Mojave Basin Area Watermaster

Appendix G

Upper Mojave River Basin Groundwater Model

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February 28, 2024

1.0 Introduction

The Upper Mojave River Basin (UMRB) was originally developed in 2007 (SWS, 2007) for the Mojave Water Agency (MWA) as a predictive tool for the Regional Recharge and recovery (R3) project. The current UMRB model is an expanded and updated version of the 2007 version of the model, which was calibrated from water year 1997 to water year 2005. The original model was more groundwater-focused and had limited surface water features. The model presented in this technical memorandum (TM) extends the spatial boundaries of the original UMRB model to include the upper basin (the watersheds of Deep Creek and West Fork) and is a fully integrated groundwater/surface-water numerical model. The calibration period was also extended and covers water years from 1951 to water year 2020. This model is intended to be used as a management tool to support the groundwater banking program, conjunctive use, the optimization of existing water supply project, and potential future water resources projects. This technical memorandum summarizes the model design, calibration process results, and preliminary scenario runs

2.0 Model Overview

The updated UMRB model domain and active area is shown on Figure 1. The United State Geological Survey (USGS) finite difference code MODFLOW-NWT (Niswonger et al., 2011) was used to design the UMRB model. The model has 6 layers, 900 rows, and 1600 columns. The cell size is 200 feet by 200 feet. The layering is based on the hydraulic behaviour from existing production wells where available and hydrostratigraphic markers otherwise. Hydraulic parameters (hydraulic conductivity and storativity) are distributed by zones based on the USGS model (Stamos et al, 2001). Aquifer production estimate prior to 1995 are derived from the USGS model (Stamos et al, 2001). The surface water model component of the UMRB model is derived from the California Basin Characterization Model (BCM) which will be presented in more details further in this TM. The BCM and the calibration process will be presented below. More details about the model conceptual model and overall design can be found in Wood's report (Wood, 2021).

2.1 Discussion of the BCM

The BCM is a gridded mathematical computer model that calculates the hydrologic inputs and outputs at a monthly time step for the whole State of California. Specific climate data inputs, such as precipitation and air temperature, are combined with soils type and topography data to calculate the water balance for each cell. Model calculations include potential evapotranspiration, calculated from solar radiation with topographic shading and cloudiness; contributions from snow based on simulated accumulation and melting; and excess water moving through the soil profile, which is used to calculate actual evapotranspiration and climatic water deficit. Soil properties and the permeability of underlying alluvial or bedrock materials embedded in the model are used to estimate recharge and runoff (Flint et al, 2013). The BCM was calibrated to 159 unimpaired basins across California. The model grid is 270 m by 270 m (889 ft by 889 ft) and it covers the period from 1896 to 2020. An overview of the various components of the BCM are shown on Figure 2 and Figure 3

Output from the BCM model include: PET (potential ET), AET (Actual ET), runoff, recharge, snowmelt, snow sublimation..etc.

A spreadsheet tool provided by the BCM authors allows the recalibration of the BCM to local gages. The inputs for the spreadsheet tool are runoff and recharge from the BCM, observed gage data, and watershed areas. This tool was used to calibrate the BCM output to local gages prior to incorporating them into the UMRB model using the Surface Flow Routing package of MODFLOW-NWT.

2.2 Model Calibration

Calibration of a groundwater flow model is a process through which the model parameters are varied within reasonable and plausible ranges to produce the best fit between the model results and observation values in the real world. Observation values used for this calibration were the groundwater levels at 193 monitoring locations and the river discharges at three stream gages. The calibration process can be either automated or manual. In the automated approach, a parameter estimation tool is used to run the model multiple times to automatically select the best combination of parameter values for optimal matching between measured and observed targets. In the case of the manual calibration, the modeler changes the parameters manually and uses a combination of visual trend matching and a set of statistical parameter to decide whether calibration was achieved. Because of the large size and long runtime of this model, the automatic approach for calibration was impractical, hence the manual calibration approach was used.

As stated in the previous section, a combination of qualitative and quantitative calibration criteria were used to assess the goodness of fit. For the groundwater levels the calibration process was conducted in general accordance with the "Guidelines for Evaluating Ground-Water Flow Models" (Reilly and Harbaugh, 2004). This includes establishing calibration targets, identifying calibration parameters, using history matching, and using both qualitative and quantitative criteria to evaluate model performance. Criteria used included:

- Hydrographs of observed versus model-simulated groundwater levels
- Scatterplots of observed versus model-simulated groundwater levels
- Hydrographs of observed versus model-simulated streamflow
- Scatterplots of observed versus model-simulated streamflow
- Residual statistics, including:
    - Root Mean Square Error (RMSE): Root mean square error provides a measure of the spread of the residuals. Model calibration seeks to minimize RMSE and generally, a lower RMSE indicates a calibration closer to the observed data. Note: the RMSE is the same as the standard deviation of the residuals.
    - Mean Residual: Average of the residuals. Mean residual can help to identify bias in modelsimulated versus observed water level data. Calibration seeks to minimize mean residual. A value close to zero is ideal but the range of the data should also be considered.
    - Relative Error: Relative error is the standard deviation of the residuals or RMSE normalized by the range of observed groundwater levels. Calibration seeks to minimize relative error. A value lower than 10% (0.1) is generally recommended but not an absolute indicator of goodness of fit.
- R^2: Indicates the "goodness of fit" between measured and model-simulated values. For a perfect calibration, all points (observed along the x-axis and model-simulated along the y-axis) would fall on the diagonal line (regression line) with a R^2 value of 1. A greater deviation of points from the diagonal line corresponds with lower R^2 values and poorer model calibration performance. Streamflow was examined in accordance with the R^2 performance criteria suggested by Donigian (2002).

A more detailed discussion of the calibration process and the range of the parameters can be found in Wood (2021). A few of the updated calibration assessment criteria are shown on Figure 4 to Figure 6. Figure 4 shows the model simulated groundwater heads vs the observed values. The scatter observed is typical for regional groundwater models of this size. However a low value for the residual mean means that the model isn't under or over predicting the groundwater heads and the adjusted root mean square (RMS) is below the 0.1 (10%) recommended upper limit. Also the bulk of the values are within one standard deviation of the residuals (red dashed line) which also suggests a good calibration to the observed data. Figure 5 shows hydrographs of observed and simulated water levels at selected monitoring locations.

Figure 6 shows the annual surface water calibration results (Observed vs simulated) at three gages: Deep Creek, West Fork and the Lower Narrows. With R^2 varying from

3.0 Water Budget

3.1 Water Budget Spatial Discretization

The water budget was extracted from the UMRB model results using the USGS Zonebudget program (). The water budget was restricted to the actual UMRB area excluding the upper basin (Deep Creek and West Fork watersheds). This domain is shown on Figure 7. The water budget was further divided into subareas. The subareas combined with the active model domain for water budget estimation purposes is shown in Figure 8. It should be noted that only a portion of the Transition Zone is covered by the model, hence the area termed "Transition Zone" on Figure 8 is only the southern portion of the legal extent of the Transition Zone. Similarly, the area termed "Este" is actually Fifteen Miles Valley which is the Western portion of the legal extent of the Este Subarea.

3.2 Mountain Front Recharge

A detail discussion of the inflows and outflow in the UMRB area can be found in the model calibration report published by Wood (2021). In the previous model (Wood, 2021) values for the mountain front recharge were extracted from the USGS model (Stamos et al, 2001). For this update effort, the Mountain Front recharge for Alto, Oeste, and Este (Fifteen Mile Valley) were derived from the BCM, hence the need to discuss the mountain front recharge in this technical memorandum (TM). By definition, Mountain Front recharge (MFR) is all water that enters a basin-fill aquifer with its source in the mountain block. It is composed of two components. Surface MFR is infiltration through the basin fill of mountain-sourced perennial and ephemeral stream water after these streams exit the mountain block. Subsurface MFR is groundwater inflow to a lowland aquifer from an adjacent mountain block (Markovich et al, 2019). For the purpose of this study, It is assumed that recharge and ungagged inflow mainly from the San Bernardino mountains become mountain front recharge on the valley floor. Direct infiltration from precipitation on the valley floor is assumed negligible. The sub-watersheds used for the BCM gridded results tabulation for recharge and runoff are shown on Figure 9. Subwatershed that drain directly into the Mojave river were not included into the mountain front recharge estimate and are shown on Figure 10 in light green. These sub-watersheds shown in light green on Figure 10 are considered tributary to the Mojave River.

3.3 Water Budget and Change in Storage

The water budget for the subareas within the active model doimain are presented in Table 1, Table 2, and Table 3. The change in storage and the cumulative change of storage from water year 1951 to water year 2020 for the Alto subarea is shown on Figure 11. Overall Alto experienced an average change in storage of 15,000 Acre-feet per year (AFY) for the past seventy (70) years. And 17,500 AFY for the past 20 years. The cumulative change of storage shows a continuous decline in storage for the past 70 years.

4.0 Scenario Run

The calibrated and updated UMRB model was used to run a 20-year future scenario. The main objective of this scenario was to assess the impact of importing enough water to off-set the average yearly storage deficit of 17,500 AF. Due to the uncertainty of future hydrology and demand conditions, some assumptions need to be made in order to define future conditions. The assumptions used for these scenarios are listed below:

1. Water year 2020 is used as the current and initial year
2. The hydrology for the last 20 years was used and assumed representative for the next 20 years
3. The production and demand levels for the year 2020 was used for the 20 year-run and maintain constant throughout the 20 years of scenario run
4. The 17,500 AF imported was delivered at the Deep Creek (directly into the river) site and spread over a three month period from June to August
5. A baseline scenario with the same assumptions as above was run without the imported water for comparison purposes.

4.1 Scenario Results

The main focus will be to quantify the change in flow at the lower narrows gage when enough water is imported and delivered at the Deep Creek Site to offset the long term average loss in storage. Table 4 summarizes the difference between the baseline and Scenario 1. Due to the long term storage loss, it takes about four years of continuopus water delivery to see any impact at the lower narrows (Figure 13). On average an increase of 9,800 AFY is observed at the lower narrows over 20 years as a results of importing a total of 380,000 AF. This would increase water availability downstream of the Lower Narrows (i.e. Centro and potentially Baja)

5.0 Conclusion

The current updated and calibrated UMRB model will be used for safe yield estimate and management decision in the near future. Calibrated groundwater models are powerful and flexible tools for water resources management, projects impact assessment and various conceptual analyses. Though only one scenario was assessed in this report and limited output were analyzed, various options can be explored. They include delivery location and temporal distribution, amount delivered, future demand projections, various climate change scenarios…etc. Also the spatial impact of these projects on water levels can also be explored by looking at water level changes at specific times or water level changes over time at specific locations. As more data are being collected, it is anticipated that the model will be updated every five years or so with newly collected data to keep it current and improve future predictions.

6.0 References

Harbaugh, A.W., 1990, A computer program for calculating subregional water budgets using results from the U.S. Geological Survey modular three-dimensional ground-water flow model: U.S. Geological Survey Open-File Report 90-392, 46 p

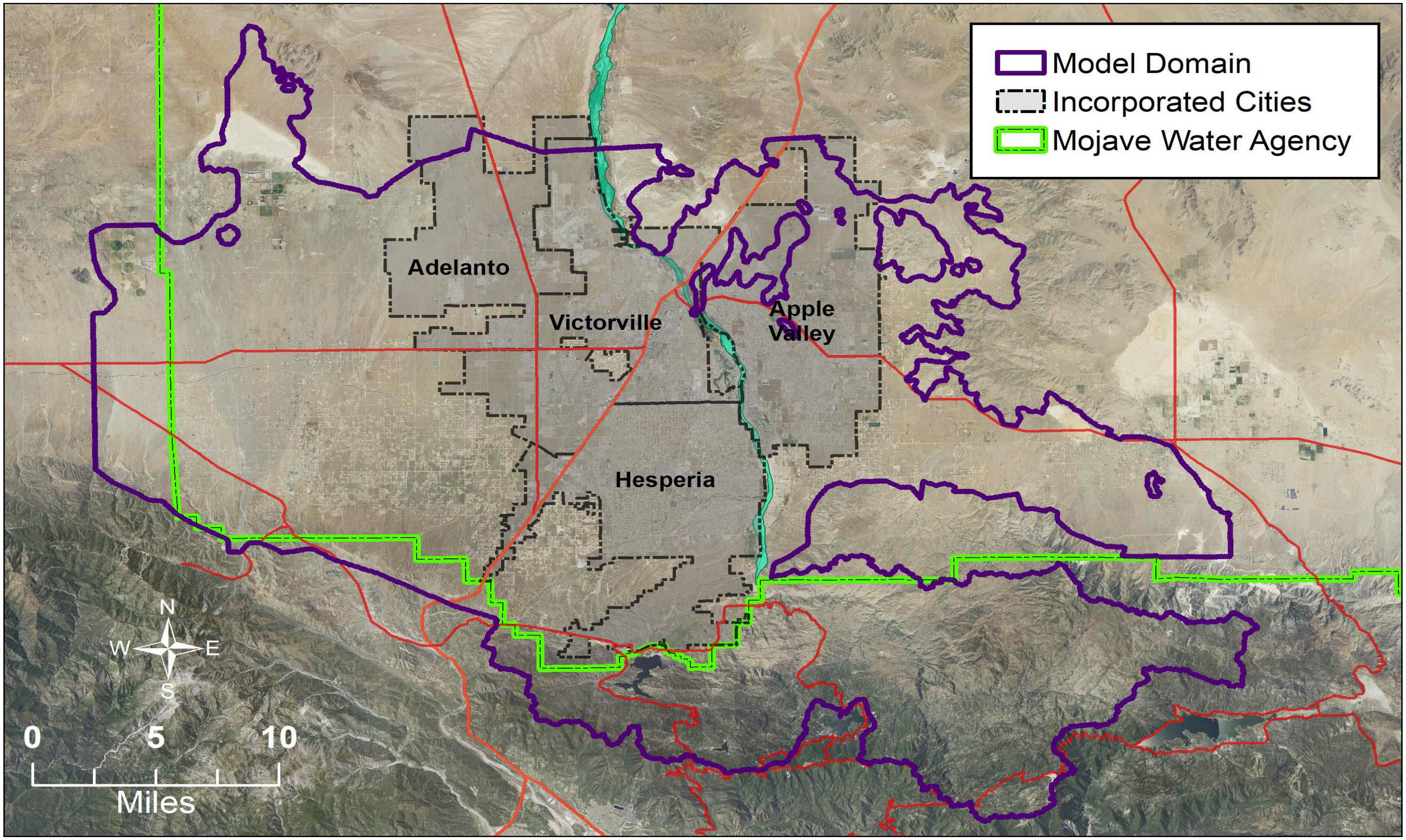
Markovich, K. H., Manning A. H., Condon L. E., and McIntosh J. C. 2019. Mountain-Block Recharge: A Review of Current Understanding, Water Resour. Res., 55(11), 8278-8304.

Niswonger, R.G., S. Panday, and M. Ibaraki, 2011. MODFLOW-NWT, a Newton Formulation of MODFLOW 2005: U.S. Geological Survey Techniques and Methods 6-A37

Stamos, C.L., P. Martin, T. Nishikawa, and B. F. Cox. 2001. Simulation of Groundwater Flow in the Mojave River Basin, California. U. S. Geological Survey Water-Resources Investigations Report 01-4002, Version 1.1. 129 p

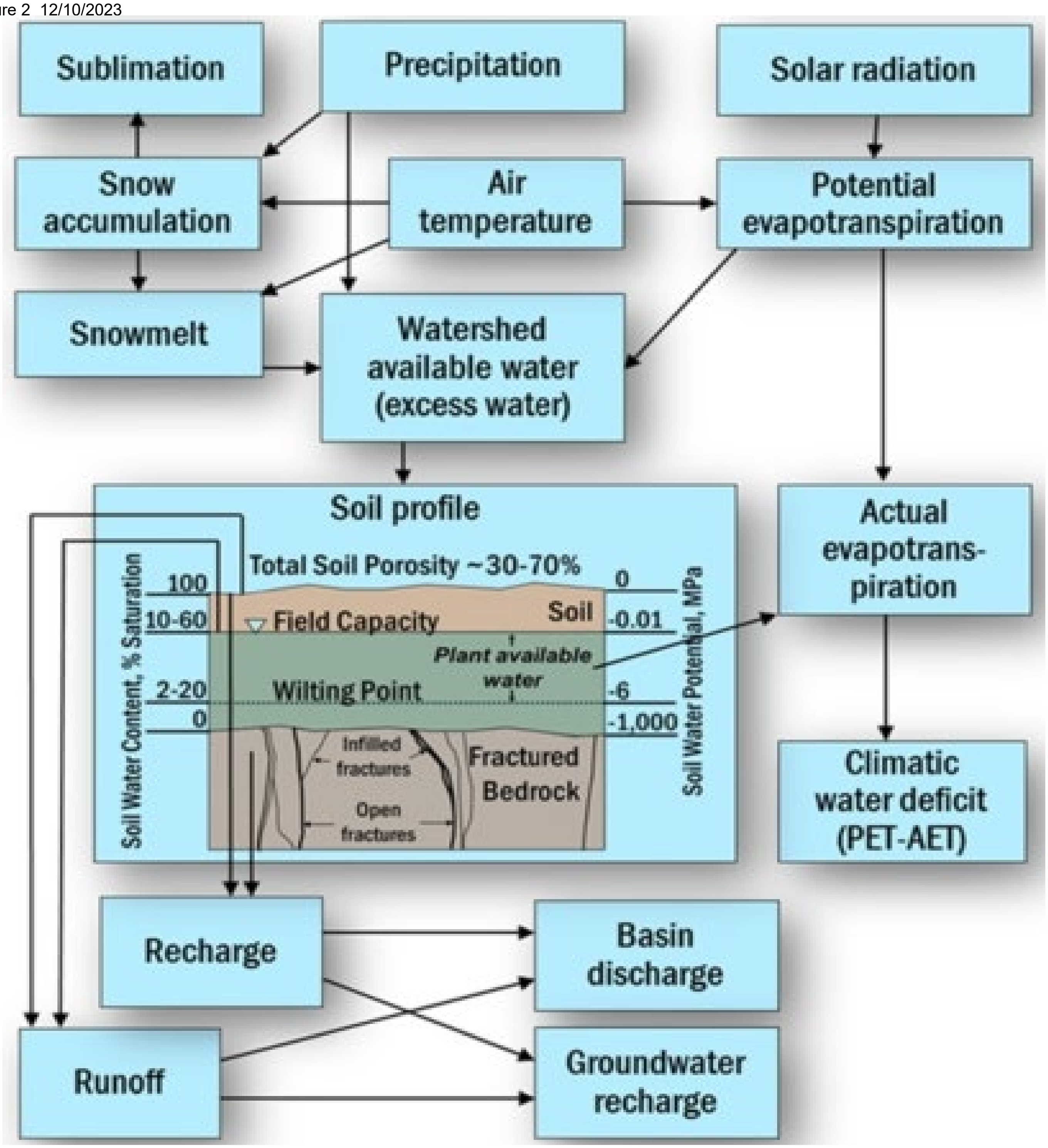
SWS (Schlumberger Water Services), Bookman-Edmonston, and Richard C. Slade and Associates, 2007c. Technical Memorandum #4: Transient Model Development – DRAFT. Upper Mojave River Basin Groundwater Modeling Project. Prepared for Mojave Water Agency, dated September.

Wood, 2021. Project Completion report, Integrated Surface Water/Groundwater Model, Upper Mojave River Basin Prepared for Mojave Water Agency, dated October 2021.



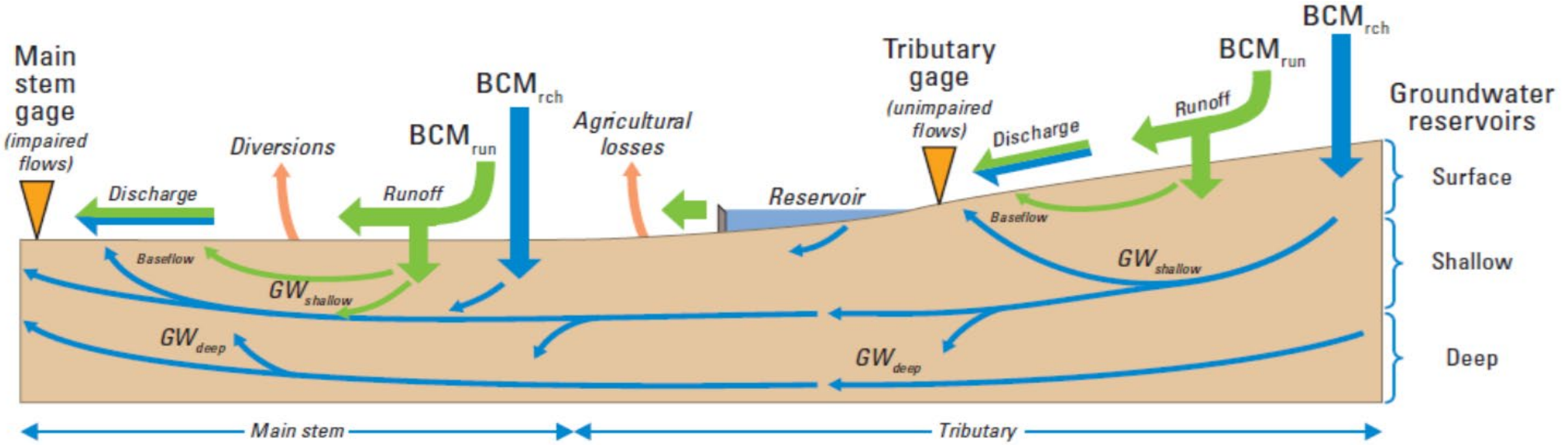
Model Location

By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 1



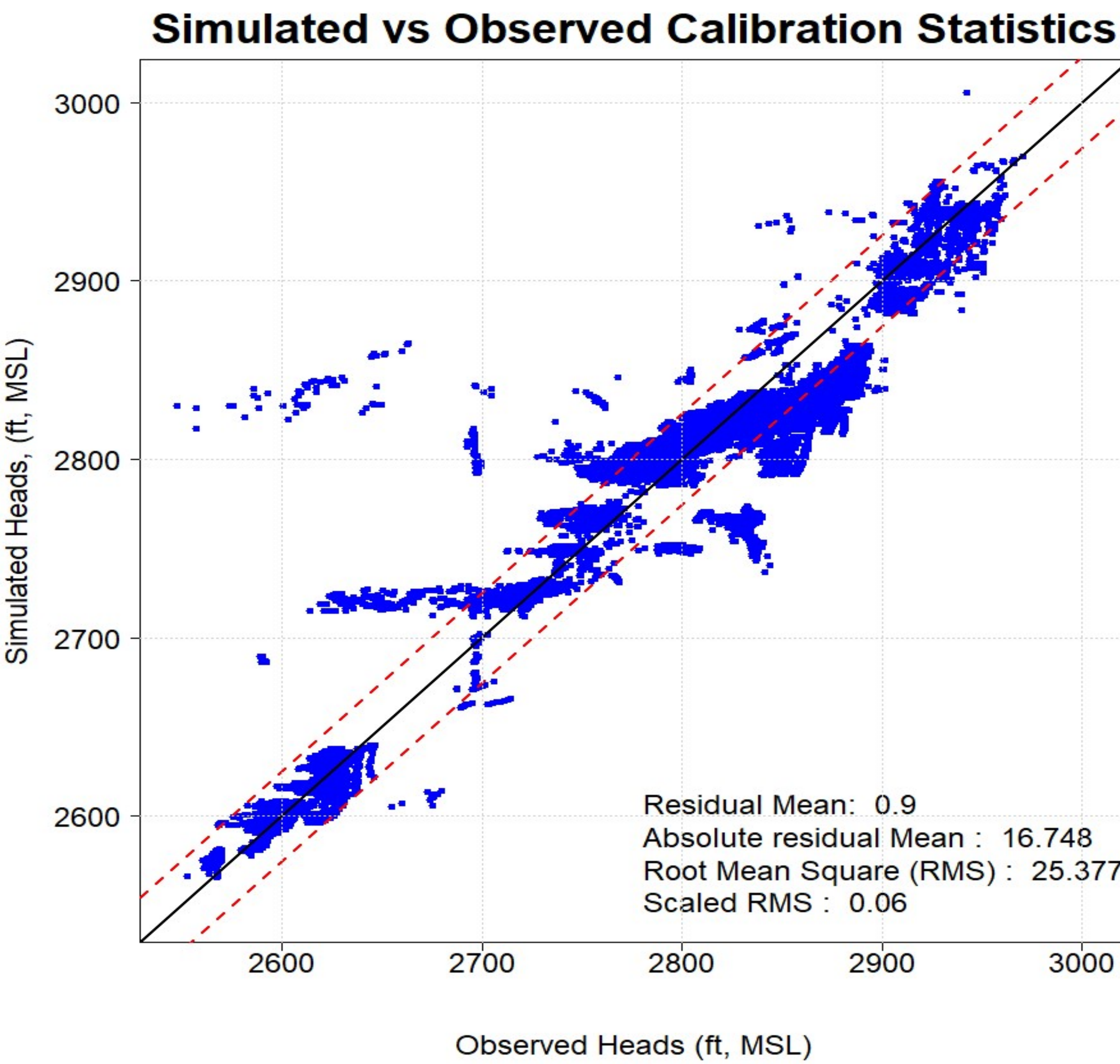
Basin Characterization Model Processes

By: KMC	Date: 12/04/2023	Project .:
	Mojave Water Agency	Figure 2



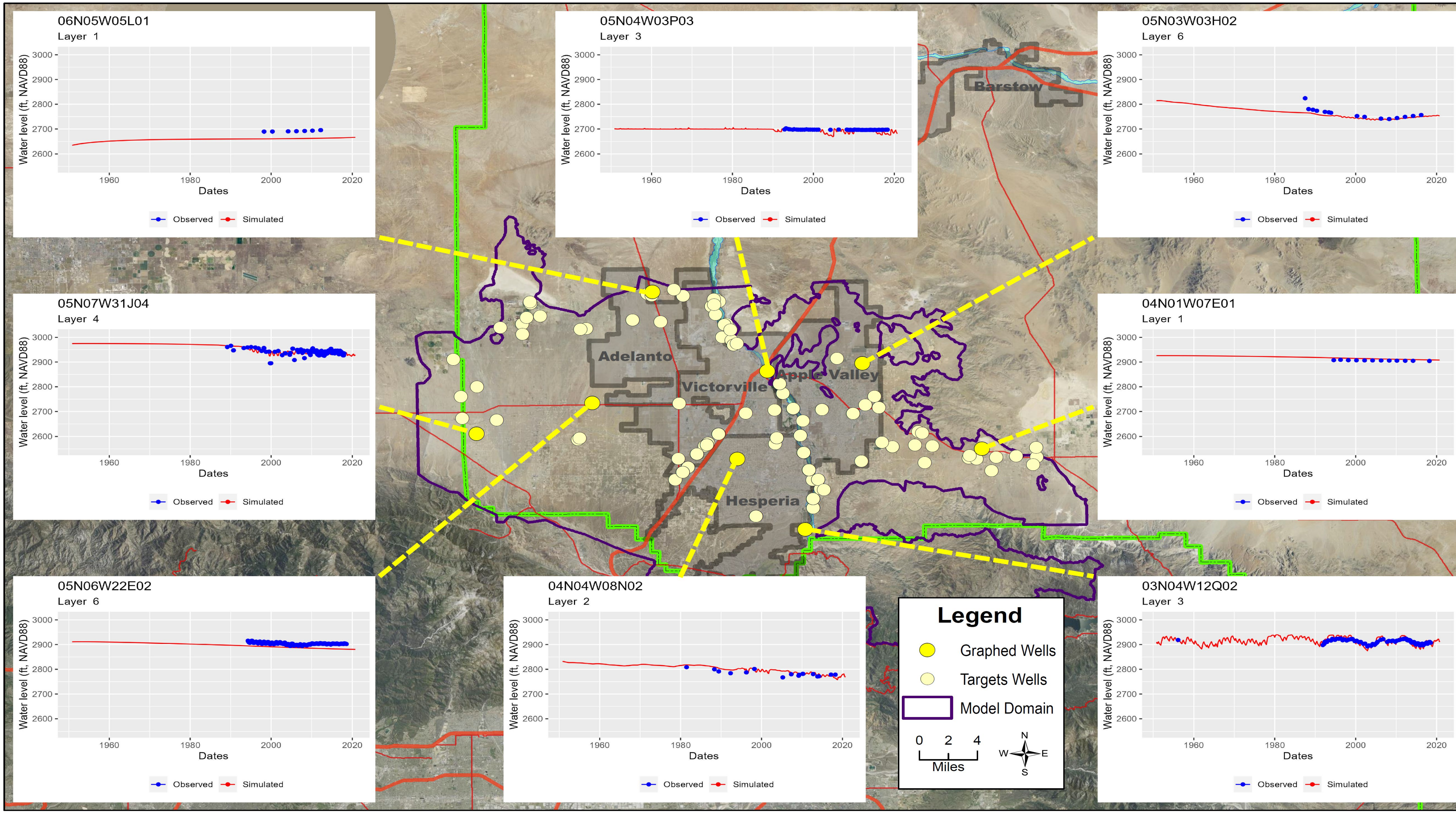
BCM Surface Water/Groundwater Conceptual Model

By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 3



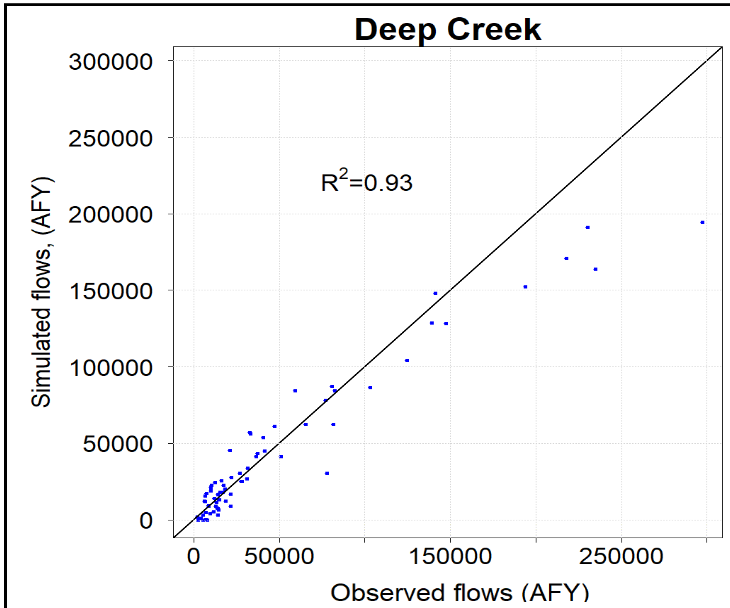
Simulated vs Observed Goundwater Levels

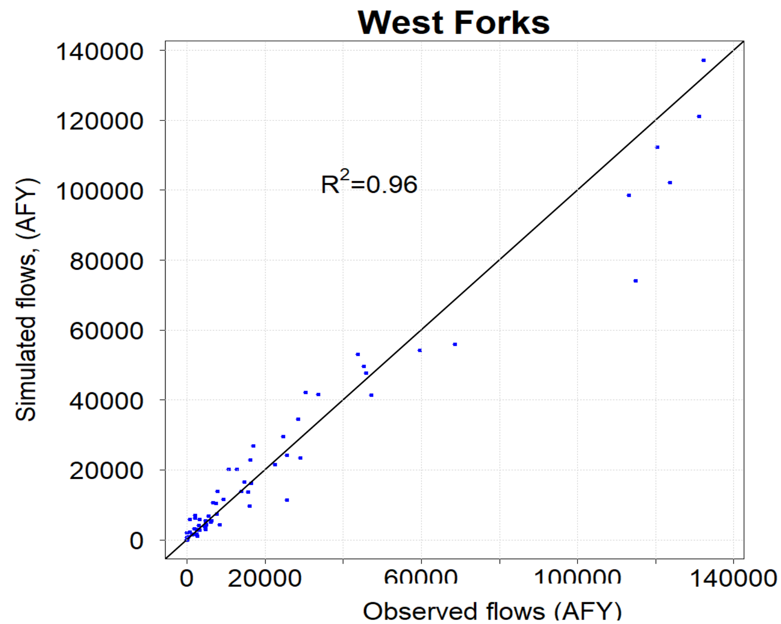
By: KMC	Date: 12/04/2023	Project .:
	Mojave Water Agency	Figure 4

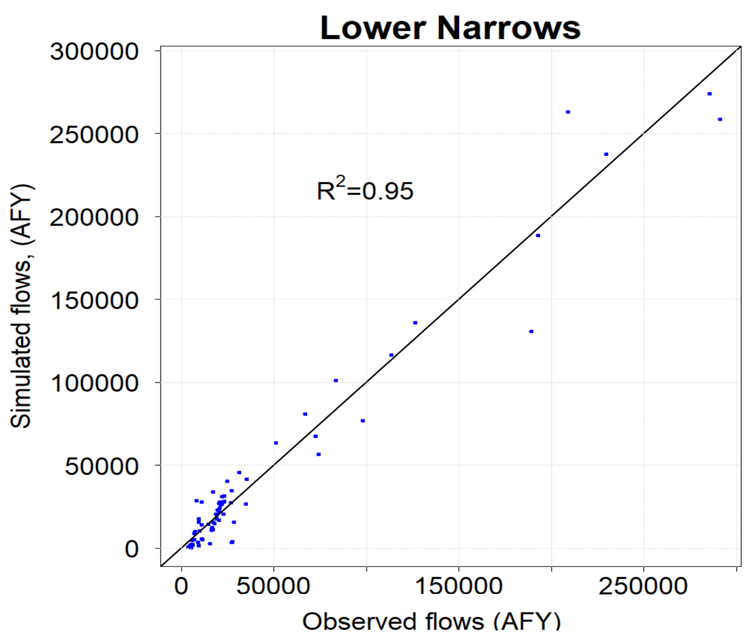


Selected Hydrograph

By: xxx	Date: 01/08/2015	Project No.: IR0000000000
Mojave Water Agency		Figure 5

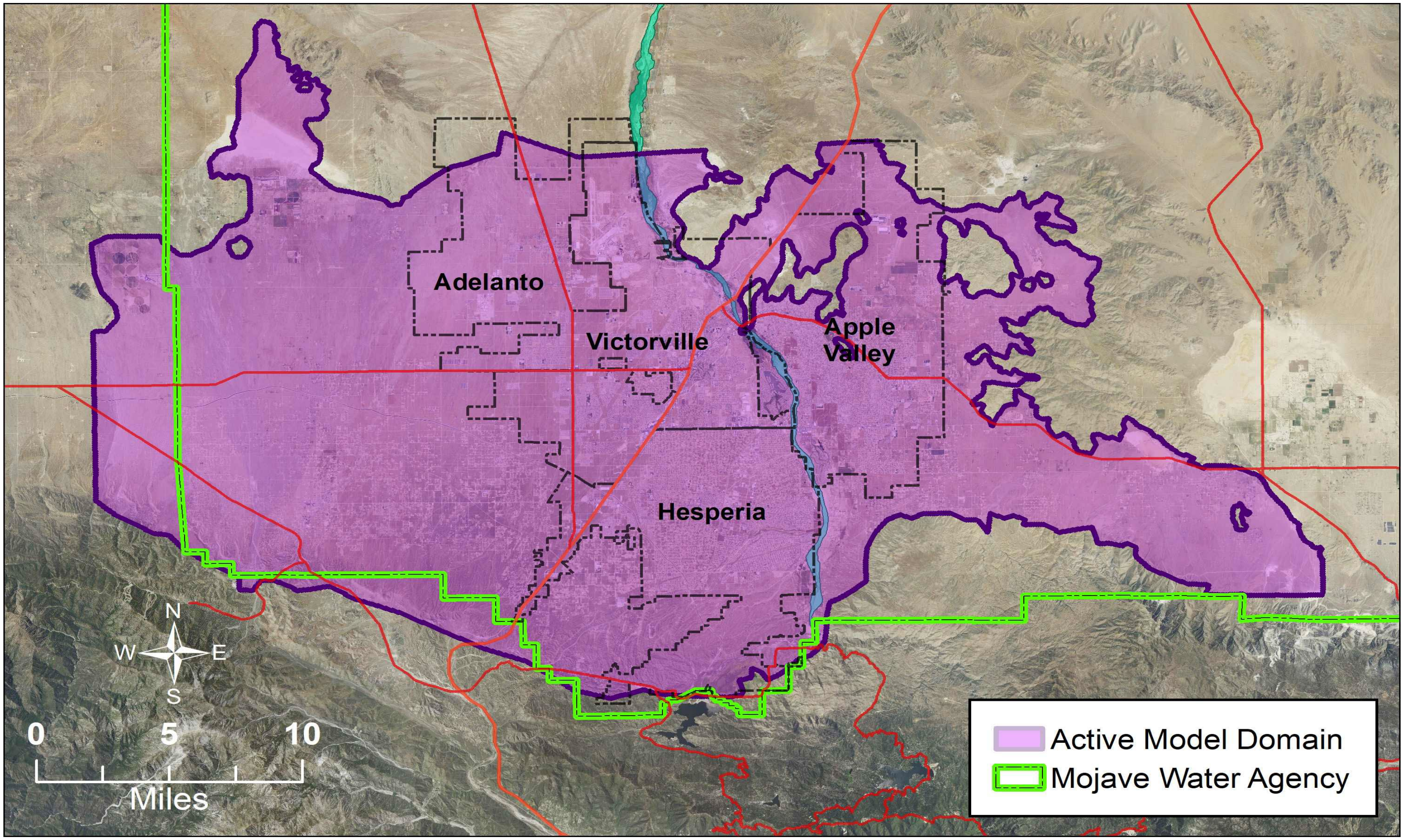






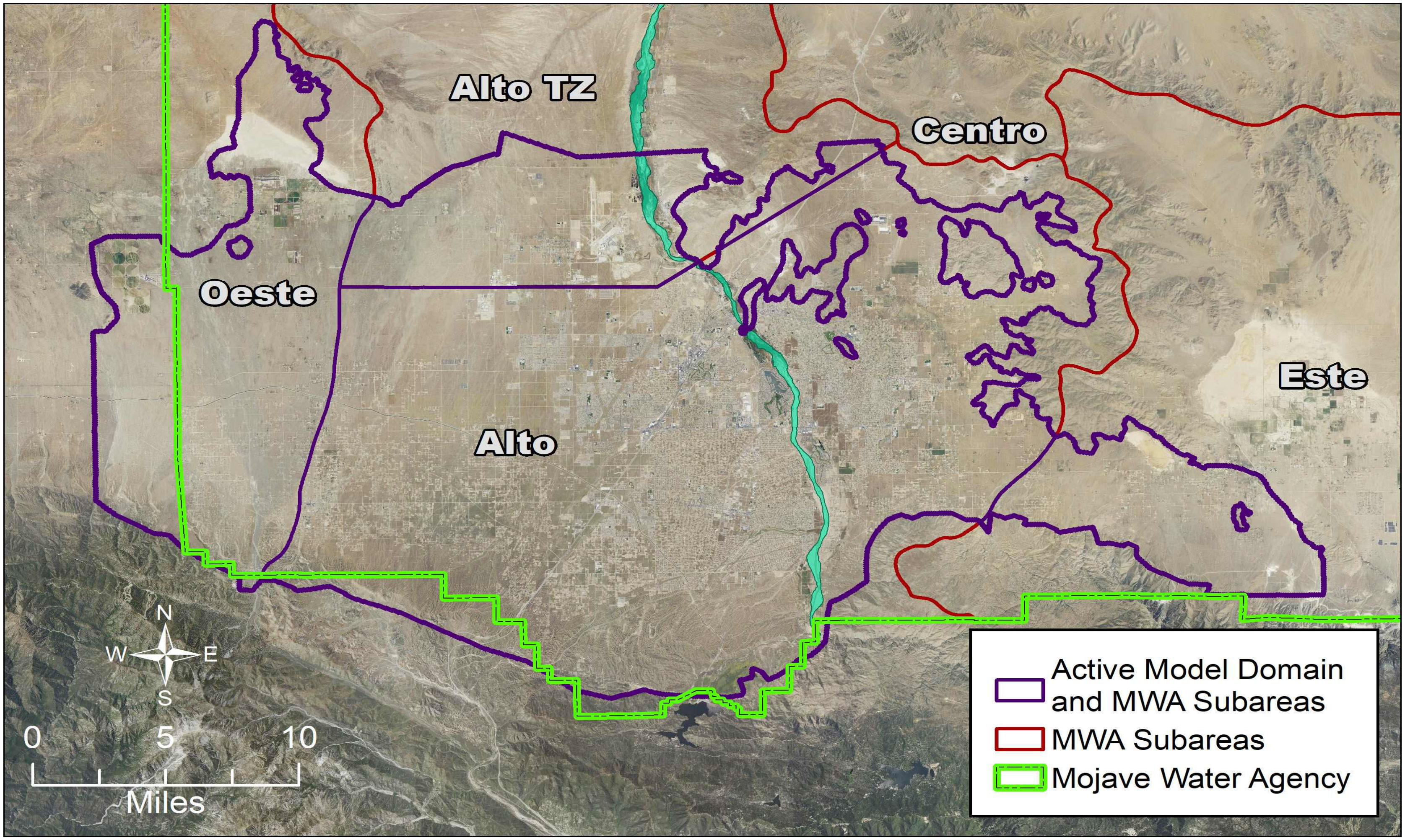
Obserbed vs Simulated Annual Flow

By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 6



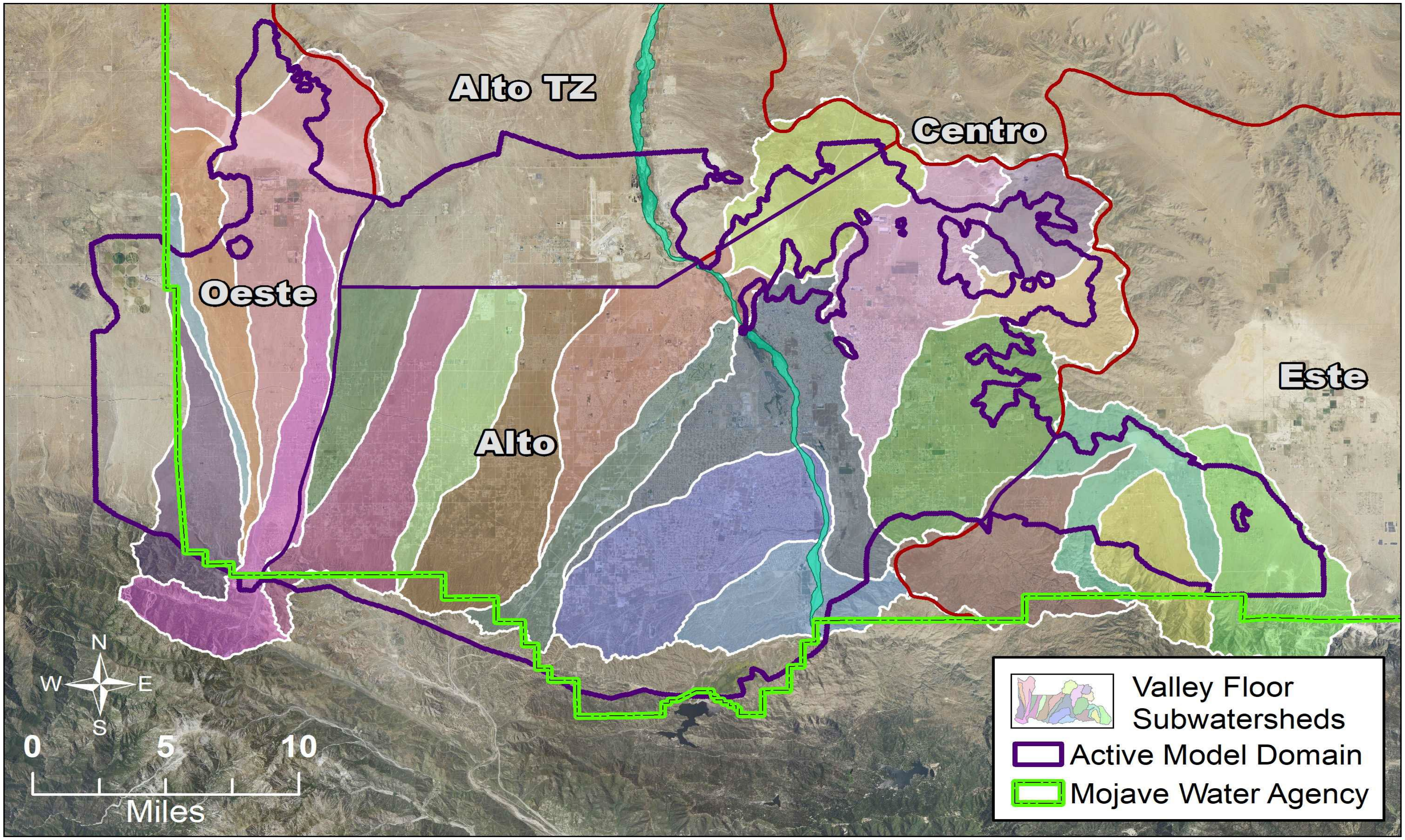
Model Water Budget Area

By: KMC	Date: 12/04/2023	Project No.: CM20167800
Mojave Water Agency		Figure 7



Water Budget Subareas

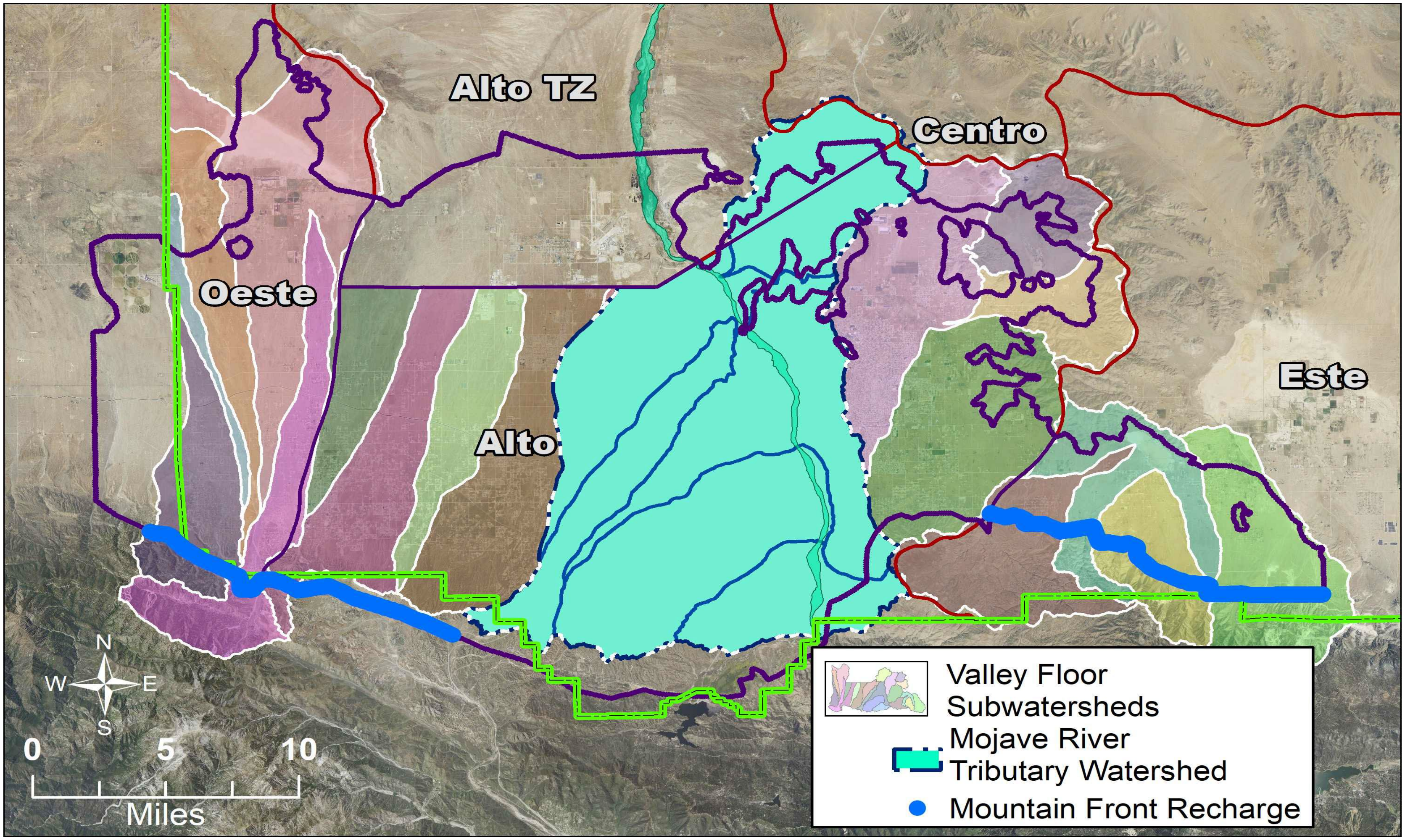
By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 8



Upper Mojave Basin Subwatersheds Used for Mountain Front Recharge Estimates

By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 9

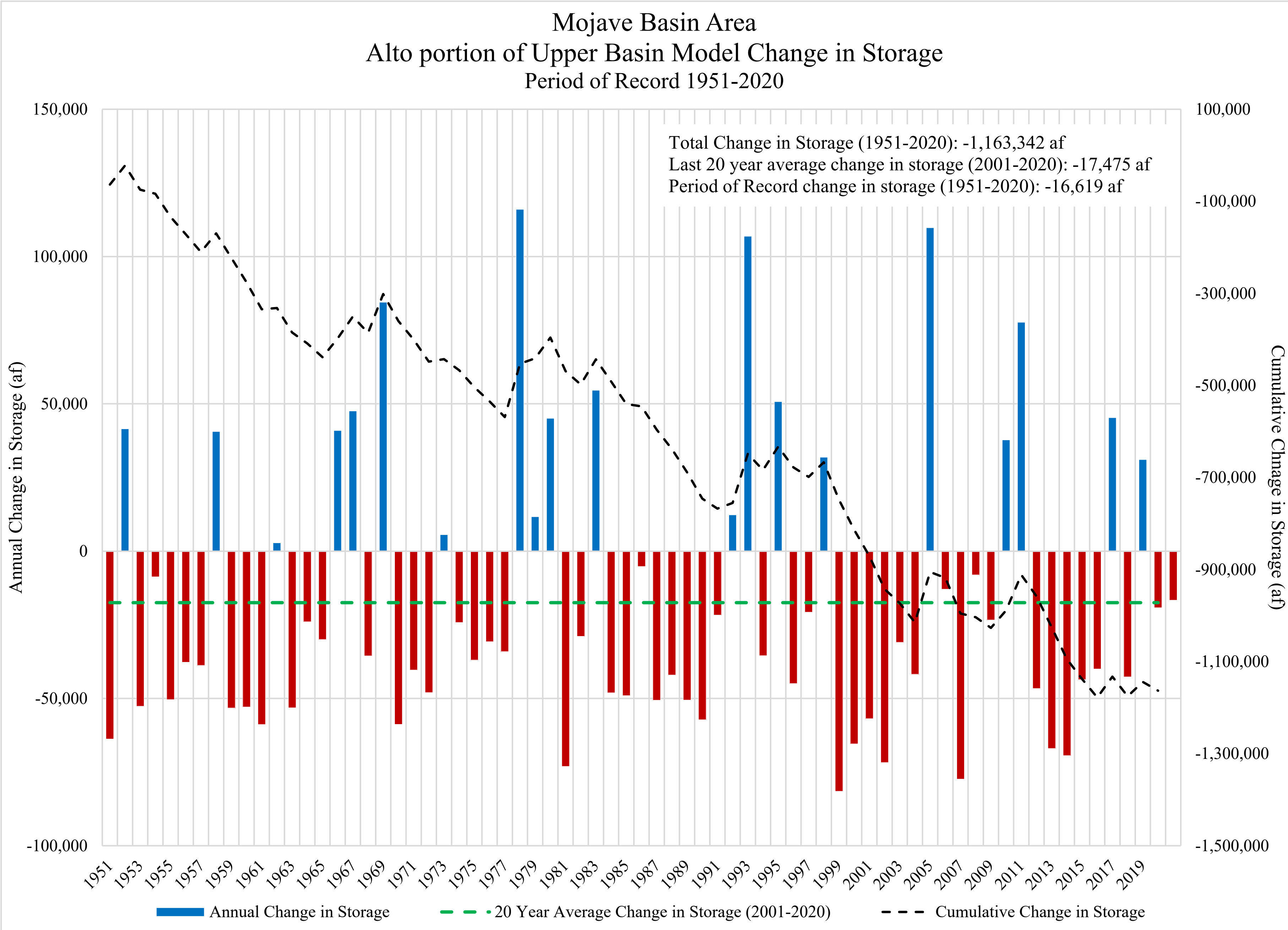
https://mojavewater-my.sharepoint.com/personal/kcoulibaly_mojavewater_org/Documents/Projects/WagnerRequests/PSY_Calc/Figures/ModelingTMFigures.xlsxFigure 10 12/10/2023



Upper Mojave Basin Subwatersheds Draining in the Mojave River (Tributaries)

By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 10

FIGURE 11



Mojave Basin Area
Alto portion of Upper Basin Model Change in Storage
Period of Record 1951-2020
Total Change in Storage (1951-2020): -1,163,342 af
Last 20 year average change in storage (2001-2020): -17,475 af
Period of Record change in storage (1951-2020): -16,619 af
Annual Change in Storage (af)
Cumulative Change in Storage (af)
150,000
100,000
50,000
0
-50,000
-100,000
100,000
-100,000
-300,000
-500,000
-700,000
-900,000
-1,100,000
-1,300,000
-1,500,000
1951
1953
1955
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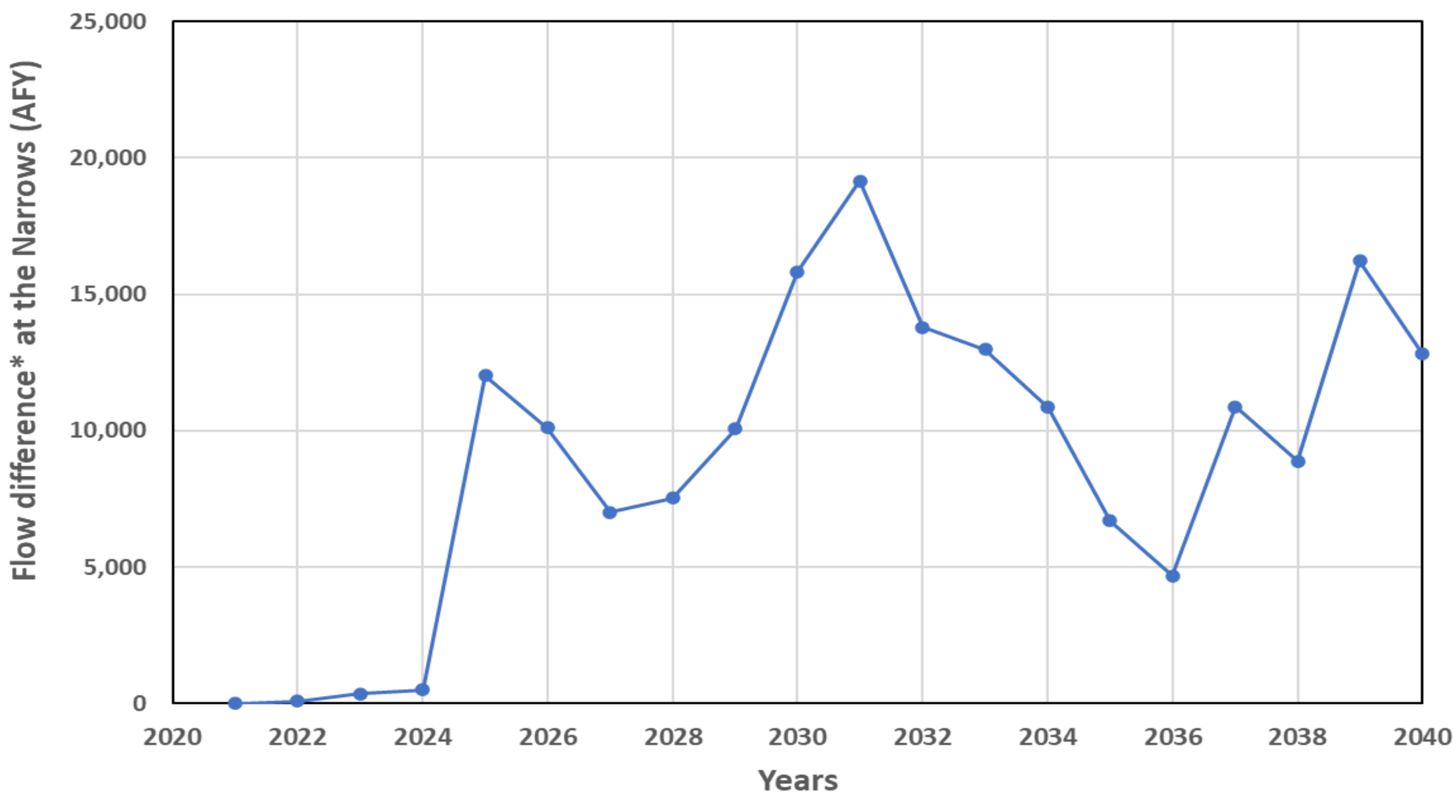
Annual Change in Storage
20 Year Average Change in Storage (2001-2020)
Cumulative Change in Storage



* Difference = Scenario 1 flow - base case flow at the Lower Narrows.
Scenario 1 consists of a 16,000 AFY delivered at Deep Creek.

Change in Flow at the Lower Narrows after Importing 17,500 AFY for 20 Years

By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 12

Figure 13

Alto Subarea Excluding Transition Zone

Simulated Water Budget Water Year 1951 - 2020

Upper Mojave River Basin Model

San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s
	Inflows										Outflows							
Water Year	**Art Rech (AF)**	**Mtn Rech (AF)**	**Ag Ret (AF)**	**Jess Ret (AF)**	**Septic Ret (AF)**	**Stream Leakage (AF)**	**Underflow Inflow from Este (AF)**	**Underflow Inflow Oeste (AF)**	**Total Inflow (AF)**	**Min Prod (AF)**	**Production (AF)**	**ET (AF)**	**Dry Lakes (AF)**	**Underflow Outflow TZ (AF)**	**Stream Leakage (AF)**	**Total Outflow**	**Change in Storage (AF)**	**Cumulative change in Storage (AF)**
1951	0	6,408	17,347	500	556	17,535	1,591	1,829	45,765	-1,381	-59,720	-6,618	0	-9,943	-31,853	-109,515	-63,750	-63,750
1952	0	11,094	22,108	1,327	619	126,956	1,590	1,918	165,611	-1,385	-77,283	-6,905	0	-9,866	-28,680	-124,118	41,493	-22,257
1953	0	7,250	22,619	1,236	683	40,002	1,596	2,003	75,389	-1,381	-81,505	-6,756	0	-9,774	-28,573	-127,988	-52,600	-74,857
1954	0	8,775	21,938	1,021	747	78,836	1,633	2,098	115,047	-1,381	-78,668	-6,785	0	-9,702	-27,195	-123,731	-8,683	-83,540
1955	0	7,073	21,440	1,369	810	36,183	1,658	2,193	70,727	-1,381	-77,153	-6,681	0	-9,643	-26,225	-121,084	-50,356	-133,897
1956	0	7,039	18,972	1,516	874	43,133	1,662	2,289	75,485	-1,385	-71,019	-6,622	0	-9,652	-24,507	-113,185	-37,700	-171,596
1957	0	6,970	18,473	1,756	938	39,179	1,666	2,362	71,343	-1,381	-70,634	-6,597	0	-9,591	-21,882	-110,085	-38,742	-210,338
1958	0	10,417	19,733	2,371	1,002	118,041	1,684	2,437	155,685	-1,381	-74,231	-6,817	0	-9,542	-23,154	-115,124	40,560	-169,778
1959	0	6,852	22,017	2,826	1,065	34,979	1,694	2,507	71,940	-1,381	-83,257	-6,619	0	-9,501	-24,365	-125,124	-53,184	-222,961
1960	0	6,519	23,604	3,455	1,129	35,847	1,696	2,580	74,830	-1,385	-89,129	-6,589	0	-9,477	-21,144	-127,723	-52,893	-275,855
1961	0	6,184	23,675	3,141	1,193	27,319	1,688	2,635	65,834	-1,381	-89,177	-6,562	0	-9,418	-18,111	-124,649	-58,815	-334,670
1962	0	8,505	22,613	2,665	1,256	83,339	1,690	2,694	122,761	-1,381	-85,861	-6,604	0	-9,382	-16,742	-119,969	2,792	-331,878
1963	0	6,200	22,832	3,285	1,320	31,690	1,683	2,749	69,758	-1,381	-89,535	-6,545	0	-9,343	-16,085	-122,889	-53,131	-385,009
1964	0	7,302	23,333	2,834	1,384	58,226	1,685	2,808	97,572	-1,385	-89,654	-6,522	0	-9,353	-14,563	-121,477	-23,905	-408,914
1965	0	6,941	23,784	3,255	1,448	53,507	1,682	2,849	93,467	-1,381	-92,433	-6,522	0	-9,324	-13,723	-123,383	-29,916	-438,830
1966	0	10,227	22,918	2,064	1,511	120,565	1,686	2,894	161,865	-1,381	-87,816	-6,669	0	-9,330	-15,750	-120,946	40,919	-397,911
1967	0	10,016	21,898	2,453	1,575	129,806	1,688	2,935	170,371	-1,381	-85,618	-6,700	0	-9,317	-19,793	-122,809	47,562	-350,349
1968	0	7,425	22,394	2,081	1,639	49,748	1,691	2,982	87,959	-1,385	-85,508	-6,605	0	-9,336	-20,649	-123,482	-35,523	-385,873
1969	0	15,149	23,970	2,105	1,702	167,731	1,686	3,008	215,352	-1,381	-89,563	-7,405	0	-9,256	-23,295	-130,900	84,452	-301,421
1970	0	6,664	21,162	1,049	1,766	31,291	1,681	3,040	66,653	-1,381	-81,885	-6,614	0	-9,225	-26,319	-125,424	-58,771	-360,191
1971	0	7,143	20,708	797	1,830	41,851	1,675	3,068	77,072	-1,381	-76,688	-6,580	0	-9,206	-23,512	-117,366	-40,294	-400,486
1972	0	6,649	19,002	1,353	1,894	33,442	1,676	3,103	67,117	-1,385	-76,894	-6,571	0	-9,201	-21,028	-115,080	-47,963	-448,449
1973	0	7,447	19,504	3,091	1,957	95,468	1,670	3,119	132,256	-1,381	-90,355	-6,589	0	-9,135	-19,234	-126,694	5,563	-442,886
1974	0	7,291	20,085	1,821	2,021	53,825	1,667	3,140	89,850	-1,381	-76,413	-6,555	0	-9,106	-20,577	-114,032	-24,182	-467,068
1975	0	7,147	20,312	1,840	2,085	41,810	1,665	3,159	78,017	-1,381	-78,564	-6,533	0	-9,075	-19,375	-114,928	-36,911	-503,979
1976	0	7,076	20,553	1,859	2,148	55,969	1,668	3,185	92,459	-1,385	-90,002	-6,534	0	-9,070	-16,182	-123,172	-30,714	-534,693
1977	0	7,242	20,752	1,877	2,212	55,741	1,664	3,190	92,678	-1,381	-95,740	-6,526	0	-9,018	-14,029	-126,695	-34,017	-568,709
1978	0	9,645	20,993	1,896	2,488	207,824	1,661	3,201	247,710	-1,381	-97,084	-6,824	0	-8,982	-17,443	-131,715	115,995	-452,715
1979	0	7,559	21,220	1,915	2,818	111,172	1,653	3,211	149,548	-1,381	-97,611	-6,837	0	-8,974	-23,108	-137,910	11,637	-441,077
1980	0	8,896	21,462	1,934	3,149	149,848	1,646	3,227	190,162	-1,385	-100,757	-7,001	0	-8,963	-27,031	-145,136	45,026	-396,051
1981	0	6,787	21,660	1,953	3,479	32,884	1,628	3,222	71,613	-1,381	-98,977	-6,766	0	-8,925	-28,610	-144,659	-73,046	-469,097
1982	0	7,092	21,902	1,972	3,809	73,810	1,616	3,224	113,425	-1,381	-101,608	-6,654	0	-8,896	-23,783	-142,323	-28,898	-497,995
1983	0	8,425	22,129	1,991	4,139	158,942	1,606	3,224	200,455	-1,381	-103,823	-6,837	0	-8,868	-24,984	-145,893	54,562	-443,433
1984	0	7,424	22,371	2,009	4,470	61,985	1,597	3,231	103,088	-1,385	-107,889	-6,806	0	-8,875	-26,172	-151,127	-48,039	-491,471
1985	0	7,758	22,567	1,985	4,800	56,567	1,580	3,219	98,477	-1,381	-109,712	-6,679	0	-8,826	-20,912	-147,510	-49,033	-540,504
1986	0	8,175	22,809	2,239	5,130	92,611	1,571	3,212	135,749	-1,381	-103,345	-6,699	0	-8,802	-20,696	-140,922	-5,173	-545,677
1987	0	7,528	22,371	1,667	5,460	46,920	1,563	3,185	88,694	-1,381	-103,774	-6,627	0	-8,806	-18,672	-139,259	-50,565	-596,242
1988	0	7,580	22,424	1,307	5,790	55,781	1,559	3,147	97,589	-1,385	-107,092	-6,564	0	-8,809	-15,731	-139,581	-41,992	-638,234
1989	0	7,352	23,207	1,304	6,121	49,006	1,547	3,150	91,687	-1,381	-112,094	-6,460	0	-8,736	-13,531	-142,202	-50,515	-688,749
1990	0	7,389	21,271	1,153	6,451	40,460	1,542	3,183	81,450	-1,381	-111,628	-5,982	0	-8,684	-10,967	-138,642	-57,192	-745,941
1991	0	7,944	19,705	2,141	6,543	73,177	1,544	3,212	114,266	-1,381	-110,947	-5,833	0	-8,586	-9,215	-135,963	-21,697	-767,638
1992	0	8,567	18,957	0	6,635	107,799	1,550	3,193	146,701	-1,385	-107,964	-6,252	0	-8,356	-10,475	-134,432	12,269	-755,369
1993	0	10,310	17,995	0	6,727	205,820	1,541	3,202	245,596	-1,381	-106,028	-6,856	0	-8,214	-16,272	-138,751	106,844	-648,524
1994	0	5,891	2,151	0	6,820	62,841	1,537	3,322	82,562	-1,381	-81,775	-6,770	0	-8,193	-19,888	-118,007	-35,445	-683,969
1995	0	7,203	1,828	0	6,912	144,399	1,525	3,289	165,156	-1,381	-74,741	-6,649	0	-8,033	-23,635	-114,439	50,716	-633,253
1996	0	6,084	626	0	7,004	58,397	1,515	3,301	76,927	-1,385	-79,084	-6,877	0	-8,064	-26,428	-121,837	-44,911	-678,163
1997	0	5,936	860	0	7,096	80,612	1,496	3,298	99,297	-1,381	-78,676	-6,887	0	-8,018	-25,035	-119,997	-20,700	-698,863
1998	0	7,808	524	0	7,188	125,160	1,483	3,319	145,483	-1,381	-71,472	-6,292	0	-7,967	-26,510	-113,621	31,861	-667,002
1999	0	6,613	610	0	7,280	20,430	1,469	3,315	39,719	-1,381	-79,245	-6,532	0	-7,929	-26,112	-121,198	-81,480	-748,482

Alto Subarea Excluding Transition Zone

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s
	Inflows										Outflows							
Water Year	**Art Rech (AF)**	**Mtn Rech (AF)**	**Ag Ret (AF)**	**Jess Ret (AF)**	**Septic Ret (AF)**	**Stream Leakage (AF)**	**Underflow Inflow from Este (AF)**	**Underflow Inflow Oeste (AF)**	**Total Inflow (AF)**	**Min Prod (AF)**	**Production (AF)**	**ET (AF)**	**Dry Lakes (AF)**	**Underflow Outflow TZ (AF)**	**Stream Leakage (AF)**	**Total Outflow**	**Change in Storage (AF)**	**Cumulative change in Storage (AF)**
2000	0	7,100	562	0	6,860	34,096	1,476	3,311	53,403	-1,385	-83,462	-6,634	0	-7,928	-19,355	-118,763	-65,360	-813,842
2001	0	7,390	410	0	7,065	33,802	1,481	3,303	53,451	-1,381	-80,266	-6,000	0	-7,772	-14,831	-110,250	-56,798	-870,640
2002	1658	6,869	314	0	7,271	15,572	1,483	3,286	36,453	-1,381	-83,204	-5,546	0	-7,679	-10,363	-108,172	-71,719	-942,359
2003	2940	7,494	248	0	7,477	49,650	1,484	3,265	72,557	-1,381	-82,958	-4,621	0	-7,607	-6,902	-103,469	-30,912	-973,271
2004	1499	7,230	247	0	7,683	43,901	1,486	3,239	65,284	-1,385	-89,462	-4,111	0	-7,484	-4,589	-107,031	-41,747	-1,015,017
2005	2423	9,434	204	0	7,888	194,886	1,485	3,213	219,534	-1,381	-86,263	-5,559	0	-7,056	-9,552	-109,811	109,723	-905,295
2006	1505	7,044	407	0	8,094	86,466	1,484	3,188	108,189	-1,381	-92,688	-6,172	0	-7,379	-13,459	-121,079	-12,890	-918,185
2007	1695	6,298	396	0	8,300	24,175	1,477	3,138	45,479	-1,381	-95,525	-6,014	0	-7,452	-12,451	-122,823	-77,344	-995,529
2008	1010	6,842	520	0	8,506	81,427	1,481	3,157	102,942	-1,361	-86,378	-5,411	0	-7,206	-10,574	-110,930	-7,988	-1,003,518
2009	1453	6,838	480	0	8,712	64,287	1,478	3,205	86,452	-1,357	-84,832	-5,368	0	-7,109	-11,081	-109,748	-23,296	-1,026,814
2010	1395	7,460	283	0	8,917	121,802	1,477	3,289	144,623	-1,357	-79,571	-5,942	0	-7,047	-13,004	-106,922	37,701	-989,112
2011	1234	8,424	138	0	8,997	167,516	1,474	3,365	191,148	-1,357	-77,586	-6,648	0	-6,970	-20,928	-113,490	77,658	-911,454
2012	975	7,066	287	0	9,076	49,999	1,468	3,398	72,270	-1,361	-80,287	-6,829	0	-6,981	-23,394	-118,852	-46,582	-958,037
2013	888	6,829	265	0	9,156	29,370	1,453	3,377	51,337	-1,357	-84,438	-6,714	0	-6,881	-18,885	-118,275	-66,938	-1,024,975
2014	754	6,876	196	0	9,235	23,753	1,448	3,368	45,630	-1,357	-86,951	-6,163	0	-6,791	-13,721	-114,984	-69,354	-1,094,329
2015	779	7,219	125	0	9,315	31,240	1,448	3,392	53,518	-1,357	-74,448	-5,454	0	-6,628	-9,164	-97,051	-43,533	-1,137,862
2016	765	7,181	202	0	9,394	27,074	1,452	3,411	49,480	-1,361	-71,219	-4,804	0	-6,582	-5,479	-89,446	-39,966	-1,177,828
2017	1078	8,023	104	0	9,474	112,277	1,443	3,411	135,810	-1,357	-71,169	-5,242	0	-6,592	-6,181	-90,541	45,269	-1,132,560
2018	0	7,420	27	0	9,474	34,250	1,437	3,426	56,034	-1,357	-79,570	-4,914	0	-6,719	-6,124	-98,684	-42,650	-1,175,210
2019	0	8,104	16	0	9,474	104,335	1,439	3,463	126,831	-1,357	-74,175	-5,548	0	-6,632	-8,071	-95,782	31,048	-1,144,162
2020	0	8,130	13	0	9,502	58,944	1,442	3,479	81,509	-1,361	-78,375	-5,433	0	-6,487	-9,033	-100,689	-19,180	-1,163,342
Entire POR Average	315	7,661	13,326	1,149	4,822	72,961	1,575	3,051	104,859	-1,377	-87,035	-6,349	0	-8,447	-18,270	-121,478	-16,619	
Last 20 Year Average	1,102	7,409	244	0	8,651	67,736	1,466	3,319	89,926	-1,366	-81,968	-5,625	0	-7,053	-11,389	-107,401	-17,475	

Column	**Description**	**Source**
A	Oct 1 to Sept 30, model period of record 1951-2020.	Watermaster
B	Oro Grande + LACSD.	Watermaster
C	Ungaged inflow, deep percolation precipitation and mountain front recharge.	BCM
D	Estimate return flow from agriculture.	Watermaster and USGS (2001)
E	Estimate return flow from Jess Ranch.	Watermaster
F	Estimated portion of indoor water use returned to the aquifer via septic.	MWA
G	Percolation from Mojave River to the aquifer.	Model
H	Subsurface inflow from Este.	Model
I	Subsurface inflow from Oeste.	Model
J	Sum of elements of inflow.	-
K	Estimated production by Minimal Producers.	Watermaster
L	Estimated total pumping within Alto above Lower Narrows.	Watermaster and USGS (2001)
M	Evapotranspiration from riparian vegetation.	Model
N	Evaporation from dry lakes.	Model
O	Subsurface outflow to Transition Zone.	Model
P	Discharge from aquifer to the Mojave River.	Model
Q	Sum of elements of outflow.	-
R	Gains or losses in storage on an annual basis.	-
S	Total accumulation of gains or losses at any point in time.	-

Transition Zone
Modeled Portion

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
	Inflows							Outflows							
Water Year	Art Rech (AF)	Ag Ret (AF)	Septic Ret (AF)	Stream Leakage (AF)	Underflow Inflow Alto (AF)	Underflow Inflow Oeste (AF)	Total Inflow (AF)	Min Prod (AF)	Production (AF)	ET (AF)	Dry Lakes (AF)	Stream Leakage (AF)	Total Outflow	Change in Storage (AF)	Cumulative change in Storage (AF)
1951	0	1,324	0	7,179	9,943	160	18,607	-93	-3,847	-6,055	0	-6,901	-16,895	1,712	1,712
1952	0	1,716	0	7,259	9,866	162	19,005	-93	-4,775	-6,138	0	-6,838	-17,843	1,162	2,873
1953	0	1,749	0	7,283	9,774	166	18,972	-93	-4,863	-6,077	0	-6,413	-17,445	1,527	4,400
1954	0	1,733	0	7,155	9,702	170	18,760	-93	-4,821	-6,093	0	-6,438	-17,445	1,314	5,714
1955	0	2,512	0	7,473	9,643	174	19,803	-93	-6,524	-6,043	0	-5,432	-18,091	1,712	7,426
1956	0	2,537	0	7,649	9,652	179	20,018	-93	-6,780	-6,028	0	-5,317	-18,217	1,800	9,227
1957	0	2,264	0	7,729	9,591	183	19,767	-93	-6,165	-6,044	0	-6,083	-18,385	1,382	10,609
1958	0	2,014	0	7,784	9,542	185	19,526	-93	-6,064	-6,096	0	-6,428	-18,681	845	11,454
1959	0	1,657	0	8,472	9,501	187	19,818	-93	-5,849	-5,993	0	-3,872	-15,807	4,010	15,464
1960	0	2,003	0	11,506	9,477	188	23,174	-93	-6,793	-5,873	0	-1,687	-14,445	8,728	24,193
1961	0	2,106	0	10,709	9,418	188	22,421	-93	-7,101	-5,889	0	-1,942	-15,025	7,396	31,589
1962	0	2,178	0	8,908	9,382	187	20,654	-93	-7,443	-5,963	0	-4,383	-17,881	2,773	34,362
1963	0	2,287	0	10,706	9,343	185	22,522	-93	-7,872	-5,870	0	-1,717	-15,552	6,970	41,332
1964	0	2,719	0	10,835	9,353	183	23,090	-93	-9,260	-5,711	0	-1,685	-16,749	6,342	47,673
1965	0	2,692	0	10,199	9,324	180	22,395	-93	-9,855	-5,696	0	-2,647	-18,291	4,104	51,778
1966	0	2,260	0	10,927	9,330	177	22,694	-93	-9,896	-5,948	0	-5,452	-21,389	1,305	53,083
1967	0	2,269	0	10,688	9,317	173	22,447	-93	-10,063	-5,961	0	-5,193	-21,310	1,137	54,220
1968	0	2,254	0	10,868	9,336	170	22,628	-93	-10,667	-5,896	0	-3,035	-19,691	2,937	57,157
1969	0	1,860	0	10,829	9,256	165	22,109	-93	-9,294	-6,083	0	-5,162	-20,632	1,477	58,635
1970	0	1,720	0	10,556	9,225	160	21,661	-93	-8,823	-5,907	0	-2,430	-17,253	4,408	63,043
1971	0	1,479	0	12,341	9,206	155	23,181	-93	-8,454	-5,823	0	-1,418	-15,788	7,393	70,436
1972	0	1,426	0	15,519	9,201	150	26,297	-93	-8,257	-5,758	0	-1,188	-15,296	11,001	81,437
1973	0	1,321	0	12,435	9,135	145	23,035	-93	-8,060	-5,894	0	-2,596	-16,644	6,392	87,829
1974	0	1,276	0	10,730	9,106	139	21,252	-93	-8,067	-5,790	0	-1,896	-15,845	5,406	93,235
1975	0	1,265	0	11,629	9,075	133	22,103	-93	-8,139	-5,295	0	-1,064	-14,592	7,512	100,747
1976	0	1,256	0	15,090	9,070	128	25,543	-93	-8,218	-5,667	0	-1,109	-15,088	10,455	111,202
1977	0	1,243	0	13,658	9,018	122	24,041	-93	-8,280	-5,791	0	-1,472	-15,635	8,406	119,608
1978	0	1,234	88	10,574	8,982	116	20,993	-93	-8,358	-6,097	0	-5,307	-19,856	1,138	120,745
1979	0	1,223	100	10,015	8,974	109	20,421	-93	-8,431	-6,027	0	-6,335	-20,886	-464	120,281
1980	0	1,213	112	10,237	8,963	103	20,628	-93	-8,510	-6,075	0	-5,426	-20,103	525	120,807
1981	3	1,201	124	12,132	8,925	97	22,481	-93	-8,571	-5,874	0	-1,810	-16,347	6,134	126,940
1982	430	1,191	135	11,879	8,896	90	22,623	-93	-8,649	-6,003	0	-7,384	-22,130	493	127,433
1983	914	1,180	147	11,719	8,868	84	22,912	-93	-8,722	-6,084	0	-8,146	-23,044	-132	127,301
1984	962	1,171	159	11,768	8,875	77	23,012	-93	-8,801	-6,018	0	-8,073	-22,984	27	127,328
1985	772	1,158	170	12,145	8,826	70	23,142	-93	-8,862	-5,996	0	-7,699	-22,649	492	127,820
1986	576	1,149	182	11,718	8,802	62	22,489	-93	-8,941	-5,978	0	-7,051	-22,063	426	128,246
1987	345	1,307	194	12,361	8,806	55	23,067	-93	-9,575	-5,917	0	-5,191	-20,776	2,291	130,537
1988	463	1,526	206	11,585	8,809	48	22,636	-93	-10,002	-5,666	0	-4,372	-20,132	2,504	133,041
1989	829	1,308	217	7,913	8,736	42	19,045	-93	-9,064	-4,432	0	-4,545	-18,134	911	133,952
1990	69	1,335	229	6,399	8,684	36	16,753	-93	-8,696	-3,468	0	-4,825	-17,082	-329	133,623
1991	70	1,385	232	6,859	8,586	30	17,163	-93	-8,675	-3,556	0	-6,687	-19,011	-1,847	131,776
1992	702	1,398	236	8,444	8,356	26	19,161	-93	-8,593	-4,131	0	-6,900	-19,717	-556	131,220
1993	569	1,522	239	12,690	8,214	24	23,258	-93	-8,691	-5,825	0	-7,134	-21,743	1,516	132,735
1994	692	318	242	9,946	8,193	26	19,417	-93	-3,751	-5,929	0	-8,740	-18,513	903	133,639
1995	792	313	245	9,626	8,033	26	19,035	-93	-3,694	-5,984	0	-8,838	-18,608	427	134,066
1996	539	164	249	11,478	8,064	27	20,521	-93	-6,581	-6,125	0	-8,973	-21,773	-1,252	132,814
1997	1,009	178	252	11,391	8,018	21	20,869	-93	-6,513	-6,150	0	-9,164	-21,919	-1,050	131,764
1998	1,147	139	255	10,061	7,967	13	19,583	-93	-5,187	-5,603	0	-9,179	-20,061	-478	131,285
1999	1,409	155	258	10,718	7,929	9	20,479	-93	-6,525	-5,845	0	-8,357	-20,819	-341	130,945

Transition Zone
Modeled Portion

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
	Inflows							Outflows							
Water Year	Art Rech (AF)	Ag Ret (AF)	Septic Ret (AF)	Stream Leakage (AF)	Underflow Inflow Alto (AF)	Underflow Inflow Oeste (AF)	Total Inflow (AF)	Min Prod (AF)	Production (AF)	ET (AF)	Dry Lakes (AF)	Stream Leakage (AF)	Total Outflow	Change in Storage (AF)	Cumulative change in Storage (AF)
2000	803	160	41	7,949	7,928	7	16,889	-93	-7,061	-5,063	0	-7,458	-19,675	-2,786	128,158
2001	1,072	102	43	6,751	7,772	10	15,748	-93	-6,462	-4,310	0	-7,568	-18,433	-2,685	125,474
2002	2,141	82	44	4,398	7,679	16	14,360	-93	-7,667	-3,357	0	-7,023	-18,139	-3,779	121,694
2003	3,558	83	45	4,201	7,607	22	15,517	-93	-7,191	-3,285	0	-7,371	-17,939	-2,422	119,272
2004	5,222	85	46	2,479	7,484	28	15,345	-93	-6,197	-3,068	0	-7,746	-17,103	-1,758	117,514
2005	5,050	108	47	7,192	7,056	33	19,487	-93	-6,810	-4,245	0	-9,037	-20,184	-698	116,816
2006	2,782	83	49	5,447	7,379	39	15,778	-93	-6,975	-3,892	0	-8,429	-19,389	-3,610	113,206
2007	3,626	81	50	3,984	7,452	44	15,238	-93	-5,556	-3,434	0	-8,264	-17,347	-2,109	111,097
2008	5,065	78	51	3,489	7,206	48	15,937	-93	-5,511	-3,502	0	-9,430	-18,535	-2,598	108,499
2009	4,795	78	52	3,393	7,109	48	15,476	-93	-5,074	-3,502	0	-9,921	-18,590	-3,115	105,384
2010	4,276	36	54	6,123	7,047	48	17,583	-93	-4,480	-4,686	0	-10,372	-19,631	-2,048	103,337
2011	4,939	13	54	8,951	6,970	46	20,973	-93	-4,127	-5,942	0	-10,186	-20,348	625	103,962
2012	4,471	5	55	8,830	6,981	45	20,385	-93	-4,327	-6,295	0	-10,132	-20,847	-462	103,500
2013	6,167	0	55	7,157	6,881	49	20,310	-93	-4,065	-6,036	0	-10,117	-20,311	-1	103,499
2014	7,602	6	56	5,686	6,791	66	20,206	-93	-4,072	-5,434	0	-11,308	-20,906	-700	102,799
2015	6,514	1	56	4,739	6,628	83	18,020	-93	-3,526	-5,160	0	-10,961	-19,739	-1,719	101,080
2016	7,219	8	57	3,273	6,582	97	17,236	-93	-3,678	-4,794	0	-10,424	-18,988	-1,752	99,328
2017	5,601	7	57	4,300	6,592	108	16,666	-93	-3,571	-4,945	0	-10,183	-18,792	-2,126	97,202
2018	7,358	0	57	2,475	6,719	117	16,725	-93	-3,767	-4,390	0	-9,950	-18,200	-1,474	95,728
2019	8,432	0	57	4,571	6,632	126	19,818	-93	-3,676	-4,901	0	-11,035	-19,705	113	95,840
2020	7,053	0	57	4,800	6,487	134	18,532	-93	-3,850	-5,213	0	-11,055	-20,212	-1,679	94,161
Entire POR Average	1,658	1,056	76	8,828	8,447	99	20,163	-93	-6,932	-5,395	0	-6,399	-18,818	1,345	
Last 20 Year Average	5,147	43	52	5,112	7,053	60	17,467	-93	-5,029	-4,520	0	-9,526	-19,167	-1,700	

Column	Description	Source
A	Oct 1 to Sept 30, model period of record 1951-2020.	Watermaster
B	VVWRA discharge to percolation ponds.	Watermaster
C	Estimate return flow from agriculture.	Watermaster and USGS (2001)
D	Estimated portion of indoor water use returned to the aquifer via septic.	MWA
E	Percolation from Mojave River to the aquifer.	Model
F	Subsurface inflow from Alto.	Model
G	Subsurface inflow from Oeste.	Model
H	Sum of elements of inflow.	-
I	Estimated production by Minimal Producers.	Watermaster
J	Estimated total pumping within Alto below Lower Narrows.	Watermaster and USGS (2001)
K	Evapotranspiration from riparian vegetation.	Model
L	Evaporation from dry lakes.	Model
M	Percolation from Mojave River to the aquifer.	Model
N	Sum of elements of outflow.	-
O	Gains or losses in storage on an annual basis.	-
P	Total accumulation of gains or losses at any point in time.	-

Este Subarea
Fifteen Mile Valley Portion

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l
	Inflows				Outflows						
Water Year	Mtn Rech (AF)	Ag Ret (AF)	Septic Ret (AF)	Total Inflow (AF)	Min Prod (AF)	Production (AF)	Dry Lakes (AF)	Underflow Outflow to Alto	Total Outflow	Change in Storage (AF)	Cumulative change in Storage (AF)
1951	2,690	0	0	2,690	-899	0	-692	-1,650	-3,241	-550	-550
1952	2,696	0	0	2,696	-901	0	-641	-1,656	-3,199	-502	-1,053
1953	2,689	0	0	2,689	-899	0	-639	-1,667	-3,206	-516	-1,569
1954	2,689	0	0	2,689	-899	0	-579	-1,706	-3,183	-494	-2,063
1955	2,689	0	0	2,689	-899	0	-535	-1,732	-3,166	-477	-2,540
1956	2,697	0	0	2,697	-901	0	-497	-1,741	-3,139	-442	-2,982
1957	2,690	0	0	2,690	-899	0	-456	-1,747	-3,103	-413	-3,394
1958	2,689	0	0	2,689	-899	0	-419	-1,767	-3,086	-397	-3,791
1959	2,690	0	0	2,690	-899	0	-397	-1,779	-3,075	-385	-4,176
1960	2,698	0	0	2,698	-901	0	-370	-1,785	-3,056	-358	-4,534
1961	2,690	0	0	2,690	-899	0	-356	-1,780	-3,035	-345	-4,879
1962	2,689	0	0	2,689	-899	0	-323	-1,785	-3,007	-317	-5,196
1963	2,691	0	0	2,691	-899	0	-302	-1,782	-2,983	-293	-5,489
1964	2,696	0	0	2,696	-901	0	-284	-1,788	-2,973	-277	-5,765
1965	2,689	0	0	2,689	-899	0	-267	-1,788	-2,954	-265	-6,030
1966	2,689	0	0	2,689	-899	0	-253	-1,795	-2,947	-258	-6,288
1967	2,689	0	0	2,689	-899	0	-237	-1,799	-2,935	-246	-6,534
1968	2,697	0	0	2,697	-901	0	-223	-1,804	-2,928	-232	-6,766
1969	2,689	0	0	2,689	-899	0	-207	-1,799	-2,905	-216	-6,981
1970	2,690	0	0	2,690	-899	0	-193	-1,794	-2,886	-196	-7,177
1971	2,689	0	0	2,689	-899	0	-178	-1,788	-2,866	-176	-7,353
1972	2,697	0	0	2,697	-901	0	-166	-1,789	-2,856	-159	-7,513
1973	2,689	0	0	2,689	-899	0	-153	-1,782	-2,834	-145	-7,658
1974	2,690	4	0	2,694	-899	-38	-141	-1,780	-2,858	-164	-7,823
1975	2,690	9	0	2,699	-899	-89	-129	-1,777	-2,895	-197	-8,019
1976	2,698	14	0	2,712	-901	-141	-118	-1,781	-2,942	-230	-8,249
1977	2,689	19	0	2,708	-899	-191	-106	-1,777	-2,973	-265	-8,514
1978	2,689	25	4	2,718	-899	-243	-95	-1,775	-3,011	-294	-8,807
1979	2,689	30	5	2,723	-899	-294	-83	-1,767	-3,043	-320	-9,127
1980	2,697	35	5	2,737	-901	-345	-73	-1,760	-3,080	-343	-9,470
1981	2,691	40	6	2,736	-899	-395	-63	-1,741	-3,099	-362	-9,832
1982	2,690	45	6	2,741	-899	-447	-53	-1,728	-3,126	-385	-10,217
1983	2,689	51	7	2,746	-899	-498	-42	-1,716	-3,156	-409	-10,626
1984	2,696	56	7	2,760	-901	-549	-32	-1,707	-3,190	-430	-11,056
1985	2,689	61	8	2,758	-899	-599	-21	-1,689	-3,209	-451	-11,507
1986	2,689	66	8	2,764	-899	-651	-12	-1,679	-3,241	-477	-11,985
1987	2,689	68	9	2,766	-899	-651	-3	-1,671	-3,224	-458	-12,442
1988	2,696	68	9	2,774	-901	-681	0	-1,667	-3,249	-476	-12,918
1989	2,690	68	10	2,767	-899	-717	0	-1,656	-3,272	-504	-13,423
1990	2,690	61	11	2,762	-899	-676	0	-1,651	-3,227	-465	-13,887
1991	2,690	53	11	2,753	-899	-600	0	-1,654	-3,153	-400	-14,287
1992	2,697	44	11	2,751	-901	-536	0	-1,661	-3,099	-347	-14,635
1993	2,689	35	11	2,735	-899	-524	0	-1,653	-3,076	-341	-14,975

Este Subarea
Fifteen Mile Valley Portion

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l
	Inflows				Outflows						
Water Year	Mtn Rech (AF)	Ag Ret (AF)	Septic Ret (AF)	Total Inflow (AF)	Min Prod (AF)	Production (AF)	Dry Lakes (AF)	Underflow Outflow to Alto	Total Outflow	Change in Storage (AF)	Cumulative change in Storage (AF)
1994	2,690	34	11	2,735	-899	-413	0	-1,649	-2,961	-226	-15,201
1995	2,689	30	11	2,730	-899	-326	0	-1,636	-2,861	-131	-15,332
1996	2,697	13	11	2,722	-901	-418	0	-1,625	-2,944	-222	-15,555
1997	2,689	3	12	2,704	-899	-399	0	-1,604	-2,902	-197	-15,752
1998	2,689	9	12	2,710	-899	-402	0	-1,589	-2,890	-180	-15,932
1999	2,692	14	12	2,718	-899	-409	0	-1,573	-2,881	-163	-16,095
2000	2,698	14	240	2,952	-901	-448	0	-1,576	-2,925	27	-16,068
2001	2,691	10	247	2,948	-899	-440	0	-1,577	-2,916	32	-16,036
2002	2,693	9	255	2,957	-899	-446	0	-1,578	-2,923	34	-16,003
2003	2,690	4	262	2,955	-899	-414	0	-1,578	-2,891	64	-15,939
2004	2,697	4	269	2,971	-901	-478	0	-1,582	-2,961	9	-15,929
2005	2,689	4	276	2,969	-899	-400	0	-1,581	-2,880	89	-15,840
2006	2,690	3	283	2,976	-899	-530	0	-1,580	-3,009	-32	-15,873
2007	2,693	7	291	2,990	-899	-527	0	-1,573	-2,999	-8	-15,881
2008	2,697	10	298	3,005	-886	-492	0	-1,576	-2,954	51	-15,830
2009	2,690	7	305	3,002	-884	-478	0	-1,572	-2,933	69	-15,761
2010	2,689	7	312	3,009	-884	-407	0	-1,570	-2,861	148	-15,613
2011	2,689	7	315	3,011	-884	-363	0	-1,566	-2,813	198	-15,415
2012	2,698	7	318	3,022	-886	-358	0	-1,559	-2,804	219	-15,196
2013	2,692	7	321	3,019	-884	-349	0	-1,543	-2,776	243	-14,953
2014	2,692	6	323	3,021	-884	-342	0	-1,536	-2,762	259	-14,694
2015	2,690	6	326	3,022	-884	-319	0	-1,535	-2,738	284	-14,410
2016	2,698	19	329	3,046	-886	-348	0	-1,540	-2,774	272	-14,138
2017	2,689	31	332	3,052	-884	-386	0	-1,531	-2,800	252	-13,886
2018	2,691	36	332	3,058	-884	-419	0	-1,526	-2,828	230	-13,655
2019	2,689	33	332	3,054	-884	-471	0	-1,527	-2,882	172	-13,483
2020	2,697	29	333	3,058	-886	-550	0	-1,530	-2,966	92	-13,391
Average	2,692	17	93	2,802	-897	-289	-133	-1,674	-2,993	-191	
L20 Year Average	2,692	12	303	3,007	-890	-426	0	-1,558	-2,874	134	

Column	Description	Source
A	Oct 1 to Sept 30, model period of record 1951-2020.	Watermaster
B	Ungaged inflow, deep percolation precipitation and mountain front recharge.	BCM
C	Estimate return flow from agriculture.	Watermaster and USGS (2001)
D	Estimated portion of indoor water use returned to the aquifer via septic.	MWA
E	Sum of elements of inflow.	-
F	Estimated production by Minimal Producers.	Watermaster
G	Estimated total pumping within Este.	Watermaster and USGS (2001)
H	Evaporation from dry lakes.	Model
I	Subsurface outflow to Alto.	Model
J	Sum of elements of outflow.	-
K	Gains or losses in storage on an annual basis.	-
L	Total accumulation of gains or losses at any point in time.	-

Oeste Subarea

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l	m
	Inflows				Outflows							
Water Year	Mtn Rech (AF)	Ag Ret (AF)	Septic Ret (AF)	Total Inflow (AF)	Min Prod (AF)	Production (AF)	Dry Lakes (AF)	Oeste to Alto	Outflow to TZ	Total Outflow	Change in Storage (AF)	Cumulative change in Storage (AF)
1951	4,627	0	0	4,627	-117	0	-515	-1,829	-160	-2,622	2,005	2,005
1952	4,670	0	0	4,670	-118	0	-521	-1,918	-162	-2,719	1,951	3,957
1953	4,680	0	0	4,680	-117	0	-534	-2,003	-166	-2,820	1,860	5,817
1954	4,699	0	0	4,699	-117	0	-545	-2,098	-170	-2,931	1,768	7,584
1955	4,714	0	0	4,714	-117	0	-558	-2,193	-174	-3,044	1,671	9,255
1956	4,742	29	0	4,771	-118	-154	-570	-2,289	-179	-3,311	1,460	10,715
1957	4,742	68	0	4,810	-117	-360	-571	-2,362	-183	-3,593	1,217	11,932
1958	4,756	107	0	4,862	-117	-566	-566	-2,437	-185	-3,872	990	12,922
1959	4,769	145	0	4,915	-117	-772	-564	-2,507	-187	-4,148	766	13,688
1960	4,796	184	0	4,980	-118	-979	-556	-2,580	-188	-4,422	559	14,247
1961	4,797	223	0	5,020	-117	-1,184	-545	-2,635	-188	-4,669	351	14,598
1962	4,812	262	0	5,073	-117	-1,390	-528	-2,694	-187	-4,916	157	14,755
1963	4,826	300	0	5,126	-117	-1,596	-516	-2,749	-185	-5,164	-37	14,718
1964	4,854	339	0	5,193	-118	-1,804	-497	-2,808	-183	-5,410	-217	14,500
1965	4,855	377	0	5,232	-117	-2,007	-477	-2,849	-180	-5,630	-398	14,102
1966	4,869	416	0	5,285	-117	-2,214	-455	-2,894	-177	-5,857	-572	13,530
1967	4,883	455	0	5,338	-117	-2,421	-434	-2,935	-173	-6,080	-742	12,788
1968	4,909	494	0	5,403	-118	-2,628	-412	-2,982	-170	-6,309	-906	11,882
1969	4,908	532	0	5,441	-117	-2,831	-385	-3,008	-165	-6,506	-1,066	10,816
1970	4,920	571	0	5,491	-117	-3,039	-365	-3,040	-160	-6,721	-1,230	9,586
1971	4,930	610	0	5,541	-117	-3,245	-338	-3,068	-155	-6,923	-1,383	8,203
1972	4,954	649	0	5,603	-118	-3,453	-308	-3,103	-150	-7,132	-1,529	6,674
1973	4,950	687	0	5,637	-117	-3,654	-271	-3,119	-145	-7,306	-1,669	5,005
1974	4,956	726	0	5,683	-117	-3,863	-239	-3,140	-139	-7,498	-1,816	3,189
1975	4,963	765	0	5,728	-117	-4,069	-211	-3,159	-133	-7,689	-1,961	1,228
1976	4,982	804	0	5,787	-118	-4,278	-177	-3,185	-128	-7,885	-2,098	-870
1977	4,973	842	0	5,815	-117	-4,478	-140	-3,190	-122	-8,047	-2,232	-3,102
1978	4,977	881	0	5,858	-117	-4,687	-114	-3,201	-116	-8,235	-2,377	-5,479
1979	4,979	920	0	5,899	-117	-4,893	-74	-3,211	-109	-8,404	-2,505	-7,984
1980	4,993	960	0	5,952	-118	-5,102	-42	-3,227	-103	-8,592	-2,640	-10,624
1981	4,978	997	0	5,974	-117	-5,301	-24	-3,222	-97	-8,762	-2,788	-13,411
1982	4,976	1,036	0	6,013	-117	-5,511	-13	-3,224	-90	-8,956	-2,943	-16,354
1983	4,972	1,075	0	6,047	-117	-5,717	-5	-3,224	-84	-9,148	-3,100	-19,455
1984	4,981	1,115	0	6,096	-118	-5,927	-2	-3,231	-77	-9,355	-3,259	-22,714
1985	4,962	1,152	0	6,114	-117	-6,125	0	-3,219	-70	-9,531	-3,417	-26,131
1986	4,954	1,191	0	6,146	-117	-6,335	0	-3,212	-62	-9,727	-3,581	-29,712
1987	4,960	1,164	0	6,124	-117	-6,629	0	-3,185	-55	-9,986	-3,862	-33,575
1988	4,991	1,157	0	6,148	-118	-6,729	0	-3,147	-48	-10,042	-3,894	-37,469
1989	4,971	1,163	0	6,134	-117	-6,582	0	-3,150	-42	-9,892	-3,758	-41,226
1990	4,978	1,171	0	6,148	-117	-6,857	0	-3,183	-36	-10,194	-4,045	-45,272
1991	4,990	1,181	0	6,171	-117	-6,851	0	-3,212	-30	-10,210	-4,039	-49,311
1992	5,009	1,194	0	6,203	-118	-6,983	0	-3,193	-26	-10,320	-4,117	-53,428
1993	5,019	1,204	0	6,222	-117	-6,626	0	-3,202	-24	-9,970	-3,748	-57,175

Oeste Subarea

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l	m
	Inflows				Outflows							
Water Year	**Mtn Rech (AF)**	**Ag Ret (AF)**	**Septic Ret (AF)**	**Total Inflow (AF)**	**Min Prod (AF)**	**Production (AF)**	**Dry Lakes (AF)**	**Oeste to Alto**	**Outflow to TZ**	**Total Outflow**	**Change in Storage (AF)**	**Cumulative change in Storage (AF)**
1994	5,108	1,199	0	6,307	-117	-6,433	0	-3,322	-26	-9,899	-3,591	-60,767
1995	5,023	973	0	5,996	-117	-5,277	0	-3,289	-26	-8,709	-2,713	-63,480
1996	5,174	469	0	5,643	-118	-6,091	0	-3,301	-27	-9,536	-3,893	-67,373
1997	5,195	478	0	5,674	-117	-6,329	0	-3,298	-21	-9,765	-4,091	-71,464
1998	5,125	316	0	5,442	-117	-5,191	0	-3,319	-13	-8,641	-3,199	-74,663
1999	5,114	166	0	5,280	-117	-5,110	0	-3,315	-9	-8,551	-3,271	-77,934
2000	5,149	143	790	6,082	-118	-4,891	0	-3,311	-7	-8,327	-2,245	-80,178
2001	5,011	108	813	5,932	-117	-4,377	0	-3,303	-10	-7,807	-1,874	-82,052
2002	5,110	160	837	6,107	-117	-5,131	0	-3,286	-16	-8,550	-2,443	-84,495
2003	5,033	118	861	6,013	-117	-4,653	0	-3,265	-22	-8,058	-2,045	-86,540
2004	5,117	185	885	6,187	-118	-5,234	0	-3,239	-28	-8,619	-2,432	-88,972
2005	4,925	173	908	6,006	-117	-4,667	0	-3,213	-33	-8,031	-2,025	-90,997
2006	5,012	169	932	6,112	-117	-4,912	0	-3,188	-39	-8,256	-2,144	-93,141
2007	5,263	170	956	6,389	-117	-5,622	0	-3,138	-44	-8,921	-2,533	-95,674
2008	5,146	264	979	6,388	-116	-5,415	0	-3,157	-48	-8,736	-2,347	-98,021
2009	5,046	196	1,003	6,245	-115	-5,030	0	-3,205	-48	-8,399	-2,154	-100,175
2010	5,023	174	1,027	6,224	-115	-4,319	0	-3,289	-48	-7,771	-1,547	-101,722
2011	4,964	220	1,036	6,220	-115	-4,371	0	-3,365	-46	-7,897	-1,678	-103,399
2012	4,981	233	1,045	6,259	-116	-4,542	0	-3,398	-45	-8,101	-1,842	-105,241
2013	4,963	145	1,054	6,162	-115	-3,250	0	-3,377	-49	-6,791	-629	-105,870
2014	4,954	159	1,063	6,177	-115	-3,403	0	-3,368	-66	-6,952	-775	-106,645
2015	4,914	177	1,072	6,164	-115	-3,309	0	-3,392	-83	-6,900	-736	-107,381
2016	4,745	253	1,082	6,079	-116	-3,315	0	-3,411	-97	-6,939	-860	-108,241
2017	4,752	146	1,091	5,988	-115	-2,936	0	-3,411	-108	-6,570	-582	-108,823
2018	5,018	0	1,091	6,108	-115	-3,392	0	-3,426	-117	-7,051	-942	-109,765
2019	4,837	0	1,091	5,928	-115	-3,207	0	-3,463	-126	-6,912	-984	-110,749
2020	4,820	0	1,094	5,914	-116	-2,931	0	-3,479	-134	-6,660	-746	-111,495
Entire POR Average	4,939	485	296	5,720	-117	-3,874	-172	-3,051	-99	-7,313	-1,593	-113,088
Last 20 Year Average	4,982	152	996	6,130	-116	-4,201	0	-3,319	-60	-7,696	-1,566	

Column	**Description**	**Source**
A	Oct 1 to Sept 30, model period of record 1951-2020.	Watermaster
B	Ungaged inflow, deep percolation precipitation and mountain front recharge.	BCM
C	Estimate return flow from agriculture.	Watermaster and USGS (2001)
D	Estimated portion of indoor water use returned to the aquifer via septic.	MWA
E	Sum of elements of inflow.	-
F	Estimated production by Minimal Producers.	Watermaster
G	Estimated total pumping within Oeste.	Watermaster and USGS (2001)
H	Evaporation from dry lakes.	Model
I	Subsurface outflow to Alto.	Model
J	Subsurface outflow to Transition Zone.	Model
K	Sum of elements of outflow.	-
L	Gains or losses in storage on an annual basis.	-
M	Total accumulation of gains or losses at any point in time.	-