6. Water Budgets

6.1 Water Budget Information

Water budgets were developed to provide a quantitative account of water entering and leaving the NASb. Water entering the Subbasin includes water entering at the surface and through the subsurface. Similarly, water leaving the Subbasin leaves at the surface and through the subsurface. Water enters and leaves naturally, such as precipitation and streamflow, and through human activities, such as pumping and recharge from irrigation or outdoor water use. As in the California Department of Water Resources' (DWR's) Water Budget BMP (DWR 2016c), water budgets are presented separately for the land surface system, stream and canal system, and groundwater system. The different frame of reference for each of these systems provides insight into how the overall system behaves, which is critical for successful management. **Figure 6-1** highlights the interconnectivity of stream, surface, and groundwater components of the natural and human related hydrologic system used in this analysis.

The values presented in the water budget provide information on historical, current, and projected conditions as they relate to hydrology, water demand, water supply, land use, population, climate conditions, such as climate change, groundwater and surface water interaction, and subsurface groundwater flow. This information can assist in management of the Subbasin groundwater and surface water resources, by identifying the scale of different uses, highlighting potential risks, and identifying potential opportunities to improve water supply conditions, among others.

Water budgets can be developed on different scales. In agricultural use, water budgets may be limited to the root zone, improving irrigation techniques by estimating the inflows and outflows of water from the upper portion of the soil accessible to plants through their roots. In a pure groundwater study, water budgets may be limited to water flow within the subsurface, aiding in understanding how water flows beneath the surface. Global climate models simulate water budgets that incorporate atmospheric water, allowing for simulation of climate change conditions. In this document, consistent with the Regulations (CCR, Title 23), the water budgets investigate the combined land surface, stream, and groundwater systems for the NASb.

Water budgets can also be developed at different temporal scales. Daily water budgets may be used to demonstrate how evaporation and transpiration increase during the day and decrease at night. Monthly water budgets may be used to demonstrate how groundwater pumping increases in the dry, hot summer months and decreases in the cool, wet winter months. The water budget analyses are performed on a monthly basis using the CoSANA model and are aggregated to annual budgets. However, for the purposes of this Groundwater Sustainability Plan (GSP), the water budgets are presented on a long-term average annual basis, as well by hydrologic year type.

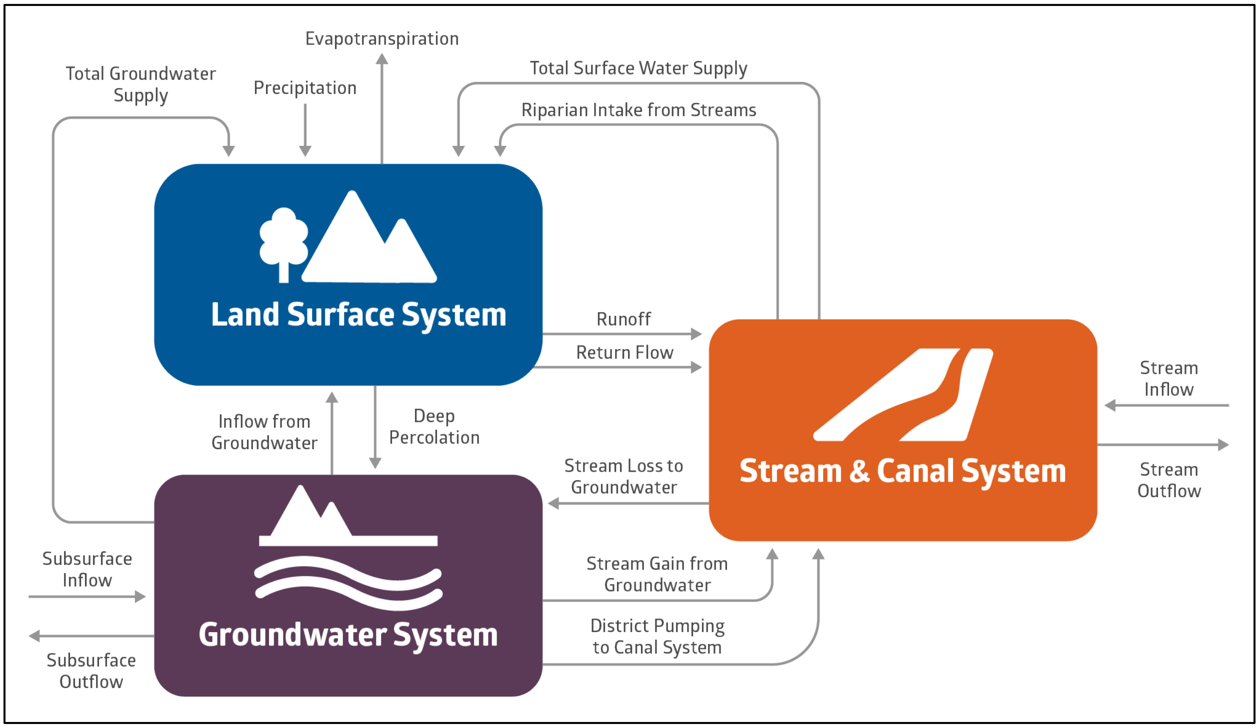

Figure 6-1. Generalized Water Budget Diagram

The Regulations require the annual water budgets to be based on three different levels of development: historical, current, and projected conditions. Budgets are developed to capture typical conditions during these time periods. Typical conditions are developed through averaging hydrologic conditions that incorporate droughts, wet periods, and normal periods. By incorporating these varied conditions within the budgets, analysis of the system under certain hydrologic conditions, such as drought, can be performed along with analysis of long-term averages. Information is provided in the following subsections on the hydrology dataset used to identify time periods for budget analysis; the usage of the CoSANA model and associated data in water budget development; and on the budget estimates.

6.2 Identification of Hydrologic Periods

Hydrologic periods were selected to meet the needs of developing historical, current, and projected water budgets. The Regulations require that the projected water budget incorporate a 50-year hydrologic period in order to reflect long-term average hydrologic conditions. Precipitation data for the Subbasin is derived from the PRISM (Precipitation-Elevation Regressions on Independent Slopes Model) dataset of DWR's California Simulation of Evapotranspiration of Applied Water model. Precipitation for the NASb was used to identify hydrologic periods that would provide a representation of wet and dry periods and long-term average conditions needed for water budget analyses.

Identification of periods with a balance of wet and dry periods was performed by evaluating the cumulative departure from mean precipitation. Under this method, the long-term average precipitation is subtracted from annual precipitation within each water year to develop the departure from mean precipitation for each water year. Wet years have a positive departure and dry years have a negative departure; a year with exactly average precipitation would have zero departure. Starting at the first year analyzed, the departures are added cumulatively for each year. So, if the departure for Year 1 is 5 inches and the departure for Year 2 is -2 inches, the cumulative departure would be 5 inches for Year 1 and 3 inches (5 plus -2) for Year 2. A chart is used to graphically illustrate the cumulative departure of the spatially averaged rainfall within the Subbasin (**Figure 6-2**). The chart includes bars displaying annual precipitation for each water year from 1970 through 2019 and a horizontal line representing the mean precipitation of 20.2 inches. This is less than 1 inch per year greater than the long-term (1922-2019) average of 19.3 inches. The cumulative departure from mean precipitation is based on these data sets and is displayed as a line that starts at zero and highlights wet periods with upward slopes and dry periods with downward slopes. More severe events are shown by steeper slopes and greater changes. Thus, the period from 1976 to 1977 illustrates a short period with dramatically dry conditions (23-inch decline in cumulative departure over 2 years). In addition to the 1976-1977 drought, the 1970-2019 period also includes the extended drought periods of 1987-1992 and 2012-2016 and the historical wet periods of 1982-1983 and 1995-1998.

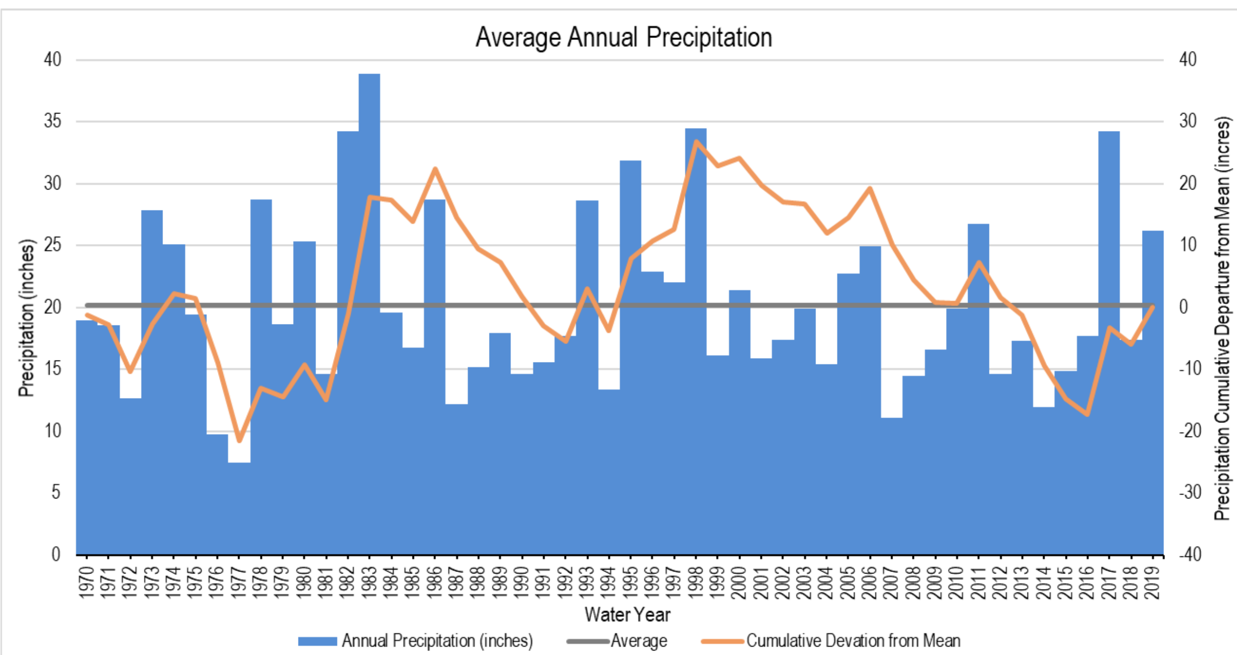

Figure 6-2. 50-Year Historical Precipitation and Cumulative Departure from Mean Precipitation in the North American Groundwater Basin

6.3 Usage of the CoSANA Model and Associated Data in Water Budget Development

Water budgets were developed utilizing the CoSANA model, a fully integrated surface and groundwater flow model that covers the entire NASb as well as the adjoining South American and Cosumnes Subbasins. CoSANA was developed with the RWA as the lead agency with collaboration by GSAs in each respective Subbasin. CoSANA is a quasi-three-dimensional finite element model that was developed using the Integrated Water Flow Model 2015 software package to simulate the relevant hydrologic processes prevailing in the region. CoSANA integrates the groundwater aquifer with the surface hydrologic system and land surface processes and operations. Using data from federal, state, and local resources, CoSANA was calibrated for the hydrologic period of October 1994 to September 2018 by comparing simulated evapotranspiration, groundwater levels, and streamflow records with historical observed records. Development of the model involved the study and analyses of hydrogeologic conditions, agricultural and urban water demands, agricultural and urban water supplies, and an evaluation of regional water quality conditions. Two baseline models were developed reflecting the current and projected levels of development for each Subbasin to support GSP development.

Additional information on the data and assumptions used to develop the CoSANA model is included in **Appendix P**.

With the CoSANA model as the underlying framework, model simulations were developed to allow for the estimation of water budgets. Four model simulations were used to develop the water budgets for historical, current, projected and projected with climate change conditions, which are discussed in detail below:

- The **historical water budget** is based on a simulation of historical conditions in the NASb.
- The **current water budget** is based on a simulation of current land and water use over historical hydrologic conditions, assuming no other changes in population, water demands, land use, or other conditions.
- The **projected water budget** is based on a simulation of future land and water use over historical hydrologic conditions.
- The **projected with climate change water budget** is based on a simulation of future land and water use over hydrologic conditions modified to reflect future climate.

6.4 Water Budget Definitions and Assumptions

Definitions and assumptions for the historical, current, and projected water budgets are provided below.

6.4.1 Historical Water Budget

The historical water budget is intended to evaluate availability and reliability of past surface water supply deliveries, aquifer response to water supply, and demand trends relative to water year type. The hydrologic period of WY 2009 through 2018 was analyzed to provide a period of representative hydrology while capturing recent operations in the Subbasin. The period WY 2009 through 2018 has an average annual precipitation of approximately 19.0 inches, compared to the long-term (1970 - 2019) average of 20.2 inches and includes wet and dry periods as follows, according to the Sacramento Valley Index:

- Critical: 2014, 2015
- Dry: 2009, 2013
- Below normal: 2010, 2012, 2016, 2018
- Above normal: none
- Wet: 2011, 2017

6.4.2 Current Water Budget

While a budget indicative of current conditions could be developed using the most recent historical conditions, like the historical water budget, such an analysis would be difficult to interpret due to the extreme weather conditions of the past several years and its effect on local water system operations. Instead, to analyze the long-term effects of current land and water use on groundwater conditions and to accurately estimate current inflows and outflows for the basin, a Current Conditions Baseline scenario is developed using the CoSANA model. This baseline applies current land and water use conditions to historical hydrology.

The Current Conditions Baseline includes the conditions described in **Table 6-1**.

Table 6-3. Current Water Budget Conditions Summary

Component	Description
Hydrologic Period	Water years 1970-2019 (50-year hydrology)
River Flow	Historical records from the United States Geological Survey (USGS) and California Data Exchange Center (CDEC), and the simulation of small-stream watersheds
Land Use	2014 statewide California crop mapping
	2015 Sacramento County land use survey
	Local ground truthing and refinement
Urban Water Demand	2015 demands as reported in the 2015 Urban Water Management Plan (UWMP)
	Municipal pumping records
Agricultural Water Demand	2015 land use and cropping conditions, adjusted for urban growth areas based on General Plans
	Irrigation practices are assumed to be similar to those in 2019

6.4.3 Projected Water Budget

The projected water budget is intended to assess the conditions of the Subbasin under projected conditions of land use; water supply; and agricultural and urban demand. The Projected Conditions Baseline applies future land and water use conditions and uses a 50-year hydrologic period of WY 1970-2019. The Projected Conditions Baseline is analyzed with and without climate change.

The Projected Conditions Baseline includes the conditions described in **Table 6-2**

Table 6-4. Projected Water Budget Conditions Summary

Component	Description
Hydrologic Period	Water Years 1970-2019 (50-year hydrology)
River Flow	Historical records from the USGS and CDEC, and the simulation of small-stream watersheds
Land Use	2014 statewide California crop mapping
	2015 Sacramento County land use survey
	Agricultural Water Management Plan projections
	Direct communication on future projections with local agencies
Urban Water Demand	Decadal population projections from 2015 UWMPs for most users
Agricultural Water Demand	2015 land use and cropping conditions, adjusted for urban growth areas based on General Plans
	Irrigation practices are assumed to be similar to those in 2019

Table 6-3 provides a summary of the groundwater budget assumptions for each of the three water budget types.

Table 6-5. Summary of Groundwater Budget Assumptions

Water Budget Type	Historical	Current	Projected
Scenario	Historical Simulation	Current Conditions Baseline	Projected Conditions Baseline
Hydrologic Years	WY 2009-2018	WY 1970-2019	WY 1970-2019
Level of Development	Historical	Current	General Plan buildout
Agricultural Demand	Historical Records	Current Conditions	Projected based on projected land use changes
Urban Demand	Historical Records	Current Conditions	Projected based on local UWMP data
Water Supplies	Historical Records	Current Conditions	Projected based on local UWMP data

6.4.4 Water Budget Estimates

For each baseline condition, water budgets have been developed for the stream and canal system, the land surface system, and for the groundwater system.

The water budget components for the stream and canal system are shown separately for the following river reaches:

- American River from Folsom Lake to the confluence with Sacramento River (**Table 6-4**)
- Bear River starting at the boundary of the groundwater subbasin, approximately 1.5 miles downstream from Camp Far West Dam, to the confluence with Feather River (**Table 6-5**)
- Sacramento River from the Feather River confluence to the American River confluence (**Table 6-6**)
- Feather River from Bear River confluence to the Sacramento River confluence (**Table 6-7**)

A composite water budget for these stream reaches is shown in **Table 6-8**. The primary components that are reported in each of these tables are:

- Inflows:
    - Upstream inflows
    - Tributary inflows
    - Stream gain from the groundwater system
    - Surface runoff to the stream system
    - Return flow to stream system

- Outflows:
    - Stream losses to groundwater system
    - Surface water deliveries
    - Stream outflows

Total inflows to the subbasin are summarized in **Table 6-9**. Note that **Tables 6-4 through 6-8** include upstream inflows, which are the inflows of the four major rivers into the Subbasin, and tributary inflows, which are inflows from the tributaries into the major rivers. As such, **Tables 6-4 through 6-8** do not include total inflows entering the subbasin, values which are provided in **Table 6-9**.

The primary components of the land surface system in the NASb (**Table 6-10**) are:

- Inflows:
    - Precipitation
    - Surface water supplies
    - Groundwater supplies
    - Recycled water supplies
    - Riparian intake from streams
- Outflows:
    - Evapotranspiration
    - Surface runoff to the stream system
    - Return flow to the stream system
    - Deep percolation

The primary components of the groundwater system in the NASb (**Table 6-11**) are:

- Inflows:
    - Deep percolation
    - Infiltration from the stream system
    - Subsurface inflow
- Outflows:

  - Discharge to the stream system
  - Groundwater production
  - Subsurface outflow
- Change in groundwater storage

The estimated water budgets are provided below for the historical, current, and projected water budgets in AFY in the tables below.

Table 6-6. Average Annual Water Budget – American River (AFY)

Component	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Projected Condition Water Budget with Climate Change
Hydrologic Period	WY 2009-2018	WY 1970 - 2019	WY 1970 - 2019	WY 1970 – 2019
Inflows				
Upstream Inflow	2,524,600	2,688,100	2,688,100	2,337,800
Tributary Inflows[1]	57,400	58,400	66,800	69,100
Groundwater Discharge	24,200	29,400	26,100	24,900
Surface Runoff	-	-	-	-
Direct Return Flow to Streams	15,800	17,800	17,800	17,800
Total Inflow	2,622,100	2,793,700	2,798,700	2,449,500
Outflows				
Infiltration to Groundwater	46,300	43,900	52,500	53,700
Surface Water Diversions	46,000	43,000	62,900	62,900
Outflow to Sacramento River	2,529,800	2,706,800	2,683,400	2,333,000
Total Outflow	2,622,100	2,793,700	2,798,700	2,449,500

Notes:

[1]Local Tributaries include Alder Creek, Buffalo Creek, and small watersheds for unmodeled streams. Alder Creek and Buffalo Creek are both within the South American Subbasin

Table 6-7. Average Annual Water Budget – Bear River (AFY)

Component	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Projected Condition Water Budget with Climate Change
Hydrologic Period	WY 2009-2018	WY 1970 - 2019	WY 1970 - 2019	WY 1970 – 2019
Inflows				
Upstream Bear River Inflow	305,800	257,100	257,100	251,200
Tributary Inflows[1]	1,300	1,700	1,700	1,700
Groundwater Discharge	12,800	15,500	14,300	7,700
Surface Runoff	3,400	3,700	3,700	3,800
Direct Return Flow to Streams	12,900	15,400	15,200	15,600
Total Inflow	*336,200*	*293,400*	*292,000*	*280,000*
Outflows				
Infiltration to Groundwater	-	-	-	-
Surface Water Diversions[2]	-	-	-	-
Outflow to Feather River	336,200	293,400	292,000	280,000
Total Outflow	*336,200*	*293,400*	*292,000*	*280,000*

Notes:

[1]Local Tributaries include small watersheds for unmodelled streams

[2]Diversions incorporated within CoSANA from the Bear River occur upstream of the groundwater subbasin

Table 6-8. Average Annual Water Budget – Sacramento River (AFY)

Component	**Historical Condition Water Budget**	**Current Condition Water Budget**	**Projected Condition Water Budget**	**Projected Condition Water Budget with Climate Change**
Hydrologic Period	**WY 2009-2018**	**WY 1970 - 2019**	**WY 1970 - 2019**	**WY 1970 – 2019**
Inflows				
Upstream Feather River & Sacramento River Inflow	12,161,000	14,330,700	14,330,700	12,111,200
Tributary Inflows[1]	292,000	327,900	367,000	361,400
Groundwater Discharge	29,200	30,500	24,500	22,800
Surface Runoff	8,800	8,600	13,700	13,800
Direct Return Flow to Streams	28,900	32,800	34,800	35,100
Total Inflow	12,519,800	14,730,400	14,770,700	12,544,200
Outflows				
Infiltration to Groundwater	-	-	-	-
Surface Water Diversions	90,400	89,400	64,100	66,700
Outflow Downstream of American River Confluence	12,429,500	14,641,000	14,706,600	12,477,500
Total Outflow	12,519,800	14,730,400	14,770,700	12,544,200

Notes:

[1]Local Tributaries include Natomas East Drain and Natomas Cross Canal

Table 6-9. Average Annual Water Budget – Feather River (AFY)

Component	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Projected Condition Water Budget with Climate Change
Hydrologic Period	WY 2009-2018	WY 1970 - 2019	WY 1970 - 2019	WY 1970 – 2019
Inflows				
Upstream Bear River Inflow	336,200	293,400	292,000	280,000
Upstream Feather River Inflow	4,563,200	5,860,300	5,860,300	4,679,600
Tributary Inflows	-	-	-	-
Groundwater Discharge	-	-	-	-
Surface Runoff	-	1	-	-
Direct Return Flow to Streams	-	-	-	-
Total Inflow	*4,899,400*	*6,153,700*	*6,152,300*	*4,959,600*
Outflows				
Infiltration to Groundwater	25,900	30,700	30,800	27,300
Surface Water Diversions	11,000	11,000	11,000	11,000
Outflow to Sacramento River	4,862,400	6,112,000	6,110,500	4,921,400
Total Outflow	*4,899,400*	*6,153,700*	*6,152,300*	*4,959,600*

Table 6-10. Average Annual Water Budget – Composite of All Major Rivers (AFY)

Component	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Projected Condition Water Budget with Climate Change
Hydrologic Period	WY 2009-2018	WY 1970 - 2019	WY 1970 - 2019	WY 1970 – 2019
Inflows				
Upstream Inflow[1]	14,681,100	17,013,200	17,014,700	14,447,500
Tributary Inflows[2]	350,700	388,000	435,500	432,200
Groundwater Discharge	66,200	75,400	64,800	55,300
Surface Runoff	12,200	12,200	17,400	17,600
Direct Return Flow to Streams	57,600	66,000	67,700	68,400
Total Inflow	15,167,800	17,554,800	17,600,200	15,021,000
Outflows				
Infiltration to Groundwater	72,200	74,600	83,300	80,900
Surface Water Diversions	147,400	143,400	138,000	140,600
Outflow from Sacramento and American Rivers	14,948,300	17,336,800	17,379,000	14,799,500
Total Outflow	15,167,800	17,554,800	17,600,200	15,021,000

Notes:

[1]Upstream inflows include Bear River, Feather River, Sacramento River, and American River flows into the North American Subbasin

[2]Local Tributaries include Racoon Creek, East Side Canal, Auburn Ravine, Pleasant Grove Creek, Pleasant Grove Creek Canal, Cross Canal. Natomas East Drain, Dry Creek, Magpie Creek, Arcade Creek, Buffalo Creek, and Alder Creek inflow into major rivers. Note that this list includes simulated tributaries within the South American Subbasin as well.

Table 6-11. Total Inflows to the Subbasin

Component	Historical Calibration (AFY)	Current Conditions (AFY)	Projected Conditions (AFY)	Projected Conditions with Climate Change (AFY)
Hydrologic Period	WY 2009 - 2018	50-Year Period	50-Year Period	50-Year Period
Auburn Ravine Upstream Flow	14,600	16,600	16,600	16,600
Pleasant Grove Creek Upstream Flow	22,100	25,200	25,200	25,200
Dry Creek Upstream Flow	29,600	33,500	33,500	34,000
Bear River Upstream Flow	305,800	257,100	257,100	251,200
Feather River Upstream Flow	4,563,200	5,860,300	5,860,300	4,679,600
Sacramento River Upstream Flow	7,287,600	8,207,700	8,209,200	7,178,800
American River Upstream Flows	2,524,600	2,688,100	2,688,100	2,337,800
Total Inflows	*14,747,500*	*17,088,400*	*17,090,000*	*14,523,300*
Outflow to Sacramento River	*14,948,300*	*17,336,800*	*17,379,000*	*14,799,500*

Table 6-12. Average Annual Water Budget – Land Surface System, North American Subbasin (AFY)

Component	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Projected Condition Water Budget with Climate Change
Hydrologic Period	WY 2009-2018	WY 1970 - 2019	WY 1970 - 2019	WY 1970 – 2019
Inflows				
Precipitation	551,000	590,800	590,800	592,800
Total Surface Water Supply				
Municipal and Industrial	117,900	117,600	220,200	220,200
Agricultural	189,900	189,000	149,900	152,500
Total Groundwater Supply				
Municipal and Industrial	66,600	69,000	102,400	102,400
Agricultural	200,300	206,100	200,500	*220,400*
Ag Residential	20,600	20,600	14,600	14,600
Total Recycled Water Supply				
Remediated Municipal and Industrial	-	-	-	-
Recycled Water	-	-	-	-
Total Inflow	*1,146,300*	*1,193,000*	*1,278,400*	*1,302,900*
Outflows				
Evapotranspiration				
Municipal and Domestic	127,200	128,900	203,600	207,700
Agricultural	299,200	297,900	270,400	293,600
Refuge, Native, and Riparian	68,500	69,900	42,000	43,300
Runoff to the Stream System	297,000	328,400	356,300	358,400
Return Flow to the Stream System				
Agricultural	68,600	73,300	59,400	59,800
Municipal and Domestic	102,900	104,800	171,900	171,900
Deep Percolation				
Precipitation	53,100	55,700	42,600	39,900
Applied Surface Water				
Urban and Industrial	24,600	25,000	40,000	37,500
Agricultural	39,700	40,100	27,200	26,000
Applied Groundwater				
Urban and Industrial	13,900	14,600	18,600	17,500
Agricultural	41,900	43,700	36,400	37,600
Ag Residential	4,300	4,400	2,700	2,500
Applied Recycled Water				
Urban and Industrial	-	-	-	-
Applied Remediated Water				
Urban	-	-	-	-
Other Flows[1]	5,500	6,300	7,300	7,200
Total Outflow	*1,146,300*	*1,193,000*	*1,278,400*	*1,302,900*

Notes: [1] "Other Flows" is a closure term that captures the gains and losses due to land expansion and temporary seasonal storage in the root-zone.

Table 6-13. Average Annual Water Budget – Groundwater System, North American Subbasin (AFY)

Component	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Projected Condition Water Budget with Climate Change
Hydrologic Period	WY 2009-2018	WY 1970 - 2019	WY 1970 - 2019	WY 1970 – 2019
Inflows				
Deep Percolation				
Precipitation	53,100	55,700	42,600	39,900
Applied Surface Water				
Urban and Industrial	24,600	25,000	40,000	37,500
Agricultural	39,700	40,100	27,200	26,000
Applied Groundwater				
Urban and Industrial	13,900	14,600	18,600	17,500
Agricultural	41,900	43,700	36,400	37,600
Ag Residential	4,300	4,400	2,700	2,500
Applied Recycled Water				
Urban and Industrial	-	-	-	-
Applied Remediated Water				
Urban	-	-	-	-
Infiltration from Streams				
American River	23,500	21,700	27,100	28,100
Bear River	3,300	2,700	3,000	5,000
Feather River	10,900	12,300	12,400	13,500
Sacramento River	3,700	6,100	7,600	8,400
Local Tributaries[1]	92,600	91,700	104,200	108,600
Groundwater Injection (from ASR and Remediation)	300	200	2,100	2,100
Other Recharge[2]	16,700	16,700	16,400	16,400
Subsurface Inflow				
South American Subbasin	21,800	16,600	18,300	18,400
Sutter Subbasin	1,400	1,400	1,400	2,100
Yolo Subbasin	10,200	9,000	10,800	11,800
Yuba Subbasin	6,500	6,700	6,800	7,600
Foothills	12,100	13,600	13,600	13,200
Outside B118 Subbasin	2,600	2,600	2,700	3,200
Total Inflow	*383,000*	*384,700*	*393,800*	*399,500*
Outflows				
Discharge to Streams				
American River	6,100	7,100	6,600	6,500
Bear River	9,500	10,000	9,100	6,400
Feather River	4,300	4,900	4,800	5,300
Sacramento River	16,300	20,300	15,800	16,200

Component	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget	Projected Condition Water Budget with Climate Change
Local Tributaries[1]	8,200	10,700	10,000	7,200
Groundwater Pumping				
Urban and Industrial	66,600	69,000	102,400	102,400
Ag Residential	20,600	20,600	14,600	14,600
Agricultural	200,300	206,100	200,500	220,400
Remediation	8,900	7,700	7,700	7,700
Subsurface Outflow				
South American Subbasin	7,700	9,700	13,000	13,200
Sutter Subbasin	1,400	2,000	2,000	1,400
Yolo Subbasin	400	500	400	400
Yuba Subbasin	100	100	100	100
Outside B118 Subbasin	900	1,400	1,300	1,100
Other Flows[3]	-	-	-	100
Total Outflow	*351,100*	*369,900*	*388,400*	*403,000*
Change in Groundwater Storage	*31,900*	*14,900*	*5,400*	*(3,500)*

Notes:

[1]Local Tributaries include Racoon Creek, East Side Canal, Auburn Ravine, Pleasant Grove Creek, Pleasant Grove Creek Canal, Cross Canal. Natomas East Drain, Dry Creek, Magpie Creek, and Arcade Creek.

[2]Other Recharge includes primarily unlined canals seepage.

[3] Other Flows is a closure term to help balance the model in the projected conditions with climate change scenario only.

6.5 Historical Water Budget

The historical water budget is a quantitative evaluation of the historical surface and groundwater supply covering the 10-year period from WY 2009 to 2018. This period was selected as the most recent, modeled, representative hydrologic period to represent recent historical conditions in the subbasin and as a subset of the CoSANA model calibration period of WY 1995 to 2018. The goal of the historical water budget analysis is to characterize the supply and demand, while summarizing the hydrologic flow within the Subbasin, including the movement of all primary sources of water such as rainfall, irrigation, streamflow, and subsurface flows.

The existing stream and canal network supplies multiple water users and agencies in the NASb, including the City of Sacramento, Carmichael Water District (WD), Natomas MWC, and Pleasant Grove Verona MWC. In addition to these entities, South Sutter WD, City of Roseville, City of Lincoln, San Juan WD, Orange Vale WC, Citrus Heights WD, California American WC, Sacramento Suburban WD, Fair Oaks WD, and Placer County WA supplied areas receive surface water that originates outside of the model boundaries.

When analyzing the stream and canal system, it is important to note potentially significant effects resulting from the natural interactions and managed operations of adjacent groundwater subbasins. Because the CoSANA model covers multiple subbasins, it is not always possible to distinguish between stream system inflows and outflows by subbasin. Because of this, the water budgets in **Tables 6-4 through Table 6-7** quantify budgets based on the major rivers and their associated tributaries. **Figure 6-3** below shows the composite inflows and outflows for portions of the American, Feather, Bear, and Sacramento Rivers that are adjacent to the NASb.

During the historical period, average annual surface water inflows of about 14,681,100 acre-feet (AF) enter the CoSANA model boundary via the American, Feather, Bear, and Sacramento Rivers. These flows are supplemented by tributary inflows (350,700 AFY), gain from groundwater (66,200 AFY), runoff (12,200 AFY), and direct return flows (57,600 AFY). These are offset by an equal quantity of stream outflows on these river reaches. Most of the streamflows flow out to the Sacramento and American Rivers (14,948,300 AFY). However, additional water exits the stream system as seepage to groundwater (72,200 AFY) and surface water diversions (147,400 AFY).

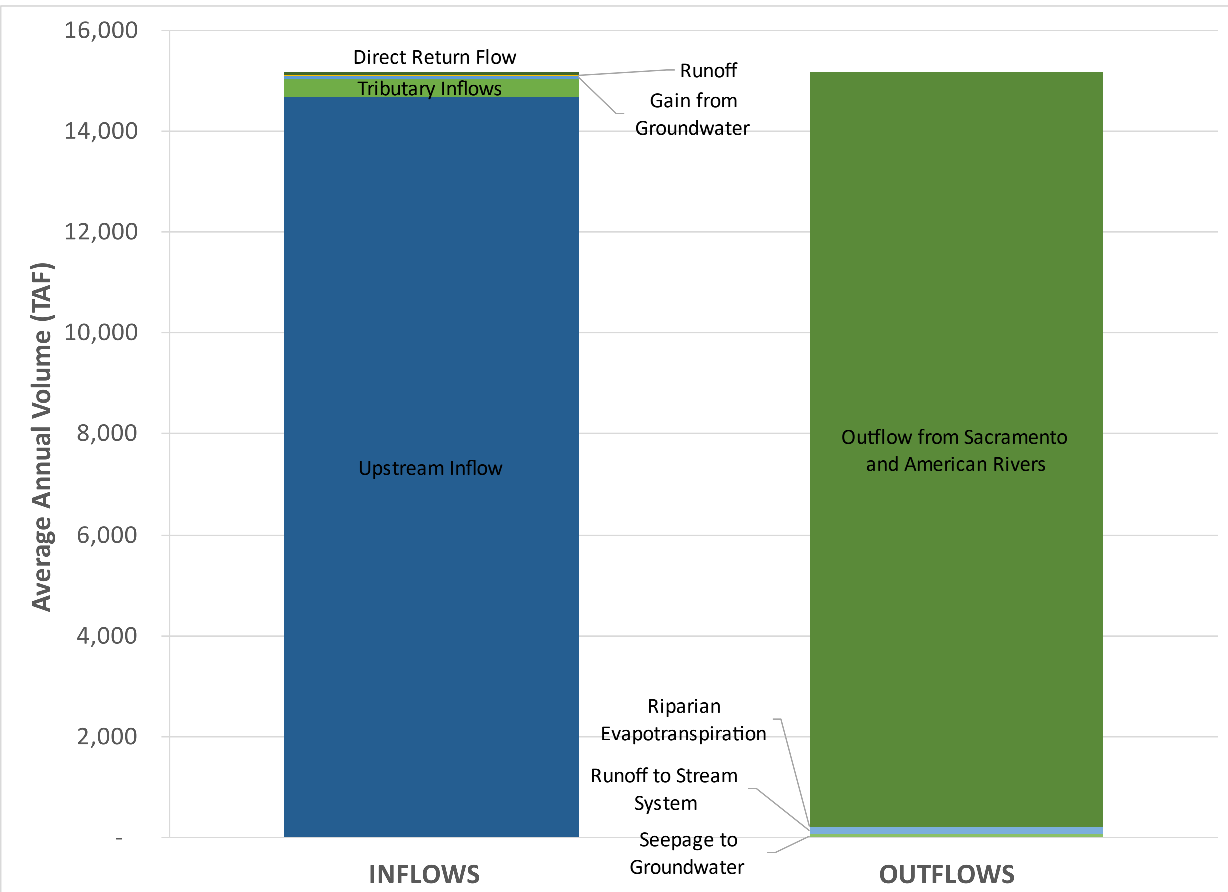

Figure 6-3. Historical Average Annual Water Budget – Stream and Canal Systems, North American Subbasin

The NASb land surface system water budget, shown below in **Figure 6-4**, includes approximately 1,146,300 AF of inflows each year, a combination of precipitation (551,000 AFY), surface water deliveries (307,800 AFY), and groundwater supplies (287,500 AFY). These inflows are balances with the outflows, which are comprised of evapotranspiration (494,900 AFY), surface runoff (297,000 AFY), return flow (171,500 AFY) to the stream and canal system, deep percolation (177,500 AFY), and other flows (5,500 AFY).

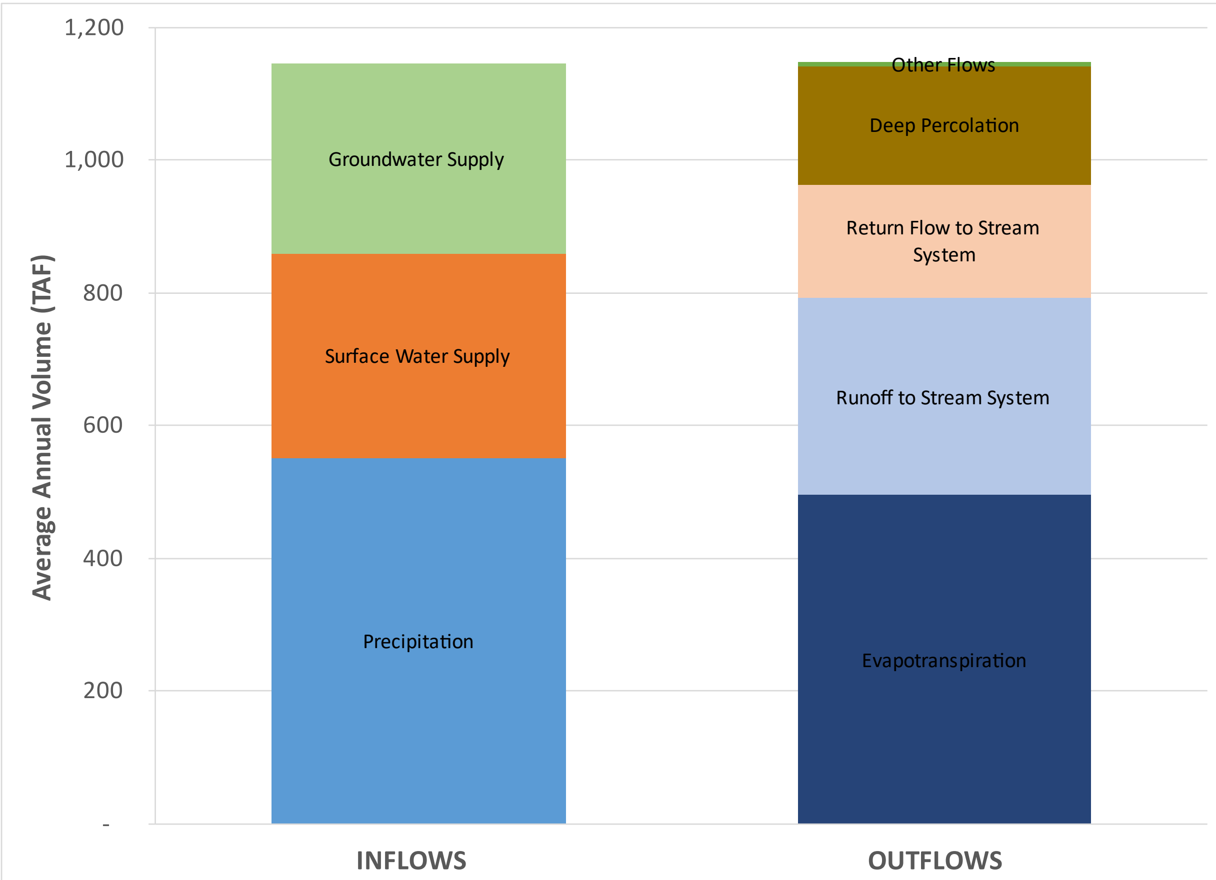

Figure 6-4. Historical Average Annual Water Budget – Land Surface System, North American Subbasin

The groundwater system of the NASb experiences approximately 383,000 AF of inflows each year, of which 177,500 AF is deep percolation. Additional inflows include infiltration from the stream system (134,000 AFY), injection of remediated water to the groundwater system (300 AFY), subsurface inflows (54,600 AFY) from the Sierra Nevada foothills and the neighboring subbasins (primarily Yolo and Yuba), and other recharge (16,700 AFY) which is primarily seepage from irrigation water canal system.

On average, the inflows exceed the groundwater outflows. The primary components of outflow from the groundwater system are groundwater pumping (296,400 AFY), followed by groundwater discharge to streams (44,400 AYF) and subsurface outflow to neighboring subbasins (10,400 AFY).

The NASb average historical groundwater budget has greater inflows than outflows, leading to an average annual increase in groundwater storage of approximately 31,900 AFY. **Figure 6-5** summarizes the average historical groundwater inflows and outflows in the NASb.

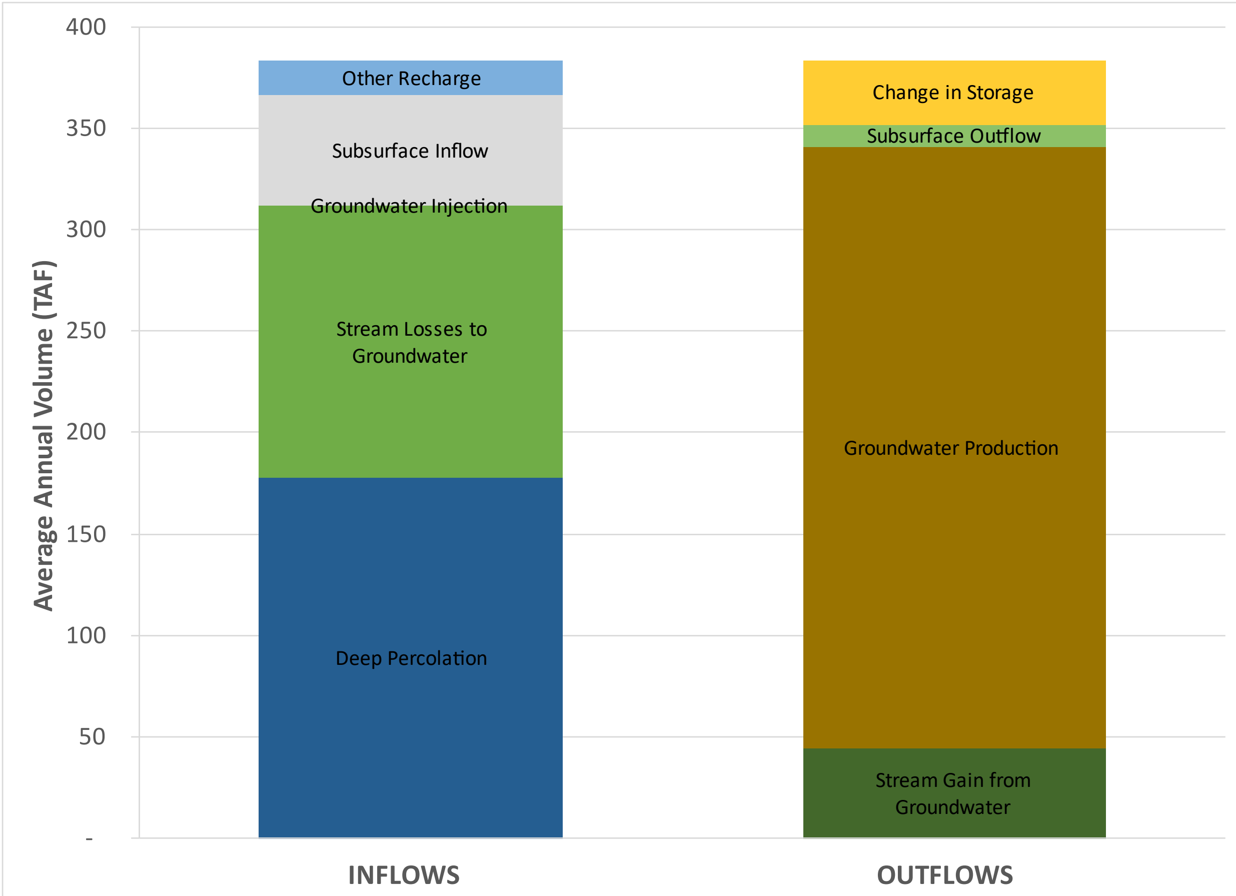

Figure 6-5. Historical Average Annual Water Budget – Groundwater System, North American Subbasin

Historical inflows and outflows change by water year type. In wet years, precipitation meets more of the water demand and greater recharge occurs from precipitation and streams. In dry years, more groundwater is pumped to meet the agricultural demand not met by precipitation and less recharge occurs from precipitation and streamflows. This contributes to an increase in groundwater storage in wet years and a decrease in dry years. Further, many urban water users practice conjunctive use, using more surface water in wet years and more groundwater in dry years to optimize these water supplies. While agricultural demand for applied water increases in dry years due to lack of precipitation, agricultural surface water supplies remain relatively consistent in most non-critical years. Note the agricultural surface water supply in this water budget is reflective of the volume available to the grower, and thus does not include operational spills, canal seepage, or evaporative losses. **Table 6-12** breaks down the average historical water supply and demand, by water year type, from the CoSANA simulated 29-year period of 1990 through 2018. Also shown are the average annual values for the 2009-2018 period.

During the 2009-2018 historical period, the availability of surface water supplies were largely reliable. During the period, the only water right curtailment experienced by an urban water user was to a post-1914 water right permit held by Carmichael Water District on the lower American River. This occurred in parts of 2014 and 2015.

Table 6-14. Average Annual Values for Key Components of Water Budget by Year Type (AFY)

Component	Water Year Type (Sacramento River Index)					
	Wet	Above Normal	Below Normal	Dry	Critical	10-Year Average WY 2009-2018
Water Demand						
Ag Demand	417,300	413,800	434,300	449,600	436,000	410,800
Urban Demand	212,600	223,800	213,900	218,900	197,300	184,500
Total Demand	*633,400*	*659,100*	*653,900*	*672,800*	*637,400*	*602,800*
Water Supply						
Total Surface Water Supply						
Agricultural	215,500	233,900	211,300	213,100	181,900	189,900
Urban	116,500	126,400	126,600	133,800	110,700	117,900
Total Groundwater Supply						
Agricultural	181,200	177,300	202,400	215,900	233,500	200,300
Ag Residential	20,600	20,600	20,600	20,600	20,600	20,600
Urban	96,100	97,400	87,300	85,100	86,600	66,600
Remediation	3,500	3,500	5,700	4,300	4,100	7,500
Total Supply	*633,400*	*659,100*	*653,900*	*672,800*	*637,400*	*602,800*
Change in GW Storage	*102,300*	*29,300*	*12,600*	*(7,300)*	*(66,400)*	*31,800*

Note:
Information is presented here to show variability in historical conditions based on water year type. However, as these data are based on historical conditions, other differences are present beyond water year type that influence the values shown. For instance, the Above Normal year of 1991 will have different conditions and results than the Critical year of 2015 due to level of development, changes in management, nuances of the water year, and a variety of other factors. In some cases, these distinctions may be more significant than the impact of the water year type, resulting in some results and trends in this table that may seem nonintuitive.

6.6 Current Water Budget

The current water budget quantifies inflows to and outflows from the basin using 50-years of hydrology in conjunction with water supply, demand, and land use information reflecting the current level of development. Current level of development for most of the entities in the NASb is defined as the average demand and supply conditions during the most recent 10 years (approx. 2009-2018). The only exception is the supply mix for the current level of development for the City of Sacramento, which is defined per the city's Groundwater Master Plan. These conditions are incorporated in the Current Conditions Baseline simulation of the CoSANA model.

In the Current Conditions Baseline, average annual surface water inflows of approximately 17,013,200 AFY enter the CoSANA model boundary via the American, Feather, Bear, and Sacramento Rivers. These flows are supplemented by tributary inflows (388,000 AFY), gain from groundwater (75,400 AFY), runoff (12,200 AFY), and direct return flows (66,000 AFY). These are offset by an equal quantity of stream outflows on these river reaches. Most of the streamflows flow out to the Sacramento and American Rivers (17,336,900 AFY). However, additional water exits the stream system as seepage to groundwater (74,600 AFY) and surface water diversions (143,400 AFY).

Figure 6-6 summarizes the average annual current conditions inflows and outflows in the NASb surface water network.

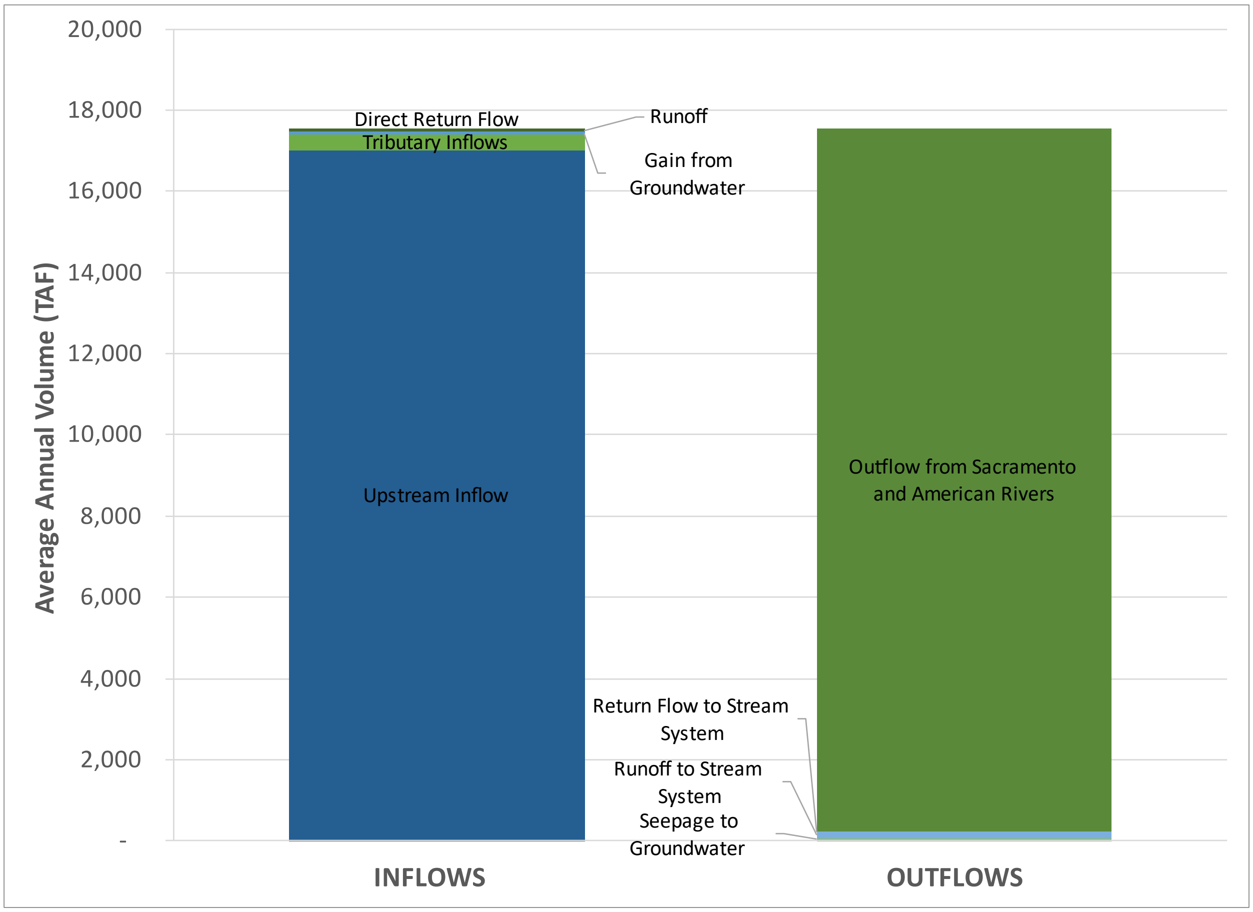

Figure 6-6. Average Annual Current Water Budget – Stream and Canal Systems, North American Subbasin

The current land surface water budget simulates annual inflows of 1,193,000 AFY, including 590,800 AFY of precipitation and 602,200 AFY of applied water (306,600 AFY of surface water and 295,600 AFY of groundwater). Balancing the current land surface water budget, the 1,193,000 AFY of outflows include evapotranspiration (496,700 AFY), surface runoff to the stream system (328,400 AFY), return flow to the stream system (178,100 AFY), deep percolation (183,500 AFY), and other flows (6,300 AFY). **Figure 6-7** summarizes the average annual current inflows and outflows in the NASb land surface water budget.

There are small but important differences between the historical and current conditions land surface system water budget. The Current Conditions Baseline uses a 50-year hydrology that is more similar to long-term average precipitation conditions in the NASb, while the 2009-2018 recent historical period is slightly drier. The more normal conditions are shown as slightly higher precipitation inflows under the Current Conditions Baseline as well as higher runoff to streams.

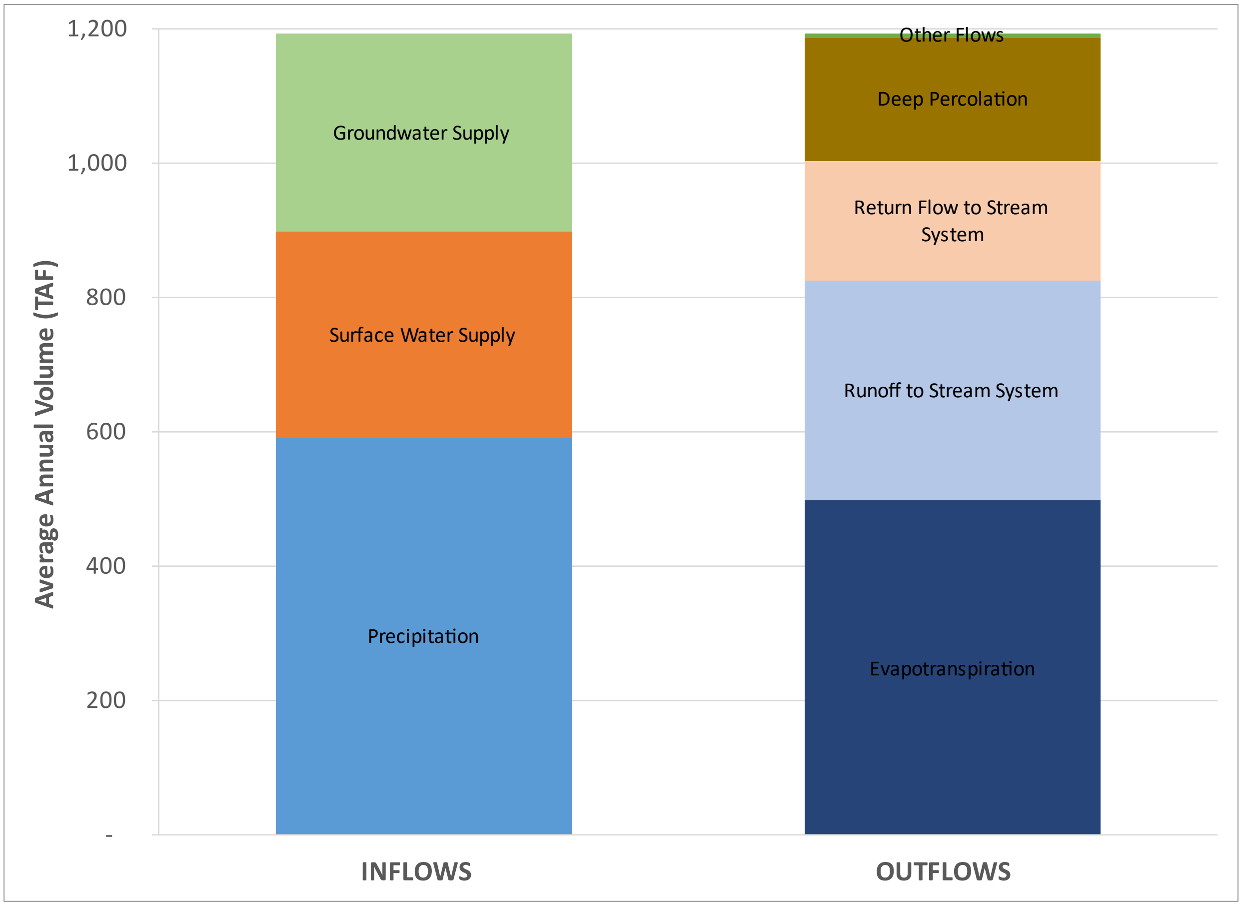

Figure 6-7. Average Annual Current Water Budget – Land Surface System, North American Subbasin

Over the simulation period, the current groundwater budget simulates annual inflows of 384,700 AFY, including 183,500 AFY of deep percolation, 134,500 AFY of stream seepage, subsurface inflows totaling 49,900 AFY, groundwater injection of 200 AFY, and 16,700 AFY of other recharge (which is primarily canal system seepage).

Similar to the historical groundwater budget, average aquifer inflows exceed the outflows under the current water budget. Groundwater production (303,300 AFY) remains the largest component of aquifer discharge, with losses to the local stream system (53,000 AFY) and subsurface outflows (13,600 AFY) bringing the total system outflows to 369,900 AFY annually.

The NASb current groundwater budget has an average annual increase in groundwater storage of about 14,900 AFY. **Figure 6-8** summarizes the average current conditions groundwater inflows and outflows in the NASb. It should be noted that groundwater conditions are variable across the

NASb, with some areas showing greater increases in groundwater storage and some areas showing lower increases or declines in groundwater storage.

Similar to the land surface system water budget, the groundwater system budget shows the influences of slightly different hydrologic conditions, but also shows influences of slightly higher groundwater levels. Higher average groundwater level conditions under current conditions, due to positive change in groundwater storage in historical conditions, results in generally lower stream seepage, higher outflow to streams, higher subsurface outflows, and lower subsurface inflows. Otherwise, the values in the historical and current groundwater budgets are generally similar.

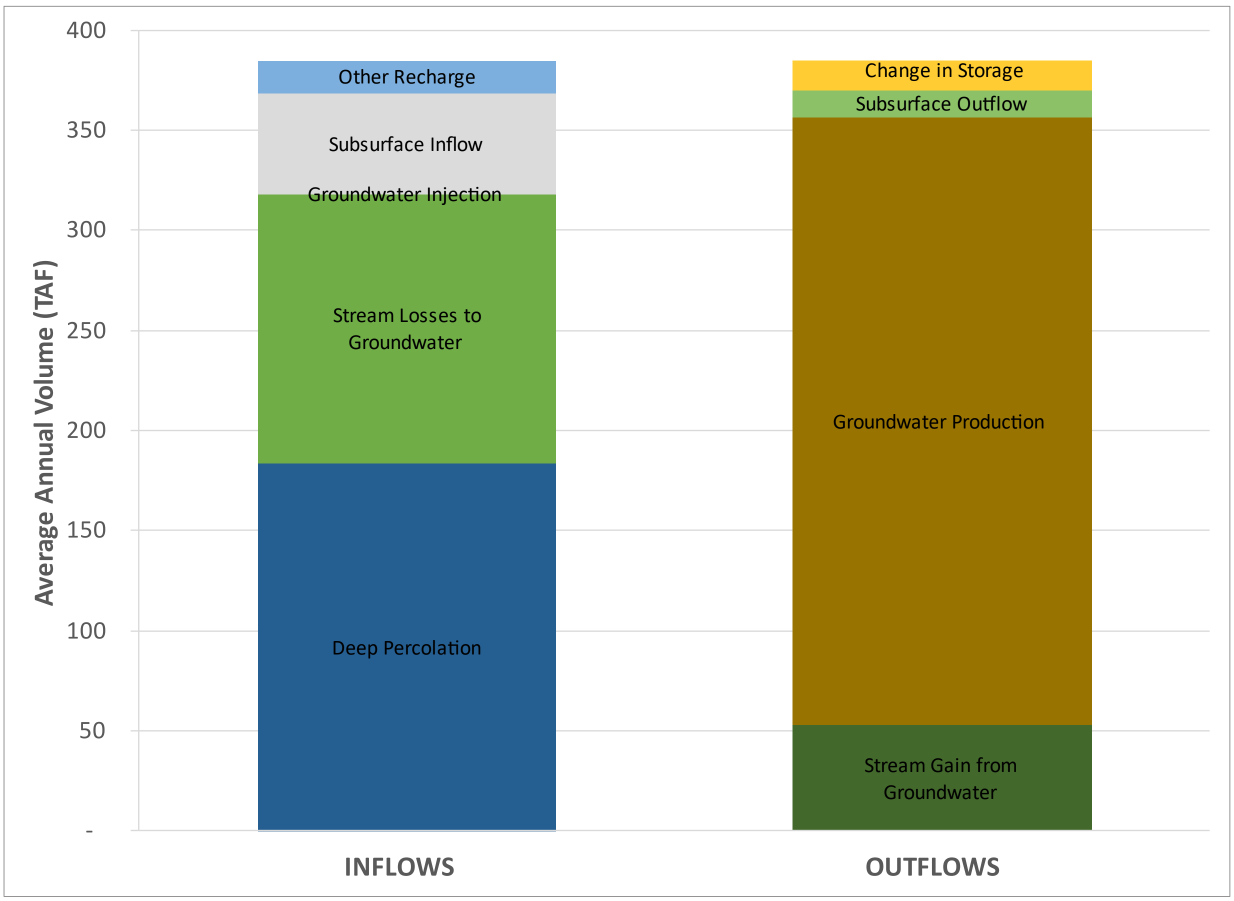

Figure 6-8. Average Annual Current Water Budget – Groundwater System, North American Subbasin

6.7 Projected Water Budget

The projected water budget is used to estimate future baseline conditions of supply, demand, and aquifer response to plan implementation. The Projected Conditions Baseline simulation of the CoSANA model is used to evaluate the projected water budget using the historical hydrology from 1970 to 2019. As previously discussed, this represents a hydrologic period of at least 50 years and has average precipitation similar to the long-term average. Development of the projected water demand is based on information reported in 2015 UWMPs, general plans, and other planning documents, or information provided by purveyors. The projected water budget then reflects the water supply and demand conditions at the projected level of development, which is set at the 2040 projections for most entities, other than the supply mix for the City of Sacramento, which is based on the city's Groundwater Master Plan.

In the Projected Conditions Baseline, average annual surface water inflows of approximately 17,014,700 AFY enter the CoSANA model boundary via the American, Feather, Bear, and Sacramento Rivers. These flows are supplemented by tributary inflows (435,500 AFY), gain from groundwater (64,800 AFY), runoff (17,400 AFY), and direct return flows (67,700 AFY). These are offset by an equal volume of stream outflows on these river reaches. Most of the streamflows flow out to the Sacramento and American Rivers (17,379,000 AFY). However, additional water exits the stream system as seepage to groundwater (83,300 AFY) and surface water diversions (138,000 AFY).

Figure 6-9 summarizes the average projected inflows and outflows in the NASb surface water network.

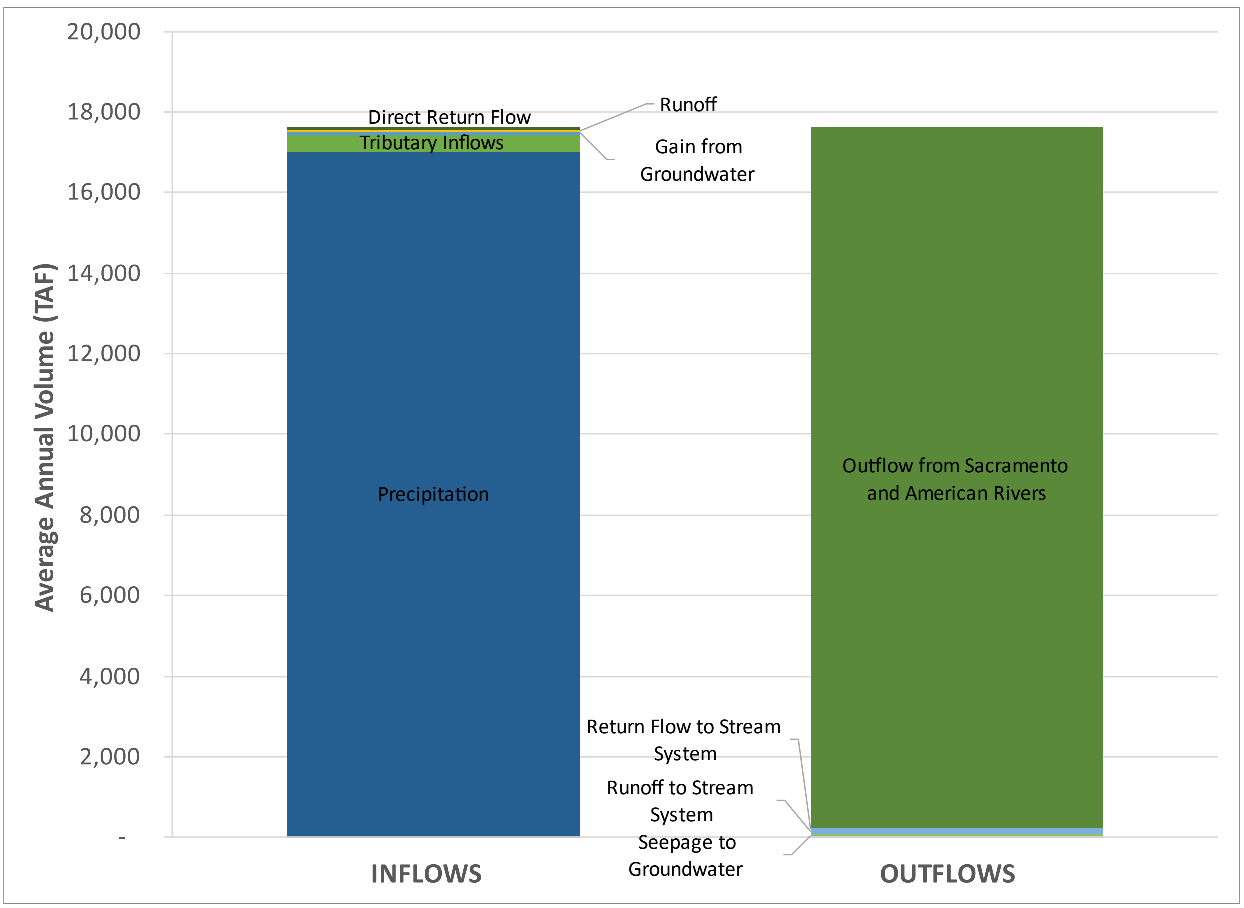

Figure 6-9. Average Annual Projected Water Budget – Stream and Canal Systems, North American Subbasin

The projected land surface water budget shows annual inflows of 1,278,400 AFY, including 590,800 AFY of precipitation and 687,600 AFY of applied water (370,000 AFY of surface water and 317,600 AFY of groundwater). Balancing the projected land surface water budget are 1,278,400 AFY of outflows, including evapotranspiration (516,100 AFY), surface runoff to the stream system (356,300 AFY), return flow to the stream system (231,300 AFY), deep percolation (167,400 AFY), and other flows (7,300 AFY). A summary of these flows can be seen below in **Figure 6-10**.

There are several key differences between the current and projected land surface system water budget. The current and projected conditions use the same hydrologic period, and as such, the rainfall amounts are same. However, runoff and percolation conditions are different due to the impact of land conversion from agricultural and native to urban land uses. The urban growth also results in increases in demand and urban water supplies. Both groundwater and surface water urban supplies increase, with the bulk of increased surface water use the result of increased supply for new developments within Placer County. Agricultural water supplies decline due to reduced irrigated acreage. These changes in inflows are also reflected in the outflows, with increased urban land and water use resulting in increased urban evapotranspiration, urban return flow, and runoff. Conversely, reduced agricultural uses and native lands results in lower levels of evapotranspiration and return flow from these areas.

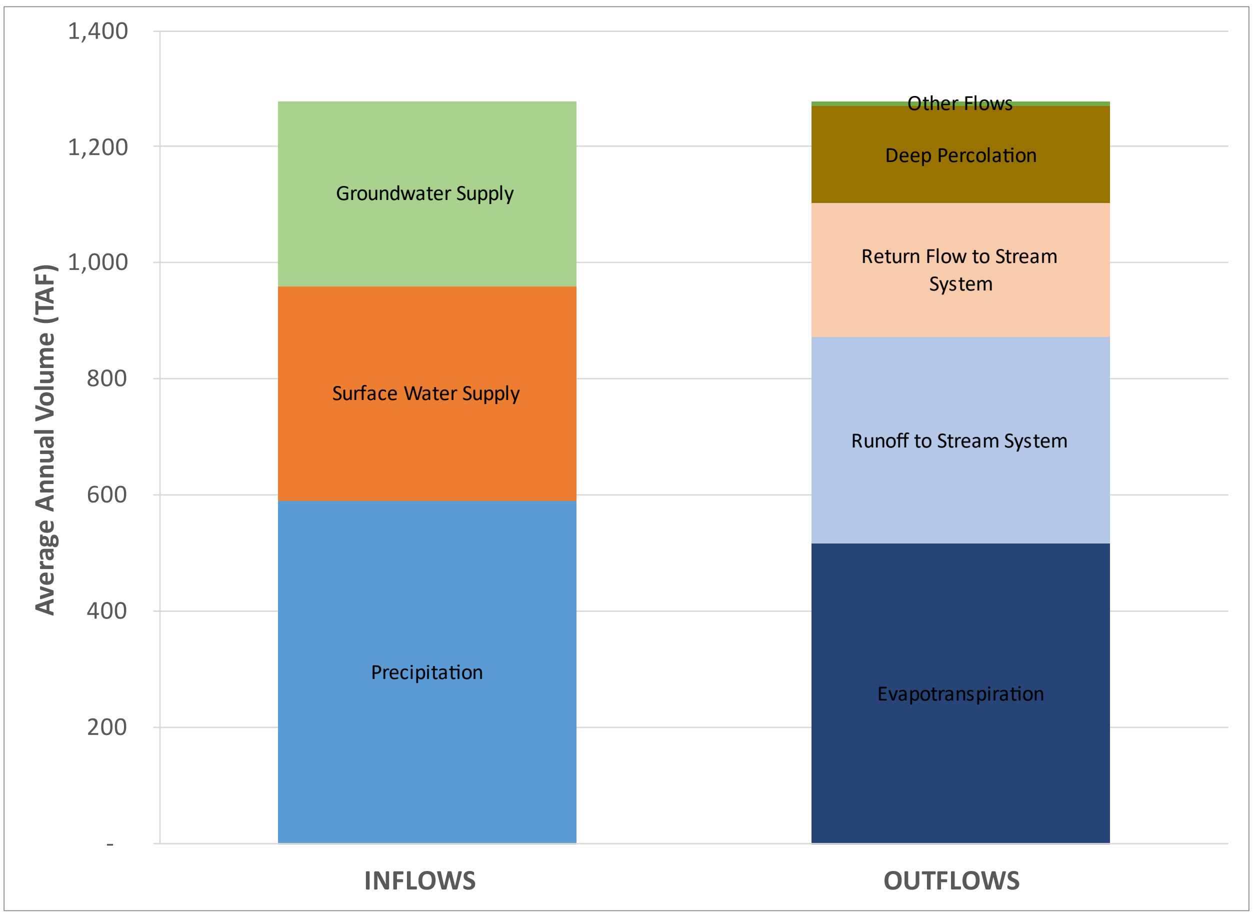

Figure 6-10. Average Annual Projected Water Budget – Land Surface System, North American Subbasin

Over the simulation period, the projected groundwater budget shows annual inflows of 393,800 AFY, including 167,400 AFY of deep percolation, 154,300 AFY of stream seepage, subsurface inflows totaling 53,600 AFY, groundwater injection of 2,100 AFY, and other recharge of 16,400 AFY (which is primarily canal system seepage).

Similar to the current and historical conditions groundwater budgets, average aquifer inflows exceed the outflows in the projected groundwater budget. Groundwater production (325,300 AFY) remains the largest point of aquifer discharge, with losses to the local stream system (46,400 AFY), and subsurface outflows (16,800 AFY) bringing the total system outflows to 388,400 AFY.

The NASb projected groundwater budget has an average annual surplus in groundwater storage of about 5,400 AFY. **Figure 6-11** summarizes the average projected groundwater inflows and outflows in the NASb.

Similar to the land surface system water budget, the groundwater system water budget shows the influences of land conversion and changes to water supplies when compared to the current water budget. Deep percolation from precipitation is lower in the Projected Conditions Baseline compared to current conditions largely due to the changes in land use and increase in impervious surfaces that comes with urban development. Changes in deep percolation of applied water are largely the result of changes in volumes of water supplies, as noted within the land surface system water budget. Stream losses increase in the Projected Conditions Baseline in comparison to the Current Conditions Baseline due to lower groundwater levels caused largely by increases in pumping for urban uses and increases in runoff from urban land.

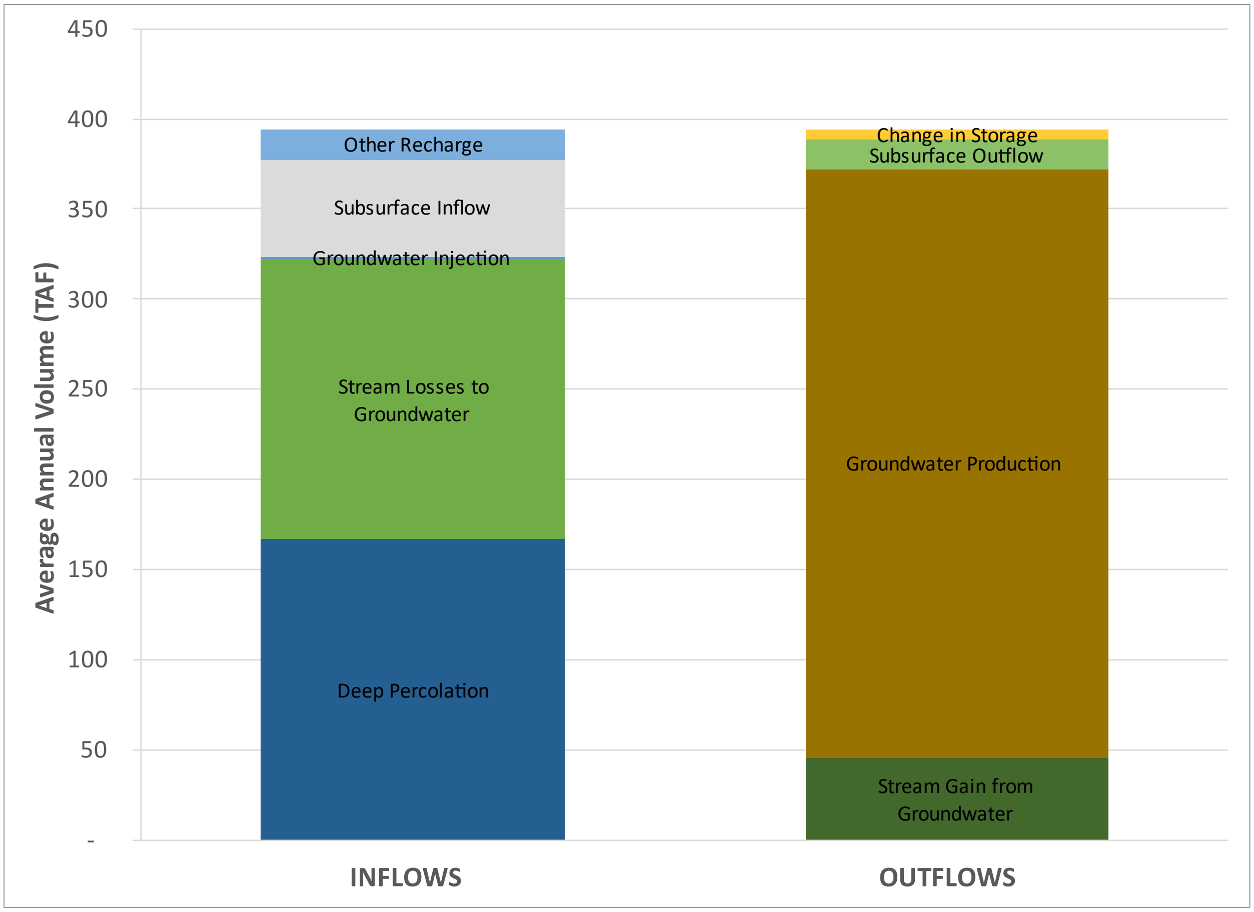

Figure 6-11. Average Annual Projected Water Budget – Groundwater System, North American Subbasin

6.8 Projected Water Budget with Climate Change

The Projected Conditions Baseline with Climate Change is used to estimate future conditions of supply, demand, and aquifer response to plan implementation with consideration of climate impacts. The Projected Conditions Baseline with Climate Change simulation of the CoSANA model is used to evaluate the Projected Conditions Baseline with Climate Change water budget using hydrology from 1970 to 2019, adjusted for projected climate change. As previously discussed, this represents a hydrologic period of at least 50 years and has average precipitation similar to the long-term average. To account for climate change, model inputs for precipitation, evapotranspiration and stream inflow were adjusted using data developed for the American River Basin Study. Additional discussion of the climate change analysis approach, including a description of a sensitivity analysis under a more extreme climate change scenario, can be found in **Appendix P**. Other model data remained the same as the Projected Conditions Baseline.

In the Projected Conditions Baseline with Climate Change water budget, average annual surface water inflows of about 14,447,500 AFY enter the CoSANA model boundary via the American, Feather, Bear, and Sacramento Rivers. These flows are supplemented by tributary inflows (432,200 AFY), gain from groundwater (55,300 AFY), runoff (17,600 AFY), and direct return flows (68,400 AFY). These are offset by an equal quantity of stream outflows on these river reaches. Most of the streamflows flow out to the Sacramento and American rivers (14,799,500 AFY). However, additional water exits the stream system as seepage to groundwater (80,900 AFY) and surface water diversions (140,600 AFY).

Figure 6-12 summarizes the average projected inflows and outflows in the NASb surface water network.

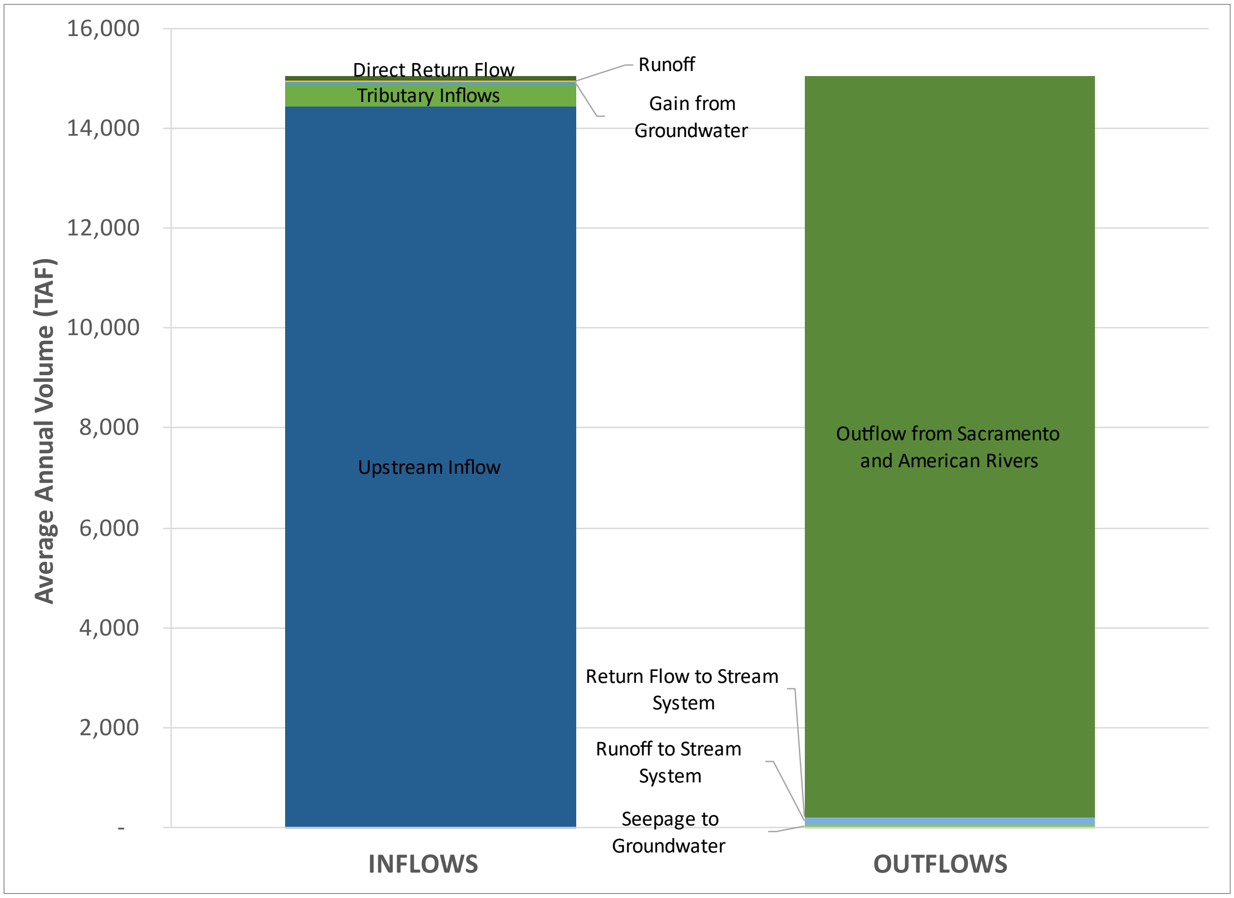

Figure 6-12. Average Annual Projected with Climate Change Water Budget – Stream and Canal Systems, North American Subbasin

The Projected Conditions Baseline with Climate Change land surface water budget shows annual inflows of 1,302,900 AFY, including 592,800 AFY of precipitation and 710,100 AFY of applied water (372,700 AFY of surface water and 337,400 AFY of groundwater). Balancing the projected land surface water budget is 1,302,900 AFY of outflows including evapotranspiration (544,600 AFY), surface runoff to the stream system (358,400 AFY), return flow to the stream system (231,700 AFY), deep percolation (161,000 AFY), and other flows (7,200 AFY). A summary of these flows can be seen below in **Figure 6-13**.

With land use conditions the same between the Projected Conditions Baseline and the Projected Conditions Baseline with Climate Change, the differences between the two associated land surface systems water budgets are the result of climate change hydrology. The substantial change in the budget is an increase in agricultural evapotranspiration. This results in an increase in irrigation needs for agricultural lands and an associated increase in agricultural groundwater production.

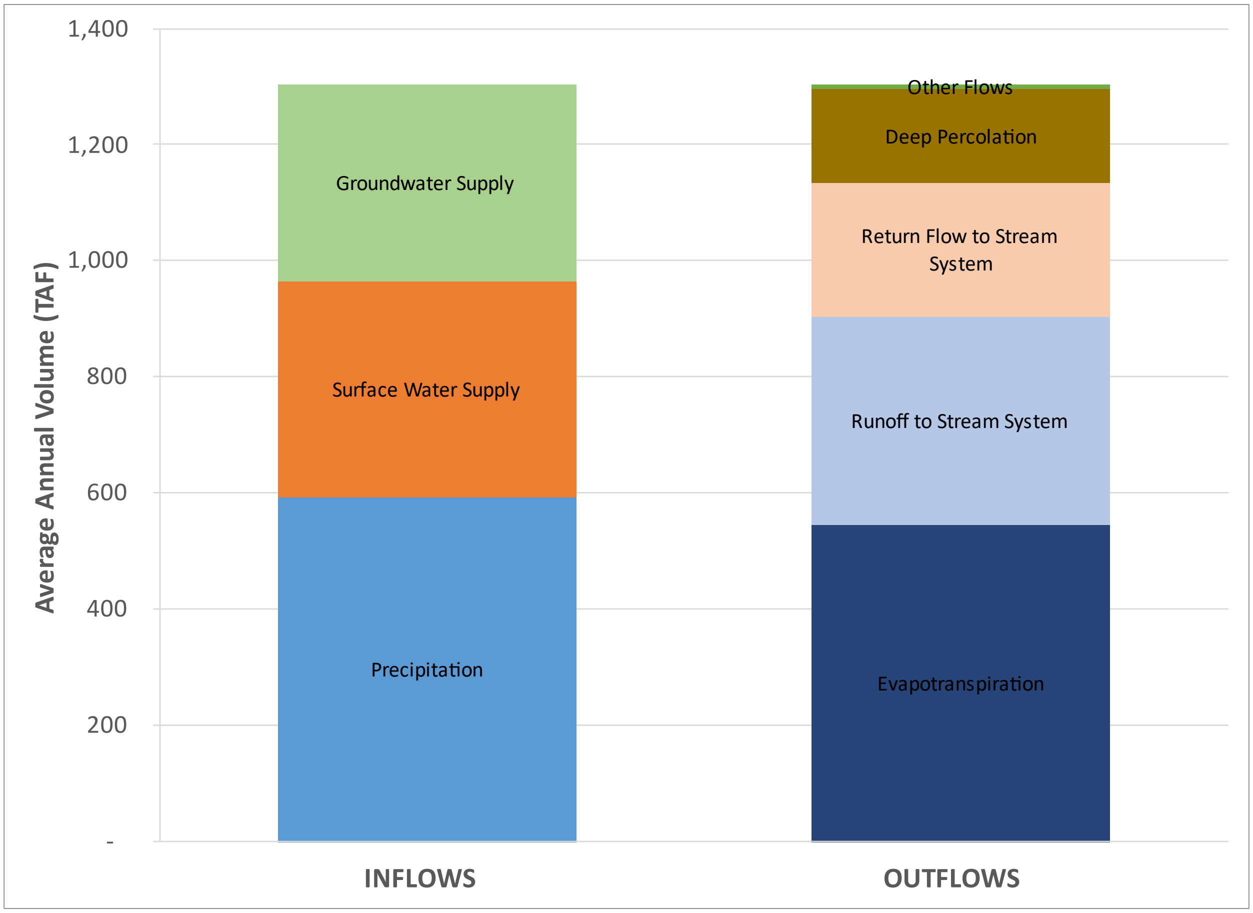

Figure 6-13. Average Annual Projected with Climate Change Water Budget – Land Surface System, North American Subbasin

Over the simulation period, the Projected Conditions Baseline with Climate Change groundwater budget simulates annual inflows of 399,500 AFY, including 161,000 AFY of deep percolation, 163,700 AFY of stream seepage, subsurface inflows totaling 56,300 AFY, groundwater injection of 2,100 AFY, and other recharge of 16,400 AFY (which is primarily canal system seepage).

In contrast to the projected, current, and historical water budgets, average aquifer outflows exceed the inflows in the Projected Conditions Baseline with Climate Change water budget. Groundwater production (345,100 AFY) remains the largest point of aquifer discharge, with losses to the local stream system (41,500 AFY), and subsurface outflows (16,300 AFY) bringing the total system outflows to 403,000 AFY.

The NASb Projected Conditions Baseline with Climate Change water budget has an average annual decline in groundwater storage of about 3,500 AFY. **Figure 6-14** summarizes the average groundwater inflows and outflows in the NASb in the projected with climate change water budget.

Similar to the land surface system water budget, the groundwater system budget shows the influences of climate change when compared to the projected groundwater budget. Changes are largely the result of increased agricultural pumping resulting from climate-related increases in evapotranspiration and associated demand. This increase in outflow is a large component of increased stream losses, which is the largest change to inflows and is primarily the result of lowered groundwater levels near the rivers and streams due primarily to increased pumping and decreased deep percolation.

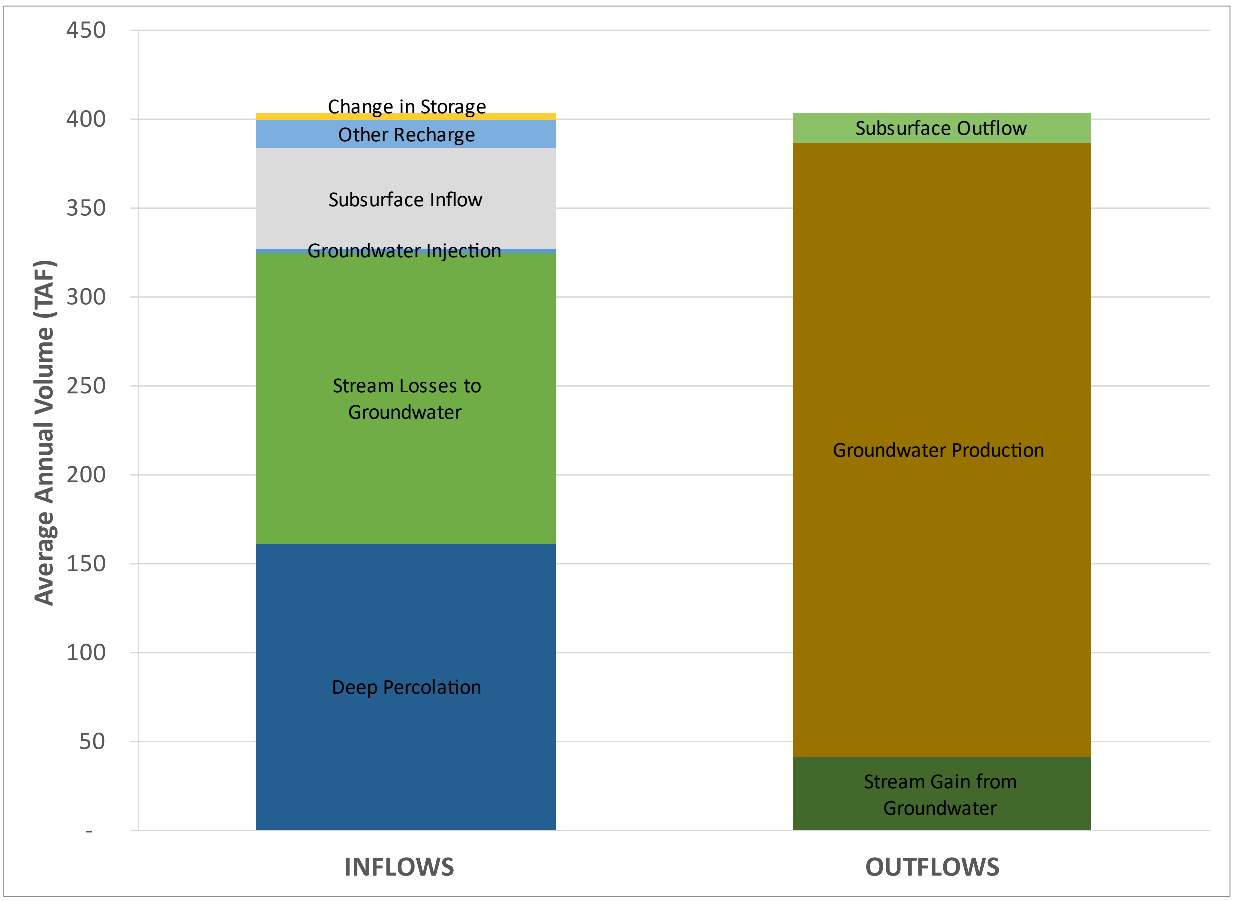

Figure 6-14. Average Annual Projected with Climate Change Water Budget – Groundwater System, North American Subbasin

6.9 Sustainable Yield Estimate

Sustainable yield is defined by the SGMA 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." (California Water Code Section 10721(w)) In short, sustainable yield is the amount of groundwater that can be withdrawn on a long-term average basis without causing undesirable results. The value is intended to assist in identifying projects and management actions needed to achieve sustainability, if any. Note that SGMA does not incorporate sustainable yield estimates directly into the sustainable management criteria, which are the regulatory drivers of SGMA. Basinwide pumping within the sustainable yield estimate is neither a measure of, nor proof of, sustainability. Sustainability under SGMA is only demonstrated by avoiding undesirable results for the sustainability indicators (DWR, 2017).

For the NASb, the sustainable yield was estimated by identifying a level of pumping that would result in no long-term change in groundwater in storage and then verifying that this level of pumping would avoid undesirable results. This approach was selected for two primary reasons:

- Current levels of storage and current groundwater levels are broadly considered satisfactory by stakeholders and are not known to have caused significant and unreasonable conditions. Thus, maintenance of these conditions, on a subbasin scale, is a desired outcome.

- Minimum thresholds for groundwater levels and depletions of interconnected surface water, discussed later in **Section 8 – Sustainable Management Criteria**, are defined based wholly or partly on CoSANA-simulated conditions using the same modeling simulation showing zero change in storage. Simulated groundwater levels do not go below the minimum thresholds. Thus, management of pumping using the long-term sustainable yield volume is expected to prevent undesirable results for these sustainability indicators.

Pumping that achieves zero change in storage can be estimated through the sum of pumping and change in storage. A positive change in storage suggests that more pumping is possible to achieve zero change in groundwater in storage, while a negative change in storage suggests that less pumping is necessary to achieve zero groundwater in storage. Due to the complexities of groundwater systems, this method is most accurate when change in storage is small, as the relationship between change in storage and additional pumping is not one-to-one. Modeling of projected conditions with both climate change and projects and management actions estimated total NASB groundwater pumping as 336,000 AFY and an associated change in groundwater in storage of 0 AFY. With simulated zero change in storage, no additions or subtractions for storage change are necessary from the 336,000 AFY of pumping, which is thus the estimated volume of pumping that would result in zero change in storage. This value, like others in the GSP, may be updated in the future based on new information or new conditions in the Subbasin.