Wagner&Bonsignore
Consulting Civil Engineers, A Corporation

Nicholas F. Bonsignore, P.E.
Robert C. Wagner, P.E.
Paula J. Whealen

Martin Berber, P.E.
Patrick W. Ervin, P.E.
David P. Lounsbury, P.E.
Vincent Maples, P.E.
Leah Orloff, Ph.D, P.E.
David H. Peterson, C.E.G., C.H.G.
Ryan E. Stolfus

TECHNICAL MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E. Watermaster Engineer
A. Leonardo Urrego-Vallowe, P.E. Project Engineer

Date: June 5, 2026

Re: **Production Safe Yield Update and Recommendation for Free Production Allowance for Water Year 2026-27**

Introduction

Pursuant to the Court's Order dated April 21, 2026, Watermaster evaluated the Production Safe Yield (PSY) based upon the Judgment's initial hydrologic base period, for Water Years 1931-1990. The water balance presented on Table C-1 of Judgment, was based on this 60-year base period (see **Attachment A**); Table C-1 was further refined by Webb Associates (Webb 2000); pursuant to the requirements of the Judgment, Webb (2000) adopted the same 60-year hydrologic base period.

Updating PSY involves both evaluation of the elements of water supply that existed for the 1931-1990 period and the consumptive uses and changes that occurred after 1990, and an estimate of the near future land use conditions. As noted in Table C-1, the near future land use conditions (current cultural conditions) were represented by the conditions of 1990. For the PSY evaluation by Webb (2000), it was determined that Water Year 1997-98 was the representative year for cultural conditions. For this evaluation, Watermaster is proposing that Water Year 2024-25 is the representative land use condition for the near future. Changes in land use that occurred since 1990 were documented by Watermaster and submitted to the Court on November 12, 2025 and available via the following link:
https://www.mojavewater.org/wp-content/uploads/2025/11/20251112_WM_Engineer_Reasons_2001-2020_Base_Period.pdf

The Upper Mojave Basin Model (UMBM) is not sufficient for evaluating the PSY for the period 1931-1990, as it was developed for the period 1951-2020 and thus does not capture the full base period. Further, the UMBM did not include a complete evaluation of the Transition Zone, which is part of the Alto Subarea, and therefore is geographically incomplete. USGS Water

Resources Investigation Report 01-4002, "Simulation of Ground-Water Flow in the Mojave River Basin, California" (Stamos et al. 2001) captures both the entire Mojave Basin Area (MBA) and the Court ordered 1931-1990 base period. Stamos et al. (2001) will allow for a model-to-model comparison of the elements of water supply, use, and disposal when MWA finalizes the Regional Mojave Basin Model. Thus, because the Stamos et al. (2001) model covers the 1931-1990 time period, and the MBA entirely, and can be compared to the Regional Mojave Basin Model, when finished, we have prepared a hydrologic inventory for each subarea in the format consistent with the Table C-1 and using the Stamos et al. (2001) model. This hydrologic inventory is traditionally included in the Watermaster Annual Report and commonly referred to as Table 5-1.

Watermaster has adjusted some inputs to account for cultural changes since 1990 that have affected water supply. Most of the adjustments relate to changes in consumptive use that have occurred since 1990. The conceptual model assumes that 1931-1990 water supply conditions, apply to the 2024-25 cultural conditions as if those conditions existed over the entire 60-year hydrologic base period. This is the same conceptual model that was used to prepare Table C-1, and adopted by Webb (2000), and consistently used by Watermaster in previous PSY evaluations.

Our analysis for the Este and Oeste subareas deviates from the foregoing in that the inflow estimates by previous researchers (see Table C-1, Table 5-1) and values for inflow from the Stamos et al. (2001) model, do not represent the water level observations for the last 30 years in Este, and past 16 years in Oeste. For these two subareas, we interpret the water level data as indicating little to no change in storage over time leading to conclude that the average pumping amount over that period of time is the better representation of conditions in Este and Oeste. Our recommendation to set PSY and FPA in Este and Oeste follows this logic. This is discussed in more detail hereinafter.

This memorandum describes the methods for updating the PSY values for each of the five subareas consistent with the direction from the Court on April 20, 2026. The PSY, calculated FPA and proposed FPA for 2026-27 are provided in Table 1.

Table 1. Updated Production Safe Yield and Proposed Free Production Allowance 2026-27

	Water Year 2025-26			Water Year 2026-27			
Subarea	**Base Annual Production**	**Current PSY**	**Current FPA**	**Indicated PSY**	**Indicated FPA**	**Proposed PSY**	**Proposed FPA**
Alto	116,412	62,005	50.4%	63,442	54.5%	63,442	54.5%
Baja	66,157	12,189	19.5%	16,211	24.5%	16,211	19.5%
Centro	51,030	31,420	56%	28,473	55.8%	28,473	55.8%
Este	20,205	6,582	45%	***6,677***	***33.0%***	6,677	40%
Oeste	7,095	3,287	45%	***3,685***	***51.9%***	3,685	51.9%

Table 5-1 from the Watermaster Annual Report is included as **Attachment B** to this memorandum and provides the updated values of the PSY analysis for each subarea. In general, elements of supply such as flow between subareas, tributary inflow, mountain front recharge, deep percolation of precipitation were obtained from the USGS model report by Stamos et al. (2001). Watermaster evaluated the production and consumptive uses during recent years and determined that Water Year 2024-25 represents current and near future cultural conditions, except for Este and Oeste, as explained in those sections. Outflows and imports were also evaluated by Watermaster and were reported based on the best available information, while considering the 1931-1990 base period constraint, and changed conditions that affect water supply, use and disposal.

Production Safe Yield

The definition of PSY in the Judgment compares long-term average supply to near term consumptive uses. Table 5-1 in **Attachment B** provides the results of the PSY calculations for each of the five subareas; footnotes in Table 5-1 provide the source of data for each element; values shown in italics and purple are explained in the section for the respective subarea.

Total Groundwater Production and Consumptive Uses

Watermaster considers the pumping and consumptive use values for Water Year 2024-25 representative for future planning. For this reason, consumptive uses and production values used in the PSY calculations of Table 5-1 are based on Water Year 2024-25, under the assumption that the water supply during the Water Years 1931 to 1990 and current cultural conditions would repeat themselves in the future. **Table 2** shows the total production, including production by Minimal Producers, and consumptive uses for each subarea from Water Years 2020 to 2025. As previously noted, the period for evaluating pumping in Este and Oeste is explained under those subarea sections.

Table 2. Historical Production and Consumptive Uses

Production

Subarea	2020	2021	2022	2023	2024	2025	Average
Alto	65,094	69,764	67,105	62,442	65,662	66,640	66,118
Transition Zone	12,618	11,809	10,351	10,039	9,872	9,689	10,730
Alto Total	77,712	81,573	77,456	72,481	75,534	76,329	76,847
Baja	20,894	15,095	12,749	11,419	10,707	10,481	13,558
Centro	18,309	19,685	16,995	16,393	16,646	15,884	17,319
Este	***5,181***	***5,258***	***5,068***	***4,501***	***4,758***	***4,334***	***4,850***
Oeste	***3,677***	***3,798***	***3,131***	***2,845***	***2,871***	***2,939***	***3,210***
Total	125,773	125,409	115,399	107,639	110,516	109,967	115,784

Note:
Production values include minimal producers.

Consumptive Use

Subarea	2020	2021	2022	2023	2024	2025	Average
Alto	33,489	37,871	33,745	31,927	35,246	35,781	34,676
Transition Zone	8,052	7,301	7,375	6,606	6,277	5,455	6,844
Alto Total	41,541	45,172	41,120	38,533	41,523	41,236	41,521
Baja	20,144	13,589	12,025	10,834	8,485	7,619	12,116
Centro	14,044	14,035	12,748	12,279	11,597	11,286	12,665
Este	***4,116***	***4,377***	***4,388***	***3,812***	***3,646***	***3,479***	***3,970***
Oeste	***2,528***	***2,574***	***2,046***	***1,869***	***2,086***	***2,279***	***2,230***
Total	82,372	79,746	72,328	67,326	67,337	65,900	72,502

Note:
Consumptive Use values include minimal producers.

Water Supply to Alto Subarea

Surface water inflow to the Basin Area is mostly from the Mojave River flow measured by the USGS gage stations at West Fork Mojave River near Hesperia, CA and Deep Creek near Hesperia, CA. The average gaged flow at the Forks during the base period 1931-1990 is 65,538 acre-feet per year (AFY). Additional elements of water supply to Alto Subarea are ungaged inflow including mountain front recharge, deep percolation of precipitation, and subsurface inflow from Oeste and Este subareas. Stamos et al. (2001) provides an estimate of mountain front recharge to the Alto Subarea; the term mountain front recharge includes ungaged surface water and deep percolation of precipitation. According to Stamos et al. (2001), the 1931-1990 average mountain front recharge to Alto is 7,763 AFY. Stamos et al. (2001) further describes tributary inflows between the Forks and Lower Narrows to be about 2,400 AFY between 1931-1994. This has been adjusted to the base period 1931-1990 to be 2,280 AFY.

Water Supply to Este and Oeste Subareas

Stamos et al. (2001) provides the following estimates for the 1931-1990 average ungaged surface flow: 1,035 AFY to Este and 1,941 AFY to Oeste. There is no measured surface water inflow or measured outflow from the Este and Oeste Subareas. As described later herein, these estimates are not supported by observations of water levels in those subareas.

Water Supply to Centro Subarea

Surface water flow from Alto to Centro is reported as the model estimated surface flow near Helendale (at Vista Road) as extracted from the USGS model by Stamos et al. (2001). The value, 32,972 AFY, represents the surface flow at Helendale Fault between 1931-1990, under the conditions that existed during that time period. Historical pumping in the Transition Zone (TZ) is provided in **Figure 1**, and shows that pumping has been in decline since at least the mid-1990's. Notably, total production and consumptive uses in the TZ have been decreasing over time.

Watermaster evaluated water levels in the TZ since 1990 and since entry of Judgment in January 1996. Our recent analysis demonstrates that water levels in the TZ are trending upwards or are stable. This evaluation can be found in the Watermaster's Technical Memorandum "Responses to Court's questions to be addressed in the next motion to adjust FPA", available via the following link:

https://www.mojavewater.org/wp-content/uploads/2025/06/TM_Addressing_Court_Questions_20250530.pdf

The evaluation demonstrated the stability of water levels supporting the conclusion that change in storage over time is nearly zero.

For the Water Year 2024-25, we estimated the consumptive use in the TZ to be 5,455 acre-feet and use this value to approximate the consumptive uses in the TZ for the near future. As the Stamos model includes consumptive uses from 1931-1990, which were on average much higher (12,367 acre-feet) than current and near future estimates (5,455 acre-feet), we can adjust the model flow at Vista Road (near Helendale) according to the change (difference) in consumptive use as estimated by Stamos et al. (2001) and as estimated by Watermaster over different time periods. Since water levels in the TZ are stable, and have been for many years, the change in flow through the TZ can be approximated by the change in the consumptive use. Thus, we can expect that future surface flow, under current land use conditions, will increase accordingly. Based on the foregoing, Watermaster's calculation shows that the surface outflow from Alto to Centro near Helendale is the average 1931-1990 modeled flow (32,972 acre-feet) plus the change in consumptive uses within the TZ (difference between 12,367 and 5,455) equals 39,884 acre-feet. The USGS model by Stamos et al. (2001) shows a storage depletion of 1,813 AFY during the period 1931-1990, thus the surface flow was adjusted to account for this change in storage. As shown on Table 5-1 (**Attachment B**), Watermaster's calculation result is 38,071 AFY.

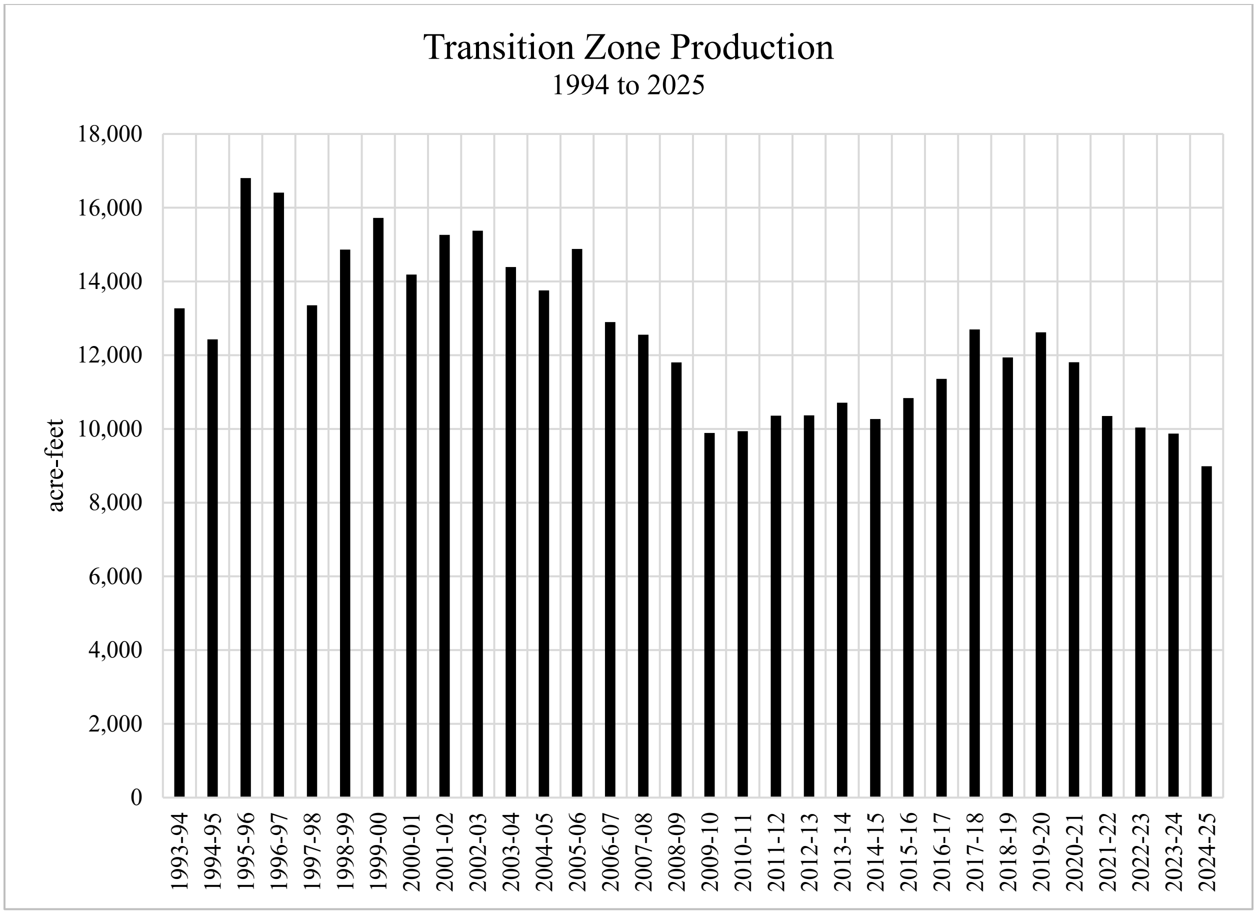


Figure 1. Historical production in the Transition Zone.

Surface Water Flow Centro to Baja

There are no gages measuring the surface flow from Centro to Baja. The Centro Subarea has a USGS gage station located in Barstow. The average gaged flow of the Mojave River at Barstow during the 1931-1990 base period is 17,097 AFY (Wagner & Bonsignore, 2012). The subarea boundary between Baja and Centro is the Waterman Fault, located several miles downstream of the Barstow gage and downstream of the Barstow Wastewater discharge. In 2012, Watermaster investigated the surface outflow from Centro to Baja at the Waterman Fault and determined this to be on average 16,406 AFY for 1931-1990. The average water flow from Centro to Baja has been studied and reported by Webb (2000) and the USGS Stamos model (2001). Table 3 is a compilation of the values reported by previous investigations.

Table 3. Estimates of surface water flow from Centro to Baja

	Source	Time Period Evaluated	Average Surface Water Flow (AFY)
Barstow	USGS Stamos (2001)	1931-1990	14,421
	USGS Streamflow Gage No. 10262500	1931-1990	17,097

	Source	Time Period Evaluated	Average Surface Water Flow (AFY)
Waterman Fault	USGS Stamos (2001)	1931-1990	10,678
	Wagner & Bonsignore (2012)	1931-1990	16,406
	Webb Associates (2000)	1931-1990	14,400
	Page C-3 of the Judgment After Trial (1996)	1931-1990	11,948 (based on the average gaged flow 17,097 at Barstow)

In addition to the Mojave River, there is ungaged inflow to Baja from tributaries and desert washes or mountain front recharge. The USGS report by Stamos et al. (2001) provides an estimated 647 acre-feet of recharge from Kane Wash and 3,705 acre-feet of tributary inflow (adjusted to 1931-1990). Watermaster has previously reported local surface inflow from Kane Wash and Boom Creek to be about 747 acre-feet (see **Attachment G**).

Estimates of subsurface inflow were determined by USGS, Stamos et al. (2001), and are assumed representative of the subsurface inflow currently, as water levels near the subarea boundary between Centro and Baja are reasonably stable over time.

Surface Water Outflow from Baja

The surface water outflow from the Baja Subarea is estimated from the USGS gage of Mojave River at Afton. However, this gage station is located about six miles downstream of the Baja Subarea boundary. Thus, we assumed that the flow at the downstream end of the Baja Subarea is the same as the flow measured at the Afton gage, assuming that ungaged tributary inflows between the boundary of the Baja Subarea and Afton are lost due to evaporation (Webb, 2000). The average gaged flow at Afton for the 1931-1990 base period is 8,732 acre-feet. Base flow of the Mojave River at Afton has changed substantially from the 1931-1990 base period (743 AFY) to the recent and current conditions (210 AFY during the years 1991-2025). To account for this change, an adjustment to the estimate of the total flow that includes the base flow representative of the current cultural conditions is needed. To achieve this, we calculated the average base flow of the Mojave River at Afton during the 1931-1990 period as follows: Storm Flow of Mojave River at Afton = Total Mojave River – Base Flow of Mojave River at Afton.

The average 1931-1990 storm flow of Mojave River at Afton is 7,989 acre-feet. The average of the 1991-2025 base flow of the Mojave River at Afton is 210 AFY. Therefore, total surface outflow from Baja that is representative of recent and present conditions is 8,199 AFY (rounded to 8,200 AFY for simplicity). The Judgment provides an estimate for long term average outflow at Afton of 8,200 AFY. This value includes an estimate for storm flow and base flow (subsurface discharge) and is based on the sixty-year hydrologic base period 1931-1990 (Wagner and Bonsignore, 2012).

The USGS model by Stamos et al. (2001) provides a subsurface outflow from Baja of 170 AFY. For purposes of the PSY calculations for Baja, Watermaster recommends using 8,030 AFY to be the surface outflow from Baja (see Table 5-1 in **Attachment B**).

Table 4. Estimates of surface water outflow from Baja

	Source	Time Period Evaluated	Average Surface Water Flow (AFY)
Afton	USGS Streamflow Gage No. 10263000	1931-1990	8,732
	USGS Streamflow Gage No. 10263000	1953-1990	6,066

	Source	Time Period Evaluated	Average Surface Water Flow (AFY)
MWA Boundary	Judgment After Trial (1996)	1931-1990	8,200
	Webb Associates (2000)	1931-1990	8,200
	Watermaster (2026)	1931-1990 (storm flow) + 1991-2025 (base flow)	8,030

Phreatophytes

Consumptive use values by phreatophytes are being evaluated by the California Department of Fish and Wildlife. For this analysis, Watermaster reported the annual amounts of riparian water use provided by the U. S. Geological Survey Water-Resources Investigations Report 96-4241 titled “Riparian Vegetation and Its Water Use During 1995 Along the Mojave River, Southern California”.

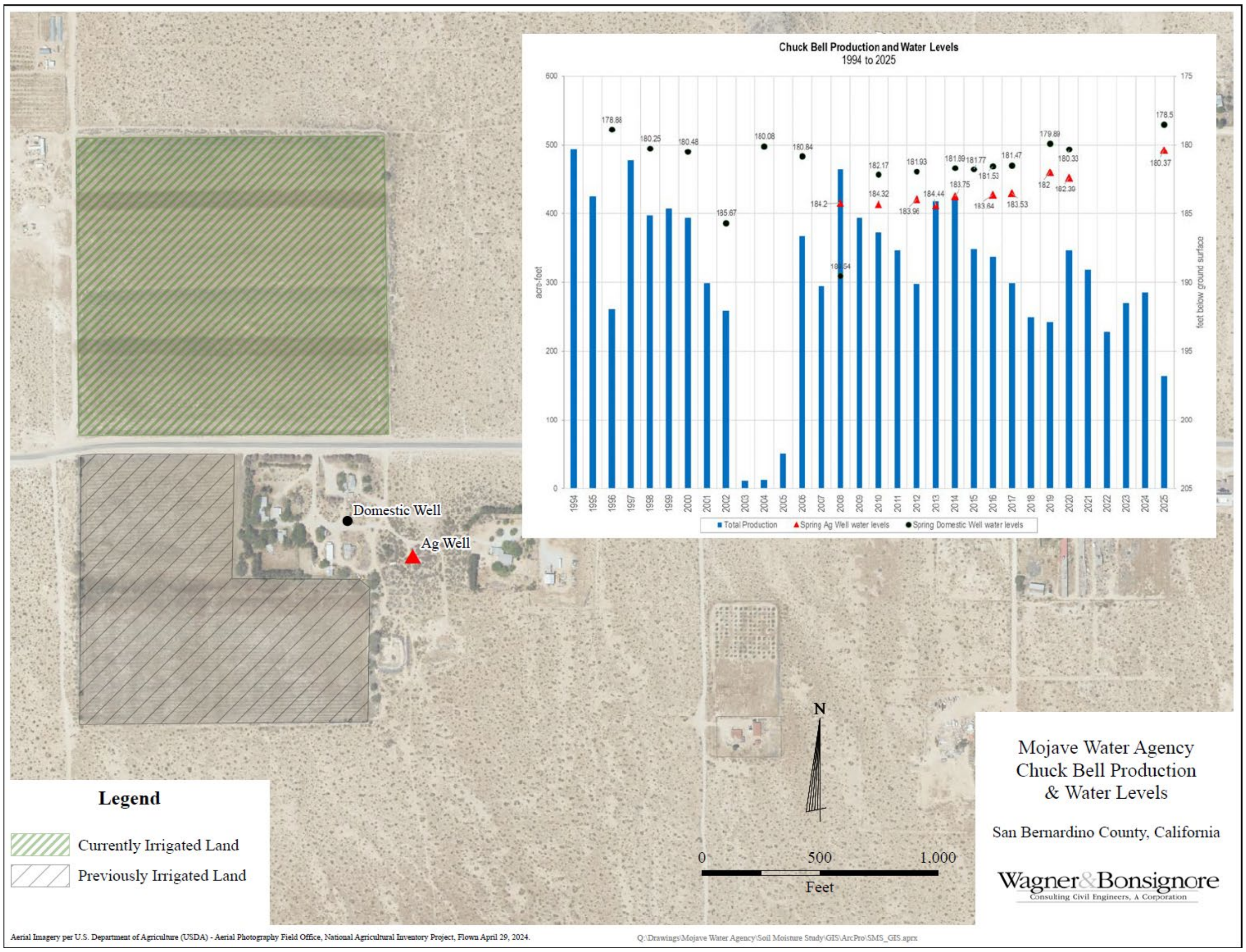
PSY Determination for each Subarea

Este Subarea

Table 5-1 (**Attachment B**) provides the estimates of water supply, pumping, outflows and consumptive use for Este Subarea. The water budget calculation shows a deficit of 1,439 AFY. Historical water levels are shown on the MWA Hydrograph Map for 2026 (see **Attachment D**). However, the observation of historical water levels since the mid-1990s indicates that change in storage within Este Subarea is nearly zero. In general, the historical water levels shown on the hydrograph are relatively stable or are only changing at a small rate.

A review of the well hydrographs indicates that water levels throughout Lucerne Valley generally remain unchanged in recent years and within Fifteenmile Valley, water levels are either relatively stable (see wells 04N01W09P06, 04N01W10R01), or are declining slowly (see wells 04N01W07R01, 04N01W18Q01, 04N02W09Q01). Based on these observations, net water supply and pumping are fairly closely balanced. For these reasons, Watermaster does not recommend PSY and FPA values based upon the 1931-1990 water budget (Table 5-1) which indicates a deficit.

An example of the relationship between water levels and production was evaluated by Watermaster at the Chuck Bell property in Este (see **Figure 2**). The Chuck Bell wells are indicative of the water level behavior we see in Este where the water levels have remained stable during the last 30 years.



Aerial Imagery per U.S. Department of Agriculture (USDA) - Aerial Photography Field Office, National Agricultural Inventory Project, Flown April 29, 2024.

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Figure 2. Chuck Bell production and water levels.

Historical pumping in Este is shown in **Figure 3**. Total production in Este Subarea has been in continuous decline since about 1996. In Water Year 2024-25, total pumping was 4,334 acre-feet. The average pumping during the period of record during which water levels have remained relatively constant (1996-2025) is 6,677 AFY.

The PSY can be defined as total pumping plus change in storage: PSY = Pumping + Change in Storage. Because water levels have remained relatively stable for several years, it is reasonable to conclude that the change in storage is near zero. Therefore, Watermaster recommends Este PSY of 6,677 acre-feet (total pumping plus change in storage).

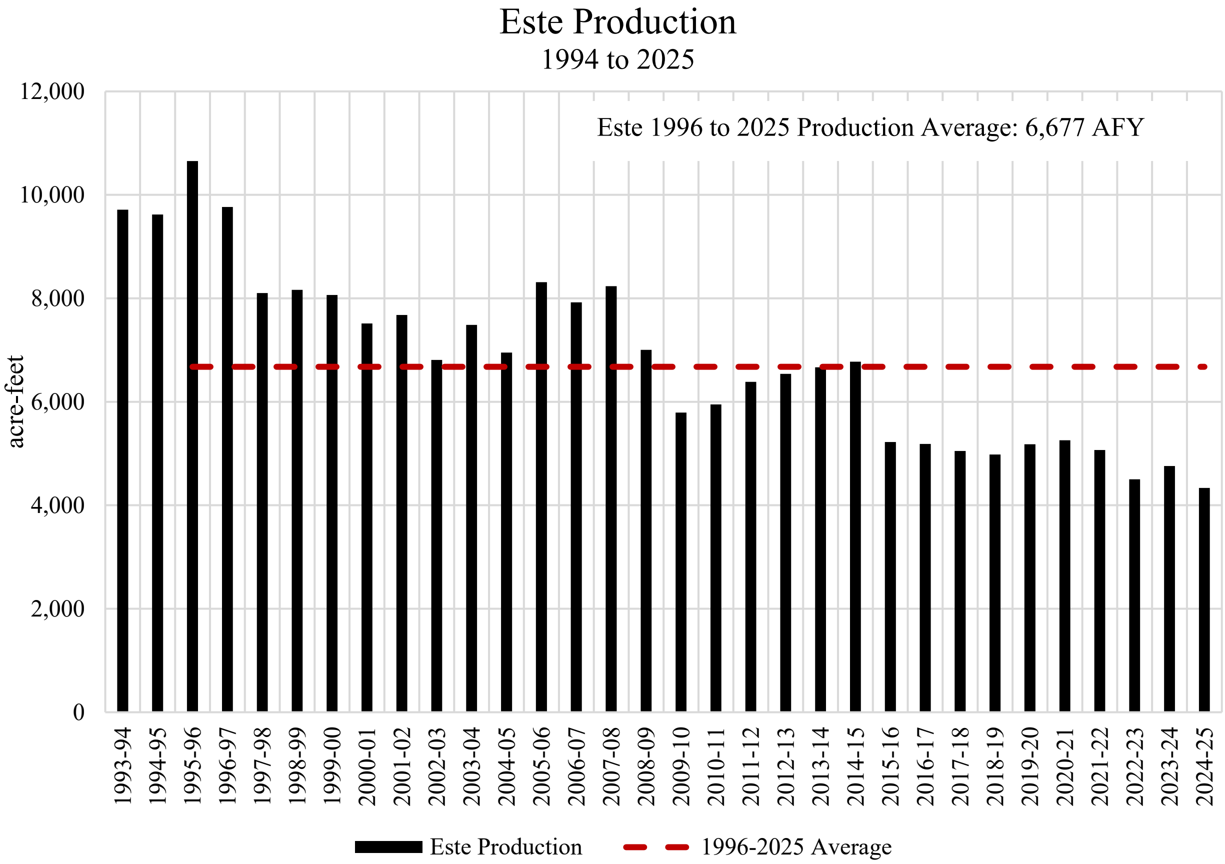

Figure 3. Historical production in Este Subarea.

Oeste Subarea

The PSY calculations (Table 5-1) for Oeste Subarea show a deficit of 841 acre-feet.

Review of well hydrographs prepared annually by MWA (see **Attachment E**) and groundwater elevation maps prepared by USGS from 1996 to 2016 indicate that groundwater levels in the Oeste subarea generally range widely, from about 500 to 600 feet below ground surface in the Phelan-Pinion Hills area in the more southerly part of the subarea, to about 100 to 300 feet in the vicinity of El Mirage and El Mirage Dry Lake. Water levels in the vicinity of a perched aquifer zone near Mirage Dry Lake identified by USGS are generally shallower than surrounding areas. The USGS Regional Water Table Maps spanning the period from 1996 to 2016 show a groundwater depression, presumably due to pumping, at the southern margin of El Mirage Dry Lake. However, monitoring by MWA indicates that groundwater levels are generally rising within the pumping depression.

Interpreting water-level trends in many of the wells is problematic, as levels are likely affected by pumping and can vary widely from year to year. This is the case for the wells in the Phelan-Pinion Hills area (05N07W31J03, 04N07W33J04, and 05N07W24D03). Further north in the area of El Mirage, water levels in the wells that are not influenced by pumping show generally little change or stability over time (06N07W17K01, 06N07W20D01, 06N07W26N02, and 06N06W18P03). And a few wells show increase in their water levels since around 2010 by about 70 feet (well 06N07W23C01-C03), and by about 30 feet (well 06N07W26C01). Because of the overall water level stability over time, it is reasonable to conclude that the change in storage is near zero during this time.

Table 5-1 (**Attachment B**) shows the total water supply of 2,477 AFY. Table 2Based on the general trends in water levels, and the continued decline in groundwater production, the PSY for Oeste is estimated to be approximately equal to the pumping (PSY = Total Pumping + Change in Storage). Historical pumping in Oeste is shown on **Figure 4**. Total pumping has been in decline during recent years. The average total production for the period 2010 to 2025 is 3,685 AFY. Table 5-1 shows a deficit of -841 AFY, which is in conflict with the overall behavior of the water levels. This is likely due to the uncertainty of the estimates of the ungaged inflows and outflows. Given the land use and pumping have changed noticeably during the recent years, Watermaster recommends basing the PSY on the average total pumping of 3,685 acre-feet for the period 2010-2025.

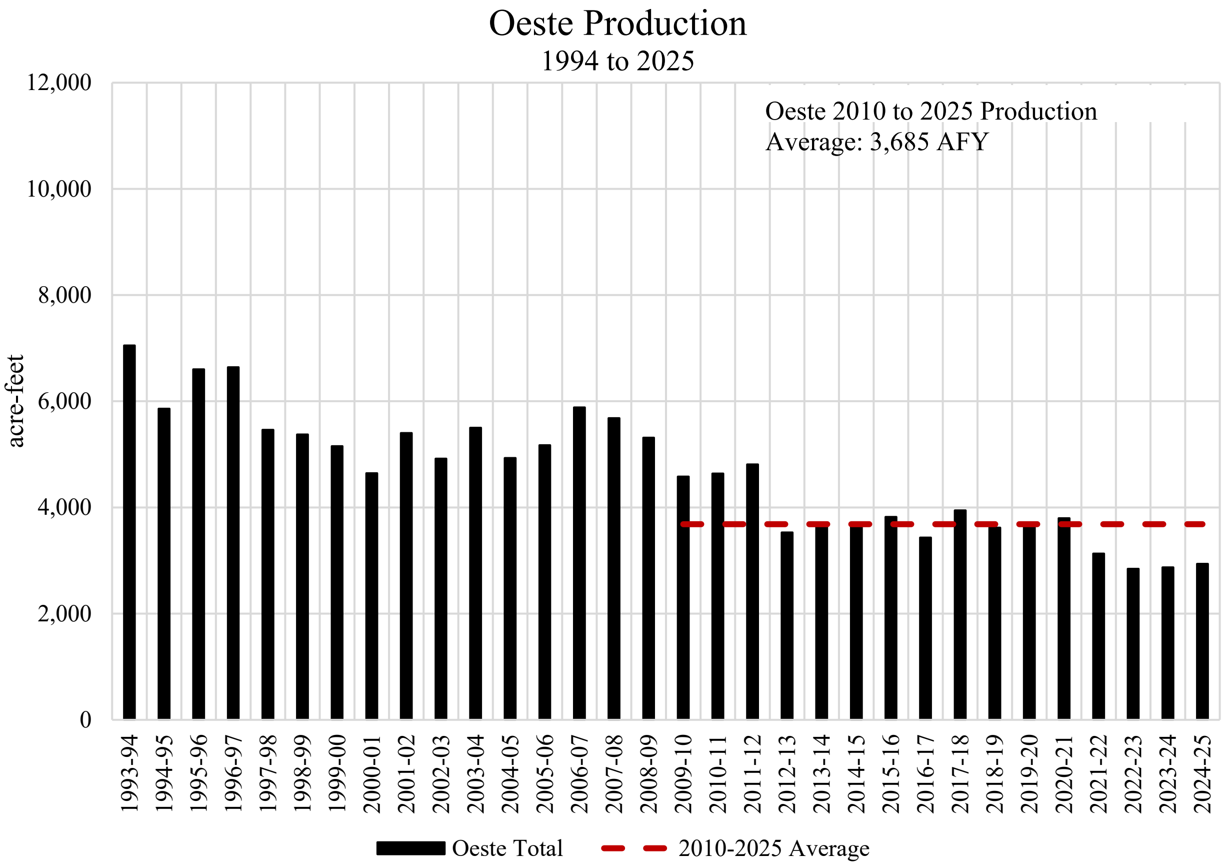

Figure 4. Historical production in Oeste Subarea.

Alto Subarea

For Alto Subarea, the PSY calculation indicates a total deficit of 12,887 acre-feet. Total pumping during Water Year 2024-25 was 76,329 acre-feet. PSY = Pumping + Surplus/(Deficit). Therefore, PSY for Alto is 63,442 acre-feet.

Centro Subarea

For the Centro Subarea, the water balance calculation shows a surplus of 9,763 acre-feet (Table 5-1 in **Attachment B**). The PSY is calculated as the sum of total pumping (15,884) and the indicated surplus (9,763). Initial calculation of the PSY is 25,647 acre-feet. However, we note that if the surplus were to be pumped and water use was similar to the current patterns of use, a portion of the surplus (equal to 28.9% which is the return flow percentage) increases the PSY to 28,473 acre-feet.

Baja Subarea

Table 5-1 (**Attachment B**) indicates a surplus of 4,501 AFY based on the 1931-1990 average water supply and outflow, and consumptive uses for the Water Year 2024-25 which is representative of future land uses and pumping in Baja Subarea. Consumptive uses by riparian vegetation is consistent with the estimates by Lines and Bilhorn (1996) of 2,000 AFY as explained in the *Phreatophytes* section above.

The calculation of PSY for Baja is 14,982 AFY (total pumping plus surplus). If the surplus were to be pumped and water use was similar to the current patterns of use, a portion of the surplus (equal to 27.3% which is the return flow percentage) increases the PSY to 16,211 AFY.

Historical water production and irrigated acreages in Baja Subarea are shown in **Figure 5**. Total pumping in Baja has been declining since before entry of Judgment (1996), decreasing from approximately 50,000 acre-feet in 1996 to 10,481 acre-feet in Water Year 2024-25 —a reduction of roughly 79%. Since 2016, pumping has been steadily decreasing by approximately 65%. The total average pumping during the last five years is 12,090 AFY.

The impact of this reduction is evident in the water level hydrographs (see **Attachment F**), which depict groundwater level changes across Baja over time. For several decades, most wells have exhibited a long-term downward trend, indicating depletion of groundwater storage. However, consistent with the substantial decline in pumping over the past 10 to 12 years—and the overall reduction over the past 30 years—water levels in some wells appear to be stabilizing, suggesting they may have reached, or are approaching, a low point.

In certain wells, water levels have begun to recover, while others continue to decline. Wells showing stabilization or recovery are generally located in areas where pumping has significantly decreased in recent years. Water level hydrographs are attached for review.

Assuming the water levels will continue to behave as shown for the recent years, and assuming that future pumping does not increase, the PSY for Baja is likely equal to or slightly greater than the average pumping during recent years (12,090 AFY for the Water Years 2020-21 through 2024-25). However, based on the Table 5-1 calculation, current land uses, and the 60-year average water supply, PSY would be 16,211 acre feet.

The Department of Fish and Wildlife has indicated that the riparian habitat area shown on exhibit H-1 near Camp Cady is stressed, and water levels remain depressed. Exhibit H, paragraph 2.a of the Judgment states *"In considering whether to increase or decrease the Free Production Allowance in a Subarea, Watermaster shall, among other factors, take into consideration for the areas shown on Figure H-1 the Consumptive Use of water by riparian habitat, the protection of public trust resources, including the species listed in Table H-1 and the riparian habitat areas shown on Figure H-1, and whether an increase would be detrimental to the protection of public trust resources."*

Following the direction in Exhibit H-1, paragraph 2a, to consider whether an increase in PSY and FPA "would be detrimental to the protection of public trust resources" and, particularly, the challenges experienced in attempting to protect public trust resources in the Camp Cady area, Watermaster recommends the Baja Subarea PSY remain unchanged (although the indicated PSY for the Baja Subarea is 16,211 acre feet).

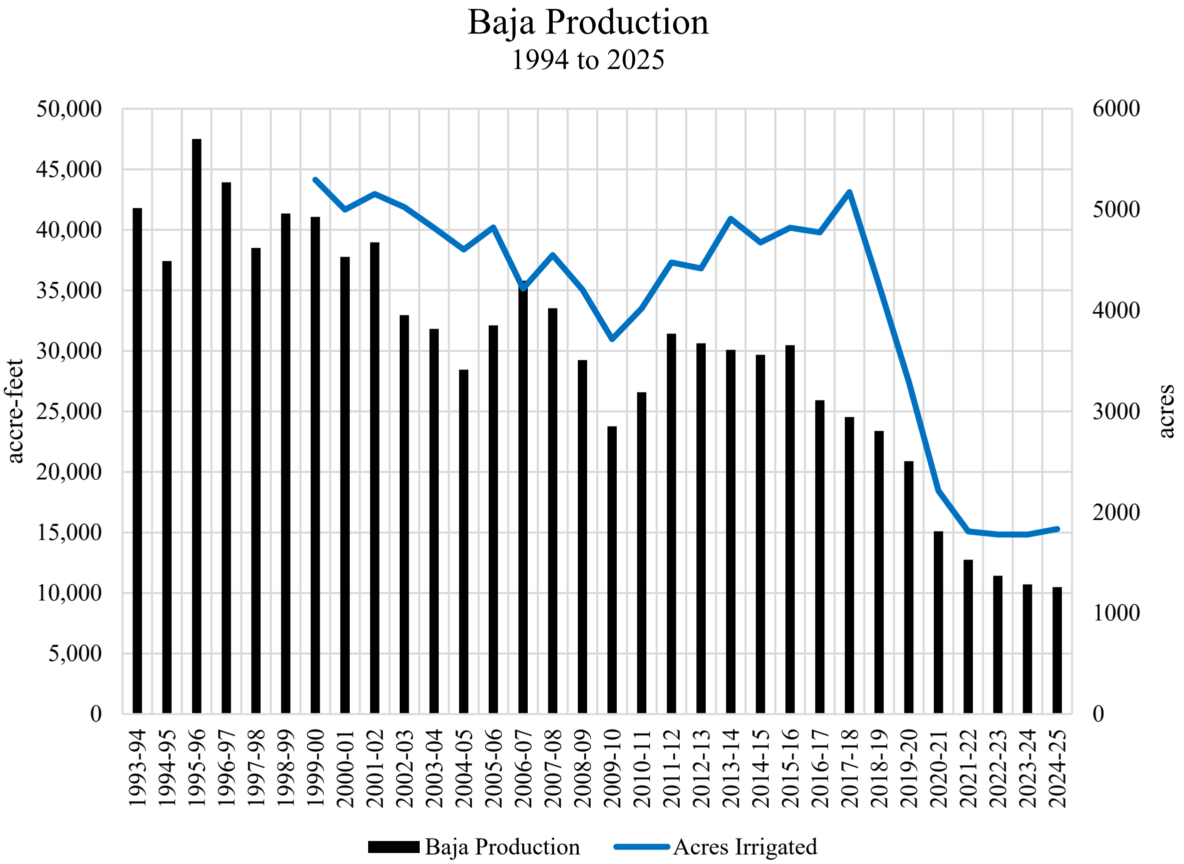

Figure 5. Historical production in Baja Subarea.

Imports

Elements of supply included in PSY include certain imports that have been long-term reliable supplies but could be interrupted. Wastewater effluent discharged to the MBA in Alto by Lake Arrowhead Community Services District (LACSD), and wastewater effluent discharged to Este by Big Bear Area Wastewater Reclamation Authority (BBAWRA), is included in the PSY calculation for those subareas. The amounts of discharge are reported in the Watermaster Annual Report (page 23) and considered representative for future planning. Changes that occur in the annual amount discharged by these entities are evaluated annually and reported in the Annual

Reports. Makeup Water Obligations are not included in the PSY calculations given that those started around 1993, and therefore not part of the water supply during the period 1931 to 1990.

Enclosures:

Attachment A Table C-1 of Judgment

Attachment B Table 5-1 Production Safe Yield Update

Attachment C Alto Subarea Transition Zone Hydrographs 2026

Attachment D Este Subarea Hydrographs 2026

Attachment E Oeste Subarea Hydrographs 2026

Attachment F Baja Subarea Hydrographs 2026

Attachment G Analysis of Baja Water Supply and Outflow by Wagner and Bonsignore dated February 22, 2012

Attachment A

TABLE C-1

Mojave Basin Area Adjudication
Subarea Hydrological Inventory Based On Long-Term Average Natural Water Supply and Outflow and Current Year Imports and Consumptive Use
(All Amounts in Acre-Feet)

	Este	Oeste	Alto	Centro	Baja	Basin Totals
WATER SUPPLY						
Surface Water Inflow						
Gaged	0	0	65,000	0	0	65,000
Ungaged	1,700	1,500	3,000	37,300[1]	14,300[2]	6,500[3]
Subsurface Inflow	0	0	1,000	2,000	1,200	0[4]
Deep Percolation of Precipitation	0	0	3,500	0	100	3,600
Imports						
Lake Arrowhead CSD	0	0	1,500	0	0	1,500
Big Bear ARWWA	2,000	0	0	0	0	2,000
TOTAL	3,700	1,500	74,000	39,300	15,600	78,600
CONSUMPTIVE USE AND OUTFLOW						
Surface Water Outflow						
Gaged	0	0	0	0	8,200	8,200
Ungaged	0	0	37,300[1]	14,000[5]	0	0
Subsurface Outflow	200	800	2,000	1,200	0	0
Consumptive Use						
Agriculture	6,800	2,900	16,300	20,300	30,200	76,500
Urban	1,900	1,200	36,300	9,500	9,700	58,600
Phreatophytes	0	0	5,100	900	1,500	7,500[6]
Exports	0	0	0	0	0	0
TOTAL	8,900	4,900	97,000	45,900	49,600	150,800
Surplus / (Deficit)	(5,200)	(3,400)	(23,000)	(6,600)	(34,000)	(72,200)
Total Estimated Production (Current Year)[7]	15,700	7,600	98,900	46,500	54,300	223,000
PRODUCTION SAFE YIELD (Current Year)[7]	10,500	4,200	75,900	39,900	20,300	150,800

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[1] Estimated from reported flows at USGS gaging station, Mojave River at Victorville Narrows.

[2] Includes 14,000 acre-feet of Mojave River surface flow across the Waterman Fault estimated from reported flows at USGS gaging station, Mojave River at Barstow, and 300 acre-feet of local surface inflow from Kane Wash.

[3] Represents the sum of Este (1,700 af), Oeste (1,500 af), Alto (3,000 af) and Baja (300 af from Kane Wash).

[4] Inter subarea subsurface flows do not accrue to the total basin water supply.

[5] Estimated from reported flows at USGS gaging station, Mojave River at Barstow.

[6] Estimated by Bookman-Edmonston.

[7] For purposes of this Table, the current year is 1990.

Attachment B

TABLE 5-1
Production Safe Yield Update
Based on 1931-1990 Average Natural Water Supply and Outflow, Average Imports, and Consumptive Use, and Production for 2024-25, except as noted

(all amounts in acre-feet)

WATER SUPPLY	**Este**	**Oeste**	**Alto**	**Centro**	**Baja**	**Basin Totals**
Surface Water Inflow						
Gaged	0	0	65,538 [2]	0	0	65,538
Ungaged	1,035 [1]	1,941 [1]	7,763 [1]	38,071 [3]	17,153 [5]	10,739 [7]
Tributary Inflow[4]	0	0	2,280	2,280	3,705	2,280 [7]
Subsurface Inflow	0 [9]	536 [8]	2,034 [9]	1,566 [9]	1,462 [9]	0 [10]
Imports						
Lake Arrowhead CSD	0	0	1,371 [11]	0	0	1,371
Big Bear ARWWA	2,000 [6]	0	0	0	0	2,000
TOTAL	**3,035**	**2,477**	**78,986**	**41,917**	**22,320**	**81,928**
CONSUMPTIVE USE AND OUTFLOW						
Surface Water Outflow	0	0	38,071 [3]	16,406 [12]	8,030 [13]	8,030
Subsurface Outflow	995 [9]	1,039 [9]	1,566 [9]	1,462 [9]	170 [9]	0 [6]
Consumptive use						
Agriculture[14]	1,660	13	800	5,786	4,592	12,851
Urban[14,15]	1,819	2,266	40,436	5,500	3,027	53,048
Phreatophytes[16]	0	0	11,000	3,000	2,000	16,000
TOTAL	**4,474**	**3,318**	**91,873**	**32,154**	**17,819**	**89,929**
Surplus / (Deficit)	***~~(1,439)~~***	***~~(841)~~***	(12,887)	9,763	4,501	(8,001)
Total Estimated Production[17]	6,677	3,685	76,329	15,884	10,481	113,056
PRODUCTION SAFE YIELD[18]	**6,677** [19]	**3,685** [19]	**63,442**	**28,473** [20]	**16,211** [20]	**105,055**
INDICATED FREE PRODUCTION ALLOWANCE	***33.0%***	***51.9%***	***54.5%***	***55.8%***	***24.5%***	

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[1] Mountain-front recharge values from Table 10 of Stamos et al (2001), simulated hydrologic budgets for the average 1931-1990. Mountain-front recharge includes ungaged surface water and deep percolation of precipitation.

[2] Average discharge of Mojave River at The Forks, 1931-1990 (The Forks is the addition of reported values from USGS stations at West Fork Mojave River Near Hesperia, CA (10261000) and Deep Creek Near Hesperia, CA (10260500).

[3] Average 1931-1990 surface flow near the Helendale Fault from the USGS model by Stamos et al (2001), adjusted by decreases in the consumptive use from production within the Transition Zone from model period 1931-1990 to the Water Year 2024-25.

[4] Tributary inflow from page 15 of Stamos et al (2001) averaged about 2,400 AFY to Alto (above the Lower Narrows), about 2,400 AFY to both the Transition Zone and Centro, and about 3,900 AFY to Baja for 1931-1994. Reported values are adjusted for the base period 1931-1990.

[5] Includes 16,406 af of Mojave River surface flow across the Waterman Fault estimated by "Evaluations of Potential Mojave River Recharge Losses between Barstow and Waterman Fault", and 747 af of local surface inflow from Kane Wash and Boom Creek (Wagner & Bonsignore, 2012).

[6] Judgment After Trial, 1996, Table C-1.

[7] Represents the sum of Este, Oeste, and Alto.

[8] Additional subsurface flow from Sheep Creek of 536 af.

[9] Average 1931-1990 subsurface flows per Figure 34 of Stamos et al, 2001 (USGS).

[10] Inter subarea subsurface flows do not accrue to the total basin water supply.

[11] Lake Arrowhead CSD average Water Year 1996 to 2025

[12] Estimated by "Evaluations of Potential Mojave River Recharge Losses between Barstow and Waterman Fault", Wagner & Bonsignore, 2012.

[13] Watermaster calculation based on average 1931-1990 storm flow and 1991-2025 base flow of the USGS gage Mojave River at Afton, CA (10263000), minus subsurface flow from Baja of 170 AFY.

[14] Consumptive Use Analysis by Watermaster for Water Year 2024-25.

[15] Includes consumptive use of "Minimals Pool" (estimated Minimal's production is 7,077 af).

[16] From USGS Water-Resources Investigation Report 96-4241 "Riparian Vegetation and Its Water Use During 1995 Along the Mojave River, Southern California" by Lines and Bilhorn (1996).

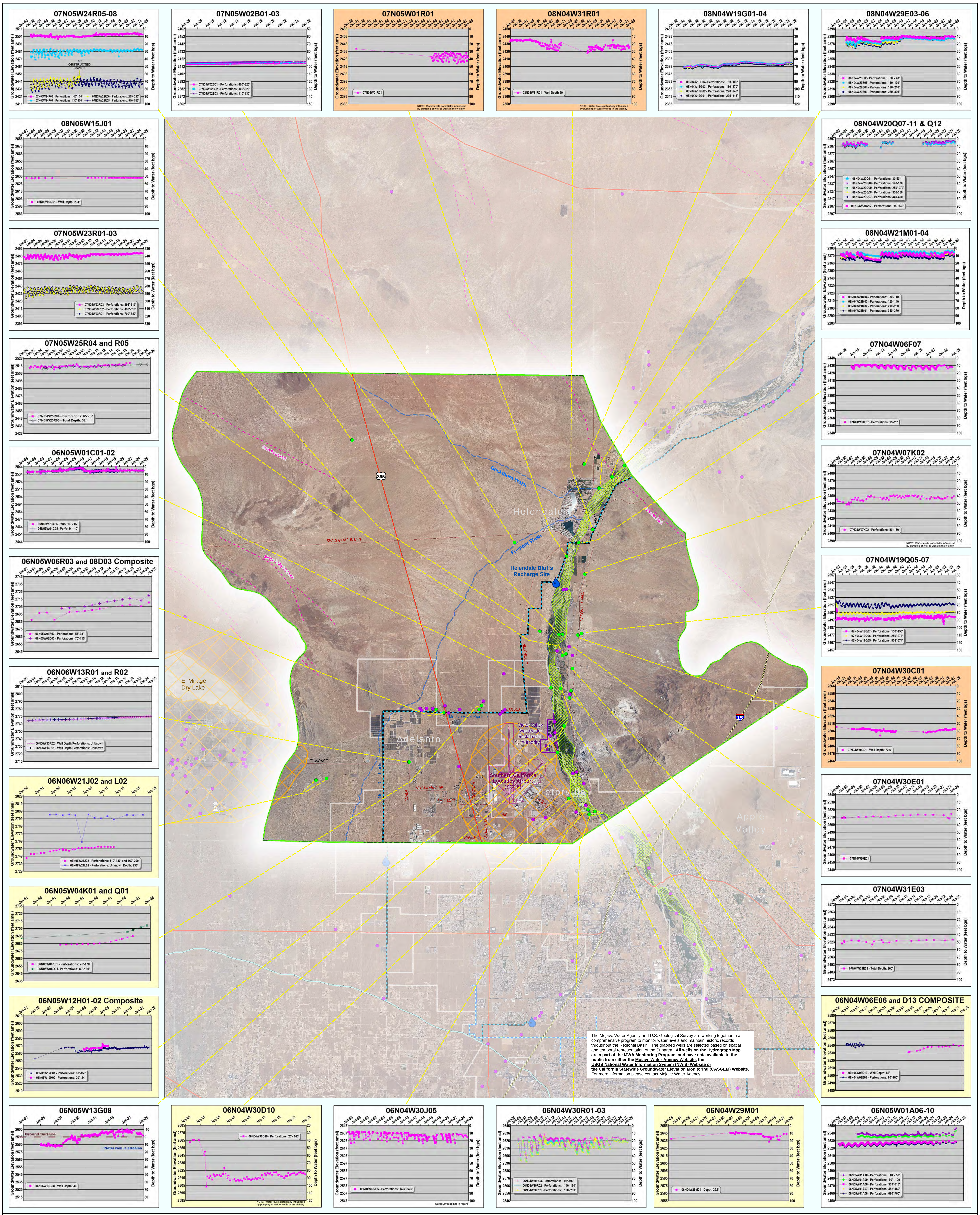
[17] Production data for Alto, Centro and Baja for Water Year 2024-25. Production for Este is the 1996-2025 average, and for Oeste is the 2010-2025 average. Included in the production values are the estimated minimal producer's water use by Subarea.

[18] Imported State Water Project water purchased by MWA is not reflected in the above table.

[19] For Este and Oeste Subareas, the Production Safe Yield is assumed equal to the average production during the period of time when change in storage is approximately zero (see pages 9 through 12 of Watermaster's Technical Memorandum).

[20] For Centro and Baja Subareas, calculated PSY includes a portion of the surplus corresponding to return flow percentage during Water Year 2024-25 as follows: 28.9% for Centro and 27.3% for Baja.

Attachment C



The Mojave Water Agency and U.S. Geological Survey are working together in a comprehensive program to monitor water levels and maintain historic records throughout the Regional Basin. The graphed wells are selected based on spatial and temporal representation of the Subarea. **All wells on the Hydrograph Map are a part of the MWA Monitoring Program, and have data available to the public from either the Mojave Water Agency Website, the USGS National Water Information System (NWIS) Website or the California Statewide Groundwater Elevation Monitoring (CASGEM) Website.** For more information please contact Mojave Water Agency.

Mojave Water Agency

Data Sources:
MWA, US Census
USGS/NWIS,
DWR Bulletin 84 1967
Date: January 2024
Mojave Water Agency
Water Resources Department

● Graphed Wells
● MWA Monitoring Program Wells
- - - MWA Potable Pipeline
- - - MWA Recharge Pipeline
- - - CA Geologic Faults (CGS, USGS)
▨ USGS Perched Water Table

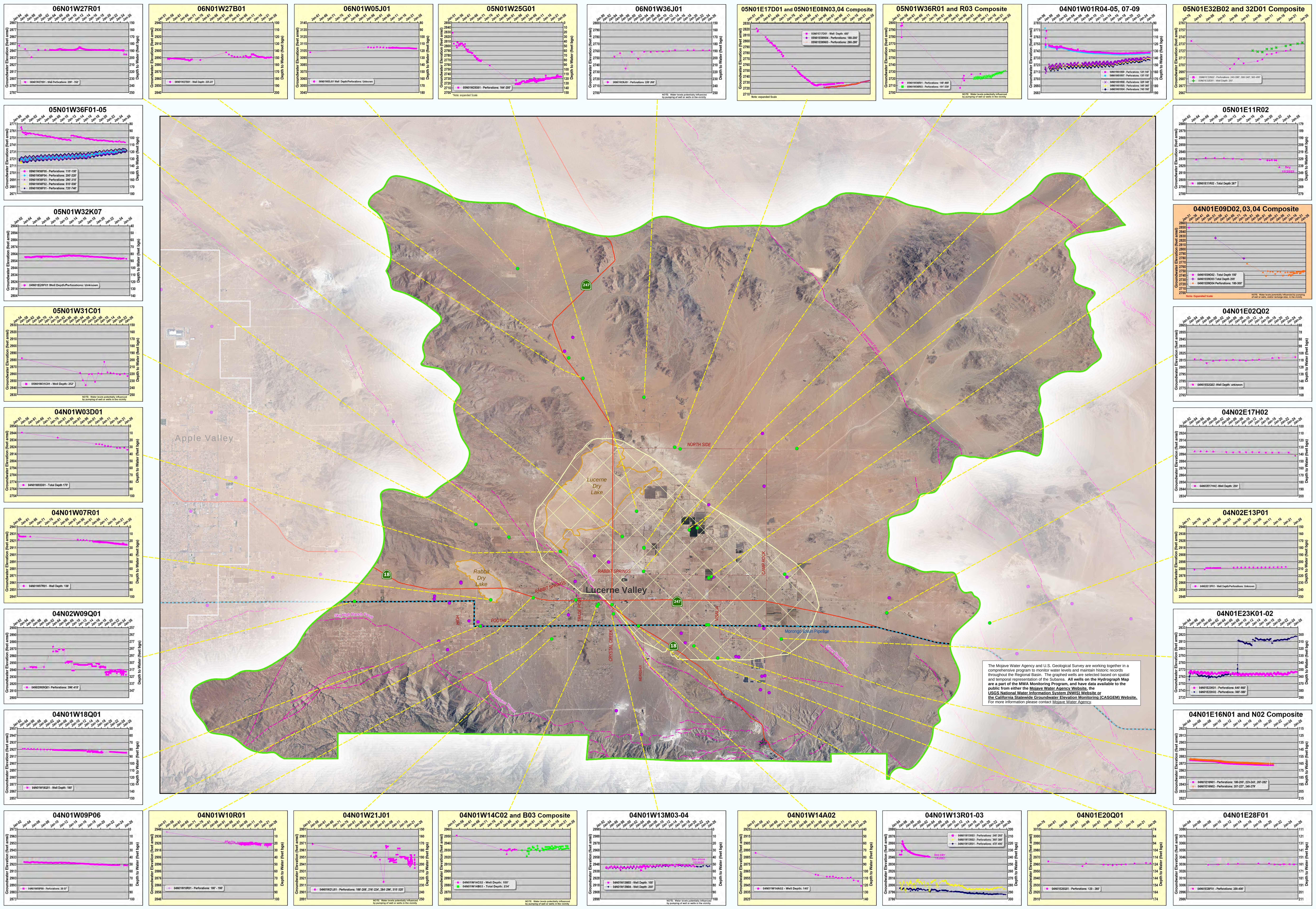
Alto Subarea Transition Zone Hydrographs 2026

☐ Recent record
🟨 Long-term record (begins ~1950 to ~ 1980)
🟧 Very long-term record (begins ~1920)

0 0.5 1 2
Miles

N

Attachment D



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Data Sources:
MWA, US Census,
USGS/NWIS,
DWR Bulletin 84 1967
Date: 02/2026
Mojave Water Agency
Water Resources Department

● Graphed Wells
● MWA Monitoring Program Wells
MWA Recharge Pipeline
CA Geologic Faults (CGS, USGS)
USGS Perched Water Table

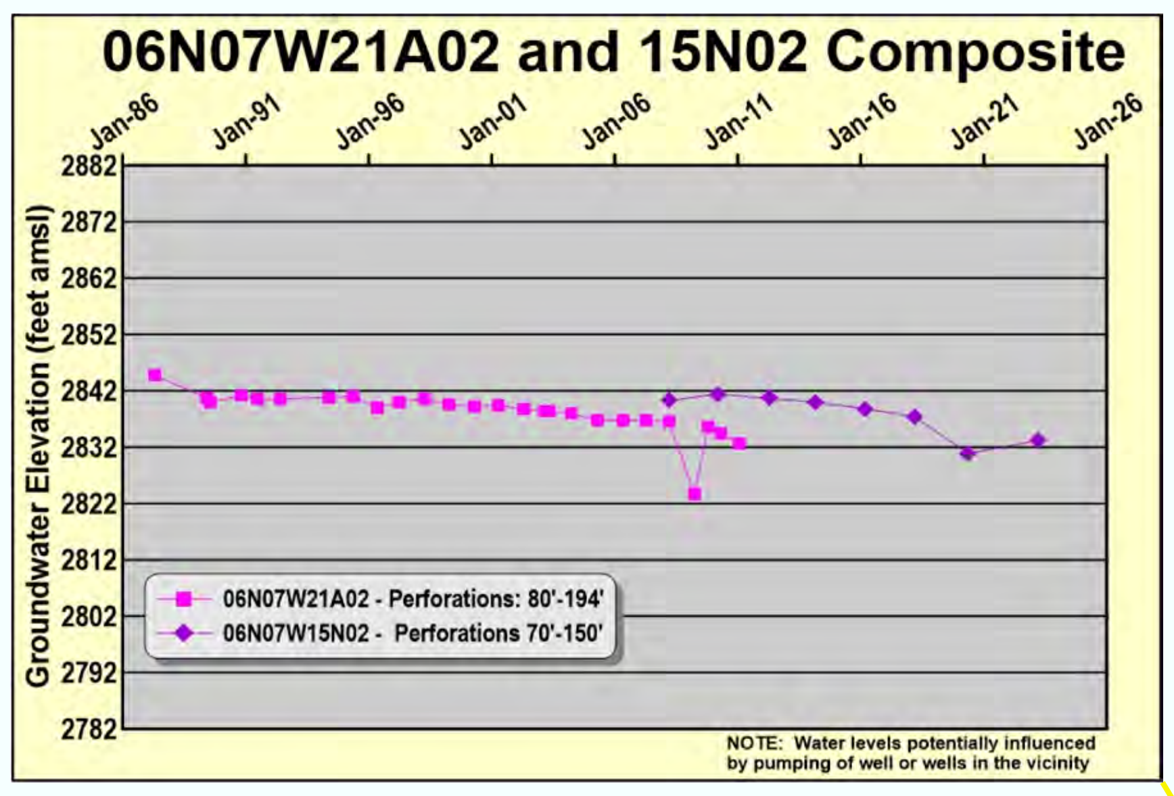
Este Subarea Hydrographs
2026

☐ Recent record
🟨 Long-term record (begins ~1950 to ~1980)
🟧 Very long-term record (begins ~1920)

0 1 2 4
Miles

N

Attachment E



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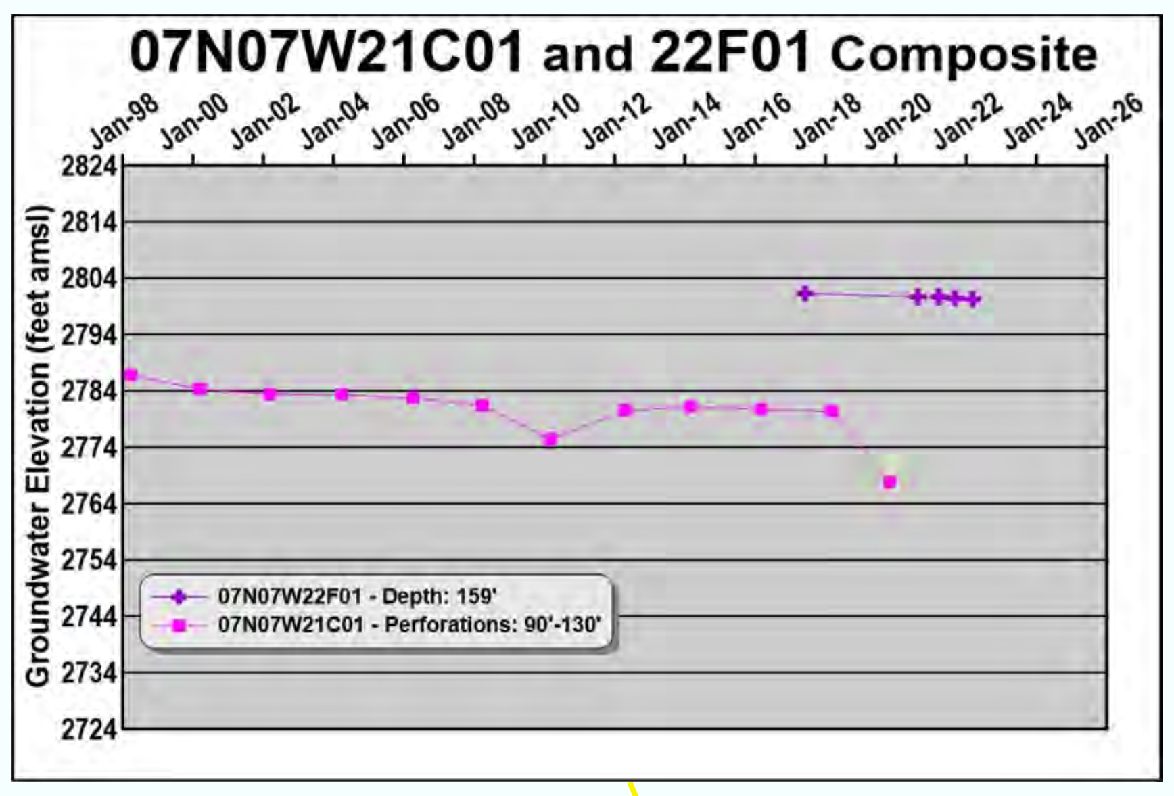

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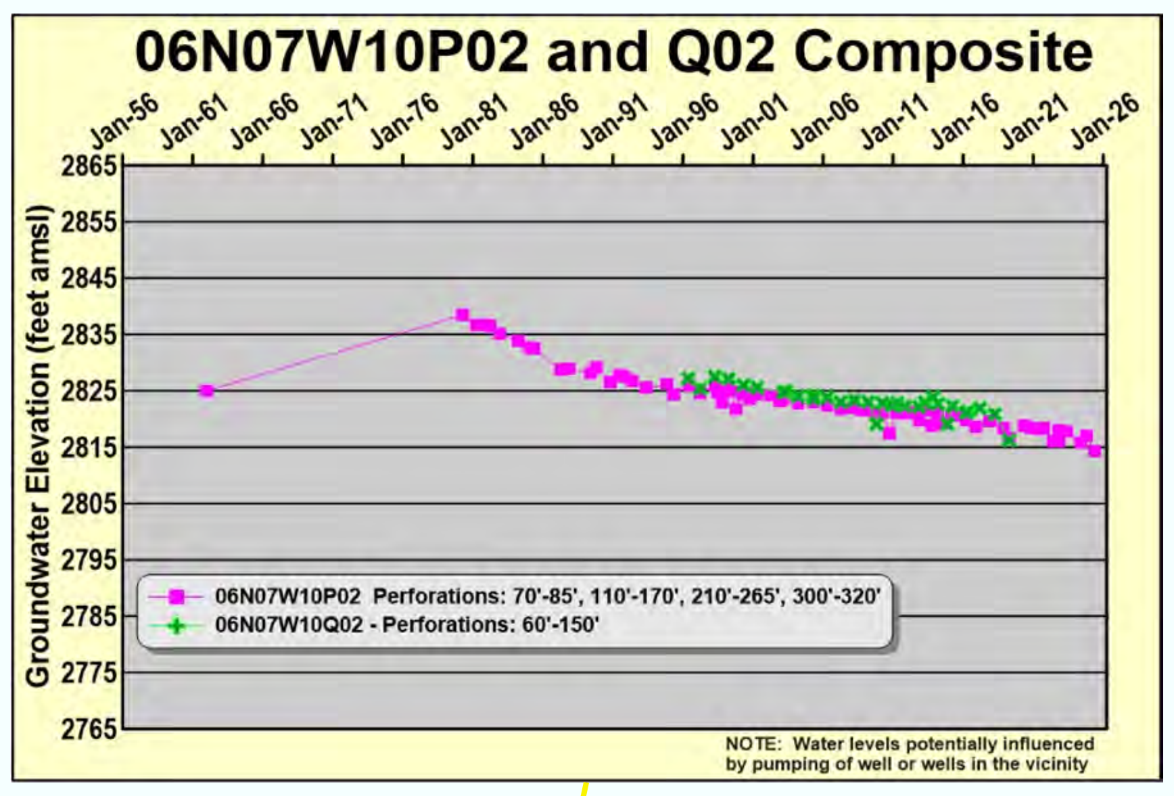

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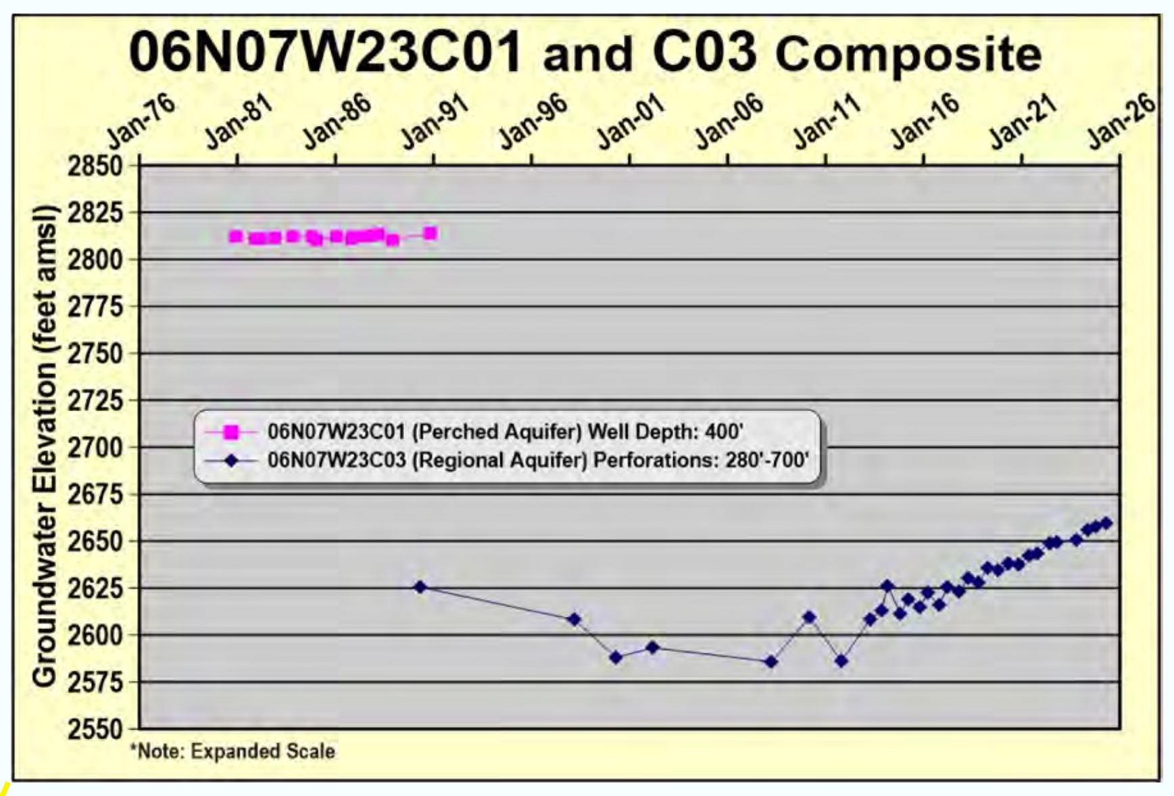

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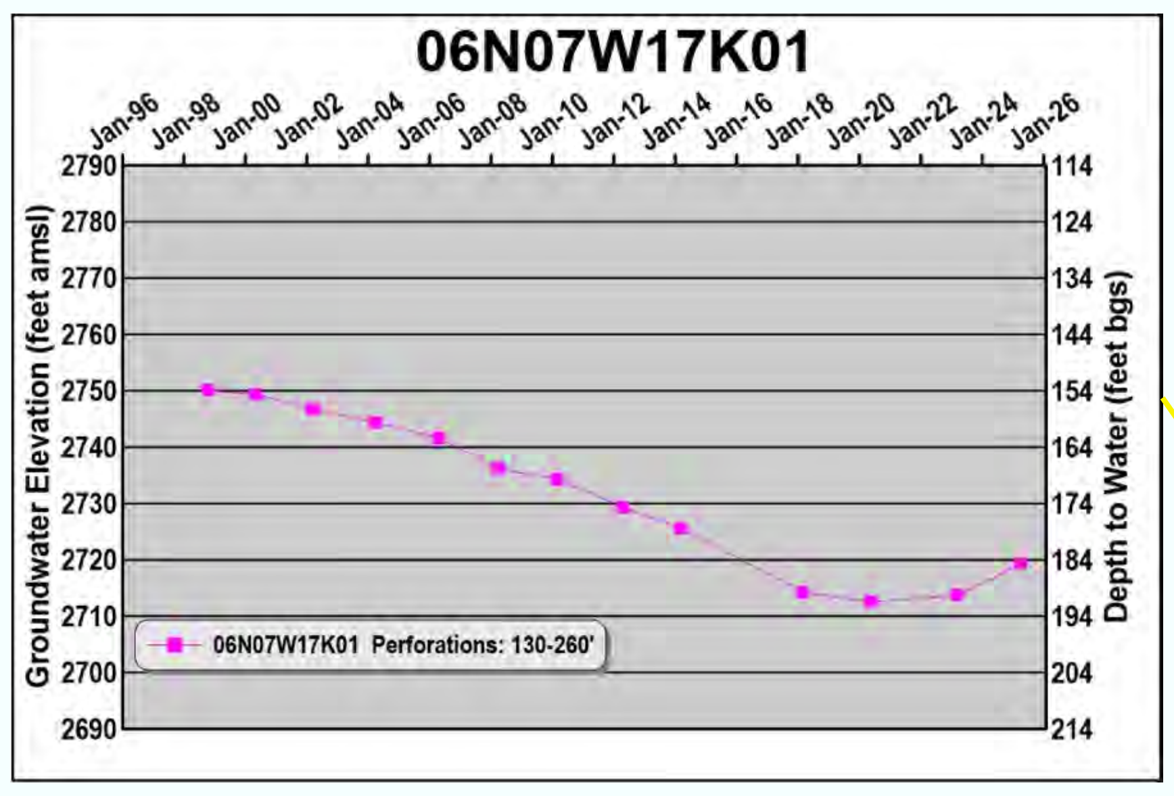

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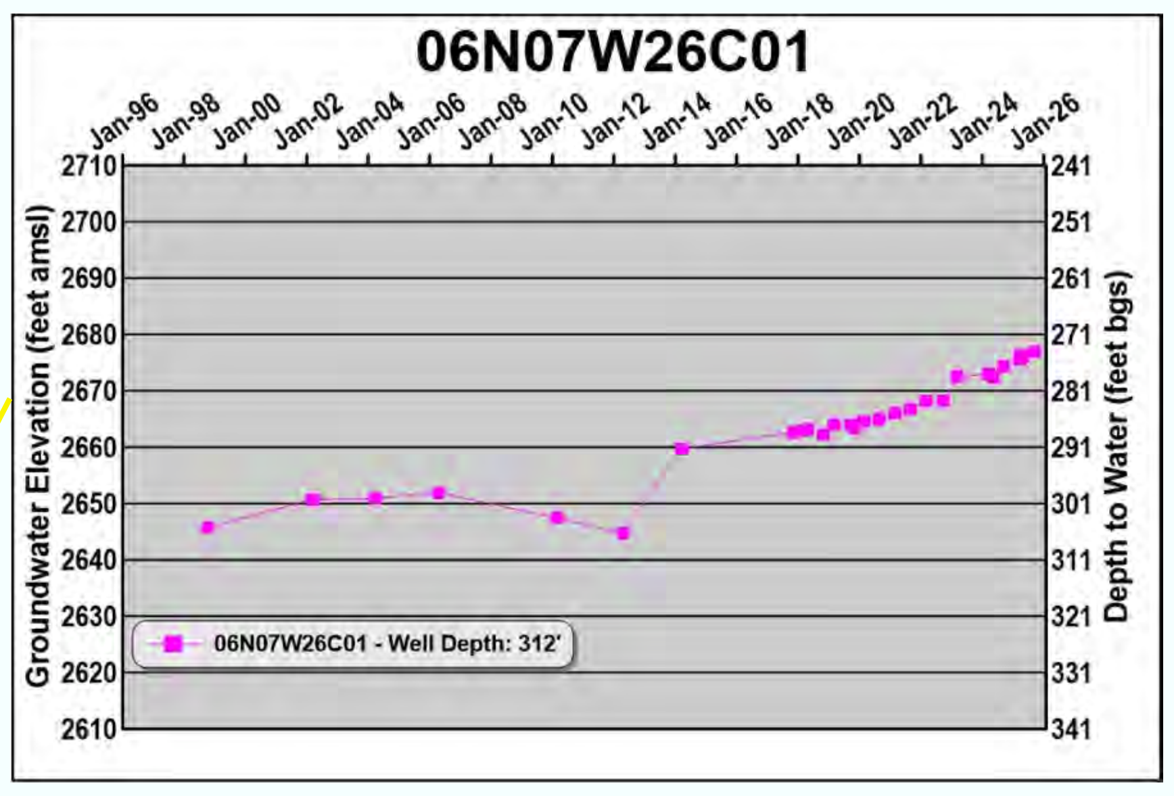

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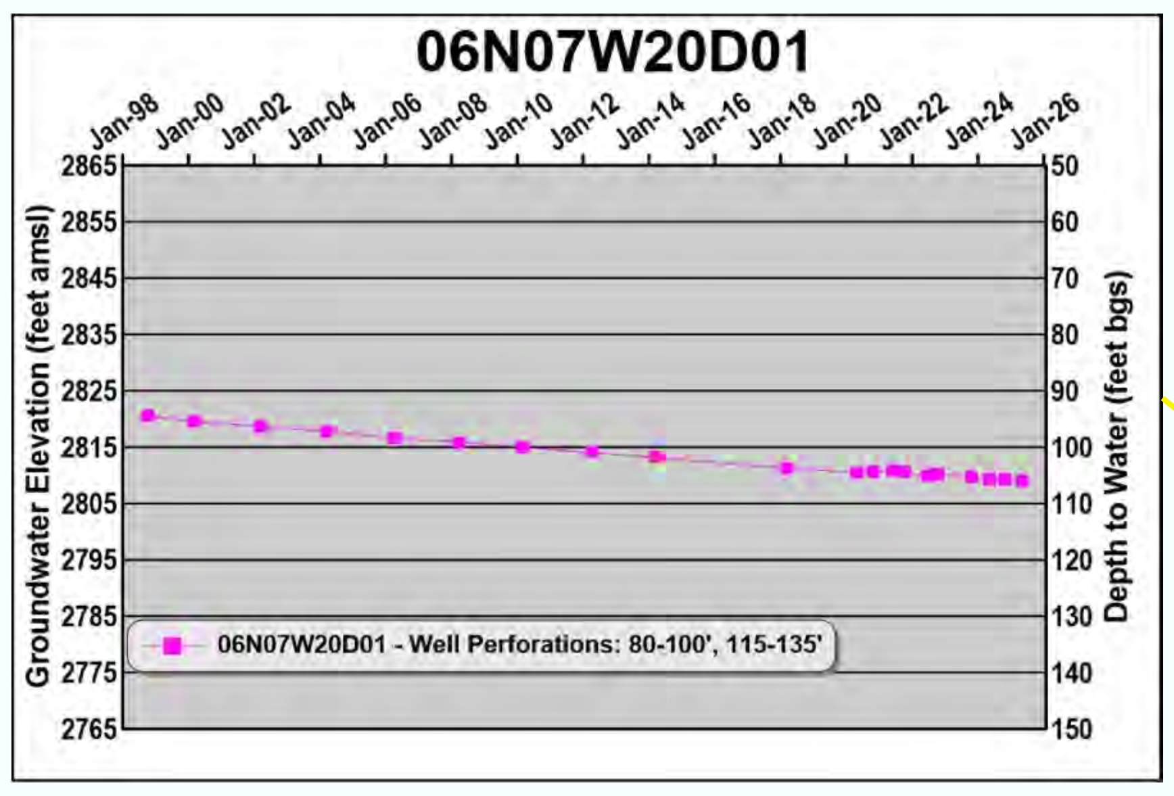

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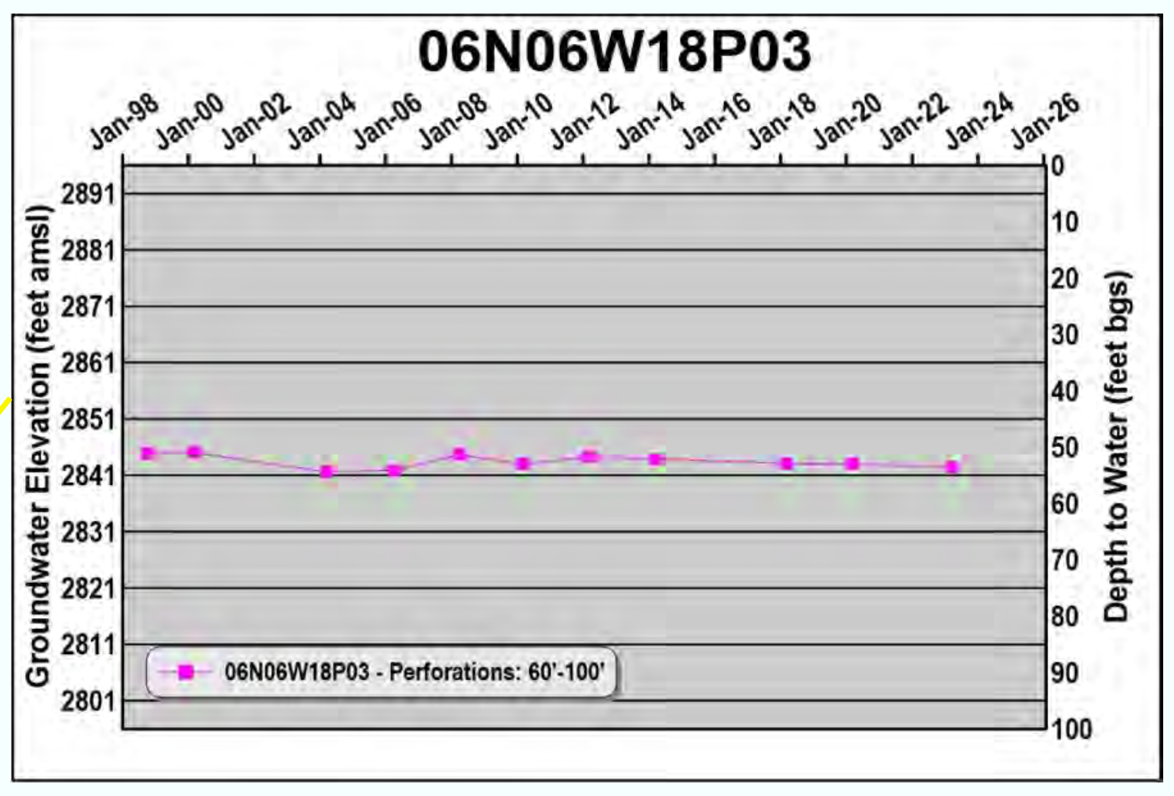

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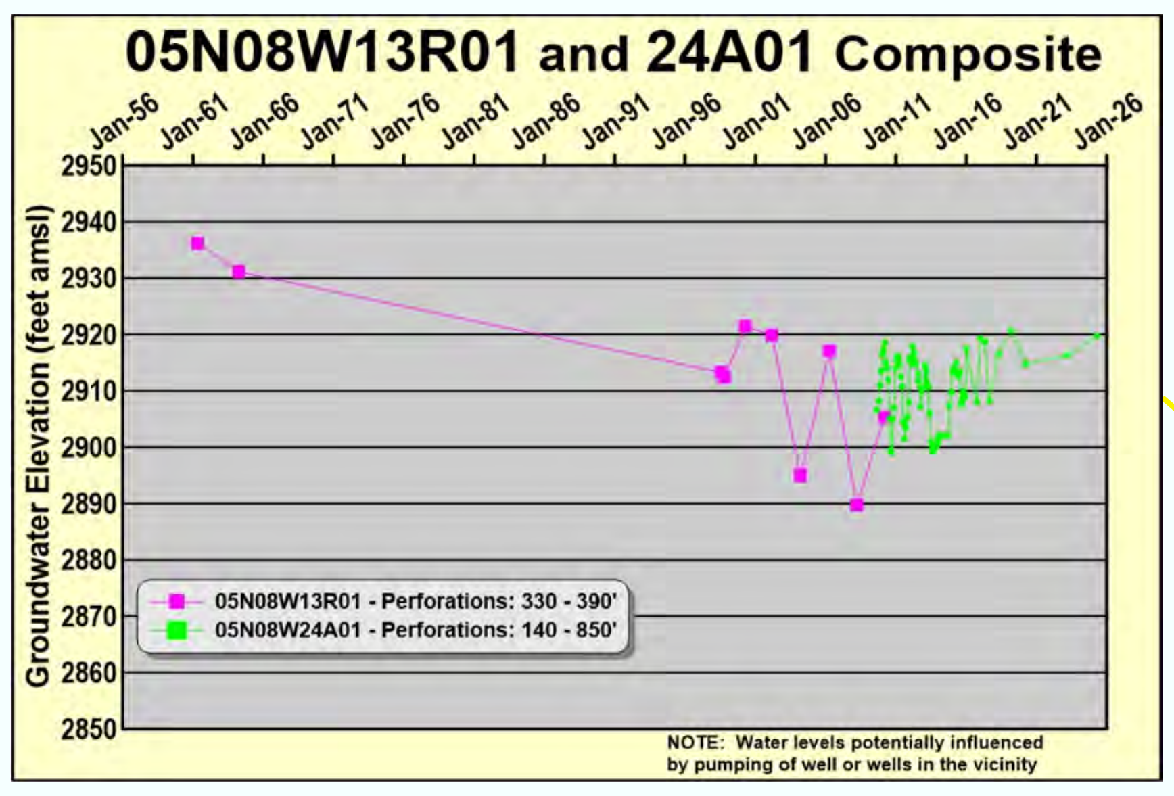

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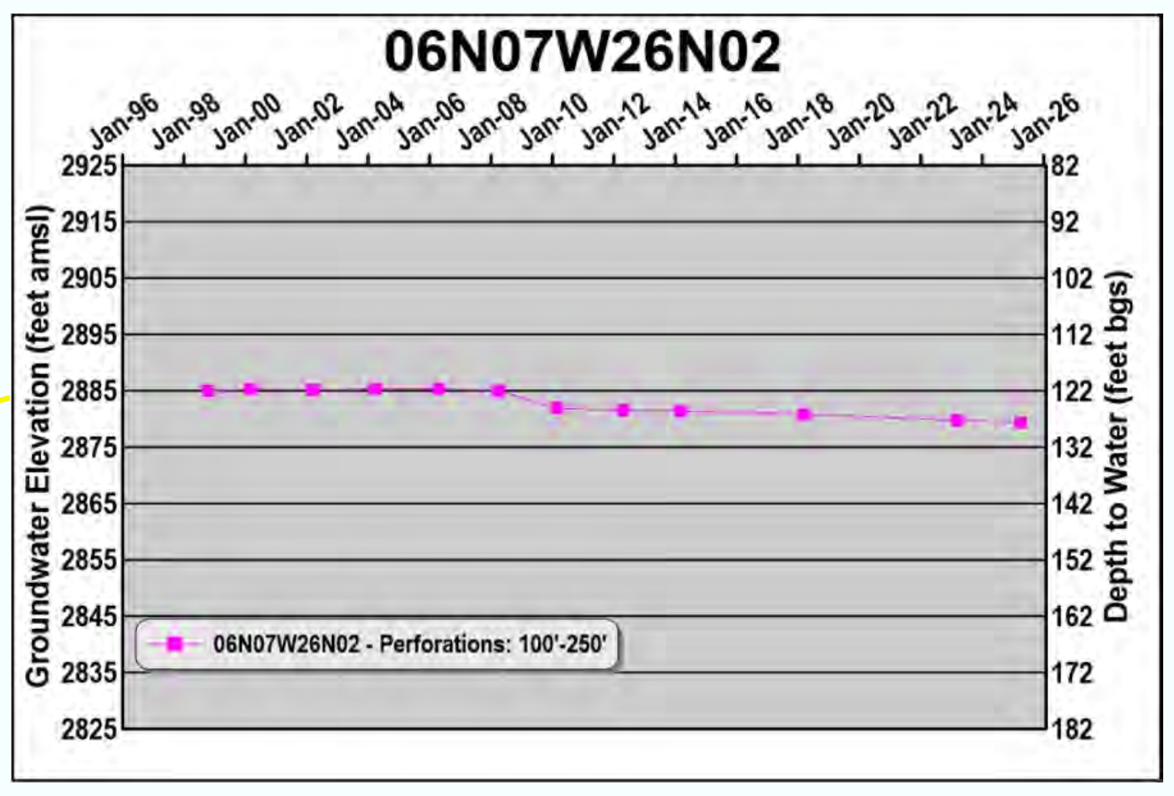

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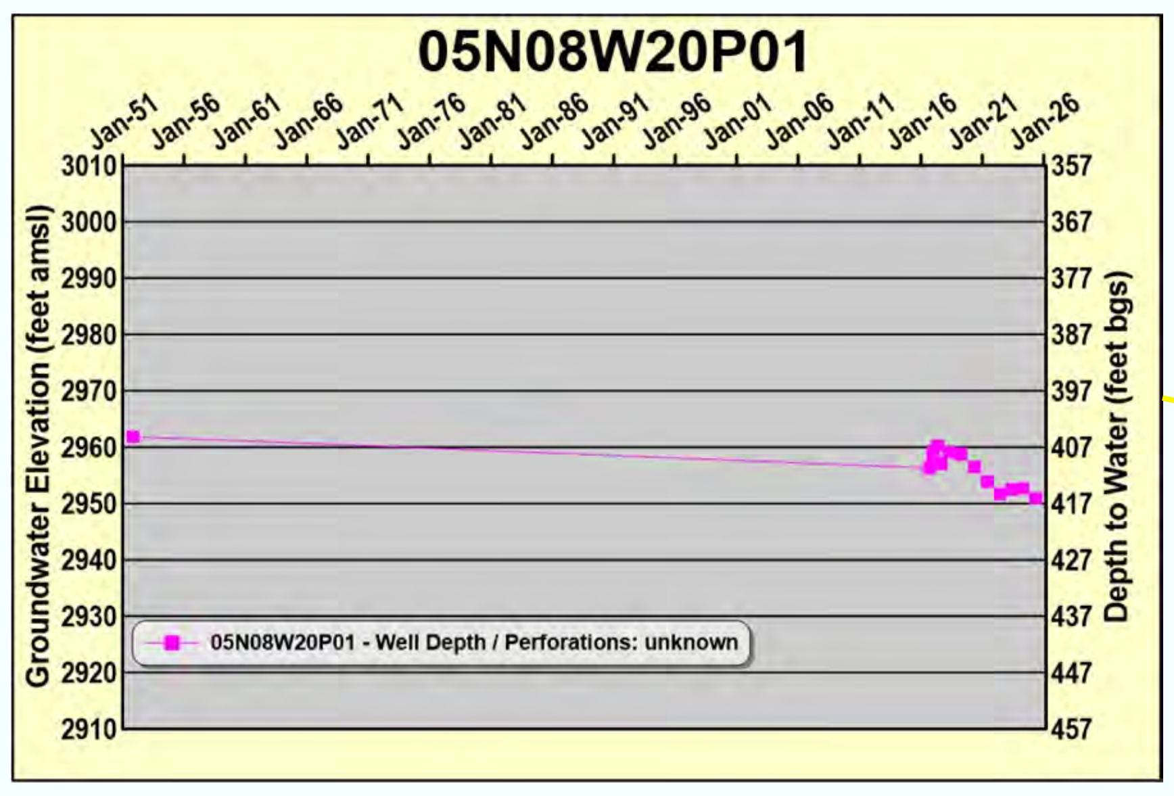

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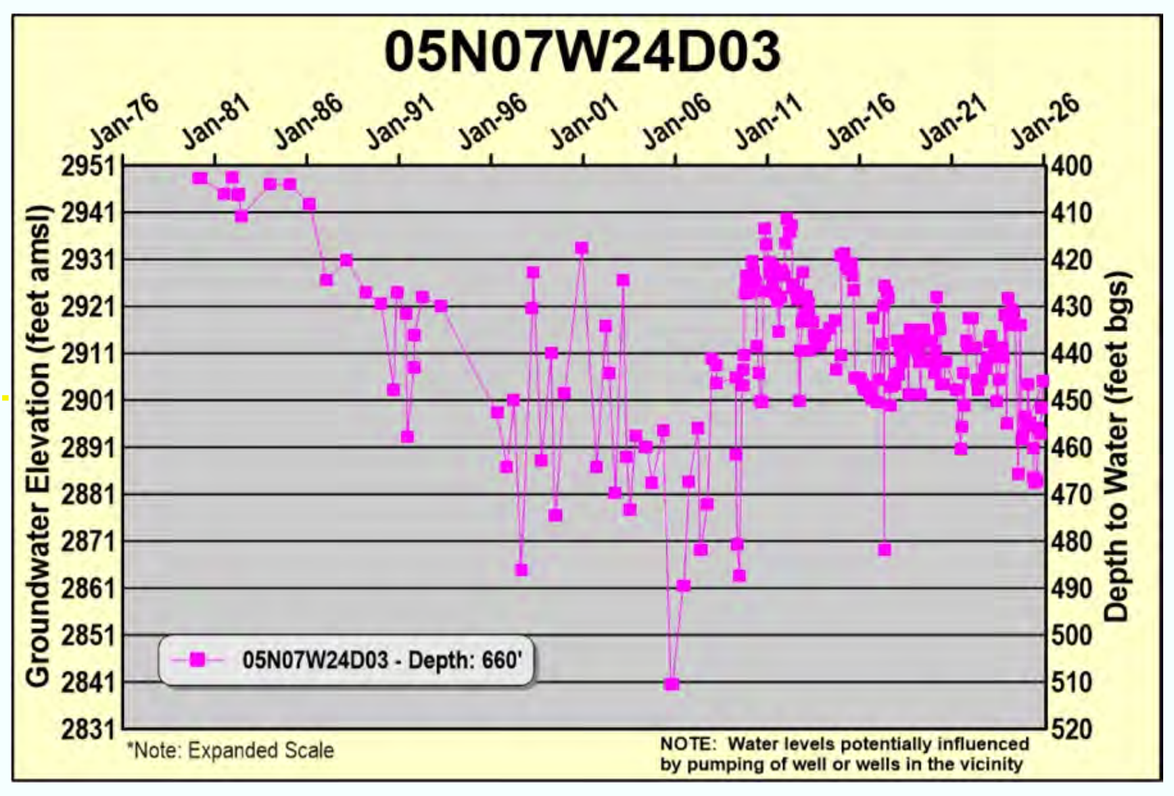

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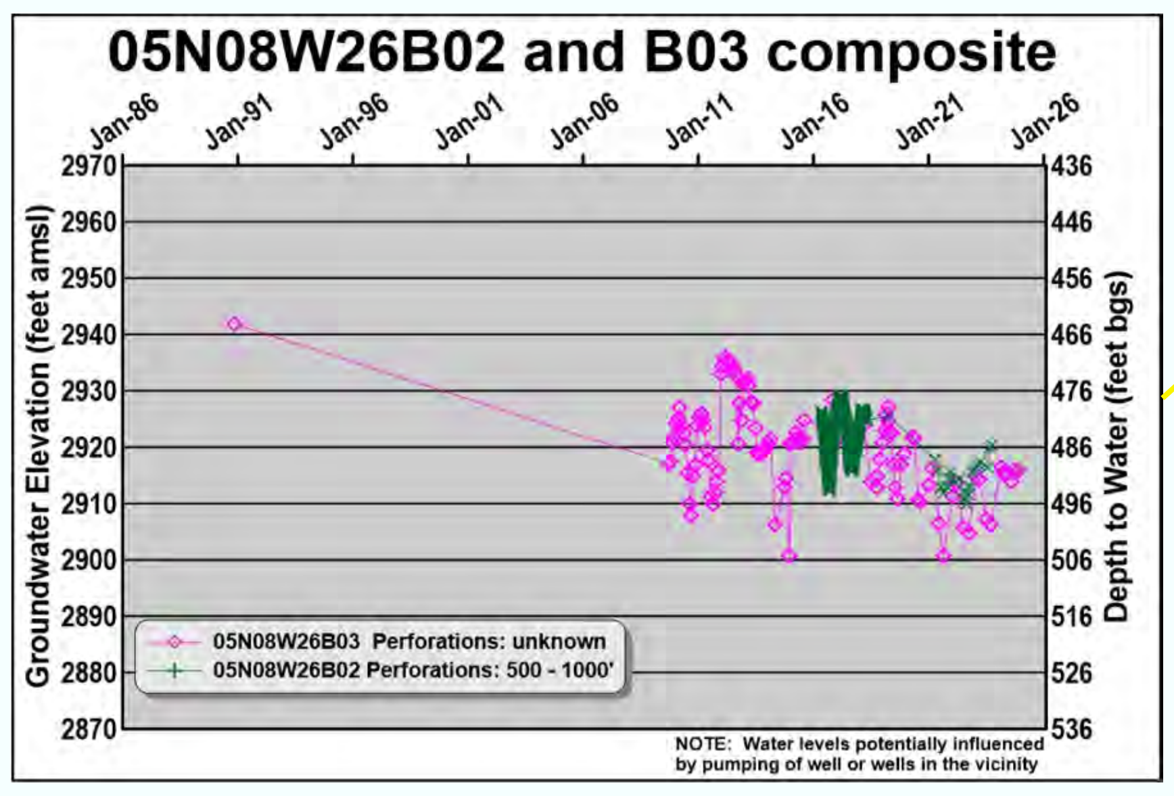
For more information please contact Mojave Water Agency.

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



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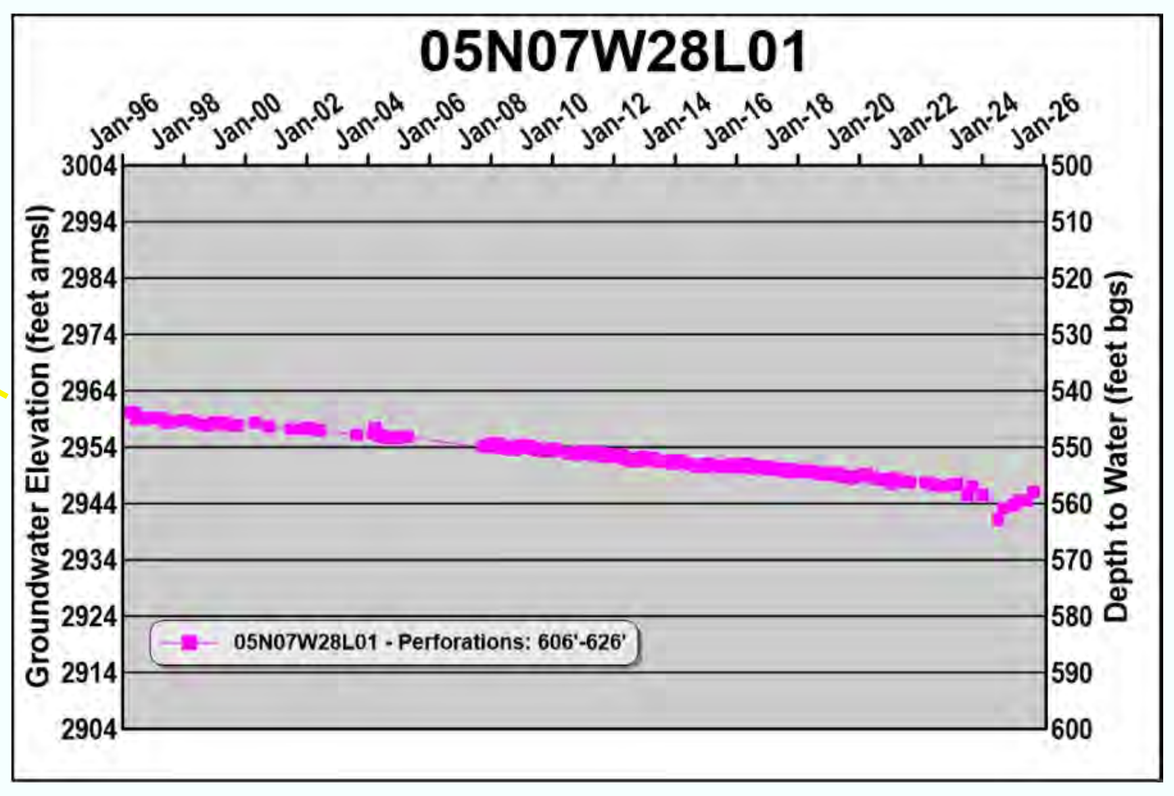

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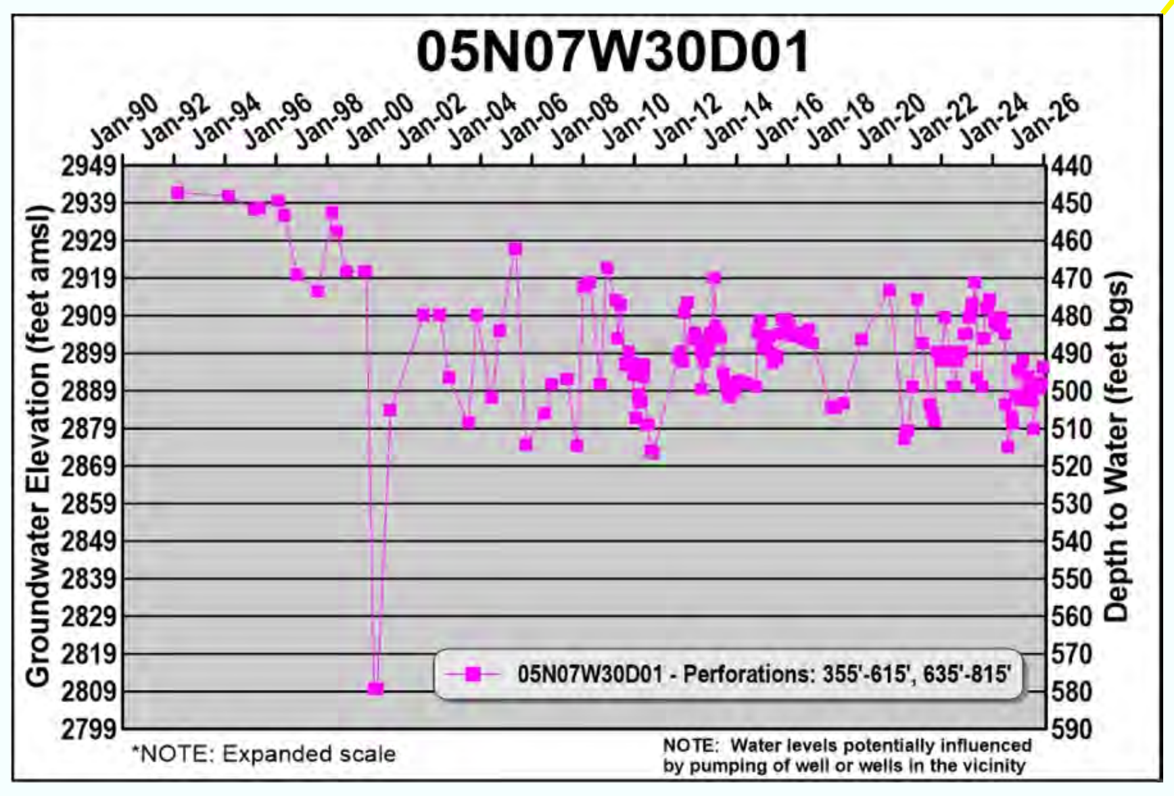

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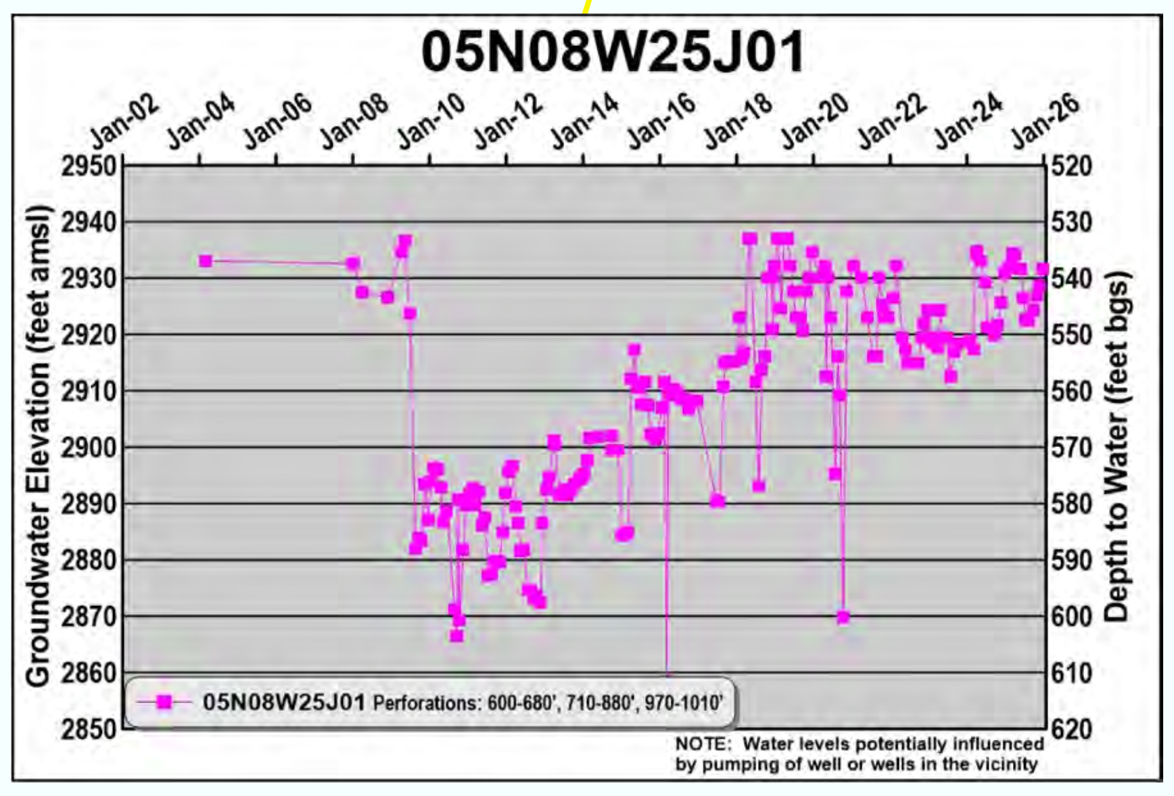

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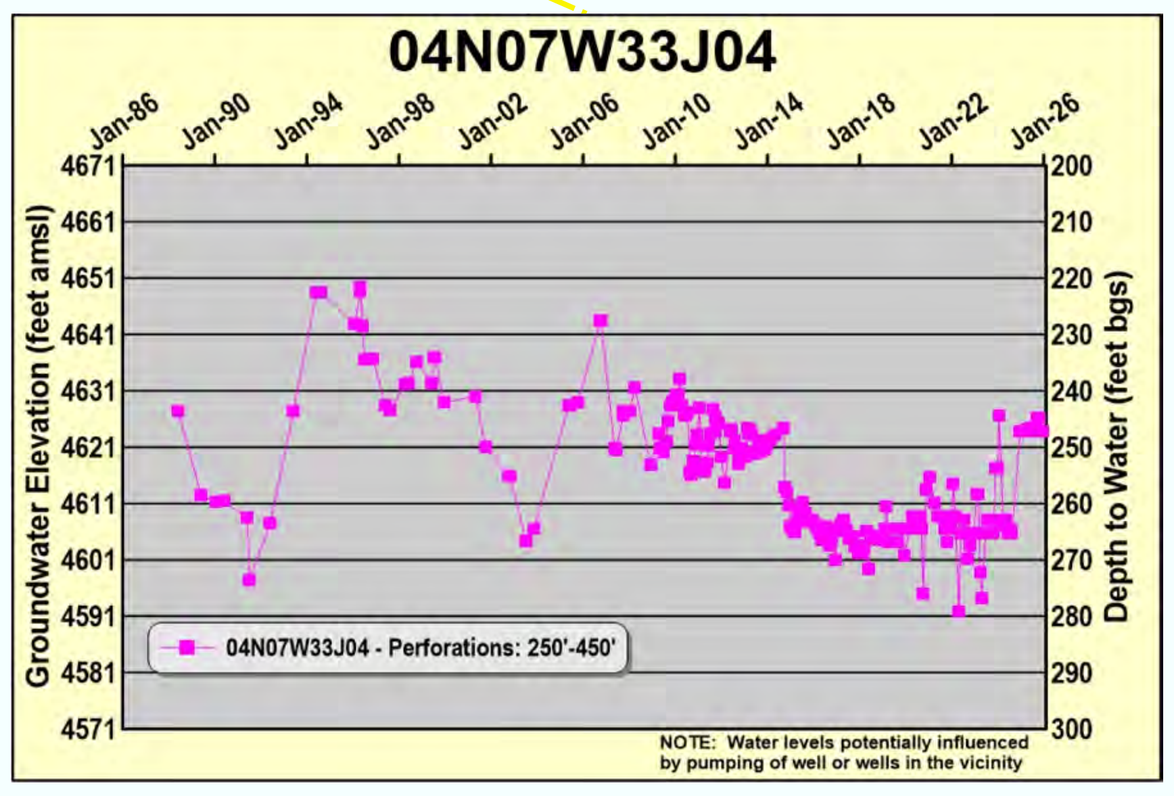

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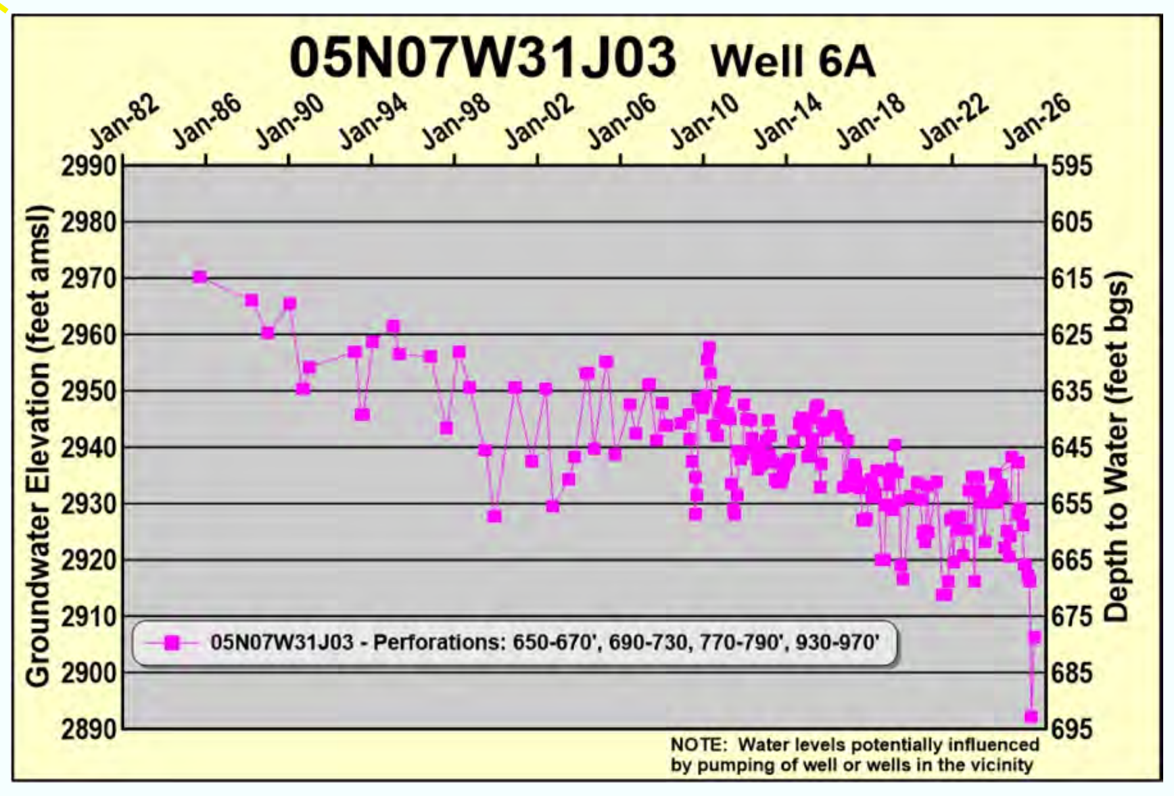


05N07W31J03 Well 6A

Mojave Water Agency

Data Sources:
MWA, US Census,
USGS/NWIS,
Date: 02/2026
Mojave Water Agency
Water Resources Department

Graphed Wells
- 🟡 Perched
- 🟢 Water Table
- ● Water Table and Perched

- 🟣 MWA Monitoring Program Wells
- USGS Perched Water Table
- – – CA Geologic Faults (CGS, USGS)

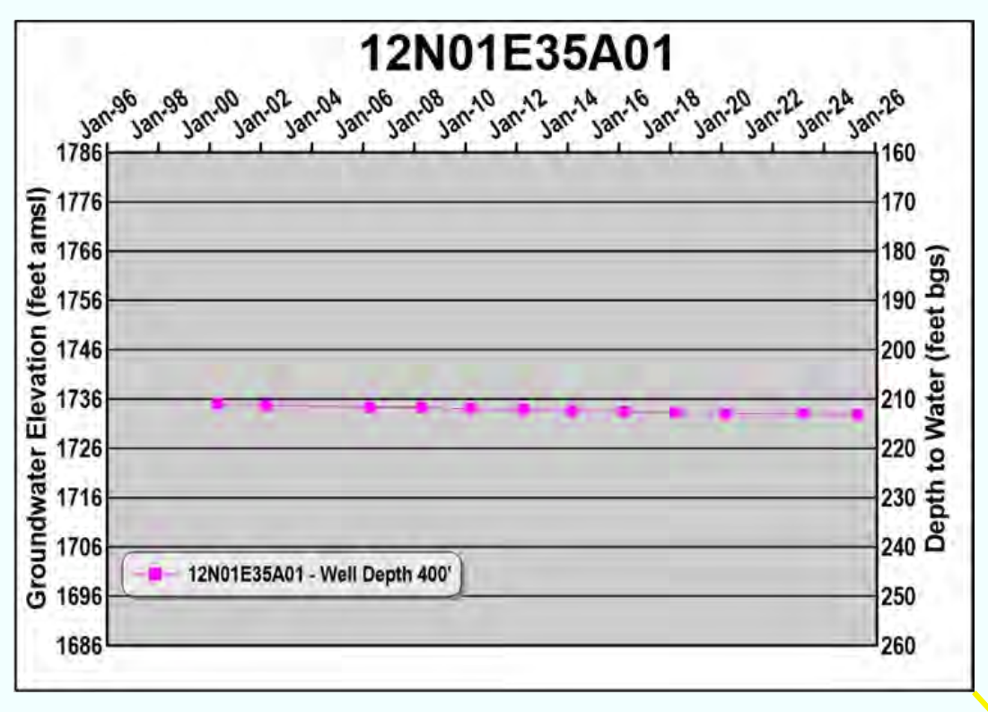
Oeste Subarea Hydrographs 2026

- ☐ Recent record
- ☐ Long-term record (begins ~1950 to ~1980)
- ☐ Very long-term record (begins ~1920)

0 0.5 1 2
Miles

N

Attachment F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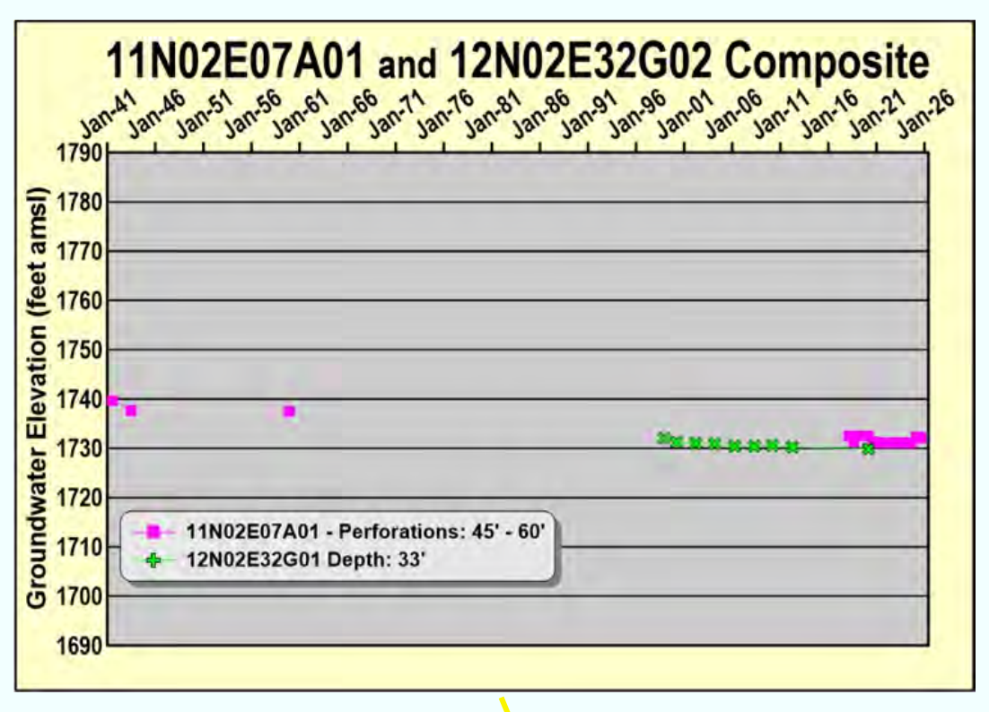
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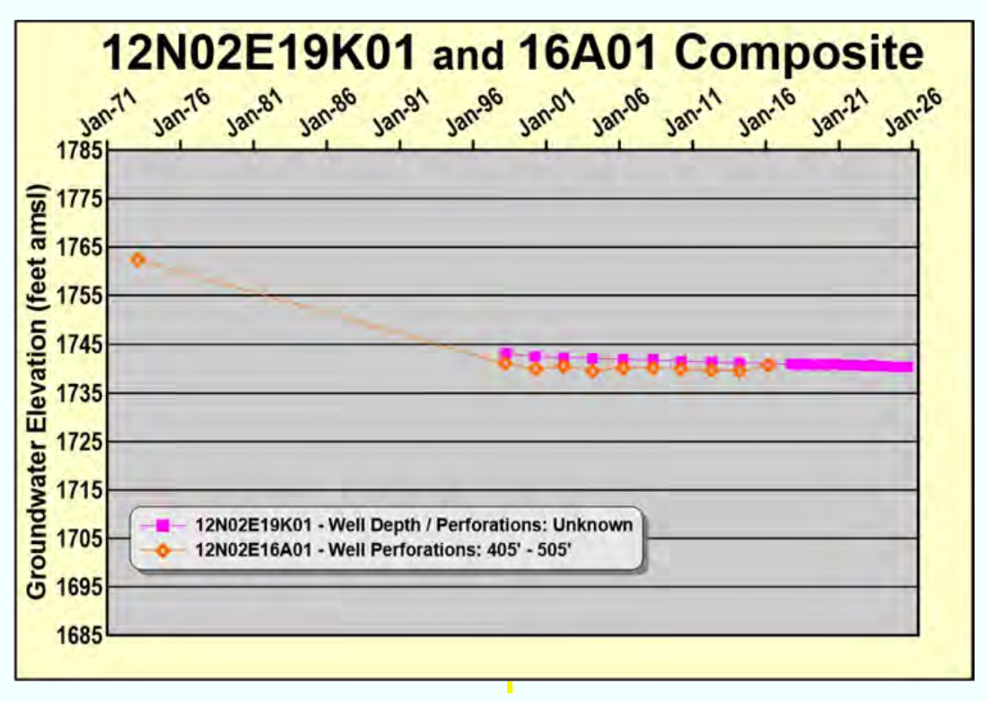
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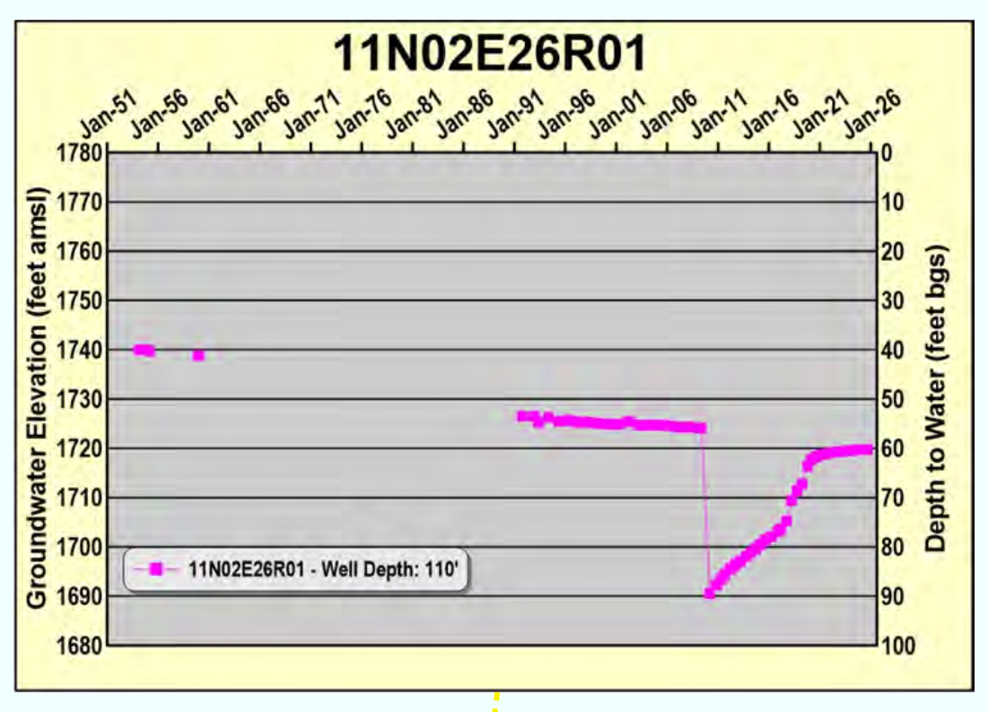
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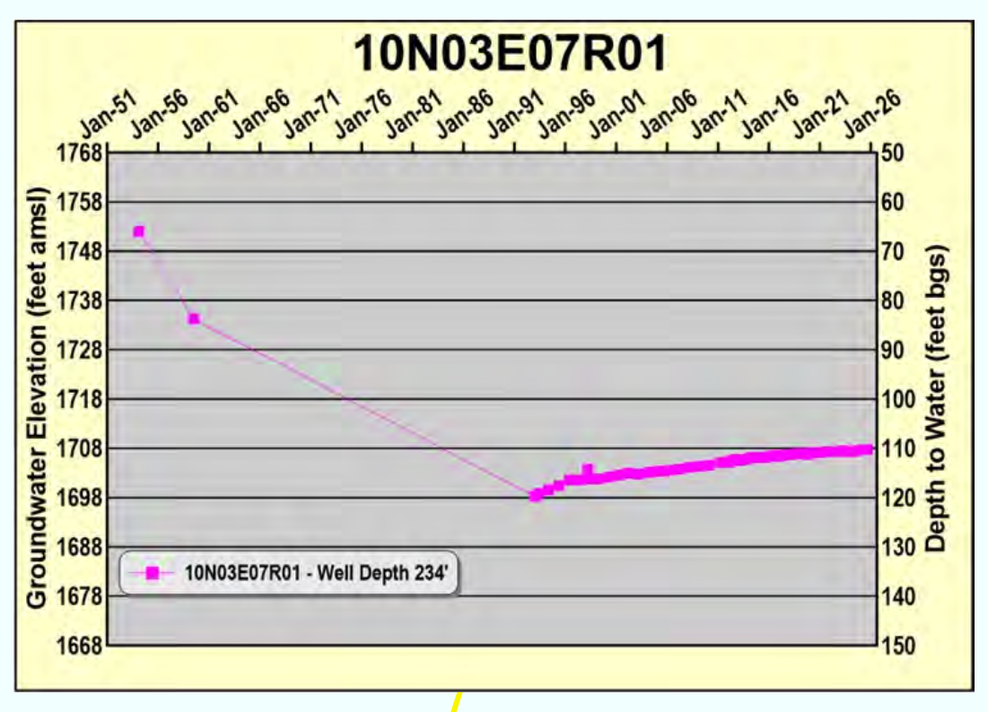
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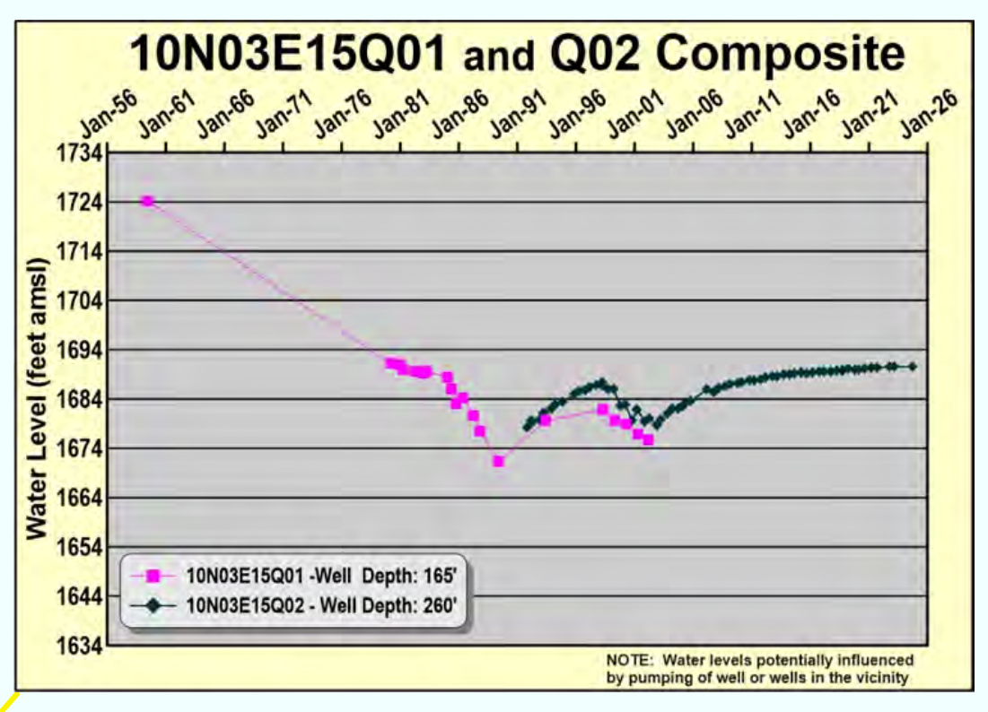
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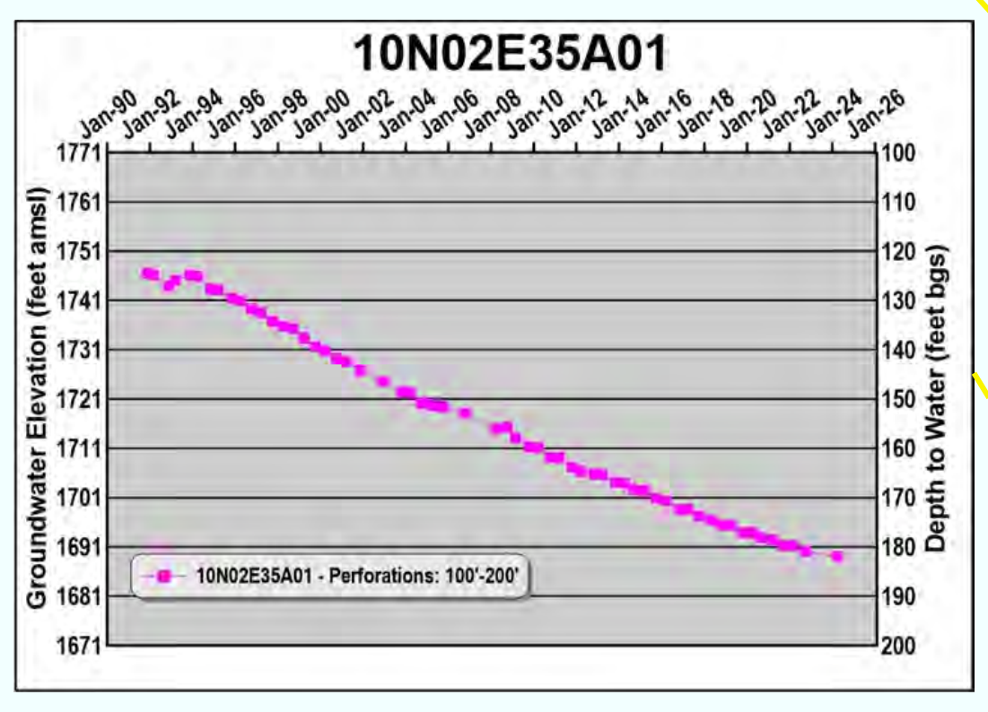
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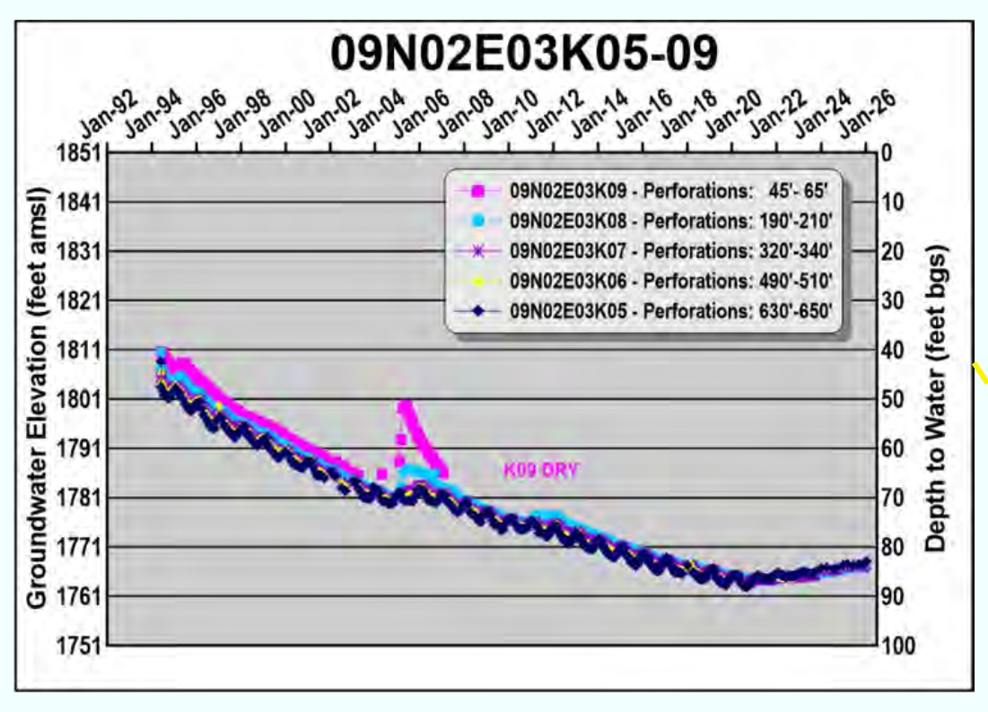
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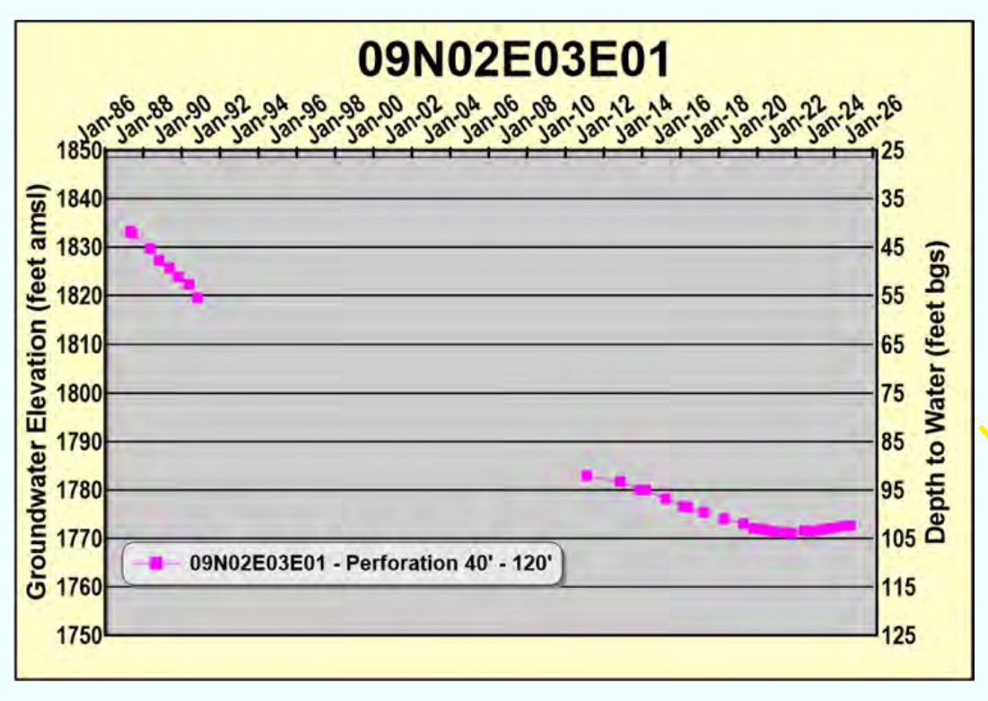
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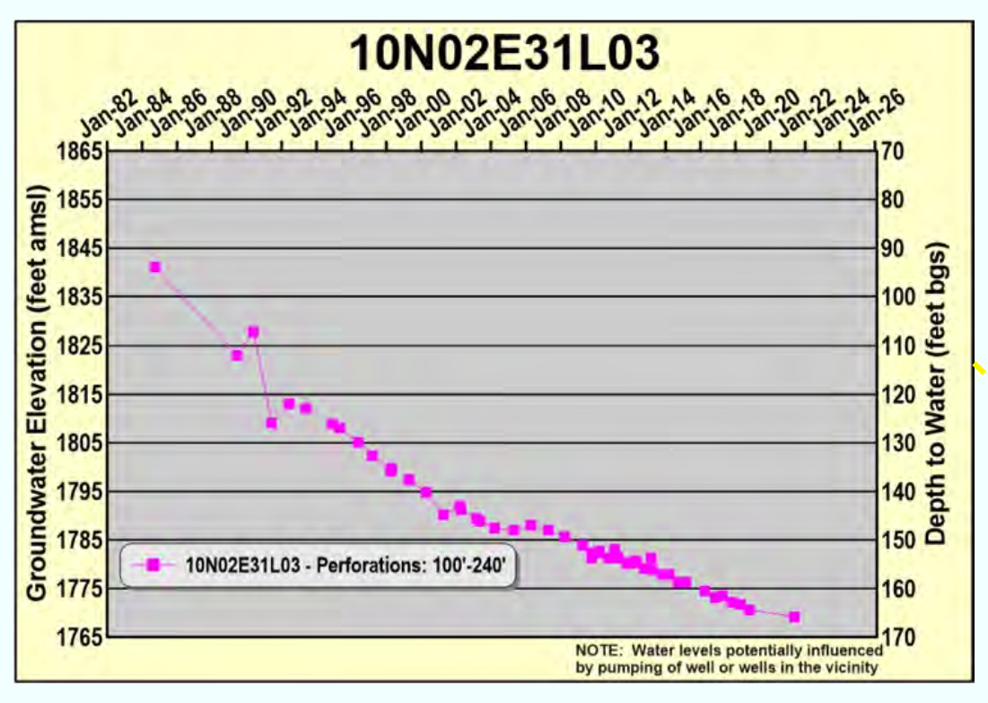
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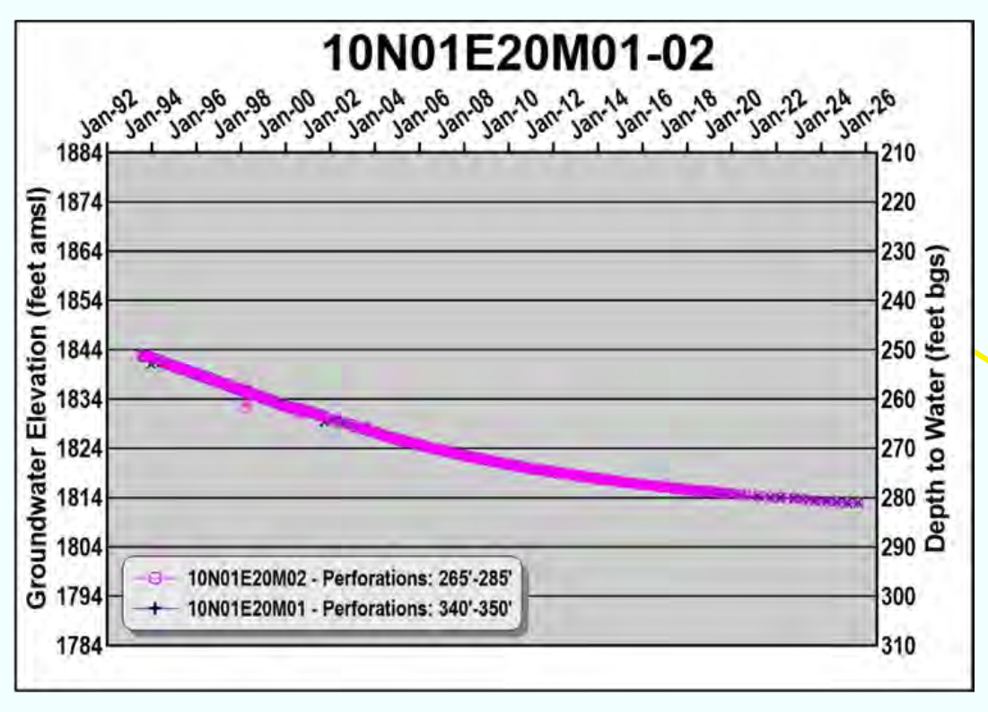
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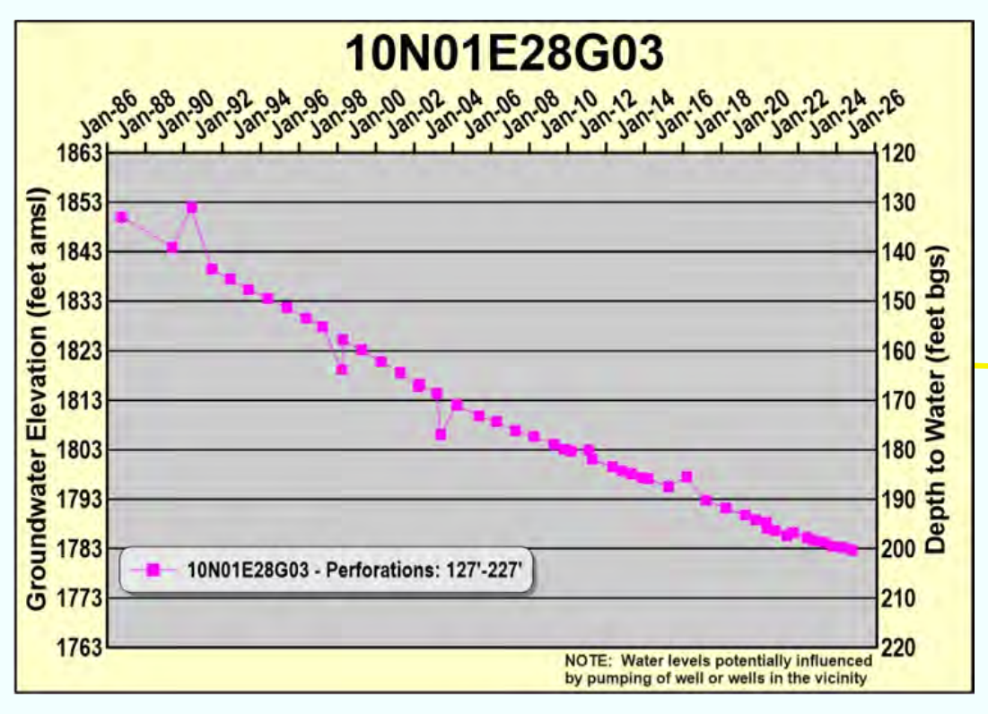
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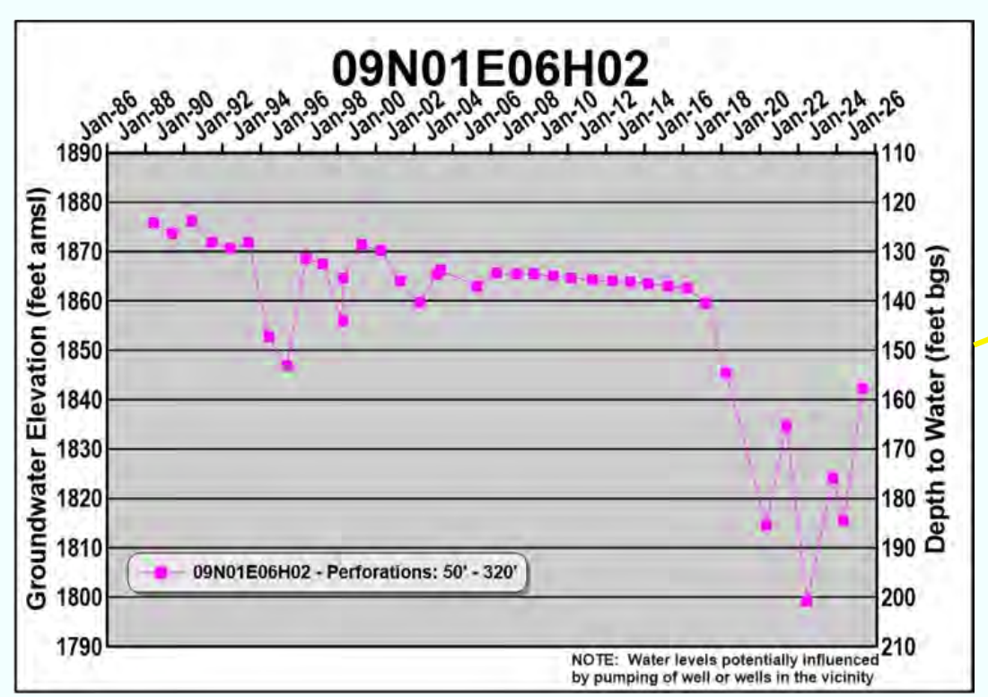
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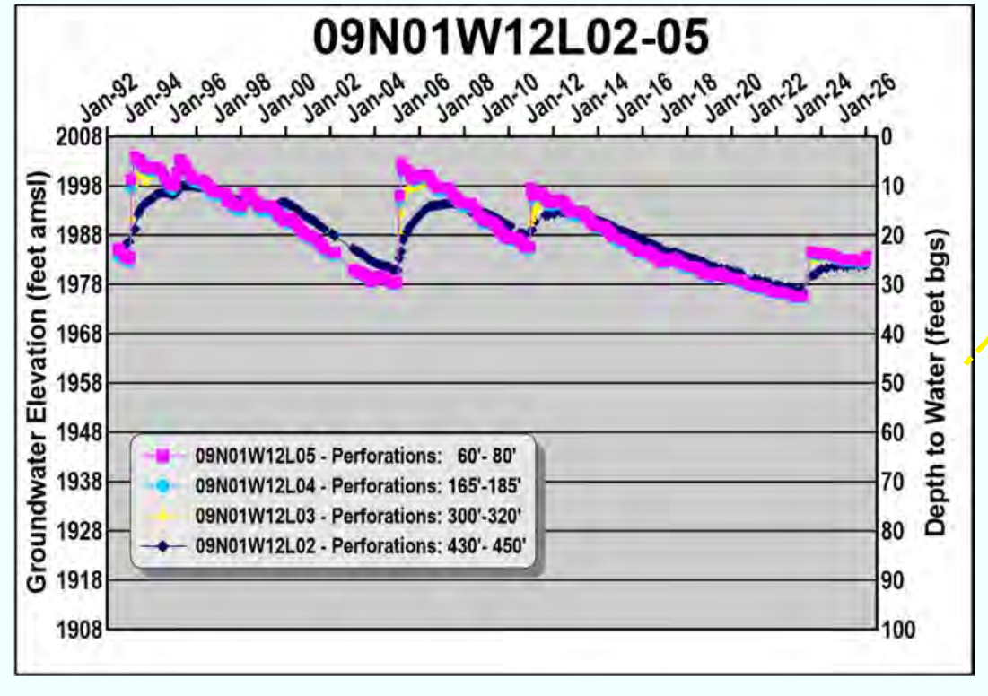
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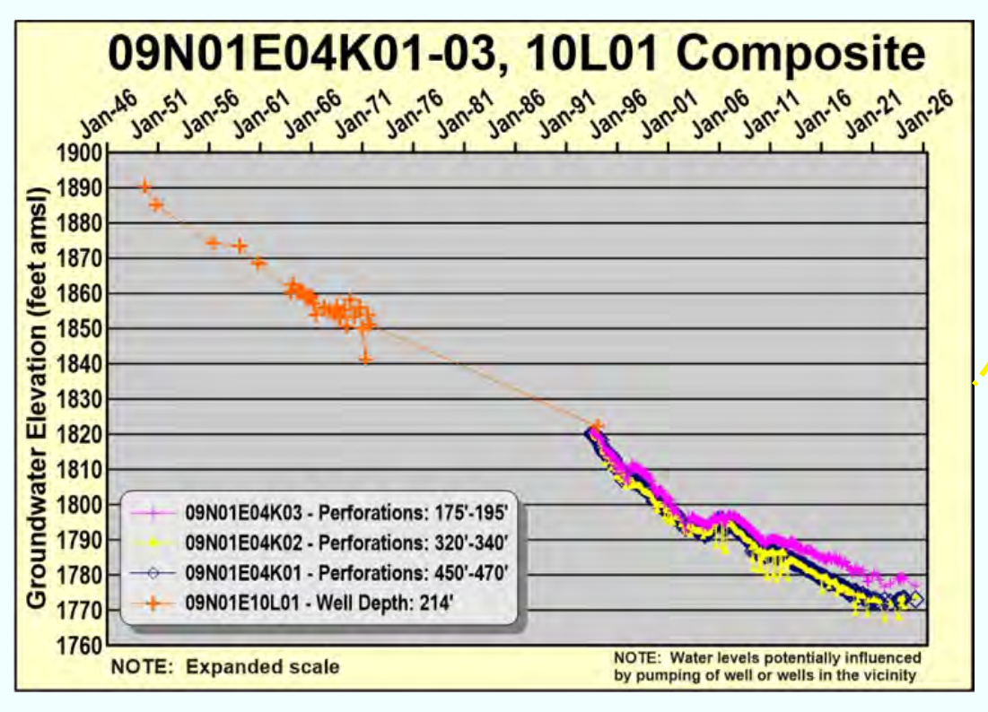
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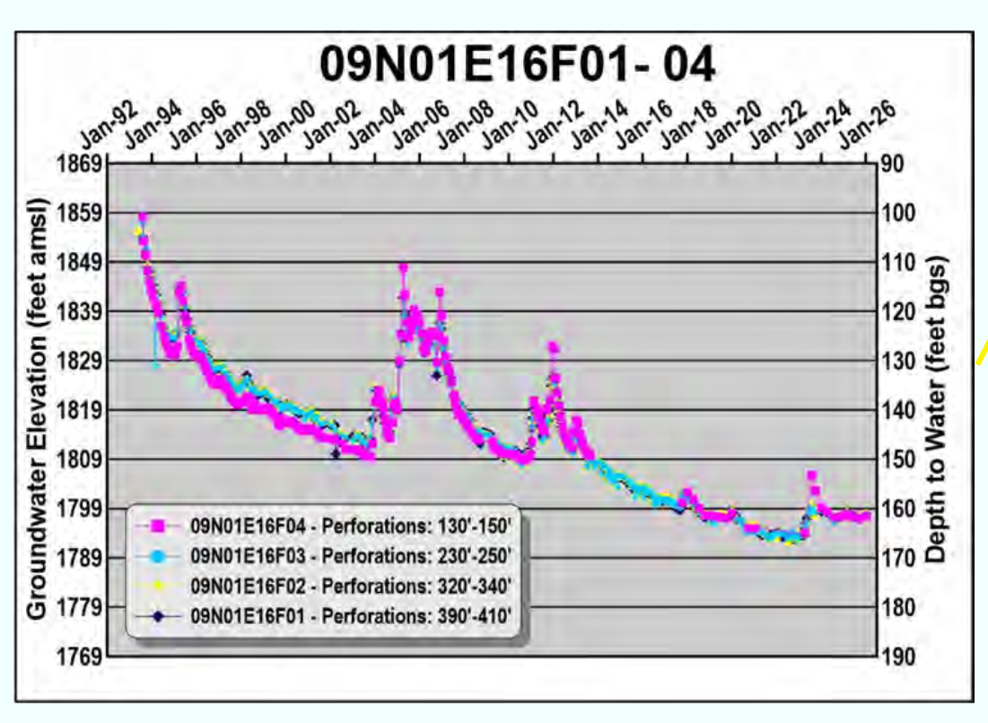
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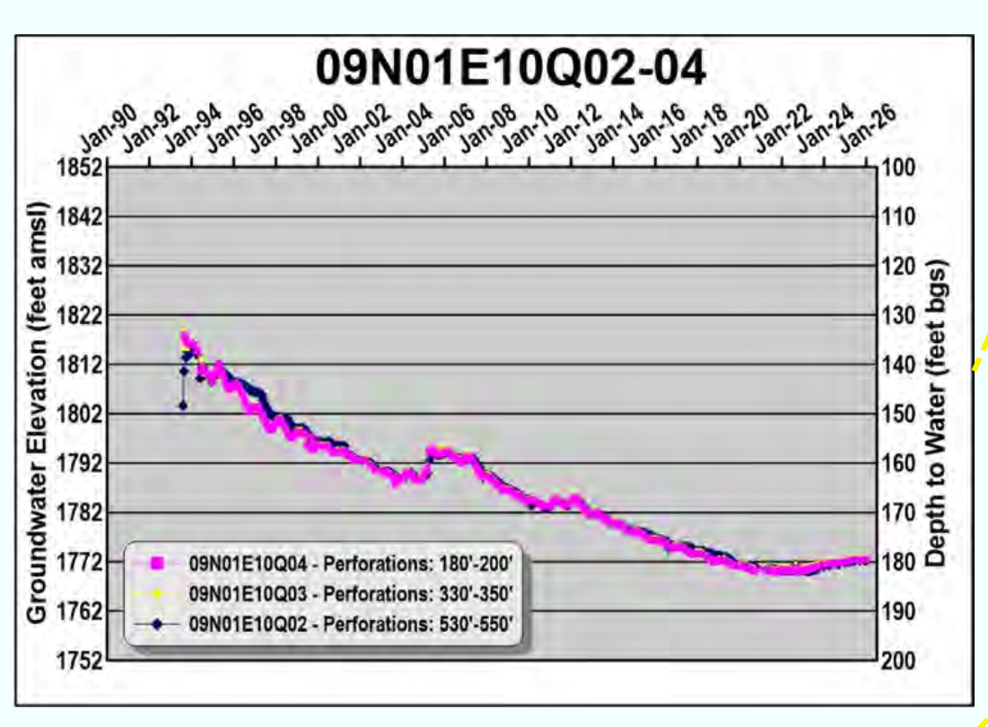
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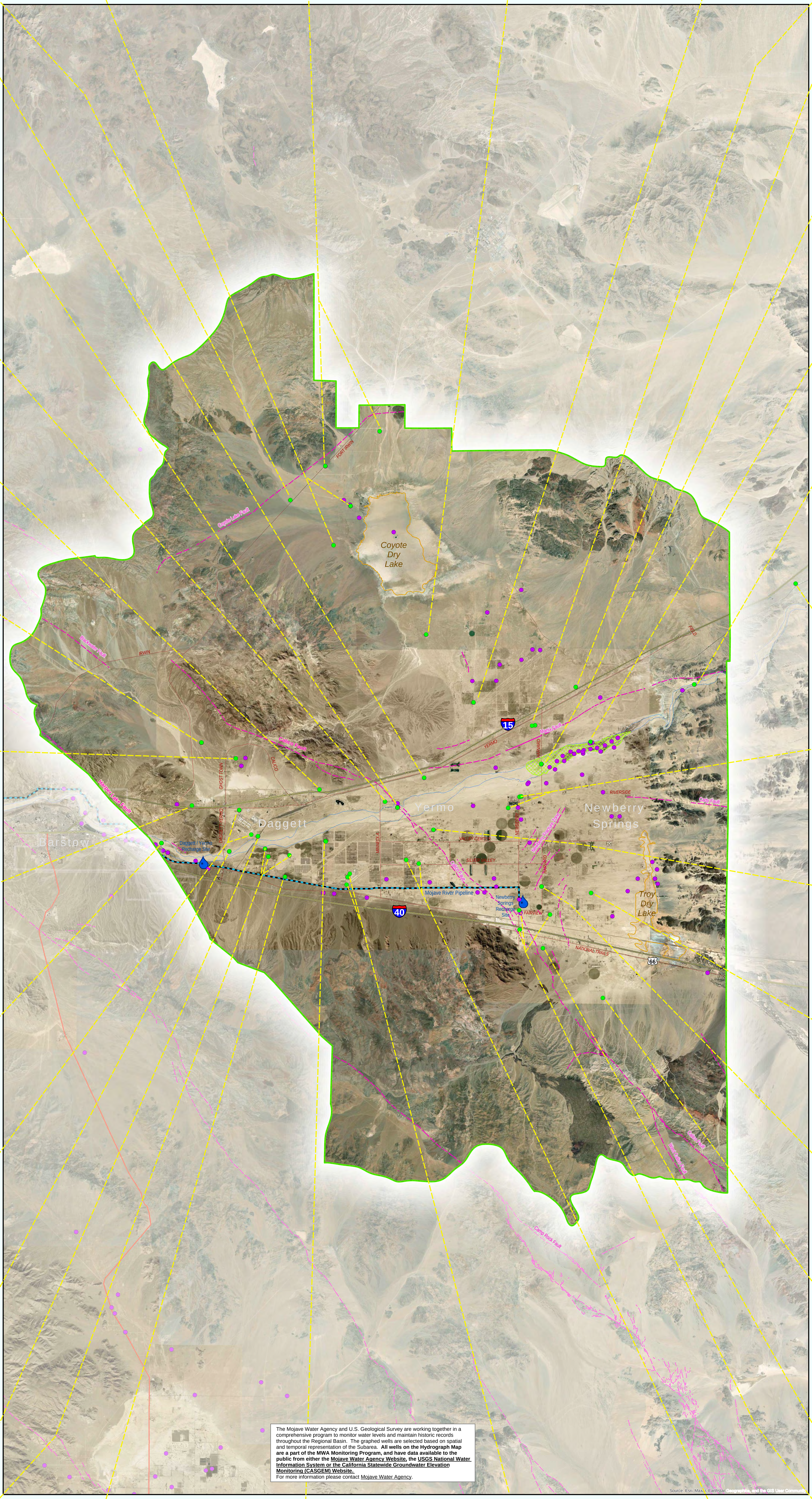

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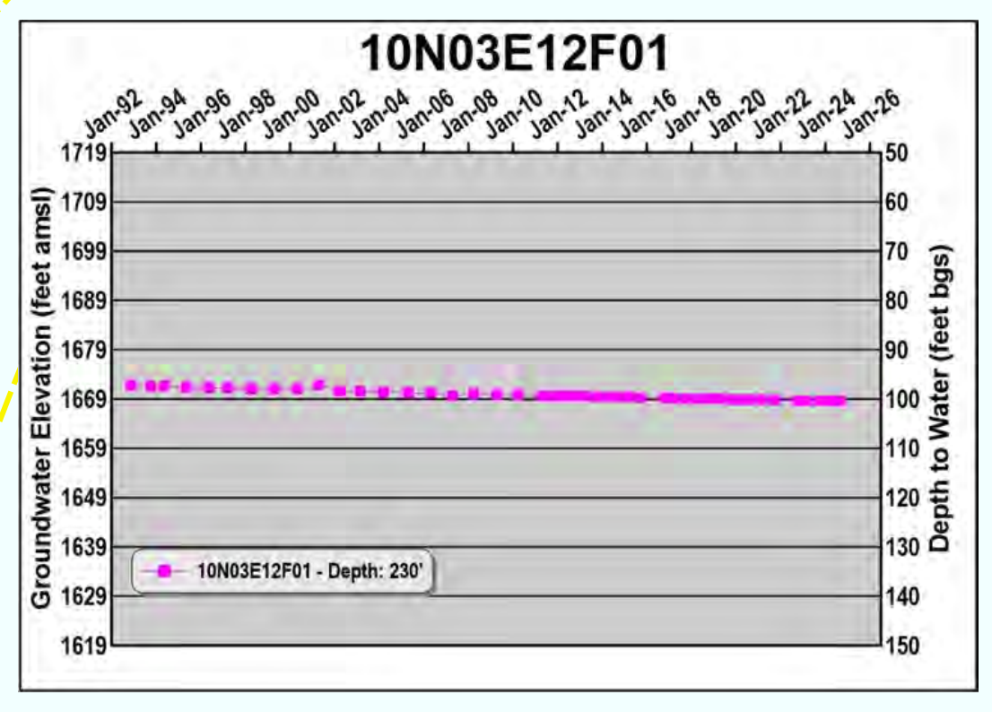
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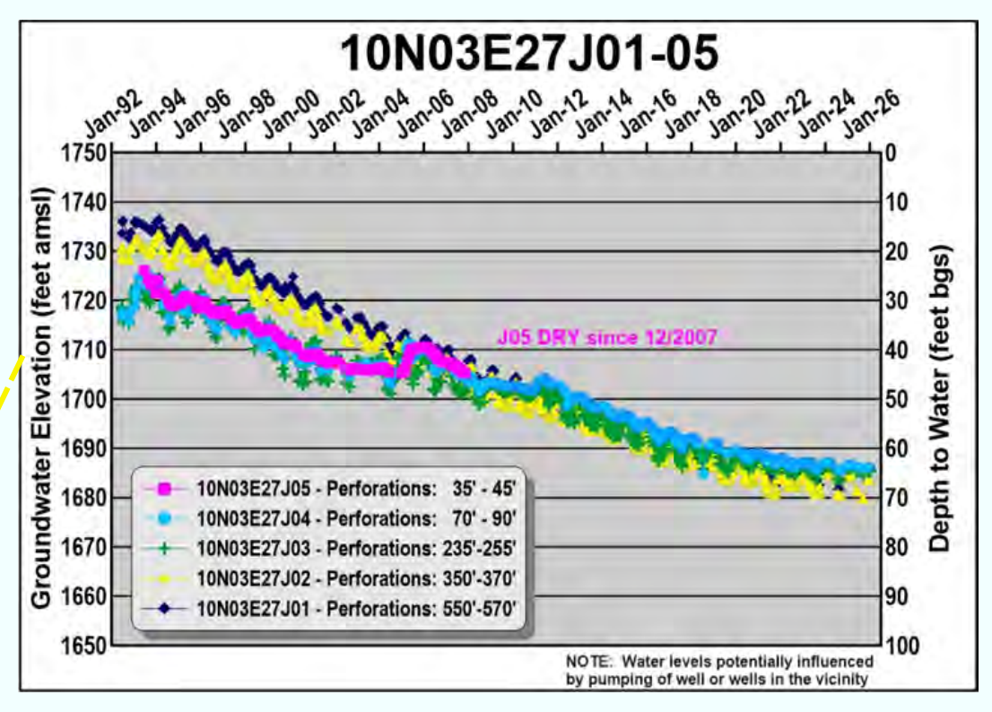
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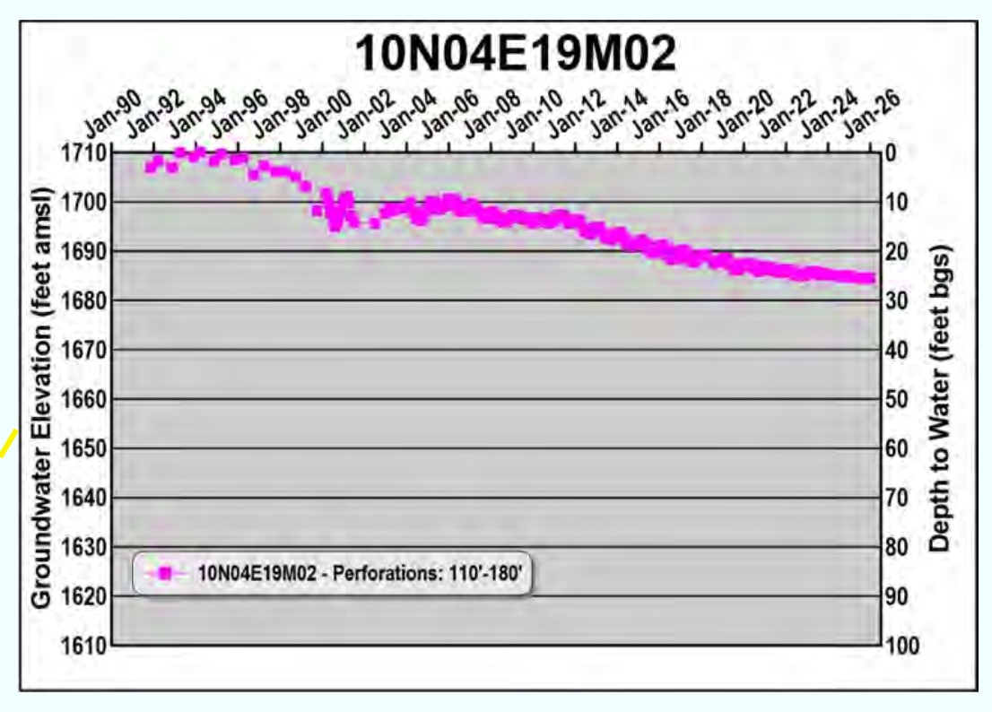
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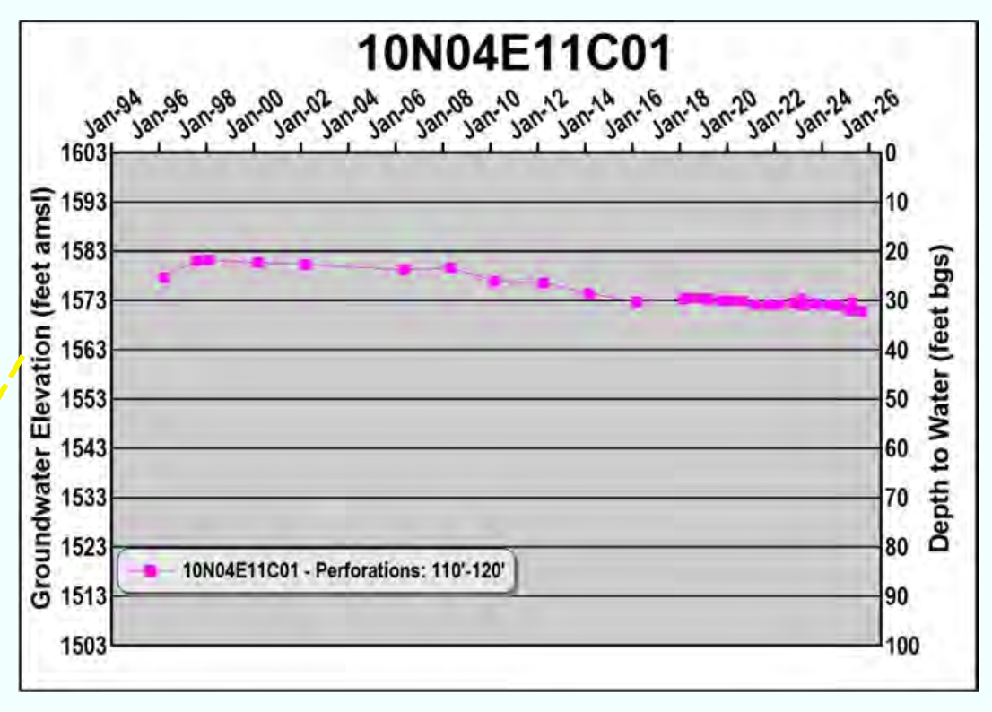
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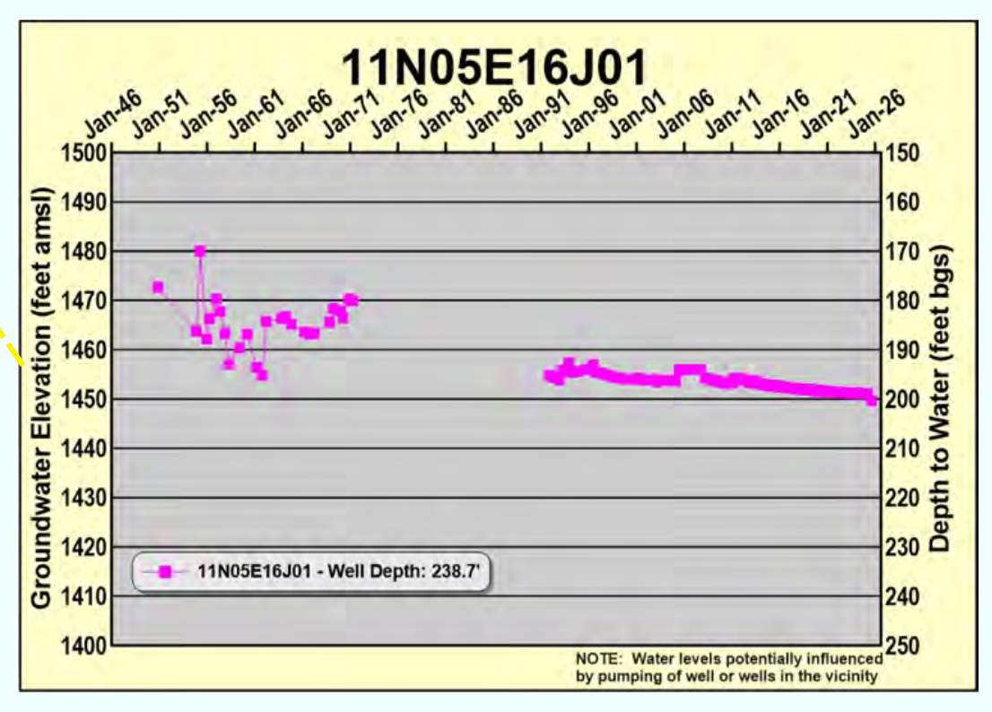
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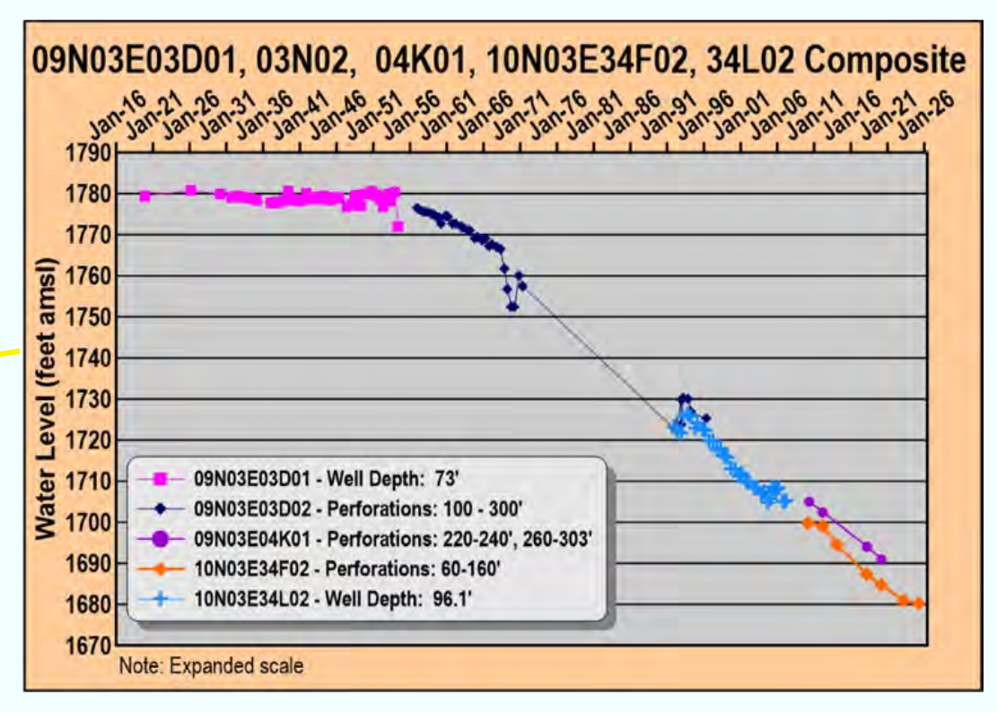
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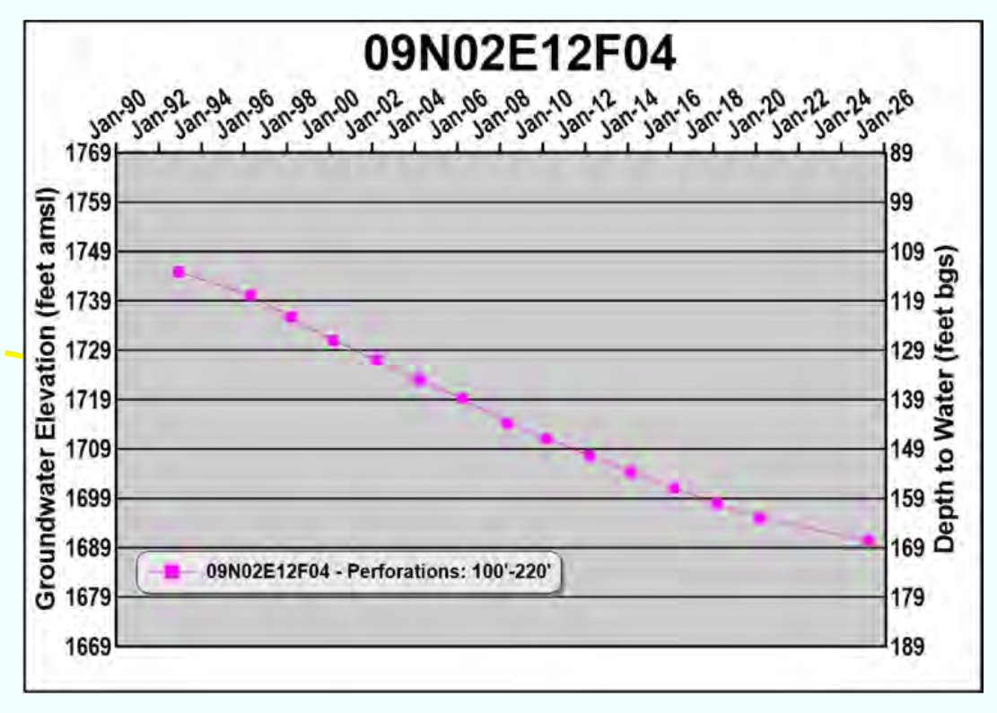
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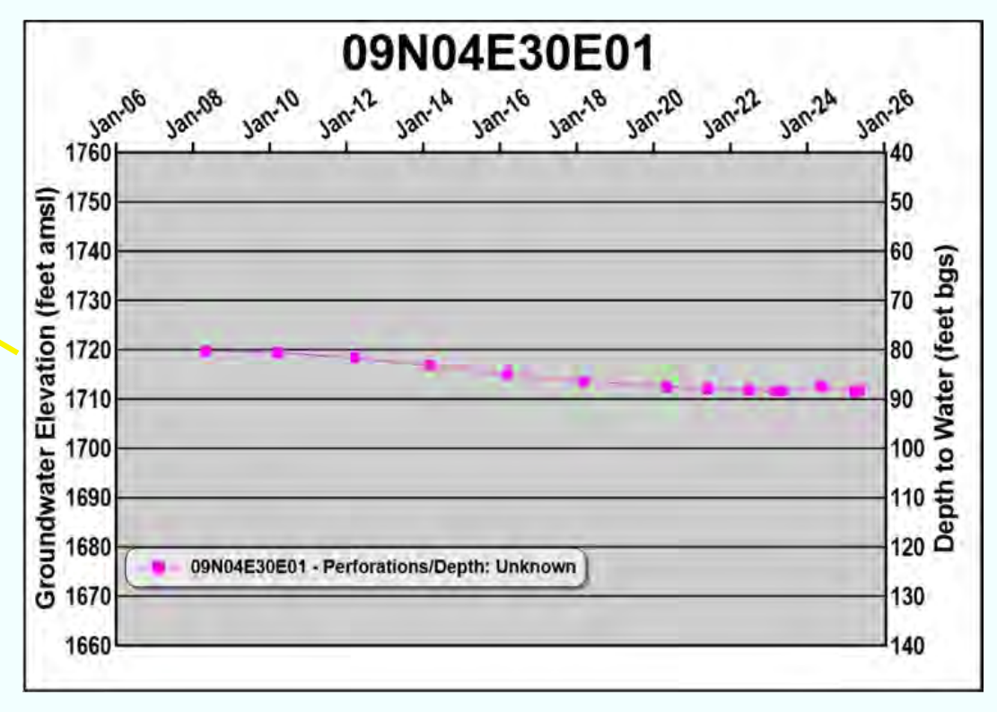
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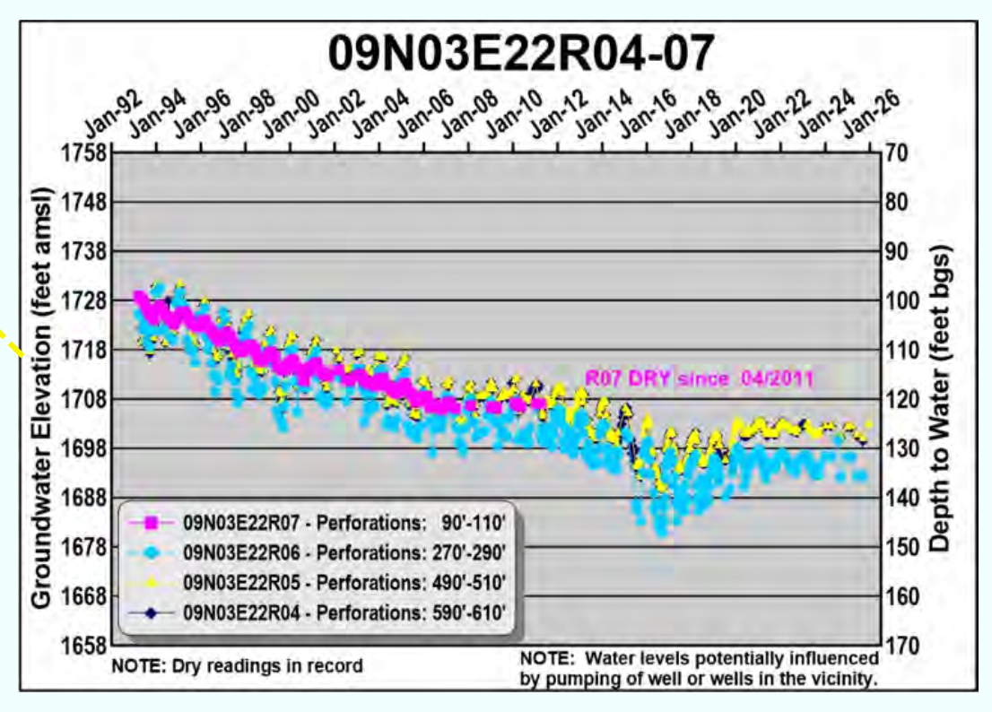
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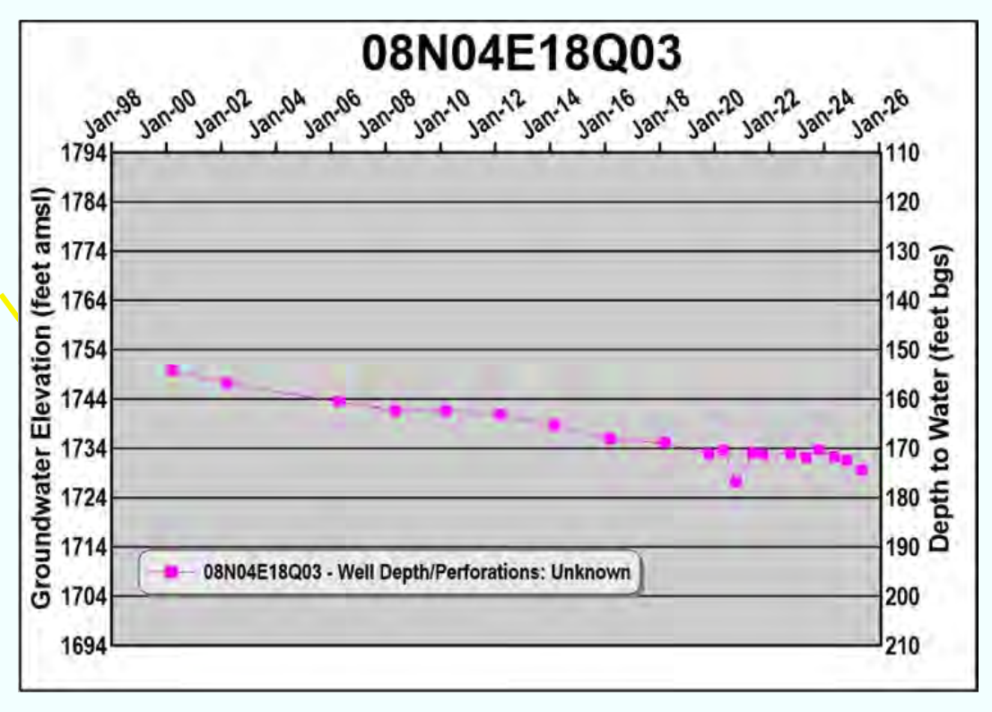
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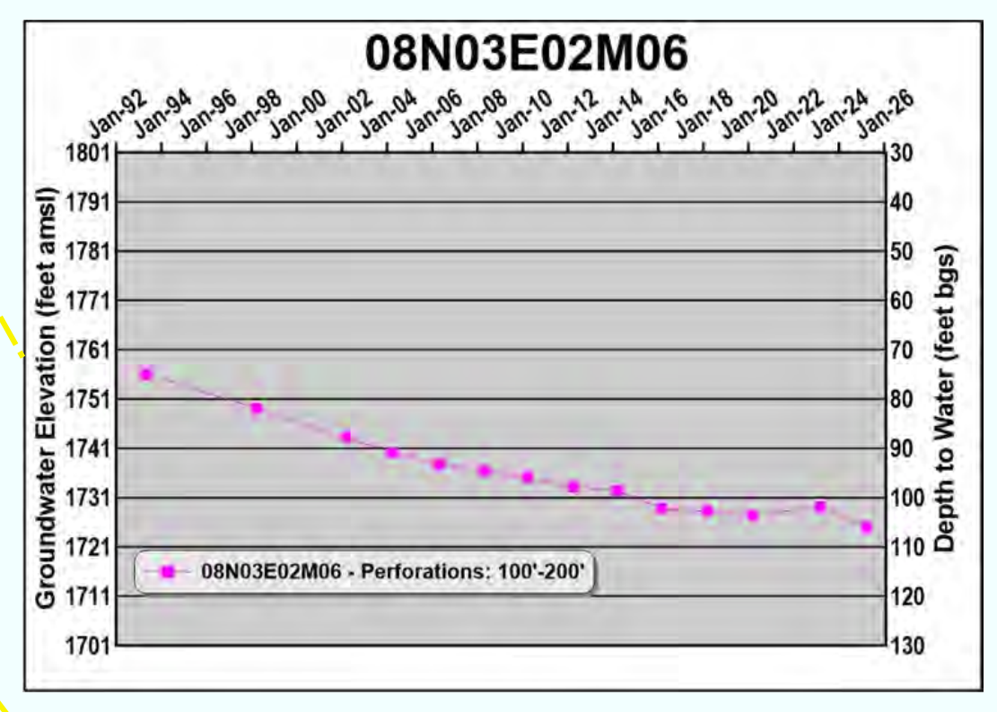
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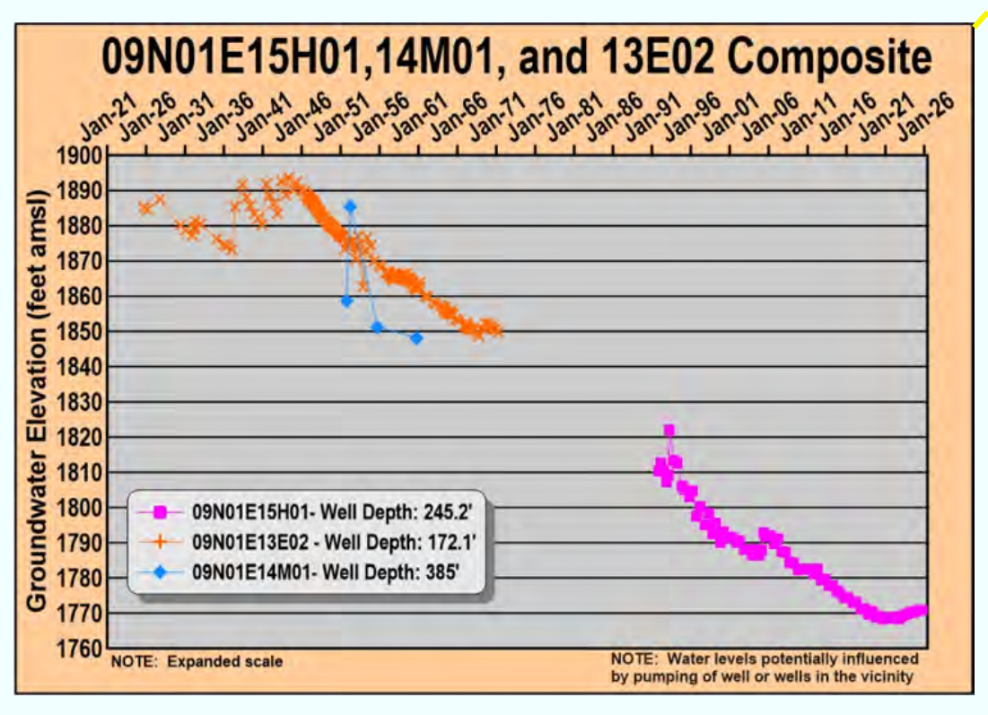
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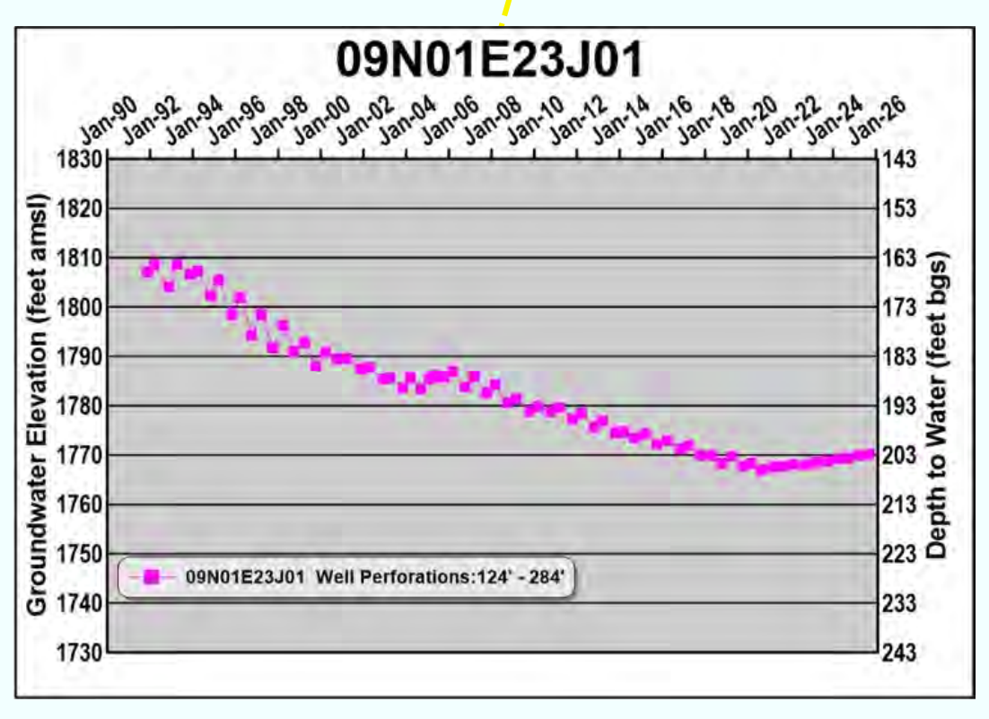
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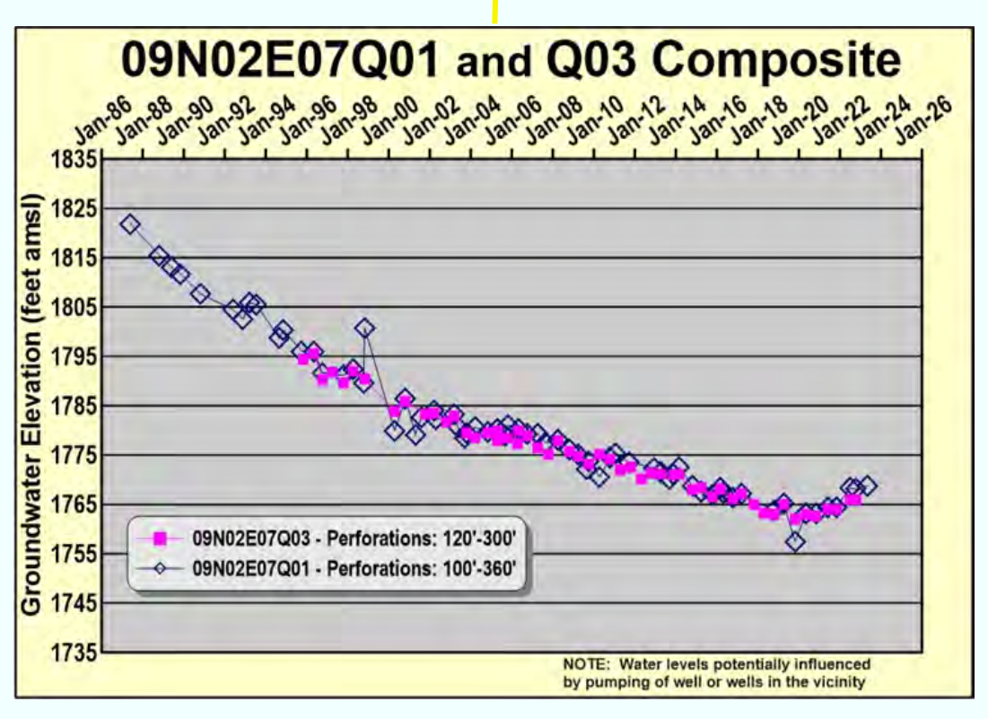
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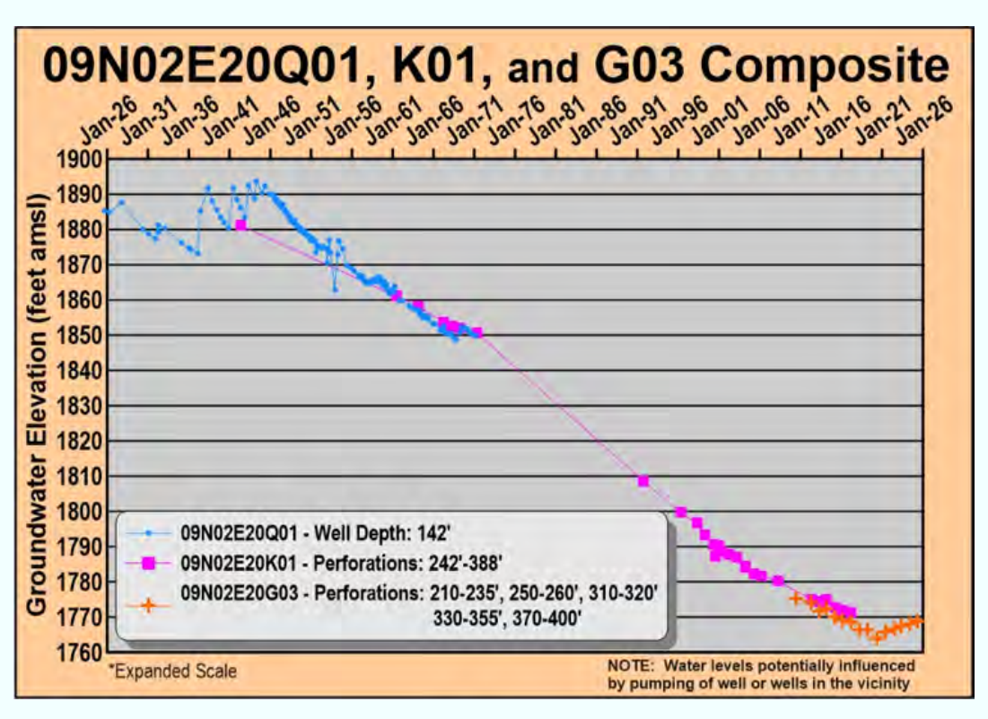
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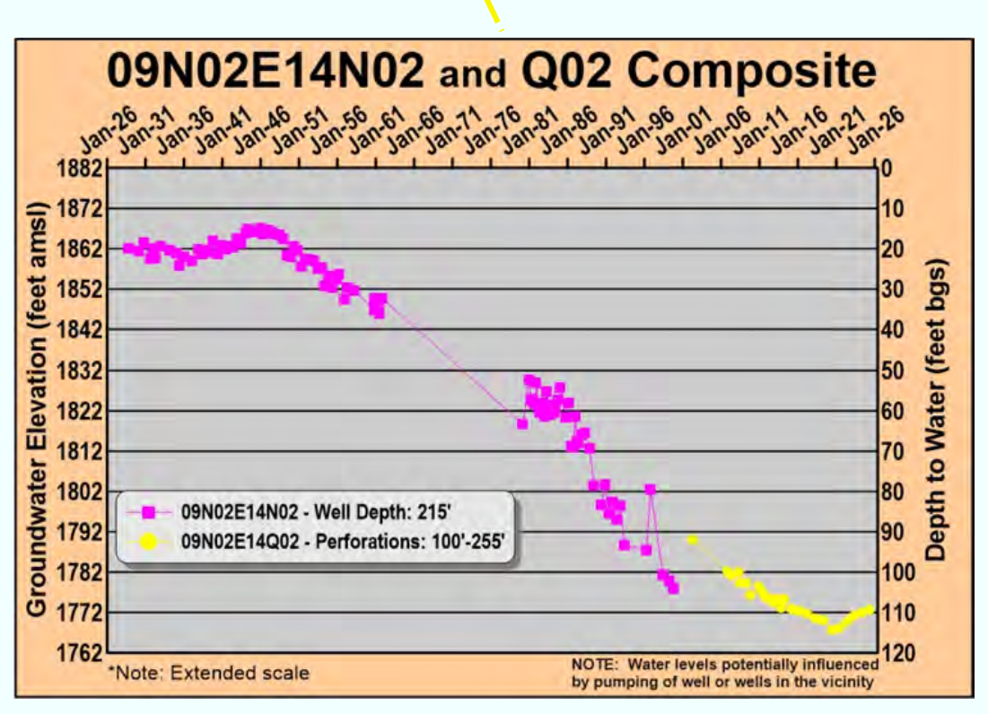
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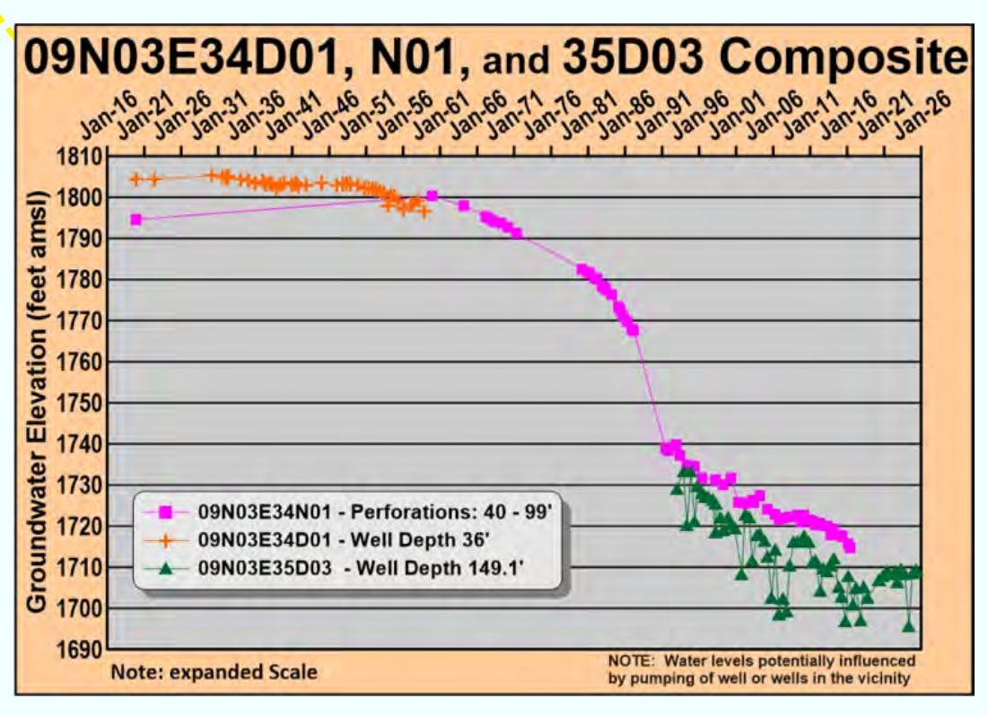
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Mojave Water Agency

Data Sources:
MWA, US Census,
USGS/ NWIS,
DWR Bulletin 84 1967
Date: 02/2026
Mojave Water Agency
Water Resources Department

● Graphed Wells
● MWA Monitoring Program Wells
▨ Exhibit H Riparian Habitat Area
- - CA Geologic Faults (CGS, USGS)
MWA Recharge Pipeline
MWA Recharge Site

Baja Subarea
Hydrographs 2026

☐ Recent record
🟨 Long-term record (begins ~1950 to ~1980)
🟧 Very long-term record (begins ~1920)

0 2 4
Miles

N

Attachment G

Mojave Water Basin Area Watermaster

ANALYSIS OF BAJA WATER SUPPLY AND OUTFLOW

February 22, 2012

Robert C. Wagner, P.E., Watermaster Engineer

Wagner&Bonsignore
Consulting Civil Engineers, A Corporation
2151 River Plaza Drive, Suite 100
Sacramento, CA 95833-4133
916-441-6850
916-779-3120 *fax*

ANALYSIS OF BAJA WATER SUPPLY AND OUTFLOW

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APPENDICES

INTRODUCTION

The following report provides the basis for adjusting on a short term basis elements of water supply, use, and disposal as shown on Table 5-2 of the Watermaster's Annual Report to the Court. Additionally, Watermaster requested guidance for a recommendation on adjusting Free Production Allowance for the Baja Subarea in the short term and for the future. During a series of workshops and meetings with Watermaster and the Baja Subarea Advisory Committee (BSAC) over the past several years, we provided data and analysis to support the recommendations contained herein.

The following items are discussed in this report:

1) Long term average Inflow at Waterman Fault
2) Long term average outflow at Afton
3) Phreatophyte Usage in Baja Subarea
4) Supply Contribution from Desert Washes
5) Recommendation for Future Rampdown

LONG TERM AVERAGE ANNUAL INFLOW AT WATERMAN FAULT

The boundary between the Centro and Baja subareas is generally located near the Waterman Fault. Discharge is measured by the USGS stream gage at Barstow about 5 miles upstream from the boundary. Consequently surface flow into Baja carried by the Mojave River is un-gauged. The Judgment After Trial, January 10, 1996 (Judgment) sets forth the average annual inflow to Baja as 14,000 acre-feet per year (Judgment appendix C). Paragraph 2, page C-3 of the Judgment presents a schedule to be used to estimate the surface flow at the Waterman Fault based on measured flow at Barstow. The long term average annual flow as measured at Barstow during the sixty year hydrologic base period of the Judgment is 17,097 acre-feet (USGS stream gage records).

The schedule shown on page C-3 of the Judgment indicates that the first 2,000 acre-feet of flow at Barstow is completely consumed as recharge or consumptive use and produces zero surface flow at Waterman Fault. According to the schedule, when 100,000 acre-feet is measured at Barstow, there will be surface flow at Waterman Fault of 85,400 acre-feet, or that 14,600 acre-feet will be lost to recharge between the gage at Barstow and the boundary at Waterman. To ascertain the validity of the assumption inherent in the schedule and determine the volume of recharge that could be stored annually, we evaluated the area located roughly between the gage at Bartow and the Waterman Fault. The results of our investigation are provided in the accompanying Technical Memorandum (Appendix A), and the findings were presented to Watermaster in September of 2011.

An important part of the analysis involves the determination of available storage space in a finite period of time. The results, presented in Table 6 of Appendix A, indicate that the average annual discharge across the Waterman Fault for the sixty year hydrologic base period, 1931 to 1990 would be 16,406 acre-feet. We recommend that the inflow to Baja be changed to 16,406 acre-feet from 14,000 acre-feet for two reasons:

1. Losses between the Barstow gage and Waterman Fault are a function of channel conditions, pumping and return flow, consumptive use of native vegetation, discharges by the City of Barstow wastewater treatment plant and are represented in the aggregate by the change in water levels shown on Figure 7 of Attachment A.
2. The analysis resulting in the recommendation of 16,406 acre-feet is based on a data set that is more complete than the assumptions that were made for the Judgment. Primarily, substantially more water level data and water use data are available since 1992 than prior to 1992.

The assumptions set forth in the Judgment for this particular inflow element were based on information developed for prior years. Consequently, we are better able to relate stream flow and losses to estimates of change in storage quantifiable by reasonable estimates of hydrologic conditions and measured water level changes.

LONG TERM AVERAGE ANNUAL OUTFLOW AT AFTON

The Judgment includes an estimate for long term average annual outflow at Afton of 8,200 acre-feet. This value includes an estimate for storm flow and base flow (subsurface discharge), and is based on the sixty year hydrologic base period 1931-1990. Since surface flow at Waterman Fault is inflow to Baja and outflow at Afton represents surface discharge from Baja, the estimated average annual surface water recharge to Baja is represented by the difference. From the foregoing discussion, 16,406 acre-feet of inflow at Waterman Fault, less 8,200 acre-feet of outflow at Afton, would result in 8,206 of average annual recharge to Baja.

USGS Water Resources Investigation Report 01-4002, "Simulation of Ground-Water Flow in the Mojave River Basin, California" (Stamos et al 2001) provides an estimate for stream leakage in the amount of 12,013 acre-feet from the Mojave River to the Baja subarea during the hydrologic base period, (Stamos et al, page 83). Previous work regarding stream leakage is reprinted below:

Estimates of Annual Discharge from
the Mojave River Groundwater Basin

Study	Net stream leakage *(acre-feet)*
1930 (Hardt 1971)	10,050
1963 (Hardt 1971)	11,650
1937-61 (DWR 1967)	12,642
1931-90 (MBAW Judgment Table C-1)	7,400
1931-90 (USGS)	12,013

Although these values cover different time periods and different conditions, they are consistent, with the exception of the value included in the Judgment. If we use an inflow value of 17,153 acre-feet (16,406 plus 647 acre-feet from Kane wash and 100 acre-feet of precipitation) the stream leakage number would be 8,953 acre-feet (17,153-8,200 acre-feet), which is still less than reported by the others. However, there is no reason to prefer any one of the values listed in the table as closer to a true value than another. Each is based on a set of assumptions that is true for the given circumstances and supportable by the data available at the time.

To evaluate the long term water supply conditions in Baja, it is necessary to understand the long term average annual discharge at Afton reported in the Judgment, which includes a period of twenty three years of incomplete records from 1932-1952, and 1979 and 1980. An estimate for the incomplete record from the 1932 to 1952 was made by USGS (Hardt, 1971 page 16) and independently by Hanson Engineers (February 1993), prior to trial. The estimated average annual discharge at Afton based on Hardt, was 8,549 acre-feet and 8,247 acre-feet based on Hanson's estimate.

Despite the agreement in the estimates, it is possible that both values are overstated. It is also possible that the USGS reported discharge value at Barstow on which the estimate for Waterman fault and the incomplete data at Afton are based, is too low. Further, it is possible that the USGS reported value for stream leakage as determined by Stamos by modeling is not representative of the actual conditions that result in recharge. It would be very difficult to establish with certainty the true value of average annual discharge at Barstow, Waterman and Afton, as it occurred in the past. Accordingly, we propose using the USGS record at Afton from 1953 -1990 with minor modification to represent outflow at Afton Canyon. The results are shown on the proposed Table 5-2, which estimates stream leakage as surface inflow less outflow, or 17,153-5,611 =11,542 acre-feet. This value is more consistent with the previous work.

The period of missing record at Afton occurred during a period of time preceding the date that overdraft is generally considered to have commenced (around 1950), and the condition of the groundwater system and river channel in Baja that relate to recharge prior to 1950 no longer exist. The actual period of complete record for the USGS gage at Afton, includes 1931, 1953-1978, 1981-2010.

We recommend using the average discharge at Afton, represented by the actual record, but including data synthesized for 1979 and 1980, as this period spans the period of overdraft condition in Baja. The average discharge at Afton for this period is 5,611 acre-feet including storm flow of 5,475 and base flow of 137 acre-feet, as shown on table below:

Mojave Basin Area Watermaster
Estimated Future Average Discharge of the Mojave River at Afton, CA
Based on Estimated Potential Base Flow

(all values in acre-feet)

Water Year	Reported/Estimated(1)			Adjusted for Potential Base Flow(2)	
	Total Flow	Storm Flow	Base Flow	Base Flow	Total Flow
1931	1,268	143	1,125	137	280
1932	18,850	17,864	986	137	18,001
1933	1,000	0	1,000	137	137
1934	1,000	0	1,000	137	137
1935	1,000	0	1,000	137	137
1936	1,000	0	1,000	137	137
1937	54,070	53,070	1,000	137	53,207
1938	72,200	71,200	1,000	137	71,337
1939	1,000	0	1,000	137	137
1940	1,000	0	1,000	137	137
1941	49,900	48,900	1,000	137	49,037
1942	1,000	0	1,000	137	137
1943	47,200	46,200	1,000	137	46,337
1944	18,200	17,200	1,000	137	17,337
1945	10,800	9,800	1,000	137	9,937
1946	6,720	5,720	1,000	137	5,857
1947	1,000	0	1,000	137	137
1948	1,000	0	1,000	137	137
1949	1,000	0	1,000	137	137
1950	1,000	0	1,000	137	137
1951	1,000	0	1,000	137	137
1952	2,190	1,190	1,000	137	1,327
1953	990	7	983	137	144
1954	952	0	952	137	137
1955	912	34	878	137	171
1956	902	49	853	137	186
1957	753	0	753	137	137
1958	2,784	2,112	672	137	2,249
1959	597	18	579	137	155
1960	684	5	679	137	142
1961	668	22	646	137	159
1962	563	10	553	137	147
1963	751	178	573	137	315
1964	539	8	531	137	145
1965	566	54	512	137	191
1966	4,781	4,349	432	137	4,486
1967	1,466	1,168	298	137	1,305
1968	358	65	293	137	202
1969	72,725	72,282	443	137	72,419

Mojave Basin Area Watermaster
Estimated Future Average Discharge of the Mojave River at Afton, CA
Based on Estimated Potential Base Flow

(all values in acre-feet)

	Reported/Estimated[1]			Adjusted for Potential Base Flow[2]	
Water Year	**Total Flow**	**Storm Flow**	**Base Flow**	**Base Flow**	**Total Flow**
1970	542	0	542	137	137
1971	360	0	360	137	137
1972	598	0	598	137	137
1973	311	0	311	137	137
1974	435	0	435	137	137
1975	160	0	160	137	137
1976	297	0	297	137	137
1977	897	580	317	137	717
1978	46,749	46,271	478	137	46,408
1979	1,200	657	543	137	793
1980	66,700	66,157	543	137	66,293
1981	1,381	89	1,292	137	226
1982	1,052	100	952	137	237
1983	13,312	12,482	830	137	12,619
1984	1,820	1,106	714	137	1,243
1985	684	0	684	137	137
1986	550	0	550	137	137
1987	562	0	562	137	137
1988	915	234	681	137	371
1989	434	0	434	137	137
1990	546	0	546	137	137
1991	744	224	520	137	361
1992	628	307	321	137	444
1993	66,590	65,900	690	137	66,037
1994	483	0	483	137	137
1995	391	24	367	137	161
1996	633	280	353	137	417
1997	646	241	405	137	378
1998	1,287	935	352	137	1,072
1999	578	234	344	137	371
2000	283	7	275	137	144
2001	350	110	240	137	247
2002	239	0	239	137	137
2003	249	0	249	137	137
2004	394	113	281	137	250
2005	44,638	44,434	204	137	44,571
2006	186	14	172	137	151
2007	150	0	150	137	137
2008	166	36	130	137	173

Mojave Basin Area Watermaster
Estimated Future Average Discharge of the Mojave River at Afton, CA
Based on Estimated Potential Base Flow

(all values in acre-feet)

Water Year	Reported/Estimated(1)			Adjusted for Potential Base Flow(2)	
	Total Flow	**Storm Flow**	**Base Flow**	**Base Flow**	**Total Flow**
2009	112	7	105	137	144
2010	190	63	127	137	200
Average (all)	**8,035**	**7,403**	**632**	**137**	**7,540**
Average (measured)	**4,961**	**4,461**	**500**	**137**	**4,598**
Average (1953-1990 all)	**6,066**	**5,475**	**591**	**137**	**5,611**
Average (1953-1990 measured)	**4,517**	**3,923**	**594**	**137**	**4,060**
Average (1953-2010 all)	**6,025**	**5,534**	**491**	**137**	**5,671**
Average (1953-2010 measured)	**5,027**	**4,538**	**489**	**137**	**4,675**

Notes:

(1) Discharge of Mojave River at Afton, CA from water years 1932 through 1952 by William Hardt and published by USGS in Open - File Report, "Hydrologic Analysis of Mojave River Basin California using Electric Analog Model" dated August 18, 1971. Water Years 1979 and 1980 estimated by Mojave Basin Area Watermaster All other water year discharge values as reported by USGS station Mojave River at Afton, CA (10263000)..

(2) Potential future base flow estimated as the five-year average base flow from 2006 through 2010.

No Measured Data at Afton

Used to Estimate Future Base Flow

A fundamental premise of the Judgment is that arresting overdraft by purchasing supplemental water will result in stabilizing water levels in the upstream basins. Further, it is assumed that the sixty year base period hydrology that produced the average annual water supply will be repeated. Conditions in Alto have resulted in water level stability in the near river aquifer, Free Production Allowance is 60% of the Base Annual Production, and supplemental water has been purchased to offset the deficit. In Centro, there is a slight surplus in supply based on current pumping conditions and long term water supply. Also, total water production in Centro is about 60% less than it was during the Judgment’s base period. As conditions is Alto and Centro are significantly different today than they were 20 years ago (at the end of the hydrologic base period), we should expect long term supply conditions at Barstow in the future to be similar to the past.

However, it is unlikely that a similar conclusion can be made about Baja. Water levels have fallen significantly downstream from the Waterman Fault and upstream and downstream of the Calico Newberry Fault (at Minneola Road). The reduction in pumping in the past several years will at best stabilize water levels, but without purchase and recharge of imported water, water levels are unlikely to rise. Consequently the hydrologic conditions that exist currently are likely to remain in future.

The Judgment’s water supply conditions are based on a hydrologic base period, 1931-1990 with the assumption that the future water supply will mimic the past. Under the assumption that the water supply will be repeated, the Alto and Centro subareas will remain balanced in the future, imported water will continue to be purchased and recharged. Therefore we expect the water supply conditions at least to the Waterman Fault, to be consistent with history.

PHREATOPHYTES

As part of this evaluation of the Baja water supply conditions, and consistent with the information provided to Watermaster in September 2011, we are not recommending any change to the value assigned to phreatophyte use which is currently 2,000 acre-feet. We have discussed with Mr. Thomas Bilhorn, consultant to DFG, the process for re-evaluating this number. The Department is considering its position relative to the current health of the riparian habitat at Camp Cady, and in the Baja subarea in general. We have previously said that the conditions under which phreatophyte use was estimated to be 2,000 acre-feet per year have changed. Further, declines in water levels resulting from over pumping in Baja are not likely to recover sufficiently to support riparian plants to a past condition. At best, water levels under either current pumping conditions, or reduced pumping, will stabilize at or near the current levels. If this assumption is true, it is unlikely that a healthy riparian habitat will return in Baja beyond the limits of Camp Cady.

According to Mr. Bilhorn the Department is most concerned about two things

1. Preserving and restoring Camp Cady.
2. Potentially restoring habitat elsewhere in Baja.

Consequently, the Department’s goal may depend in part on using the 2,000 acre-feet assumed to be used by riparian plants in a different manner. Until the Department and Watermaster staff understand the relationship between the current 2,000 acre-foot estimate for phreatophyte use and the longer term goals of the Department, we are unprepared to make a recommendation on the fate of the water identified as phreatophyte use in the Judgment (Table 5-1 of the Watermaster Annual Report).

SUPPLY CONTRIBUTION FROM DESERT WASHES

For purposes of this report, we have included an estimated 647 acre-feet of recharge from Kane Wash as determined by USGS (Stamos, 2001). Also, we estimate that desert washes contribute to the water supply, although estimates of inflow volume vary. In work previously submitted to Watermaster, the desert wash contribution was conservatively estimated to be 205 acre-feet.

PROPOSED
TABLE 5-2

BAJA SUBAREA HYDROLOGICAL INVENTORY BASED ON LONG TERM AVERAGE NATURAL WATER SUPPLY AND OUTFLOW AND 2009-10 IMPORTS AND CONSUMPTIVE USE

(ALL AMOUNTS IN ACRE-FEET)

WATER SUPPLY	**Table 5-1**	**Table 5-2**	**Table 5-2 Proposed**
Surface Water Inflow			
Gaged	0	0	0
Ungaged	14,400	14,400	**17,153** [1]
Other Ungaged	0	0	**205** [2]
Subsurface Inflow	1,200	1,200	**1,581** [3]
Deep Percolation of Precipitation	100	100	100
Imports			
Replacement Water Deliveries	0	0	0
Water Storage Accounts[4]	0	0	0
Lake Arrowhead CSD	0	0	0
Big Bear Area RWA	0	0	0
TOTAL	**15,700**	**15,700**	**19,039**
CONSUMPTIVE USE AND OUTFLOW			
Surface Water Outflow			
Gaged	8,200	8,200	**5,611** [5]
Ungaged	0	0	0
Subsurface Outflow	0	0	0
Consumptive use			
Agriculture	20,800	10,400	10,400
Urban[6]	7,900	5,300	5,300
Phreatophytes[7]	2,000	2,000	2,000
Exports	0	0	0
TOTAL	**38,900**	**25,900**	**23,311**
Surplus / (Deficit)	(23,200)	(10,200)	**(4,272)**
Total Estimated Production (Current Year)[8]	43,879	23,767	23,400
PRODUCTION SAFE YIELD (Current Year)	**20,679**	**13,567**	**19,128**

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[1] Estimated from reported flows at USGS gaging station, Mojave River at Barstow. Includes 16,406 acre-feet of Mojave River surface flow across the Waterman Fault estimated by "Evaluations of Potential Mojave River Recharge Losses between Barstow and Waterman Fault", Wagner & Bonsignore, 2012 (see Appendix A, Table 6), and 747 acre-feet of local surface inflow from Kane Wash and Boom Creek.

[2] Estimated contribution from washes (Wagner, 2011).

[3] USGS Stamos modeling results 2001, pg. 87 Figure 34

[4] Water that was pre-purchased under the MWA Claim Program.

[5] Based on stormflow at Afton for water years 1931, 1953-78, 1981-1990 (from USGS) 1979-1980 estimated by Hanson Engineering 1992 plus base flow of 137 acre-feet (Watermaster 2010)

[6] Includes consumptive use of "Minimals Pool".

[7] From USGS Water-Resurces Investigation Report 96-4241 "Riparian Vegetation and Its Water Use During 1995 Along the Mojave River, Southern California" 1996.

[8] Based on Water Production Data for the 2009-10 Water Year.
Included in the production values are the estimated minimal producer's water use by Subarea.

RECOMMENDATION FOR FUTURE RAMPDOWN

Based on the foregoing, there is a deficit in Baja of 4,272 acre-feet. The annual deficit in Baja has averaged about 15,000 acre-feet per year since about 1950. If the current hydrologic conditions are consistent with the assumptions made herein, we might expect water level decline to slow, or possibly begin to stabilize. However, given the episodic nature of recharge to Baja, it may be several years before we know. Consequently we recommend reducing the Free Production allowance by 2.5% per year for two more years (2012-2013 and 2013-2014) consistent with the existing court order. At that time, we would evaluate the water supply conditions and changes in water levels since entry of Judgment.

The full extent of the Rampdown required in Baja to reach a balance is dependent of three conditions:

1. The amount of natural water supply.
2. The type of use.
3. The extent and distribution of pumping.

Assuming that the current pattern of land use remains the same, pumping would be sustainable, in the aggregate at around 20,000 acre-feet per year, with a lower consumptive use. A pattern of land use representing a lower consumptive use (meaning less agriculture and more domestic use) would allow for additional pumping. Assuming that water levels stabilize over a reasonable period of time (spanning the past 20 years and the next 5 years) Rampdown could be stopped (at 50% of BAP) at least for a few years to evaluate conditions.

We note that none of the proposed revisions discussed herein actually provide additional water. Rather, the revisions provide a framework to evaluate Free Production Allowance under different assumptions. Water level changes in Baja will ultimately provide the best measure of health in the groundwater system.

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5. Mojave Basin Area Watermaster Annual Reports

6. Stream gage data for the Mojave River, U.S. Geological Survey, 2012

APPENDICES

Appendix A - Evaluations of Potential Mojave River Recharge Losses between Barstow and Waterman Fault

Appendix B - Evaluation of Discharge for Mojave River Between Barstow and Waterman Fault

Appendix C - Analysis of Baja Subarea Desert Wash Discharge

Appendix D - Explanation of computed potential evapotranspiration and actual evapotranspiration for Harter project

APPENDIX A

Evaluations of Potential Mojave River Recharge Losses between Barstow and Waterman Fault

TECHNICAL
MEMORANDUM

TO: Mojave Basin Area Watermaster

FROM: Robert C. Wagner, P.E, Watermaster Engineer,
David M. Houston, P.E.

DATE: January 24, 2012

RE: Evaluations of Potential Mojave River Recharge Losses between Barstow and Waterman Fault

Information contained herein is intended to summarize the results of evaluations of potential groundwater recharge along the Mojave River between the USGS stream gage near Barstow, CA and Waterman Fault (see location map, Figure 1).

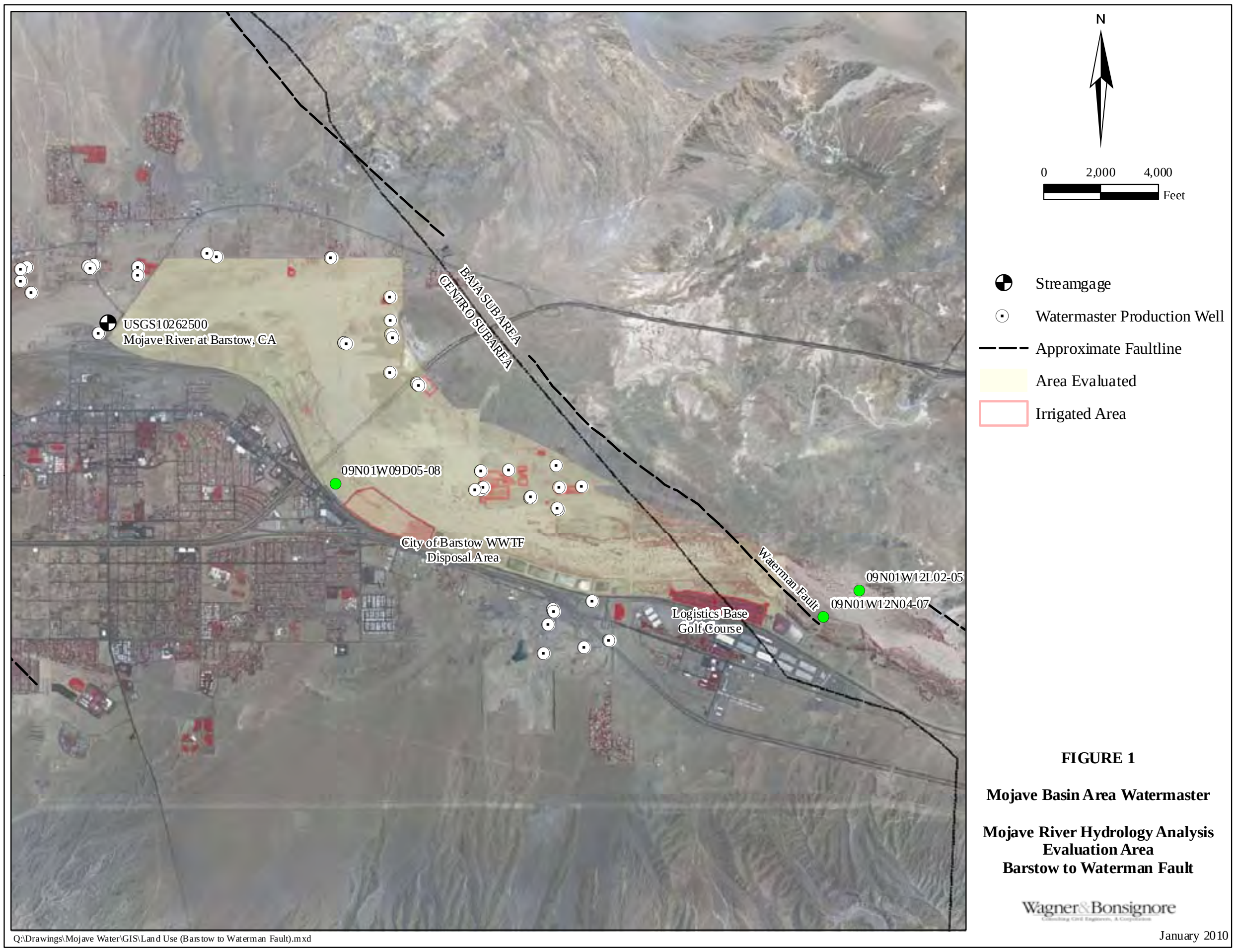


FIGURE 1

Mojave Basin Area Watermaster

Mojave River Hydrology Analysis
Evaluation Area
Barstow to Waterman Fault

January 2010

Evaluations were conducted as a free body mass-balance and an evaluation of Centro recharge potential based on an analysis conducted by Mojave Water Agency (MWA) in which surface water losses were calculated based on potential change in groundwater levels indicating recharge in the study area.

1.0 MASS-BALANCE EVALUATION

The 2,452 acre evaluated area is an approximated boundary of alluvial soils along the Mojave River, between the USGS streamgage 10262500 at Barstow, CA and the Waterman Fault, which potentially recharges to the groundwater aquifer below. The evaluated area was treated as a free body and an estimation of total supply and demand for the area was quantified. Based on an analysis of historic groundwater level measurements, we began our evaluation with the assumption that the area was nearly in balance. Groundwater levels decline slightly in dry years and rise following storm events. Water balances for three periods were evaluated; water year 2008, 15-year period from water year 1994 through 2008, and the last balance utilized various maximum periods of record available for each parameter. Results of our analysis, as shown in Tables 1 through 3, support our original hypothesis.

Measureable elements of supply to the area consist of discharge of the Mojave River, precipitation, and City of Barstow Wastewater Treatment Facility (WWTF) effluent. Measureable elements of demand on the area consist of verified pumping production and acreages of land likely consumptively using water. Other elements of supply or demand were estimated in order to complete a water mass balance for the evaluated area. Measured and estimated elements of supply and demand are described in sections below.

1.1 Supply

USGS 10262500 Mojave River at Barstow, CA

Discharge of the Mojave River is measured by the USGS near the North 1st Avenue bridge. Discharge is reported in the Annual Reports (Annual Reports) of the Mojave Basin Area Watermaster (MBAW). As shown on the location map, the streamgage is the westernmost edge of the evaluated area. See chart, Figure 2, for measured values of Mojave River discharge at Barstow. Measurements at the gage show the area is characterized by long periods of negligible surface flow interrupted by infrequent storm events producing large spikes of discharge, as shown on the hydrograph in Figure 2.

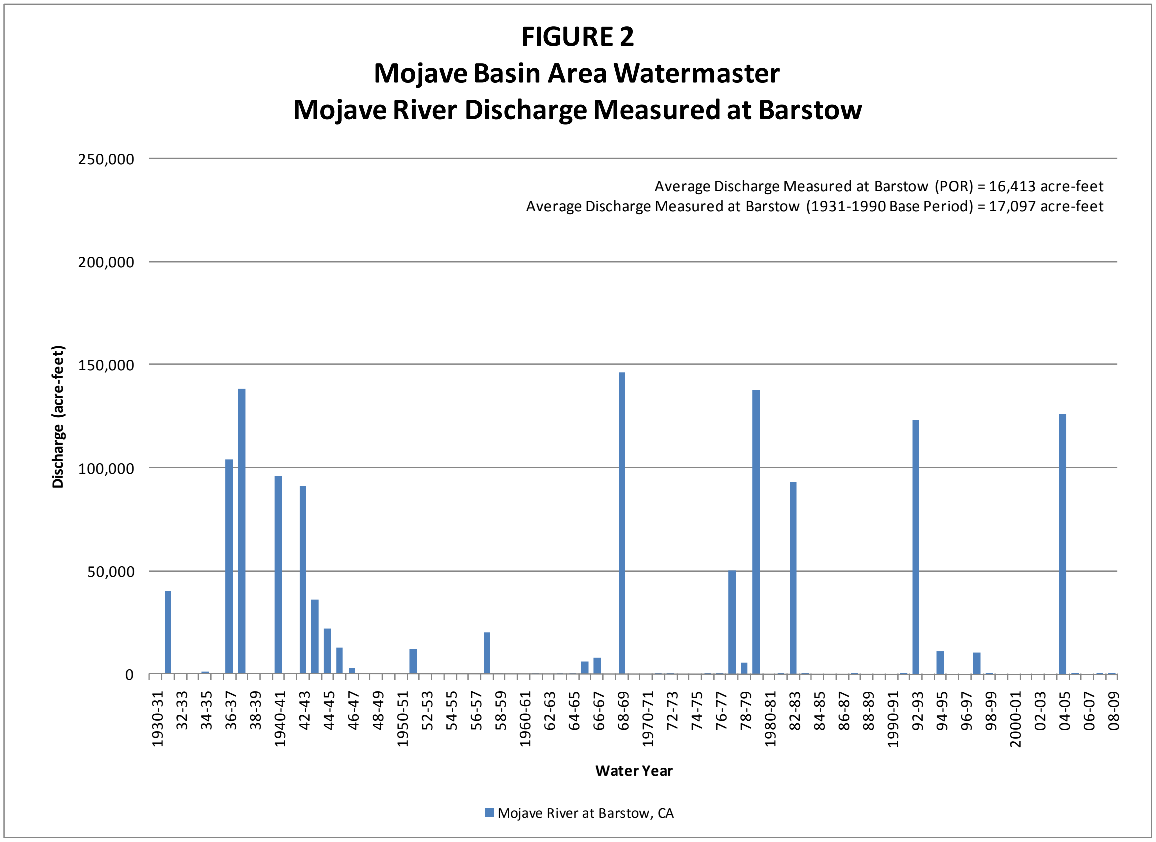


FIGURE 2
Mojave Basin Area Watermaster
Mojave River Discharge Measured at Barstow

Surface Runoff

A small percentage of precipitation results in surface runoff and a smaller percentage of surface runoff will contribute to groundwater recharge. The majority of precipitation will be lost to evaporation, used by vegetation, or simply not percolate past the top layer of soil. For the evaluated area, the surface runoff is assumed to be negligible.

Subsurface Inflow

Subsurface inflow entering Centro Subarea is reported as an estimated 2,000 acre-feet. According to the Regional Water Table (2008) in the Mojave River and Morongo Groundwater Basins, Southwestern Mojave Desert, California, the groundwater elevation changes about 400 feet from 2,350 feet to about 1,950 feet in roughly 25 miles along the Mojave River from the western boundary to the eastern boundary of Centro. However, in the roughly 10 miles upstream of the evaluation area, the water table only changes 100 feet. Due to limited availability of more detailed data regarding subsurface inflow, based on the small change in water table elevation upstream of the evaluation area, to simplify the evaluation, we assumed subsurface inflow to the evaluated area was minimal. This is a limitation of the evaluation.

Precipitation

As described in the Surface Runoff section, the majority of precipitation is assumed to be consumptively used between Barstow and Waterman fault. The amount of precipitation falling on the evaluated area was estimated using measurements reported for the California Irrigation Management Information System (CIMIS) station Barstow NE. Data from this station was available from water years 1998 through 2009.

Deep Percolation of Precipitation

Deep Percolation of Precipitation is assumed to be negligible.

City of Barstow WWTF Effluent

City of Barstow Wastewater Treatment Facility effluent was approximated at by influent data provided by City of Barstow. Data was available from 2006 through 2009.

Irrigation Return Flow

Irrigation return flow is roughly estimated as 30% of agricultural pumping and 70% of domestic pumping based on previous studies reported in “Simulation of Ground-Water Flow in the Mojave River Basin, California” USGS WRIR 01-4002. Municipal return flow was estimated as 46% of pumping based on independent studies in the Alto subarea by MBAWM.

1.2 Demand

Mojave River Estimated Outflow

Groundwater levels monitored using wells in the evaluated area, with perforation depths varying from 60 to 640 feet below ground surface, appear to indicate that the supply and demand for the evaluated area is nearly balanced (see charts below, Figures 3 and 4).

FIGURE 3
Mojave Basin Area Watermaster
09N01W12N04-07

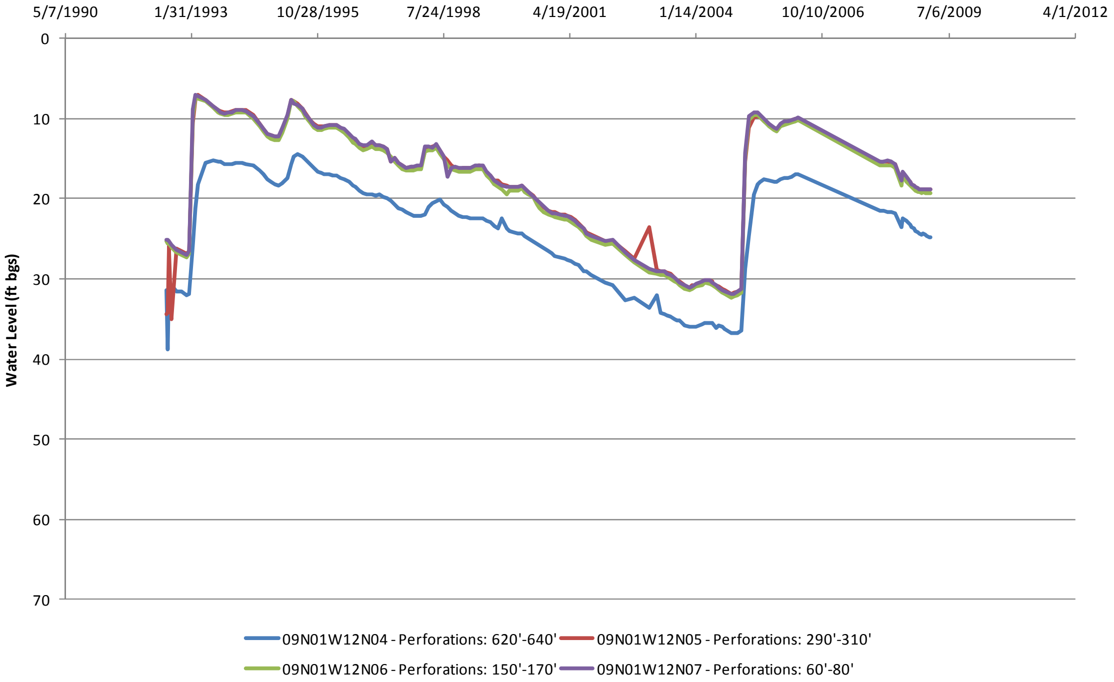
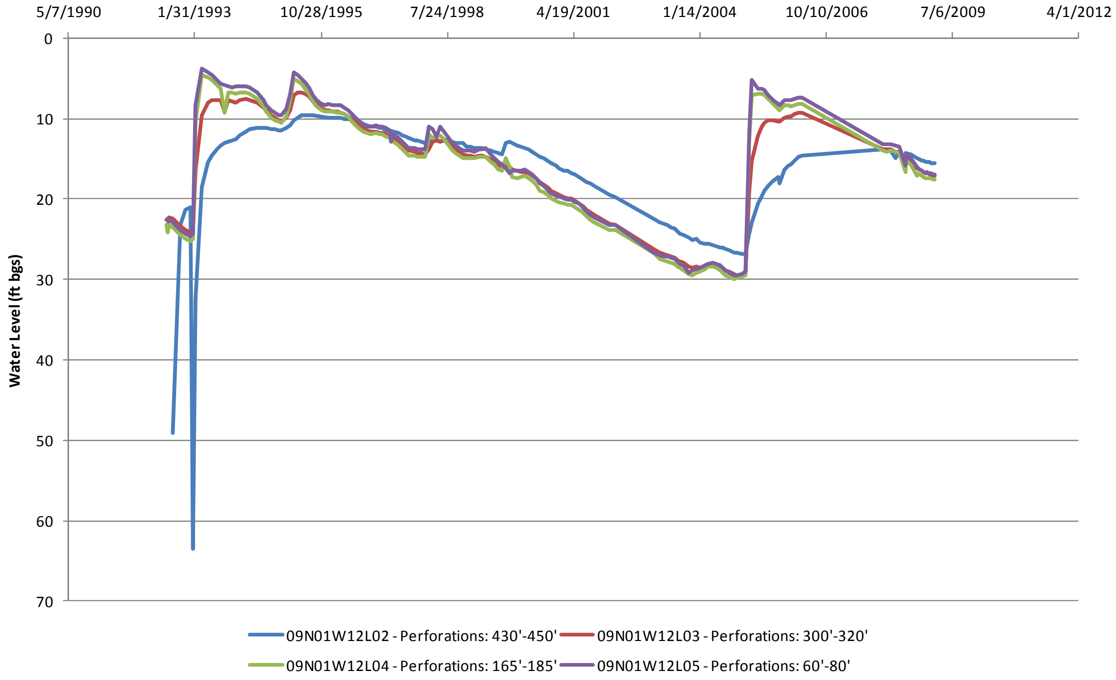


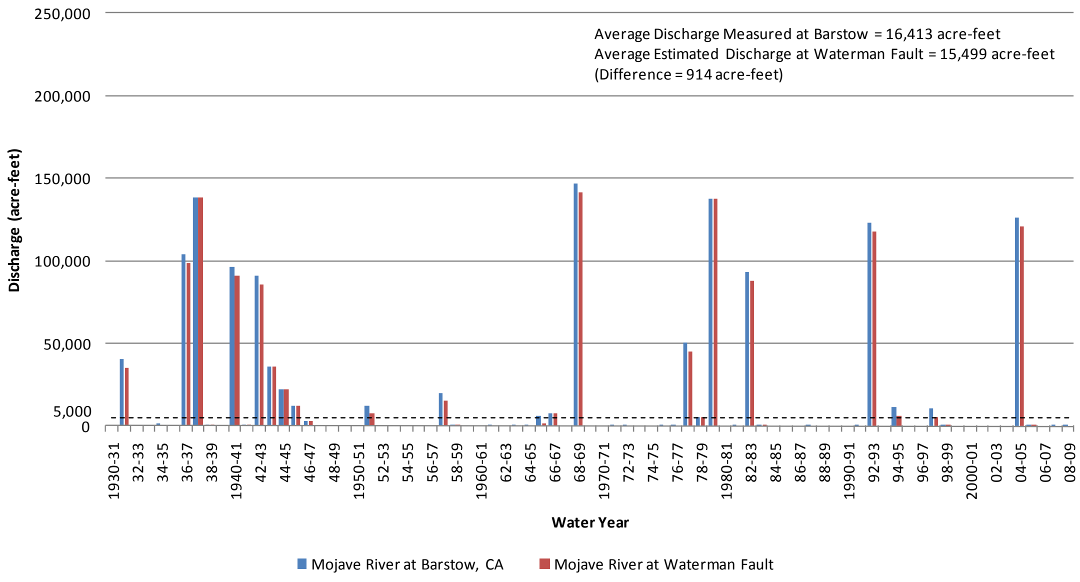
FIGURE 4
Mojave Basin Area Watermaster
09N01W12L02-05



Over the course of the 12 year dry period from water years 1993 through 2004 water levels declined about 20 to 25 feet. A large storm at the beginning of water year 2005 raised the water levels about 20 feet. Based on the available water level data, we estimated outflow at the Waterman Fault assuming that the groundwater recharge for the evaluated area has a maximum value. We estimated this maximum value based on an estimated soil available water capacity of about 10 percent. Based on an estimated maximum depth between 20 and 25 feet, an effective porosity of 10 percent, and an evaluated area of about 2,500 acres, the maximum groundwater recharge value is about 5,000 acre-feet.

We created a historic discharge hydrograph for Waterman Fault (Figure 5) based on the assumption that a maximum of 5,000 acre-feet could recharge between the Barstow streamgage and Waterman Fault. Mojave River discharge at Waterman Fault was assumed to be 5,000 acre-feet per year less than discharge measured at Barstow. We also assumed that the soil would be saturated in any year following a year with greater than 5,000 acre-feet of discharge and accordingly would not recharge. In such a year the streamflow losses between Barstow and Waterman Fault were assumed to be negligible.

FIGURE 5
Mojave Basin Area Watermaster
Mojave River Discharge Measured at Barstow and Estimated at Waterman Fault



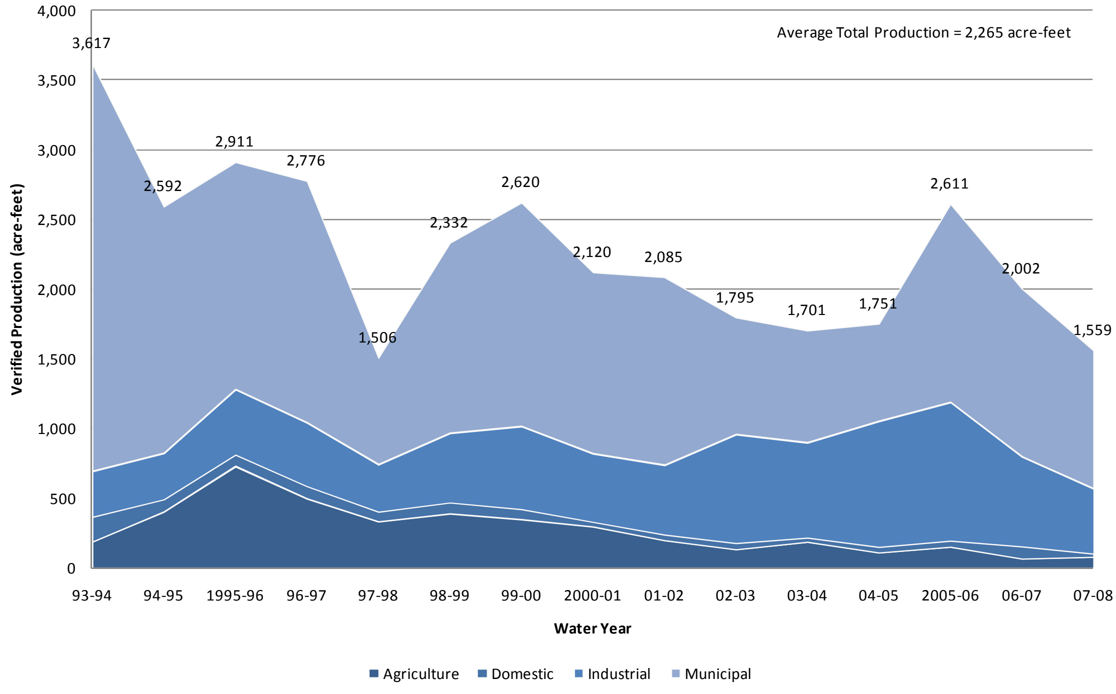
Subsurface Outflow

Subsurface outflow from Centro Subarea is reported in the Annual Reports to be about 1,200 acre-feet per year. Waterman Fault nearly coincides with the boundary of Centro Subarea, accordingly this value is used for the subsurface outflow of the evaluated area.

Water Production (Pumping)

Verified production for the evaluated area was provided by Watermaster for water years 1994 through 2008. The production uses are identified as Agricultural, Domestic, Industrial, and Municipal. Industrial uses in the evaluated area are represented solely by Service Rock Products Corporation. Municipal uses are only by Golden State Water Company. Verified production is shown on Figure 6.

FIGURE 6
Mojave Basin Area Watermaster
Verified Production Between Barstow and Waterman Fault



Consumptive Use

Irrigation

The majority of lands irrigated in water year 2007 were delineated by Watermaster and provided in GIS files. We identified additional lands receiving water by reviewing infrared aerial imagery of the area. Lands identified by Watermaster indicated the crop type being irrigated. We used a Consumptive Use estimation program, called CUP-Plus, that was developed by California Department of Water Resources (DWR) and UC Davis. The program estimates Crop Evapotranspiration (ET_C) for an irrigated crop in an identified area based on input daily climate data specific for the area. Daily climate data measured at CIMIS station Barstow NE was used to estimated ET_C values. ET_C values were then used to estimate the consumptive use of each crop. Irrigated areas identified based on review of infrared aerial imagery were assumed to have the same consumptive use as improved pasture areas.

Urban Areas

Urban areas within the evaluated area were identified using infrared aerial imagery. A percentage of irrigated area was estimated and a consumptive use similar to turfgrass was assumed for urban outdoor use.

Phreatophytes

Native vegetation areas were identified using infrared aerial imagery. A percentage of the identified areas consumptively using water was estimated and the use of the riparian plants was calculated based on information for the Centro Subarea in "Riparian Vegetation and its Water Use During 1995 Along the Mojave River, Southern California" by G. Lines and T. Bilhorn, USGS WRIR 96-4241.

Surface Water Evaporation

Ponds and Lakes were identified by Watermaster and through review of aerial imagery. Evaporation from the surface of the water bodies was estimated based on surface area and the average reference evapotranspiration (ET_O) for the CIMIS Barstow NE station.

1.3 Results

Water year 2008 was a dry year; very little flow was measured in the Mojave River at the Barstow gage. Accordingly, it was assumed that flow at Waterman Fault was negligible and a water balance concluded that the area was slightly in deficit, as expected (see Table 1).

TABLE 1

Water Balance - Water Year 2007-08
(all measurements in acre-feet)

Component	Barstow to Waterman Fault
Supply	
Mojave River Measured Inflow (Barstow)(1)	10
Surface Runoff(2)	0
Subsurface Inflow	0
Precipitation(3)	375
Deep Percolation of Precipitation	0
City of Barstow WWTF Effluent(4)	2,810
Subtotal	**3,196**
Return Flow(5)	497
Total Available Supply	**3,692**
Demand	
Mojave River Estimated Outflow (Waterman Fault)	0
Subsurface Outflow (from Judgement After Trial)	1,200
Production(6)	
Agricultural	78
Domestic	26
Industrial	466
Municipal	989
Consumptive Use of Irrigation (Water Year 2007 Acreage)(7)	
Logistics Base Golf Course	189
City of Barstow WWTF Disposal Area	406
All Other Irrigated Areas	176
Urban Area Consumptive Use(8)	47
Phreatophytes Consumptive Use(9)	490
Surface Water Evaporation(10)	113
Total Demand	**4,180**
Surplus/(Deficit)	**(488)**

Notes:
(1) From Annual Reports of Mojave Basin Area Watermaster (MBAW).
(2) Surface runoff is assumed to be negligible.
(3) Precipitation reported by Barstow NE CIMIS station, falling on evaluated area.
(4) Approximate, based on influent data provided by City of Barstow.
(5) Return flow is estimated as 30% of agricultural pumping, 70% domestic and 46% municipal.
(6) 2007-08 verified production from MBAW.
(7) Irrigated acreage provided by MBAW. Additional acreage was estimated using infrared aerial imagery and assuming an ET_C value from CA DWR CUP plus Program.
(8) Urban areas estimated using infrared aerial imagery and assuming an ET_C value from CA DWR CUP plus Program.
(9) Consumptive use of riparian plants calculated based on information for Centro Subarea in "Riparian Vegetation and Its Water Use During 1995 Along the Mojave River, Southern California" by G. Lines and T. Bilhorn, USGS WRIR 96-4241.
(10) Evaporation is calculated based on water surface areas estimated using aerial imagery and CIMIS average ET_O for Barstow NE station (68.04 in.).

The second water balance was evaluated from water year 1994 through 2008, see Table 2. Verified water production from 1994 through 2008 was readily available and precipitation was near average for this period. As shown on Figures 3 and 4, storms in 1993 and 2005 appear to recharge the groundwater basin while dry periods between storms correspond to a slight decline in storage. This phenomenon was used to estimate potential flows at Waterman Fault based on flows measured at Barstow (as shown in Figure 5). For the 1994-2008 water balance, Mojave River average outflow at Waterman Fault was estimated in such a manner and the balance yielded a surplus of about 711 acre-feet.

TABLE 2

Water Balance - Water Years 1993-94 Through 2007-08
(all measurements in acre-feet)

Component	Barstow to Waterman Fault
Supply	
Mojave River Measured Inflow (Barstow)(1)	9,865
Surface Runoff(2)	0
Subsurface Inflow	0
Precipitation(3)	1,010
Deep Percolation of Precipitation	0
City of Barstow WWTF Effluent(4)	2,818
Subtotal	**13,694**
Return Flow(5)	756
Total Available Supply	**14,450**
Demand	
Mojave River Estimated Outflow (Waterman Fault)(6)	8,853
Subsurface Outflow (from Judgement After Trial)	1,200
Production(7)	
Agricultural	273
Domestic	70
Industrial	564
Municipal	1,358
Consumptive Use of Irrigation (Water Year 2007 Acreage)(8)	
Logistics Base Golf Course	189
City of Barstow WWTF Disposal Area	406
All Other Irrigated Areas	176
Urban Area Consumptive Use(9)	47
Phreatophytes Consumptive Use(10)	490
Surface Water Evaporation(11)	113
Total Demand	**13,739**
Surplus/(Deficit)	**711**

Notes:

(1) From Annual Reports of Mojave Basin Area Watermaster (MBAW).

(2) Surface runoff is assumed to be negligible.

(3) 1998-2009 precipitation reported by Barstow NE CIMIS station, falling on evaluated area.

(4) Approximate, based on influent data provided by City of Barstow.

(5) Return flow is estimated as 30% of agricultural pumping, 70% domestic and 46% municipal.

(6) Estimated average flow at Waterman Fault from based on an analysis of estimated losses between the fault and the USGS gage at Barstow, CA, as shown in Figure 5.

(7) 1993-94 through 2007-08 verified production from MBAW.

(8) Irrigated acreage provided by MBAW. Additional acreage was estimated using infrared aerial imagery and assuming an ET_C value from CA DWR CUP plus Program.

(9) Urban areas estimated using infrared aerial imagery and assuming an ET_C value from CA DWR CUP plus Program.

(10) Consumptive use of riparian plants calculated based on information for Centro Subarea in "Riparian Vegetation and Its Water Use During 1995 Along the Mojave River, Southern California" by G. Lines and T. Bilhorn, USGS WRIR 96-4241.

(11) Evaporation is calculated based on water surface areas estimated using aerial imagery and CIMIS average ET_O for Barstow NE station (68.04 in.).

The third evaluation assumes the area is in balance with the goal of estimating long term average outflow at Waterman Fault, see Table 3. Available long term periods of record were used for various elements of supply and demand in the water balance. Water year 2007 land uses were used to estimate consumptive use demands. Subtracting elements of demand from elements of supply results in a calculated long term average outflow at Waterman Fault of about 16,795 acre-feet, about 300 acre-feet less than the long term average inflow at Barstow.

Results of the three water balance evaluations, though all elements cannot be known at this time, support the assumption that the evaluated area is nearly in hydrologic balance. Accordingly, Mojave River flow measured at Barstow can be used to in a similar manner to estimate flow at Waterman Fault, thence inflow to the Baja Subarea.

TABLE 3

Water Balance - Using Data from Historical Periods of Record
(all measurements in acre-feet)

Component	Barstow to Waterman Fault
Supply	
Mojave River Inflow (Barstow)(1)	17,097
Surface Runoff(2)	0
Subsurface Inflow	0
Precipitation(3)	1,010
Deep Percolation of Precipitation	0
City of Barstow WWTF Effluent(4)	2,818
Subtotal	**20,925**
Return Flow(5)	756
Total Available Supply	**21,681**
Demand	
Subsurface Outflow (from Judgement After Trial)	1,200
Production(6)	
Agricultural	273
Domestic	70
Industrial	564
Municipal	1,358
Consumptive Use of Irrigation (Water Year 2007 Acreage)(7)	
Logistics Base Golf Course	189
City of Barstow WWTF Disposal Area	406
All Other Irrigated Areas	176
Urban Area Consumptive Use(8)	47
Phreatophytes Consumptive Use(9)	490
Surface Water Evaporation(10)	113
Total Demand	**4,886**
Mojave River Outflow (Waterman Fault)	**16,795**

Notes:

(1) 1931-1990 average, from USGS.

(2) Surface runoff is assumed to be negligible.

(3) 1998-2009 precipitation reported by Barstow NE CIMIS station, falling on evaluated area.

(4) Approximate, based on influent data provided by City of Barstow.

(5) Return flow is estimated as 30% of agricultural pumping, 70% domestic and 46% municipal.

(6) 1993-94 through 2007-08 verified production from MBAW.

(7) Irrigated acreage provided by MBAW. Additional acreage was estimated using infrared aerial imagery and assuming an ET_C value from CA DWR CUP plus Program.

(8) Urban areas estimated using infrared aerial imagery and assuming an ET_C value from CA DWR CUP plus Program.

(9) Consumptive use of riparian plants calculated based on information for Centro Subarea in "Riparian Vegetation and Its Water Use During 1995 Along the Mojave River, Southern California" by G. Lines and T. Bilhorn, USGS WRIR 96-4241.

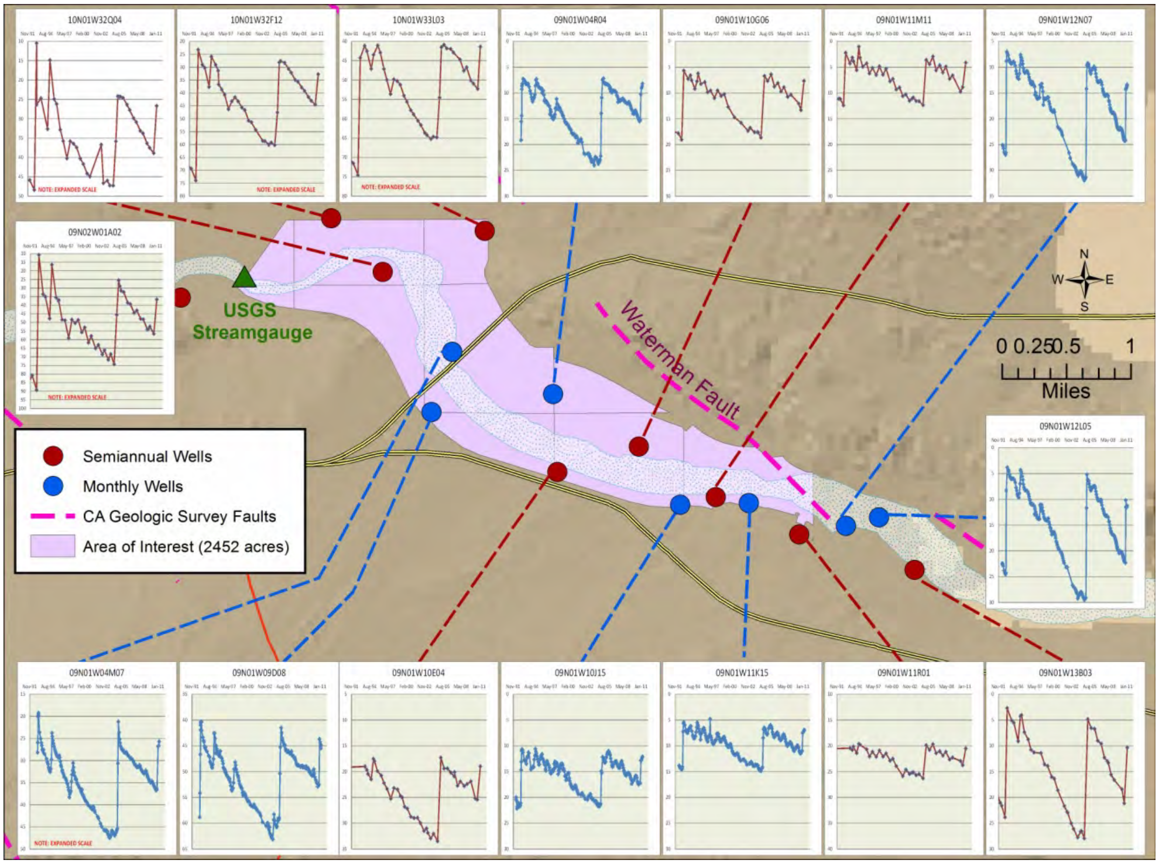
(10) Evaporation is calculated based on water surface areas estimated using aerial imagery and CIMIS average ET_O for Barstow NE station (68.04 in.).

2.0 RECHARGE POTENTIAL EVALUATION

Groundwater Monitoring

The evaluated area along the Mojave River, between the USGS streamgage 10262500 at Barstow, CA and the Waterman Fault, is monitored by MWA at 16 locations (see Figure 7 below). Groundwater levels gradually fall during dry periods and recover during each storm as discussed in Section 1.0 and shown on the hydrographs dating from water years 1992 through 2011.

FIGURE 7



Aquifer Change in Storage

MWA analyzed the porosity of samples taken from the Centro area and compared their findings with the reported findings of similar analyses. Samples were evaluated for total porosity (the space between soil grains) and effective porosity (the volume of pore space that will drain under the influence of gravity). Findings of porosity are shown on Table 4 below.

TABLE 4
Total and Effective Porosity in Centro Subarea

Type	Porosity	Source
Total Porosity	19.5 & 33.7%	Analog Model (Hardt, 1971)
	20 & 20%	Numeric Model (Stamos, 2001)
	24 & 26%	MR-1 & MR-2 Advanced elogs (Schlumberger, 2009)
	30, 15, 25, 24 & 24%	MWA Samples (MWA, 2011)
Average	**~24%**	
Effective Porosity	9 & 10%	MR-1 & MR-2 Advanced elogs (Schlumberger, 2009)
	8, 2, 1, 4, & 8%	MWA Samples (MWA, 2011)
Average	**~9%**	

MWA analyzed water level recovery resulting from each storm, and based on an estimated effective porosity of the soils in the evaluated area of 9% (Winkel, Tony MWA, See Attachment A), approximated a volume of water recharging to the aquifer for each storm. A maximum estimated change in groundwater storage of 6,196 acre-feet resulted from the storm in water year 1993. The reported discharge of the Mojave River at Barstow in 1993 was about 122,800 acre-feet; the resulting discharge at Waterman Fault would be 116,604 acre-feet (See Table 5).

TABLE 5
Estimated Change in Groundwater Storage and Resulting Discharge of the Mojave River at Waterman Fault

Water Year	Reported Discharge at Barstow	Estimated Change in Groundwater Storage	Resulting Discharge at Waterman Fault	Waterman Percentage of Barstow	Years Between Storms	Average Annual Change in Storage
1993	122,800	6,196	116,604	95%	10	628
1995	11,110	1,869	9,241	83%	2	935
1998	10,512	985	9,527	91%	3	328
2005	126,168	4,365	121,803	97%	7	624
2011	NA	2,034	NA	NA	6	433
Average	67,648	3,090	64,294	91%	6	589

The storm occurring in water year 1993 was preceded by a dry period lasting about 10 years. Accordingly, the recharge volume of 6,196 acre-feet was assumed to be about the capacity of the groundwater aquifer. The resulting average annual change in storage for the 10-year period between 1983 and 1993 was about -628 acre-feet per year, accounting for small intermittent storms. For the purposes of this analysis, it was assumed that the groundwater aquifer increased in available storage by 628 acre-feet per year and accumulated each year during a dry period. Each storm was assumed to recharge the aquifer to a maximum of 6,196 acre-feet. Resulting surface water loss rates between Barstow and Waterman Fault were estimated to be equivalent to the available aquifer storage.

As shown in Table 6 below, the resulting average annual loss between Barstow and Waterman Fault is estimated to be about 697 acre-feet from 1931 through 2010 (690 acre-feet from 1931-1990). The resulting average annual estimated discharge at Waterman Fault was 15,516 acre-feet per year from 1931 through 2010 (16,406 acre-feet from 1931-1990).

TABLE 6

Estimated Annual Surface Water Losses from the Mojave River Between Barstow and Waterman Fault

Water Year	Reported Discharge at Barstow	Estimated Available Aquifer Storage	Estimated Surface Water Losses	Estimated Discharge at Waterman Fault
1931	0	6,196	0	0
1932	40,305	0	6,196	34,109
1933	0	628	0	0
1934	0	1,255	0	0
1935	1,180	1,883	1,180	0
1936	0	2,510	0	0
1937	103,879	0	3,138	100,741
1938	138,094	0	628	137,466
1939	550	78	550	0
1940	0	705	0	0
1941	96,003	0	1,333	94,670
1942	101	527	101	0
1943	90,974	0	1,154	89,820
1944	36,254	0	628	35,626
1945	22,087	0	628	21,459
1946	12,577	0	628	11,949
1947	2,877	628	628	2,249
1948	0	1,255	0	0
1949	0	1,883	0	0
1950	0	2,510	0	0
1951	0	3,138	0	0
1952	12,548	0	3,766	8,782
1953	0	628	0	0
1954	0	1,255	0	0
1955	0	1,883	0	0
1956	0	2,510	0	0
1957	0	3,138	0	0
1958	20,063	0	3,766	16,297
1959	4	624	4	0
1960	0	1,251	0	0
1961	0	1,879	0	0
1962	735	2,506	735	0
1963	0	3,134	0	0
1964	1	3,761	1	0
1965	6	4,382	6	0

Water Year	Reported Discharge at Barstow	Estimated Available Aquifer Storage	Estimated Surface Water Losses	Estimated Discharge at Waterman Fault
1966	6,350	0	5,010	1,340
1967	7,691	0	628	7,063
1968	0	628	0	0
1969	146,601	0	1,255	145,346
1970	0	628	0	0
1971	0	1,255	0	0
1972	44	1,839	44	0
1973	151	2,315	151	0
1974	0	2,943	0	0
1975	0	3,571	0	0
1976	1	4,197	1	0
1977	2	4,823	2	0
1978	50,463	0	5,450	45,013
1979	5,560	628	628	4,932
1980	137,654	0	1,255	136,399
1981	0	628	0	0
1982	1	1,254	1	0
1983	92,995	0	1,882	91,113
1984	42	586	42	0
1985	0	1,213	0	0
1986	0	1,841	0	0
1987	0	2,468	0	0
1988	8	3,088	8	0
1989	0	3,716	0	0
1990	0	4,343	0	0
1991	0	4,971	0	0
1992	30	5,568	30	0
1993	122,800	0	6,196	116,604
1994	0	628	0	0
1995	11,110	0	1,255	9,855
1996	0	628	0	0
1997	0	1,255	0	0
1998	10,512	0	1,883	8,629
1999	0	627	0	0
2000	0	1,255	0	0
2001	0	1,882	0	0
2002	0	2,510	0	0
2003	0	3,138	0	0
2004	0	3,765	0	0
2005	126,168	0	4,393	121,775
2006	182	446	182	0
2007	0	1,073	0	0
2008	10	1,691	10	0
2009	0	2,318	0	0
2010	374	2,572	374	0

Water Year	Reported Discharge at Barstow	Estimated Available Aquifer Storage	Estimated Surface Water Losses	Estimated Discharge at Waterman Fault
1931-2010 Avg	**16,212**	**1,580**	**697**	**15,516**
1931-1990 Avg	**17,097**	**1,535**	**690**	**16,406**

3.0 CONCLUSIONS

Estimated discharge of the Mojave River at Waterman Fault based on these two evaluations seems to be in agreement. Results of the three water balance evaluations in Section 1.0, though all elements cannot be known at this time, support the assumption that the evaluated area is nearly in hydrologic balance. Similarly, the evaluation of recharge potential in Section 2.0 suggests an average surface water loss of 690 acre-feet, for water years 1931 through 1990, resulting in an estimated discharge of 16,406 acre-feet at Waterman Fault, which is about a difference of 2% from the 16,795 estimated in Section 1.0. Accordingly, Mojave River flow measured at Barstow can be used to in a similar manner to estimate flow at Waterman Fault, thence inflow to the Baja Subarea.

APPENDIX B

Evaluation of Discharge for Mojave River Between Barstow and Waterman Fault

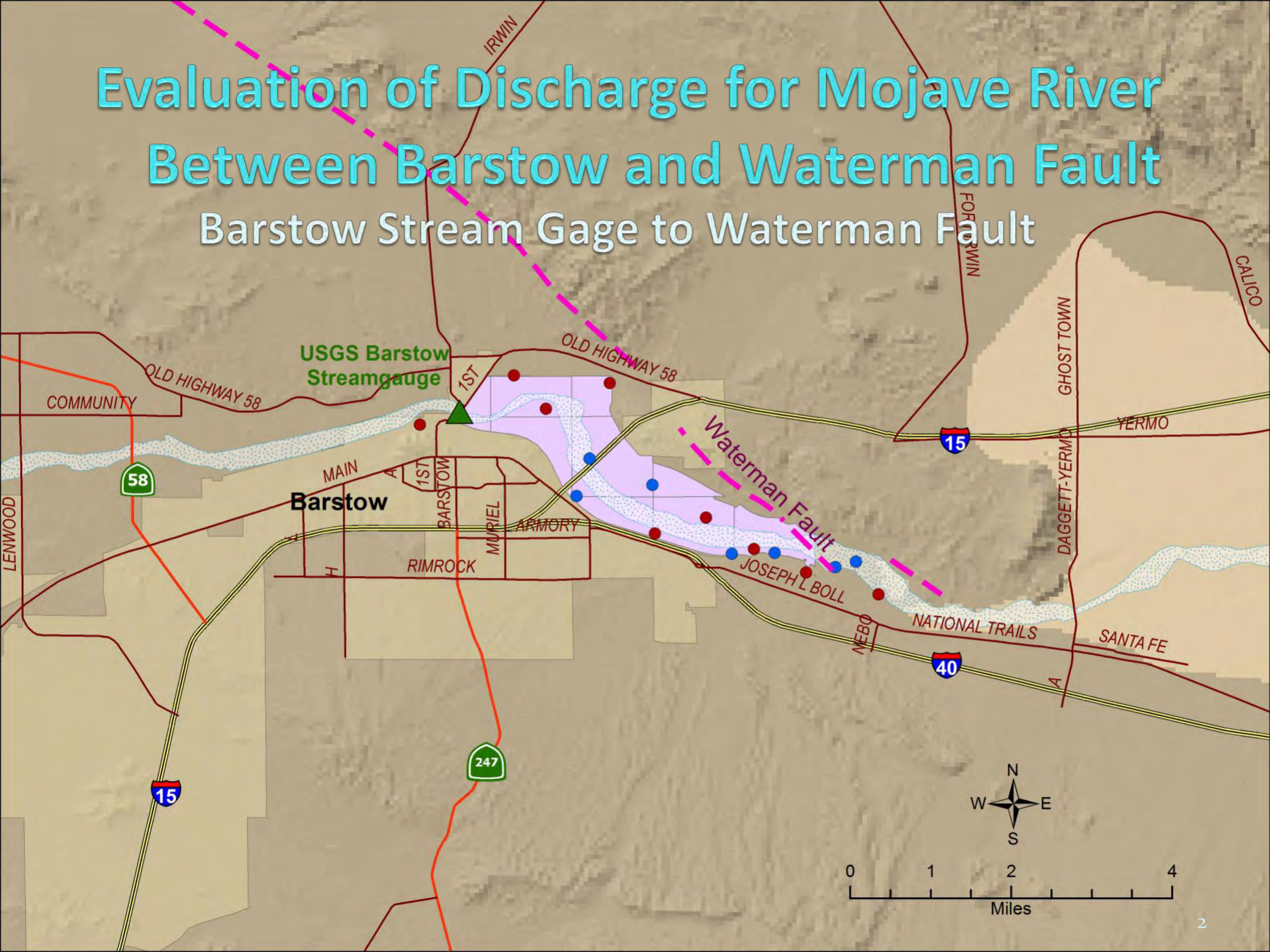
APPENDIX B

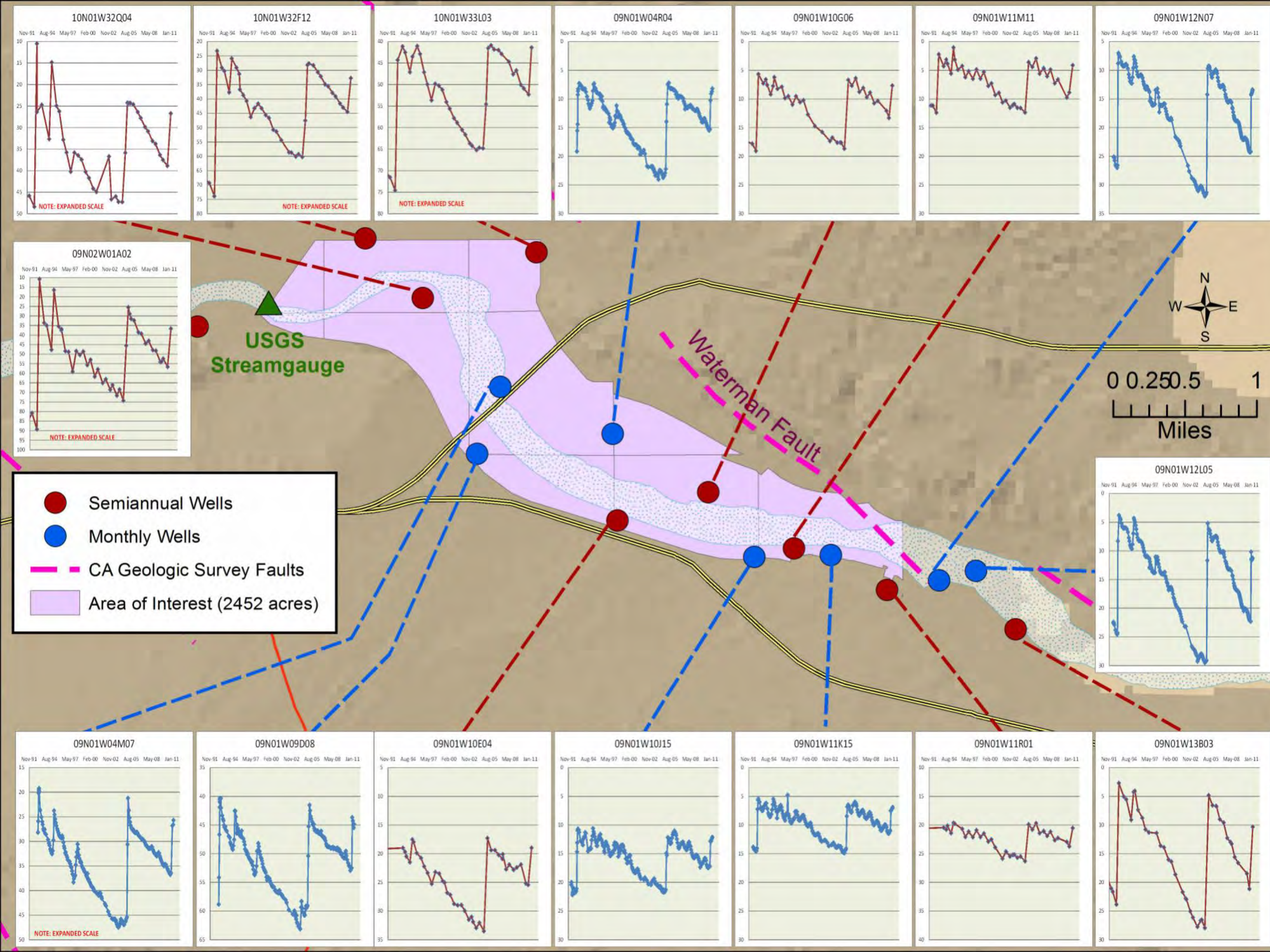
Evaluation of Discharge for Mojave River Between Barstow and Waterman Fault

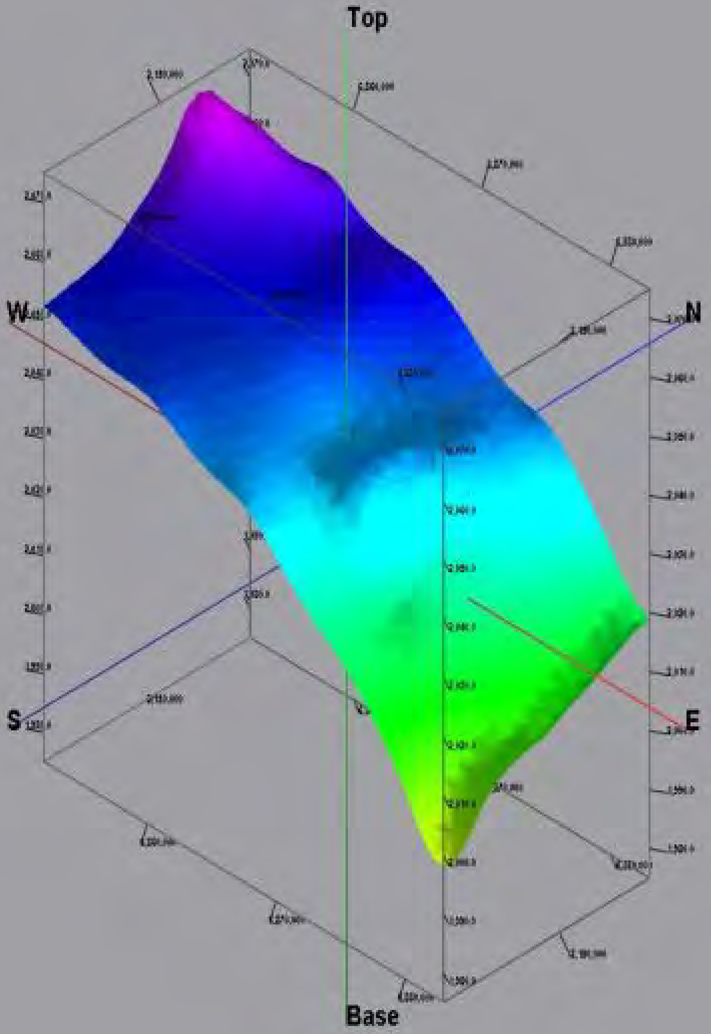
Robert C. Wagner, P. E. Watermaster Engineer
Tony Winkel, P. E. Mojave Water Agency

Evaluation of Discharge for Mojave River Between Barstow and Waterman Fault

Barstow Stream Gage to Waterman Fault

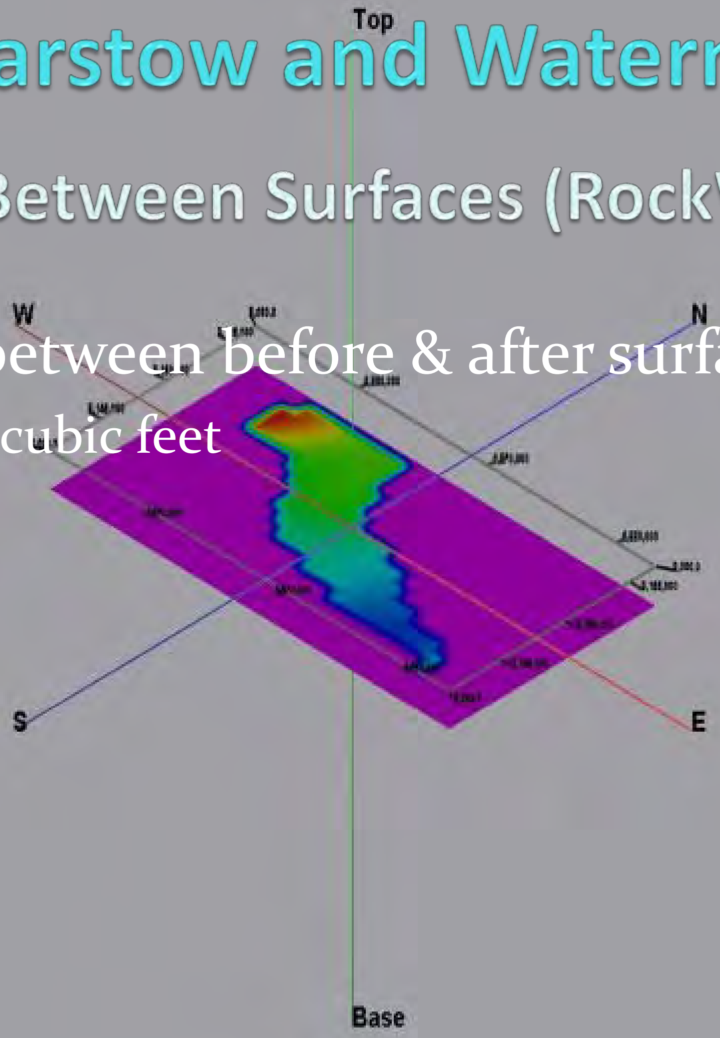



10N01W32Q04
NOTE: EXPANDED SCALE
10N01W32F12
NOTE: EXPANDED SCALE
10N01W33L03
NOTE: EXPANDED SCALE
09N01W04R04
09N01W10G06
09N01W11M11
09N01W12N07
09N02W01A02
NOTE: EXPANDED SCALE
Nov-91
Aug-94
May-97
Feb-00
Nov-02
Aug-05
May-08
Jan-11
USGS Streamgauge
Waterman Fault
N
W
E
S
0 0.250.5 1
Miles
09N01W12L05
Semiannual Wells
Monthly Wells
CA Geologic Survey Faults
Area of Interest (2452 acres)
09N01W04M07
NOTE: EXPANDED SCALE
09N01W09D08
09N01W10E04
09N01W10J15
09N01W11K15
09N01W11R01
09N01W13B03


Top
W
N
S
E
Base

Evaluation of Discharge for Mojave River Between Barstow and Waterman Fault

Volume Between Surfaces (RockWorks)

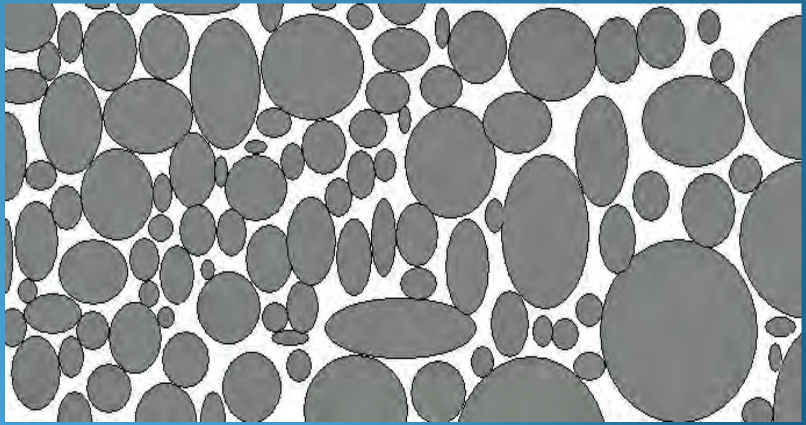


- Total volume between before & after surfaces
  - 2,112,876,826 cubic feet

Evaluation of Discharge for Mojave River Between Barstow and Waterman Fault

Porosity

- Total Porosity
  - The space between the grains
- Effective porosity
  - The volume of pore space that will drain under the influence of gravity.



Evaluation of Discharge for Mojave River Between Barstow and Waterman Fault

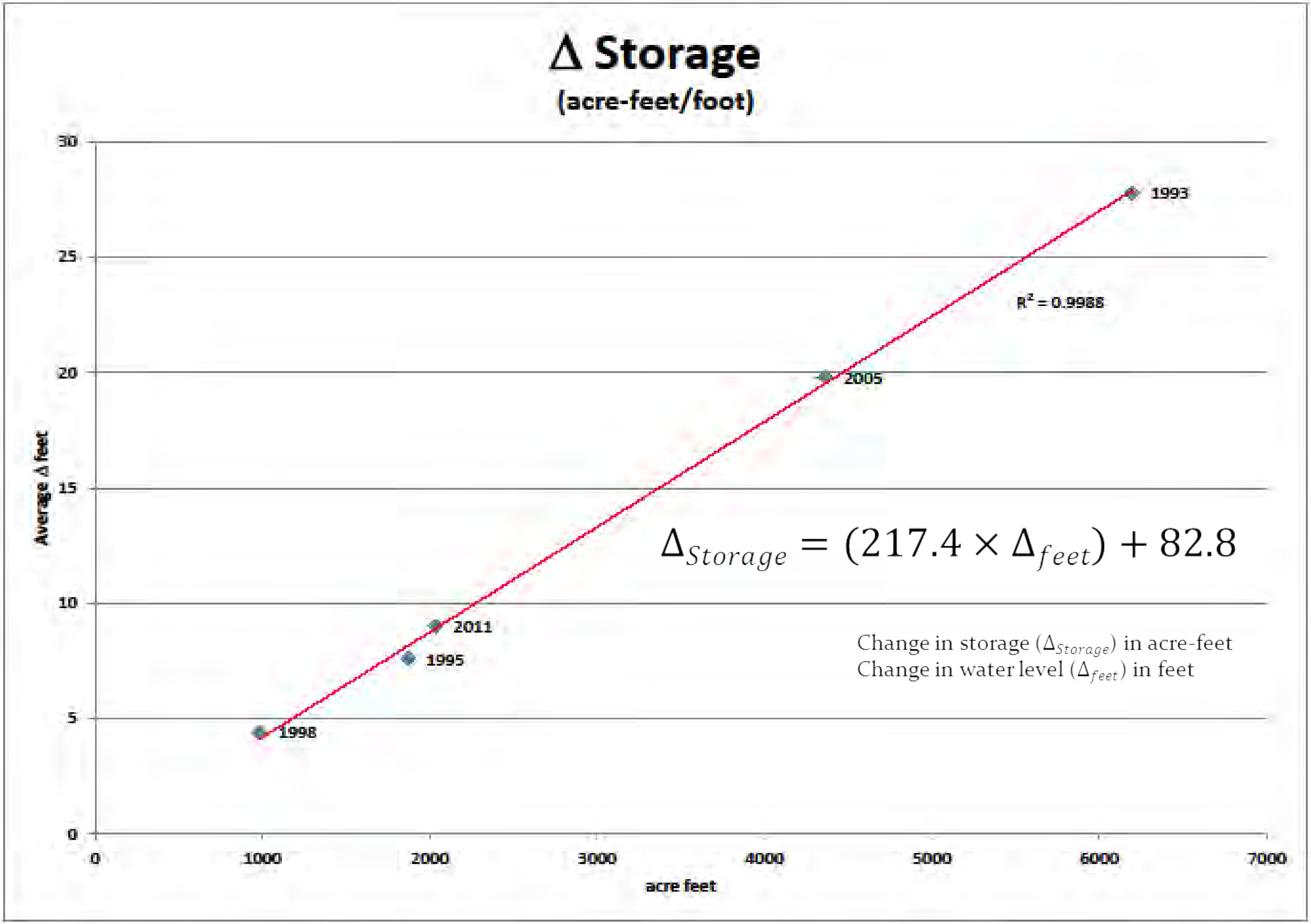
Total vs. Effective Porosity

- Total Porosity ~24%
  - 19.5 & 33.7%
    - Analog Model (Hardt, 1971)
  - 20-20%
    - Numeric Model (Stamos, 2001)
  - 24 & 26%
    - MR-1 & MR-2 Advanced elogs (Schlumberger, 2009)
  - 30, 15, 25, 24, & 24%
    - MWA samples (MWA, 2011)
- Effective Porosity ~9%
  - 9 & 10%
    - MR-1 & MR-2 Advanced elogs (Schlumberger, 2009)
  - 8, 2, 1, 4, & 8%
    - MWA samples (MWA, 2011)

Evaluation of Discharge for Mojave River Between Barstow and Waterman Fault

Storm Recharge

- Change in Storage at 9% Porosity
  - 1993 - 6,196 acft
  - 1995 - 1,869 acft
  - 1998 - 985 acft
  - 2005 - 4,365 acft
  - 2011 - 2,034 acft



$$\Delta_{Storage} = (217.4 \times \Delta_{feet}) + 82.8$$

Change in storage ($\Delta_{Storage}$) in acre-feet
Change in water level (Δ_{feet}) in feet

Evaluation of Discharge for Mojave River Between Barstow and Waterman Fault

Summary

- Change in storage can be calculated
  - $\Delta_{Storage}=217.4\times\Delta_{feet}+82.8$

APPENDIX C

Analysis of Baja Subarea Desert Wash Discharge

May 4, 2011

Robert C. Wagner, P.E., Watermaster Engineer

ANALYSIS OF BAJA SUBAREA DESERT WASH DISCHARGE

INTRODUCTION

The following report was prepared as part of the ongoing discussions between Watermaster staff and the Baja Subarea Advisory Committee regarding the evaluation of water supply to Baja, and to advance the general understanding of ungaged inflow to the Mojave River.

The Mojave River originates at the confluence of Deep Creek and West Fork Mojave River, near Hesperia at the Mojave River Dam. The Dam is a flood control facility that does not store water. The river flows in a general north north-easterly direction toward Barstow, and eventually exits the Mojave Basin Area a few miles upstream from Afton. Continuous surface flow in the river primarily occurs only when winter storms produce runoff from the mountains. Flow occurs along the entire reach of the river only during episodes of floodflow (USGS, Stamos et al 2001). Flow in the river measured at the Barstow gauging station and the supply to Baja is primarily the result of runoff from precipitation in the San Bernardino Mountains.

U. S. Geological Survey Water-Resources Investigation Report 95-4189 (WRIR 95-4189) authored by Gregory Lines (1996) presents an estimate of ungaged tributary inflow to the Mojave River by adopting a methodology published in USGS Water-Supply Paper 1999-E, “Mean Annual Runoff as Related to Channel Geometry of Selected Streams in California (E.R. Hedman 1970).” The Baja Subarea Advisory Committee has asked that Watermaster consider the estimated annual discharge of 3900 acre-feet from ungaged tributaries presented in WRIR 95-4189 (Lines, 1996), and whether the estimate should be included in the supply to the Baja Subarea.

BACKGROUND

Rain resulting in groundwater recharge occurs either as direct deposition onto the landscape infiltrating the soil surface and percolating past the root zone, or rainfall in excess of infiltration as runoff accumulating in channels percolating through the channel bed to recharge the groundwater.

Recharge from precipitation on the desert valley floor is considered to be minimal in the Mojave area and adjacent Antelope Valley. Fundamental to this understanding is the basic mechanics of rainfall, soil storage capacity, and evapotranspiration. For example, if the typical rooting depth is approximately 6 feet and the soil water field capacity (water held in pore space) is 12 percent by volume, then the total water held within the rooting depth is approximately 8.5 inches. Therefore, for these conditions, the rainfall amount sufficient to produce water percolating past the root zone would be greater than 8.5 inches and the water held within the root zone becomes evapotranspiration. Several studies conducted in the greater Mojave Desert or comparable regions have concluded similar results as follows:

- California Department of Water Resources, Bulletin No. 84 (DWR 1967) found “for this study, all precipitation less than 8 inches annually was considered to be used in satisfying the growth and transpiration requirements of the [sic] native vegetation and, therefore, was not considered an item of water supply or consumption.”
- USGS (Hardt, 1971) found “recharge to the aquifers from direct precipitation on the desert floor probably is negligible.”

- USGS (Nishikawa et. al., 2001) found "it was assumed that areal recharge from periods of precipitation and runoff was insignificant because of the infrequent occurrence of these periods and the low precipitation and high pan evaporation rates in the study area. This assumption is supported by other studies in the Mojave Desert [for example, Izbicki et. al. (1998)]."
- USGS (Stamos et. al., 2001) found "recharge to the aquifer system from direct precipitation is considered to be minimal because precipitation or runoff do not adequately meet evapotranspiration and soil-moisture requirements."
- USGS (Durbin, 1978) found "because the average annual precipitation on the valley floor is less than 10 in. (250 mm) (Rantz, 1969), very little runoff is generated on the valley floor, and probably very little precipitation penetrates below the root zone.
- In an environment somewhat similar to that of Antelope Valley, Blaney, Taylor, and Young (1930) and Young and Blaney (1942) found that precipitation does not penetrate below the root zone if the annual precipitation is less than about 12 in. (300 mm). Therefore, precipitation on the valley floor was not considered to be an important source of ground-water recharge."
- USGS (Leighton, 2003) found "precipitation over the valley floor generally is less than 10 in./yr (Rantz, 1969) and evapotranspiration rates [pan evaporation rate is about 114 in./yr (Bloyd, 1967)] and soil moisture requirements are high; therefore, recharge from direct infiltration of precipitation is negligible (Snyder, 1955; Durbin, 1978)."
- USGS (Mendez, 1997) found "recharge to the ground-water system from direct infiltration (areal recharge) of precipitation is minimal."

The other pathway rain recharges groundwater is by percolation through the channel bed during flow events. Flow events occurring in watersheds tributary to the Mojave River are typically sporadic and likely occur on timescales comparable to the rain event. The bed material and soil moisture are likely identical to the surrounding landscape. Therefore, the percolation mechanics are likely governed by the same circumstances and the probability for recharge is negligible. Consequently, recharge from precipitation on the valley floor is considered insignificant.

Lines (1996) estimated the ungaged tributary inflow to the Mojave River from desert washes by adopting a methodology published in USGS Water-Supply Paper 1999-E, "Mean Annual Runoff as Related to Channel Geometry of Selected Streams in California (E.R. Hedman 1970)." Hedman employed a methodology that related channel forms to mean annual discharge by carefully measuring the channel geometry of various streams in California, where the mean annual runoff was known. Hedman related depth and width of 48 stream channels throughout California and developed a statistical relationship between channel geometry and mean annual discharge from his measurements and USGS stream gage records. It is important to note that Lines (1996) did not estimate recharge occurring in the washes.

Lines (1996) made measurements at 29 sites over a wide geographical and hydrological area of Southern California near active stream gages and at sites where streamflow measurements had been taken previously. Lines (1996) was unable to develop a statistically significant relationship using channel depth. However, Lines (1996) did report that a relationship developed using channel width was statistically significant. Figure 17, page 20 of Lines (1996) shows the relationship graphically (Figure 1 of this report). An inspection of Figure 1 shows the wide range of discharge that is indicated by the statistical relationship. For example the data is well scattered for channel widths less than 5 feet. At a width of about 4 feet, the discharge is within a range of about 20 acre-feet annually to about 2,000 acre-feet annually. For a channel width of about 2 feet to about 3 feet, the discharge is between 10 acre-feet and 4,000 acre-feet.

We do not conclude from the foregoing that the methodology employed by Hedman and then adopted by Lines (1996) to relate channel forms to known discharge is flawed. Rather, the methodology is not easily adopted for desert washes, as used by Lines (1996), and the methodology itself is difficult to apply. The stream systems studied by Hedman relate two variables to discharge, depth and width. Lines (1996) was unable to find a relationship with depth and relied only on width. As pointed out in the foregoing discussion, for channel widths less than 5 feet, the methodology and data collected in this study is a poor predictor of discharge.

Lines (1996) estimates the average annual ungaged tributary inflow of 3900 acre-feet contributes to the Mojave River lower main stem (Baja subarea) based on a weighted average of watershed area. To arrive at this value, Lines (1996) uses a ratio of area draining to the lower main stem (432 square miles, and the area of the Baja washes 180 square miles; 432/180 = 2.4) multiplied by the estimated discharge from the Baja washes (1630 acre-feet). If the estimate of discharge from Baja washes is overstated by the statistical relationship, then the estimate of ungaged tributary inflow is also overstated.

Lines (1996) assumed that tributary inflow to the Mojave River from ephemeral streams (desert washes) occurred at the same relative magnitude as ephemeral runoff in the Mojave River at Barstow. There is little basis to support this assumption. As noted by USGS (Stamos, et al 2001), runoff at Barstow is a function of precipitation events in the San Bernardino Mountains to the south. Runoff in the desert washes is a function of local precipitation. There is nothing cited in Lines (1996) indicating that precipitation events in the San Bernardino mountains produce runoff to the tributary areas of the desert washes in Baja of a similar pattern as discharge at Barstow. Notably, about 60% of precipitation as measured at Daggett (east of Barstow) occurs during periods of the year when there is little or no flow at Barstow (see Figure 2).

We believe that the estimate presented in Lines (1996) is overstated by a factor of 10 and that the amount of ungaged supply to Baja is already accounted for on Table 5-1 of the Watermaster Annual Reports.

ALTERNATE APPROACH

Boom Creek, Daggett Wash, Calico Wash, Manix Wash, Wilhelm Wash, and Unnamed Wash are ungaged desert washes tributary to the Mojave River, and are located within the Baja Subarea of the Mojave Basin. In order to determine the amount of discharge contributing to the Mojave River from these desert washes, reference streams measured by USGS in the surrounding area were utilized. These reference gaged streams are Cushenbury Creek, Pipes Creek, Cache Creek, Cottonwood Creek, Spencer Canyon Creek, Goler Gulch, and Beacon Creek (Plate 1). Based on mean annual precipitation, mean annual discharge, and approximate drainage area, a unit-discharge figure was produced for each gaged watershed, seven in total. Each unit-discharge was then applied to each desert wash, incorporating its own watershed size, ranging from about 1,000 acres to more than 65,000 acres, and mean annual precipitation, ranging from 3.5 to 4.5 inches in an average year. The results range from 11 acre-feet to a maximum of 205 acre-feet of discharge in an average year for the desert washes tributary to the Mojave River.

Utilizing ArcGIS, watershed boundaries for the desert washes and reference gaged streams were delineated using 7.5 minute USGS quadrangles to determine drainage area. Once completed, a GIS database composed of isohyetal lines of equal rainfall (Rantz, 1972) was overlaid to determine the approximate mean annual precipitation for each watershed (Plate 1). Rantz (1972) provides a simple and reliable estimation of mean annual precipitation over very large areas. Although dated, the Rantz data is reasonably consistent with long-term mean annual precipitation for reference gages. For example, mean annual precipitation is 4.5 inches at the Barstow station (period of record is 1913 through 1980) and 3.8 inches at the Daggett F.A.A. station (period of record is 1949 through 2010), while Rantz estimates that both stations receive approximately 4.5 inches of average annual precipitation. Also shown on Table 1, for the channels studied by Lines (1996), is the mean annual precipitation, reported discharge, and corresponding mean annual precipitation for those watersheds as a percentage of the mean annual precipitation for the area surrounding the Baja washes.

The reference gaged streams are at higher elevation and are located in the San Bernardino Mountains to the south of the Baja washes, and to the west in the Tehachapi and San Gabriel Mountains. These watersheds receive much higher average annual rainfall, and vary in drainage area but are comparable in size to the desert washes. Total drainage area is about 132,000 for the reference gaged streams, and about 116,000 acres for the desert washes. Average annual rainfall for the reference gaged streams is approximately 12 inches, whereas the desert washes receive 4.25 inches on average.

Using the USGS methodology (Lines, 1996) for estimating discharge (Figure 1), the reference gaged streams would produce a total of 1,573 acre-feet of discharge during an average year. However, according to USGS streamgage records, the average annual discharge for these streams is a combined 159 acre-feet, about 10% of what was predicted by Lines (1996) (see Table 2).

Estimated average annual discharge was calculated for each Baja wash using the reference gaged streams (Table 3). This analysis was performed by using the ratio of average annual discharge to the total amount of water from precipitation within the reference gaged streams watershed, and applying the resulting unit-discharge to the total amount of water from precipitation within the watersheds of each Baja wash. The results provide a range of values due to the wide array of different characteristics in each reference gaged watershed, including, but not limited to, slope, aspect, canopy cover, evapotranspiration, and elevation. The seven values are intended to provide a range of average annual discharge estimates for comparison to the discharge estimates of the USGS (Lines, 1996).

To further understand the desert stream system, closer analysis of Cushenbury Creek and Pipes Creek was conducted. It was found that rainfall of up to 2 inches in a day did not result in any flow at the Cushenbury Creek streamgage, and only storm events in excess of 2 inches created any consistent response in recorded flow (Figure 3). Furthermore, discharge was only recorded when annual precipitation was greater than 9 inches, with the exception of water year 1962, when rainfall was 9.3 inches and produced no discharge at the Cushenbury Creek streamgage (Figure 4). The situation is similar for Pipes Creek; less than 3 inches of rainfall per day did not produce a response in measured flow (Figure 5). Moreover, recorded annual discharge required in excess of 10 inches of precipitation annually, with the exception of 1970 when annual rainfall totaled 1.4 inches and yielded 4 acre-feet of discharge (Figure 6).

We also evaluated the discharge from the Oak Creek watershed situated between Cottonwood Creek and Cache Creek watersheds (see Plate 1). These three watersheds discharge to the Antelope Valley from the east slope of the mountains near Tehachapi. A comparison of the discharge records during the period of overlapping record (Figure 7) shows that Oak Creek produces more discharge than the two adjacent watershed despite all three having about the same weighted mean annual precipitation. Figure 8 indicates that Oak Creek has at times, an extended recession hydrograph and base discharge, not apparent in the other two. Oak Creek also exhibits a runoff pattern similar to snow melt driven watersheds. During the winter of 1969, Oak Creek discharge was limited, and rapidly increased in early spring and rapidly decreased into late spring.

The discharge was limited but constant through summer and fall and the pattern repeats each season. The Baja washes do not exhibit this behavior nor do the watersheds adjacent to Oak Creek. Oak Creek is not considered to be representative of the expected discharge patterns experienced in the desert washes and was not included in this analysis.

CONCLUSION

From the results of the Cushenbury and Pipes Creek analysis we can conclude that at least of 9 inches of rainfall per year is needed in order to produce any measurable amount of discharge. The Baja washes are located at a much lower elevation, and receive about 3.5 to 4.5 inches of rainfall per year. If Cushenbury and Pipes Creeks are indicators of what is required in order to see discharge from a desert wash, the Baja washes cannot be expected to produce significant discharge. We estimate for the Baja washes the total average annual contribution to the Mojave River is less than 205 acre-feet. The average based on the seven referenced gages is 105 acre-feet per year and the median is 74 acre-feet per year. The Judgment After Trial, January 10, 1996, estimated the contribution from ungaged inflow to be 300 acre-feet, all of which was attributed toKane Wash, and 100 acre feet of deep percolation of precipitation for a total of 400 acre feet. Lines (1996) does not include contributions from Kane Wash, because Kane does not discharge to the river.

RECOMMENDATION

Based on the foregoing, we do not recommend a change to the estimated amount of ungaged tributary inflow to Baja adopted by the court in the Judgment After Trial, January 10, 1996.

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Rantz, S.E., 1972: Mean Annual Precipitation in the California Region, U.S. Geological Survey basic-data compilation, scale 1:1,000,000.

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

TABLE 1

Mojave Watermaster

Weighted Mean Annual Precipitation of Baja Washes and Streamgages used in USGS Report(1)

Baja Washes	Approximate Drainage Area(2) (ac)	Weighted Mean Annual Precipitation(3) (in)
Boom Creek	1,032	4.5
Daggett Wash	15,468	3.5
Calico Wash	65,163	4.5
Manix Wash	28,399	4.5
Wilhelm Wash	4,826	4.25
Unnamed	1,012	4.25
Average		**4.25**

Streamgages used in USGS Analysis(1)	Approximate Drainage Area(2) (ac)	Mean Annual Discharge(4) (af)	Weighted Mean Annual Precipitation(3) (in)	Percent of Baja Wash Mean Annual Precipitation
USGS 10252550 Caruthers Creek Near Ivanpah, CA	525	94	11	259%
USGS 10255700 San Felipe Creek Near Julian, CA	63,084	710	16.8	395%
USGS 10255805 Coyote Creek Bl Box Canyon Near Borrego Springs, CA	99,467	1,930	9.7	228%
USGS 10255810 Borrego Palm Creek Near Borrego Springs, CA	13,960	750	12.5	294%
USGS 10256000 Whitewater River at White Water, CA	36,805	12,600	26	612%
USGS 10257720 Chino Canyon Creek Bl Tramway Near Palm Springs, CA	3,015	658	15.8	372%
USGS 10258000 Tahquitz Creek Near Palm Springs, CA	10,785	3,880	22.2	522%
USGS 10258500 Palm Canyon Creek Near Palm Springs, CA	11,576	3,960	12.9	304%
USGS 10259000 Andreas Creek Near Palm Springs, CA	5,532	2,220	15.4	362%
USGS 10260200 Pipes Creek Near Yucca Valley, CA(5)	9,603	20	18.1	426%
USGS 10260400 Cushenbury Creek Near Lucerne Valley, CA	4,071	46	14	329%
USGS 10260500 Deep Creek Near Hesperia, CA	85,974	52,700	25	588%
USGS 10260620 Houston Creek Above Lake Gregory at Crestline, CA	244	518	44.8	1054%
USGS 10260630 Abondigas Creek Above Lake Gregory at Crestline, CA	756	878	45	1059%
USGS 10260950 West Fork Mojave River Above Mojave River Forks Res Near Hesperia, CA	44,771	33,140	28.3	666%
USGS 10261100 Mojave River Bl Forks Res Near Hesperia, CA	134,057	45,920	26	612%
USGS 10261500 Mojave River at Lower Narrows Near Victorville, CA	334,772	56,700	15.8	372%
USGS 10261800 Beacon Creek at Helendale, CA	473	0.7	4.5	106%
USGS 10262500 Mojave River at Barstow, CA	873,361	18,190	9.4	221%
USGS 10263000 Mojave River at Afton, CA	1,369,506	5,730	7.6	179%
USGS 10263500 Big Rock Creek Near Valyermo, CA	14,660	13,040	30.7	722%
USGS 10264560 Spencer Canyon Creek Near Fairmont, CA	2,267	38	12.1	285%
USGS 10264590 Cottonwood Creek Near Rosamond, CA	21,765	10	19	447%
USGS 10264600 Oak Creek Near Mojave, CA	10,135	920	19	447%
USGS 10264710 Goler Gulch Near Randsburg, CA	26,560	14	3.5	82%
USGS 10264740 Cache Creek Near Mojave, CA	67,273	87	13.6	320%
USGS 10264750 Pine Tree Creek Near Mojave, CA	21,451	188	12.4	292%
USGS 10264770 Cottonwood Creek Near Cantil, CA	104,508	46	13.2	311%
USGS 10264878 Ninemile Creek Near Brown, CA	6,680	500	10.5	247%
USGS 11031500 Agua Caliente Creek Near Warner Springs, CA	12,184	1,960	17.1	402%
Average			**17.7**	**417%**

Notes:

(1) Ground-Water and Surface-Water Relations along the Mojave River, Southern California, G.C. Lines, U.S. Geological Survey, 1996.

(2) Measured based on USGS 7.5 Minute Quadrangles.

(3) Based on GIS data from California Department of Forestry and Fire Protection, 2010, digitized from Mean Annual Precipitation in the California Region, S.E. Rantz, 1972.

(4) As reported in Ground-Water and Surface-Water Relations along the Mojave River, Southern California, G.C. Lines, U.S. Geological Survey, 1996.

(5) Not included in USGS Analysis; however, included in this calculation due to it's geographic location.

TABLE 2

Mojave Basin Area Watermaster

Predicted and Measured Average Annual Discharge for USGS Streamgages of Interest

Watershed	Approximate Drainage Area(1) (acres)	Weighted Mean Annual Precipitation(2) (inches)	Average Annual Discharge Predicted by USGS Methodology(3) (acre-feet)	Average Annual Discharge Measured by USGS(4) (acre-feet)
Cushenbury Creek(5)	4,071	14	564.5	23.1
Pipes Creek(6)	9,603	18.1	-	20.1
Cache Creek(7)	67,273	13.6	722.8	83.7
Cottonwood Creek(8)	21,765	19	111.1	8.7
Spencer Canyon Creek(9)	2,267	12.1	111.1	9.0
Goler Gulch(10)	26,560	3.5	35.0	13.6
Beacon Creek(11)	473	4.5	28.0	0.7
Total			**1,573**	**159**

Notes:

(1) Measured based on USGS 7.5 Minute Quadrangles.

(2) Based on GIS data from California Department of Forestry and Fire Protection, 2010, digitized from Mean Annual Precipitation in the California Region, S.E. Rantz, 1972.

(3) Ground-Water and Surface-Water Relations along the Mojave River, Southern California, G.C. Lines, U.S. Geological Survey, 1996.

(4) USGS National Water Information System (NWIS) application (http://waterdata.usgs.gov/ca/nwis/), accessed February 2011.

(5) USGS 10260400 Cushenbury Creek Near Lucerne, CA water years 1958 through 1971.

(6) USGS 10260200 Pipes Creek Near Yucca Valley, CA water years 1959 through 1971. Channel width of Pipes Creek is not known, therefore discharge could not be predicted using Lines' methodology.

(7) USGS 10264740 Cache Creek Near Mojave, CA water years 1965 through 1972.

(8) USGS 10264590 Cottonwood Creek Near Rosamond, CA water years 1964 through 1972.

(9) USGS 10264560 Spencer Canyon Creek Near Fairmont, CA water years 1964 through 1973.

(10) USGS 10264710 Goler Gulch Near Randsburg, CA water years 1967 through 1972.

(11) USGS 10261800 Beacon Creek at Helendale, CA water years 1961 through 1967.

TABLE 3

Mojave Basin Area Watermaster

Estimated Unit Discharge and Mean Annual Precipitation for Gaged Watersheds and Estimated Average Annual Discharge for Baja Washes Tributary to Mojave River

Gaged Watershed	**Approximate Drainage Area(1)** (acres)	**Weighted Mean Annual Precipitation(2)** (inches)	**Average Annual Discharge Measured by USGS(3)** (acre-feet)	**Unit Discharge(4)**	**Referenced Precipitation Station**	**Mean Annual Precipitation for Period of Record** (inches)	**Mean Annual Precipitation During Streamgage Period of Record** (inches)	**Percent of Period of Record Mean Annual Precipitation During Streamgage Period of Record**
Cushenbury Creek(5)	4,071	14	23.1	0.0049	Cushenbury Springs(12)	8.3	8.0	96%
Pipes Creek(6)	9,603	18.1	20.1	0.0014	Kee Ranch(13)	8.6	7.2	84%
Cache Creek(7)	67,273	13.6	83.7	0.0011	Tehachapi(14)	11.2	11.1	99%
Cottonwood Creek(8)	21,765	19	8.7	0.0003	Tehachapi(14)	11.2	10.5	93%
Spencer Canyon Creek(9)	2,267	12.1	9.0	0.0039	Fairmont(15)	15.6	16.4	105%
Goler Gulch(10)	26,560	3.5	13.6	0.0018	Randsburg(16)	5.7	5.1	89%
Beacon Creek(11)	473	4.5	0.7	0.0042	Barstow(17)	4.5	3.3	73%

Baja Washes	**Approximate Drainage Area(1)** (acres)	**Weighted Mean Annual Precipitation(2)** (inches)	**Estimated Average Annual Discharge Based on Cushenbury Creek Unit Discharge** (acre-feet)	**Estimated Average Annual Discharge Based on Pipes Creek Unit Discharge** (acre-feet)	**Estimated Average Annual Discharge Based on Cache Creek Unit Discharge** (acre-feet)	**Estimated Average Annual Discharge Based on Cottonwood Creek Unit Discharge** (acre-feet)	**Estimated Average Annual Discharge Based on Spencer Canyon Creek Unit Discharge** (acre-feet)	**Estimated Average Annual Discharge Based on Goler Gulch Unit Discharge** (acre-feet)	**Estimated Average Annual Discharge Based on Beacon Creek Unit Discharge** (acre-feet)	**Estimated by Lines, 1996** (acre-feet)
Boom Creek	1,032	4.5	1.9	0.5	0.4	0.1	1.5	0.7	1.6	100
Daggett Wash	15,468	3.5	22.0	6.3	5.0	1.1	17.8	7.9	18.7	400
Calico Wash	65,163	4.5	119.0	33.9	26.8	6.2	96.3	43.0	101.5	400
Manix Wash	28,399	4.5	51.8	14.8	11.7	2.7	42.0	18.8	44.2	500
Wilhelm Wash	4,826	4.25	8.3	2.4	1.9	0.4	6.7	3.0	7.1	200
Unnamed	1,012	4.25	1.7	0.5	0.4	0.1	1.4	0.6	1.5	30
Total			**205**	**58**	**46**	**11**	**166**	**74**	**175**	**1,630**

Notes:

(1) Measured based on USGS 7.5 Minute Quadrangles.
(2) Based on GIS data from California Department of Forestry and Fire Protection, 2010, digitized from Mean Annual Precipitation in the California Region, S.E. Rantz, 1972.
(3) USGS National Water Information System (NWIS) application (http://waterdata.usgs.gov/ca/nwis/), accessed February 2011.
(4) Unit discharge is the ratio of average annual discharge to the total amount of water from precipitation within the watershed.
(5) USGS 10260400 Cushenbury Creek Near Lucerne, CA water years 1958 through 1971.
(6) USGS 10260200 Pipes Creek Near Yucca Valley, CA water years 1959 through 1971.
(6) USGS 10264740 Cache Creek Near Mojave, CA water years 1965 through 1972.
(8) USGS 10264590 Cottonwood Creek Near Rosamond, CA water years 1964 through 1972.
(9) USGS 10264560 Spencer Canyon Creek Near Fairmont, CA water years 1964 through 1973.
(10) USGS 10264710 Goler Gulch Near Randsburg, CA water years 1967 through 1972.
(11) USGS 10261800 Beacon Creek at Helendale, CA water years 1961 through 1967.
(12) Period of record is water years 1961 through 2001. Data from County of San Bernardino, Flood Control District (http://www.sbcounty.gov/dpw/floodcontrol/default.asp).
(13) Period of record is water years 1951 through 1984. Data from County of San Bernardino, Flood Control District (http://www.sbcounty.gov/dpw/floodcontrol/default.asp).
(14) Period of record is water years 1927 through 1996. Data from Western Regional Climate Center Webpage, NOAA (http://www.wrcc.dri.edu/index.html).
(15) Period of record is water years 1927 through 2007. Data from Western Regional Climate Center Webpage, NOAA (http://www.wrcc.dri.edu/index.html).
(16) Period of record is water years 1937 through 1990. Data from County of San Bernardino, Flood Control District (http://www.sbcounty.gov/dpw/floodcontrol/default.asp).
(17) Period of record is water years 1913 through 1980. Data from Western Regional Climate Center Webpage, NOAA (http://www.wrcc.dri.edu/index.html).

FIGURE 1
Analysis of USGS Methodology for Estimating Discharge from Desert Washes (Lines 1996)

Annual Mean Discharge vs. Average Channel Width

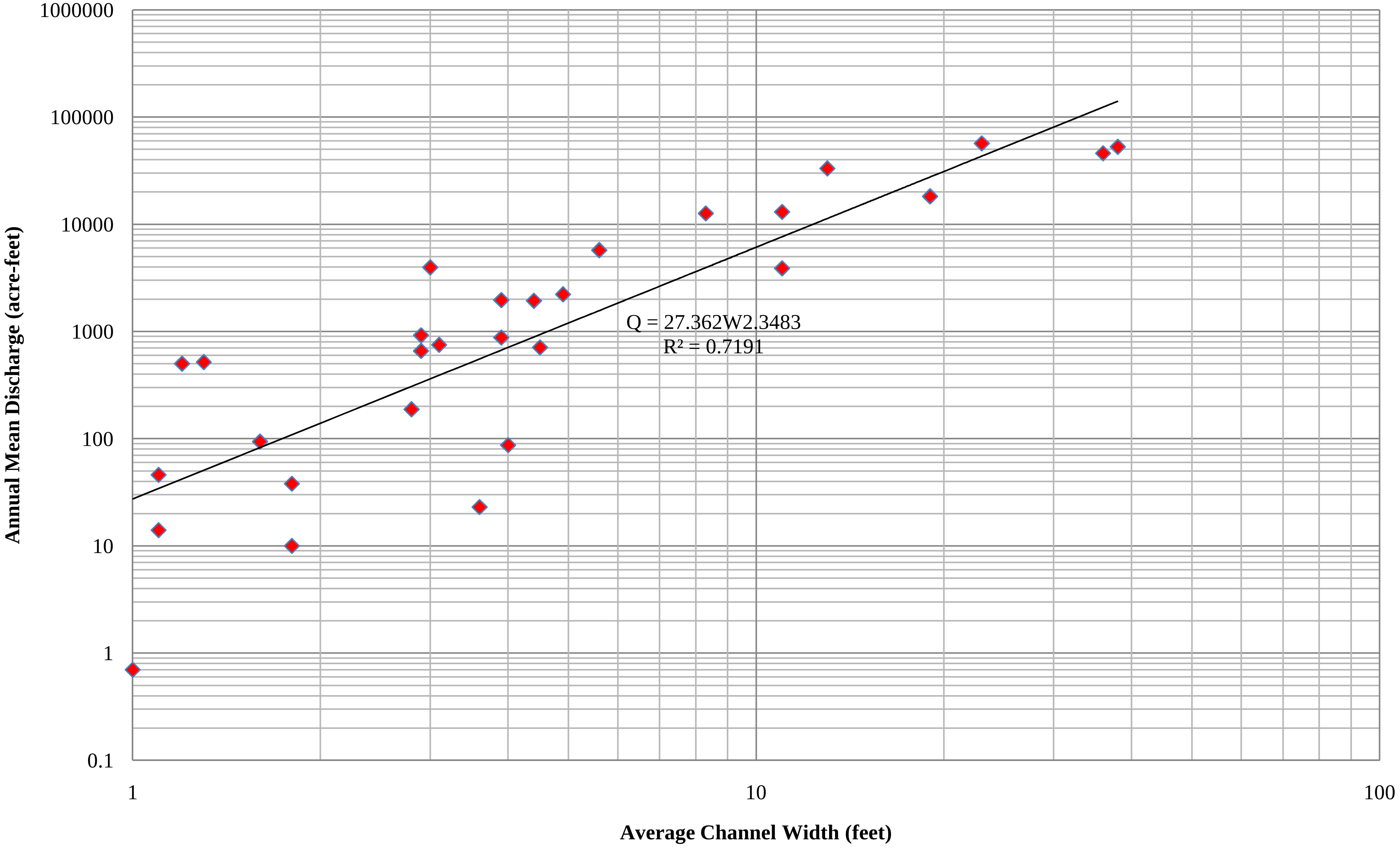


FIGURE 2
Average Monthly Discharge for Mojave at Barstow and Average Monthly Precipitation at Daggett

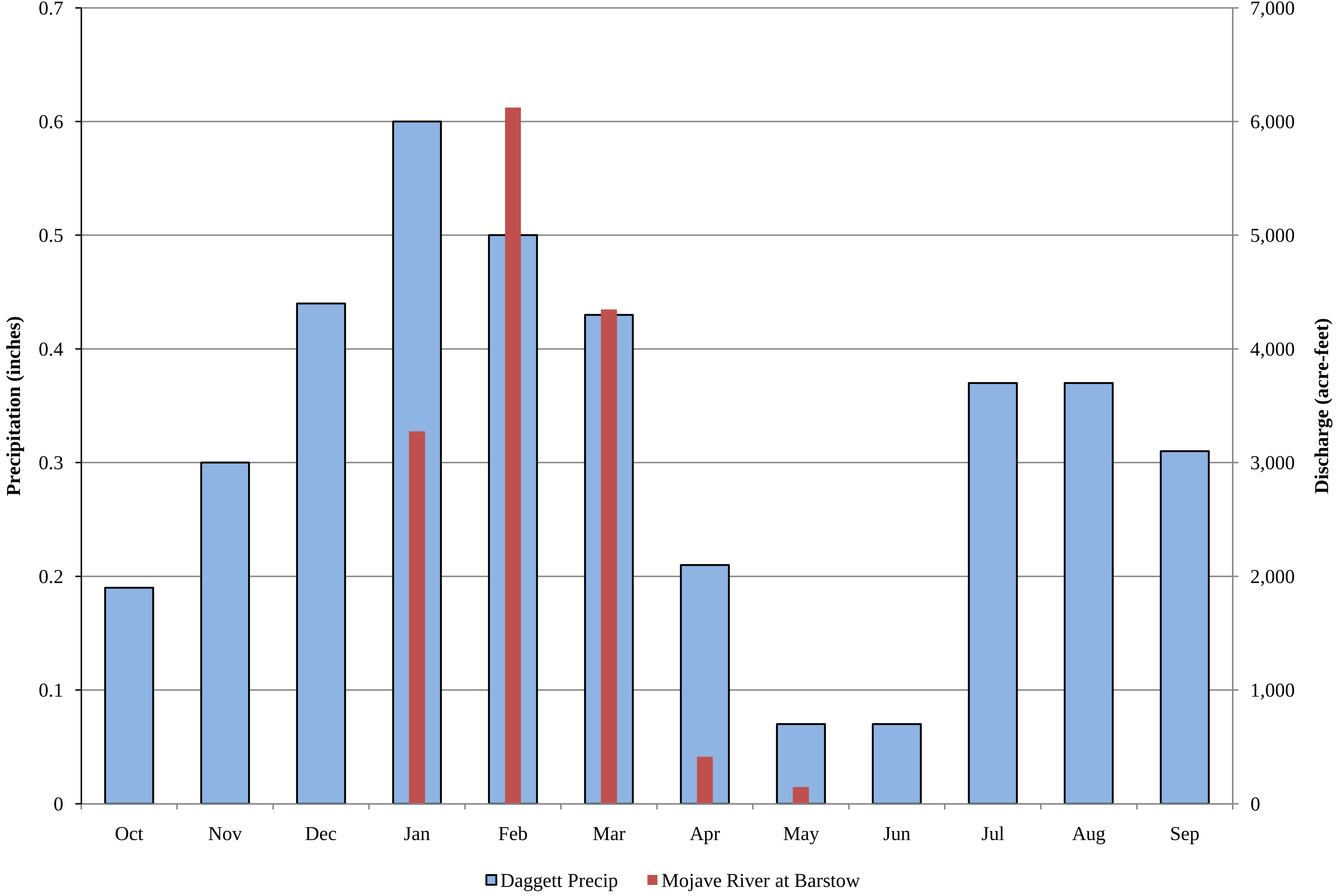


FIGURE 3
Comparison of Daily Precipitation and Cushenbury Creek Daily Flow
Water Years 1961 through 1971

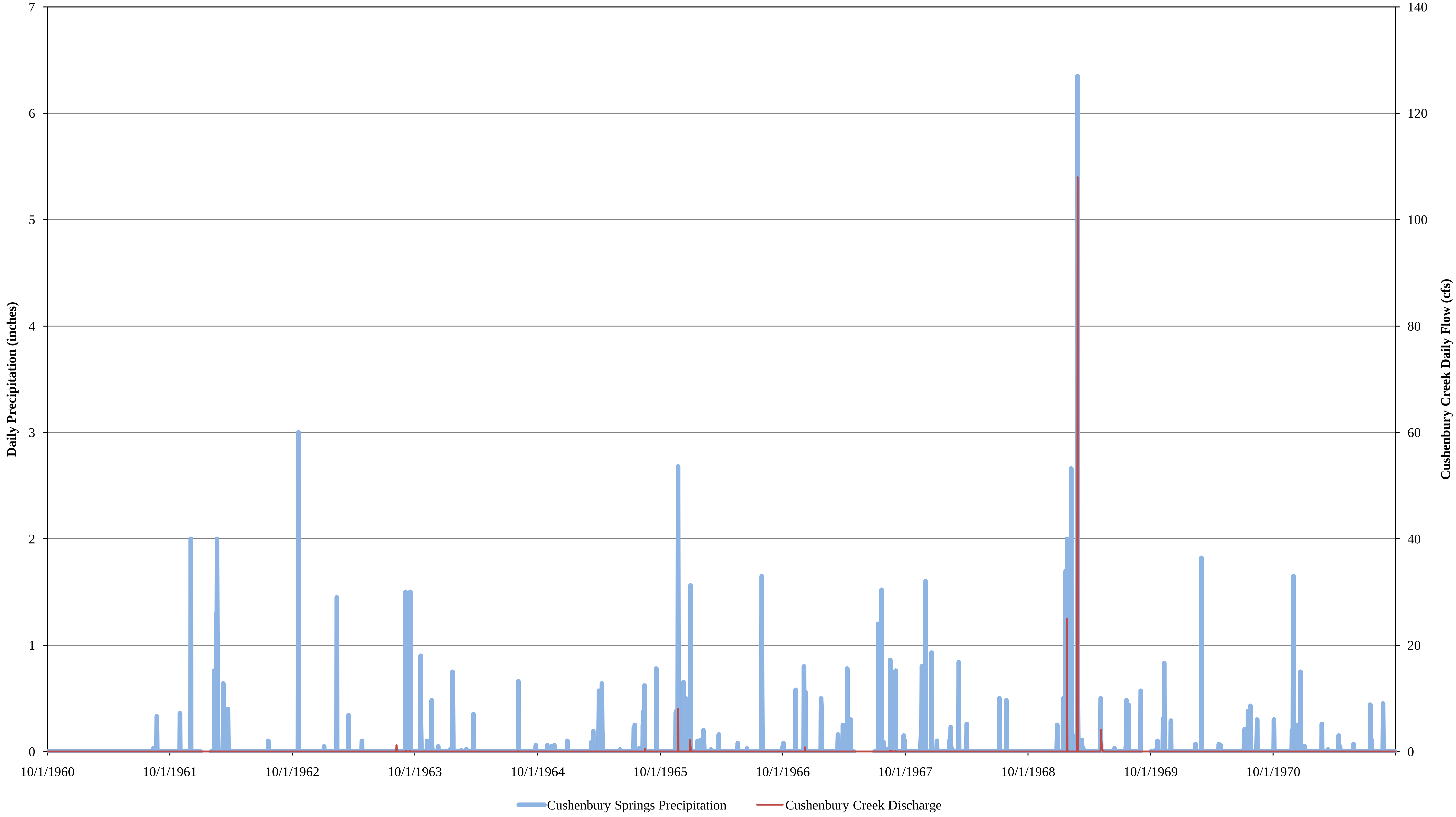


FIGURE 4
Comparison of Cushenbury Creek Annual Discharge and Cushenbury Springs Annual Precipitation
Water Years 1961-1971

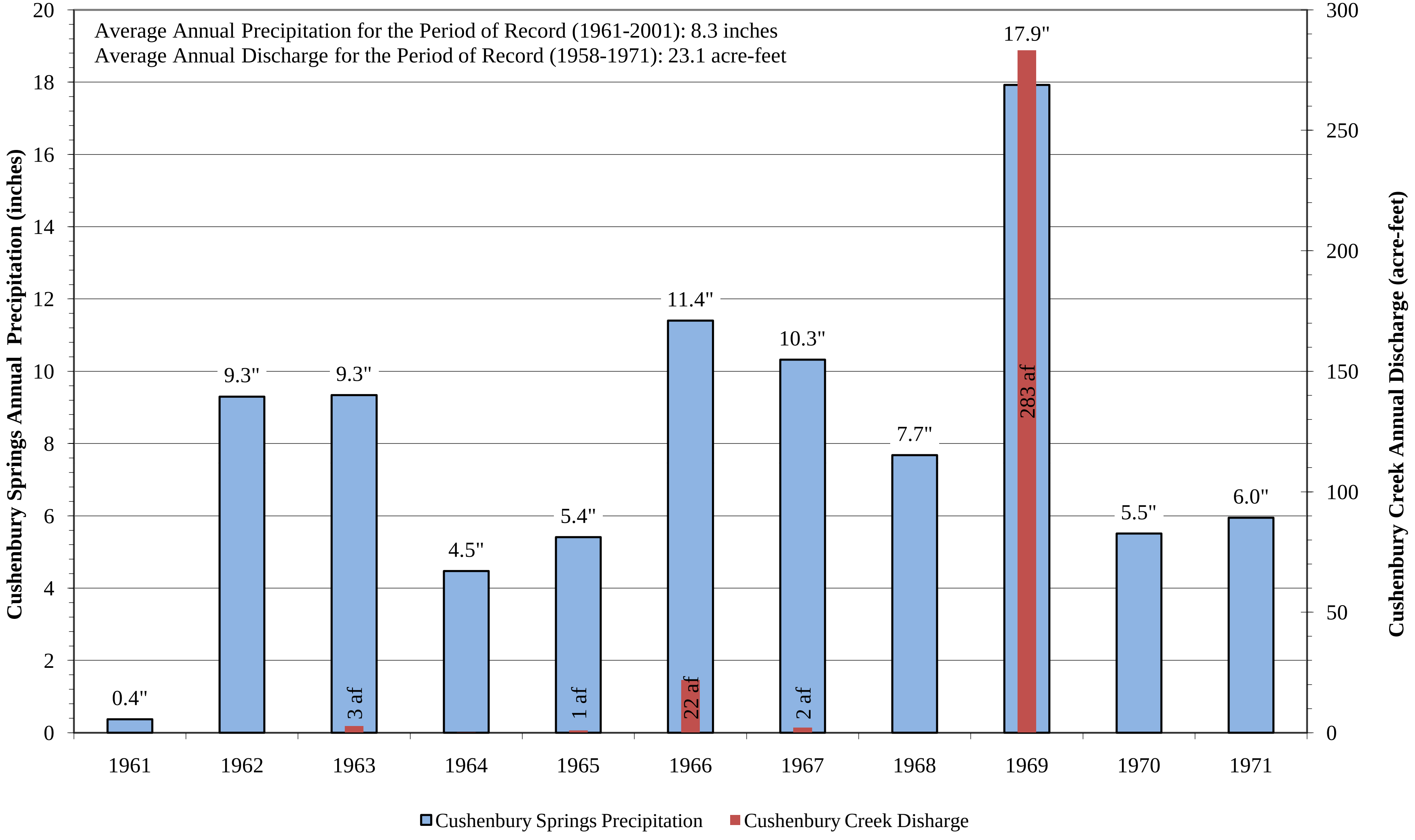
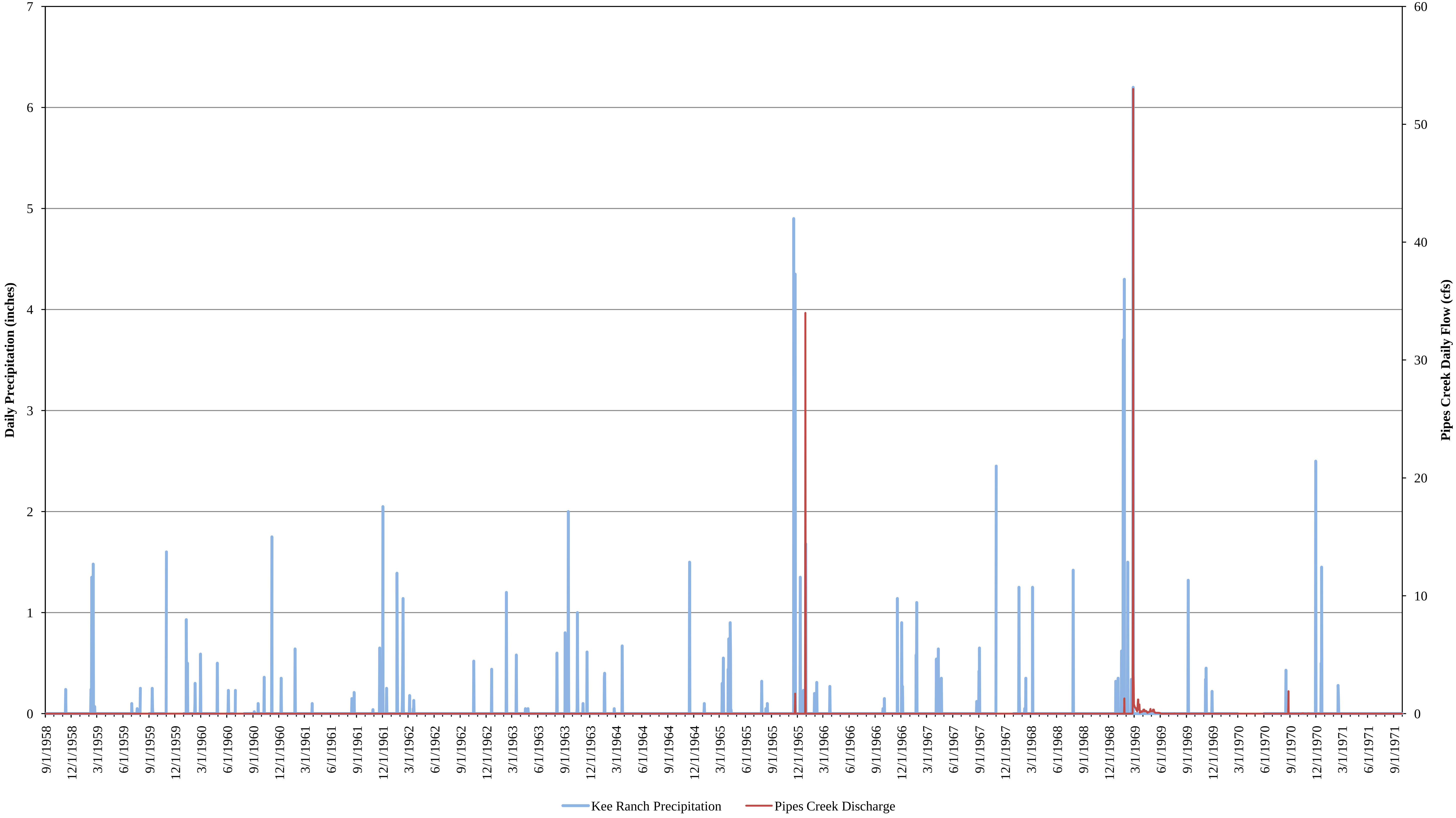
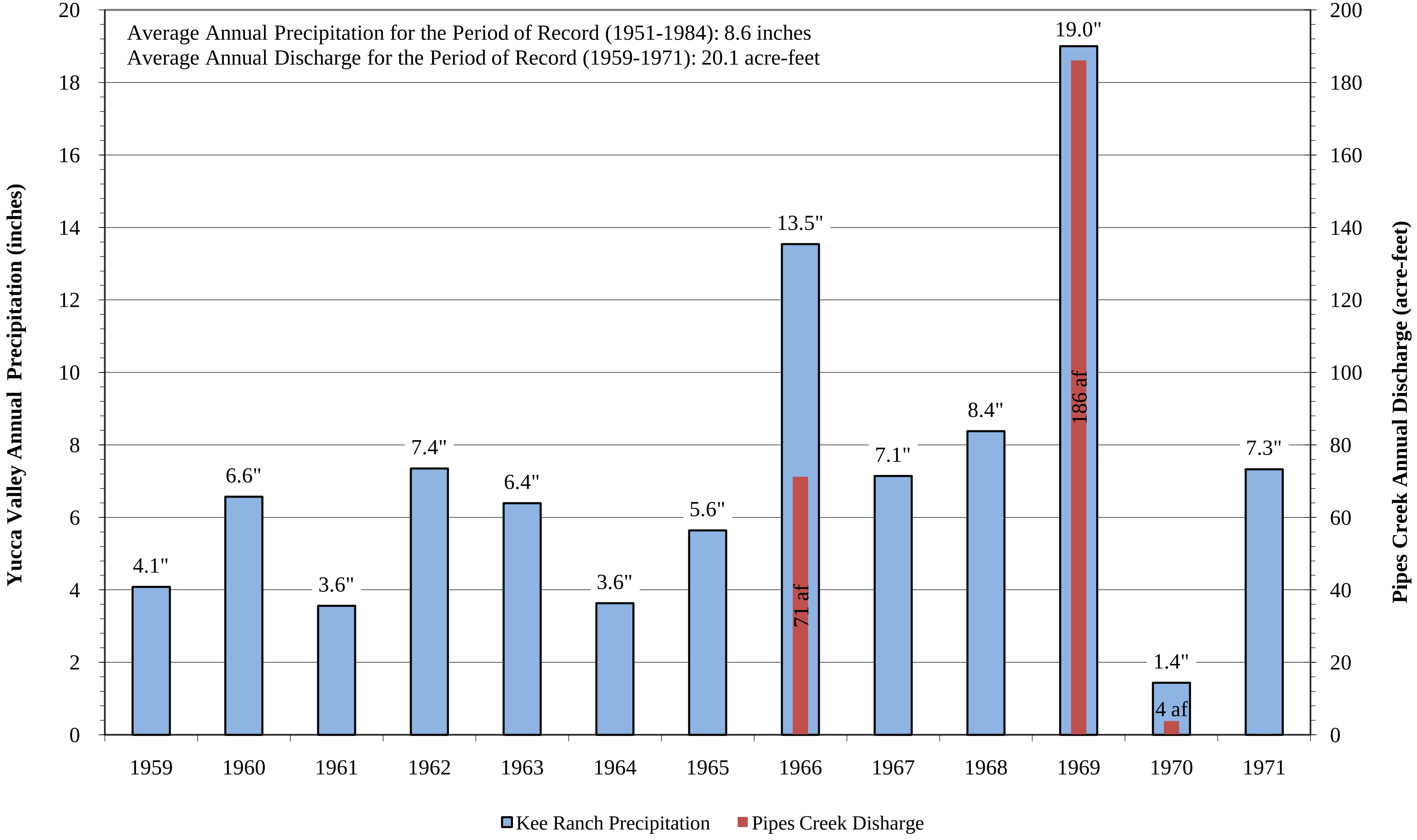


FIGURE 5
Comparison of Daily Precipitation at Kee Ranch and Pipes Creek Daily Flow
Water Years 1959 through 1971



5/3/2011

FIGURE 6
Comparison of Pipes Creek Annual Discharge and Kee Ranch Annual Precipitation
Water Years 1959-1971



Average Annual Precipitation for the Period of Record (1951-1984): 8.6 inches
Average Annual Discharge for the Period of Record (1959-1971): 20.1 acre-feet

G:\MOJAVE ADJUDICATION\Analysis\3020-001x-mojox048 & 050 Este Historic Precipitation Analysis.xlsx, FIGURE 6

FIGURE 7
Daily Flow for Oak Creek, Cache Creek, and Cottonwood Creek
During the Period of Overlapping Record, Water Years 1966 through 1972

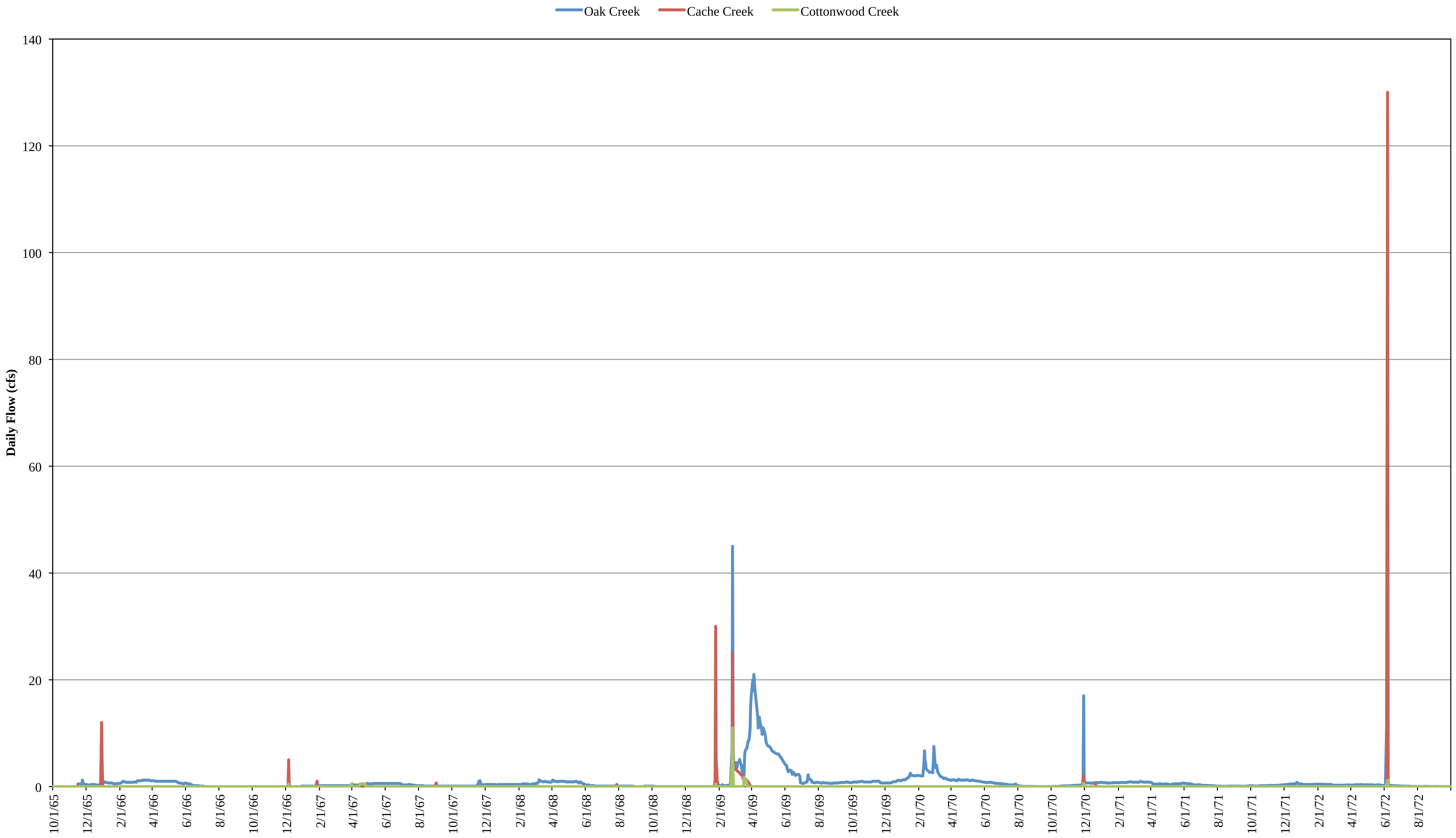
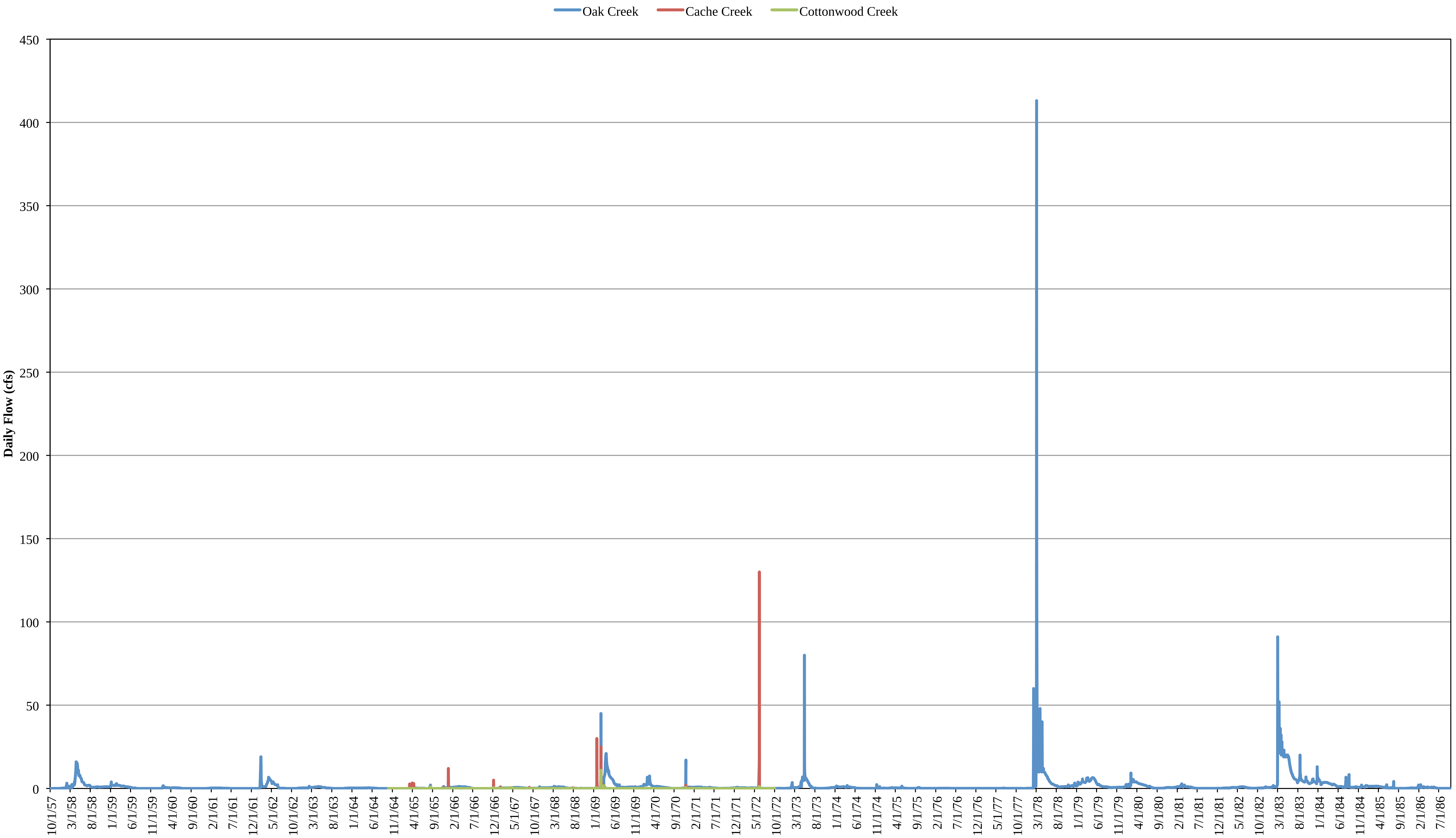
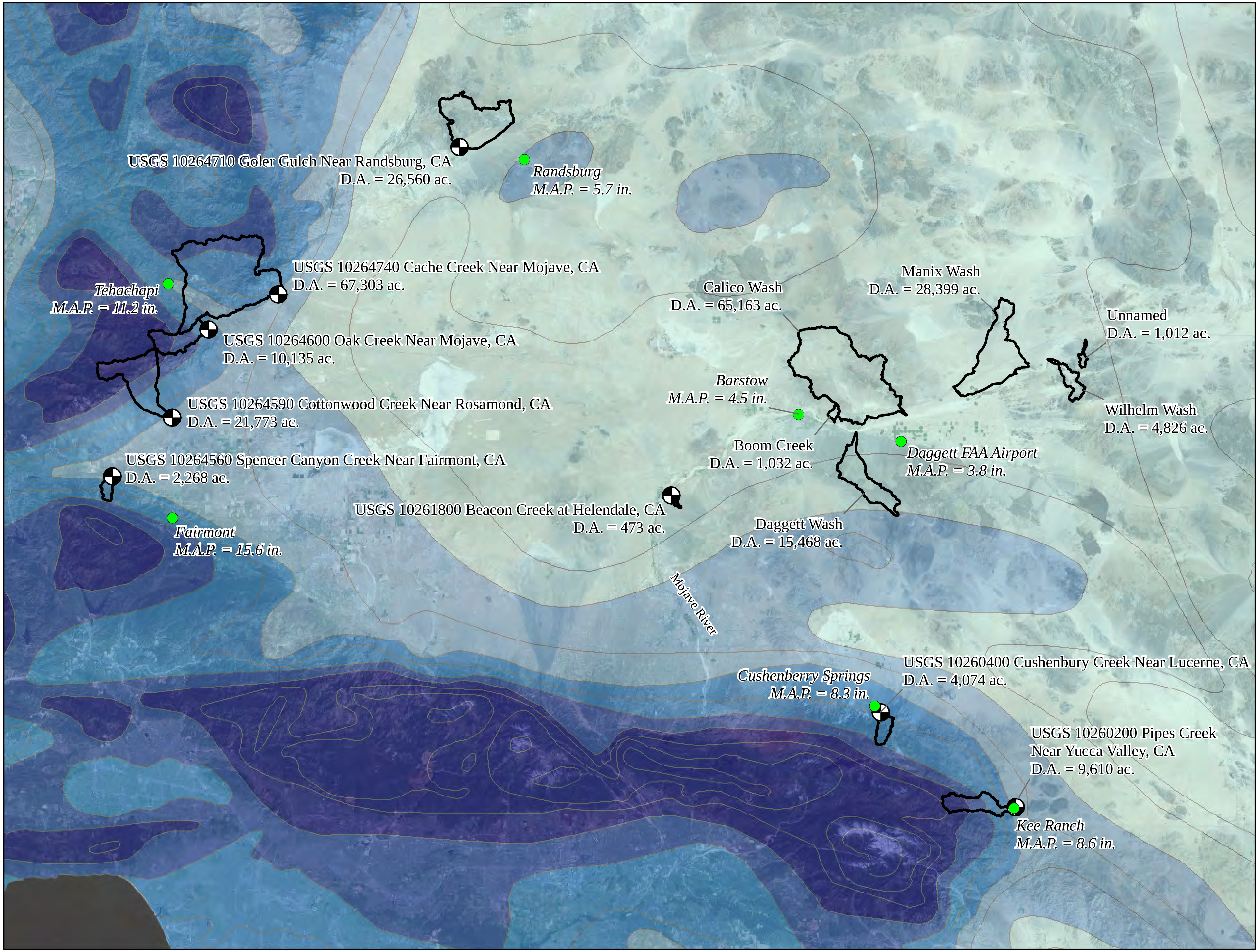


FIGURE 8
Daily Flow for Oak Creek, Cache Creek, and Cottonwood Creek
Water Years 1958 through 1986





N

0 6 12 24
Miles

● Precipitation Station

◐ USGS Streamgage

Watershed Boundary

Areas of Equal Mean Annual Precipitation (inches)

0 - 5.0	15.1 - 20.0
5.1 - 10.0	20.1 - 45.0
10.1 - 15.0	

Notes:
M.A.P. = Mean Annual Precipitation
D.A. = Drainage Area

PLATE 1

Mojave Basin Area Watermaster

Watersheds Investigated
for
Estimated Mean Annual Discharge
Within the
Mojave River Basin

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

May 2011

Mean Annual Precipitation per California Department of Forestry and Fire Protection, 2010 and were digitized from *Mean Annual Precipitation in the California Region*, Compiled by S.E. Rantz, 1972.
Aerial photograph per Microsoft Corporation and its data suppliers, 2010.

Q:\Drawings\Mojave Water\GIS\PLATE 1 - Overview Map of Watersheds and MAP.mxd

APPENDIX D

Explanation of Computed Potential Evapotranspiration and Actual Evapotranspiration for Harter Project

Wagner&Bonsignore
Consulting Civil Engineers, A Corporation

TECHNICAL MEMORANDUM

TO: Watermaster, MWA

FROM: Bob Wagner, Wagner & Bonsignore, CCE

RE: Explanation of computed potential evapotranspiration and actual evapotranspiration for Harter project

DATE: December 09, 2010

No averages of data were used in computing return flow from the Harter project.

Potential evapotranspiration (PET) represents the atmospheric capacity to hold water. The factors that determine the magnitude of PET are solar radiation, relative humidity, air temperature, and wind speed. Actual evapotranspiration (AET) is the loss of water to the atmosphere by the combined processes of evaporation (from soil and plant surfaces) and transpiration (from plant tissues). For a specific crop type, AET is related to PET.

The California Irrigation Management Information System (CIMIS) is a program in the Office of Water Use Efficiency (OWUE), California Department of Water Resources (DWR) that manages a network of over 120 automated weather stations in the state of California. The data measured at the weather station include solar radiation, relative humidity, air temperature, and wind speed. CIMIS data is compiled on an hourly time-step and represents the amount of AET from a well water homogenous surface of turf, and is reported as the reference crop evapotranspiration, ET_0. The reference crop evapotranspiration is related to AET from any crop by a crop coefficient, K_c, which is empirically determined for a wide variety of crops and for a range of crop growth stages. The formalization of this relationship is $PET * K_c = AET$.

In this analysis, CIMIS data was summed to a monthly value and an estimate of AET for alfalfa was computed from a monthly value of K_c for alfalfa. The CIMIS station is located in Barstow, CA, approximately 12 miles west of the study area.

g:\mojave watermaster - 3040\analysis\3040-038h-harter production analysis - pet aet tech memo.docx

TABLE 1

Aggregated Yearly Summary Utilizing Varying Monthly K_c Values based on 6 Alfalfa Cuttings per Year[1] for

09N02E07Q01 Well #01, 09N02E15Q01 Well #03, 09N02E15R03 Well #04, 09N02E21H03 Well #01A, 09N02E21J01 Well #02, and 09N02E22E02 Well #04 + E05 Well #04a

Water Year	Crop Acreage	Calculated Production (af)	Production per Acre (af/ac)	Rainfall (af)	Total Applied Water (af)	Total Applied Water per Acre (af/ac)	Consumptive Use[2] (af)	Consumptive Use per Acre (af/ac)	Estimated Return Flow (af)	Estimated Return Flow per Acre (af/ac)	Return Flow as a Percentage of Calculated Production
1998	160	1,161	7.3	81	1,242	7.8	810	5.1	432	2.7	37%
1999	160	1,118	7.0	37	1,154	7.2	913	5.7	241	1.5	22%
2000	160	1,286	8.0	18	1,304	8.2	948	5.9	356	2.2	28%
2001	288	2,006	7.0	115	2,121	7.4	1,680	5.8	441	1.5	22%
2002	456	3,403	7.5	316	3,719	8.2	2,681	5.9	1,038	2.3	31%
2003	456	2,911	6.4	158	3,069	6.7	2,540	5.6	528	1.2	18%
2004	344	2,406	7.0	175	2,581	7.5	1,968	5.7	613	1.8	25%
2005	476	3,210	6.7	657	3,867	8.1	2,440	5.1	1,427	3.0	44%
2006	607	3,910	6.4	127	4,038	6.7	3,288	5.4	749	1.2	19%
2007	498	3,544	7.1	24	3,568	7.2	2,740	5.5	828	1.7	23%
2008	534	3,775	7.1	80	3,855	7.2	3,080	5.8	775	1.5	21%
2009	534	3,631	6.8	138	3,770	7.1	2,991	5.6	779	1.5	21%
										Average:	26%

[1] Cutting periods per *High Desert Research Results, Alfalfa and Other Forages* , 1989.

TABLE 2

Aggregated Yearly Summary Utilizing Varying Monthly K_c Values based on 6 Alfalfa Cuttings per Year[1] Assuming All Crops Irrigated Were Alfalfa[2] for 09N02E07Q01 Well #01, 09N02E15Q01 Well #03, 09N02E15R03 Well #04, 09N02E21H03 Well #01A, 09N02E21J01 Well #02, and 09N02E22E02 Well #04 + E05 Well #04a

Water Year	Crop Acreage	Calculated Production (af)	Production per Acre (af/ac)	Rainfall (af)	Total Applied Water (af)	Total Applied Water per Acre (af/ac)	Consumptive Use (af)	Consumptive Use per Acre (af/ac)	Estimated Return Flow (af)	Consumptive Use as a Percentage of Total Applied Water
1998	160	1,160.8	7.3	81.1	1,241.8	7.8	810.0	5.1	431.8	65.23%
1999	160	1,117.6	7.0	36.5	1,154.2	7.2	912.9	5.7	241.3	79.09%
2000	160	1,285.6	8.0	18.4	1,304.0	8.2	948.2	5.9	355.8	72.71%
2001	382	2,331.9	6.1	152.0	2,484.0	6.5	2,226.1	5.8	257.9	89.62%
2002	592	3,909.9	6.6	316.7	4,226.6	7.1	3,481.0	5.9	745.5	82.36%
2003	532	3,278.1	6.2	158.1	3,436.2	6.5	2,963.9	5.6	472.3	86.26%
2004	592	3,244.5	5.5	174.9	3,419.4	5.8	3,386.2	5.7	33.2	99.03%
2005	600	3,652.6	6.1	657.3	4,309.9	7.2	3,075.1	5.1	1,234.8	71.35%
2006	607	3,910.2	6.4	127.5	4,037.6	6.7	3,288.5	5.4	749.1	81.45%
2007	610	3,939.5	6.5	29.0	3,968.5	6.5	3,356.2	5.5	612.3	84.57%
2008	610	3,962.4	6.5	80.1	4,042.5	6.6	3,518.3	5.8	524.2	87.03%
2009	610	3,750.9	6.1	138.4	3,889.3	6.4	3,416.5	5.6	472.8	87.84%
										82.21%

[1] Cutting periods per *High Desert Research Results, Alfalfa and Other Forages* , 1989.

[2] Assumes crops identified as grain or unidentified crops irrigated as Alfalfa.

TABLE 3

Yearly Summary Utilizing Varying Monthly K_c Values based on 6 Alfalfa Cuttings per Year[1]

Water Year	Crop Acreage	Calculated Production (in)	Rainfall (in)	Total Applied Water (in)	Actual Evapotranspiration (in)	Estimated Return Flow (in)	Return Flow as a Percentage of Calculated Production
1998	160	87	6	93	61	32	37%
1999	160	84	3	87	68	18	22%
2000	160	96	1	98	71	27	28%
2001	288	84	5	88	70	18	22%
2002	456	90	8	98	71	27	31%
2003	456	77	4	81	67	14	18%
2004	344	84	6	90	69	21	25%
2005	476	81	17	97	62	36	44%
2006	607	77	3	80	65	15	19%
2007	498	85	1	86	66	20	23%
2008	534	85	2	87	69	17	21%
2009	534	82	3	85	67	18	21%
Average	**-**	**84**	**5**	**89**	**67**	**22**	**26%**

[1] Cutting periods per *High Desert Research Results, Alfalfa and Other Forages* , 1989.

TABLE 4

Aggregated Monthly Summary of Calculated Production, Consumptive Use, ET, and Total Applied Water

Calculated Production (af)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1998	49.0	39.9	0.0	7.6	0.0	60.5	103.1	141.6	189.8	114.0	224.0	231.2	**1,160.8**
1999	46.5	0.0	18.1	54.5	31.6	130.5	210.2	139.1	208.3	148.0	47.1	83.6	**1,117.6**
2000	38.0	58.1	28.7	19.0	53.6	72.4	126.2	172.2	190.3	177.8	139.5	209.8	**1,285.6**
2001	39.5	68.3	5.6	21.1	15.8	63.5	204.2	291.9	317.6	320.3	267.1	391.0	**2,005.9**
2002	128.3	102.3	14.9	47.0	46.6	229.3	357.8	403.3	443.5	542.3	466.8	621.1	**3,403.1**
2003	160.8	157.6	8.8	3.3	92.4	194.0	274.1	395.1	463.1	391.2	340.1	430.1	**2,910.8**
2004	100.4	94.4	17.6	3.4	47.5	141.9	152.9	322.2	433.5	326.2	322.7	443.6	**2,406.2**
2005	146.4	35.0	16.9	0.1	25.4	69.9	349.3	530.8	500.8	475.3	491.6	568.0	**3,209.6**
2006	218.6	96.6	11.3	47.3	133.9	200.7	587.0	444.7	670.3	471.2	460.9	567.8	**3,910.2**
2007	204.9	80.8	37.1	45.6	89.4	268.4	281.7	472.0	500.8	559.0	399.3	605.4	**3,544.5**
2008	243.9	164.4	36.5	2.1	70.6	294.4	346.2	503.8	504.3	470.2	457.6	681.1	**3,775.1**
2009	200.2	100.3	41.6	2.3	44.3	300.9	331.2	469.5	461.0	484.6	565.5	629.8	**3,631.3**
Total	**1,576.6**	**997.5**	**237.0**	**253.4**	**651.2**	**2,026.2**	**3,324.0**	**4,286.2**	**4,883.6**	**4,480.1**	**4,182.4**	**5,462.5**	**32,360.7**

Consumptive Use (af)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1998	65.3	26.3	17.0	22.0	34.6	72.3	80.1	93.0	111.3	111.0	104.7	72.4	**810.0**
1999	61.8	31.2	20.5	29.2	48.3	85.9	93.4	116.1	121.3	115.8	107.9	81.5	**912.9**
2000	68.0	32.5	21.7	27.0	43.5	85.3	116.9	126.7	122.6	130.9	93.9	79.2	**948.2**
2001	109.2	55.5	34.0	35.5	66.1	149.5	185.6	221.7	239.2	223.4	202.8	157.2	**1,679.7**
2002	184.2	83.9	44.9	67.5	149.2	248.1	309.3	329.2	357.8	341.0	333.6	232.6	**2,681.3**
2003	169.5	91.0	37.0	76.0	113.2	246.2	288.4	304.8	337.6	335.3	288.7	252.7	**2,540.5**
2004	152.3	52.1	34.8	52.1	86.7	192.6	227.0	258.4	250.9	259.0	219.5	182.2	**1,967.7**
2005	164.3	76.9	44.6	51.4	93.1	223.7	290.6	320.8	339.8	320.2	273.0	241.1	**2,439.6**
2006	221.3	117.4	65.2	101.6	183.8	269.5	336.1	420.8	421.3	413.3	414.6	323.7	**3,288.5**
2007	186.3	102.4	56.4	86.7	149.4	287.3	316.4	274.4	370.6	348.9	314.5	246.6	**2,740.0**
2008	214.5	104.4	58.5	72.3	164.7	322.0	386.7	361.9	417.5	362.4	346.3	268.8	**3,079.9**
2009	222.2	101.1	51.2	84.0	132.6	290.0	357.3	392.1	326.5	396.9	353.7	283.2	**2,990.8**
Total	**1,818.9**	**874.7**	**485.9**	**705.2**	**1,265.3**	**2,472.5**	**2,987.8**	**3,220.0**	**3,416.3**	**3,358.0**	**3,053.1**	**2,421.3**	**26,079.1**

Actual ET (ET_c) (in)

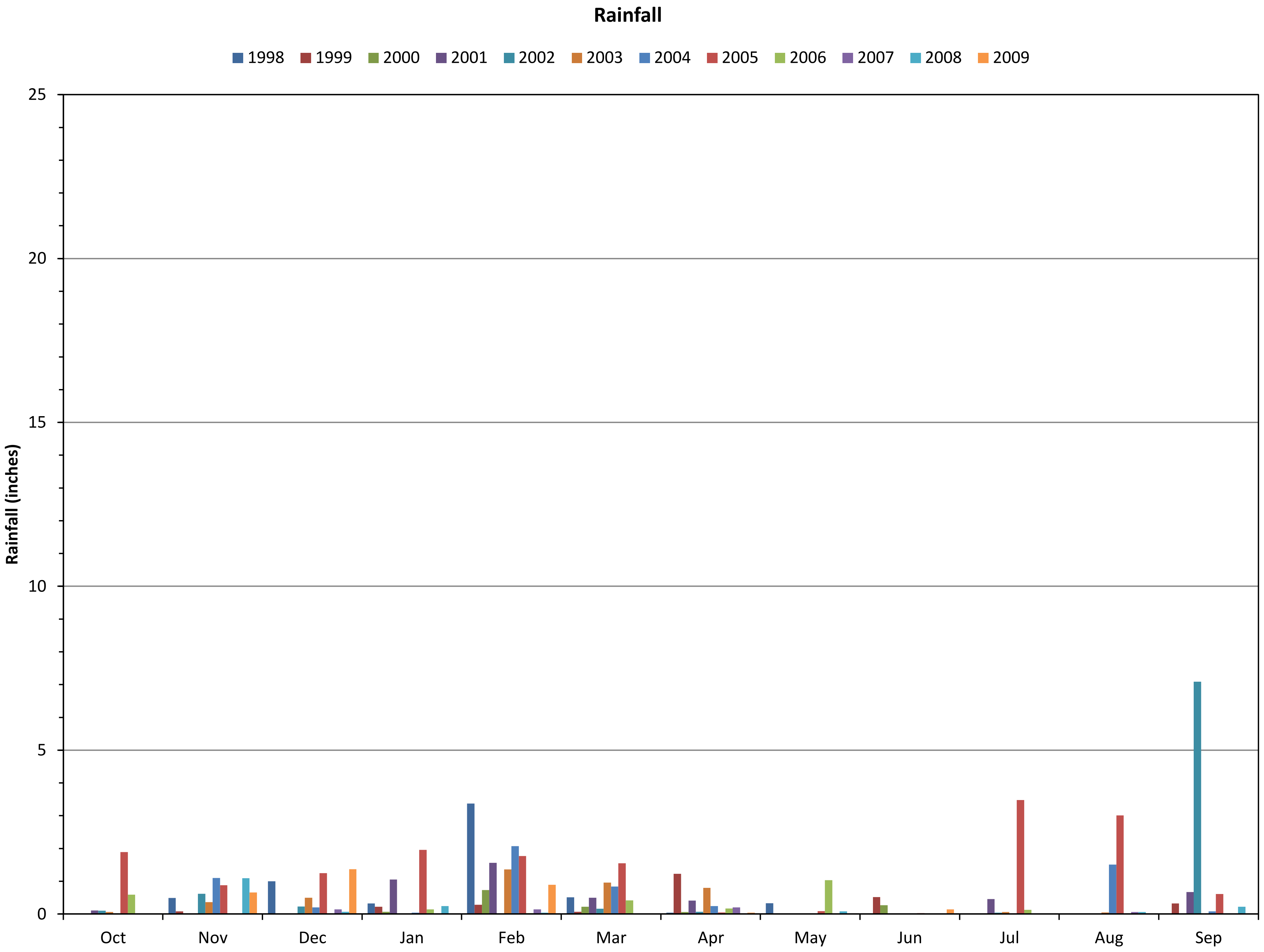
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1998	4.9	2.0	1.3	1.6	2.6	5.4	6.0	7.0	8.3	8.3	7.9	5.4	**60.8**
1999	4.6	2.3	1.5	2.2	3.6	6.4	7.0	8.7	9.1	8.7	8.1	6.1	**68.5**
2000	5.1	2.4	1.6	2.0	3.3	6.4	8.8	9.5	9.2	9.8	7.0	5.9	**71.1**
2001	4.5	2.3	1.4	1.5	2.8	6.2	7.7	9.2	10.0	9.3	8.5	6.6	**70.0**
2002	4.8	2.2	1.2	1.8	3.9	6.5	8.1	8.7	9.4	9.0	8.8	6.1	**70.6**
2003	4.5	2.4	1.0	2.0	3.0	6.5	7.6	8.0	8.9	8.8	7.6	6.6	**66.9**
2004	5.3	1.8	1.2	1.8	3.0	6.7	7.9	9.0	8.8	9.0	7.7	6.4	**68.6**
2005	4.1	1.9	1.1	1.3	2.3	5.6	7.3	8.1	8.6	8.1	6.9	6.1	**61.5**
2006	4.4	2.3	1.3	2.0	3.6	5.3	6.6	8.3	8.3	8.2	8.2	6.4	**65.0**
2007	4.5	2.5	1.4	2.1	3.6	6.9	7.6	6.6	8.9	8.4	7.6	5.9	**66.0**
2008	4.8	2.3	1.3	1.6	3.7	7.2	8.7	8.1	9.4	8.1	7.8	6.0	**69.2**
2009	5.0	2.3	1.2	1.9	3.0	6.5	8.0	8.8	7.3	8.9	7.9	6.4	**67.2**
Total	**56.6**	**26.8**	**15.5**	**21.8**	**38.4**	**75.9**	**91.5**	**100.1**	**106.2**	**104.7**	**93.9**	**74.0**	**805.3**

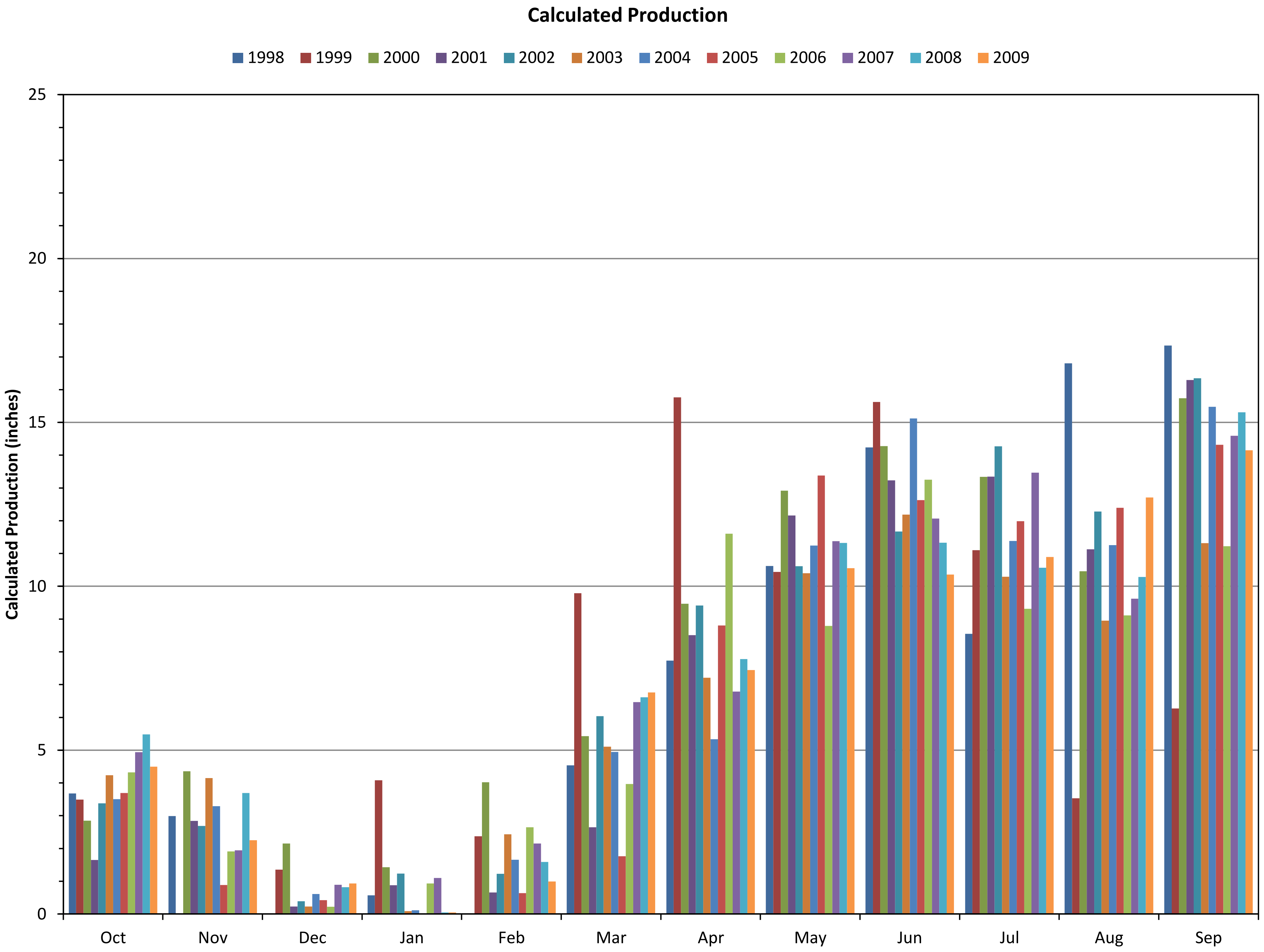
Potential ET (ET_o) (in)

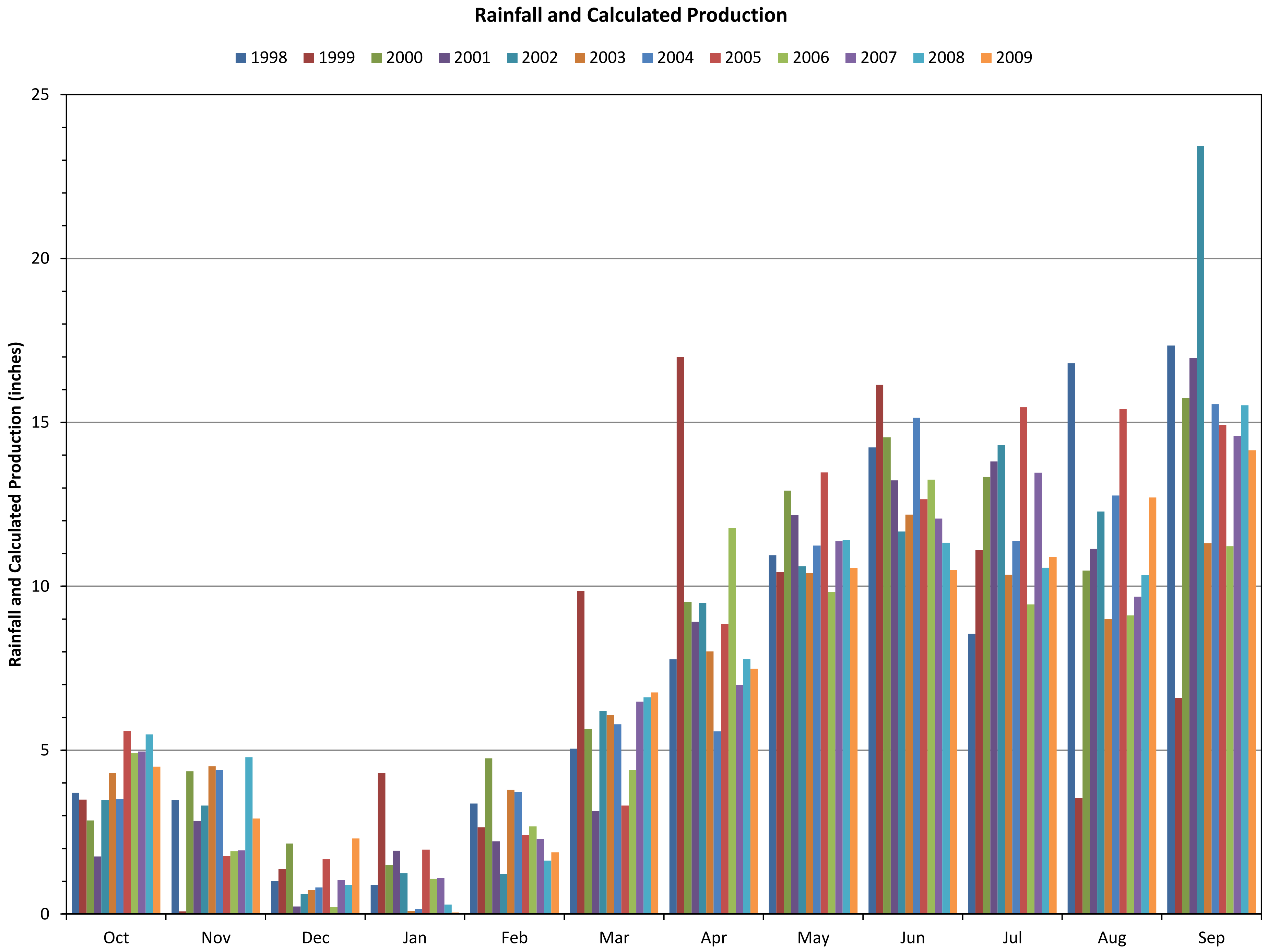
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1998	5.1	2.4	2.0	2.1	2.3	4.5	5.5	7.5	9.4	9.4	8.9	6.1	**65.2**
1999	4.8	2.9	2.4	2.7	3.2	5.4	6.4	9.4	10.3	9.8	9.2	6.8	**73.3**
2000	5.3	3.0	2.6	2.5	2.9	5.3	8.0	10.3	10.4	11.1	8.0	6.6	**76.0**
2001	4.7	2.9	2.2	1.9	2.4	5.2	7.0	10.0	11.3	10.6	9.6	7.3	**75.0**
2002	5.0	2.7	1.9	2.2	3.5	5.4	7.4	9.3	10.6	10.2	10.0	6.8	**75.1**
2003	4.6	3.0	1.5	2.5	2.6	5.4	6.9	8.7	10.0	10.0	8.6	7.4	**71.3**
2004	5.5	2.2	1.9	2.3	2.7	5.6	7.2	9.7	9.9	10.2	8.7	7.1	**73.0**
2005	4.3	2.4	1.8	1.6	2.1	4.7	6.7	8.7	9.7	9.2	7.8	6.8	**65.7**
2006	4.5	2.9	2.0	2.5	3.2	4.4	6.0	9.0	9.4	9.3	9.3	7.2	**69.7**
2007	4.6	3.0	2.2	2.6	3.2	5.8	6.9	7.1	10.1	9.5	8.6	6.6	**70.3**
2008	5.0	2.9	2.1	2.0	3.3	6.0	7.9	8.8	10.6	9.2	8.8	6.8	**73.4**
2009	5.2	2.8	1.8	2.4	2.6	5.4	7.3	9.5	8.3	10.1	9.0	7.1	**71.5**
Total	**58.5**	**33.1**	**24.5**	**27.3**	**34.1**	**63.2**	**83.2**	**107.9**	**120.0**	**118.7**	**106.4**	**82.7**	**859.4**

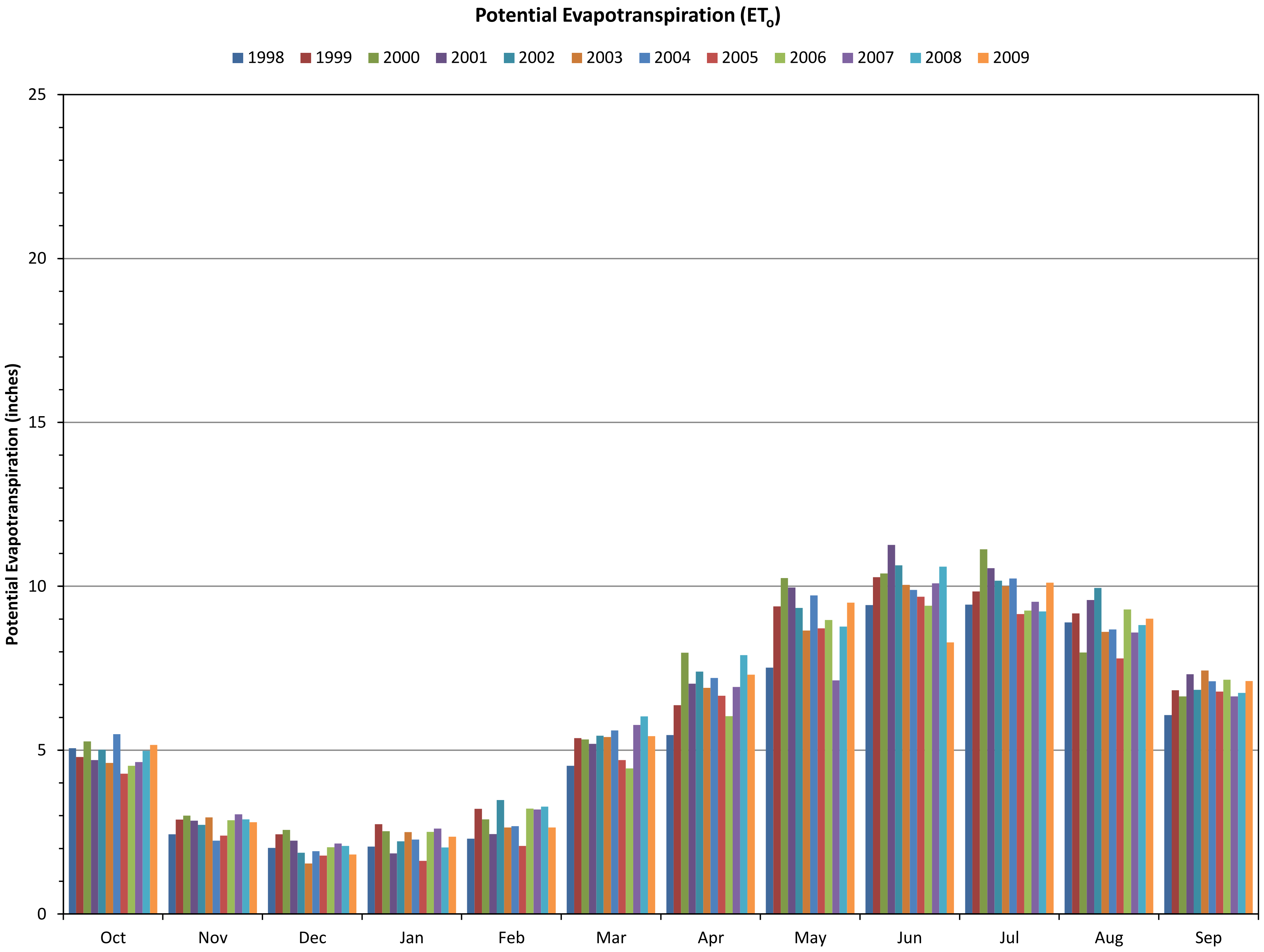
Total Applied Water (af)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1998	49.0	39.9	0.0	7.6	0.0	60.5	103.1	141.6	189.8	114.0	224.0	231.2	**1,160.8**
1999	46.5	0.0	18.1	54.5	31.6	130.5	210.2	139.1	208.3	148.0	47.1	83.6	**1,117.6**
2000	38.0	58.1	28.7	19.0	53.6	72.4	126.2	172.2	190.3	177.8	139.5	209.8	**1,285.6**
2001	39.5	68.3	5.6	21.1	15.8	63.5	204.2	291.9	317.6	320.3	267.1	391.0	**2,005.9**
2002	128.3	102.3	14.9	47.0	46.6	229.3	357.8	403.3	443.5	542.3	466.8	621.1	**3,403.1**
2003	160.8	157.6	8.8	3.3	92.4	194.0	274.1	395.1	463.1	391.2	340.1	430.1	**2,910.8**
2004	100.4	94.4	17.6	3.4	47.5	141.9	152.9	322.2	433.5	326.2	322.7	443.6	**2,406.2**
2005	146.4	35.0	16.9	0.1	25.4	69.9	349.3	530.8	500.8	475.3	491.6	568.0	**3,209.6**
2006	218.6	96.6	11.3	47.3	133.9	200.7	587.0	444.7	670.3	471.2	460.9	567.8	**3,910.2**
2007	204.9	80.8	37.1	45.6	89.4	268.4	281.7	472.0	500.8	559.0	399.3	605.4	**3,544.5**
2008	243.9	164.4	36.5	2.1	70.6	294.4	346.2	503.8	504.3	470.2	457.6	681.1	**3,775.1**
2009	200.2	100.3	41.6	2.3	44.3	300.9	331.2	469.5	461.0	484.6	565.5	629.8	**3,631.3**
Total	**1,576.6**	**997.5**	**237.0**	**253.4**	**651.2**	**2,026.2**	**3,324.0**	**4,286.2**	**4,883.6**	**4,480.1**	**4,182.4**	**5,462.5**	**32,360.7**

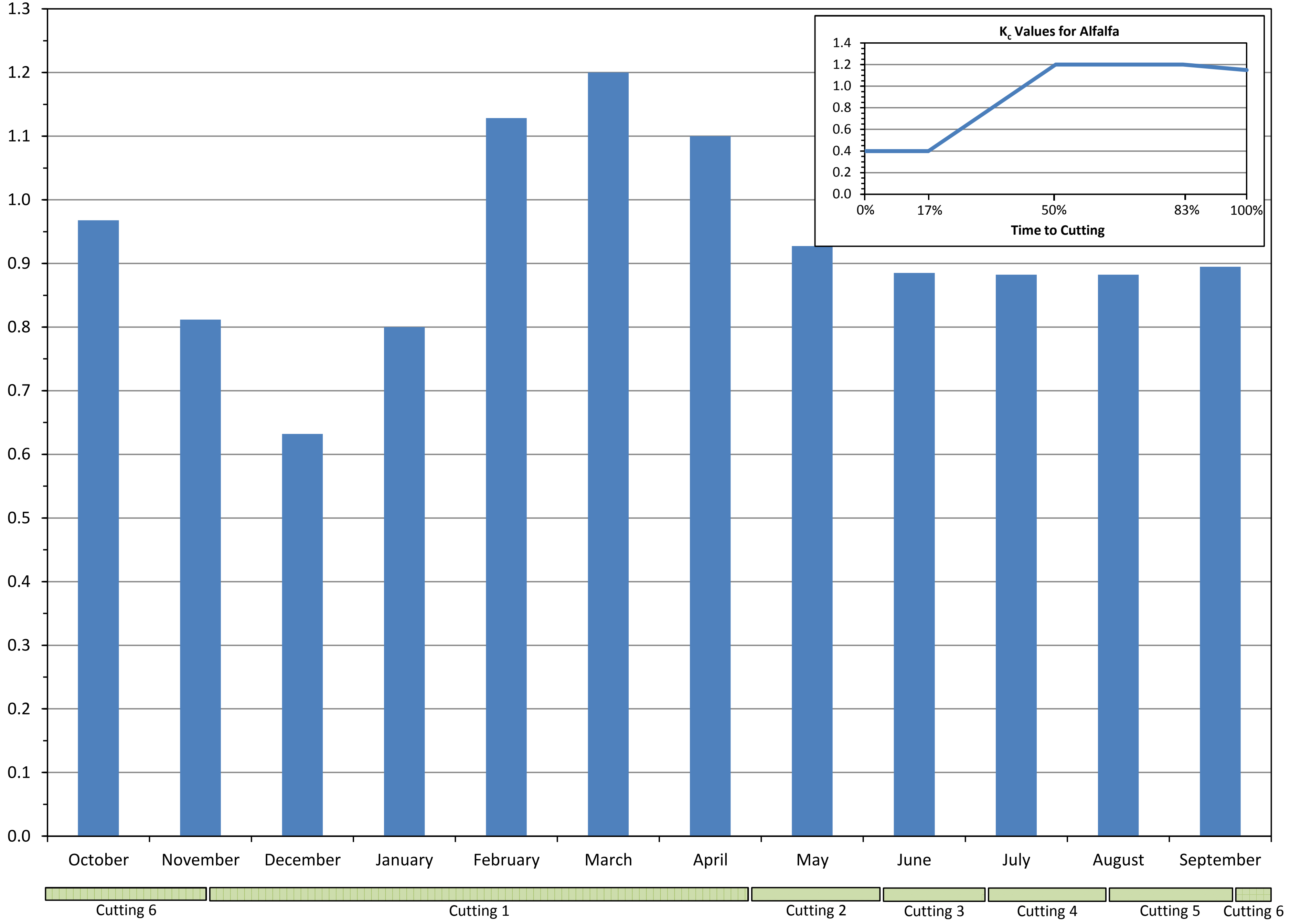

Rainfall
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Rainfall (inches)
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep

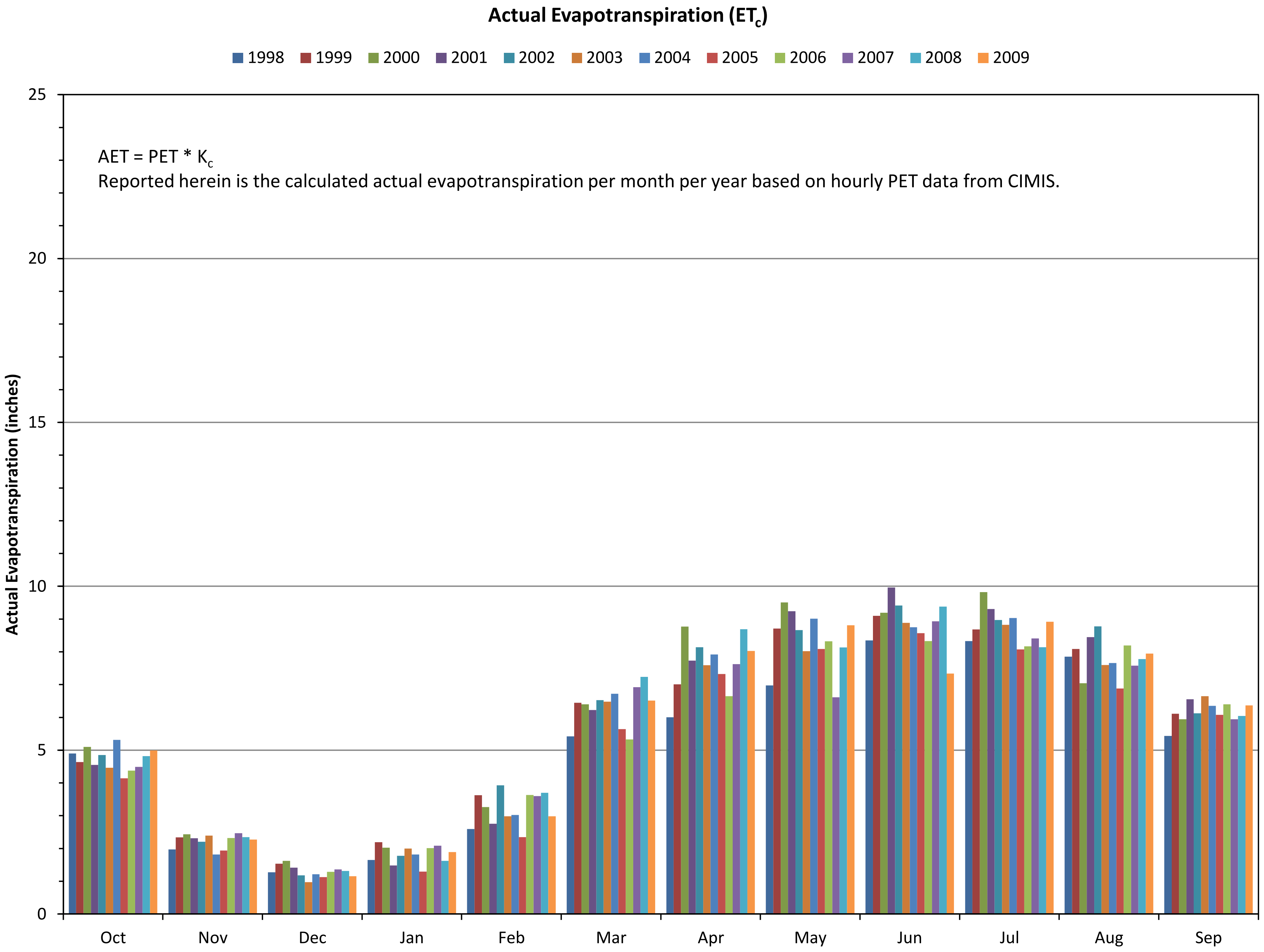

Calculated Production
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Calculated Production (inches)
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep


Rainfall and Calculated Production
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Rainfall and Calculated Production (inches)
0
5
10
15
20
25
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep


Potential Evapotranspiration (ET_o)
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Potential Evapotranspiration (inches)
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep

Monthly K_c Values for Alfalfa

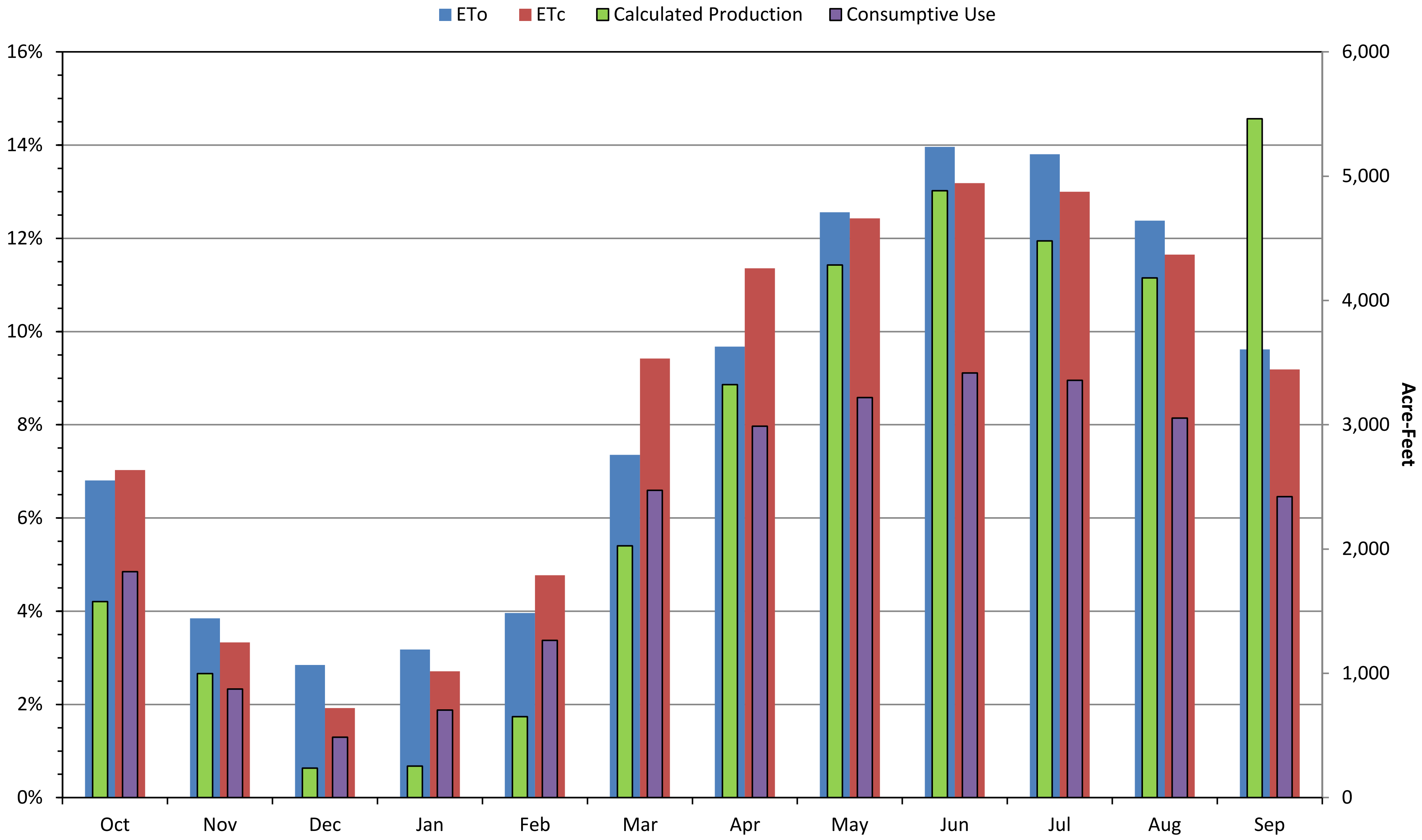



Actual Evapotranspiration (ET_c)
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
AET = PET * K_c
Reported herein is the calculated actual evapotranspiration per month per year based on hourly PET data from CIMIS.
Actual Evapotranspiration (inches)
25
20
15
10
5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep


Retuen Flow - Total Water compared to Actual Evapotranspiration
Total Water
Actual Evapotranspiration
Average Annual Return Flow (1998-2009)
Estimated Return Flow: 22.0"
Percent of Calculated Production: 26.0%
Inches
120
100
80
60
40
20
0
32" 37%
18" 22%
27" 28%
18" 22%
27" 31%
14" 18%
21" 25%
36" 44%
15" 19%
20" 23%
17" 21%
18" 21%
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009

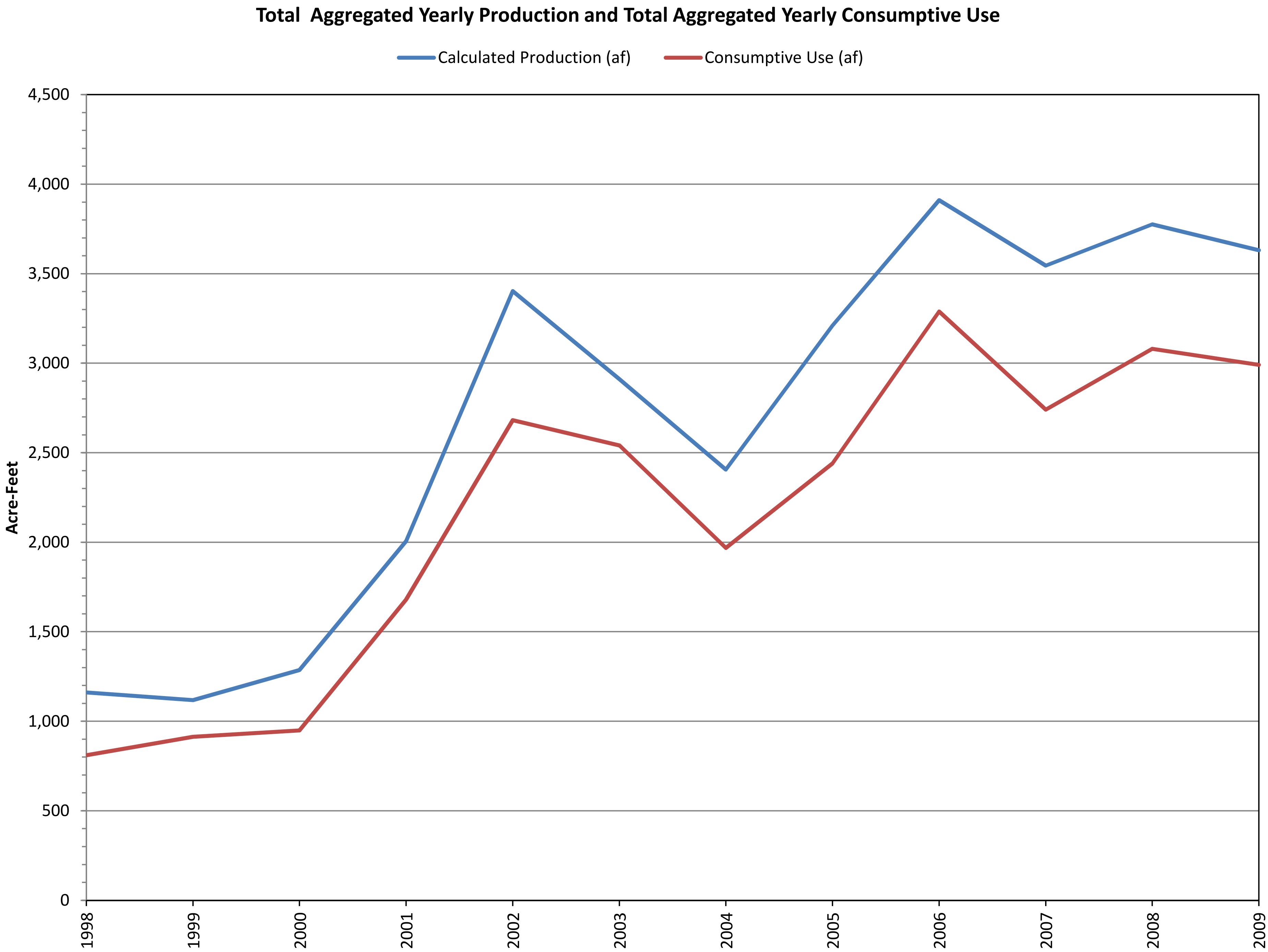
Monthly ET$_o$ and Potential ET$_c$ for Alfalfa[1] as a Percentage of Total and Aggregated Calculated Production and Consumptive Use[2]

Water Years 1998 through 2009



[1] Assumes 6 cuttings per year.

[2] Includes only production and consumptive use for fields irrigating Alfalfa.


Total Aggregated Yearly Production and Total Aggregated Yearly Consumptive Use
Calculated Production (af)
Consumptive Use (af)
Acre-Feet
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009