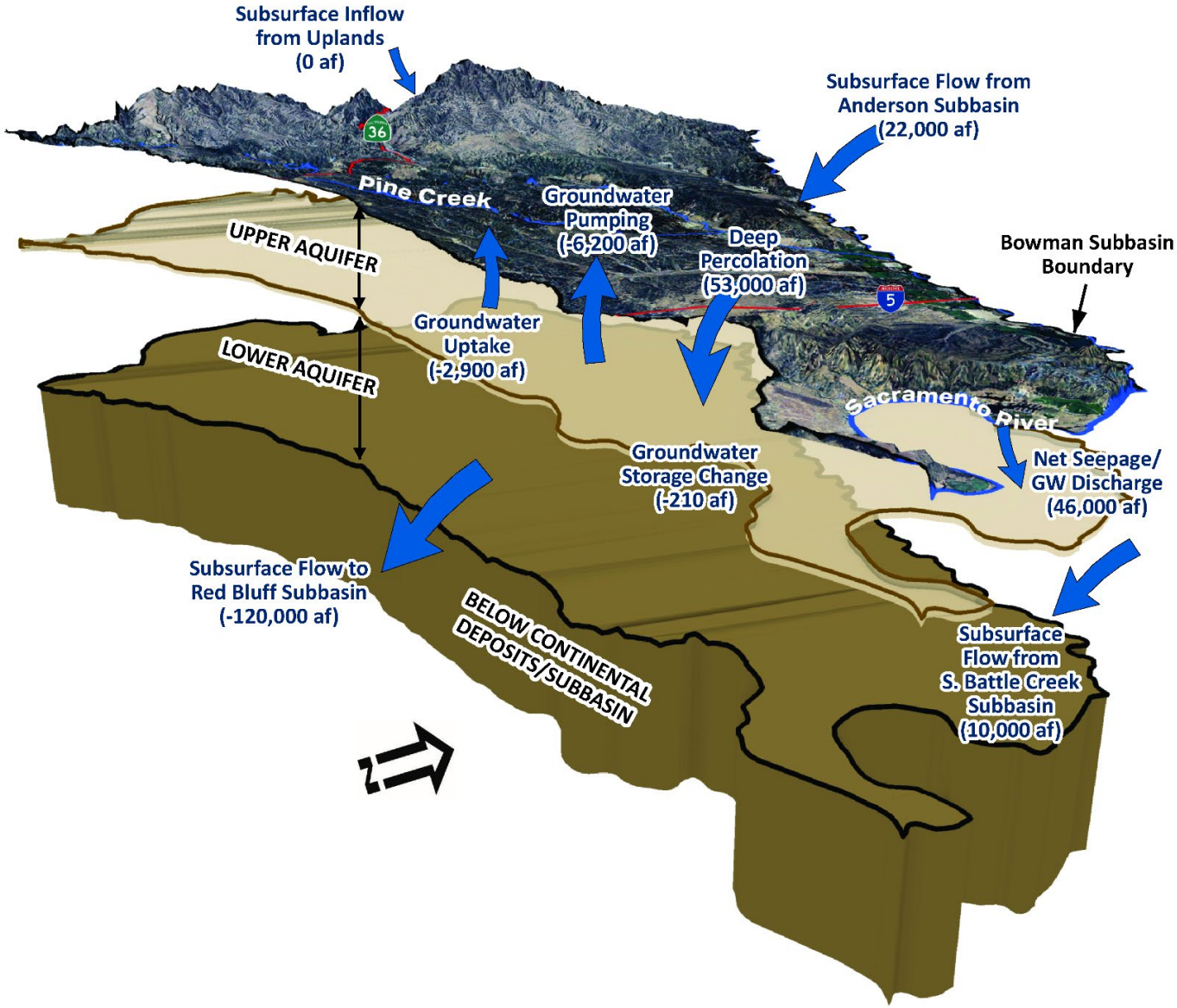


Figure 2-64. Diagram of the Bowman Subbasin Projected (Current Land Use) Average Annual Water Budget, 2022-2072

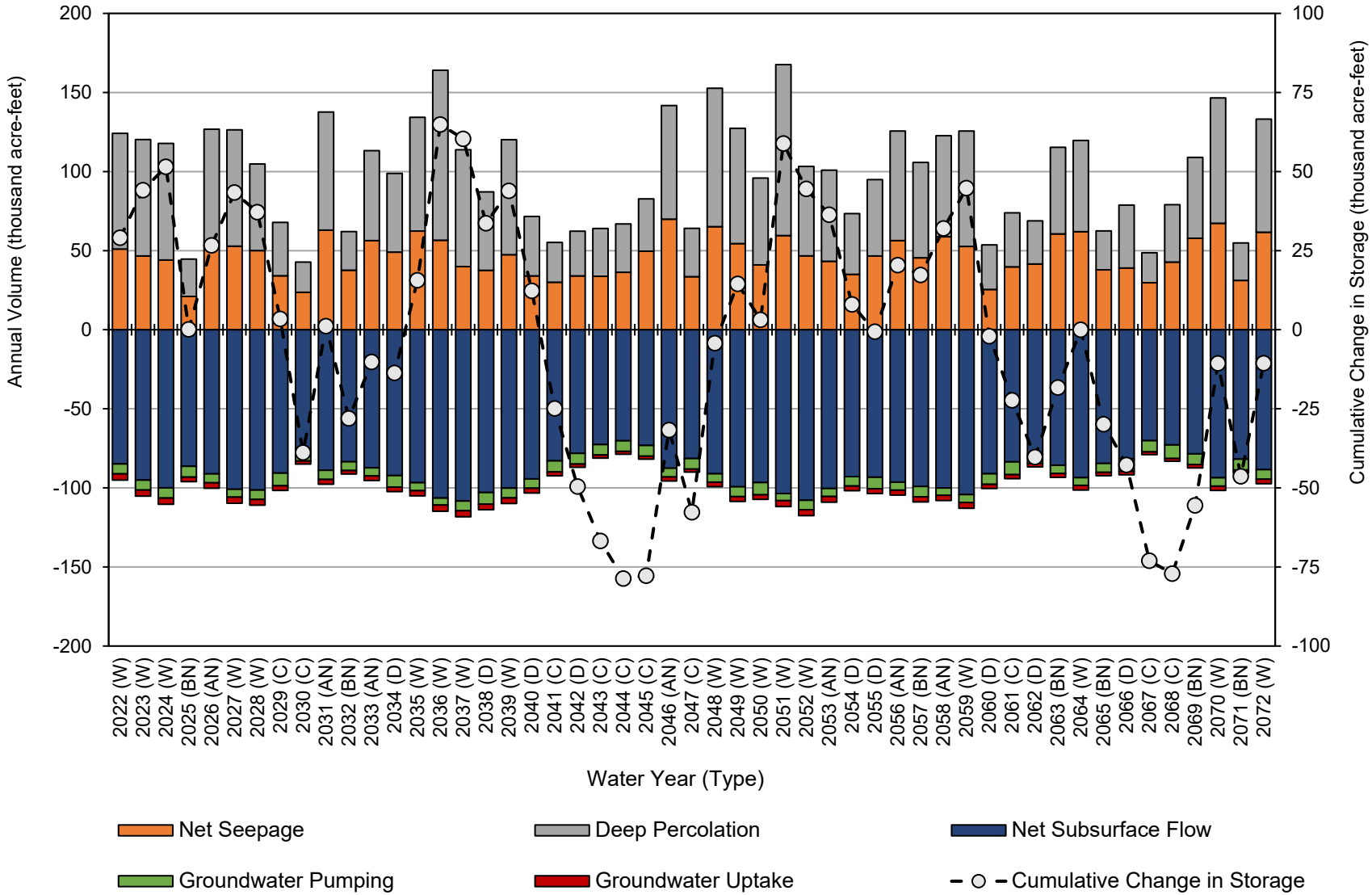


Figure 2-65 Bowman Subbasin Projected (Current Land Use) Water Budget Summary

Table 2-26. Bowman Subbasin Projected (Current Land Use) Water Budget Summary (acre-feet)

WATER YEAR (TYPE)	NET SEEPAGE	DEEP PERCOLATION	NET SUBSURFACE FLOWS	GROUND-WATER PUMPING	GROUND-WATER UPTAKE	ANNUAL GROUNDWATER STORAGE CHANGE	CUMULATIVE GROUNDWATER STORAGE CHANGE
2022 (W)	51,000	73,000	-85,000	-6,400	-3,900	29,000	29,000
2023 (W)	47,000	74,000	-95,000	-6,300	-3,800	15,000	44,000
2024 (W)	44,000	74,000	-100,000	-6,500	-4,000	7,400	52,000
2025 (BN)	21,000	24,000	-86,000	-6,900	-2,900	-51,000	100
2026 (AN)	55,000	72,000	-91,000	-5,600	-3,500	27,000	27,000
2027 (W)	53,000	74,000	-100,000	-5,100	-3,800	17,000	43,000
2028 (W)	50,000	55,000	-100,000	-5,900	-3,700	-6,200	37,000
2029 (C)	34,000	34,000	-91,000	-8,000	-3,000	-34,000	3,400
2030 (C)	24,000	19,000	-76,000	-6,700	-2,000	-42,000	-39,000
2031 (AN)	63,000	75,000	-89,000	-5,800	-3,000	40,000	1,100
2032 (BN)	38,000	24,000	-83,000	-5,600	-2,200	-29,000	-28,000
2033 (AN)	56,000	57,000	-87,000	-5,100	-2,900	18,000	-10,000
2034 (D)	49,000	50,000	-92,000	-7,300	-2,800	-3,500	-14,000
2035 (W)	62,000	72,000	-97,000	-5,100	-3,200	29,000	16,000
2036 (W)	57,000	110,000	-110,000	-4,500	-3,900	49,000	65,000
2037 (W)	40,000	74,000	-110,000	-6,200	-3,900	-4,500	60,000
2038 (D)	38,000	50,000	-100,000	-7,400	-3,500	-27,000	34,000
2039 (W)	47,000	73,000	-100,000	-6,200	-3,500	10,000	44,000
2040 (D)	34,000	38,000	-94,000	-5,800	-3,000	-32,000	12,000
2041 (C)	30,000	25,000	-83,000	-7,100	-2,500	-37,000	-25,000
2042 (D)	34,000	28,000	-78,000	-6,800	-2,100	-25,000	-50,000
2043 (C)	34,000	30,000	-73,000	-6,700	-1,900	-17,000	-67,000
2044 (C)	36,000	31,000	-70,000	-6,700	-1,800	-12,000	-79,000
2045 (C)	50,000	33,000	-73,000	-6,800	-1,800	910	-78,000
2046 (AN)	70,000	72,000	-88,000	-5,600	-2,500	46,000	-32,000
2047 (C)	34,000	31,000	-81,000	-6,700	-1,900	-26,000	-58,000
2048 (W)	65,000	88,000	-91,000	-5,300	-2,900	53,000	-4,300
2049 (W)	54,000	73,000	-99,000	-6,200	-3,000	19,000	15,000
2050 (W)	41,000	55,000	-97,000	-7,800	-2,900	-11,000	3,100
2051 (W)	60,000	110,000	-100,000	-4,500	-3,800	56,000	59,000
2052 (W)	47,000	57,000	-110,000	-6,000	-3,800	-14,000	45,000
2053 (AN)	43,000	58,000	-100,000	-5,100	-3,600	-8,200	36,000
2054 (D)	35,000	38,000	-93,000	-5,900	-2,900	-28,000	8,000
2055 (D)	47,000	48,000	-93,000	-7,300	-3,000	-8,600	-630
2056 (AN)	56,000	69,000	-96,000	-5,100	-3,100	21,000	20,000
2057 (BN)	45,000	60,000	-99,000	-6,500	-3,300	-3,100	17,000
2058 (AN)	59,000	64,000	-100,000	-4,700	-3,200	15,000	32,000

WATER YEAR (TYPE)		NET SEEPAGE	DEEP PERCOLATION	NET SUBSURFACE FLOWS	GROUND-WATER PUMPING	GROUND-WATER UPTAKE	ANNUAL GROUNDWATER STORAGE CHANGE	CUMULATIVE GROUNDWATER STORAGE CHANGE
2059 (W)		53,000	73,000	-100,000	-5,100	-3,600	13,000	45,000
2060 (D)		25,000	28,000	-91,000	-6,700	-2,700	-47,000	-2,000
2061 (C)		40,000	34,000	-84,000	-8,100	-2,500	-20,000	-22,000
2062 (D)		42,000	27,000	-79,000	-6,000	-2,100	-18,000	-40,000
2063 (BN)		61,000	55,000	-86,000	-5,200	-2,500	22,000	-18,000
2064 (W)		62,000	58,000	-94,000	-4,900	-2,900	18,000	-19
2065 (BN)		38,000	25,000	-85,000	-5,600	-2,100	-30,000	-30,000
2066 (D)		39,000	40,000	-82,000	-7,900	-2,200	-13,000	-43,000
2067 (C)		30,000	19,000	-70,000	-7,100	-1,700	-30,000	-73,000
2068 (C)		43,000	36,000	-73,000	-8,600	-1,700	-4,100	-77,000
2069 (BN)		58,000	51,000	-79,000	-6,700	-2,100	22,000	-56,000
2070 (W)		67,000	79,000	-94,000	-5,300	-2,700	45,000	-11,000
2071 (BN)		31,000	24,000	-82,000	-6,900	-1,900	-36,000	-46,000
2072 (W)		62,000	72,000	-88,000	-6,100	-2,800	36,000	-11,000
Average (2022-2072)		46,000	53,000	-90,000	-6,200	-2,900	-210	
2022-2072	W	53,000	74,000	-98,000	-5,700	-3,500	20,000	29,000
	AN	57,000	67,000	-93,000	-5,300	-3,100	23,000	11,000
	BN	42,000	38,000	-86,000	-6,200	-2,400	-15,000	-23,000
	D	38,000	39,000	-89,000	-6,800	-2,700	-22,000	-11,000
	C	35,000	29,000	-77,000	-7,200	-2,100	-22,000	-51,000

2.3.8 Projected (Future Land Use) Water Budget Summary

This section presents the results of the Projected (Future Land Use) scenario. The Future Land Use scenario assumes a static (held constant over the entire projected period) land use condition reflecting an anticipated future development or land use condition that is expected to exist at the end of the 50-year GSP planning horizon. The future land use condition was developed through discussion with local stakeholders and consultation with the Tehama County Planning Department. The future land use condition includes an increase in urban area reflective of the recent rate of urban increase experienced for the County.

Land use areas are used to distinguish the water use sector in which water is consumed, as required by the GSP Regulations. **Figure 2-66** and **Table 2-27** summarize the land use areas over the projected (future land use) period (2022-2072) in the Bowman Subbasin by water use sector, as defined by the GSP Regulations (23 CCR § 351(al)). In the Bowman Subbasin, water use sectors include agricultural, urban, and native vegetation land uses. The urban water use sector covers all urban, residential, industrial, and semi-agricultural[7] land uses. Agricultural, urban, and native vegetation land uses covered approximately 6,060 acres, 2,200 acres, and 114,400 acres, respectively, between 2022 and 2072.

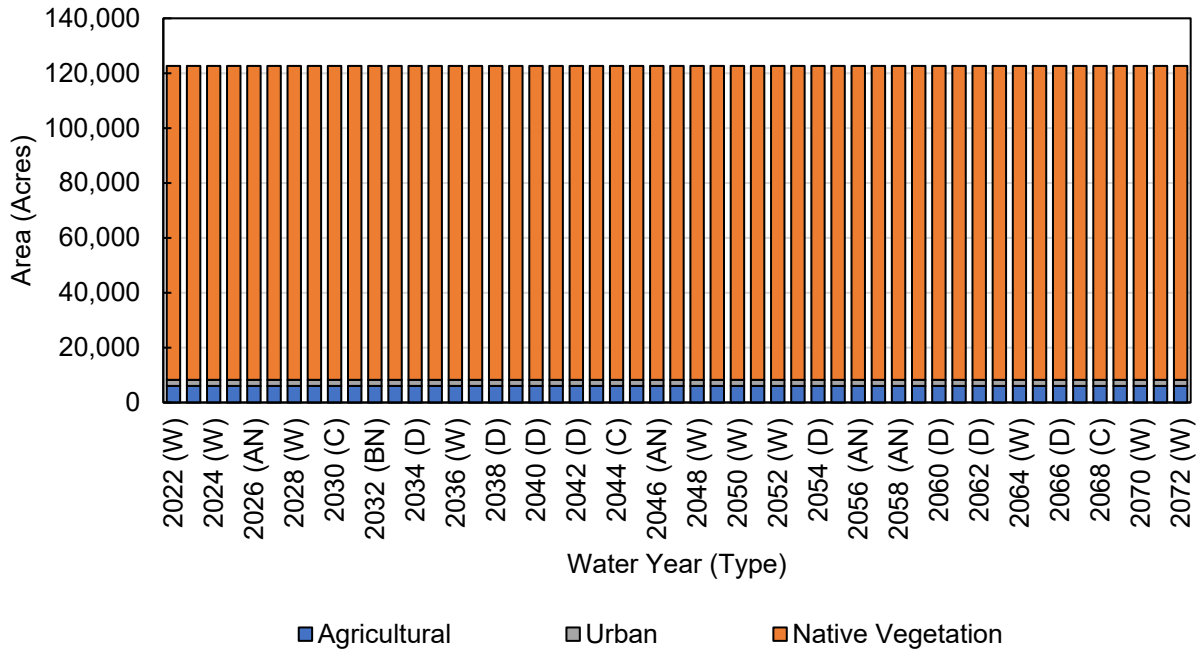


Figure 2-66. Bowman Subbasin Future Land Use Areas, by Water Use Sector

[7] As defined in the DWR crop mapping metadata, semi-agricultural land use subclasses include farmsteads, livestock feed lot operations, dairies, poultry farms, and miscellaneous semi-agricultural land use incidental to agriculture (small roads, ditches, non-planted areas of cropped fields (DWR, 2016b).

Table 2-27. Bowman Subbasin Future Land Use Areas, by Water Use Sector (acres)

PROJECTED PERIOD (FUTURE LAND USE)	AGRICULTURAL	URBAN[1]	NATIVE VEGETATION	TOTAL
2022 -2072	6,060	2,200	114,400	122,660

[1] Area includes land classified as urban, residential, industrial, and semi-agricultural.

Agricultural land uses are further detailed in **Figure 2-67** and **Table 2-28**. In the future, a majority of the agricultural area in the Bowman Subbasin is projected to consist of pasture and grain. Irrigated agricultural areas within the Bowman Subbasin are projected to remain relatively constant at these acreages during the entire projected period.

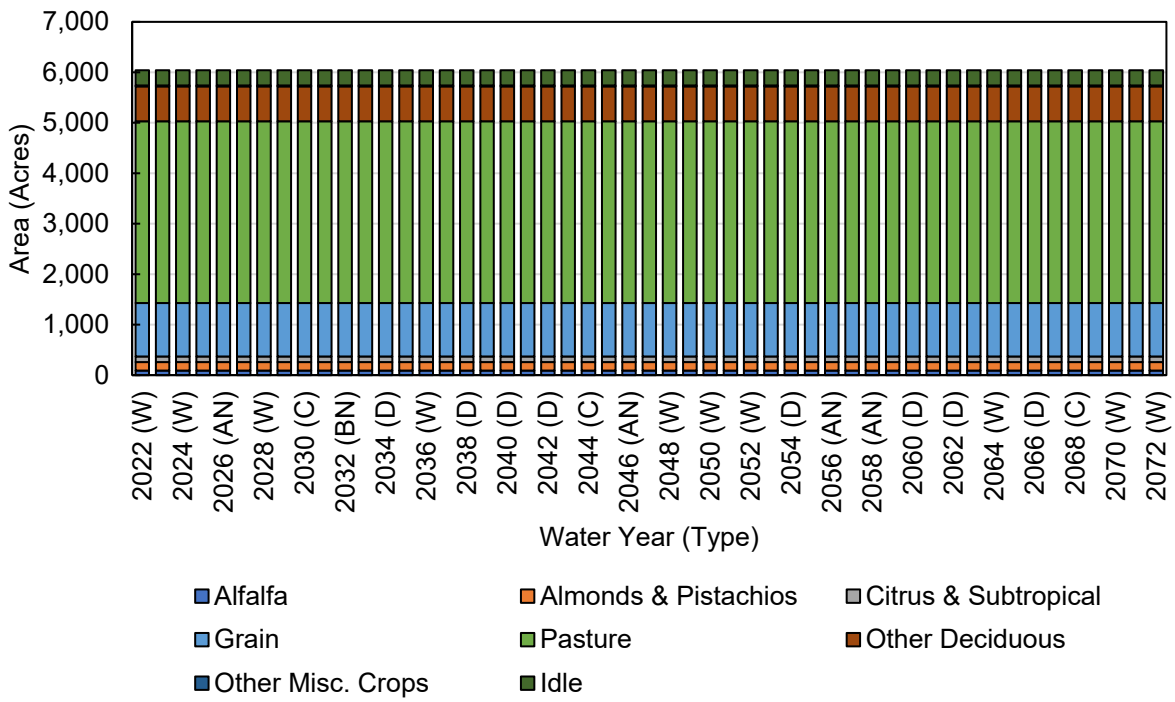


Figure 2-67. Bowman Subbasin Projected Agricultural Land Use Areas

Table 2-28. Bowman Subbasin Projected Agricultural Land Use Areas (acres)

PROJECTED PERIOD (FUTURE LAND USE)	ALFALFA	ALMONDS & PISTACHIOS	CITRUS & SUB-TROPICAL	GRAIN	PASTURE	PONDED (RICE, REFUGE)	OTHER DECIDUOUS	OTHER MISC. CROPS	IDLE	TOTAL
2022 - 2072	90	170	110	1,060	3,600	20	690	20	300	6,060

2.3.9.1 Projected (Future Land Use) Surface Water System Water Budget Summary

Annual inflows, outflows, and change in SWS root zone storage during the projected (future land use) water budget period (2022-2072) are summarized in **Figure 2-68** and **Table 2-29**. Inflows in **Figure 2-68** are shown as positive values, while outflows are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the SWS water budget.

Of particular note in the projected (future land use) SWS water budget results is the volume of precipitation that makes up the largest part of the Subbasin SWS inflows averaging about 300 taf per year over the projected period. By comparison, other SWS inflows in the Subbasin are relatively smaller. Surface water inflows average about 83 taf per year. Groundwater extraction and uptake represents a relatively small SWS inflow averaging about 9.2 taf per year, and groundwater discharge to surface water is negligible over the projected (current land use) water budget period.

Among the outflows from the Subbasin SWS, ET of precipitation makes up a large fraction of the total Subbasin SWS outflows averaging about 160 taf per year over the projected (future land use) period. The surface water outflows total about 120 taf per year on average, a value that corresponds with the large volumes of precipitation and surface water inflow (a total of about 380 taf per year). By comparison, other SWS outflows in the Subbasin are relatively smaller, with values for infiltration (seepage) of surface water and deep percolation of precipitation totaling about 48 taf and 43 taf per year on average, respectively. ET of applied water, and deep percolation of applied water are about 11 and 7.3 taf per year on average, respectively. The outflows of ET of groundwater uptake and evaporation from surface water average about 2.8 and 0.85 taf per year, respectively.

Detailed results for the projected (current land use) SWS water budget are presented in **Appendix 2-K**.

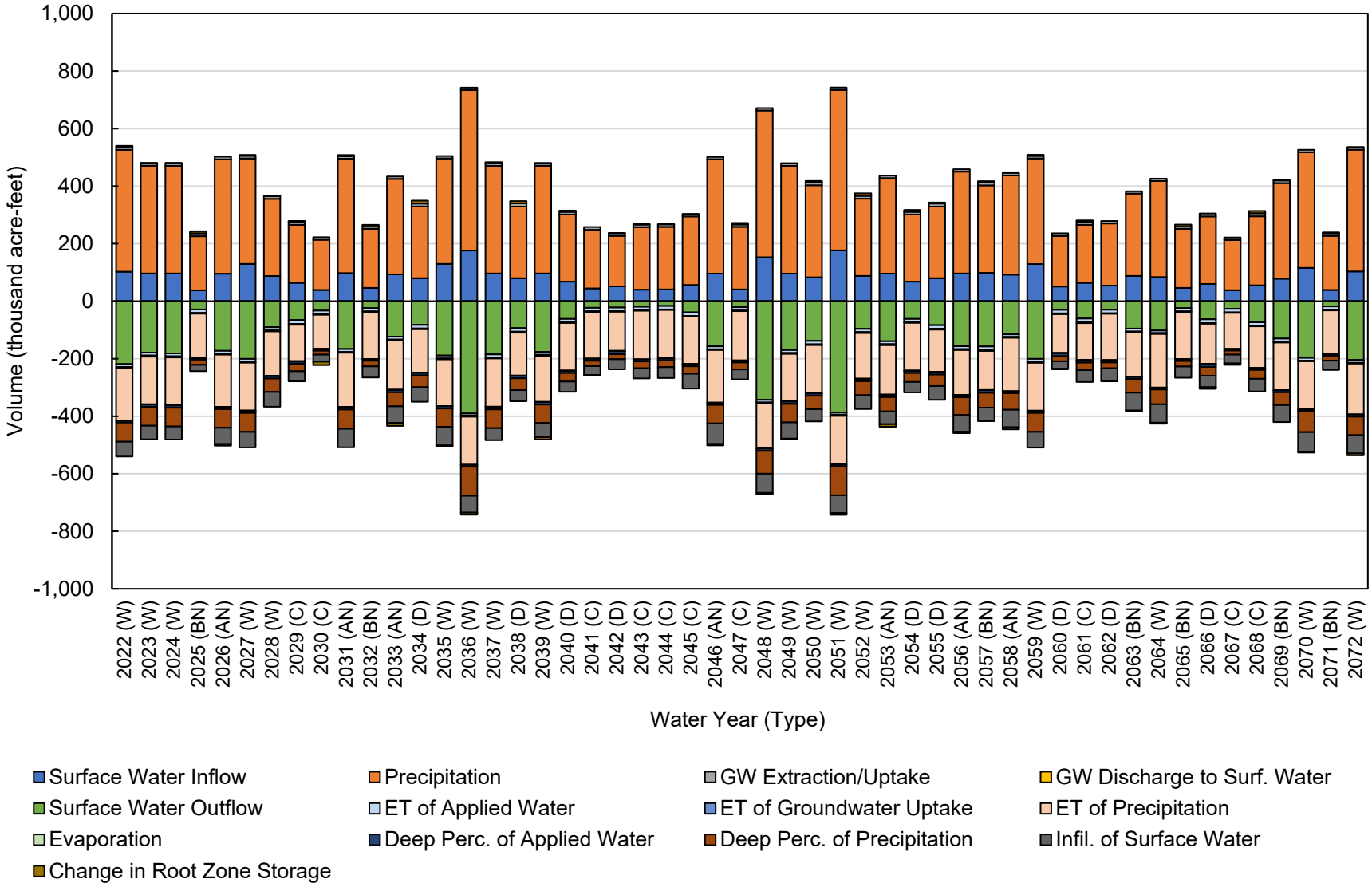


Figure 2-68. Bowman Subbasin Surface Water System Projected (Future Land Use) Water Budget, 2022-2072

Table 2-29. Bowman Subbasin Surface Water System Projected (Future Land Use) Water Budget, 2022-2072 (acre-feet)

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								
	SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND -WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION[1]	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	CHANGE IN ROOT ZONE STORAGE
2022 (W)	100,000	420,000	10,000	0	220,000	10,000	3,800	180,000	740	6,600	66,000	52,000	-3,400
2023 (W)	96,000	370,000	10,000	0	180,000	10,000	3,800	170,000	810	8,300	65,000	48,000	640
2024 (W)	96,000	370,000	11,000	0	180,000	10,000	3,900	170,000	810	8,300	65,000	45,000	0
2025 (BN)	38,000	190,000	9,900	0	29,000	12,000	2,800	150,000	810	5,800	18,000	22,000	-7,300
2026 (AN)	96,000	400,000	9,200	0	170,000	10,000	3,400	180,000	860	7,100	65,000	56,000	5,800
2027 (W)	130,000	370,000	9,000	0	200,000	9,800	3,700	170,000	790	7,600	66,000	54,000	-3,500
2028 (W)	87,000	270,000	9,700	0	91,000	11,000	3,600	160,000	950	7,700	47,000	51,000	-1,700
2029 (C)	64,000	200,000	11,000	0	66,000	13,000	2,900	130,000	1,000	7,800	26,000	35,000	-2,200
2030 (C)	39,000	170,000	8,800	0	33,000	13,000	1,900	120,000	840	5,200	14,000	25,000	12,000
2031 (AN)	98,000	400,000	8,900	0	170,000	9,900	2,900	190,000	860	7,800	67,000	65,000	-4,200
2032 (BN)	46,000	200,000	8,000	0	25,000	11,000	2,100	160,000	820	5,200	19,000	39,000	-6,400
2033 (AN)	93,000	330,000	8,200	0	120,000	10,000	2,800	170,000	850	8,000	49,000	58,000	9,900
2034 (D)	80,000	250,000	10,000	0	83,000	12,000	2,700	150,000	960	8,300	41,000	51,000	-10,000
2035 (W)	130,000	370,000	8,400	0	190,000	10,000	3,200	160,000	790	7,500	64,000	64,000	3,200
2036 (W)	180,000	560,000	8,500	0	390,000	7,200	3,800	170,000	650	6,400	100,000	59,000	7,300
2037 (W)	96,000	370,000	10,000	0	190,000	10,000	3,800	170,000	810	8,300	65,000	42,000	-2,300
2038 (D)	80,000	250,000	11,000	0	94,000	12,000	3,400	150,000	970	8,500	41,000	39,000	-8,200
2039 (W)	97,000	370,000	9,700	0	180,000	11,000	3,400	160,000	810	8,500	64,000	49,000	8,200
2040 (D)	68,000	230,000	8,900	0	62,000	11,000	2,900	170,000	900	7,400	30,000	35,000	-4,600
2041 (C)	44,000	200,000	9,600	0	23,000	12,000	2,400	160,000	920	6,400	19,000	31,000	540

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								
	SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND -WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION[1]	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	CHANGE IN ROOT ZONE STORAGE
2042 (D)	52,000	180,000	9,00 0	0	22,000	13,000	2,000	140,000	960	11,000	18,000	35,000	-500
2043 (C)	40,000	220,000	8,800	0	20,000	12,000	1,900	170,000	840	6,300	24,000	35,000	-2,200
2044 (C)	41,000	220,000	8,700	0	17,000	12,000	1,800	170,000	840	6,700	24,000	37,000	-20
2045 (C)	56,000	240,000	8,800	0	39,000	13,000	1,800	170,000	880	6,700	26,000	51,000	260
2046 (AN)	96,000	400,000	8,300	0	160,000	10,000	2,500	180,000	860	7,200	64,000	72,000	4,900
2047 (C)	41,000	220,000	8,800	0	21,000	12,000	1,800	170,000	840	6,200	24,000	35,000	-5,100
2048 (W)	150,000	510,000	8,300	0	340,000	9,500	2,800	160,000	760	8,100	79,000	67,000	4,500
2049 (W)	96,000	370,000	9,400	0	170,000	11,000	2,900	160,000	800	8,200	64,000	56,000	2,100
2050 (W)	83,000	320,000	11,000	0	140,000	12,000	2,800	170,000	940	8,100	47,000	42,000	-4,000
2051 (W)	180,000	560,000	8,400	0	390,000	7,300	3,700	170,000	650	6,600	100,000	62,000	6,400
2052 (W)	88,000	270,000	9,900	0	96,000	11,000	3,700	160,000	950	7,800	49,000	48,000	-8,900
2053 (AN)	96,000	330,000	8,800	0	140,000	10,000	3,500	170,000	860	8,300	49,000	45,000	8,800
2054 (D)	68,000	230,000	9,000	0	62,000	11,000	2,800	170,000	900	7,200	31,000	36,000	-6,800
2055 (D)	80,000	250,000	10,000	0	83,000	13,000	2,900	150,000	960	8,400	40,000	48,000	-3,700
2056 (AN)	96,000	350,000	8,300	0	160,000	10,000	3,000	160,000	820	7,400	62,000	58,000	4,700
2057 (BN)	98,000	300,000	9,900	0	160,000	12,000	3,200	140,000	970	8,800	51,000	47,000	-4,600
2058 (AN)	92,000	340,000	8,100	0	120,000	9,000	3,100	190,000	770	5,700	58,000	61,000	7,000
2059 (W)	130,000	370,000	8,800	0	200,000	9,900	3,500	170,000	800	7,400	65,000	54,000	-3,900
2060 (D)	51,000	180,000	9,500	0	30,000	13,000	2,600	130,000	960	10,000	18,000	27,000	420
2061 (C)	64,000	200,000	11,000	0	60,000	14,000	2,500	130,000	1,000	8,000	26,000	41,000	-4,400
2062 (D)	54,000	220,000	8,300	0	30,000	12,000	2,100	160,000	950	7,100	20,000	43,000	2,700

WATER YEAR (TYPE)		INFLOWS				OUTFLOWS								
		SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND -WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION[1]	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	CHANGE IN ROOT ZONE STORAGE
2063 (BN)		88,000	290,000	7,800	0	96,000	9,800	2,400	150,000	860	6,700	48,000	62,000	1,800
2064 (W)		84,000	330,000	7,900	0	100,000	9,100	2,800	190,000	750	5,900	52,000	64,000	3,900
2065 (BN)		46,000	200,000	7,900	0	24,000	11,000	2,100	160,000	820	5,300	19,000	39,000	-7,300
2066 (D)		60,000	230,000	10,000	0	63,000	13,000	2,200	140,000	970	9,600	30,000	40,000	5,700
2067 (C)		38,000	170,000	9,000	0	27,000	12,000	1,700	130,000	840	4,900	14,000	31,000	4,900
2068 (C)		55,000	240,000	10,000	0	73,000	12,000	1,700	150,000	780	5,700	31,000	44,000	-8,000
2069 (BN)		78,000	330,000	9,000	0	130,000	12,000	2,100	170,000	840	6,800	44,000	59,000	-730
2070 (W)		120,000	400,000	8,200	0	200,000	9,800	2,600	170,000	750	5,800	73,000	69,000	1,700
2071 (BN)		39,000	190,000	8,900	0	18,000	12,000	1,800	150,000	790	6,400	17,000	32,000	-3,100
2072 (W)		100,000	420,000	9,000	0	200,000	10,000	2,700	180,000	740	7,000	64,000	63,000	6,600
Average (2022-2072)		83,000	300,000	9,200	0	120,000	11,000	2,800	160,000	850	7,300	46,000	48,000	-70
2022-2072	W	110,000	390,000	9,300	0	200,000	9,900	3,400	170,000	790	7,500	67,000	55,000	930
	AN	95,000	370,000	8,500	0	150,000	10,000	3,000	180,000	840	7,400	59,000	59,000	5,300
	BN	62,000	240,000	8,800	0	69,000	11,000	2,400	160,000	840	6,400	31,000	43,000	-3,900
	D	66,000	220,000	9,600	0	59,000	12,000	2,600	150,000	950	8,600	30,000	39,000	-2,800
	C	48,000	210,000	9,500	0	38,000	12,000	2,000	150,000	880	6,400	23,000	36,000	-460

[1] Diversions for some years were estimated based on average monthly data, resulting in a generally constant evaporation volume for some years.

2.3.8.1 Projected (Future Land Use) Groundwater System Water Budget Summary

Summarized results for major components of the projected (future land use) water budget as they relate to the GWS are presented in **Figure 2-69** and **Table 2-30**. Deep percolation represents the largest inflow averaging nearly 53 taf per year while net seepage represents an inflow of about 47 taf per year. Net subsurface flows (combined subsurface flows with adjacent subbasins and upland areas) represent the largest net outflow totaling about -91 taf per year of outflow from the Bowman Subbasin on average. Groundwater pumping (on average -6.4 taf per year) and groundwater (root water) uptake directly from shallow groundwater (on average -2.8 taf per year) represent smaller outflows from the GWS.

Overall, the water budget results for the projected (future land use) period indicate a cumulative change in groundwater storage of about -15 taf, which equals an average annual change in groundwater storage of about -0.30 taf per year. These changes in storage estimates equate to decreases in storage in the Subbasin of about 0.1 acre-feet per acre over the 51 years across the entire Subbasin (approximately 122,425 acres). **Figure 2-69** provides a conceptual illustration of the projected water budget. **Figure 2-70** highlights the cumulative change in groundwater storage that would occur during anticipated multi-year wet and dry periods and over the entire projected period.

Detailed results for the projected (future land use) GWS water budget are presented in **Appendix 2-K**.

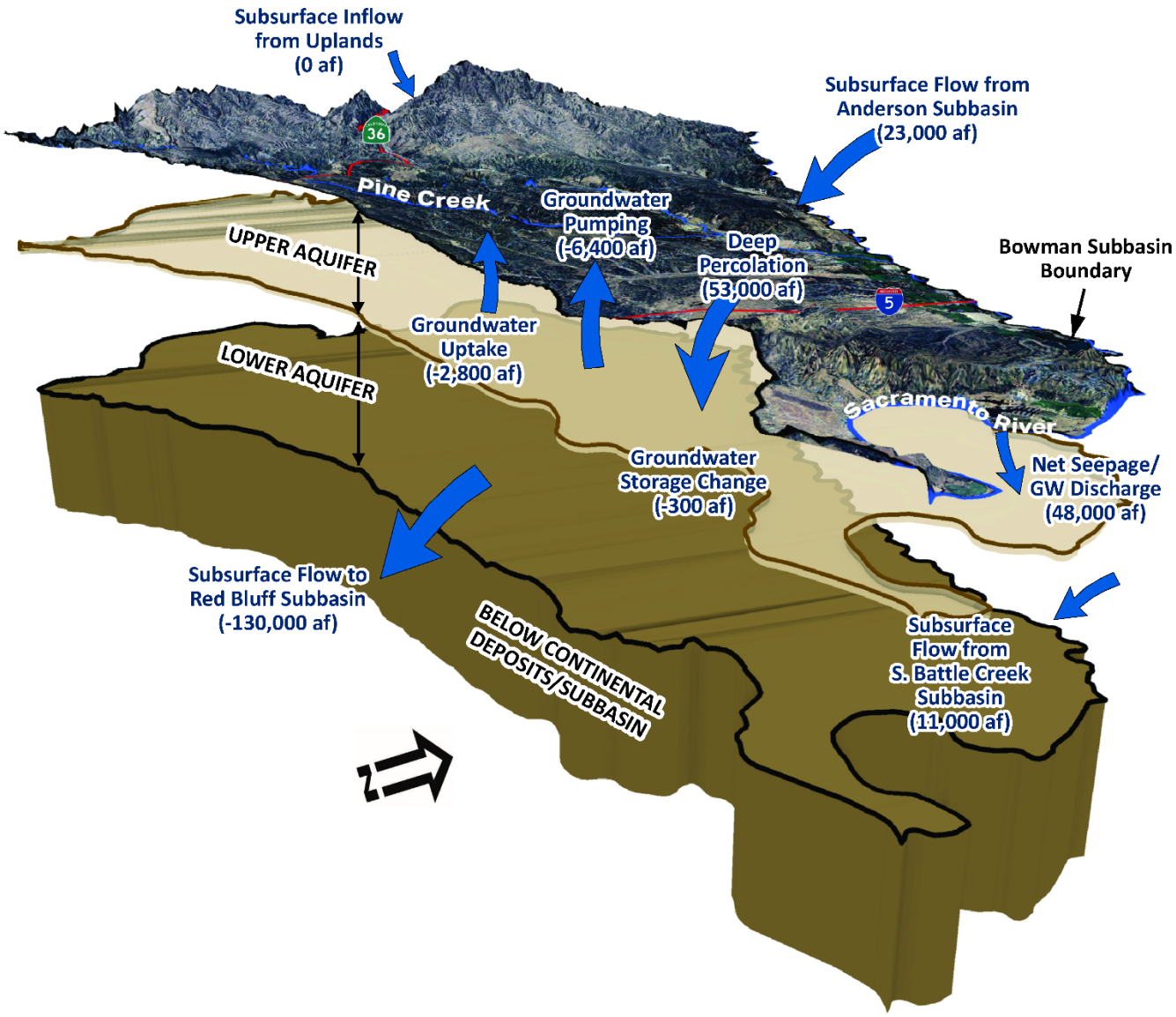


Figure 2-69. Diagram of the Bowman Subbasin Projected (Future Land Use) Average Annual Water Budget, 2022-2072

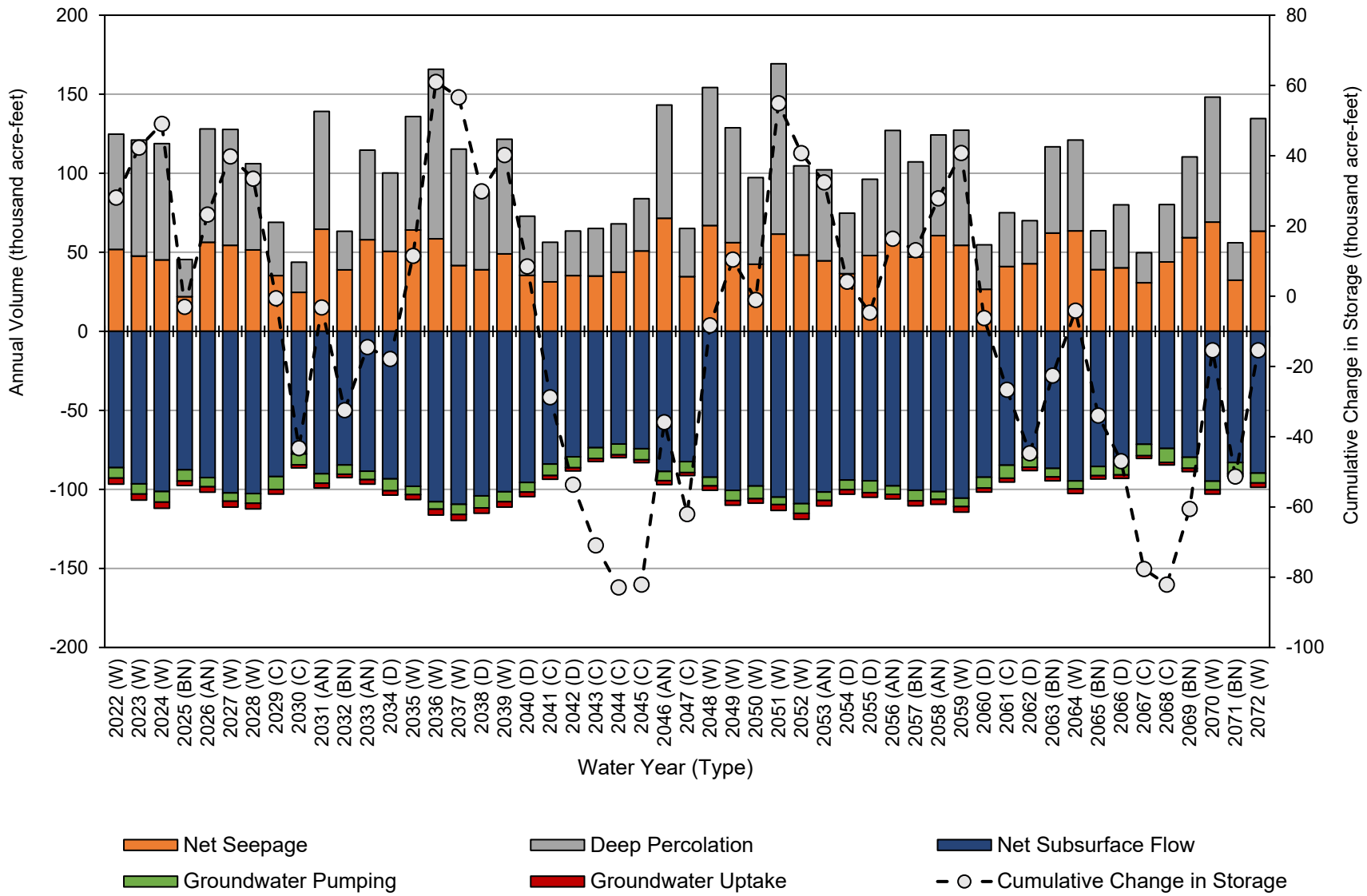


Figure 2-70. Bowman Subbasin Projected (Future Land Use) Water Budget Summary

Table 2-30. Bowman Subbasin Projected (Future Land Use) Water Budget Summary (acre-feet)

WATER YEAR (TYPE)	NET SEEPAGE	DEEP PERCOLATION	NET SUBSURFACE FLOWS	GROUND-WATER PUMPING	GROUND-WATER UPTAKE	ANNUAL GROUNDWATER STORAGE CHANGE	CUMULATIVE GROUNDWATER STORAGE CHANGE
2022 (W)	52,000	73,000	-86,000	-6,600	-3,800	28,000	28,000
2023 (W)	48,000	73,000	-96,000	-6,500	-3,800	14,000	42,000
2024 (W)	45,000	74,000	-100,000	-6,700	-3,900	6,800	49,000
2025 (BN)	22,000	24,000	-88,000	-7,100	-2,800	-52,000	-3,000
2026 (AN)	56,000	72,000	-93,000	-5,800	-3,400	26,000	23,000
2027 (W)	54,000	73,000	-100,000	-5,300	-3,700	17,000	40,000
2028 (W)	51,000	55,000	-100,000	-6,100	-3,600	-6,300	33,000
2029 (C)	35,000	34,000	-92,000	-8,200	-2,900	-34,000	-580
2030 (C)	25,000	19,000	-78,000	-6,900	-1,900	-43,000	-43,000
2031 (AN)	65,000	75,000	-90,000	-6,000	-2,900	40,000	-3,200
2032 (BN)	39,000	24,000	-85,000	-5,800	-2,100	-29,000	-32,000
2033 (AN)	58,000	57,000	-88,000	-5,400	-2,800	18,000	-14,000
2034 (D)	51,000	50,000	-93,000	-7,600	-2,700	-3,400	-18,000
2035 (W)	64,000	72,000	-98,000	-5,300	-3,200	29,000	11,000
2036 (W)	59,000	110,000	-110,000	-4,700	-3,800	50,000	61,000
2037 (W)	42,000	74,000	-110,000	-6,400	-3,800	-4,400	57,000
2038 (D)	39,000	49,000	-100,000	-7,600	-3,400	-27,000	30,000
2039 (W)	49,000	73,000	-100,000	-6,300	-3,400	10,000	40,000
2040 (D)	35,000	37,000	-96,000	-6,100	-2,900	-32,000	8,500
2041 (C)	31,000	25,000	-84,000	-7,300	-2,400	-37,000	-29,000
2042 (D)	35,000	28,000	-79,000	-7,000	-2,000	-25,000	-54,000
2043 (C)	35,000	30,000	-74,000	-6,900	-1,900	-17,000	-71,000
2044 (C)	37,000	30,000	-71,000	-6,900	-1,800	-12,000	-83,000
2045 (C)	51,000	33,000	-74,000	-7,000	-1,800	810	-82,000
2046 (AN)	72,000	72,000	-89,000	-5,800	-2,500	46,000	-36,000
2047 (C)	35,000	30,000	-82,000	-6,900	-1,800	-26,000	-62,000
2048 (W)	67,000	87,000	-92,000	-5,500	-2,800	54,000	-8,300
2049 (W)	56,000	73,000	-100,000	-6,400	-2,900	19,000	10,000
2050 (W)	42,000	55,000	-98,000	-8,000	-2,800	-11,000	-1,100
2051 (W)	62,000	110,000	-100,000	-4,700	-3,700	56,000	55,000
2052 (W)	48,000	56,000	-110,000	-6,200	-3,700	-14,000	41,000
2053 (AN)	45,000	58,000	-100,000	-5,300	-3,500	-8,300	32,000
2054 (D)	36,000	38,000	-94,000	-6,100	-2,800	-28,000	4,200
2055 (D)	48,000	48,000	-95,000	-7,500	-2,900	-8,800	-4,700
2056 (AN)	58,000	69,000	-98,000	-5,300	-3,000	21,000	16,000
2057 (BN)	47,000	60,000	-100,000	-6,700	-3,200	-3,300	13,000
2058 (AN)	61,000	64,000	-100,000	-4,900	-3,100	15,000	28,000
2059 (W)	54,000	73,000	-110,000	-5,300	-3,500	13,000	41,000

WATER YEAR (TYPE)		NET SEEPAGE	DEEP PERCOLATION	NET SUBSURFACE FLOWS	GROUND-WATER PUMPING	GROUND-WATER UPTAKE	ANNUAL GROUNDWATER STORAGE CHANGE	CUMULATIVE GROUNDWATER STORAGE CHANGE
2060 (D)		27,000	28,000	-92,000	-6,900	-2,600	-47,000	-6,200
2061 (C)		41,000	34,000	-85,000	-8,300	-2,500	-20,000	-27,000
2062 (D)		43,000	27,000	-80,000	-6,200	-2,100	-18,000	-45,000
2063 (BN)		62,000	55,000	-87,000	-5,400	-2,400	22,000	-23,000
2064 (W)		64,000	57,000	-95,000	-5,100	-2,800	18,000	-4,100
2065 (BN)		39,000	25,000	-86,000	-5,900	-2,100	-30,000	-34,000
2066 (D)		40,000	40,000	-83,000	-8,200	-2,200	-13,000	-47,000
2067 (C)		31,000	19,000	-71,000	-7,300	-1,700	-31,000	-78,000
2068 (C)		44,000	36,000	-74,000	-8,800	-1,700	-4,400	-82,000
2069 (BN)		59,000	51,000	-80,000	-6,900	-2,100	22,000	-61,000
2070 (W)		69,000	79,000	-95,000	-5,500	-2,600	45,000	-15,000
2071 (BN)		32,000	24,000	-83,000	-7,100	-1,800	-36,000	-51,000
2072 (W)		63,000	71,000	-90,000	-6,300	-2,700	36,000	-15,000
Average (2022-2072)		47,000	53,000	-91,000	-6,400	-2,800	-300	
2022-2072	W	55,000	74,000	-100,000	-5,900	-3,400	20,000	
	AN	59,000	66,000	-94,000	-5,500	-3,000	23,000	
	BN	43,000	37,000	-87,000	-6,400	-2,300	-15,000	
	D	39,000	38,000	-91,000	-7,000	-2,600	-22,000	
	C	36,000	29,000	-79,000	-7,500	-2,000	-22,000	

2.3.9 Projected Water Budgets with Climate Change

Additional projected scenarios were developed to model potential climate change scenarios. Climate change scenarios were developed using the DWR guidance for the 2030 and 2070 central tendencies. Additional detail about the development and results of these scenarios can be found in **Appendices 2-J and 2-K**. The climate change scenarios were implemented following DWR's guidance related to the 2030 and 2070 central tendency climate change scenarios and associated adjustment factors applied to model inputs such as precipitation, ET, and surface water inflows. In the Tehama IHM area, the DWR climate change guidance and adjustment factors tend to result in increases in precipitation, ET, and streamflows.

2.3.9.1 Projected (Current Land Use) Water Budget

A comparison of the major components of the projected (current land use) water budget as they relate to the GWS are presented in **Table 2-31**. Net seepage becomes less negative under climate change scenarios, indicating less groundwater flow to SWS. However, the decrease in the net volume of groundwater discharging to surface water (less negative net seepage) is partly a result of greater streamflow entering the Subbasin under the climate change scenarios and resulting in greater stream seepage. Deep percolation and net subsurface flows remain nearly unchanged under climate change scenarios. Groundwater pumping increases under climate change scenarios, becoming a greater outflow from the groundwater system.

Table 2-31. Comparison of Annual Projected (Current Land Use) GWS Water Budgets with Climate Change Adjustments (acre-feet)

GWS WATER BUDGET COMPONENT	PROJECTED (CURRENT LAND USE)		
	NO CLIMATE CHANGE ADJUSTMENT	CLIMATE CHANGE (2030)	CLIMATE CHANGE (2070)
Net Seepage	46,000	47,000	48,000
Deep Percolation	53,000	53,000	51,000
Net Subsurface Flows	-90,000	-91,000	-89,000
Groundwater Extractions (Pumping and Uptake)	-9,100	-9,300	-9,800
Annual Groundwater Storage Change	***-210***	***-240***	***-420***

Note: positive values indicate inflows/increasing storage, negative values indicate outflows/decreasing storage.

2.3.9.2 Projected (Future Land Use) Water Budget

A comparison of the major components of the projected (future land use) water budget as they relate to the GWS are presented in **Table 2-32**. Overall, the climate change scenarios to not appear to change the overall Subbasin GWS water budget in a considerable way. Net seepage increases very minimally under both 2030 and 2070 climate change scenarios and deep percolation decreases by a small amount. Net subsurface flows also do not change much under climate change scenarios. Groundwater extraction increases minimally by about 200 to 700 acre-feet per year under climate change scenarios.

Table 2-32. Comparison of Annual Projected (Future Land Use) GWS Water Budgets with Climate Change Adjustments (acre-feet)

GWS WATER BUDGET COMPONENT	PROJECTED (FUTURE LAND USE)		
	NO CLIMATE CHANGE ADJUSTMENT	CLIMATE CHANGE (2030)	CLIMATE CHANGE (2070)
Net Seepage	47,000	48,000	49,000
Deep Percolation	53,000	53,000	51,000
Net Subsurface Flows	-91,000	-92,000	-90,000
Groundwater Extractions (Pumping and Uptake)	-9,200	-9,500	-9,900
Annual Groundwater Storage Change	***-300***	***-340***	***-530***

Note: positive values indicate inflows/increasing storage, negative values indicate outflows/decreasing storage.

2.3.10 Projected Groundwater Storage Change by Aquifer

This section presents the projected groundwater storage change in the Upper Aquifer and Lower Aquifer under Current Land Use and Future Land Use conditions with and without the climate change conditions. Note that the total water budget numbers presented below by aquifer may differ from the sum of the average annual values because of rounding. Additional detail about the development and results of these scenarios can be found in **Appendices 2-J and 2-K**.

2.3.10.1 Projected (Current Land Use) Storage Change

A comparison of the groundwater storage change, including by primary aquifer, under the projected (current land use) conditions with different climate change assumptions is presented in **Table 2-33**. The water budget results suggest reduction of storage is only slightly greater under climate chance scenarios, with most of the storage change occurring in the Upper Aquifer. Overall projected storage change in the Subbasin is small and differs little between the different climate change conditions. The projected average annual storage change decreases range from -210 to -420 acre-feet per year and are equivalent to very minimal change on a per-acre basis over the 51-year projected period. Projected annual storage changes in the Upper Aquifer range from annual storage decreases of -320 to -380 acre-feet per year with and without climate change conditions. Storage changes in the Lower Aquifer range from an increase of about 110 acre-feet per year without climate change to a small decrease in storage of -33 acre-feet per year on average with 2070 climate change. The small amounts of change in the entire Subbasin, including individual aquifers, is very small and within the range of uncertainty of the water budget results.

Table 2-33. Comparison of Projected (Current Land Use) Aquifer-Specific GWS Water Budgets with Climate Change Adjustments

PROJECTED (CURRENT LAND USE)		AVERAGE ANNUAL CHANGE IN STORAGE			CUMULATIVE CHANGE IN STORAGE		
		UPPER AQUIFER	LOWER AQUIFER	TOTAL	UPPER AQUIFER	LOWER AQUIFER	TOTAL
No Climate Change Adjustment	acre-feet	-320	110	-210	-16,000	5,600	-11,000
	acre-feet per acre	*0.00*	*0.00*	*0.00*	*-0.13*	*0.05*	*-0.09*
Climate Change 2030	acre-feet	-330	91	-240	-17,000	4,600	-12,000
	acre-feet per acre	*0.00*	*0.00*	*0.00*	*-0.14*	*-0.04*	*-0.10*
Climate Change 2070	acre-feet	-380	-33	-420	-20,000	-1,700	-21,000
	acre-feet per acre	*0.00*	*0.00*	*0.00*	*-0.16*	*-0.01*	*-0.17*

Note: positive values indicate increasing storage, negative values indicate decreasing storage.

2.3.10.2 Projected (Future Land Use) Water Budget

A comparison of the groundwater storage change under the projected (future land use) conditions with different climate change assumptions is presented in **Table 2-34**. As with the projected (current land use) water budget results, the results suggest reduction of storage is only slightly greater under climate chance scenarios, with most of the storage change occurring in the Upper Aquifer. Overall projected storage change in the Subbasin is small and differs little between the different climate change conditions. The projected average annual storage change decreases range from -300 to -530 acre-feet per year and are equivalent to very minimal change on a per-acre basis over the 51-year projected period. Projected annual storage changes in the Upper Aquifer range from annual storage decreases of -340 to -400 acre-feet per year with and without climate change conditions. Storage changes in the Lower Aquifer range from an increase of about 35 acre-feet per year without climate change to a small decrease in storage of -120 acre-feet per year on average with 2070 climate change. The small amounts of change in the entire Subbasin, including individual aquifers, is very small and within the range of uncertainty of the water budget results.

Table 2-34. Comparison of Projected (Future Land Use) Aquifer-specific GWS Water Budgets with Climate Change Adjustments

PROJECTED (CURRENT LAND USE)		AVERAGE ANNUAL CHANGE IN STORAGE			CUMULATIVE CHANGE IN STORAGE		
		UPPER AQUIFER	LOWER AQUIFER	TOTAL	UPPER AQUIFER	LOWER AQUIFER	TOTAL
No Climate Change Adjustment	acre-feet	-340	35	-300	-17,000	1,800	-15,000
	acre-feet per acre	*0.00*	*0.00*	*0.00*	*-0.14*	*0.01*	*-0.12*
Climate Change 2030	acre-feet	-350	11	-340	-18,000	580	-17,000
	acre-feet per acre	*0.00*	*0.00*	*0.00*	*-0.15*	*0.00*	*-0.14*
Climate Change 2070	acre-feet	-400	-120	-530	-21,000	-6,200	-27,000
	acre-feet per acre	*0.00*	*0.00*	*0.00*	*-0.17*	*-0.05*	*-0.22*

Note: positive values indicate increasing storage, negative values indicate decreasing storage.

2.3.11 Uncertainty in Water Budget Estimates

2.3.11.1 Uncertainty in SWS Water Budget

Uncertainties associated with each SWS water budget component have been computed or estimated following the process described by Clemmens and Burt (1997). In summary:

1. The uncertainty of each independently-estimated water budget component (excluding the closure term) is calculated or estimated as a percentage that approximately represents a 95 percent confidence interval for the average annual component volume of the component. Uncertainty percentages are based on the accuracy of measurement devices, the uncertainty of supporting calculations and estimation procedures, and professional judgement.
2. Assuming random, normally-distributed error, the standard deviation is calculated for each independently-estimated component as the average uncertainty on a volumetric basis (uncertainty percentage multiplied by the average annual component volume) divided by two.
3. The variance is calculated for each independently-estimated component as the square of the standard deviation.
4. The variance of the closure term is estimated as the sum of variances of all independently-estimated components.
5. The standard deviation of the closure term is estimated as the square root of the sum of variances.
6. The 95 percent confidence interval of the closure term is estimated as twice the estimated standard deviation.

Estimated uncertainties were calculated following the above procedure for the Subbasin water budget and all GSA water budgets. **Table 2-35** provides a summary of typical uncertainty values associated with major SWS inflows and outflows, along with the sources of these uncertainty values. For surface water flows, deliveries, and diversions, the uncertainty is estimated based on typical accuracy of streamflow gages and measurement devices. For IDC root zone water budget inflows and outflows, the uncertainty is based on typical accuracies given in technical literature and the cumulative estimated accuracy of all inputs used to calculate the components. These uncertainties provide a basis for evaluating confidence in water budget results and help to identify data needs that may be addressed during GSP implementation.

Table 2-35. Estimated Uncertainty of Major Water Budget Components

FLOWPATH DIRECTION (RELATIVE TO SWS)	WATER BUDGET COMPONENT	DATA SOURCE	ESTIMATED UNCERTAINTY (%)	SOURCE
Inflows	Surface Water Inflows	Measurement	5%[1]	Accuracy of USGS streamflow gages, with adjustment for infiltration and evaporation of inflows upstream/downstream of nearest measurement site.
	Deliveries	Measurement	6%	Required delivery measurement accuracy for Reclamation contractors, per the USGS 2017 Standard Criteria for Agricultural Water Management Plans)
	Water Rights Diversions	Measurement/ Estimate	10%	Required diversion measurement accuracy, per California Senate Bill 88.
	Precipitation	Calculation	20%[2]	Clemmens, A.J. and C.M. Burt, 1997.
	Groundwater Extraction	Calculation	20%	Typical uncertainty when calculated for Land Surface System water budget closure. The uncertainty of the accounting center closure is a product of the combined uncertainty of all other inflows and outflows, and the relative magnitude of each component.
Outflows	Surface Water Outflows	Measurement	15%	Estimated streamflow measurement accuracy with adjustment for infiltration and evaporation.
	Evaporation	Calculation	20%	Clemmens and Burt, 1997; typical accuracy of calculation based on CIMIS reference ET and free water surface evaporation coefficient.

FLOWPATH DIRECTION (RELATIVE TO SWS)	WATER BUDGET COMPONENT	DATA SOURCE	ESTIMATED UNCERTAINTY (%)	SOURCE
	ET of Applied Water	Calculation	10%	Clemmens and Burt, 1997; typical accuracy of total irrigation water consumption on irrigated land, parsed into ET of Applied Water and ET of Precipitation by daily root zone water budget component based on reference ET, precipitation, surface energy balance crop coefficients, and annual land use.
	ET of Precipitation	Calculation	10%[2]	Clemmens and Burt, 1997; accuracy of total water consumption on irrigated land, parsed into ET of Applied Water and ET of Precipitation by daily root zone water budget component based on reference ET, precipitation, surface energy balance crop coefficients, and annual land use.
	Infiltration of Applied Water	Calculation	20%[2]	Estimated accuracy of daily IDC root zone water budget based on annual land use and NRCS soils characteristics. Similar accuracy anticipated for monthly results.
	Infiltration of Precipitation	Calculation	20%[2]	Estimated accuracy of daily IDC root zone water budget based on annual land use, NRCS soils characteristics, and CIMIS precipitation.
	Infiltration of Surface Water	Calculation	15%	Typical accuracy of daily seepage calculation using NRCS soils characteristics and measured streamflow data compared to field measurements.

[1] Higher uncertainty of 10-20 percent is typical for estimated surface water inflows, including ungaged inflows from small watersheds into creeks that enter the Subbasin.

[2] IDC root zone water budget inflows and outflows. The uncertainty of these water budget components is based on typical accuracies given in technical literature and the cumulative estimated accuracy of all inputs used to calculate the components

2.3.11.2 GWS Water Budget Uncertainty

Uncertainty associated with the GWS water budget results estimated using the Tehama IHM depends in part on the model inputs relating to the SWS with additional sources of uncertainty associated with model inputs relating to the GWS, including aquifer and streambed properties, specification of boundary conditions, and other factors. The uncertainty estimates associated with SWS water budget components that are also inputs or outputs of the GWS water budget are noted above. The overall uncertainty of other water budget components simulated for the GWS, including subsurface flows, groundwater discharging to surface water, and change in groundwater storage are estimated to be slightly higher, in the range of 15 to 30 percent. These GWS water budget components are subject to higher uncertainty as a result of limitations in available input data and simplification required in modeling of the subsurface heterogeneity. However, the uncertainty in GWS water budget results derived from a numerical model such as the Tehama IHM depends to a considerable degree on the calibration of the model and can vary by location and depth within the Subbasin. The Tehama IHM is a product of local refinement and improvements made to the SVSim model and calibration at a more local scale. The Tehama IHM simulates the integrated groundwater and surface water system and metrics relating to the calibration of the model indicate the model is reasonably well calibrated in accordance with generally accepted professional guidelines and is sufficient for GSP-related applications. The calibration and sensitivity of the model and different model parameters are presented in **Appendix 2-J**.

2.3.12 Estimate of Sustainable Yield

GSP Regulations require the GSP quantify the sustainable yield for the Subbasin. Sustainable yield is defined as “the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result” (CWC Section 10721(w)). Historical and projected model results show that the conditions in the Subbasin under the historical and anticipated future land use conditions and hydrology, including with potential climate change conditions (2030 and 2070), will not cause the occurrence of undesirable results in the Subbasin over the 50-year GSP planning period based on sustainability indicator Minimum Thresholds (MTs) developed for the Subbasin.

The Bowman Subbasin has historically pumped on average about 6,100 acre-feet per year of groundwater. An additional 3,000 acre-feet of groundwater is estimated to be taken up and consumed directly by plants reflecting a total historical groundwater extraction volume of about 9,100 acre-feet per year on average. Observed groundwater level conditions and simulated water budget results suggest there has been little or no historical long-term change in groundwater storage in the Subbasin. Although some of the water budget components change under the different projected scenarios as a result of changes in land use and climate conditions being simulated, total groundwater extraction (combination of groundwater pumping and uptake) within the Subbasin does not change considerably with estimated increases in groundwater extraction of less than a thousand acre-feet per year. Under the projected future land use with 2070 climate change, groundwater extractions total only slightly more at about 9,900 acre-feet per year on average. The groundwater extraction water budget component is relatively small in comparison to the net seepage, deep percolation, and subsurface flow water budget components. Under all of the projected

scenarios, the change in storage is simulated to be very small or zero recognizing typical uncertainty associated with water budget estimates.

Accordingly, for the purpose of the GSP, the sustainable yield is estimated to be 10,000 acre-feet per year, which is equal to the volume of groundwater extracted annually in the Subbasin (by pumping and by uptake) under the projected model scenario with future land use and 2070 climate change conditions and considering the level of uncertainty associated with water budget estimates. Assuming potential uncertainty of 25 percent associated with the water budget estimates, an associated range of values for the estimated sustainable yield would be 7,500 to 12,500 acre-feet per year. It is possible that the true sustainable yield is higher as no model scenarios were developed to test the maximum possible volume of groundwater extraction. The sustainable yield estimate provided here is consistent with the sustainability goal for the Subbasin and will be reviewed as the Subbasin implements the GSP, including through periodic review and updates to the Tehama IHM and water budget results and ongoing monitoring of Subbasin conditions as required by GSP Regulations.

2.4 References

California Department of Water Resources (DWR). 2021. SVSim: Sacramento Valley Groundwater-Surface Water Simulation Model. Downloaded May 5, 2020. Available online: https://data.cnra.ca.gov/dataset/svsim.

California Department of Water Resources (DWR). 2016a. Best Management Practices for Sustainable Management of Groundwater, Water Budget, BMP. California DWR Sustainable Groundwater Management Program. December 2016. Available online: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-4-Water-Budget_ay_19.pdf.

California Department of Water Resources (DWR). 2016b. 2016 Statewide Crop Mapping Metadata. Updated January 2020. Available online: https://data.cnra.ca.gov/dataset/statewide-crop-mapping/resource/d5841996-ba8b-455c-819f-222006db7b85

California Department of Water Resources (DWR). 2003. California's Groundwater, Bulletin 118 – Update 2003. Available online: https://data.cnra.ca.gov/dataset/california-s-groundwater-bulletin-118-archive

Clemmens, A. J. and C. M. Burt. 1997. Accuracy of irrigation efficiency estimates. J. Irrig. and Drain. Engng. 123(6): 443-453.