APPENDIX 2.F. WATER BUDGET INFORMATION

2.F.a. Surface Water System Water Budget: Chowchilla Water District GSA

Prepared as part of the

Groundwater Sustainability Plan
Chowchilla Subbasin

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1 INTRODUCTION

To ensure sustainable groundwater management throughout California's groundwater basins, the Sustainable Groundwater Management Act of 2014 (SGMA) requires Groundwater Sustainability Agencies (GSAs) to prepare and adopt Groundwater Sustainability Plans (GSPs) with strategies to achieve subbasin groundwater sustainability within 20 years of plan adoption. Integral to each GSP is a water budget used to quantify the subbasin's groundwater overdraft (if applicable) and sustainable yield.

In 2016, Chowchilla Water District (CWD) GSA formed to manage approximately 85,200 acres of the Chowchilla Subbasin. This document presents results of the surface water system (SWS) water budgets developed for historical and current land use conditions in CWD GSA. The CWD GSA water budgets were integrated with separate water budgets developed for four (4) other subregions of the Chowchilla Subbasin representing the three (3) other subbasin GSAs. Together, these water budgets provide the boundary water budget for the Chowchilla Subbasin SWS. Results of the subbasin boundary water budget are reported in the Chowchilla Subbasin GSP Section 2.2.3 and were integrated with a subbasin groundwater model (GSP Appendix 6.E) to estimate subbasin sustainable yield (GSP Section 2.2.3).

2 WATER BUDGET CONCEPTUAL MODEL

A water budget is defined as a complete accounting of all water flowing into and out of a defined volume (e.g., a subbasin or a GSA) over a specified period of time. The conceptual model (or structure) of the CWD GSA water budget developed for this investigation is consistent with the GSP Regulations defined under Title 23 of California Code of Regulations[1] (CCR) and adheres to sound water budget principles and practices defined by California Department of Water Resources (DWR) in the Water Budget Best Management Practice (BMP) guidelines (DWR, 2016).

The lateral extent of CWD GSA is defined by the boundaries indicated in Figure A2.F.a-1. The vertical extent of CWD GSA is the land surface (top) and the base of fresh water at the bottom of the basin (bottom), as described in the hydrogeologic conceptual model (HCM) developed in GSP Section 2.2.1. The vertical extent of Chowchilla Subbasin and its GSAs is subdivided into a surface water system (SWS) and the underlying groundwater system (GWS), with separate but related water budgets prepared for each that together represent the overall subbasin water budget.

A conceptual representation of the CWD GSA water budget is represented in Figure A2-F.a-2. This document details only the SWS portion of the CWD GSA water budget. The SWS is divided into three primary accounting centers: the Land Surface System, the Rivers and Streams System, and the Canal System. The Land Surface System is further divided into four accounting centers representing CWD GSA's water use sectors: Agricultural Land, Native Vegetation Land, and Urban Land (urban, semi-agricultural, and industrial), and Managed Recharge Land.

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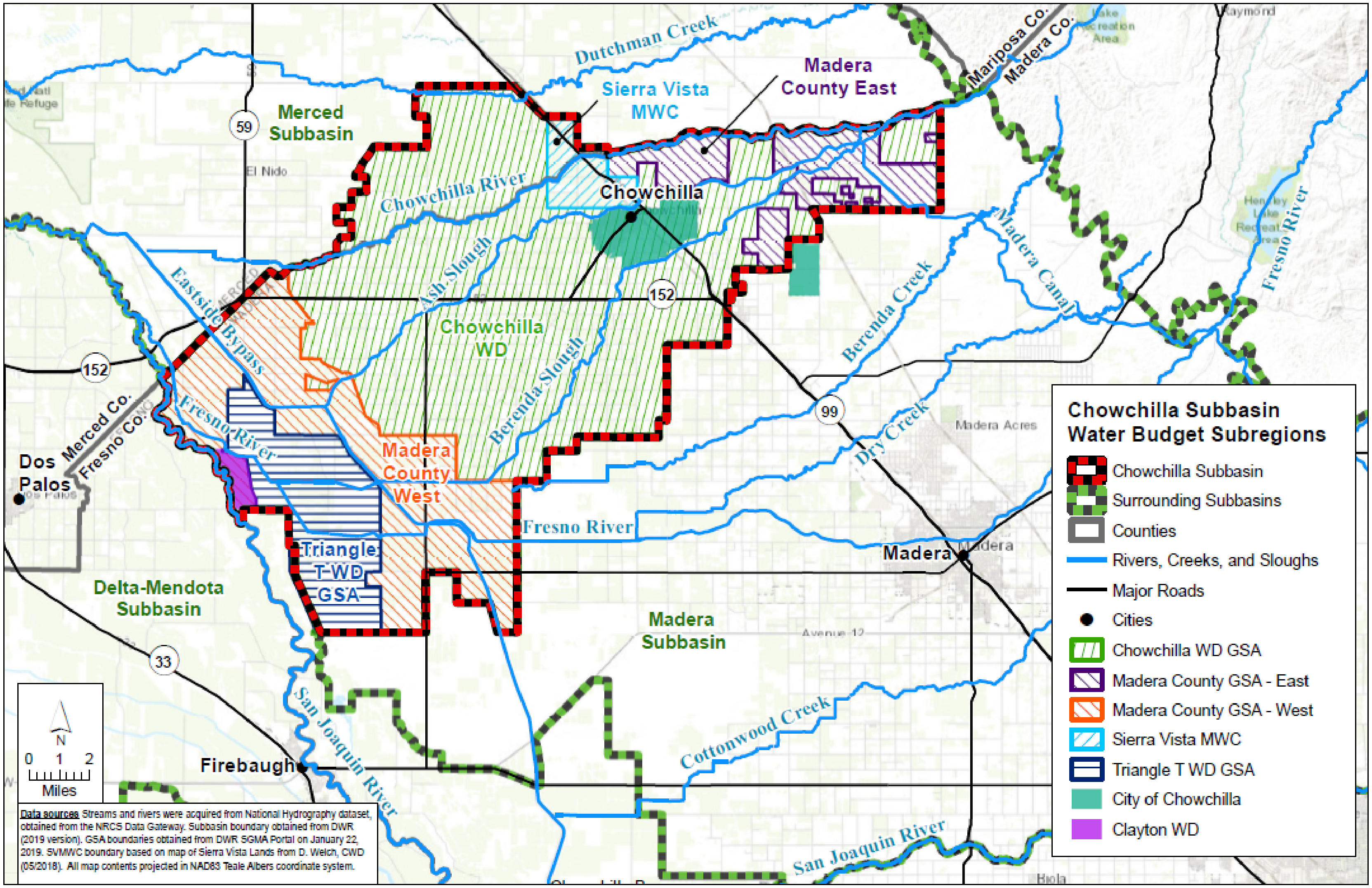
[1] California Code of Regulations Title 23. Waters, Division 2. Department of Water Resources, Chapter 1.5. Groundwater Management, Subchapter 2. Groundwater Sustainability Plans.



Data sources Streams and rivers were acquired from National Hydrography dataset, obtained from the NRCS Data Gateway. Subbasin boundary obtained from DWR (2019 version). GSA boundaries obtained from DWR SGMA Portal on January 22, 2019. SVMWC boundary based on map of Sierra Vista Lands from D. Welch, CWD (05/2018). All map contents projected in NAD83 Teale Albers coordinate system.

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Chowchilla Subbasin Water Budget Subregion Map

Chowchilla Subbasin Groundwater Sustainability Plan

Figure A2.F.a-1. Chowchilla Subbasin Water Budget Subregion Map

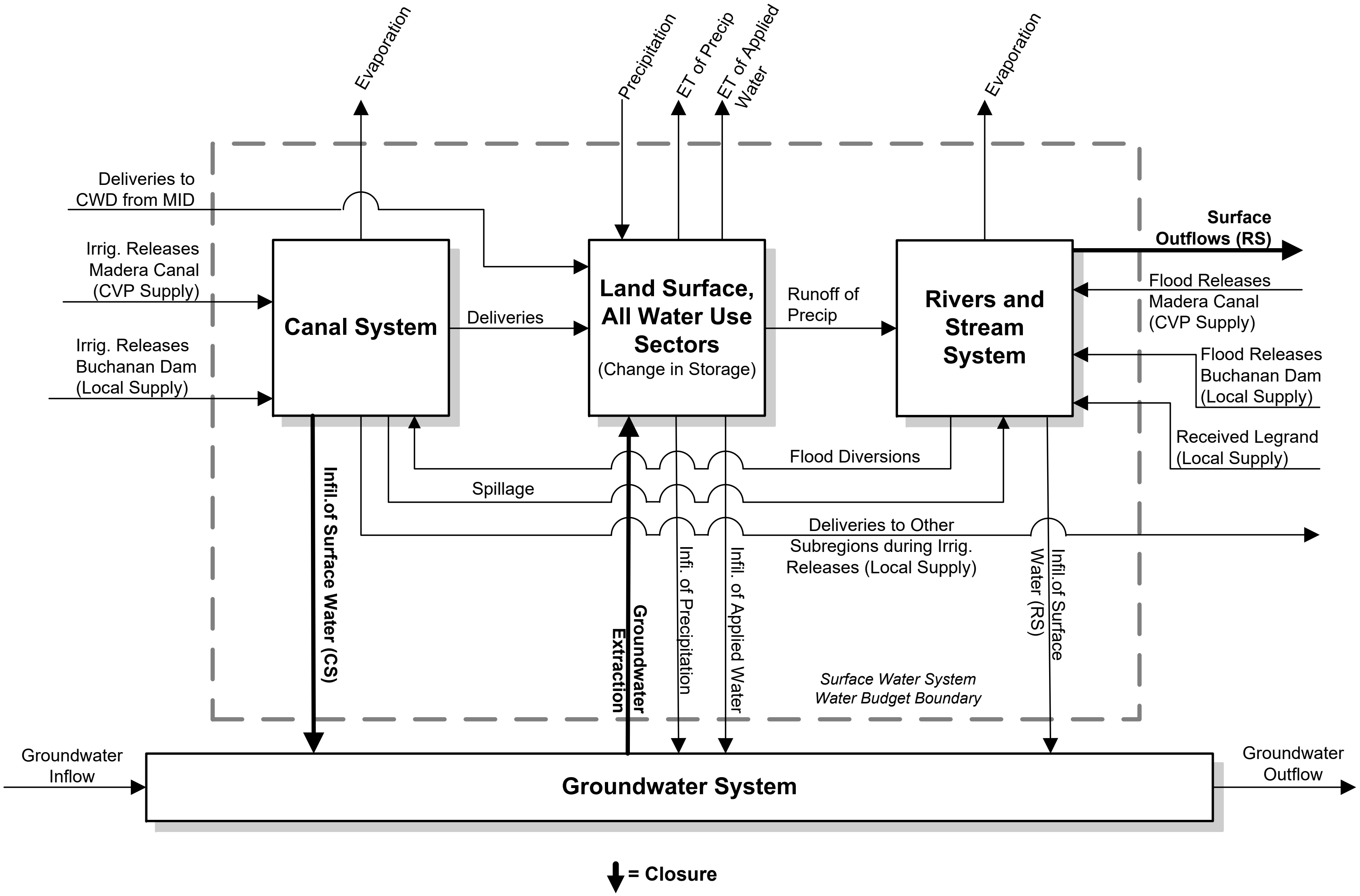

Figure A2.F.a-2. Chowchilla Water District GSA Water Budget Structure

Water budget components, or directional flow of water between accounting centers and across the SWS boundary, are indicated by arrows. Inflows and outflows were calculated using measurements and other historical data or were calculated as the water budget closure term – the difference between all other estimated or measured inflows and outflows from each accounting center or water use sector (bold arrows).

Inflows to the SWS include precipitation, surface water inflows (in various canals, rivers, and streams), and groundwater extraction. Outflows from the SWS include evapotranspiration (ET), surface water outflows (in various canals and streams), and infiltration to the groundwater system (seepage and deep percolation). Also represented in Figure A2.F.a-2 are inflows and outflows from the GWS, which are discussed and quantified at the subbasin level in the GWS water budget in GSP Section 2.2.3. Subsurface GWS inflows and outflows are not quantified on the water budget subregion scale.

Inflows and outflows were quantified following the process described in GSP Section 2.2.3 on a monthly time step for water years in the historical water budget base period (1989-2014 hydrologic and land use conditions), the current water budget (2015 land use using 1989-2014 average hydrologic conditions), and projected water budget. Four projected water budgets were prepared for the years 2019 through 2090 based on 1965 through 2015 hydrologic conditions, projected water supplies, and 2017 land use adjusted for urban area projected growth from 2017-2070 (areas were held constant from 2071-2090):

1. Historical hydrologic conditions and water supply data, with adjustment for projected alteration of available Friant releases by the San Joaquin River Restoration Program (SJRRP)[2]
    a. Without projects and management actions, and
    b. With projects and management actions
2. Historical hydrologic conditions and water supply data, with adjustment for projected alteration of available Friant releases by the SJRRP and adjustment for anticipated climate change per DWR-provided 2030 climate change factors
    a. Without projects and management actions, and
    b. With projects and management actions.

Information regarding the data sources and adjustments used to prepare the historical, current, and projected water budgets are described in GSP Section 2.2.3.

3 WATER BUDGET ANALYSIS

The historical water budget and current land use water budget for CWD GSA are presented below following a summary of land use data relevant to water budget development. Land use data is provided for the 1989-2014 historical water budget period and for 2015, the current land use water budget period.

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[2] Adjustments were based on the Friant Report ("Estimate of Future Friant Division Supplies for use in Groundwater Sustainability Plans, California," Friant Water Authority, 2018). Although the Friant Report accounts for climate change, it is considered the best available estimate of projected Friant releases under SJRRP. For comparison, projected Madera Canal deliveries under SJRRP were also estimated without account for climate change from the Kondolf Hydrographs (in “Effects to Water Supply and Friant Operations Resulting From Plaintiffs' Friant Release Requirements,” Steiner, 2005). These estimates were approximately equal to the Friant Report 2030 climate change adjusted deliveries. Thus, the Friant Report projections were used instead to maintain consistent assumptions in estimating Madera Canal deliveries across all projected simulations.

3.1 Land Use

Land use estimates for 1989 through 2015 corresponding to water use sectors (as defined by the GSP Regulations) are summarized in Figure A2.F.a-3 and Table A2.F.a-1 for the CWD GSA. According to GSP Regulations (23 CCR § 351(al)):

> *"Water use sector" refers to 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.*

In CWD GSA, water use sectors include agricultural, native vegetation, urban, and managed recharge land use. The urban land use category includes urban and semi-agricultural[3] lands as well as industrial land, which covers only a small area in the subbasin. In CWD GSA, the managed recharge water use sector represents a portion of agricultural lands that receive flood water for recharge during non-irrigation season months. As no land in the GSA is purposed exclusively for managed recharge, managed recharge acreage is not summarized below.

As indicated, the majority of land in CWD GSA is used for agriculture, covering an average of approximately 73,100 acres between 1989 and 2014. Agricultural acreage has gradually been reduced over time with the expansion of urban lands from 4,400 acres in 1989 to over 9,000 acres in 2015.

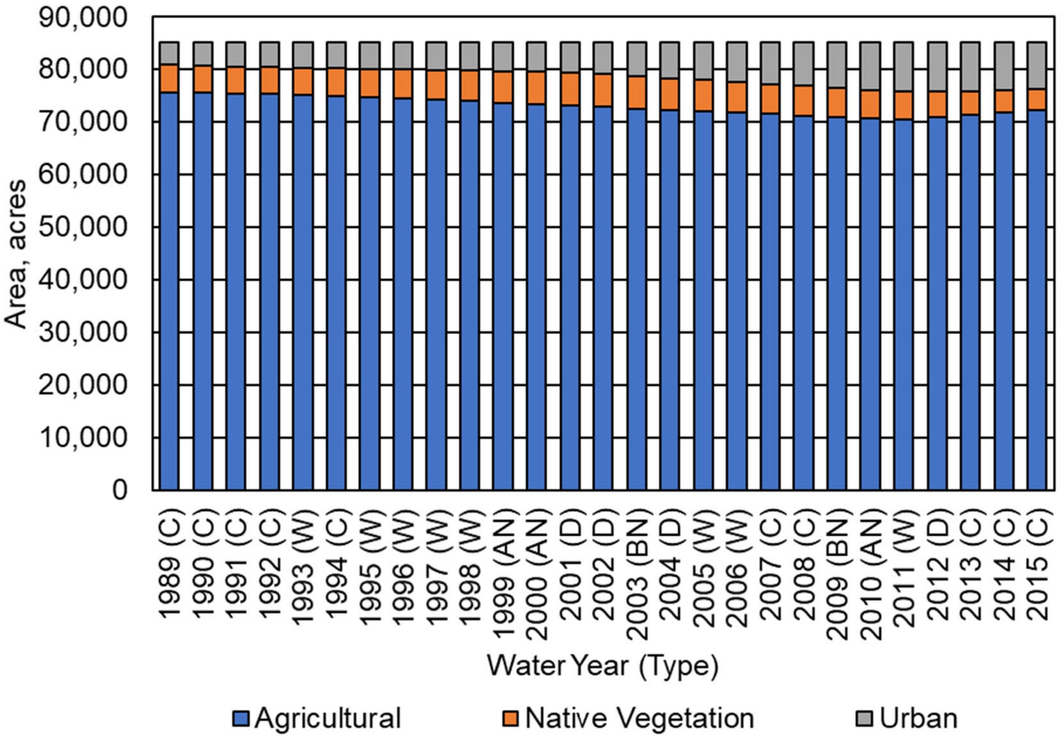

Figure A2.F.a-3. Chowchilla Water District GSA Land Use Areas

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[3] As defined in the DWR county land use surveys, 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, 2009).

Table A2.F.a-1. Chowchilla Water District GSA Land Use Areas, acres

Water Year (Type)	Agricultural	Native Vegetation[1]	Urban[2]	Total
1989 (C)	75,658	5,175	4,396	85,229
1990 (C)	75,524	5,193	4,513	85,229
1991 (C)	75,400	5,189	4,640	85,229
1992 (C)	75,267	5,185	4,778	85,229
1993 (W)	75,148	5,163	4,918	85,229
1994 (C)	74,980	5,190	5,060	85,229
1995 (W)	74,769	5,257	5,203	85,229
1996 (W)	74,494	5,429	5,306	85,229
1997 (W)	74,218	5,602	5,409	85,229
1998 (W)	73,942	5,774	5,512	85,229
1999 (AN)	73,667	5,947	5,615	85,229
2000 (AN)	73,392	6,119	5,718	85,229
2001 (D)	73,116	6,292	5,821	85,229
2002 (D)	72,843	6,233	6,153	85,229
2003 (BN)	72,571	6,132	6,526	85,229
2004 (D)	72,299	6,032	6,898	85,229
2005 (W)	72,026	5,932	7,271	85,229
2006 (W)	71,754	5,832	7,643	85,229
2007 (C)	71,482	5,731	8,016	85,229
2008 (C)	71,210	5,631	8,388	85,229
2009 (BN)	70,938	5,531	8,761	85,229
2010 (AN)	70,665	5,431	9,133	85,229
2011 (W)	70,393	5,330	9,505	85,229
2012 (D)	70,832	4,932	9,466	85,229
2013 (C)	71,293	4,560	9,377	85,229
2014 (C)	71,752	4,189	9,287	85,229
2015 (C)	72,332	3,836	9,061	85,229
Average (1989-2014)	73,063	5,501	6,666	85,229

[1] Area includes land classified as native vegetation and water surfaces.

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

Agricultural land uses are further detailed in Figure A2.F.a-4 and Table A2.F.a-2. Historically, a majority of the agricultural area in CWD has been used to cultivate orchard crops, mixed pasture, alfalfa, and corn. While mixed pasture and alfalfa acreage has decreased since the early 1990s, orchard acreage more than doubled between 1989 and 2015.

3.2 Surface Water System Water Budget

This section presents surface water system water budget components within CWD GSA as per GSP regulations. These are followed by a summary of the water budget results by accounting center.

3.2.1 Inflows

3.2.1.1 Surface Water Inflow by Water Source Type

Surface water inflows include surface water flowing into CWD across the subregion boundary. Per the Regulations, surface inflows must be reported by water source type. According to the Regulations:

> *"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.*

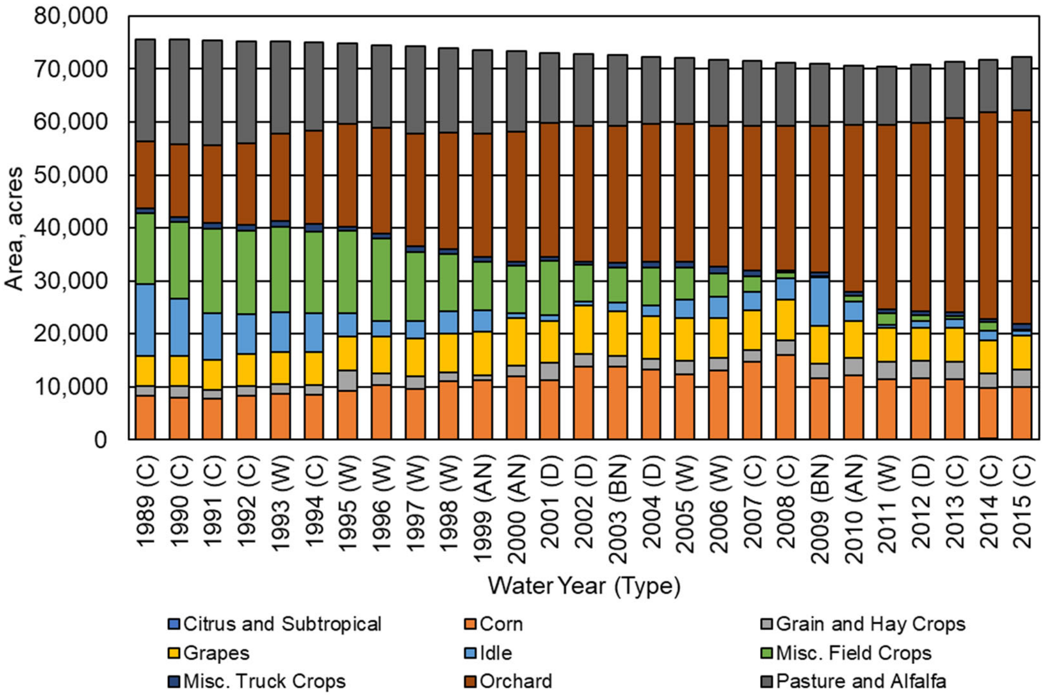

Figure A2.F.a-4. Chowchilla Water District GSA Agricultural Land Use Areas

Table A2.F.a-2. Chowchilla Water District GSA Agricultural Land Use Areas

Water Year (Type)	Citrus and Subtropical	Corn	Grain and Hay Crops	Grapes	Idle	Misc. Field Crops	Misc. Truck Crops	Orchard	Pasture and Alfalfa	Total
1989 (C)	29	8,340	1,718	5,773	13,578	13,369	807	12,801	19,243	75,658
1990 (C)	29	7,971	2,116	5,755	10,797	14,398	976	13,733	19,749	75,524
1991 (C)	31	7,695	1,645	5,781	8,643	16,127	1,015	14,699	19,763	75,400
1992 (C)	30	8,264	1,897	6,009	7,571	15,691	1,121	15,360	19,324	75,267
1993 (W)	29	8,638	1,842	6,071	7,451	16,102	1,243	16,438	17,335	75,148
1994 (C)	27	8,496	1,749	6,315	7,313	15,324	1,613	17,542	16,601	74,980
1995 (W)	25	9,184	3,836	6,393	4,515	15,565	664	19,472	15,114	74,769
1996 (W)	67	10,231	2,262	6,858	3,012	15,548	950	19,993	15,574	74,494
1997 (W)	73	9,451	2,343	7,259	3,278	12,968	1,132	21,222	16,493	74,218
1998 (W)	19	10,992	1,587	7,395	4,248	10,785	895	22,117	15,904	73,942
1999 (AN)	7	11,231	914	8,167	4,069	9,174	1,013	23,222	15,871	73,667
2000 (AN)	35	11,877	2,136	8,891	888	9,109	736	24,565	15,154	73,392
2001 (D)	14	11,167	3,319	7,945	1,140	10,177	716	25,301	13,336	73,116
2002 (D)	40	13,678	2,504	9,038	798	6,901	680	25,718	13,484	72,843
2003 (BN)	12	13,770	1,994	8,407	1,676	6,687	783	25,983	13,257	72,571
2004 (D)	10	13,199	2,083	8,082	1,961	7,226	1,068	25,931	12,739	72,299
2005 (W)	10	12,353	2,565	7,970	3,467	6,115	1,139	25,952	12,455	72,026
2006 (W)	9	12,980	2,502	7,417	4,072	4,403	1,289	26,674	12,409	71,754
2007 (C)	8	14,745	2,228	7,475	3,388	2,980	1,202	27,305	12,152	71,482
2008 (C)	6	16,021	2,763	7,608	4,158	941	367	27,484	11,861	71,210
2009 (BN)	5	11,664	2,583	7,172	9,200	276	622	27,792	11,624	70,938
2010 (AN)	4	12,130	3,345	6,862	3,648	1,210	646	31,537	11,283	70,665
2011 (W)	6	11,393	3,376	6,294	604	2,246	657	34,880	10,938	70,393
2012 (D)	34	11,596	3,237	6,263	1,188	1,267	674	35,520	11,052	70,832
2013 (C)	58	11,346	3,394	6,238	1,781	482	741	36,727	10,527	71,293
2014 (C)	172	9,520	2,849	6,213	1,864	1,546	648	38,973	9,967	71,752
2015 (C)	112	9,803	3,387	6,295	909	239	1,108	40,279	10,199	72,332
Average (1989-2014)	30	11,074	2,415	7,063	4,397	8,331	900	24,498	14,354	73,063

Additionally, runoff of precipitation from upgradient areas adjacent to the subregion represents a potential source of surface water inflow.

Local Supplies

Local supplies to CWD GSA include water received from Legrand Dam. Local supplies to SVMWC, which include pre-1914, riparian, and prescriptive water rights deliveries, also pass through CWD along Chowchilla River.

CVP Supplies

CVP supplies to CWD GSA include irrigation releases and flood releases from Buchanan Dam along the Chowchilla River and from Millerton Reservoir along Madera Canal. Both irrigation and flood releases from Millerton Reservoir are diverted to CWD at Madera Canal Miles 33.6 and 35.6. Irrigation releases are accounted as inflows to the water budget Canal System, while flood releases are accounted as inflows to the Rivers and Stream System.

Recycling and Reuse

Recycling and reuse are not a significant source of supply within CWD.

Other Surface Inflows

For the water budgets presented herein, precipitation runoff from outside the subregion is considered relatively minimal and is expected to pass through the waterways accounted above following relatively large storm events. Precipitation runoff from lands inside the subregion is internal to the surface water system and is thus not considered as surface inflows to the subregion boundary.

Summary of Surface Inflows

The surface water inflows described above are summarized by water source type in Figure A2.F.a-5 and Table A2.F.a-3. During the study period, total surface inflows vary by water year type, averaging 256 taf during wet years and 73 taf during critical years.

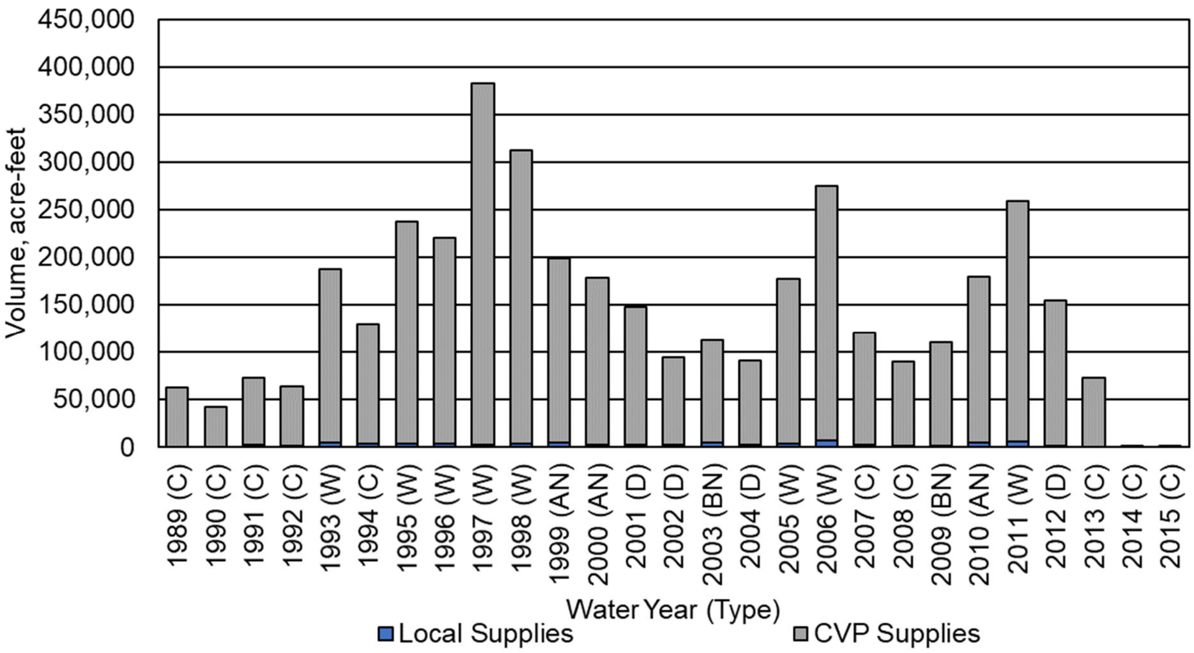

Figure A2.F.a-5. Chowchilla Water District GSA Surface Water Inflows by Water Source Type.

Table A2.F.a-3. Chowchilla Water District GSA Surface Water Inflows by Water Source Type (Acre-Feet).

Water Year (Type)	Local Supply	CVP Supply[1]	Total
1989 (C)	0	62,620	62,620
1990 (C)	0	42,270	42,270
1991 (C)	2,270	71,070	73,340
1992 (C)	1,650	62,570	64,220
1993 (W)	4,320	183,200	187,520
1994 (C)	3,550	126,060	129,610
1995 (W)	3,890	232,970	236,860
1996 (W)	3,680	217,160	220,840
1997 (W)	2,330	380,110	382,440
1998 (W)	3,360	309,450	312,810
1999 (AN)	4,850	194,270	199,120
2000 (AN)	2,600	176,300	178,890
2001 (D)	2,460	145,830	148,280
2002 (D)	2,760	91,120	93,880
2003 (BN)	5,030	107,190	112,220
2004 (D)	2,970	88,490	91,450
2005 (W)	3,570	173,440	177,010
2006 (W)	6,540	267,870	274,410
2007 (C)	2,070	118,440	120,510
2008 (C)	1,680	87,840	89,520

Water Year (Type)	Local Supply	CVP Supply[1]	Total
2009 (BN)	1,590	109,170	110,760
2010 (AN)	5,210	174,400	179,610
2011 (W)	5,730	253,280	259,000
2012 (D)	1,370	152,750	154,120
2013 (C)	80	72,990	73,070
2014 (C)	0	440	440
2015 (C)	0	530	530
Average (1989-2014)	2,830	150,050	152,880
Average (1989-2014) W	4,180	252,180	256,360
Average (1989-2014) AN	4,220	181,660	185,870
Average (1989-2014) BN	3,310	108,180	111,490
Average (1989-2014) D	2,390	119,540	121,930
Average (1989-2014) C	1,260	71,590	72,850

[1] CVP Supply is considered as all water supply released from CVP storage facilities. The volume of CVP Supply includes CVP deliveries to CWD, and flood releases from CVP facilities that pass through the subbasin.

3.2.1.2 Precipitation

Precipitation estimates for CWD GSA are provided in Figure A2.F.a-6 and Table A2.F.a-4. Precipitation estimates are reported by water use sector.

Total precipitation is highly variable between years in the study area, ranging from approximately 54 taf (7.6 inches) during average dry years to 102 taf (14.4 inches) during average wet years.

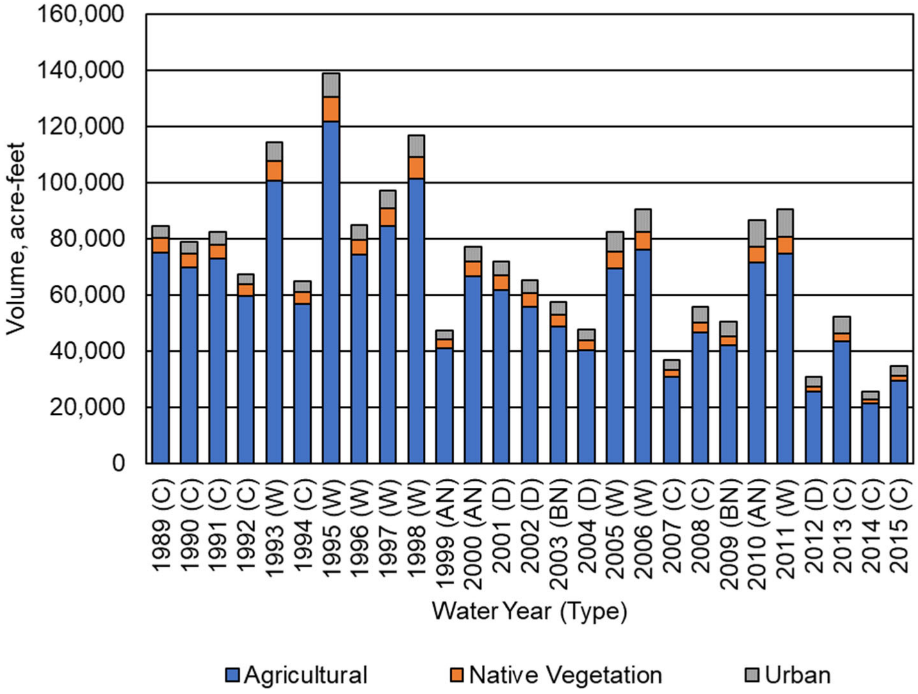

Figure A2.F.a-6. Chowchilla Water District GSA Precipitation by Water Use Sector.

Table A2.F.a-4. Chowchilla Water District GSA Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	75,130	5,160	4,380	84,670
1990 (C)	69,950	4,830	4,190	78,970
1991 (C)	73,000	5,040	4,500	82,540
1992 (C)	59,550	4,110	3,790	67,450
1993 (W)	100,740	6,940	6,610	114,290
1994 (C)	56,960	3,950	3,850	64,760
1995 (W)	121,930	8,600	8,510	139,040
1996 (W)	74,270	5,430	5,300	85,000
1997 (W)	84,540	6,400	6,180	97,110
1998 (W)	101,250	7,930	7,570	116,740
1999 (AN)	40,910	3,310	3,130	47,350
2000 (AN)	66,460	5,550	5,190	77,200
2001 (D)	61,770	5,330	4,930	72,020
2002 (D)	55,840	4,790	4,730	65,360
2003 (BN)	48,880	4,140	4,410	57,420
2004 (D)	40,460	3,380	3,870	47,710
2005 (W)	69,510	5,740	7,040	82,280
2006 (W)	76,280	6,220	8,150	90,640
2007 (C)	30,780	2,470	3,460	36,720
2008 (C)	46,580	3,690	5,500	55,770
2009 (BN)	41,880	3,280	5,190	50,350
2010 (AN)	71,720	5,530	9,290	86,540
2011 (W)	74,830	5,680	10,120	90,630
2012 (D)	25,630	1,790	3,430	30,850
2013 (C)	43,580	2,800	5,740	52,110
2014 (C)	21,420	1,250	2,780	25,450
2015 (C)	29,480	1,570	3,700	34,750
Average (1989-2014)	62,840	4,740	5,460	73,040
Average (1989-2014) W	87,920	6,610	7,430	101,970
Average (1989-2014) AN	59,700	4,800	5,870	70,360
Average (1989-2014) BN	45,380	3,710	4,800	53,890
Average (1989-2014) D	45,920	3,820	4,240	53,990
Average (1989-2014) C	52,990	3,700	4,250	60,940

3.2.1.3 Groundwater Extraction by Water Use Sector

Estimates of groundwater extraction by water use sector are provided in Figure A2.F.a-7 and Table A2.F.a-5. For agricultural and urban (urban, semi-agricultural, industrial) lands, groundwater extraction represents pumping, while for native lands, groundwater extraction by riparian vegetation was considered to be negligible. In all water use sector water budgets, groundwater extraction served as the water budget closure term. Groundwater extraction is dominated by irrigated agriculture, varying substantially from year to year based on variability and/or uncertainty in surface water supplies.

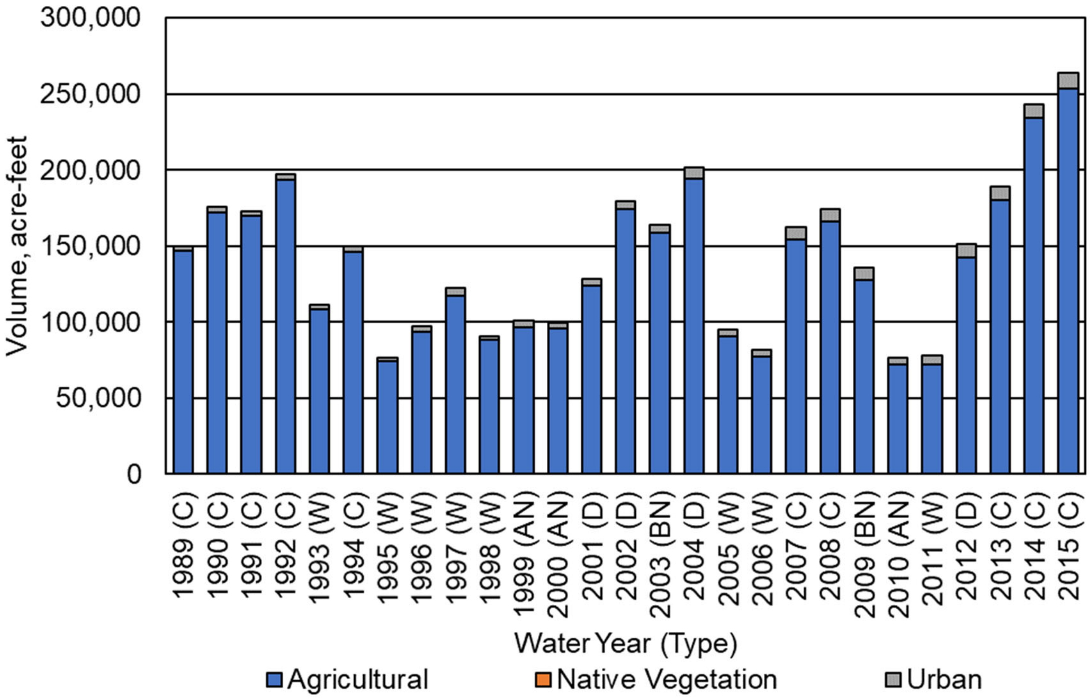

Figure A2.F.a-7. Chowchilla Water District GSA Groundwater Extraction by Water Use Sector.

Table A2.F.a-5. Chowchilla Water District GSA Groundwater Extraction by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	146,590	0	2,940	149,540
1990 (C)	172,140	0	3,210	175,360
1991 (C)	169,450	0	3,260	172,710
1992 (C)	193,130	0	4,220	197,350
1993 (W)	108,100	0	3,350	111,440
1994 (C)	145,860	0	4,160	150,020
1995 (W)	74,280	0	2,260	76,540
1996 (W)	93,530	0	3,410	96,940
1997 (W)	117,060	0	5,620	122,680
1998 (W)	88,050	0	2,900	90,960
1999 (AN)	96,300	0	4,690	100,990
2000 (AN)	95,730	0	4,110	99,840
2001 (D)	124,090	0	3,950	128,040
2002 (D)	174,170	0	5,390	179,570
2003 (BN)	158,620	0	5,460	164,080
2004 (D)	194,300	0	7,190	201,490
2005 (W)	90,380	0	4,720	95,110
2006 (W)	77,020	0	4,740	81,760
2007 (C)	154,600	0	7,810	162,410
2008 (C)	166,120	0	8,020	174,140
2009 (BN)	127,920	0	8,090	136,010
2010 (AN)	71,860	0	4,790	76,650

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2011 (W)	72,460	0	5,310	77,770
2012 (D)	142,410	0	8,940	151,350
2013 (C)	180,310	0	8,960	189,270
2014 (C)	233,860	0	8,830	242,690
2015 (C)	253,730	0	9,760	263,480
Average (1989-2014)	133,400	0	5,240	138,640
Average (1989-2014) W	90,110	0	4,040	94,150
Average (1989-2014) AN	87,960	0	4,530	92,490
Average (1989-2014) BN	143,270	0	6,770	150,050
Average (1989-2014) D	158,740	0	6,370	165,110
Average (1989-2014) C	173,560	0	5,710	179,280

3.2.1.4 Groundwater Discharge to Surface Water Sources

The depth to groundwater is greater than 100-200 ft across much of the Chowchilla Subbasin. Given the depth to the water table in the Chowchilla Subbasin, groundwater discharge to surface water sources is negligible.

3.2.2 Outflows

3.2.2.1 Evapotranspiration by Water Use Sector

Evapotranspiration (ET) by water use sector is reported in Figures A2.F.a-8 to A2.F.a-10 and Tables A2.F.a-6 to A2.F.a-8. First, total ET is reported, followed by ET from applied water and ET from precipitation.

Total ET varies between years, with the lowest observed in 1989, at approximately 188 taf, and greatest in 2004, at approximately 241 taf. Agricultural ET tends to increase in drier years, while native ET decreases.

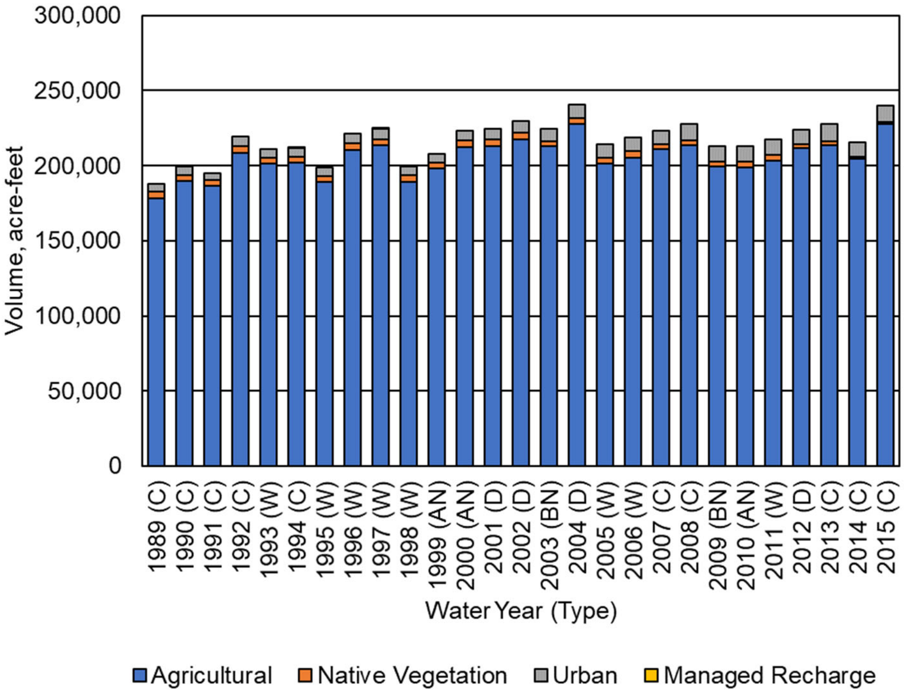

Figure A2.F.a-8. Chowchilla Water District GSA Evapotranspiration by Water Use Sector.

Table A2.F.a-6. Chowchilla Water District GSA Evapotranspiration by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Managed Recharge	Total
1989 (C)	178,550	3,980	5,100	0	187,630
1990 (C)	189,820	3,960	5,450	0	199,230
1991 (C)	186,710	3,530	4,950	0	195,190
1992 (C)	208,710	4,250	6,190	0	219,150
1993 (W)	201,120	4,160	6,060	0	211,340
1994 (C)	202,290	3,420	6,150	10	211,870
1995 (W)	189,100	4,170	5,770	0	199,040
1996 (W)	210,270	4,470	6,320	0	221,060
1997 (W)	213,540	4,050	6,790	20	224,400
1998 (W)	189,450	4,020	6,050	30	199,550
1999 (AN)	198,160	3,670	6,220	0	208,050
2000 (AN)	212,340	4,240	6,740	0	223,320
2001 (D)	212,800	4,730	6,770	0	224,300
2002 (D)	217,510	4,430	7,660	0	229,600
2003 (BN)	212,940	3,520	7,850	0	224,310
2004 (D)	227,920	3,710	9,210	0	240,840
2005 (W)	201,340	4,220	8,460	0	214,020
2006 (W)	205,540	4,530	9,050	0	219,120
2007 (C)	210,920	3,170	9,430	0	223,520
2008 (C)	213,710	3,290	10,670	0	227,670
2009 (BN)	199,680	2,770	10,870	0	213,320

Water Year (Type)	Agricultural	Native Vegetation	Urban	Managed Recharge	Total
2010 (AN)	198,630	3,950	10,120	0	212,700
2011 (W)	203,050	4,140	10,620	0	217,810
2012 (D)	211,970	2,110	9,890	0	223,970
2013 (C)	213,790	2,480	11,500	0	227,770
2014 (C)	204,430	1,260	9,610	0	215,300
2015 (C)	227,950	1,320	10,740	0	240,010
Average (1989-2014)	204,400	3,700	7,830	0	215,930
Average (1989-2014) W	201,680	4,220	7,390	10	213,300
Average (1989-2014) AN	203,050	3,950	7,700	0	214,700
Average (1989-2014) BN	206,310	3,150	9,360	0	218,820
Average (1989-2014) D	217,540	3,740	8,380	0	229,660
Average (1989-2014) C	200,990	3,260	7,670	0	211,920

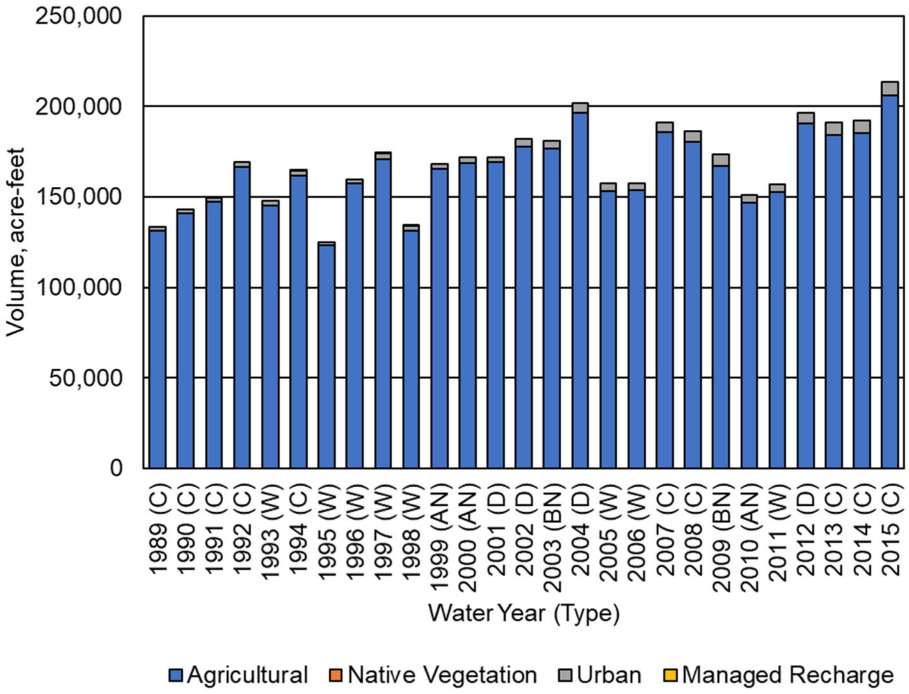

Figure A2.F.a-9. Chowchilla Water District GSA Evapotranspiration of Applied Water by Water Use Sector.

Table A2.F.a-7. Chowchilla Water District GSA Evapotranspiration of Applied Water by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Managed Recharge	Total
1989 (C)	131,170	0	2,230	0	133,400
1990 (C)	140,700	0	2,330	0	143,030
1991 (C)	147,320	0	2,300	0	149,620
1992 (C)	166,440	0	2,950	0	169,390
1993 (W)	145,110	0	2,490	0	147,600
1994 (C)	161,510	0	3,110	10	164,630
1995 (W)	123,080	0	1,890	0	124,970
1996 (W)	157,560	0	2,180	0	159,740
1997 (W)	170,730	0	3,190	20	173,940
1998 (W)	131,250	0	2,510	30	133,790
1999 (AN)	165,320	0	3,060	0	168,380
2000 (AN)	168,400	0	3,300	0	171,700
2001 (D)	169,070	0	2,960	0	172,030
2002 (D)	177,880	0	3,880	0	181,760
2003 (BN)	176,590	0	4,380	0	180,970
2004 (D)	196,430	0	5,470	0	201,900
2005 (W)	153,270	0	3,990	0	157,260
2006 (W)	153,680	0	3,920	0	157,600
2007 (C)	185,560	0	5,310	0	190,870
2008 (C)	180,250	0	6,270	0	186,520
2009 (BN)	166,910	0	6,730	0	173,640
2010 (AN)	146,840	0	4,450	0	151,290
2011 (W)	152,750	0	4,060	0	156,810
2012 (D)	190,440	0	5,820	0	196,260
2013 (C)	183,930	0	7,050	0	190,980
2014 (C)	185,340	0	6,890	0	192,230
2015 (C)	205,820	0	7,850	0	213,670
Average (1989-2014)	162,600	0	3,950	0	166,550
Average (1989-2014) W	148,430	0	3,030	10	151,470
Average (1989-2014) AN	160,190	0	3,610	0	163,800
Average (1989-2014) BN	171,750	0	5,560	0	177,310
Average (1989-2014) D	183,450	0	4,530	0	187,980
Average (1989-2014) C	164,690	0	4,270	0	168,960

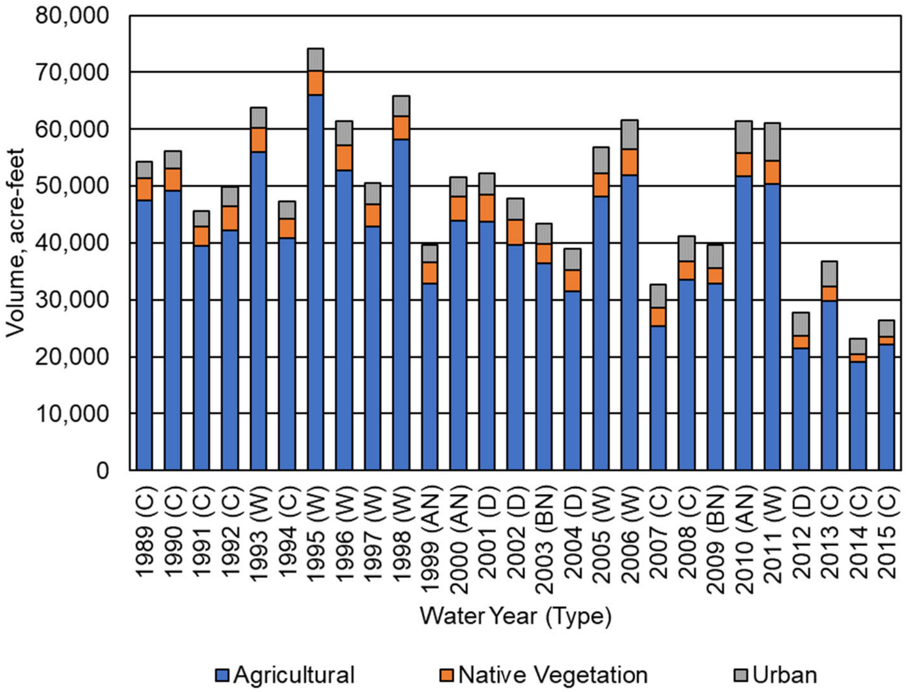

Figure A2.F.a-10. Chowchilla Water District GSA Evapotranspiration of Precipitation by Water Use Sector.

Table A2.F.a-8. Chowchilla Water District GSA Evapotranspiration of Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	47,380	3,980	2,870	54,230
1990 (C)	49,120	3,960	3,120	56,200
1991 (C)	39,390	3,530	2,650	45,570
1992 (C)	42,270	4,250	3,240	49,760
1993 (W)	56,010	4,160	3,570	63,740
1994 (C)	40,780	3,420	3,040	47,240
1995 (W)	66,020	4,170	3,880	74,070
1996 (W)	52,710	4,470	4,140	61,320
1997 (W)	42,810	4,050	3,600	50,460
1998 (W)	58,200	4,020	3,540	65,760
1999 (AN)	32,840	3,670	3,160	39,670
2000 (AN)	43,940	4,240	3,440	51,620
2001 (D)	43,730	4,730	3,810	52,270
2002 (D)	39,630	4,430	3,780	47,840
2003 (BN)	36,350	3,520	3,470	43,340
2004 (D)	31,490	3,710	3,740	38,940
2005 (W)	48,070	4,220	4,470	56,760
2006 (W)	51,860	4,530	5,130	61,520
2007 (C)	25,360	3,170	4,120	32,650
2008 (C)	33,460	3,290	4,400	41,150
2009 (BN)	32,770	2,770	4,140	39,680
2010 (AN)	51,790	3,950	5,670	61,410

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2011 (W)	50,300	4,140	6,560	61,000
2012 (D)	21,530	2,110	4,070	27,710
2013 (C)	29,860	2,480	4,450	36,790
2014 (C)	19,090	1,260	2,720	23,070
2015 (C)	22,130	1,320	2,890	26,340
Average (1989-2014)	41,800	3,700	3,880	49,380
Average (1989-2014) W	53,250	4,220	4,360	61,830
Average (1989-2014) AN	42,860	3,950	4,090	50,900
Average (1989-2014) BN	34,560	3,150	3,800	41,510
Average (1989-2014) D	34,090	3,740	3,850	41,680
Average (1989-2014) C	36,300	3,260	3,400	42,960

In addition to ET from land surfaces, estimates of evaporation from CWD canals and rivers and streams are reported in Figure A2.F.a-11 and Table A2.F.a-9. Evaporation from the Rivers and Streams System includes evaporation of both surface inflows and of precipitation runoff within local sloughs and depressions. Evaporation from the canals includes evaporation of irrigation releases in CWD canals and waterways. Evaporation from the Rivers and Streams system includes evaporation of flood releases and natural flows along waterways in the district, varying between years according to water availability. Total evaporation from all sources averaged approximately 2 taf per year between 1989 and 2014.

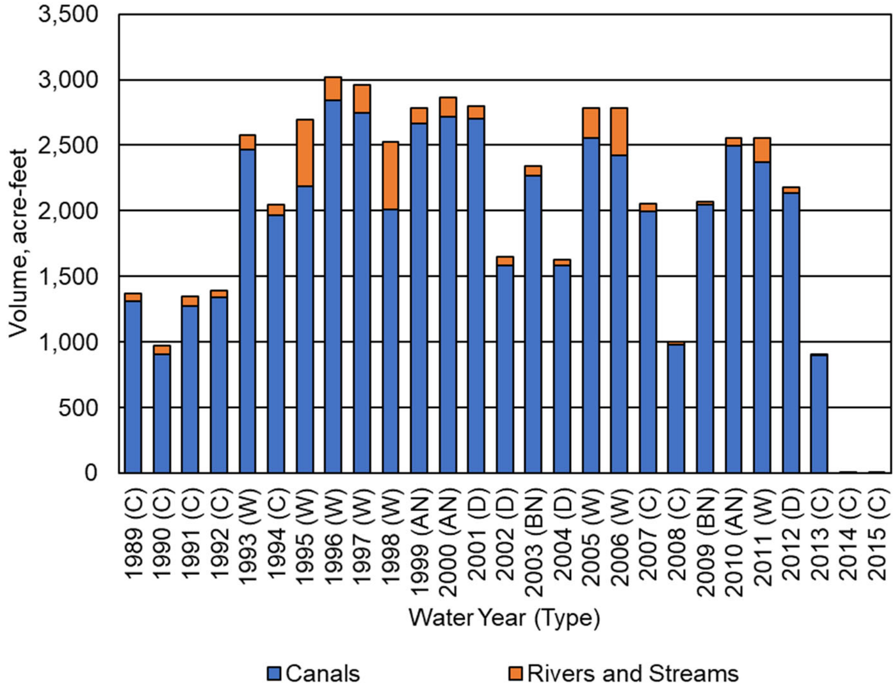

Figure A2.F.a-11. Chowchilla Water District GSA Evaporation from the Surface Water System.

Table A2.F.a-9. Chowchilla Water District GSA Evaporation from the Surface Water System (Acre-Feet).

Water Year (Type)	Canals	Rivers and Streams[1]	Total
1989 (C)	1,310	60	1,370
1990 (C)	910	60	970
1991 (C)	1,270	80	1,350
1992 (C)	1,340	50	1,390
1993 (W)	2,460	110	2,570
1994 (C)	1,970	80	2,050
1995 (W)	2,190	510	2,700
1996 (W)	2,840	180	3,020
1997 (W)	2,750	210	2,960
1998 (W)	2,010	510	2,520
1999 (AN)	2,660	120	2,780
2000 (AN)	2,720	140	2,860
2001 (D)	2,710	90	2,800
2002 (D)	1,590	60	1,650
2003 (BN)	2,270	70	2,340
2004 (D)	1,580	50	1,630
2005 (W)	2,560	230	2,790
2006 (W)	2,420	360	2,780
2007 (C)	2,000	60	2,060
2008 (C)	980	30	1,010
2009 (BN)	2,050	30	2,080
2010 (AN)	2,490	60	2,550
2011 (W)	2,370	180	2,550
2012 (D)	2,140	40	2,180
2013 (C)	900	10	910
2014 (C)	0	0	0
2015 (C)	0	10	10
Average (1989-2014)	1,940	130	2,070
Average (1989-2014) W	2,450	290	2,740
Average (1989-2014) AN	2,630	110	2,740
Average (1989-2014) BN	2,160	50	2,210
Average (1989-2014) D	2,000	60	2,060
Average (1989-2014) C	1,190	50	1,240

[1] Includes evaporation of surface inflows and of precipitation runoff.

3.2.2.2 Surface Water Outflow by Water Source Type

Surface water outflows by water source type are summarized in Figure A2.F.a-12 and Table A2.F.a-10. In CWD GSA, runoff of applied water is assumed negligible and runoff of precipitation is collected in waterways within CWD GSA, with most infiltrating to the groundwater system except following the largest storm events. Thus, surface outflows from the GSA are expected to be primarily a mixture of CVP supplies along Chowchilla River, Ash Slough, and Berenda Slough and deliveries of local supplies to growers in other water budget subregions during irrigation releases into the CWD conveyance system. Between 1989 and 2014, these combined outflows averaged nearly 76 taf during wet years and less than 2 taf during below normal, dry, and critical years.

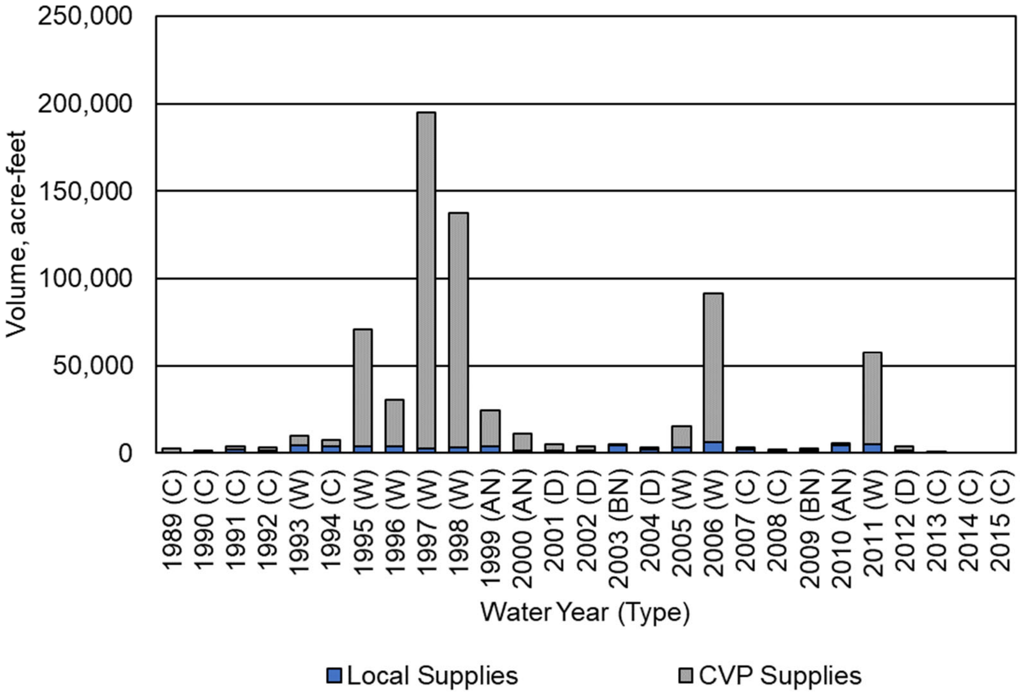

Figure A2.F.a-12. Chowchilla Water District GSA Surface Outflows by Water Source Type.

Table A2.F.a-10. Chowchilla Water District GSA Surface Outflows by Water Source Type (Acre-Feet).

Water Year (Type)	Local Supplies	CVP Supplies	Total
1989 (C)	0	2,730	2,730
1990 (C)	0	1,710	1,710
1991 (C)	2,270	1,530	3,800
1992 (C)	1,650	1,520	3,170
1993 (W)	4,320	5,500	9,820
1994 (C)	3,550	3,680	7,230
1995 (W)	3,890	66,910	70,800
1996 (W)	3,680	27,030	30,710
1997 (W)	2,330	192,310	194,640
1998 (W)	3,360	133,940	137,300
1999 (AN)	3,930	20,680	24,610
2000 (AN)	1,580	9,760	11,340
2001 (D)	1,580	3,540	5,120
2002 (D)	1,640	2,120	3,760
2003 (BN)	4,710	500	5,210
2004 (D)	2,280	650	2,930
2005 (W)	3,500	11,640	15,140
2006 (W)	6,000	85,640	91,640
2007 (C)	1,890	1,400	3,290
2008 (C)	1,680	250	1,930
2009 (BN)	1,590	1,310	2,900
2010 (AN)	4,690	1,100	5,790

Water Year (Type)	Local Supplies	CVP Supplies	Total
2011 (W)	5,190	52,660	57,850
2012 (D)	1,240	2,380	3,620
2013 (C)	0	1,020	1,020
2014 (C)	0	0	0
2015 (C)	0	0	0
Average (1989-2014)	2,560	24,290	26,850
Average (1989-2014) W	4,030	71,950	75,990
Average (1989-2014) AN	3,400	10,510	13,910
Average (1989-2014) BN	3,150	910	4,060
Average (1989-2014) D	1,690	2,170	3,860
Average (1989-2014) C	1,230	1,540	2,760

3.2.2.3 Infiltration of Precipitation

Estimated infiltration of precipitation (deep percolation of precipitation) by water use sector is provided in Figure A2.F.a-13 and Table A2.F.a-11. Infiltration of precipitation to the groundwater system is highly variable from year to year due to variation in the timing and amount of precipitation, ranging from less than 10 taf annually during some critical and dry years to nearly 50 taf during 1995.

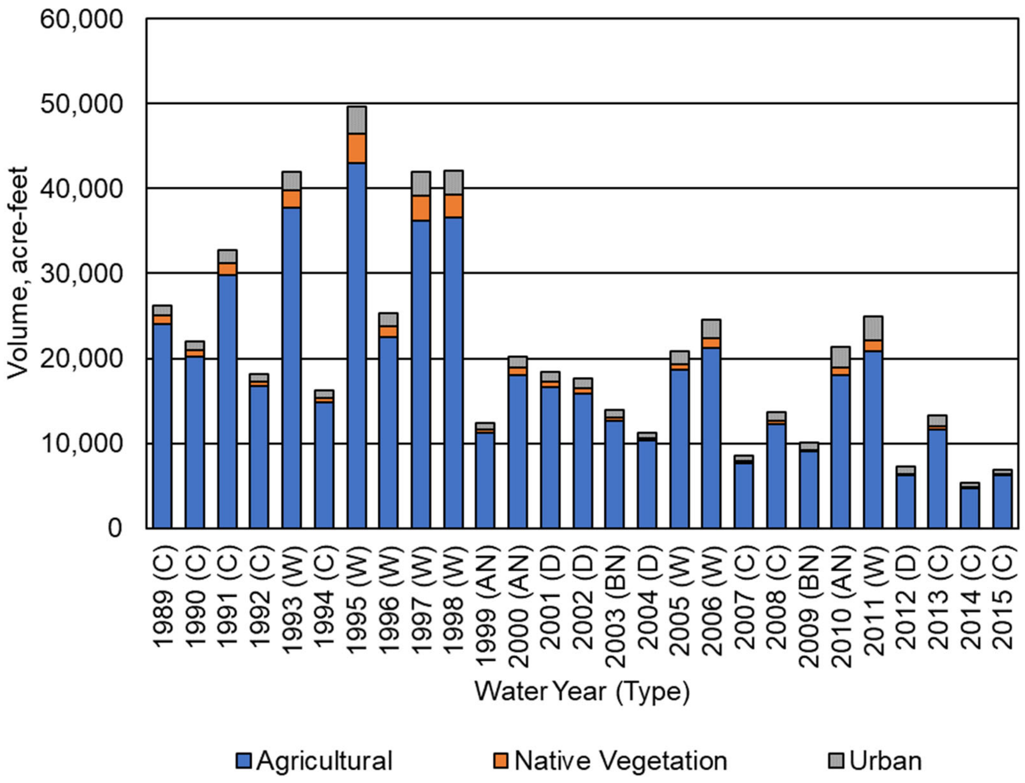

Figure A2.F.a-13. Chowchilla Water District GSA Infiltration of Precipitation by Water Use Sector.

Table A2.F.a-11. Chowchilla Water District GSA Infiltration of Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	24,080	940	1,170	26,190
1990 (C)	20,190	820	990	22,000
1991 (C)	29,870	1,370	1,570	32,810
1992 (C)	16,770	520	830	18,120
1993 (W)	37,740	2,040	2,240	42,020
1994 (C)	14,860	520	860	16,240
1995 (W)	42,970	3,530	3,120	49,620
1996 (W)	22,490	1,300	1,540	25,330
1997 (W)	36,160	3,010	2,790	41,960
1998 (W)	36,610	2,670	2,770	42,050
1999 (AN)	11,260	400	740	12,400
2000 (AN)	18,060	880	1,230	20,170
2001 (D)	16,640	660	1,060	18,360
2002 (D)	15,890	590	1,100	17,580
2003 (BN)	12,600	430	890	13,920
2004 (D)	10,290	280	670	11,240
2005 (W)	18,630	690	1,550	20,870
2006 (W)	21,190	1,200	2,190	24,580
2007 (C)	7,650	220	700	8,570
2008 (C)	12,260	410	1,050	13,720
2009 (BN)	9,000	230	840	10,070
2010 (AN)	17,960	990	2,370	21,320
2011 (W)	20,860	1,210	2,810	24,880
2012 (D)	6,190	200	890	7,280
2013 (C)	11,580	360	1,300	13,240
2014 (C)	4,720	70	510	5,300
2015 (C)	6,180	130	620	6,930
Average (1989-2014)	19,096	982	1,452	21,530
Average (1989-2014) W	29,580	1,960	2,380	33,920
Average (1989-2014) AN	15,760	760	1,450	17,970
Average (1989-2014) BN	10,800	330	870	12,000
Average (1989-2014) D	12,250	430	930	13,610
Average (1989-2014) C	15,780	580	1,000	17,360

3.2.2.4 Infiltration of Surface Water

Estimated infiltration of surface water (seepage) by source is provided in Figure A2.F.a-14 and Table A2.F.a-12. Seepage from the Rivers and Streams System includes seepage of surface inflows during flood releases and natural flows, and seepage of precipitation runoff into local sloughs and depressions. Seepage from the Canals System includes seepage along CWD canals and seepage along rivers and sloughs used to transport irrigation deliveries to CWD and its customers. During non-flood releases, some seepage along reach C-2 of the Chowchilla River is allocated to SVMWC. Per an agreement between SVMWC and CWD, 70% of non-flood seepage along reach C-2 is allocated to SVMWC, and 30% is allocated to CWD.

The canal system predominantly contributes to seepage in CWD, with seepage averaging 29 taf per year between 1989 and 2014. Seepage from rivers and streams is comparatively lower, averaging approximately 13 taf per year between 1989 and 2014.

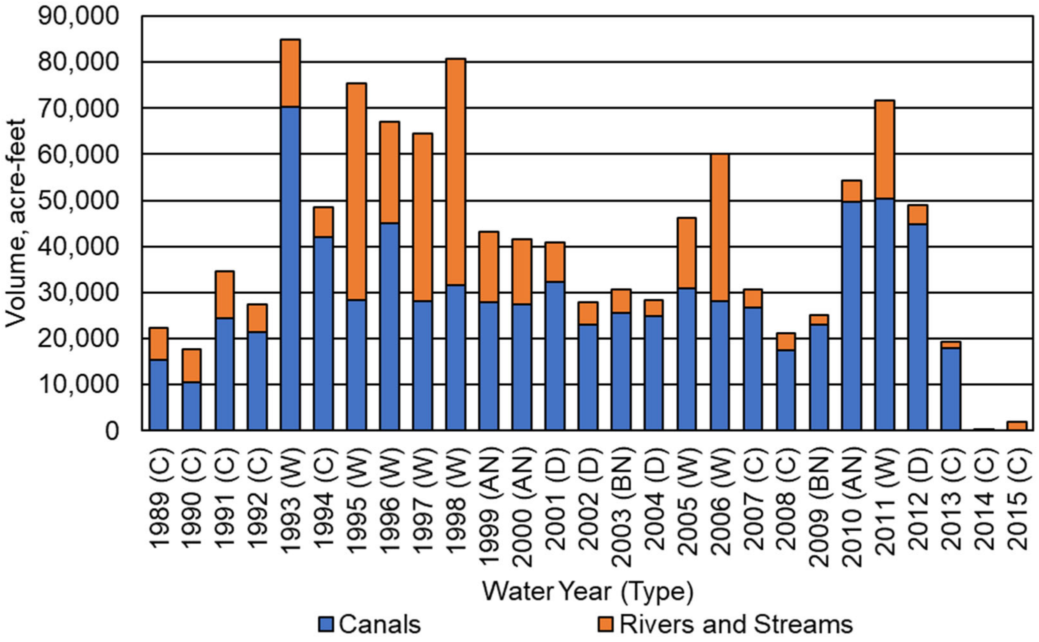

Figure A2.F.a-14. Chowchilla Water District GSA Infiltration of Surface Water.

Table A2.F.a-12. Chowchilla Water District GSA Infiltration of Surface Water (Acre-Feet).

Water Year (Type)	Canals	Rivers and Streams[1]	Total
1989 (C)	15,270	7,100	22,370
1990 (C)	10,580	7,200	17,780
1991 (C)	24,430	10,120	34,550
1992 (C)	21,310	6,130	27,440
1993 (W)	70,310	14,580	84,890
1994 (C)	41,950	6,650	48,600
1995 (W)	28,410	46,970	75,380
1996 (W)	45,020	21,950	66,970
1997 (W)	28,080	36,510	64,590
1998 (W)	31,610	49,170	80,780
1999 (AN)	27,820	15,430	43,250
2000 (AN)	27,450	14,110	41,560
2001 (D)	32,390	8,410	40,800
2002 (D)	22,890	5,040	27,930
2003 (BN)	25,580	5,080	30,660
2004 (D)	24,810	3,450	28,260
2005 (W)	30,980	15,290	46,270
2006 (W)	28,030	32,150	60,180
2007 (C)	26,760	3,900	30,660
2008 (C)	17,490	3,640	21,130

Water Year (Type)	Canals	Rivers and Streams[1]	Total
2009 (BN)	22,970	2,030	25,000
2010 (AN)	49,550	4,670	54,220
2011 (W)	50,360	21,380	71,740
2012 (D)	44,730	4,140	48,870
2013 (C)	17,930	1,430	19,360
2014 (C)	30	210	240
2015 (C)	10	1,950	1,960
Average (1989-2014)	29,490	13,340	42,830
Average (1989-2014) W	39,100	29,750	68,850
Average (1989-2014) AN	34,940	11,400	46,340
Average (1989-2014) BN	24,280	3,560	27,840
Average (1989-2014) D	31,210	5,260	36,470
Average (1989-2014) C	19,530	5,150	24,680

[1] Includes infiltration of surface inflows and of precipitation runoff within the subregion. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.2.2.5 Infiltration of Applied Water

Estimated infiltration of applied water (deep percolation of applied water) by water use sector is provided in Figure A2.F.a-15 and Table A2.F.a-13. Infiltration of applied water is dominated by agricultural irrigation and has slowly decreased over time, likely due to increase use of drip and micro-irrigation systems in place of flood irrigation.

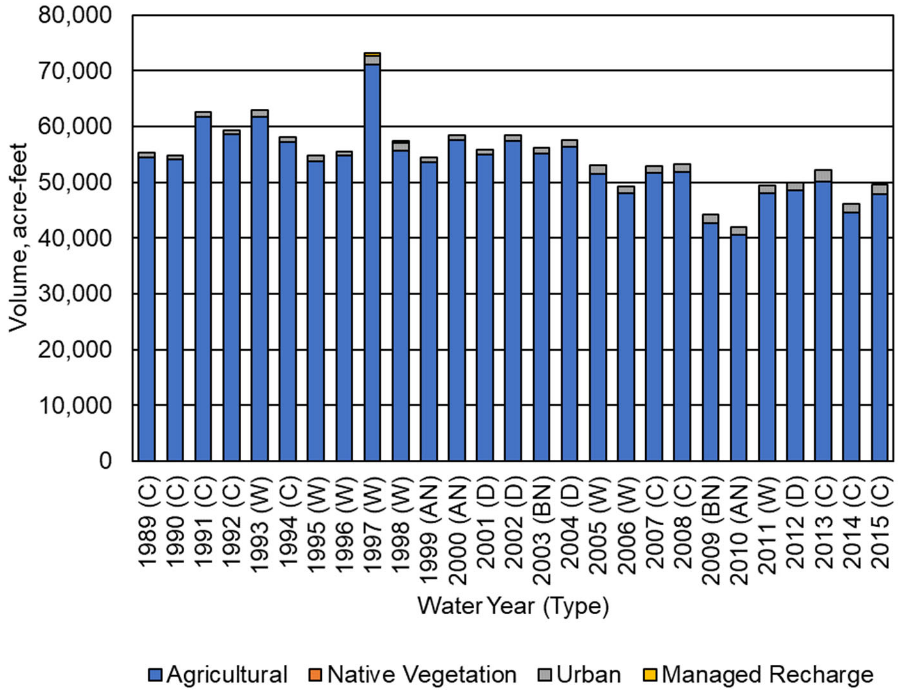

Figure A2.F.a-15. Chowchilla Water District GSA Infiltration of Applied Water by Water Use Sector.

Table A2.F.a-13. Chowchilla Water District GSA Infiltration of Applied Water by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Managed Recharge	Total
1989 (C)	54,400	0	850	0	55,250
1990 (C)	54,030	0	750	0	54,780
1991 (C)	61,680	0	860	0	62,540
1992 (C)	58,530	0	780	0	59,310
1993 (W)	61,750	0	1,200	0	62,950
1994 (C)	57,180	0	850	0	58,030
1995 (W)	53,720	0	1,030	0	54,750
1996 (W)	54,800	0	650	0	55,450
1997 (W)	71,100	0	1,580	530	73,210
1998 (W)	55,730	0	1,350	390	57,470
1999 (AN)	53,630	0	790	0	54,420
2000 (AN)	57,560	0	940	0	58,500
2001 (D)	54,930	0	880	0	55,810
2002 (D)	57,380	0	1,110	0	58,490
2003 (BN)	55,160	0	1,090	0	56,250
2004 (D)	56,410	0	1,170	0	57,580
2005 (W)	51,530	0	1,490	0	53,020
2006 (W)	48,020	0	1,170	0	49,190
2007 (C)	51,670	0	1,180	0	52,850
2008 (C)	51,770	0	1,510	0	53,280
2009 (BN)	42,700	0	1,450	0	44,150
2010 (AN)	40,620	0	1,410	0	42,030
2011 (W)	47,990	0	1,440	0	49,430
2012 (D)	48,530	0	1,410	0	49,940
2013 (C)	50,200	0	1,930	0	52,130
2014 (C)	44,650	0	1,420	0	46,070
2015 (C)	47,880	0	1,690	0	49,570
Average (1989-2014)	53,680	0	1,170	40	54,890
Average (1989-2014) W	55,580	0	1,240	120	56,940
Average (1989-2014) AN	50,600	0	1,050	0	51,650
Average (1989-2014) BN	48,930	0	1,270	0	50,200
Average (1989-2014) D	54,310	0	1,140	0	55,450
Average (1989-2014) C	53,790	0	1,130	0	54,920

3.2.3 Change in Surface Water System Storage

Estimates of change in SWS storage are provided in Figure A2.F.a-16 and Table A2.F.a-14. Inter-annual changes in storage within the surface water system consist primarily of root zone soil moisture storage changes, are relatively small, and tend to average near zero over many years.

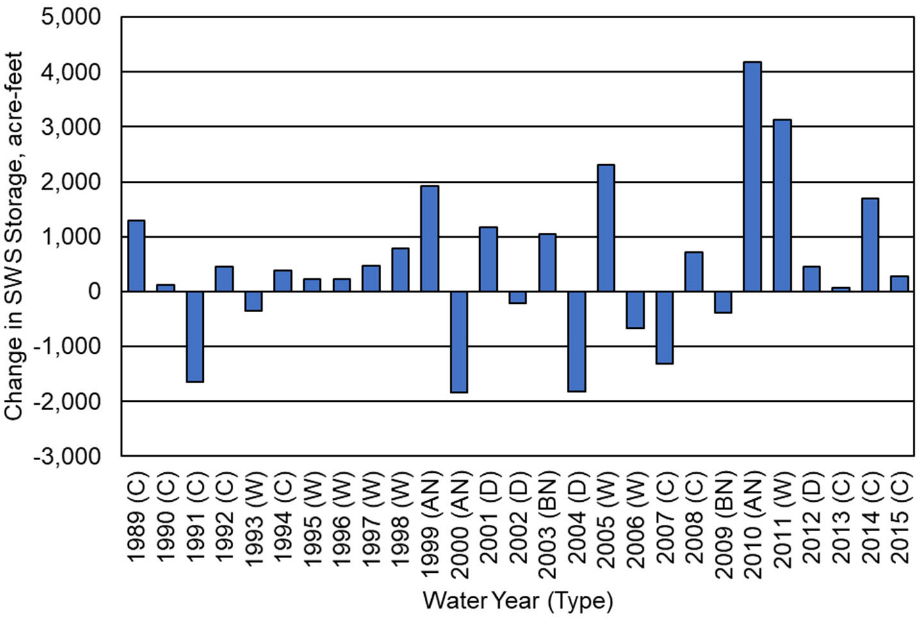

Figure A2.F.a-16. Chowchilla Water District GSA Change in Surface Water System Storage.

Table A2.F.a-14. Chowchilla Water District GSA Change in Surface Water System Storage (Acre-Feet).

Water Year (Type)	Change in SWS Storage
1989 (C)	1,300
1990 (C)	130
1991 (C)	-1,640
1992 (C)	460
1993 (W)	-350
1994 (C)	380
1995 (W)	220
1996 (W)	230
1997 (W)	480
1998 (W)	780
1999 (AN)	1,930
2000 (AN)	-1,830
2001 (D)	1,170
2002 (D)	-210
2003 (BN)	1,040
2004 (D)	-1,820
2005 (W)	2,300
2006 (W)	-670
2007 (C)	-1,310
2008 (C)	710
2009 (BN)	-390
2010 (AN)	4,180
2011 (W)	3,130
2012 (D)	460
2013 (C)	70
2014 (C)	1,700
2015 (C)	280
Average (1989-2014)	480
Average (1989-2014) W	770
Average (1989-2014) AN	1,430
Average (1989-2014) BN	330
Average (1989-2014) D	-100
Average (1989-2014) C	200

3.3 Historical Water Budget Summary

Annual inflows, outflows, and change in SWS storage during the historical water budget period (1989-2014) are summarized in Figure A2.F.a-17 and Table A2.F.a-15. Inflows are shown as positive values, while outflows and change in SWS storage are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the surface water system water budget.

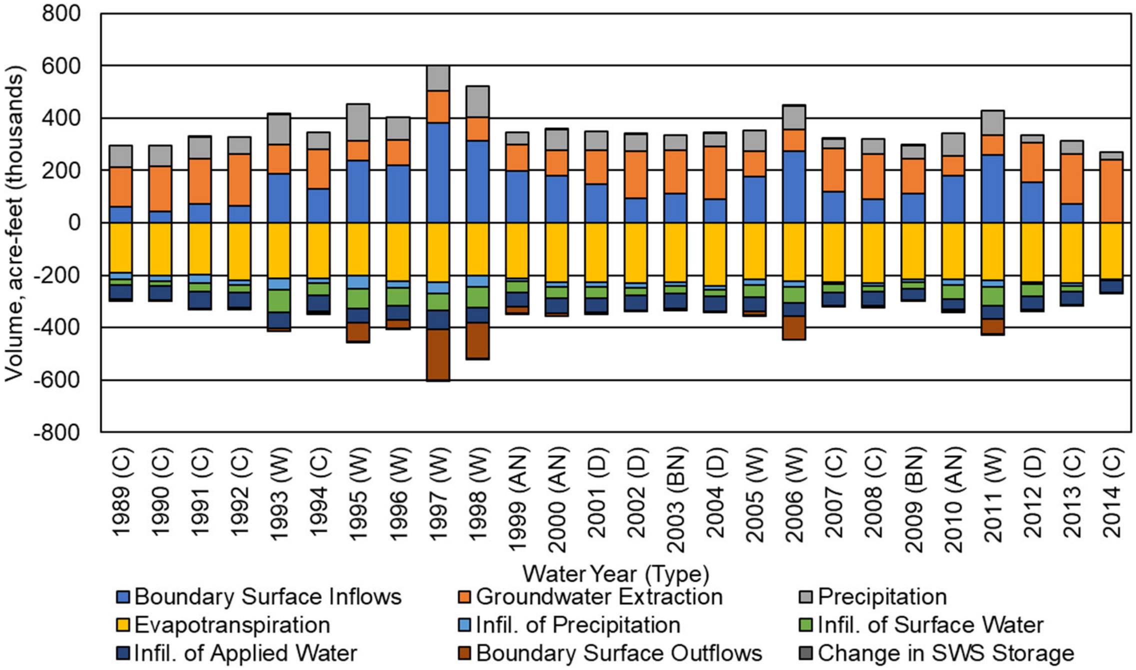

Figure A2.F.a-17. Chowchilla Water District GSA Surface Water System Historical Water Budget, 1989-2014.

Table A2.F.a-15. Chowchilla Water District GSA Surface Water System Historical Water Budget, 1989-2014 (Acre-Feet).

Water Year	Boundary Surface Inflows	Groundwater Extraction	Precipitation	Evapotranspiration[1]	Infil. of Precipitation	Infil. of Surface Water[2]	Infil. of Applied Water	Boundary Surface Outflows	Change in SWS Storage
1989 (C)	62,620	149,540	84,670	-189,000	-26,180	-22,370	-55,240	-2,730	-1,300
1990 (C)	42,270	175,360	78,970	-200,190	-22,010	-17,780	-54,770	-1,710	-130
1991 (C)	73,340	172,710	82,540	-196,540	-32,810	-34,550	-62,530	-3,800	1,640
1992 (C)	64,220	197,350	67,450	-220,540	-18,110	-27,440	-59,310	-3,160	-460
1993 (W)	187,520	111,440	114,290	-213,920	-42,020	-84,890	-62,950	-9,820	350
1994 (C)	129,610	150,020	64,760	-213,910	-16,250	-48,600	-58,030	-7,230	-380
1995 (W)	236,930	76,540	139,040	-201,740	-49,610	-75,380	-54,750	-70,800	-220
1996 (W)	220,820	96,940	85,000	-224,080	-25,330	-66,960	-55,450	-30,710	-230
1997 (W)	382,420	122,680	97,110	-227,360	-41,950	-64,590	-73,210	-194,640	-480
1998 (W)	312,780	90,960	116,740	-202,080	-42,050	-80,780	-57,480	-137,300	-780
1999 (AN)	199,110	100,990	47,350	-210,850	-12,390	-43,250	-54,430	-24,610	-1,930
2000 (AN)	178,890	99,840	77,200	-226,190	-20,170	-41,560	-58,500	-11,340	1,830
2001 (D)	148,280	128,040	72,020	-227,090	-18,370	-40,800	-55,800	-5,120	-1,170
2002 (D)	93,880	179,570	65,360	-231,240	-17,580	-27,930	-58,500	-3,770	210
2003 (BN)	112,220	164,080	57,420	-226,660	-13,920	-30,660	-56,240	-5,210	-1,040
2004 (D)	91,450	201,490	47,710	-242,460	-11,240	-28,260	-57,580	-2,930	1,820
2005 (W)	177,010	95,110	82,280	-216,800	-20,870	-46,270	-53,020	-15,140	-2,300
2006 (W)	274,410	81,760	90,640	-221,900	-24,570	-60,180	-49,200	-91,640	670
2007 (C)	120,510	162,410	36,720	-225,580	-8,570	-30,660	-52,850	-3,280	1,310
2008 (C)	89,520	174,140	55,770	-228,670	-13,720	-21,130	-53,280	-1,930	-710
2009 (BN)	110,760	136,010	50,350	-215,390	-10,070	-25,010	-44,150	-2,890	390
2010 (AN)	179,610	76,650	86,540	-215,260	-21,320	-54,220	-42,030	-5,780	-4,180
2011 (W)	259,000	77,770	90,630	-220,380	-24,870	-71,740	-49,430	-57,840	-3,130
2012 (D)	154,120	151,350	30,850	-226,150	-7,280	-48,870	-49,950	-3,620	-460
2013 (C)	73,070	189,270	52,110	-228,660	-13,230	-19,360	-52,130	-1,020	-70
2014 (C)	470	242,690	25,450	-215,310	-5,300	-240	-46,070	0	-1,700
Average (1989-2014)	152,880	138,640	73,040	-218,000	-21,530	-42,830	-54,880	-26,850	-480
W	256,360	94,150	101,970	-216,030	-33,910	-68,850	-56,930	-75,990	-760
AN	185,870	92,490	70,360	-217,430	-17,960	-46,350	-51,650	-13,910	-1,430
BN	111,490	150,050	53,890	-221,020	-11,990	-27,830	-50,200	-4,050	-330
D	121,930	165,110	53,990	-231,740	-13,610	-36,460	-55,460	-3,860	100
C	72,850	179,280	60,940	-213,150	-17,350	-24,680	-54,910	-2,760	-200

[1] Includes ET of applied water, ET of precipitation, and evaporation from the Rivers and Streams System and Canal System.

[2] Includes infiltration from the Canal System and Rivers and Streams System. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.4 Current Water Budget Summary

The current water budget was developed following a similar process to the historical water budget using the 2015 land use in Table A2.F.a-1 and the same 1989-2014 average hydrologic conditions of the historical base period, including surface water flows, precipitation, and weather parameters. This allowed quantification of groundwater inflows and outflows for current consumptive use in the context of average water supply conditions.

Annual inflows, outflows, and change in SWS storage from the current water budget are summarized in Figure A2.F.a-18 and Table A2.F.a-16. Inflows are shown as positive values, while outflows and change in SWS storage are shown as negative values.

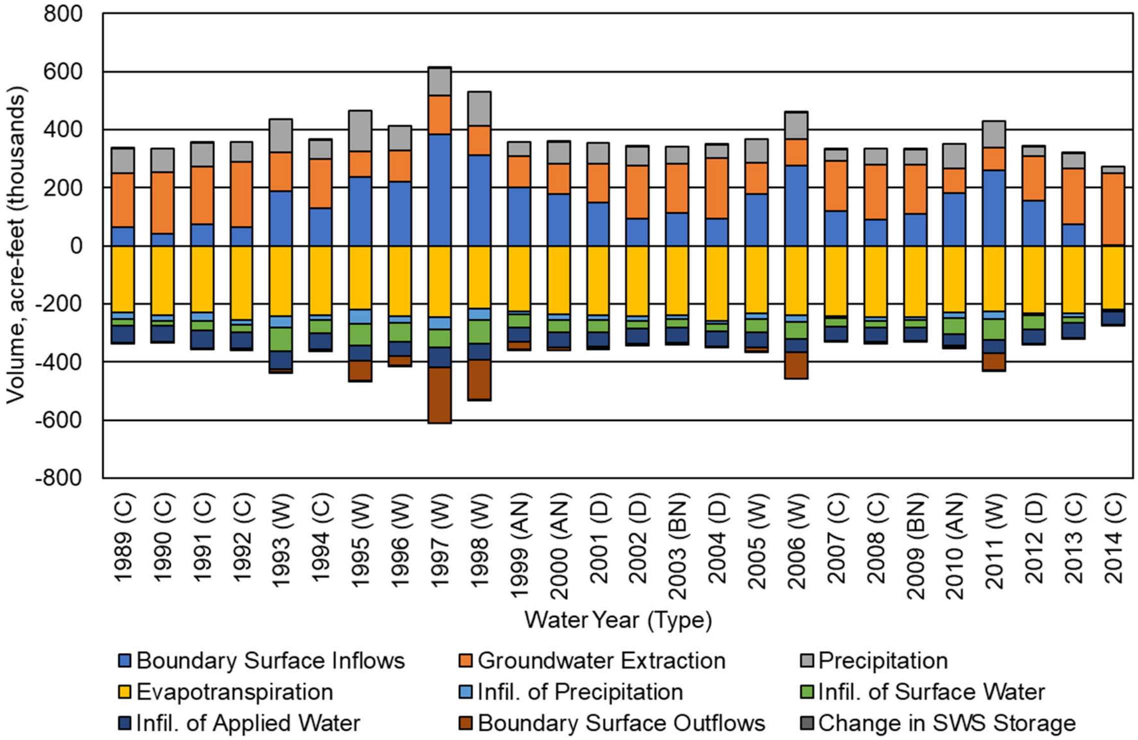

Figure A2.F.a-18. Chowchilla Water District GSA Surface Water System Current Water Budget.

Table A2.F.a-16. Chowchilla Water District GSA Surface Water System Current Water Budget (Acre-Feet).

Water Year	Boundary Surface Inflows	Groundwater Extraction	Precipitation	Evapo-transpiration[1]	Infil. of Precipitation	Infil. of Surface Water[2]	Infil. of Applied Water	Boundary Surface Outflows	Change in SWS Storage
1989 (C)	62,620	187,770	84,810	-229,580	-23,850	-20,390	-59,130	-2,730	490
1990 (C)	42,270	211,490	79,060	-238,420	-19,620	-15,880	-55,780	-1,710	-1,410
1991 (C)	73,340	199,180	82,610	-228,820	-30,210	-32,280	-61,420	-3,800	1,400
1992 (C)	64,220	225,010	67,510	-254,350	-16,250	-26,130	-56,150	-3,160	-690
1993 (W)	187,520	133,580	114,380	-241,660	-40,090	-82,360	-61,350	-9,810	-190
1994 (C)	129,610	167,770	64,810	-240,910	-14,100	-47,670	-53,390	-7,240	1,120
1995 (W)	236,930	87,950	139,120	-221,100	-47,040	-74,440	-52,040	-69,250	-130
1996 (W)	220,820	106,270	85,020	-241,270	-23,200	-66,640	-49,910	-30,070	-1,030
1997 (W)	382,420	132,900	97,140	-246,210	-41,010	-63,460	-67,930	-194,230	360
1998 (W)	312,780	99,420	116,790	-216,960	-39,910	-80,050	-54,820	-136,740	-490
1999 (AN)	199,110	109,690	47,370	-226,550	-11,100	-43,240	-50,270	-24,520	-490
2000 (AN)	178,890	101,860	77,220	-237,450	-18,790	-41,230	-52,260	-11,140	2,890
2001 (D)	148,280	132,960	72,040	-240,640	-16,690	-40,440	-50,280	-4,970	-260
2002 (D)	93,880	182,690	65,380	-242,810	-16,200	-27,620	-52,050	-3,720	450
2003 (BN)	112,220	169,630	57,440	-238,980	-12,580	-30,430	-50,970	-5,200	-1,120
2004 (D)	91,450	209,660	47,720	-258,020	-10,010	-28,000	-51,400	-3,000	1,600
2005 (W)	177,010	107,800	82,320	-233,420	-19,460	-45,790	-50,710	-15,050	-2,710
2006 (W)	274,410	92,950	90,690	-238,660	-22,860	-59,730	-46,970	-91,180	1,350
2007 (C)	120,510	172,950	36,730	-241,320	-7,580	-30,530	-48,450	-3,290	970
2008 (C)	89,520	188,050	55,810	-247,200	-12,690	-20,590	-50,030	-1,940	-930
2009 (BN)	110,760	169,180	50,420	-246,560	-9,520	-24,670	-47,320	-2,900	600
2010 (AN)	179,610	85,080	86,580	-228,980	-20,540	-53,840	-42,070	-5,790	-60
2011 (W)	259,000	79,440	90,620	-226,980	-24,190	-71,630	-48,020	-57,710	-520
2012 (D)	154,120	154,330	30,850	-232,350	-6,990	-48,810	-48,320	-3,620	800
2013 (C)	73,070	194,150	52,120	-234,600	-13,010	-19,260	-51,760	-1,020	310
2014 (C)	470	247,910	25,460	-219,780	-5,290	-220	-46,820	0	-1,740
Average (1989-2014)	152,880	151,910	73,080	-236,680	-20,110	-42,130	-52,290	-26,680	20
W	256,360	105,040	102,010	-233,280	-32,220	-68,010	-53,970	-75,500	-420
AN	185,870	98,880	70,390	-230,990	-16,810	-46,100	-48,200	-13,820	780
BN	111,490	169,410	53,930	-242,770	-11,050	-27,550	-49,140	-4,050	-260
D	121,930	169,910	54,000	-243,450	-12,470	-36,220	-50,510	-3,830	650
C	72,850	199,360	60,990	-237,220	-15,840	-23,660	-53,660	-2,770	-50

[1] Includes ET of applied water, ET of precipitation, and evaporation from the Rivers and Streams System and Canal System.

[2] Includes infiltration from the Canal System and Rivers and Streams System. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.5 Net Recharge from SWS

Overdraft is defined in DWR Bulletin 118 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” (DWR 2003). The Chowchilla Subbasin water budget indicates that overdraft conditions occurred during the 1989-2014 historical base period. Per 23 CCR Section 354.18(b)(5), the subbasin overdraft has been quantified for this base period. The evaluation of overdraft conditions includes estimates of recharge from subsurface flows. However, estimates of recharge from subsurface flows are less accurate when estimated for areas less that an entire subbasin. Thus, for estimates of GSA level contribution to overdraft, the term net recharge from the SWS is defined as groundwater recharge minus groundwater extraction. Net recharge from the SWS is useful for understanding and analyzing the combined effects of land surface processes on the underlying GWS.

When calculated from the historical water budget, average net recharge from the SWS represents the average recharge (when positive) or shortage of recharge (when negative) based on historical cropping, land use practices, and average hydrologic conditions. When calculated from the current land use water budget, average net recharge represents the average recharge or shortage (when negative) based on current cropping, land use practices, and average hydrologic conditions.

Average net recharge from the SWS is presented below for the CWD GSA portion of the Chowchilla Subbasin. Table A2.F.a-17 shows the average net recharge from the SWS for 1989-2014 based on the historical water budget, and Table A2.F.a-18 shows the same for the current water budget. Historically, the average net recharge in CWD GSA was approximately -15.5 taf per year between 1989 and 2014. Under current land use conditions, the average net recharge in CWD GSA is approximately -33.4 taf, indicating shortage conditions.

Table A2.F.a-17. Historical Water Budget: Average Net Recharge from SWS by Water Year Type, 1989-2014 (Acre-Feet).

Year Type	Number of Years	Infiltration of Applied Water (a)	Infiltration of Precipitation (b)	Infiltration of Surface Water[1] (c)	Groundwater Extraction (d)	Net Recharge from SWS (a+b+c-d)
W	8	56,930	33,910	79,230	94,150	75,920
AN	3	51,650	17,960	48,970	92,490	26,090
BN	2	50,200	11,990	27,800	150,050	-60,060
D	4	55,460	13,610	37,300	165,110	-58,740
C	9	54,910	17,350	25,410	179,280	-81,610
Annual Average (1989-2014)	26	54,880	21,530	46,700	138,640	-15,530

[1] Includes infiltration from the CWD Canal System and the Rivers and Streams System, as calculated from the total subbasin Rivers and Streams System seepage summed and redistributed to each subregion in proportion to gross area.

Table A2.F.a-18. Current Water Budget: Average Net Recharge from SWS by Water Year Type (Acre-Feet).

Year Type	Number of Years	Infiltration of Applied Water (a)	Infiltration of Precipitation (b)	Infiltration of Surface Water[1] (c)	Groundwater Extraction (d)	Net Recharge from SWS (a+b+c-d)
W	8	53,970	32,220	78,570	105,040	59,720
AN	3	48,200	16,810	48,700	98,880	14,830
BN	2	49,140	11,050	27,440	169,410	-81,780
D	4	50,510	12,470	37,010	169,910	-69,920
C	9	53,660	15,840	24,570	199,360	-105,290
Annual Average (1989-2014)	26	52,290	20,110	46,100	151,910	-33,410

[1] Includes infiltration from the CWD Canal System and the Rivers and Streams System, as calculated from the total subbasin Rivers and Streams System seepage and redistributed to each subregion in proportion to gross area.

3.6 Uncertainties in Water Budget Components

Uncertainties associated with each water budget component were estimated as a percentage representing approximately a 95% confidence interval following the procedure described by Clemmens and Burt (1997). Uncertainties for all independently measured or estimated water budget components were estimated based on the measurement accuracy, typical values reported in technical literature, typical values calculated in other water budgets, and professional judgement.

Table A2.F.a-19 provides a summary of typical uncertainty values associated with major SWS inflow and outflow 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 A2.F.a-19. Estimated Uncertainty of GSA Water Budget Components.

Flowpath Direction (relative to SWS)	Water Budget Component	Data Source	Estimated Uncertainty (%)	Source
Inflows	Surface Water Inflows	Measurement	5%	Estimated streamflow measurement accuracy
	Deliveries	Measurement	6%	Estimated delivery measurement accuracy
	Precipitation	Calculation	30%	Clemmens, A.J. and C.M. Burt, 1997.
	Groundwater Extraction	Calculation	20%	Typical uncertainty calculated for Land Surface System water balance closure; Estimated accuracy of groundwater pumping measurements.
Outflows	Surface Water Outflows	Measurement	20%	Typical uncertainty calculated for Rivers and Streams System water balance closure.
	Evaporation	Calculation	20%	Estimated accuracy of calculation based on CIMIS reference ET and free water surface evaporation coefficient.
	ET of Applied Water	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, estimated crop coefficients from SEBAL energy balance, and annual land use.
	ET of Precipitation	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, precipitation, estimated crop coefficients from SEBAL energy balance, and annual land use.
	Infiltration of Applied Water	Calculation	20%	Estimated accuracy of daily IDC root zone water budget based on annual land use and NRCS soils characteristics.
	Infiltration of Precipitation	Calculation	20%	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%	Estimated accuracy of daily seepage calculation using NRCS soils characteristics and measured streamflow data compared to field measurements.
	Change in SWS Storage	Calculation	50%	Professional Judgment.
Net Recharge from SWS		Calculation	25%	Estimated water budget accuracy; typical value calculated for GSA-level net recharge from SWS.

APPENDIX 2.F. WATER BUDGET INFORMATION

2.F.b. Surface Water System Water Budget: Madera County GSA – East Subregion

Prepared as part of the

Groundwater Sustainability Plan
Chowchilla Subbasin

January 2020

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Stillwater Sciences and
California State University, Sacramento

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1 INTRODUCTION

To ensure sustainable groundwater management throughout California's groundwater basins, the Sustainable Groundwater Management Act of 2014 (SGMA) requires Groundwater Sustainability Agencies (GSAs) to prepare and adopt Groundwater Sustainability Plans (GSPs) with strategies to achieve subbasin groundwater sustainability within 20 years of plan adoption. Integral to each GSP is a water budget used to quantify the subbasin's groundwater overdraft (if applicable) and sustainable yield.

In 2016, Madera County (Madera Co) GSA formed to manage approximately 45,100 acres of the Chowchilla Subbasin. Madera Co GSA includes noncontiguous areas on the eastern and western sides of the Chowchilla Subbasin. Portions of Madera Co GSA's eastern jurisdictional area also overlap with Sierra Vista Mutual Water Company (SVMWC). In the interests of separately accounting for inflows to each side of Madera County GSA and to SVMWC, two water budgets were prepared for Madera Co GSA: one for the western subregion, and one for the eastern subregion, excluding land in SVMWC.

This document presents results of the surface water system (SWS) water budgets developed for historical and current land use conditions in the Madera Co GSA – East Subregion. The Madera Co GSA – East water budgets were integrated with separate water budgets developed for four (4) other subregions covering the remainder of the Chowchilla Subbasin. Together, these water budgets provide the boundary water budget for the Chowchilla Subbasin SWS. Results of the subbasin boundary water budget are reported in the Chowchilla Subbasin GSP Section 2.2.3 and were integrated with a subbasin groundwater model (GSP Appendix 6.E) to estimate subbasin sustainable yield (GSP Section 2.2.3).

2 WATER BUDGET CONCEPTUAL MODEL

A water budget is defined as a complete accounting of all water flowing into and out of a defined volume (e.g., a subbasin or a GSA) over a specified period of time. The conceptual model (or structure) of the Madera Co GSA – East water budget developed for this investigation is consistent with the GSP Regulations defined under Title 23 of California Code of Regulations[1] (CCR) and adheres to sound water budget principles and practices defined by California Department of Water Resources (DWR) in the Water Budget Best Management Practice (BMP) guidelines (DWR, 2016).

The lateral extent of Madera Co GSA – East is defined by the boundaries indicated in Figure A2.F.b-1. The vertical extent of Madera Co GSA – East is the land surface (top) and the base of fresh water at the bottom of the basin (bottom), as described in the hydrogeologic conceptual model (HCM) developed in GSP Section 2.2.1. The vertical extent of Chowchilla Subbasin and its GSAs is subdivided into a surface water system (SWS) and the underlying groundwater system (GWS), with separate but related water budgets prepared for each that together represent the overall subbasin water budget.

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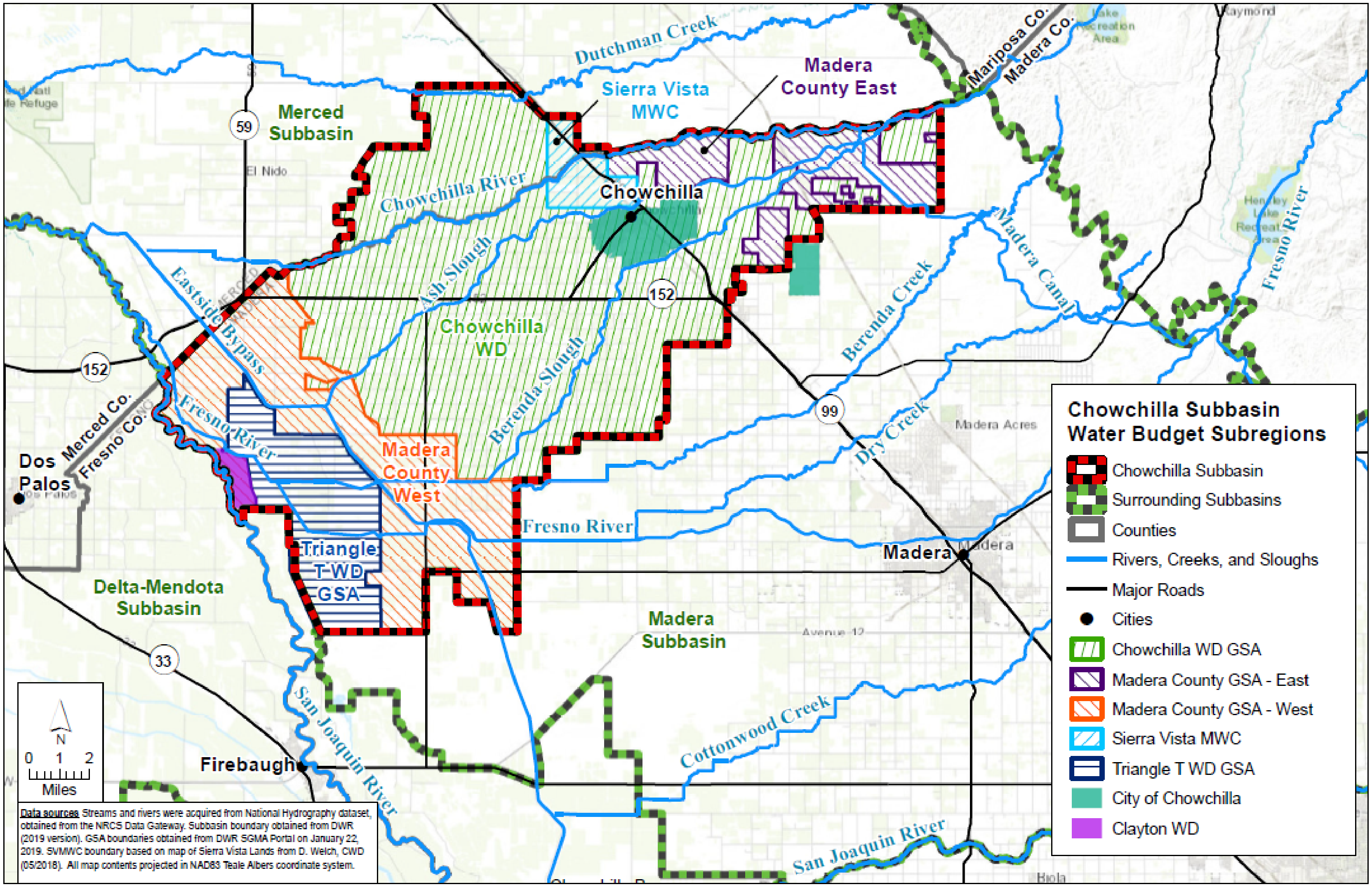
[1] California Code of Regulations Title 23. Waters, Division 2. Department of Water Resources, Chapter 1.5. Groundwater Management, Subchapter 2. Groundwater Sustainability Plans.



Data sources Streams and rivers were acquired from National Hydrography dataset, obtained from the NRCS Data Gateway. Subbasin boundary obtained from DWR (2019 version). GSA boundaries obtained from DWR SGMA Portal on January 22, 2019. SVMWC boundary based on map of Sierra Vista Lands from D. Welch, CWD (05/2018). All map contents projected in NAD83 Teale Albers coordinate system.

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Chowchilla Subbasin Water Budget Subregion Map

Chowchilla Subbasin Groundwater Sustainability Plan

Figure A2.F.b-1. Chowchilla Subbasin Water Budget Subregion Map

A conceptual representation of the Madera Co GSA – East water budget is represented in Figure A2.F.b-2. This document details only the SWS portion of the Madera Co GSA – East water budget. The SWS is divided into two primary accounting centers: the Land Surface System and the Rivers and Streams System. The Land Surface System is further divided into three accounting centers representing the subregion water use sectors: Agricultural Land, Native Vegetation Land, and Urban Land (urban, industrial, and semi-agricultural).

Water budget components, or directional flow of water between accounting centers and across the SWS boundary, are indicated by arrows. Inflows and outflows were calculated using measurements and other historical data or were calculated as the water budget closure term – the difference between all other estimated or measured inflows and outflows from each accounting center or water use sector (bold arrows).

Inflows to the SWS include precipitation, surface water inflows (in various canals and streams), and groundwater extraction. Outflows from the SWS include evapotranspiration (ET), surface water outflows (in various canals and streams), and infiltration to the groundwater system (seepage and deep percolation). Also represented in Figure 2A.F.b-2 are inflows and outflows from the GWS, which are discussed and quantified at the subbasin level in the GWS water budget in GSP Section 2.2.3. Subsurface GWS inflows and outflows are not quantified on the water budget subregion scale.

Inflows and outflows were quantified following the process described in GSP Section 2.2.3 on a monthly time step for water years in the historical water budget base period (1989-2014 hydrologic and land use conditions), the current water budget (2015 land use using 1989-2014 average hydrologic conditions), and projected water budget. Four projected water budgets were prepared for the years 2019 through 2090 based on 1965 through 2015 hydrologic conditions, projected water supplies, and 2017 land use adjusted for urban area projected growth from 2017-2070 (areas were held constant from 2071-2090):

1. Historical hydrologic conditions and water supply data, with adjustment for projected alteration of available Friant releases by the San Joaquin River Restoration Program (SJRRP)[2]
    a. Without projects and management actions, and
    b. With projects and management actions
2. Historical hydrologic conditions and water supply data, with adjustment for projected alteration of available Friant releases by the SJRRP and adjustment for anticipated climate change per DWR-provided 2030 climate change factors
    a. Without projects and management actions, and
    b. With projects and management actions.

Information regarding the data sources and adjustments used to prepare the historical, current, and projected water budgets are described in GSP Section 2.2.3.

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[2] Adjustments were based on the Friant Report ("Estimate of Future Friant Division Supplies for use in Groundwater Sustainability Plans, California," Friant Water Authority, 2018). Although the Friant Report accounts for climate change, it is considered the best available estimate of projected Friant releases under SJRRP. For comparison, projected Madera Canal deliveries under SJRRP were also estimated without account for climate change from the Kondolf Hydrographs (in “Effects to Water Supply and Friant Operations Resulting From Plaintiffs' Friant Release Requirements,” Steiner, 2005). These estimates were approximately equal to the Friant Report 2030 climate change adjusted deliveries. Thus, the Friant Report projections were used instead to maintain consistent assumptions in estimating Madera Canal deliveries across all projected simulations.

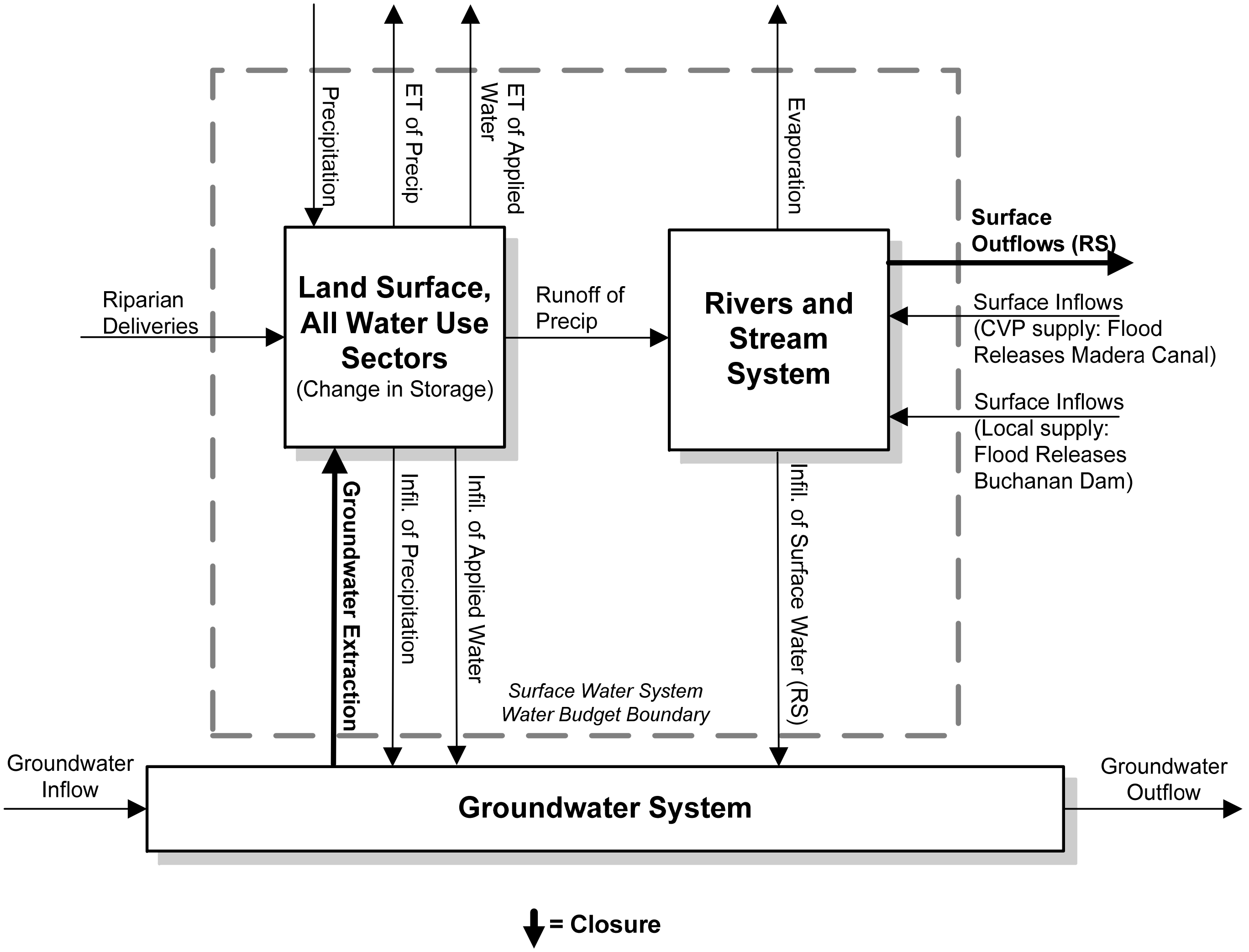

Figure A2.F.b-2. Madera County GSA – East Water Budget Structure

3 WATER BUDGET ANALYSIS

The historical water budget and current land use water budget for Madera Co GSA – East are presented below following a summary of land use data relevant to water budget development. Land use data is provided for the 1989-2014 historical water budget period and for 2015, the current land use water budget period.

3.1 Land Use

Land use estimates for 1989 through 2015 corresponding to water use sectors (as defined by the GSP Regulations) are summarized in Figure A2.F.b-3 and Table A2.F.b-1 for the Madera Co GSA – East subregion. According to GSP Regulations (23 CCR § 351(al)):

> *"Water use sector" refers to 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.*

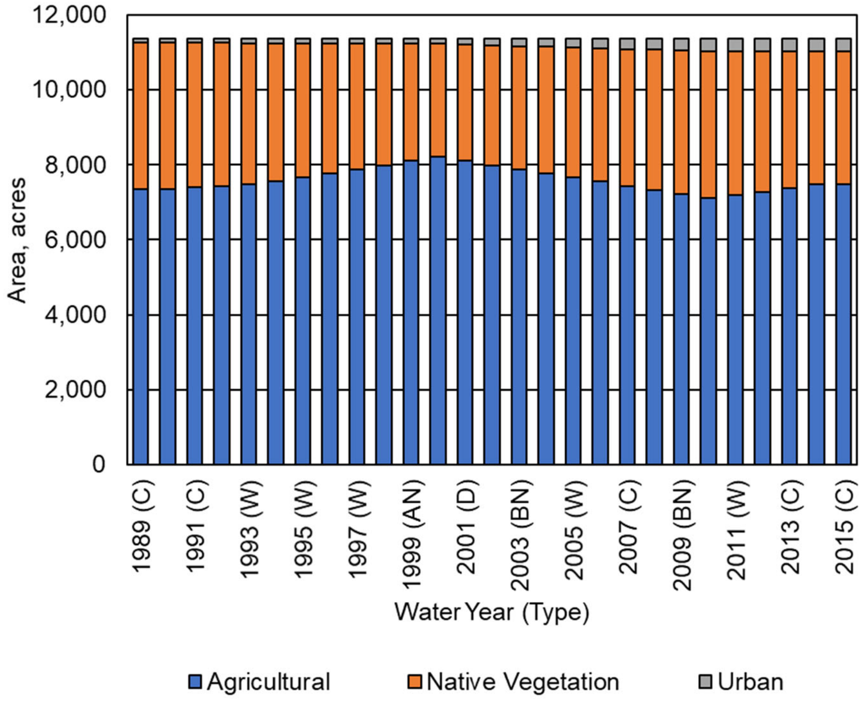

Figure A2.F.b-3. Madera County GSA – East Land Use Areas

Table A2.F.b-1. Madera County GSA – East Land Use Areas, acres

Water Year (Type)	Agricultural	Native Vegetation[1]	Urban[2]	Total
1989 (C)	7,354	3,905	103	11,362
1990 (C)	7,352	3,903	107	11,362
1991 (C)	7,403	3,849	110	11,362
1992 (C)	7,427	3,821	114	11,362
1993 (W)	7,477	3,767	118	11,362
1994 (C)	7,547	3,693	122	11,362
1995 (W)	7,657	3,579	125	11,362
1996 (W)	7,769	3,465	128	11,362
1997 (W)	7,880	3,351	131	11,362
1998 (W)	7,991	3,237	134	11,362
1999 (AN)	8,102	3,123	137	11,362
2000 (AN)	8,213	3,009	140	11,362
2001 (D)	8,102	3,100	159	11,362
2002 (D)	7,991	3,192	179	11,362
2003 (BN)	7,880	3,284	198	11,362
2004 (D)	7,768	3,375	218	11,362
2005 (W)	7,657	3,467	237	11,362
2006 (W)	7,546	3,559	257	11,362
2007 (C)	7,435	3,650	276	11,362
2008 (C)	7,324	3,742	296	11,362
2009 (BN)	7,213	3,834	315	11,362
2010 (AN)	7,102	3,925	334	11,362
2011 (W)	7,192	3,838	332	11,362
2012 (D)	7,282	3,750	329	11,362
2013 (C)	7,373	3,662	327	11,362
2014 (C)	7,486	3,537	338	11,362
2015 (C)	7,486	3,537	338	11,362
Average (1989-2014)	7,597	3,562	202	11,362

[1] Area includes land classified as native vegetation and water surfaces.
[2] Area includes land classified as urban, industrial, and semi-agricultural.

In Madera Co GSA – East, water use sectors include agricultural, native vegetation, and urban land use. The urban land use category includes urban and semi-agricultural[3] lands as well as industrial land, which covers only a small area in the subbasin.

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[3] As defined in the DWR county land use surveys, 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, 2009).

As indicated, the majority of land in Madera Co GSA – East is used for agriculture, covering an average of approximately 7,600 acres between 1989 and 2014. The remainder of the subregion is primarily native vegetation, averaging approximately 3,600 acres between 1989 and 2014.

Agricultural land uses are further detailed in Figure A2.F.b-4 and Table A2.F.b-2. Historically, a majority of the agricultural area in Madera Co has been used to cultivate permanent crops, including grapes and orchard crops. While the acreage of grapes and other crops have decreased since the 1990s, orchard acreage more than doubled between 1989 and 2015.

3.2 Surface Water System Water Budget

This section presents surface water system water budget components within Madera Co GSA – East as per GSP regulations. These are followed by a summary of the water budget results by accounting center.

3.2.1 Inflows

3.2.1.1 Surface Water Inflow by Water Source Type

Surface water inflows include surface water flowing into Madera Co GSA – East across the subregion boundary. Per the Regulations, surface inflows must be reported by water source type. According to the Regulations:

> *"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.*

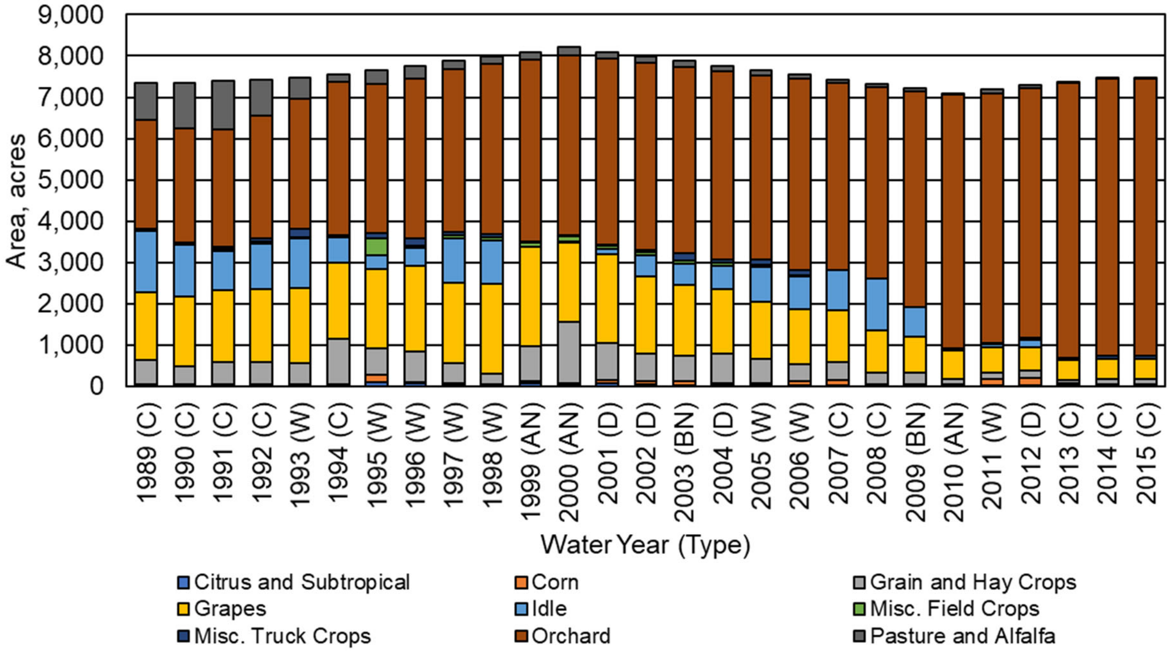

Figure A2.F.b-4. Madera County GSA – East Agricultural Land Use Areas

Table A2.F.b-2. Madera County GSA – East Agricultural Land Use Areas

Water Year (Type)	Citrus and Subtropical	Corn	Grain and Hay Crops	Grapes	Idle	Misc. Field Crops	Misc. Truck Crops	Orchard	Pasture and Alfalfa	Total
1989 (C)	30	9	588	1,647	1,493	45	8	2,630	905	7,354
1990 (C)	35	8	443	1,679	1,250	49	10	2,768	1,109	7,352
1991 (C)	36	10	534	1,740	963	46	33	2,861	1,181	7,403
1992 (C)	37	11	534	1,764	1,106	46	72	2,983	873	7,427
1993 (W)	38	11	503	1,833	1,185	43	205	3,136	523	7,477
1994 (C)	37	13	1,084	1,848	624	43	7	3,709	184	7,547
1995 (W)	87	171	666	1,921	315	418	120	3,622	337	7,657
1996 (W)	78	20	745	2,072	420	67	169	3,874	322	7,769
1997 (W)	35	29	487	1,950	1,074	72	88	3,954	189	7,880
1998 (W)	15	35	235	2,185	1,067	75	60	4,130	189	7,991
1999 (AN)	71	43	841	2,417	9	93	22	4,410	195	8,102
2000 (AN)	36	41	1,479	1,930	13	130	26	4,368	191	8,213
2001 (D)	57	84	901	2,144	143	81	26	4,489	177	8,102
2002 (D)	31	76	680	1,872	507	79	40	4,543	162	7,991
2003 (BN)	26	78	639	1,704	506	83	187	4,508	148	7,880
2004 (D)	27	35	712	1,568	574	67	90	4,562	134	7,768
2005 (W)	23	37	590	1,392	844	44	123	4,484	119	7,657
2006 (W)	22	87	430	1,322	806	27	118	4,630	105	7,546
2007 (C)	18	123	431	1,255	982	6	5	4,526	91	7,435
2008 (C)	14	18	294	1,034	1,243	1	5	4,639	76	7,324
2009 (BN)	13	17	280	885	721	5	3	5,227	62	7,213
2010 (AN)	18	12	151	670	49	0	0	6,155	48	7,102
2011 (W)	12	161	145	611	98	0	14	6,037	114	7,192
2012 (D)	12	183	188	552	191	0	31	6,062	63	7,282
2013 (C)	29	28	79	493	39	0	0	6,683	21	7,373
2014 (C)	17	29	112	492	18	0	69	6,717	33	7,486
2015 (C)	17	29	112	492	18	0	69	6,717	33	7,486
Average (1989-2014)	33	53	530	1,499	625	58	59	4,450	291	7,597

Additionally, runoff of precipitation from upgradient areas adjacent to the subregion represents a potential source of surface water inflow.

Local Supplies

Madera Co GSA – East does not receive local supplies for irrigation purposes.

CVP Supplies

CVP supply inflows to Madera Co GSA – East include flood releases from Buchanan Dam along the Chowchilla River (much of which flows through the subregion), riparian diversions from Chowchilla River by water rights users, and flood releases from Millerton Reservoir along Madera Canal.

Recycling and Reuse

Recycling and reuse are not a significant source of supply within Madera Co GSA – East.

Other Surface Inflows

For the water budgets presented herein, precipitation runoff from outside the subregion is considered relatively minimal and is expected to pass through the waterways accounted above following relatively large storm events. Precipitation runoff from lands inside the subregion is internal to the surface water system and is thus not considered as surface inflows to the subregion boundary.

Summary of Surface Inflows

The surface water inflows described above are summarized by water source type in Figure A2.F.b-5 and Table A2.F.b-3. During the study period, surface water inflows vary by water year type, averaging 95 taf per wet year.

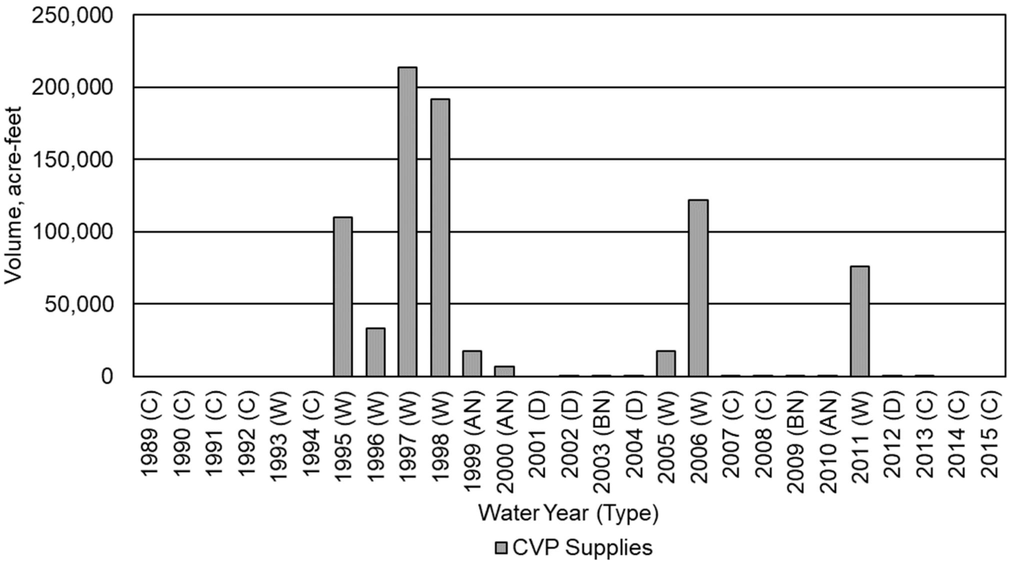

Figure A2.F.b-5. Madera County GSA – East Surface Water Inflows by Water Source Type.

Table A2.F.b-3. Madera County GSA – East Surface Water Inflows by Water Source Type (Acre-Feet).

Water Year (Type)	Local Supply	CVP Supply[1]	Total
1989 (C)	0	0	0
1990 (C)	0	0	0
1991 (C)	0	0	0
1992 (C)	0	0	0
1993 (W)	0	0	0
1994 (C)	0	0	0
1995 (W)	0	109,760	109,760
1996 (W)	0	32,950	32,950
1997 (W)	0	213,510	213,510
1998 (W)	0	191,690	191,690
1999 (AN)	0	17,620	17,620
2000 (AN)	0	6,850	6,850
2001 (D)	0	0	0
2002 (D)	0	530	530
2003 (BN)	0	280	280
2004 (D)	0	360	360
2005 (W)	0	17,540	17,540
2006 (W)	0	121,690	121,690
2007 (C)	0	360	360
2008 (C)	0	260	260
2009 (BN)	0	330	330
2010 (AN)	0	410	410
2011 (W)	0	76,050	76,050
2012 (D)	0	60	60
2013 (C)	0	110	110
2014 (C)	0	0	0
2015 (C)	0	0	0
Average (1989-2014)	0	30,400	30,400
Average (1989-2014) W	0	95,400	95,400
Average (1989-2014) AN	0	8,290	8,290
Average (1989-2014) BN	0	310	310
Average (1989-2014) D	0	240	240
Average (1989-2014) C	0	80	80

[1] CVP Supply is considered as all water supply released from CVP storage facilities. The volume of CVP Supply includes CVP deliveries to CWD, and flood releases from CVP facilities that pass through the subbasin. In Madera County GSA - East, all CVP supply pass through the GSA.

3.2.1.2 Precipitation

Precipitation estimates for Madera Co GSA – East are provided in Figure A2.F.b-6 and Table A2.F.b-4. Precipitation estimates are reported by water use sector.

Total precipitation is highly variable between years in the study area, ranging from approximately 7 taf (7.6 inches) during average dry years to 14 taf (14.4 inches) during average wet years.

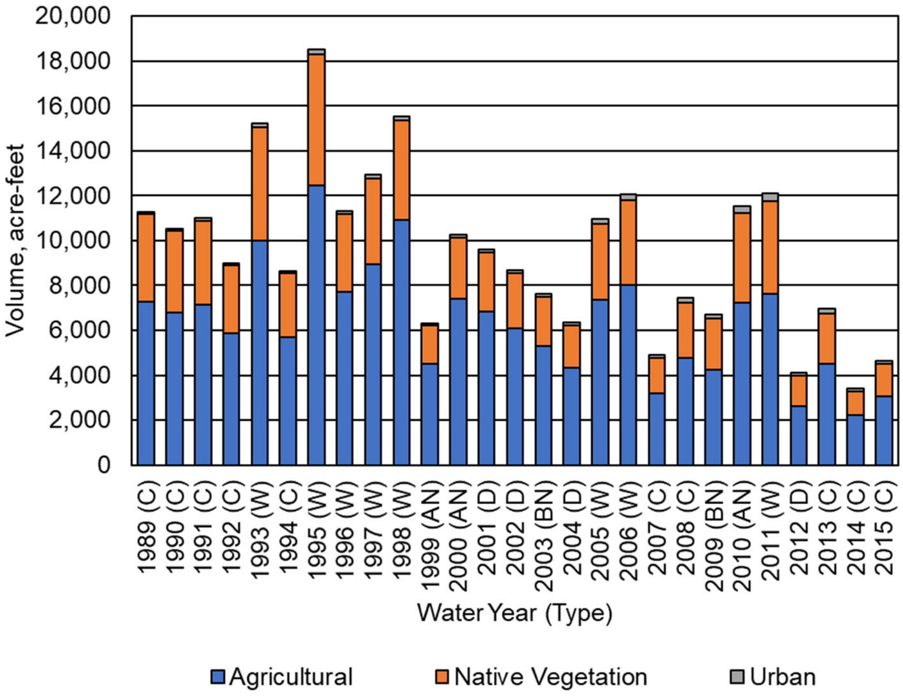

Figure A2.F.b-6. Madera County GSA – East Precipitation by Water Use Sector.

Table A2.F.b-4. Madera County GSA – East Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	7,280	3,890	100	11,270
1990 (C)	6,790	3,630	100	10,520
1991 (C)	7,150	3,740	110	10,990
1992 (C)	5,860	3,030	90	8,980
1993 (W)	9,990	5,060	160	15,210
1994 (C)	5,720	2,810	90	8,620
1995 (W)	12,460	5,850	200	18,520
1996 (W)	7,720	3,460	130	11,310
1997 (W)	8,950	3,830	150	12,920
1998 (W)	10,910	4,440	180	15,530
1999 (AN)	4,490	1,740	80	6,300
2000 (AN)	7,410	2,730	130	10,270
2001 (D)	6,830	2,630	140	9,590
2002 (D)	6,110	2,460	140	8,700
2003 (BN)	5,290	2,220	130	7,650
2004 (D)	4,340	1,890	120	6,350
2005 (W)	7,380	3,350	230	10,960
2006 (W)	8,010	3,800	280	12,080
2007 (C)	3,200	1,580	120	4,890
2008 (C)	4,780	2,450	190	7,430
2009 (BN)	4,260	2,270	190	6,720
2010 (AN)	7,220	4,000	340	11,550
2011 (W)	7,650	4,090	350	12,090
2012 (D)	2,640	1,360	120	4,120
2013 (C)	4,510	2,240	200	6,960
2014 (C)	2,240	1,060	100	3,400
2015 (C)	3,050	1,440	140	4,640
Average (1989-2014)	6,510	3,060	160	9,730
Average (1989-2014) W	9,130	4,240	210	13,580
Average (1989-2014) AN	6,370	2,820	180	9,370
Average (1989-2014) BN	4,780	2,240	160	7,180
Average (1989-2014) D	4,980	2,080	130	7,190
Average (1989-2014) C	5,280	2,710	120	8,120

3.2.1.3 Groundwater Extraction by Water Use Sector

Estimates of groundwater extraction by water use sector are provided in Figure A2.F.b-7 and Table A2.F.b-5. For agricultural and urban (urban, semi-agricultural, industrial) lands, groundwater extraction represents pumping, while for native lands, groundwater extraction by riparian vegetation was considered to be negligible. In all water use sector water budgets, groundwater extraction served as the water budget closure term. Groundwater extraction is dominated by irrigated agriculture and increases over time, following the trend of increasing orchard acreage in the subregion. The consumptive water use of orchards is higher than most other crops grown in the subbasin, and groundwater serves as a major source of supply for the pressurized irrigation systems typical of orchards.

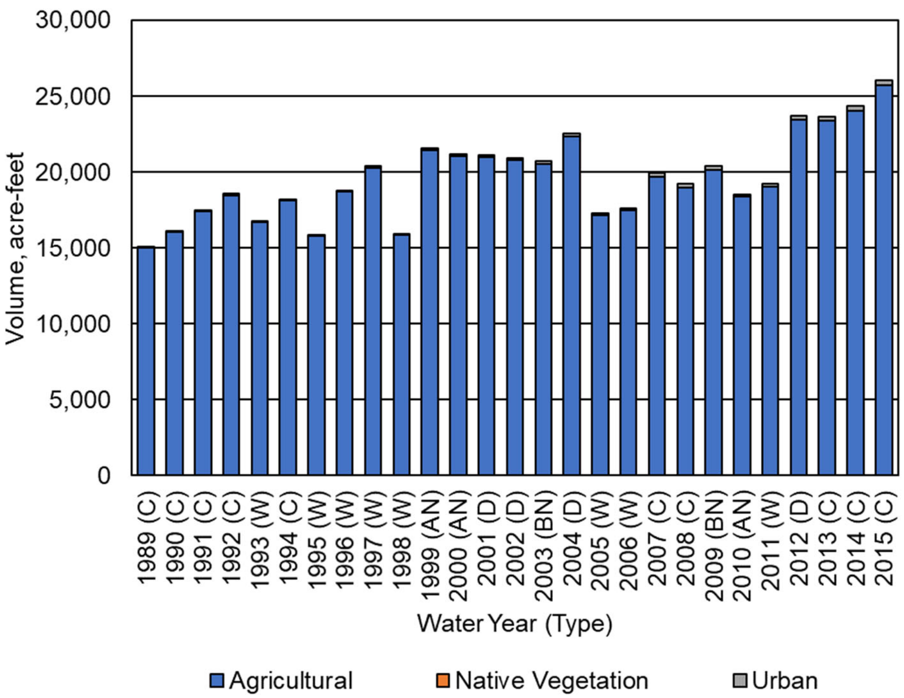

Figure A2.F.b-7. Madera County GSA – East Groundwater Extraction by Water Use Sector.

Table A2.F.b-5. Madera County GSA – East Groundwater Extraction by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	15,010	0	70	15,080
1990 (C)	16,060	0	70	16,130
1991 (C)	17,430	0	80	17,500
1992 (C)	18,470	0	100	18,570
1993 (W)	16,710	0	80	16,790
1994 (C)	18,120	0	100	18,220
1995 (W)	15,770	0	50	15,820
1996 (W)	18,690	0	80	18,760
1997 (W)	20,300	0	130	20,430
1998 (W)	15,840	0	70	15,910
1999 (AN)	21,460	0	100	21,560
2000 (AN)	21,070	0	100	21,170
2001 (D)	20,990	0	110	21,100
2002 (D)	20,760	0	150	20,910
2003 (BN)	20,550	0	160	20,710
2004 (D)	22,340	0	220	22,560
2005 (W)	17,160	0	140	17,300
2006 (W)	17,470	0	150	17,620
2007 (C)	19,710	0	260	19,970
2008 (C)	18,950	0	270	19,220
2009 (BN)	20,160	0	270	20,430
2010 (AN)	18,380	0	160	18,550

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2011 (W)	19,060	0	180	19,230
2012 (D)	23,430	0	300	23,730
2013 (C)	23,380	0	300	23,680
2014 (C)	24,070	0	300	24,370
2015 (C)	25,740	0	340	26,080
Average (1989-2014)	19,280	0	150	19,430
Average (1989-2014) W	17,620	0	110	17,730
Average (1989-2014) AN	20,300	0	120	20,430
Average (1989-2014) BN	20,350	0	220	20,570
Average (1989-2014) D	21,880	0	190	22,080
Average (1989-2014) C	19,020	0	170	19,190

3.2.1.4 Groundwater Discharge to Surface Water Sources

The depth to groundwater is greater than 100-200 ft across much of the Chowchilla Subbasin. Given the depth to the water table in the Chowchilla Subbasin, groundwater discharge to surface water sources is negligible.

3.2.2 Outflows

3.2.2.1 Evapotranspiration by Water Use Sector

Evapotranspiration (ET) by water use sector is reported in Figures A2.F.b-8 to A2.F.b-10 and Tables A2.F.b-6 to A2.F.b-8. First, total ET is reported, followed by ET from applied water and ET from precipitation.

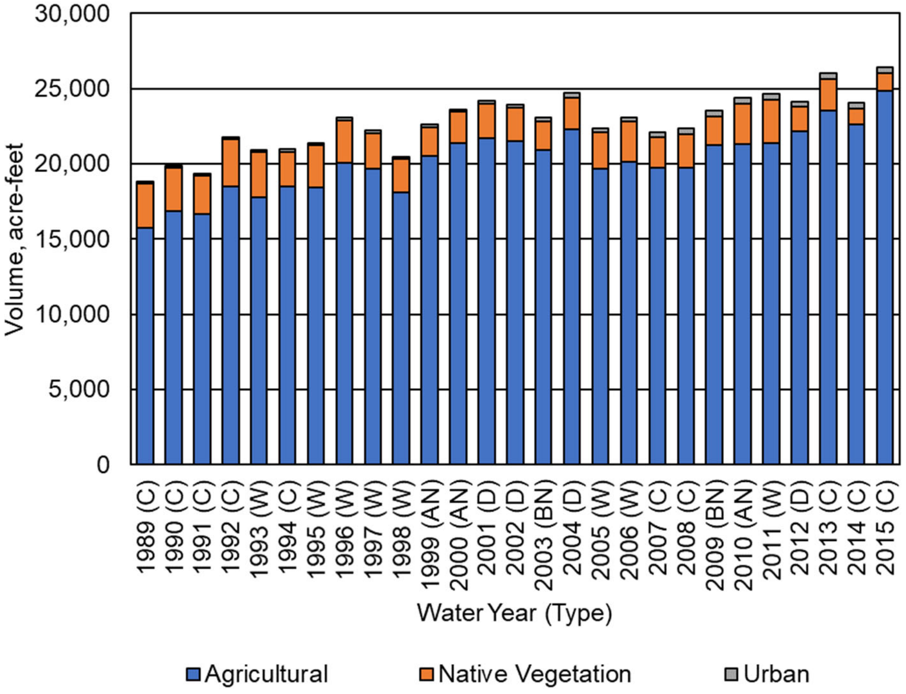

Figure A2.F.b-8. Madera County GSA – East Evapotranspiration by Water Use Sector.

Table A2.F.b-6. Madera County GSA – East Evapotranspiration by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	15,720	2,990	120	18,830
1990 (C)	16,840	2,920	130	19,890
1991 (C)	16,670	2,580	110	19,360
1992 (C)	18,530	3,090	150	21,770
1993 (W)	17,800	3,010	140	20,950
1994 (C)	18,470	2,350	140	20,970
1995 (W)	18,440	2,800	140	21,380
1996 (W)	20,050	2,850	150	23,050
1997 (W)	19,650	2,400	160	22,230
1998 (W)	18,110	2,220	150	20,510
1999 (AN)	20,560	1,890	150	22,600
2000 (AN)	21,400	2,060	160	23,620
2001 (D)	21,720	2,300	180	24,200
2002 (D)	21,500	2,240	220	23,960
2003 (BN)	20,950	1,860	240	23,050
2004 (D)	22,320	2,100	290	24,710
2005 (W)	19,650	2,420	270	22,340
2006 (W)	20,110	2,690	300	23,100
2007 (C)	19,710	2,050	320	22,080
2008 (C)	19,760	2,210	380	22,350
2009 (BN)	21,260	1,870	390	23,520
2010 (AN)	21,300	2,700	370	24,370
2011 (W)	21,390	2,880	370	24,640
2012 (D)	22,170	1,650	340	24,160
2013 (C)	23,560	2,060	400	26,020
2014 (C)	22,650	1,050	340	24,040
2015 (C)	24,850	1,210	390	26,450
Average (1989-2014)	20,010	2,360	240	22,610
Average (1989-2014) W	19,400	2,660	210	22,280
Average (1989-2014) AN	21,080	2,220	220	23,520
Average (1989-2014) BN	21,100	1,870	310	23,280
Average (1989-2014) D	21,930	2,070	260	24,260
Average (1989-2014) C	19,100	2,370	230	21,700

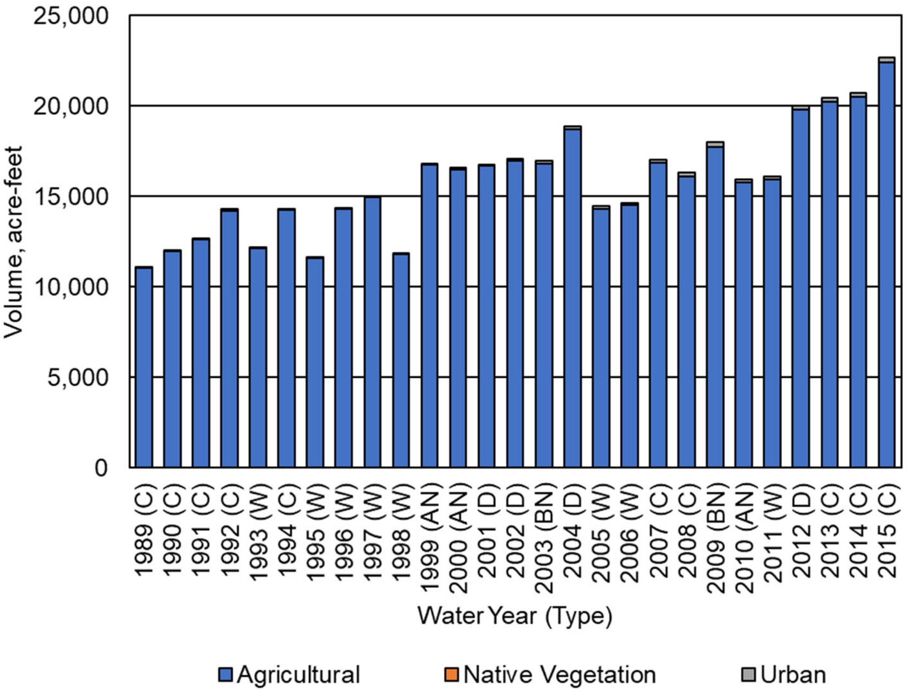

Figure A2.F.b-9. Madera County GSA – East Evapotranspiration of Applied Water by Water Use Sector.

Table A2.F.b- 7. Madera County GSA – East Evapotranspiration of Applied Water by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	11,050	0	50	11,100
1990 (C)	11,970	0	60	12,030
1991 (C)	12,650	0	50	12,700
1992 (C)	14,220	0	70	14,290
1993 (W)	12,150	0	60	12,210
1994 (C)	14,250	0	70	14,330
1995 (W)	11,610	0	50	11,660
1996 (W)	14,320	0	50	14,370
1997 (W)	14,940	0	70	15,030
1998 (W)	11,790	0	60	11,880
1999 (AN)	16,750	0	70	16,820
2000 (AN)	16,510	0	80	16,590
2001 (D)	16,690	0	80	16,770
2002 (D)	16,950	0	110	17,060
2003 (BN)	16,820	0	130	16,950
2004 (D)	18,710	0	170	18,880
2005 (W)	14,320	0	130	14,450
2006 (W)	14,520	0	130	14,650
2007 (C)	16,860	0	170	17,030
2008 (C)	16,110	0	220	16,330
2009 (BN)	17,740	0	240	17,980
2010 (AN)	15,760	0	160	15,920

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2011 (W)	15,950	0	140	16,090
2012 (D)	19,810	0	190	20,000
2013 (C)	20,230	0	240	20,470
2014 (C)	20,510	0	240	20,750
2015 (C)	22,410	0	280	22,690
Average (1989-2014)	15,510	0	120	15,630
Average (1989-2014) W	13,700	0	90	13,800
Average (1989-2014) AN	16,340	0	100	16,440
Average (1989-2014) BN	17,280	0	180	17,460
Average (1989-2014) D	18,040	0	140	18,180
Average (1989-2014) C	15,320	0	130	15,450

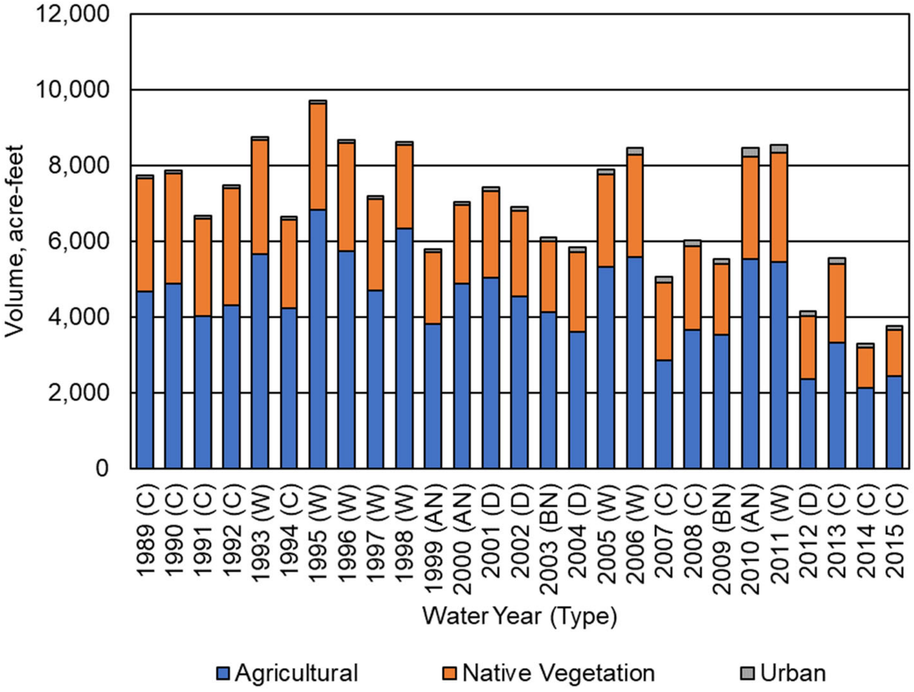

Figure A2.F.b-10. Madera County GSA – East Evapotranspiration of Precipitation by Water Use Sector.

Table A2.F.b-8. Madera County GSA – East Evapotranspiration of Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	4,670	2,990	70	7,730
1990 (C)	4,870	2,920	70	7,860
1991 (C)	4,020	2,580	60	6,660
1992 (C)	4,310	3,090	80	7,480
1993 (W)	5,650	3,010	80	8,740
1994 (C)	4,220	2,350	70	6,640
1995 (W)	6,830	2,800	90	9,720
1996 (W)	5,730	2,850	100	8,680

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1997 (W)	4,710	2,400	90	7,200
1998 (W)	6,320	2,220	90	8,630
1999 (AN)	3,810	1,890	80	5,780
2000 (AN)	4,890	2,060	80	7,030
2001 (D)	5,030	2,300	100	7,430
2002 (D)	4,550	2,240	110	6,900
2003 (BN)	4,130	1,860	110	6,100
2004 (D)	3,610	2,100	120	5,830
2005 (W)	5,330	2,420	140	7,890
2006 (W)	5,590	2,690	170	8,450
2007 (C)	2,850	2,050	150	5,050
2008 (C)	3,650	2,210	160	6,020
2009 (BN)	3,520	1,870	150	5,540
2010 (AN)	5,540	2,700	210	8,450
2011 (W)	5,440	2,880	230	8,550
2012 (D)	2,360	1,650	150	4,160
2013 (C)	3,330	2,060	160	5,550
2014 (C)	2,140	1,050	100	3,290
2015 (C)	2,440	1,210	110	3,760
Average (1989-2014)	4,500	2,360	120	6,980
Average (1989-2014) W	5,700	2,660	120	8,480
Average (1989-2014) AN	4,740	2,220	120	7,080
Average (1989-2014) BN	3,820	1,870	130	5,820
Average (1989-2014) D	3,890	2,070	120	6,080
Average (1989-2014) C	3,780	2,370	100	6,250

Total ET varies between years, with the lowest observed in 1989, at approximately 19 taf, and greatest in 2015, at approximately 26 taf. Total ET generally increases over time, again following the trend of increasing orchard acreage, which has higher water demand than many other crops grown in the subbasin.

In addition to ET from land surfaces, estimates of evaporation from Madera Co GSA – East rivers and streams are reported in Figure A2.F.b-11 and Table A2.F.b-9. Evaporation from the Rivers and Streams System includes evaporation of both surface inflows and of precipitation runoff within local sloughs and depressions. Total evaporation from all sources averaged less than 0.1 taf per year between 1989 and 2014.

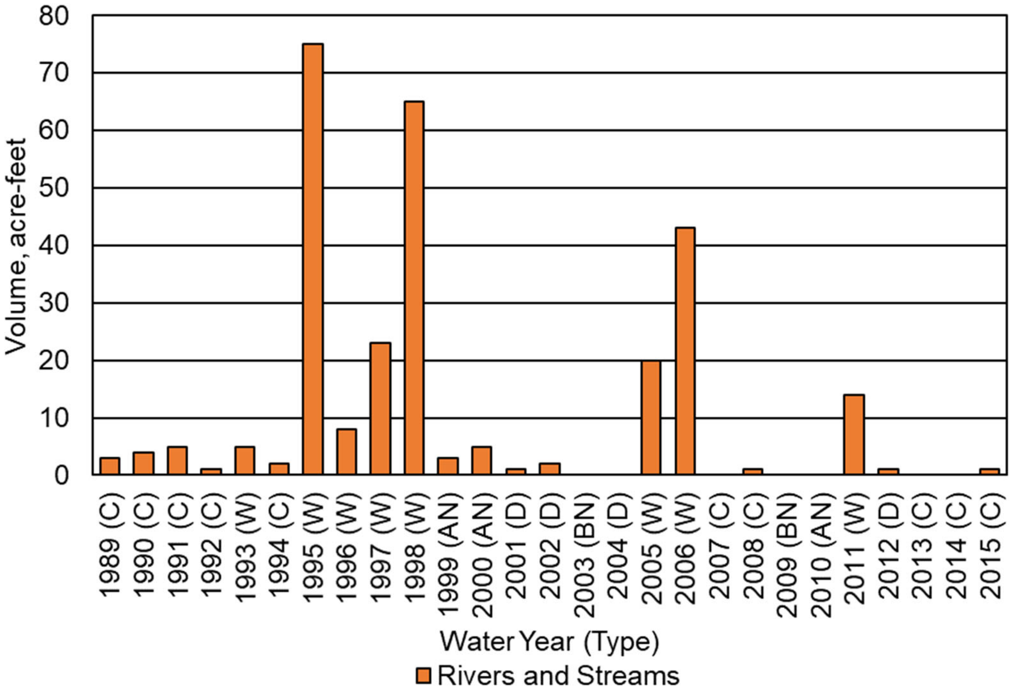

Figure A2.F.b-11. Madera County GSA – East Evaporation from the Surface Water System.

Table A2.F.b-9. Madera County GSA – East Evaporation from the Surface Water System (Acre-Feet).

Water Year (Type)	Rivers and Streams[1]
1989 (C)	0
1990 (C)	0
1991 (C)	10
1992 (C)	0
1993 (W)	10
1994 (C)	0
1995 (W)	80
1996 (W)	10
1997 (W)	20
1998 (W)	70
1999 (AN)	0
2000 (AN)	10
2001 (D)	0
2002 (D)	0
2003 (BN)	0
2004 (D)	0
2005 (W)	20
2006 (W)	40
2007 (C)	0
2008 (C)	0
2009 (BN)	0
2010 (AN)	0

Water Year (Type)	Rivers and Streams[1]
2011 (W)	10
2012 (D)	0
2013 (C)	0
2014 (C)	0
2015 (C)	0
Average (1989-2014)	10
Average (1989-2014) W	32
Average (1989-2014) AN	3
Average (1989-2014) BN	0
Average (1989-2014) D	1
Average (1989-2014) C	2

[1] Includes evaporation of surface inflows and of precipitation runoff.

3.2.2.2 Surface Water Outflow by Water Source Type

Surface water outflows by water source type are summarized in Figure A2.F.b-12 and Table A2.F.b-10. In Madera Co GSA – East, runoff of applied water is assumed negligible and runoff of precipitation is collected in waterways within Madera Co GSA – East, with most infiltrating to the groundwater system except following the largest storm events. Thus, surface outflows from the GSA – East are expected to be CVP supplies during flood releases from Buchanan Dam and Madera Canal. Between 1989 and 2014, these combined outflows averaged over 92 taf during wet years.

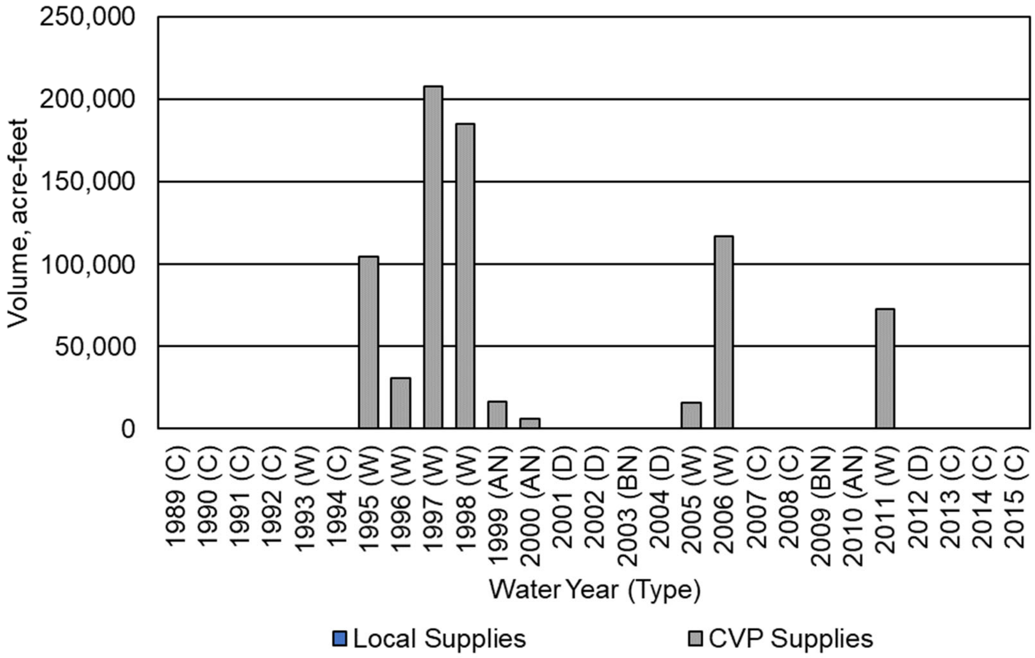

Figure A2.F.b-12. Madera County GSA – East Surface Outflows by Water Source Type.

Table A2.F.b-10. Madera County GSA – East Surface Outflows by Water Source Type (Acre-Feet).

Water Year (Type)	Local Supplies	CVP Supplies	Total
1989 (C)	0	0	0
1990 (C)	0	0	0
1991 (C)	0	0	0
1992 (C)	0	0	0
1993 (W)	0	0	0
1994 (C)	0	0	0
1995 (W)	0	104,543	104,543
1996 (W)	0	30,747	30,747
1997 (W)	0	207,633	207,633
1998 (W)	0	184,924	184,924
1999 (AN)	0	16,843	16,843
2000 (AN)	0	6,370	6,370
2001 (D)	0	0	0
2002 (D)	0	0	0
2003 (BN)	0	0	0
2004 (D)	0	0	0
2005 (W)	0	15,939	15,939
2006 (W)	0	116,785	116,785
2007 (C)	0	0	0
2008 (C)	0	0	0
2009 (BN)	0	0	0
2010 (AN)	0	0	0
2011 (W)	0	72,907	72,907
2012 (D)	0	0	0
2013 (C)	0	0	0
2014 (C)	0	0	0
2015 (C)	0	0	0
Average (1989-2014)	0	29,103	29,103
Average (1989-2014) W	0	91,685	91,685
Average (1989-2014) AN	0	7,738	7,738
Average (1989-2014) BN	0	0	0
Average (1989-2014) D	0	0	0
Average (1989-2014) C	0	0	0

3.2.2.3 Infiltration of Precipitation

Estimated infiltration of precipitation (deep percolation of precipitation) by water use sector is provided in Figure A2.F.b-13 and Table A2.F.b-11. Infiltration of precipitation to the groundwater system is highly variable from year to year due to variation in the timing and amount of precipitation, ranging from less than 1 taf annually during some critical and dry years to over 6 taf during 1995.

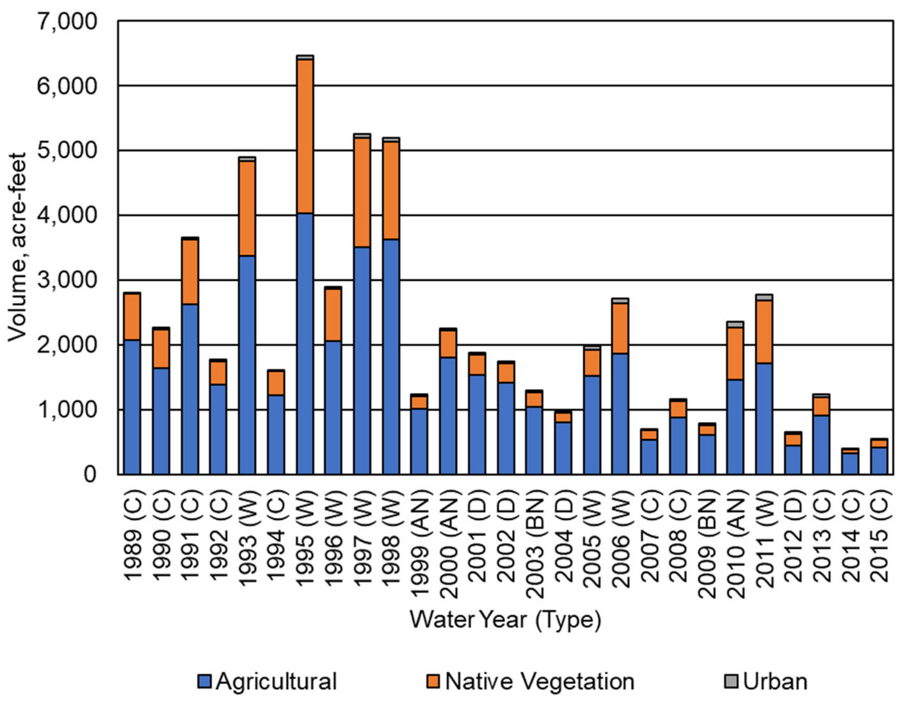

Figure A2.F.b-13. Madera County GSA – East Infiltration of Precipitation by Water Use Sector.

Table A2.F.b-11. Madera County GSA – East Infiltration of Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	2,070	720	20	2,810
1990 (C)	1,640	600	20	2,260
1991 (C)	2,620	1,010	30	3,660
1992 (C)	1,380	370	20	1,770
1993 (W)	3,370	1,470	50	4,890
1994 (C)	1,220	370	20	1,610
1995 (W)	4,030	2,370	70	6,470
1996 (W)	2,060	810	30	2,900
1997 (W)	3,500	1,700	60	5,260
1998 (W)	3,630	1,500	60	5,190
1999 (AN)	1,010	200	20	1,230
2000 (AN)	1,800	420	30	2,250
2001 (D)	1,530	320	30	1,880
2002 (D)	1,410	300	30	1,740
2003 (BN)	1,040	230	20	1,290
2004 (D)	800	150	20	970
2005 (W)	1,520	410	50	1,980
2006 (W)	1,860	780	70	2,710
2007 (C)	530	150	20	700
2008 (C)	880	250	30	1,160
2009 (BN)	610	150	30	790

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2010 (AN)	1,460	810	80	2,350
2011 (W)	1,710	980	90	2,780
2012 (D)	440	190	30	660
2013 (C)	910	280	40	1,230
2014 (C)	320	60	20	400
2015 (C)	410	120	20	550
Average (1989-2014)	1,670	640	40	2,350
Average (1989-2014) W	2,710	1,250	60	4,020
Average (1989-2014) AN	1,420	480	40	1,940
Average (1989-2014) BN	830	190	30	1,050
Average (1989-2014) D	1,050	240	30	1,320
Average (1989-2014) C	1,290	420	20	1,730

3.2.2.4 Infiltration of Surface Water

Estimated infiltration of surface water (seepage) by source is provided in Figure A2.F.b-14 and Table A2.F.b-12. Seepage from the Rivers and Streams System includes seepage of both surface inflows and of precipitation runoff into local sloughs and depressions. Seepage from rivers and streams follows the pattern of surface water inflows, averaging approximately 4.4 taf per wet year between 1989 and 2014.

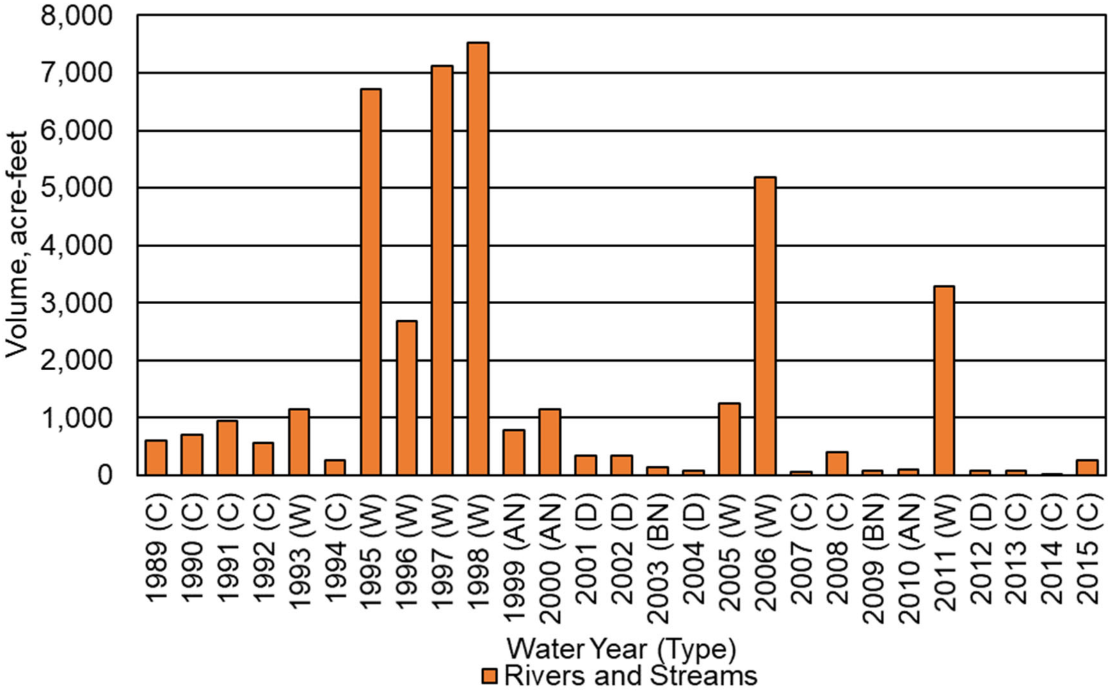

Figure A2.F.b-14. Madera County GSA – East Infiltration of Surface Water.

Table A2.F.b-12. Madera County GSA – East Infiltration of Surface Water (Acre-Feet).

Water Year (Type)	Rivers and Streams[1]
1989 (C)	600
1990 (C)	710
1991 (C)	950
1992 (C)	560
1993 (W)	1,150
1994 (C)	270
1995 (W)	6,720
1996 (W)	2,680
1997 (W)	7,120
1998 (W)	7,530
1999 (AN)	790
2000 (AN)	1,140
2001 (D)	340
2002 (D)	340
2003 (BN)	150
2004 (D)	90
2005 (W)	1,260
2006 (W)	5,180
2007 (C)	60
2008 (C)	410
2009 (BN)	90
2010 (AN)	110
2011 (W)	3,290
2012 (D)	90
2013 (C)	80
2014 (C)	10
2015 (C)	270
Average (1989-2014)	1,600
Average (1989-2014) W	4,370
Average (1989-2014) AN	680
Average (1989-2014) BN	120
Average (1989-2014) D	220
Average (1989-2014) C	410

[1] Includes infiltration of surface inflows and of precipitation runoff within the subregion. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.2.2.5 Infiltration of Applied Water

Estimated infiltration of applied water (deep percolation of applied water) by water use sector is provided in Figure A2.F.b-15 and Table A2.F.b-13. Infiltration of applied water is dominated by agricultural irrigation and has slowly decreased over time, likely due to increase use of drip and micro-irrigation systems in place of flood irrigation.

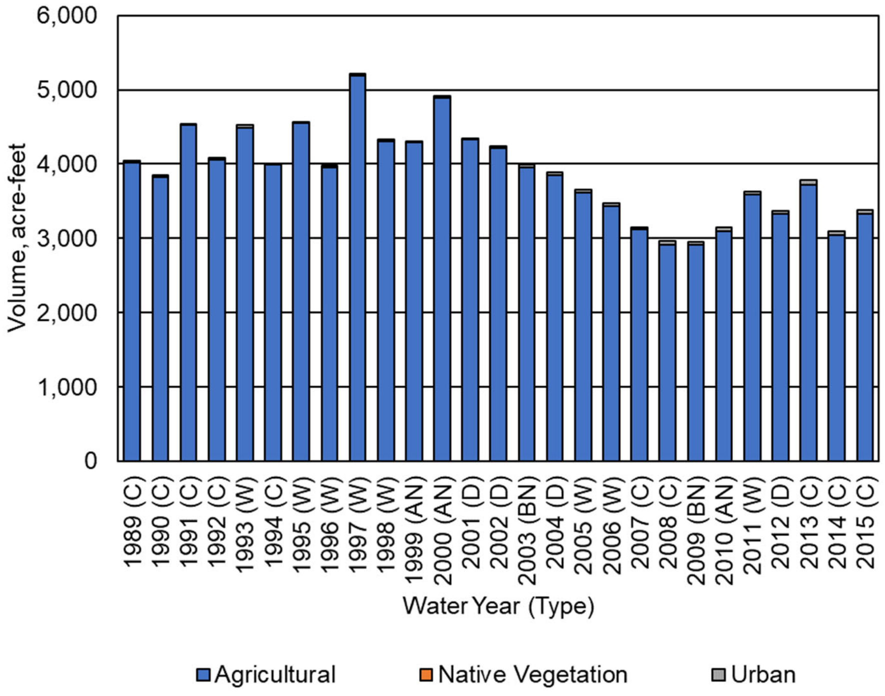

Figure A2.F.b-15. Madera County GSA – East Infiltration of Applied Water by Water Use Sector.

Table A2.F.b-13. Madera County GSA – East Infiltration of Applied Water by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	4,020	0	20	4,040
1990 (C)	3,830	0	20	3,850
1991 (C)	4,520	0	20	4,540
1992 (C)	4,060	0	20	4,080
1993 (W)	4,490	0	30	4,520
1994 (C)	3,990	0	20	4,010
1995 (W)	4,550	0	20	4,570
1996 (W)	3,960	0	20	3,980
1997 (W)	5,190	0	30	5,220
1998 (W)	4,300	0	30	4,330
1999 (AN)	4,290	0	10	4,300
2000 (AN)	4,890	0	20	4,910
2001 (D)	4,330	0	20	4,350
2002 (D)	4,210	0	30	4,240
2003 (BN)	3,960	0	30	3,990
2004 (D)	3,850	0	40	3,890
2005 (W)	3,620	0	40	3,660
2006 (W)	3,430	0	40	3,470
2007 (C)	3,120	0	30	3,150
2008 (C)	2,920	0	40	2,960
2009 (BN)	2,910	0	40	2,950
2010 (AN)	3,100	0	50	3,150

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2011 (W)	3,590	0	40	3,630
2012 (D)	3,330	0	40	3,370
2013 (C)	3,720	0	60	3,780
2014 (C)	3,050	0	40	3,090
2015 (C)	3,330	0	50	3,380
Average (1989-2014)	3,890	0	30	3,920
Average (1989-2014) W	4,140	0	30	4,170
Average (1989-2014) AN	4,090	0	30	4,120
Average (1989-2014) BN	3,440	0	40	3,480
Average (1989-2014) D	3,930	0	30	3,960
Average (1989-2014) C	3,690	0	30	3,720

3.2.3 Change in Surface Water System Storage

Estimates of change in SWS storage are provided in Figure A2.F.b-16 and Table A2.F.b-14. Inter-annual changes in storage within the surface water system consist primarily of root zone soil moisture storage changes, are relatively small, and tend to average near zero over many years.

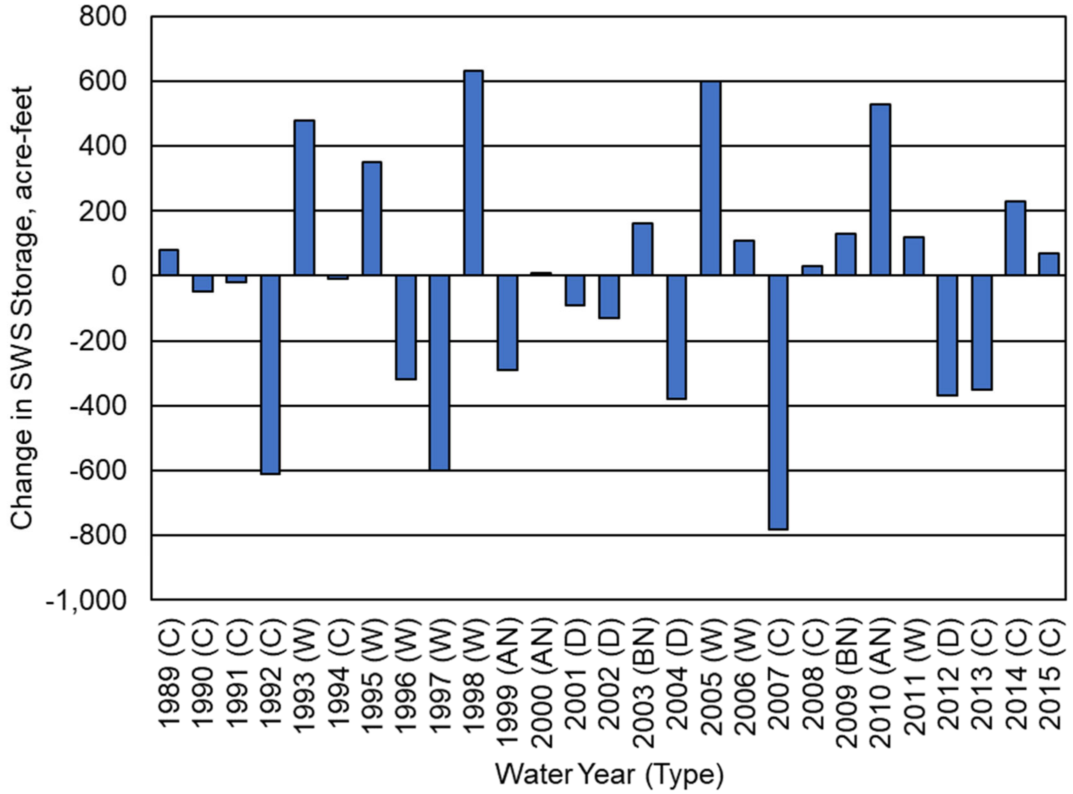

Figure A2.F.b-16. Madera County GSA – East Change in Surface Water System Storage.

Table A2.F.b-14. Madera County GSA – East Change in Surface Water System Storage (Acre-Feet).

Water Year (Type)	Change in SWS Storage
1989 (C)	80
1990 (C)	-50
1991 (C)	-20
1992 (C)	-610
1993 (W)	480
1994 (C)	-10
1995 (W)	350
1996 (W)	-320
1997 (W)	-600
1998 (W)	630
1999 (AN)	-290
2000 (AN)	10
2001 (D)	-90
2002 (D)	-130
2003 (BN)	160
2004 (D)	-380
2005 (W)	600
2006 (W)	110
2007 (C)	-780
2008 (C)	30
2009 (BN)	130
2010 (AN)	530
2011 (W)	120
2012 (D)	-370
2013 (C)	-350
2014 (C)	230
2015 (C)	70
Average (1989-2014)	-20
Average (1989-2014) W	170
Average (1989-2014) AN	80
Average (1989-2014) BN	150
Average (1989-2014) D	-240
Average (1989-2014) C	-160

3.3 Historical Water Budget Summary

Annual inflows, outflows, and change in SWS storage during the historical water budget period (1989-2014) are summarized in Figure A2.F.b-17 and Table A2.F.b-15. Inflows are shown as positive values, while outflows and change in SWS storage are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the surface water system water budget.

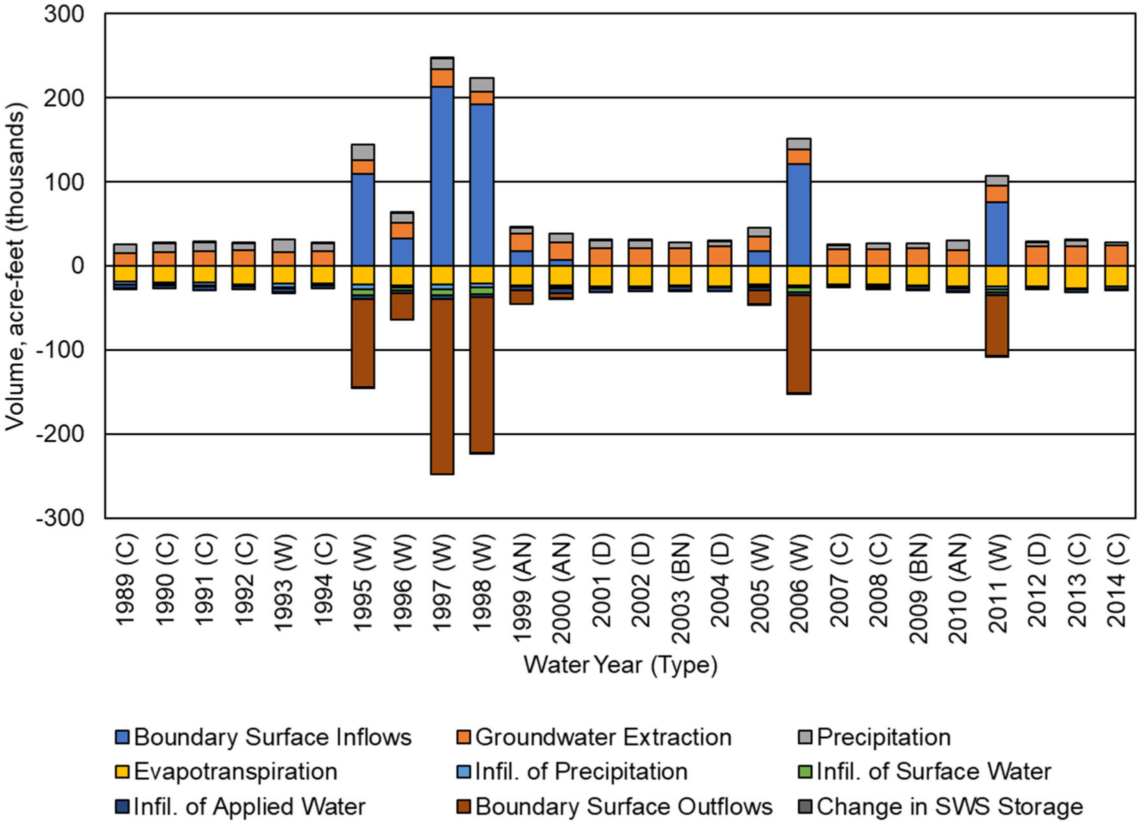

Figure A2.F.b-17. Madera County GSA – East Surface Water System Historical Water Budget, 1989-2014.

Table A2.F.b-15. Madera County GSA – East Surface Water System Historical Water Budget, 1989-2014 (Acre-Feet).

Water Year	Boundary Surface Inflows	Groundwater Extraction	Precipitation	Evapo-transpiration[1]	Infil. of Precipitation	Infil. of Surface Water[2]	Infil. of Applied Water	Boundary Surface Outflows	Change in SWS Storage
1989 (C)	0	15,080	11,270	-18,830	-2,810	-600	-4,040	0	-80
1990 (C)	0	16,130	10,520	-19,890	-2,260	-710	-3,850	0	50
1991 (C)	0	17,500	10,990	-19,360	-3,660	-950	-4,540	0	20
1992 (C)	0	18,570	8,980	-21,760	-1,760	-560	-4,080	0	610
1993 (W)	0	16,790	15,210	-20,960	-4,890	-1,150	-4,510	0	-480
1994 (C)	0	18,220	8,620	-20,970	-1,610	-270	-4,000	0	10
1995 (W)	109,760	15,820	18,520	-21,450	-6,470	-6,720	-4,570	-104,540	-350
1996 (W)	32,950	18,760	11,310	-23,050	-2,900	-2,680	-3,970	-30,750	320
1997 (W)	213,510	20,430	12,920	-22,230	-5,260	-7,120	-5,220	-207,630	600
1998 (W)	191,690	15,910	15,530	-20,540	-5,190	-7,530	-4,330	-184,920	-630
1999 (AN)	17,620	21,560	6,300	-22,600	-1,240	-790	-4,300	-16,840	290
2000 (AN)	6,850	21,170	10,270	-23,620	-2,250	-1,140	-4,910	-6,370	-10
2001 (D)	0	21,100	9,590	-24,200	-1,870	-340	-4,350	0	90
2002 (D)	530	20,910	8,700	-23,960	-1,730	-340	-4,240	0	130
2003 (BN)	280	20,710	7,650	-23,050	-1,290	-150	-3,990	0	-160
2004 (D)	360	22,560	6,350	-24,700	-970	-90	-3,890	0	380
2005 (W)	17,540	17,300	10,960	-22,360	-1,980	-1,260	-3,660	-15,940	-600
2006 (W)	121,690	17,620	12,080	-23,140	-2,710	-5,180	-3,470	-116,780	-110
2007 (C)	360	19,970	4,890	-22,080	-710	-60	-3,150	0	780
2008 (C)	260	19,220	7,430	-22,350	-1,160	-410	-2,960	0	-30
2009 (BN)	330	20,430	6,720	-23,520	-790	-90	-2,950	0	-130
2010 (AN)	410	18,550	11,550	-24,370	-2,350	-110	-3,140	0	-530
2011 (W)	76,050	19,230	12,090	-24,640	-2,770	-3,290	-3,640	-72,910	-120
2012 (D)	60	23,730	4,120	-24,160	-660	-90	-3,370	0	370
2013 (C)	110	23,680	6,960	-26,010	-1,230	-80	-3,770	0	350
2014 (C)	0	24,370	3,400	-24,040	-390	-10	-3,100	0	-230
Average (1989-2014)	30,400	19,430	9,730	-22,610	-2,340	-1,600	-3,920	-29,100	20
W	95,400	17,730	13,580	-22,300	-4,020	-4,370	-4,170	-91,680	-170
AN	8,290	20,430	9,370	-23,530	-1,940	-680	-4,120	-7,740	-80
BN	310	20,570	7,180	-23,280	-1,040	-120	-3,470	0	-140
D	240	22,080	7,190	-24,260	-1,310	-220	-3,960	0	240
C	80	19,190	8,120	-21,700	-1,730	-400	-3,720	0	170

[1] Includes ET of applied water, ET of precipitation, and evaporation from the Rivers and Streams System.

[2] Includes infiltration from the Rivers and Streams System within the subregion. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.4 Current Water Budget Summary

The current water budget was developed following a similar process to the historical water budget using the 2015 land use in Table A2.F.b-1 and the same 1989-2014 average hydrologic conditions of the historical base period, including surface water flows, precipitation, and weather parameters. This allowed quantification of groundwater inflows and outflows for current consumptive use in the context of average water supply conditions.

Annual inflows, outflows, and change in SWS storage from the current water budget are summarized in Figure A2.F.b-18 and Table A2.F.b-16. Inflows are shown as positive values, while outflows and change in SWS storage are shown as negative values.

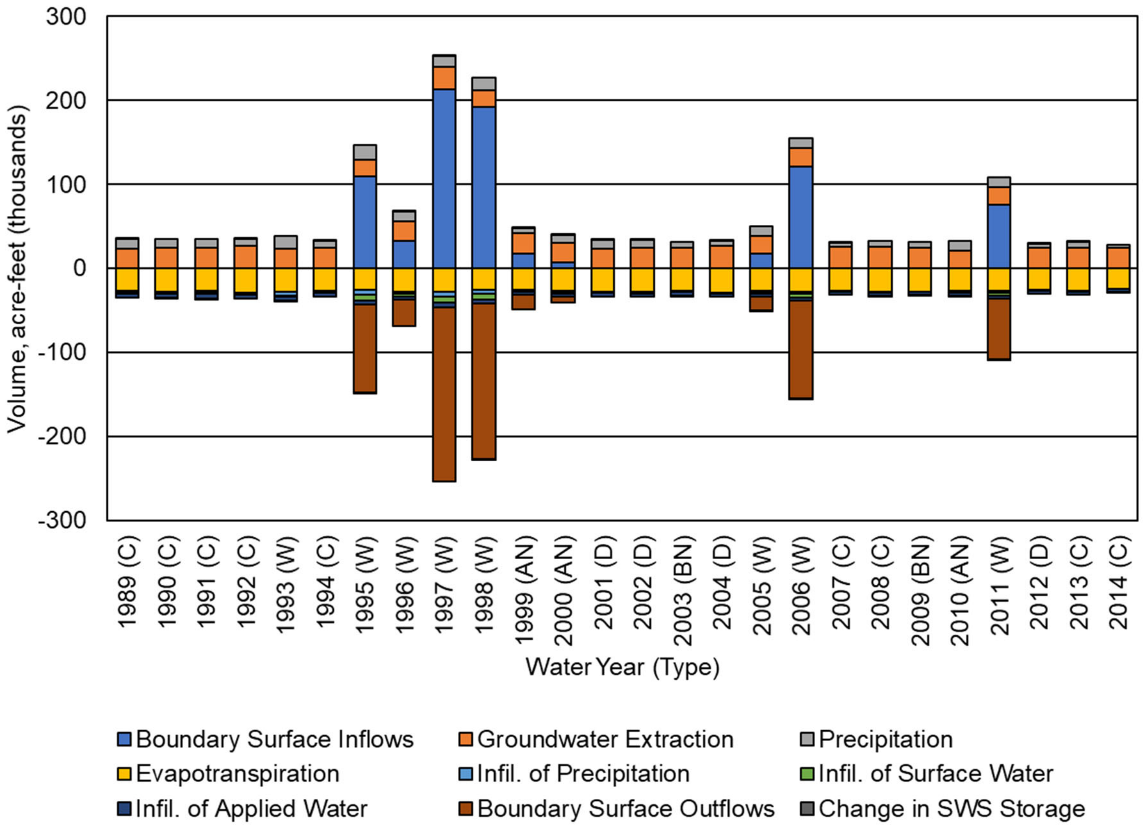

Figure A2.F.b-18. Madera County GSA – East Surface Water System Current Water Budget.

Table A2.F.b-16. Madera County GSA – East Surface Water System Current Water Budget (Acre-Feet).

Water Year	Boundary Surface Inflows	Groundwater Extraction	Precipitation	Evapotranspiration[1]	Infil. of Precipitation	Infil. of Surface Water[2]	Infil. of Applied Water	Boundary Surface Outflows	Change in SWS Storage
1989 (C)	0	23,400	11,320	-26,580	-2,580	-360	-5,320	0	130
1990 (C)	0	24,210	10,550	-27,450	-2,040	-490	-4,740	0	-40
1991 (C)	0	24,420	11,020	-26,130	-3,350	-740	-5,170	0	-60
1992 (C)	0	26,450	9,010	-29,360	-1,550	-370	-4,620	0	450
1993 (W)	0	23,890	15,260	-27,840	-4,650	-800	-5,350	0	-520
1994 (C)	0	24,250	8,650	-27,130	-1,400	-160	-4,330	0	120
1995 (W)	109,760	19,080	18,560	-25,620	-6,070	-6,470	-4,570	-104,540	-130
1996 (W)	32,950	23,520	11,340	-27,850	-2,650	-2,560	-4,150	-30,750	130
1997 (W)	213,510	26,900	12,960	-28,160	-5,100	-6,810	-5,970	-207,630	290
1998 (W)	191,690	19,830	15,580	-24,860	-4,940	-7,250	-4,840	-184,920	-290
1999 (AN)	17,620	24,110	6,320	-25,620	-1,010	-790	-3,920	-16,840	130
2000 (AN)	6,850	23,070	10,300	-26,970	-1,930	-1,010	-4,080	-6,370	140
2001 (D)	0	23,770	9,610	-27,530	-1,620	-280	-4,000	0	50
2002 (D)	530	24,380	8,720	-27,770	-1,540	-260	-4,160	0	100
2003 (BN)	280	24,080	7,660	-26,780	-1,120	-80	-3,870	0	-170
2004 (D)	360	26,620	6,370	-29,130	-820	-40	-3,770	0	400
2005 (W)	17,540	21,610	10,980	-26,620	-1,820	-1,110	-3,940	-15,940	-690
2006 (W)	121,690	21,450	12,100	-27,220	-2,510	-4,960	-3,680	-116,780	-100
2007 (C)	360	24,890	4,900	-26,940	-630	-20	-3,450	0	900
2008 (C)	260	25,290	7,450	-27,880	-1,150	-260	-3,650	0	-50
2009 (BN)	330	24,770	6,730	-27,500	-780	-50	-3,370	0	-140
2010 (AN)	410	20,330	11,550	-26,110	-2,310	-120	-3,340	0	-410
2011 (W)	76,050	20,640	12,090	-26,110	-2,690	-3,250	-3,680	-72,910	-140
2012 (D)	60	25,030	4,120	-25,510	-630	-80	-3,340	0	340
2013 (C)	110	24,330	6,950	-26,530	-1,240	-80	-3,910	0	370
2014 (C)	0	24,360	3,400	-24,040	-400	-10	-3,090	0	-220
Average (1989-2014)	30,400	23,640	9,750	-26,890	-2,170	-1,480	-4,170	-29,100	20
W	95,400	22,110	13,610	-26,780	-3,800	-4,150	-4,520	-91,680	-180
AN	8,290	22,500	9,390	-26,230	-1,750	-640	-3,780	-7,740	-50
BN	310	24,420	7,200	-27,140	-950	-60	-3,620	0	-150
D	240	24,950	7,200	-27,490	-1,150	-160	-3,810	0	220
C	80	24,620	8,140	-26,890	-1,590	-280	-4,250	0	180

[1] Includes ET of applied water, ET of precipitation, and evaporation from the Rivers and Streams System.

[2] Includes infiltration from the Rivers and Streams System within the subregion. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.5 Net Recharge from SWS

Overdraft is defined in DWR Bulletin 118 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" (DWR 2003). The Chowchilla Subbasin water budget indicates that overdraft conditions occurred during the 1989-2014 historical base period. Per 23 CCR Section 354.18(b)(5), the subbasin overdraft has been quantified for this base period. The evaluation of overdraft conditions includes estimates of recharge from subsurface flows. However, estimates of recharge from subsurface flows are less accurate when estimated for areas less that an entire subbasin. Thus, for estimates of GSA level contribution to overdraft, the term net recharge from the SWS is defined as groundwater recharge minus groundwater extraction. Net recharge from the SWS is useful for understanding and analyzing the combined effects of land surface processes on the underlying GWS.

When calculated from the historical water budget, average net recharge from the SWS represents the average recharge (when positive) or shortage of recharge (when negative) based on historical cropping, land use practices, and average hydrologic conditions. When calculated from the current land use water budget, average net recharge represents the average recharge or shortage (when negative) based on current cropping, land use practices, and average hydrologic conditions.

Average net recharge from the SWS is presented below for the Madera Co GSA – East portion of the Chowchilla Subbasin. Table A2.F.b-17 shows the average net recharge from the SWS for 1989-2014 based on the historical water budget, and Table A2.F.b-18 shows the same for the current water budget. Historically, the average net recharge in Madera Co GSA – East was approximately -11.5 taf per year between 1989 and 2014. Under current land use conditions, the average net recharge in Madera Co GSA – East is approximately -15.7 taf, indicating shortage conditions.

The Madera Co GSA - East recognizes that groundwater users within its boundaries want to understand potential future limitations on groundwater resources available to meet their beneficial uses. As shown in both Table A2.F.b-17 and Table A2.F.b-18, average values for infiltration of precipitation and infiltration of surface water are provided (columns "b" and "c"). The slight variation between the tables reflects the modified land use conditions. Together, these values represent the sustainable native groundwater for the Madera Co GSA – East, a value of about 4,000 acre-feet per year.

The Madera Co GSA – East has not determined whether an allocation approach, or other methods, will best allow the Madera Co GSA – East to achieve needed reductions in the consumptive use of groundwater (see GSP Chapter 4). However, the Madera Co GSA – East recognize the correlative nature of overlying groundwater rights, which, when coupled with appropriated groundwater use, provides that all the users share in the sustainable quantity of native groundwater. For purposes of analyzing the availability of sustainable quantities of native groundwater for all lands within the Madera Co GSA – East, the estimated total quantity of sustainable native groundwater – estimated at 4,000 acre-feet per year – can be calculated to be approximately 0.5 acre-feet per acre within the Madera Co GSA – East (based upon estimates of about 4,000 acre-feet of total sustainable native groundwater available for about 7,600 acres within the Madera Co GSA – East). The achievement of sustainability may or may not involve an equal allocation across the Madera Co GSA – East, and the Madera Co GSA – East will use its SGMA-granted authority to manage the basin so as to achieve this end. Furthermore, other GSAs within the Chowchilla Subbasin may choose to manage their proportion of the estimated sustainable native groundwater differently than the Madera Co GSA – East, but they are also subject to the overall subbasin sustainability requirements.

Table A2.F.b-17. Historical Water Budget: Average Net Recharge from SWS by Water Year Type, 1989-2014 (Acre-Feet).

Year Type	Number of Years	Infiltration of Applied Water (a)	Infiltration of Precipitation (b)	Infiltration of Surface Water[1] (c)	Groundwater Extraction (d)	Net Recharge from SWS (a+b+c-d)
W	8	4,170	4,020	4,340	17,730	-5,200
AN	3	4,120	1,940	990	20,430	-13,380
BN	2	3,470	1,040	130	20,570	-15,930
D	4	3,960	1,310	330	22,080	-16,480
C	9	3,720	1,730	510	19,190	-13,230
Annual Average (1989-2014)	26	3,920	2,340	1,690	19,430	-11,480

[1] Calculated from the total subbasin Rivers and Streams System seepage summed and redistributed to each subregion in proportion to gross area.

Table A2.F.b-18. Current Water Budget: Average Net Recharge from SWS by Water Year Type (Acre-Feet).

Year Type	Number of Years	Infiltration of Applied Water (a)	Infiltration of Precipitation (b)	Infiltration of Surface Water[1] (c)	Groundwater Extraction (d)	Net Recharge from SWS (a+b+c-d)
W	8	4,520	3,800	4,250	22,110	-9,540
AN	3	3,780	1,750	950	22,500	-16,020
BN	2	3,620	950	80	24,420	-19,770
D	4	3,810	1,150	290	24,950	-19,700
C	9	4,250	1,590	400	24,620	-18,380
Annual Average (1989-2014)	26	4,170	2,170	1,610	23,640	-15,690

[11] Calculated from the total subbasin Rivers and Streams System seepage summed and redistributed to each subregion in proportion to gross area.

3.6 Uncertainties in Water Budget Components

Uncertainties associated with each water budget component were estimated as a percentage representing approximately a 95% confidence interval following the procedure described by Clemmens and Burt (1997). Uncertainties for all independently measured or estimated water budget components were estimated based on the measurement accuracy, typical values reported in technical literature, typical values calculated in other water budgets, and professional judgement.

Table A2.F.b-19 provides a summary of typical uncertainty values associated with major SWS inflow and outflow 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 A2.F.b-19. Estimated Uncertainty of GSA Water Budget Components.

Flowpath Direction (SWS Boundary)	Water Budget Component	Data Source	Estimated Uncertainty (%)	Source
Inflows	Surface Water Inflows	Measurement	5%	Estimated streamflow measurement accuracy.
	Riparian Deliveries	Measurement	10%	Estimated measurement accuracy.
	Precipitation	Calculation	30%	Clemmens, A.J. and C.M. Burt, 1997.
	Groundwater Extraction	Closure	20%	Typical uncertainty calculated for Land Surface System water balance closure.
Outflows	Surface Water Outflows	Closure	20%	Typical uncertainty calculated for Rivers and Streams System water balance closure.
	Evaporation	Calculation	20%	Estimated accuracy of calculation based on CIMIS reference ET and free water surface evaporation coefficient.
	ET of Applied Water	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, estimated crop coefficients from SEBAL energy balance, and annual land use.
	ET of Precipitation	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, precipitation, estimated crop coefficients from SEBAL energy balance, and annual land use.
	Infiltration of Applied Water	Calculation	20%	Estimated accuracy of daily IDC root zone water budget component based on annual land use and NRCS soils characteristics.
	Infiltration of Precipitation	Calculation	20%	Estimated accuracy of daily IDC root zone water budget component based on annual land use, NRCS soils characteristics, and CIMIS precipitation.
	Infiltration of Surface Water	Calculation	15%	Estimated accuracy of daily seepage calculation using NRCS soils characteristics and calculated runoff of precipitation.
	Change in SWS Storage	Calculation	50%	Professional Judgment.
Net Recharge from SWS		Calculation	25%	Estimated water budget accuracy; typical value calculated for GSA-level net recharge from SWS.

APPENDIX 2.F. WATER BUDGET INFORMATION

2.F.c. Surface Water System Water Budget: Madera County GSA – West Subregion

Prepared as part of the

Groundwater Sustainability Plan
Chowchilla Subbasin

January 2020

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1 INTRODUCTION

To ensure sustainable groundwater management throughout California's groundwater basins, the Sustainable Groundwater Management Act of 2014 (SGMA) requires Groundwater Sustainability Agencies (GSAs) to prepare and adopt Groundwater Sustainability Plans (GSPs) with strategies to achieve subbasin groundwater sustainability within 20 years of plan adoption. Integral to each GSP is a water budget used to quantify the subbasin's groundwater overdraft (if applicable) and sustainable yield.

In 2016, Madera County (Madera Co) GSA formed to manage approximately 45,100 acres of the Chowchilla Subbasin. Madera Co GSA includes noncontiguous areas on the eastern and western sides of the Chowchilla Subbasin. Portions of Madera Co GSA's eastern jurisdictional area also overlap with Sierra Vista Mutual Water Company (SVMWC). In the interests of separately accounting for inflows to each side of Madera County GSA and to SVMWC, two water budgets were prepared for Madera Co GSA: one for the western subregion, and one for the eastern subregion, excluding land in SVMWC.

This document presents results of the surface water system (SWS) water budgets developed for historical and current land use conditions in the Madera Co GSA – West Subregion. The Madera Co GSA – West water budgets were integrated with separate water budgets developed for four (4) other subregions covering the remainder of the Chowchilla Subbasin. Together, these water budgets provide the boundary water budget for the Chowchilla Subbasin SWS. Results of the subbasin boundary water budget are reported in the Chowchilla Subbasin GSP Section 2.2.3 and were integrated with a subbasin groundwater model (GSP Appendix 6.E) to estimate subbasin sustainable yield (GSP Section 2.2.3).

2 WATER BUDGET CONCEPTUAL MODEL

A water budget is defined as a complete accounting of all water flowing into and out of a defined volume (e.g., a subbasin or a GSA) over a specified period of time. The conceptual model (or structure) of the Madera Co GSA – West water budget developed for this investigation is consistent with the GSP Regulations defined under Title 23 of California Code of Regulations[1] (CCR) and adheres to sound water budget principles and practices defined by California Department of Water Resources (DWR) in the Water Budget Best Management Practice (BMP) guidelines (DWR, 2016).

The lateral extent of Madera Co GSA – West is defined by the boundaries indicated in Figure A2.F.c-1. The vertical extent of Madera Co GSA – West is the land surface (top) and the base of fresh water at the bottom of the basin (bottom), as described in the hydrogeologic conceptual model (HCM) developed in GSP Section 2.2.1. The vertical extent of Chowchilla Subbasin and its GSAs is subdivided into a surface water system (SWS) and the underlying groundwater system (GWS), with separate but related water budgets prepared for each that together represent the overall subbasin water budget.

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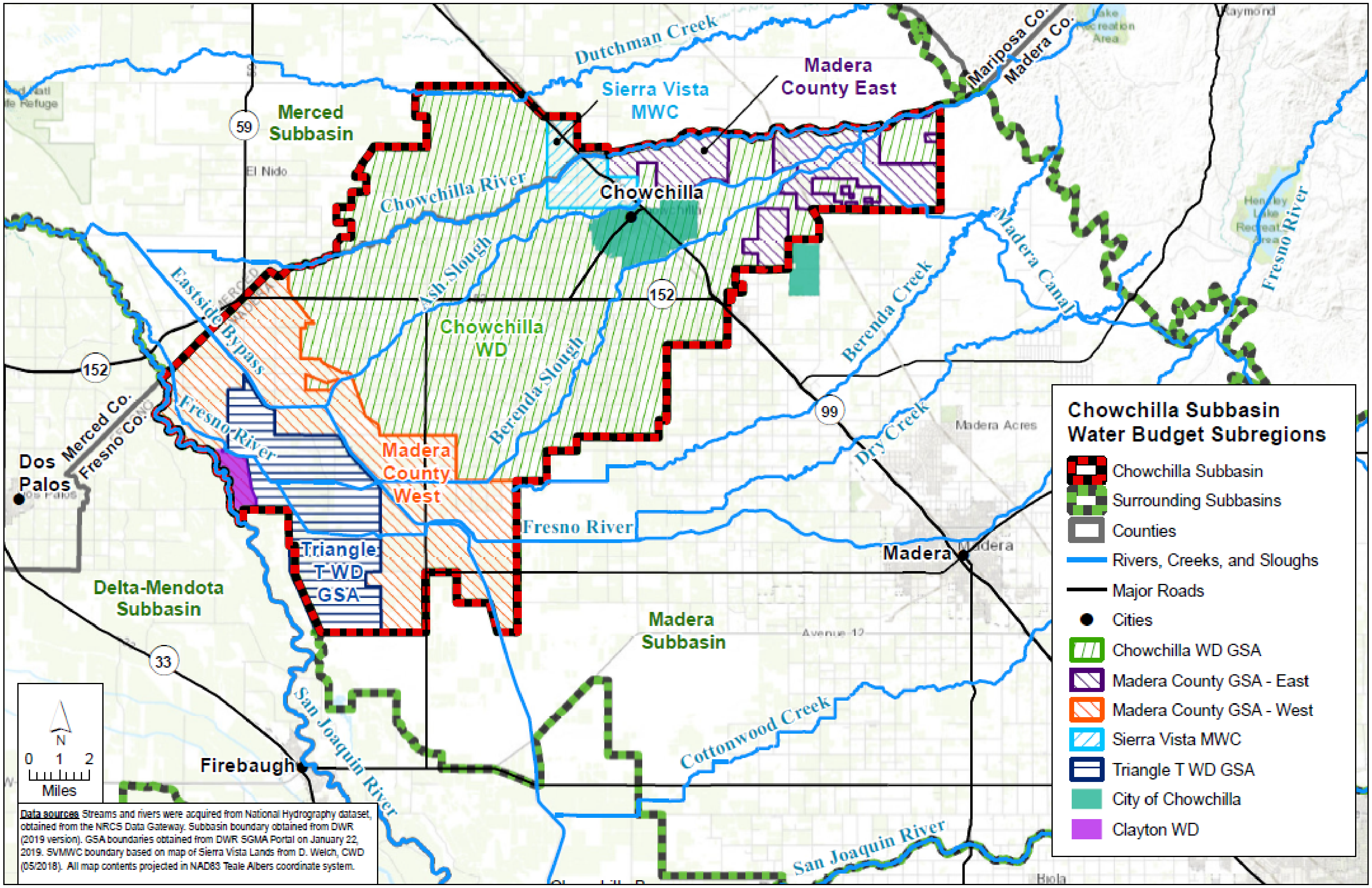
[1] California Code of Regulations Title 23. Waters, Division 2. Department of Water Resources, Chapter 1.5. Groundwater Management, Subchapter 2. Groundwater Sustainability Plans.



Data sources Streams and rivers were acquired from National Hydrography dataset, obtained from the NRCS Data Gateway. Subbasin boundary obtained from DWR (2019 version). GSA boundaries obtained from DWR SGMA Portal on January 22, 2019. SVMWC boundary based on map of Sierra Vista Lands from D. Welch, CWD (05/2018). All map contents projected in NAD83 Teale Albers coordinate system.

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Chowchilla Subbasin Water Budget Subregion Map

Chowchilla Subbasin Groundwater Sustainability Plan

Figure A2.F.c-1. Chowchilla Subbasin Water Budget Subregion Map

A conceptual representation of the Madera Co GSA – West water budget is represented in Figure A2.F.c-2. This document details only the SWS portion of the Madera Co GSA – West water budget. The SWS is divided into two primary accounting centers: the Land Surface System and the Rivers and Streams System. The Land Surface System is further divided into three accounting centers representing the subregion water use sectors: Agricultural Land, Native Vegetation Land, and Urban Land (urban, industrial, and semi-agricultural).

Water budget components, or directional flow of water between accounting centers and across the SWS boundary, are indicated by arrows. Inflows and outflows were calculated using measurements and other historical data or were calculated as the water budget closure term – the difference between all other estimated or measured inflows and outflows from each accounting center or water use sector (bold arrows).

Inflows to the SWS include precipitation, surface water inflows (in various canals and streams), and groundwater extraction. Outflows from the SWS include evapotranspiration (ET), surface water outflows (in various canals and streams), and infiltration to the groundwater system (seepage and deep percolation). Also represented in Figure A2.F.c-2 are inflows and outflows from the GWS, which are discussed and quantified at the subbasin level in the GWS water budget in GSP Section 2.2.3. Subsurface GWS inflows and outflows are not quantified on the water budget subregion scale.

Inflows and outflows were quantified following the process described in GSP Section 2.2.3 on a monthly time step for water years in the historical water budget base period (1989-2014 hydrologic and land use conditions), the current water budget (2015 land use using 1989-2014 average hydrologic conditions), and projected water budget. Four projected water budgets were prepared for the years 2019 through 2090 based on 1965 through 2015 hydrologic conditions, projected water supplies, and 2017 land use adjusted for urban area projected growth from 2017-2070 (areas were held constant from 2071-2090):

1. Historical hydrologic conditions and water supply data, with adjustment for projected alteration of available Friant releases by the San Joaquin River Restoration Program (SJRRP)[2]
    a. Without projects and management actions, and
    b. With projects and management actions
2. Historical hydrologic conditions and water supply data, with adjustment for projected alteration of available Friant releases by the SJRRP and adjustment for anticipated climate change per DWR-provided 2030 climate change factors
    a. Without projects and management actions, and
    b. With projects and management actions.

Information regarding the data sources and adjustments used to prepare the historical, current, and projected water budgets are described in GSP Section 2.2.3.

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[2] Adjustments were based on the Friant Report ("Estimate of Future Friant Division Supplies for use in Groundwater Sustainability Plans, California," Friant Water Authority, 2018). Although the Friant Report accounts for climate change, it is considered the best available estimate of projected Friant releases under SJRRP. For comparison, projected Madera Canal deliveries under SJRRP were also estimated without account for climate change from the Kondolf Hydrographs (in "Effects to Water Supply and Friant Operations Resulting From Plaintiffs' Friant Release Requirements," Steiner, 2005). These estimates were approximately equal to the Friant Report 2030 climate change adjusted deliveries. Thus, the Friant Report projections were used instead to maintain consistent assumptions in estimating Madera Canal deliveries across all projected simulations.

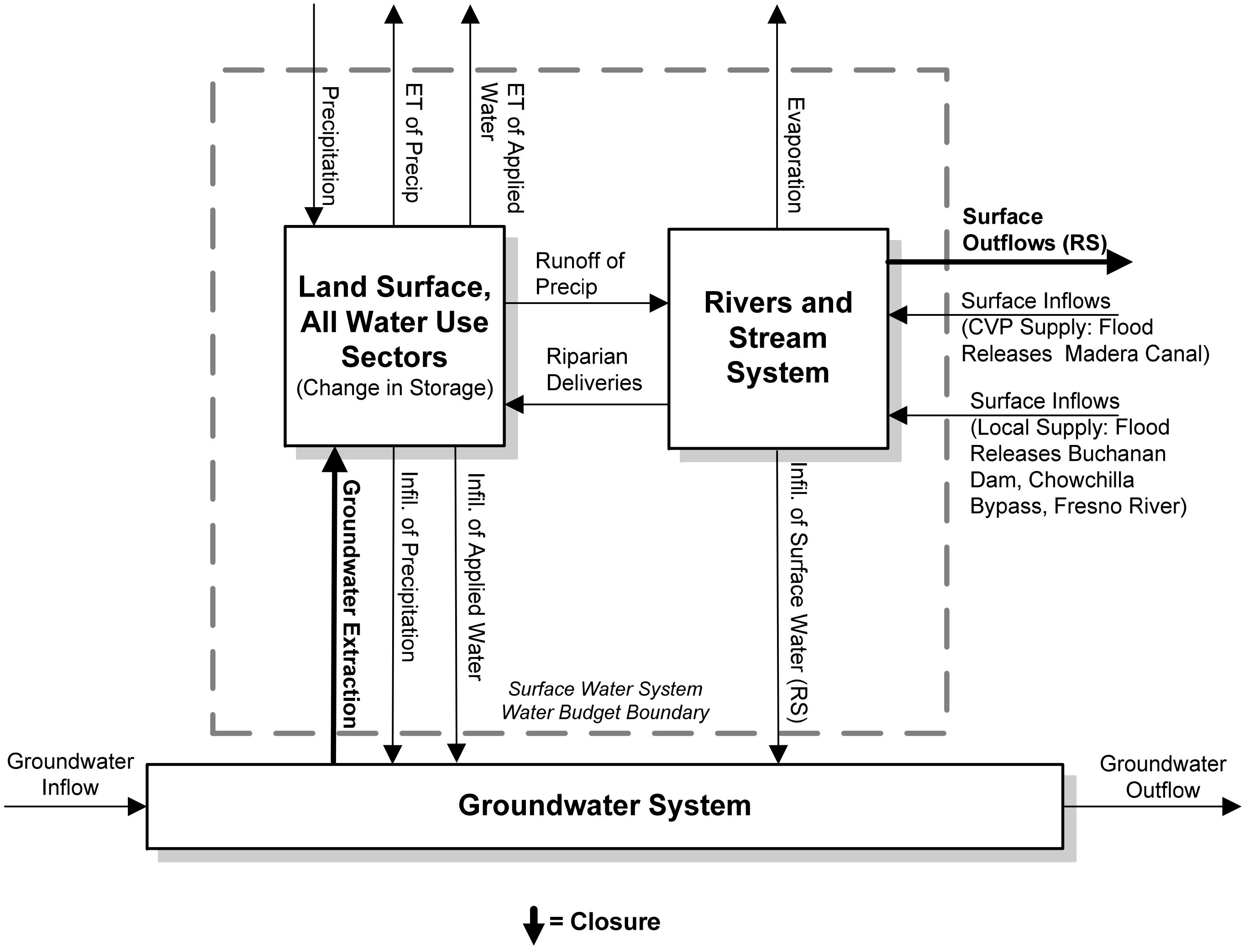

Figure A2.F.c-2. Madera County GSA – West Water Budget Structure

3 WATER BUDGET ANALYSIS

The historical water budget and current land use water budget for Madera Co GSA – West are presented below following a summary of land use data relevant to water budget development. Land use data is provided for the 1989-2014 historical water budget period and for 2015, the current land use water budget period.

3.1 Land Use

Land use estimates for 1989 through 2015 corresponding to water use sectors (as defined by the GSP Regulations) are summarized in Figure A2.F.c-3 and Table A2.F.c-1 for the Madera Co GSA – West subregion. According to GSP Regulations (23 CCR § 351(al)):

> *"Water use sector" refers to 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*

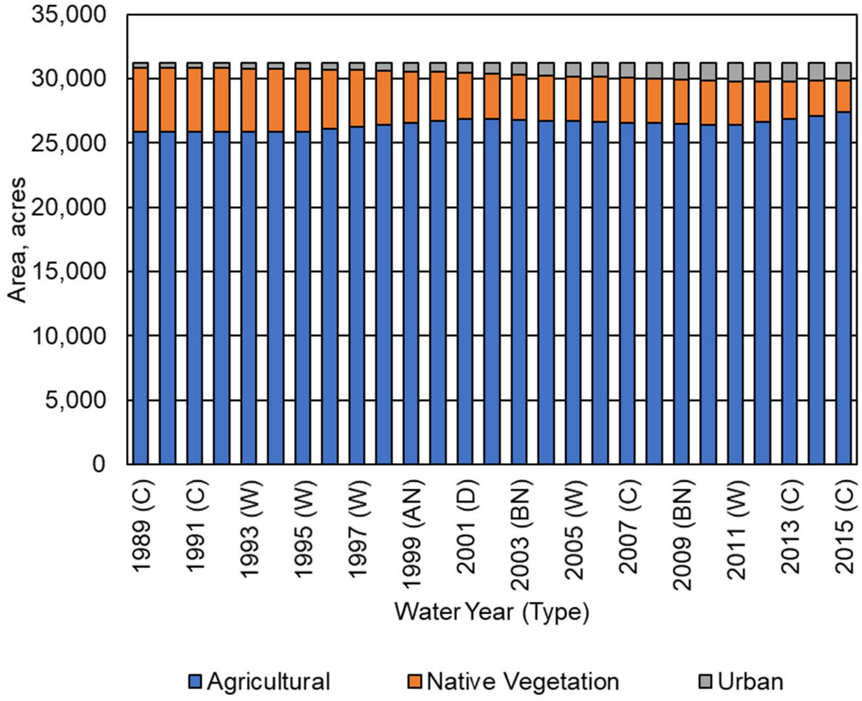

Figure A2.F.c-3. Madera County GSA – West Land Use Areas

Table A2.F.c-1. Madera County GSA – West Land Use Areas, acres

Water Year (Type)	Agricultural	Native Vegetation[1]	Urban[2]	Total
1989 (C)	25,911	4,939	363	31,213
1990 (C)	25,897	4,943	372	31,213
1991 (C)	25,903	4,928	382	31,213
1992 (C)	25,871	4,950	392	31,213
1993 (W)	25,885	4,926	401	31,213
1994 (C)	25,887	4,912	415	31,213
1995 (W)	25,905	4,876	432	31,213
1996 (W)	26,068	4,661	485	31,213
1997 (W)	26,231	4,445	537	31,213
1998 (W)	26,394	4,229	590	31,213
1999 (AN)	26,557	4,014	643	31,213
2000 (AN)	26,720	3,798	695	31,213
2001 (D)	26,883	3,582	748	31,213
2002 (D)	26,835	3,564	814	31,213
2003 (BN)	26,786	3,546	881	31,213
2004 (D)	26,738	3,528	948	31,213
2005 (W)	26,689	3,509	1,015	31,213
2006 (W)	26,641	3,491	1,081	31,213
2007 (C)	26,592	3,473	1,148	31,213
2008 (C)	26,544	3,455	1,214	31,213
2009 (BN)	26,496	3,436	1,281	31,213
2010 (AN)	26,447	3,418	1,348	31,213
2011 (W)	26,399	3,400	1,414	31,213
2012 (D)	26,636	3,170	1,407	31,213
2013 (C)	26,873	2,940	1,400	31,213
2014 (C)	27,110	2,710	1,393	31,213
2015 (C)	27,408	2,472	1,333	31,213
Average (1989-2014)	26,419	3,956	838	31,213

[1] Area includes land classified as native vegetation and water surfaces.

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

In Madera Co GSA – West, water use sectors include agricultural, native vegetation, and urban land use. The urban land use category includes urban and semi-agricultural[3] lands as well as industrial land, which covers only a small area in the subbasin.

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[3] As defined in the DWR county land use surveys, 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, 2009).

As indicated, the majority of land in Madera Co GSA – West is used for agriculture, covering an average of approximately 26,400 acres between 1989 and 2014. The remainder of the subregion is primarily native vegetation, averaging approximately 4,000 acres between 1989 and 2014.

Agricultural land uses are further detailed in Figure A2.F.c-4 and Table A2.F.c-2. In the 1990s, a majority of the agricultural area in Madera Co was used to cultivate alfalfa, mixed pasture, and miscellaneous field crops. In recent years, these crops have been increasingly replaced by corn and orchard crops, which have each more than tripled in area between 1989 and 2015.

3.2 Surface Water System Water Budget

This section presents surface water system water budget components within Madera Co GSA – West as per GSP regulations. These are followed by a summary of the water budget results by accounting center.

3.2.1 Inflows

3.2.1.1 Surface Water Inflow by Water Source Type

Surface water inflows include surface water flowing into Madera Co GSA – West across the subregion boundary. Per the Regulations, surface inflows must be reported by water source type. According to the Regulations:

> *"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.*

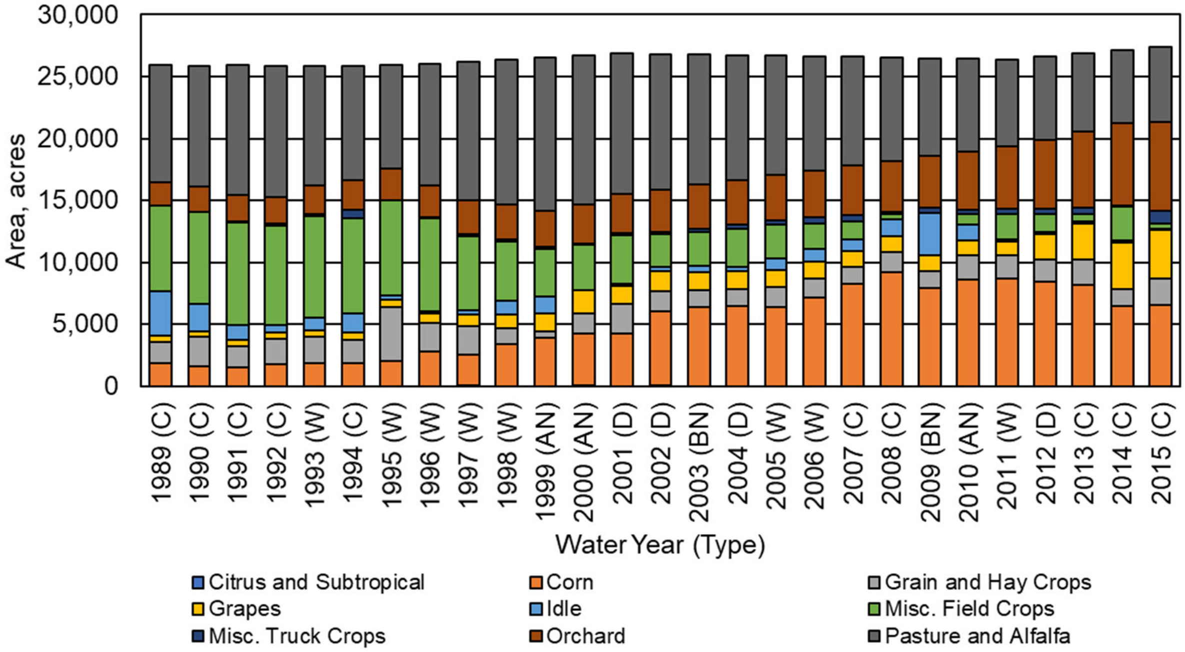

Figure A2.F.c-4. Madera County GSA – West Agricultural Land Use Areas

Table A2.F.c-2. Madera County GSA – West Agricultural Land Use Areas

Water Year (Type)	Citrus and Subtropical	Corn	Grain and Hay Crops	Grapes	Idle	Misc. Field Crops	Misc. Truck Crops	Orchard	Pasture and Alfalfa	Total
1989 (C)	0	1,820	1,772	467	3,575	6,938	40	1,854	9,444	25,911
1990 (C)	0	1,617	2,329	473	2,200	7,406	67	2,000	9,806	25,897
1991 (C)	0	1,531	1,703	489	1,224	8,266	71	2,133	10,486	25,903
1992 (C)	0	1,714	2,094	516	626	7,980	152	2,206	10,582	25,871
1993 (W)	0	1,853	2,094	531	1,060	8,144	244	2,302	9,656	25,885
1994 (C)	0	1,810	1,950	568	1,528	7,716	677	2,364	9,273	25,887
1995 (W)	0	1,988	4,383	576	404	7,611	34	2,602	8,307	25,905
1996 (W)	1	2,755	2,353	739	219	7,472	59	2,597	9,873	26,068
1997 (W)	20	2,491	2,293	1,000	322	5,980	176	2,712	11,238	26,231
1998 (W)	0	3,356	1,300	1,086	1,146	4,806	176	2,824	11,699	26,394
1999 (AN)	0	3,876	540	1,484	1,284	3,867	154	2,955	12,397	26,557
2000 (AN)	9	4,225	1,652	1,821	16	3,703	108	3,100	12,086	26,720
2001 (D)	0	4,197	2,453	1,432	158	3,959	124	3,159	11,400	26,883
2002 (D)	5	6,031	1,602	1,633	332	2,623	196	3,447	10,966	26,835
2003 (BN)	0	6,407	1,307	1,482	542	2,699	254	3,562	10,532	26,786
2004 (D)	0	6,472	1,345	1,425	417	3,075	325	3,580	10,097	26,738
2005 (W)	0	6,334	1,664	1,394	883	2,720	390	3,641	9,662	26,689
2006 (W)	0	7,145	1,560	1,324	1,043	2,037	486	3,818	9,228	26,641
2007 (C)	0	8,275	1,320	1,308	955	1,447	539	3,954	8,794	26,592
2008 (C)	0	9,196	1,595	1,293	1,385	398	199	4,118	8,360	26,544
2009 (BN)	0	7,895	1,393	1,253	3,399	57	367	4,207	7,925	26,496
2010 (AN)	0	8,628	1,889	1,206	1,349	783	405	4,697	7,491	26,447
2011 (W)	0	8,663	1,858	1,156	173	1,999	428	5,065	7,057	26,399
2012 (D)	0	8,384	1,841	2,014	195	1,440	467	5,558	6,736	26,636
2013 (C)	0	8,184	2,032	2,875	207	551	571	6,167	6,287	26,873
2014 (C)	0	6,427	1,392	3,733	191	2,761	58	6,701	5,847	27,110
2015 (C)	0	6,513	2,125	3,945	85	424	1,071	7,193	6,053	27,408
Average (1989-2014)	1	5,049	1,835	1,280	955	4,094	260	3,513	9,432	26,419

Additionally, runoff of precipitation from upgradient areas adjacent to the subregion represents a potential source of surface water inflow.

Local Supplies

Local supply inflows to Madera Co GSA – West include inflows along Fresno River and Chowchilla Bypass.

CVP Supplies

CVP supply inflows to Madera Co GSA – West include flood releases from Buchanan Dam and Millerton Reservoir that enter the subregion along Ash Slough and Berenda Slough.

Recycling and Reuse

Recycling and reuse are not a significant source of supply within Madera Co GSA – West.

Other Surface Inflows

For the water budgets presented herein, precipitation runoff from outside the subregion is considered relatively minimal and is expected to pass through the waterways accounted above following relatively large storm events. Precipitation runoff from lands inside the subregion is internal to the surface water system and is thus not considered as surface inflows to the subregion boundary.

Summary of Surface Inflows

The surface water inflows described above are summarized by water source type in Figure A2.F.c-5 and Table A2.F.c-3. During the study period, total surface water inflows vary by water year type, averaging 761 taf per wet year and less than 3 taf during below normal, dry, and critical years.

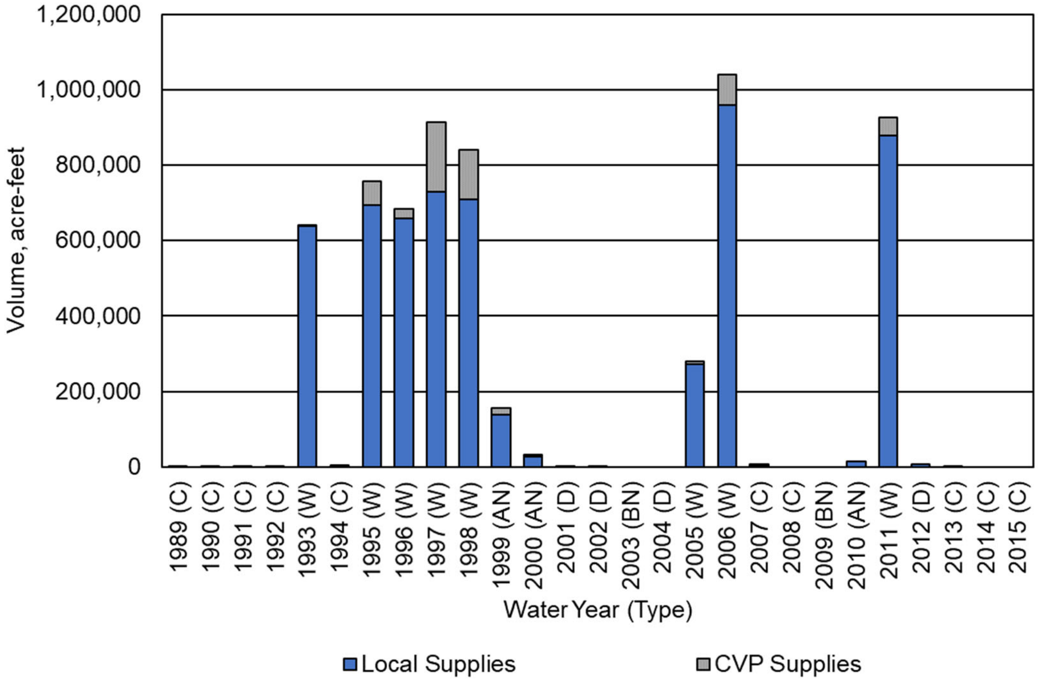

Figure A2.F.c-5. Madera County GSA – West Surface Water Inflows by Water Source Type.

Table A2.F.c-3. Madera County GSA – West Surface Water Inflows by Water Source Type (Acre-Feet).

Water Year (Type)	Local Supply	CVP Supply[1]	Total
1989 (C)	0	1,590	1,590
1990 (C)	0	960	960
1991 (C)	0	1,530	1,530
1992 (C)	0	1,520	1,520
1993 (W)	638,130	3,370	641,500
1994 (C)	170	3,040	3,210
1995 (W)	692,960	64,510	757,460
1996 (W)	658,970	24,440	683,410
1997 (W)	729,140	185,250	914,390
1998 (W)	709,340	130,890	840,230
1999 (AN)	139,110	17,680	156,790
2000 (AN)	26,250	6,550	32,800
2001 (D)	330	710	1,040
2002 (D)	0	0	0
2003 (BN)	0	0	0
2004 (D)	0	0	0
2005 (W)	271,760	9,140	280,900
2006 (W)	958,720	82,190	1,040,910
2007 (C)	4,640	120	4,760
2008 (C)	0	0	0
2009 (BN)	0	0	0
2010 (AN)	13,940	0	13,940
2011 (W)	877,900	49,190	927,090
2012 (D)	8,140	0	8,140
2013 (C)	1,700	0	1,700
2014 (C)	0	0	0
2015 (C)	0	0	0
Average (1989-2014)	220,430	22,410	242,840
Average (1989-2014) W	692,110	68,620	760,740
Average (1989-2014) AN	59,760	8,080	67,840
Average (1989-2014) BN	0	0	0
Average (1989-2014) D	2,120	180	2,300
Average (1989-2014) C	720	970	1,700

[1] CVP Supply is considered as all water supply released from CVP storage facilities. The volume of CVP Supply includes CVP deliveries to CWD, and flood releases from CVP facilities that pass through the subbasin. In Madera County GSA - West, all CVP supply pass through the GSA.

3.2.1.2 Precipitation

Precipitation estimates for Madera Co GSA – West are provided in Figure A2.F.c-6 and Table A2.F.c-4. Precipitation estimates are reported by water use sector.

Total precipitation is highly variable between years in the study area, ranging from approximately 19 taf (7.6 inches) during average dry years to 36 taf (14.4 inches) during average wet years.

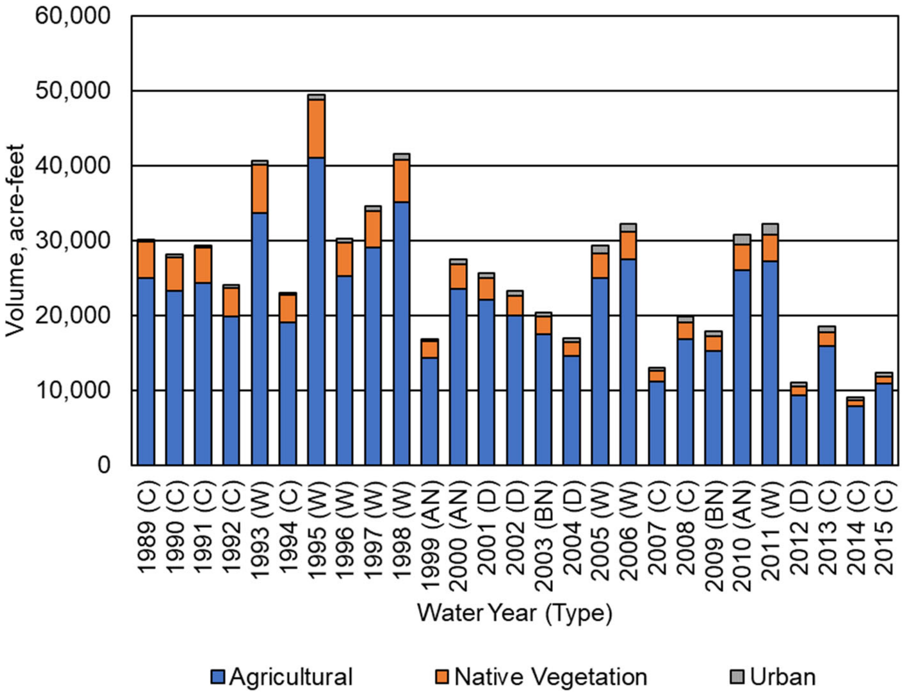

Figure A2.F.c-6. Madera County GSA – West Precipitation by Water Use Sector.

Table A2.F.c-4. Madera County GSA – West Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	25,040	4,770	350	30,170
1990 (C)	23,330	4,460	340	28,130
1991 (C)	24,390	4,640	360	29,390
1992 (C)	19,900	3,810	300	24,010
1993 (W)	33,740	6,420	520	40,680
1994 (C)	19,120	3,630	310	23,060
1995 (W)	41,070	7,730	680	49,490
1996 (W)	25,260	4,520	470	30,240
1997 (W)	29,040	4,920	590	34,560
1998 (W)	35,130	5,630	790	41,540
1999 (AN)	14,340	2,170	350	16,850
2000 (AN)	23,510	3,340	610	27,470
2001 (D)	22,070	2,940	610	25,630
2002 (D)	19,990	2,660	610	23,260
2003 (BN)	17,530	2,320	580	20,430

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2004 (D)	14,540	1,920	520	16,980
2005 (W)	25,040	3,290	950	29,290
2006 (W)	27,530	3,610	1,120	32,260
2007 (C)	11,130	1,450	480	13,060
2008 (C)	16,880	2,200	770	19,850
2009 (BN)	15,220	1,980	740	17,930
2010 (AN)	26,090	3,370	1,330	30,800
2011 (W)	27,270	3,510	1,460	32,240
2012 (D)	9,360	1,110	490	10,970
2013 (C)	15,960	1,750	830	18,540
2014 (C)	7,870	790	400	9,050
2015 (C)	10,850	980	530	12,360
Average (1989-2014)	21,940	3,420	640	25,990
Average (1989-2014) W	30,510	4,950	820	36,290
Average (1989-2014) AN	21,310	2,960	760	25,040
Average (1989-2014) BN	16,380	2,150	660	19,180
Average (1989-2014) D	16,490	2,160	560	19,210
Average (1989-2014) C	18,180	3,050	460	21,700

3.2.1.3 Groundwater Extraction by Water Use Sector

Estimates of groundwater extraction by water use sector are provided in Figure A2.F.c-7 and Table A2.F.c-5. For agricultural and urban (urban, semi-agricultural, industrial) lands, groundwater extraction represents pumping, while for native lands, groundwater extraction by riparian vegetation was considered to be negligible. In all water use sector water budgets, groundwater extraction served as the water budget closure term. Groundwater extraction is dominated by irrigated agriculture and increases over time, following the trend of increasing orchard acreage in the subregion. The consumptive water use of orchards is higher than most other crops grown in the subbasin, and groundwater serves as a major source of supply for the pressurized irrigation systems typical of orchards.

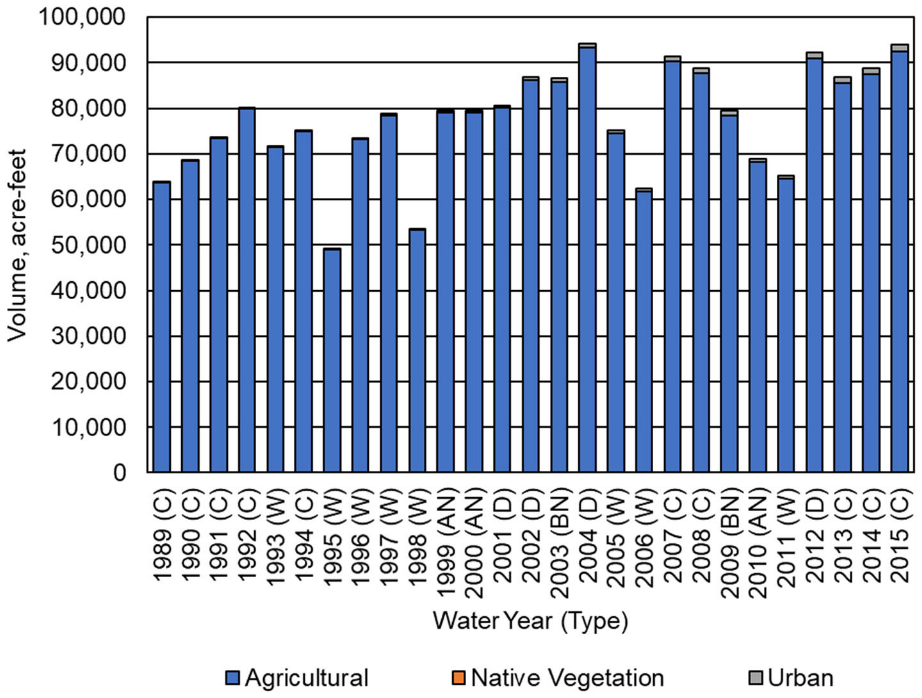

Figure A2.F.c-7. Madera County GSA – West Groundwater Extraction by Water Use Sector.

Table A2.F.c-5. Madera County GSA – West Groundwater Extraction by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	63,760	0	230	63,990
1990 (C)	68,380	0	250	68,630
1991 (C)	73,380	0	250	73,640
1992 (C)	79,830	0	320	80,160
1993 (W)	71,390	0	260	71,640
1994 (C)	74,930	0	330	75,260
1995 (W)	48,930	0	170	49,100
1996 (W)	73,170	0	300	73,470
1997 (W)	78,320	0	520	78,840
1998 (W)	53,270	0	290	53,570
1999 (AN)	79,080	0	500	79,580
2000 (AN)	79,100	0	460	79,560
2001 (D)	80,060	0	490	80,550
2002 (D)	86,220	0	670	86,900
2003 (BN)	85,840	0	690	86,530
2004 (D)	93,320	0	940	94,260
2005 (W)	74,470	0	600	75,070
2006 (W)	61,830	0	620	62,450
2007 (C)	90,260	0	1,060	91,320
2008 (C)	87,660	0	1,090	88,750
2009 (BN)	78,450	0	1,120	79,560
2010 (AN)	68,170	0	650	68,820

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2011 (W)	64,510	0	730	65,250
2012 (D)	90,890	0	1,270	92,160
2013 (C)	85,560	0	1,280	86,830
2014 (C)	87,450	0	1,250	88,700
2015 (C)	92,550	0	1,360	93,910
Average (1989-2014)	76,090	0	630	76,710
Average (1989-2014) W	65,740	0	440	66,170
Average (1989-2014) AN	75,450	0	540	75,990
Average (1989-2014) BN	82,150	0	900	83,050
Average (1989-2014) D	87,620	0	840	88,470
Average (1989-2014) C	79,020	0	670	79,700

3.2.1.4 Groundwater Discharge to Surface Water Sources

The depth to groundwater is greater than 100-200 ft across much of the Chowchilla Subbasin. Given the depth to the water table in the Chowchilla Subbasin, groundwater discharge to surface water sources is negligible.

3.2.2 Outflows

3.2.2.1 Evapotranspiration by Water Use Sector

Evapotranspiration (ET) by water use sector is reported in Figures A2.F.c-8 to A2.F.c-10 and Tables A2.F.c-6 to A2.F.c-8. First, total ET is reported, followed by ET from applied water and ET from precipitation.

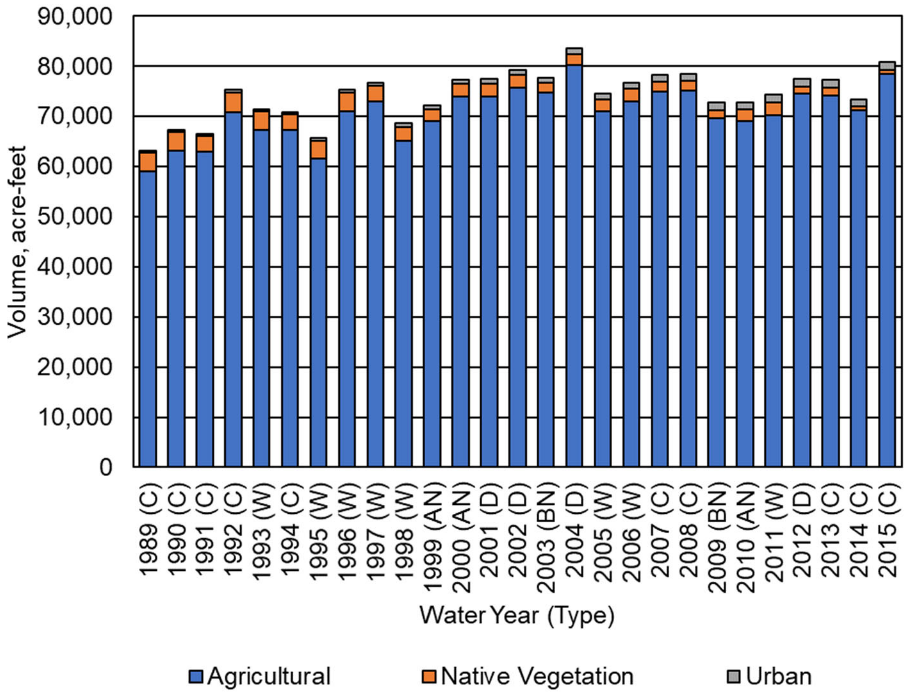

Figure A2.F.c-8. Madera County GSA – West Evapotranspiration by Water Use Sector.

Table A2.F.c-6. Madera County GSA – West Evapotranspiration by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	59,100	3,680	410	63,190
1990 (C)	63,250	3,670	430	67,350
1991 (C)	62,910	3,270	390	66,570
1992 (C)	70,740	4,020	490	75,250
1993 (W)	67,200	3,820	480	71,500
1994 (C)	67,240	3,170	490	70,900
1995 (W)	61,540	3,650	460	65,650
1996 (W)	70,950	3,740	560	75,250
1997 (W)	72,880	3,200	660	76,740
1998 (W)	65,130	2,800	630	68,560
1999 (AN)	69,000	2,450	690	72,140
2000 (AN)	73,880	2,560	790	77,230
2001 (D)	73,960	2,620	840	77,420
2002 (D)	75,780	2,470	970	79,220
2003 (BN)	74,670	1,970	1,030	77,670
2004 (D)	80,270	2,130	1,210	83,610
2005 (W)	71,060	2,380	1,140	74,580
2006 (W)	72,960	2,600	1,230	76,790
2007 (C)	74,980	1,920	1,300	78,200
2008 (C)	75,080	1,980	1,490	78,550
2009 (BN)	69,630	1,640	1,530	72,800
2010 (AN)	68,980	2,340	1,440	72,760
2011 (W)	70,220	2,530	1,520	74,270
2012 (D)	74,620	1,380	1,430	77,430
2013 (C)	74,150	1,580	1,660	77,390
2014 (C)	71,160	790	1,390	73,340
2015 (C)	78,520	820	1,530	80,870
Average (1989-2014)	70,440	2,630	940	74,010
Average (1989-2014) W	69,000	3,090	830	72,920
Average (1989-2014) AN	70,620	2,450	970	74,040
Average (1989-2014) BN	72,140	1,810	1,270	75,220
Average (1989-2014) D	76,150	2,150	1,120	79,420
Average (1989-2014) C	68,730	2,680	890	72,300

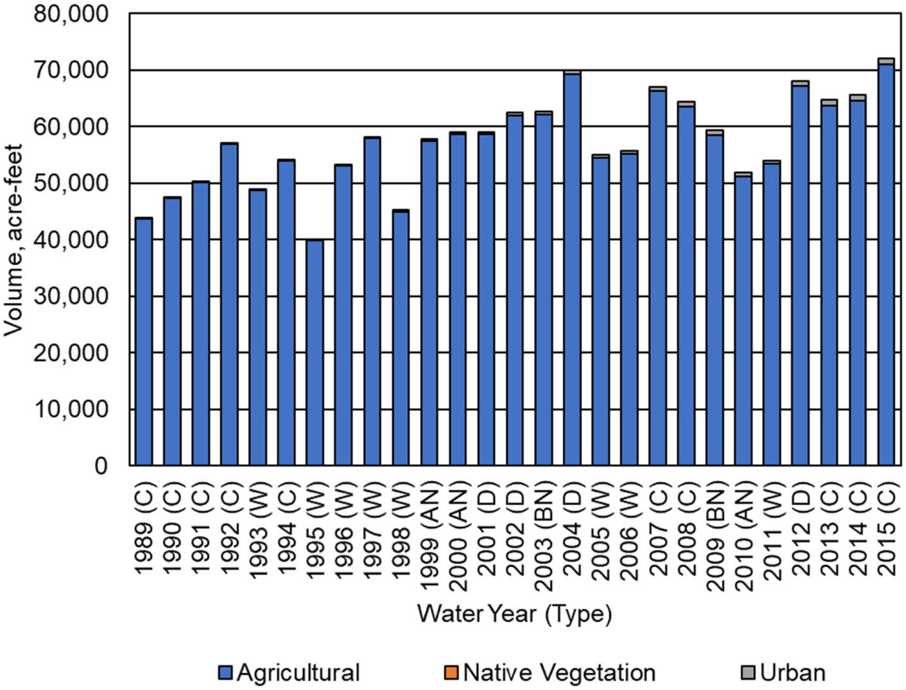

Figure A2.F.c-9. Madera County GSA – West Evapotranspiration of Applied Water by Water Use Sector.

Table A2.F.c-7. Madera County GSA – West Evapotranspiration of Applied Water by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	43,740	0	180	43,920
1990 (C)	47,340	0	180	47,520
1991 (C)	50,060	0	180	50,240
1992 (C)	56,930	0	230	57,160
1993 (W)	48,670	0	200	48,870
1994 (C)	53,970	0	250	54,220
1995 (W)	39,810	0	150	39,960
1996 (W)	53,160	0	190	53,350
1997 (W)	57,900	0	300	58,200
1998 (W)	44,980	0	260	45,240
1999 (AN)	57,500	0	330	57,830
2000 (AN)	58,610	0	390	59,000
2001 (D)	58,670	0	370	59,040
2002 (D)	62,030	0	490	62,520
2003 (BN)	62,160	0	570	62,730
2004 (D)	69,340	0	710	70,050
2005 (W)	54,510	0	540	55,050
2006 (W)	55,120	0	530	55,650
2007 (C)	66,250	0	720	66,970
2008 (C)	63,610	0	870	64,480
2009 (BN)	58,490	0	940	59,430
2010 (AN)	51,200	0	630	51,830

2011 (W)	53,420	0	570	53,990
2012 (D)	67,220	0	830	68,050
2013 (C)	63,760	0	1,010	64,770
2014 (C)	64,580	0	990	65,570
2015 (C)	70,970	0	1,120	72,090
Average (1989-2014)	56,270	0	480	56,750
Average (1989-2014) W	50,950	0	340	51,290
Average (1989-2014) AN	55,770	0	450	56,220
Average (1989-2014) BN	60,320	0	750	61,070
Average (1989-2014) D	64,310	0	600	64,910
Average (1989-2014) C	56,690	0	510	57,200

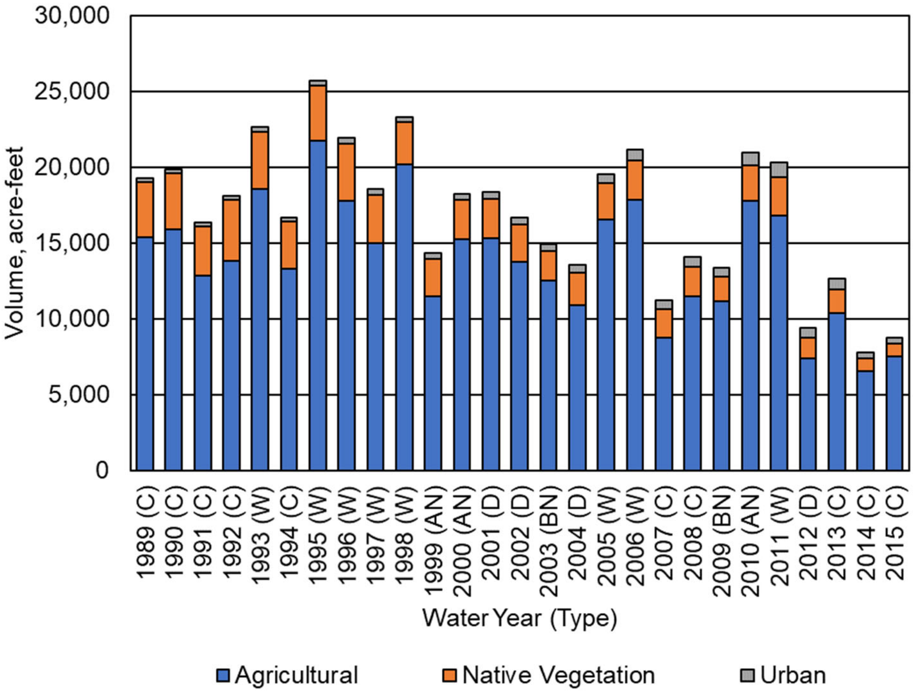

Figure A2.F.c-10. Madera County GSA – West Evapotranspiration of Precipitation by Water Use Sector.

Table A2.F.c-8. Madera County GSA – West Evapotranspiration of Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	15,360	3,680	230	19,270
1990 (C)	15,910	3,670	250	19,830
1991 (C)	12,850	3,270	210	16,330
1992 (C)	13,810	4,020	260	18,090
1993 (W)	18,530	3,820	280	22,630
1994 (C)	13,270	3,170	240	16,680
1995 (W)	21,730	3,650	310	25,690
1996 (W)	17,790	3,740	370	21,900
1997 (W)	14,980	3,200	360	18,540

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1998 (W)	20,150	2,800	370	23,320
1999 (AN)	11,500	2,450	360	14,310
2000 (AN)	15,270	2,560	400	18,230
2001 (D)	15,290	2,620	470	18,380
2002 (D)	13,750	2,470	480	16,700
2003 (BN)	12,510	1,970	460	14,940
2004 (D)	10,930	2,130	500	13,560
2005 (W)	16,550	2,380	600	19,530
2006 (W)	17,840	2,600	700	21,140
2007 (C)	8,730	1,920	580	11,230
2008 (C)	11,470	1,980	620	14,070
2009 (BN)	11,140	1,640	590	13,370
2010 (AN)	17,780	2,340	810	20,930
2011 (W)	16,800	2,530	950	20,280
2012 (D)	7,400	1,380	600	9,380
2013 (C)	10,390	1,580	650	12,620
2014 (C)	6,580	790	400	7,770
2015 (C)	7,550	820	410	8,780
Average (1989-2014)	14,170	2,630	460	17,260
Average (1989-2014) W	18,050	3,090	490	21,630
Average (1989-2014) AN	14,850	2,450	520	17,820
Average (1989-2014) BN	11,820	1,810	520	14,150
Average (1989-2014) D	11,840	2,150	520	14,510
Average (1989-2014) C	12,040	2,680	380	15,100

Total ET varies between years, with the lowest observed in 1989, at approximately 63 taf, and greatest in 2004, at approximately 84 taf. Total ET generally increases over time, again following the trend of increasing orchard acreage.

In addition to ET from land surfaces, estimates of evaporation from Madera Co GSA – West rivers and streams are reported in Figure A2.F.c-11 and Table A2.F.c-9. Evaporation from the Rivers and Streams System includes evaporation of both surface inflows and of precipitation runoff within local sloughs and depressions. Total evaporation from all sources averaged less than 1 taf per year between 1989 and 2014.

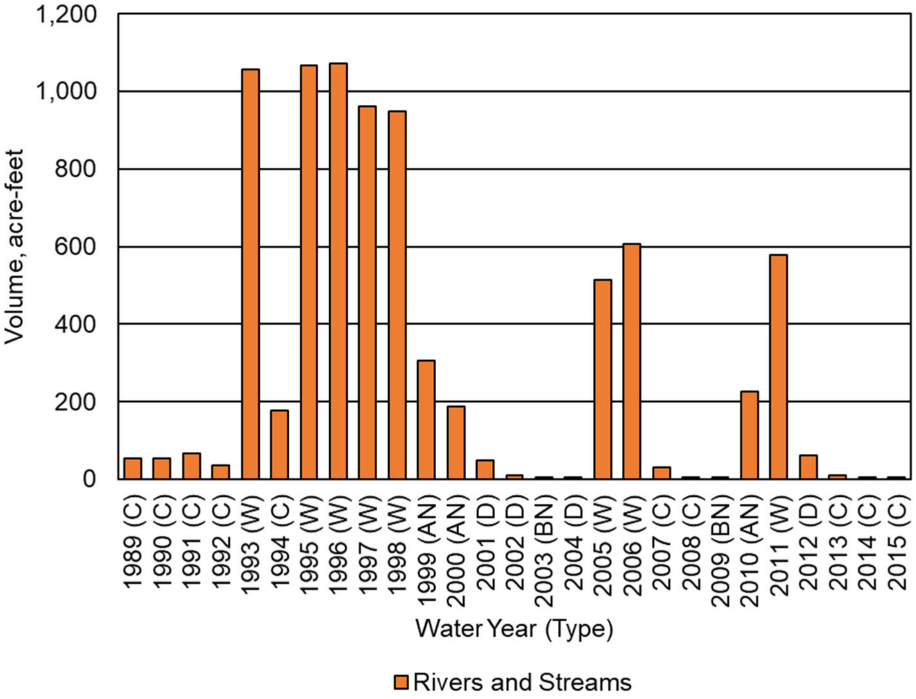

Figure A2.F.c-11. Madera County GSA – West Evaporation from the Surface Water System.

Table A2.F.c-9. Madera County GSA – West Evaporation from the Surface Water System (Acre-Feet).

Water Year (Type)	Rivers and Streams[1]
1989 (C)	60
1990 (C)	50
1991 (C)	70
1992 (C)	40
1993 (W)	1,060
1994 (C)	180
1995 (W)	1,070
1996 (W)	1,070
1997 (W)	960
1998 (W)	950
1999 (AN)	310
2000 (AN)	190
2001 (D)	50
2002 (D)	10
2003 (BN)	10
2004 (D)	10
2005 (W)	520
2006 (W)	610
2007 (C)	30
2008 (C)	10
2009 (BN)	10
2010 (AN)	230

2011 (W)	580
2012 (D)	60
2013 (C)	10
2014 (C)	10
2015 (C)	10
Average (1989-2014)	310
Average (1989-2014) W	850
Average (1989-2014) AN	240
Average (1989-2014) BN	10
Average (1989-2014) D	30
Average (1989-2014) C	50

[1] Includes evaporation of surface inflows and of precipitation runoff.

3.2.2.2 Surface Water Outflow by Water Source Type

Surface water outflows by water source type are summarized in Figure A2.F.c-12 and Table A2.F.c-10. In Madera Co GSA – West, runoff of applied water is assumed negligible and runoff of precipitation is collected in waterways within Madera Co GSA – West, with most infiltrating to the groundwater system except following the largest storm events. Thus, surface outflows from the GSA – West are expected to be a mixture of local supplies and CVP supplies along Eastside Bypass. Between 1989 and 2014, these combined outflows averaged approximately 735 taf during wet years.

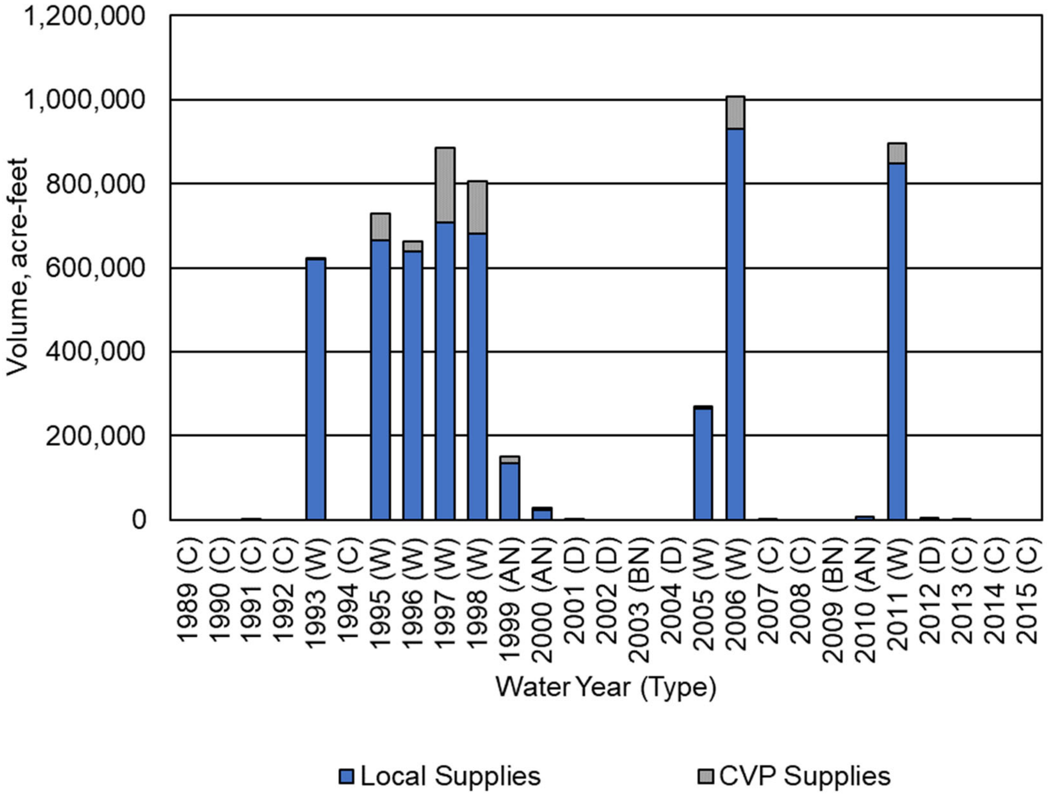

Figure A2.F.c-12. Madera County GSA – West Surface Outflows by Water Source Type.

Table A2.F.c-10. Madera County GSA – West Surface Outflows by Water Source Type (Acre-Feet).

Water Year (Type)	Local Supplies	CVP Supplies	Total
1989 (C)	0	0	0
1990 (C)	0	0	0
1991 (C)	240	0	240
1992 (C)	0	0	0
1993 (W)	619,400	3,270	622,670
1994 (C)	0	0	0
1995 (W)	666,290	61,860	728,150
1996 (W)	638,500	22,940	661,440
1997 (W)	708,150	177,050	885,200
1998 (W)	682,020	124,100	806,120
1999 (AN)	135,870	15,150	151,020
2000 (AN)	22,330	5,640	27,970
2001 (D)	0	110	110
2002 (D)	0	0	0
2003 (BN)	0	0	0
2004 (D)	0	0	0
2005 (W)	263,610	6,470	270,080
2006 (W)	929,750	77,470	1,007,220
2007 (C)	1,900	0	1,900
2008 (C)	0	0	0
2009 (BN)	0	0	0
2010 (AN)	7,470	0	7,470
2011 (W)	847,610	47,930	895,540
2012 (D)	4,310	0	4,310
2013 (C)	350	0	350
2014 (C)	0	0	0
2015 (C)	0	0	0
Average (1989-2014)	212,610	20,850	233,450
Average (1989-2014) W	669,420	65,140	734,550
Average (1989-2014) AN	55,220	6,930	62,150
Average (1989-2014) BN	0	0	0
Average (1989-2014) D	1,080	30	1,110
Average (1989-2014) C	280	0	280

3.2.2.3 Infiltration of Precipitation

Estimated infiltration of precipitation (deep percolation of precipitation) by water use sector is provided in Figure A2.F.c-13 and Table A2.F.c-11. Infiltration of precipitation to the groundwater system is highly variable from year to year due to variation in the timing and amount of precipitation, ranging from less than 4 taf annually during some critical and dry years to over 17 taf during 1995.

3.2.2.4 Infiltration of Surface Water

Estimated infiltration of surface water (seepage) by source is provided in Figure A2.F.c-14 and Table A2.F.c-12. Seepage from the Rivers and Streams System includes seepage of both surface inflows and of precipitation runoff into local sloughs and depressions. Seepage from rivers and streams follows the pattern of surface water inflows, averaging approximately 21 taf per wet year between 1989 and 2014. While flows in the San Joaquin River were not accounted directly as water budget components[4], boundary seepage from the San Joaquin River contributes an additional 11 taf per wet year to net recharge in Madera County GSA – West.

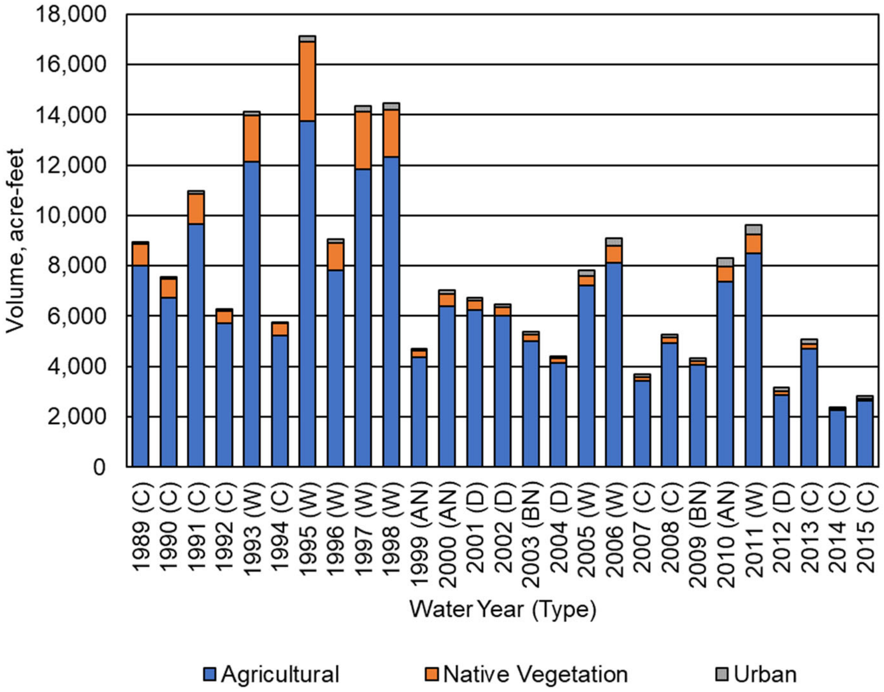

Figure A2.F.c-13. Madera County GSA – West Infiltration of Precipitation by Water Use Sector.

Table A2.F.c-11. Madera County GSA – West Infiltration of Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	7,990	860	90	8,940
1990 (C)	6,740	730	70	7,540
1991 (C)	9,650	1,210	110	10,970
1992 (C)	5,730	480	60	6,270
1993 (W)	12,120	1,840	160	14,120
1994 (C)	5,220	490	60	5,770
1995 (W)	13,750	3,140	230	17,120
1996 (W)	7,820	1,100	130	9,050
1997 (W)	11,840	2,270	250	14,360
1998 (W)	12,310	1,880	270	14,460

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[4] The San Joaquin River does not cross the lateral boundaries of the Chowchilla Subbasin, as defined above. Thus, San Joaquin River flows are not considered surface water inflows within this water budget. A portion of infiltration of surface water from the San Joaquin River is considered to cross the subbasin boundaries into the groundwater system and is included in the calculation of the subbasin estimates of overdraft and net recharge from SWS.

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1999 (AN)	4,350	290	80	4,720
2000 (AN)	6,400	490	130	7,020
2001 (D)	6,240	370	120	6,730
2002 (D)	6,010	330	130	6,470
2003 (BN)	5,020	250	110	5,380
2004 (D)	4,150	160	90	4,400
2005 (W)	7,210	400	200	7,810
2006 (W)	8,130	680	280	9,090
2007 (C)	3,430	150	100	3,680
2008 (C)	4,920	230	130	5,280
2009 (BN)	4,080	150	110	4,340
2010 (AN)	7,370	610	320	8,300
2011 (W)	8,480	750	370	9,600
2012 (D)	2,880	150	120	3,150
2013 (C)	4,690	210	170	5,070
2014 (C)	2,250	50	70	2,370
2015 (C)	2,650	80	80	2,810
Average (1989-2014)	6,880	740	150	7,770
Average (1989-2014) W	10,210	1,510	240	11,960
Average (1989-2014) AN	6,040	460	180	6,680
Average (1989-2014) BN	4,550	200	110	4,860
Average (1989-2014) D	4,820	250	120	5,190
Average (1989-2014) C	5,620	490	100	6,210

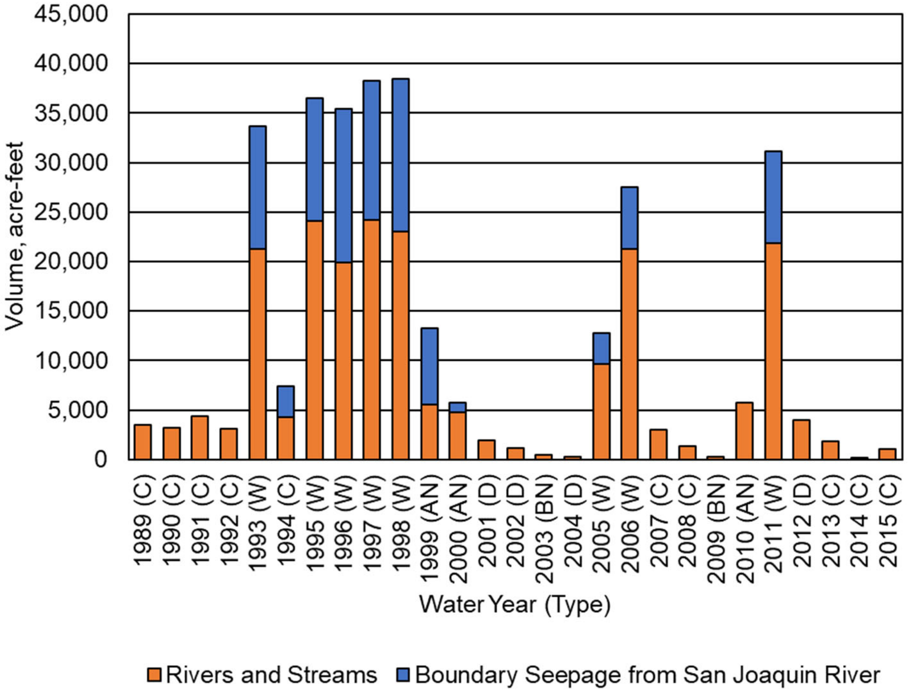

Figure A2.F.c-14. Madera County GSA – West Infiltration of Surface Water.

Table A2.F.c-12. Madera County GSA – West Infiltration of Surface Water (Acre-Feet).

Water Year (Type)	Rivers and Streams[1]	Boundary Seepage from San Joaquin River	Total
1989 (C)	3,530	0	3,530
1990 (C)	3,230	0	3,230
1991 (C)	4,380	0	4,380
1992 (C)	3,080	0	3,080
1993 (W)	21,220	12,450	33,670
1994 (C)	4,270	3,100	7,370
1995 (W)	24,090	12,450	36,540
1996 (W)	19,890	15,540	35,430
1997 (W)	24,220	14,020	38,240
1998 (W)	22,980	15,450	38,430
1999 (AN)	5,560	7,670	13,230
2000 (AN)	4,800	910	5,710
2001 (D)	1,950	0	1,950
2002 (D)	1,110	0	1,110
2003 (BN)	460	0	460
2004 (D)	290	0	290
2005 (W)	9,680	3,100	12,780
2006 (W)	21,270	6,200	27,470
2007 (C)	3,040	0	3,040
2008 (C)	1,340	0	1,340
2009 (BN)	310	0	310
2010 (AN)	5,770	0	5,770
2011 (W)	21,800	9,350	31,150
2012 (D)	3,930	0	3,930
2013 (C)	1,850	0	1,850
2014 (C)	140	0	140
2015 (C)	1,070	0	1,070
Average (1989-2014)	8,240	3,860	12,100
Average (1989-2014) W	20,640	11,070	31,710
Average (1989-2014) AN	5,380	2,860	8,240
Average (1989-2014) BN	390	0	390
Average (1989-2014) D	1,820	0	1,820
Average (1989-2014) C	2,760	340	3,100

[1] Includes infiltration of surface inflows and of precipitation runoff within the subregion. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.2.2.5 Infiltration of Applied Water

Estimated infiltration of applied water (deep percolation of applied water) by water use sector is provided in Figure A2.F.c-15 and Table A2.F.c-13. Infiltration of applied water is dominated by agricultural irrigation and has slowly decreased over time, likely due to increase use of drip and micro-irrigation systems in place of flood irrigation.

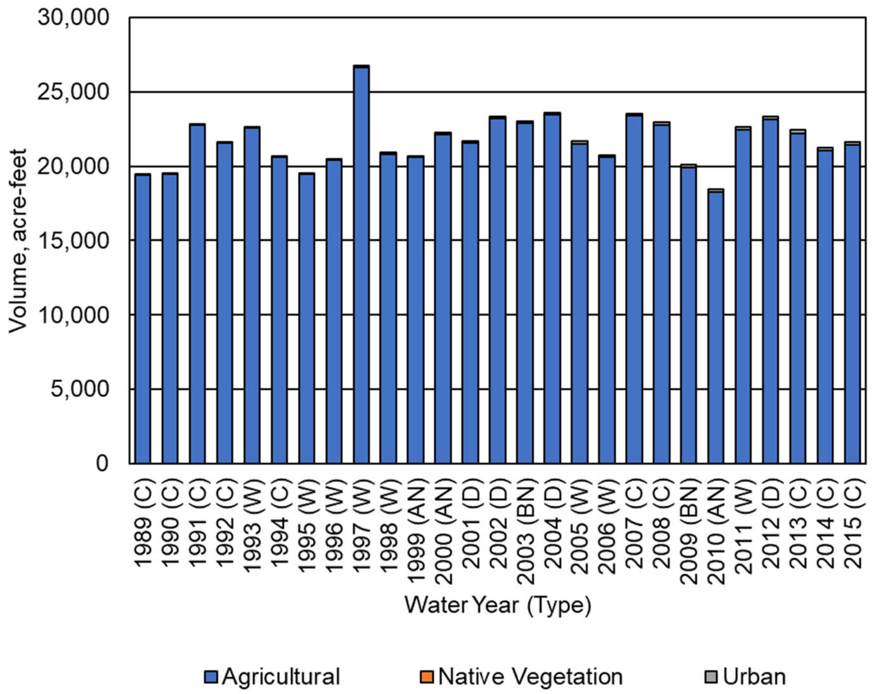

Figure A2.F.c-15. Madera County GSA – West Infiltration of Applied Water by Water Use Sector.

Table A2.F.c-13. Madera County GSA – West Infiltration of Applied Water by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	19,430	0	60	19,490
1990 (C)	19,490	0	60	19,550
1991 (C)	22,770	0	60	22,830
1992 (C)	21,580	0	60	21,640
1993 (W)	22,570	0	90	22,660
1994 (C)	20,600	0	70	20,670
1995 (W)	19,470	0	80	19,550
1996 (W)	20,390	0	50	20,440
1997 (W)	26,640	0	140	26,780
1998 (W)	20,820	0	130	20,950
1999 (AN)	20,610	0	80	20,690
2000 (AN)	22,140	0	100	22,240
2001 (D)	21,570	0	100	21,670
2002 (D)	23,220	0	130	23,350
2003 (BN)	22,870	0	130	23,000
2004 (D)	23,440	0	140	23,580
2005 (W)	21,490	0	180	21,670
2006 (W)	20,620	0	150	20,770
2007 (C)	23,380	0	150	23,530
2008 (C)	22,760	0	200	22,960
2009 (BN)	19,890	0	190	20,080

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2010 (AN)	18,250	0	190	18,440
2011 (W)	22,440	0	190	22,630
2012 (D)	23,120	0	190	23,310
2013 (C)	22,210	0	260	22,470
2014 (C)	21,080	0	190	21,270
2015 (C)	21,420	0	220	21,640
Average (1989-2014)	21,650	0	130	21,780
Average (1989-2014) W	21,810	0	130	21,940
Average (1989-2014) AN	20,330	0	120	20,450
Average (1989-2014) BN	21,380	0	160	21,540
Average (1989-2014) D	22,840	0	140	22,980
Average (1989-2014) C	21,480	0	120	21,600

3.2.3 Change in Surface Water System Storage

Estimates of change in SWS storage are provided in Figure A2.F.c-16 and Table A2.F.c-14. Inter-annual changes in storage within the surface water system consist primarily of root zone soil moisture storage changes, are relatively small, and tend to average near zero over many years.

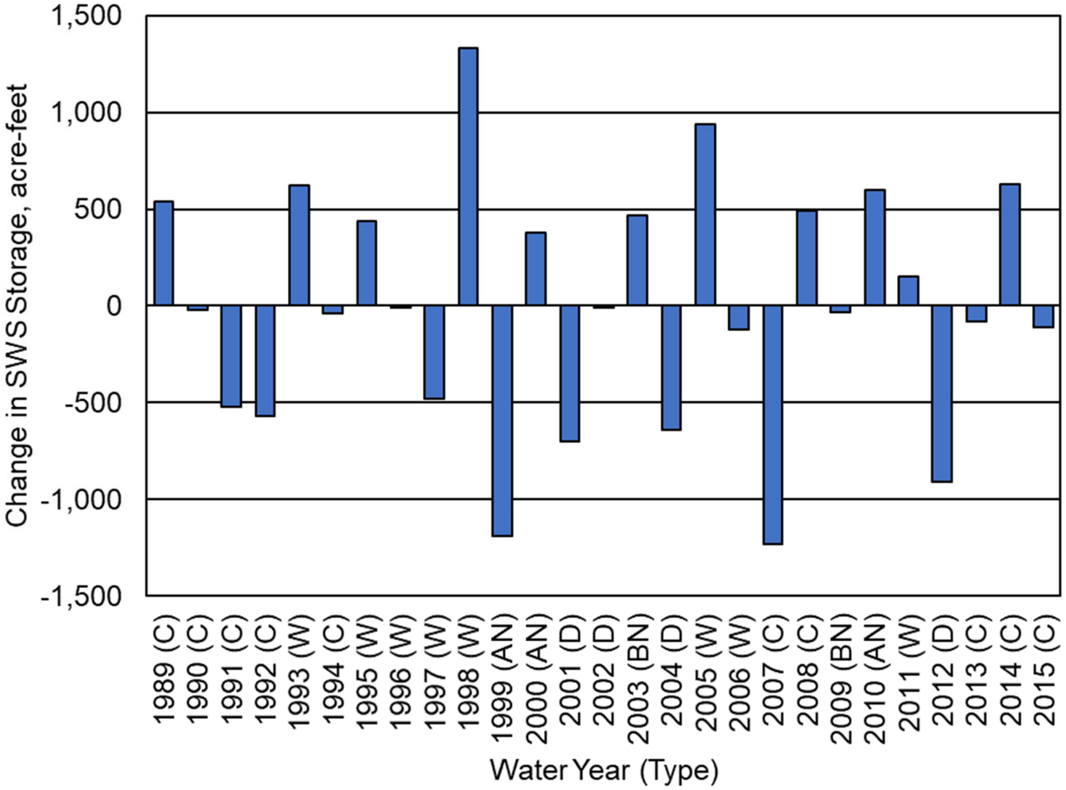

Figure A2.F.c-16. Madera County GSA – West Change in Surface Water System Storage.

Table A2.F.c-14. Madera County GSA – West Change in Surface Water System Storage (Acre-Feet).

Water Year (Type)	Change in SWS Storage
1989 (C)	540
1990 (C)	-20
1991 (C)	-520
1992 (C)	-570
1993 (W)	620
1994 (C)	-40
1995 (W)	440
1996 (W)	-10
1997 (W)	-480
1998 (W)	1,330
1999 (AN)	-1,190
2000 (AN)	380
2001 (D)	-700
2002 (D)	-10
2003 (BN)	470
2004 (D)	-640
2005 (W)	940
2006 (W)	-120
2007 (C)	-1,230
2008 (C)	490
2009 (BN)	-30
2010 (AN)	600
2011 (W)	150
2012 (D)	-910
2013 (C)	-80
2014 (C)	630
2015 (C)	-110
Average (1989-2014)	0
Average (1989-2014) W	360
Average (1989-2014) AN	-70
Average (1989-2014) BN	220
Average (1989-2014) D	-570
Average (1989-2014) C	-90

3.3 Historical Water Budget Summary

Annual inflows, outflows, and change in SWS storage during the historical water budget period (1989-2014) are summarized in Figure A2.F.c-17 and Table A2.F.c-15. Inflows are shown as positive values, while outflows and change in SWS storage are shown as negative values. During wet years, boundary surface inflow and outflow volumes are substantially higher than other components. Figure A2.F.c-17 thus only shows the difference between the surface inflows and surface outflows after seepage and evaporation are accounted within Madera Co GSA – West. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the surface water system water budget.

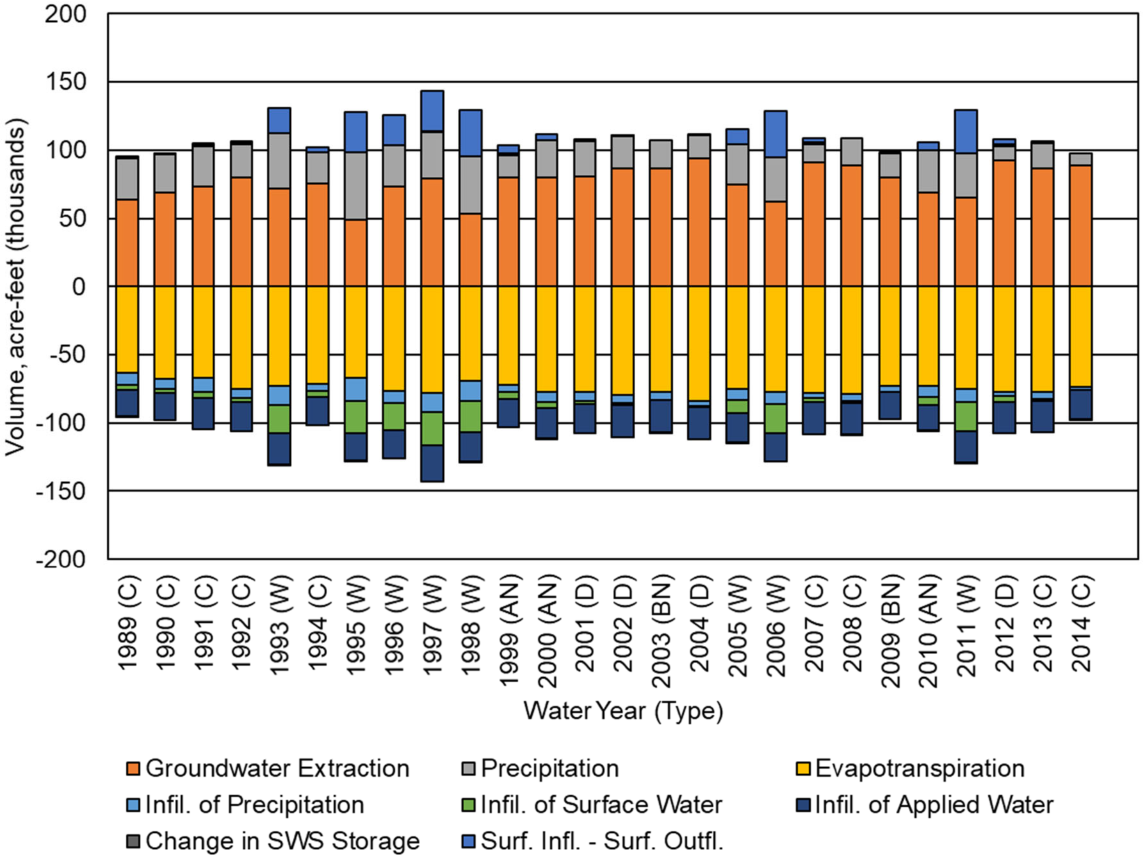

Figure A2.F.c-17. Madera County GSA – West Surface Water System Historical Water Budget, 1989-2014.

Table A2.F.c-15. Madera County GSA – West Surface Water System Historical Water Budget, 1989-2014 (Acre-Feet).

Water Year	Boundary Surface Inflows	Groundwater Extraction	Precipitation	Evapo-transpiration[1]	Infil. of Precipitation	Infil. of Surface Water[2]	Infil. of Applied Water	Boundary Surface Outflows	Change in SWS Storage
1989 (C)	1,590	63,990	30,170	-63,250	-8,940	-3,530	-19,490	0	-540
1990 (C)	960	68,630	28,130	-67,410	-7,550	-3,230	-19,540	0	20
1991 (C)	1,530	73,640	29,390	-66,650	-10,970	-4,380	-22,840	-240	520
1992 (C)	1,520	80,160	24,010	-75,280	-6,260	-3,080	-21,640	0	570
1993 (W)	641,500	71,650	40,680	-72,550	-14,120	-21,220	-22,660	-622,670	-620
1994 (C)	3,210	75,260	23,060	-71,070	-5,780	-4,270	-20,670	0	260
1995 (W)	757,460	49,100	49,490	-66,720	-17,110	-24,090	-19,540	-728,150	-440
1996 (W)	683,410	73,470	30,240	-76,320	-9,040	-19,890	-20,440	-661,440	10
1997 (W)	914,390	78,840	34,560	-77,700	-14,350	-24,220	-26,780	-885,200	480
1998 (W)	840,230	53,570	41,540	-69,500	-14,460	-22,980	-20,950	-806,120	-1,330
1999 (AN)	156,790	79,580	16,850	-72,430	-4,720	-5,560	-20,680	-151,020	1,190
2000 (AN)	32,800	79,560	27,470	-77,420	-7,020	-4,800	-22,240	-27,970	-380
2001 (D)	1,040	80,550	25,630	-77,460	-6,730	-1,950	-21,670	-110	700
2002 (D)	0	86,900	23,260	-79,240	-6,470	-1,110	-23,350	0	10
2003 (BN)	0	86,530	20,430	-77,660	-5,380	-460	-23,000	0	-470
2004 (D)	0	94,260	16,980	-83,610	-4,400	-290	-23,580	0	640
2005 (W)	280,900	75,080	29,290	-75,090	-7,800	-9,680	-21,670	-270,080	-940
2006 (W)	1,040,910	62,450	32,260	-77,390	-9,090	-21,270	-20,770	-1,007,220	120
2007 (C)	4,760	91,320	13,060	-78,230	-3,670	-3,040	-23,530	-1,900	1,230
2008 (C)	0	88,750	19,850	-78,550	-5,270	-1,340	-22,950	0	-490
2009 (BN)	0	79,560	17,930	-72,800	-4,340	-310	-20,080	0	30
2010 (AN)	13,940	68,820	30,800	-72,980	-8,290	-5,770	-18,440	-7,470	-600
2011 (W)	927,090	65,250	32,240	-74,850	-9,600	-21,800	-22,630	-895,540	-150
2012 (D)	8,140	92,160	10,970	-77,480	-3,150	-3,930	-23,310	-4,310	910
2013 (C)	1,700	86,830	18,540	-77,400	-5,070	-1,850	-22,470	-350	80
2014 (C)	0	88,700	9,050	-73,330	-2,380	-140	-21,270	0	-630
Average (1989-2014)	242,840	76,710	25,990	-74,320	-7,770	-8,240	-21,780	-233,450	10
W	760,740	66,170	36,290	-73,770	-11,950	-20,640	-21,930	-734,550	-360
AN	67,840	75,990	25,040	-74,280	-6,680	-5,380	-20,450	-62,150	70
BN	0	83,050	19,180	-75,230	-4,860	-390	-21,540	0	-220
D	2,300	88,470	19,210	-79,450	-5,190	-1,820	-22,980	-1,110	570
C	1,700	79,700	21,700	-72,350	-6,210	-2,760	-21,600	-280	110

[1] Includes ET of applied water, ET of precipitation, and evaporation from the Rivers and Streams System.

[2] Includes infiltration from the Rivers and Streams System within the subregion. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.4 Current Water Budget Summary

The current water budget was developed following a similar process to the historical water budget using the 2015 land use in Table A2.F.c-1 and the same 1989-2014 average hydrologic conditions of the historical base period, including surface water flows, precipitation, and weather parameters. This allowed quantification of groundwater inflows and outflows for current consumptive use in the context of average water supply conditions.

Annual inflows, outflows, and change in SWS storage from the current water budget are summarized in Figure A2.F.c-18 and Table A2.F.c-16. Inflows are shown as positive values, while outflows and change in SWS storage are shown as negative values. Similar to Figure A2.F.c-17, Figure A2.F.c-18 only shows the difference between the surface inflows and surface outflows after seepage and evaporation are accounted within Madera Co GSA – West.

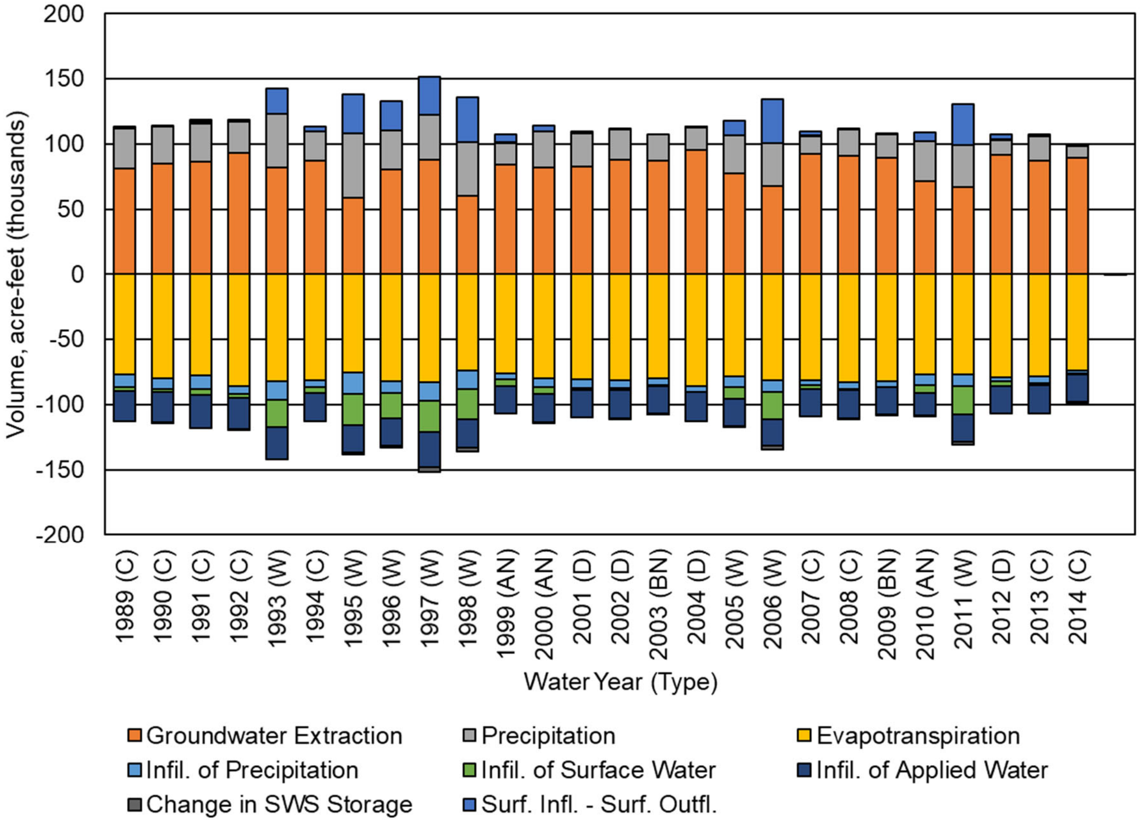

Figure A2.F.c-18. Madera County GSA – West Surface Water System Current Water Budget.

Table A2.F.c-16. Madera County GSA – West Surface Water System Current Water Budget (Acre-Feet).

Water Year	Boundary Surface Inflows	Groundwater Extraction	Precipitation	Evapo-transpiration[1]	Infil. of Precipitation	Infil. of Surface Water[2]	Infil. of Applied Water	Boundary Surface Outflows	Change in SWS Storage
1989 (C)	1,590	81,420	30,170	-77,260	-9,030	-2,980	-23,910	0	10
1990 (C)	960	84,930	28,120	-80,210	-7,610	-2,840	-22,770	0	-580
1991 (C)	1,530	86,450	29,380	-77,320	-10,670	-4,370	-25,870	-10	870
1992 (C)	1,520	93,220	24,010	-85,600	-6,390	-2,960	-23,630	0	-170
1993 (W)	641,500	82,110	40,680	-82,170	-14,200	-21,190	-24,730	-622,090	90
1994 (C)	3,210	86,830	23,050	-81,100	-5,770	-3,900	-22,350	0	30
1995 (W)	757,460	58,680	49,490	-75,190	-16,430	-24,070	-20,770	-727,690	-1,480
1996 (W)	683,410	80,360	30,240	-81,960	-8,880	-19,890	-20,720	-661,090	-1,480
1997 (W)	914,390	87,820	34,560	-82,820	-14,130	-24,220	-26,860	-885,000	-3,730
1998 (W)	840,230	59,840	41,540	-73,900	-14,340	-22,980	-21,700	-805,830	-2,860
1999 (AN)	156,790	83,750	16,850	-75,810	-4,710	-5,550	-21,160	-150,990	830
2000 (AN)	32,800	81,760	27,470	-79,790	-7,000	-4,790	-22,100	-27,820	-530
2001 (D)	1,040	82,420	25,630	-80,610	-6,500	-1,790	-20,800	-70	680
2002 (D)	10	87,760	23,260	-81,460	-6,300	-1,030	-21,980	0	-250
2003 (BN)	0	86,730	20,430	-80,070	-5,140	-370	-21,560	0	-20
2004 (D)	0	95,220	16,980	-86,260	-4,220	-240	-21,830	0	350
2005 (W)	280,900	77,310	29,280	-78,770	-7,550	-9,610	-21,010	-269,830	-730
2006 (W)	1,040,910	67,970	32,260	-81,490	-8,780	-21,270	-20,100	-1,006,640	-2,860
2007 (C)	4,760	92,590	13,070	-81,490	-3,390	-3,000	-21,560	-1,860	880
2008 (C)	0	91,180	19,850	-83,100	-4,970	-1,080	-21,390	0	-490
2009 (BN)	0	89,130	17,930	-82,240	-4,090	-110	-20,830	0	200
2010 (AN)	13,940	71,460	30,800	-77,200	-7,940	-5,660	-17,770	-7,160	-460
2011 (W)	927,090	66,630	32,240	-76,990	-9,200	-21,660	-20,700	-895,140	-2,270
2012 (D)	8,140	91,500	10,970	-78,950	-2,990	-3,750	-21,410	-4,340	820
2013 (C)	1,700	87,070	18,540	-78,780	-4,930	-1,810	-21,560	-270	40
2014 (C)	0	89,130	9,060	-74,150	-2,350	-130	-21,030	0	-530
Average (1989-2014)	242,840	82,430	25,990	-79,800	-7,600	-8,120	-21,930	-233,300	-520
W	760,740	72,590	36,290	-79,160	-11,690	-20,610	-22,070	-734,160	-1,920
AN	67,840	78,990	25,040	-77,600	-6,550	-5,330	-20,340	-61,990	-50
BN	0	87,930	19,180	-81,160	-4,610	-240	-21,190	0	90
D	2,300	89,220	19,210	-81,820	-5,000	-1,700	-21,510	-1,100	400
C	1,700	88,090	21,690	-79,890	-6,120	-2,560	-22,680	-240	10

[1] Includes ET of applied water, ET of precipitation, and evaporation from the Rivers and Streams System.

[2] Includes infiltration from the Rivers and Streams System within the subregion. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.5 Net Recharge from SWS

Overdraft is defined in DWR Bulletin 118 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" (DWR 2003). The Chowchilla Subbasin water budget indicates that overdraft conditions occurred during the 1989-2014 historical base period. Per 23 CCR Section 354.18(b)(5), the subbasin overdraft has been quantified for this base period. The evaluation of overdraft conditions includes estimates of recharge from subsurface flows. However, estimates of recharge from subsurface flows are less accurate when estimated for areas less that an entire subbasin. Thus, for estimates of GSA level contribution to overdraft, the term net recharge from the SWS is defined as groundwater recharge minus groundwater extraction. Net recharge from the SWS is useful for understanding and analyzing the combined effects of land surface processes on the underlying GWS.

When calculated from the historical water budget, average net recharge from the SWS represents the average recharge (when positive) or shortage of recharge (when negative) based on historical cropping, land use practices, and average hydrologic conditions. When calculated from the current land use water budget, average net recharge represents the average recharge or shortage (when negative) based on current cropping, land use practices, and average hydrologic conditions.

Average net recharge from the SWS is presented below for the Madera Co GSA – West portion of the Chowchilla Subbasin. Table A2.F.c-17 shows the average net recharge from the SWS for 1989-2014 based on the historical water budget, and Table A2.F.c-18 shows the same for the current water budget. Historically, the average net recharge in Madera Co GSA – West was approximately -38 taf per year between 1989 and 2014. Under current land use conditions, the average net recharge in Madera Co GSA – West is approximately -44 taf, indicating shortage conditions.

The Madera Co GSA - West recognizes that groundwater users within its boundaries want to understand potential future limitations on groundwater resources available to meet their beneficial uses. As shown in both Table A2.F.c-17 and Table A2.F.c-18, average values for infiltration of precipitation and infiltration of surface water are provided (columns "b" and "c"). The slight variation between the tables reflects the modified land use conditions. Together, these values represent the sustainable native groundwater for the Madera Co GSA – West, a value of about 17,300 acre-feet per year.

The Madera Co GSA – West has not determined whether an allocation approach, or other methods, will best allow the Madera Co GSA – West to achieve needed reductions in the consumptive use of groundwater (see GSP Chapter 4). However, the Madera Co GSA – West recognize the correlative nature of overlying groundwater rights, which, when coupled with appropriated groundwater use, provides that all the users share in the sustainable quantity of native groundwater. For purposes of analyzing the availability of sustainable quantities of native groundwater for all lands within the Madera Co GSA – West, the estimated total quantity of sustainable native groundwater – estimated at 17,300 acre-feet per year – can be calculated to be approximately 0.5 acre-feet per acre within the Madera Co GSA – West (based upon estimates of about 17,300 acre-feet of total sustainable native groundwater available for about 31,200 acres within the Madera Co GSA – West). The achievement of sustainability may or may not involve an equal allocation across the Madera Co GSA – West, and the Madera Co GSA – West will use its SGMA-granted authority to manage the basin so as to achieve this end. Furthermore, other GSAs within the Chowchilla Subbasin may choose to manage their proportion of the estimated sustainable native groundwater differently than the Madera Co GSA – West, but they are also subject to the overall subbasin sustainability requirements.

Table A2.F.c-17. Historical Water Budget: Average Net Recharge from SWS by Water Year Type, 1989-2014 (Acre-Feet).

Year Type	Number of Years	Infiltration of Applied Water (a)	Infiltration of Precipitation (b)	Infiltration of Surface Water[1] (c)	Groundwater Extraction (d)	Net Recharge from SWS (a+b+c-d)
W	8	21,930	11,950	25,160	66,170	-7,130
AN	3	20,450	6,680	6,980	75,990	-41,880
BN	2	21,540	4,860	360	83,050	-56,290
D	4	22,980	5,190	1,080	88,470	-59,220
C	9	21,600	6,210	2,160	79,700	-49,730
Annual Average (1989-2014)	26	21,780	7,770	9,490	76,710	-37,670

[1] Includes seepage from the Rivers and Streams System and boundary seepage from San Joaquin River. Rivers and Streams System seepage is calculated from the total subbasin Rivers and Streams System seepage redistributed to each subregion in proportion to gross area.

Table A2.F.c-18. Current Water Budget: Average Net Recharge from SWS by Water Year Type (Acre-Feet).

Year Type	Number of Years	Infiltration of Applied Water (a)	Infiltration of Precipitation (b)	Infiltration of Surface Water[1] (c)	Groundwater Extraction (d)	Net Recharge from SWS (a+b+c-d)
W	8	22,070	11,690	24,910	72,590	-13,920
AN	3	20,340	6,550	6,880	78,990	-45,220
BN	2	21,190	4,610	220	87,930	-61,910
D	4	21,510	5,000	970	89,220	-61,740
C	9	22,680	6,120	1,850	88,090	-57,440
Annual Average (1989-2014)	26	21,930	7,600	9,270	82,430	-43,630

[1] Includes seepage from the Rivers and Streams System and boundary seepage from San Joaquin River. Rivers and Streams System seepage is calculated from the total subbasin Rivers and Streams System seepage redistributed to each subregion in proportion to gross area.

3.6 Uncertainties in Water Budget Components

Uncertainties associated with each water budget component were estimated as a percentage representing approximately a 95% confidence interval following the procedure described by Clemmens and Burt (1997). Uncertainties for all independently measured or estimated water budget components were estimated based on the measurement accuracy, typical values reported in technical literature, typical values calculated in other water budgets, and professional judgement.

Table A2.F.c-19 provides a summary of typical uncertainty values associated with major SWS inflow and outflow 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 A2.F.c-19. Estimated Uncertainty of GSA Water Budget Components.

Flowpath Direction (SWS Boundary)	Water Budget Component	Data Source	Estimated Uncertainty (%)	Source
Inflows	Surface Water Inflows	Measurement	20%	Estimated streamflow measurement accuracy and adjustment for losses.
	Riparian Deliveries	Measurement	10%	Estimated measurement accuracy.
	Precipitation	Calculation	30%	Clemmens, A.J. and C.M. Burt, 1997.
	Groundwater Extraction	Closure	20%	Typical uncertainty calculated for Land Surface System water balance closure.
Outflows	Surface Water Outflows	Closure	20%	Typical uncertainty calculated for Rivers and Streams System water balance closure.
	Evaporation	Calculation	20%	Estimated accuracy of calculation based on CIMIS reference ET and free water surface evaporation coefficient.
	ET of Applied Water	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, estimated crop coefficients from SEBAL energy balance, and annual land use.
	ET of Precipitation	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, precipitation, estimated crop coefficients from SEBAL energy balance, and annual land use.
	Infiltration of Applied Water	Calculation	20%	Estimated accuracy of daily IDC root zone water budget component based on annual land use and NRCS soils characteristics.
	Infiltration of Precipitation	Calculation	20%	Estimated accuracy of daily IDC root zone water budget component based on annual land use, NRCS soils characteristics, and CIMIS precipitation.
	Infiltration of Surface Water	Calculation	15%	Estimated accuracy of daily seepage calculation using NRCS soils characteristics and calculated runoff of precipitation.
	Change in SWS Storage	Calculation	50%	Professional Judgment.
Net Recharge from SWS		Calculation	25%	Estimated water budget accuracy; typical value calculated for GSA-level net recharge from SWS.

APPENDIX 2.F. WATER BUDGET INFORMATION

2.F.d. Surface Water System Water Budget: Sierra Vista Mutual Water Company

Prepared as part of the

Groundwater Sustainability Plan
Chowchilla Subbasin

January 2020

GSP Team:

Davids Engineering, Inc
Luhdorff & Scalmanini
ERA Economics
Stillwater Sciences and
California State University, Sacramento

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1 INTRODUCTION

To ensure sustainable groundwater management throughout California's groundwater basins, the Sustainable Groundwater Management Act of 2014 (SGMA) requires Groundwater Sustainability Agencies (GSAs) to prepare and adopt Groundwater Sustainability Plans (GSPs) with strategies to achieve subbasin groundwater sustainability within 20 years of plan adoption. Integral to each GSP is a water budget used to quantify the subbasin's groundwater overdraft (if applicable) and sustainable yield.

In 2017, Merced County (Merced Co) GSA and Madera County (Madera Co) GSA each formed to separately manage approximately 1,300 acres and 45,100 acres of the Chowchilla Subbasin, respectively. The jurisdictional areas of both GSAs overlap with Sierra Vista Mutual Water Company (SVMWC). In the interests of separately accounting for inflows to SVMWC, a water budget was prepared encompassing the total area within SVMWC, including the entirety of Merced Co GSA in the Chowchilla Subbasin and a portion of Madera Co GSA.

This document presents results of the surface water system (SWS) water budgets developed for historical and current land use conditions in SVMWC. The SVMWC water budgets were integrated with separate water budgets developed for four (4) other subregions covering the remainder of the Chowchilla Subbasin. Together, these water budgets provide the boundary water budget for the Chowchilla Subbasin SWS. Results of the subbasin boundary water budget are reported in the Chowchilla Subbasin GSP Section 2.2.3 and were integrated with a subbasin groundwater model (GSP Appendix 6.E) to estimate subbasin sustainable yield (GSP Section 2.2.3).

2 WATER BUDGET CONCEPTUAL MODEL

A water budget is defined as a complete accounting of all water flowing into and out of a defined volume (e.g., a subbasin or a GSA) over a specified period of time. The conceptual model (or structure) of the SVMWC water budget developed for this investigation is consistent with the GSP Regulations defined under Title 23 of California Code of Regulations[1] (CCR) and adheres to sound water budget principles and practices defined by California Department of Water Resources (DWR) in the Water Budget Best Management Practice (BMP) guidelines (DWR, 2016).

The lateral extent of SVMWC is defined by the boundaries indicated in Figure A2.F.d-1. The vertical extent of SVMWC is the land surface (top) and the base of fresh water at the bottom of the basin (bottom), as described in the hydrogeologic conceptual model (HCM) developed in GSP Section 2.2.1. The vertical extent of Chowchilla Subbasin and its GSAs is subdivided into a surface water system (SWS) and the underlying groundwater system (GWS), with separate but related water budgets prepared for each that together represent the overall subbasin water budget.

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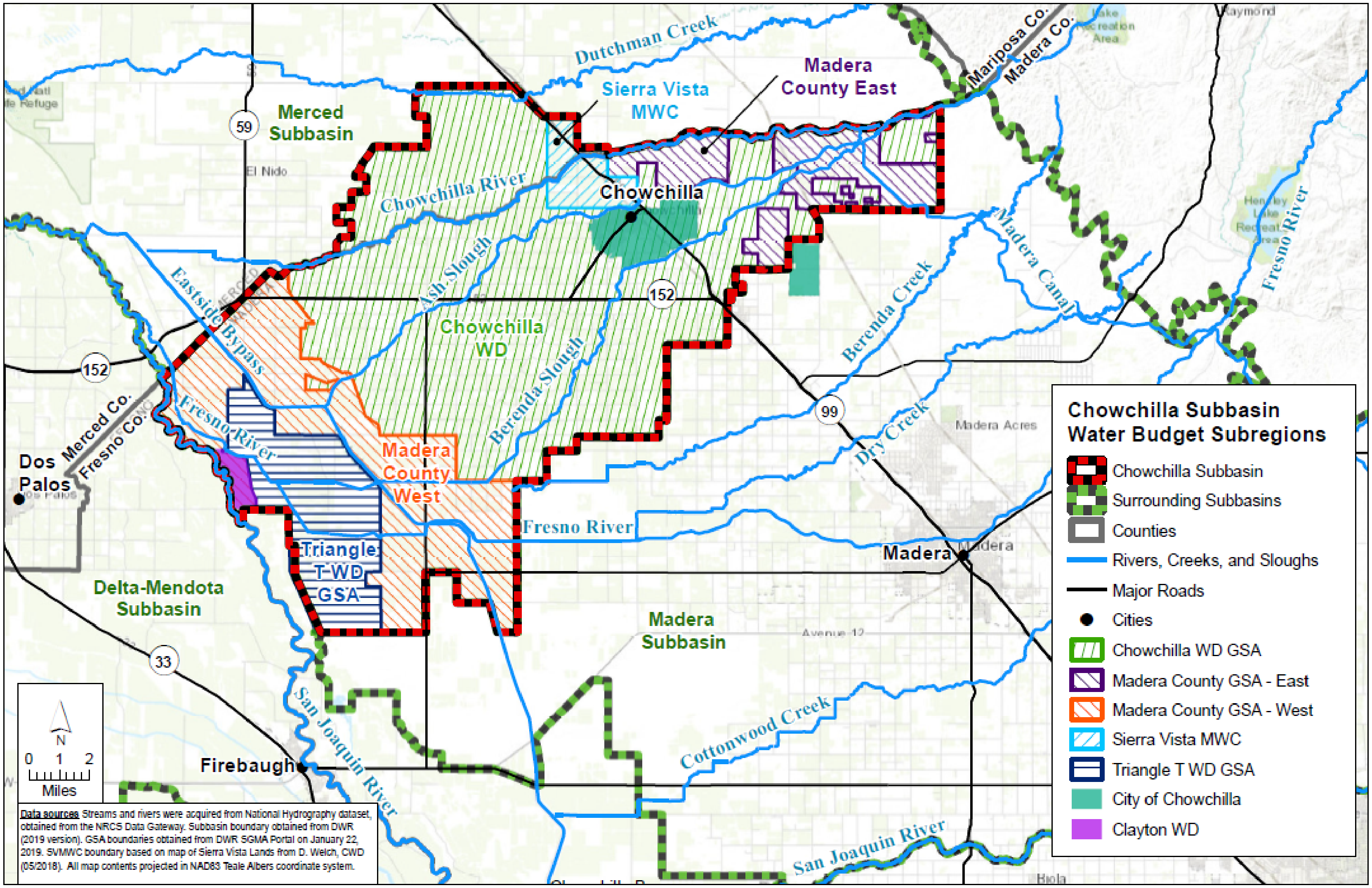
[1] California Code of Regulations Title 23. Waters, Division 2. Department of Water Resources, Chapter 1.5. Groundwater Management, Subchapter 2. Groundwater Sustainability Plans.



<u>Data sources</u> Streams and rivers were acquired from National Hydrography dataset, obtained from the NRCS Data Gateway. Subbasin boundary obtained from DWR (2019 version). GSA boundaries obtained from DWR SGMA Portal on January 22, 2019. SVMWC boundary based on map of Sierra Vista Lands from D. Welch, CWD (05/2018). All map contents projected in NAD83 Teale Albers coordinate system.

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Chowchilla Subbasin Water Budget Subregion Map

Chowchilla Subbasin Groundwater Sustainability Plan

Figure A2.F.d-1. Chowchilla Subbasin Water Budget Subregion Map

A conceptual representation of the SVMWC water budget is represented in Figure A2.F.d-2. This document details only the SWS portion of the SVMWC water budget. The SWS is divided into two primary accounting centers: the Land Surface System and the Rivers and Streams System[2]. The Land Surface System is further divided into three accounting centers representing the subregion water use sectors: Agricultural Land, Native Vegetation Land, and Urban Land (urban, industrial, and semi-agricultural).

Water budget components, or directional flow of water between accounting centers and across the SWS boundary, are indicated by arrows. Inflows and outflows were calculated using measurements and other historical data or were calculated as the water budget closure term – the difference between all other estimated or measured inflows and outflows from each accounting center or water use sector (bold arrows).

Inflows to the SWS include precipitation, surface water inflows (in various rivers and streams), and groundwater extraction. Outflows from the SWS include evapotranspiration (ET), surface water outflows (in various canals and streams), and infiltration to the groundwater system (seepage and deep percolation). Also represented in Figure A2.F.d-2 are inflows and outflows from the GWS, which are discussed and quantified at the subbasin level in the GWS water budget in GSP Section 2.2.3. Subsurface GWS inflows and outflows are not quantified on the water budget subregion scale.

Inflows and outflows were quantified following the process described in GSP Section 2.2.3 on a monthly time step for water years in the historical water budget base period (1989-2014 hydrologic and land use conditions), the current water budget (2015 land use using 1989-2014 average hydrologic conditions), and projected water budget. Four projected water budgets were prepared for the years 2019 through 2090 based on 1965 through 2015 hydrologic conditions, projected water supplies, and 2017 land use adjusted for urban area projected growth from 2017-2070 (areas were held constant from 2071-2090):

1. Historical hydrologic conditions and water supply data, with adjustment for projected alteration of available Friant releases by the San Joaquin River Restoration Program (SJRRP)[3]
    a. Without projects and management actions, and
    b. With projects and management actions
2. Historical hydrologic conditions and water supply data, with adjustment for projected alteration of available Friant releases by the SJRRP and adjustment for anticipated climate change per DWR-provided 2030 climate change factors
    a. Without projects and management actions, and
    b. With projects and management actions.

Information regarding the data sources and adjustments used to prepare the historical, current, and projected water budgets are described in GSP Section 2.2.3.

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[2] The Chowchilla River is used for conveyance of pre-1914, riparian, and prescriptive water rights deliveries to growers in SVMWC. These inflows, deliveries, and associated seepage are summarized within the Rivers and Streams System in SVMWC.

[3] Adjustments were based on the Friant Report ("Estimate of Future Friant Division Supplies for use in Groundwater Sustainability Plans, California," Friant Water Authority, 2018). Although the Friant Report accounts for climate change, it is considered the best available estimate of projected Friant releases under SJRRP. For comparison, projected Madera Canal deliveries under SJRRP were also estimated without account for climate change from the Kondolf Hydrographs (in “Effects to Water Supply and Friant Operations Resulting From Plaintiffs' Friant Release Requirements,” Steiner, 2005). These estimates were approximately equal to the Friant Report 2030 climate change adjusted deliveries. Thus, the Friant Report projections were used instead to maintain consistent assumptions in estimating Madera Canal deliveries across all projected simulations.

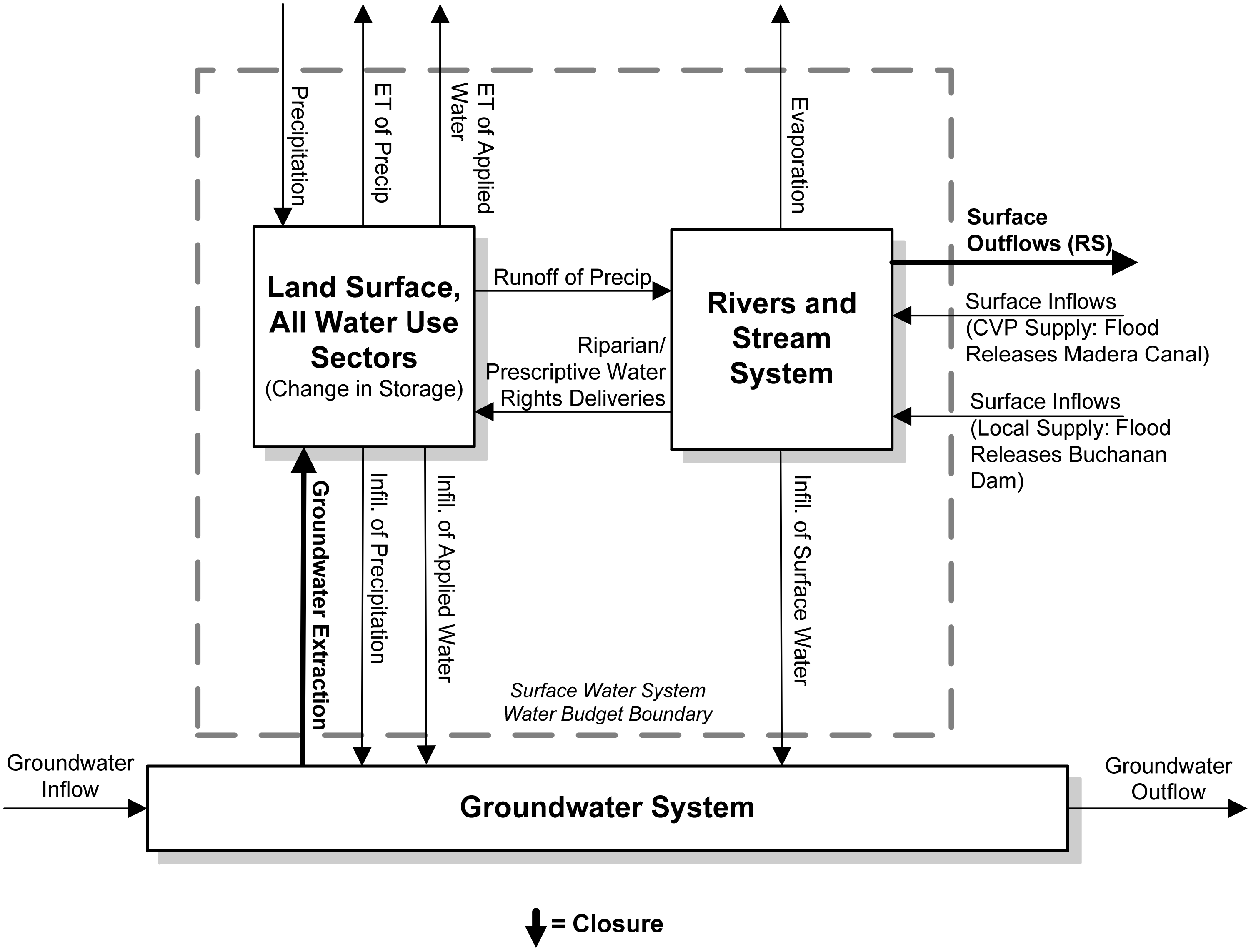

Figure A2.F.d-2. Sierra Vista Mutual Water Company Water Budget Structure

3 WATER BUDGET ANALYSIS

The historical water budget and current land use water budget for SVMWC are presented below following a summary of land use data relevant to water budget development. Land use data is provided for the 1989-2014 historical water budget period and for 2015, the current land use water budget period.

3.1 Land Use

Land use estimates for 1989 through 2015 corresponding to water use sectors (as defined by the GSP Regulations) are summarized in Figure A2.F.d-3 and Table A2.F.d-1 for SVMWC. According to GSP Regulations (23 CCR § 351(al)):

> *"Water use sector" refers to 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.*

In SVMWC, water use sectors include agricultural, native vegetation, and urban land use. The urban land use category includes urban and semi-agricultural[4] lands as well as industrial land, which covers only a small area in the subbasin.

As indicated, the majority of land in SVMWC is currently used for agriculture, covering an average of 3,400 acres between 1989 and 2015. Urban land has slightly expanded since the mid-2000s, but still covers a relatively small area in the subregion.

Agricultural land uses are further detailed in Figure A2.F.d-4 and Table A2.F.d-2. In the 1990s, a majority of agricultural land in SVMWC was used to cultivate alfalfa, mixed pasture, and miscellaneous field crops. In recent years, alfalfa and mixed pasture acreage has continued to expand while the remaining agricultural land is used in cultivating mostly corn and orchard crops.

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[4] As defined in the DWR county land use surveys, 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, 2009).

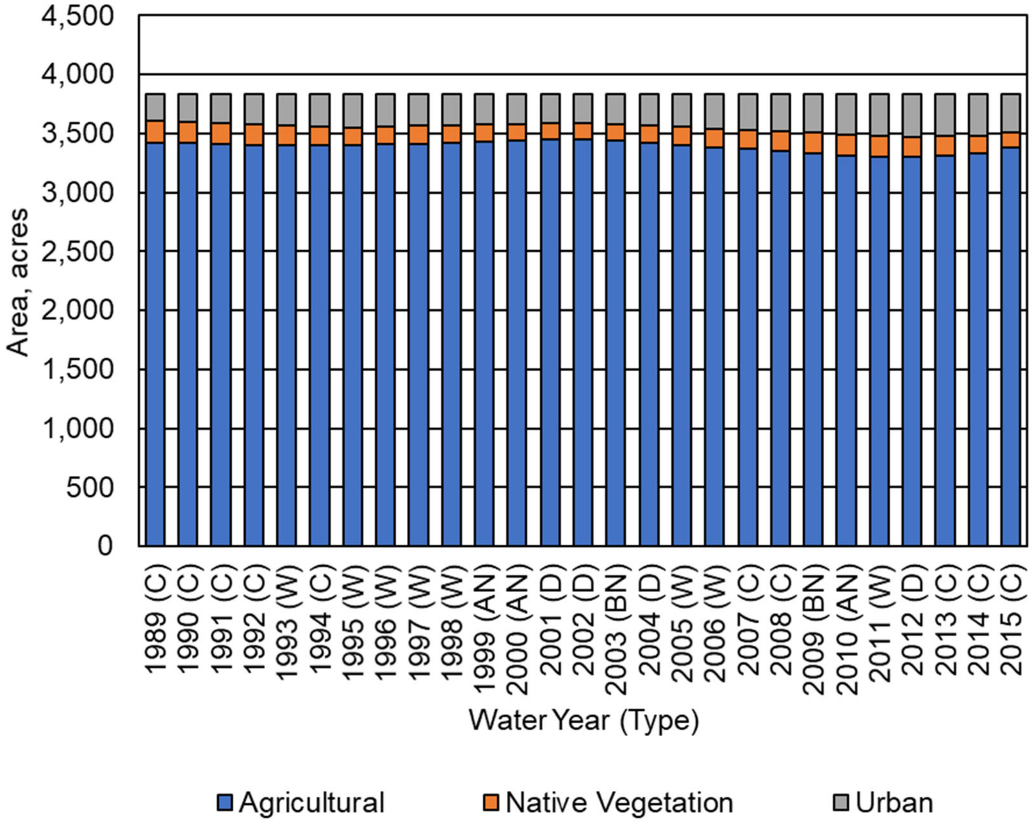

Figure A2.F.d-3. Sierra Vista Mutual Water Company Land Use Areas

Table A2.F.d-1. Sierra Vista Mutual Water Company Land Use Areas, acres

Water Year (Type)	Agricultural	Native Vegetation[1]	Urban[2]	Total
1989 (C)	3,419	184	227	3,830
1990 (C)	3,418	176	236	3,830
1991 (C)	3,410	175	246	3,830
1992 (C)	3,404	172	254	3,830
1993 (W)	3,401	166	262	3,830
1994 (C)	3,404	156	271	3,830
1995 (W)	3,397	155	279	3,830
1996 (W)	3,405	152	273	3,830
1997 (W)	3,414	150	266	3,830
1998 (W)	3,423	147	260	3,830
1999 (AN)	3,431	145	254	3,830
2000 (AN)	3,440	142	248	3,830
2001 (D)	3,448	140	242	3,830
2002 (D)	3,453	137	241	3,830
2003 (BN)	3,436	142	253	3,830

Water Year (Type)	Agricultural	Native Vegetation[1]	Urban[2]	Total
2004 (D)	3,418	147	265	3,830
2005 (W)	3,401	152	277	3,830
2006 (W)	3,384	157	290	3,830
2007 (C)	3,367	162	302	3,830
2008 (C)	3,349	167	314	3,830
2009 (BN)	3,332	172	326	3,830
2010 (AN)	3,315	177	338	3,830
2011 (W)	3,297	182	351	3,830
2012 (D)	3,300	173	357	3,830
2013 (C)	3,313	162	355	3,830
2014 (C)	3,326	151	353	3,830
2015 (C)	3,378	128	325	3,830
Average (1989-2014)	3,389	159	282	3,830

[1] Area includes land classified as native vegetation and water surfaces.

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

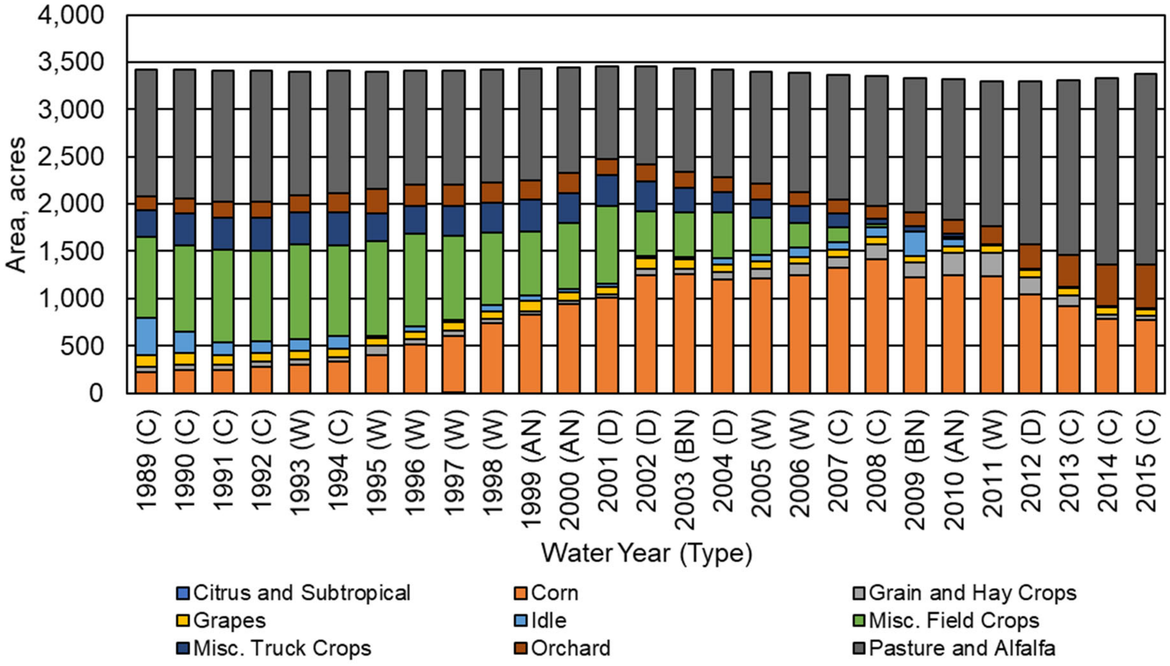

Figure A2.F.d-4. Sierra Vista Mutual Water Company Agricultural Land Use Areas

Table A2.F.d-2. Sierra Vista Mutual Water Company Agricultural Land Use Areas

Water Year (Type)	Citrus and Subtropical	Corn	Grain and Hay Crops	Grapes	Idle	Misc. Field Crops	Misc. Truck Crops	Orchard	Pasture and Alfalfa	Total
1989 (C)	0	225	49	131	391	856	281	148	1,337	3,419
1990 (C)	0	241	64	121	222	909	343	162	1,357	3,418
1991 (C)	0	248	47	104	139	983	331	174	1,383	3,410
1992 (C)	0	276	57	92	122	963	341	174	1,380	3,404
1993 (W)	0	304	53	88	127	996	342	186	1,305	3,401
1994 (C)	0	335	48	86	131	957	355	201	1,291	3,404
1995 (W)	0	400	101	84	18	1,006	287	262	1,239	3,397
1996 (W)	0	513	56	83	52	977	301	225	1,198	3,405
1997 (W)	2	598	54	100	18	890	311	227	1,214	3,414
1998 (W)	0	742	39	81	73	764	316	207	1,201	3,423
1999 (AN)	0	830	31	119	55	677	337	198	1,184	3,431
2000 (AN)	0	941	37	85	36	695	317	215	1,114	3,440
2001 (D)	0	1,008	33	77	39	817	330	171	974	3,448
2002 (D)	0	1,241	77	103	21	484	305	183	1,038	3,453
2003 (BN)	0	1,252	64	102	25	467	256	172	1,098	3,436
2004 (D)	0	1,198	77	86	60	493	210	163	1,132	3,418
2005 (W)	0	1,209	106	76	71	396	189	166	1,187	3,401
2006 (W)	0	1,250	119	74	97	264	170	148	1,262	3,384
2007 (C)	0	1,324	118	74	82	160	141	149	1,318	3,367
2008 (C)	0	1,411	161	77	107	36	52	135	1,371	3,349
2009 (BN)	0	1,218	160	74	251	4	58	141	1,426	3,332
2010 (AN)	0	1,245	235	74	74	27	29	148	1,482	3,315
2011 (W)	0	1,230	257	72	13	0	0	188	1,537	3,297
2012 (D)	0	1,047	180	74	11	0	0	261	1,726	3,300
2013 (C)	0	914	120	76	9	0	0	344	1,848	3,313
2014 (C)	0	783	49	79	8	0	0	436	1,971	3,326
2015 (C)	0	768	46	77	3	0	0	460	2,024	3,378
Average (1989-2014)	0	846	92	88	87	532	215	199	1,330	3,389

3.2 Surface Water System Water Budget

This section presents surface water system water budget components within SVMWC as per GSP regulations. These are followed by a summary of the water budget results by accounting center.

3.2.1 Inflows

3.2.1.1 Surface Water Inflow by Water Source Type

Surface water inflows include surface water flowing into SVMWC across the subregion boundary. Per the Regulations, surface inflows must be reported by water source type. According to the Regulations:

> *"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.*

Additionally, runoff of precipitation from upgradient areas adjacent to the subregion represents a potential source of surface water inflow.

Local Supplies

Local supplies to SVMWC include pre-1914, riparian, and prescriptive water rights deliveries received by growers along Chowchilla River.

CVP Supplies

SVMWC does not receive CVP supplies for irrigation purposes. However, some CVP supplies flow into SVMWC along Chowchilla River in the form of releases from Buchanan Dam and Millerton Reservoir. Much of this water passes through and exits SVMWC as surface water outflows.

Recycling and Reuse

Recycling and reuse are not a significant source of supply within SVMWC.

Other Surface Inflows

For the water budgets presented herein, precipitation runoff from outside the subregion is considered relatively minimal and is expected to pass through the waterways accounted above following relatively large storm events. Precipitation runoff from lands inside the subregion is internal to the surface water system and is thus not considered as surface inflows to the subregion boundary.

Summary of Surface Inflows

The surface water inflows described above are summarized by water source type in Figure A2.F.d-5 and Table A2.F.d-3. During the study period, total surface water inflows vary by water year type, averaging 4.5 taf per year.

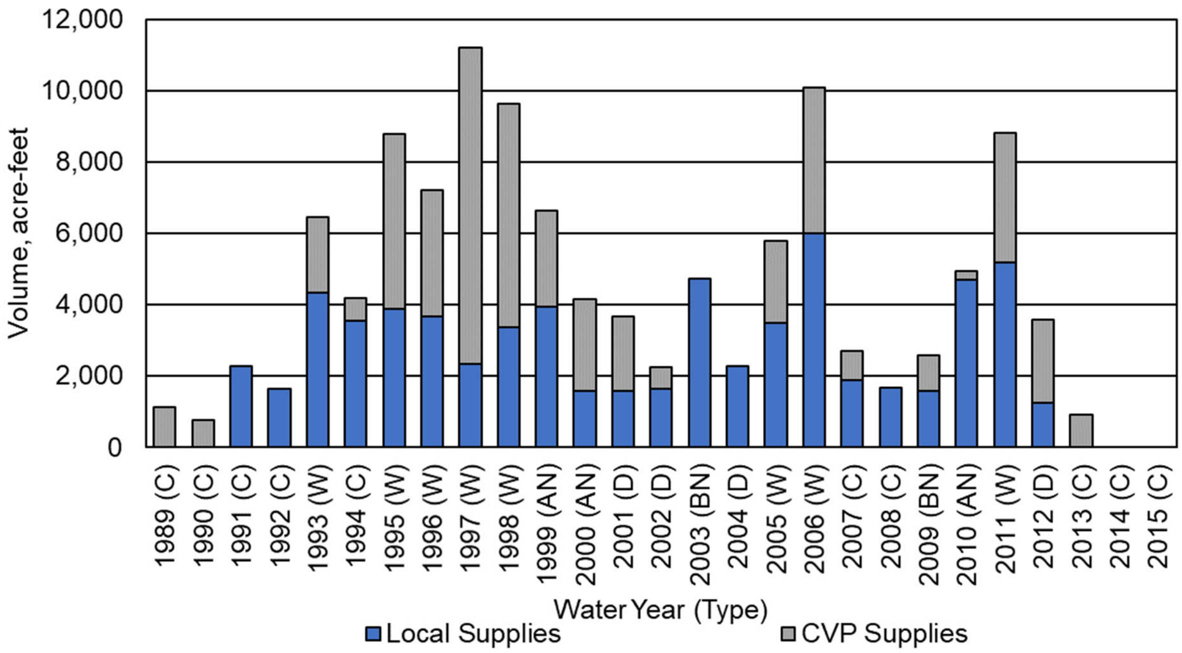

Figure A2.F.d-5. Sierra Vista Mutual Water Company Surface Water Inflows by Water Source Type.

Table A2.F.d-3. Sierra Vista Mutual Water Company Surface Water Inflows by Water Source Type (Acre-Feet).

Water Year (Type)	Local Supply	CVP Supply[1]	Total
1989 (C)	0	1,140	1,140
1990 (C)	0	750	750
1991 (C)	2,270	0	2,270
1992 (C)	1,650	0	1,650
1993 (W)	4,320	2,140	6,450
1994 (C)	3,550	650	4,200
1995 (W)	3,890	4,900	8,790
1996 (W)	3,680	3,530	7,220
1997 (W)	2,330	8,870	11,200
1998 (W)	3,360	6,260	9,620
1999 (AN)	3,930	2,690	6,630
2000 (AN)	1,580	2,570	4,150
2001 (D)	1,580	2,080	3,660
2002 (D)	1,640	600	2,240
2003 (BN)	4,710	0	4,710
2004 (D)	2,280	0	2,280
2005 (W)	3,500	2,300	5,800
2006 (W)	6,000	4,070	10,070
2007 (C)	1,890	810	2,690
2008 (C)	1,680	0	1,680

Water Year (Type)	Local Supply	CVP Supply[1]	Total
2009 (BN)	1,590	980	2,570
2010 (AN)	4,690	260	4,950
2011 (W)	5,190	3,620	8,810
2012 (D)	1,240	2,330	3,560
2013 (C)	0	910	910
2014 (C)	0	0	0
2015 (C)	0	0	0
Average (1989-2014)	2,560	1,980	4,540
Average (1989-2014) W	4,030	4,460	8,490
Average (1989-2014) AN	3,400	1,840	5,240
Average (1989-2014) BN	3,150	490	3,640
Average (1989-2014) D	1,680	1,250	2,940
Average (1989-2014) C	1,230	470	1,700

[1] CVP Supply is considered as all water supply released from CVP storage facilities. The volume of CVP Supply includes CVP deliveries to CWD, and flood releases from CVP facilities that pass through the subbasin.

3.2.1.2 Precipitation

Precipitation estimates for SVMWC are provided in Figure A2.F.d-6 and Table A2.F.d-4. Precipitation estimates are reported by water use sector.

Total precipitation is highly variable between years in the study area, ranging from approximately 2.4 taf (7.6 inches) during average dry years to 4.6 taf (14.4 inches) during average wet years.

3.2.1.3 Groundwater Extraction by Water Use Sector

Estimates of groundwater extraction by water use sector are provided in Figure A2.F.d-7 and Table A2.F.d-5. For agricultural and urban (urban, semi-agricultural, industrial) lands, groundwater extraction represents pumping, while for native lands, groundwater extraction by riparian vegetation was considered to be negligible. In all water use sector water budgets, groundwater extraction served as the water budget closure term. Groundwater extraction is dominated by irrigated agriculture and increases over time, following the trend of increasing alfalfa, pasture, and orchard acreage. During some wet years, the groundwater extraction closure term is reduced in months when surface water is available to water rights users.

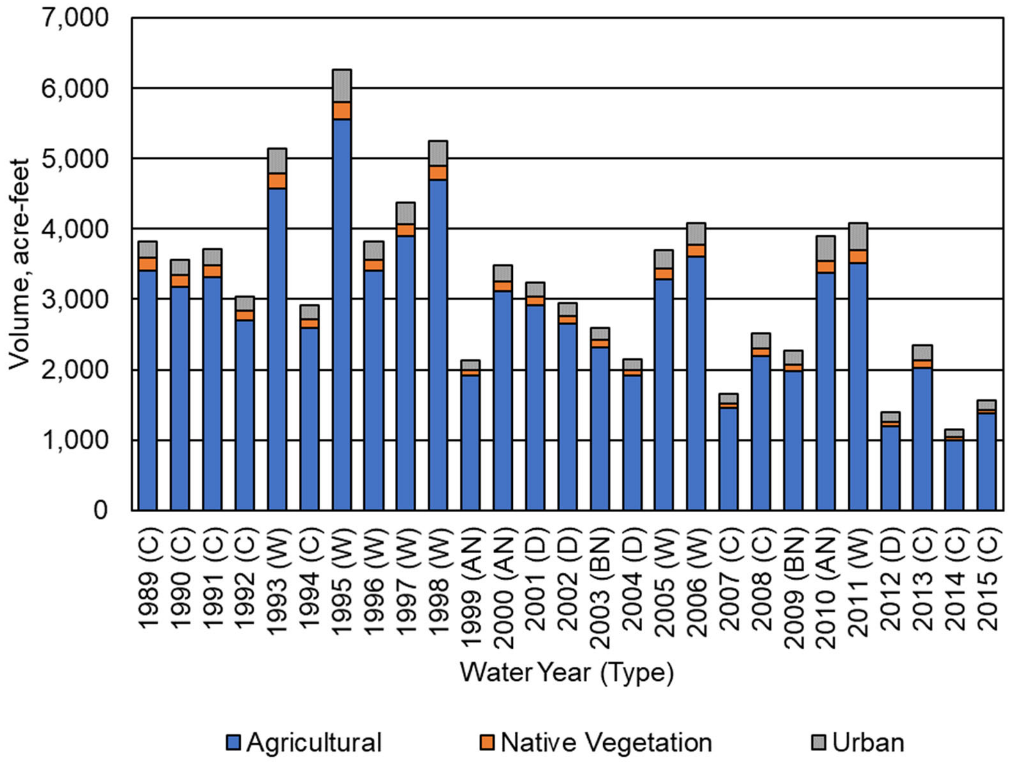

Figure A2.F.d-6. Sierra Vista Mutual Water Company Precipitation by Water Use Sector.

Table A2.F.d-4. Sierra Vista Mutual Water Company Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	3,410	180	230	3,820
1990 (C)	3,180	160	220	3,560
1991 (C)	3,310	170	240	3,720
1992 (C)	2,700	140	200	3,040
1993 (W)	4,570	220	350	5,150
1994 (C)	2,590	120	210	2,920
1995 (W)	5,550	250	460	6,260
1996 (W)	3,400	150	270	3,830
1997 (W)	3,900	170	310	4,370
1998 (W)	4,700	200	360	5,260
1999 (AN)	1,910	80	140	2,130
2000 (AN)	3,120	130	230	3,480
2001 (D)	2,920	120	210	3,240
2002 (D)	2,650	110	190	2,940
2003 (BN)	2,320	100	170	2,590
2004 (D)	1,920	80	150	2,150
2005 (W)	3,290	150	270	3,710
2006 (W)	3,610	170	310	4,080
2007 (C)	1,450	70	130	1,650

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2008 (C)	2,200	110	210	2,510
2009 (BN)	1,970	100	190	2,270
2010 (AN)	3,370	180	340	3,900
2011 (W)	3,510	190	370	4,080
2012 (D)	1,200	60	130	1,390
2013 (C)	2,030	100	220	2,350
2014 (C)	1,000	40	110	1,150
2015 (C)	1,380	50	130	1,560
Average (1989-2014)	2,910	140	240	3,290
Average (1989-2014) W	4,070	190	340	4,590
Average (1989-2014) AN	2,800	130	240	3,170
Average (1989-2014) BN	2,150	100	180	2,430
Average (1989-2014) D	2,170	90	170	2,430
Average (1989-2014) C	2,430	120	190	2,750

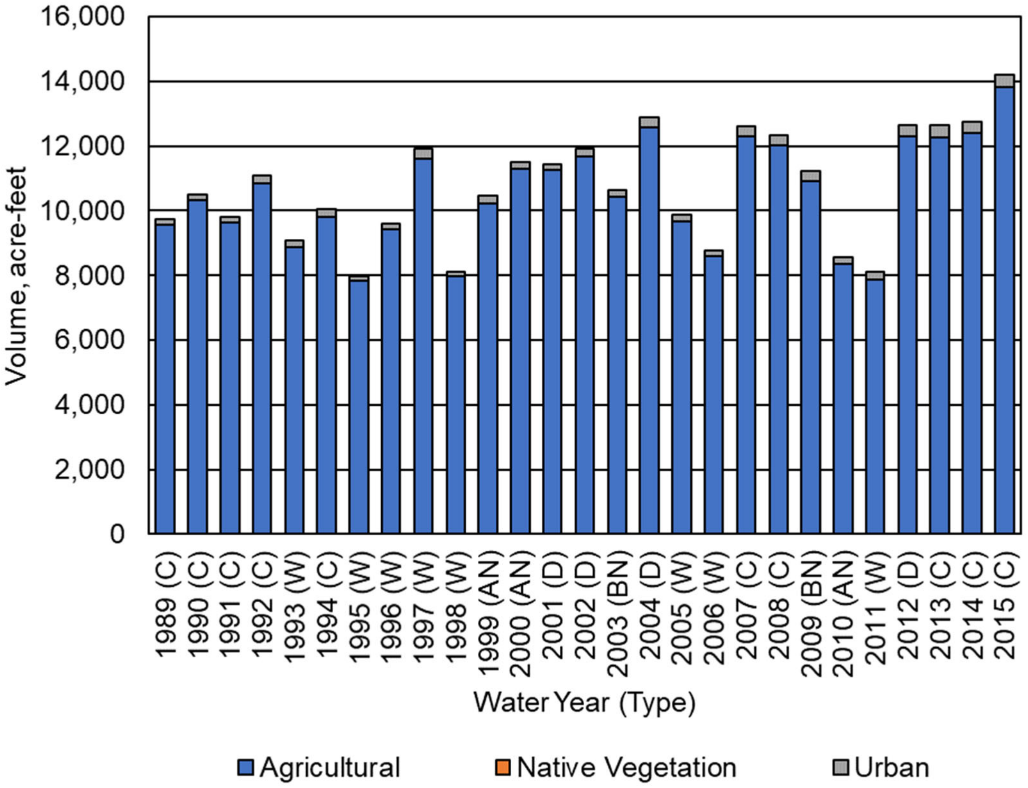

Figure A2.F.d-7. Sierra Vista Mutual Water Company Groundwater Extraction by Water Use Sector.

Table A2.F.d-5. Sierra Vista Mutual Water Company Groundwater Extraction by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	9,580	0	170	9,750
1990 (C)	10,320	0	190	10,510
1991 (C)	9,620	0	190	9,810
1992 (C)	10,850	0	240	11,080
1993 (W)	8,890	0	200	9,090
1994 (C)	9,820	0	240	10,060
1995 (W)	7,820	0	140	7,960
1996 (W)	9,420	0	190	9,610
1997 (W)	11,620	0	290	11,910
1998 (W)	7,970	0	160	8,120
1999 (AN)	10,230	0	230	10,450
2000 (AN)	11,310	0	190	11,500
2001 (D)	11,270	0	180	11,450
2002 (D)	11,690	0	230	11,920
2003 (BN)	10,440	0	220	10,660
2004 (D)	12,590	0	300	12,890
2005 (W)	9,680	0	200	9,880
2006 (W)	8,590	0	200	8,780
2007 (C)	12,300	0	310	12,610
2008 (C)	12,020	0	320	12,340
2009 (BN)	10,920	0	320	11,230
2010 (AN)	8,370	0	200	8,560
2011 (W)	7,890	0	220	8,110
2012 (D)	12,290	0	350	12,640
2013 (C)	12,270	0	370	12,640
2014 (C)	12,420	0	350	12,770
2015 (C)	13,840	0	360	14,200
Average (1989-2014)	10,390	0	240	10,630
Average (1989-2014) W	8,980	0	200	9,180
Average (1989-2014) AN	9,970	0	200	10,170
Average (1989-2014) BN	10,680	0	270	10,950
Average (1989-2014) D	11,960	0	260	12,220
Average (1989-2014) C	11,020	0	260	11,290

3.2.1.4 Groundwater Discharge to Surface Water Sources

The depth to groundwater is greater than 100-200 ft across much of the Chowchilla Subbasin. Given the depth to the water table in the Chowchilla Subbasin, groundwater discharge to surface water sources is negligible.

3.2.2 Outflows

3.2.2.1 Evapotranspiration by Water Use Sector

Evapotranspiration (ET) by water use sector is reported in Figures A2.F.d-8 to A2.F.d-10 and Tables A2.F.d-6 to A2.F.d-8. First, total ET is reported, followed by ET from applied water and ET from precipitation.

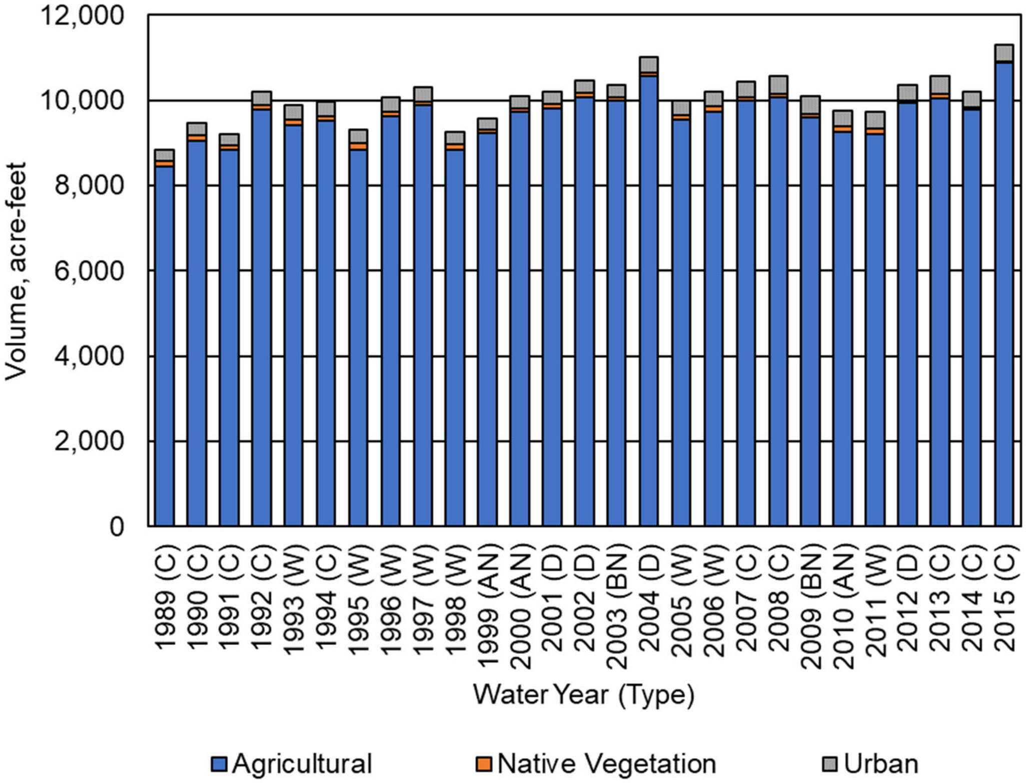

Figure A2.F.d-8. Sierra Vista Mutual Water Company Evapotranspiration by Water Use Sector.

Table A2.F.d-6. Sierra Vista Mutual Water Company Evapotranspiration by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	8,440	140	270	8,850
1990 (C)	9,040	130	290	9,460
1991 (C)	8,840	110	260	9,210
1992 (C)	9,770	120	320	10,210
1993 (W)	9,410	140	330	9,880
1994 (C)	9,530	100	330	9,960
1995 (W)	8,850	150	310	9,310
1996 (W)	9,620	120	320	10,060
1997 (W)	9,880	90	340	10,310
1998 (W)	8,840	120	290	9,250
1999 (AN)	9,220	80	280	9,580
2000 (AN)	9,720	100	290	10,110
2001 (D)	9,810	100	280	10,190
2002 (D)	10,080	90	300	10,470
2003 (BN)	9,990	80	300	10,370
2004 (D)	10,580	80	360	11,020
2005 (W)	9,540	110	330	9,980
2006 (W)	9,730	120	340	10,190
2007 (C)	9,990	80	360	10,430
2008 (C)	10,070	90	400	10,560
2009 (BN)	9,600	80	410	10,090
2010 (AN)	9,260	120	380	9,760
2011 (W)	9,200	140	390	9,730
2012 (D)	9,930	70	370	10,370
2013 (C)	10,050	90	430	10,570
2014 (C)	9,790	40	370	10,200
2015 (C)	10,880	40	380	11,300
Average (1989-2014)	9,570	100	330	10,000
Average (1989-2014) W	9,380	120	330	9,830
Average (1989-2014) AN	9,400	100	310	9,810
Average (1989-2014) BN	9,790	80	350	10,220
Average (1989-2014) D	10,100	90	320	10,510
Average (1989-2014) C	9,500	100	340	9,940

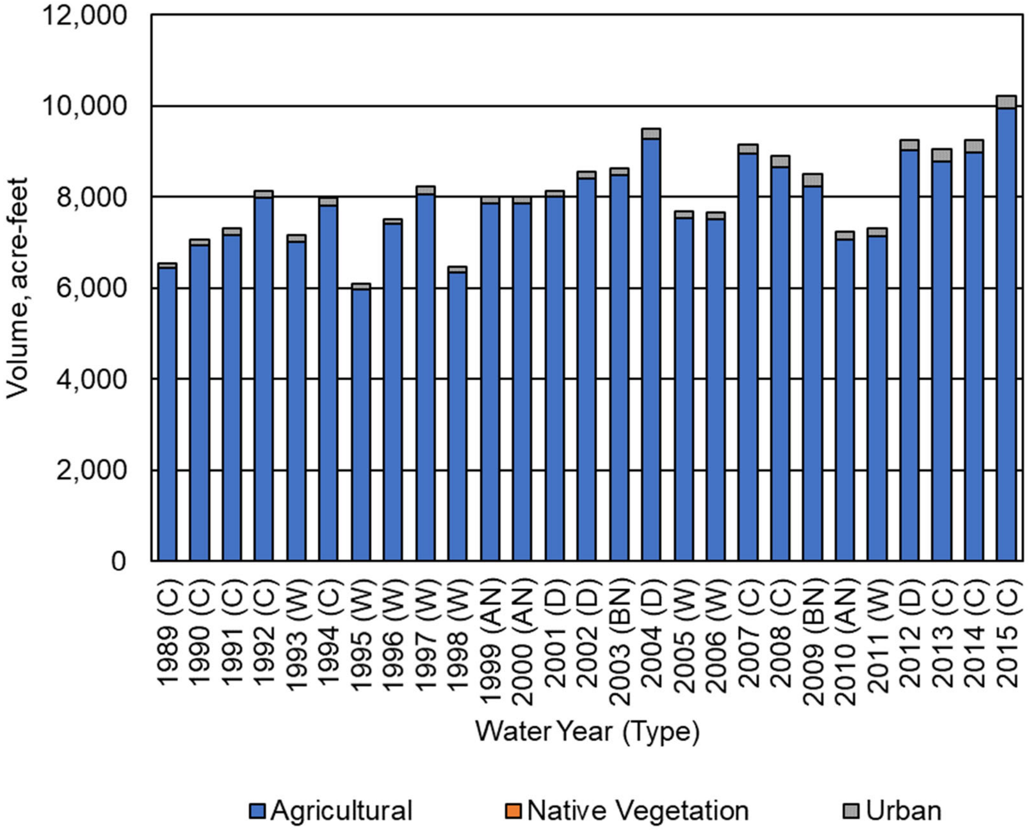

Figure A2.F.d-9. Sierra Vista Mutual Water Company Evapotranspiration of Applied Water by Water Use Sector.

Table A2.F.d-7. Sierra Vista Mutual Water Company Evapotranspiration of Applied Water by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	6,430	0	120	6,550
1990 (C)	6,930	0	130	7,060
1991 (C)	7,170	0	130	7,300
1992 (C)	7,980	0	160	8,140
1993 (W)	7,020	0	140	7,160
1994 (C)	7,800	0	180	7,980
1995 (W)	5,980	0	110	6,090
1996 (W)	7,400	0	120	7,520
1997 (W)	8,060	0	170	8,230
1998 (W)	6,350	0	120	6,470
1999 (AN)	7,850	0	150	8,000
2000 (AN)	7,860	0	150	8,010
2001 (D)	8,010	0	130	8,140
2002 (D)	8,400	0	160	8,560
2003 (BN)	8,470	0	170	8,640
2004 (D)	9,270	0	220	9,490
2005 (W)	7,530	0	160	7,690

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2006 (W)	7,500	0	150	7,650
2007 (C)	8,940	0	210	9,150
2008 (C)	8,660	0	240	8,900
2009 (BN)	8,240	0	260	8,500
2010 (AN)	7,070	0	170	7,240
2011 (W)	7,140	0	160	7,300
2012 (D)	9,030	0	230	9,260
2013 (C)	8,790	0	270	9,060
2014 (C)	8,980	0	270	9,250
2015 (C)	9,940	0	280	10,220
Average (1989-2014)	7,800	0	170	7,970
Average (1989-2014) W	7,120	0	140	7,260
Average (1989-2014) AN	7,590	0	150	7,740
Average (1989-2014) BN	8,350	0	210	8,560
Average (1989-2014) D	8,680	0	180	8,860
Average (1989-2014) C	7,960	0	190	8,150

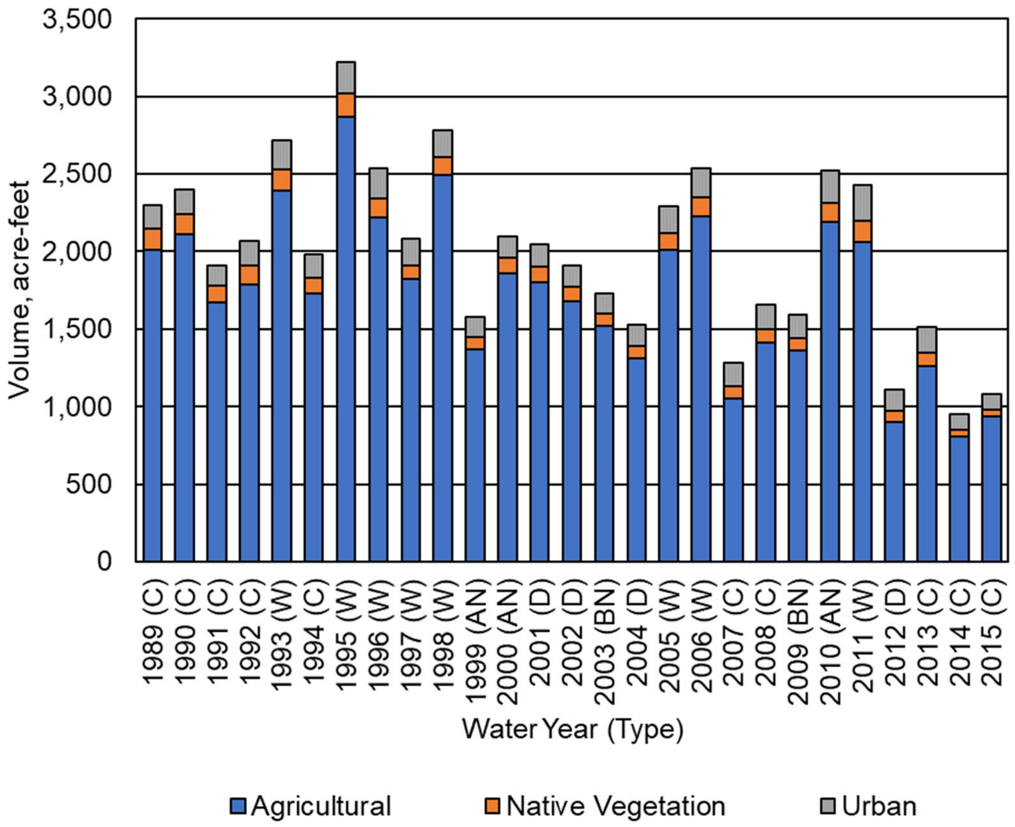

Figure A2.F.d-10. Sierra Vista Mutual Water Company Evapotranspiration of Precipitation by Water Use Sector.

Table A2.F.d-8. Sierra Vista Mutual Water Company Evapotranspiration of Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	2,010	140	150	2,300
1990 (C)	2,110	130	160	2,400
1991 (C)	1,670	110	130	1,910
1992 (C)	1,790	120	160	2,070
1993 (W)	2,390	140	190	2,720
1994 (C)	1,730	100	150	1,980
1995 (W)	2,870	150	200	3,220
1996 (W)	2,220	120	200	2,540
1997 (W)	1,820	90	170	2,080
1998 (W)	2,490	120	170	2,780
1999 (AN)	1,370	80	130	1,580
2000 (AN)	1,860	100	140	2,100
2001 (D)	1,800	100	150	2,050
2002 (D)	1,680	90	140	1,910
2003 (BN)	1,520	80	130	1,730
2004 (D)	1,310	80	140	1,530
2005 (W)	2,010	110	170	2,290
2006 (W)	2,230	120	190	2,540
2007 (C)	1,050	80	150	1,280
2008 (C)	1,410	90	160	1,660
2009 (BN)	1,360	80	150	1,590
2010 (AN)	2,190	120	210	2,520
2011 (W)	2,060	140	230	2,430
2012 (D)	900	70	140	1,110
2013 (C)	1,260	90	160	1,510
2014 (C)	810	40	100	950
2015 (C)	940	40	100	1,080
Average (1989-2014)	1,770	100	160	2,030
Average (1989-2014) W	2,260	120	190	2,570
Average (1989-2014) AN	1,810	100	160	2,070
Average (1989-2014) BN	1,440	80	140	1,660
Average (1989-2014) D	1,420	90	140	1,650
Average (1989-2014) C	1,540	100	150	1,790

Total ET varies between years, with the lowest observed in 1989, at approximately 8.9 taf, and greatest in 2015, at approximately 11.3 taf. Total ET generally increases over time, again following the trend of increasing alfalfa, pasture, and orchard acreage.

In addition to ET from land surfaces, estimates of evaporation from SVMWC rivers and streams are reported in Figure A2.F.d-11 and Table A2.F.d-9. Evaporation from the Rivers and Streams System includes evaporation of flood inflows and of precipitation runoff within local sloughs and depressions. Total evaporation from all sources averaged less than 0.1 taf per year between 1989 and 2014.

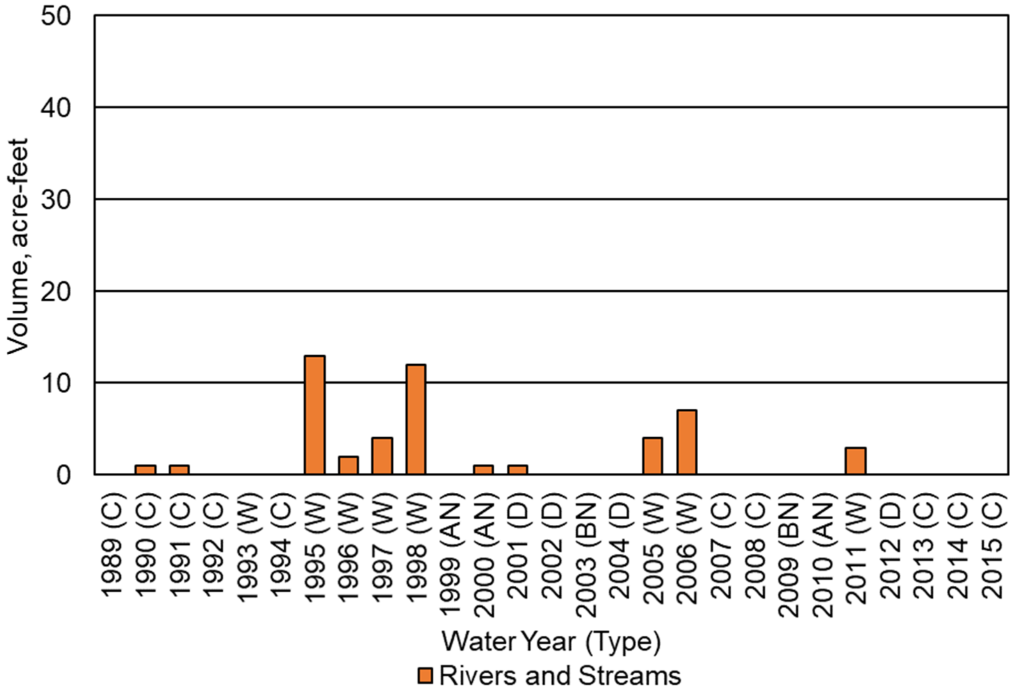

Figure A2.F.d-11. Sierra Vista Mutual Water Company Evaporation from the Surface Water System.

Table A2.F.d-9. Sierra Vista Mutual Water Company Evaporation from the Surface Water System (Acre-Feet).

Water Year (Type)	Rivers and Streams
1989 (C)	0
1990 (C)	1
1991 (C)	1
1992 (C)	0
1993 (W)	0
1994 (C)	0
1995 (W)	13
1996 (W)	2
1997 (W)	4
1998 (W)	12
1999 (AN)	0
2000 (AN)	1
2001 (D)	1
2002 (D)	0
2003 (BN)	0
2004 (D)	0
2005 (W)	4
2006 (W)	7
2007 (C)	0
2008 (C)	0
2009 (BN)	0
2010 (AN)	0

Water Year (Type)	Rivers and Streams
2011 (W)	3
2012 (D)	0
2013 (C)	0
2014 (C)	0
2015 (C)	0
Average (1989-2014)	1.9
Average (1989-2014) W	5.6
Average (1989-2014) AN	0.3
Average (1989-2014) BN	0.0
Average (1989-2014) D	0.3
Average (1989-2014) C	0.2

3.2.2.2 Surface Water Outflow by Water Source Type

Surface water outflows by water source type are summarized in Figure A2.F.d-12 and Table A2.F.d-10. In SVMWC, runoff of applied water is assumed negligible and runoff of precipitation is collected in waterways within SVMWC, with most infiltrating to the groundwater system except following the largest storm events. Thus, surface outflows from SVMWC are expected to be a mixture of flood releases from Buchanan Dam and Millerton Reservoir along Chowchilla River. Between 1989 and 2014, these combined outflows averaged approximately 2.1 taf during wet years.

3.2.2.3 Infiltration of Precipitation

Estimated infiltration of precipitation (deep percolation of precipitation) by water use sector is provided in Figure A2.F.d-13 and Table A2.F.d-11. Infiltration of precipitation to the groundwater system is highly variable from year to year due to variation in the timing and amount of precipitation, ranging from less than 0.5 taf annually during some critical and dry years to over 2.4 taf during 1995.

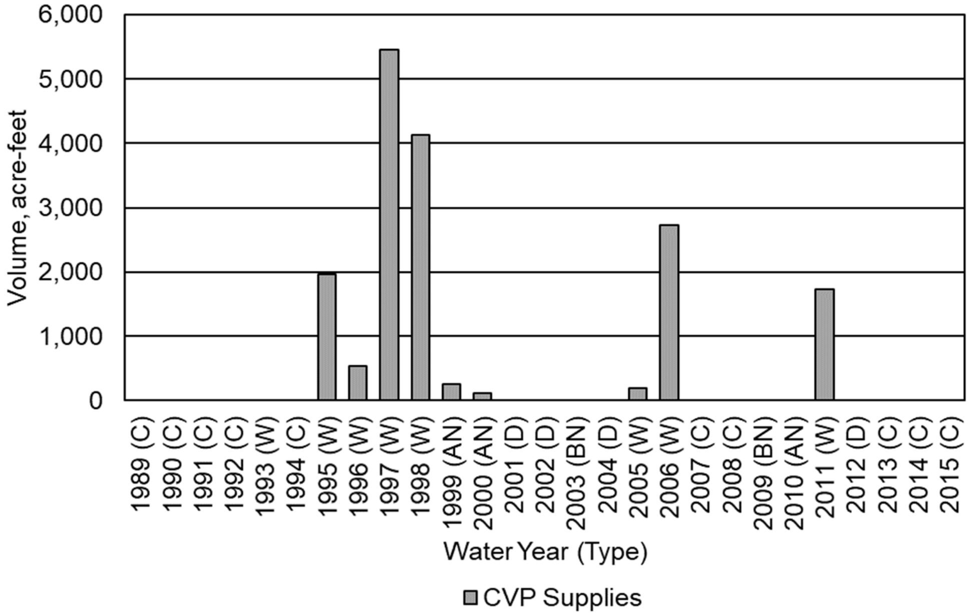

Figure A2.F.d-12. Sierra Vista Mutual Water Company Surface Outflows by Water Source Type.

Table A2.F.d-10. Sierra Vista Mutual Water Company Surface Outflows by Water Source Type (Acre-Feet).

Water Year (Type)	Local Supplies	CVP Supplies	Total
1989 (C)	0	0	0
1990 (C)	0	0	0
1991 (C)	0	0	0
1992 (C)	0	0	0
1993 (W)	0	0	0
1994 (C)	0	0	0
1995 (W)	0	1,970	1,970
1996 (W)	0	540	540
1997 (W)	0	5,450	5,450
1998 (W)	0	4,130	4,130
1999 (AN)	0	260	260
2000 (AN)	0	110	110
2001 (D)	0	0	0
2002 (D)	0	0	0
2003 (BN)	0	0	0
2004 (D)	0	0	0
2005 (W)	0	190	190
2006 (W)	0	2,730	2,730
2007 (C)	0	0	0
2008 (C)	0	0	0
2009 (BN)	0	0	0
2010 (AN)	0	0	0
2011 (W)	0	1,730	1,730
2012 (D)	0	0	0
2013 (C)	0	0	0
2014 (C)	0	0	0
2015 (C)	0	0	0
Average (1989-2014)	0	660	660
Average (1989-2014) W	0	2,090	2,090
Average (1989-2014) AN	0	120	120
Average (1989-2014) BN	0	0	0
Average (1989-2014) D	0	0	0
Average (1989-2014) C	0	0	0

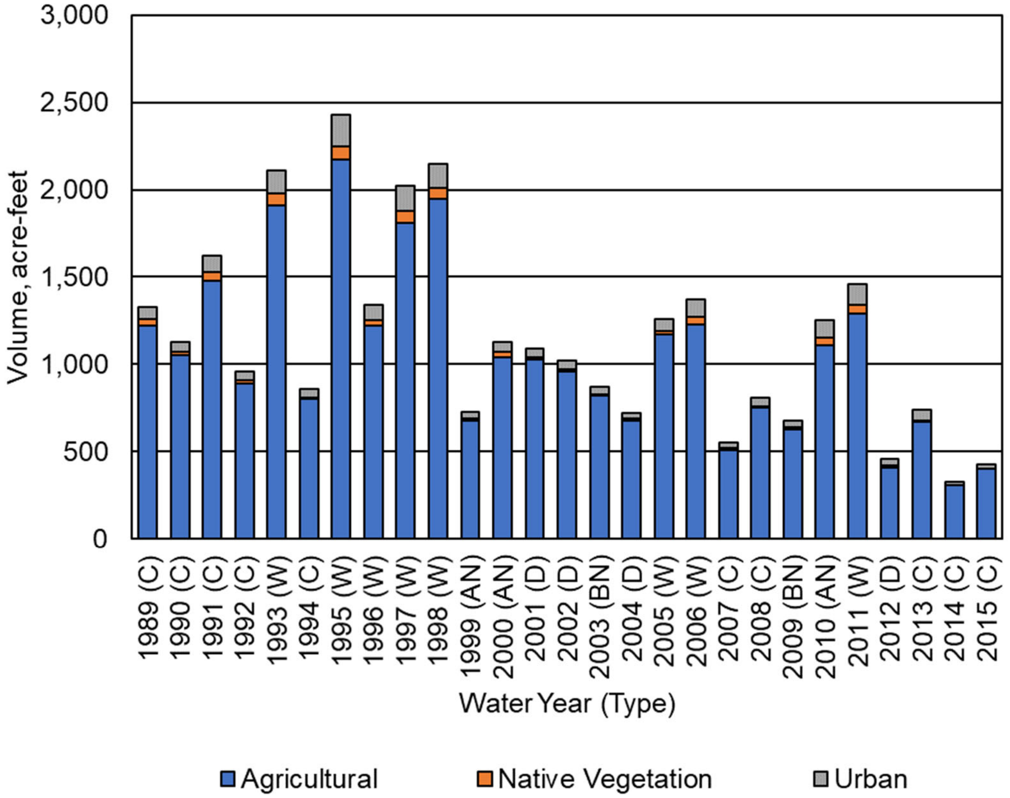

Figure A2.F.d-13. Sierra Vista Mutual Water Company Infiltration of Precipitation by Water Use Sector.

Table A2.F.d-11. Sierra Vista Mutual Water Company Infiltration of Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	1,220	40	70	1,330
1990 (C)	1,050	20	60	1,130
1991 (C)	1,480	50	90	1,620
1992 (C)	890	20	50	960
1993 (W)	1,910	70	130	2,110
1994 (C)	800	10	50	860
1995 (W)	2,170	80	180	2,430
1996 (W)	1,220	30	90	1,340
1997 (W)	1,810	70	140	2,020
1998 (W)	1,950	60	140	2,150
1999 (AN)	680	10	40	730
2000 (AN)	1,040	30	60	1,130
2001 (D)	1,030	10	50	1,090
2002 (D)	960	10	50	1,020
2003 (BN)	820	10	40	870
2004 (D)	680	10	30	720
2005 (W)	1,170	20	70	1,260
2006 (W)	1,230	40	100	1,370
2007 (C)	510	10	30	550

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2008 (C)	750	10	50	810
2009 (BN)	630	10	40	680
2010 (AN)	1,110	40	100	1,250
2011 (W)	1,290	50	120	1,460
2012 (D)	410	10	40	460
2013 (C)	670	10	60	740
2014 (C)	310	0	20	330
2015 (C)	400	0	30	430
Average (1989-2014)	1,070	30	70	1,170
Average (1989-2014) W	1,590	50	120	1,760
Average (1989-2014) AN	940	30	70	1,040
Average (1989-2014) BN	730	10	40	780
Average (1989-2014) D	770	10	40	820
Average (1989-2014) C	850	20	50	920

3.2.2.4 Infiltration of Surface Water

Estimated infiltration of surface water (seepage) by source is provided in Figure A2.F.d-14 and Table A2.F.d-12. Seepage from the Rivers and Streams System includes seepage of surface inflows along Chowchilla River and of precipitation runoff into local sloughs and depressions. Seepage from rivers and streams follows the pattern of surface water inflows, averaging approximately 2.9 taf per year between 1989 and 2014. During non-flood releases, seepage is also allocated to SVMWC along reach C-2 of the Chowchilla River upstream of SVMWC. Per an agreement between SVMWC and CWD, 70% of non-flood seepage along reach C-2 is allocated to SVMWC, and 30% is allocated to CWD.

3.2.2.5 Infiltration of Applied Water

Estimated infiltration of applied water (deep percolation of applied water) by water use sector is provided in Figure A2.F.d-15 and Table A2.F.d-13. Infiltration of applied water is dominated by agricultural irrigation and has slightly increased in recent years with shifts in agricultural land use.

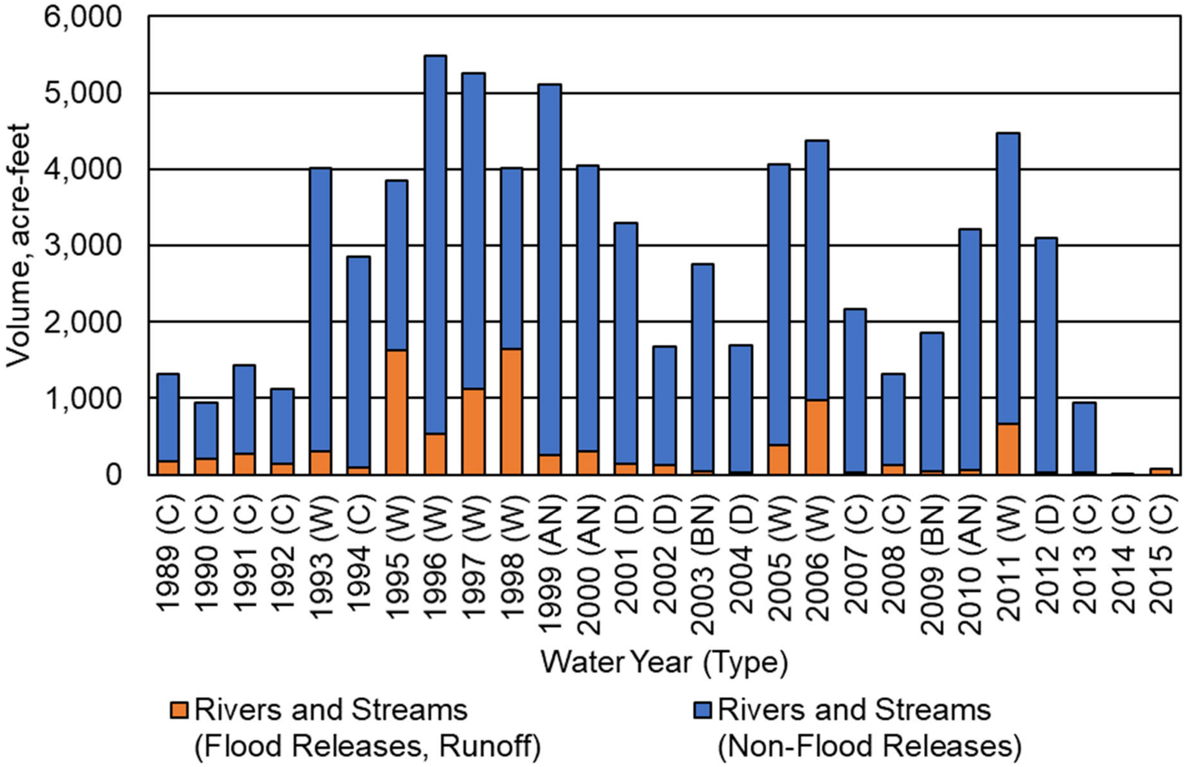

Figure A2.F.d-14. Sierra Vista Mutual Water Company Infiltration of Surface Water.

Table A2.F.d-12. Sierra Vista Mutual Water Company Infiltration of Surface Water (Acre-Feet).

Water Year (Type)	Rivers and Streams (Flood Releases, Runoff)[1]	Rivers and Streams (Non-Flood Releases)[2]	Total
1989 (C)	170	1,140	1,310
1990 (C)	200	750	950
1991 (C)	280	1,160	1,440
1992 (C)	150	980	1,130
1993 (W)	310	3,710	4,020
1994 (C)	90	2,770	2,860
1995 (W)	1,630	2,220	3,850
1996 (W)	540	4,940	5,480
1997 (W)	1,120	4,130	5,250
1998 (W)	1,640	2,380	4,020
1999 (AN)	250	4,850	5,100
2000 (AN)	310	3,730	4,040
2001 (D)	150	3,150	3,300
2002 (D)	120	1,560	1,680
2003 (BN)	50	2,700	2,750
2004 (D)	30	1,660	1,690
2005 (W)	390	3,680	4,070
2006 (W)	970	3,400	4,370
2007 (C)	20	2,140	2,160

Water Year (Type)	Rivers and Streams (Flood Releases, Runoff)[1]	Rivers and Streams (Non-Flood Releases)[2]	Total
2008 (C)	120	1,190	1,310
2009 (BN)	40	1,820	1,860
2010 (AN)	60	3,150	3,210
2011 (W)	660	3,810	4,470
2012 (D)	20	3,080	3,100
2013 (C)	30	910	940
2014 (C)	10	0	10
2015 (C)	80	0	80
Average (1989-2014)	360	2,500	2,860
Average (1989-2014) W	910	3,530	4,440
Average (1989-2014) AN	210	3,910	4,120
Average (1989-2014) BN	50	2,260	2,310
Average (1989-2014) D	80	2,360	2,440
Average (1989-2014) C	120	1,230	1,350

[1] Includes infiltration of flood releases and of precipitation runoff within the subregion. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

[2] Includes infiltration of non-flood releases along Chowchilla River upstream of SVMWC.

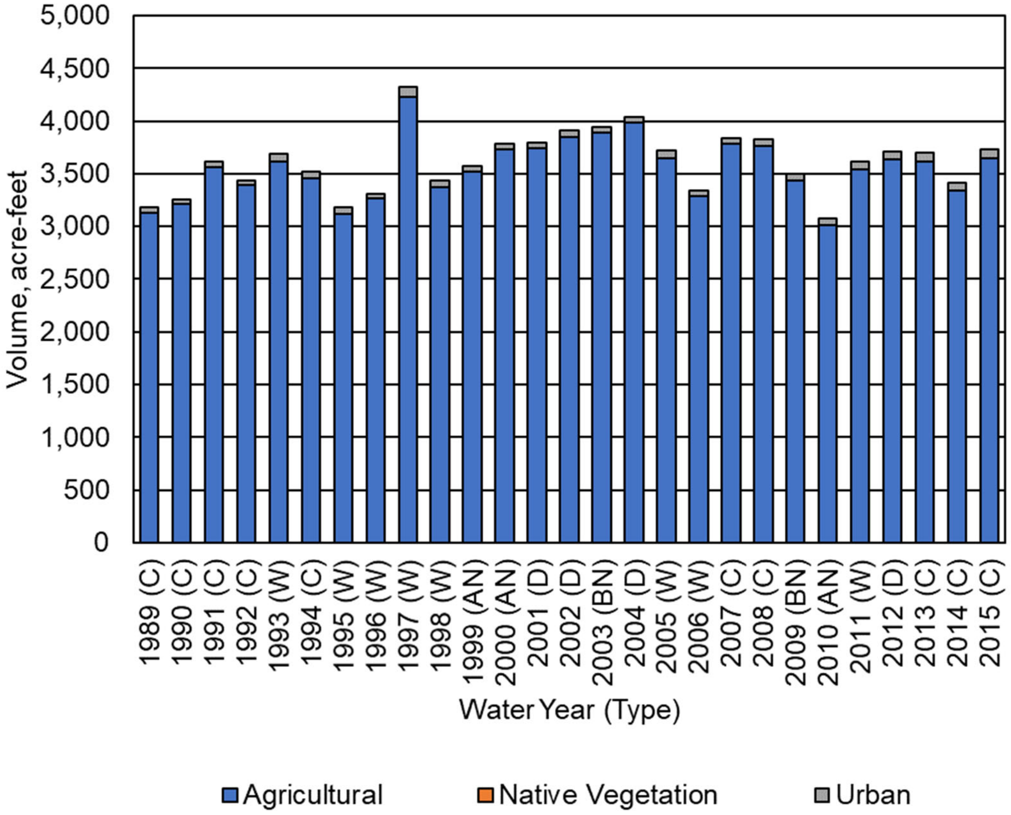

Figure A2.F.d-15. Sierra Vista Mutual Water Company Infiltration of Applied Water by Water Use Sector.

Table A2.F.d-13. Sierra Vista Mutual Water Company Infiltration of Applied Water by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	3,130	0	50	3,180
1990 (C)	3,210	0	50	3,260
1991 (C)	3,560	0	50	3,610
1992 (C)	3,390	0	50	3,440
1993 (W)	3,610	0	80	3,690
1994 (C)	3,460	0	60	3,520
1995 (W)	3,120	0	60	3,180
1996 (W)	3,270	0	40	3,310
1997 (W)	4,230	0	90	4,320
1998 (W)	3,370	0	70	3,440
1999 (AN)	3,520	0	50	3,570
2000 (AN)	3,730	0	50	3,780
2001 (D)	3,740	0	50	3,790
2002 (D)	3,850	0	60	3,910
2003 (BN)	3,890	0	50	3,940
2004 (D)	3,980	0	60	4,040
2005 (W)	3,650	0	70	3,720
2006 (W)	3,290	0	50	3,340
2007 (C)	3,780	0	60	3,840
2008 (C)	3,760	0	70	3,830
2009 (BN)	3,430	0	70	3,500
2010 (AN)	3,010	0	70	3,080
2011 (W)	3,540	0	70	3,610
2012 (D)	3,640	0	70	3,710
2013 (C)	3,610	0	90	3,700
2014 (C)	3,340	0	70	3,410
2015 (C)	3,650	0	80	3,730
Average (1989-2014)	3,540	0	60	3,600
Average (1989-2014) W	3,510	0	70	3,580
Average (1989-2014) AN	3,420	0	60	3,480
Average (1989-2014) BN	3,660	0	60	3,720
Average (1989-2014) D	3,800	0	60	3,860
Average (1989-2014) C	3,470	0	60	3,530

3.2.3 Change in Surface Water System Storage

Estimates of change in SWS storage are provided in Figure A2.F.d-16 and Table A2.F.d-14. Inter-annual changes in storage within the surface water system consist primarily of root zone soil moisture storage changes, are relatively small, and tend to average near zero over many years. During some wet years, change in SWS storage is estimated as higher during months when prescriptive water rights deliveries satisfy much of the crop water demand, substantially reducing groundwater pumping closure estimates.

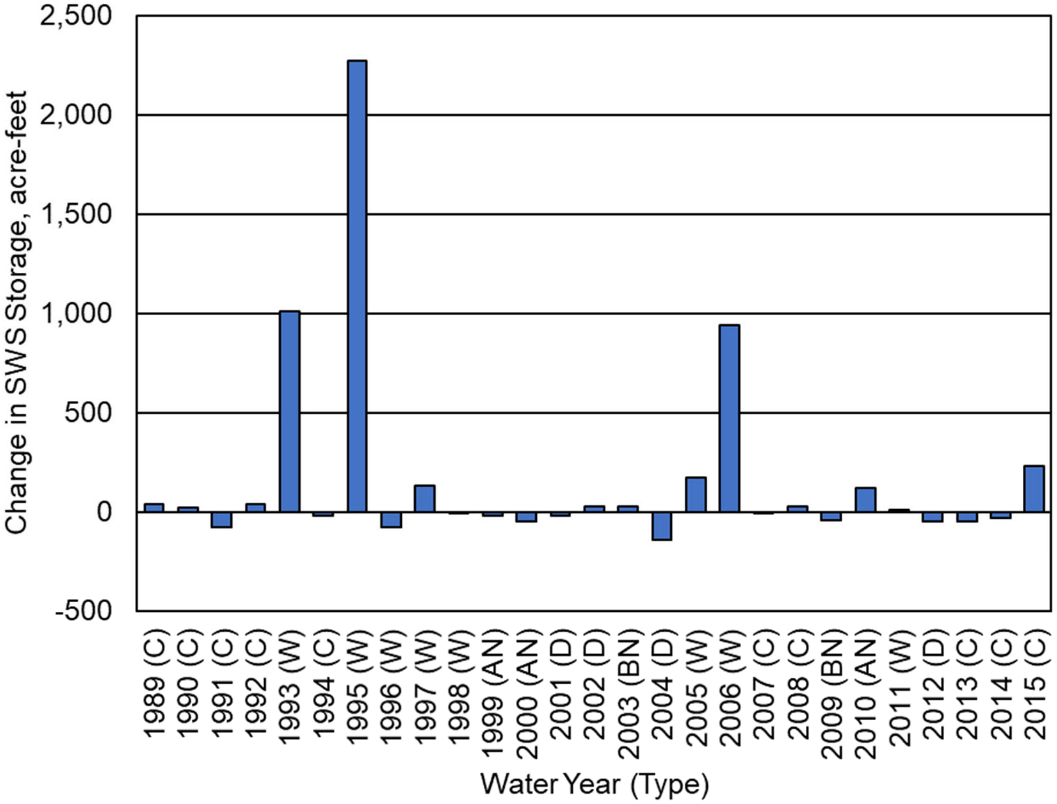

Figure A2.F.d-16. Sierra Vista Mutual Water Company Change in Surface Water System Storage.

Table A2.F.d-14. Sierra Vista Mutual Water Company Change in Surface Water System Storage (Acre-Feet).

Water Year (Type)	Change in SWS Storage
1989 (C)	40
1990 (C)	20
1991 (C)	-80
1992 (C)	40
1993 (W)	1,010
1994 (C)	-20
1995 (W)	2,270
1996 (W)	-80
1997 (W)	130
1998 (W)	-10
1999 (AN)	-20
2000 (AN)	-50
2001 (D)	-20
2002 (D)	30
2003 (BN)	30
2004 (D)	-140
2005 (W)	170
2006 (W)	940

Water Year (Type)	Change in SWS Storage
2007 (C)	-10
2008 (C)	30
2009 (BN)	-40
2010 (AN)	120
2011 (W)	10
2012 (D)	-50
2013 (C)	-50
2014 (C)	-30
2015 (C)	230
Average (1989-2014)	160
Average (1989-2014) W	560
Average (1989-2014) AN	20
Average (1989-2014) BN	-10
Average (1989-2014) D	-50
Average (1989-2014) C	-10

3.3 Historical Water Budget Summary

Annual inflows, outflows, and change in SWS storage during the historical water budget period (1989-2014) are summarized in Figure A2.F.d-17 and Table A2.F.d-15. Inflows are shown as positive values, while outflows and change in SWS storage are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the surface water system water budget.

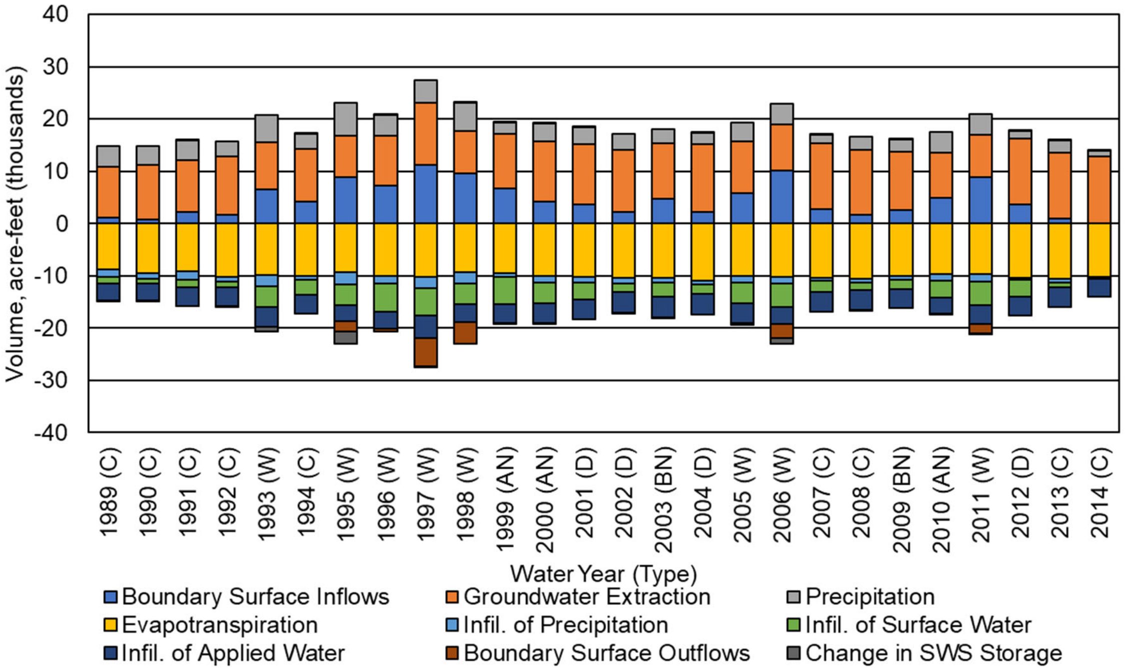

Figure A2.F.d-17. Sierra Vista Mutual Water Company Surface Water System Historical Water Budget, 1989-2014.

Table A2.F.d-15. Sierra Vista Mutual Water Company Surface Water System Historical Water Budget, 1989-2014 (Acre-Feet).

Water Year	Boundary Surface Inflows	Groundwater Extraction	Precipitation	Evapo-transpiration[1]	Infil. of Precipitation	Infil. of Surface Water[2]	Infil. of Applied Water	Boundary Surface Outflows	Change in SWS Storage
1989 (C)	1,140	9,750	3,820	-8,850	-1,330	-1,300	-3,180	0	-40
1990 (C)	750	10,510	3,560	-9,460	-1,130	-950	-3,260	0	-20
1991 (C)	2,270	9,810	3,720	-9,210	-1,630	-1,440	-3,610	0	80
1992 (C)	1,650	11,080	3,040	-10,220	-950	-1,130	-3,440	0	-40
1993 (W)	6,450	9,090	5,150	-9,870	-2,110	-4,020	-3,690	0	-1,010
1994 (C)	4,200	10,060	2,920	-9,960	-870	-2,850	-3,520	0	20
1995 (W)	8,790	7,960	6,260	-9,320	-2,430	-3,850	-3,180	-1,970	-2,270
1996 (W)	7,220	9,610	3,830	-10,070	-1,340	-5,480	-3,310	-540	80
1997 (W)	11,200	11,910	4,370	-10,310	-2,020	-5,250	-4,320	-5,450	-130
1998 (W)	9,620	8,120	5,260	-9,260	-2,150	-4,020	-3,440	-4,130	10
1999 (AN)	6,630	10,450	2,130	-9,580	-720	-5,100	-3,570	-260	20
2000 (AN)	4,150	11,500	3,480	-10,110	-1,130	-4,040	-3,780	-110	50
2001 (D)	3,660	11,450	3,240	-10,190	-1,100	-3,300	-3,780	0	20
2002 (D)	2,240	11,920	2,940	-10,470	-1,020	-1,680	-3,910	0	-30
2003 (BN)	4,710	10,660	2,590	-10,370	-870	-2,750	-3,940	0	-30
2004 (D)	2,280	12,890	2,150	-11,010	-710	-1,700	-4,030	0	140
2005 (W)	5,800	9,880	3,710	-9,980	-1,260	-4,070	-3,710	-190	-170
2006 (W)	10,070	8,780	4,080	-10,190	-1,360	-4,370	-3,350	-2,730	-940
2007 (C)	2,690	12,610	1,650	-10,420	-550	-2,150	-3,840	0	10
2008 (C)	1,680	12,340	2,510	-10,560	-810	-1,310	-3,830	0	-30
2009 (BN)	2,570	11,230	2,270	-10,090	-670	-1,860	-3,500	0	40
2010 (AN)	4,950	8,560	3,900	-9,760	-1,240	-3,210	-3,080	0	-120
2011 (W)	8,810	8,110	4,080	-9,730	-1,460	-4,460	-3,610	-1,730	-10
2012 (D)	3,560	12,640	1,390	-10,370	-450	-3,100	-3,710	0	50
2013 (C)	910	12,640	2,350	-10,570	-740	-940	-3,700	0	50
2014 (C)	0	12,770	1,150	-10,190	-340	-10	-3,400	0	30
Average (1989-2014)	4,540	10,630	3,290	-10,000	-1,170	-2,860	-3,600	-660	-160
W	8,490	9,180	4,590	-9,840	-1,770	-4,440	-3,580	-2,090	-550
AN	5,240	10,170	3,170	-9,820	-1,030	-4,120	-3,480	-120	-20
BN	3,640	10,950	2,430	-10,230	-770	-2,300	-3,720	0	0
D	2,940	12,220	2,430	-10,510	-820	-2,440	-3,860	0	40
C	1,700	11,290	2,750	-9,940	-930	-1,340	-3,530	0	10

[1] Includes ET of applied water, ET of precipitation, and evaporation from the Rivers and Streams system.

[2] Includes infiltration from flood releases along Chowchilla River and runoff of precipitation in SVMWC, and 70% of non-flood releases along Chowchilla River reach C-2. To calculate Net Recharge from SWS below, Rivers and Streams System seepage from flood releases and runoff of precipitation is summed across the subbasin and redistributed to each subregion in proportion to gross area

3.4 Current Water Budget Summary

The current water budget was developed following a similar process to the historical water budget using the 2015 land use in Table A2.F.d-1 and the same 1989-2014 average hydrologic conditions of the historical base period, including surface water flows, precipitation, and weather parameters. This allowed quantification of groundwater inflows and outflows for current consumptive use in the context of average water supply conditions.

Annual inflows, outflows, and change in SWS storage from the current water budget are summarized in Figure A2.F.d-18 and Table A2.F.d-16. Inflows are shown as positive values, while outflows and change in SWS storage are shown as negative values.

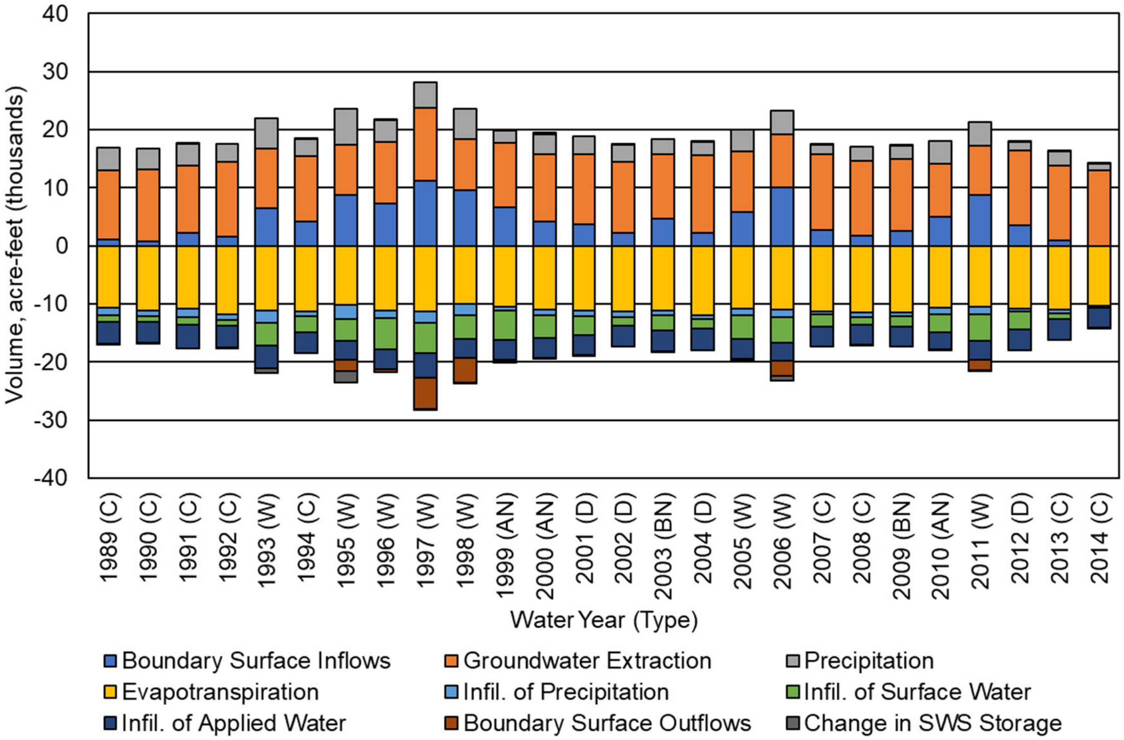

Figure A2.F.d-18. Sierra Vista Mutual Water Company Surface Water System Current Water Budget.

Table A2.F.d-16. Sierra Vista Mutual Water Company Surface Water System Current Water Budget (Acre-Feet).

Water Year	Boundary Surface Inflows	Groundwater Extraction	Precipitation	Evapotranspiration[1]	Infil. of Precipitation	Infil. of Surface Water[2]	Infil. of Applied Water	Boundary Surface Outflows	Change in SWS Storage
1989 (C)	1,140	11,920	3,820	-10,660	-1,270	-1,230	-3,690	0	-20
1990 (C)	750	12,430	3,560	-11,100	-1,090	-880	-3,590	0	-80
1991 (C)	2,270	11,550	3,720	-10,740	-1,550	-1,350	-3,990	0	80
1992 (C)	1,650	12,840	3,040	-11,830	-920	-1,080	-3,670	0	-30
1993 (W)	6,450	10,280	5,150	-11,170	-2,030	-3,910	-3,920	0	-850
1994 (C)	4,200	11,310	2,920	-11,240	-830	-2,820	-3,640	0	100
1995 (W)	8,790	8,540	6,260	-10,230	-2,300	-3,810	-3,260	-1,890	-2,100
1996 (W)	7,220	10,640	3,830	-11,170	-1,260	-5,460	-3,370	-510	80
1997 (W)	11,200	12,600	4,370	-11,350	-1,990	-5,190	-4,230	-5,380	-20
1998 (W)	9,620	8,690	5,260	-10,040	-1,980	-3,960	-3,380	-4,090	-110
1999 (AN)	6,630	11,120	2,130	-10,450	-670	-5,100	-3,400	-260	-10
2000 (AN)	4,150	11,640	3,480	-10,950	-1,010	-3,960	-3,430	-90	190
2001 (D)	3,660	12,020	3,240	-11,140	-980	-3,220	-3,520	0	-70
2002 (D)	2,240	12,160	2,940	-11,280	-920	-1,620	-3,580	0	70
2003 (BN)	4,710	11,000	2,590	-11,110	-770	-2,720	-3,620	0	-80
2004 (D)	2,280	13,370	2,150	-12,000	-610	-1,680	-3,670	0	170
2005 (W)	5,800	10,440	3,710	-10,820	-1,130	-4,030	-3,520	-180	-260
2006 (W)	10,070	9,050	4,080	-11,050	-1,240	-4,330	-3,120	-2,690	-770
2007 (C)	2,690	13,000	1,650	-11,280	-470	-2,140	-3,500	0	40
2008 (C)	1,680	12,870	2,510	-11,530	-720	-1,260	-3,510	0	-40
2009 (BN)	2,570	12,380	2,270	-11,450	-590	-1,840	-3,420	0	90
2010 (AN)	4,950	9,200	3,900	-10,640	-1,140	-3,190	-2,920	0	-170
2011 (W)	8,810	8,490	4,080	-10,510	-1,350	-4,440	-3,340	-1,710	-30
2012 (D)	3,560	12,900	1,390	-10,890	-430	-3,100	-3,510	0	80
2013 (C)	910	12,960	2,350	-10,940	-720	-940	-3,670	0	50
2014 (C)	0	12,950	1,150	-10,340	-340	-10	-3,440	0	30
Average (1989-2014)	4,540	11,400	3,290	-11,000	-1,090	-2,820	-3,540	-650	-140
W	8,490	9,840	4,590	-10,790	-1,660	-4,390	-3,520	-2,060	-510
AN	5,240	10,650	3,170	-10,680	-940	-4,080	-3,250	-120	0
BN	3,640	11,690	2,430	-11,280	-680	-2,280	-3,520	0	0
D	2,940	12,610	2,430	-11,330	-740	-2,410	-3,570	0	60
C	1,700	12,430	2,750	-11,070	-880	-1,300	-3,630	0	10

[1] Includes ET of applied water, ET of precipitation, and evaporation from the Rivers and Streams System.

[2] Includes infiltration from flood releases along Chowchilla River and runoff of precipitation in SVMWC, and 70% of non-flood releases along Chowchilla River reach C-2. To calculate Net Recharge from SWS below, Rivers and Streams System seepage from flood releases and runoff of precipitation is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.5 Net Recharge from SWS

Overdraft is defined in DWR Bulletin 118 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" (DWR 2003). The Chowchilla Subbasin water budget indicates that overdraft conditions occurred during the 1989-2014 historical base period. Per 23 CCR Section 354.18(b)(5), the subbasin overdraft has been quantified for this base period. The evaluation of overdraft conditions includes estimates of recharge from subsurface flows. However, estimates of recharge from subsurface flows are less accurate when estimated for areas less that an entire subbasin. Thus, for estimates of GSA level contribution to overdraft, the term net recharge from the SWS is defined as groundwater recharge minus groundwater extraction. Net recharge from the SWS is useful for understanding and analyzing the combined effects of land surface processes on the underlying GWS.

When calculated from the historical water budget, average net recharge from the SWS represents the average recharge (when positive) or shortage of recharge (when negative) based on historical cropping, land use practices, and average hydrologic conditions. When calculated from the current land use water budget, average net recharge represents the average recharge or shortage (when negative) based on current cropping, land use practices, and average hydrologic conditions.

Average net recharge from the SWS is presented below for the SVMWC portion of the Chowchilla Subbasin. Table A2.F.d-17 shows the average net recharge from the SWS for 1989-2014 based on the historical water budget, and Table A2.F.d-18 shows the same for the current water budget. Historically, the average net recharge in SVMWC was approximately -2.8 taf per year between 1989 and 2014. Under current land use conditions, the average net recharge in SVMWC is approximately -3.7 taf, indicating shortage conditions.

Table A2.F.d-17. Historical Water Budget: Average Net Recharge from SWS by Water Year Type, 1989-2014 (Acre-Feet).

Year Type	Number of Years	Infiltration of Applied Water (a)	Infiltration of Precipitation (b)	Infiltration of Surface Water[1] (c)	Groundwater Extraction (d)	Net Recharge from SWS (a+b+c-d)
W	8	3,580	1,770	5,000	9,180	1,170
AN	3	3,480	1,030	4,240	10,170	-1,420
BN	2	3,720	770	2,300	10,950	-4,160
D	4	3,860	820	2,470	12,220	-5,070
C	9	3,530	930	1,400	11,290	-5,430
Annual Average (1989-2014)	26	3,600	1,170	3,070	10,630	-2,790

[1] Includes infiltration from flood releases along Chowchilla River and runoff of precipitation in SVMWC, and 70% of non-flood releases along Chowchilla River reach C-2. To calculate Net Recharge from SWS below, Rivers and Streams System seepage from flood releases and runoff of precipitation is summed across the subbasin and redistributed to each subregion in proportion to gross area

Table A2.F.d-18. Current Water Budget: Average Net Recharge from SWS by Water Year Type (Acre-Feet).

Year Type	Number of Years	Infiltration of Applied Water (a)	Infiltration of Precipitation (b)	Infiltration of Surface Water[1] (c)	Groundwater Extraction (d)	Net Recharge from SWS (a+b+c-d)
W	8	3,520	1,660	4,970	9,840	310
AN	3	3,250	940	4,230	10,650	-2,230
BN	2	3,520	680	2,290	11,690	-5,200
D	4	3,570	740	2,460	12,610	-5,840
C	9	3,630	880	1,360	12,430	-6,560
Annual Average (1989-2014)	26	3,540	1,090	3,040	11,400	-3,730

[1] Includes infiltration from flood releases along Chowchilla River and runoff of precipitation in SVMWC, and 70% of non-flood releases along Chowchilla River reach C-2. To calculate Net Recharge from SWS below, Rivers and Streams System seepage from flood releases and runoff of precipitation is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.6 Uncertainties in Water Budget Components

Uncertainties associated with each water budget component were estimated as a percentage representing approximately a 95% confidence interval following the procedure described by Clemmens and Burt (1997). Uncertainties for all independently measured or estimated water budget components were estimated based on the measurement accuracy, typical values reported in technical literature, typical values calculated in other water budgets, and professional judgement.

Table A2.F.d-19 provides a summary of typical uncertainty values associated with major SWS inflow and outflow 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 A2.F.d-19. Estimated Uncertainty of Subregion Water Budget Components.

Flowpath Direction (SWS Boundary)	Water Budget Component	Data Source	Estimated Uncertainty (%)	Source
Inflows	Surface Water Inflows	Measurement	20%	Estimated streamflow measurement accuracy and adjustment for losses.
	Precipitation	Calculation	30%	Clemmens, A.J. and C.M. Burt, 1997.
	Groundwater Extraction	Closure	20%	Typical uncertainty calculated for Land Surface System water balance closure.
Outflows	Surface Water Outflows	Closure	20%	Typical uncertainty calculated for Rivers and Streams System water balance closure.
	Evaporation	Calculation	20%	Estimated accuracy of calculation based on CIMIS reference ET and free water surface evaporation coefficient.
	ET of Applied Water	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, estimated crop coefficients from SEBAL energy balance, and annual land use.
	ET of Precipitation	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, precipitation, estimated crop coefficients from SEBAL energy balance, and annual land use.
	Infiltration of Applied Water	Calculation	20%	Estimated accuracy of daily IDC root zone water budget component based on annual land use and NRCS soils characteristics.
	Infiltration of Precipitation	Calculation	20%	Estimated accuracy of daily IDC root zone water budget component based on annual land use, NRCS soils characteristics, and CIMIS precipitation.
	Infiltration of Surface Water	Calculation	15%	Estimated accuracy of daily seepage calculation using NRCS soils characteristics and calculated runoff of precipitation.
	Change in SWS Storage	Calculation	50%	Professional Judgment.
Net Recharge from SWS		Calculation	25%	Estimated water budget accuracy; typical value calculated for subregion-level net recharge from SWS.

APPENDIX 2.F. WATER BUDGET INFORMATION

2.F.e. Surface Water System Water Budget: Triangle T Water District GSA

Prepared as part of the

Groundwater Sustainability Plan
Chowchilla Subbasin

January 2020

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1 INTRODUCTION

To ensure sustainable groundwater management throughout California's groundwater basins, the Sustainable Groundwater Management Act of 2014 (SGMA) requires Groundwater Sustainability Agencies (GSAs) to prepare and adopt Groundwater Sustainability Plans (GSPs) with strategies to achieve subbasin groundwater sustainability within 20 years of plan adoption. Integral to each GSP is a water budget used to quantify the subbasin's groundwater overdraft (if applicable) and sustainable yield.

In 2017, Triangle T Water District (TTWD) GSA formed to manage approximately 14,700 acres of the Chowchilla Subbasin. This document presents results of the surface water system (SWS) water budgets developed for historical and current land use conditions in TTWD GSA. The TTWD GSA water budgets were integrated with separate water budgets developed for four (4) other subregions covering the remainder of the Chowchilla Subbasin. Together, these water budgets provide the boundary water budget for the Chowchilla Subbasin SWS. Results of the subbasin boundary water budget are reported in the Chowchilla Subbasin GSP Section 2.2.3 and were integrated with a subbasin groundwater model (GSP Appendix 6.E) to estimate subbasin sustainable yield (GSP Section 2.2.3).

2 WATER BUDGET CONCEPTUAL MODEL

A water budget is defined as a complete accounting of all water flowing into and out of a defined volume (e.g., a subbasin or a GSA) over a specified period of time. The conceptual model (or structure) of the TTWD GSA water budget developed for this investigation is consistent with the GSP Regulations defined under Title 23 of California Code of Regulations[1] (CCR) and adheres to sound water budget principles and practices defined by California Department of Water Resources (DWR) in the Water Budget Best Management Practice (BMP) guidelines (DWR, 2016).

The lateral extent of TTWD GSA is defined by the boundaries indicated in Figure A2.F.e-1. The vertical extent of TTWD GSA is the land surface (top) and the base of fresh water at the bottom of the basin (bottom), as described in the hydrogeologic conceptual model (HCM) developed in GSP Section 2.2.1. The vertical extent of Chowchilla Subbasin and its GSAs is subdivided into a surface water system (SWS) and the underlying groundwater system (GWS), with separate but related water budgets prepared for each that together represent the overall subbasin water budget.

A conceptual representation of the TTWD GSA water budget is represented in Figure A2.F.e-2. This document details only the SWS portion of the TTWD GSA water budget. The SWS is divided into two primary accounting centers: the Land Surface System and the Rivers and Streams System. The Land Surface System is further divided into three accounting centers representing the subregion water use sectors: Agricultural Land, Native Vegetation Land, and Urban Land (urban, industrial, and semi-agricultural).

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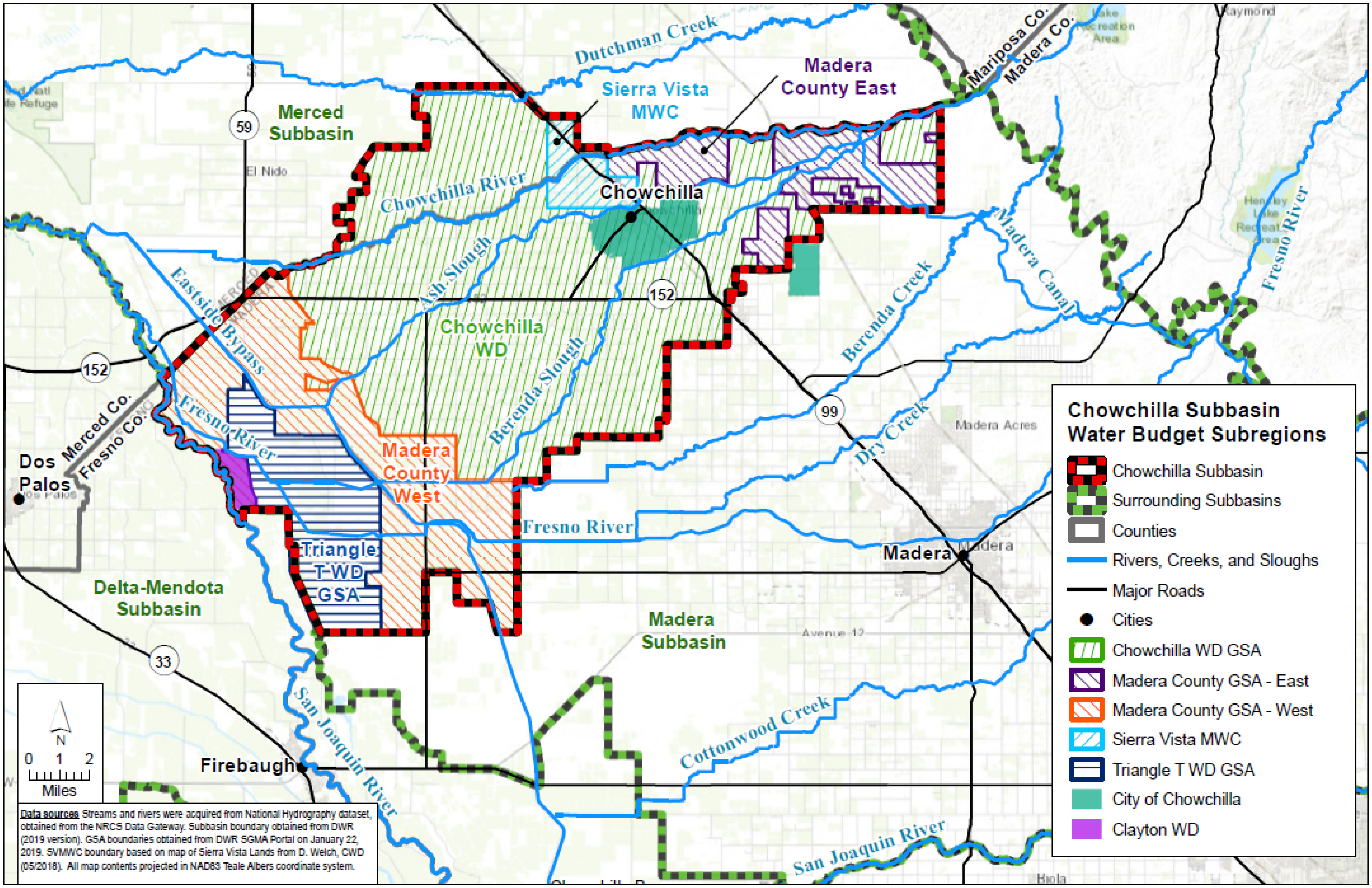
[1] California Code of Regulations Title 23. Waters, Division 2. Department of Water Resources, Chapter 1.5. Groundwater Management, Subchapter 2. Groundwater Sustainability Plans.



<u>Data sources</u> Streams and rivers were acquired from National Hydrography dataset, obtained from the NRCS Data Gateway. Subbasin boundary obtained from DWR (2019 version). GSA boundaries obtained from DWR SGMA Portal on January 22, 2019. SVMWC boundary based on map of Sierra Vista Lands from D. Welch, CWD (05/2018). All map contents projected in NAD83 Teale Albers coordinate system.

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Chowchilla Subbasin Water Budget Subregion Map

Chowchilla Subbasin Groundwater Sustainability Plan

Figure A2.F.e-1. Chowchilla Subbasin Water Budget Subregion Map

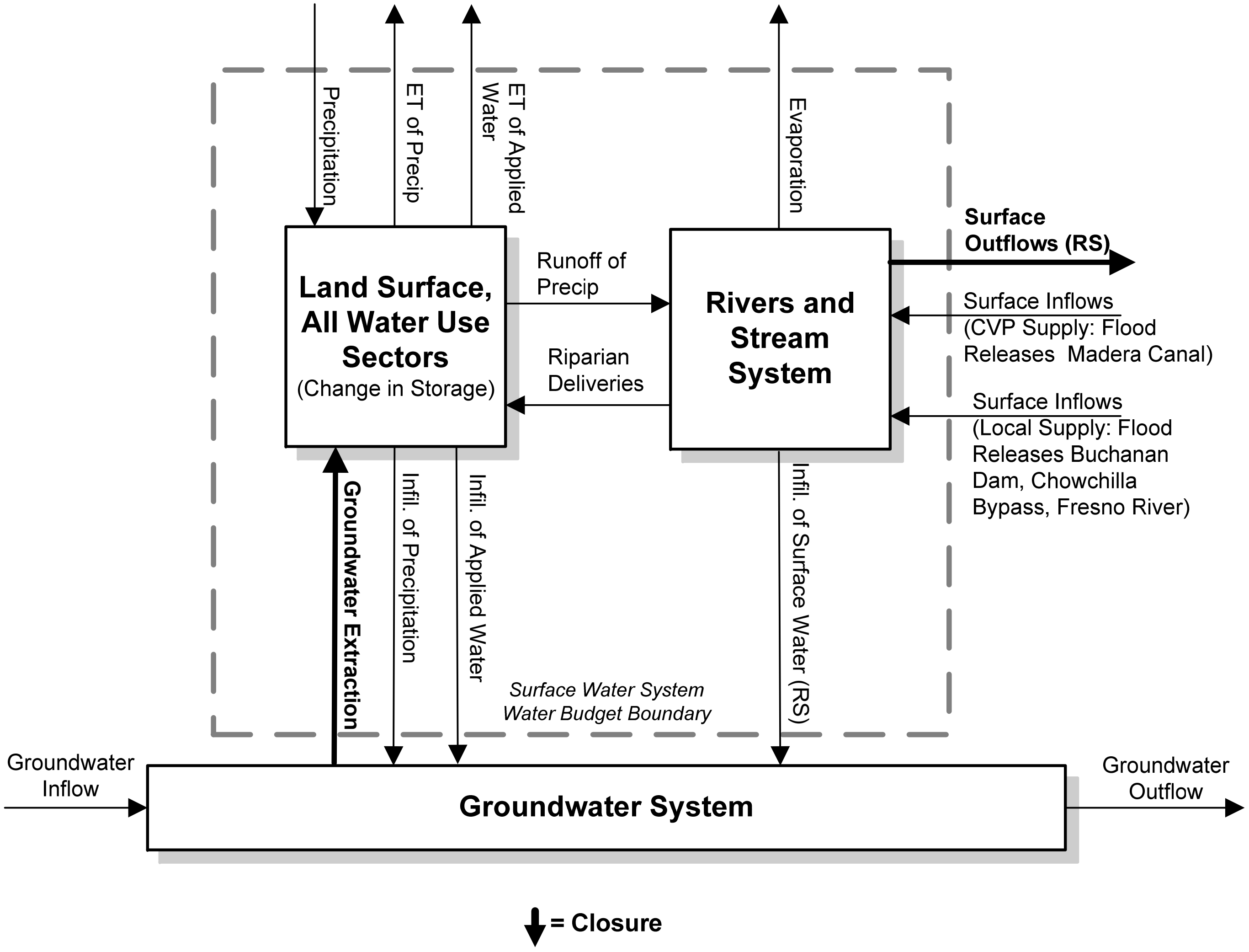

Figure A2.F.e-2. Triangle T Water District GSA Water Budget Structure

Water budget components, or directional flow of water between accounting centers and across the SWS boundary, are indicated by arrows. Inflows and outflows were calculated using measurements and other historical data or were calculated as the water budget closure term – the difference between all other estimated or measured inflows and outflows from each accounting center or water use sector (bold arrows).

Inflows to the SWS include precipitation, surface water inflows (in various canals and streams), and groundwater extraction. Outflows from the SWS include evapotranspiration (ET), surface water outflows (in various canals and streams), and infiltration to the groundwater system (seepage and deep percolation). Also represented in Figure A2.F.e-2 are inflows and outflows from the GWS, which are discussed and quantified at the subbasin level in the GWS water budget in GSP Section 2.2.3. Subsurface GWS inflows and outflows are not quantified on the water budget subregion scale.

Inflows and outflows were quantified following the process described in GSP Section 2.2.3 on a monthly time step for water years in the historical water budget base period (1989-2014 hydrologic and land use conditions), the current water budget (2015 land use using 1989-2014 average hydrologic conditions), and projected water budget. Four projected water budgets were prepared for the years 2019 through 2090 based on 1965 through 2015 hydrologic conditions, projected water supplies, and 2017 land use adjusted for urban area projected growth from 2017-2070 (areas were held constant from 2071-2090):

1. Historical hydrologic conditions and water supply data, with adjustment for projected alteration of available Friant releases by the San Joaquin River Restoration Program (SJRRP)[2]
   a. Without projects and management actions, and
   b. With projects and management actions
2. Historical hydrologic conditions and water supply data, with adjustment for projected alteration of available Friant releases by the SJRRP and adjustment for anticipated climate change per DWR-provided 2030 climate change factors
   a. Without projects and management actions, and
   b. With projects and management actions.

Information regarding the data sources and adjustments used to prepare the historical, current, and projected water budgets are described in GSP Section 2.2.3.

3 WATER BUDGET ANALYSIS

The historical water budget and current land use water budget for TTWD GSA are presented below following a summary of land use data relevant to water budget development. Land use data is provided for the 1989-2014 historical water budget period and for 2015, the current land use water budget period.

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[2] Adjustments were based on the Friant Report ("Estimate of Future Friant Division Supplies for use in Groundwater Sustainability Plans, California," Friant Water Authority, 2018). Although the Friant Report accounts for climate change, it is considered the best available estimate of projected Friant releases under SJRRP. For comparison, projected Madera Canal deliveries under SJRRP were also estimated without account for climate change from the Kondolf Hydrographs (in "Effects to Water Supply and Friant Operations Resulting From Plaintiffs' Friant Release Requirements," Steiner, 2005). These estimates were approximately equal to the Friant Report 2030 climate change adjusted deliveries. Thus, the Friant Report projections were used instead to maintain consistent assumptions in estimating Madera Canal deliveries across all projected simulations.

3.1 Land Use

Land use estimates for 1989 through 2015 corresponding to water use sectors (as defined by the GSP Regulations) are summarized in Figure A2.F.e-3 and Table A2.F.e-1 for the TTWD GSA. According to GSP Regulations (23 CCR § 351(al)):

> *"Water use sector" refers to 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.*

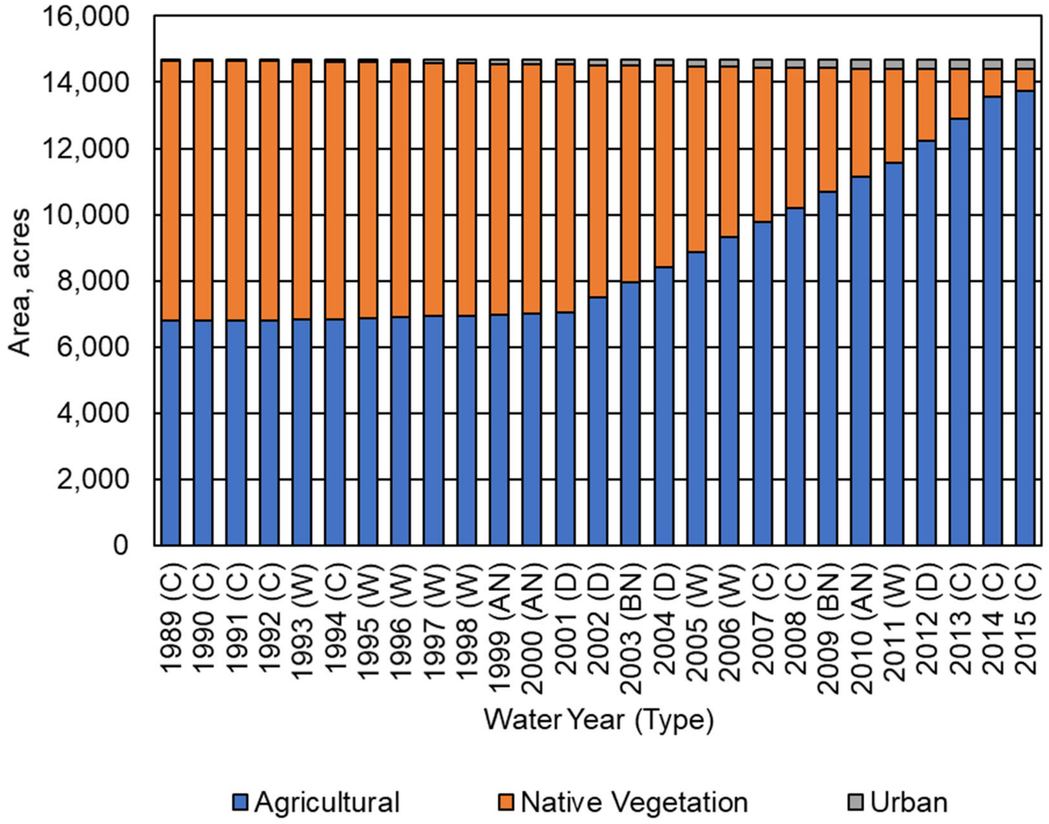

Figure A2.F.e-3. Triangle T Water District GSA Land Use Areas

Table A2.F.e-1. Triangle T Water District GSA Land Use Areas, acres

Water Year (Type)	Agricultural	Native Vegetation[1]	Urban[2]	Total
1989 (C)	6,792	7,844	55	14,691
1990 (C)	6,809	7,825	56	14,691
1991 (C)	6,813	7,819	58	14,691
1992 (C)	6,815	7,814	61	14,691
1993 (W)	6,825	7,801	64	14,691
1994 (C)	6,842	7,780	69	14,691
1995 (W)	6,872	7,745	74	14,691

Water Year (Type)	Agricultural	Native Vegetation[1]	Urban[2]	Total
1996 (W)	6,898	7,704	89	14,691
1997 (W)	6,924	7,663	104	14,691
1998 (W)	6,950	7,622	119	14,691
1999 (AN)	6,976	7,580	134	14,691
2000 (AN)	7,002	7,539	149	14,691
2001 (D)	7,029	7,498	164	14,691
2002 (D)	7,484	7,030	177	14,691
2003 (BN)	7,938	6,563	190	14,691
2004 (D)	8,393	6,095	202	14,691
2005 (W)	8,849	5,626	215	14,691
2006 (W)	9,304	5,159	228	14,691
2007 (C)	9,759	4,691	241	14,691
2008 (C)	10,214	4,223	253	14,691
2009 (BN)	10,670	3,754	266	14,691
2010 (AN)	11,125	3,287	279	14,691
2011 (W)	11,580	2,819	292	14,691
2012 (D)	12,243	2,159	288	14,691
2013 (C)	12,908	1,498	285	14,691
2014 (C)	13,571	838	281	14,691
2015 (C)	13,746	671	273	14,691
Average (1989-2014)	8,600	5,922	169	14,691

[1] Area includes land classified as native vegetation and water surfaces.

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

In TTWD GSA, water use sectors include agricultural, native vegetation, and urban land use. The urban land use category includes urban and semi-agricultural[3] lands as well as industrial land, which covers only a small area in the subbasin.

As indicated, the majority of land in TTWD GSA is currently used for agriculture, covering approximately 13,700 acres in 2015. Much of this land has gone into agricultural production since the early 2000s, largely replacing native vegetation in the GSA.

Agricultural land uses are further detailed in Figure A2.F.e-4 and Table A2.F.e-2. In the 1990s, a majority of the agricultural area in TTWD GSA was used to cultivate alfalfa, mixed pasture, and miscellaneous field crops. In recent years, these crops have been increasingly replaced by orchard crops, which expanded from less than 100 acres in 1989 to over 11,000 acres in 2015.

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[3] As defined in the DWR county land use surveys, 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, 2009).

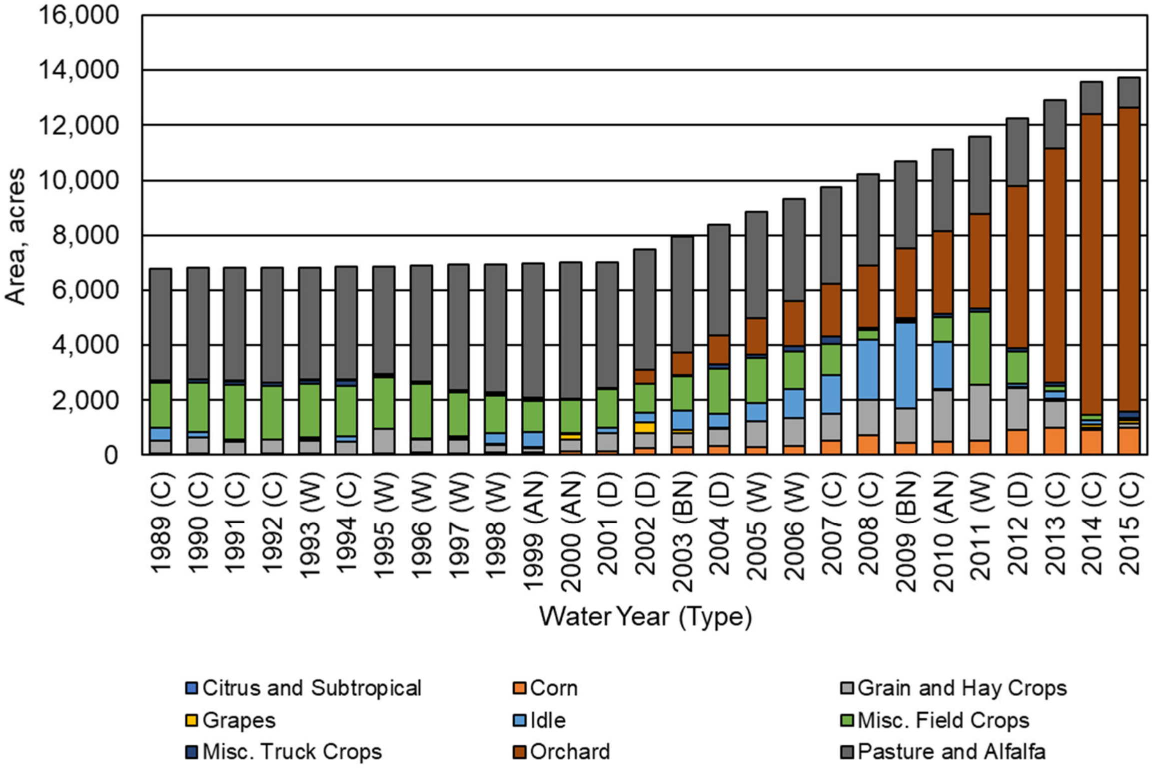

Figure A2.F.e-4. Triangle T Water District GSA Agricultural Land Use Areas

Table A2.F.e-2. Triangle T Water District GSA Agricultural Land Use Areas

Water Year (Type)	Citrus and Subtropical	Corn	Grain and Hay Crops	Grapes	Idle	Misc. Field Crops	Misc. Truck Crops	Orchard	Pasture and Alfalfa	Total
1989 (C)	0	45	463	5	473	1,643	65	16	4,083	6,792
1990 (C)	0	38	593	5	220	1,767	124	17	4,044	6,809
1991 (C)	0	35	439	5	96	1,989	116	21	4,111	6,813
1992 (C)	0	38	514	6	24	1,925	129	16	4,162	6,815
1993 (W)	0	40	500	6	89	1,964	127	16	4,082	6,825
1994 (C)	0	37	456	6	166	1,872	183	16	4,105	6,842
1995 (W)	0	38	905	7	12	1,886	72	16	3,935	6,872
1996 (W)	0	77	502	7	26	1,976	64	20	4,225	6,898
1997 (W)	5	59	509	16	75	1,616	78	24	4,543	6,924
1998 (W)	0	86	301	7	396	1,369	82	28	4,682	6,950
1999 (AN)	0	104	131	75	509	1,172	66	32	4,888	6,976
2000 (AN)	4	127	426	214	14	1,207	12	44	4,954	7,002
2001 (D)	0	118	677	7	201	1,410	1	39	4,576	7,029
2002 (D)	9	247	545	397	325	1,069	18	477	4,398	7,484
2003 (BN)	0	278	532	124	683	1,253	53	795	4,220	7,938
2004 (D)	0	313	643	37	508	1,623	183	1,043	4,043	8,393
2005 (W)	0	295	920	13	661	1,631	139	1,326	3,865	8,849
2006 (W)	0	350	985	3	1,052	1,386	206	1,635	3,687	9,304
2007 (C)	0	545	943	3	1,421	1,117	287	1,932	3,510	9,759
2008 (C)	0	730	1,279	12	2,194	349	54	2,263	3,332	10,214
2009 (BN)	0	452	1,248	2	3,125	57	104	2,528	3,155	10,670
2010 (AN)	0	499	1,879	11	1,746	898	121	2,994	2,977	11,125
2011 (W)	0	532	2,043	0	1	2,643	130	3,431	2,799	11,580
2012 (D)	0	921	1,505	36	137	1,167	128	5,888	2,461	12,243
2013 (C)	0	993	979	72	271	221	115	8,490	1,767	12,908
2014 (C)	0	900	108	108	155	189	11	10,925	1,174	13,571
2015 (C)	0	1,004	136	126	70	3	232	11,051	1,126	13,746
Average (1989-2014)	1	304	770	46	561	1,362	103	1,694	3,761	8,600

3.2 Surface Water System Water Budget

This section presents surface water system water budget components within TTWD GSA as per GSP regulations. These are followed by a summary of the water budget results by accounting center.

3.2.1 Inflows

3.2.1.1 Surface Water Inflow by Water Source Type

Surface water inflows include surface water flowing into TTWD GSA across the subregion boundary. Per the Regulations, surface inflows must be reported by water source type. According to the Regulations:

> *"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.*

Additionally, runoff of precipitation from upgradient areas adjacent to the subregion represents a potential source of surface water inflow.

Local Supplies

Local supply inflows to TTWD GSA include inflows along Fresno River and Chowchilla Bypass.

CVP Supplies

CVP supply inflows to TTWD GSA include flood releases from Buchanan Dam and Millerton Reservoir that enter the subregion along Berenda Slough.

Recycling and Reuse

Recycling and reuse are not a significant source of supply within TTWD GSA.

Other Surface Inflows

For the water budgets presented herein, precipitation runoff from outside the subregion is considered relatively minimal and is expected to pass through the waterways accounted above following relatively large storm events. Precipitation runoff from lands inside the subregion is internal to the surface water system and is thus not considered as surface inflows to the subregion boundary.

Summary of Surface Inflows

The surface water inflows described above are summarized by water source type in Figure A2.F.e-5 and Table A2.F.e-3. During the study period, total surface water inflows vary by water year type, averaging 747 thousand acre-feet (taf) per wet year.

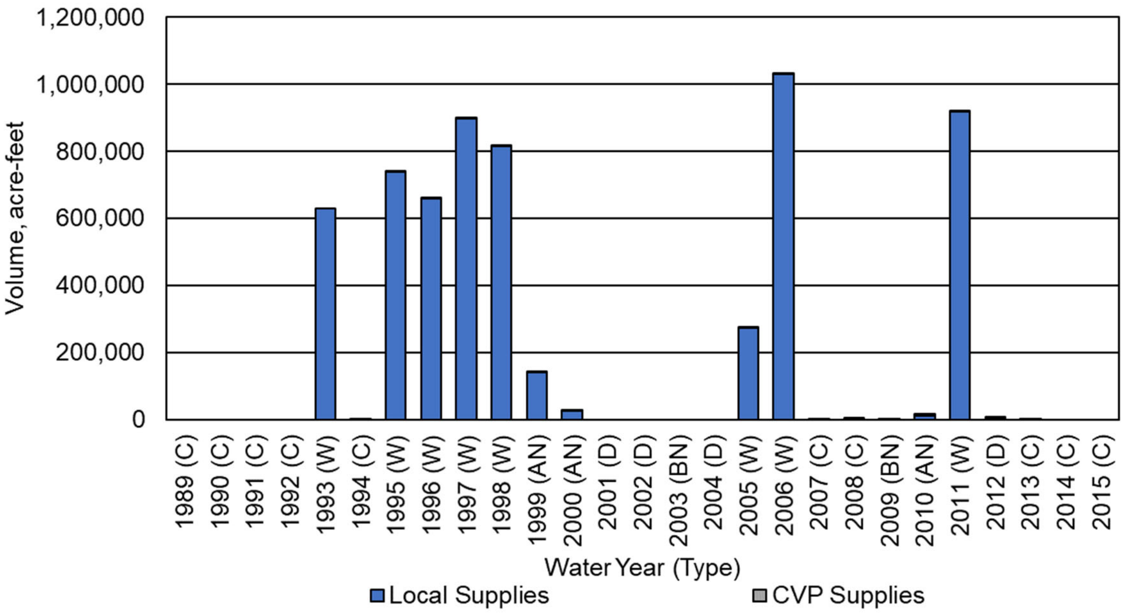

Figure A2.F.e-5. Triangle T Water District GSA Surface Water Inflows by Water Source Type.

Table A2.F.e-3. Triangle T Water District GSA Surface Water Inflows by Water Source Type (Acre-Feet).

Water Year (Type)	Local Supply	CVP Supply[1]	Total
1989 (C)	0	0	0
1990 (C)	0	0	0
1991 (C)	0	0	0
1992 (C)	0	0	0
1993 (W)	630,140	0	630,140
1994 (C)	0	870	870
1995 (W)	739,540	1,320	740,860
1996 (W)	660,590	900	661,490
1997 (W)	897,730	1,920	899,650
1998 (W)	815,570	2,820	818,390
1999 (AN)	141,120	660	141,780
2000 (AN)	27,460	270	27,730
2001 (D)	0	0	0
2002 (D)	0	0	0
2003 (BN)	0	0	0
2004 (D)	0	0	0
2005 (W)	274,160	360	274,520
2006 (W)	1,030,340	1,320	1,031,660
2007 (C)	3,380	0	3,380
2008 (C)	2,320	20	2,330
2009 (BN)	620	500	1,120

Water Year (Type)	Local Supply	CVP Supply[1]	Total
2010 (AN)	10,710	6,160	16,870
2011 (W)	916,970	2,620	919,590
2012 (D)	5,960	850	6,810
2013 (C)	1,040	510	1,550
2014 (C)	0	0	0
2015 (C)	0	0	0
Average (1989-2014)	236,830	810	237,640
Average (1989-2014) W	745,630	1,410	747,040
Average (1989-2014) AN	59,760	2,360	62,130
Average (1989-2014) BN	310	250	560
Average (1989-2014) D	1,490	210	1,700
Average (1989-2014) C	750	150	900

[1] CVP Supply is considered as all water supply released from CVP storage facilities. The volume of CVP Supply includes CVP deliveries to CWD, and flood releases from CVP facilities that pass through the subbasin. In Triangle T Water District GSA, all CVP supply pass through the GSA.

3.2.1.2 Precipitation

Precipitation estimates for TTWD GSA are provided in Figure A2.F.e-6 and Table A2.F.e- 4. Precipitation estimates are reported by water use sector.

Total precipitation is highly variable between years in the study area, ranging from approximately 9 taf (7 inches) during average dry years to 17 taf (14 inches) during average wet years.

3.2.1.3 Groundwater Extraction by Water Use Sector

Estimates of groundwater extraction by water use sector are provided in Figure A2.F.e-7 and Table A2.F.e-5. For agricultural and urban (urban, semi-agricultural, industrial) lands, groundwater extraction represents pumping, while for native lands, groundwater extraction by riparian vegetation was considered to be negligible. In all water use sector water budgets, groundwater extraction served as the water budget closure term. Groundwater extraction is dominated by irrigated agriculture and increases over time, following the trend of increasing orchard acreage in the subregion. The consumptive water use of orchards is higher than most other crops grown in the subbasin, and groundwater serves as a major source of supply for the pressurized irrigation systems typical of orchards. During wet years, groundwater extraction is reduced in months when surface water is available to water rights users.

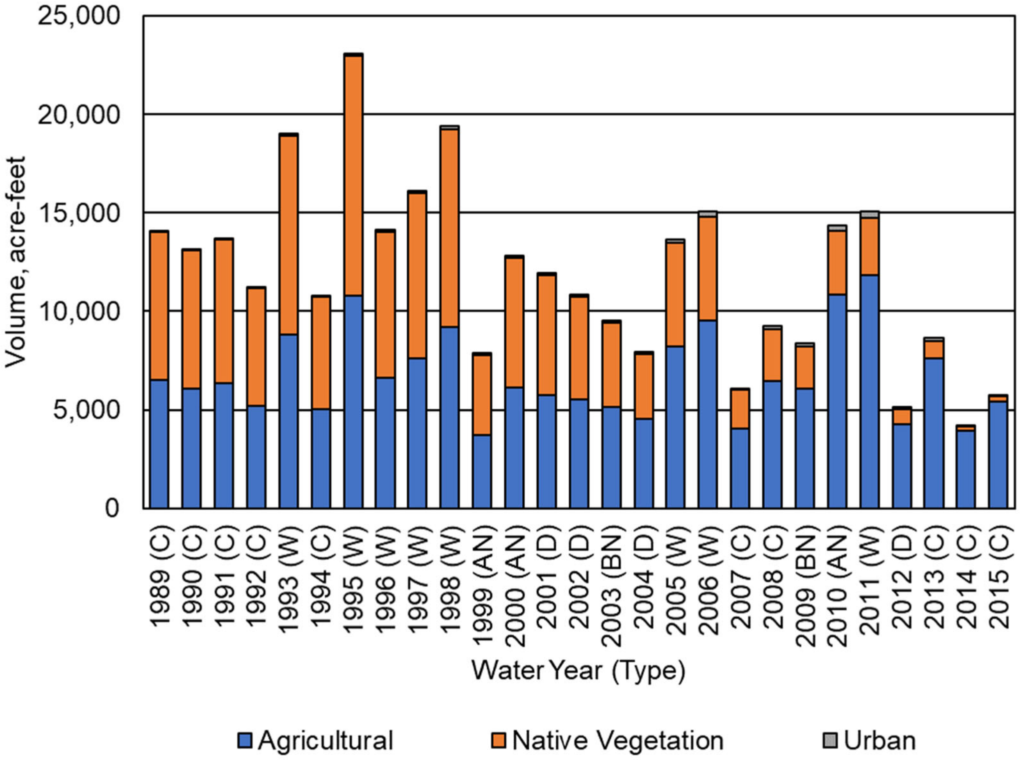

Figure A2.F.e-6. Triangle T Water District GSA Precipitation by Water Use Sector.

Table A2.F.e-4. Triangle T Water District GSA Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	6,510	7,530	50	14,090
1990 (C)	6,090	7,000	50	13,140
1991 (C)	6,370	7,310	60	13,730
1992 (C)	5,200	5,970	50	11,210
1993 (W)	8,830	10,100	80	19,010
1994 (C)	5,010	5,710	50	10,770
1995 (W)	10,810	12,190	120	23,110
1996 (W)	6,630	7,410	90	14,130
1997 (W)	7,610	8,420	110	16,140
1998 (W)	9,180	10,070	160	19,410
1999 (AN)	3,740	4,060	70	7,870
2000 (AN)	6,110	6,590	130	12,830
2001 (D)	5,730	6,110	130	11,970
2002 (D)	5,530	5,200	130	10,860
2003 (BN)	5,150	4,260	120	9,540
2004 (D)	4,530	3,290	110	7,930
2005 (W)	8,230	5,240	200	13,670
2006 (W)	9,530	5,290	230	15,060
2007 (C)	4,050	1,950	100	6,100
2008 (C)	6,440	2,670	160	9,260

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2009 (BN)	6,070	2,140	150	8,360
2010 (AN)	10,880	3,220	270	14,370
2011 (W)	11,860	2,890	300	15,050
2012 (D)	4,270	750	100	5,120
2013 (C)	7,610	880	170	8,660
2014 (C)	3,910	240	80	4,230
2015 (C)	5,400	260	110	5,770
Average (1989-2014)	6,760	5,250	130	12,140
Average (1989-2014) W	9,080	7,700	160	16,950
Average (1989-2014) AN	6,910	4,620	160	11,690
Average (1989-2014) BN	5,610	3,200	140	8,950
Average (1989-2014) D	5,010	3,840	120	8,970
Average (1989-2014) C	5,690	4,360	80	10,130

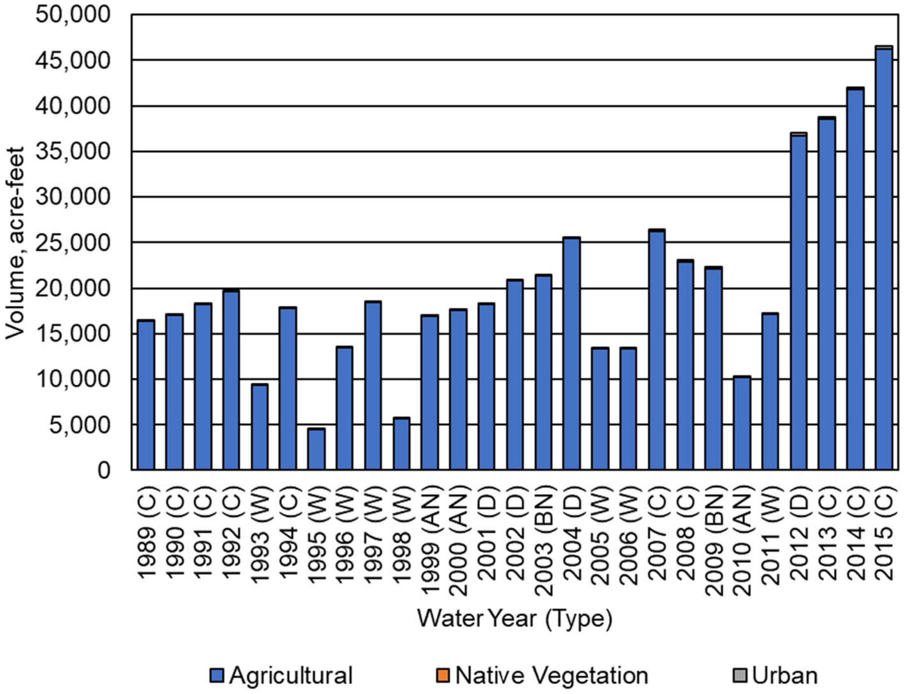

Figure A2.F.e-7. Triangle T Water District GSA Groundwater Extraction by Water Use Sector.

Table A2.F.e-5. Triangle T Water District GSA Groundwater Extraction by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	16,394	0	31	16,425
1990 (C)	17,065	0	33	17,098
1991 (C)	18,175	0	39	18,214
1992 (C)	19,632	0	47	19,679
1993 (W)	9,383	0	36	9,419
1994 (C)	17,755	0	48	17,803
1995 (W)	4,526	0	24	4,550
1996 (W)	13,425	0	50	13,475
1997 (W)	18,475	0	92	18,567
1998 (W)	5,703	0	50	5,753
1999 (AN)	16,940	0	97	17,037
2000 (AN)	17,613	0	91	17,704
2001 (D)	18,213	0	98	18,311
2002 (D)	20,786	0	135	20,921
2003 (BN)	21,344	0	137	21,481
2004 (D)	25,414	0	190	25,604
2005 (W)	13,324	0	119	13,443
2006 (W)	13,319	0	120	13,439
2007 (C)	26,217	0	212	26,429
2008 (C)	22,910	0	211	23,121
2009 (BN)	22,076	0	215	22,291
2010 (AN)	10,222	0	120	10,342
2011 (W)	17,120	0	134	17,254
2012 (D)	36,765	0	252	37,017
2013 (C)	38,526	0	243	38,769
2014 (C)	41,814	0	239	42,053
2015 (C)	46,248	0	264	46,512
Average (1989-2014)	19,351	0	118	19,469
Average (1989-2014) W	11,909	0	78	11,988
Average (1989-2014) AN	14,925	0	103	15,027
Average (1989-2014) BN	21,710	0	176	21,886
Average (1989-2014) D	25,295	0	169	25,463
Average (1989-2014) C	24,276	0	123	24,399

3.2.1.4 Groundwater Discharge to Surface Water Sources

The depth to groundwater is greater than 100-200 ft across much of the Chowchilla Subbasin. Given the depth to the water table in the Chowchilla Subbasin, groundwater discharge to surface water sources is negligible.

3.2.2 Outflows

3.2.2.1 Evapotranspiration by Water Use Sector

Evapotranspiration (ET) by water use sector is reported in Figures A2.F.e-8 to A2.F.e-10 and Tables A2.F.e-6 to A2.F.e-8. First, total ET is reported, followed by ET from applied water and ET from precipitation.

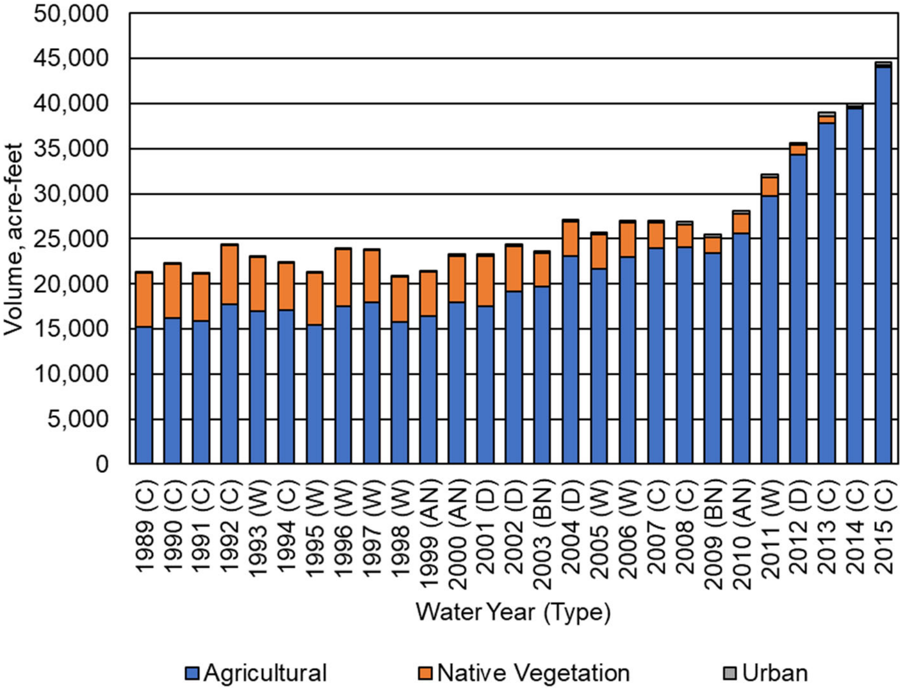

Figure A2.F.e-8. Triangle T Water District GSA Evapotranspiration by Water Use Sector.

Table A2.F.e-6. Triangle T Water District GSA Evapotranspiration by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	15,240	5,940	70	21,250
1990 (C)	16,200	5,980	70	22,250
1991 (C)	15,850	5,320	70	21,240
1992 (C)	17,770	6,560	80	24,410
1993 (W)	16,930	6,090	80	23,100
1994 (C)	17,050	5,240	80	22,370
1995 (W)	15,480	5,790	80	21,350
1996 (W)	17,510	6,320	100	23,930
1997 (W)	17,970	5,720	120	23,810
1998 (W)	15,720	5,030	120	20,870
1999 (AN)	16,460	4,850	140	21,450
2000 (AN)	17,950	5,180	170	23,300
2001 (D)	17,480	5,590	190	23,260
2002 (D)	19,130	5,010	210	24,350

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2003 (BN)	19,700	3,710	220	23,630
2004 (D)	23,050	3,800	260	27,110
2005 (W)	21,690	3,790	240	25,720
2006 (W)	22,940	3,850	260	27,050
2007 (C)	23,960	2,810	270	27,040
2008 (C)	24,070	2,480	310	26,860
2009 (BN)	23,360	1,800	310	25,470
2010 (AN)	25,550	2,210	300	28,060
2011 (W)	29,700	2,110	310	32,120
2012 (D)	34,350	1,020	290	35,660
2013 (C)	37,800	830	340	38,970
2014 (C)	39,430	250	280	39,960
2015 (C)	44,010	230	310	44,550
Average (1989-2014)	21,630	4,130	190	25,950
Average (1989-2014) W	19,740	4,840	170	24,750
Average (1989-2014) AN	19,990	4,080	200	24,270
Average (1989-2014) BN	21,540	2,750	270	24,560
Average (1989-2014) D	23,500	3,850	230	27,580
Average (1989-2014) C	23,040	3,930	180	27,150

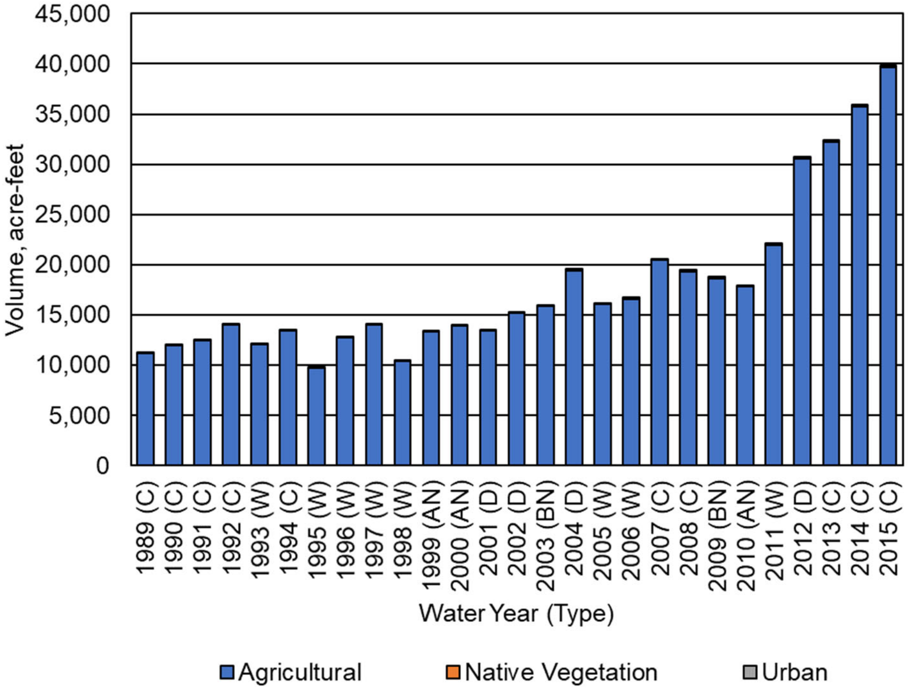

Figure A2.F.e-9. Triangle T Water District GSA Evapotranspiration of Applied Water by Water Use Sector.

Table A2.F.e-7. Triangle T Water District GSA Evapotranspiration of Applied Water by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	11,200	0	30	11,230
1990 (C)	11,960	0	30	11,990
1991 (C)	12,450	0	30	12,480
1992 (C)	14,060	0	40	14,100
1993 (W)	12,050	0	30	12,080
1994 (C)	13,470	0	40	13,510
1995 (W)	9,690	0	20	9,710
1996 (W)	12,730	0	30	12,760
1997 (W)	14,020	0	50	14,070
1998 (W)	10,400	0	50	10,450
1999 (AN)	13,360	0	60	13,420
2000 (AN)	13,900	0	80	13,980
2001 (D)	13,390	0	80	13,470
2002 (D)	15,180	0	100	15,280
2003 (BN)	15,850	0	120	15,970
2004 (D)	19,440	0	150	19,590
2005 (W)	16,040	0	110	16,150
2006 (W)	16,610	0	110	16,720
2007 (C)	20,470	0	140	20,610
2008 (C)	19,350	0	180	19,530
2009 (BN)	18,580	0	190	18,770
2010 (AN)	17,830	0	130	17,960
2011 (W)	21,990	0	110	22,100
2012 (D)	30,550	0	160	30,710
2013 (C)	32,260	0	200	32,460
2014 (C)	35,700	0	200	35,900
2015 (C)	39,670	0	220	39,890
Average (1989-2014)	17,020	0	90	17,110
Average (1989-2014) W	14,190	0	70	14,260
Average (1989-2014) AN	15,030	0	90	15,120
Average (1989-2014) BN	17,220	0	160	17,380
Average (1989-2014) D	19,640	0	120	19,760
Average (1989-2014) C	18,990	0	100	19,090

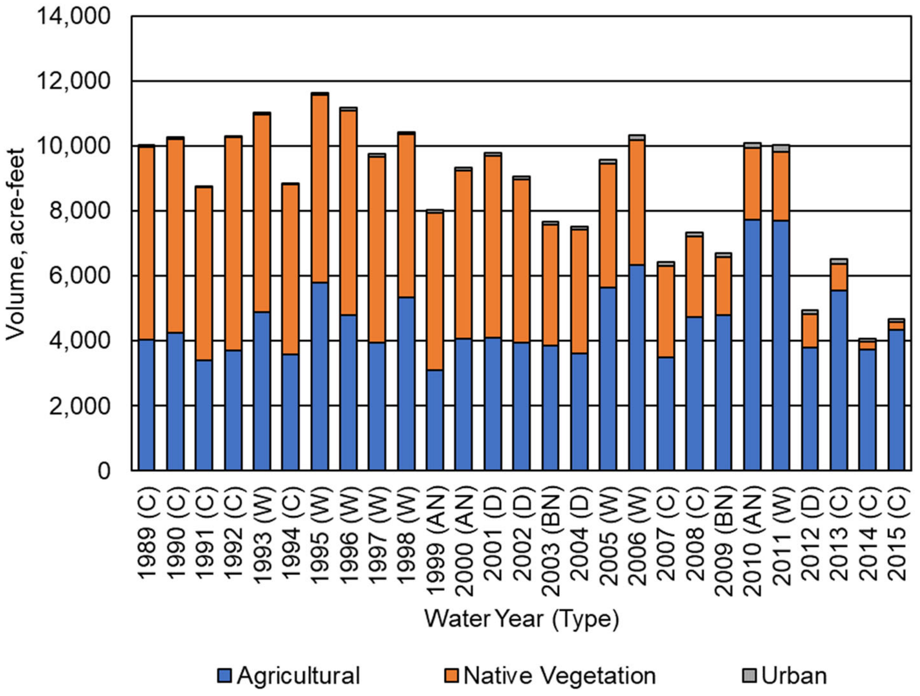

Figure A2.F.e-10. Triangle T Water District GSA Evapotranspiration of Precipitation by Water Use Sector.

Table A2.F.e-8. Triangle T Water District GSA Evapotranspiration of Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	4,040	5,940	40	10,020
1990 (C)	4,240	5,980	40	10,260
1991 (C)	3,400	5,320	40	8,760
1992 (C)	3,710	6,560	40	10,310
1993 (W)	4,880	6,090	50	11,020
1994 (C)	3,580	5,240	40	8,860
1995 (W)	5,790	5,790	60	11,640
1996 (W)	4,780	6,320	70	11,170
1997 (W)	3,950	5,720	70	9,740
1998 (W)	5,320	5,030	70	10,420
1999 (AN)	3,100	4,850	80	8,030
2000 (AN)	4,050	5,180	90	9,320
2001 (D)	4,090	5,590	110	9,790
2002 (D)	3,950	5,010	110	9,070
2003 (BN)	3,850	3,710	100	7,660
2004 (D)	3,610	3,800	110	7,520
2005 (W)	5,650	3,790	130	9,570
2006 (W)	6,330	3,850	150	10,330
2007 (C)	3,490	2,810	130	6,430
2008 (C)	4,720	2,480	130	7,330
2009 (BN)	4,780	1,800	120	6,700
2010 (AN)	7,720	2,210	170	10,100

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
2011 (W)	7,710	2,110	200	10,020
2012 (D)	3,800	1,020	130	4,950
2013 (C)	5,540	830	140	6,510
2014 (C)	3,730	250	80	4,060
2015 (C)	4,340	230	90	4,660
Average (1989-2014)	4,610	4,130	100	8,840
Average (1989-2014) W	5,550	4,840	100	10,490
Average (1989-2014) AN	4,960	4,080	110	9,150
Average (1989-2014) BN	4,320	2,750	110	7,180
Average (1989-2014) D	3,860	3,850	110	7,820
Average (1989-2014) C	4,050	3,930	80	8,060

Total ET varies between years, with the lowest observed in 1998, at less than 21 taf, and greatest in 2015, at approximately 45 taf. Total ET generally increases over time, again following the trend of increasing orchard acreage.

In addition to ET from land surfaces, estimates of evaporation from TTWD GSA rivers and streams are reported in Figure A2.F.e-11 and Table A2.F.e-9. Evaporation from the Rivers and Streams System includes evaporation of both surface inflows and of precipitation runoff within local sloughs and depressions. Total evaporation from all sources averaged less than 1 taf per year between 1989 and 2014.

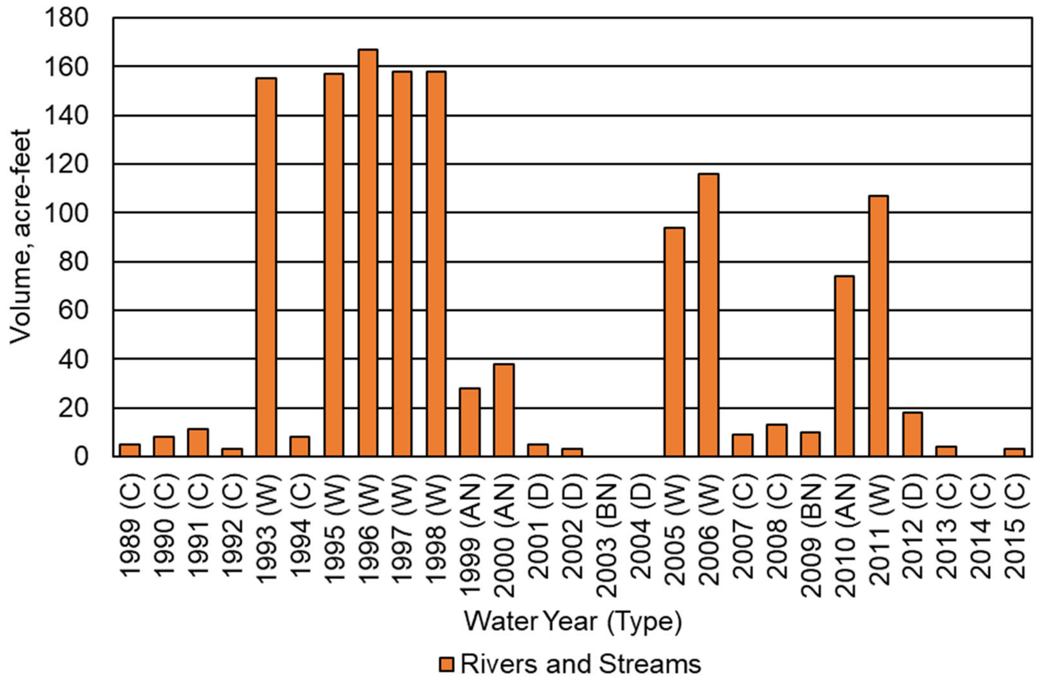

Figure A2.F.e-11. Triangle T Water District GSA Evaporation from the Surface Water System.

Table A2.F.e-9. Triangle T Water District GSA Evaporation from the Surface Water System (Acre-Feet).

Water Year (Type)	Rivers and Streams[1]
1989 (C)	10
1990 (C)	10
1991 (C)	10
1992 (C)	0
1993 (W)	160
1994 (C)	10
1995 (W)	160
1996 (W)	170
1997 (W)	160
1998 (W)	160
1999 (AN)	30
2000 (AN)	40
2001 (D)	10
2002 (D)	0
2003 (BN)	0
2004 (D)	0
2005 (W)	90
2006 (W)	120
2007 (C)	10
2008 (C)	10
2009 (BN)	10
2010 (AN)	70
2011 (W)	110
2012 (D)	20
2013 (C)	0
2014 (C)	0
2015 (C)	0
Average (1989-2014)	50
Average (1989-2014) W	140
Average (1989-2014) AN	50
Average (1989-2014) BN	10
Average (1989-2014) D	10
Average (1989-2014) C	10

[1] Includes evaporation of surface inflows and of precipitation runoff.

3.2.2.2 Surface Water Outflow by Water Source Type

Surface water outflows by water source type are summarized in Figure A2.F.e-12 and Table A2.F.e-10. In TTWD GSA, runoff of applied water is assumed negligible and runoff of precipitation is collected in waterways within TTWD GSA, with most infiltrating to the groundwater system except following the largest storm events. Thus, surface outflows from the GSA are expected to be a mixture of local supplies and CVP supplies along Eastside Bypass and Fresno River. Between 1989 and 2014, these combined outflows averaged approximately 726 taf during wet years.

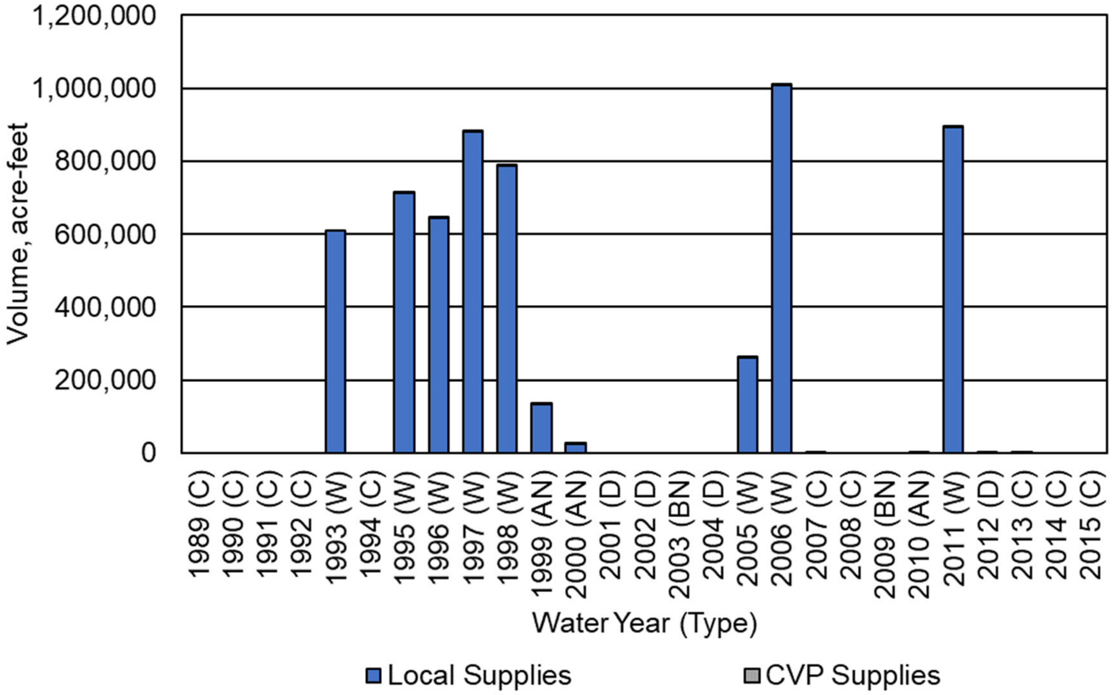

Figure A2.F.e-12. Triangle T Water District GSA Surface Outflows by Water Source Type.

Table A2.F.e-10. Triangle T Water District GSA Surface Outflows by Water Source Type (Acre-Feet).

Water Year (Type)	Local Supplies	CVP Supplies	Total
1989 (C)	0	0	0
1990 (C)	0	0	0
1991 (C)	0	0	0
1992 (C)	0	0	0
1993 (W)	609,400	0	609,400
1994 (C)	0	0	0
1995 (W)	712,830	1,280	714,110
1996 (W)	642,890	840	643,730
1997 (W)	882,030	1,870	883,900
1998 (W)	786,740	2,690	789,430
1999 (AN)	134,560	640	135,200
2000 (AN)	23,670	250	23,920
2001 (D)	0	0	0
2002 (D)	0	0	0
2003 (BN)	0	0	0
2004 (D)	0	0	0
2005 (W)	260,810	350	261,160
2006 (W)	1,009,250	1,260	1,010,510
2007 (C)	1,740	0	1,740
2008 (C)	0	0	0
2009 (BN)	0	0	0
2010 (AN)	370	0	370

Water Year (Type)	Local Supplies	CVP Supplies	Total
2011 (W)	892,570	740	893,310
2012 (D)	3,900	0	3,900
2013 (C)	270	0	270
2014 (C)	0	0	0
2015 (C)	0	0	0
Average (1989-2014)	229,270	380	229,650
Average (1989-2014) W	724,570	1,130	725,690
Average (1989-2014) AN	52,870	300	53,160
Average (1989-2014) BN	0	0	0
Average (1989-2014) D	980	0	980
Average (1989-2014) C	220	0	220

3.2.2.3 Infiltration of Precipitation

Estimated infiltration of precipitation (deep percolation of precipitation) by water use sector is provided in Figure A2.F.e-13 and Table A2.F.e-11. Infiltration of precipitation to the groundwater system is highly variable from year to year due to variation in the timing and amount of precipitation, ranging from less than 2 taf annually during some critical and dry years to over 8 taf during 1995.

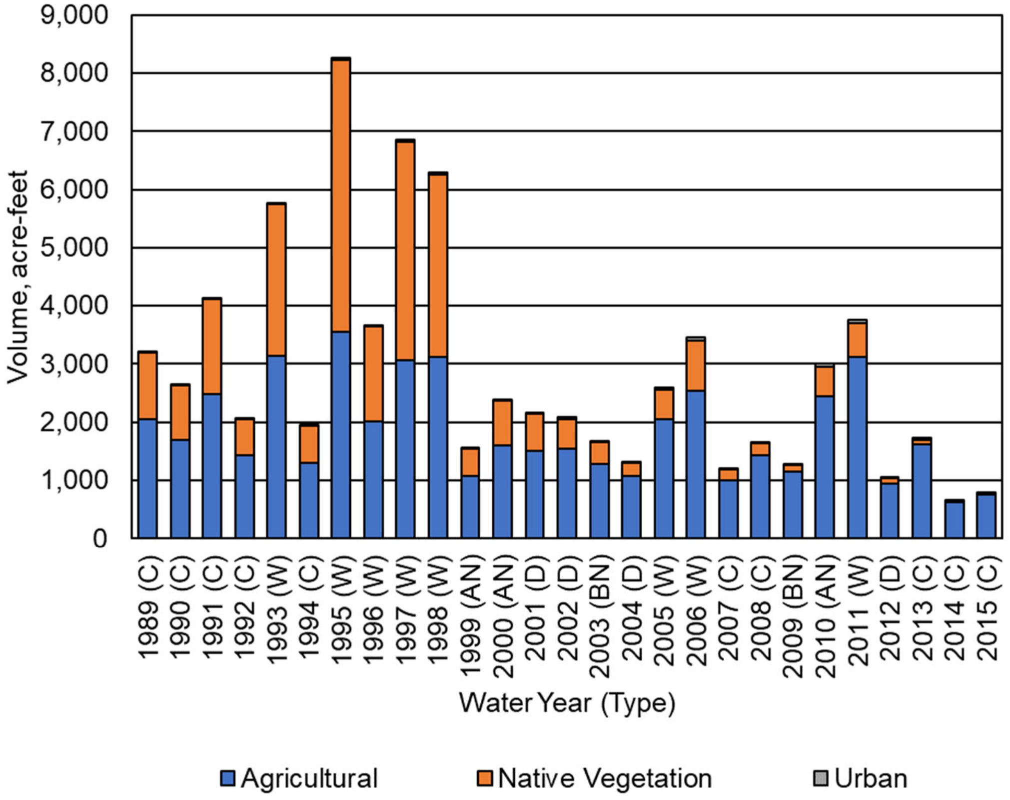

Figure A2.F.e-13. Triangle T Water District GSA Infiltration of Precipitation by Water Use Sector.

Table A2.F.e-11. Triangle T Water District GSA Infiltration of Precipitation by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	2,050	1,150	10	3,210
1990 (C)	1,690	940	10	2,640
1991 (C)	2,490	1,630	20	4,140
1992 (C)	1,430	620	10	2,060
1993 (W)	3,130	2,610	20	5,760
1994 (C)	1,310	630	10	1,950
1995 (W)	3,560	4,660	40	8,260
1996 (W)	2,010	1,640	20	3,670
1997 (W)	3,070	3,750	40	6,860
1998 (W)	3,120	3,130	50	6,300
1999 (AN)	1,080	460	10	1,550
2000 (AN)	1,600	770	20	2,390
2001 (D)	1,510	630	20	2,160
2002 (D)	1,540	520	20	2,080
2003 (BN)	1,280	370	20	1,670
2004 (D)	1,080	220	20	1,320
2005 (W)	2,050	510	30	2,590
2006 (W)	2,530	870	50	3,450
2007 (C)	1,010	180	20	1,210
2008 (C)	1,430	210	20	1,660
2009 (BN)	1,150	120	20	1,290
2010 (AN)	2,450	500	60	3,010
2011 (W)	3,120	580	60	3,760
2012 (D)	940	90	20	1,050
2013 (C)	1,620	80	30	1,730
2014 (C)	630	10	10	650
2015 (C)	760	20	10	790
Average (1989-2014)	1,880	1,030	30	2,940
Average (1989-2014) W	2,820	2,220	40	5,080
Average (1989-2014) AN	1,710	580	30	2,320
Average (1989-2014) BN	1,220	250	20	1,490
Average (1989-2014) D	1,270	370	20	1,660
Average (1989-2014) C	1,520	610	20	2,150

3.2.2.4 Infiltration of Surface Water

Estimated infiltration of surface water (seepage) by source is provided in Figure A2.F.e-14 and Table A2.F.e-12. Seepage from the Rivers and Streams System includes seepage of both surface inflows and of precipitation runoff into local sloughs and depressions. Seepage from rivers and streams follows the pattern of surface water inflows, averaging approximately 10 taf per wet year between 1989 and 2014.

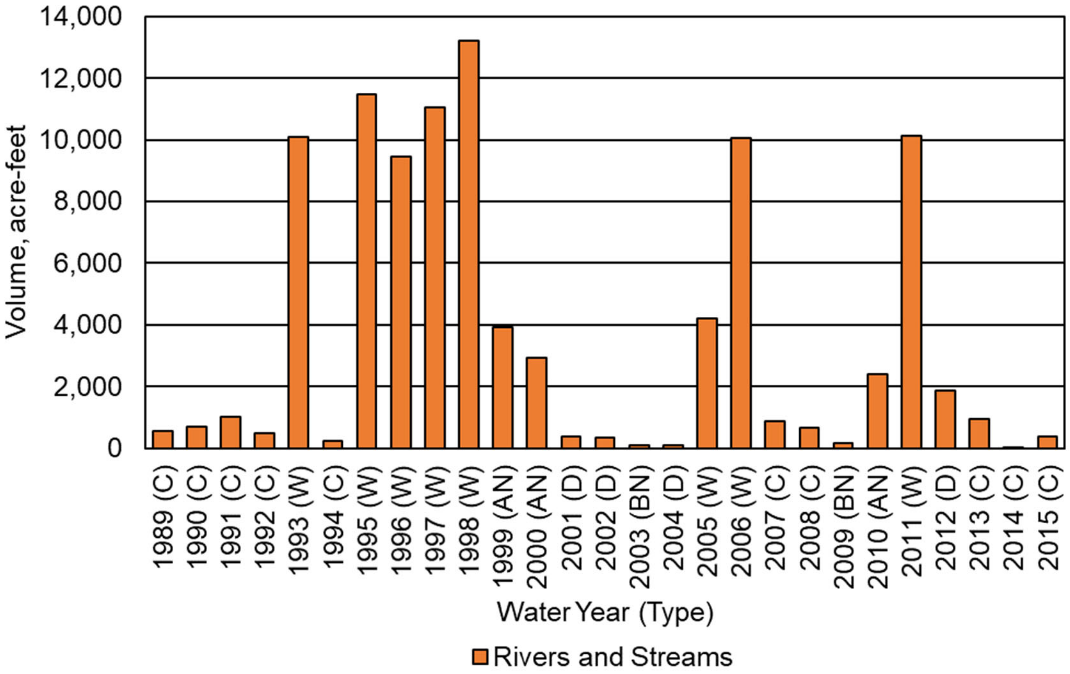

Figure A2.F.e-14. Triangle T Water District GSA Infiltration of Surface Water.

Table A2.F.e-12. Triangle T Water District GSA Infiltration of Surface Water (Acre-Feet).

Water Year (Type)	Rivers and Streams[1]
1989 (C)	540
1990 (C)	690
1991 (C)	1,010
1992 (C)	480
1993 (W)	10,110
1994 (C)	240
1995 (W)	11,470
1996 (W)	9,440
1997 (W)	11,040
1998 (W)	13,210
1999 (AN)	3,910
2000 (AN)	2,920
2001 (D)	370
2002 (D)	330
2003 (BN)	100
2004 (D)	80
2005 (W)	4,210
2006 (W)	10,070
2007 (C)	890
2008 (C)	660
2009 (BN)	150
2010 (AN)	2,390
2011 (W)	10,140

Water Year (Type)	Rivers and Streams[1]
2012 (D)	1,880
2013 (C)	940
2014 (C)	30
2015 (C)	390
Average (1989-2014)	3,740
Average (1989-2014) W	9,960
Average (1989-2014) AN	3,070
Average (1989-2014) BN	130
Average (1989-2014) D	670
Average (1989-2014) C	610

[1] Includes infiltration of surface inflows and of precipitation runoff within the subregion. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.2.2.5 Infiltration of Applied Water

Estimated infiltration of applied water (deep percolation of applied water) by water use sector is provided in Figure A2.F.e-15 and Table A2.F.e-13. Infiltration of applied water is dominated by agricultural irrigation and has increased over time due to the expansion of agriculture land in the GSA.

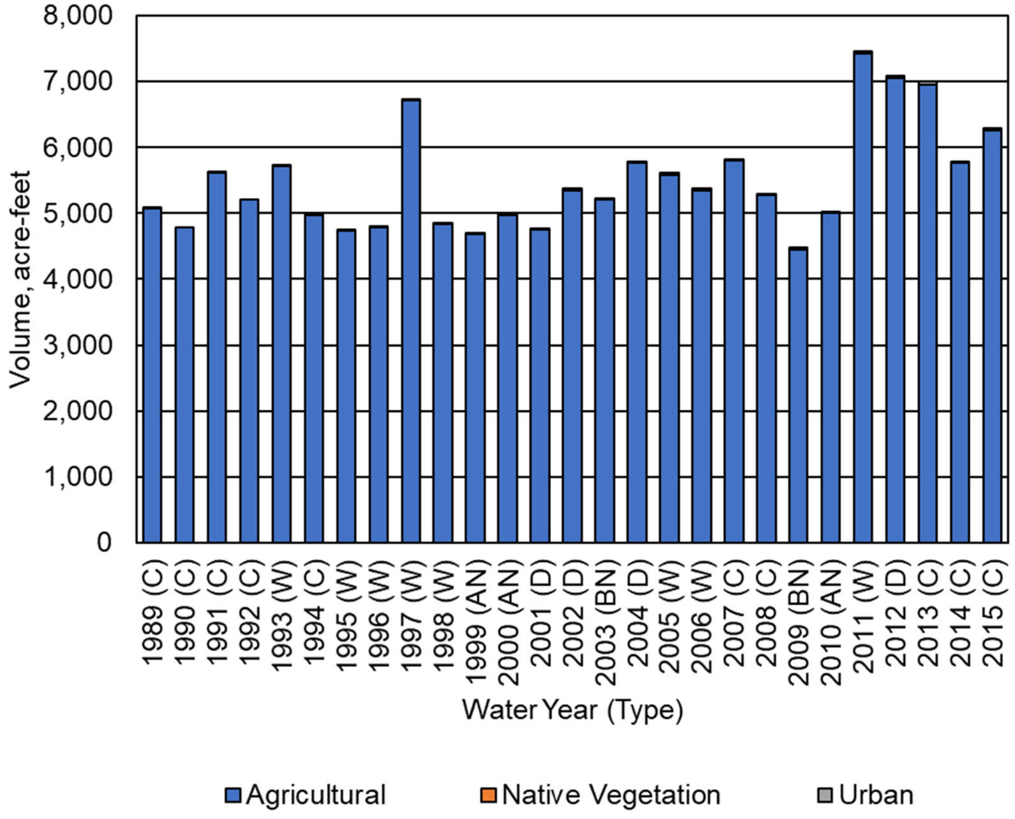

Figure A2.F.e-15. Triangle T Water District GSA Infiltration of Applied Water by Water Use Sector.

Table A2.F.e-13. Triangle T Water District GSA Infiltration of Applied Water by Water Use Sector (Acre-Feet).

Water Year (Type)	Agricultural	Native Vegetation	Urban	Total
1989 (C)	5,080	0	10	5,090
1990 (C)	4,790	0	0	4,790
1991 (C)	5,620	0	10	5,630
1992 (C)	5,210	0	0	5,210
1993 (W)	5,710	0	10	5,720
1994 (C)	4,980	0	10	4,990
1995 (W)	4,730	0	10	4,740
1996 (W)	4,790	0	10	4,800
1997 (W)	6,720	0	20	6,740
1998 (W)	4,830	0	20	4,850
1999 (AN)	4,690	0	10	4,700
2000 (AN)	4,970	0	20	4,990
2001 (D)	4,750	0	20	4,770
2002 (D)	5,350	0	20	5,370
2003 (BN)	5,210	0	20	5,230
2004 (D)	5,760	0	20	5,780
2005 (W)	5,580	0	30	5,610
2006 (W)	5,350	0	30	5,380
2007 (C)	5,800	0	20	5,820
2008 (C)	5,270	0	30	5,300
2009 (BN)	4,450	0	30	4,480
2010 (AN)	5,000	0	30	5,030
2011 (W)	7,430	0	30	7,460
2012 (D)	7,050	0	30	7,080
2013 (C)	6,960	0	40	7,000
2014 (C)	5,760	0	30	5,790
2015 (C)	6,260	0	30	6,290
Average (1989-2014)	5,460	0	20	5,480
Average (1989-2014) W	5,640	0	20	5,660
Average (1989-2014) AN	4,890	0	20	4,910
Average (1989-2014) BN	4,830	0	30	4,860
Average (1989-2014) D	5,730	0	20	5,750
Average (1989-2014) C	5,500	0	20	5,520

3.2.3 Change in Surface Water System Storage

Estimates of change in SWS storage are provided in Figure A2.F.e-16 and Table A2.F.e-14. Inter-annual changes in storage within the surface water system consist primarily of root zone soil moisture storage changes, are relatively small, and tend to average near zero over many years. During wet years, change in SWS storage is estimated as higher during some months when estimated riparian deliveries satisfy much of the crop water demand, substantially reducing groundwater pumping estimates.

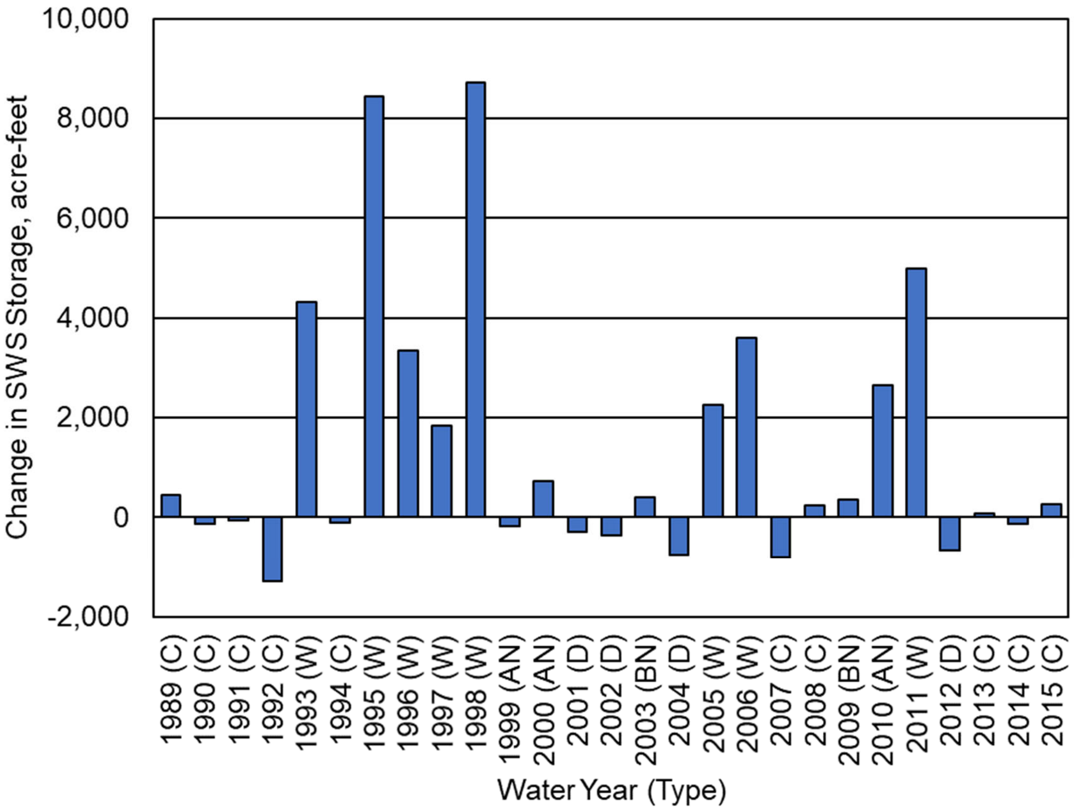

Figure A2.F.e-16. Triangle T Water District GSA Change in Surface Water System Storage.

Table A2.F.e-14. Triangle T Water District GSA Change in Surface Water System Storage (Acre-Feet).

Water Year (Type)	Change in SWS Storage
1989 (C)	440
1990 (C)	-140
1991 (C)	-60
1992 (C)	-1,280
1993 (W)	4,320
1994 (C)	-100
1995 (W)	8,440
1996 (W)	3,350
1997 (W)	1,840
1998 (W)	8,730
1999 (AN)	-170
2000 (AN)	720
2001 (D)	-280
2002 (D)	-350
2003 (BN)	410
2004 (D)	-760
2005 (W)	2,250
2006 (W)	3,590

Water Year (Type)	Change in SWS Storage
2007 (C)	-790
2008 (C)	250
2009 (BN)	360
2010 (AN)	2,650
2011 (W)	5,000
2012 (D)	-650
2013 (C)	70
2014 (C)	-140
2015 (C)	270
Average (1989-2014)	1,450
Average (1989-2014) W	4,690
Average (1989-2014) AN	1,070
Average (1989-2014) BN	390
Average (1989-2014) D	-510
Average (1989-2014) C	-190

3.3 Historical Water Budget Summary

Annual inflows, outflows, and change in SWS storage during the historical water budget period (1989-2014) are summarized in Figure A2.F.e-17 and Table A2.F.e-15. Inflows are shown as positive values, while outflows and change in SWS storage are shown as negative values. During wet years, boundary surface inflow and outflow volumes are substantially higher than other components. Figure A2.F.e-17 thus only shows the difference between the surface inflows and surface outflows after seepage and evaporation are accounted within TTWD GSA. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the surface water system water budget.

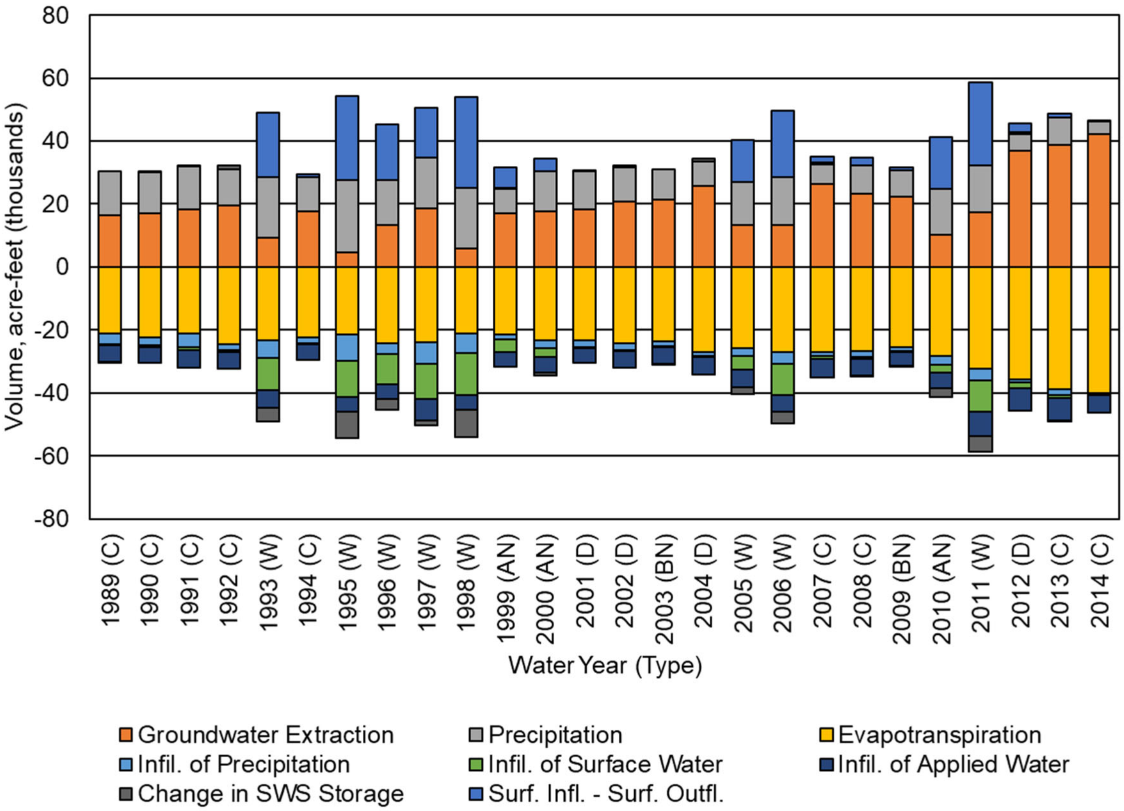

Figure A2.F.e-17. Triangle T Water District GSA Surface Water System Historical Water Budget, 1989-2014.

Table A2.F.e-15. Triangle T Water District GSA Surface Water System Historical Water Budget, 1989-2014 (Acre-Feet).

Water Year	Boundary Surface Inflows	Groundwater Extraction	Precipitation	Evapo-transpiration[1]	Infil. of Precipitation	Infil. of Surface Water[2]	Infil. of Applied Water	Boundary Surface Outflows	Change in SWS Storage
1989 (C)	0	16,430	14,090	-21,240	-3,210	-540	-5,090	0	-440
1990 (C)	0	17,100	13,140	-22,250	-2,640	-690	-4,790	0	140
1991 (C)	0	18,210	13,730	-21,230	-4,140	-1,010	-5,620	0	60
1992 (C)	0	19,680	11,210	-24,420	-2,060	-480	-5,210	0	1,280
1993 (W)	630,140	9,420	19,010	-23,260	-5,760	-10,110	-5,720	-609,400	-4,320
1994 (C)	870	17,800	10,770	-22,370	-1,940	-240	-4,990	0	100
1995 (W)	740,860	4,550	23,110	-21,510	-8,260	-11,470	-4,740	-714,110	-8,440
1996 (W)	661,490	13,480	14,130	-24,100	-3,670	-9,440	-4,800	-643,730	-3,350
1997 (W)	899,650	18,570	16,140	-23,970	-6,860	-11,040	-6,740	-883,900	-1,840
1998 (W)	818,390	5,750	19,410	-21,030	-6,300	-13,210	-4,850	-789,430	-8,730
1999 (AN)	141,780	17,040	7,870	-21,480	-1,560	-3,910	-4,710	-135,200	170
2000 (AN)	27,730	17,700	12,830	-23,340	-2,390	-2,920	-4,980	-23,920	-720
2001 (D)	0	18,310	11,970	-23,270	-2,160	-370	-4,760	0	280
2002 (D)	0	20,920	10,860	-24,350	-2,080	-330	-5,370	0	350
2003 (BN)	0	21,480	9,540	-23,630	-1,670	-100	-5,230	0	-410
2004 (D)	0	25,600	7,930	-27,100	-1,320	-80	-5,790	0	760
2005 (W)	274,520	13,440	13,670	-25,810	-2,590	-4,210	-5,620	-261,160	-2,250
2006 (W)	1,031,670	13,440	15,060	-27,170	-3,450	-10,070	-5,370	-1,010,510	-3,590
2007 (C)	3,380	26,430	6,100	-27,060	-1,200	-890	-5,820	-1,740	790
2008 (C)	2,330	23,120	9,260	-26,860	-1,660	-660	-5,290	0	-250
2009 (BN)	1,120	22,290	8,360	-25,490	-1,290	-150	-4,480	0	-360
2010 (AN)	16,870	10,340	14,370	-28,130	-3,000	-2,390	-5,030	-370	-2,650
2011 (W)	919,590	17,250	15,050	-32,230	-3,760	-10,140	-7,460	-893,310	-5,000
2012 (D)	6,810	37,020	5,120	-35,680	-1,060	-1,880	-7,080	-3,900	650
2013 (C)	1,560	38,770	8,660	-38,970	-1,730	-940	-7,010	-270	-70
2014 (C)	0	42,050	4,230	-39,950	-650	-30	-5,800	0	140
Average (1989-2014)	237,640	19,470	12,140	-26,000	-2,940	-3,740	-5,470	-229,650	-1,450
W	747,040	11,990	16,950	-24,890	-5,080	-9,960	-5,660	-725,690	-4,690
AN	62,130	15,030	11,690	-24,320	-2,320	-3,070	-4,910	-53,160	-1,070
BN	560	21,890	8,950	-24,560	-1,480	-120	-4,850	0	-390
D	1,700	25,460	8,970	-27,600	-1,650	-670	-5,750	-980	510
C	900	24,400	10,130	-27,150	-2,140	-610	-5,510	-220	190

[1] Includes ET of applied water, ET of precipitation, and evaporation from the Rivers and Streams System.

[2] Includes infiltration from the Rivers and Streams System within the subregion. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.4 Current Water Budget Summary

The current water budget was developed following a similar process to the historical water budget using the 2015 land use in Table A2.F.e-1 and the same 1989-2014 average hydrologic conditions of the historical base period, including surface water flows, precipitation, and weather parameters. This allowed quantification of groundwater inflows and outflows for current consumptive use in the context of average water supply conditions.

Annual inflows, outflows, and change in SWS storage from the current water budget are summarized in Figure A2.F.e-18 and Table A2.F.e-16. Inflows are shown as positive values, while outflows and change in SWS storage are shown as negative values. Similar to Figure A2.F.e-17, Figure A2.F.e-18 only shows the difference between the surface inflows and surface outflows after seepage and evaporation are accounted within TTWD GSA.

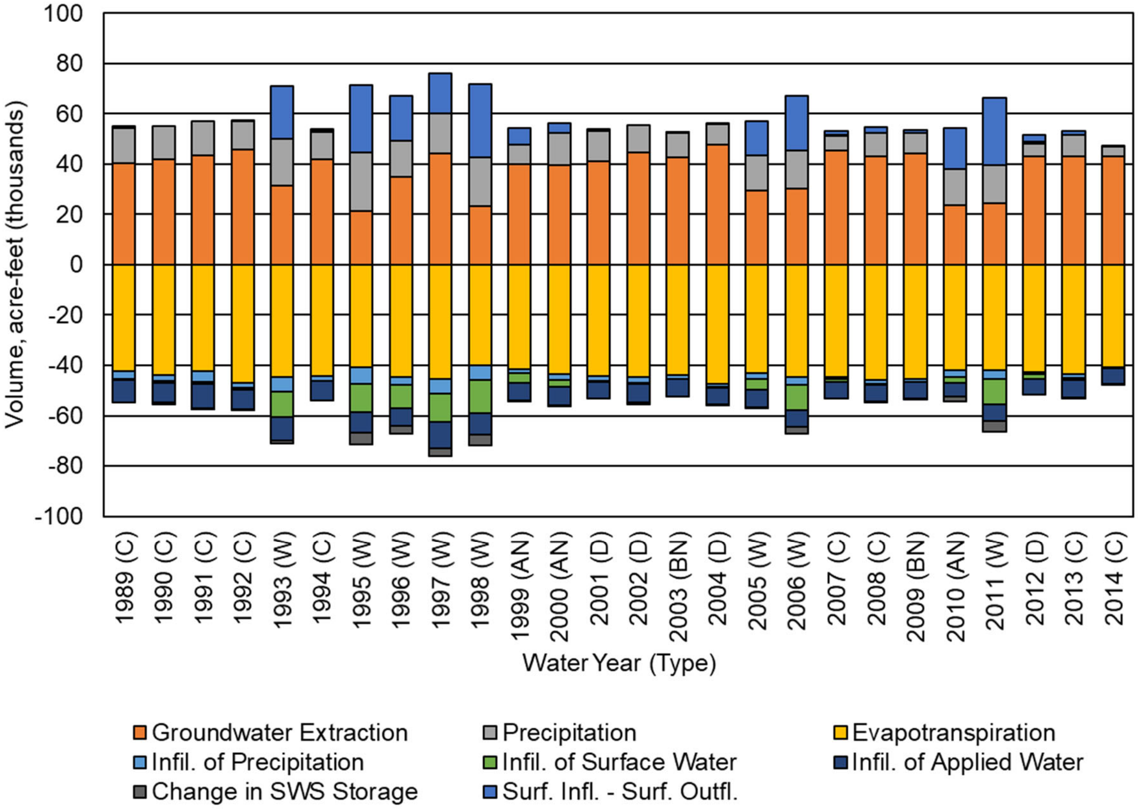

Figure A2.F.e-18. Triangle T Water District GSA Surface Water System Current Water Budget.

Table A2.F.e-16. Triangle T Water District GSA Surface Water System Current Water Budget (Acre-Feet).

Water Year	Boundary Surface Inflows	Groundwater Extraction	Precipitation	Evapo-transpiration[1]	Infil. of Precipitation	Infil. of Surface Water[2]	Infil. of Applied Water	Boundary Surface Outflows	Change in SWS Storage
1989 (C)	0	40,210	14,090	-42,260	-3,270	-480	-8,800	0	510
1990 (C)	0	42,010	13,140	-43,690	-2,590	-670	-7,850	-20	-330
1991 (C)	0	43,380	13,730	-42,260	-4,260	-1,010	-9,380	-90	-110
1992 (C)	0	45,860	11,220	-46,960	-2,110	-480	-7,860	-10	340
1993 (W)	630,140	31,210	19,010	-44,760	-5,660	-10,110	-9,460	-609,200	-1,160
1994 (C)	870	41,960	10,770	-44,300	-1,860	-220	-7,560	0	350
1995 (W)	740,860	21,320	23,120	-40,770	-6,520	-11,470	-8,130	-713,860	-4,550
1996 (W)	661,490	34,970	14,130	-44,620	-3,120	-9,440	-7,010	-643,460	-2,940
1997 (W)	899,650	44,110	16,140	-45,440	-5,840	-11,040	-10,680	-883,760	-3,140
1998 (W)	818,390	23,240	19,410	-40,070	-5,690	-13,210	-8,410	-789,240	-4,420
1999 (AN)	141,780	39,890	7,870	-41,670	-1,490	-3,900	-7,000	-135,160	-330
2000 (AN)	27,730	39,590	12,830	-43,370	-2,410	-2,920	-7,030	-24,010	-420
2001 (D)	0	41,010	11,970	-44,310	-2,040	-350	-6,670	0	390
2002 (D)	0	44,440	10,860	-44,770	-2,190	-320	-7,560	-20	-430
2003 (BN)	0	42,730	9,550	-43,880	-1,610	-40	-7,000	0	260
2004 (D)	0	47,750	7,930	-47,470	-1,240	-30	-6,770	0	-160
2005 (W)	274,520	29,650	13,680	-42,980	-2,500	-4,160	-7,100	-260,950	-140
2006 (W)	1,031,660	30,290	15,070	-44,490	-3,120	-10,070	-6,880	-1,010,030	-2,430
2007 (C)	3,380	45,210	6,100	-44,660	-970	-860	-6,590	-1,700	70
2008 (C)	2,330	43,160	9,270	-45,630	-1,600	-370	-6,660	-10	-500
2009 (BN)	1,120	44,030	8,380	-45,560	-1,230	30	-6,420	-10	-350
2010 (AN)	16,870	23,540	14,390	-42,020	-2,680	-2,120	-5,680	-310	-1,990
2011 (W)	919,590	24,580	15,060	-42,090	-3,170	-10,130	-6,760	-892,750	-4,330
2012 (D)	6,810	43,090	5,130	-42,830	-830	-1,830	-6,140	-3,900	500
2013 (C)	1,560	43,020	8,660	-43,300	-1,660	-910	-6,930	-260	-170
2014 (C)	0	42,860	4,230	-40,660	-660	-30	-5,940	0	190
Average (1989-2014)	237,640	38,200	12,140	-43,650	-2,710	-3,700	-7,400	-229,570	-970
W	747,040	29,920	16,950	-43,150	-4,450	-9,950	-8,060	-725,410	-2,890
AN	62,130	34,340	11,700	-42,350	-2,190	-2,980	-6,570	-53,160	-910
BN	560	43,380	8,960	-44,720	-1,420	0	-6,710	0	-40
D	1,700	44,070	8,970	-44,850	-1,580	-630	-6,790	-980	70
C	900	43,070	10,140	-43,750	-2,110	-560	-7,510	-230	40

[1] Includes ET of applied water, ET of precipitation, and evaporation from the Rivers and Streams System.

[2] Includes infiltration from the Rivers and Streams System within the subregion. To calculate Net Recharge from SWS below, Rivers and Streams System seepage is summed across the subbasin and redistributed to each subregion in proportion to gross area.

3.5 Net Recharge from SWS

Overdraft is defined in DWR Bulletin 118 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" (DWR 2003). The Chowchilla Subbasin water budget indicates that overdraft conditions occurred during the 1989-2014 historical base period. Per 23 CCR Section 354.18(b)(5), the subbasin overdraft has been quantified for this base period. The evaluation of overdraft conditions includes estimates of recharge from subsurface flows. However, estimates of recharge from subsurface flows are less accurate when estimated for areas less that an entire subbasin. Thus, for estimates of GSA level contribution to overdraft, the term net recharge from the SWS is defined as groundwater recharge minus groundwater extraction. Net recharge from the SWS is useful for understanding and analyzing the combined effects of land surface processes on the underlying GWS.

When calculated from the historical water budget, average net recharge from the SWS represents the average recharge (when positive) or shortage of recharge (when negative) based on historical cropping, land use practices, and average hydrologic conditions. When calculated from the current land use water budget, average net recharge represents the average recharge based on current cropping, land use practices, and average hydrologic conditions.

Average net recharge from the SWS is presented below for the TTWD GSA portion of the Chowchilla Subbasin. Table A2.F.e-17 shows the average net recharge from the SWS for 1989-2014 based on the historical water budget, and Table A2.F.e-18 shows the same for the current water budget. Historically, the average net recharge in TTWD GSA was approximately -8.9 taf per year between 1989 and 2014. Under current land use conditions, the average net recharge in TTWD GSA is approximately -26 taf, indicating shortage conditions.

Table A2.F.e-17. Historical Water Budget: Average Net Recharge from SWS by Water Year Type, 1989-2014 (Acre-Feet).

Year Type	Number of Years	Infiltration of Applied Water (a)	Infiltration of Precipitation (b)	Infiltration of Surface Water[1] (c)	Groundwater Extraction (d)	Net Recharge from SWS (a+b+c-d)
W	8	5,660	5,080	5,610	11,990	4,360
AN	3	4,910	2,320	1,280	15,030	-6,520
BN	2	4,850	1,480	170	21,890	-15,390
D	4	5,750	1,650	430	25,460	-17,630
C	9	5,510	2,140	660	24,400	-16,090
Annual Average (1989-2014)	26	5,470	2,940	2,180	19,470	-8,880

[1] Calculated from the total subbasin Rivers and Streams System seepage summed and redistributed to each subregion in proportion to gross area.

Table A2.F.e-18. Current Water Budget: Average Net Recharge from SWS by Water Year Type (Acre-Feet).

Year Type	Number of Years	Infiltration of Applied Water (a)	Infiltration of Precipitation (b)	Infiltration of Surface Water[1] (c)	Groundwater Extraction (d)	Net Recharge from SWS (a+b+c-d)
W	8	8,060	4,450	5,490	29,920	-11,920
AN	3	6,570	2,190	1,230	34,340	-24,350
BN	2	6,710	1,420	110	43,380	-35,140
D	4	6,790	1,580	380	44,070	-35,320
C	9	7,510	2,110	510	43,070	-32,940
Annual Average (1989-2014)	26	7,400	2,710	2,080	38,200	-26,010

[1] Calculated from the total subbasin Rivers and Streams System seepage summed and redistributed to each subregion in proportion to gross area.

3.6 Uncertainties in Water Budget Components

Uncertainties associated with each water budget component were estimated as a percentage representing approximately a 95% confidence interval following the procedure described by Clemmens and Burt (1997). Uncertainties for all independently measured or estimated water budget components were estimated based on the measurement accuracy, typical values reported in technical literature, typical values calculated in other water budgets, and professional judgement.

Table A2.F.e-19 provides a summary of typical uncertainty values associated with major SWS inflow and outflow 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 A2.F.e-19. Estimated Uncertainty of GSA Water Budget Components.

Flowpath Direction (SWS Boundary)	Water Budget Component	Data Source	Estimated Uncertainty (%)	Source
Inflows	Surface Water Inflows	Measurement	20%	Estimated streamflow measurement accuracy and adjustment for losses.
	Riparian Deliveries	Measurement	10%	Estimated measurement accuracy.
	Precipitation	Calculation	30%	Clemmens, A.J. and C.M. Burt, 1997.
	Groundwater Extraction	Closure	20%	Typical uncertainty calculated for Land Surface System water balance closure.
Outflows	Surface Water Outflows	Closure	20%	Typical uncertainty calculated for Rivers and Streams System water balance closure.
	Evaporation	Calculation	20%	Estimated accuracy of calculation based on CIMIS reference ET and free water surface evaporation coefficient.
	ET of Applied Water	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, estimated crop coefficients from SEBAL energy balance, and annual land use.
	ET of Precipitation	Calculation	10%	Estimated accuracy of daily IDC root zone water budget component based on CIMIS reference ET, precipitation, estimated crop coefficients from SEBAL energy balance, and annual land use.
	Infiltration of Applied Water	Calculation	20%	Estimated accuracy of daily IDC root zone water budget component based on annual land use and NRCS soils characteristics.
	Infiltration of Precipitation	Calculation	20%	Estimated accuracy of daily IDC root zone water budget component based on annual land use, NRCS soils characteristics, and CIMIS precipitation.
	Infiltration of Surface Water	Calculation	15%	Estimated accuracy of daily seepage calculation using NRCS soils characteristics and calculated runoff of precipitation.
	Change in SWS Storage	Calculation	50%	Professional Judgment.
Net Recharge from SWS		Calculation	25%	Estimated water budget accuracy; typical value calculated for GSA-level net recharge from SWS.

APPENDIX 2.F. WATER BUDGET INFORMATION

2.F.f. Daily Reference Evapotranspiration and Precipitation Quality Control

Prepared as part of the

Groundwater Sustainability Plan
Chowchilla Subbasin

January 2020

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1 PURPOSE

The purpose of this report is to describe the development of daily reference evapotranspiration (ET_{ref}) and precipitation values for water years 1989 through 2015 for use to determine consumptive use of irrigation water. The Study Area is the Chowchilla Subbasin.

This report describes the methodology for developing ET_{ref} and precipitation records, the results and the findings.

2 METHODOLOGY

Scientifically sound and widely accepted methods for determining consumptive use of irrigation water utilize daily ET_{ref} determined using the standardized Penman-Monteith (PM) method as described by the ASCE Task Committee Report on the Standardized Reference Evapotranspiration Equation (ASCE-EWRI, 2005). The PM method requires measurements of incoming solar radiation (R_s), air temperature (T_a), relative humidity (RH) and wind speed (W_s) at hourly or daily time steps. The task committee report standardizes the ASCE PM method for application to a full-cover alfalfa reference (ET_r) and to a clipped cool season grass reference (ET_o). The clipped cool season grass reference is widely used throughout the western United States and was selected for this application. Additionally, the Task Committee Report provides recommended methods for estimating required inputs to the standardized equation when measured data are unavailable. The remainder of this section describes an inventory of weather stations and available data, weather data quality control (QC), and the methods used to estimate ET_o.

2.1 Weather Data Inventory

Weather data from irrigated areas are needed to develop estimates of consumptive use of irrigation water. Automatic Weather Stations (AWS) provide measurements of R_s, T_a, RH and W_s over hourly or shorter periods used to compute ET_o. AWS data are often available from state extension services and weather station networks. Prior to the advent of the AWS, National Oceanic and Atmospheric Administration (NOAA) stations recorded daily minimum and maximum air temperatures and daily precipitation. Data from these NOAA stations are available from the National Centers for Environmental Information (NCEI) formerly National Climatic Data Center (NCDC).

In recent years, several gridded climate data sets have become available for public use. Daymet and PRISM (Parameter-elevation Relationships on Independent Slopes Model) are two of the more well-known data sets. The gridded estimates are developed by a collection of algorithms that interpolate and extrapolate from daily meteorological observations at available weather stations. Generally, the gridded estimates do not include all necessary parameters to calculate ET_o. PRISM[1] provides estimates for precipitation, daily maximum air temperature, daily minimum air temperature and daily average dewpoint temperature by interpolating between weather stations based on the physiographic similarity of the station to the grid cell.

For developing ET_o values to use in determining crop water depletions, the weather data used must represent irrigated agriculture. This is because ET from irrigated areas in arid regions is generally lower than that from surrounding not irrigated areas. The evaporation process tends to both cool and humidify the near-surface boundary layer over irrigated fields. This cooling and humidifying effect tends to reduce ET rates, including the reference ET estimate, and should be considered when calculating reference ET.

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[1] http://www.prism.oregonstate.edu/ accessed on May 18, 2014.

Weather stations used to develop the gridded data are from both irrigated and not irrigated areas. For this reason, AWS inside the irrigated area are the preferred source for weather data to calculate ET_o for use in determining consumptive use of irrigation water.

A complete inventory of weather stations both inside and near irrigated areas was conducted to select the most appropriate weather station, or stations, for the historical crop water consumptive use analysis.

2.2 Weather Data Quality Control

Accurate estimation of consumptive use of irrigation water requires accurate and representative weather data. Weather data from each station were reviewed and corrected when necessary, following accepted, scientific procedures (Allen, et al 1996, Allen, et al, 1998, ASCE-EWRI, 2005 and ASCE, 2016). Daily data obtained for the AWS stations were quality checked using spreadsheets and graphs of weather data parameters for analysis and application of quality control methods according to the guidelines specified in Appendix-D of the ASCE Task Committee Report on the Standardized Reference Evapotranspiration Equation (ASCE-EWRI, 2005). Quality control procedures applied to R_s, T_a, RH and W_s are briefly described in the following sections.

2.2.1 Solar Radiation

Solar radiation data were quality controlled by plotting measured R_s and computed clear sky envelopes of solar radiation on cloudless days (R_{so}) for hourly or daily time steps (Allen, et al 1996, Allen, et al, 1998, ASCE-EWRI, 2005 and ASCE, 2016). Recommended equations for R_{so} that include the influence of sun angle, turbidity, atmospheric thickness, and precipitable water were used. The measured R_s should reach the clear sky envelope on cloud-free days. On cloudy or hazy days, the measured R_s will not reach the clear sky envelope. Measured R_s values that consistently fall above or below the curve indicate improper calibration or other problems, such as the presence of dust, bird droppings or something else on the sensor. Values for R_s that were found to be consistently above or below R_{so} on clear days were adjusted by dividing R_s by the average value of R_s/R_{so} on clear days at intervals of 60-day groupings for daily data and 30-day periods for hourly data. The values resulting from these adjustments were carefully reviewed for reasonableness of the adjustments.

2.2.2 Air Temperature

Air temperature is the simplest weather parameter to measure and the parameter most likely to be of high quality (Allen, et al 1996, Allen, et al, 1998, ASCE-EWRI, 2005 and ASCE, 2016). Nevertheless, daily maximum and minimum air temperatures were plotted together vs. time, and the extreme values were compared against historical extremes. Temperatures that consistently exceed the recorded extremes for a region may indicate a problem with the sensor or environment and may need to be adjusted based on air temperatures collected at a nearby station.

2.2.3 Relative Humidity

Daily maximum and minimum relative humidity values were plotted and examined for values chronically lower than five to ten percent and values that were consistently over 100 percent (Allen, et al 1996, Allen, et al, 1998, ASCE-EWRI, 2005 and ASCE, 2016). Additionally, relative humidity was checked on days having recorded rainfall to confirm that the measured maximum RH values approached 90 to 100 percent. Where necessary, reasonable adjustments such as setting all values above 100 percent equal to 100 percent were made.

2.2.4 Wind Speed

Wind speed records were plotted and visually inspected for consistently low wind speed values (Allen, et al 1996, Allen, et al, 1998, ASCE-EWRI, 2005 and ASCE, 2016). Low wind speeds can indicate dirty or worn anemometer bearings that lead to failure of the anemometer. Any period of more than thirty days with wind speeds below 1.0 meters per second was compared to available nearby stations and, if the wind speed at the nearby station did not indicate a period of unusually low wind speeds, adjusted based on the nearby station.

3 RESULTS

This section describes the results of an inventory of weather stations and available data, weather data quality control, and ET_o estimates.

3.1 Weather Station Inventory

Table A2.F.f-1 lists the stations and time periods used for the Chowchilla Subbasin weather data.

Table A2.F.f-1. Chowchilla Subbasin Weather Data Time Series Summary for the period 1989 – 2015.

Weather Station	Start Date	End Date	Comment
Fresno State (#80)	Oct. 2, 1988	May 12, 1998	AWS. Before Madera was installed.
Madera (#145)	May 13, 1998	Apr. 2, 2013	AWS. Moved East 2 miles and renamed “Madera II”
Madera II (#188)	Apr. 3, 2013	Dec. 31, 2015	AWS.

3.2 Weather Data Quality Control

Hourly checks and necessary adjustments performed on AWS station data and daily checks are described in the following sections. However, the following sections only include examples of common data adjustments observed in the quality-controlling process. A complete list of adjustments can be found in Attachment A2.F.f-A.

3.2.1 Solar Radiation

CIMIS AWS solar radiation data were generally of good quality, but it was apparent that some records required adjustment to fall within reasonable bounds. Two different types of quality control were performed on the solar radiation data. First, there are time periods in certain years where there is an obvious drop or rise in solar radiation values which cause them to fall significantly above or below the expected values. One instance of an unreasonable, sudden drop in solar radiation occurred in 1996 at the Madera CIMIS station. This is displayed in Figure A2.F.f-1 below. This data was then adjusted up by a factor of 1.08, and the calibrated data is displayed in Figure A2.F.f-2 below.

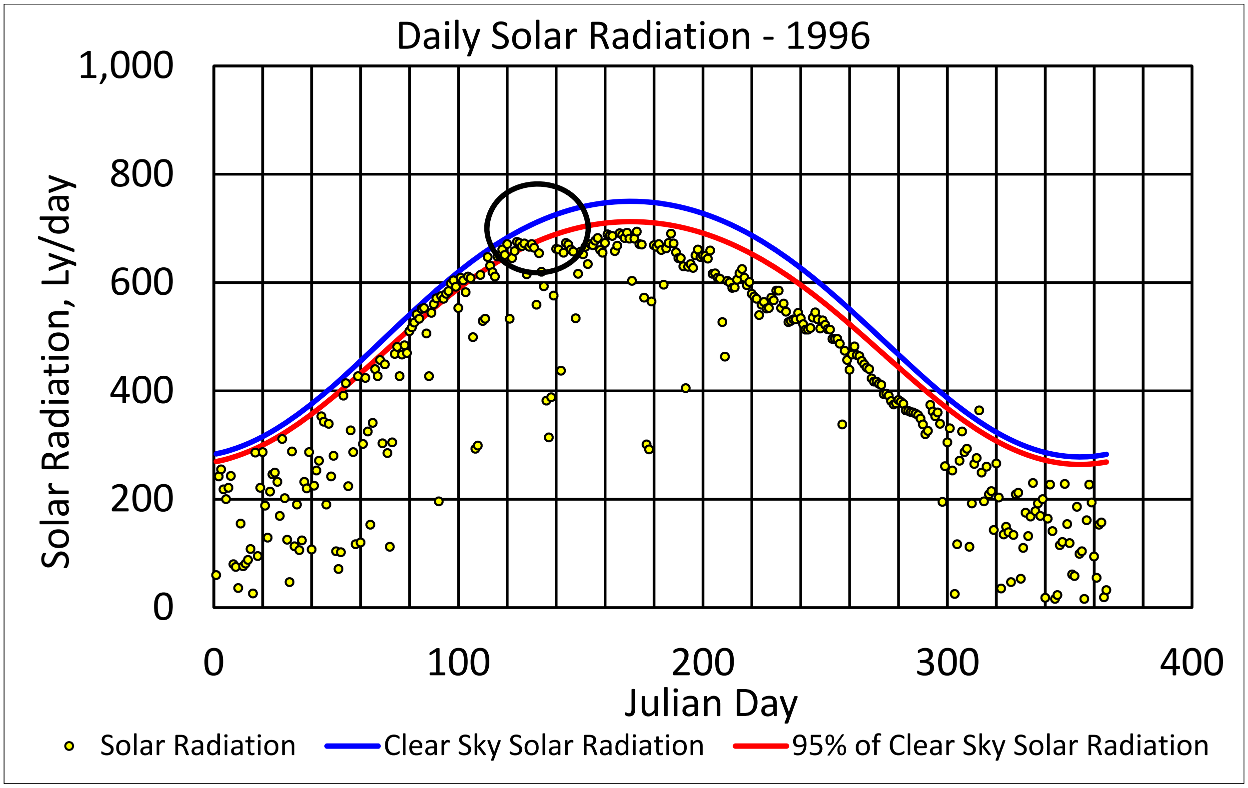

Figure A2.F.f-1. Daily Solar Radiation (Ly/day) for Madera CIMIS station (#145) for 1996 before QC.

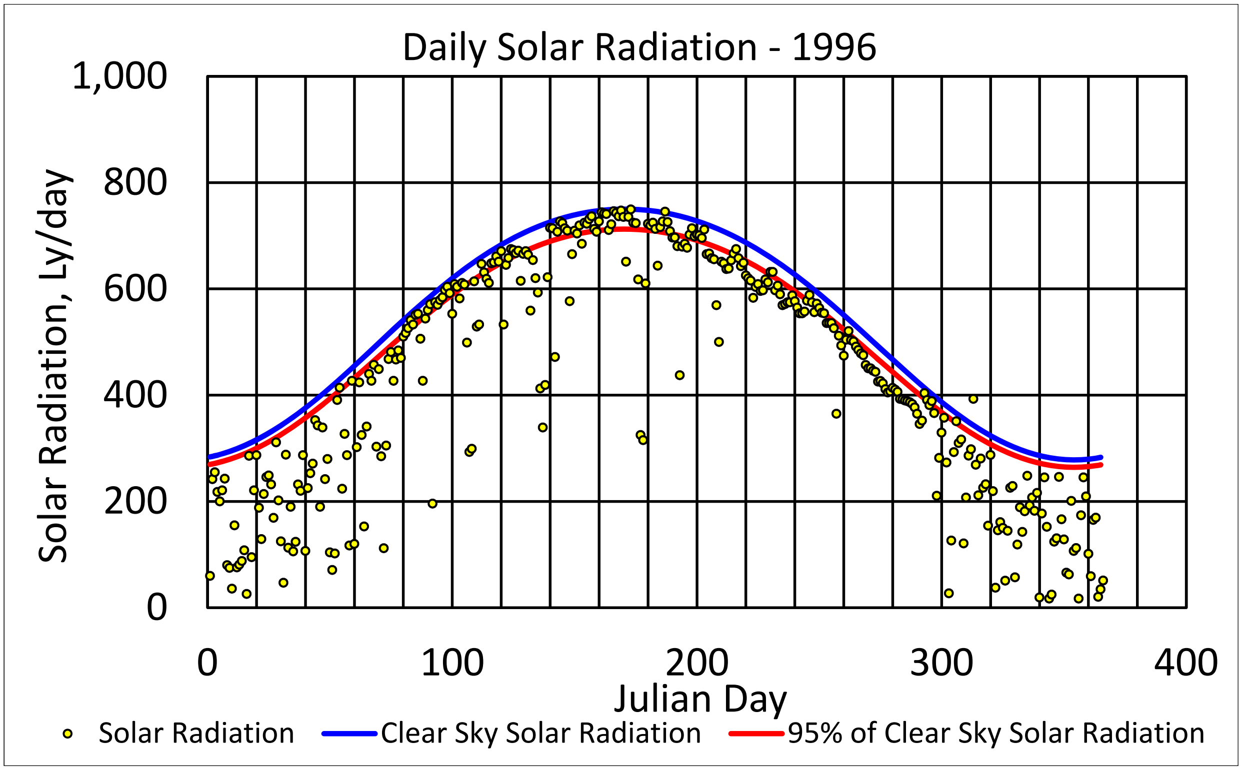

Figure A2.F.f-2. Daily Solar Radiation (Ly/day) for Madera CIMIS station (#145) for 1996 after QC.

3.2.2 Air Temperature

For the most part, CIMIS AWS air temperature data were consistent and followed expected values and behavior. However, adjustments were applied to some data points to more closely reflect the expected temperatures within the seasons for each year. There were two common problems observed within this parameter: missing data points and minimum temperatures automatically being assigned a value of 32 degrees Fahrenheit. The latter is made obvious by the season in which the data points reside, and the difference between this point and those immediately before and after. Examples of both issues are displayed in Figure A2.F.f-3. Missing data points were filled in with a value of the corresponding parameter from a nearby CIMIS station. The same process was applied to the points that were automatically set to 32 degrees Fahrenheit. The adjusted data can be observed in Figure A2.F.f-4.

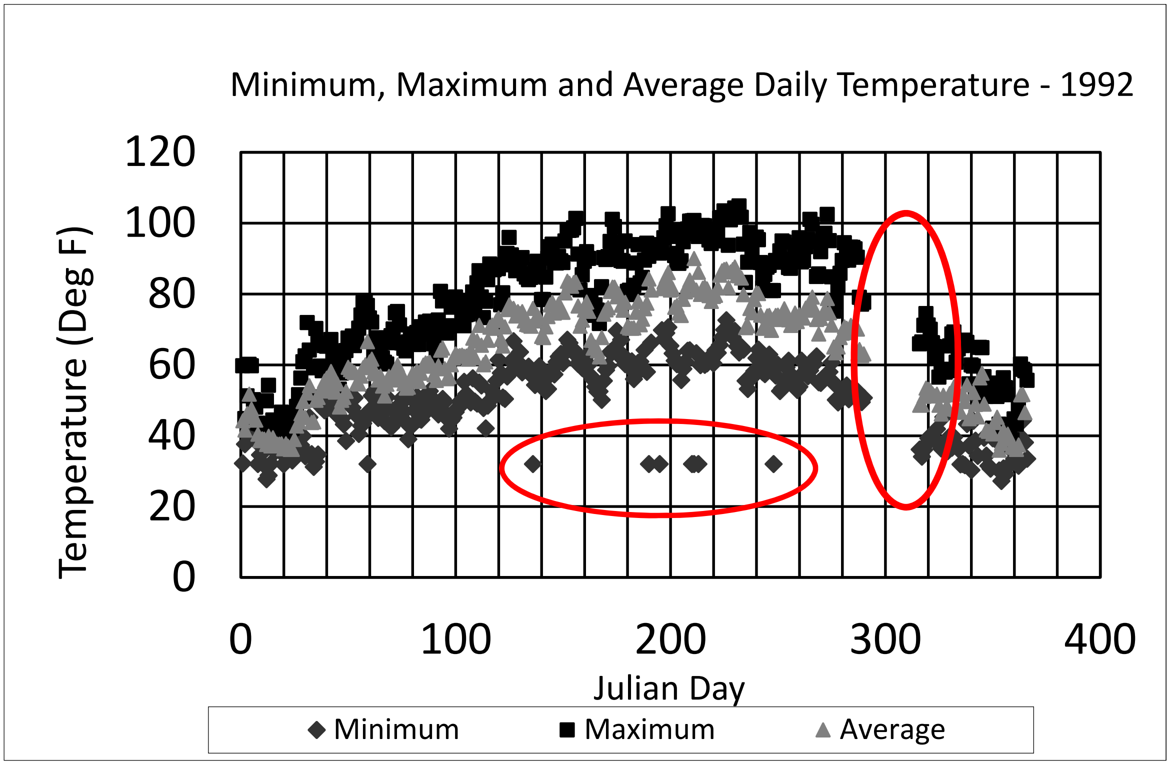

Figure A2.F.f-3. Average, Maximum, and Minimum Daily Temperatures (DegF) for Fresno State CIMIS station (#80) for 1992 before QC.

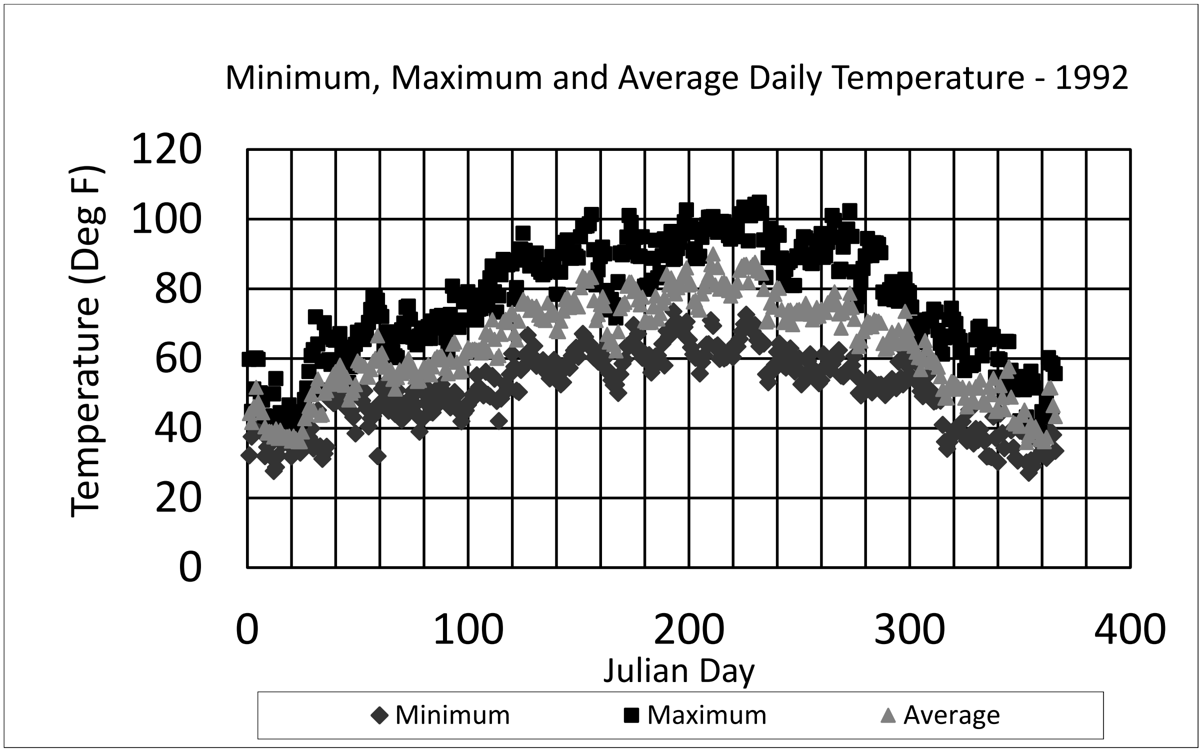

Figure A2.F.f-4. Average, Maximum, and Minimum Daily Temperatures (DegF) for Fresno State CIMIS station (#80) for 1992 after QC.

3.2.3 Relative Humidity

CIMIS AWS Relative Humidity (RH) data was analyzed for all of the time period and station combinations listed in Table A2.F.f-1 above and the necessary adjustments were made. Maximum RH at night commonly approaches 60% during the summer period and 100% during the winter period. When values fall significantly below this expected range of values (Figure A2.F.f-5), it can be concluded that the RH sensor is in need of calibration or to be replaced and the data need to be adjusted. In years when this trend was observed, such as for the Madera station in 2005, the data was adjusted (Figure A2.F.f-6).

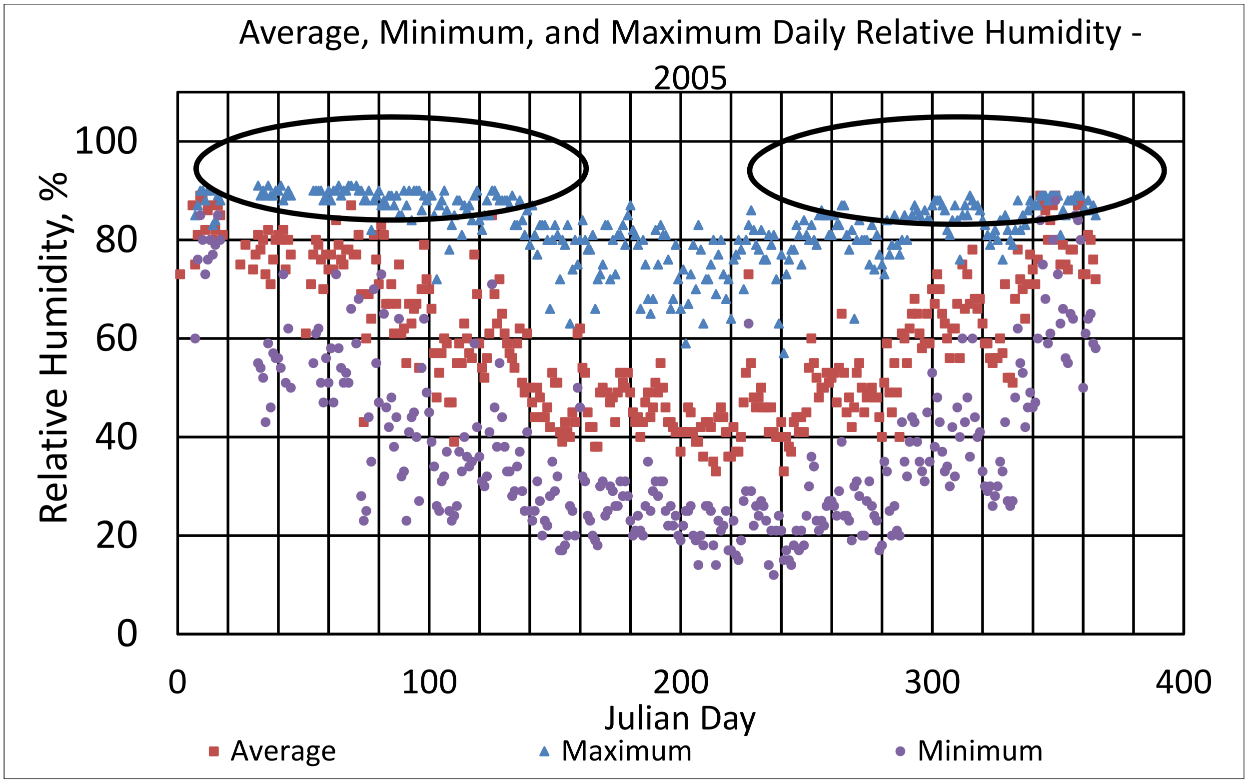

Figure A2.F.f-5. Average, Maximum, and Minimum Daily Temperature (DegF) for Madera CIMIS station (#145) for 2005 before QC.

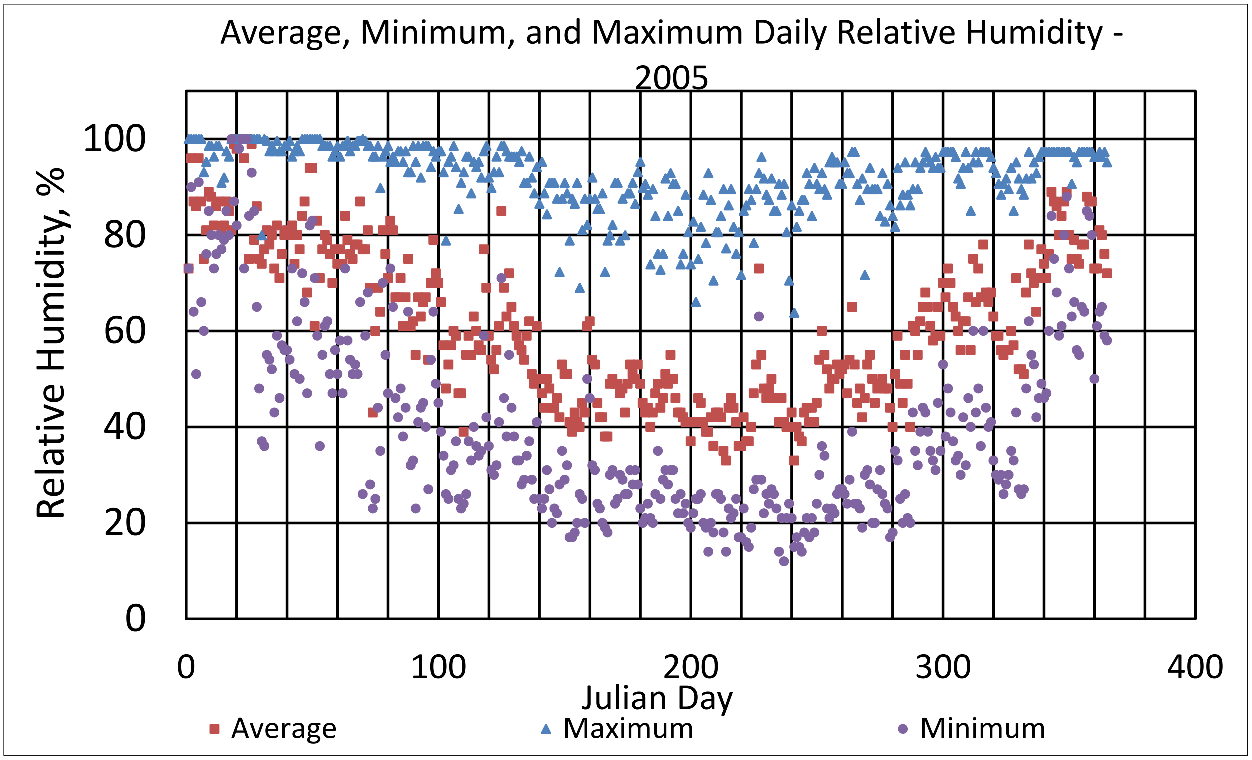

Figure A2.F.f-6. Average, Maximum, and Minimum Daily Temperature (DegF) for Madera CIMIS station (#145) for 2005 after QC.

3.2.4 Wind Speed

CIMIS AWS wind speed data were generally reasonable and usually followed expected ranges and patterns, with lower values during nighttime and higher values during the day. To calculate ET_o, all hourly wind speed values less than 0.5 m/s were set to 0.5 m/s, following the recommendation in ASCE-EWRI (2005), Appendix E, to represent a floor on wind movement and equilibrium boundary layer stability effects in the Penman-Monteith equation. A graphical example of this quality-control as it is applied to Madera windspeed data in the year 2000, can be observed in Figures A2.F.f-7 (unadjusted data) and 8 (adjusted data).

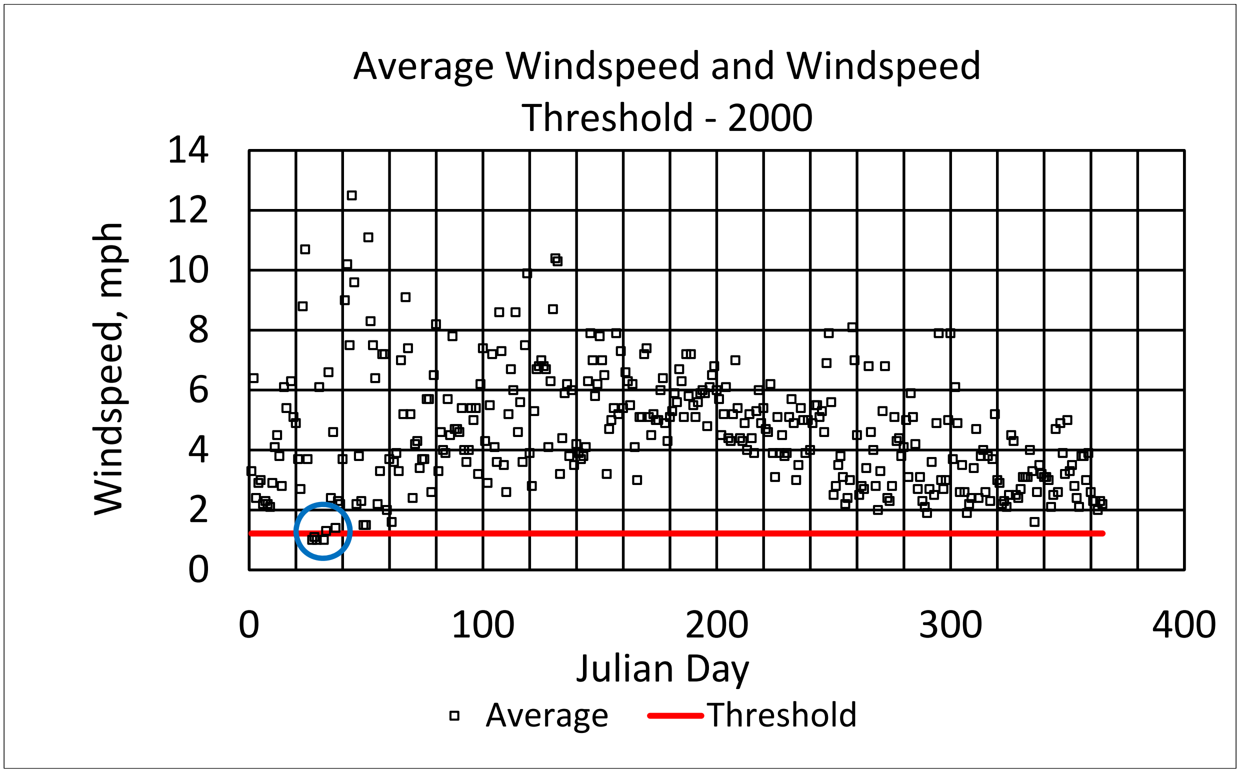

Figure A2.F.f-7. Average Windspeed (mph) for Madera CIMIS station (#145) for 2000 before quality-controlling.

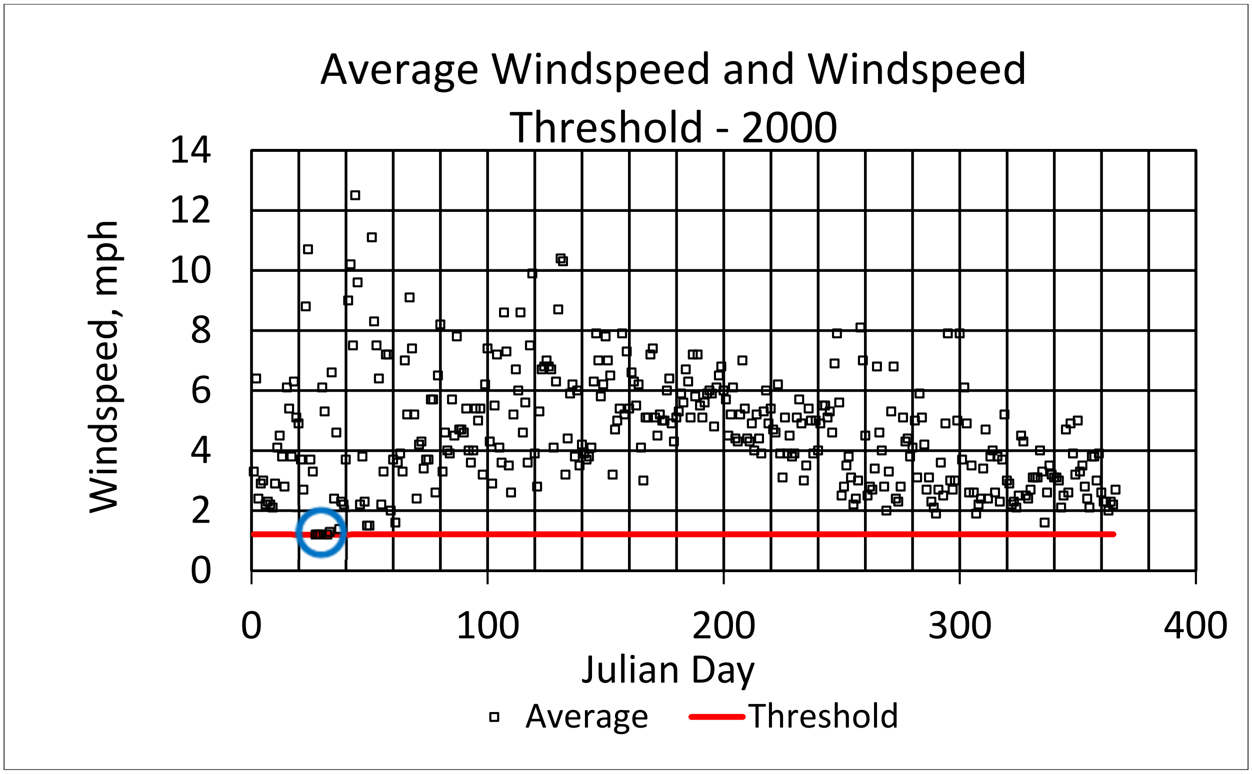

Figure A2.F.f-8. Average Windspeed (mph) for Madera CIMIS station (#145) for 2000 after quality-controlling.

3.2.5 ET$_o$ Results Summary

The average water year ET$_o$ for 1989 – 2015 was 55.34 inches and ranged from 50.64 inches in 1995 to 59.79 inches in 2004. This indicates that the differences in the average ET$_o$ values computed from the weather data collected at the various stations (Table A2.F.f-2) is most likely due to natural and expected variability in the record.

Table A2.F.f-2. Weather Data Time Series Summary for the period 1989 – 2015.

Weather Station	Start Date	End Date	Average Water Year ET$_o$, inches	Minimum Water Year ET$_o$, inches	Maximum Water Year ET$_o$, inches
Fresno State	Oct. 1, 1988	May 12, 1998	55.13	50.64 (1995)	59.27 (1992)
Madera	May 13, 1998	Apr. 2, 2013	55.67	52.56 (2011)	59.79 (2004)
Madera II	Apr. 3, 2013	Dec. 31, 2015	55.51	53.79 (2014)	57.24 (2015)
Overall	Oct. 2, 1988	Dec. 31, 2015	55.34	50.64	59.79

Water year ET$_o$ totals for the complete 1989 to 2015 period are included in Attachment A2.F.f-A.

3.2.6 Precipitation Results Summary

The 26-year average water year precipitation from 1989 to 2015, was 10.11 inches, varying from 3.59 inches in 2014 to 19.62 inches in 1995 (Table A2.F.f-3).

Table A2.F.f-3. Water Year Precipitation Statistics for 1989-2015.

Weather Station	Start Date	End Date	Average Water Year Rainfall, inches	Minimum Water Year Rainfall, inches	Maximum Water Year Rainfall, inches
Fresno State	Oct. 1, 1988	May 12, 1998	12.76	9.14 (1994)	19.62 (1995)
Madera	May 13, 1998	Apr. 2, 2013	8.98	4.35 (2012	12.79 (2006)
Madera II	Apr. 3, 2013	Dec. 31, 2015	4.25	3.59 (2014)	4.90 (2015)
Overall	Oct. 2, 1988	Dec. 31, 2015	10.11	3.59 (2014)	19.62 (1995)

Water year rainfall totals for the complete 1989 to 2015 period are included in Attachment A2.F.f-B.

4 FINDINGS

All weather stations considered near the Chowchilla Subbasin are located in agricultural areas. Quality control and quality assessment protocols were followed with review of hourly data and necessary adjustments performed on AWS data and daily checks and necessary adjustments performed on NOAA data. In conclusion, the time period was of such duration that at some point each parameter needed some adjustment. Minor adjustments to short periods of the wind data were necessary at all three sites. Air temperature data were mostly acceptable with the exception of multiple errors in the minimum temperature values for individual points within each site. Regarding both solar radiation and relative humidity for each site, erroneous trends were noticed and corrected, though the adjustment factors generally remained minimal (under 5%).

The average water year ET_o for 1989 – 2015 was 55.34 inches. The 26-year average precipitation from 1989 to 2015, was 10.11 inches.

5 REFERENCES

Allen, R. G. 1996. Assessing integrity of weather data for use in reference evapotranspiration estimation. J. Irrig. And Drain. Engrg., ASCE. 122(2): 97-106.

Allen, R. G., L. S. Pereira, D. Raes and M. Smith. 1998. Crop Evapotranspiration: Guidelines for computing crop water requirements. Irrig. And Drain. Paper 56, Food and Agriculture Organization of the United Nations, Rome, 300 pp.

Allen, R. G., I. A. Walter, R. Elliot, T. Howell, D. Itenfisu, and M. Jensen. 2005. The ASCE Standardized Reference Evapotranspiration Equation. Publication, American Society of Civil Engineers.

Attachment A2.F.f-A. List of Quality Control Adjustments Completed

Madera II Weather Station data:

Air Temperature:

2013: bad minimum temperature for 4-2, 10-7, 11-12,

2014: bad minimum temperature on 3-10, 4-7, 11-10, 11-12,

2015: bad minimum temperature on 3-9, 12-8,

2016: bad minimum temperature on 2-26, 5-27, 10-18,

Solar Radiation:

2013: data values need replacement on 4-2, 7-2, 7-5, 8-12, 9-4, 9-11, 9-17,

2014: 1% increase until 6-29, 4% increase the rest of the year, data values need replacement on 3-10, 4-3, 4-7, 6-4, 6-6, 8-12, 9-4, 9-8, 10-22, 11-10, 11-14

2015: 2% increase all year, data values need replacement on 2-9, 3-9, 7-8, 8-17, 9-16, 11-13

Relative Humidity:

2013: increase data up 3% all year (from 4-2 when station starts through the end of year)

2014: apply 3% increase for first half of year

2015: good

Windspeed*:

2013-2015: Good

Fresno State Weather Station data:

Air Temperature:

1989: missing average air temperature for 1-1 and 1-2, 10-13, missing all data for 10-12

1990: missing/bad data for 3-26 and 3-27, missing all data from 8-20 through 9-1

1991: bad data point on 3-8, missing data on 10-18 through 10-21 and 12-23

1992: missing data from 7-10 through 7-13 and from 10-17 through 11-10, data points need replacement on 5-15, 7-8, 7-13, 7-28, 7-29, 7-31, 9-4, 11-6, and 12-1

1993: bad minimum temperature readings on 2-1, 3-23, 4-21, 5-21, 6-25, 7-2, 9-10, and 10-29

1994: bad minimum temperature readings on 5-20, 7-18, 9-9, missing average temperature on 1-3

1995: all good

1996: bad minimum temperature on 4-30, 11-8, 12-31

1997: bad minimum temperature on 7-29, 4-1, 4-18, 10-2, and 10-10

1998: bad minimum temperature on 7-17, 8-17, bad average temp on 9-4

1999: bad minimum temperature on 4-10, 10-15, missing minimum temperature on 6-11, 7-23, 9-22, bad average temperature on 2-25, 3-1

2000: bad minimum temperature values on 4-12, 5-2, 5-16, 10-20,

2001: bad minimum temperature values on 4-10, 5-31, and 10-12

2002: bad minimum temperature values on 2-25, 4-30, 5-28,

2003: bad minimum temperature values on 3-11,

Solar Radiation:

1989: Good

1990: Good

1991: Adjust data down 9% from 5-30 through 6-7

1992: data points need replacement on 5-15, 7-13, 7-29, 7-31, 9-4, 12-1; adjust all data for this year up 2.5%

1993: data points need replacement on 2-1, 5-21, 6-25, 7-2, 9-10, 10-29

1994: data points need replacement on 7-18

1995: adjust data down 1%

1996: Adjust data up 8% from 5-15 on

1997: Adjust data up 8% until 4-1, then no adjustment; data points need replacement on 4-1, 4-18, 7-29

1998: data points need replacement on 5-1, 7-17, 11-25, adjust data down 2% from 5-9 through 7-1

1999: data points need replacement for 4-23, 6-11, 7-23, moved data up 5% from beginning until 8-10, move data up 7% from 8-10 until 9-2, then move data up 12% for the rest of the year

Relative Humidity:

1989: good

1990: move data up 1% for the whole year

1991: move data up 4% from 9-21 through end of the year

1992: move data up 1% all year

1993: Good

1994: Good

1995: Good

1996: Good

1997: Good

1998: Good

1999: Good

Windspeed*:

1989-1999: Good

Madera Weather Station Data:

Air temperature:

1998: Bad minimum temperature on 10-1,

1999: bad minimum temperature on 4-23,

2000: bad minimum temperature on 3-7, 10-2,

2001: bad minimum temperature on 10-11,

2002: bad minimum temperature on 4-15, 4-22, 2-27,

2003: bad minimum temperature on 3-2, 4-8, 5-12, 10-29,

2004: bad minimum temperature on 4-21, 12-5, 12-9,

2005: bad minimum temperature on 1-6, 1-12, 1-31, 4-20,

2006: bad minimum temperature on 2-6,

2007: bad average temperature on 1-1,

2008: bad minimum temperature on 4-14,

2009: bad minimum temperature on 1-16, 3-13,

2010: bad minimum temperature on 1-27,

2011: bad minimum temperatures on 1-22 through 2-1, 2-16, 3-17, 4-14, bad average temperature on 11-29,

2012: bad minimum temperature on 5-9, 2-6, 2-28, 1-23,

2013: good through 4-2 (end of record)

Solar Radiation:

1998: Data points need replacement on 8-26, 12-23, 12-31,

1999: Data points need replacement on 4-2, 4-23, 6-11, 7-2, 9-7, move all data up 3.5%,

2000: move data down 1% until 6-6, and then move data up 1% through the rest of the year

2001: data points need replacement on 7-20, 8-13, 8-15, 9-10, move data up 3% until 5-10, then move data up 4% until 7-11, then unadjusted data through the end of the year

2002: move all data down 1.5%, data points need replacement on 8-21, 8-24, 8-25,

2003: From 7-15 on, move data up 3.5%, data points need replacement on 3-10, 4-8, 5-12, 7-10, 8-14,

2004: data points need replacement on 6-18, 7-19, 8-18, move all data up 2.5%,

2005: data points need replacement on 2-22, 3-15, move all data up 4%

2006: move data up 10% until 6-19, and then move data up 14% through the end of the year

2007: data points need replacement on 8-16, move data down 3% until 5-2, and then move data down 8% until 8-14, then move data up 3% for the rest of the year,

2008: move data up 13% until 4-13, then move data down 12% through the end of the year, 2009: move data down 6% until 6-7, then move data down 2% for the rest of the year, data points need replacement on 6-16, 6-19, 8-7, 8-10,

2010: move data up 2% for the year, data points need replacement on 1-27, 11-24,

2011: move data up 3.5% until 5-25, then move data down 6% until end of year, data points need replacement on 7-18, 9-7, 11-2,

2012: replace data from 4-29 through 5-7, and on 3-19, 5-9, 6-5, 6-6, move data up 5% from 5-14 through the end of the year,

2013: data points need replacement from 3-29 through 4-2

Relative Humidity:

1998: good

1999: apply 2% increase to the second half of the year

2000: apply 2% increase to first half of year, and 3% increase to second half of year

2001: apply 3% increase to first half of year, and 4% increase to second half of year

2002: apply 4% increase all year

2003: apply 4% increase to first half of year, and 6.5% increase to second half of year

2004: apply 7% increase to first half of year, and 8.5% increase to second half of year

2005: apply 9.5% increase to first half of year, and 12% increase to second half of year

2006: apply % increase until 6-9, then no adjustment factor

2007: good

2008: good

2009: apply 2% increase all year

2010: apply 2% increase all year

2011: apply 2% increase all year

2012: apply 1% increase all year

2013: Good

Windspeed*:

1998-2013: Good

*Windspeed values that fell below the threshold may have been replaced with replacement stations data but are not listed here because they were not replaced in the manual review QC process.

Attachment A2.F.f-B. Annual ET_o and Precipitation Results

Table A2.F.f-B-1. Water Year ET_o and Precipitation Results

Water Year	ETo, inches	Precip, inches
1989	52.68	11.96
1990	55.16	11.15
1991	54.96	11.65
1992	59.27	9.52
1993	55.29	16.13
1994	55.75	9.14
1995	50.64	19.62
1996	55.76	11.99
1997	56.63	13.70
1998	53.05	16.55
1999	52.63	6.68
2000	55.02	10.89
2001	56.16	10.16
2002	56.07	9.22
2003	55.42	8.10
2004	59.79	6.73
2005	53.94	11.61
2006	55.44	12.79
2007	57.25	5.18
2008	57.36	7.87
2009	57.62	7.11
2010	53.24	12.21
2011	52.56	12.78
2012	56.89	4.35
2013	54.50	7.35
2014	53.79	3.59
2015	57.24	4.90

APPENDIX 2.F. WATER BUDGET INFORMATION

2.F.g. Development of Daily Time Step IDC Root Zone Water Budget Model

Prepared as part of the

Groundwater Sustainability Plan
Chowchilla Subbasin

January 2020

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Table A2.F.g-6. Average Acreages and Annual Evapotranspiration Rates for Chowchilla Subbasin, 1989 to 2014.

1 OVERVIEW

The water budget uses available data and estimates to develop an accurate accounting of all water inflows and outflows from the Chowchilla Subbasin. The information supporting the water budget for 1989 through 2015 has been assembled to complete the historical Chowchilla Subbasin water budget. As part of water budget development, the stand-alone root zone water budget modeling tool used with the Integrated Water Flow Model (IWFM) developed and maintained by the California Department of Water Resources (DWR) is used to partition ET into ET from applied water and ET from precipitation. This stand-alone version of the root zone model is known as the IWFM Demand Calculator (IDC). The root zone water budget included with IWFM is designed such that it can be used as a stand-alone model to complete the root zone water budget for agricultural, urban, and native lands. IDC was used to develop time series estimates for the following outputs which were then combined with surface water delivery and groundwater pumping information to complete the subbasin boundary water budget and to provide estimates of the infiltration of precipitation and runoff of precipitation:

- ET of precipitation (ET_{pr});
- ET of applied water (ET_{aw}); and
- Deep percolation of precipitation (DP_{pr})
- Uncollected surface runoff of precipitation (RO_{pr})

IDC files were developed for a stand-alone, daily time step IDC application and these inputs were later adapted into IDC files used to simulate root zone moisture within IWFM. Thus, the IWFM results for the surface layer of the Chowchilla Subbasin area should be carefully reviewed and IDC Model parameters may require some adjustment to align the results with the agricultural lands water budget results. In particular, IDC was not calibrated to ensure estimated applied water demands match historical deliveries and pumping.

Inputs provided to the IDC root zone model include:

- Daily crop evapotranspiration (ET_c) representing actual ET (as compared to potential ET) for each crop or land use class from January 1, 1985 through December 31, 2015 developed by multiplying reference ET (ET_o) by the appropriate crop coefficient (developed from a 2009 SEBAL (remotely sensed energy balance analysis)).
- Daily precipitation (P_r) from January 1, 1985 through December 31, 2015.
- Soil properties for each soil texture simulated
- Rooting depth for each crop or land use class
- Other model parameters for the land use classes and soil texture combinations simulated, including soil moisture parameters and runoff curve numbers

2 IDC MODEL SETUP

The IDC Model was used as a stand-alone root zone modeling tool to develop a surface layer water budget for the Chowchilla Subbasin to provide preliminary information regarding subbasin water overdraft prior to the development of the groundwater model. The IDC Model was then linked with IWFM to develop a groundwater model for the Chowchilla and Madera Subbasins.

The stand-alone IDC Model uses a daily time step to accurately parse crop ET_c into ET_{aw} and ET_{pr} for the Chowchilla Subbasin agricultural water budget between January 1, 1985 and December 31, 2015. The model is set up as a unitized model (as compared to a spatial model) that provides per acre results by specifying one unique land use class-soil-runoff combination per element with the area of each element set to approximately 10,000 acres. A total of 17 land use classes and 15 soil textures were evaluated with one specified curve number representing runoff conditions for each. To allow land use class-soil-runoff combinations to be added in future years, 450 elements comprised of 902 nodes were configured in the model. The land use class-soil-runoff combinations are described in the following sections. The provided input files were used with the IWFM Version 2015.0.0036, Root Zone Component Version 4.0 (DWR, 2015). All land use classes were modeled as non-ponded crops except the urban land use class, which was modeled using the IDC urban module.

The linked IDC Model uses a monthly time step to link with the IWFM groundwater model. The monthly linked model results should match daily model results summed to monthly and annual time steps. Because of the differing time steps, some of the IDC parameters in the daily model must be revised. Those revisions are described in the appropriate sections below.

2.1 Weather Inputs

2.1.1 Evapotranspiration Inputs

Daily reference ET (ET_o) values used for 1985 through 2015 were based on measured weather data from three California Irrigation Management Information System (CIMIS) stations (Table A2.F.g-1). Measured weather parameters supporting daily ET_o calculations were quality controlled following standard procedures (ASCE-EWRI, 2005) to produce a high quality daily ET_o time series for use with crop coefficients to develop the ET time series for each land use class as described in Appendix 2A.

Table A2.F.g-1. Chowchilla Subbasin Weather Data Time Series Summary for the period 1989 – 2015.

Weather Station	Start Date	End Date	Comment
Fresno State (#80)	Jan. 1, 1985	May 12, 1998	CIMIS. Before Madera was installed.
Madera (#145)	May 13, 1998	Apr. 2, 2013	CIMIS. Moved East 2 miles and renamed “Madera II”
Madera II (#188)	Apr. 3, 2013	Dec. 31, 2015	CIMIS.

Crop coefficients were derived using ET_o values described in the previous paragraph and actual ET (ET_a) estimates based on remotely sensed surface energy balance results from Surface Energy Balance Algorithm for Land (SEBAL) (Bastiaanssen, et al. 2005). Spatially distributed ET_a results were available with spatial cropping data for 2009. SEBAL results account for effects of salinity, deficit irrigation, disease, fertilization, immature permanent crops, crop canopy structure, and any other factors resulting in differences between potential and actual crop ET. Studies by Bastiaanssen et al. (2005), Allen et al. (2007, 2011), Thoreson et al. (2009), and others have found that when performed by an expert analyst, seasonal ET_a estimates by these models are expected to be within five percent of actual ET determined using other reliable methods.

2.1.2 Precipitation Inputs

Precipitation values were obtained from the three CIMIS stations (Table A2.F.g-1) for 1985 through 2015 and averaged 10.1 inches per water year during the 1989 through 2015 period. The precipitation records were carefully reviewed and standard quality control procedures (ASCE-EWRI, 2005) were applied as described in Appendix 2.F.f.

2.2 Soil Inputs

2.2.1 Soil Textural Classes and Calibrated Model Parameters

Soil textural classes and associated soil hydraulic parameters were estimated from the Soil Survey Geographic (SSURGO) database (Soil Survey Staff, 2014) for use in IDC. The SSURGO database contains information collected by the National Cooperative Soil Survey (NCSS) about soils in the United States. The United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS), formerly known as the Soil Conservation Service (SCS), organizes the NCSS and publishes soil surveys. The IDC model includes fifteen soil textures representing approximately 98 percent of the Chowchilla Subbasin area (Table A2.F.g-2). Sandy clay loam and sandy loam soil textures together cover nearly 88 percent of the Chowchilla Subbasin area.

The following five soil parameters were provided as inputs to the IDC Model and are summarized for each soil texture class in Table A2.F.g-3:

1. Permanent Wilting Point (PWP), dimensionless
2. Field Capacity (FC), dimensionless
3. Total Porosity (ϕ), dimensionless
4. Pore Size Distribution Index (λ), dimensionless
5. Saturated Hydraulic Conductivity (K_{sat}) in feet per day (ft/day)

For each soil texture class derived from SSURGO, initial soil hydraulic parameters were estimated based on pedotransfer functions reported by Saxton and Rawls (2006) and refined to provide drainage from saturation to field capacity within a reasonable amount of time, as determined from the percentage of drainage after 3 days (generally exceeding 60-80%), and to predict minimal gravitational drainage once field capacity was reached (Table A2.F.g-3).

2.2.2 Initial Soil Moisture

In many years, sufficient precipitation occurs during the winter months to fill the root zone to field capacity. Thus, the initial soil moisture at the IDC model start date (January 1, 1985) was set to field capacity. The IDC model runs for the Subbasin water budget were started four years before the first year in the water budget period (1989) to minimize any potential effect from incorrectly specifying the initial soil moisture value.

2.3 Non-Ponded Crop Inputs

All land use classes, except for urban, were modeled as non-ponded crops. For non-ponded crops, the IDC model stimulates irrigation events (i.e., applied water) based on user-defined inputs. The following sections describe these land use classes and inputs.

Table A2.F.g-2. Soil Textures by Area.

Soil Texture (% Sand, % Silt, % Clay)	Acres	% of Area	Represented in IDC Model
sandy clay loam (50, 20, 30)	26,566	18.2%	×
sandy loam - sandy clay loam (60, 20, 20)	19,774	13.5%	×
sandy loam (70, 20, 10)	18,335	12.5%	×
loam (50, 30, 20)	16,989	11.6%	×
sandy loam - sandy clay loam (70, 10, 20)	13,547	9.3%	×
silt loam - loam (40, 50, 10)	12,851	8.8%	×
loam (40, 40, 20)	11,073	7.6%	×
loamy sand (80, 20, 0)	7,081	4.8%	×
silty clay loam (20, 50, 30)	4,650	3.2%	×
sandy clay loam (60, 10, 30)	2,906	2.0%	×
clay loam (40, 30, 30)	2,835	1.9%	×
sand (100, 0, 0)	2,600	1.8%	×
clay loam (30, 40, 30)	1,468	1.0%	×
sandy loam (80, 10, 10)	1,144	0.8%	×
clay - clay loam (30, 30, 40)	859	0.6%	×
sandy loam (60, 30, 10)	761	0.5%	
sand (90, 10, 0)	597	0.4%	
clay - clay loam (40, 20, 40)	245	0.2%	
clay (20, 30, 50)	239	0.2%	
silt loam - loam (30, 50, 20)	80	0.1%	
clay (30, 20, 50)	29	0.0%	
loam (50, 40, 10)	5	0.0%	
Other (i.e., water, urban, etc.)	1,690	1.2%	
Total	146,325	100%	

Table A2.F.g-3. Soil Texture with IDC Model Soil Parameters.

Soil Texture (% Sand, % Silt, % Clay)	PWP	FC	φ	λ	Ksat (ft/d)
sandy clay loam (50, 20, 30)	0.16	0.26	0.40	0.16	5.70
sandy loam - sandy clay loam (60, 20, 20)	0.11	0.21	0.39	0.26	8.40
sandy loam (70, 20, 10)	0.07	0.15	0.38	0.48	9.00
loam (50, 30, 20)	0.11	0.22	0.39	0.23	5.75
sandy loam - sandy clay loam (70, 10, 20)	0.09	0.17	0.38	0.38	8.60
silt loam - loam (40, 50, 10)	0.07	0.22	0.38	0.21	9.00
loam (40, 40, 20)	0.15	0.28	0.40	0.15	3.60
loamy sand (80, 20, 0)	0.01	0.07	0.40	1.83	10.60
silty clay loam (20, 50, 30)	0.16	0.32	0.42	0.14	0.60
sand (100, 0, 0)	0.01	0.04	0.42	10.10	15.50
sandy clay loam (60, 10, 30)	0.15	0.24	0.39	0.19	5.85
clay loam (40, 30, 30)	0.16	0.29	0.41	0.14	3.00

Soil Texture (% Sand, % Silt, % Clay)	PWP	FC	φ	λ	Ksat (ft/d)
clay loam (30, 40, 30)	0.19	0.33	0.42	0.10	2.50
clay - clay loam (30, 30, 40)	0.26	0.39	0.46	0.06	2.00
sandy loam (80, 10, 10)	0.04	0.10	0.39	0.93	10.50
clay (30, 20, 50)	0.27	0.40	0.47	0.07	0.90

2.3.1 Agricultural Water Supply Requirement (Target Soil Moisture Fraction)

Water supplied to each crop is estimated within the simulation. The target soil moisture data file allows the user to specify irrigation target soil moisture as a fraction of field capacity. When simulating an irrigation event, the IDC model will apply water until the soil reaches the specified percent of field capacity. Target soil moisture fractions were estimated as approximately 1.0 for all land use classes based on common irrigation methods and scheduling practices in the Chowchilla Subbasin, where growers typically irrigate to field capacity.

When IDC is run on a monthly time step, if the TSMF used for the daily model is used, greater volumes of deep percolation results. This is because when the IDC equations are applied on a monthly basis, the TSMF values used for the daily model result in greater values of soil moisture in the equation computing deep percolation. Thus, the TSMF values must be adjusted to result in deep percolation of applied water volumes consistent with the daily model results. The revised TSMF values are also adjusted to simulate the increase in consumptive use fraction that occurs when over time flood irrigation systems are converted to pressurized systems.

2.3.2 Minimum Soil Moisture

The minimum soil moisture value for each crop corresponds to the moisture content at the Management Allowable Depletion (MAD) specified for that crop. Management Allowed Depletion (MAD) is defined as the desired soil water deficit at the time of irrigation and can vary with growth stage (ASABE, 2007). The MAD is often set as the percent of total available moisture that the crop can withstand without suffering stress or yield loss. Water stress is estimated within the IDC model when the percent of total available moisture exceeds 50 percent. The IDC Model allows different values to be input for different crops and different growth stages. Values for the minimum soil moisture were set to 50 percent for all land use classes at all growth stages to prevent stress from occurring in the simulation. It is important to note here that the crop coefficients, as described previously, are developed from remotely sensed energy balance ET data and thus already include ET reductions that may have occurred due to water stress or other factors.

2.3.3 Irrigation Period

The irrigation period determines the cropped and non-cropped periods for each crop. A value of one represents a cropped period, during which IDC calculates applied water demand for the crop. A value of zero represents a non-cropped period, during which IDC does not compute applied water for the crop. Different irrigation periods can be defined for different land use types if necessary. In this application the irrigation period was set to one between March and October for all land use classes except corn, grain, and idle lands, and roughly corresponded with the irrigation season in the Chowchilla Subbasin. For idle lands, the irrigation period was set to zero for all months.

2.3.4 Reuse and Return Flow

The return flow fraction determines the proportion of applied water that can leave the land use cell as runoff, while the reuse fraction determines the proportion of applied water that is captured and reused for irrigation. A value of one each indicates that all applied water can leave as runoff, but that all applied water is captured and reused for irrigation. A value of zero each indicates that no applied water leaves the land use cell or is reused for irrigation. For this simulation, irrigation water return flow and reuse fractions have been set to zero in the IDC model. Return flow and reuse are internal flow paths and thus are not included in the Subbasin boundary water budget.

2.3.5 Root Depth

Root depths for each of the 17 land use classes were estimated primarily from ASCE (2016) with consideration given for local conditions. A list of the land use classes and their associated rooting depths are provided in Table A2.F.g-4. IDC provides an option that models changing root growth as the season progresses for annual crops. For this application, all land use classes were modeled with constant root depths.

Table A2.F.g-4. Root Depths Used in IDC Model by Land Use Class.

Land Use Class	Root Depth (ft)
Alfalfa	6.0
Almonds	4.0
Citrus and Subtropical	4.0
Corn (double crop)	3.5
Grain and Hay Crops	3.5
Grapes	4.0
Idle	3.0
Miscellaneous Deciduous	4.0
Miscellaneous Field Crops	3.5
Miscellaneous Truck Crops	2.5
Mixed Pasture	3.0
Native	6.0
Pistachios	4.0
Semi-agricultural	4.0
Walnuts	6.0
Water	4.0
Urban	4.0

2.3.6 Runoff Curve Numbers

The IDC uses a modified version of the SCS curve number (SCS-CN) method to compute runoff of precipitation. A curve number for each land use class and soil type is required as input to the model. Curve numbers are used as described in the National Engineering Handbook Part 630[1] (USDA, 2004, 2007)

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[1] Table 1. Runoff curve numbers for agricultural lands.

based on land use or cover type, treatments (straight rows, bare soil, etc.), hydrologic condition, and hydrologic soil group. An area weighted average curve number for each land use-soil texture combination was calculated based on the area in each hydrologic soil group assuming good hydrologic conditions (Table A2.F.g-5). The total area of each soil group within the Chowchilla Subbasin was estimated from the NRCS SSURGO database and is described in Table A2.F.g-2.

When IDC is run on a monthly time step, if the curve number used for the daily model is used, greater volumes of runoff of precipitation result. Thus, the curve number values must be adjusted to result in runoff of precipitation volumes consistent with the daily model results.

2.4 Urban Module Inputs

Urban areas were modelled using the IDC urban module. Urban inputs are described below.

2.4.1 Population

The City of Chowchilla is the only city that overlies the Chowchilla Subbasin. Population estimates were obtained from the California Department of Finance. In 1996, the City of Chowchilla annexed two local prisons into the city limits. The prisons are located approximately 7 miles east of the city limits within the Chowchilla Subbasin boundary. The prisons operate and maintain their own water supply system separate from the City of Chowchilla. Prison populations were subtracted from the City of Chowchilla population estimates following the 1996 annexation.

2.4.2 Groundwater Pumping

The City of Chowchilla pumps groundwater to serve residences within the city limits. Monthly pumping records were provided by the City from 2003 through 2016. Groundwater pumping from 1985 through 2002 were estimated based on annual population records from the California Department of Finance and the average per capita water use from 2003 through 2016.

Table A2.F.g-5. Curve Number Used to Represent Runoff Conditions in Chowchilla Subbasin.

Soil Texture (% Sand, % Silt, % Clay)	Alfalfa	Almonds	Citrus and Subtropical	Corn	Grain and Hay Crops	Grapes	Idle	Misc. Deciduous	Misc. Field Crops	Misc. Truck Crops	Mixed Pasture	Native	Pistachios	Semi-agricultural	Walnuts	Water	Urban
silt loam - loam (40, 50, 10)	58	58	58	78	75	58	86	58	78	78	58	58	58	74	58	78	69
clay - clay loam (30, 30, 40)	78	79	79	89	87	79	94	79	89	89	78	78	79	86	79	89	
clay loam (40, 30, 30)	73	74	74	86	84	74	92	74	86	86	73	73	74	83	74	86	
clay loam (30, 40, 30)	78	79	79	89	87	79	94	79	89	89	78	78	79	86	79	89	
loam (40, 40, 20)	71	72	72	85	83	72	91	72	85	85	71	71	72	82	72	85	
loam (50, 30, 20)	73	74	74	86	84	74	92	74	86	86	73	73	74	83	74	86	
sandy clay loam (60, 10, 30)	78	79	79	89	87	79	94	79	89	89	78	78	79	86	79	89	
loamy sand (80, 20, 0)	30	32	32	67	63	32	77	32	67	67	30	30	32	59	32	67	
sandy loam - sandy clay loam (70, 10, 20)	78	79	79	89	87	79	94	79	89	89	78	78	79	86	79	89	
sand (100, 0, 0)	58	59	59	80	77	59	87	59	80	80	58	58	59	74	59	80	
sandy clay loam (50, 20, 30)	76	77	77	88	86	77	93	77	88	88	76	76	77	85	77	88	
sandy loam (80, 10, 10)	52	52	52	76	72	52	84	52	76	76	52	52	52	71	52	76	
silty clay loam (20, 50, 30)	58	58	58	78	75	58	86	58	78	78	58	58	58	74	58	78	
sandy loam (70, 20, 10)	59	59	59	78	75	59	86	59	78	78	59	59	59	74	59	78	
sandy loam - sandy clay loam (60, 20, 20)	59	59	59	78	75	59	86	59	78	78	59	59	59	74	59	78	

2.4.3 Indoor Use Fractions

Applied water estimates are divided into the amount of water that is used indoors versus outdoors based on user-defined indoor use fractions. Monthly time series of indoor use fractions were estimated based on indoor water use divided by the total amount of groundwater pumped. Indoor water use was estimated as 90% of the groundwater pumped in February and was assumed to be constant throughout the year.

2.4.4 Urban Main Inputs

The urban main input file contains several pertinent inputs necessary to estimate runoff and evapotranspiration. These inputs include the pervious fraction and curve number. It is assumed that only pervious areas are available for ET. In all impervious areas, the ET is assumed to be zero. The ET of pervious areas was assumed equal to the ET of pasture. The pervious fraction was estimated as 0.66 based on the proportion of 'built-up' and undeveloped areas within the city limits. The curve number was estimated as 69 for urban areas, which was based on Hydrologic Soil Group B, fair hydrologic condition, and pasture. Root zone depth for urban lands was assumed to be two feet.

2.5 Land Use Inputs and Parameters

2.5.1 Land Use

Annual land use was estimated based primarily on spatially distributed land use information from DWR Land Use surveys for Madera and Merced Counties and Land IQ[2] remote sensing-based land use identification for 2014. Madera County DWR Land Use surveys were available for 1995, 2001, and 2011. Merced County DWR Land Use surveys were available for 1995, 2002, and 2012. County Agriculture Commission land use areas were used to interpolate between years with available spatial land use information. Lands in the Subbasin were assigned to one of 17 land use classes.

The Chowchilla Subbasin overlies both Madera and Merced Counties. The following five steps were used to develop the Madera and Merced County-wide annual, spatial land use datasets.

1.) Developed spatial land use coverages for:
   Madera County: 1995, 2001, 2011, and 2014
   Merced County: 1995, 2002, 2012, and 2014
   and made adjustments to the spatial coverage, including:
   a) Filled missing area from LandIQ coverage with 2011 DWR coverage (native, semi-agricultural, urban, and water account for 86% of the missing area in Madera County and 95% of missing area in Merced County)
   b) Madera County: Used the water area from 2001 for the 1995 DWR survey (water surfaces were not included in the 1995 DWR survey).

2.) Calculated agricultural area:
   a) Assumed county data does not include idle land (county data has idle equal to zero for all years)
   b) Excluded idle land from DWR agricultural totals to be consistent with county totals

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[2] Land IQ is a firm that was contracted by DWR to use remote sensing methodologies to identify crops in fields.

   c) Calculated the ratio of the DWR agricultural total area (not including idle lands) to county agricultural production area for years with DWR (or Land IQ) land use data
   d) Estimated agricultural area for missing years between the first and last available county data by interpolating the ratio calculated in step (c)
   e) Estimated agricultural area for missing years outside the available county data by extending the annual trend or estimating as equal to the nearest available county data

3.) Multiplied county agricultural acres for each crop by the ratio calculated in step 2 (c) to adjust county agricultural areas for each crop scaling each crop area in each year by an estimate of the difference between the areas in the DWR land use surveys and County Commissioner reports. This procedure assumes DWR areas are the most accurate.
   a) Interpolated native, semi-agricultural, urban, and water land uses between DWR years.
   b) Calculated idle area as the remaining area (total DWR land use minus total cropped area)

4.) Reviewed calculated idle and crop area graphs and adjusted individual annual cropped areas with abnormal crop area shifts based on professional judgement to eliminate calculated negative idle areas.
   Madera County:
   a) 1996 adjustments--replaced high miscellaneous truck areas with interpolated values between 1995 and 1997
   b) 2002, 2003, 2004 and 2005 adjustments--replaced high areas for mixed pasture and alfalfa between 2001 and 2011 DWR areas by interpolating areas between 2001 and 2011.
   c) 2012 adjustments--replaced high miscellaneous deciduous, field and truck with interpolated value between 2011 and 2013

   Merced County:
   a) Almond acreage adjustments--interpolated years 2013 and 2015 using 2012 and 2014 land use coverages
   b) Citrus and Subtropical acreage adjustments--interpolated between 2002 and 2015 using 2002, 2012, and 2014 land use surveys
   c) Grain and Hay Crops--interpolated years 2013 and 2015 using 2012 and 2014 land use coverages
   d) Grapes--interpolated between 1989 through 2015 using land use surveys
   e) Miscellaneous Field Crops--replaced low acreage in 1991 by interpolating between 1990 and 1992
   f) Miscellaneous Truck Crop--interpolated years 2006, 2009, 2010, 2013, and 2015 based on land use surveys
   g) Water--assumed acreage from 1995 DWR survey for 1989 through 1994

5.) Implemented the DWR Land Use interpolation tool to create annual spatial cropping data sets.

Complete land use areas for the entire subbasin for 1989 through 2015 are provided in Section 2 of the GSP.

3 RESULTS

Table A2.F.g-6 summarizes average acreage and evapotranspiration rates across Chowchilla Subbasin based on the IDC model and land use analysis.

Table A2.F.g-6. Average Acreages and Annual Evapotranspiration Rates for Chowchilla Subbasin, 1989 to 2014.

Land Use Sector	Land Use Class	Acres	ET_c (in)	ET_{pr} (in)	ET_{aw} (in)
Agricultural	Alfalfa	22,743	38.4	7.3	31.1
	Almonds	26,296	41.5	7.7	33.8
	Citrus and Subtropical	65	40.2	7.7	32.5
	Corn (double crop)	17,325	34.9	5.5	29.5
	Grain and Hay Crops	5,642	19.6	5.8	13.7
	Grapes	9,976	26.6	7.0	19.6
	Idle	6,624	6.8	6.8	0.0
	Miscellaneous Deciduous	3,791	32.5	7.4	25.1
	Miscellaneous Field Crops	14,377	30.7	5.8	24.9
	Miscellaneous Truck Crops	1,537	30.4	5.7	24.7
	Mixed Pasture	6,424	28.5	6.6	22.0
	Pistachios	3,951	36.9	7.3	29.7
	Walnuts	315	33.9	7.7	26.2
Native Vegetation	Native	17,702	7.9	7.9	0.0
	Water	1,397	8.1	8.1	0.0
Urban	Urban	4,691	14.2	7.2	6.9
	Semi-agricultural	3,467	13.8	7.0	6.7

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APPENDIX 2.G. CHOWCHILLA SUBBASIN DOMESTIC WELL INVENTORY

Prepared as part of the

Groundwater Sustainability Plan
Chowchilla Subbasin

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Technical Memorandum:

Domestic Well Inventory for the Chowchilla Subbasin

Prepared for Madera County and the
Chowchilla Subbasin Groundwater Sustainability Agencies

April 2022

Prepared by

Luhdorff & Scalmanini
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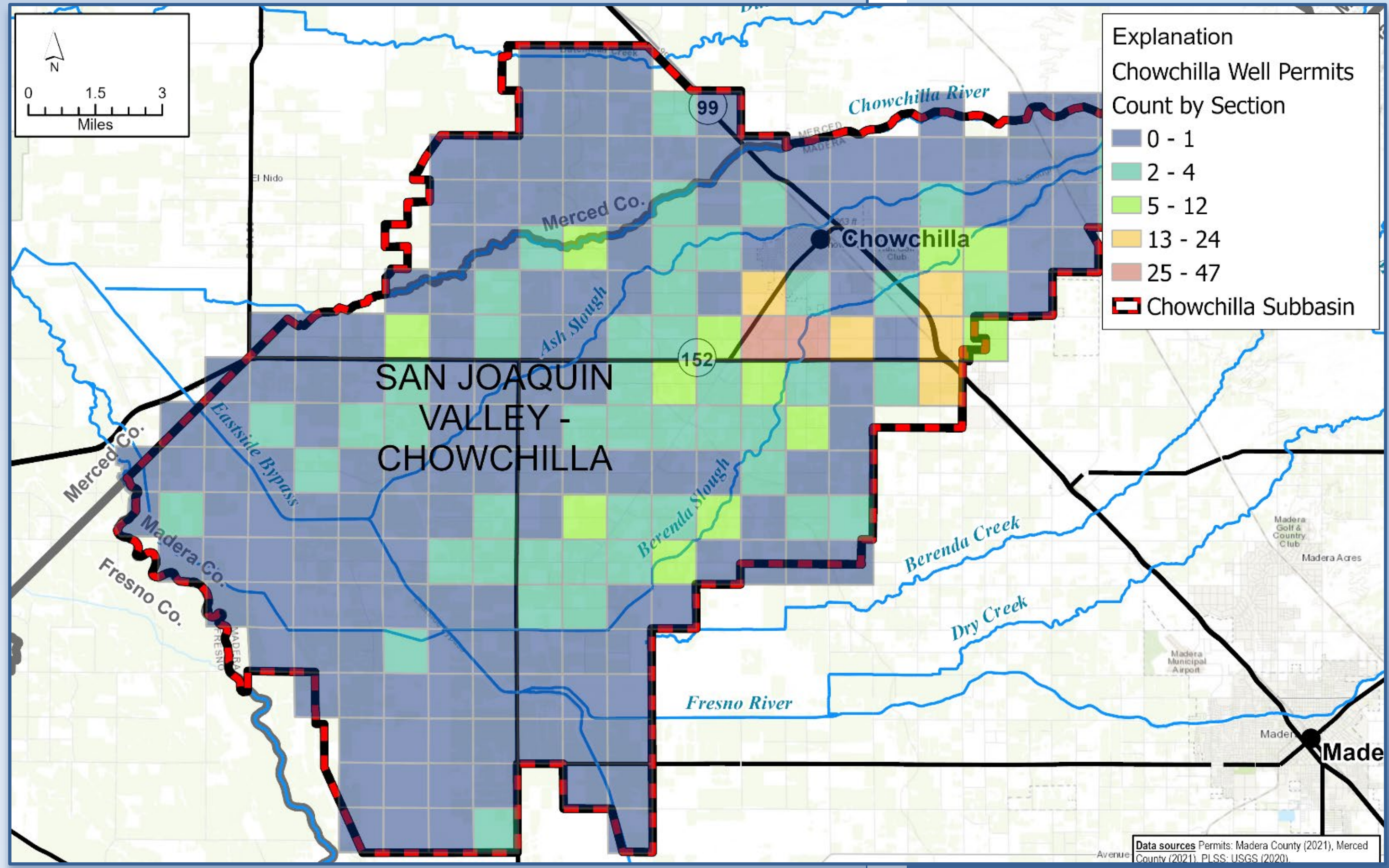

Data sources Permits: Madera County (2021), Merced County (2021). PLSS: USGS (2020).

Technical Memorandum:

Domestic Well Inventory for the Chowchilla Subbasin

This memorandum was prepared for Madera County and the Chowchilla Subbasin Groundwater Sustainability Agencies to support implementation of the Chowchilla Subbasin Groundwater Sustainability Plan.

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Luhdorff and Scalmanini Consulting Engineers conducted the Domestic Well Inventory project for the Chowchilla Subbasin and prepared this technical memorandum with assistance from ERA Economics.

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LIST OF ABBREVIATIONS & ACRONYMS

Acronym	Meaning
APN	Assessor Parcel Number
CDP	Census-Designated Place
CDWR	California Department of Water Resources
CEHTP	California Environmental Health Tracking Program
DAC	Disadvantaged Communities
DDW	Division of Drinking Water
DTW	depth to water
GPS	Global Positioning Satellite
GSP	Groundwater Sustainability Plan
LSCE	Luhdorff & Scalmanini, Consulting Engineers
LSWS	Local Small Water System
MCSIM	groundwater model
MD	Maintenance District
MHI	median household income
OSWCR	Online System for WCRs
PLSS	Public Land Survey System
PWS	Public Water System
SDAC	Severely Disadvantaged Communities
SDWIS	Safe Drinking Water Information System
SGMA	Sustainable Groundwater Management Act
SHE	Self-Help Enterprises
SSWS	State Small Water System
SSWS	State Small Water System
SWRCB	State Water Resources Control Board
TM	Technical Memorandum
WCR	Well Completion Report

1 INTRODUCTION

The Chowchilla Subbasin Groundwater Sustainability Plan (GSP) includes maps, figures, analysis, and discussion of domestic wells and potential impacts from continued decline in regional groundwater levels during the GSP Implementation Period (2020 through 2040) while the Subbasin works to achieve sustainability. The GSP provided the background and data analyses to illustrate the need for a Domestic Well Mitigation Program in Chowchilla Subbasin and described how it is the most economically viable way to transition from current overdraft conditions to sustainable conditions in 2040. However, there was insufficient time during GSP development to conduct the more thorough inventory of domestic wells and the potential range of impacts to domestic wells under various scenarios of future groundwater conditions. This study supplements domestic well information provided in the GSP and provides an updated analysis that includes anticipated impacts to domestic wells during the GSP Implementation Period.

Madera County was successful in applying for a DWR grant under Prop 68 to conduct a more detailed well inventory, which is documented in this Technical Memorandum (TM). In addition, the grant funding provides for drilling and installation of nested monitoring wells at three sites in proximity to clusters of domestic wells to provide monitoring of current and future groundwater levels and quality. This TM includes recommendations for locations of these three nested well sites.

To prepare this domestic well inventory, approximations of the number, depths, and locations of domestic wells were developed from multiple available data sources. The total number of domestic wells indicated to be present according to different data sources were reviewed and compared. Domestic well depths were then compared to historical, current, and predicted future local groundwater depths based on observed and modeled data from the groundwater model (MCSIM) developed for and described in the 2020 Chowchilla Subbasin GSP. Due to the uncertainty in future climatic conditions for the GSP Implementation Period; two primary future condition scenarios were evaluated to bracket the range of domestic wells that are estimated to go dry during the GSP Implementation Period. Estimates of costs to replace domestic wells are included in this TM.

This TM documents the available data sources for estimating numbers and locations of domestic wells, domestic well construction details, and occurrence of domestic wells inside and outside of public and small community water systems, analyses to estimate the number of domestic wells that may go dry through 2040 based on two different climatic sequences, and sensitivity analyses to evaluate how various assumptions impact estimates of the number of dry wells. Using the results from the domestic well inventory and analysis, an updated economic analysis was also conducted comparing the tradeoffs of implementing a Domestic Well Mitigation Program during the Implementation Period versus immediately implementing demand reduction in the Subbasin to avoid significant and unreasonable adverse impacts on domestic well users. This economic analysis is included as **Attachment 1** (Domestic Well Replacement Economic Analysis) and provides an update to Appendix 3.C of the Chowchilla Subbasin GSP. **Attachment 1** incorporates the latest results from the domestic well inventory relative to the total number of domestic wells estimated to go dry during the GSP Implementation Period. The economic analysis evaluated the difference in costs for implementing a Domestic Well Mitigation

Program concurrent with gradual reductions in groundwater pumping over the twenty-year Implementation Period compared to not having a Domestic Well Mitigation Program and immediately implementing demand management and other PMAs to eliminate the overdraft in the Subbasin.

2 DOMESTIC WELL INVENTORY DATA SOURCES AND COMPILATION

Data from a variety of public agencies were assembled for consideration in the project. Compiled datasets included the following.

- Well Completion Report (WCR) Database from California Department of Water Resources (CDWR) Online System for WCRs (OSWCR)
- Madera County well permit database (records since 1990)
- Madera County Assessor's Parcel data
- Merced County well permit database (records since 1999)
- Merced County Assessor's Parcel data
- Public Water System (PWS) service area boundaries and PWS well locations from State Water Resources Control Board (SWRCB) Division of Drinking Water (DDW)
- State Small Water System (SSWS) service area boundaries from Madera County
- Census block-level household counts from the US Census Bureau
- Disadvantaged Community boundaries from DWR

With the exception of the Madera and Merced County well permit databases, all of the above-listed datasets were available in geospatial (e.g., GIS) formats. The well permit databases were provided as tabular data, which were converted to geospatial information as described below.

2.1 DWR WCR Database

The primary source for well construction data in the Subbasin is the CDWR OSWCR database (CDWR, 2020). Well drillers are required to submit a WCR to DWR for all wells drilled and constructed in the State of California. DWR has tabulated information from WCRs for the State, including data from WCRs dating as far back as the early 1900s. The tabulated WCR information include well type and construction characteristics such as the intended use of the well, well depths, and screened intervals along with location, construction date, permit information, and other details included on the WCR. Although completed WCRs commonly include additional notes on borehole lithology and a variety of other types of information; however, lithology and some other well information included on WCRs is not entered or maintained in the OSWCR database. It is notable that many well attributes in the WCR database are blank or incomplete because of missing or illegible information provided on the WCRs. Additionally, well locations in the WCR database are commonly only provided to the center of the Public Land Survey System (PLSS) section in which it is located, which translates to a locational accuracy of approximately +/- 0.5 mile.

2.1.1 Domestic Well WCRs

As part of the project, initial quality checks were conducted on the WCR database to identify obvious inconsistencies in well data, including conflicting well locations (e.g., latitude, longitude, PLSS coordinates) and construction (e.g., well depths, top and bottom of screens). Such questionable information and records were flagged for additional consideration during subsequent analyses. For the purpose of this domestic well inventory project, only WCRs indicated to be domestic water supply wells were included in the analysis. To limit potential double counting of domestic wells, only WCRs for new well construction (i.e., not well repairs/modifications or destruction) were included in the domestic well inventory.

The number of well records within the Chowchilla Subbasin in the WCR database exhibit a notable increase starting in about 1970 as indicated by domestic WCR counts by decade presented in **Table 1**. This shift may be partly due to changes in the Water Code relating to well data collection methods and reporting requirements that were instituted in 1969. The number of WCRs for domestic wells in the Chowchilla Subbasin increased by a factor of two around 1970, from 46 WCRs in the 1960s to 76 in the 1970s.

2.1.2 WCR Dates

The typical lifespan of a small water well is estimated to be 30 to 50 years based on the durability and longevity of typical domestic well materials, which are commonly constructed of steel or polyvinyl chloride (PVC) casing. Wells drilled prior to 1970 are also less likely to still be in operation because of long-term trends in groundwater levels in the Subbasin.

For these reasons, only WCRs for wells with dates on or after 1970, were included in the domestic well inventory and associated analyses. The OSWCR database includes 62 domestic well new construction WCRs located in the Chowchilla Subbasin that do not have any recorded installation or permit dates. For this well inventory and analysis, these 62 wells were included in the analysis even though some fraction of them may have been constructed prior to 1970. A total of 500 domestic wells constructed since 1970 were considered in the project based on WCR records.

2.1.3 WCR Locations

Wells with WCRs marked as domestic were selected and mapped based on one of four geolocation methods, depending on what information was available in the tabulated data. Only wells with installations in 1970 or later were considered, or those with no available date of installation. The geolocation methods, in order of priority, are as follows:

1. Assessor Parcel Number (APN) – 236 wells
2. Address – 95 wells
3. Public Land Survey System (PLSS) – 169 wells

A total of 500 domestic well were located within the Chowchilla Subbasin using these methods (**Figure 1a**). Wells located by PLSS are typically placed at the center of the section in which they are located, and thus may be out of position by as much as about 0.5 mile (half the typical width of a section). Other sources of location error include changes in APNs over time; poorly matched addresses; and incorrect WCR entries for PLSS values, GPS coordinates, APNs, or addresses. Since many of the location dots for domestic wells plot on top of each other in **Figure 1a**, the locations of domestic wells in the Subbasin by Township/Range/Section are displayed in **Figure 1b**. Of the 500 domestic well WCRs, only 17 are located in Merced County, and the rest are located in Madera County.

2.2 Well Permit Records

Madera and Merced Counties require a well permit be obtained prior to drilling and constructing a domestic well. Records of well permits were provided by Madera and Merced Counties as tabular datasets (Madera County Environmental Health, 2020; Merced County Environmental Health, 2020); no GIS data were initially available for the well permits. The period of record for the well permits begins in 1990 for Madera County and 1998 for Merced County. Limited information on individual wells is available in the well permit dataset, although most well permits include Assessor Parcel Numbers (APNs) or well addresses that can be used for locating wells. Well uses in the permit dataset were inconsistently entered and required considerable review and assessment to standardize well uses for identifying likely domestic well permits.

2.2.1 Domestic Well Permits

2.2.1.1 Madera County Domestic Well Permits and Locations

A subset of 7,505 permits for all of Madera County was identified as likely domestic wells based on the indicated well use. The well uses retained as representative of likely domestic wells include the following:

1. Domestic (7300 permits),
2. Domestic Replacement (25 permits),
3. Shared (54 permits),
4. Dairy (36 permits),
5. No Use listed (90 permits).

“Shared” wells are typically domestic wells that are also used for irrigation. “Dairy” wells are typically used for semi-industrial, and irrigation uses on a dairy, but in some cases can also be used for domestic water supply. Wells without a listed use were included in an effort to be conservative in the domestic well inventory.

Of the 7,505 domestic well permits (7,362 with APNs) for all of Madera County, the portion applicable to Chowchilla Subbasin were identified based on locations derived from APNs and addresses. Multiple permits refer to the same APN in some cases with only 6,498 unique APNs listed as having domestic well permits in the database. Domestic well permits in the County well permit database were located by matching the listed APN with the county parcel data when possible. Following this approach, 426 permits were matched to 378 unique parcel locations within Chowchilla Subbasin. For the 143 Madera County well permits without APNs, 8 permits were expected to be located within the Subbasin based on the fraction of permits with APNs that were determined to be within the Subbasin.

In addition to APNs, the Madera well permit database includes site addresses for most (7,323) of the wells. Through geocoding of addresses in the well permit database, 6 more well permits were located within the Subbasin.

Through locating of well permits based on APNs and site addresses, approximate locations for 6,709 of the 7,505 Madera County domestic well permits were determined. Using these locations, the total number of domestic well permits in the Madera County portion of the Chowchilla Subbasin was determined to be 432 permits (at 384 unique locations) out of 7,505 domestic well permits in the data base. Madera County well permit information is summarized in **Table 2 and Figures 2a and 2b**.

2.2.1.2 Merced County Domestic Well Permits and Locations

Two datasets of well permit records were provided by Merced County. The first well permit dataset includes 2,034 domestic wells drilled since 1996, with depths and locations (as latitude and longitude) provided for all wells. Locations for these wells were determined using the coordinates included in the dataset. None of these wells are located in the Chowchilla Subbasin. The second dataset of well permit information available from Merced County includes 291 domestic wells that were installed in 1998 and later. These permit locations were determined based on addresses provided in the dataset for all wells. Most of these wells (all but 12) also have depth information. Seven of these 291 domestic wells with permits are located within the Chowchilla Subbasin. Merced County well permit information is summarized in **Table 2 and Figures 2a and 2b**.

2.3 County Assessor Parcel Data

County Assessor parcel GIS data were provided by Madera and Merced Counties (Madera County Assessor's Office, 2020; Merced County Assessor's Office, 2020), including land use and other characteristics for each APN indicating the presence of a dwelling. The Madera County parcels dataset includes 7,033 unique APNs within the Chowchilla Subbasin. Of those, 4,494 are listed as having dwellings associated with them. The Merced County parcels dataset includes 160 unique APNs within the Subbasin. Of those, four are listed as having dwellings associated with them, for a total of 4,498 in the Subbasin (**Figure 3)**. Although the County parcel datasets do not include records related to the presence of domestic wells on parcels, the presence of a dwelling on a parcel is interpreted to suggest the presence of a drinking water supply, including in some areas the potential for a domestic well to exist. This includes parcels that are located within a public water system service area.

2.4 Water System Data

Public Water System (PWS), State Small Water System (SSWS), and Local Small Water System (LSWS) service area boundaries from State and local data sources were used to map and evaluate where and how many inferred well locations occur inside of a water system service area and therefore may not be supplied by a domestic well. Water system boundaries are a key dataset for comparing with potential domestic well locations identified through analysis of WCRs, parcels, and permits. The service area boundaries for water systems identified in the Subbasin are presented on **Figure 4** based on the evaluation of PWS, SSWS, and LSWS boundaries as described below

2.4.1 State Regulated Systems

The PWS boundaries are part of an archived dataset developed by the California Environmental Health Tracking Program (CEHTP) and now maintained by the State Water Resources Control Board (SWRCB) Division of Drinking Water (DDW) (SWRCB, 2021). This dataset is a publicly available GIS feature class of system boundaries provided voluntarily by water system operators over the period from 2012 to 2019. Previous assessments of this dataset suggest it includes approximately 85 percent of community water systems, although this can vary by region within the state. Of the state regulated community PWS boundaries, two were identified to have service areas within Chowchilla Subbasin.

2.4.2 County Regulated Systems

The PWS service area dataset from DDW is not intended to include county-regulated systems. Madera County Public Works provided additional service area boundary data for county-regulated water systems (Madera County Environmental Health, 2021), but none of these County water system boundaries are within the Chowchilla Subbasin. Merced County Environmental Health was asked to provide locations of county-regulated systems in the Chowchilla Subbasin and indicated that none exist in that area.

2.4.3 Public Water System Wells

PWS well locations were downloaded from the SWRCB GAMA website (SWRCB, 2021) and used to check for any water system wells in areas not covered by the water systems service area boundaries data. All PWS wells were located within previously delineated water system service area boundaries.

2.5 Community Data

2.5.1 Census

United States Census data (US Census, 2016) were used for cross-checking and comparison with domestic well WCRs, domestic well permits, and parcels with dwellings in the Subbasin. The Census data include counts of households by Census area (e.g., block, tract, designated place). The Census data were evaluated to assess whether they could inform the count and locations of domestic wells in the Subbasin. To approximate the number of households that might have a domestic well, Census block area were converted to randomly located points within each block equal in number to the count of households per block. The resulting 2,739 points represent an estimate of the total number of households within the Subbasin that might have a domestic well (**Figure 5**). This includes households that are included within a public water system service area.

2.5.2 Disadvantaged Communities

DWR defines Disadvantaged Communities (DACs) as communities with an annual median household income (MHI) less than 80 percent of the Statewide annual MHI (PRC Section 75005(g)), and SDACs as communities with an annual MHI less than 60 percent of the Statewide annual MHI. The statewide median household income (MHI) for the Census American Community Survey (ACS): 2014-2018 dataset is $71,228. Therefore, a community where the MHI is less than $56,982 meets the DAC threshold and a community where the MHI is less than $42,737 meets the SDAC threshold.

DWR provides a standardized GIS layer of Disadvantaged Communities and Severely Disadvantaged Communities (DACs, SDACs) (DWR, 2021). These data are available as Census Designated Places, Census Tracts, or Census Blockgroups. The Tract-level data are simply aggregated from the Blockgroup-level data and were not used in the current analysis. Place-level data are not congruent with Blockgroups or Tracts, typically following established neighborhood boundaries. Place-level data provide a more focused description of the regions that qualify as DAC or SDAC; however, the Place-level data is only available in Census-Designated Places (CDPs), and these do not capture more diffuse residential neighborhoods. DACs and SDACs are found in both urban and rural areas in Chowchilla Subbasin. **Figure 6** shows the locations of the Census Designated Places and Census Blockgroups identified as DACs or SDACs by the definition above.

3 ANALYSIS AND RESULTS

Estimates of domestic wells were developed through analysis and comparison of the data sources discussed above. Evaluation of the number and locations of domestic wells in Chowchilla Subbasin were made using four different sources of data and approaches: from WCRs, well permits, parcels with dwellings, and Census households. Domestic well WCRs and well permits provide a more direct indication of the existence (past or present) of a domestic well, whereas the parcel data and Census data provide a basis for inferring the existence of domestic wells. The County well permit databases are believed to provide the most accurate estimate of the numbers and locations of domestic wells constructed during the available data record (since 1990 in Madera County and from 1998 in Merced County).

The completeness of the well records in County well permit data are expected to be greater than the WCR database because although regulations state that WCRs are required to be submitted to DWR for all constructed wells, there has historically been little or no verification at the County or State level that a well driller submits a WCR to DWR after a well is completed. In cases where a WCR is submitted, the time elapsed between when a well is drilled and when a WCR is submitted to DWR can be highly variable and information provided on WCRs may not be complete. There are also additional steps involved in entering WCRs into DWR's database after receiving a WCR, which may also introduce timing delays or data entry errors. In contrast, although there is generally no information about a given well's design provided in the County well permit database, there is a fee to obtain a well permit and permits are typically obtained by the driller immediately prior to starting work on a project. Therefore, it is believed that most permitted wells are constructed even if a corresponding WCR is never submitted to DWR by the well driller.

The locational accuracy of well permit records are also believed to be better because most well permit records include data on the parcel where the well is permitted. Many of the WCR records only indicate location by the PLSS section in which the well is located.

Although the well permit data are believed to be more complete and provide better locational accuracy of wells, only the WCR data have information on well depths and other well construction details (**Figure 7a**, **Figure 7b**). Additionally, while WCRs and well permits generally have a date associated with each record indicating the approximate date of well construction, the parcel and Census datasets do not.

However, estimates of well counts based on parcel and Census data do provide a sense for the maximum possible number of domestic wells, and also a comparative check on the relative spatial density of domestic wells in the Subbasin.

Water system service area boundaries were used to refine domestic well estimates derived from parcel and Census household counts, with the expectation that all parcels and households within a water system boundary are served water from the water system and therefore do not rely on a domestic well. The locations and count of permits and WCRs were assumed to be correct, regardless of their location relative to a PWS service area.

With this information, estimated locations and counts of domestic wells in the Subbasin were developed and well depths were compared to historical groundwater levels and model-simulated future groundwater levels (based on the modeling conducted during GSP development) to evaluate potential impacts to domestic wells from changing groundwater levels in the Subbasin. The methods and results from these analyses are described below.

3.1 Analysis of Domestic Well Locations and Counts

3.1.1 Domestic Well WCRs

The domestic well WCRs since 1970 were compared with water system boundaries. Because the WCRs are records of actual wells that were constructed, those located within a water system service area are assumed to be correctly located. It is possible that wells that pre-existed the establishment of a water system in an area may remain in use after the water system is operational; however, the frequency of this occurring is not known.

Of the 500 domestic wells represented by WCRs in the Subbasin, 12 are located within the known water system boundaries (**Figure 8**). This represents 2.4 percent of the domestic well WCRs in the Subbasin. Some of these domestic well WCRs may be associated with wells that no longer actively supply domestic drinking water. Nevertheless, WCRs within a water service area boundary were still considered in the domestic well inventory and analysis described below, which is a conservative assumption relative to likely domestic well counts.

3.1.2 Domestic Well Permits

Similar to the WCR estimate, permits are expected to accurately identify well locations, but domestic well permits may exist for wells drilled and constructed prior to the operation of a water system in an area. The use of such wells may have been discontinued when a residence was hooked up to a water system, although this may not always be the case and some domestic wells within water system service areas may still be operational.

In contrast to the WCR dataset, which relies on submittal and entry of a WCR in DWR's database, the County well permit datasets are expected to be a more comprehensive representation of the wells drilled in the County for the period it covers (1990 to present for Madera, 1998 to present for Merced). Although the comparisons across different datasets described below highlight differences between data sources and the estimates of domestic wells derived from each, this study did not attempt to assess the accuracy of the well permit database in relation to actual domestic wells.

Of the 439 domestic well permits in the Subbasin, two are located within known water system boundaries, which represents about 0.5 percent of the domestic well permits in the Subbasin. These two permits within a water service area boundary were still considered in the domestic well inventory and analysis described below.

3.1.3 Parcels with Dwellings

For the purpose of assessing the maximum possible number of domestic wells in the Subbasin, all parcels with a dwelling but not within a water system service area were counted. In this approach, a parcel is considered within a water system service area if its centroid is within the service area.

Based on these criteria, within the Chowchilla Subbasin there are a total of 4,498 parcels with dwellings, 967 (963 in Madera County, four in Merced County) of which are outside of water system service area boundaries. These 967 parcels representing potential domestic well locations are presented on **Figure 9**. There are several areas within the Chowchilla Subbasin with a relatively high density of parcels with dwellings that are not covered by a water system boundary.

3.1.4 Census households

Due to the irregular shape of Census blocks and the inconsistent alignment of blocks with other important boundaries in the Subbasin (e.g., Subbasin, water service areas) the Census data provided have limited utility to inventory domestic wells, although they do provide an approximate check on the maximum overall number of potential domestic wells in the Subbasin. Conversion of the Census household counts to points and comparing to water system service areas provides as estimate of 1,294 potential households outside of water system service areas. Within that set of 1,294 potential wells, 1,241 are in Madera County, and 53 are in Merced County. Although the total number of parcels with dwellings is almost twice as large as the total number of households within the Subbasin, the number of households estimated to be outside of the water system service areas is about 33% higher than the number of parcels outside of the water system service areas.

3.1.5 Comparisons of Domestic Well Location Information Sources

3.1.5.1 Domestic Wells Within PWS Service Areas

While most residences within a PWS service area are supplied with drinking water by that PWS, it is not unusual for wells drilled prior to the creation of the PWS would be retained and used for part or all of a residence's use, including for drinking water or landscape irrigation.

Of the 500 WCRs since 1970 located in the Chowchilla Subbasin, 12 are located within a water system service area. Of the 436 permits (since 1990) located within the Madera County portion of the Chowchilla Subbasin, two were located within a water system service area. None of the seven permits (since 1998) located within the Merced County portion of the Chowchilla Subbasin were located within a water system service area. Overall, less than 0.5 percent of domestic well permits are located within a water system service area.

Of the 4,498 parcels with dwellings noted in the two county APN datasets, 3,531 are within a water system boundary. Of the 2,739 households in the Subbasin indicated by the 2010 Census data, 1,445 are within a water system service area.

The count of known locations of permits and WCRs within water systems, when compared to the number of residences within those systems based on parcel and Census data, represent between zero and three percent of the number of residences within those service areas. This suggests that the number of domestic well permits and WCRs located within water system boundaries is a very small fraction of the number of likely residences within those water system areas. Accordingly, this comparison suggests that neither the WCR nor well permit data identify a large number of domestic wells within water system boundaries. Although this does not speak to the accuracy of the WCR and well permit data in locating wells in other areas of the Subbasin, they do not appear to identify an unreasonable number of domestic wells within areas covered by water systems.

3.1.5.2 Comparing WCR Locations to Well Permits

The Madera County well permits dataset is believed to be more complete in representing wells drilled in the County, but it only extends back to 1990. To provide an appropriate comparison between the WCR dataset and the well permit dataset, a subset of the WCRs since 1990 (those dated after 1989), were considered. In the Madera County portion of Chowchilla Subbasin, 304 domestic well WCRs have construction dates after 1989. An additional 58 domestic well WCRs have no installation date recorded. For this analysis, WCR records without dates are assumed to be drilled in 1990.

The subset of domestic wells with WCRs since 1990 has many similar characteristics as the dataset for WCRs since 1970, with several noteworthy differences. As shown in **Table 3**, proportionally, the WCR dataset since 1990 has fewer WCR records located in water system service areas. This is reasonable, as it is consistent with the understanding that many of the domestic well WCRs located within water system service areas are for wells drilled prior to the creation or expansion of those water systems.

There is no direct linkage between WCRs and well permits on record (i.e., WCRs commonly do not indicate well permit numbers) for majority of the wells, and the available method for geolocating records for a given well present in both datasets may differ. However, it was determined that 166 of the parcels associated with permit locations coincided with WCR locations for domestic wells for Madera County (and another two wells for Merced County), and the spatial distribution of Madera and Merced County domestic well permits and WCRs are similar within the Subbasin (**Figure 10**).

This relatively low rate of coincidence is most likely a function of poor accuracy of the WCR locations. The permit location error is generally related to the area of the parcel within which they are located and is commonly less than half the distance of the maximum parcel dimension. As parcel size decreases, the accuracy of the locating of well permits tends to increase. Many WCR locations have much higher error, especially those that rely on locations from the PLSS section centroid. In addition, the subset of domestic well WCRs since 1990 in the Madera County portion of the Chowchilla Subbasin has a similar spatial distribution to the dataset of WCRs since 1970. Therefore, the WCRs since 1970 likely reasonably represent the distribution of permits since 1970 similar to the way WCRs from 1990 and later represent permits from 1990 and later.

The Merced County well permits dataset only has records for 1998 and later, so a comparison with the WCRs for the Merced County portion of the Chowchilla Subbasin can only be made with WCRs from 1998 and later. Of the 17 WCRs for wells in the Merced County portion of the Chowchilla Subbasin, eight were installed after 1998. Four more WCRs in the area had no installation date.

Two of the seven permits for wells in the Merced County portion of the Chowchilla Subbasin are on the same parcel as WCRs for the area. Of those two, one also shares an address with the WCR that overlies it. Another permit shares an address with a WCR, but is not located on the same parcel, based on the APN location of the WCR. This may be due to an error on the WCR, or to changes in the APN since the well was installed. The APN identified on the permit matches the APN identified on a WCR for four of the wells.

3.1.5.3 Comparing Domestic Well Permits with Parcel Characteristics

Of the 439 domestic well permit locations identified within the Chowchilla Subbasin, 350 (80 percent) are located on parcels with dwellings, as indicated in the parcel datasets for Madera and Merced Counties, suggesting that a residence is present on the parcel associated with the well permit (**Figures 11a and 11b**).

3.1.5.4 Comparisons of Parcels with Dwellings and WCRs

Of the 967 parcels listed as having dwellings in the Chowchilla Subbasin, and not within a water system boundary, 202 coincide with the location of domestic well WCRs located as described above. All 202 of these were in Madera County. Only one parcel listed (in Madera County) with a dwelling was located within a water system and also coincided with a WCR location (**Figure 12**). As discussed above, WCRs are poorly located due to lack of APN, GPS, or address data.

3.1.6 Final Domestic Well Count and Location Estimates

The Madera County permit database includes 432 domestic (or considered domestic for this analysis) wells installed since 1990. For providing a direct comparison of the domestic wells counts from the WCR database, the count of WCRs was limited to WCRs with dates since 1990 (362 domestic well WCRs) to allow for direct comparison to available County permits. This comparison yields a ratio of 1.19 between the domestic well permit count and the domestic well WCR count. Well permits are believed to provide a more complete representation of wells constructed in the Subbasin, but these permit records do not contain information on well perforations and depths and only date back to 1990. As a result, the ration of well permits to WCRs for the period since 1990 provides a useful scaling metric of results derived during the evaluation of potential impacts on domestic wells from changing water levels, an analysis which relies heavily on well construction information available only on WCRs. The domestic well impacts analysis is described below.

3.2 Evaluation of Potential Domestic Well Impacts

A key consideration in the implementation of the GSP for the Chowchilla Subbasin is the potential occurrence of impacts to domestic well users due to declining water levels. As part of implementing the GSP, the Subbasin is in the process of evaluating and designing a Domestic Well Mitigation Program targeting domestic wells that may be impacted by future declines in groundwater levels. To support this effort, the effects of historical and future groundwater levels on domestic wells in the Subbasin were evaluated.

This analysis involved comparing domestic well perforation and depth information to historical groundwater levels and potential future groundwater levels, as simulated by the groundwater model (MCSim) utilized during the GSP development. Simulated groundwater level conditions from MCSim were used to estimate the number of domestic wells that may go dry during the GSP implementation period from 2020 through 2040, the period during which the Subbasin will be working towards achieving sustainability as required by SGMA. WCR records for domestic wells (and the well construction information provided on WCRs) were used to estimate well depth information for evaluating impacts. The ratio of well permits to WCRs (1.19) was used to upscale the results derived from these analyses conducted using WCR data.

3.2.1 WCR Domestic Well Construction Information

Of the 500 domestic well WCRs in the Chowchilla Subbasin, 479 included some information on bottom of perforated interval (top and bottom of perforations) or total depth. As mentioned earlier, several inconsistencies in construction information were noted in the initial WCR dataset (e.g., total well depth less than depth to top of perforations, depth to bottom of perforations less than top of perforations), so multiple levels of quality checks were conducted on the well construction data in the WCR database to assess the reliability of the information. Only WCR records determined to have sufficiently reliable well construction information (i.e., lack of obviously conflicting information on the well construction) were included in the summary and analyses relating to domestic well construction in the Subbasin. In analyses using well perforations (screens), where data for bottom of perforations was not available, the reported total well depth was used. A total of 454 WCRs included top of screened interval information. For wells lacking information for either bottom of perforations or top of perforations, the average values for wells in the same section were used. Where a section had fewer than three wells with reported depth or top of screen data, the average values from wells in the same section and the eight surrounding sections were used. This resulted in estimates of top and bottom of perforated Intervals for all 500 domestic well WCRs in the Subbasin. **Figure 7a** and **Figure 7b** show the depth of domestic wells in the Subbasin based on these estimates.

3.2.2 Domestic Well Impacts Analysis Methods

Simulated groundwater levels output from the MCSim model developed by Luhdorff & Scalmanini Consulting Engineers (LSCE) and described in the 2020 GSP for Chowchilla Subbasin were queried to produce depth to water (DTW) datasets for the Subbasin for the period from 1989 through 2070. MCSim is a multi-layered model and based on review of the well data and consideration of the hydrogeologic conceptual model and groundwater conditions described in the GSP, model layers 3 and 4 were determined to most appropriately correspond with the production zones for most domestic wells in the Subbasin. The simulated DTW datasets for model Layers 3 and 4 were used to extract DTW values for different time periods at all WCR locations; DTW values at each domestic well WCR location were compared with the top and bottom of perforations (screens) values for each WCR. Based on this comparison, the wells were assigned DTW values for either model Layer 3 or 4. If a well was screened at least 50 percent in Layer 4 or deeper, the well was assigned DTW values for Layer 4. If more than 50 percent of the screened interval was above Layer 4 (in Layer 3 or shallower) then Layer 3 DTW values were assigned to the well.

Simulated depth to water model output for Layers 3 and 4 for the years from 1989 to 2039 were then compared to the screened intervals for each domestic well (WCR) to assess if each well was wet or dry during each year. For each year, the fall simulated DTW (on October 31st) in Layers 3 and 4 of the model were assessed for each well location.

The analysis was performed using different analysis periods and methods. Generally, the analysis was conducted using five-year analysis periods, with the first analysis period starting in 1989 and extending to 2014 or 2015 followed by shorter five-year intervals thereafter. Analyses included comparisons based on snapshots of DTW conditions at the end of each analysis interval (generally five-year analysis periods) and separate comparisons based on the maximum depth to water found during each analysis period. Variations of analyses were also performed using simulated model output from the projected model run used in the GSP, and also separately for a model run utilizing a projected future hydrology that included drier conditions during the early years of the GSP Implementation Period, conditions that are more consistent with the recent hydrology experienced in the area. In all analyses, if the simulated DTW in the assigned model layer at a well location falls below the required minimum level of saturation in relation to the depth of the well, either at the end of each analysis period (or in the year within each five-year period that generally had the lowest water levels for the maximum DTW scenario), the well was considered to have gone dry during the analysis period. Once a well was concluded to have gone dry in an analysis scenario, it was removed from the pool of potential wells that could go dry in subsequent years. The sensitivity of model results to different assumptions, analysis periods, and WCR data restrictions were tested and evaluated.

The parameters used in the analysis are defined as follows:

P = the base year for the analysis periods. This defines the end of the initial historical analysis period (after 1989) during which wells were evaluated for historically having gone dry. This is generally Fall 2019, indicating a historical analysis period of 1989-2019, but 2018 was also used as the ending year for the historical period during sensitivity analyses (because groundwater levels in 2018 were generally lower than in 2019).

S = minimum saturation threshold above the well total depth for a well to remain wetted. This is assumed to be 10 feet in the baseline analysis, but the sensitivity of analysis results to varying this value was conducted to evaluate the influence of this parameter on analysis results.

E = the earliest year of installation for the WCRs considered. This reflects the cutoff year for the construction date on WCRs intended to reflect wells that may have been active at the time of the base year considered based on typical domestic well life expectancy.

Appropriate scaling of the results of these impacts analyses based on WCR was also considered based on the ratio (1.19) of domestic well permits to domestic well WCRs determined previously. The ratio is developed from a direct comparison of domestic well permits and WCRs with dates since 1990. The scaling ratio is applied for the entire Subbasin (including the Merced County portion) and is assumed to have limited spatial or temporal bias across the Subbasin or across the period since 1990. The potential for bias in the ratio has not been evaluated.

The baseline analysis scenario of potential domestic well impacts involved the parameters listed below.

- Snapshots of DTW at the end of each analysis period
- The ending year for historical analysis is 2019, with historical analysis period 1989-2019 (P = 2019). Corresponding analysis periods as follows:
  - 1989-2019
  - 2020-2024
  - 2025-2029
  - 2030-2034
  - 2035-2039

  The analysis periods were selected to correspond with the dates of the Interim Milestones and preparation of Five-Year Update Reports.

- Minimum well saturation threshold of 10 feet (S = 10).
- Using projected model run from GSP (without early sequence of dry years).
- Wells analyzed based on the WCR count of wells installed since 1970 (E = 1970).

Because the early years of the projected model period, including during the early GSP implementation period, have been dry, an alternative analysis scenario evaluated potential domestic well impacts based on simulated groundwater levels from a model run that starts with a drier sequence of years. This analysis involved the same parameters as the baseline analysis (described above) but used simulated groundwater levels from a different projected model run with an early dry period.

3.2.3 Results of Domestic Well Impacts Analyses for Baseline GSP Climate Scenario

In the baseline analysis scenario described above, a total of 95 of the 500 domestic wells (from WCRs) analyzed are indicated to have gone dry during years prior to 2020. A total of 83 wells are projected to go dry between 2020 and 2039 (**Table 4a**). The analysis suggests 40 of the total of 83 domestic wells are estimated to become dry between 2020 and 2024. **Table 5a** includes the results for this analysis when scaled up by a multiplier of 1.19, the ratio of well permits to WCRs.

3.2.3.1 Spatial Distribution of Dry Wells

Figures 13a to **13e** show the distribution of dry wells (and remaining wetted wells) in each of the analysis years for the baseline analysis. The predicted dry wells are generally north of Highway 152 and south of the Chowchilla River.

Most of the domestic wells that are predicted to go dry over the 20-Year GSP Implementation Period in the Base Case occur in the 2020-2024 and 2030-2034 five-year intervals (**Tables 4a and 5a**). Groundwater levels stabilize and begin to recover after 2035 and no additional wells are predicted to go dry in the Base Case after 2035. The timing of domestic wells going dry is closely related to the assumed sequence of average, dry, and wet years applied for the Base Case, which is based on a historical sequence of years that represent overall average conditions for the 20-year Period.

3.2.3.2 Impacts on Disadvantaged Communities

Some dry domestic wells are predicted to occur in DAC and SDAC areas, but these areas are not disproportionately impacted by groundwater level declines. The analysis suggests that the percent of domestic wells in DAC/SDAC areas estimated to go dry is similar to the Subbasin as a whole although it is slightly lower than for areas outside of DACs or SDACs..

Some DACs and SDACs in the Chowchilla Subbasin are located near urban centers, and thus near existing water system service areas. Opportunities for annexation or consolidation of DACs and SDACs in close proximity to existing (or creating new) State- or County-regulated systems may provide a better solution than replacement of existing wells in these areas.

3.2.3.3 Scaling Estimates

The previous analyses are all based on WCR counts of wells drilled since 1970 or 1990. A more accurate number of wells, however, is more likely the number of Permits in the permit database provided by Madera County.

Figure 14 shows that the spatial distributions of the two datasets are similar. As shown in that figure, the agreement between WCR and permit data is relatively good in most of Madera County; however, interspersed throughout the region there are sections with some differences between the numbers of permits and WCRs. The largest portion of the Subbasin is represented by ratios (permits to WCRs) near 1.0 (from 0.5 to 1.5). One section near the town of Chowchilla had notably higher numbers of permits compared to WCRs, but this is likely due to the denser population and presence of municipal water systems in that area of the Subbasin. The relatively similar distributions of permits and WCRs indicates that simply scaling the count of wells up for each period should be adequate. The number of Permits for wells installed since 1990 is 119% of the number of WCRs for wells in the same period, averaged over the Subbasin (**Table 2**).

Scaling the results up to match the expected number of wells based on the Permits-to-WCRs ratio of 1.19:1 yields 99 domestic wells going dry between 2020 and 2040 (**Table 5a**).

3.2.4 Results of Domestic Well Impacts Analyses for Alternative Dry-Start Climate Scenario

The same analysis was conducted as described above for the GSP Climate Scenario, but instead using an alternative climate sequence for the GSP Implementation Period with more dry years at the beginning of the 20-year climate sequence. In the alternative analysis scenario, a total of 100 of the 500 domestic wells (from WCRs) analyzed are indicated to have gone dry during years prior to 2020. A total of 147 wells are projected to go dry between 2020 and 2039 (**Table 4b**); the analysis suggests 85 dry wells of the total of 147 occurring during the period 2020-2024. **Table 5b** includes the results for this analysis when scaled up by a multiplier of 1.19 based on the ratio of well permits to WCRs.

3.2.5 Sensitivity Analyses on Potential Domestic Well Impacts

To understand influences from different analysis assumptions and parameters, sensitivity analyses were conducted on a number of aspects of the analysis. These sensitivity analyses evaluated different approaches to evaluating the DTW at well locations over each analysis period (e.g., DTW at end of period vs maximum DTW during analysis period), the required minimum saturation threshold for concluding a well is dry, and different cutoff dates for WCRs included in the analysis.

3.2.5.1 Snapshot of Depth at End of Reporting Period vs. Maximum Depth During Reporting Period

The baseline analysis described above compares domestic well depths to groundwater levels at the end of each Five-Year Update reporting period using the years 2019, 2024, 2029, 2034 and 2039. As noted previously, these baseline analysis periods were selected because the final year of each period aligns with the IM and Five-Year Update reporting periods. However, if the lowest groundwater levels do not align with the end of each analysis period, this method may not capture the full extent of potential impacts on domestic wells.

By choosing analysis period ending years as 2023, 2028, 2033, and 2038, the lowest groundwater levels in each five-year period will typically be captured along with the lowest pre-2020 groundwater levels (generally occurring in 2015 or 2018). Therefore, a separate analysis was performed using the maximum DTW in each five-year period. This analysis results in a slight decrease (2 wells) in the total number of wells (81) expected to go dry between 2020 and 2040 compared to the Base Case (**Table 6**). The reason for the decrease of dry well occurrence between 2020 and 2040 is this analysis has more wells going dry prior to the start of the GSP implementation period in 2020 due to the lowest pre-2020 groundwater levels occurring prior to Fall 2019, (which is the year used in the Base Case to determine well going dry prior to 2020). Therefore, the base case with a greater number of wells going dry between 2020 and 2040 is used for further sensitivity analyses described below because it is a more conservative estimate of dry wells.

3.2.5.2 Minimum Saturation Threshold

The baseline analysis comparing DTW, and total well depths included a minimum well saturation threshold that a well is considered dry when the groundwater levels fall below a level less than 10 feet above the bottom of the well. This baseline assumption was based on the expectation that the required saturation in a domestic well is not great because of the generally low pumping rates required for domestic wells. The sensitivity of analysis results for this minimum saturation assumption were evaluated using alternative minimum well saturation levels. Sensitivity to the minimum saturation threshold was tested by varying the parameter (S) and observing the change in the count of wells going dry in each analysis period (**Table 7**).

The number of wells going dry over the period from 2020 to 2039 increases as the minimum saturation threshold is increased from 0 feet to 30 feet and then decreases with greater minimum saturation thresholds (**Figure 15**). The reason for this pattern is that at minimum saturation thresholds exceeding 30 feet, more wells are considered to be going dry before 2020 relative to after 2020 for those greater thresholds (i.e., the threshold applies both before and after 2020). The number of dry wells at the saturation threshold of 10 feet is 83 wells, it increases to 100 wells at 30 feet, and at 50 feet it declines to 84 wells. This analysis suggests that the number of wells expected to go dry is sensitive to the saturation threshold applied, but the relationship between saturation threshold and number of dry wells predicted after 2019 varies depending on how many wells go dry before 2020. Considering the results of this sensitivity analysis and the previous discussion regarding saturation needed to support typical domestic well pumping rates, the application of a minimum saturation threshold of 10 feet is interpreted to be a reasonable threshold for estimating the potential number of domestic wells that may go dry during the GSP implementation period.

3.2.5.3 WCR Cutoff Dates

The influence on results from varying the earliest year of WCR records used in the dry well analysis was also evaluated. As expected, the average well depths for older wells tend to be shallower than younger wells, likely because of the declining water levels that have occurred in the area and the resulting need to drill to greater depths to ensure reliable water supply. This trend towards deeper wells is illustrated in a comparison of the average total well depths for WCRs since 1970 and those since 1990 and 1998, as presented in **Table 3.**

The changes in the numbers of total wells analyzed and the resulting numbers of dry wells drop as the cutoff date for WCRs is increased. The change from a WCR cutoff year of 1970 to 1975 has minimal (less than 10 percent) impact on all counts, but as this cutoff date in increased further the dry well count drops faster than the total well count (**Table 8**). The implication of this trend is that as the WCR cutoff date is moved forward in time from 1970, older wells that would be counted as going dry are not included in the analysis, resulting in a smaller number of wells predicted to go dry. Although many wells constructed since 1970 likely are no longer in existence or active use, the 1970 WCR cutoff date provides an appropriately conservative estimate of wells predicted to go dry during the implementation period.

3.2.6 Potential Replacement Costs for Wells Impacted

The potential costs for addressing domestic well issues were evaluated in some detail. These costs were largely based on discussions with drillers who install domestic wells and replace pumps on a regular basis. These costs are summarized in **Table 9**, and include lowering a domestic well pump ($1,000 to $2,000), replacing a domestic well pump ($5,000 to $7,000), and drilling/installing a new domestic well to replace an existing well ($25,000 to $35,000). Estimates of total costs for a Domestic Well Mitigation Program were based on estimates of total number of dry wells expected to occur between 2020 to 2039, with WCRs scaled to the number of County well permits and considering both the GSP climate scenario and the alternative dry-start climate scenario for the GSP Implementation Period.

3.2.7 Updated Economic Analysis

As described in the Introduction, **Attachment 1** (Domestic Well Replacement Economic Analysis) incorporates updated estimates provided in this TM for the number of dry domestic wells into an economic analysis intended to replace Appendix 3.C of the Chowchilla Subbasin GSP with newer information. The economic analysis evaluated the difference in costs for implementing a Domestic Well Mitigation Program concurrent with gradual reductions in groundwater pumping over a twenty-year period vs. not having a Domestic Well Mitigation Program and immediately implementing demand management and other PMAs to eliminate the overdraft in the subbasin to avoid significant and unreasonable adverse impacts on domestic well users. The overall conclusion remains consistent with the GSP: the cost of implementing a Domestic Well Mitigation Program is significantly less than the alternative.

3.3 Public Water System Wells

PWS wells data are maintained by the State Water Resources Control Board Division of Drinking Water in the Safe Drinking Water Information System (SDWIS); however, these data are incomplete at this time. In the Chowchilla Subbasin, only 8 PWS wells (7 for Chowchilla City Water Department, and one for Valeta Municipal Services District 85) are listed in SDWIS. Therefore, the WCR database was queried for PWS wells. There were 18 PWS wells drilled in the Subbasin and tagged as “Municipal” or “Public” on the WCR. This discrepancy may be due, in part, to the fact that WCRs do not typically distinguish between Public Water Systems and other residential water systems serving more than one household. When a well driller fills out the WCR, the “Municipal” box is checked if the well is to be used for any purpose other than irrigation, industrial processes, or domestic single-household use. These can include PWS wells but can also include Local Small and State Small Water System wells (LSWS and SSWS, respectively), and wells used for drinking water at facilities such as rest stops, churches, schools, and other locations that sometimes are not supplied by a local PWS. The wells identified here are shown in **Figure 16**.

Depth to the bottom of perforated interval ranged from 174 to 980 feet below ground surface in these wells. Of the 18 PWS wells, three were drilled prior to 1970 and are not considered here. The remaining 15 wells were compared to the snapshots of groundwater DTW results for the model years 2019, 2024, 2029, 2034, and 2039, with the GSP climate scenario. **Table 10** shows the results of this analysis.

Based on the comparison with the modeled groundwater levels at the 5-year intervals, one PWS well is expected to have gone dry by 2020, and another one over the implementation period. Further analysis with data provided by individual well-operators would be required to identify specific water systems that are vulnerable.

3.4 Comparison of Estimated Domestic Well Impacts to Online Databases

The estimated numbers and locations of dry wells described in this TM (modeled dry wells) were compared to two available datasets related to reported domestic well supply issues: DWR’s Household Water Supply Shortage Reporting System, and Self-Help Enterprises (SHE) Tank Water Program participants (**Attachment 2**). While the assumptions underlying the estimates of modeled dry wells in this TM differ in some regards to the well issues included in these two datasets, the spatial patterns in modeled dry wells are very similar to the spatial patterns in the DWR and SHE datasets. Overall, the total numbers of modeled dry wells estimated in this TM are greater than the number of well issues included in the DWR and SHE datasets; however, it is likely that not all dry wells have been reported in these other two datasets. More details on the DWR Household Water Supply Shortage Reporting System dataset and the SHE Tank Water Program participants dataset and comparisons of these datasets to modeled dry wells presented in this TM are provided in **Attachment 2**.

4 PRIORITIZATION OF AREAS FOR ADDITIONAL MONITORING

Expansion of monitoring network is important for areas of the Subbasin with higher densities of domestic drinking water wells. In addition, the domestic well impacts analyses provide a guide to locating areas that should be more closely monitored. The monitoring network should consider the presence of vulnerable populations, such as those reliant on groundwater and DAC/SDAC areas. Another key variable was to consider the locations of existing nested monitoring wells installed recently at eight locations throughout the Chowchilla Subbasin.

The domestic well inventory analysis conducted for this study illustrates that domestic wells are most concentrated along the Highway 152 corridor, and that the occurrence of dry domestic wells are predicted to be most common along and just north of Highway 152. There are four existing nested monitoring wells relatively far to the north of Highway 152, and four existing nested monitoring wells relatively far to the south of Highway 152 in Chowchilla Subbasin. Two large and dense clusters of domestic wells occur just north of the junction of Highway 152 and Highway 99 and just northeast of the junction of Highway 152 and Highway 233 (Robertson Blvd.). These are considered primary areas for siting of new nested monitoring wells (**Figure 17**). A third primary area is located further west and south of Highway 152 between Robertson Blvd. and Berenda Slough. Two secondary areas for potential consideration of monitoring well siting are in areas of significant, but somewhat less dense, clusters of domestic wells; these locations would fill gaps between existing nested monitoring wells and improve overall spacing and density of dedicated nested well monitoring sites in the Chowchilla Subbasin.

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6 TABLES

Table 1. Summary of Domestic Well WCRs by Decade (no WCRs prior to 1950).

WCR Date Range	WCRs in Date Range	Cumulative WCRs
1950-1959	3	3
1960-1969	46	49
1970-1979	76	125
1980-1989	49	174
1990-1999	82	256
2000-2009	123	379
2010-2019	107	486
2020-Plus	1	487
Unknown	62	549

Table 2. Comparisons Between Different Domestic Well Count Estimation Methods.

	WCRs Chowchilla SB 1970+	WCRs Madera Co. Chowchilla SB 1990+	WCRs Merced Co. Chowchilla SB 1999+	Permits Madera Co. Chowchilla SB 1990+	Permits Merced Co. Chowchilla SB 1999+
Domestic Well Count	500	362	12	436	7
Domestic Well Count Outside of Water System Boundaries	488	350	12	434	7
Domestic Well Count Inside Water System Boundaries	12	12	0	2	0
Percent of WCR-Based Count (since Permit earliest date)	n/a	n/a	n/a	120%	58%
With Depth Recorded	500	362	12	0	7
Location Precision	Varies	Varies	Varies	Parcel	Parcel

Table 3. Relative Similarity Between Wells Recorded Since 1970 and Those Recorded Since 1990.

	Count of WCRs within the Chowchilla Subbasin		
	Since 1970	Since 1990	Since 1999
Total Count	500	375	303
Count within PWS	12	8	7
Count Outside of PWS	488	367	296
Average Total Depth (ft)	377	402	423

Table 4a. Summary of Dry Wells for Base Case. Wells drilled in 1970 or later, based on snapshot of depth to groundwater at end of period. Assumes 10 feet of well saturation above bottom of screen.

Year Range	New Wells Drilled	Total Wetted Wells Year Start	**Wells Going Dry**	Total Wetted Wells Year End	Sum Of Dry Wells
2020 to 2024	6	405	**40**	365	40
2025 to 2029	0	365	**0**	365	40
2030 to 2034	0	365	**42**	323	82
2035 to 2039	0	323	**1**	322	83
During the period 1989 to 2019, prior to the implementation period, the model suggests 95 wells went dry.				Total	**83**

Table 4b. Summary of Dry Wells for Dry Start Case. Wells drilled in 1970 or later, based on snapshot of depth to groundwater at end of period. Assumes 10 feet of well saturation above bottom of screen.

Year Range	New Wells Drilled	Total Wetted Wells Year Start	**Wells Going Dry**	Total Wetted Wells Year End	Sum Of Dry Wells
2020 to 2024	6	400	**85**	315	85
2025 to 2029	0	315	**61**	254	146
2030 to 2034	0	254	**1**	253	147
2035 to 2039	0	253	**0**	253	147
During the period 1989 to 2019, prior to the implementation period, the model suggests 100 wells went dry.				Total	147

Table 5a: Adjusted Estimates of Dry Wells for Base Case Based on WCRs Since 1970 Upscaled Using Ratio of Permits to WCRs (1.19).

Year Range (Oct 31st Minimums)	New Wells Drilled	Total Wetted Wells Year Start	**Wells Going Dry**	Total Wetted Wells Year End	Sum Of Dry Wells
2020 to 2024	7	486	48	438	48
2025 to 2029	0	438	0	438	48
2030 to 2034	0	438	50	388	98
2035 to 2039	0	388	1	387	99
During the period 1989 to 2019, prior to the implementation period, the model suggests 114 wells went dry.				Total	99

Table 5b: Adjusted Estimates of Dry Wells for Dry Start Case Based on WCRs Since 1970 Upscaled Using Ratio of Permits to WCRs (1.19).

Year Range (Oct 31st Minimums)	New Wells Drilled	Total Wetted Wells Year Start	**Wells Going Dry**	Total Wetted Wells Year End	Sum Of Dry Wells
2020 to 2024	7	480	102	378	102
2025 to 2029	0	378	73	305	175
2030 to 2034	0	305	1	304	176
2035 to 2039	0	304	0	304	176
During the period 1989 to 2019, prior to the implementation period, the model suggests 120 wells went dry.				Total	176

Table 6: Dry Well Summary Based on Snapshots of Groundwater Depth at End of Periods Ending in 2015, 2018, 2023, 2028, 2033, and 2038.

Year Range (Oct 31st Minimums)	New Wells Drilled	Total Wetted Wells Year Start	**Wells Going Dry**	Total Wetted Wells Year End	Sum Of Dry Wells Based on 5-Year Minimum
2019 to 2023	10	378	**30**	348	30
2024 to 2028	0	348	**1**	347	31
2029 to 2033	0	347	**50**	297	81
2034 to 2038	0	297	**0**	297	81
During the period 1989 to 2018, prior to the period described in this table, the model suggests 122 wells went dry.				Total	81

Table 7: Effect of Varying Saturation Requirement on Dry Well Counts.

Saturation Setting	Dry Wells Total After 2019
0	76
10	83
20	98
30	100
40	90
50	84
60	72
70	66
80	63
90	60
100	55

Table 8: Effect of Varying Minimum Installation Year on Counts of Wells and Dry Wells.

Well Counts	Earliest Installation Year						
	1970	1975	1980	1985	1990	1995	2000
Total Count of WCRs in Comparison	500	459	424	401	375	331	293
Fraction of 1970 (Total Count of Wells)	1.00	0.92	0.85	0.80	0.75	0.66	0.59
Total Count of Dry Wells	178	159	144	127	117	91	67
Fraction of 1970 (Dry Wells)	1.00	0.89	0.81	0.71	0.66	0.51	0.38
Count of Dry Wells Prior to 2020	95	85	77	66	59	41	30
Fraction of 1970 (Dry Prior to 2020)	1.00	0.89	0.81	0.69	0.62	0.43	0.32
Count of Dry Wells from 2020 to 2039	83	74	67	61	58	50	37
Fraction of 1970 (Dry Wells 2020 to 2039)	1.00	0.89	0.81	0.73	0.70	0.60	0.45

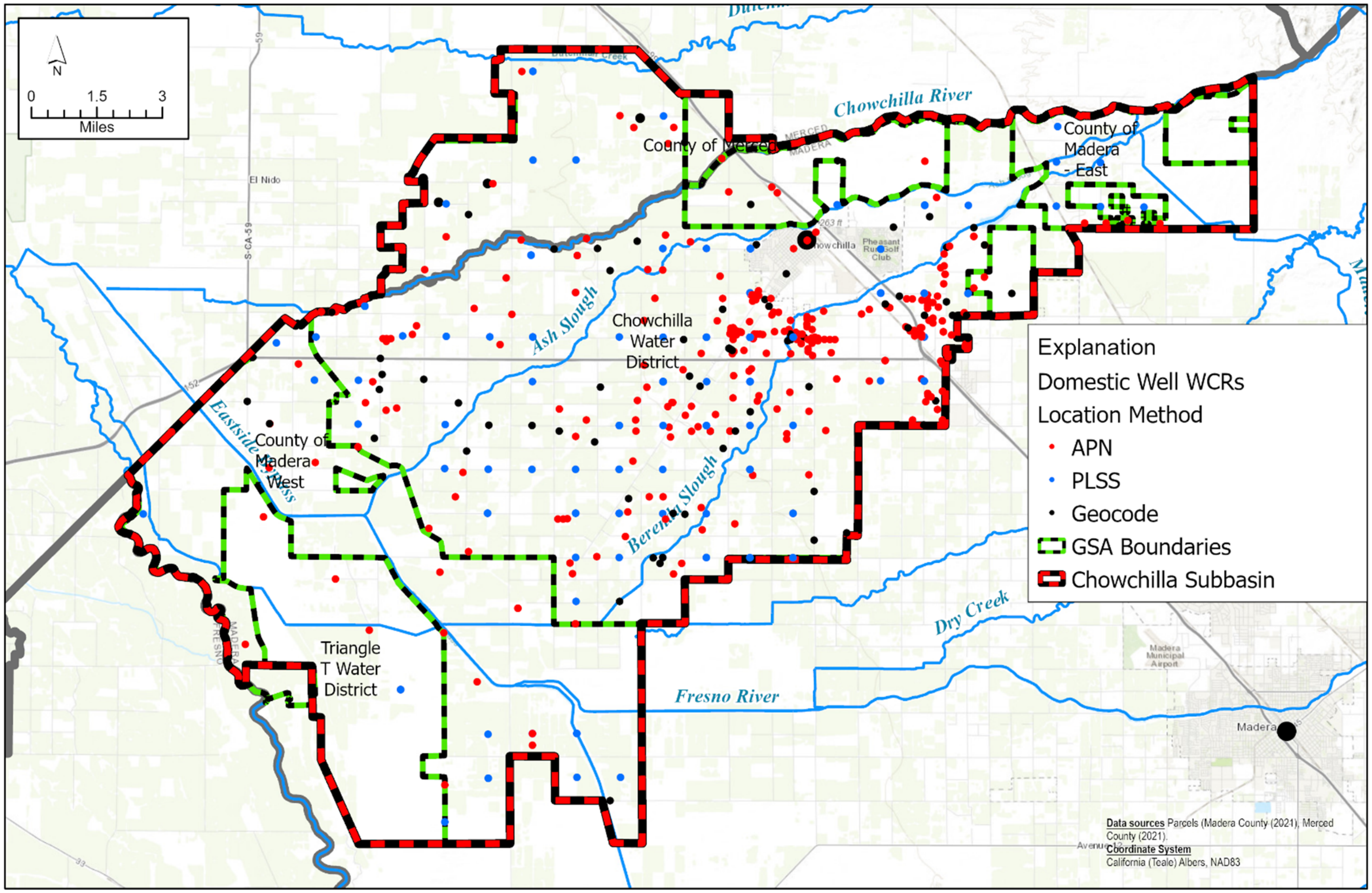
Table 9: Summary of Domestic Pump and Well Costs.

Issue	Type of Problem	Solution	Related to GSP	Typical Cost
Water level in well below pump setting depth	**Pump**	**Lower Pump**	**Yes/No**	**$1,000 to $2,000**
Pump not working (old age or pump-related issue)	**Pump**	**Replace Pump and Equipment**	**No**	**$5,000 to $7,000**
Well casing/screen failure (due to old age)	**Well**	**Replace Well**	**No**	**$25,000 to $35,000**
Water level below bottom of well	**Aquifer**	**Replace Well**	**Yes**	**$25,000 to $35,000**

Table 10: PWS and other Municipal Wells - Dry Well Summary Based on Snapshots of Groundwater Depth at End of Periods ending in 2024, 2029, 2034, and 2039, for the Base Case Climate Scenario.

Year Range (Oct 31st Minimums)	New Wells Drilled	Total Wetted Wells Year Start	**Wells Going Dry**	Total Wetted Wells Year End	Sum Of Dry Wells
2020 to 2024	1	15	1	14	1
2025 to 2029	0	14	0	14	1
2030 to 2034	0	14	0	14	1
2035 to 2039	0	14	0	14	1
During the period 1989 to 2019, prior to the implementation period, the model suggests one well went dry.				Total	1

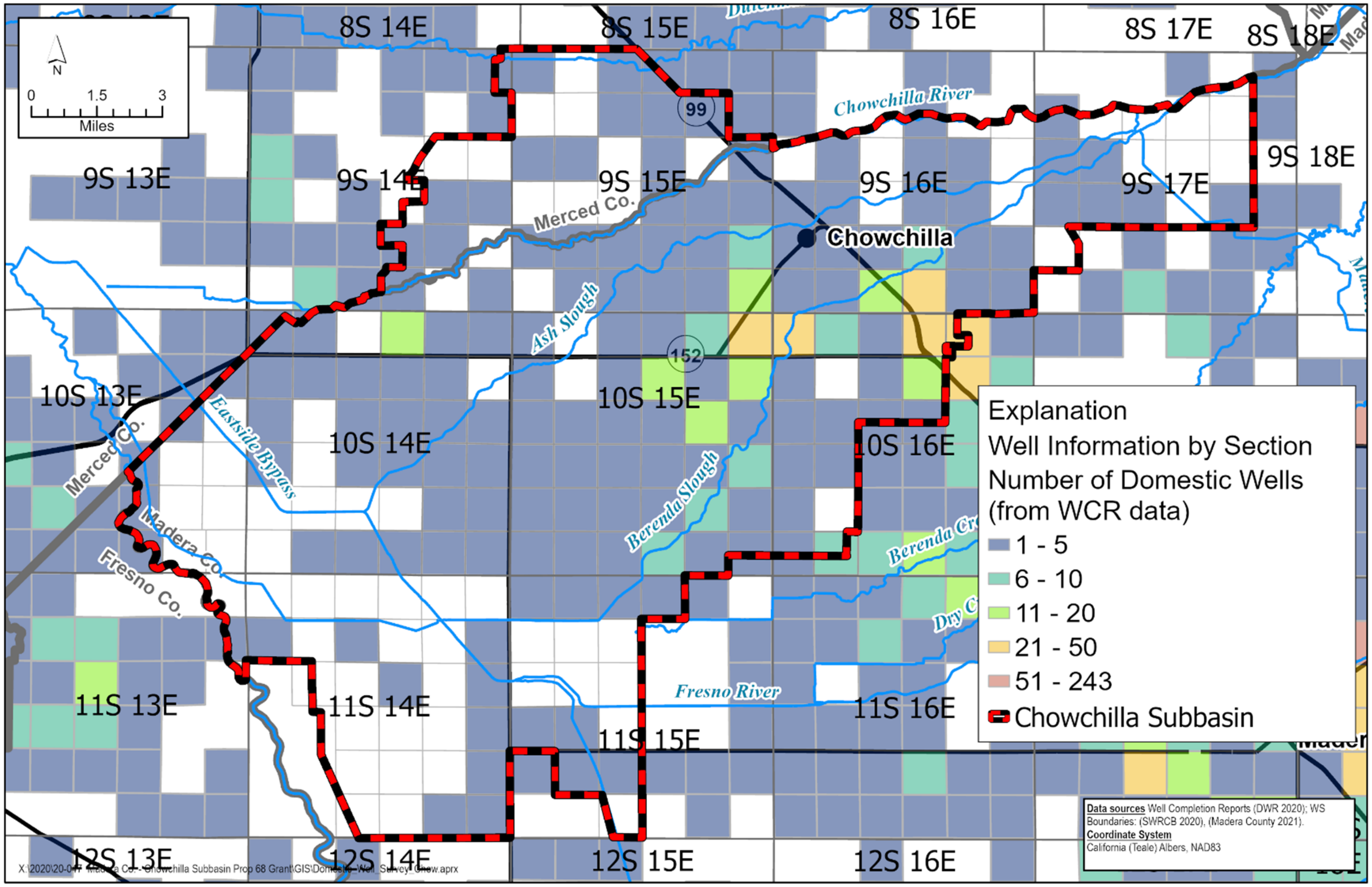
7 FIGURES



Data sources Parcels (Madera County (2021), Merced County (2021).

Coordinate System
California (Teale) Albers, NAD83

Figure 1a. Well Completion Report new construction domestic wells located by best available method.



Data sources Well Completion Reports (DWR 2020); WS Boundaries: (SWRCB 2020), (Madera County 2021).
Coordinate System
California (Teale) Albers, NAD83

Figure 1b. Well Completion Report new construction domestic well counts by Section.

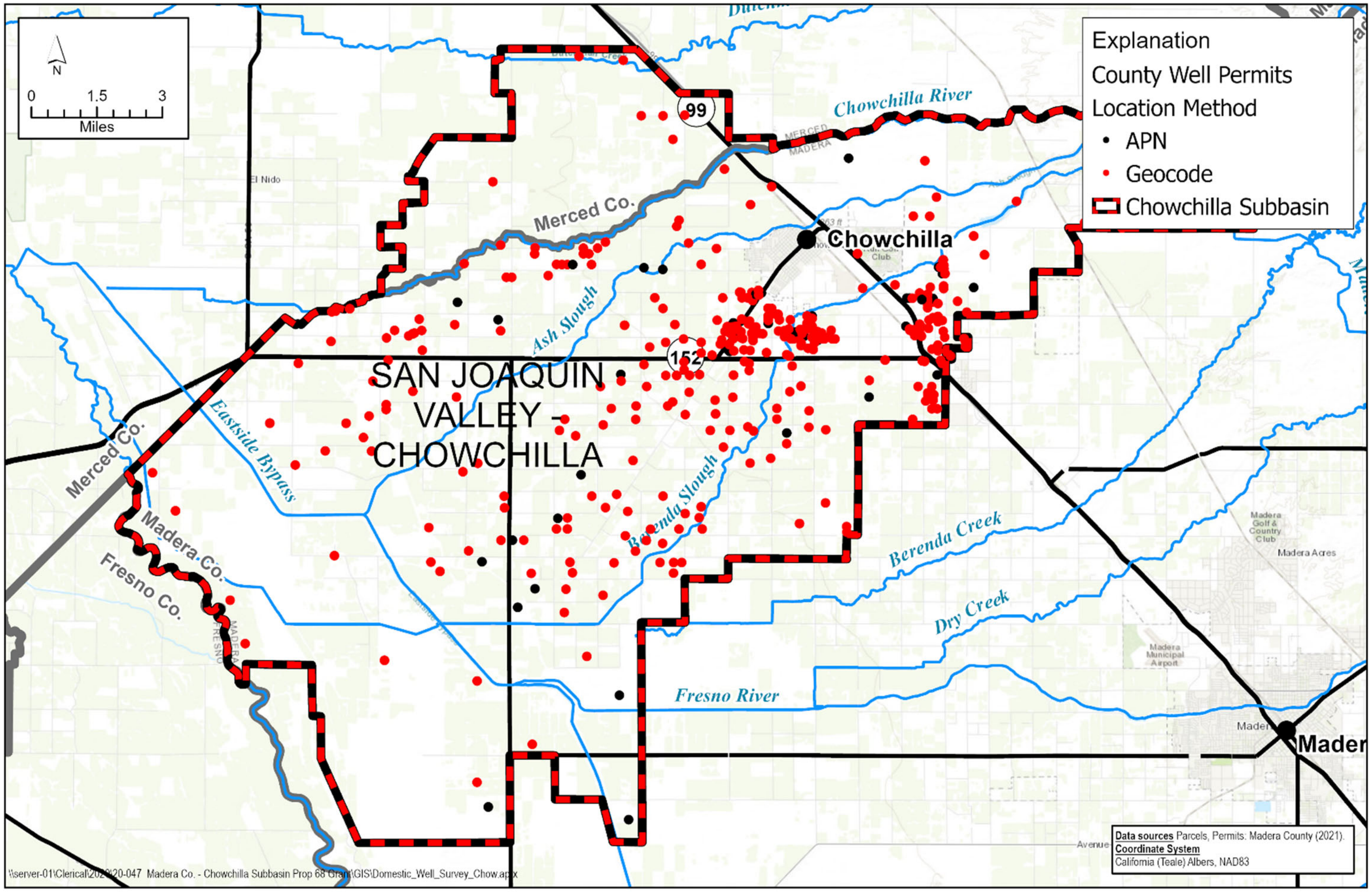
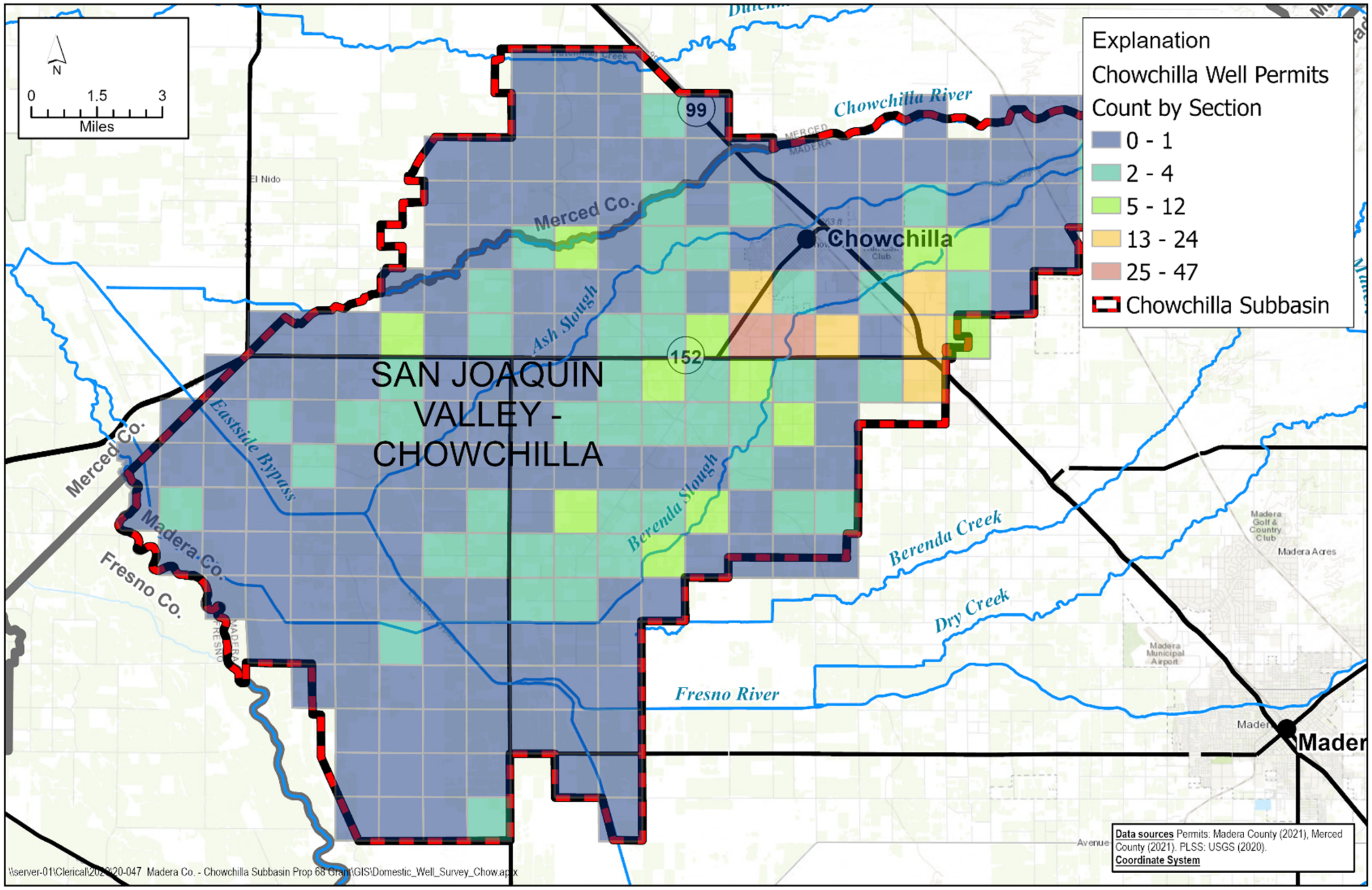


Figure 2a: Permit locations and geolocation method in Chowchilla Subbasin.



Data sources Permits: Madera County (2021), Merced County (2021). PLSS: USGS (2020).
Coordinate System

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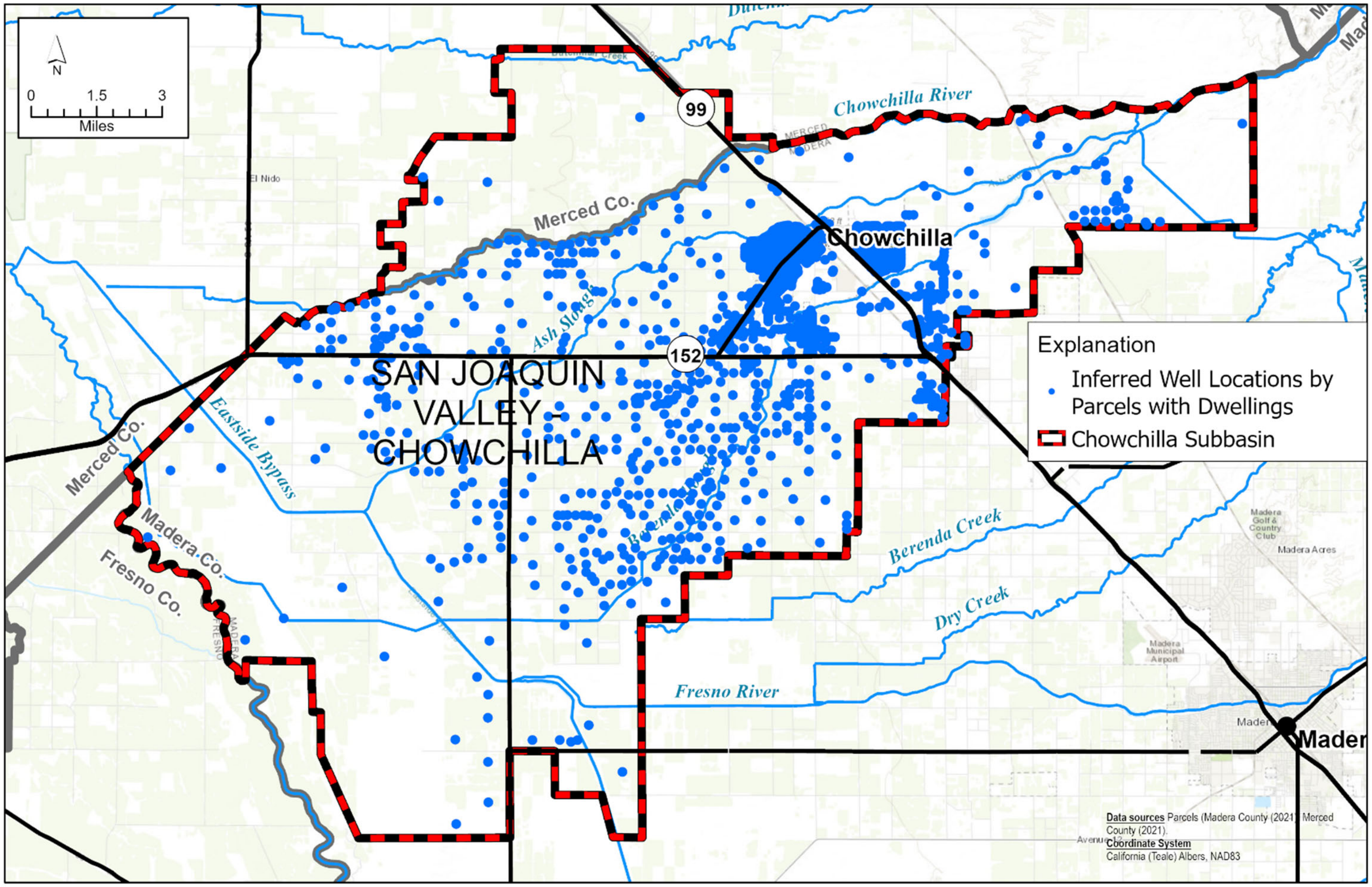
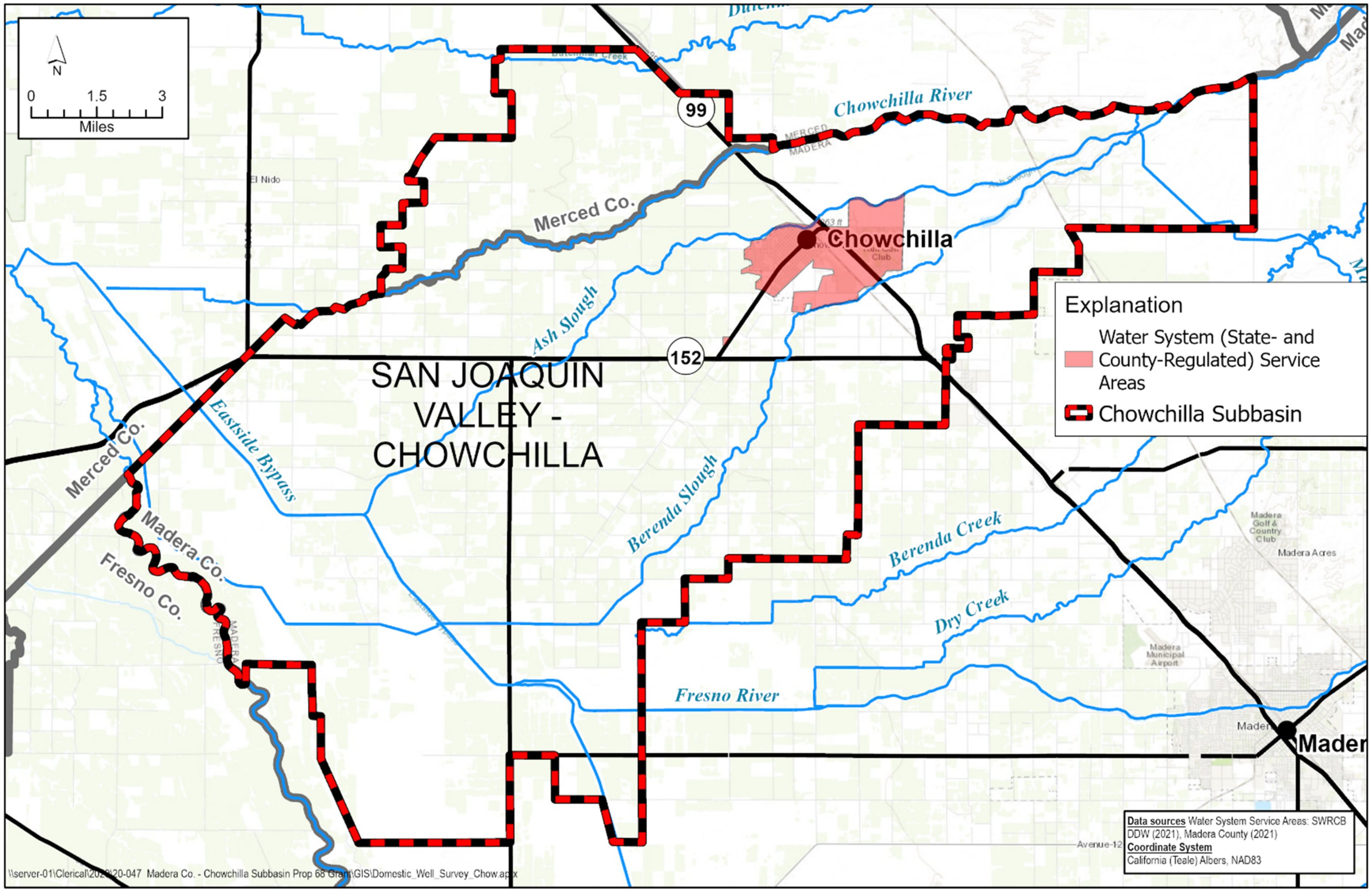
Figure 2b. Permit location counts by Township/Range/Section.



Data sources Parcels (Madera County (2021), Merced County (2021).
Coordinate System
California (Teale) Albers, NAD83

Figure 3: Inferred well locations based on Parcel Dwelling Status.



Data sources Water System Service Areas: SWRCB DDW (2021), Madera County (2021)
Coordinate System
California (Teale) Albers, NAD83

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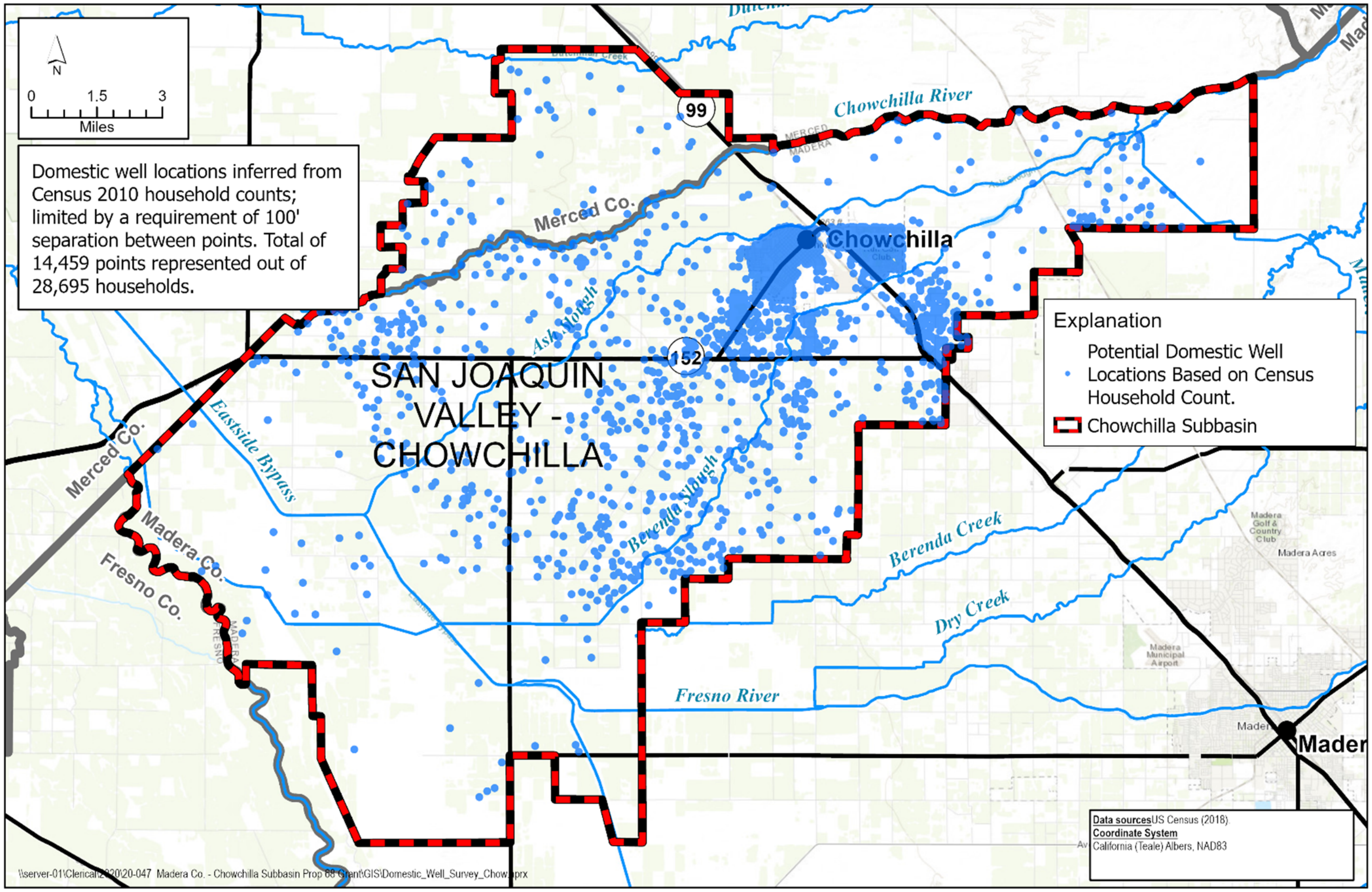
Figure 4: Water System Boundaries in Madera County.



Domestic well locations inferred from Census 2010 household counts; limited by a requirement of 100' separation between points. Total of 14,459 points represented out of 28,695 households.

Data sources US Census (2018)
Coordinate System
California (Teale) Albers, NAD83

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Figure 5: Inferred well locations based on 2010 Census Household counts.

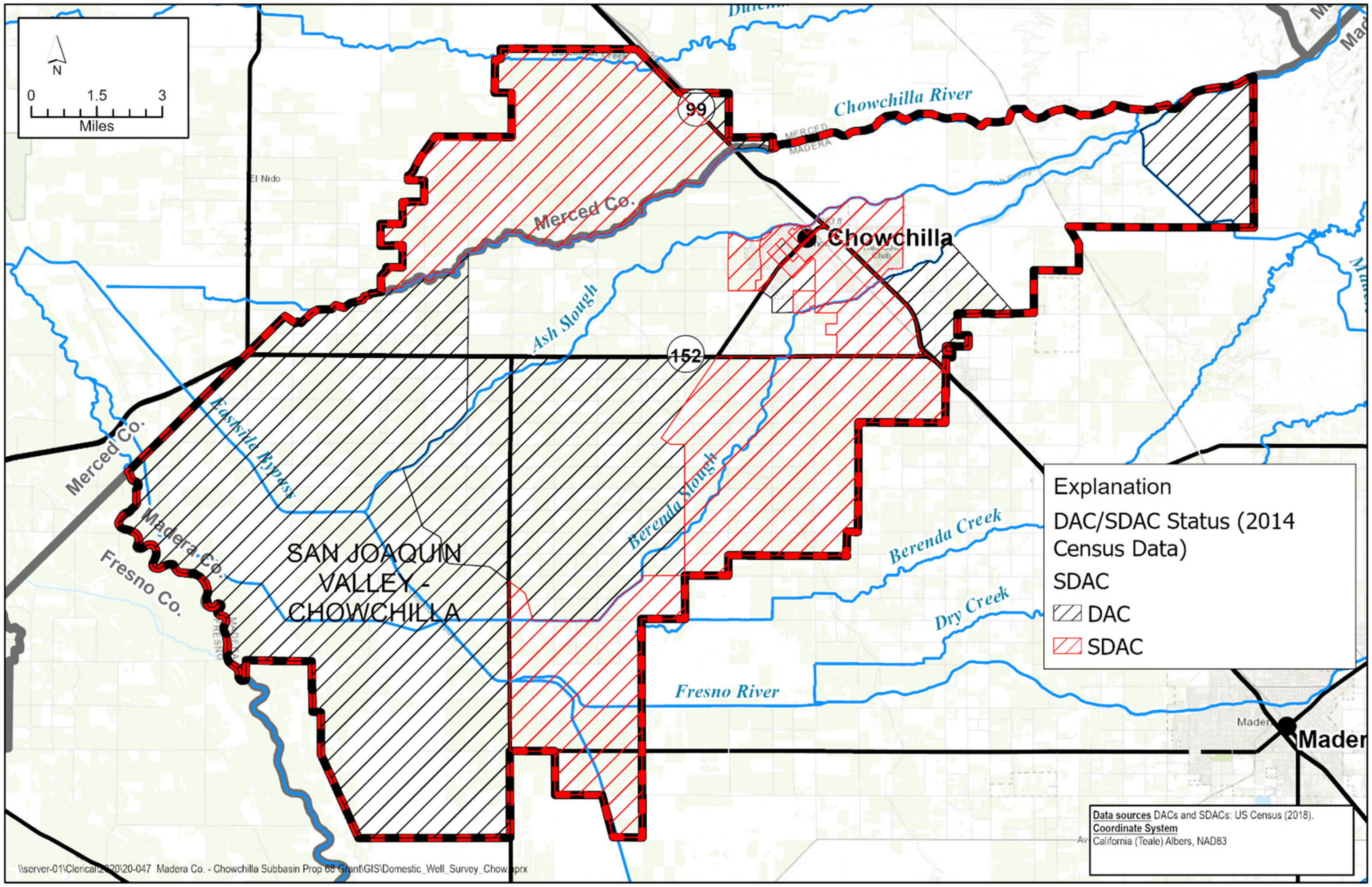


Figure 6: DACs and SDACs in the Chowchilla Subbasin.

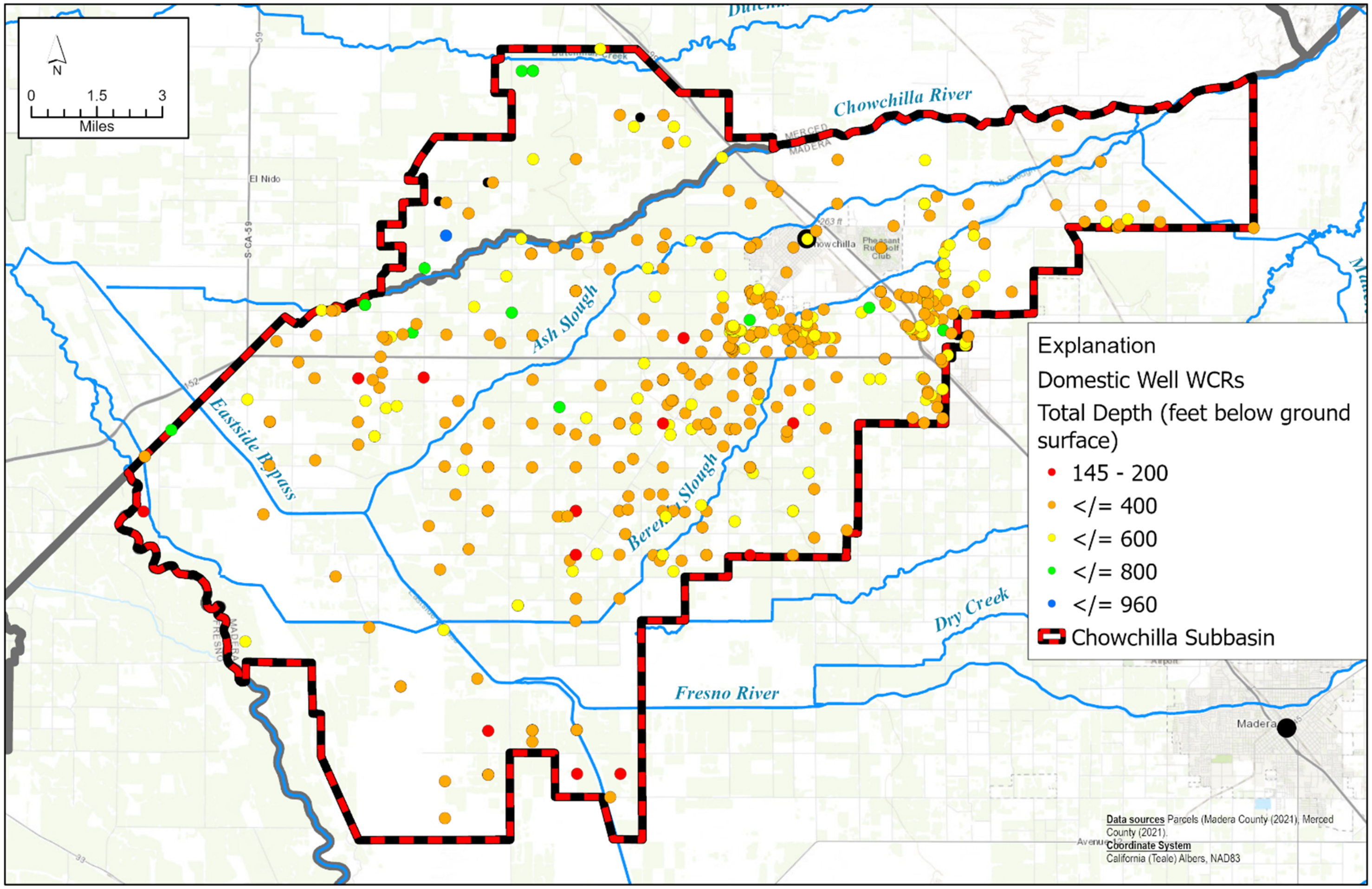


Figure 7a: Domestic wells in Chowchilla Subbasin with depth from WCR.

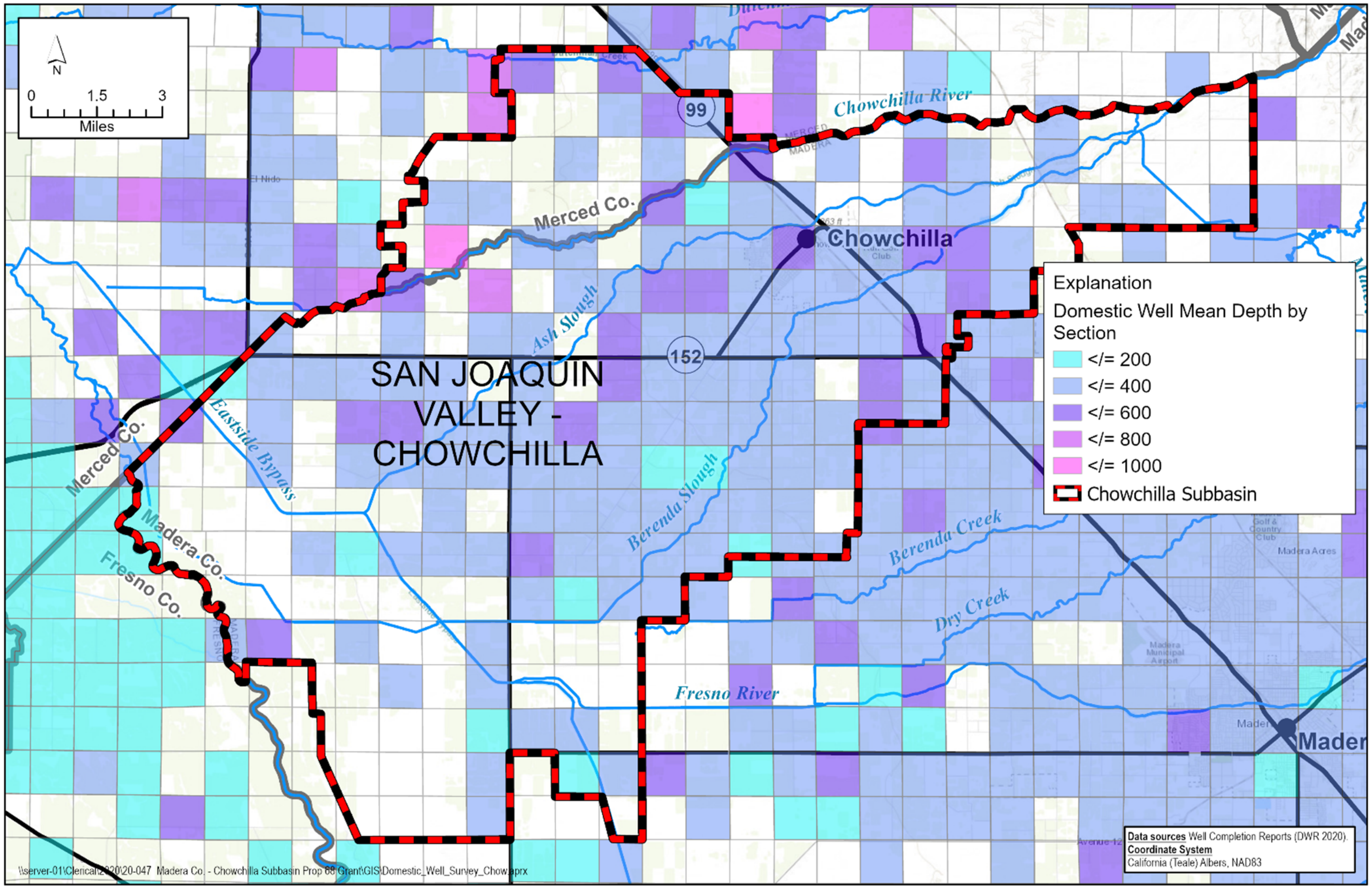


Figure 7b. Domestic Wells in Chowchilla Subbasin with Average Depth by Township/Range/Section from WCRs.

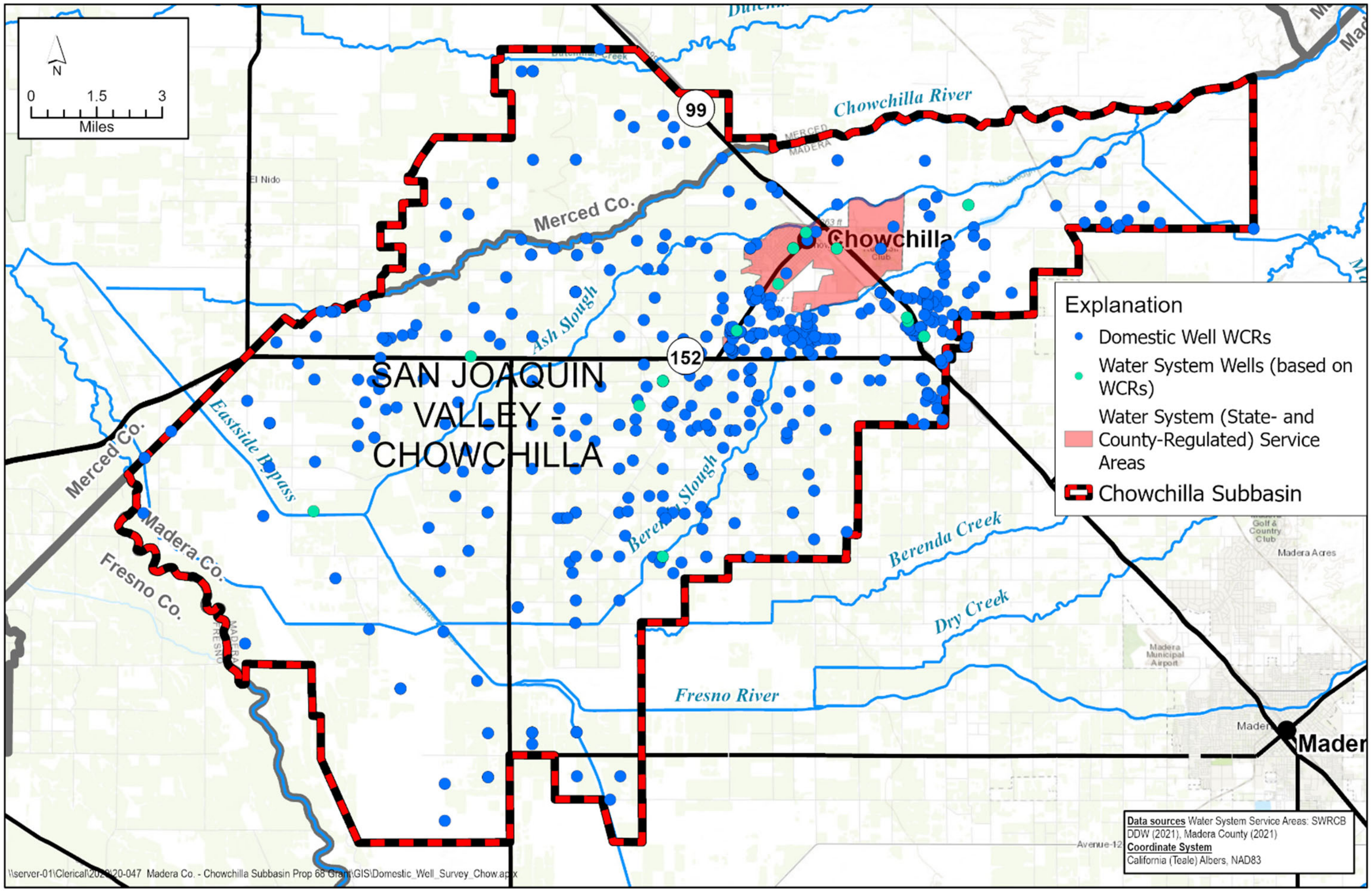
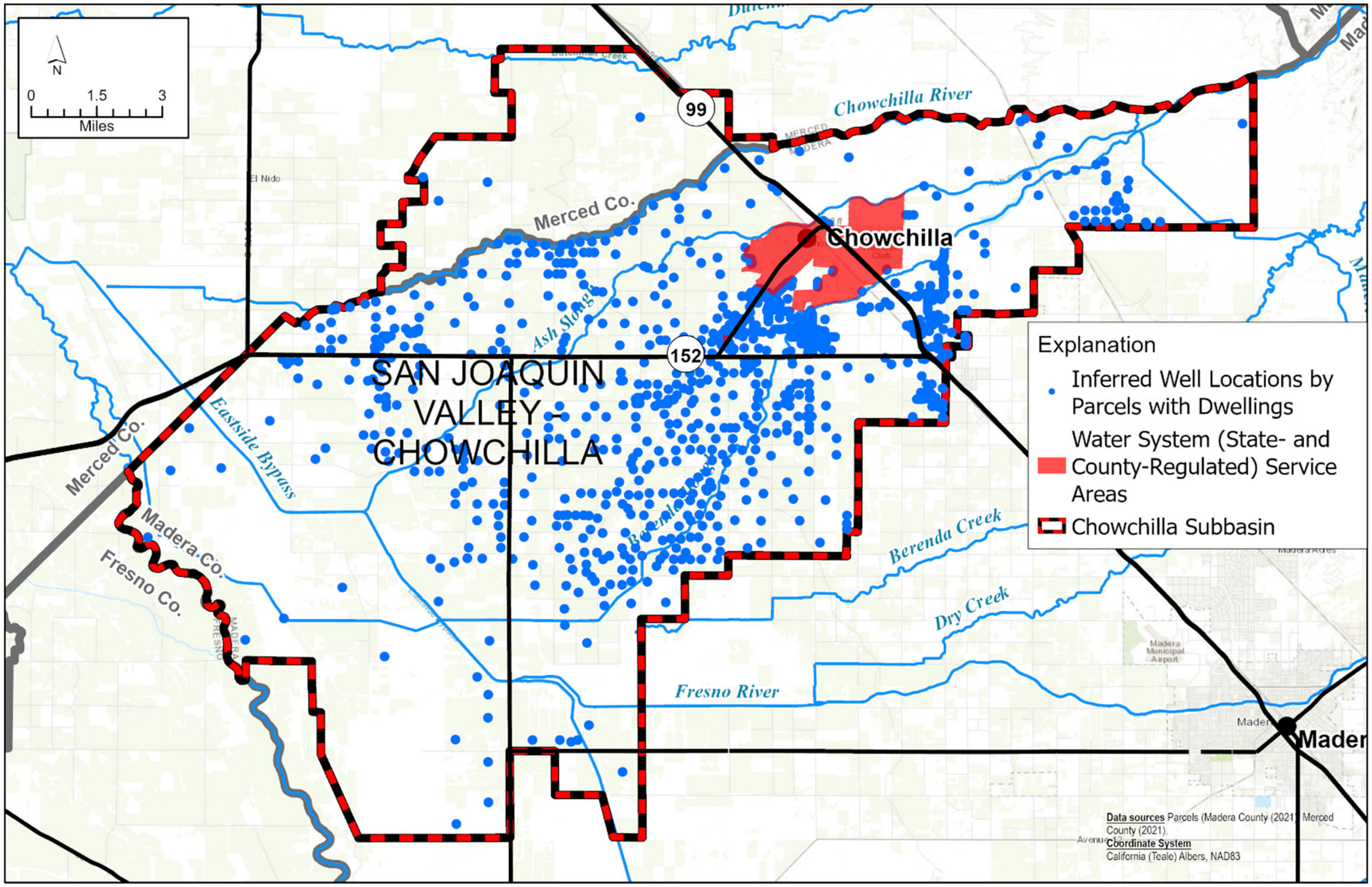
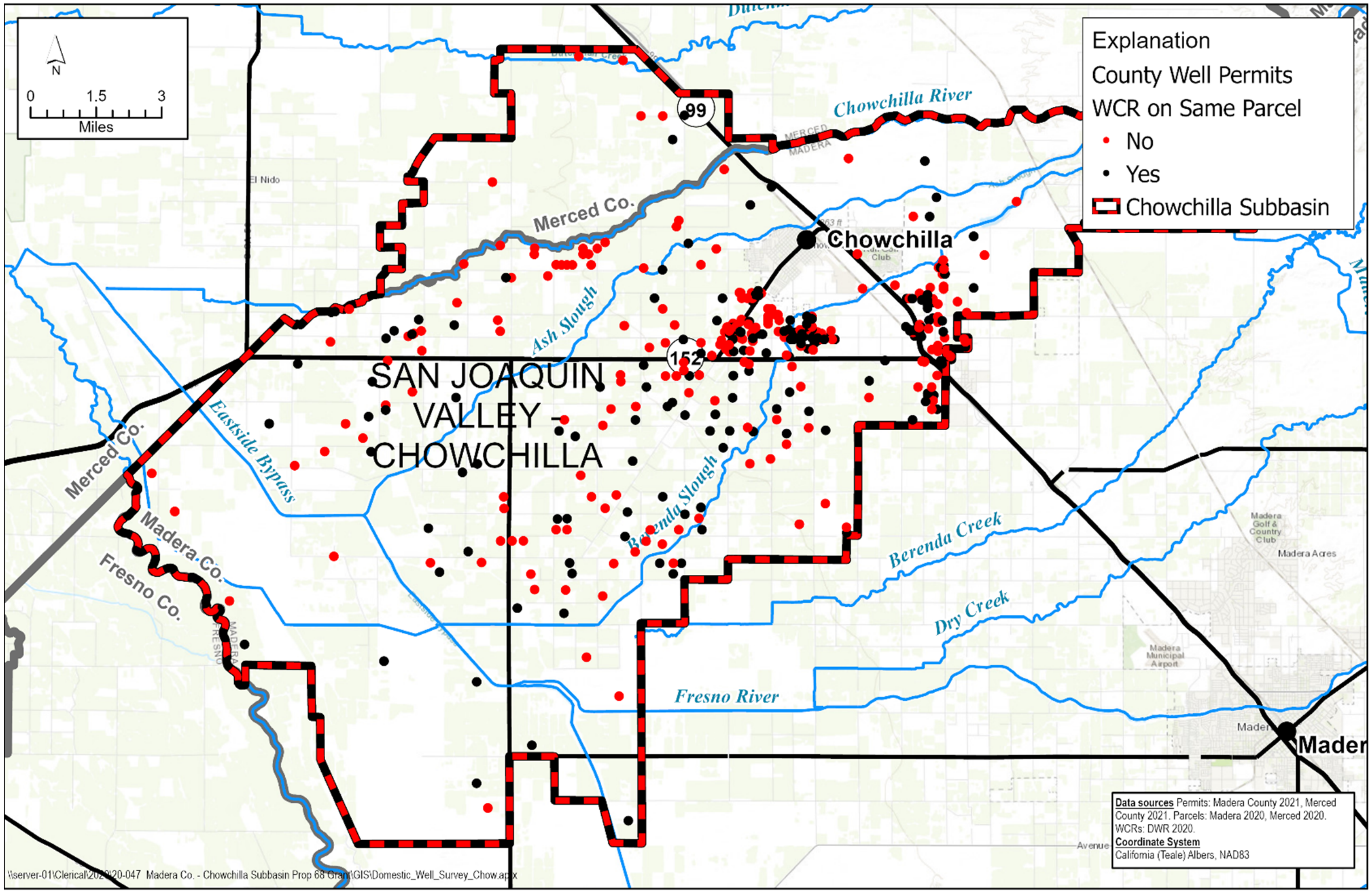


Figure 8: Domestic WCRs compared with Community PWS, County Maintenance Districts, and Community Service Areas.



Data sources Parcels (Madera County (2021), Merced County (2021).
Coordinate System
California (Teale) Albers, NAD83

Figure 9: Parcels with Dwellings as Inferred Well Locations, outside of Community PWS, County Maintenance Districts, and Community Service Areas.



Data sources Permits: Madera County 2021, Merced County 2021. Parcels: Madera 2020, Merced 2020. WCRs: DWR 2020.
Coordinate System California (Teale) Albers, NAD83

Figure 10: Parcels with Permits and WCRs.

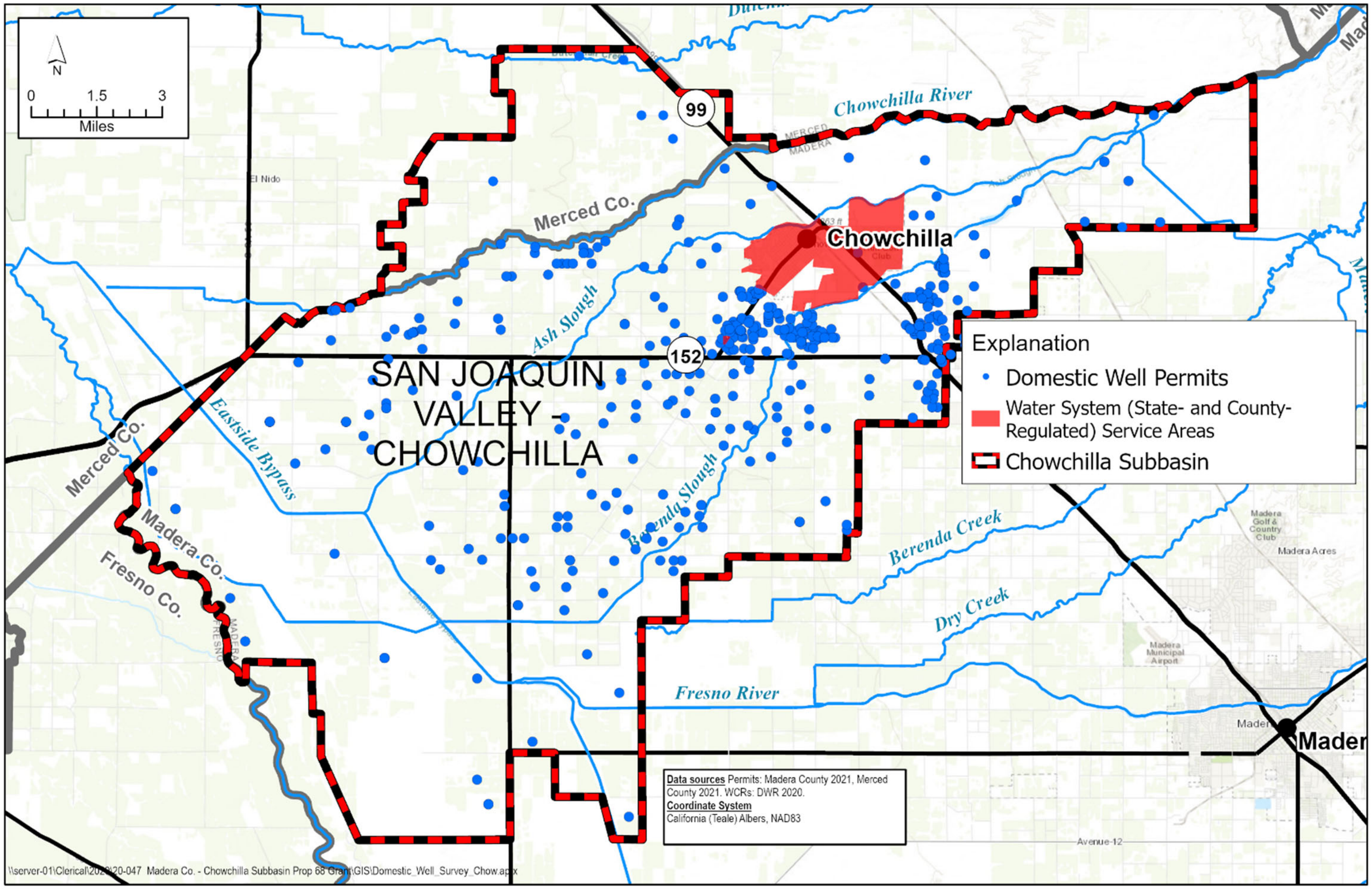


Figure 11a: Domestic Well Permits Compared with PWS, Community Service Districts and County Maintenance Districts.

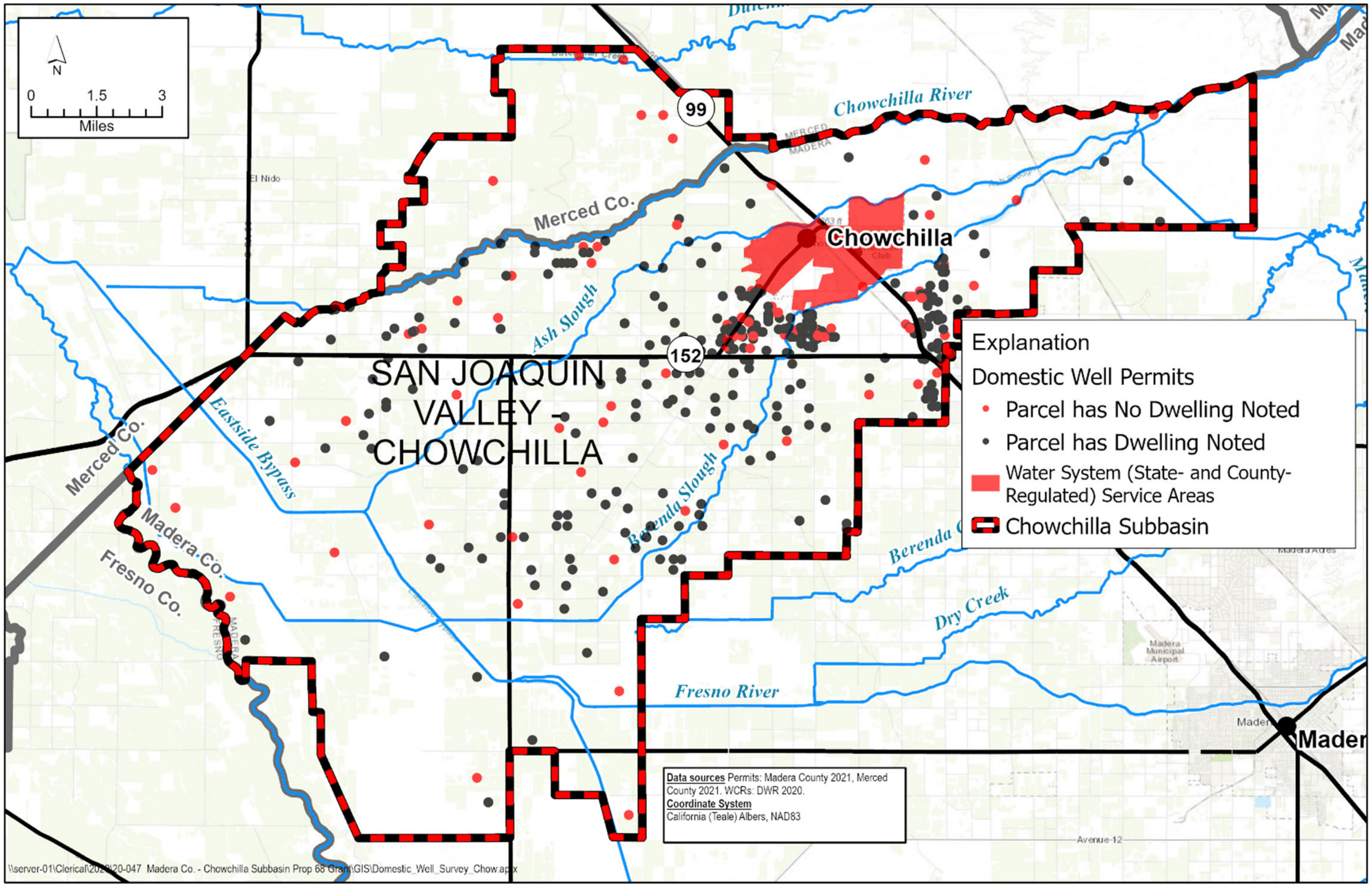
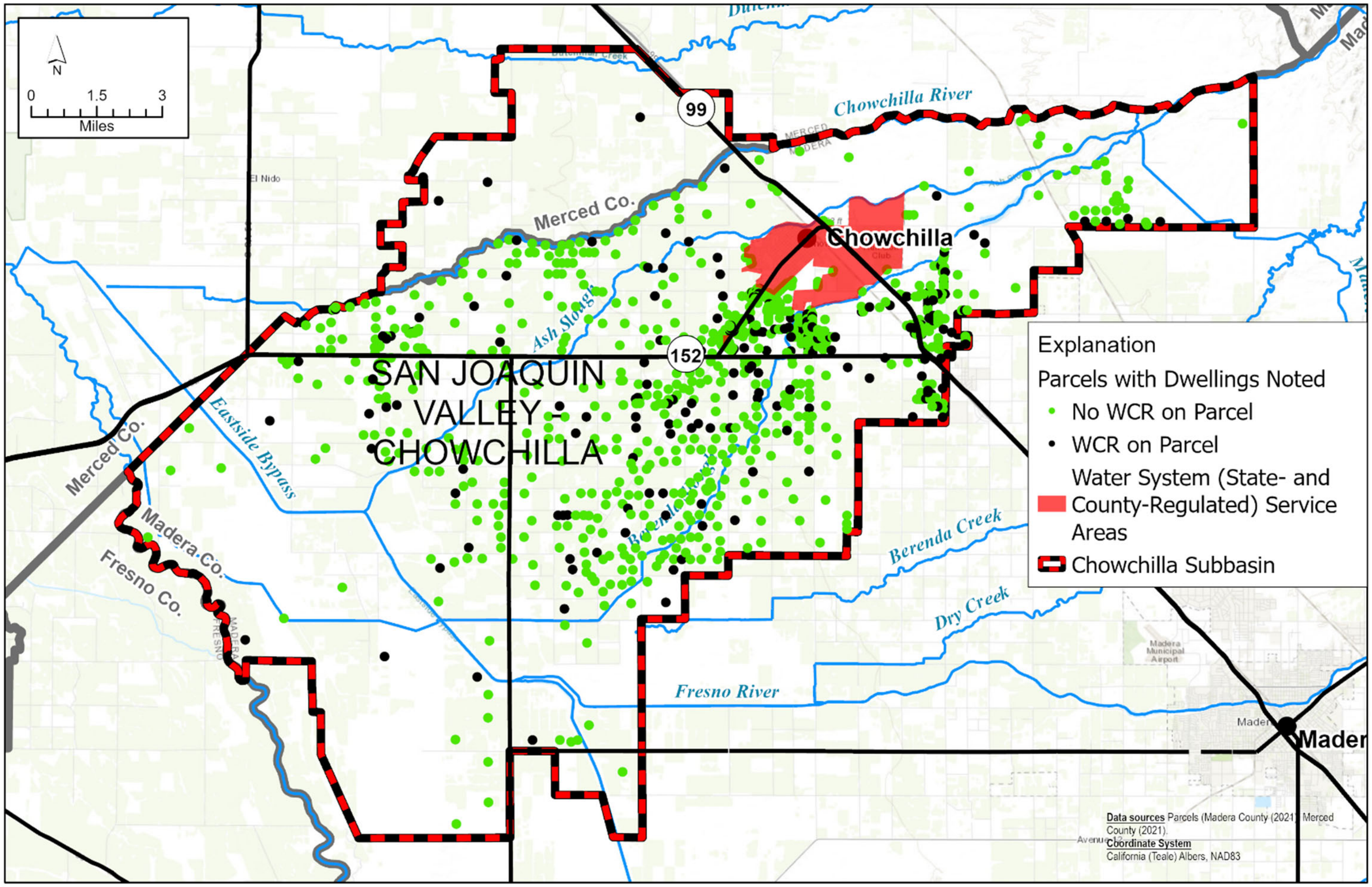


Figure 11b: Domestic Well Permits Compared with Parcel Characteristics.



Data sources Parcels (Madera County (2021), Merced County (2021).
Coordinate System
California (Teale) Albers, NAD83

Figure 12: Inferred Domestic Well locations Based on Parcels with Dwellings, with Water Systems and Presence/Absence of WCRs on Parcel.

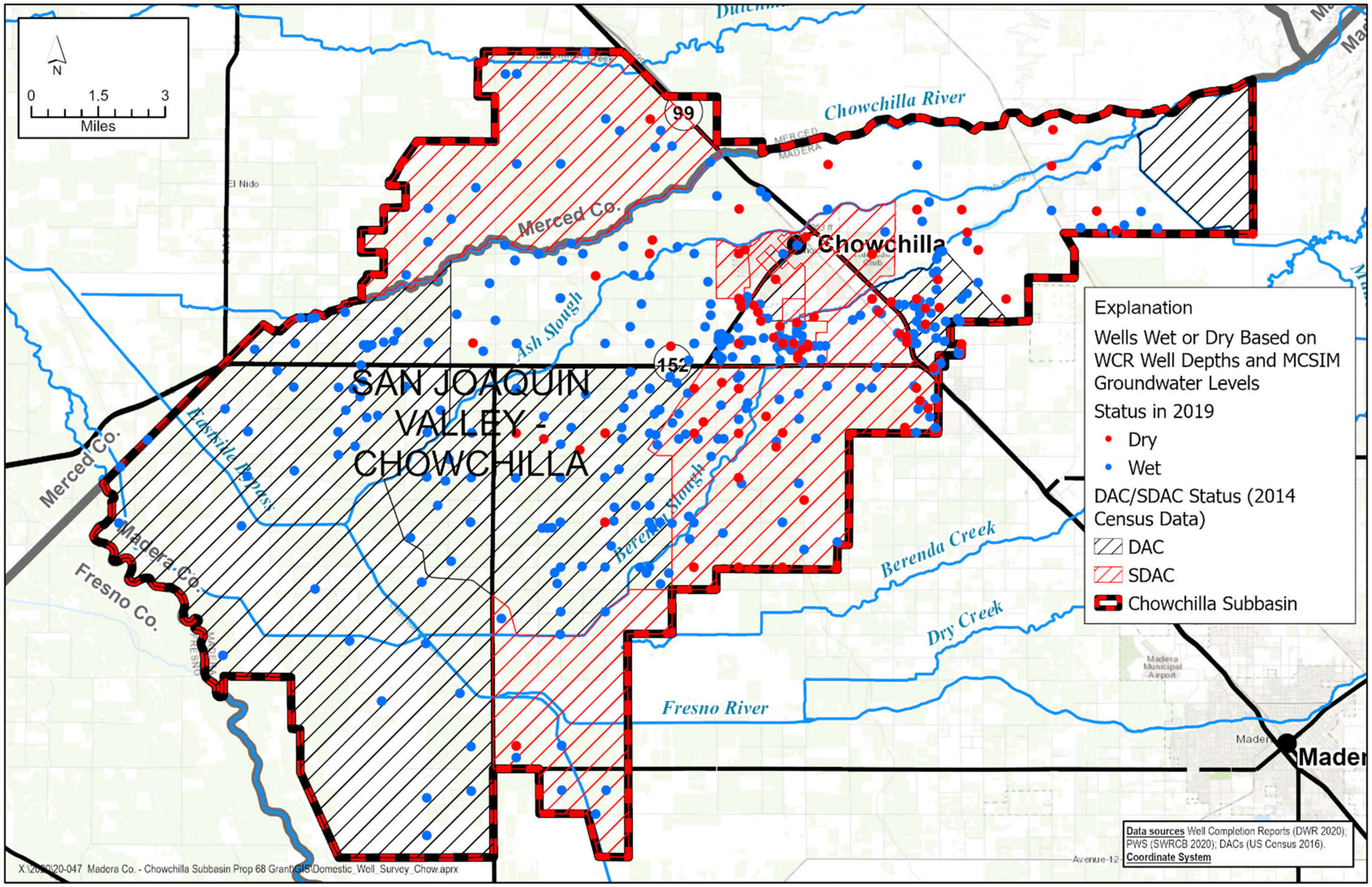


Figure 13a: Status of Domestic Wells in 2019 - Based on WCR Well Depths and Locations Compared to MCSIM Groundwater Depths.

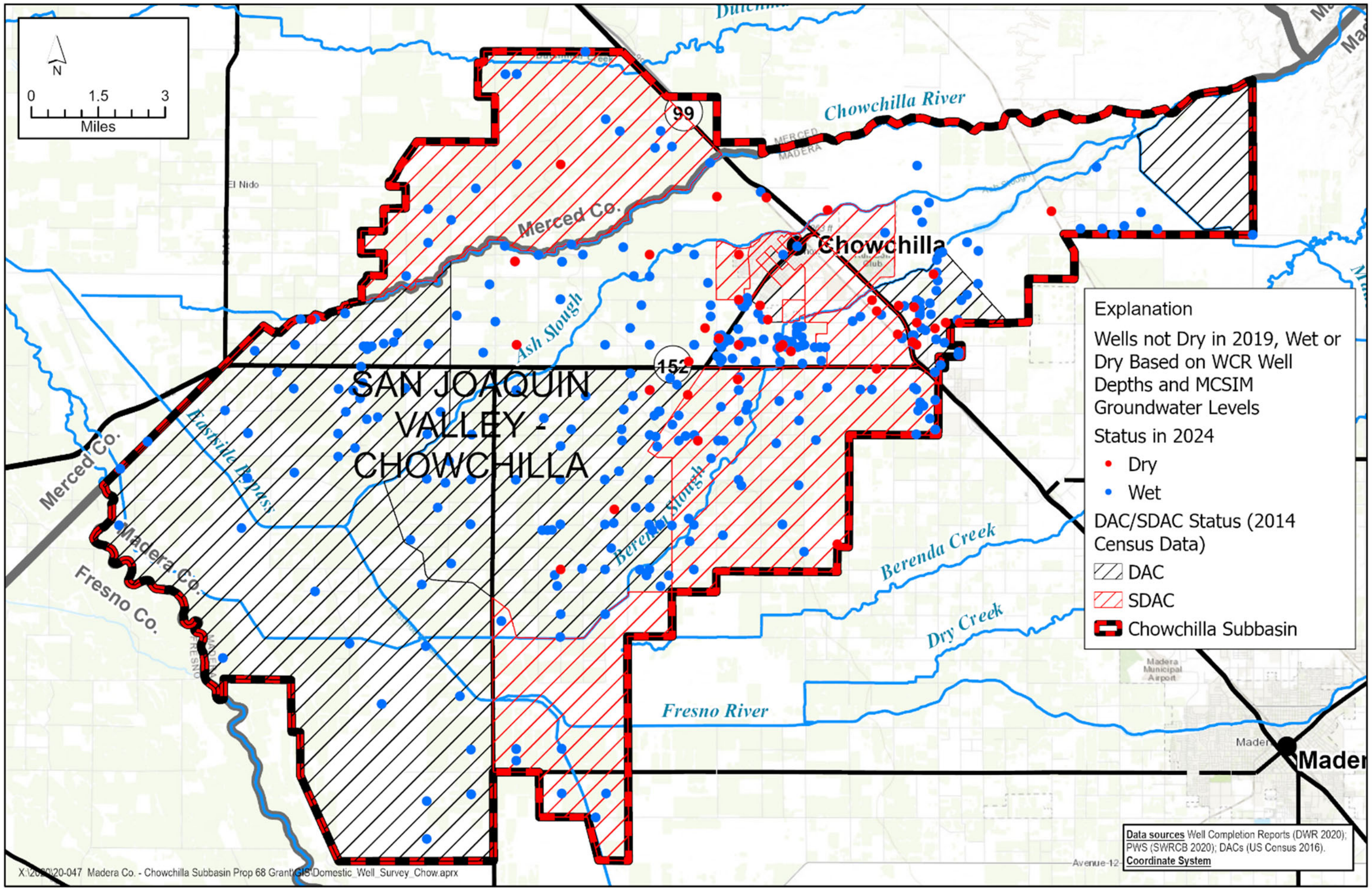


Figure 13b: Status of Wells in 2024 - Based on WCR Well Depths and Locations Compared to MCSIM Groundwater Depths.

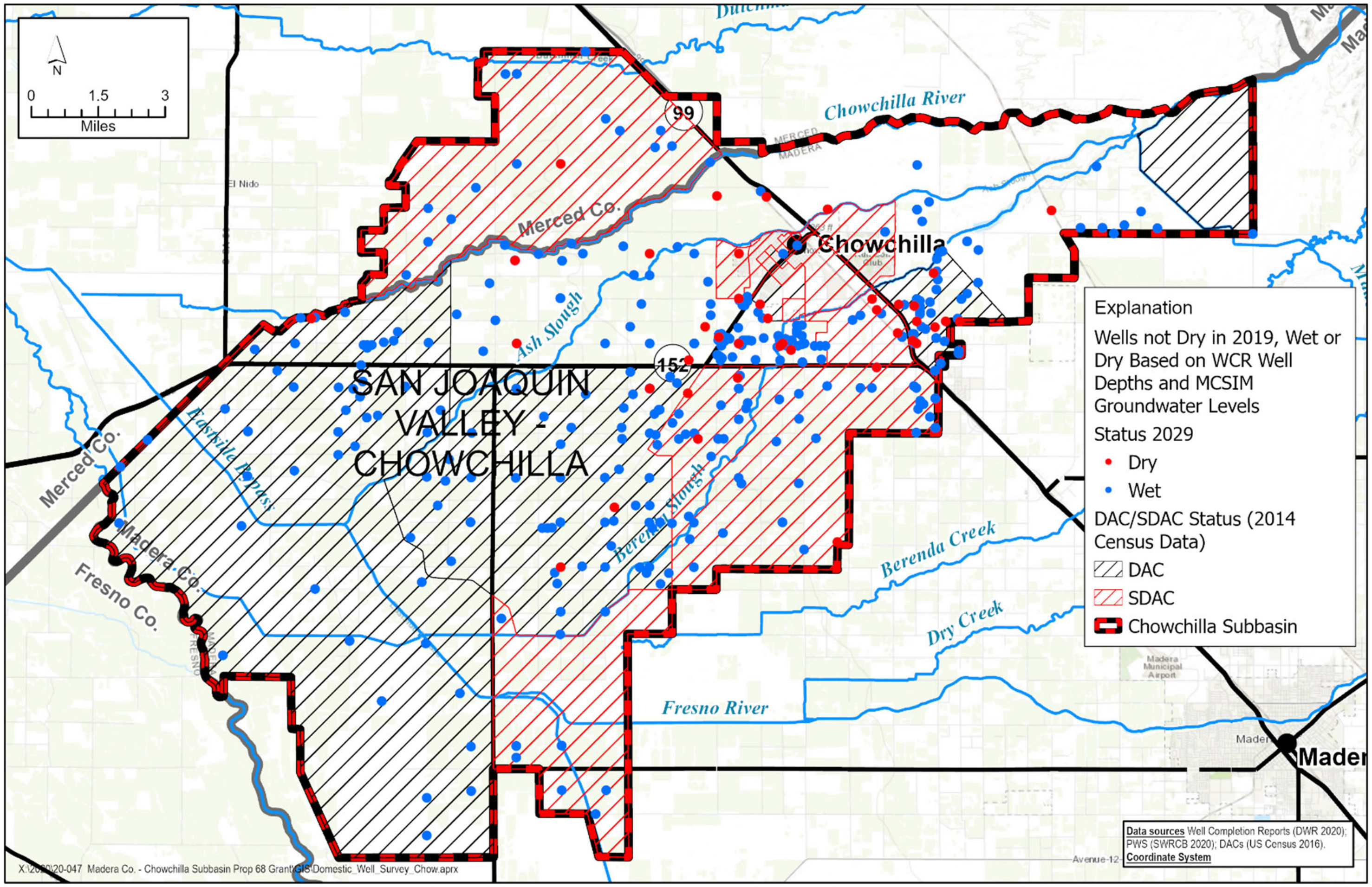


Figure 13c: Status of Wells in 2029 - Based on WCR Well Depths and Locations Compared to MCSIM Groundwater Depths.

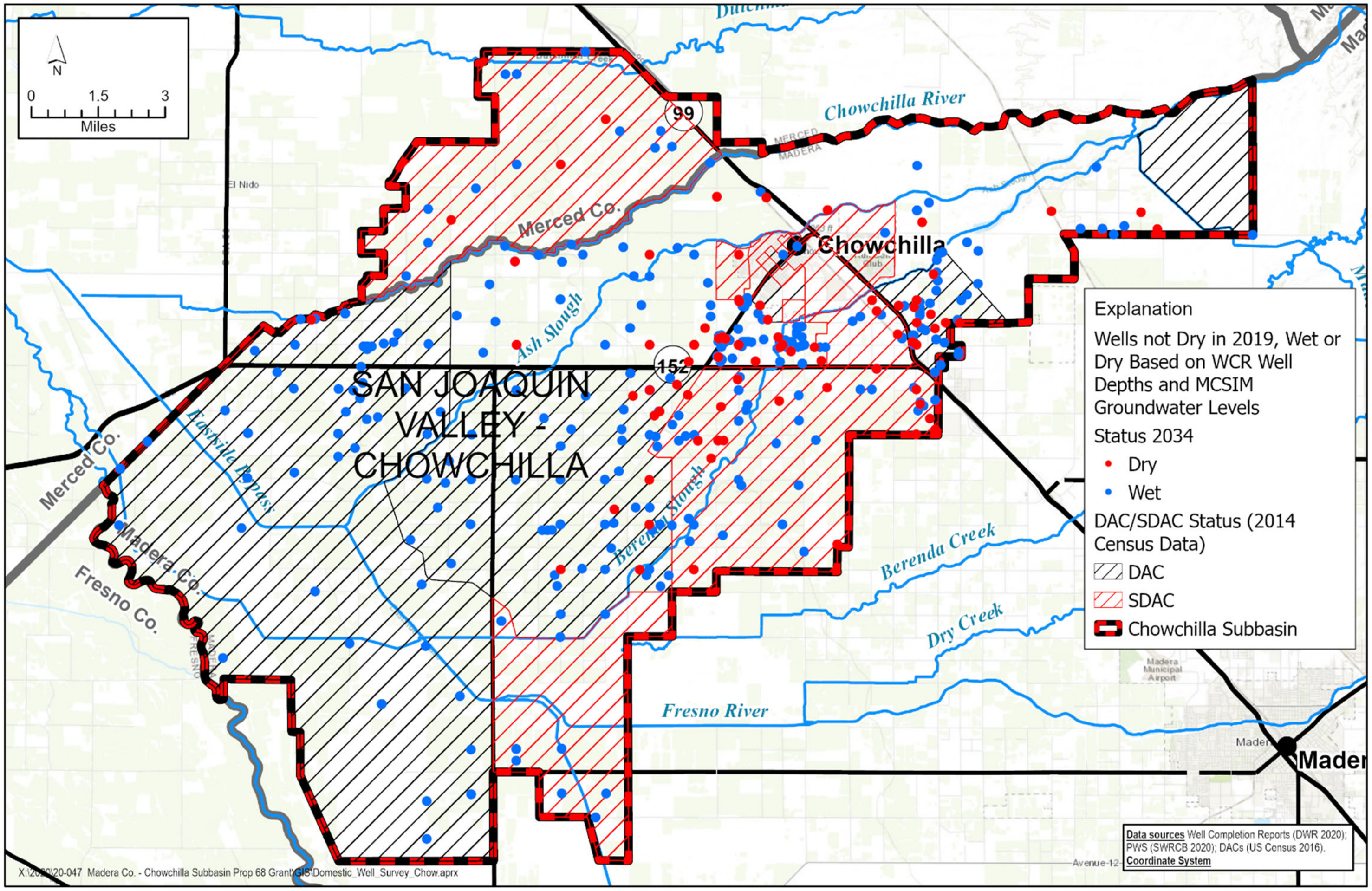


Figure 13d: Status of Wells in 2034 - Based on WCR Well Depths and Locations Compared to MCSIM Groundwater Depths.

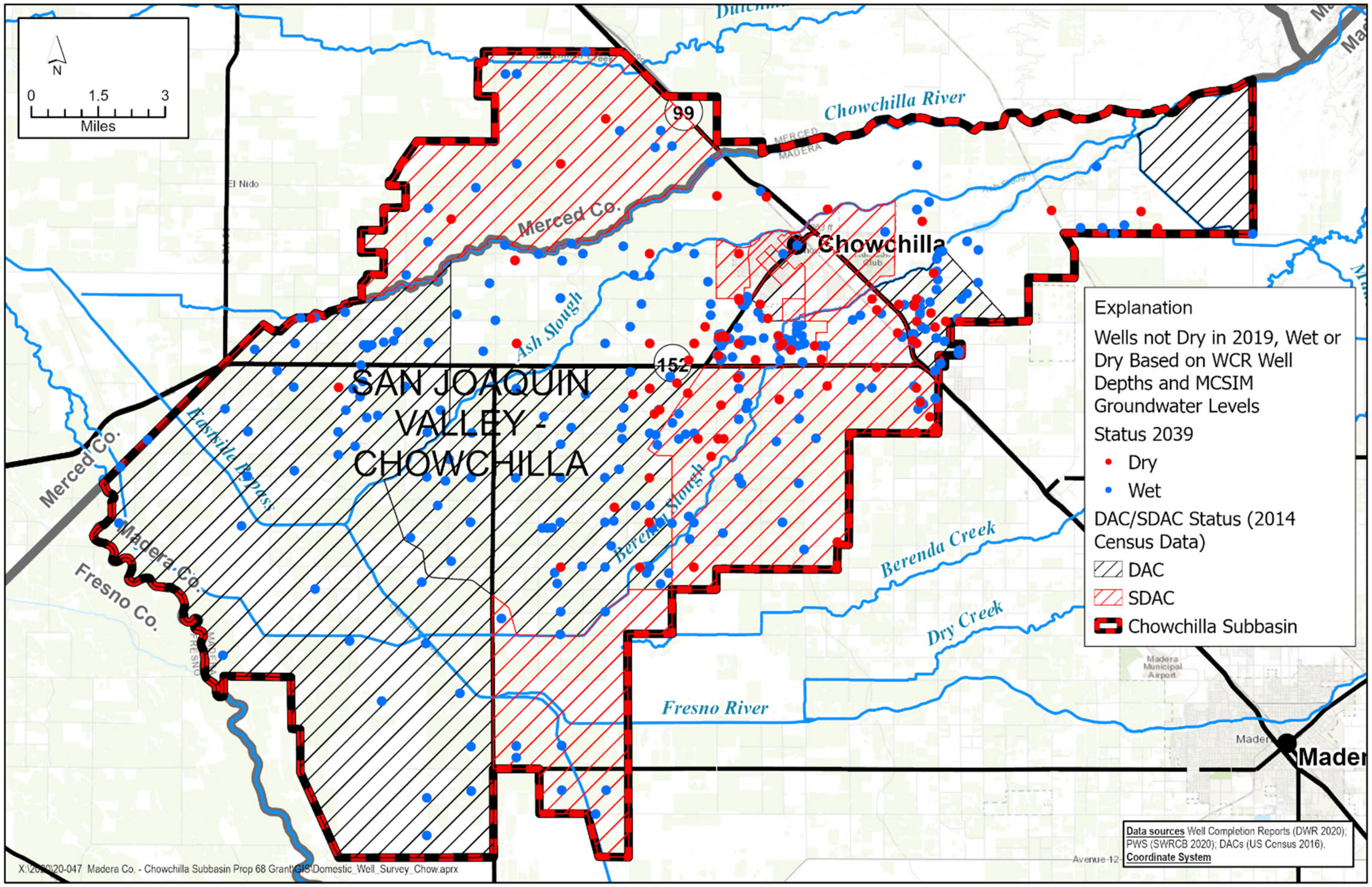
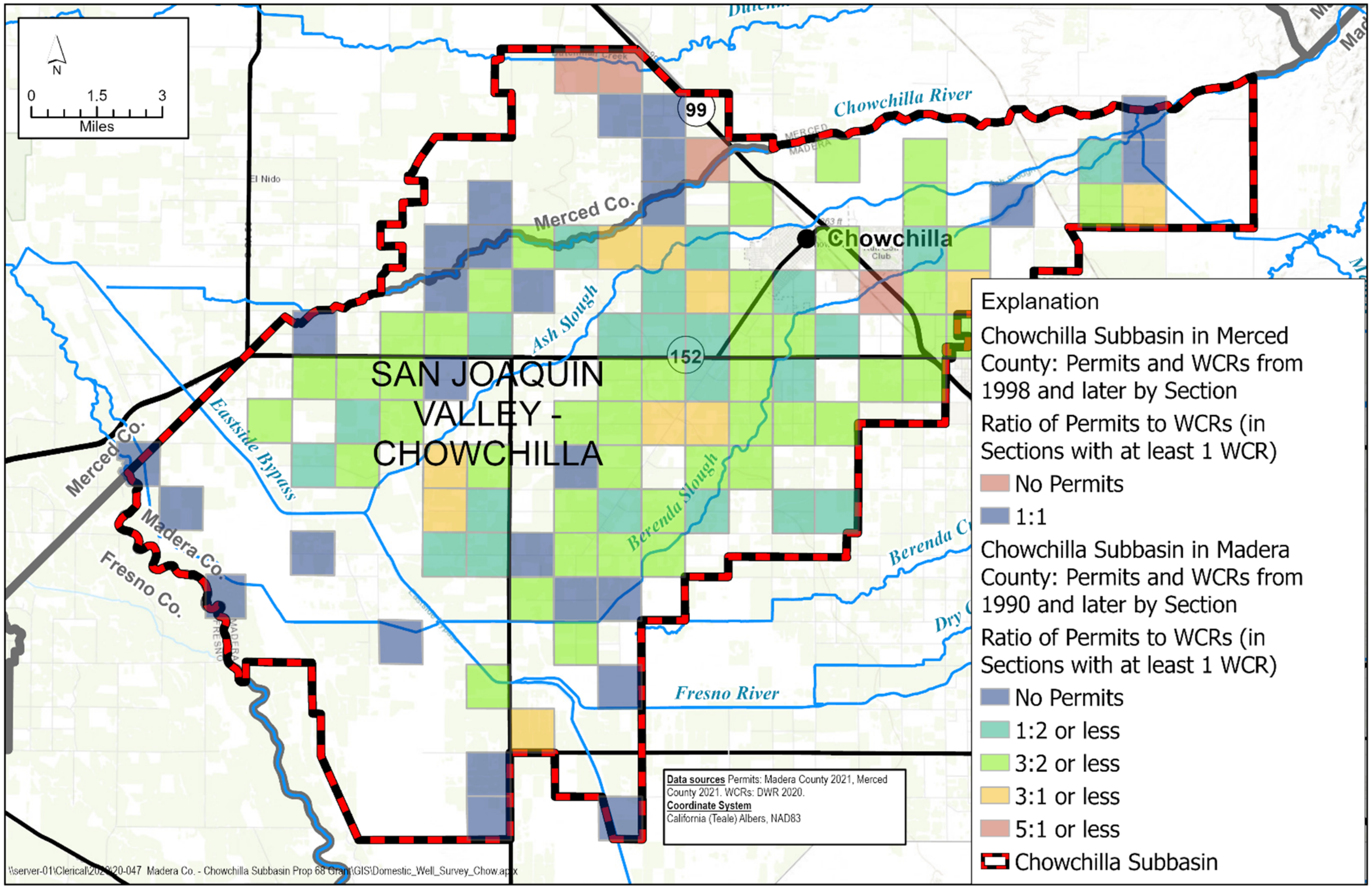


Figure 13e: Status of Wells in 2039 - Based on WCR Well Depths and Locations Compared to MCSIM Groundwater Depths.



Data sources Permits: Madera County 2021, Merced County 2021. WCRs: DWR 2020.
Coordinate System
California (Teale) Albers, NAD83

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Figure 14: Map of Domestic Well Permits Compared to Domestic Well WCR (from 1990 and later) Locations.

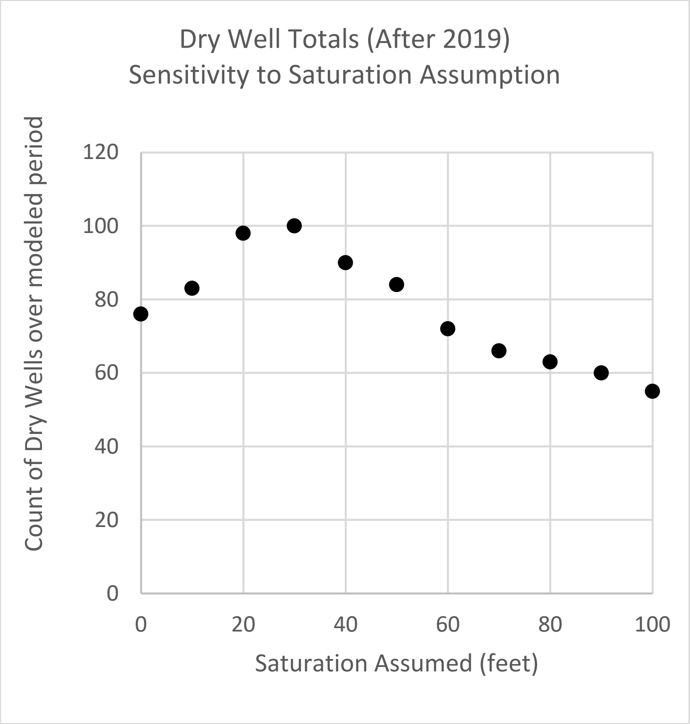


Figure 15: Counts of Dry Wells as a Function of Minimum Saturation Threshold.

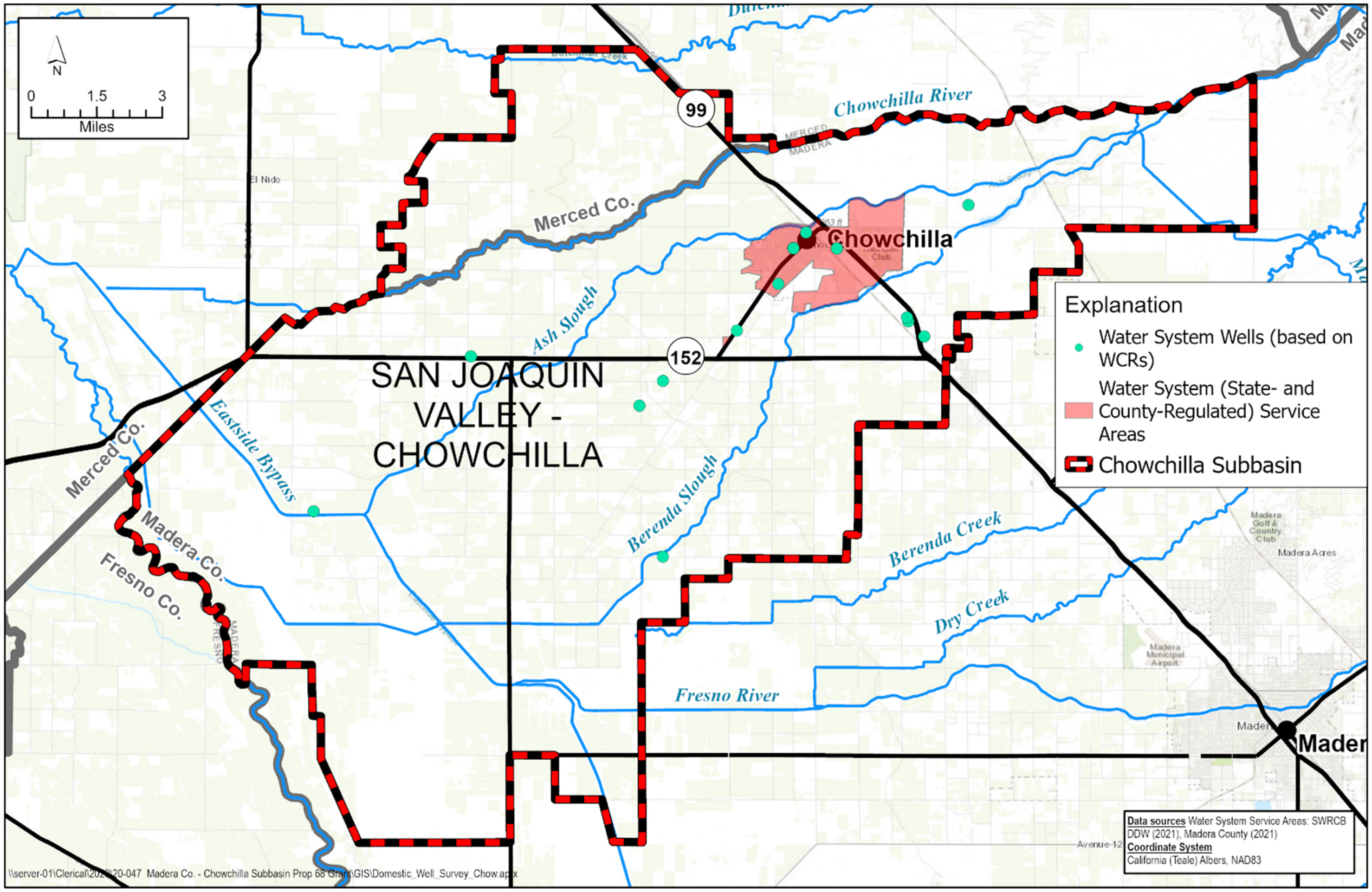
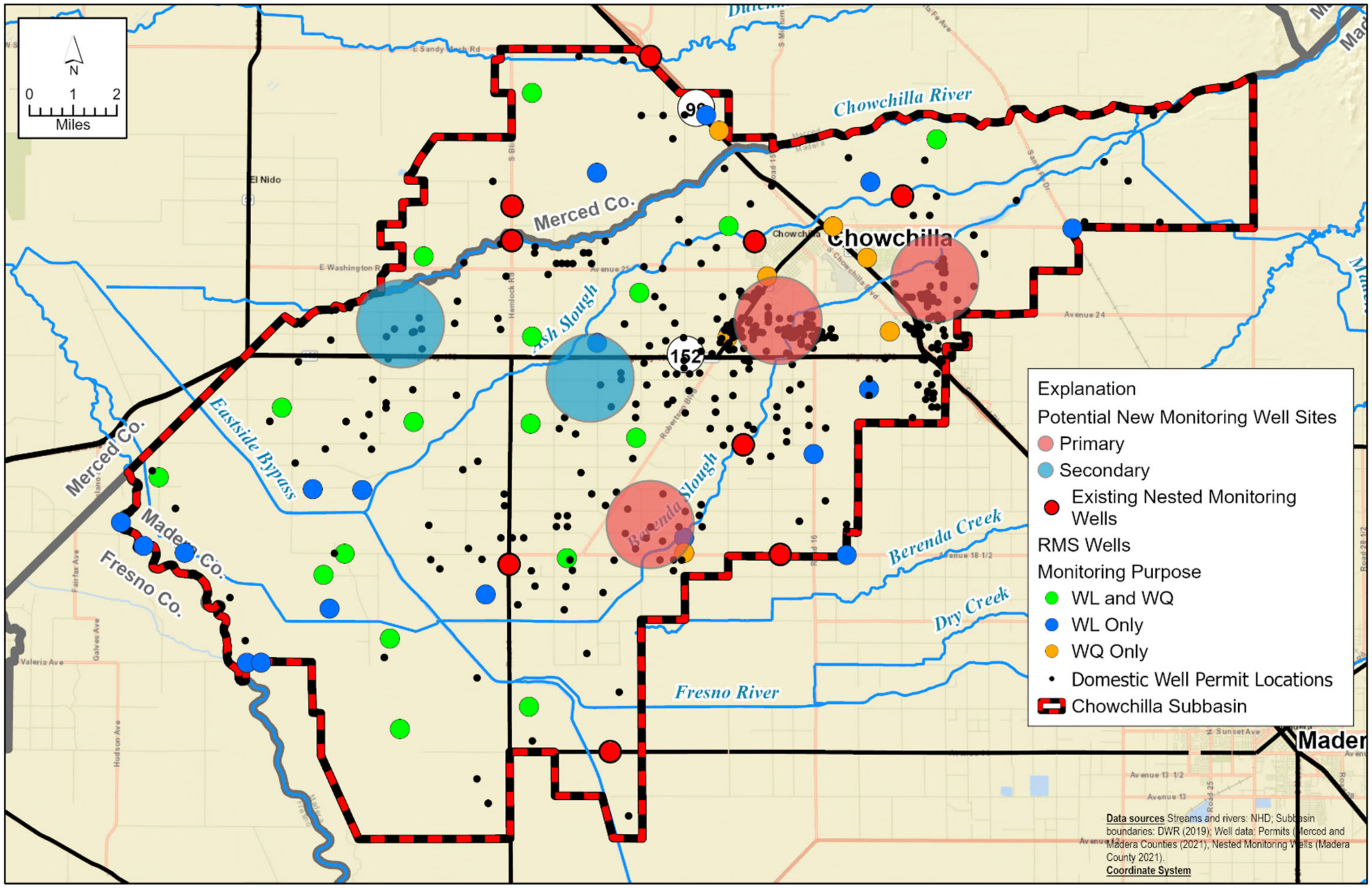


Figure 16: Public Water System and Other Municipal or Community Water System Wells. Based on WCR data.



Data sources Streams and rivers: NHD; Subbasin boundaries: DWR (2019); Well data: Permits (Merced and Madera Counties (2021), Nested Monitoring Wells (Madera County 2021).
Coordinate System

Figure 17: Map of Proposed New Monitoring Well Sites.

ATTACHMENT 1

Domestic Well Replacement Economic Analysis – Chowchilla Update

ERA Economics
Environment • Resources • Agriculture

ERA Economics
1111 Kennedy Place, Suite #4
Davis, CA 95616

Technical Memorandum

Subject: Domestic Well Replacement Economic Analysis – Chowchilla Update
By: ERA Economics
To: LSCE and the Madera County GSA
Date: January 10, 2022

Purpose and Background

In June 2019 ERA provided a technical memorandum (TM) estimating the cost and benefit of more rapid implementation of demand management under the Chowchilla Subbasin GSP. The economic analysis was included as Appendix 3C to the Chowchilla Subbasin GSP. The analysis was prepared with the best available data and information at that time. After finalizing the GSP, the LSCE and DE consultant teams have continued to assist the Chowchilla Subbasin GSAs with GSP implementation and annual GSP reporting. LSCE was engaged by the Madera County GSA to prepare an updated domestic well inventory for the subbasin.

The economic analysis included as Appendix 3C to the Chowchilla Subbasin GSP estimated the total cost of replacing domestic wells potentially impacted by declining groundwater levels under baseline conditions without SGMA and under the draft proposed GSP implementation plan (so-called "with-SGMA" scenario).

This technical memorandum (TM) serves as an update to those estimates by: (i) updating the project and demand management schedule to reflect the adopted allocation in the Chowchilla Subbasin, (ii) incorporating updated data and analysis on potentially impacted wells from the domestic well inventory, (iii) updating all costs and benefits to current dollars (e.g., well replacement costs), and (iv) refining the economic analysis to compare the cost and benefit of accelerating demand management specified in the GSP. That is, the 2019 analysis compared the draft GSP implementation to baseline conditions without SGMA, whereas this analysis compares the proposed plan with phased implementation of projects and management actions (PMAs) to an accelerated, immediate implementation of PMAs, notably with immediate full demand management to avoid further domestic well impacts.[1]

These updates to the data affect the resulting economic analysis and results. The 2019 estimate of domestic wells needing to be replaced without increased demand management was 40 wells, which at that time was doubled to account for potential under-reporting. In addition, a sensitivity calculation as

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[1] Whereas the cost of immediate demand management implementation has been included, the effect on cost of accelerating recharge and supply projects has not yet been estimated. A full cost estimate of projects for all GSAs in the subbasin is still under development. If this additional cost were included, it would strengthen the conclusion of this analysis.

part of the earlier analysis verified that the conclusions would have held even if the number of affected wells were substantially larger. The updated domestic well inventory puts the number of domestic wells potentially needing replacement at 176 over the 20-year GSP implementation period. This TM briefly summarizes the updated analysis, results, and summary conclusions.

Summary Conclusions

Results of this updated analysis comparing the cost of accelerated PMA implementation to the benefit of avoided domestic well replacement costs support the general conclusion of the 2019 analysis. The loss in agricultural value from more rapid demand management still greatly exceeds domestic well replacement costs even though the estimated number of potentially dewatered domestic wells has increased and the cost of replacement for each domestic well has increased by 20 percent. That is, the results of the economic analysis show that the additional cost of more rapid demand management is substantially greater than the cost of replacing potentially dewatered domestic wells and paying higher pumping costs due to lower water levels. This supports the phased implementation schedule and domestic well mitigation program defined in the GSP.

Updated Assumptions

Assumptions and results below are summarized for each of the cost categories considered. All costs (or savings) are expressed as constant 2021 dollars converted to present value using a 3.5 percent real (inflation-free) discount rate[2]. The two implementation scenarios compared are referred to as *GSP implementation* (the phased implementation as described in the GSP) scenario and the *immediate demand reduction* (full demand reduction to eliminate overdraft from 2021 onward) scenario.

1. **Number of dewatered wells needing replacement**. Revised estimates of dewatered wells are calculated and described in the Technical Memorandum prepared by LSCE for the Chowchilla Subbasin Domestic Well Inventory. For this analysis, a total of 176 wells were estimated to be dewatered, spread across four 5-year periods. The cost analysis further assumed that well impacts would be evenly divided by year within each 5-year period[3]. For the comparison scenario with immediate demand reduction, it was assumed that none of those wells would need replacement.
2. **Costs to replace dewatered domestic wells**. The 2019 estimate of an average $25,000 per replaced domestic well is updated to $30,000 per domestic well.
3. **Groundwater pumping depth to water (DTW).** The average DTW for the GSP implementation scenario was provided from groundwater model projections described in the Chowchilla Subbasin GSP. The immediate demand reduction scenario is intended to represent immediate elimination of average annual overdraft. A time series was created that followed the

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[2] The current federal discount rate for water projects is 2.25%, but a real rate of 3.5% better reflects borrowing conditions in Madera County. A 1.5% increase or decrease in the real discount rate does not affect the conclusions of the analysis.

[3] The timing of the well replacement within each 5-year period does not affect the conclusions of this analysis.

general hydrologic variation estimated for the GSP implementation scenario but held the DTW the same on average during the 2021-2040 implementation period. The ending (2040) difference in DTW between the two scenarios was then carried forward beyond 2040. These pumping depth differences are the basis for the estimated annual pumping cost savings.

4. **Changes in variable costs to pump groundwater, for both domestic and agricultural users.** Energy prices, estimated using a mix of PG&E's latest electricity rates for agricultural pumping, have increased substantially. The analysis now uses an average of PG&E's 2021 AG-B and AG-C peak and off-peak summer rates, resulting in an estimate of $0.40 per acre-foot per foot of lift for the variable cost to pump groundwater. As a result, more rapid demand management provides greater savings (avoided pumping lift) for domestic and agricultural pumping. All agricultural and domestic groundwater pumping in the basin would receive this avoided lift benefit from faster demand reduction.
5. **Costs of demand management under GSP implementation**. Costs of demand reduction have been revised based on the latest estimates of the net return to agricultural water use developed for planning the SALC program. In addition, pumping volumes have been updated to reflect current conditions and the planned ramp-down adopted in the Madera County GSA groundwater allocation ordinance (applicable to the GSP implementation scenario only). These values do not represent average returns to all lands and crops in the subbasin but rather the lands and crops more likely to participate in a demand reduction program. For purposes of this analysis, the lost net return from demand reduction is valued at $200 per acre-foot[4].

Results

The following discussion compares costs between the GSP implementation scenario and the (alternative) immediate demand management scenario. General observations are:

- Demand management costs are greater in the immediate implementation scenario because demand management would be implemented sooner (immediately) and for more years during the GSP implementation period. Recharge and supply projects' costs have not been included in this analysis, but their present value costs would also increase because they would be implemented sooner.
- Pumping costs are lower in the immediate demand reduction scenario because, by definition, the average annual overdraft is eliminated immediately. The effect (smaller DTW and lower pumping cost) is carried throughout the remaining years of GSP implementation and in perpetuity.

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[4] The value of water depends on future crop market conditions. Note that a higher value (greater than $200 per acre-foot applied in this TM) would further increase the cost of accelerated demand management relative to avoided well replacement and additional pumping costs.

- Well replacement costs occur in the GSP implementation scenario but are not required in the immediate demand reduction scenario.
- The net effect of these differences in costs results in the GSP implementation scenario having a substantial cost advantage (by about $36 million in present value, or 16 percent) over the immediate demand reduction scenario. In other words, the Chowchilla Subbasin is better off (i.e., realizes benefits that exceed costs) implementing its phased GSP implementation plan and developing/funding the domestic well mitigation program to replace impacted wells than it is if it were to implement immediate demand reduction to avoid dewatering any domestic wells.

Table 1 summarizes the results of the economic analysis. All values are expressed in present value terms. The first two rows show the number of and cost to replace wells estimated to go dry in each scenario. The next rows present the pumping cost savings of the immediate demand reduction scenario relative to the GSP implementation scenario, broken down by domestic pumping and agricultural pumping. The next row shows the demand management costs. For the GSP implementation scenario, demand management is phased in at two percent per year initially, increasing to 6 percent per year until full demand management is reached by 2040. In contrast, the immediate demand reduction scenario implements the full demand management required in 2020, resulting in substantially higher demand management costs.

Table 1. Costs of GSP Implementation Scenario Compared to Costs of Immediate Demand Reduction Scenario - Summary Results for Chowchilla Subbasin, Present Value ($ in Millions)

	GSP Implementation with Well Replacement	**Immediate Demand Reduction**	**Difference**
Domestic Well Replacement			
Number	176	0	176
Cost, PV	$4.60	$0.0	$4.60
Pumping Cost (Savings), PV			
Domestic	NA	-$2.87	$2.87
Agricultural	NA	-$79.58	$79.58
Demand Mgmt. Cost, PV	$219.43	$342.37	-$122.94
Total Cost, PV*	$224.03	$259.91	-$35.88

* Totals may not add exactly due to rounding.

Discussion

Results indicate that the cost of implementing demand management on a faster trajectory (in this case, in year one of the implementation period) would not be cost effective from a subbasin-wide perspective. The avoided costs (fewer domestic wells requiring replacement) would be small ($4.6 million) relative to the additional lost agricultural net return[5] from immediate implementation ($122.9 million) for the Chowchilla Subbasin, even after accounting for pumping cost savings ($82.5 million). The general conclusions are robust to the assumptions used. That is, results are not sensitive to reasonable ranges in key assumptions, including the loss in net return per acre-foot of demand management, the total level of demand management, when demand management begins to scale in, or the cost of replacing a domestic well.

This analysis only compares the cost of well replacement to net costs of immediate demand management implementation; it has not considered the timing of other projects such as new surface water supplies or groundwater recharge. That comparison is not possible with current information, and the GSP implementation schedule already reflects an aggressive timeline for project implementation. The cost (in present value) of accelerating implementation of projects has also not been included here.The additional cost of accelerating a recharge project by, say five years, would be the increased present value of the project's capital and O&M cost stream. Costs of new supply and recharge projects have not been accelerated, so the present value of costs for immediate implementation is underestimated. Simply stated, including these additional costs would further support the conclusions of the analysis.

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[5] Note that demand management would result in additional economic impacts to other county businesses and industries. These additional indirect impacts are not considered in this updated analysis but would only further support its conclusions.

ATTACHMENT 2

Chowchilla Subbasin – Evaluation of DWR Household Water Supply Shortage Reports and Self-Help Enterprises Tank Water Participants

Luhdorff & Scalmanini
Consulting Engineers

Technical Memorandum

DATE: February 8, 2022 PROJECT: 20-1-047

TO: File – Chowchilla Subbasin Domestic Well Inventory

FROM: Pete Leffler, Nick Watterson, Aaron King

SUBJECT: **Chowchilla Subbasin - Evaluation of DWR Household Water Supply Shortage Reports and Self-Help Enterprises Tank Water Participants**

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1. INTRODUCTION

To support efforts related to implementing the Chowchilla Subbasin Groundwater Sustainability Plan (GSP), the Subbasin completed a Domestic Well Inventory project that identified potential domestic wells in the Subbasin and analyzed potential impacts to domestic wells caused by lowering of groundwater levels historically and during the 20-year GSP implementation period starting in 2020. The Domestic Well Inventory for the Chowchilla Subbasin compiled information on domestic wells in the Subbasin from Well Completion Reports and County well permit datasets and compared these data to modeled groundwater levels in the Subbasin from the GSP over the period from 2014 through 2040. During development of the GSP, historical and future groundwater levels throughout the Subbasin were modeled based on historical conditions and projected future conditions. This memorandum summarizes a review of records in the Department of Water Resources (DWR) Household Water Supply Shortage Reporting System and also participants in the Self-Help Enterprises (SHE) Tank Water program, and includes a comparison of these two datasets with the results from analyses of domestic well impacts conducted as part of the Chowchilla Subbasin Domestic Well Inventory.

2. DWR HOUSEHOLD WATER SUPPLY SHORTAGE REPORTING SYSTEM

Overview of the Household Water Supply Shortage Reporting System

The DWR Household Water Supply Shortage Reporting System (https://mydrywell.water.ca.gov/report/) is a site for reporting of problems with private (self-managed, not served by public water system) household water supplies. The site was initially created in 2014 as part of drought emergency response efforts and continues to be used to collect information on household water supply shortages from private well or surface water sources. The data in the reporting system reflect information on water supply shortage issues voluntarily submitted by private, local, state, federal, and non-governmental individuals and organizations. Because the data do not undergo review or quality control by DWR, the reported information is not suggested to be complete in its accounting for all water supply shortages and it is also noted by DWR that there may be errors and omissions in data, duplicate entries, and records for non-household related water supply issues. Furthermore, during review of the data, many incomplete and inconsistent records were noted, with many reports providing very little detail for use in understanding the cause of the issue reported. There are a variety of potential causes for issues related to the quantity or quality of water produced by a well, and this can include issues related to the well pump, water distribution system, or the well structure, without relationship to groundwater conditions in the aquifer.

The submission of information to the Household Water Supply Shortage Reporting System is done through completion of a report submittal form (https://mydrywell.water.ca.gov/report/public/form), which includes questions related to the issue, including required entries on the following:

- Type of shortage: a) Dry well, b) low streamflow, or c) other
- Description of the water issue: a) well is dry (no longer producing water), b) reduction in water pressure/lower flows, c) well pumping sand/muddy water, d) well is catching air (have to wait to be able to pump, e) reduction in water quality, or f) other
- Primary use of the well or creek: a) household, b) agriculture/irrigation, c) combination of household/agriculture, or d) other
- Approximate date problem started
- County

As of January 2022, the reporting system included 3,769 entries across the state of California, with dates when the problem started spanning the period from 2012 through 2021.

Household Water Supply Shortage Records within Chowchilla Subbasin

The Household Water Supply Shortage Reporting System contains a total of 46 reports with locations in the Chowchilla Subbasin. The reports within the Subbasin were grouped into two categories according to the type of water supply issue indicated: 1) dry wells, and 2) reduced flow or impaired water quality. **Figure 1** presents the number of reported well-related issues by year within the Chowchilla Subbasin. Of the 46 reports within Chowchilla Subbasin, 41 were categorized as a dry well issue and six were categorized as reduced flow or impaired water quality issues. As illustrated on **Figure 1**, most water supply issues in the system were reported to have started in 2014, 2015, and 2021, with relatively fewer during other years. The greatest number of reports occurred during 2015 after multiple years of drought conditions in the area. **Figure 2** shows the locations of the water supply issue reports in the system. Most water shortage reports in the Subbasin are located in the central Subbasin.

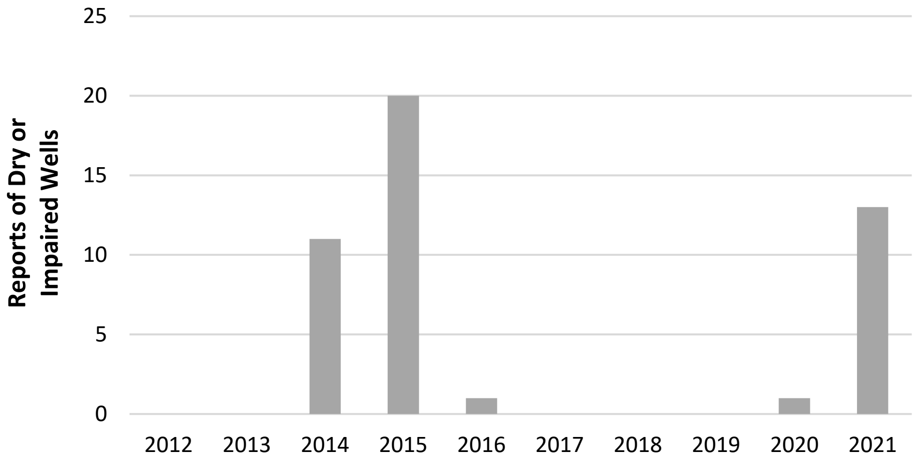
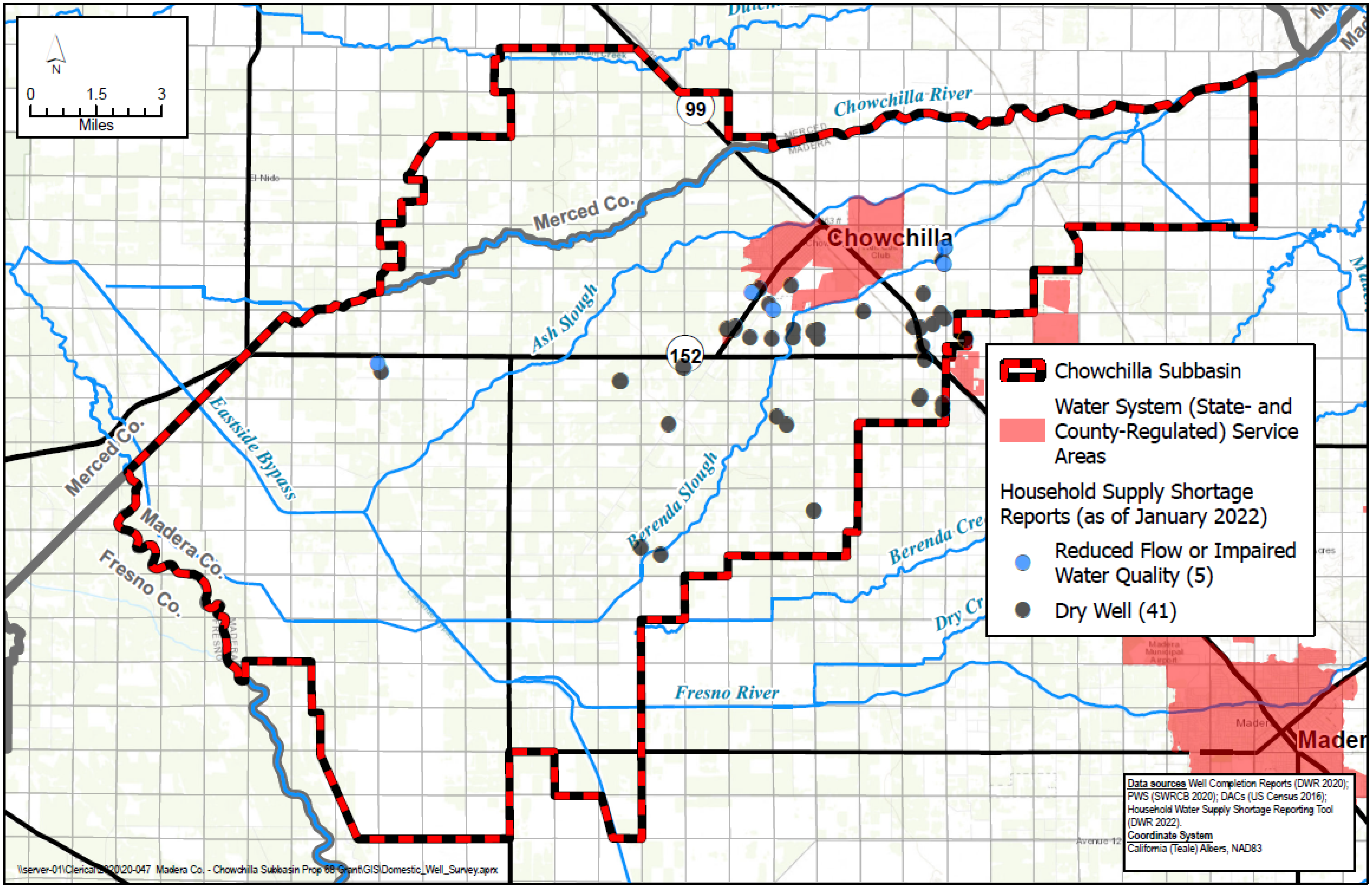


Figure 1. Chart of Household Water Supply Shortage Report Records in Chowchilla Subbasin



Data sources Well Completion Reports (DWR 2020); PWS (SWRCB 2020); DACs (US Census 2016); Household Water Supply Shortage Reporting Tool (DWR 2022).
Coordinate System
California (Teale) Albers, NAD83

Luhdorff & Scalmanini
Consulting Engineers

Figure 2
DWR Household Water Supply Shortage Reporting Data

Chowchilla Subbasin
Groundwater Sustainability Planning

3. SHE TANK WATER PROGRAM PARTICIPANT DATA

Overview of the SHE Tank Water Participant Data

The SHE Tank Water Program provides a temporary water supply solution for households experiencing a well water shortage in eight counties in and adjacent to the San Joaquin Valley: Fresno, Kern, Kings, Madera, Mariposa, Merced, Stanislaus, and Tulare. The SHE Water Tank Program assists households experiencing well water shortages by installing a water tank and hauling water and filling the tank to restore access to water for the home. The SHE Tank Water Program is intended as a short-term solution to provide participants access to water for one year while working towards a long-term solution. Data on participants in the SHE Water Tank Program as of January 2022 were provided by SHE (https://www.arcgis.com/home/webmap/viewer.html?webmap=377849cbc9c54046917d864a635e9674&extent=-120.0525,34.8083,-117.2593,36.0392). As of January 2022, the SHE Tank Water Program includes 769 participants in the eight-county area served by the program. The available Tank Water Program participant data only provide locations for participants without other attributes indicating the date or type of issue necessitating the reliance on tank water. There are a variety of potential causes for issues related to the quantity or quality of water produced by a well, and this can include issues related to the well pump, water distribution system, or the well structure, without relationship to groundwater conditions in the aquifer.

SHE Tank Water Participants within Chowchilla Subbasin

The Tank Water Program covers eight counties within the San Joaquin Valley, along with some areas located outside of the San Joaquin Valley and outside of DWR-designated groundwater basins (e.g., foothills areas). The SHE Tank Water Program includes 22 participants within the Chowchilla Subbasin. **Figure 3** presents a map of the Tank Water Program participants within the Chowchilla Subbasin. As illustrated on **Figure 3**, most of the Tank Water Program participants in the Chowchilla Subbasin are located in the area south of the City of Chowchilla. **Figure 4** is a map comparing the locations of SHE Tank Water participants and dry wells in the DWR Household Water Supply Shortage dataset. The spatial distribution of Tank Water participants and dry wells reported in the DWR dataset are very similar and likely include some of the same wells, although no information is available to evaluate such direct relationships in the two datasets.

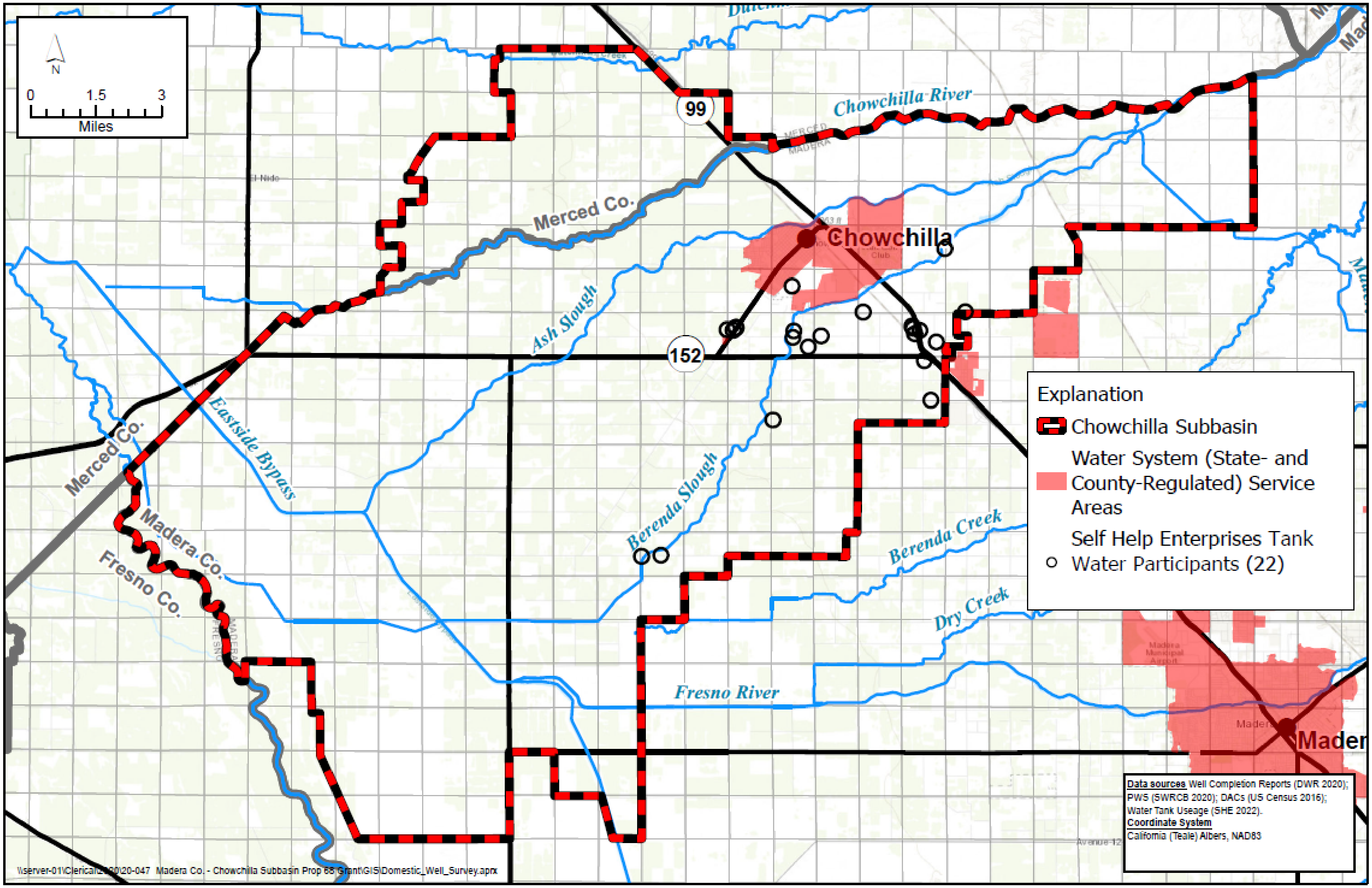


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Figure 3
Locations of Self Help Enterprises Tank Water Participants
Chowchilla Subbasin Groundwater Sustainability Planning

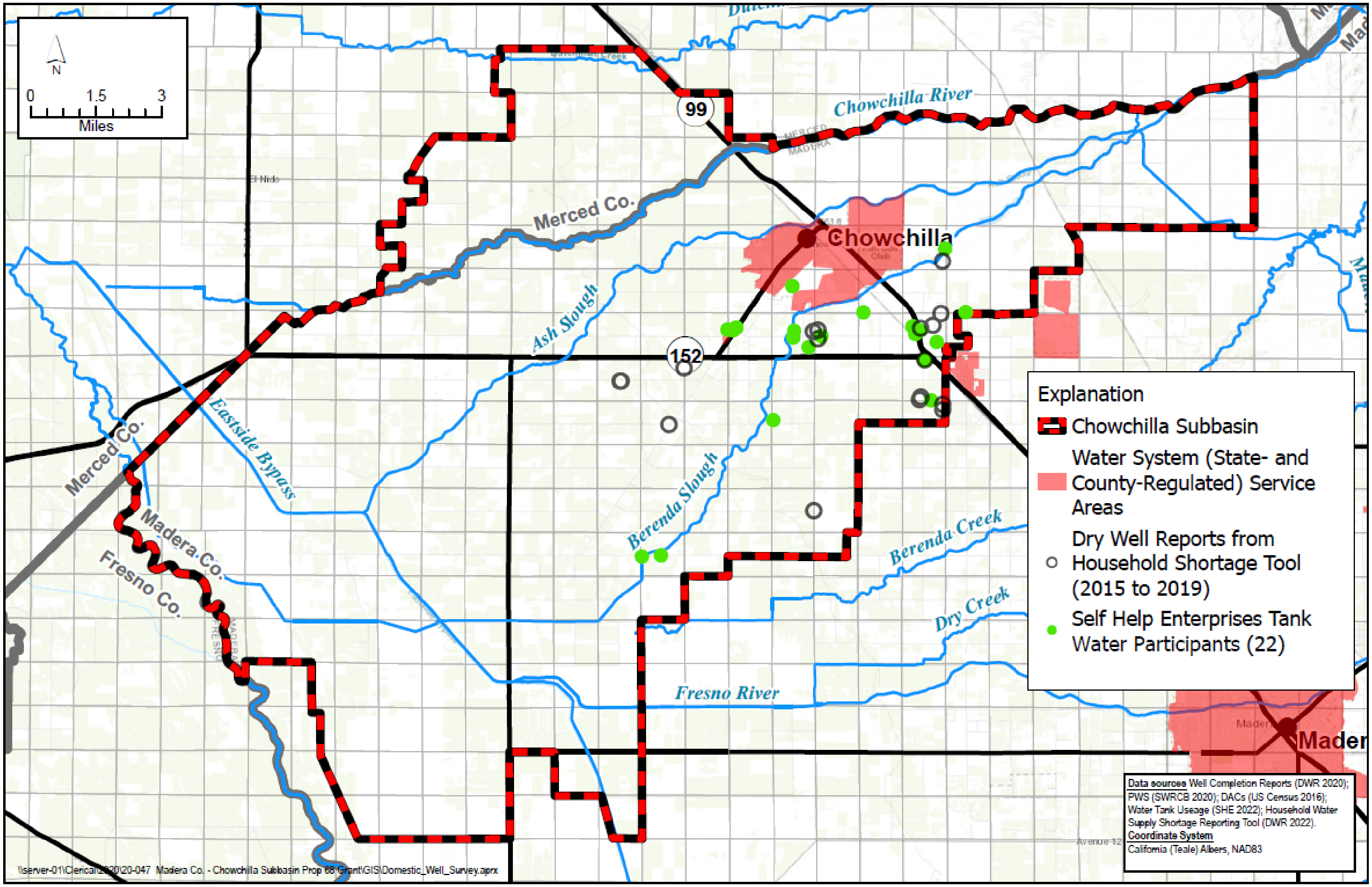

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Figure 4
Comparison of SHE Tank Water Participants and DWR Dry Well Reports
Chowchilla Subbasin
Groundwater Sustainability Planning

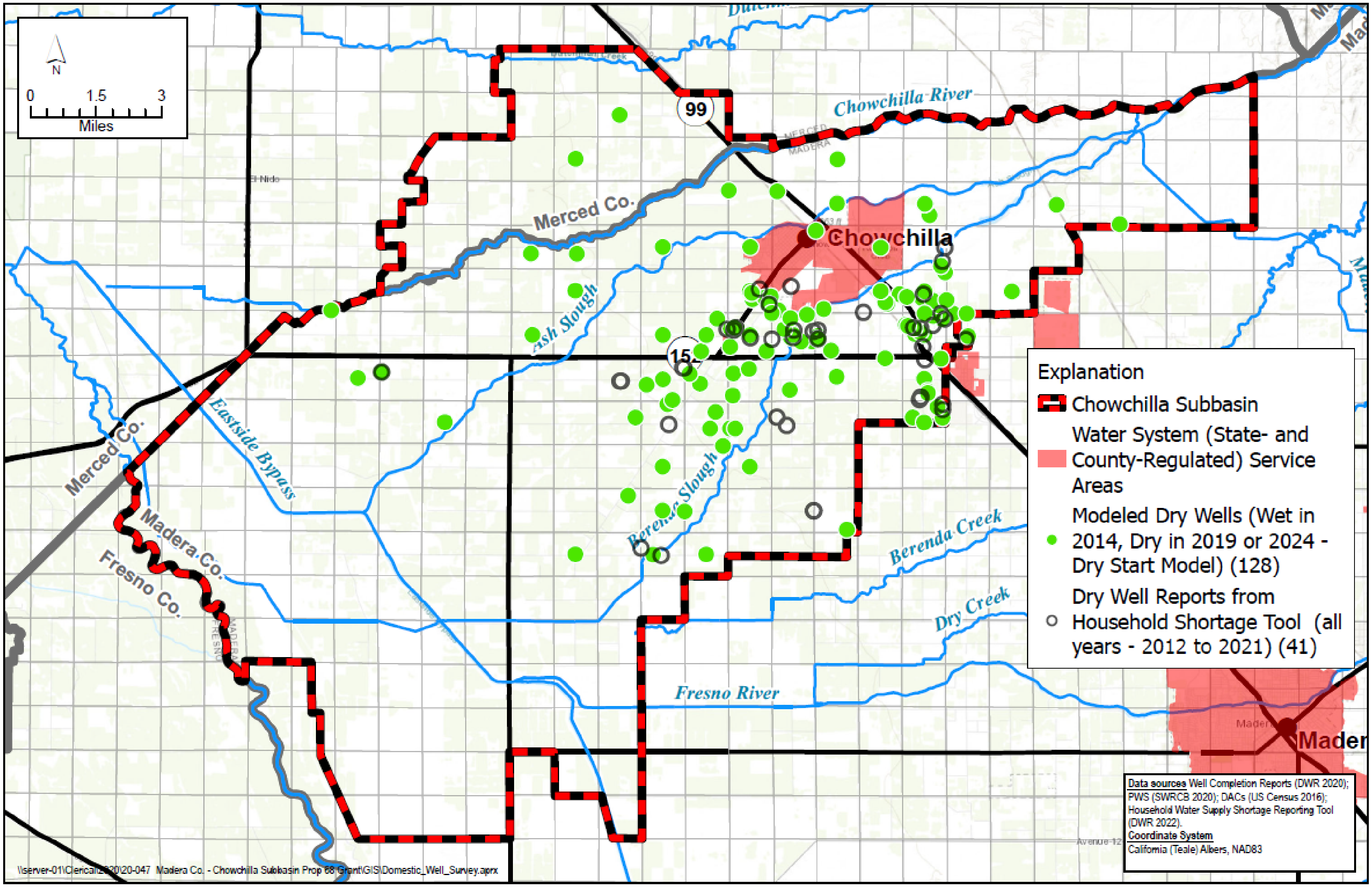
4. COMPARISONS OF DWR DRY WELL RECORDS AND SHE TANK PARTICIPANTS WITH ANALYSES OF DRY WELLS FROM THE DOMESTIC WELL INVENTORY

Analyses of potential domestic well impacts in the Domestic Well Inventory were conducted at five-year intervals based on modeled groundwater levels across the Subbasin. To understand differences between dry wells reported to the Household Water Supply Shortage Reporting System and also SHE Tank Water Program participants in relation to estimates of potential dry wells from the Chowchilla Subbasin Domestic Well Inventory analyses, the spatial distribution of dry wells in the Household Water Supply Shortage Reporting System dataset and Tank Water Participants were compared with modeled dry wells over the period from 2015 through 2024.

The comparisons presented in this TM are intended to provide a general sense for the spatial distribution of the different datasets, recognizing the datasets present different types of information related to domestic well issues. As noted above, there are a variety of potential causes for a well experiencing issues related to the quantity of water produced by a well that may be unrelated to groundwater conditions in the aquifer. Some of these issues may be reflected in the DWR Water Supply Shortage Reports and SHE Tank Water Program participants list. It is also likely that many households with wells that have gone dry have not reported such occurrences to the DWR Household Water Supply Shortage Reporting System and many of these households have also not participated in the SHE Tank Water Program. As described in the technical memorandum summarizing the Chowchilla Subbasin Domestic Well Inventory, analyses of potential dry domestic wells in the Domestic Well Inventory are based only on the relationship between available well construction (e.g., screen depth and total well depth) and simulated groundwater levels at each domestic well location.

Comparison of DWR Dry Well Records with Modeled Dry Wells in the Domestic Well Inventory

Maps comparing dry well records in DWR's Household Water Supply Reporting System with dry wells modeled as part of the Domestic Well Inventory are presented in **Figures 5 and 6**. **Figure 5** presents a comparison of all reported dry wells in DWR's system (2012 through 2021) with modeled dry wells estimated for the period 2015 through 2024 in the Domestic Well Inventory. **Figure 6** presents a comparison of reported dry wells during the years 2015 through 2019 in DWR's system with modeled dry wells between 2015 and 2019 in the Domestic Well Inventory. **Figure 6** provides a more direct spatial comparison of dry wells in the two datasets over the same five-year period, whereas **Figure 5** presents an overview of the spatial relationship between the two datasets spanning a longer timeframe. Although there are considerably more modeled dry wells than reports of dry wells in DWR's system in either comparison, the spatial patterns in the two datasets show many similarities, with most modeled dry wells and reports of dry wells occurring in areas south and southwest of the City of Chowchilla. Some of the differences in locations between the modeled dry wells and reported dry wells in **Figures 5 and 6** are likely a result of differing resolutions of locational information available in the two datasets.



Data sources Well Completion Reports (DWR 2020); PWS (SWRCB 2020); DACs (US Census 2016); Household Water Supply Shortage Reporting Tool (DWR 2022).
Coordinate System
California (Teale) Albers, NAD83

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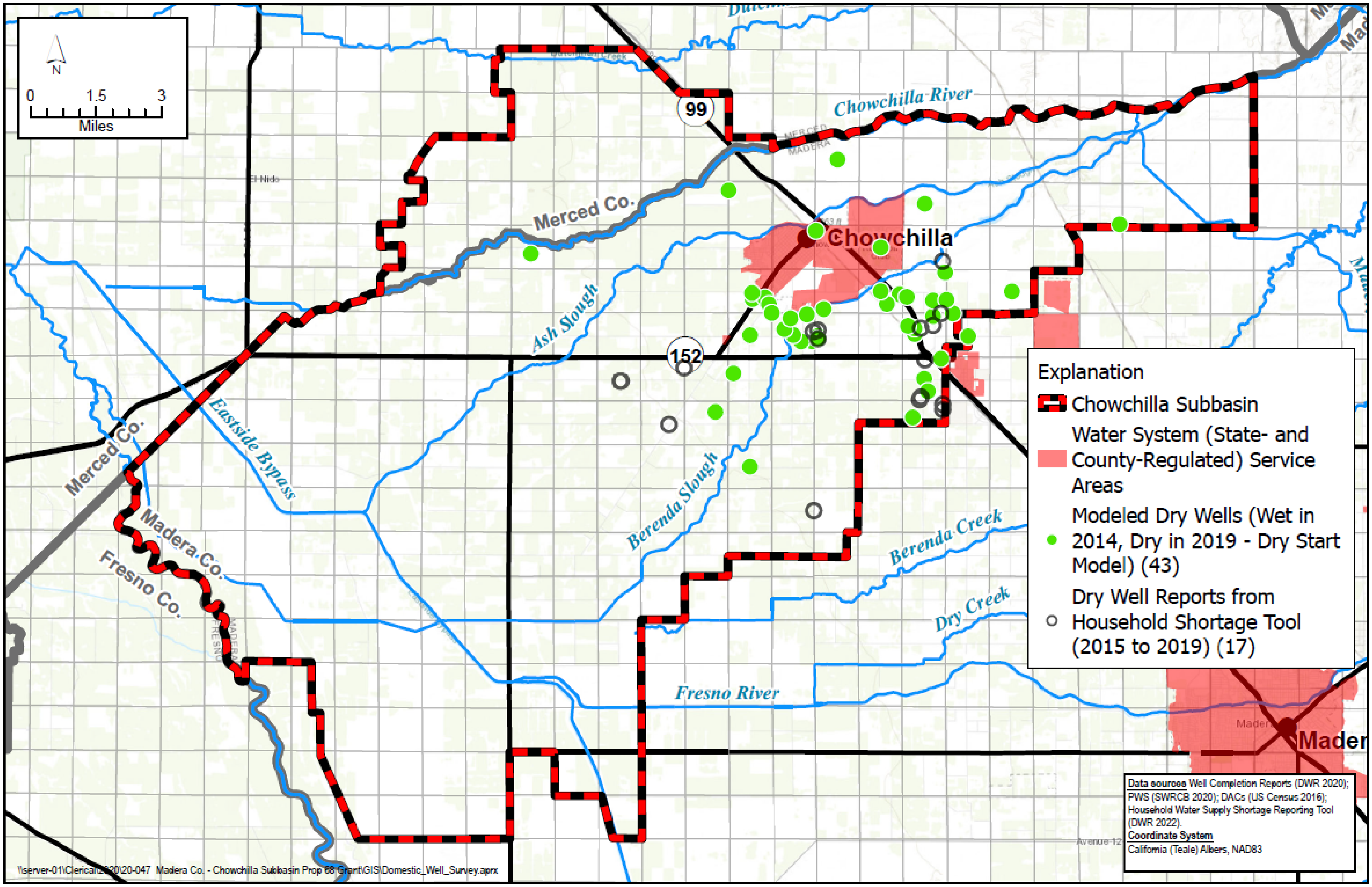
Figure 5
Comparison of DWR Dry Well Reports with Modeled Dry Wells Between 2015 and 2024
Chowchilla Subbasin
Groundwater Sustainability Planning



Data sources Well Completion Reports (DWR 2020); PWS (SWRCB 2020); DACs (US Census 2016); Household Water Supply Shortage Reporting Tool (DWR 2022).
Coordinate System
California (Teale) Albers, NAD83

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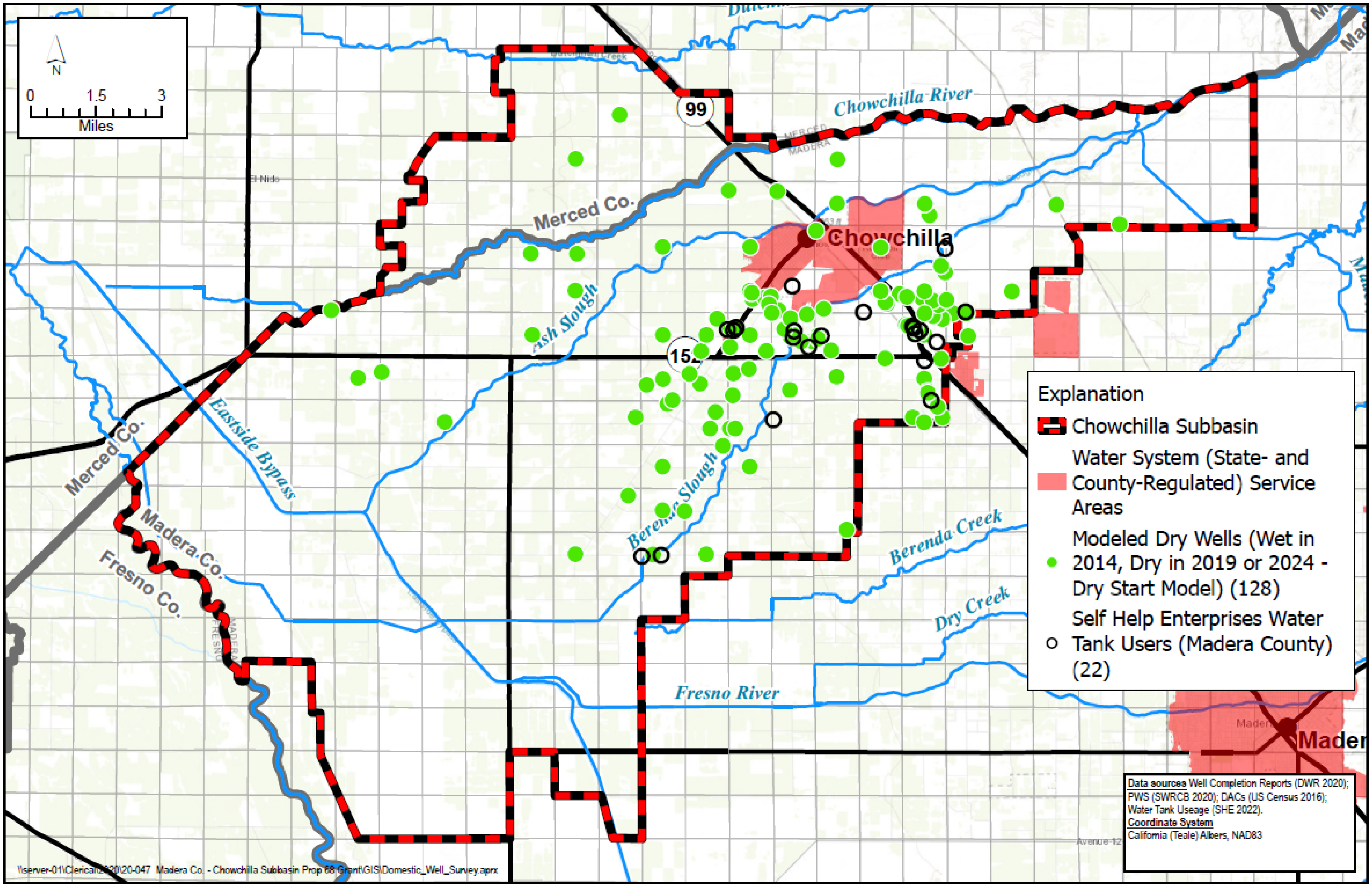
Figure 6
Comparison of DWR Dry Well Reports with Modeled Dry Wells Between 2015 and 2019
Chowchilla Subbasin
Groundwater Sustainability Planning

Comparison of SHE Tank Water Participants with Modeled Dry Wells in the Domestic Well Inventory

A map comparing SHE Tank Well Participants with dry wells modeled as part of the Chowchilla Subbasin Domestic Well Inventory are presented in **Figure 7**. **Figure 7** presents a comparison of all SHE Tank Water Program participants in the Subbasin as of January 2022 with modeled dry wells estimated for the period 2015 through 2024 in the Domestic Well Inventory. Although there are considerably more modeled dry wells than Tank Water Participants (as is the case with dry well reports in DWR’s Household Water Supply Shortage System), the spatial patterns in the two datasets show many similarities with most modeled dry wells and SHE Tank Water Participants occurring in areas south and southwest of the City of Chowchilla.



Explanation

- 🟥 Chowchilla Subbasin
- 🟥 Water System (State- and County-Regulated) Service Areas
- ● Modeled Dry Wells (Wet in 2014, Dry in 2019 or 2024 - Dry Start Model) (128)
- ○ Self Help Enterprises Water Tank Users (Madera County) (22)

Data sources Well Completion Reports (DWR 2020); PWS (SWRCB 2020); DACs (US Census 2016); Water Tank Useage (SHE 2022).

Coordinate System
California (Teale) Albers, NAD83

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Figure 7
Comparison of SHE Tank Water Participants with Modeled Dry Wells Between 2015 and 2024
Chowchilla Subbasin
Groundwater Sustainability Planning