SNMP Attachment B, Section B.2.1.2 text *(originally Section 4 in CV-SALTS Phase 2 Conceptual Model Task 5 deliverables)*

4. Basin Evaluation – Water Balance

This section will broadly describe the water budget components at the Central Valley and regional hydrologic unit scales, along with summaries of water budget components at the Initial Analysis Zone (IAZ) scale. The movement of water and the components of the water balance dictate the conveyance of salt and nitrate, and therefore are important for an SNMP. When discussing management practices, the movement of water in the context of different water balance components becomes critical for sustaining good quality groundwater sources and/or improving impaired groundwater. Water balance components such as groundwater recharge, surface water/groundwater interaction (stream leakage), horizontal movement from one area to another, vertical movement downward toward deeper aquifer units, groundwater pumping, and groundwater storage all play roles in the movement and management of salt and nitrate into and out of areas of interest. This section bases the water balance information on the Phase I Initial Conceptual Model (LWA et al. 2013) work, which divided the Central Valley Floor into 22 water balance subregions (also referred to as Initial Analysis Zones, or IAZs). These areas are based on hydrologic boundaries, and for the purposes of this section, they are grouped and summarized geographically into the Northern Central Valley, Middle Central Valley, and Southern Central Valley. Additional detail on the water balance information for each of the 22 water balance subregions is provided in **Appendix F** (see SNMP Section B.2.1.2 Appendix).

4.1 CONCEPTUAL MODEL

Salt and nitrate management requires an understanding of water movement on and beneath the land surface. Groundwater flows in response to multiple factors such as pumping, recharge of surface water, subsurface porosity, and interaction with surface water, to list a few. The direction of surface water and groundwater flow and associated volumes of those flows dictate the movement of salt and nitrate in the subsurface. In order to understand the complexity of the movement of water, salt, and nitrate in an area as large as the Central Valley, dividing the Central Valley into smaller pieces helps provide an understanding of which water balance components play more important roles in the movement (and therefore management) of salt and nitrate. Based on early recommendations from the CV-SALTS Technical Advisory Committee, the ICM work effort utilized the 2009 Central Valley Hydrologic Model (CVHM) developed by the U.S. Geological Survey (USGS) as the basis for groundwater balance determinations for the valley floor. The valley floor was the focus for the ICM work because it had the most available water budget and modeling information. It also contains the largest sources of salt and nitrate. Areas outside of the valley floor with salt/nitrate issues are mostly localized, and little water budget information is available for these areas.

<u>Horizontal Boundaries:</u> CVHM defines 21 hydrologically-delineated areas in the Central Valley floor as “Water Balance Subregions” (WBS). The determination was made to use these 21 areas as the boundaries for ICM IAZs, with one exception: the CVHM Delta-Mendota Basin was subdivided, so 22 IAZs were ultimately used to split up the Central Valley Floor for the ICM technical analyses of water, salt, and nitrate movement. The

horizontal boundaries of the 22 IAZs are hydrologically based using surface water features and alluvial aquifer boundaries, and are directly related to the model structure of the 2009 CVHM and corresponding WBS used by the California Department of Water Resources (DWR). DWR has compiled substantial information on water deliveries and diversions for subregions of the Central Valley floor, and has used these subregions as water supply planning areas. Therefore, the IAZs were used for the boundaries of the initial analysis of water, salt, and nitrate movement in the Central Valley Floor for the purposes of SNMP development.

Vertical Boundaries: The vertical dimensions of the groundwater within the IAZs are significant to the conceptualization of movement of water, salt, and nitrate for management purposes. The ICM approach included using a defined depth to the upper part of the aquifer system beneath each IAZ. The water, salt, and nitrate balance calculations in the ICM were performed for a 20-year time period. To estimate the groundwater affected by activities over a 20-year time period, the vertical travel distance must be calculated. The vertical distance represents the distance that the water, at the water table, would travel downward or upward over a 20-year period. This 20-year travel zone defines the ICM “shallow” portion of the subsurface where the ICM water, salt, and nitrate balance analyses were performed.

Water Balance Methodology: The methodology developed for the ICM water balance calculations is based on the simulated water budget components in CVHM on a quarterly basis for a 20-year time period between 1983 and 2003. The 20-year period was selected based on the most recent 20-year period in the CVHM simulation, which provided all of the water balance component flow values. The 20-year time period was also selected because of the interest in evaluating the effects of land use and water management practices during such a period. In order to calculate the movement of water, salt, and nitrate over this 20-year selected study period, datasets containing the mass loadings, CVHM water budget time series volumes, and time series of ambient surface water and groundwater quality data were developed. Calculations utilizing hundreds of complicated queries on the data to add or subtract volumes and masses of salt and nitrate (sometimes using concentrations with volumes to yield mass values) for each IAZ were performed to determine the movement of water, salt, and nitrate over the 20-year period on a quarterly basis. The adding and subtracting of masses and volumes enabled the determination of water and mass movement simultaneously between each IAZ for the entirety of the Central Valley floor, as conceptualized in **Figure 4-1**.

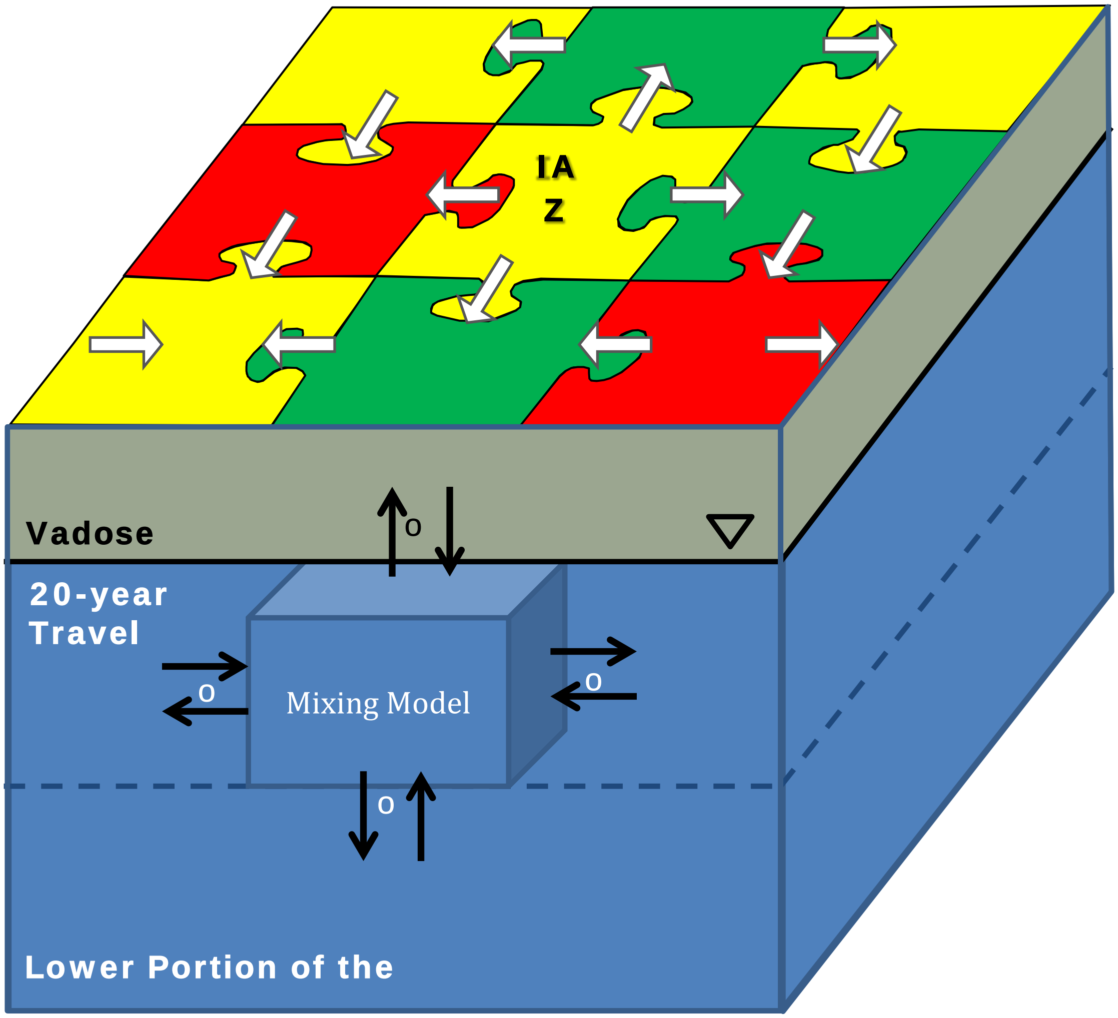

Figure 4-1. Conceptual Model of Water Balance Calculations for Each IAZ

4.2 BASIN INFLOW/OUTFLOW

22 IAZs were used to perform water balance calculations. A map of the IAZs (**Figure 4-2**) and a table describing each of the IAZs (**Table 4-1**) is included below.

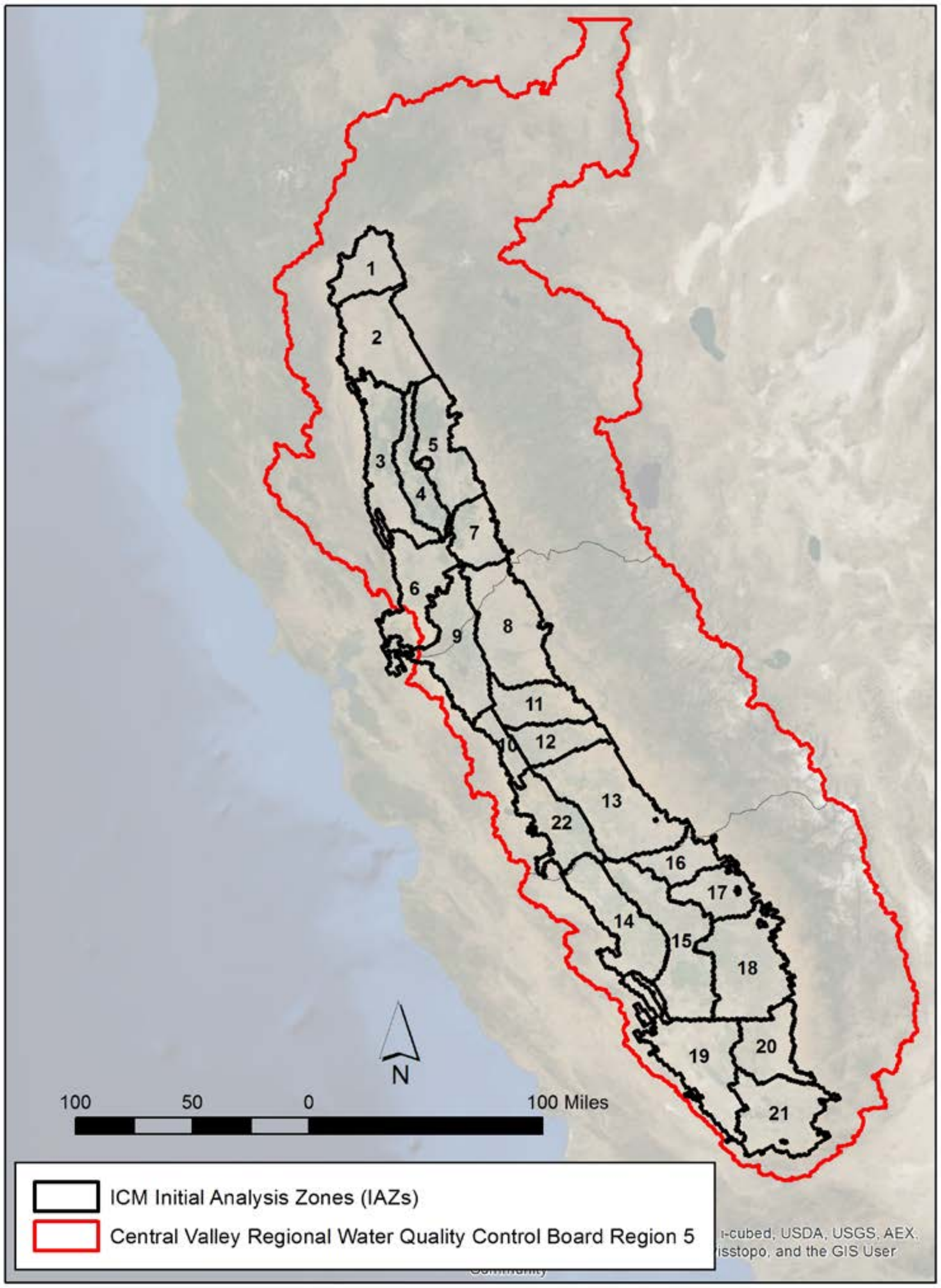

Figure 4-2. ICM Initial Analysis Zones within Region 5

Table 4-1. Initial Analysis Zone Description

	IAZ	Initial Analysis Zone Description
Northern Central Valley	1	Sacramento River above Red Bluff
	2	Red Bluff to Chico Landing
	3	Colusa Trough
	4	Chico Landing to Knights Landing proximal to the Sacramento River
	5	Eastern Sacramento Valley foothills near Sutter Buttes
	6	Cache-Putah area
	7	East of Feather and South of Yuba Rivers
Middle Central Valley	8	Valley floor east of the Delta
	9	Delta
	10	Delta-Mendota Basin – Northwest Side
	11	Modesto and Southern Eastern San Joaquin Basin
	12	Turlock Basin
	13	Merced, Chowchilla, and Madera Basins
	22	Delta-Mendota Basin – Grassland
Southern Central Valley	14	Westside and Northern Pleasant Valley Basins
	15	Tulare Lake and Western Kings Basin
	16	Northern Kings Basin
	17	Southern Kings Basin
	18	Kaweah and Tule Basins
	19	Western Kern County and Southern Pleasant Valley Basin
	20	Northeastern Kern County Basin
	21	Southeastern Kern County Basin

Generally speaking, water enters the Central Valley groundwater basins via: surface water inflow from the foothills on the edges of the valley floor; precipitation that falls on the Central Valley floor; surface water that leaks through the riverbed; recharge basins/ and excess irrigation water that percolates past the root zone to enter the water table. **Figure 4-3** illustrates the locations of major surface water inflow, and distribution of precipitation in the basin (Faunt et al. 2009). Water leaves the basin through: groundwater pumping; gaining stream conditions (where groundwater contributes water to surface water features); evaporation; evapotranspiration; and surface and subsurface flow out the Sacramento/San Joaquin Delta.

A summary of water budget inflows and outflows for the three areas within the Central Valley is provided in **Section 4.6** below. More detailed descriptions of water budget inflows and outflows for each IAZ are detailed in **Appendix F** (see SNMP Section B.2.1.2 Appendix).

Faunt et al. (2009) provides a Central Valley floor scale summary of selected average annual hydrologic budget components, representing water years 1962-2003 for the 21 water balance subregions that comprise the CVHM model. The summary table below (**Table 4-2**) is adapted for translation into the 22 IAZ areas, but the budget components represent water budget values for the *entire saturated thickness of the CVHM model*, not just the 20-year travel zone that the IAZ work is based on, and also for the entirety of the CVHM simulation period (1962-2003). This summary is provided for details regarding basin inflow/outflow, but these volumes are different than the approach used in the ICM; the ICM water balance results are summarized in **Section 4.6** and shown in detail in Appendix F (see SNMP Section B.2.1.2 Appendix). **Table 4-2** therefore provides more of a basin-wide picture of the long-term water balance for each IAZ by providing basin inflows and outflows that include a greater vertical portion of the IAZs.

Table 4-2. Selected Average Annual Water Budget Components for Water Years 1962-2003 for the Entire Saturated Thickness of Each IAZ in the Central Valley Floor (adapted from Faunt et al. 2009 Table B3)

	IAZ Area (Entire CVHM saturated thickness of each IAZ)		Area (square miles)	Total Storage[1] (AF)	Stream Leakage[1] (AF)	Groundwater Pumping (AF)	Groundwater Recharge[1] (AF)	Precipitation (AF)	Evapotranspiration (AF)	Surface Water Deliveries (AF)
Northern Central Valley	1	Sacramento River above Red Bluff	611	49,000	-144,000	-45,000	453,000	1,063,000	-547,000	46,000
	2	Red Bluff to Chico Landing	1,163	6,000	-294,000	-557,000	768,000	1,496,000	-1,269,000	129,000
	3	Colusa Trough	1,112	-36,000	-212,000	-49,000	508,000	1,125,000	-1,300,000	717,000
	4	Chico Landing to Knights Landing proximal to the Sacramento River	560	-34,000	-494,000	-6,000	-19,000	562,000	-635,000	78,000
	5	Eastern Sacramento Valley foothills near Sutter Buttes	957	-35,000	-200,000	-65,000	466,000	1,200,000	-1,101,000	439,000
	6	Cache-Putah area	1,044	-37,000	34,000	-506,000	522,000	1,137,000	-1,315,000	329,000
	7	East of Feather and South of Yuba Rivers	534	6,000	-38,000	-186,000	222,000	590,000	-512,000	172,000
Middle Central	8	Valley floor east of the Delta	1,362	-19,000	95,000	-850,000	721,000	1,365,000	-1,444,000	205,000
	9	Delta	1,026	-215,000	705,000	-467,000	-200,000	975,000	-1,603,000	64,000

Table 4-2. Selected Average Annual Water Budget Components for Water Years 1962-2003 for the Entire Saturated Thickness of Each IAZ in the Central Valley Floor (adapted from Faunt et al. 2009 Table B3)

	IAZ Area (Entire CVHM saturated thickness of each IAZ)		Area (square miles)	Total Storage[1] (AF)	Stream Leakage[1] (AF)	Groundwater Pumping (AF)	Groundwater Recharge[1] (AF)	Precipitation (AF)	Evapotranspiration (AF)	Surface Water Deliveries (AF)
	10 and 22	Delta-Mendota Basin – Northwest Side (10) and Grassland (22)[1]	1,083	-7,000	64,000	-60,000	89,000	588,000	-1,465,000	983,000
	11	Modesto and southern Eastern San Joaquin Basin	664	-21,000	-98,000	-85,000	251,000	509,000	-901,000	643,000
	12	Turlock Basin	540	-55,000	39,000	-45,000	131,000	384,000	-702,000	440,000
	13	Merced, Chowchilla, and Madera Basins	1,648	110,000	163,000	-754,000	474,000	1,092,000	-2,233,000	936,000
Southern Central Valley	14	Westside and Northern Pleasant Valley Basins	1,071	344,000	6,000	-934,000	418,000	432,000	-1,631,000	716,000
	15	Tulare Lake and Western Kings Basin	1,423	172,000	239,000	-1,603,000	708,000	607,000	-2,225,000	757,000
	16	Northern Kings Basin	478	124,000	33,000	-202,000	212,000	299,000	-518,000	358,000
	17	Southern Kings Basin	569	82,000	170,000	-445,000	348,000	358,000	-852,000	442,000
	18	Kaweah and Tule Basins	1,358	356,000	104,000	-1,135,000	710,000	715,000	-2,237,000	821,000

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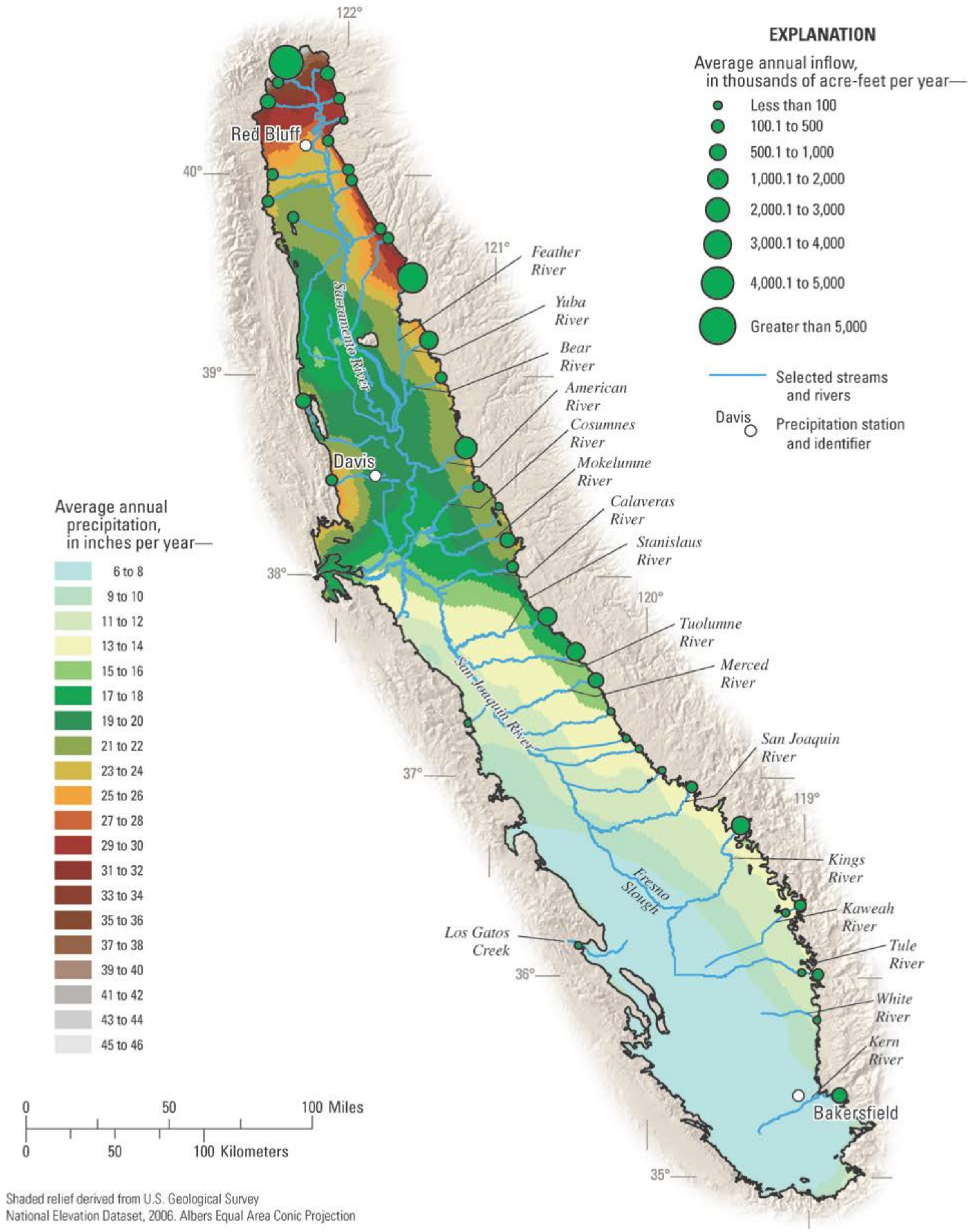
[1] CVHM's Water Balance Subregion 10 (Delta-Mendota Basin) was split up into two IAZs during the ICM work to represent the Northwest Side (IAZ 10) and the Grassland (IAZ 22) areas.

Table 4-2. Selected Average Annual Water Budget Components for Water Years 1962-2003 for the Entire Saturated Thickness of Each IAZ in the Central Valley Floor (adapted from Faunt et al. 2009 Table B3)

	IAZ Area (Entire CVHM saturated thickness of each IAZ)		Area (square miles)	Total Storage[1] (AF)	Stream Leakage[1] (AF)	Groundwater Pumping (AF)	Groundwater Recharge[1] (AF)	Precipitation (AF)	Evapotranspiration (AF)	Surface Water Deliveries (AF)
	19	Western Kern County and Southern Pleasant Valley Basin	1,365	218,000	0	-754,000	334,000	494,000	-1,275,000	367,000
	20	Northeastern Kern County Basin	705	166,000	19,000	-252,000	240,000	295,000	-892,000	610,000
	21	Southeastern Kern County Basin	1,105	164,000	130,000	-324,000	272,000	414,000	-1,333,000	1,096,000
Total			**20,378**	**1,338,000**	**300,000**	**-9,300,000**	**7,600,000**	**15,700,000**	**-25,900,000**	**10,300,000**

[1]- Negative values: Negative values are indicative of water leaving the groundwater flow model. For example, a negative storage value indicates water leaving the groundwater to replenish storage; a negative stream leakage value indicates water leaving the groundwater to enter the stream via gaining stream conditions; negative groundwater recharge indicates water leaving the groundwater body (via evaporation or transpiration) instead of entering the groundwater body (the opposite of deep percolation).

Positive Values: Conversely, positive values for these water budget categories indicate water entering the groundwater body. For example, a positive storage value indicates water leaving storage to be used by the groundwater model via storage depletion; a positive stream leakage value indicates water leaving the stream to enter into the groundwater body via losing stream conditions; and positive recharge values indicate water entering the groundwater body via deep percolation.



Shaded relief derived from U.S. Geological Survey National Elevation Dataset, 2006. Albers Equal Area Conic Projection

Figure 4-3. Surface water inflows and average annual precipitation to the IAZs (Sept. 1961-Sept. 2003) (Faunt et al. 2009, used with permission)

4.3 WATER MOVEMENT WITHIN THE CENTRAL VALLEY BASIN

Most of the water in the Central Valley groundwater basin moves from the edges (foothills) toward the center trough of the Central Valley floor, then towards the Sacramento/San Joaquin Delta. Most of the Central Valley's surface water features are highly managed. Reservoirs and conveyance facilities capture and divert a significant amount of surface water stream flows prior to entering the valley floor.

North Central Valley: Water in the Northern Central Valley flows toward the main surface water feature, the Sacramento River, which delivers water to the Delta before exiting the basin. Groundwater generally flows from the foothills on either side, towards the Sacramento River, and south towards the Delta.

Middle Central Valley: Water in the Middle Central Valley flows towards the Sacramento River from the north or towards the San Joaquin River from the south, towards the Delta to the west before exiting the basin. Groundwater follows mostly the same pattern, but is also affected by local pumping depressions which draw groundwater towards areas of concentrated groundwater pumping.

Southern Central Valley: Water in the Southern Central Valley, including the Tulare Lake Subbasin, is contained in the San Joaquin Valley, and when surface water is plentiful, flows from the foothills on the east toward the San Joaquin River, north to the Delta. Groundwater movement in the San Joaquin Valley is driven by local pumping stresses, but generally flows from the eastern foothills of the Sierra Nevada to the west toward pumping depressions and regionally groundwater flows to the north toward the Delta.

4.4 INFILTRATION, EVAPORATION, EVAPOTRANSPIRATION

Infiltration, evaporation, and evapotranspiration are three factors that can affect the movement of water in an area. These processes are surface and near-surface, taking place mostly above the subsurface water table. These processes are influenced by precipitation, soil properties, weather, and plant activities. Infiltration is important for discussion of surface activities in which salt and nitrate may enter groundwater. Evaporation and evapotranspiration can reduce the amount of water able to infiltrate and recharge the groundwater.

Infiltration: Infiltration is driven by the ability of water to enter the subsurface and move vertically down toward the water table. One way to assess the potential for infiltration is the nature of the soil texture in the upper 50 feet of sediments in the Central Valley with respect to effective porosity. **Figure 4-4** shows the percent of coarse-grained materials (sands and gravels) in the upper 50 feet of sediments in the Central Valley floor, as depicted by the spatial texture model developed by the USGS for the CVHM. Areas with a high amount of sands and gravels in the near-surface are expected to have improved infiltration of recharge water to the water table and groundwater body, which has implications for salt and nitrate loadings.

Evaporation/Evapotranspiration: Evaporation and evapotranspiration in the Central Valley can be represented using the reference evapotranspiration (ETo). In the Central Valley floor, the ETo is relatively high, ranging from 45 inches per year in the Sacramento Valley to 56 inches per year in the San Joaquin Valley (**Figure 4-5**). In general, the ETo exceeds precipitation (precipitation amounts are shown in **Figure 4-3** above), leaving most of the Central Valley floor in a state of perennial water deficiency. Overall, precipitation exceeds ETo during the winter months, but ETo exceeds precipitation during the summer months (Faunt et al. 2009). The implications of this relate to the role of irrigation and surface applications of water that contribute to the loading of water, salt, and nitrate to the groundwater body.

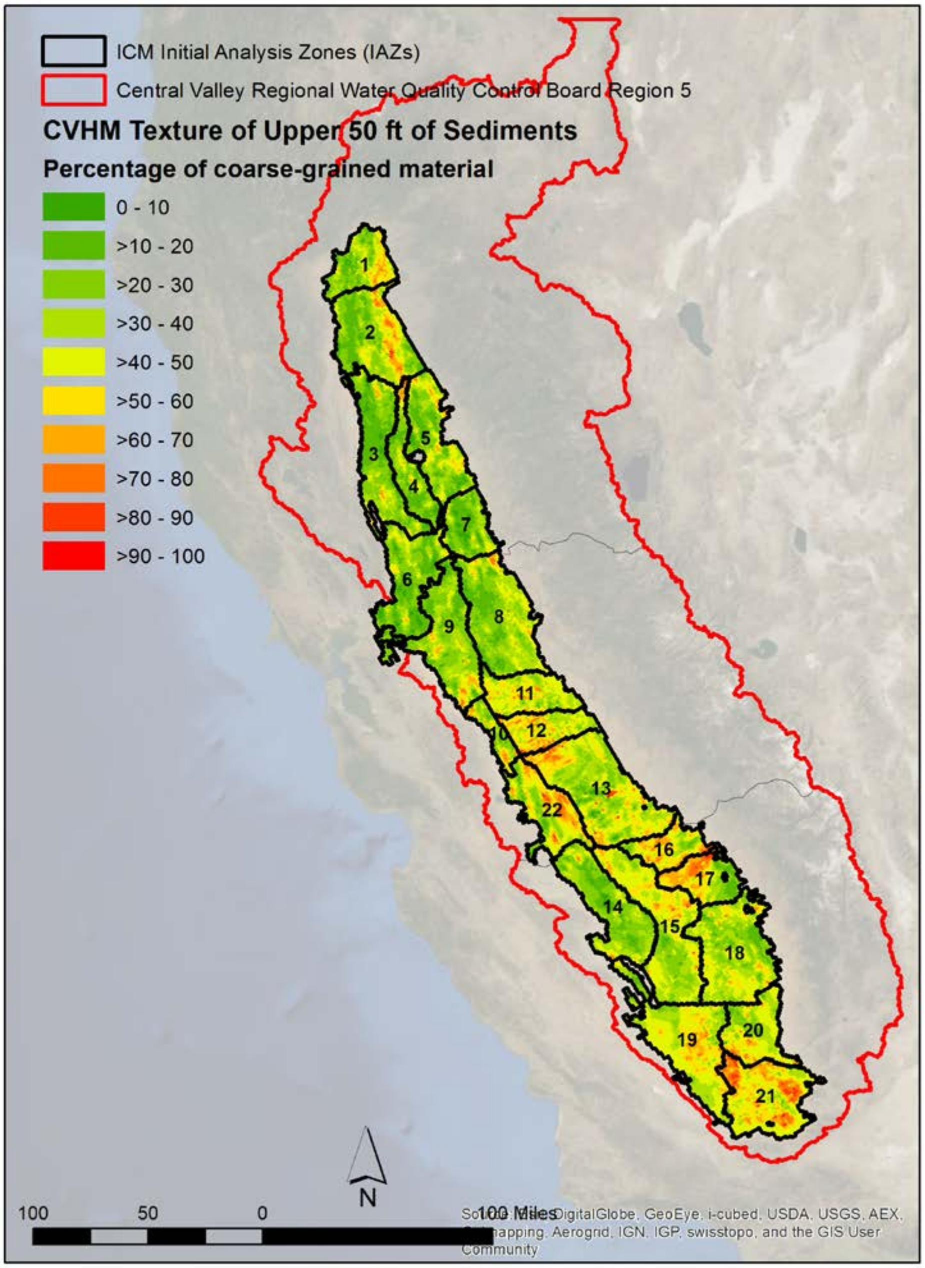
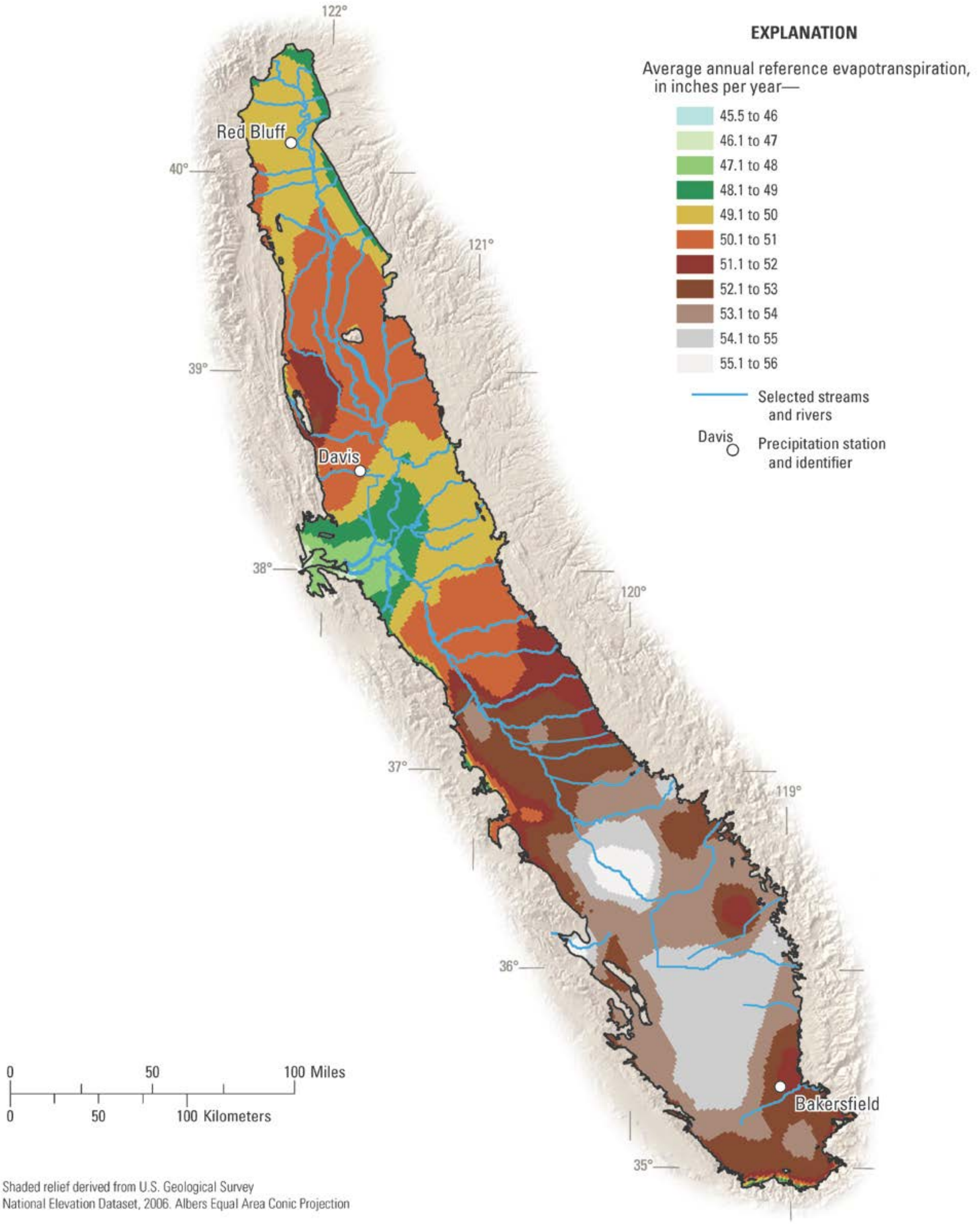


Figure 4-4. Percent Coarse-Grained Material in the Upper 50 feet of Sediments (CVHM Texture Database, Faunt et al. 2009)



Shaded relief derived from U.S. Geological Survey
National Elevation Dataset, 2006. Albers Equal Area Conic Projection

Figure 4-5. Average Annual Reference ETo (in/year) (Faunt et al. 2009, used with permission)

4.5 RECHARGE MECHANISMS

Recharge provides the vehicle for water, salt, and nitrate to enter groundwater. Understanding how recharge works and what factors can affect the amount of recharge are important for managing groundwater resources related to the influx of salt and nitrate from surface activities. The amount and spatial distribution of recharge is affected by several factors including climate variability, delivery of surface water for irrigation, and pumping for irrigation and public supply. Groundwater recharge results from artificial anthropogenic efforts or through deep percolation of water from the surface reaching past the root zone to enter the water table. Recharge can occur as a result of precipitation, leakage from streams and surface-water bodies, and return flow from irrigated agriculture. Return flows from irrigation water originate from a combination of surface-water deliveries and groundwater pumping. The dominant source of recharge in the southern half of the valley is through return irrigation flow from agriculture.

According to the USGS CVHM report, the simulated groundwater recharge conditions in the Central Valley floor for average (water years 1962-2003), typical (1975), dry (1990), and wet (1998) conditions is summarized below in **Table 4-3**, (Faunt et al. 2009 Table B-1). Of the average groundwater recharged annually from 1962 to 2003, 79 percent was from the landscape processes, including recharge from excess applied irrigation water and precipitation; 19 percent was from streams via stream leakage (losing stream conditions); and less than 1 percent was from infiltration from the Delta (Faunt et al., 2009).

Table 4-3. Average Annual Simulated Groundwater Recharge for the Entire Central Valley floor (CVHM simulated recharge WY 1962-2003) (Faunt et al. 2009 Table B-1)

Water Year Type	Groundwater Recharge (millions of acre-feet per year)
Average (WY 1962-2003)	7.7
Typical (1975	7.0
Dry (1990)	3.6
Wet (1998)	15.4

4.6 SUMMARY OF WATER BALANCE CONDITIONS

Summaries of the water balance conditions for the three major geographic areas of the Central Valley Floor are provided below in this section. For more details on each IAZ's specific water balance conditions, please refer to **Appendix F** (see SNMP Section B.2.1.2 Appendix). Water balance components include:

- Groundwater pumping
- Stream leakage (from gaining stream conditions or losing stream conditions)
- Net recharge (percolation out of the root zone towards the water table)
- Horizontal groundwater inflow and outflow to/from neighboring areas

- Vertical groundwater inflow and outflow to/from the aquifer below the starting unit volume (here, the “lower aquifer” refers to the part of the aquifer system below the 20-year travel zone)
- Groundwater storage (water is allowed to enter storage during years of surplus, and allowed to leave storage via storage depletion during years of deficit)

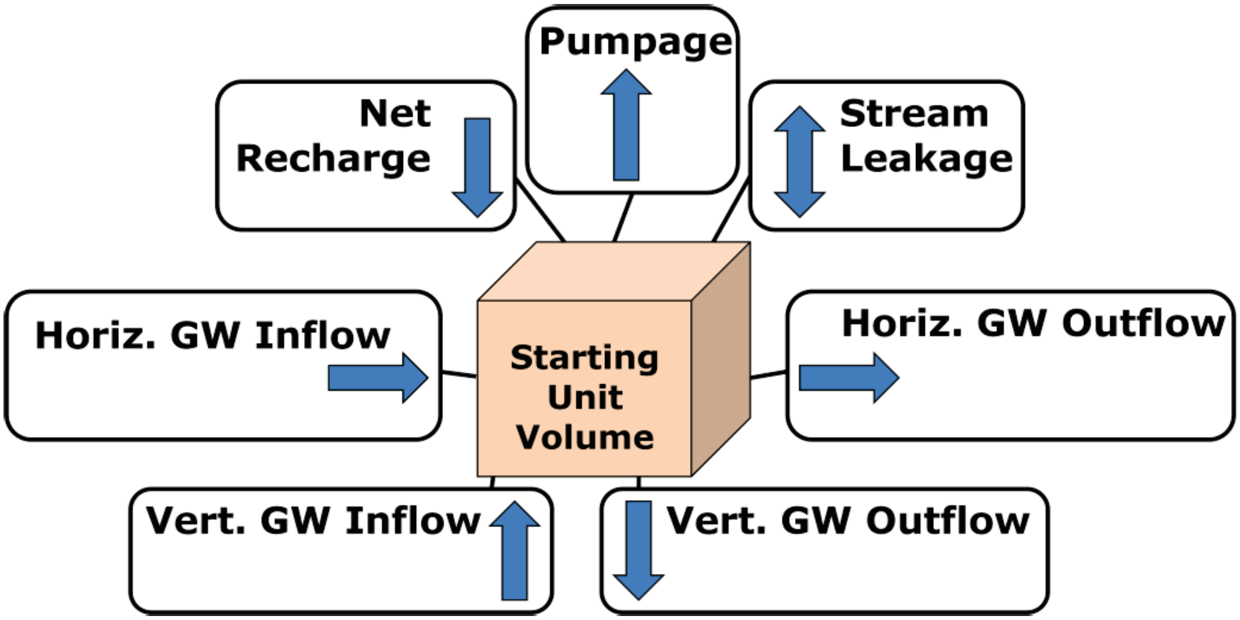


Figure 4-6. Water Balance Components and Movement

The summaries below provide tables and figures that detail water balance information for IAZs in the three areas of the Central Valley (Northern, Middle, and Southern) during the ICM study period (1983-2003) with depths according to their 20-year travel zone. The graphs included below show average starting unit volumes (**Figure 4-7**) in the IAZs, which is useful for comparing the relative differences in water balance components (some IAZs are spatially bigger than other IAZs, as seen in **Figure 4-2**). The amount of water volume in each IAZ is also an important component when calculating the movement and contributions of salt and nitrate (which is discussed in **Section 5**), as these water volumes mix with the influxes and outfluxes of salt and nitrate. The average water volumes are included in the tables below (i.e., **Tables 4-4, 4-5, and 4-6**).

The tables included in the following subsections provide the details of annual average water balance components. These tables have the following signage:

- Negative numbers indicate that these water balance components are leaving the IAZ
  - negative storage values indicate water leaving the IAZ to enter storage (via storage replenishment during times of surplus)
  - negative values for pumping indicate water being removed from the IAZ through wells;

    - negative stream leakage values indicate water leaving the IAZ groundwater body to enter streams (during gaining stream conditions)
    - negative groundwater recharge values are rare, but indicate groundwater leaving the IAZ's water table through evapotranspiration
    - negative vertical flow values indicate water leaving the IAZ to travel downwards towards the "lower aquifer" below the 20-year travel zone
    - negative horizontal flow values indicate water leaving the IAZ horizontally to travel into neighboring IAZs.
- Positive numbers indicate that these water balance components are entering the IAZ
    - positive storage values indicate water entering the IAZ from storage (via storage depletion during times of deficit)
    - positive groundwater pumping values do not occur
    - positive stream leakage values indicate water entering the IAZ groundwater body from losing stream conditions
    - positive groundwater recharge values indicate water entering the IAZ via deep percolation through the root zone
    - positive vertical flow values are rare, but indicate water entering the IAZ from the "lower aquifer" (this can occur in areas of groundwater discharge, where lower portions of the groundwater aquifer are actually pushing water upwards into the 20-year travel zone)
    - positive horizontal flow values indicate water entering the IAZ horizontally from neighboring IAZs.

Appendix F (see SNMP Section B.2.1.2 Appendix) contains more details for each of the IAZs in the three areas of the Central Valley, including: 1) time-series plots showing quarterly and annual patterns of each water balance component over time, 2) details about the average water balance components described above, 3) pie charts showing the different water balance components, and 4) a summary of the water balance conditions for each IAZ over the 20-year study period. **Appendix F** (see SNMP Section B.2.1.2 Appendix) is provided in order to present local entities the water balance details they could use for developing the basis of their own local SNMP. The subsections below summarize the details that are included in **Appendix F** (see SNMP Section B.2.1.2 Appendix).

4.1.1 Summary of Northern Central Valley IAZs

IAZs in the Northern Central Valley (IAZs 1 through 7) represent the Sacramento Valley Groundwater Basin, where gaining streams are prevalent and groundwater recharge is high. According to the ICM, the 20-year travel zones for IAZs 1 through 7 represent an average range of water volumes between about 3 million AF to about 10.5 million AF (**Figure 4-7**). A comparison of average annual water budget components (between 1983 and 2003) gives insight to the differences between the IAZs in the Northern Central Valley IAZs and also some similarities (**Table 4-4** and **Figure F-17** in SNMP Section B.2.1.2 Appendix). For example, IAZ 4 stands out as behaving differently from the other IAZs in that vertical flow from groundwater deeper than the 20-year travel zone (from the "lower aquifer") is upward instead of downward; IAZ 4 is also a sink with respect to horizontal flow, receiving more groundwater from adjacent IAZs compared to all others; also IAZ 4 is the only IAZ with an average annual negative groundwater recharge component indicating high amounts of uptake and evapotranspiration.

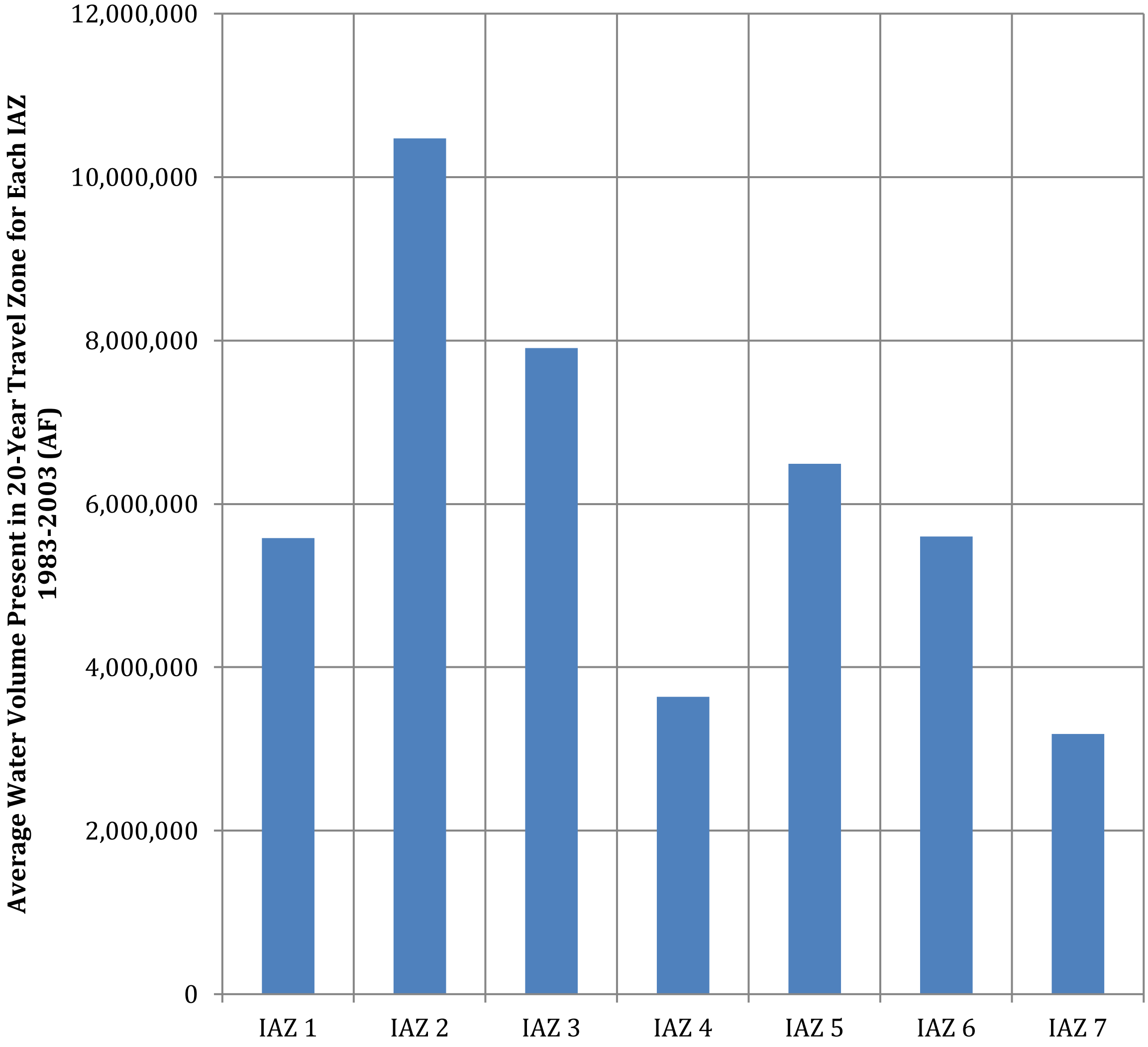


Figure 4-7. Average Water Volume Present in 20-Year Travel Zone for Northern Central Valley IAZs (1983-2003)

Table 4-4. Annual Average Water Budget Components for the 20-Year Travel Zone of Each IAZ in the Northern Central Valley (1983-2003) (TAFY)

Component	IAZ 1 (611 mi^2)	IAZ 2 (1,163 mi^2)	IAZ 3 (1,112 mi^2)	IAZ 4 (560 mi^2)	IAZ 5 (957 mi^2)	IAZ 6 (1,044 mi^2)	IAZ 7 (534 mi^2)
Average Groundwater Volume present in IAZ (TAF)	5,583	10,470	7,910	3,642	6,490	5,600	3,183
Flow Into/Out of Storage (TAFY)	52	51	18	4.5	41	-4.0	31
Groundwater Pumping (TAFY)	-34	-83	-1.1	0	-24	-67	-76
Flow Into/Out through Stream Leakage (TAFY)	-109	-289	-219	-506	-204	30	-40
Groundwater Recharge (TAFY)	403	710	441	-19	403	419	191
Vertical Flow to/from the Lower Aquifer (below the 20-year travel zone) (TAFY)	-287	-381	-205	412	-185	-371	-94
Horizontal Flow to/from Adjacent IAZs (TAFY)	-24	-7.5	-34	108	-31	-6.5	-12

4.6.1 Summary of Middle Central Valley IAZs

IAZs in the Middle Central Valley (IAZs 8 through 13 plus 22) represent the central portion of the Central Valley floor, including the Delta, where vertical flow downward to the saturated sediments below the 20-year travel zone is prevalent. According to the ICM, the 20-year travel zones for IAZs 8 through 13 plus 22 represent an average range of water volumes between about 2 million AF to almost 12 million AF (**Figure 4-8**). A comparison of average annual water budget components (between 1983 and 2003) gives insight to the differences between the IAZs in the Middle Central Valley IAZs and also some similarities (**Table 4-5** and **Figure F-33** in SNMP Section B.2.1.2 Appendix). IAZ 9 stands out as behaving different from the other IAZs in that stream leakage dominates the inflow into the IAZ, and it is the only IAZ that geographically overlays (covers) the Delta and provides groundwater from the 20-year travel zone to the Delta. IAZ 9 also has a relatively high amount of outflux from negative recharge, indicating shallow water table conditions allowing for evapotranspiration to occur and shallow groundwater leaving the IAZ instead of deep percolating. IAZ 8 and IAZ 13 have similarly high amounts of vertical flow leaving the 20-year travel zone to flow downward, as well as higher amounts of groundwater recharge compared to the other IAZs in the Middle Central Valley floor.

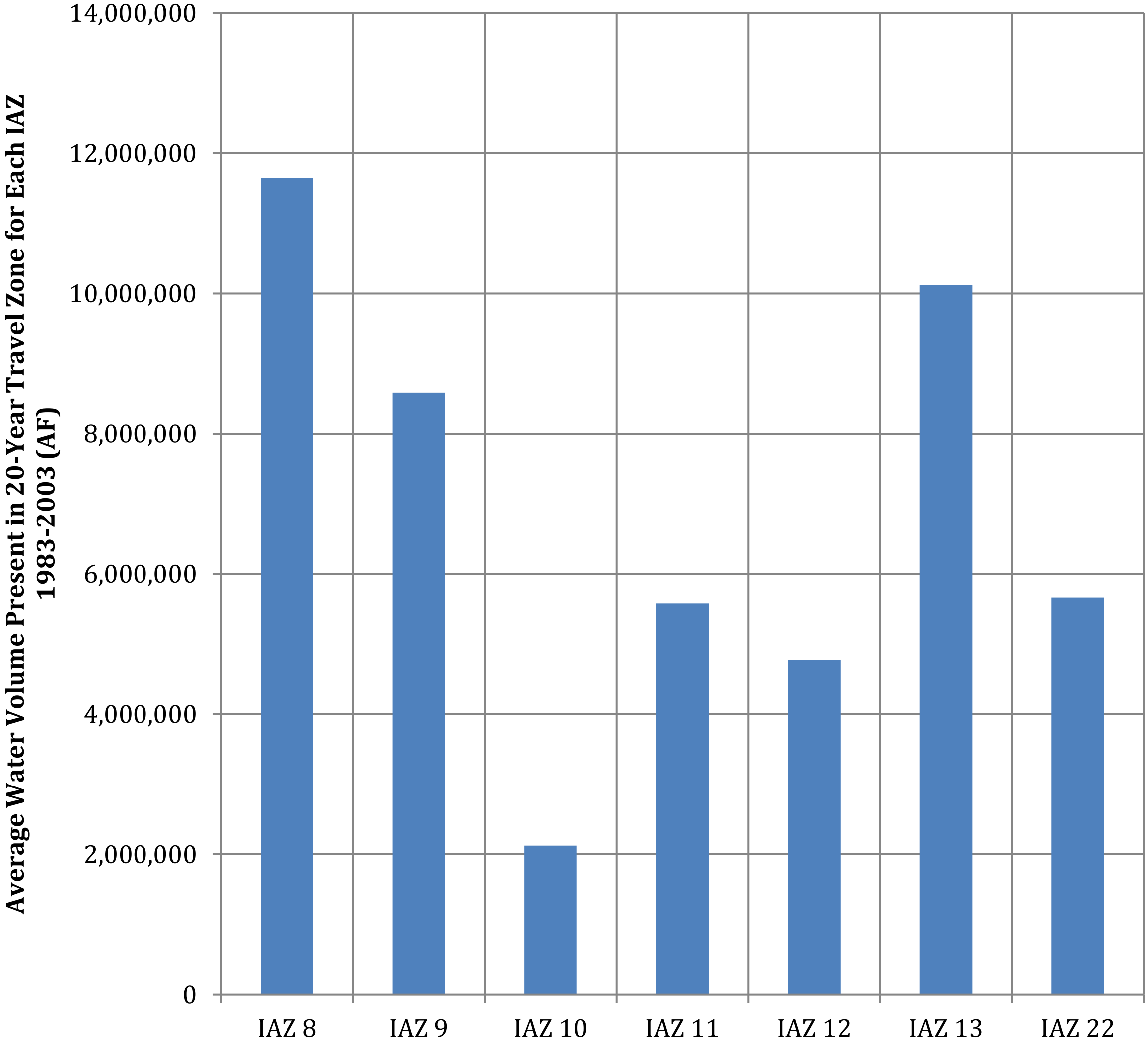


Figure 4-8. Average Water Volume Present in 20-Year Travel Zone for Middle Central Valley IAZs (1983-2003)

Table 4-5. Annual Average Water Budget Components for the 20-Year Travel Zone of Each IAZ in the Middle Central Valley (1983-2003) (TAFY) 1648

Component	IAZ 8	IAZ 9	IAZ 10	IAZ 11	IAZ 12	IAZ 13	IAZ 22
	(1,362 mi^2)	(1,026 mi^2)	(1,083 mi^2)	(664 mi^2)	(540 mi^2)	(1,648 mi^2)	
Average Groundwater Volume present in IAZ (TAF)	11,644	8,585	2,121	5,580	4,769	10,117	5,660
Flow Into/Out of Storage (TAFY)	29	-132	-10	14	-12	129	14
Groundwater Pumping (TAFY)	-70	-11	-3.1	-9.4	-0.6	-104	-5.9
Flow Into/Out through Stream Leakage (TAFY)	82	596	-1.3	-99	23	131	51
Groundwater Recharge (TAFY)	612	-294	80	204	116	415	-17
Vertical Flow to/from the Lower Aquifer (below the 20-year travel zone) (TAFY)	-664	-120	-53	-122	-88	-574	-49
Horizontal Flow to/from Adjacent IAZs (TAFY)	-6.0	13	-8.2	32	-36	4.5	7.6
Flow Through the Delta (TAFY)	-	-52	-	-	-	-	-

4.6.2 Summary of Southern Central Valley IAZs

IAZs in the Southern Central Valley (IAZs 14 through 21) represent the southern portion of the Central Valley, including portions of the San Joaquin Valley and the Tulare Basin, where major outflow components are usually groundwater pumping and vertical flow downward to the saturated sediments below the 20-year travel zone. The greatest inflow components are typically groundwater recharge, water from storage depletion, and stream leakage via losing stream conditions. According to the ICM, the 20-year travel zones for IAZs 14 through 21 represent an average range of water volumes between about 3 million AF to almost 20 million AF (**Figure 4-9**). A comparison of average annual water budget components (between 1983 and 2003) gives insight to the differences between the IAZs in the Middle Central Valley IAZs and also some similarities (**Table 4-6** and **Figure F-51** in SNMP Section B.2.1.2 Appendix). IAZ 15 and 18 show the greatest amounts of groundwater recharge and groundwater pumping out of the 20-year travel zone. IAZ 19 has no stream leakage components, whereas all of the other IAZs in this region have a somewhat small proportion of surface water contributing to the 20-year travel zone.

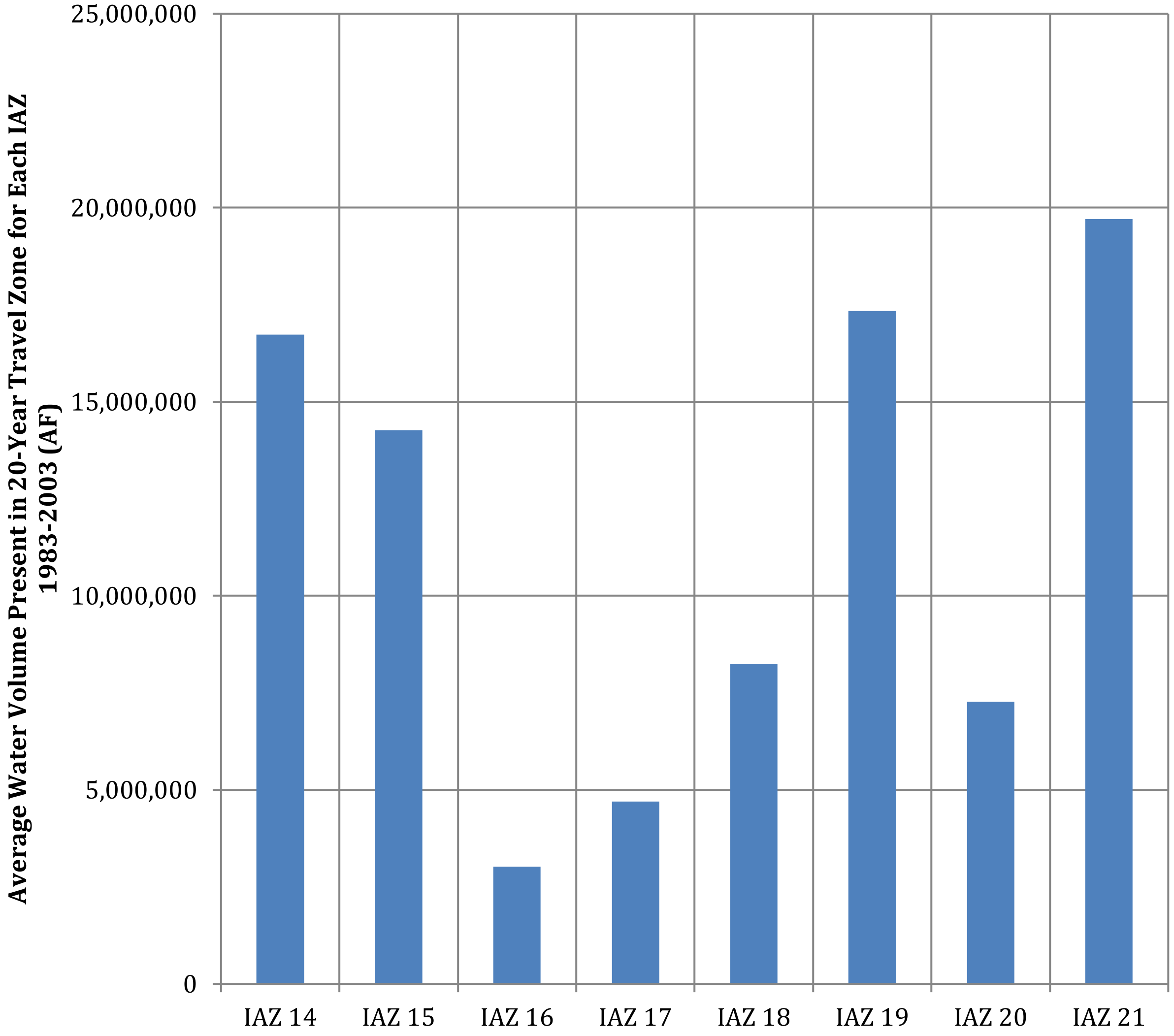


Figure 4-9. Average Water Volume Present in 20-Year Travel Zone for Southern Central Valley IAZs (1983-2003)

Table 4-6. Annual Average Water Budget Components for the 20-Year Travel Zone of Each IAZ in the Southern Central Valley (1983-2003) (TAFY)

Component	IAZ 14 (1,071 mi^2)	IAZ 15 (1,423 mi^2)	IAZ 16 (478 mi^2)	IAZ 17 (569 mi^2)	IAZ 18 (1,358 mi^2)	IAZ 19 (1,365 mi^2)	IAZ 20 (705 mi^2)	IAZ 21 (1,105 mi^2)
Average Groundwater Volume present in IAZ (TAF)	16,731	14,263	3,020	4,704	8,249	17,342	7,269	19,704
Flow Into/Out of Storage (TAFY)	134	91	107	100	235	125	100	252
Groundwater Pumping (TAFY)	-55	-502	-84	-158	-679	-168	-37	-109
Flow Into/Out through Stream Leakage (TAFY)	4.5	241	34	166	110	0	15	109
Groundwater Recharge (TAFY)	247	662	157	300	603	300	202	237
Vertical Flow to/from the Lower Aquifer (below the 20-year travel zone) (TAFY)	-332	-584	-170	-372	-352	-313	-207	-406
Horizontal Flow to/from Adjacent IAZs (TAFY)	1.3	94	-44	-36	84	56	-73	-82