Mojave Basin Area Watermaster

Appendix C

Oeste Subarea

Water Supply Update

Prepared by:

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February 28, 2024

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MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E. and David H. Peterson, C.E.G., C.Hg

Date: February 28, 2024

Re: **Water Supply Update for Oeste Subarea**

This memorandum updates the estimates of groundwater production and supply for the Oeste Subarea of the Mojave River Groundwater Basin. Sources of water supply to the subarea were previously evaluated by Wagner & Bonsignore (WBE) and summarized in a draft August 7, 2020 memorandum.

The purpose of the current evaluation is to provide Watermaster with an update on the state of knowledge about available groundwater supply for the Oeste Subarea to develop an updated Production Safe Yield. The scope of the current evaluation was limited to review of available reports and data; no field studies or modeling were performed. Because little new information has been developed for the Oeste subarea since the prior WBE water supply study in 2020, the references for that study were used in the current update.

The location of the Oeste Subarea with respect to other subareas of the Mojave River Area is shown on Figure 1. The Oeste Subarea is bounded along the western side by the San Bernardino-Los Angeles County line. The eastern boundary generally follows the basin boundary established by California Department of Water Resources for the El Mirage groundwater basin.

Water supply to the Oeste Subarea is obtained entirely from groundwater, pumped from the regional aquifer underlying the subarea and from a shallow perched aquifer in the vicinity of El Mirage Dry Lake. No subsurface inflow from other subareas has been documented. Potential sources of groundwater recharge and water supply to the subarea have been identified in various previous studies as consisting of:

- Natural recharge from infiltration of surface water runoff at the base of the mountain front bounding the southern margin of the subarea, also referred to as mountain-front recharge. The source of mountain front recharge is predominantly from surface water flows in the Sheep Creek Wash (see Figure 1), although other smaller watersheds may also contribute to basin recharge;

- Infiltration of excess water in agricultural fields, individual septic systems, and municipal and industrial sources, referred to as return flows.

As noted in the *State of the Basin* portion of the Watermaster's 29th Annual Report (2021-22), water levels have declined over time and will likely continue to decline as water production (see Fig 5) increases with projected population growth. Review of water levels over the past 15 to 20 years indicates water levels are variable but stable. However, the past 15 to 20 years may not be representative of water supply conditions in the longer term. The report also notes that population is expected to increase in the future, which will increase water demand and likely result in water level declines.

Hydrogeologic Setting

Geologic Units and Aquifers

The geology of the Oeste subarea and vicinity is shown on Figure 2. The southern margin of the subarea as bounded by the San Gabriel Mountains, made up of older, consolidated and metamorphosed bedrock units of Paleozoic age. At the northwest and northeast margins of the subarea, the alluvial deposits are bounded primarily of older granitic bedrock. These older bedrock units are generally considered to be relatively impermeable and non-water-bearing, although wells have locally been developed in more fractured areas of the bedrock units.

Within the valley floor north of the San Gabriel Mountains, the groundwater basin contains large, alluvial-filled structural depressions that are downfaulted between the Garlock and San Andreas fault zones (Stamos and others, 2017). The deposits filling the basin consists of sediments of Quaternary to Tertiary age, which are derived locally from the upland bedrock areas at the margins of the basin. As described in a hydrogeologic study by California State University Fullerton (2009), the oldest of the basin-filling formations are the Pliocene-age sandstone of the Phelan Peak formation, conglomerate and sandstone of the Harold formation, and sandstone and conglomerate of the Shoemaker Gravel. Overlying these older basin-fill formations are alluvial fan deposits ranging from early Pleistocene (deposited in past 2 million years) to Holocene (deposited in past 11,000 years) in age. In the vicinity of El Mirage dry lake, the alluvial fan sediments are interbedded and overlain by an extensive zone of clayey lake (playa) deposits.

Faulting

The main faults described in the Oeste subarea are the Mirage Valley fault, a northwest-trending fault located at the north end of the Mirage Valley, and the San Andreas fault, located south of the subarea in the area of Wrightwood. Neither of these faults was identified by the USGS (Stamos and others, 2001) as a barrier to groundwater flow in the subarea.

Groundwater Conditions

Review of well hydrographs prepared annually by MWA (see Figure 3) 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 indicate that groundwater levels are generally rising within the pumping depression.

Based on DWR (1967) and USGS (various years) water level data, a groundwater divide was identified downgradient and north of the Sheep Creek Wash. The groundwater divide (or broad high ridge) generally trends roughly north-northeast from the head of the wash. The groundwater elevation and contouring data suggest that a portion of the recharge from Sheep Creek flows north-northwest and eventually, across the western subarea boundary, toward the Antelope Valley groundwater basin. These conditions are depicted on the ground water elevation map prepared by USGS as part of a study of the Antelope Valley-El Mirage groundwater basin boundary (Stamos and others, 2017; see Figure 4).

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. In general though, water levels in the Phelan-Pinion Hills area appear to continue to decline since the 1980s to 1990s. However, water levels in some wells in this area (05N07W24D03, 05N07W31J03, 05N07W33J02), while varying year to year, are generally trending level. Further north in the area of El Mirage, shallower wells (water levels in the range of about 60 to 120 feet) presumably completed in the shallow perched aquifer, are generally little changed.

Water Supply

Estimates of Surface Flows

The U.S. Geological Survey (Hardt, 1971, Stamos and others, 2001; Izbicki, 2007) and California Department of Water Resources (1967) have concluded that the low annual precipitation on the desert floor is used to meet growth and transpiration requirements of native vegetation, but is not considered to represent a source of groundwater recharge.

Previous studies identify that native recharge to the Oeste subarea is primarily from surface water flows originating from Sheep Creek. In the 1996 *Judgement After Trial* for the adjudication of the groundwater rights in the Mojave River Basin, the ungaged surface inflow to Oeste subarea was estimated at 1,500 acre-feet per year (AFY; Appendix C, Table C-1). However, Table C-1 does not indicate the portion of the surface flows that infiltrate to become groundwater recharge.

Historically, streamflow in Sheep Creek wash did not always follow the same course every year and would occasionally shift course over the surface of the alluvial fan. In recent years, a series of levees has restricted the flow to fewer active channels (Izbicki, 2002). At the mountain front, the Sheep Creek Wash is about 250 feet wide. Based on channel geometry, Izbicki (2002) estimated that the average annual flow from Sheep Creek Wash into Oeste Subarea was about 2,027 AFY (reported as 2.5 cubic hectameters). However, flow was estimated to decrease substantially downstream, with the channel width decreasing to less than 10 feet, indicating that most surface water infiltrated near the mountain front.

An analysis of estimated discharge from the Sheep Creek watershed was also performed in 2012 (unpublished data) by Watermaster. Based on the watershed area and a weighted mean annual precipitation of 24.9 inches, average annual surface flow was estimated at about 1,132 AFY at Sheep Creek Wash.

From review of the sources above, the volume of surface flows entering Oeste subarea at Sheep Creek has been estimated to range from about 1,132 AFY (Watermaster) to 2,027 AFY (USGS; Izbicki, 2002).

Native Mountain-Front Recharge

In a USGS study by Hardt (1971), it was noted that about 92 percent of long-term groundwater recharge originates in the San Bernardino Mountains. The San Gabriel Mountains, which are the source of surface runoff to Sheep Creek and Oeste Subarea, only contributes about five percent of basin recharge. The remaining three percent were attributed to underflow from adjacent areas. Based on an analog model of the basin, Hardt (1971) estimated annual recharge from the mountain front area, extending from the Mojave River to Sheep Creek was about 9,300 AFY. At five percent of this amount, recharge from the Sheep Creek area would be less than about 500 AFY.

In a 2001 study and groundwater model by USGS (Stamos and others, 2001), estimates of mountain front recharge were presented, ranging from 10,000 to 13,000 AFY, with most of the recharge occurring in the Upper Mojave Basin (Este, Alto, and Oeste subareas). The study also concluded that the recharge occurred in the upper reaches of ephemeral streams and washes. The study was focused on developing a groundwater model for the basin and recharge was not directly measured. However, as part of model calibration, the groundwater model estimated annual recharge for the period 1931-1990 at 1,941 AFY for the Oeste subarea.

A hydrogeologic study of the Oeste subarea was performed for the Mojave Water Agency in 2009 by California State University, Fullerton (Laton and others, 2009). The water budget performed for that study cited three sources for estimates of groundwater recharge; 1,100 AFY from DWR (1967), 7,147 AFY from Horne (1989; reference not located or verified), and the estimate derived from Stamos and others (USGS, 2001). Based on analysis of long-term groundwater level trends, Laton and others (2009) concluded that the estimate by Horne (1989) was likely high, and that average annual water supply to Oeste subarea was most likely in the range of 1,000 to 3,000 AFY. Return flows associated with municipal and agricultural consumptive use were not identified in the recharge estimates.

Studies by the USGS (Izbicki, 2002, 2004) and Izbicki and Michel (2004) identified the processes leading to recharge, but did not quantify the annual recharge in Sheep Creek Wash. Age-dating of groundwater samples from wells throughout the Mojave Basin indicates that along the course of the Mojave River, shallow groundwater within the Floodplain Aquifer is very young, indicating that recharge from surface flows occurs rapidly after large storm events (Izbicki and Michel, 2004; see Figures 2 and 3). However, groundwater collected in the vicinity of the Sheep Creek fan indicates that only samples in the upper reaches of the wash (near the mountain front) contained recently recharged water (i.e., less than about 50 to 70 years old). About six miles down-valley to the northeast, a groundwater sample analyzed for carbon activity indicated the water may have been recharged as much as 18,000 to 20,000 years ago. This isotopic sample data indicates that infiltrated water moves very slowly from the base of the mountain front, northward into the Mojave Basin.

Return Flows

Consumptive use studies performed by Watermaster for the period 2012 and 2019 calculated total return flows associated with consumptive use (domestic/septic, agricultural, municipal and industrial activities) in the range of about 800 to 1,200 AFY, with most years falling in the range of about 1,000 AFY.

Water Supply Summary

Estimates of surface flow from the Sheep Creek drainage have ranged from about 1,100 to 2,000 AFY. However, arriving at a precise estimate of native recharge to the Oeste subarea is problematic because the amount of discharge from the ephemeral streams and washes has never been measured directly. Therefore, it is uncertain how much of the estimated surface runoff infiltrates the upper reaches of Sheep Creek Wash to recharge the regional aquifer (Stamos and others, 2001). Based on the previously cited studies, total groundwater recharge and water supply to Oeste subarea is estimated below:

Process	Recharge, AFY
Mountain Front Recharge	
Hardt, 1971	<500
Stamos and others, USGS, 2001	1,971
Laton and others, CSUF, 2009 (various sources)	1,000 – 3,000
Return Flows	
Watermaster	1,000

The estimate derived from Hardt (1971) is very approximate and seems low compared with available estimates of surface flows to the subarea. While the model-derived recharge estimate from Stamos and others (2001) was not directly measured, it represents an estimate based on calibration to measured groundwater level records (i.e., hydrographs) and so would appear to be a more reasonable approximation. Given the limitation that surface water flows from Sheep Creek may only be in the range of about 1,100 to 2,000 AFY, the estimate of 1,941 AFY by Stamos and others (2001) would be at the high end. When compared with the range of recharge estimates cited by Laton and others (2009), it appears that recharge to upper Sheep Creep Wash area may be in the range of about 1,000 to 2,000 AFY. Combined with annual estimates of return flows associated with consumptive use, available information suggests the annual water supply to Oeste subarea is in the range of about 2,000 to 3,000 acre-feet.

Consumptive Use and Outflows

As provided byWatermaster , the total consumptive use and outflows for the Oste Subarea for the past five years are listed below, in acre-feet:

2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	5-Year Average
3,732	3,372	3,328	3,374	3,083	3,378

The reported outflows shown above include 800 AFY of subsurface flow, as estimated in Table C-1 of the Judgment.

Change in Storage

As described above, published estimates of the annual water supply to the subarea are approximate and not well quantified. Additionally, USGS studies indicate that the rate of movement of recharged groundwater from the mountain front to the groundwater basin is very slow. This suggests that the effects of drought or wet years would be attenuated to the point that they might not be identifiable in the hydrographs. Therefore, the ability to estimate short-term changes in storage based on water levels may be limited.

From the comparison of water supply and consumptive use/outflows, it appears that at the higher end of the water supply estimate (3,000 AFY), consumptive use/outflows are relatively closely balanced. However, the lower end of the water supply estimate (2,000 AFY) suggests that the aquifer may be depleting by up to about 1,000 AFY. If the loss is distributed over the area of the 105,100-acre subarea (Laton and others, 2009), an estimated 1,000 acre-feet of annual storage loss in the regional aquifer would be expected to only cause small annual changes in water levels, on the order of a few tenths of a foot or less. However, in the vicinity of El Mirage, water levels are dropping in some wells at rates of about 0.4 to 1.7 feet per year since 1999, while others in the same area are unchanged or rising during the same period. Presumably, the larger water level changes, such as those observed near El Mirage are in response to higher amounts of local pumping in that area.

Discussion and Conclusions

Of the water supply sources discussed, the largest unknown with the widest range of published estimates is mountain-front recharge. Based on information provided in the annual Watermaster reports, the total estimated pumping for Oeste subarea for the past five water years is shown below:

	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	Average
Verified Production	3,706	3,380	3,439	3,560	2,893	3,396
Non-Stipulating Parties*	238	238	238	238	238	238
Totals	3,944	3,618	3,677	3,798	3,131	3,634

* Estimated groundwater pumping based on land use, crop type, and climate data

As indicated above, production has been fairly consistent in the most recent five years and about half of the verified production reported at the time of the Judgment (6,261 AF in 1995-96). Therefore, the decline in pumping over time should presumably correlate to changes in the trends of water levels. However, the well hydrographs do not appear to indicate changes in slope or trend of the data after 1996. Given the general low gradients of the water table and very slow rate of groundwater movement in the Regional Aquifer, it is possible that changes in the water table from historical pumping will take some time to become evident in monitoring data.

Available data reviewed indicate that water supply to the subarea may be in the range of 2,000 to 3,000 AFY. In this range, water supply is roughly equal or somewhat below verified production. The historic declines in some wells suggests that some storage loss is occurring. Given the slow water level declines and historical rate of change in the subarea, it is likely that pumping exceeds supply by a small, but unverified amount. Continued monitoring of conditions in the subarea will likely be needed to confirm a long-term rate of storage change. Based on the foregoing, and an assessment that water levels remain relatively unchanged over a long time period, the PSY is for Oeste is likely about equal to the pumping over that period of time. Given that the UMBM indicates a deficit, in conflict with water levels appearing somewhat stable, and given that pumping and land use have changed significantly, the Engineer recommends basing PSY on the most recent years of pumping, the five year average of 3,634 acre feet.

References

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Mojave Water Agency, 2020, Oeste Subarea Hydrographs: Water Resources Department, dated February 2020 (with hyperlinks to USGS well data at the National Water Information Service).

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Thomas Harder & Co., 2010, Analysis of Historical Groundwater Production by the Phelan Pinon Hills Community Services District, Antelope Valley Area of Adjudication: unpublished consultant's report to Smith Trager LLP/Phelan Pinon Hills Community Services District, dated July 13, 2010, 23p.

Todd Groundwater and Applied Geoscience and Engineering (AGE), 2020, Status Update, Oeste Subarea Managed Aquifer Recharge (MAR) Feasibility Studies: unpublished consultant's presentation to Mojave Water Agency, dated August 5, 2020.

Attachments

Figure 1 - Location Map
Figure 2 – Subarea Geologic Map
Figure 3 – MWA 2023 Hydrograph Map, Oeste Subarea
Figure 4 – Water Table Map (USGS, 2017)
Figure 5 – Oeste Production Graph

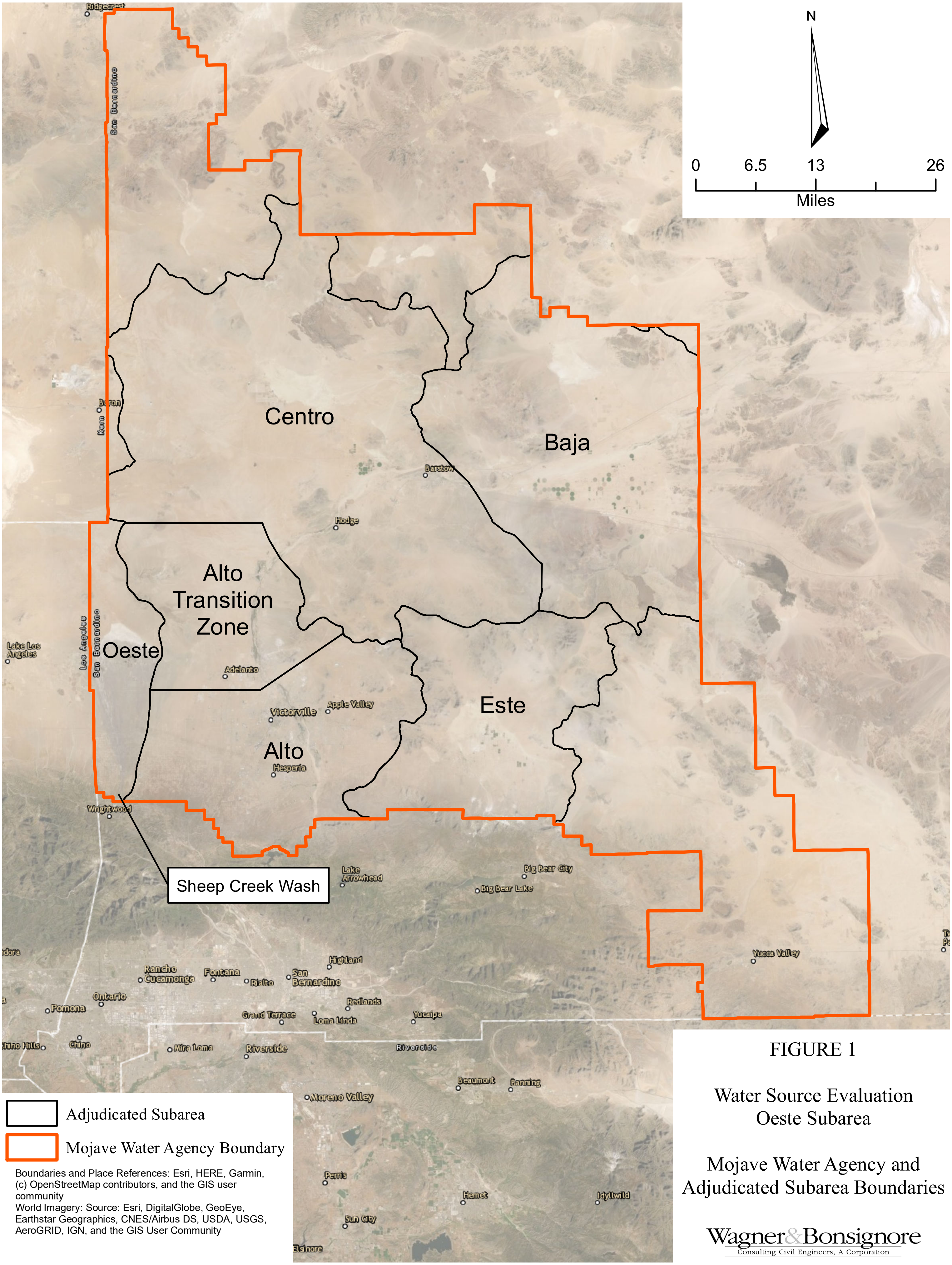


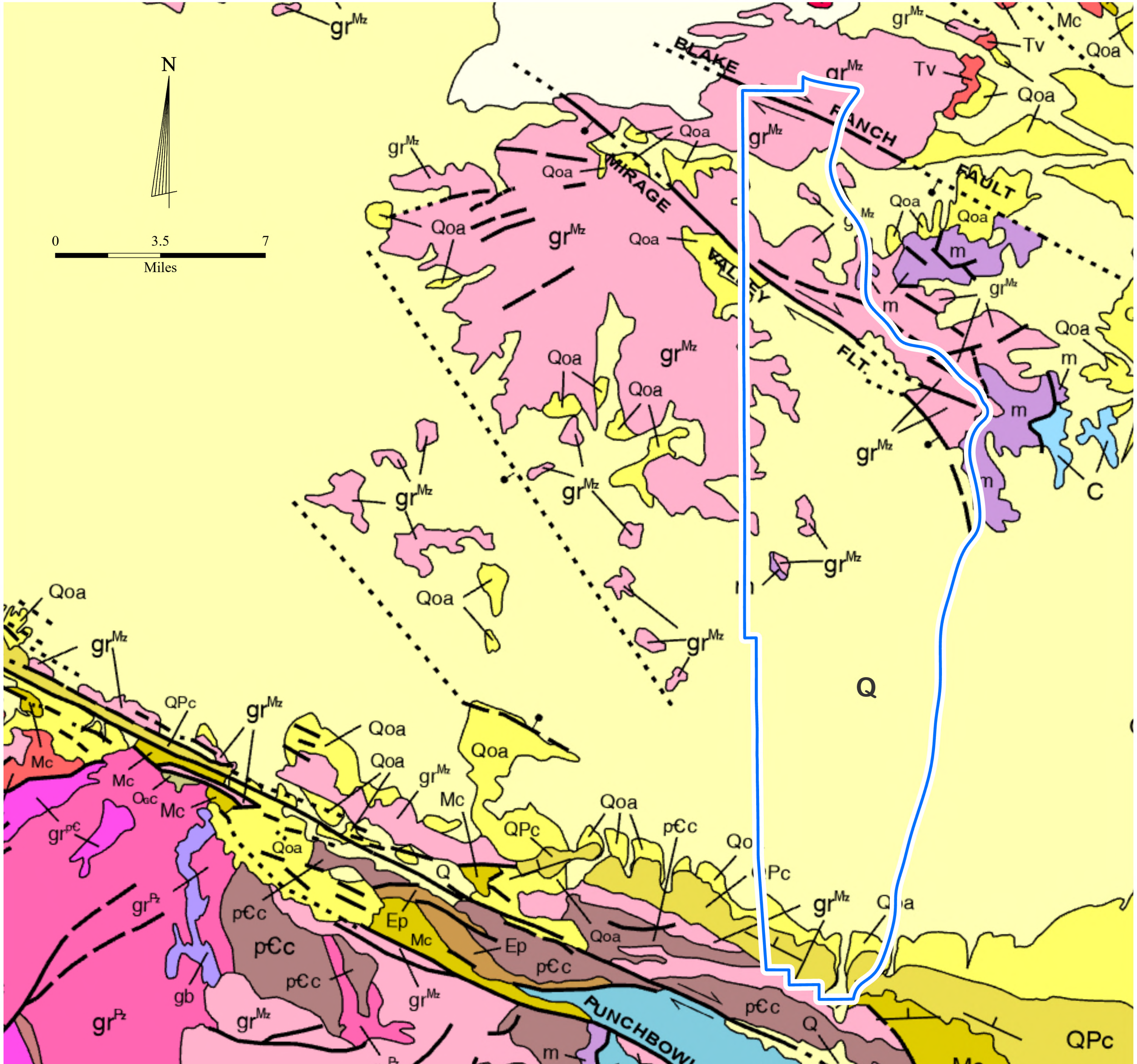
FIGURE 1

Water Source Evaluation
Oeste Subarea

Mojave Water Agency and
Adjudicated Subarea Boundaries

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Q:\Drawings\Mojave Water Agency\Oeste Subarea\Water Source Evaluation\FIGURE 1 - Subareas.mxd



- Oeste- Adjudicated Subarea
- Q; Alluvium, lake, playa, and terrace deposits; unconsolidated and semi-consolidated. Mostly nonmarine, but includes marine deposits near the coast
- Qoa; Older alluvium, lake, playa, and terrace deposits
- QPc; Pliocene and/or Pleistocene sandstone, shale, and gravel deposits; mostly loosely consolidated
- Tv; Tertiary volcanic flow rocks; minor pyroclastic deposits
- Ep Sandstone, shale, and conglomerate, well consolidated
- Mc; Sandstone, shale, conglomerate, and fanglomerate; moderately to well consolidated
- gb; Gabbro and dark dioritic rocks; chiefly Mesozoic
- grMz, grMz?; Mesozoic granite, quartz monzonite, granodiorite, and quartz diorite
- grPz Paleozoic and Permo-Triassic granitic rocks
- m; Undivided pre-Cenozoic metasedimentary and metavolcanic rocks of great variety. Mostly slate, quartzite, hornfels, chert, phyllite, mylonite, schist, gneiss, and minor marble
- C; Shale, sandstone, conglomerate, limestone, dolomite, chert, hornfels, marble, quartzite; in part pyroclastic rocks
- Sch; Schists of various types, mostly Paleozoic or Mesozoic age
- pCc; Complex of Precambrian igneous and metamorphic rocks. Mostly gneiss and schist intruded by igneous rocks; may be Mesozoic in part

FIGURE 2

Mojave Basin Area Watermaster

Regional Geology
Oeste Subarea

Wagner & Bonsignore
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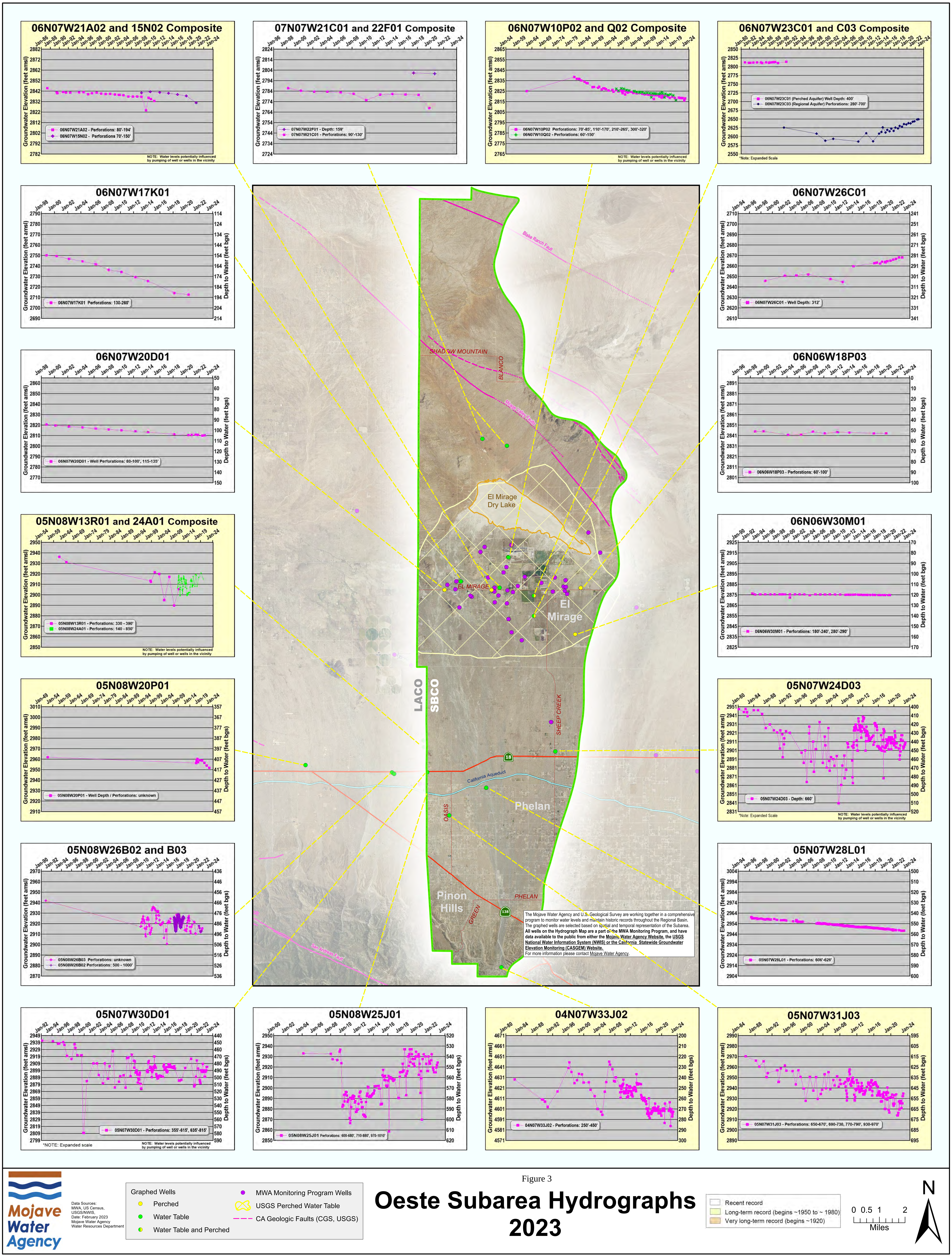
Geologic Data per California Geologic Survey REST server, based on 2010 Geologic Survey, https://gis.conservation.ca.gov/server/rest/services/CGS/Geologic_Map_of_California/MapServer accessed Oct., 23, 2023.

Path: Q:\Drawings\Mojave Water Agency\Oeste Subarea\General\GIS\Oeste Sub Area\Oeste Sub Area.aprx

October 2023



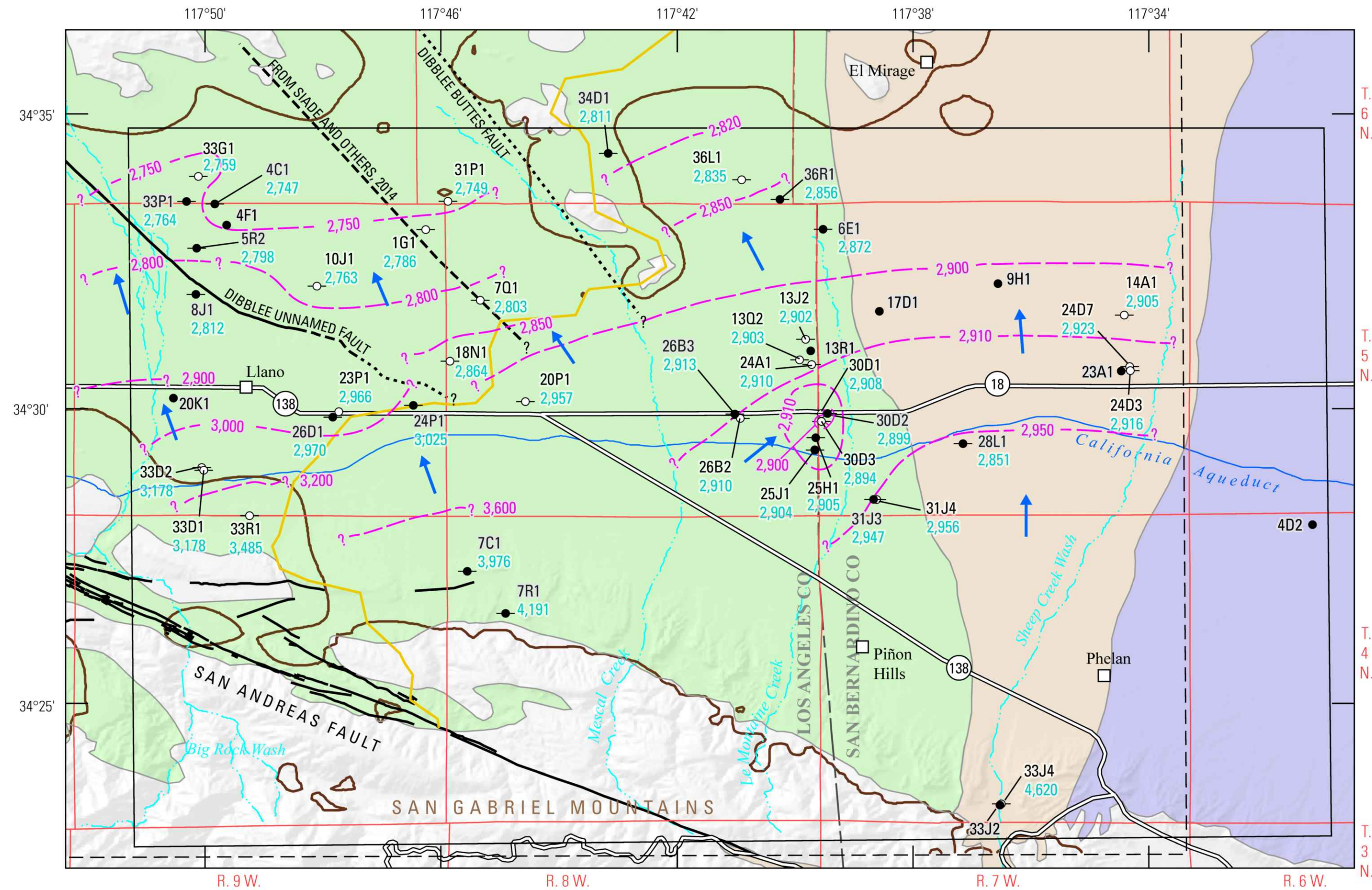
Mojave Water Agency

Data Sources:
MWA, US Census, USGS/NWIS,
Date: February 2023
Mojave Water Agency
Water Resources Department

Figure 3

Oeste Subarea Hydrographs 2023

FIGURE 4 - Groundwater Levels
Water Source Evaluation, Oeste Subarea



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Geographic Coordinate System; North American Datum of 1983

EXPLANATION

- **Antelope Valley groundwater basin**
- **El Mirage Valley groundwater basin**
- **Upper Mojave River Valley groundwater basin**
- **Groundwater-level study area**
- **Gravity study area**

–2,900–? **Approximate line of equal groundwater-level altitude, 2014**—Interval varies; dashed where approximate; queried where uncertain; hachures indicate depression.

Fault—Dashed where approximately located or inferred, dotted where concealed (modified from Dibblee, 1959, 1960c; Bryant, 2005; Siade and others, 2014).

Buried contact of alluvium and basement based on 2014 gravity data (see fig. 5)

Ridge of highest basement altitude

General direction of groundwater flow

24P1 **Well with hydrograph shown in figure 11 and abbreviated state well number**

20P1 2,957 **Well with groundwater-level data and hydrograph shown in figure 11 and identifier**—Top number is abbreviated state well number. Bottom number is altitude of groundwater level, in feet above NAVD 88.

33J4 2,956 **Well with groundwater-level data**—Top number is abbreviated state well number. Bottom number is altitude of groundwater level, in feet above NAVD 88.

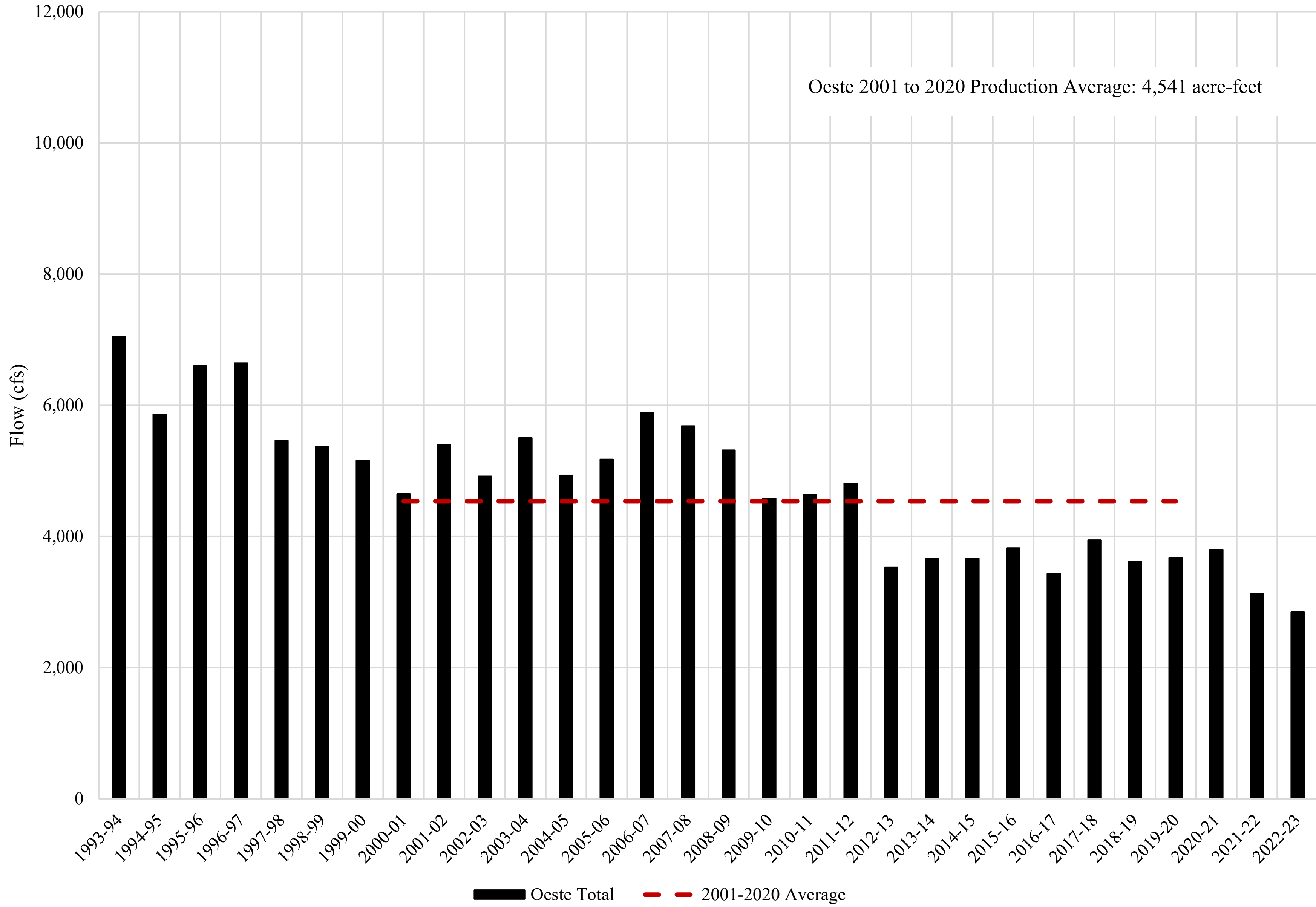
Figure 10. Groundwater-level altitude, general direction of groundwater flow, and location of wells with groundwater-level hydrographs shown in figure 11, near Piñon Hills, California.

Source: Stamos and others, 2017

FIGURE 5

Oeste Production

1993 to 2023



G:\MOJAVE ADJUDICATION - 3020\Analysis\Groundwater Modeling\3020-033M-Baja Este and Oeste Pumping History Through 2023.xlsx