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TECHNICAL MEMORANDUM

To: Mojave Basin Area Watermaster

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

Date: May 30, 2025

Re: **Production Safe Yield re-calculation per Court's Order**

Supplementing its July 3, 2024 Order, on October 23, 2024, the Superior Court of California, County of Riverside ordered the Watermaster to re-evaluate Production Safe Yield (PSY) for the Alto, Centro, Baja and Oeste subareas, including the Transition Zone.

The Court also ordered Watermaster as follows:

- In the process of re-evaluating PSY for those two subareas, to re-evaluate both (a) the sufficiency of any factual investigation conducted to quantify the factors to be used in those calculations, and (b) the reliability of any assumptions or estimates that the Watermaster relies upon when empirical data is not available to quantify factors.
- Thereafter, to draft a report regarding the Watermaster's findings and to include that report in its 31st Annual Report, i.e., the report concerning Water Year 2023-2024.

This Technical Memorandum describes the Watermaster's findings on these matters and is included as an addendum to the 31st Annual Report for Water Year 2023-2024.

DWR Bulletin 84 guidance on the selection of a hydrologic base period

The hydrologic base period is not defined in the Judgment. However, the Parties to the Judgment, the Court and Watermaster relied upon a study published in 1967, by the California Department of Water Resources (DWR). The Forward to that study states:

> *This investigation and report are the result of the recognition by the Mojave Water Agency of its need for reliable information on existing water resources, future water requirements, and sources of additional water supply to meet the needs for growth of the region it serves. Accordingly, the agency, through its legislative representatives, obtained state funds for the Department of Water Resources to undertake this investigation . . .*

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> *To provide interested agencies and persons with information as soon as it was available, informal meetings were held and two progress reports were published by the Department of Water Resources.*
>
> *The results of this study show that additional water will be required if the Mojave region is to realize its growth potential. The meager rainfall and increasing water demands of the area indicate the need for a plan of basin operation that will take full advantage of existing and potential water resources, including ground water, imported water, and the use of the ground water basins for both storage and distribution of water.*
>
> *The information provided by this study points out the need and provides a foundation for a ground water basin model simulation and operational and economic studies, leading to the selection by local agencies of an optimum plan of water resources management.*

In Bulletin 84 (which is specific to the Mojave Basin Area), DWR provides the following guidance as to the selection of a long-term base period:

> *In any watershed, precipitation is the original source of local water supply; therefore, the amount of precipitation to a groundwater basin and its tributary areas serve as an index of the water supply available to that basin. . . .*
>
> *The base period conditions should be reasonably representative of long-time hydrologic conditions and should include both normal and extreme wet and dry years. Both the beginning and the end of the base period should be preceded by a series of wet years or a series of dry years, so that the difference between the amount of water in transit within the zone of aeration at the beginning and end of the base period would be a minimum. The base period should also be within the period of available records and should include recent cultural conditions as an aid for projections under future basin operational studies.*

Based upon DWR's guidance, the Parties to the Judgment, the Court, and the Watermaster, determined that the initial base period should be from 1931 to 1990, as that period fairly includes both normal and extreme wet and dry years, and meets the other requirements set forth in Bulletin 84. Therefore, from January 10, 1996 (when the Judgment was entered) until approximately 2024, the base period from 1931 to 1990 was assumed to be the applicable long-term hydrologic base period for purposes of computing Production Safe Yield (PSY) in the Mojave Basin Area. DWR Bulletin 84 was trial exhibit number 4006.

The hydrologic base period is important because the "yield" (safe yield, production safe yield, natural safe yield, and other similar terms) require a finite time period for evaluation. As indicated in Bulletin 84, the selected base period should include recent cultural conditions, as those conditions are directly related to consumptive use and return flow which, in turn, directly impact water supply. The Court's Amended Statement of Decision in this proceeding acknowledges the importance of the cultural conditions: "Production Safe Yield is always based on a particular cultural condition." (Statement of Decision, C. 2., page 12).

The 2001-2020 hydrologic base period, which was proposed in 2024, also meets the guidance set forth in Bulletin 84 as evaluated at the Forks. It is reasonably representative of long-term hydrologic conditions for inflow at the Forks, contains normal, extreme wet and dry years, and begins and ends with dry years. It also is within the period of record and includes recent cultural conditions. The 2001-2020 base period, while similar, is drier by about 6%, compared to the 1931-1990 period as measured at the Forks. **Exhibit 1** is a hydrograph of flow at the Forks, showing various periods of average supply to the Basin Area.

Once the hydrologic base period is set, there is no reason to reset it every year, or at any other time unless the conditions upon which it is based change significantly. The long-term average water supply (1931-1990 used when the Judgment was entered, or 2001-2020 as now proposed by Watermaster) will not change from one year to the next, as it is fixed by the chosen time period.

The Judgment's definition of PSY

The Judgment defines Production Safe Yield as "The highest average Annual Amount of water that can be produced from a Subarea: (1) over a sequence of years that is representative of long-term average annual natural water supply to the Subarea net of long-term average annual natural outflow from the Subarea, (2) under given patterns of Production, applied water, return flows and Consumptive Use, and (3) without resulting in a long-term net reduction of groundwater in storage in the Subarea." (Judgment, page 11.)

As noted above, as to the first element of the PSY definition, from 1996 to approximately 2024, "long-term" was considered to be the period 1931-1990, for average annual natural water supply as measured at the Forks (the Forks is the confluence of Deep Creek and West Fork Mojave River, representing the main surface water supply to the basin). As described in greater detail below, average annual natural outflow from a Subarea has been considered to be the average outflow as determined at the Helendale Fault for Alto and the Waterman Fault for Baja. The subsurface flows between Este and Alto, Oeste and Alto, and Oeste and the Transition Zone (TZ) were estimated using the Upper Mojave River Basin Model (UMRBM).

Part (2) of the definition represents the "cultural conditions" within each subarea, reasonably representative of the patterns of "Production, applied water, return flows and Consumptive Use" to be applied to the water supply from part (1) and representing current cultural conditions and future conditions for planning. Part (2) is subject to change as land uses change but is not usually re-evaluated every year. This is so because recent cultural conditions in the Mojave Basin Area do not significantly change from one year to the next year (except in the Baja Subarea). Part (2) is the amount of water use and disposal when occurring under the supply conditions of Part (1) "without resulting in a long-term net reduction of groundwater in storage in the Subarea" (which is Part 3). The arithmetic for this definition is embodied in Exhibit C. (Table C-1 of the

Judgment.) When the calculation shows a "deficit" for a Subarea, the water producers within the Subarea must purchase replacement water to remedy the deficit (Replacement Obligations can be satisfied by the transfer provisions of the Judgment). For Table C-1 of the Judgment, the year considered for "cultural conditions" or land uses was 1990. Table C-1 was trial exhibit number 4013.

PSY for the Alto Subarea

To determine PSY for the Alto Subarea, in its 2024 analysis, Watermaster relied upon and utilized data included in the UMRBM and the TZ water balance to determine PSY for the entire Alto subarea (which includes the TZ). Appendix A titled "Alto & Centro Subarea Water Supply Update" dated February 28, 2024, describes the PSY update using the UMRBM. A copy of this document is included herein as **Exhibit 2**. A fundamental conclusion of this analysis is that there is no long-term change in storage in the TZ. This conclusion is deemed more likely than not to be correct based upon the measured historical water levels in the TZ and further discussion herein.

Figure 3 from Appendix A is the Alto Production Safe Yield Incorporating Output from the UMRBM

Alto Production above the Lower Narrows 2001- 2020 (acre-feet)	81,968
2001- 2020 Average Alto B2 Non-Consumptive Pumping* (acre-feet)	-14,118
TZ (2001 - 2020) Average Pumping (acre-feet)	+11,630
Modeled Pumping Alto + Transition Zone (acre-feet)	= 79,480
Alto above Narrows Modeled Deficit (2001 - 2020)	-17,475
Modeled Production Safe Yield (acre-feet)	= 62,005

* B2 is recirculated water as defined in the Judgment and is not included in total verified production

The PSY calculation for Alto as shown is based on the water supply conditions during 2001-2020 that will not have changed as of 2025, as the hydrologic base period is fixed. As shown on **Exhibit 1**, the pattern of inflow at the Forks while variable between wet and dry periods, for the past 95 years is similar to the 2001-2020 hydrologic base period.

These conditions, for planning purposes, are *assumed* to be repeated in the future. This assumption is necessary because what the inflow to the Basin Area will be in the future is not known. The assumption that this 20-year period is representative of current cultural conditions is also valid as those conditions, particularly in Alto, change relatively slowly (**Exhibit 3**). For example, the 2001-2020 average pumping for consumptive uses was 79,480 acre-feet (as shown above) and 77,712 acre-feet for the past five years (see **Exhibit 3**), or about a 2% difference. It is noted here that the selection of the last five years of pumping is for comparison to the 2001-2020 period, not an alternative long-term base period for evaluation.

The calculated deficit from the UMRBM (17,475 acre-feet/year) is the result of all processes related to water supply, use and disposal during the period 2001-2020. The inputs to the model and its output do not change and are assumed to be representative of the future for planning.

Importantly, this is the deficit that the Alto producers will purchase as Replacement Water pursuant to the terms of the Judgment. The modeled effect of importing 17,500 acre-feet every year is presented later in this discussion. A detailed description of the UMRBM can be found in the Mojave Water Agency website and can be accessed at the following link: https://www.mojavewater.org/wp-content/uploads/2024/02/Appendix-G-Groundwater-Model.pdf

The Transition Zone Water Balance

In this section we present the elements of water supply, use and disposal for the TZ as well as the reliability of estimates and likelihood that the information, data, calculations and estimates are more likely than not true. The elements are as follows:

- Measured Surface Inflow at the Lower Narrows (measured by USGS)
- Pumping within the TZ (reported to Watermaster, measured)
- Consumptive Use of Pumping within the TZ (estimated)
- Consumptive Use by Riparian Habitat within the TZ (calculated)
- Measured Precipitation (measured)
- Treated wastewater discharge measured and reported by Victor Valley Wastewater Reclamation Authority (VVWRA) - Amounts reported in Watermaster Annual Reports (Table 4-2)
- Calculated Surface Outflow (calculated based on the above parameters)
- Subsurface Outflow (agreed upon by the Parties, and confirmed by Watermaster)

Average Inflow to the TZ is unchanged since 1951

Exhibit 4 is a graphic of the flow at the Lower Narrows plus treated wastewater discharges by VVWRA to the Transition Zone for the period 1931-2024. The graphic indicates the average flow for the period 1951-1990 (post overdraft and prior to the Adjudication) was 49,028 acre-feet, which is similar in magnitude to the average of the period 1991-2024 of 49,100 acre-feet. This data, which consists of measured discharges from VVWRA, and measured stream flows (by the USGS) at the Lower Narrows gage (on the south end of the TZ) demonstrates the consistency of water supply to the TZ since at least 1951 and supports the conclusion that the water levels within the TZ are stable over time.

Transition Zone Pumping

Pumping in the TZ has declined significantly since the peak in the late 1960's from about 30,000 acre-feet to about 10,000 acre-feet in 2024, as shown on **Exhibit 5**. Pumping data has been reported to Watermaster since 1993, and prior to 1993 was estimated by various investigators, including Dibble, 1973 (MOJAVE WATER AGENCY vs CLARENCE L. ABBEY, et al); USGS, Hardt, 1971; and USGS, Stamos, 2001. The pumping data is considered reliable, and the best available information, and is more likely than not true.

Recent pumping data compiled by Watermaster is based on flow meter records, or other Watermaster approved methods for measuring and reporting (for the TZ):

- 99% of water pumped is metered/measured since at least 2012
- 93% by flow meters
- about 7% by pump test and electrical records (one producer)

Exhibit 6 provides various methods for measuring pumping in each subarea, including the TZ since 2012. The pumping data is considered the best available data and is considered more likely than not true.

Consumptive Use of Pumping

Consumptive uses must be estimated because there is no reliable means of measuring consumptive use. Consumptive use is the portion of pumped water lost to the atmosphere due to beneficial uses, like municipal indoor use and outdoor uses. The Judgment (Exhibit F) considered municipal consumptive use to be about 50% of production, meaning 50% of pumped water results in return flow to the basin (as supply). Since indoor and outdoor uses are not independently metered, indoor use is estimated by population and on a per capita water use rate. Outdoor water use is the difference between pumping and indoor water use. For the TZ based on these criteria, we have estimated that total consumptive use of production within the TZ is approximately ***64%*** of total pumping resulting in return flows of ***36%*** of pumping. Consumptive use of pumping is mostly due to outdoor water use within the TZ as indoor water use is assumed to return to the basin as supply (septic and sewer flow). It is also estimated that there is little to no return flow from outdoor water use due to very high rates of evapotranspiration.

Riparian Habitat Water Use in the TZ

Previous estimates of riparian habitat water use in the TZ indicate an average of 6,000 acre-feet per year based on the USGS study by Lines and Bilhorn (1996). Watermaster's most recent analysis using remote sensing technologies indicates an average of 6,178 acre-feet per year, which is consistent with Lines and Bilhorn (1996). The two estimates of riparian habitat water use in the TZ (about 6,000 acre-feet) as of now, is the best available information and is more likely than not true. The California Department of Fish and Wildlife (CDFW) has proposed to use part of the Biological Resources Trust Fund to update the consumptive use by riparian vegetation for Water Year 2025-26.

We note here that recharge from precipitation on the desert floor has been considered negligible by previous investigations because total precipitation on average is far less than potential evapotranspiration. Average precipitation at Victorville and Barstow is only about 5 inches per year, while soil evapotranspiration is estimated to be about 35.5 inches (Hardt, 1971). Surface evaporation from the Mojave River was estimated by USGS and CDFW to be 5.6 feet (Lines and Bilhorn, 1996, at page 7), and the Judgment made an assumption that evaporative losses from water bodies was 7 feet (Exhibit F of the Judgment). In any event, the potential soil moisture loss or evaporation losses are up to 7 1/2 times greater than precipitation (Hardt, 1971). In the TZ, a small portion of inflow is attributed to precipitation (1%), and all surface water evaporation is included in the net riparian habitat water use and is therefore counted.

The PSY for Alto was determined using the calibrated UMRBM, and the water balance for the TZ. The TZ water balance is necessary to calculate outflow from Alto, in order to calculate PSY for both Alto and Centro. Once finalized, the Regional Mojave River Basin Model (RMBM) will be used to calculate the outflow from Alto to Centro, through the TZ. The model, both the current UMRBM and the expanded RMBM, are calibrated to observed water levels, *not to estimates*. **While we consider the calculation of outflow from Alto (TZ) to Centro to be reliable, it is expected that the RMBM will provide an improved calculation of outflow, both surface and subsurface at the Helendale Fault**.

For the Alto PSY calculation, the sum of all the elements of inflow is subtracted from all the elements of outflow resulting in either a deficit or a surplus within Alto. Based upon the Judgment's definition, the PSY is the difference between average total pumping and the calculated deficit (surplus). The RMBM will provide a new calculation that may or may not differ from Watermaster's current evaluation of PSY for Alto (62,005 acre-feet). Until then, the PSY for Alto is considered reliable, is based on sound data and scientific analysis, is supported by the calibrated UMRBM, and is more likely than not true.

Calculated Surface and Subsurface Outflow

As mentioned above, the TZ water balance is used to estimate the long-term average annual outflow from Alto to Centro (near the Helendale Fault). Based on the above data and analysis, the calculation is reliable and more likely than not true. The TZ water balance calculation adjusts the measured streamflow at the Lower Narrows gage, and accounts for VVWRA discharges and consumptive uses within the TZ, resulting in the calculated outflow at Helendale Fault, using the following equation:

Flow at Helendale Fault = USGS Gage Lower Narrows – Consumptive Use – Riparian Habitat – Subsurface Outflow + Subsurface Inflow + VVWRA + Ungaged Inflows $\pm \Delta S_{TZ}$

Watermaster monitors water levels within the TZ, and at and near the Helendale Fault, including water levels downgradient of the Fault to help determine the average annual outflow. This is consistent with the Court's Amended Statement of Decision, Section F, paragraph 2. as follows:

"The transition zone has a fairly stable water level. It is necessary to maintain that water level so that the surface flows passing the Lower Narrows and the subsurface inflow into the transition zone will reach the Helendale Fault, and hence downstream areas; **the flows at the Helendale Fault will in the future be measured using monitoring wells to insure that water levels are maintained within the transition zone**."

Excerpt from the Court's Amended Statement of Decision is included in **Exhibit 7**.

Declining pumping within the TZ over time and consistent average water supply has resulted in the water levels stability in the TZ as acknowledged by the Amended Statement of Decision. This demonstrates that the TZ is functioning to pass to the Centro Subarea total flow less consumptive uses, and that this conclusion (based upon the reliable data noted herein) is more likely than not true.

The reliability of the estimate of long-term average annual surface water outflow at the Helendale Fault can be shown by the consistency over time of the estimates by numerous investigators as indicated below:

DWR Bulletin 84 (1967) 1936-1961	35,200 acre-feet
Judgment After Trial (1996) 1931-1990	37,300 acre-feet
USGS Stamos (2001) 1951- 1999	35,819 acre-feet
Webb Associates (2000) 1931-1990	36,700 acre-feet
Watermaster 2024	36,725 acre-feet

Watermaster's current estimate is consistent with previous researchers' who estimated flow at the Helendale Fault for various time periods and under different land use conditions. Watermaster's most recent estimate is 36,725 acre-feet (as calculated based on the above equation) and is consistent with the previous investigations noted above. The consistency is the result of stable long-term average water supply to the TZ, and the reduction in pumping and consumptive uses. The Judgment does not mandate that Centro Subarea's producers receive this quantity of water each year.

With respect to the Alto subarea, Watermaster does not have significant new information to warrant re-evaluation of PSY for Alto. The Transition Zone is within Alto and does not have a separate PSY calculation. Further, once the RMBM is complete, the model will be used to calculate the outflow at the Helendale Fault. If the modeled PSY value differs from the current estimate of PSY, Watermaster will re-evaluate the sufficiency of the PSY determination. Consequently, based on the information presently available, the Alto PSY should remain at the level proposed for 2024 of 62,005 acre-feet. Based upon the aforesaid data and information currently available to Watermaster, the proposed PSY for Alto is more likely than not to be the appropriate PSY for Alto.

PSY for Centro Subarea

The PSY calculation is based on inflow across the Helendale Fault, which as discussed is considered reliable and more likely than not true. Pumping data from Centro is either metered or established by pump test and electrical records (see **Exhibit 6**). The pumping data is considered reliable and more likely than not true.

Outflow from Centro is calculated (for the 2024 update) by adding Barstow WWTP discharges to the USGS stream flow measurements at the Barstow gage. Stream flow at Barstow is highly variable and episodic; storms are infrequent. The stream gage at Barstow has a long record but the measurement quality for several years has been noted by the USGS as "poor", some years are noted as "fair", and some other years the records are "fair" only above a specific flow value, but "poor" below it; however, the USGS continues to measure the gage and publish its results. Field measurements by the USGS indicate that some of the recent records are "poor" (for example in Water Years 2006, and 2008 through 2011).

The boundary between Centro and Baja is at the Waterman Fault, about 5 miles downstream from the Barstow gage. The surface water outflow from Centro to Baja can be determined by the RMBM once it is finalized. Other sources of inflow to Centro, including the ungaged inflow from washes and mountain front recharge, will also be determined by use of the expanded model. The best data available was used to estimate the Centro PSY of 31,420 acre-feet for 2024 and based on that analysis, it is more likely than not true. In summary, this data includes water levels in the TZ and in the Centro Subarea, verified pumping, calculated flow across the Helendale Fault, surface water gaged flow at Barstow, and treated wastewater discharges by the City of Barstow's Wastewater Treatment Plant, which are explained in further detail in **Exhibit 2** and is incorporated herein by this reference.

Geophysics investigations by Mojave Water Agency (MWA) indicate that there might be a subsurface groundwater flow gradient from the Helendale Fault area into Centro, to the northwest side of Iron Mountain in the direction of Harper Dry Lake.

While the geophysics results show that this might be true, it is not a changed condition from prior to entry of the Judgment. The geologic condition existed in the past as it exists in the present. USGS, Hardt, 1971, drew water level contours for 1930 indicating movement of groundwater across the Helendale Fault and to the west of Iron Mountain toward Harper Lake. Stamos (2001) also showed groundwater contours indicating direction of flow toward Harper Lake.

The surface water flow, as shown by USGS Hardt (1971), Lines (1995), Stamos, (2001), follows the direction of the Mojave River from the area near the Helendale Fault to Barstow. If there is a groundwater gradient toward Harper Lake and a portion of the groundwater moves in that direction, **that does not change the PSY for the Centro Subarea because Harper Lake is**

part of Centro. The expanded RMBM will include modeling of the portion of the groundwater flow into Harper Lake.

PSY Update for Baja

Watermaster presented an update of the PSY for the Baja Subarea in 2024. No additional data exists at this time that would support another evaluation of Baja PSY. There is no gaged inflow to Baja (the boundary is at the Waterman Fault which is ungaged), outflow is gaged at Afton several miles downstream of the Baja boundary. The only reliable data available is pumping data and water level measurements. This data was used to estimate the Baja PSY for 2024 and based on that analysis, it is more likely than not true. Watermaster presented the changes that have occurred in pumping in Baja over the past several years, as well as a graphical interpretation of water levels within Baja. While water levels are significantly lower than in the past, many of the wells, particularly in areas of reduced pumping are changing slope, and have stabilized or have risen. Hydrographs showing this behavior are provided in **Exhibit 8**.

The RMBM is considered the best tool for evaluating PSY for Baja; once it is calibrated, the RMBM will be used to re-evaluate the PSY for Baja. At present, Watermaster does not know the PSY in Baja with a reasonable degree of certainty. However, we know that as pumping has significantly declined, water levels are recovering. For example, verified pumping in Baja for the last five years, including production by Minimal Producers is summarized as follows:

Water Year	Pumping
2019-20	20,905
2020-21	15,095
2021-22	12,749
2022-23	11,419
2023-24	10,740

This dramatic decline in pumping within the last five years leads Watermaster to conclude that the PSY for Baja of 12,749 acre-feet will not result in continued long-term decline in groundwater storage. The current level of pumping is more likely than not to be close to the sustainable pumping amount. The July 2024 Court Order indicated that the evidentiary basis for the Baja PSY to be 12,749 acre-feet for Water Year 2024-2025 is unclear. The Court Order stated that "the PSY for Baja is 14,544 if based on water years 1931-1990, and 10,866 if based on water years 2001-2020."

The elements of water supply use and disposal for the Baja Subarea are insufficiently known to make a new recommendation for PSY in Baja. For the Baja evaluation for 2024 that was submitted to the Court, we evaluated the PSY for Baja by different methods due to the limited water supply data available. In one evaluation we used the long-term average water supply for the period of 1931-1990 and consumptive uses for Water Year 2021-2022, and compared that result to the PSY evaluation using the average water supply for the new hydrologic base period of 2001-

2020 and consumptive uses for the Water Year 2021-2022. In the PSY determination for Baja, we also evaluated the change in water level behavior to pumping.

In Baja as in other subareas, the best available data, and the only reliable data we have is water level measurements and pumping data. As explained earlier herein, the quality of streamflow data as measured by the USGS gage at Barstow, located about 5 miles upstream from the Baja boundary has been rated by the USGS as "poor" during several years, and some years were only "fair". All other data is either estimated, modeled, or assumed based on prior studies. However, the most important data, pumping and water level measurements, are also the most reliable data which are considered more likely than not true.

The long period of water level decline(s) in Baja appears to have abated beginning about 2019, corresponding to reduced pumping (see **Exhibits 3** and **8**). For the 2024 PSY update for Baja, our interpretation using the most important and reliable data is that at a given level of pumping, water levels appear to stabilize. The stabilization in the water levels is a process that will manifest over time as pumping either continues to fall or does not increase. The indication is that the pumping yield in Baja under these conditions is about 12,749 acre-feet. In the 2024 PSY update for Baja, the two time periods investigated, produced two values of PSY (with limited actual data, other than pumping and water levels), the average of these two values is 12,705 acre-feet. Consequently, we concluded that the recent pumping of 12,749 acre-feet is the best representation of the PSY in Baja, under the recent cultural conditions.

The RMBM when available will provide a better estimate of surface inflow, subsurface inflow, mountain front recharge, and recharge from ephemeral streams. As the model is calibrated to water levels, the supply to the Baja Subarea can be "modeled" to match water levels based on known pumping amounts. Consequently, at this time we have no additional information upon which to base a re-calculation of the PSY for Baja. The best information we have, and the most reliable, continues to be pumping and water levels and that leads us to conclude that the PSY for Baja proposed in 2024 is adequate until the RMBM is available.

Subsurface flows between subareas

The subsurface flow between subareas is part of the PSY calculation. According to the UMRBM, the subsurface inflow to Alto from Este and Oeste subareas during the 20-year calibration period from 2001 to 2020 are 1,466 acre-feet and 3,319 acre-feet, respectively. The Judgment provides an estimated subsurface flow of 200 acre-feet from Este to Alto and 800 acre-feet from Oeste to Alto.

The current estimate of subsurface flow from the TZ to Centro is 2,000 acre-feet per year as agreed to and estimated in the Judgment. Watermaster recently prepared updated estimates of the subsurface flows near the Helendale Fault (flow across the TZ to Centro boundary). These estimates indicate a range from 2,300 to 3,400 acre-feet per year. The average of this range, 2,650 acre-feet would increase the indicated supply to Centro (36,725 acre-feet) by about 2% and likewise increase the indicated outflow from Alto by 2%. The RMBM will provide a new estimate for subsurface flow at the Helendale Fault. At this time, our recommendation is to continue to use 2,000 acre-feet per year as the subsurface outflow until the completed RMBM is available.

USGS, Stamos, 2001 estimated that the subsurface flow near the Waterman Fault from Centro to Baja is 1,462 acre-feet. The Judgment estimated it to be 1,200 acre-feet. **All updated subsurface estimates exceed the Judgment's average and minimum obligations for subsurface flow.**

Re-calculation of the PSY for Oeste

Watermaster indicated to the Court that the PSY for Oeste will be re-evaluated once additional information on the inflow to Oeste was received.

Watermaster estimated the inflow to Oeste using the UMRBM. MWA recently updated the subsurface flow estimates from Sheep Creek into Oeste to be about 536 acre-feet per year more than previously estimated. **Exhibit 9** shows the location of the geologic cross section designated E-E' where MWA's estimated additional subsurface flows accrue to Oeste.

Using the output from the UMRBM, the average change in storage in Oeste is negative 1,566 acre-feet per year for the 20-year period of 2001-2020. As explained above, recent estimates of subsurface inflow from Sheep Creek into Oeste indicate an additional 536 acre-feet per year. Accounting for this new information, the new deficit would be about negative 1,030 acre-feet per year (of loss in storage).

Average total production in Oeste for the 20-year period is 116 acre-feet for Minimal Producers and a total verified production of 4,201 acre-feet. Thus, average total pumping is 4,317 acre-feet for the 2001 to 2020 period. Under these conditions, **Watermaster's calculation of the PSY for Oeste is 3,287 acre-feet for the 20-year period from 2001 to 2020 (PSY is equal to total pumping less the deficit, i.e., 4,317 acre-feet minus 1,030 acre-feet = 3,287 acre-feet).**

The BAP in Oeste is 7,095 acre-feet (including Minimal Producers). Therefore, Watermaster's new estimate of FPA for Oeste is 46.3%.

We address the Court's criticism regarding the previous evaluation of Oeste PSY below.

In the Court's July 3, 2024 Order, the Court expressed its concern regarding the Watermaster's representations concerning Oeste. The Court referenced the Watermaster engineer's Declaration about the modeled loss in storage in Oeste of 1,588 acre-feet per year for the last 20 years. However, the loss in storage for the last five years is 822 acre-feet per year. The Court stated that "Both of those statements may be true, because the 20-year average could be 1,588 even though the 5-year average is only 822. But the Watermaster's failure to stick with a consistent time period does not assist the Court in evaluating the evidence presented and does not enhance the Watermaster's credibility."

The time period that we used for evaluating water supply to Oeste was and is 2001-2020. During this period the graphical interpretation of water levels in Oeste, as well as reports of well performance by Phelan Pinion Hills CSD (which pumps at least 90% of the water in Oeste), indicates that water levels are relatively stable over a long period of time. Such stability would indicate that the subarea yield (PSY) would be about equal to the pumping during that time (20 years) or 4,317 acre-feet.

However, the model results indicated a storage deficit of 1,566 acre-feet[1] which is inconsistent with the observation of water level behavior. The model and the observation about change in storage cannot both be correct; there is a deficit (modeled) or there is no deficit (water level observed stability).

As an alternative to the findings from the UMRBM in 2024, we prepared an analysis of the Oeste water supply based on other available data and information. The evaluation titled "Oeste Subarea Water Supply Update" (February 28, 2024, Wagner and Peterson, 2024) can be found at page 7 at the link https://www.mojavewater.org/wp-content/uploads/2024/02/Appendix-C-Oeste.pdf. An excerpt from this evaluation is provided:

> "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 suggest that some storage loss are occurring. Given the slow water level declines and historical rate of change in the subarea, it is more likely than not 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 for Oeste is more likely than not to be about equal to the pumping over that period of time. Given that the UMRBM 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."

We note that pumping has been declining in Oeste since at least 1994, thereby significantly reducing the pumping stresses on the subarea. This would explain the relative stability in water levels over time (water levels will always be variable in the shorter term); 6,550 acre-feet of pumping in 1994 down to 3,047 acre-feet of pumping in 2020, is a decrease of 53%. It is important to note that there is no gaged inflow data, limited precipitation data, and no gaged outflow data.

[1] The Court's Order indicated a change in storage of 1,588 acre-feet for Oeste. The Upper Mojave Basin Model output indicates that the change in storage was 1,566 acre-feet for Oeste. The value reported by the court may have been reported by Watermaster incorrectly. In any event, the UMRBM showed a deficit of 1,566 acre-feet.

The only reliable measured data we have is water level(s) and pumping. We presented this analysis as an alternative and described it as a conservative approach because it produced a PSY value about **700 acre-feet** less than previously indicated using a 20-year pumping history. It is unlikely that the difference between the two interpretations is resolvable without substantially more data; data that as of now does not exist.

The UMRBM provides a valuable tool, however, for estimating inflows and outflows. To maintain consistency with use of the model for the 2024 PSY update and for future updates, we are proposing that the Court adopt the Oeste PSY of 3,287 acre-feet, which is the 20-year average pumping minus the 20-year calculated deficit. This results in an FPA at 46.3% of BAP.

Sufficiency of factual investigations conducted to quantify factors to be used in the calculations, and the reliability of assumptions or estimates that the Watermaster relies on when empirical data is not available to quantify factors

Alto Subarea (including the Transition Zone)

The factual investigations, bases and estimates for the Alto Subarea PSY calculation include the following:

1. **Surface Water Inflow at the Forks (Measured)**. It is the 2001-2020 average surface water inflow to Alto, measured at the Mojave River Forks. The Forks is the addition of reported values from USGS gage stations at West Fork Mojave River near Hesperia, CA and Deep Creek near Hesperia, CA (see **Exhibit 1**). This measured USGS gage data is sufficient and provides the best available information regarding the surface water inflow to Alto, and is more likely than not true.
2. **Surface Water Inflow at the Lower Narrows (Measured).** Surface water is also measured by USGS at Lower Narrows, the south end of the TZ. For the PSY calculation, the surface water inflow is the 2001-2020 average gaged flow. This measured USGS gage data is sufficient and provides the best available information regarding the surface water inflow to Alto, and is more likely than not true.
3. **Groundwater Production (Measured).** It is the 2001-2020 average total verified production from Parties. Verified production is mostly metered (see **Exhibit 6**), which is more likely than not true.
4. **Subsurface Inflow (Modeled) to the basin area.** Mountain front recharge, ungaged subsurface inflow (from Oeste and Este subareas) and deep percolation from precipitation. All these values were developed by the UMRBM. This modeled subsurface flow provides the best available information regarding subsurface inflow and deep percolation from precipitation; it is more likely than not true.
5. **Surface Water Outflow to Centro (Calculated).** Calculated based on reported flows from the USGS gage at the Lower Narrows, discharge records by VVWRA, pumping records, and estimates of consumptive use. This value is determined by the Transition Zone water balance (discussed below). For the reasons explained above, the investigation of the surface

water outflow to Centro is adequate and the calculated surface water outflow to Centro is more likely than not true because it is based upon: measured surface flow data at the USGS gage at the Lower Narrows (south end of the Transition Zone); and the TZ water balance, which itself is based on measured inflow from VVWRA, measured pumping, reasonably estimated consumptive use and return flow, and most importantly the verified stable water levels maintained throughout the TZ.

6. **Subsurface Outflow to Centro (Calculated)**. Calculated by the Judgment and will be computed by the RMBM. The value has also been calculated by Watermaster in 2006, 2019 and more recently in April of 2025. **Exhibit 10** provides Watermaster's 2025 Update on Subsurface Flows at and near the Helendale Fault. As explained above, the studies performed of subsurface flow are adequate and confirm that actual subsurface flow exceeds the Judgment's estimated subsurface flow.
7. **Consumptive uses from Pumping (Calculated).** Consumptive use is the portion of water production that is permanently removed from the water supply system. Consumptive use corresponds to the evapotranspiration and evaporation of water applied to beneficial uses. For the PSY calculation, it is the consumptive use from the UMRBM, and calculated as follows:
    a. Agriculture: The total consumptive use for an agricultural crop is determined using the evapotranspiration rates of applied water and the irrigated acreages. The difference between the potential consumptive use and the applied water (pumping) corresponds to return flow to the system.
    b. Urban: Consumptive use of municipal production is determined by separating indoor use from outdoor use. For the purposes of this analysis, indoor domestic use is assumed to be entirely return flow and outdoor use is considered to be entirely consumed. Indoor consumptive use is difficult to measure, and whether water is discharged to sewer or septic, it is assumed to be returned to the system as return flow.

    The investigation and estimates of consumptive uses from pumping relating to the urban and agricultural uses described above utilize accepted methodologies for accurately estimating consumptive uses from groundwater pumping and, accordingly, are more likely than not true.
8. **Consumptive uses from Phreatophytes (Calculated).** Water use (evapotranspiration) from riparian vegetation along the Mojave River is water being used by the plant community for growth. Watermaster values for the PSY calculation derive 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). This authoritative resource is recognized as providing reliable information for estimating phreatophyte water uses, and is more likely than not true. Watermaster continues to work closely with the California Department of Fish & Wildlife to further refine these estimates.

Transition Zone

The factual investigations, bases and estimates for the Transition Zone water balance calculation include the following:

1. **Stability of the groundwater levels (Measured)**. Water levels in the TZ are monitored by MWA. Watermaster relies on the observed stability of the long-term water levels to prepare a water balance calculation for the TZ. This water balance is used to compute estimates of the outflow into the Centro Subarea. There is no reason to doubt the accuracy of the measured water levels in MWA's monitoring wells, and they are more likely than not true.
2. **Groundwater pumping (Measured)**. It is 2001-2020 average verified production from Parties. Verified production is mostly metered (see **Exhibit 6**), which is more likely than not true.
3. **Treated wastewater discharge by VVWRA (Measured).** Treated wastewater discharge into the TZ is measured by VVWRA. This data, measured and reported by VVWRA, is adequate and more likely than not true.
4. **Surface Water Inflow (Measured).** Surface inflow to the TZ is the average flow measured by the USGS gage at the Lower Narrows. As noted, this data measured and reported by USGS is adequate and more likely than not true.
5. **Subsurface Inflow (Calculated).** The Judgment deemed subsurface inflow to the TZ to be 2,000 acre-feet per year. The Parties agreed for the purposes of the Makeup Obligation calculation (see Table 4-2 of Watermaster Annual Reports) to 2,000 acre-feet of subsurface inflow. For the 2024 PSY Update for Alto (including TZ), the UMRBM was used to estimate subsurface inflow to the TZ.
6. **Surface Water Outflow (Calculated)**. Surface water outflow from the TZ into the Centro Subarea is calculated by the Watermaster as reported herein. As explained, the investigation of surface water outflow to Centro is adequate because it is based on the USGS measured surface inflow at the Lower Narrows, the measured VVWRA discharge into the TZ, measured TZ pumping data, reasonable estimates of consumptive use and return flow, and verified stable water levels in the TZ; and, therefore, is more likely than not true.
7. **Subsurface Outflow (Calculated).** Subsurface outflow from the TZ into Centro Subarea is defined by the Judgment and adopted by the Parties. Measured water levels show a long-term stability behavior. As explained by the Court's Amended Statement of Decision, the stability in the water levels within the TZ ensures that subsurface inflows into the TZ reach and cross the Helendale Fault into Centro. Watermaster's recent investigation of subsurface flow across the TZ into Centro, explained earlier herein and provided in **Exhibit 10**, are more likely than not true.
8. **Consumptive uses from Pumping (Calculated).** Consumptive uses in the TZ are calculated for the purposes of the PSY calculation for Alto, and it is the consumptive use from the UMRBM, calculated as follows:
    a. Agriculture: The total consumptive use for an agricultural crop is determined using the evapotranspiration rates of applied water and the irrigated acreages. The

difference between the potential consumptive use and the applied water (pumping) corresponds to return flow to the system.

b. Urban: Consumptive use of municipal production is determined by separating indoor use from outdoor use. For the purposes of this analysis, indoor domestic use is assumed to be entirely return flow and outdoor use is considered to be entirely consumed. Indoor consumptive use is difficult to measure, and whether water is discharged to sewer or septic, it is assumed to be returned to the system as return flow.

The investigation and estimates of consumptive uses from pumping relating to the urban and agricultural uses described above utilize accepted methodologies for accurately estimating consumptive uses from groundwater pumping and, accordingly, are more likely than not true.

9. **Consumptive uses from Phreatophytes (Calculated).** Water use (evapotranspiration) from riparian vegetation along the Mojave River is water being used by the plant community for growth. Watermaster values for the PSY calculation derive 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). This authoritative resource is recognized as providing reliable information for estimating phreatophyte water uses, and is more likely than not true. Watermaster continues to work closely with the California Department of Fish & Wildlife to further refine these estimates.

Centro Subarea

The factual investigations, bases and estimates for the Centro Subarea PSY calculation include the following:

1. **Surface Water Inflow (Calculated).** Surface water inflow to the Centro Subarea is considered to be the outflow from the Alto Subarea. For the PSY calculation for Centro, it is the 2001-2020 average surface water inflow. As explained herein, the investigation of surface water inflow to Centro is adequate because it is based on the USGS measured surface inflow at the Lower Narrows, the measured VVWRA discharge into the TZ, measured TZ pumping data, reasonable estimates of consumptive use and return flow, and the measured stable water levels in monitored wells within the TZ and near the Helendale Fault. Therefore, the calculated surface water inflow to Centro is more likely than not true.
2. **Groundwater pumping (Measured)**. It is the Water Year 2021-2022 total verified production from Parties. Verified production is mostly metered (see **Exhibit 6**), which is more likely than not true.
3. **Groundwater levels (Measured)**. Water levels in the Centro Subarea are monitored by MWA. Watermaster relies on the small changes in observed water levels upstream of the Waterman Fault over time to estimate surface and subsurface outflow into the Baja Subarea. There is no reason to doubt the accuracy of the measured water levels in MWA’s monitoring wells, and they are more likely than not true.

4. **Surface Water Outflow (Measured and calculated).** Surface water outflow from Centro into Baja is the average flows (2001-2020) reported by the USGS gage station at Barstow plus the discharge of wastewater treated by the City of Barstow, Barstow Wastewater Treatment Plant. This discharge is measured by the City of Barstow as required by its Waste Discharge Requirements. The measured USGS gage data and measured treated wastewater discharges are sufficient and provide the best available information regarding the surface water outflow to Baja, and are more likely than not true. The subarea boundary between Centro and Baja is the Waterman Fault, located several miles downstream of the Barstow gage and downstream of the Barstow wastewater discharge. However, Watermaster considered that the change in groundwater storage is small in the area upstream of the Watermaster Fault based on the limited change in water levels registered over time (see Centro hydrographs). This assumption is based on observed measured water levels and thus it is adequate and more likely than not true.
5. **Subsurface Inflow (Calculated).** Subsurface water inflow to Centro is the subsurface outflow from Alto. Subsurface outflow from Alto into Centro Subarea of 2,000 acre-feet per year is defined by the Judgment, adopted by the Parties, and at least this amount has been confirmed by the Watermaster. Measured water levels in the TZ show a long-term stability behavior. As noted, Watermaster studies have demonstrated that the actual quantity of subsurface flow exceeds the Judgment's estimate.
6. **Subsurface Outflow (Calculated).** Subsurface flow from Centro to Baja is defined by the Judgment and adopted by the Parties. USGS, Stamos, 2001 estimated that the subsurface flow near the Waterman Fault from Centro to Baja is 1,462 acre-feet. The value was also calculated and confirmed by Watermaster in 2006. Once the RMBM is complete, new information about the subsurface flow from Centro to Baja will be available. Therefore, at this time, the USGS information is adequate and more likely than not true.
9. **Consumptive uses from Pumping (Calculated).** For the PSY calculation, it is the Water Year 2021-2022 consumptive use, is calculated by Watermaster as follows:
    a. Agriculture: The total consumptive use for an agricultural crop is determined using the evapotranspiration rates of applied water and the irrigated acreages. The difference between the potential consumptive use and the applied water (pumping) corresponds to return flow to the system.
    b. Urban: Consumptive use of municipal production is determined by separating indoor use from outdoor use. For the purposes of this analysis, indoor domestic use is assumed to be entirely return flow and outdoor use is considered to be entirely consumed. Indoor consumptive use is difficult to measure, and whether water is discharged to sewer or septic, it is assumed to be returned to the system as return flow.

    The investigation and estimates of consumptive uses from pumping relating to the urban and agricultural uses described above utilize accepted methodologies for accurately estimating consumptive uses from groundwater pumping and, accordingly, are more likely than not true.
7. **Consumptive uses from Phreatophytes (Calculated).** Water use (evapotranspiration) from riparian vegetation along the Mojave River is water being used by the plant

community for growth. Watermaster values for the PSY calculation derive 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). This authoritative resource is recognized as providing reliable information for estimating phreatophyte water uses, and is more likely than not true. Watermaster continues to work closely with the California Department of Fish & Wildlife to further refine these estimates.

Future model scenario projections

The Judgment is intended as a funding mechanism so that those that pump more than their FPA will be required to purchase Replacement Water from Watermaster for recharge in a given subarea. To illustrate the effect of importing water to the Mojave Basin Area and recharging within the Mojave River, the calibrated UMRBM model was run for a 20-year future scenario to Water Year 2040. It was assumed that the hydrology of the 2001-2020 period would repeat for 20 years. The UMRBM evaluated the impact of importing 17,500 acre-feet every year, delivered to the Mojave River MWA's the Deep Creek release site (the amount to offset the Alto deficit, 17,495 acre-feet). The model results indicate that the projected annual flow at the Lower Narrows would *increase* by an average of 9,000 acre-feet per year. This means that compared to the 20 years without recharge, there would be an average of 9,000 acre-feet more flow at Lower Narrows. This outcome demonstrates how the Judgment is intended to work. More water recharged upstream results in more water flowing downstream.

The total amount of Replacement Obligation in Alto for Water Year 2023-2024 is 24,910 acre-feet. 12,685 acre-feet of the obligation was satisfied by transfers and the remainder 12,225 will be provided by MWA pursuant to the Judgment. Importantly, MWA estimates that Carryover FPA, and Transferable FPA will be entirely accounted for in 3 to 5 years, meaning that from that time forward any Alto deficit based on PSY and corresponding FPA will be required to be purchased and imported as supplemental water, subject to the terms of the Judgment.

The updated Regional Mojave Basin Model (RMBM)

The UMRBM is being expanded and is expected to be used for the next Watermaster cycle for determining PSY is Alto, Centro, Oeste and Baja. The RMBM will include the TZ and will therefore calculate directly the outflow at the Helendale Fault. The calculated flow at the Helendale Fault will be used as the surface water inflow to Centro through the Transition Zone, and subsurface flow into Centro from the TZ. The modeled flow at Helendale will be an important factor in determining the PSY for Alto, and for Centro. Watermaster's current calculation of the surface outflow to Centro (average flow of 36,725 acre-feet) while consistent with previous investigations, DWR 1967, USGS, 2001, Webb Associates, 2000, Exhibit C, Table C-1 of the Judgment, will be tested by the model's independent calculation.

Conclusion

Until the RMBM is finalized, Watermaster recommends the PSY remain the same for Alto, Centro and Baja subareas as set by the Court in 2024. Except for the Oeste Subarea, the PSY calculations do not change from the 2024 PSY update because the hydrologic base period has not changed, and the cultural conditions observed in Water Year 2021-2022 are similar to the 20-year base period (2001-2020), showing a difference of only about 2.5%.

The data and assumptions used for the Alto Subarea PSY and the Transition Zone water balance are reliable and more likely than not true. The PSY for Alto will be updated using the expanded model RMBM.

The estimates and assumptions used for the Centro Subarea PSY of 31,420 acre-feet are reliable for the purposes of the 2024 PSY update and are more likely than not true, and will be updated with the new information provided by the RMBM.

For the Baja Subarea, the PSY calculation is based on the best available information and more likely than not true, but more analysis is needed to establish the reliability of the PSY determination. There is no additional data available, and the best tool for updating PSY in Baja is the RMBM, when it is available.

For the Oeste Subarea, the UMRBM is adequate for the determination of PSY and based on new information on subsurface inflow, Watermaster recommends the Oeste PSY should be updated to 3,287 acre-feet, and an FPA at 46.3% of BAP.

All of the foregoing demonstrates the reliability of the assumptions or estimates and the sufficiency of the factors used in the PSY calculations, based upon currently available data. When the RMBM is finalized, the results of the model will further inform Watermaster about the modeled PSY values. Watermaster will then adopt those PSY values.

Enclosures:

Exhibit 1 Mojave River Flow at the Forks

Exhibit 2 Alto & Centro Subarea Water Supply Update

Exhibit 3 Historic Production and Consumptive Use

Exhibit 4 Lower Narrows + VVWRA hydrograph

Exhibit 5 Hydrographs showing historical production in the TZ

Exhibit 6 Methods for Measuring Production

Exhibit 7 Section F, paragraph 2 of the Court's Amended Statement of Decision

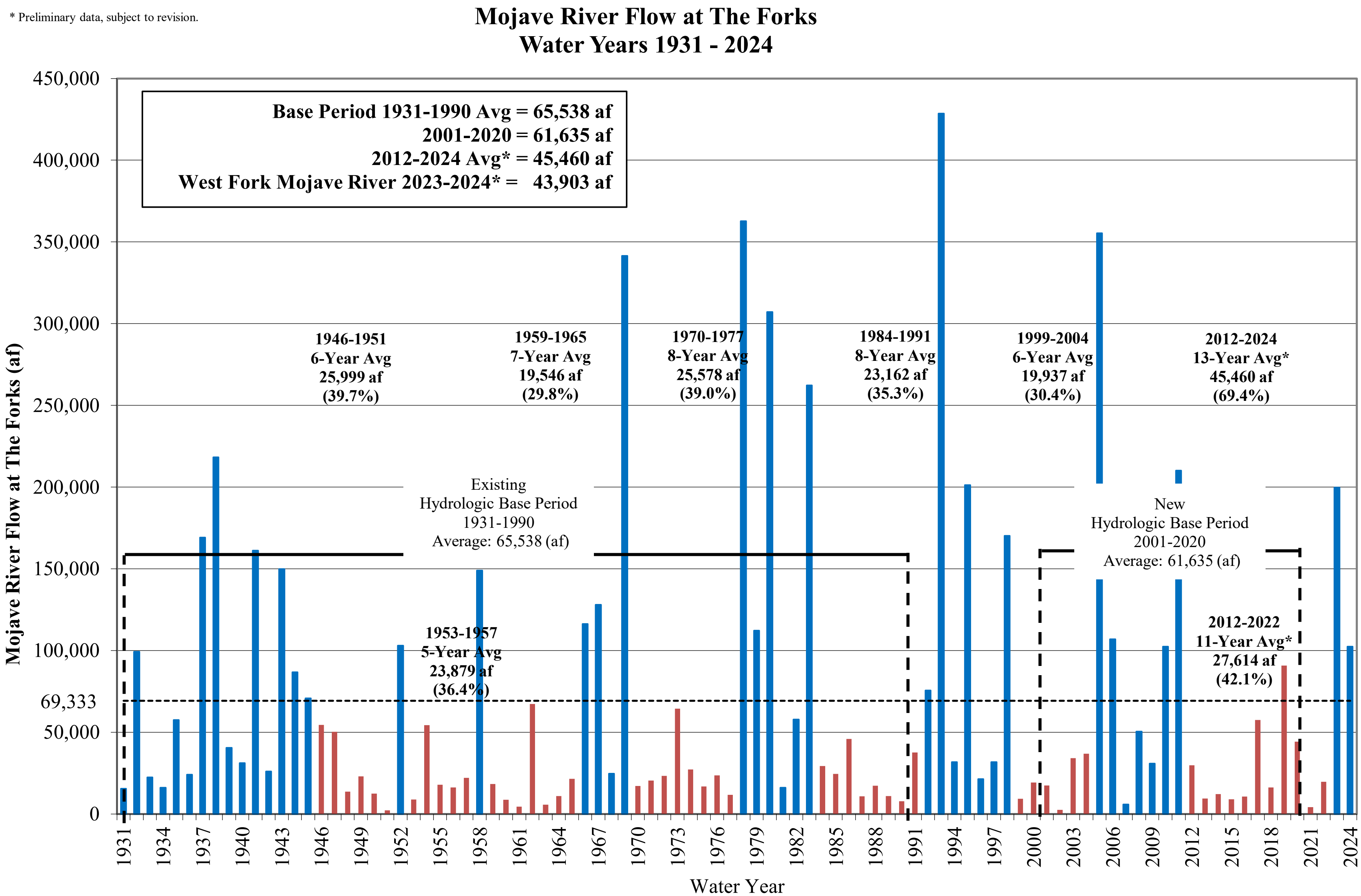
Exhibit 8 Baja Hydrographs

Exhibit 9 Geologic cross section E-E' and MWA estimate of additional subsurface flow into Oeste.

Exhibit 10 Watermaster's 2025 Update on Subsurface Flows at the Alto-Centro Boundary

EXHIBIT 1

* Preliminary data, subject to revision.



Note: Discharge of Mojave River at The Forks from the addition of values as reported from USGS stations at West Fork Mojave River Near Hesperia, CA (10261000), and Deep Creek Near Hesperia, CA (10260500) from 1931-1971, the greater of 10260500 and Mojave River Below Forks Reservoir Near Hesperia, CA (10261100) from 1972-1974, and the addition of West Fork Mojave River Above Mojave River Forks Reservoir Near Hesperia, CA (10260950) and 10260500 from 1975-Present.

EXHIBIT 2

Mojave Basin Area Watermaster

Appendix A

Alto & Centro Subarea

Water Supply Update

Prepared by:

Wagner & Bonsignore, Engineers

Robert C. Wagner, PE

Watermaster Engineer

February 28, 2024

Wagner&Bonsignore
Consulting Civil Engineers, A Corporation

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MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E.

Date: February 28, 2024

Re: **Production Safe Yield Update for Alto and Centro Subarea; Calculation of Outflow from Alto to the Transition Zone, and Calculation of Outflow to Centro.**

This memorandum presents the update for Production Safe Yield (PSY) for the Alto and Centro Subareas. These areas are shown on Figure 1, attached hereto. The Transition Zone described in Appendix B, is considered to be part of the Alto subarea by the Judgment, and serves to hydraulicly connect the portion of Alto above the Lower Narrows, to Centro, downstream from the Helendale Fault. For our analysis, the Transition Zone is treated separately in order to calculate the discharge across the Helendale Fault, as there is no long-term reliable measurement at that location. The calculation is described in Appendix B, Transition Zone Water Balance.

The Upper Mojave Basin Model (UMBM, Appendix G) was used to calculate the change in storage in Alto (above Lower Narrows), from 1951-2020, a 70 year period. For purposes of this analysis, we selected the 20 year period from 2001-2020 as the hydrologic base period for evaluating the change in storage (surplus/deficit) in Alto. Figure 2, shows the annual change and cumulative change storage in Alto, for 70 years. Approximately 1.1 million acre feet of groundwater has been depleted from the upper part of Alto since 1951.

The purpose of the Judgment is to arrest overdraft and to provide a funding mechanism to raise money to purchase imported water, to offset any annual deficit. The purpose of the PSY calculation is to help set the Free Production Allowance (FPA) to allocate the cost of imported water to producers that over pump their FPA. The UMBM is useful to determine the annual deficit (see Appendix G). The annual surplus/deficit in Alto, as indicated by the UMBM is -17,475 acre feet per year.

Table 5-1 Proposed for Alto and Centro is the water balance for Alto, Transition Zone and Centro Subareas (Table 1). Inflow to Alto, is the sum of the average gaged inflow (2001-2020) as measured at the USGS gaging stations at West Fork Mojave River, and Deep Creek near Hesperia; this sum is commonly referred to as the "flow at the Forks." Also included is mountain front recharge, ungaged inflow and deep percolation of precipitation, and subsurface inflow from Oeste and Este subareas, as developed by the UMBM. Outflow consists of subsurface outflow, consumptive uses of production, phreatophyte use, and a calculation of outflow to Centro, shown as surface water outflow. This value is determined from the water balance for the Transition Zone.

For the Alto subarea, the water balance calculation produces a PSY value of 62,333 acre feet; Total production (including the Transition Zone) for the representative year (2022) less the deficit based the 2001-2020 average water supply (Table 1).

Figure 3, compares the PSY calculation based on Table 1 (Table 5-1) described above with the PSY calculation based on the UMBM. The model treats pumping from all sources the same. The Judgment however, only considers pumping for consumptives uses, as included in the Judgment as “B1” production. “B2” production is not considered for purposes of determining PSY. In the Alto subarea, a portion the water produced by the party Jess Ranch Water Company for its fish hatchery, was excluded from the Judgment and assigned “B2” status, recirculated water. The same status was assigned to the California Department of Fish and Wildlife fish hatchery pumping. Thus, to calculate the indicated PSY using the UMBM we subtract the “B2” pumping from total pumping. The calculation, production plus the surplus/deficit then equals the PSY.

As shown on Figure 3, the PSY value from the UMBM is 62,005 acre feet, and the Water Balance calculation is 62,233 acre feet or a difference of 0.37%. We note however that the model produces a larger deficit, 17,475 acre feet vs, 15,914 acre feet (9% greater). We note an important difference between the two, is the model’s deficit is the average deficit for all uses calculated over a 20 year base period. The Water Balance calculation assumes an average water supply, but pumping, consumptive uses, and portions of outflow from a specific year (2022). The PSY is used to determine the FPA. In this case we recommend using the value from the UMBM (62,005).

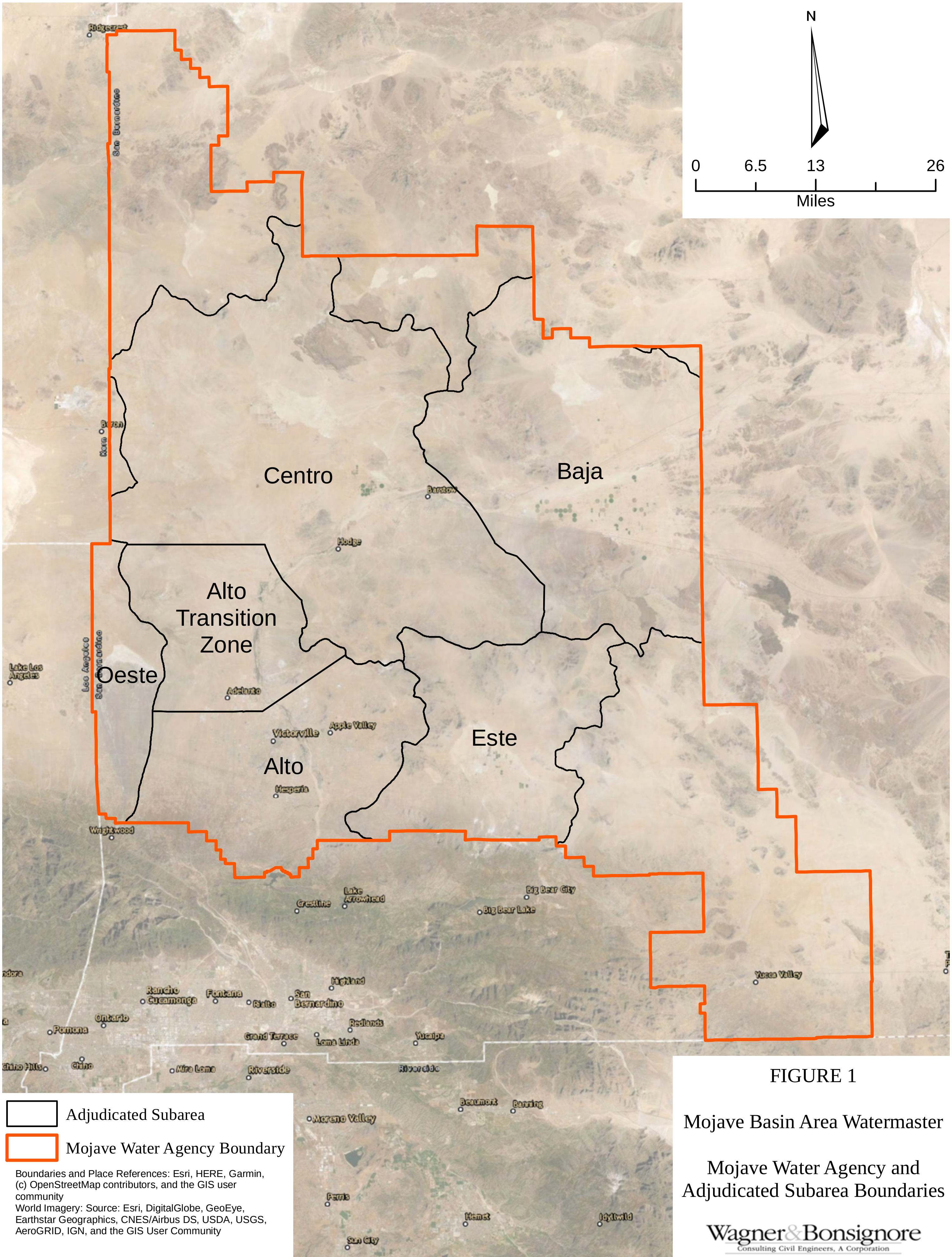
The inflow to Centro is considered to be the outflow from Alto. The outflow from Centro consists of average discharge (2001-2020) at the USGS Barstow gaging station, the net discharge from the Barstow wastewater treatment plant, subsurface discharge to the Baja subarea, water use by phreatophytes and consumptive use of production.

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. However, for this purpose we have considered that the change in groundwater storage is small in the area upstream of the Watermaster Fault based on the limited change in water levels registered over time (see Centro hydrographs)

The resulting PSY calculation for Centro shows a surplus of 11,540 acre feet. The PSY is the sum of total pumping and the indicated deficit of 28,495 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 return flow of 2,885 acre feet would result increasing the PSY to 31,420 acre feet (Table 1).

The UMBM was also used to simulate how the flow at Lower Narrows would change by purchasing and recharging the Alto deficit (-17,475 acre feet/year). Simulations assumed that the water supply for the period 2001-2020 repeated for the next 20 years, and production and consumptive uses were constant at the 2020 amount. The results are shown on Figure 4 and Table 2. Compared to no recharge, Baseline Scenario, the recharge scenario increased flow downstream of Lower Narrows by 9,022, acre feet per year.

Based on the foregoing, we recommend a PSY for Alto of 62,005 acre feet and for Centro of 31,420 acre feet.



Adjudicated Subarea

Mojave Water Agency Boundary

Boundaries and Place References: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
World Imagery: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 1

Mojave Basin Area Watermaster

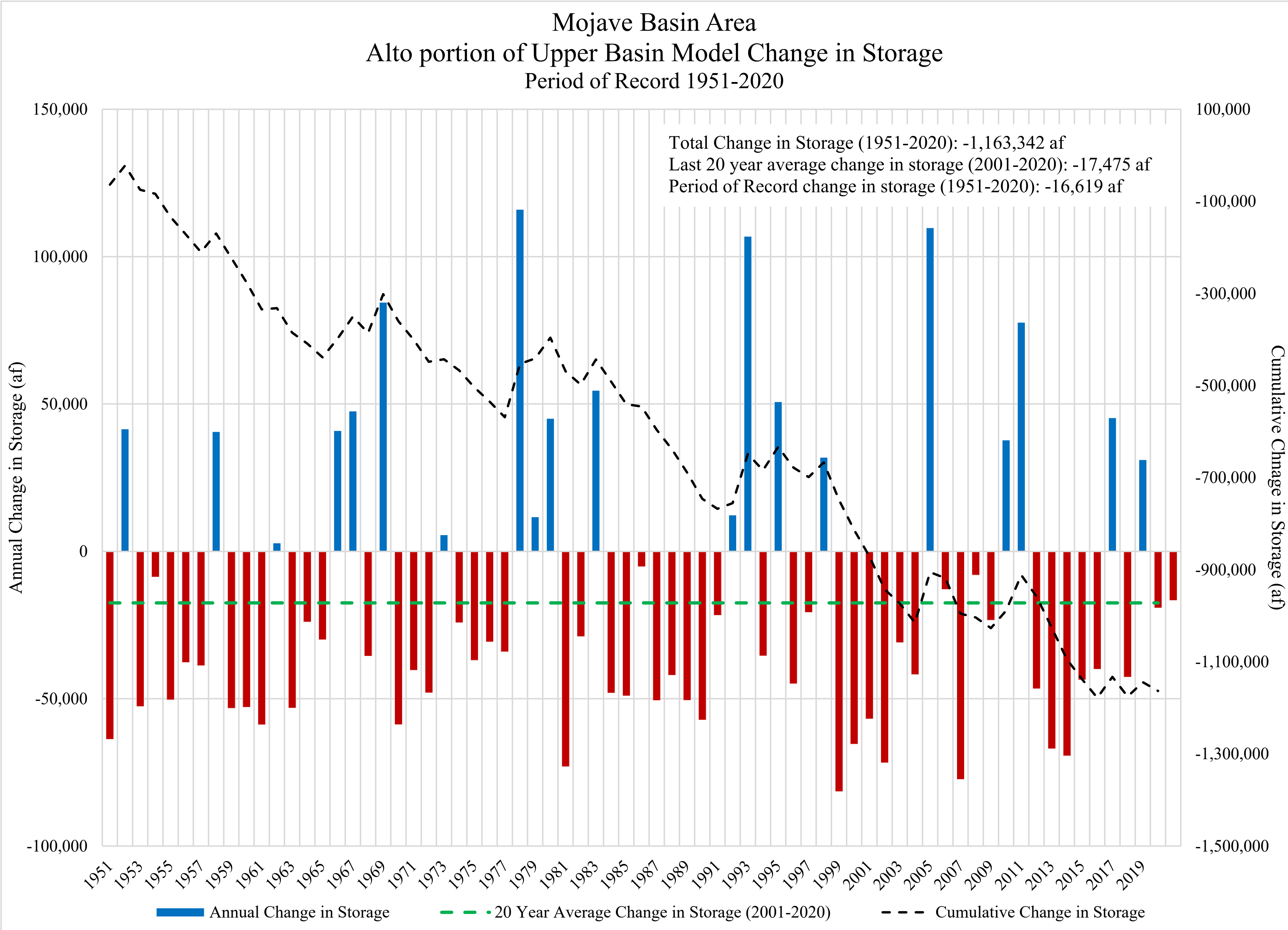
Mojave Water Agency and Adjudicated Subarea Boundaries

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

June 2020

Q:\Drawings\Mojave Water Agency\Este Subarea\Este Water Supply - FIGURE 1 - Location Map.mxd

FIGURE 2



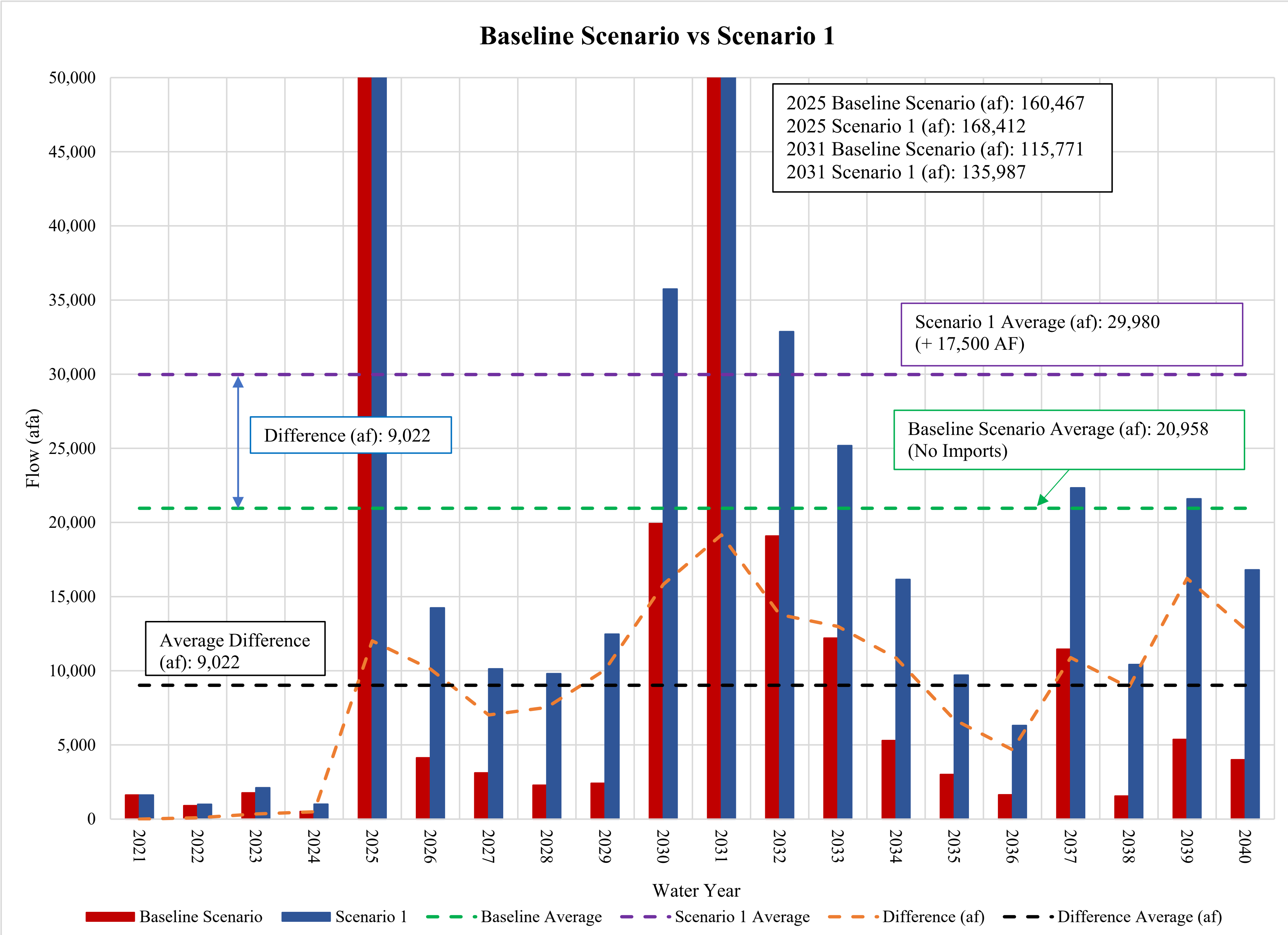
G:\MOJAVE ADJUDICATION - 3020\Analysis\Groundwater Modeling\1-Alto\3020-009M-Table 6.1 Summary of Model Parameters Alto-V4.xlsx

FIGURE 3

Production Safe Yield Based on Model Output and 2021-2022 Current Year Pumping and Consumptive Use	
Alto above Narrows Production Average 2001 - 2020 (acre-feet)	81,968
2001 - 2020 Average Alto B2 Pumping (acre-feet)	14,118
Alto above Narrows B1 Pumping (acre-feet)	67,850
TZ (2001 - 2020) Average Pumping (acre-feet)	11,630
Modeled Pumping Alto + Transition Zone (acre-feet)	79,480
Alto above Narrows Modeled Deficit (2001 - 2020)	-17,475
Modeled Production Safe Yield (acre-feet)	62,005
Table 5-1 Production Safe Yield (acre-feet)	62,233
% Difference	0.37%

Current Production Safe Yield 59,409

FIGURE 4



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DRAFT

TABLE 1

TABLE 5-1 Proposed

HYDROLOGICAL INVENTORY BASED ON VARIOUS SUPPLY ASSUMPTIONS AND 2021-22 CONSUMPTIVE USE, RETURN FLOW AND IMPORTS

(ALL AMOUNTS IN ACRE-FEET)

	ALTO 2001-2020	TRANSITION ZONE 2001-2020	CENTRO 2001-2020
WATER SUPPLY			
Surface Water Inflow [1]	61,635	24,808	36,725
Mountain Front Recharge [2]	8,511	0	0
Groundwater Discharge to the Transition Zone [3]	0	5,112	0
Subsurface Inflow [4]	0	7,053	2,000
Este/Oeste Inflow [5]	4,785	62	
Imports[6]	0	15,095	
TOTAL	**74,931**	**52,130**	**38,725**
CONSUMPTIVE USE AND OUTFLOW			
Surface Water Outflow	36,725 [7]	36,725 [7]	7,500 [14]
Barstow Treatment Plant Discharge			2,475
Subsurface Outflow [8]	2,000	2,000	1,462
Consumptive use [9]			
Agriculture	949	949	5,863
Urban	40,171	6,456	6,885
Phreatophytes [10]	11,000	6,000	3,000
TOTAL	**90,845**	**52,130**	**27,185**
Surplus / (Deficit) [11]	(15,914)		11,540
Total Estimated Production[12]	78,147		16,995
Potential Return Flow from Surplus	0		2,885
PRODUCTION SAFE YIELD[13]	**62,233**		**31,420**

1 Average discharge of Mojave River by USGS, 2001-2020 (USGS stations at West Fork Mojave River Near Hesperia, CA (10261000), Deep Creek Near Hesperia, CA (10260500) and Lower Narrows Near Victorville, CA (10261500)).

2 Mountain front recharge as developed from Upper Basin Alto Model.

3 Groundwater discharge lost to Transition Zone below the Narrows.

4 Portion of water lost to Transition Zone from Alto (Upper Basin Model). Groundwater discharge to Harper Lake (USGS Stamos 2001).

5 Subsurface Inflow to Alto from Este and Oeste Subareas (Upper Basin Model).

6 Total discharge to Transition Zone from VVWRA, 2021-22 Water Year.

7 Estimated based on reported flows at USGS gaging station, Mojave River at Victorville Narrows and 2001-2020

8 Groundwater discharge to Baja 1462 AF; 3501 AF groundwater discharge from Barstow area to Harper Lake. (USGS Stamos 2001)

9 Includes consumptive use of "Minimals Pool" (estimated Minimal's production is 2,104 af).

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

11 Amount necessary to offset overdraft under the above assumptions.

12 Water production for 2021-22. Included in the production values are the estimated minimal producer's water use.

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

14 Reported flows at USGS gaging station, Mojave River at Barstow (10262500).

TABLE 2

Annual Flow at the Lower Narrows Under Baseline Scenario and Scenario 1			
Water Year Stream Flow			
20 Year Scenario Runs			
Water Year	Baseline Scenario (af)[1]	Scenario 1 (af)[2]	Difference (af)[3]
2021	1,623	1,623	0
2022	907	994	87
2023	1,768	2,110	343
2024	515	1,006	491
2025	183,550	195,565	12,015
2026	4,128	14,243	10,115
2027	3,117	10,132	7,015
2028	2,285	9,809	7,524
2029	2,417	12,474	10,057
2030	19,925	35,744	15,819
2031	135,332	154,500	19,167
2032	19,083	32,874	13,791
2033	12,198	25,182	12,984
2034	5,296	16,157	10,861
2035	3,005	9,710	6,704
2036	1,639	6,310	4,671
2037	11,451	22,336	10,885
2038	1,550	10,425	8,876
2039	5,367	21,595	16,228
2040	4,002	16,806	12,804
Average	**20,958**	**29,980**	**9,022**

Note:

(1) Baseline Scenario: The last 20 years hydrology extended in the future with 2020 levels of production and return flows

(2) Scenario 1: Similar to the Baseline Scenario with 17,500 acre-feet imports per year spread out over three months (June-July-August) and delivered at Deep Creek.

(3) Difference: Baseline Scenario flow subtracted from Scenario 1 flow at the Lower Narrows.

EXHIBIT 3

Historic Production and Consumptive Use

Production

Subarea	2020	2021	2022	2023	2024	Average
Alto	65,094	69,764	67,105	62,442	65,662	66,013
Transition Zone	12,618	11,809	10,351	10,039	9,872	10,938
Alto Total	77,712	81,573	77,456	72,481	75,534	77,712
Baja	20,894	15,095	12,749	11,419	10,707	14,173
Centro	18,309	19,685	16,995	16,393	16,646	17,606
Este	5,181	5,258	5,068	4,501	4,758	4,953
Oeste	3,677	3,798	3,131	2,845	2,871	3,264
Total	203,485	206,982	192,855	180,120	186,050	193,898

Note:

1. Production values include minimal producers.

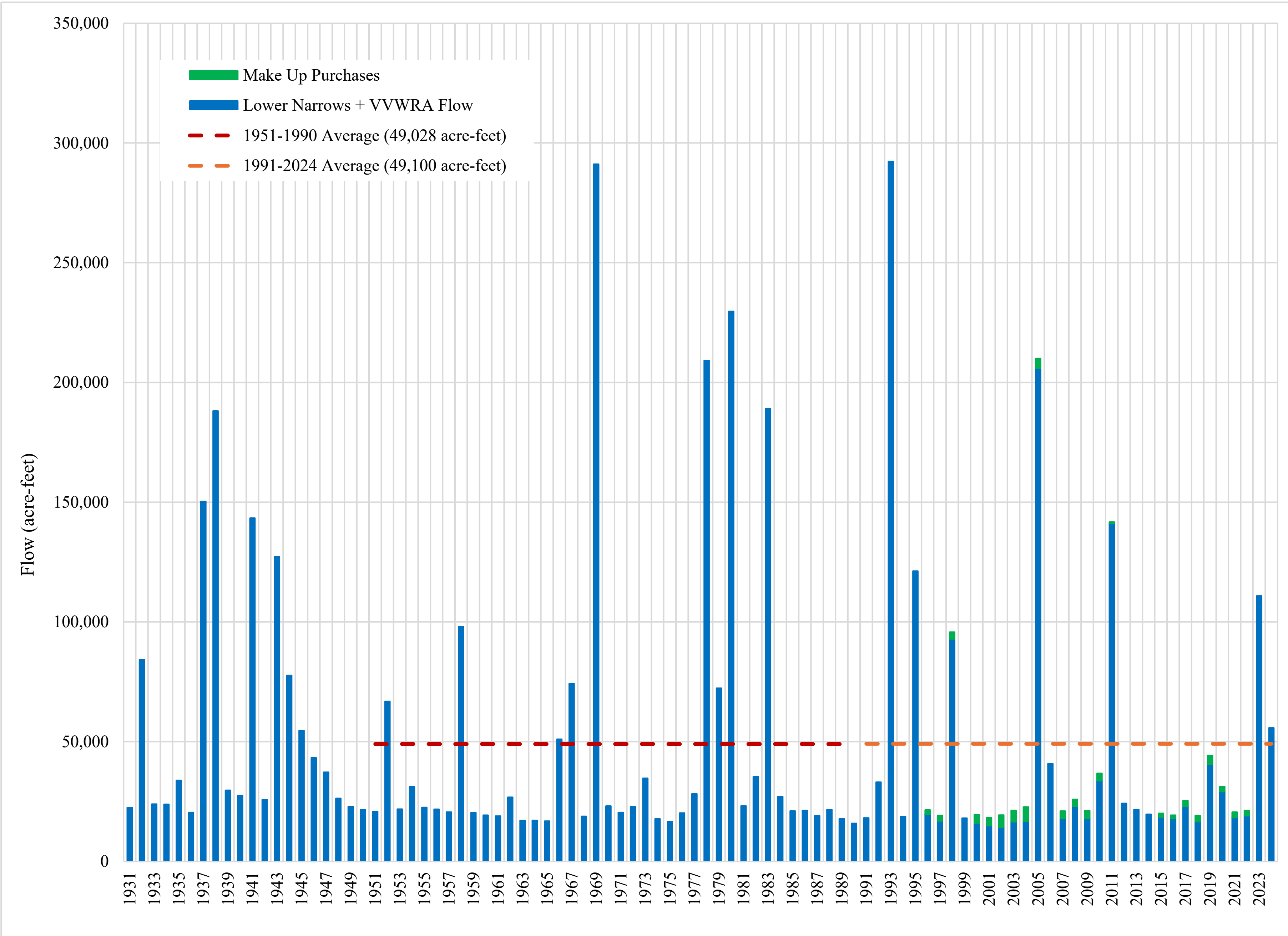
Consumptive Use

Subarea	2020	2021	2022	2023	2024	Average
Alto	33,489	37,871	33,745	31,927	35,246	34,456
Transition Zone	8,052	7,301	7,375	6,606	6,277	7,122
Alto Total	41,541	45,172	41,120	38,533	41,523	41,578
Baja	20,144	13,589	12,025	10,834	8,485	13,015
Centro	14,044	14,035	12,748	12,279	11,597	12,940
Este	4,116	4,377	4,388	3,812	3,646	4,068
Oeste	2,528	2,574	2,046	1,869	2,086	2,221
Total	123,913	124,918	113,448	105,859	108,860	115,400

Note:

1. Consumptive Use values include minimal producers.

EXHIBIT 4



Make Up Purchases
Lower Narrows + VVWRA Flow
1951-1990 Average (49,028 acre-feet)
1991-2024 Average (49,100 acre-feet)
Flow (acre-feet)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1931
1933
1935
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
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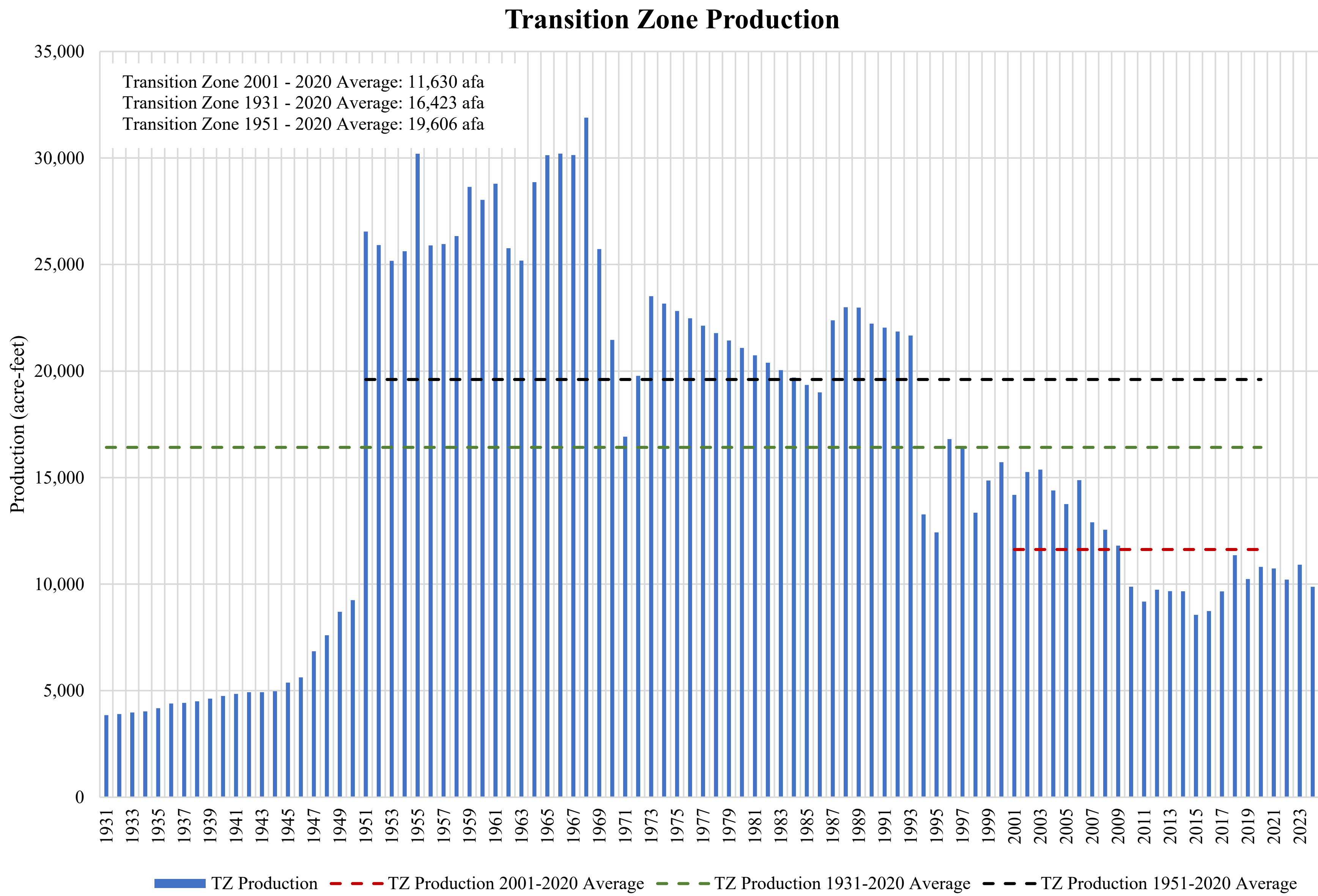
2021
2023

EXHIBIT 5



Note:
1931 - 1993 data from USGS "Simulation of Ground-Water Flow in the Mojave River Basin, California", Stamos. 2001
1994 - 2024 data from Mojave Watermaster.

G:\MOJAVE WATERMASTER - 3040\Analysis\2023-24 Consumptive Use from Watermaster\3040-004M-TZ Production Hydrograph

EXHIBIT 6

Methods for Measuring Production and their Percentage
Alto Producers

Water Year	Flowmeter	Pump Test	Natural Gas Records	Estimates	Load Count by Truck	Other	Total Production (AF)
2024	98.70%	1.27%	0.00%	0.00%	0.00%	0.02%	60,671
2023	98.35%	1.63%	0.00%	0.00%	0.00%	0.02%	57,530
2022	98.20%	1.78%	0.00%	0.00%	0.00%	0.02%	62,541
2021	97.70%	2.28%	0.00%	0.00%	0.00%	0.02%	66,012
2020	97.41%	2.55%	0.00%	0.00%	0.00%	0.04%	62,218
2019	97.08%	2.88%	0.00%	0.00%	0.00%	0.04%	58,993
2018	97.20%	2.76%	0.00%	0.00%	0.00%	0.04%	62,833
2017	97.12%	2.84%	0.00%	0.00%	0.00%	0.05%	60,152
2016	97.66%	2.31%	0.00%	0.00%	0.00%	0.04%	57,316
2015	97.12%	2.84%	0.00%	0.00%	0.00%	0.05%	58,863
2014	96.64%	3.31%	0.00%	0.00%	0.00%	0.05%	67,107
2013	96.69%	3.24%	0.00%	0.00%	0.00%	0.07%	67,818
2012	96.52%	3.35%	0.00%	0.00%	0.00%	0.13%	66,265

Note:
1. This demonstrates that the amount of verified production is reliably determined.
2. Total Production does not include minimal producers.

Methods for Measuring Production and their Percentage
Transition Zone Producers

Water Year	Flowmeter	Pump Test	Natural Gas Records	Estimates	Load Count by Truck	Other	Total Production (AF)
2024	89.85%	10.07%	0.01%	0.00%	0.04%	0.04%	11,170
2023	90.10%	9.82%	0.01%	0.00%	0.04%	0.04%	11,221
2022	89.87%	10.06%	0.01%	0.00%	0.03%	0.03%	12,040
2021	87.91%	12.01%	0.01%	0.00%	0.03%	0.03%	11,804
2020	88.58%	11.34%	0.01%	0.00%	0.04%	0.04%	11,223
2019	89.23%	10.69%	0.01%	0.00%	0.04%	0.04%	10,789
2018	89.26%	10.66%	0.01%	0.00%	0.03%	0.03%	11,484
2017	90.75%	9.16%	0.01%	0.00%	0.04%	0.04%	10,129
2016	96.26%	3.64%	0.02%	0.00%	0.04%	0.04%	9,515
2015	99.06%	0.26%	0.02%	0.00%	0.04%	0.61%	9,139
2014	99.34%	0.38%	0.02%	0.00%	0.04%	0.22%	10,524
2013	99.20%	0.69%	0.04%	0.00%	0.02%	0.05%	10,292
2012	99.09%	0.77%	0.04%	0.00%	0.04%	0.06%	10,247

Note:
1. This demonstrates that the amount of verified production is reliably determined.
2. Total Production does not include minimal producers.

Methods for Measuring Production and their Percentage
Baja Producers

Water Year	Flowmeter	Pump Test	Natural Gas Records	Estimates	Load Count by Truck	Other	Total Production (AF)
2024	44.83%	53.68%	0.00%	0.00%	0.00%	1.49%	8,512
2023	49.56%	49.05%	0.00%	0.00%	0.00%	1.39%	9,151
2022	51.18%	47.46%	0.00%	0.00%	0.00%	1.36%	10,521
2021	53.27%	45.37%	0.00%	0.00%	0.00%	1.36%	12,867
2020	63.99%	35.10%	0.00%	0.00%	0.00%	0.91%	18,667
2019	60.00%	39.07%	0.00%	0.00%	0.00%	0.92%	21,162
2018	59.29%	39.77%	0.00%	0.00%	0.00%	0.94%	22,312
2017	54.67%	44.50%	0.00%	0.00%	0.00%	0.83%	23,691
2016	52.10%	47.21%	0.00%	0.00%	0.00%	0.68%	28,239
2015	55.84%	43.40%	0.00%	0.00%	0.00%	0.75%	27,452
2014	56.34%	42.76%	0.00%	0.00%	0.00%	0.90%	27,858
2013	46.35%	52.80%	0.00%	0.00%	0.00%	0.84%	28,405
2012	45.82%	53.23%	0.00%	0.04%	0.00%	0.90%	29,188

Note:
1. This demonstrates that the amount of verified production is reliably determined.
2. Total Production does not include minimal producers.

Methods for Measuring Production and their Percentage
Centro Producers

Water Year	Flowmeter	Pump Test	Natural Gas Records	Estimates	Load Count by Truck	Other	Total Production (AF)
2024	67.77%	31.27%	0.00%	0.00%	0.00%	0.96%	15,093
2023	70.65%	28.37%	0.00%	0.00%	0.00%	0.98%	14,840
2022	71.06%	28.07%	0.00%	0.00%	0.00%	0.87%	15,442
2021	72.41%	26.84%	0.00%	0.00%	0.00%	0.74%	18,132
2020	76.31%	22.88%	0.00%	0.00%	0.00%	0.81%	16,756
2019	70.70%	28.56%	0.00%	0.00%	0.00%	0.75%	18,231
2018	70.64%	28.65%	0.00%	0.00%	0.00%	0.71%	19,112
2017	69.69%	29.51%	0.00%	0.00%	0.00%	0.80%	17,905
2016	67.06%	32.23%	0.00%	0.00%	0.00%	0.71%	19,195
2015	66.26%	32.96%	0.00%	0.00%	0.00%	0.78%	18,522
2014	64.34%	34.92%	0.00%	0.00%	0.00%	0.74%	19,616
2013	62.64%	35.94%	0.00%	0.00%	0.00%	1.42%	19,183
2012	59.83%	28.44%	0.00%	0.00%	0.00%	11.73%	21,326

Note:
1. This demonstrates that the amount of verified production is reliably determined.
2. Total Production does not include minimal producers.

Methods for Measuring Production and their Percentage
Este Producers

Water Year	Flowmeter	Pump Test	Natural Gas Records	Estimates	Load Count by Truck	Other	Total Production (AF)
2024	49.34%	45.69%	0.00%	0.00%	0.00%	4.97%	3,804
2023	50.49%	44.74%	0.00%	0.00%	0.00%	4.76%	3,547
2022	45.79%	48.69%	0.00%	0.00%	0.00%	5.52%	4,114
2021	48.26%	47.07%	0.00%	0.00%	0.00%	4.67%	4,304
2020	51.45%	43.70%	0.00%	0.00%	0.00%	4.85%	4,227
2019	46.61%	46.71%	0.00%	0.00%	0.00%	6.68%	4,029
2018	44.01%	50.35%	0.00%	0.00%	0.00%	5.63%	4,101
2017	41.39%	54.85%	0.00%	0.00%	0.00%	3.76%	4,233
2016	42.27%	54.78%	0.00%	0.00%	0.00%	2.95%	4,268
2015	48.62%	48.77%	0.00%	0.00%	0.00%	2.61%	5,823
2014	40.13%	58.63%	0.00%	0.00%	0.00%	1.24%	5,712
2013	35.03%	63.75%	0.00%	0.00%	0.00%	1.22%	5,586
2012	32.62%	66.11%	0.00%	0.00%	0.00%	1.27%	5,433

Note:
1. This demonstrates that the amount of verified production is reliably determined.
2. Total Production does not include minimal producers.

Methods for Measuring Production and their Percentage
Oeste Producers

Water Year	Flowmeter	Pump Test	Natural Gas Records	Estimates	Load Count by Truck	Other	Total Production (AF)
2024	99.89%	0.00%	0.00%	0.11%	0.00%	0.00%	2,633
2023	99.92%	0.00%	0.00%	0.08%	0.00%	0.00%	2,607
2022	99.79%	0.03%	0.00%	0.17%	0.00%	0.00%	2,893
2021	99.83%	0.03%	0.00%	0.14%	0.00%	0.00%	3,560
2020	99.74%	0.03%	0.00%	0.23%	0.00%	0.00%	3,439
2019	99.76%	0.03%	0.00%	0.21%	0.00%	0.00%	3,380
2018	99.70%	0.03%	0.00%	0.27%	0.00%	0.00%	3,706
2017	99.62%	0.03%	0.00%	0.34%	0.00%	0.00%	3,194
2016	99.64%	0.03%	0.00%	0.33%	0.00%	0.00%	3,584
2015	99.65%	0.03%	0.00%	0.32%	0.00%	0.00%	3,424
2014	99.59%	0.06%	0.00%	0.35%	0.00%	0.00%	3,421
2013	99.73%	0.06%	0.00%	0.21%	0.00%	0.00%	3,292
2012	99.69%	0.09%	0.00%	0.22%	0.00%	0.00%	4,571

Note:
1. This demonstrates that the amount of verified production is reliably determined.
2. Total Production does not include minimal producers.

EXHIBIT 7

recharge from periodic storm flows which is one of the principal sources of recharge for downgradient subareas without interference from upstream diversions. It will also benefit riparian vegetation in the lower subareas. [RT 510:4-511:0]

F. IDENTIFICATION OF SUBAREAS, SUBAREA

1. It is fair and equitable to maintain certain flow requirements between subareas as part of the physical solution. Flows to downstream subareas will be maintained either by supplemental water through the river and conveyance facilities, by purchase of transferred water by the watermaster, or by reductions in consumptive use. [RT 892:9-18; 910:14-18; 911:3-913:14]

2. The flow requirements between subareas are as follows: a) Este to Alto 200 acre-feet average annual subsurface flow as estimated in Bulletin 84; b) Oeste to Alto 800 acre-feet average annual subsurface flow as estimated in Bulletin 84; c) Alto to Centro 21,000 acre-feet average annual surface flow as measured at the lower narrows (and maintained by an immediate replacement water obligation in the transition zone to form a water bridge down to the Helendale Fault) plus a 2,000 acre-feet average annual subsurface flow as estimated in Bulletin 84; d) Centro to Baja 1,200 acre-feet average annual subsurface flow as estimated in Bulletin 84; e) Baja to the Mojave Basin 400 acre-feet average annual subsurface flow as estimated in Bulletin 84; f) these estimates and other subsurface estimates will need to be up-dated by the use of monitoring wells which will determine the water table slope at the boundaries. [RT 128:27-130:14]

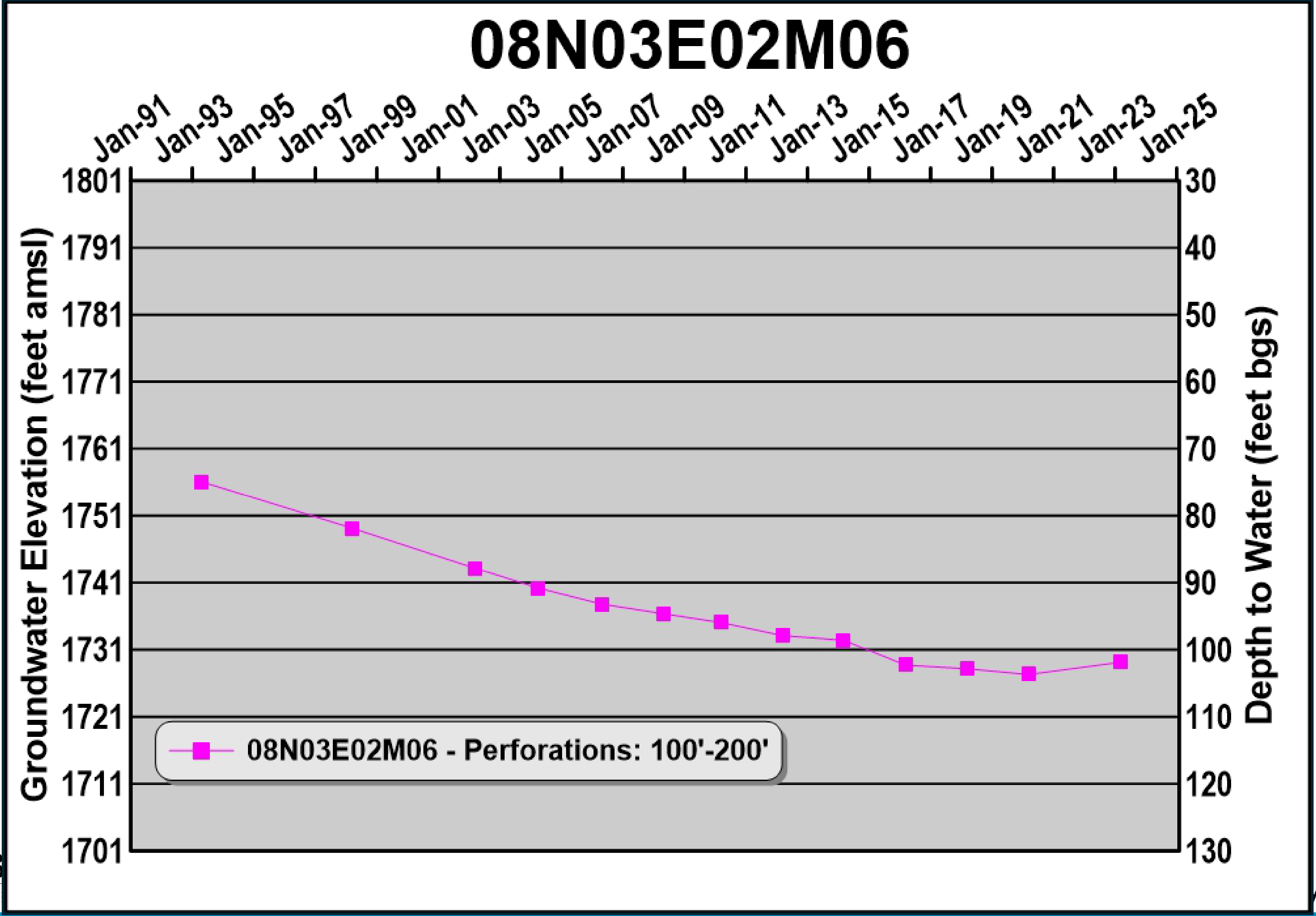
The transition zone has a fairly stable water level. It is necessary to maintain that water level so that the surface flows passing the Lower Narrows and the subsurface inflow into the transition zone will reach the Helendale Fault, and hence downstream subareas; the flows at the Helendale Fault will in the future be measured using monitoring wells to insure that water levels are maintained within the transition zone. [RT 320:9-321:9]

G. ASSESSMENTS

1. The assessments imposed by the stipulated judgment are fair and equitable. It is not appropriate to require the Mojave Water Agency (MWA) to impose an ad valorem tax as part of the Physical Solution. Such a tax is not within the scope of the judgment, and is within the political prerogative of MWA.

2. Assessments apply to all production regardless of the type of use.

EXHIBIT 8



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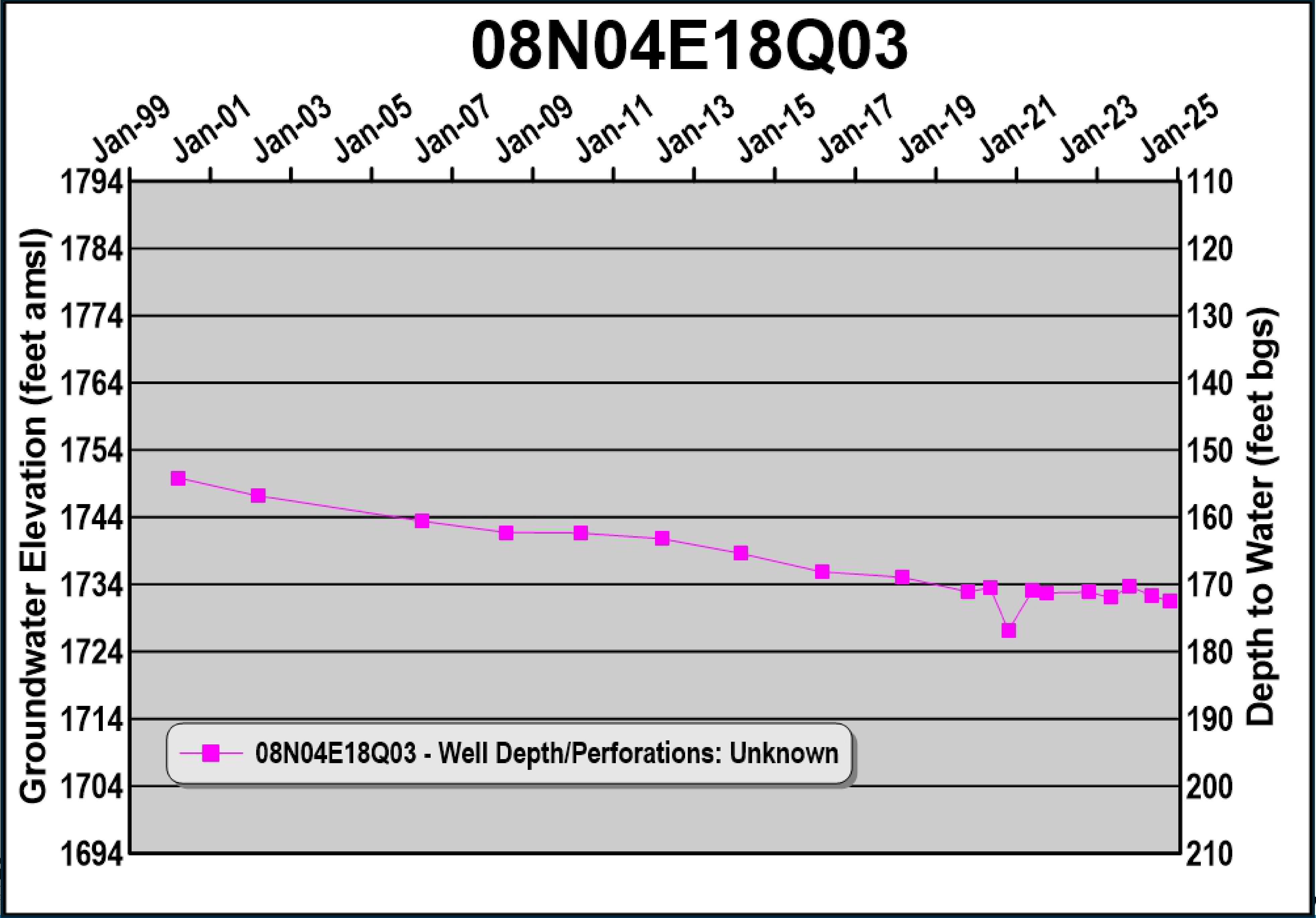
WATERMASTER



08N04E18Q03
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
1794
1784
1774
1764
1754
1744
1734
1724
1714
1704
1694
Depth to Water (feet bgs)
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120
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140
150
160
170
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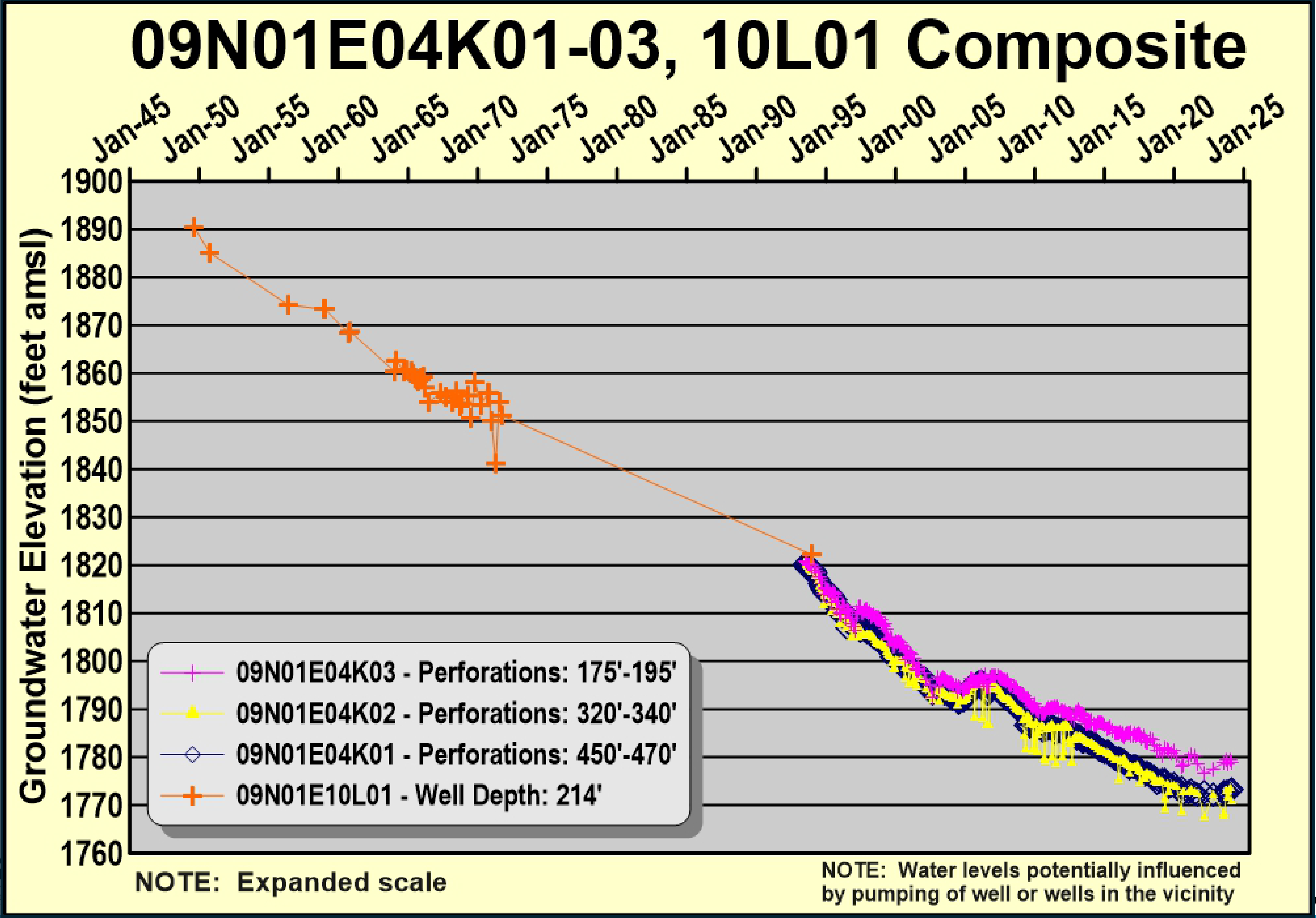

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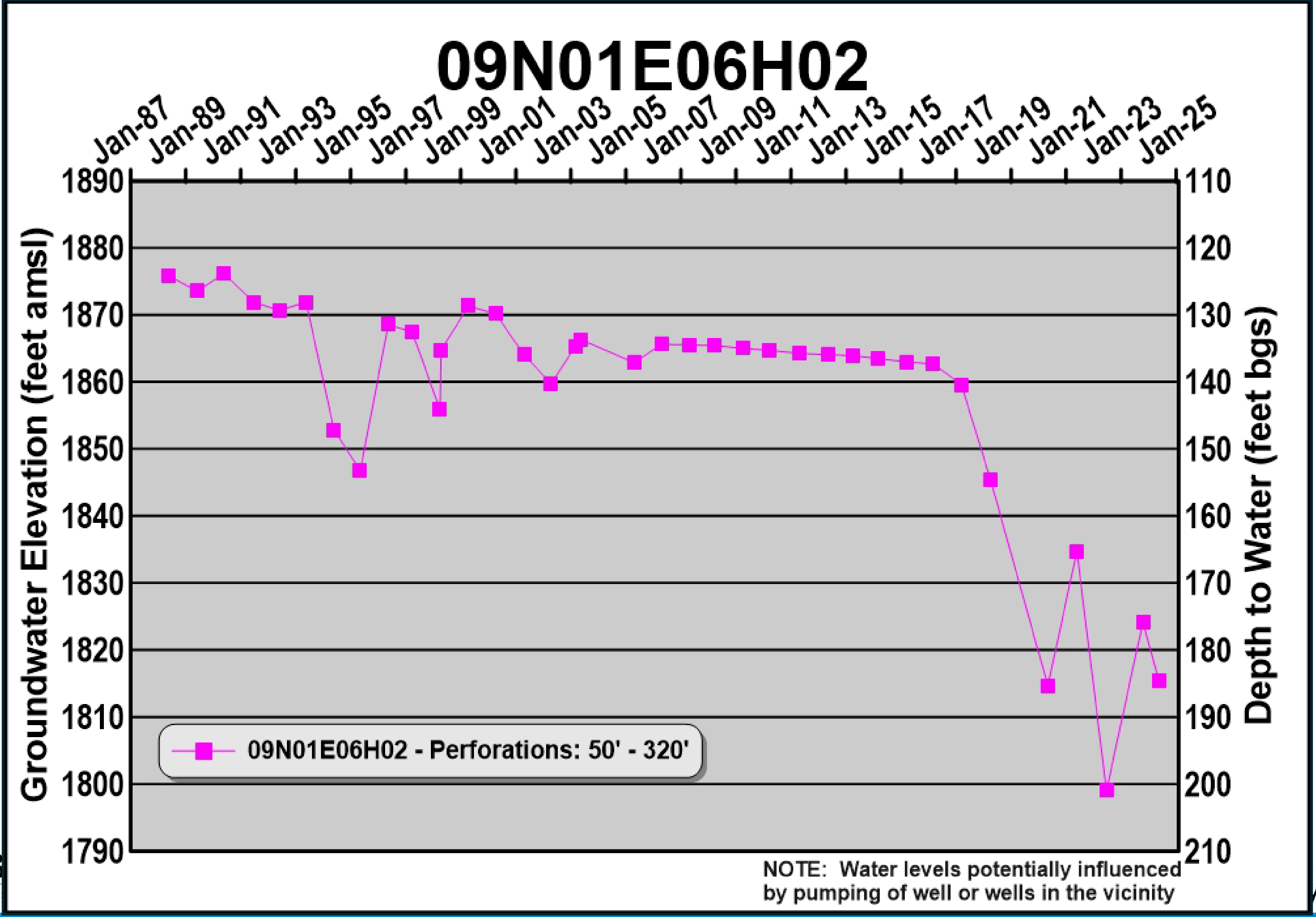

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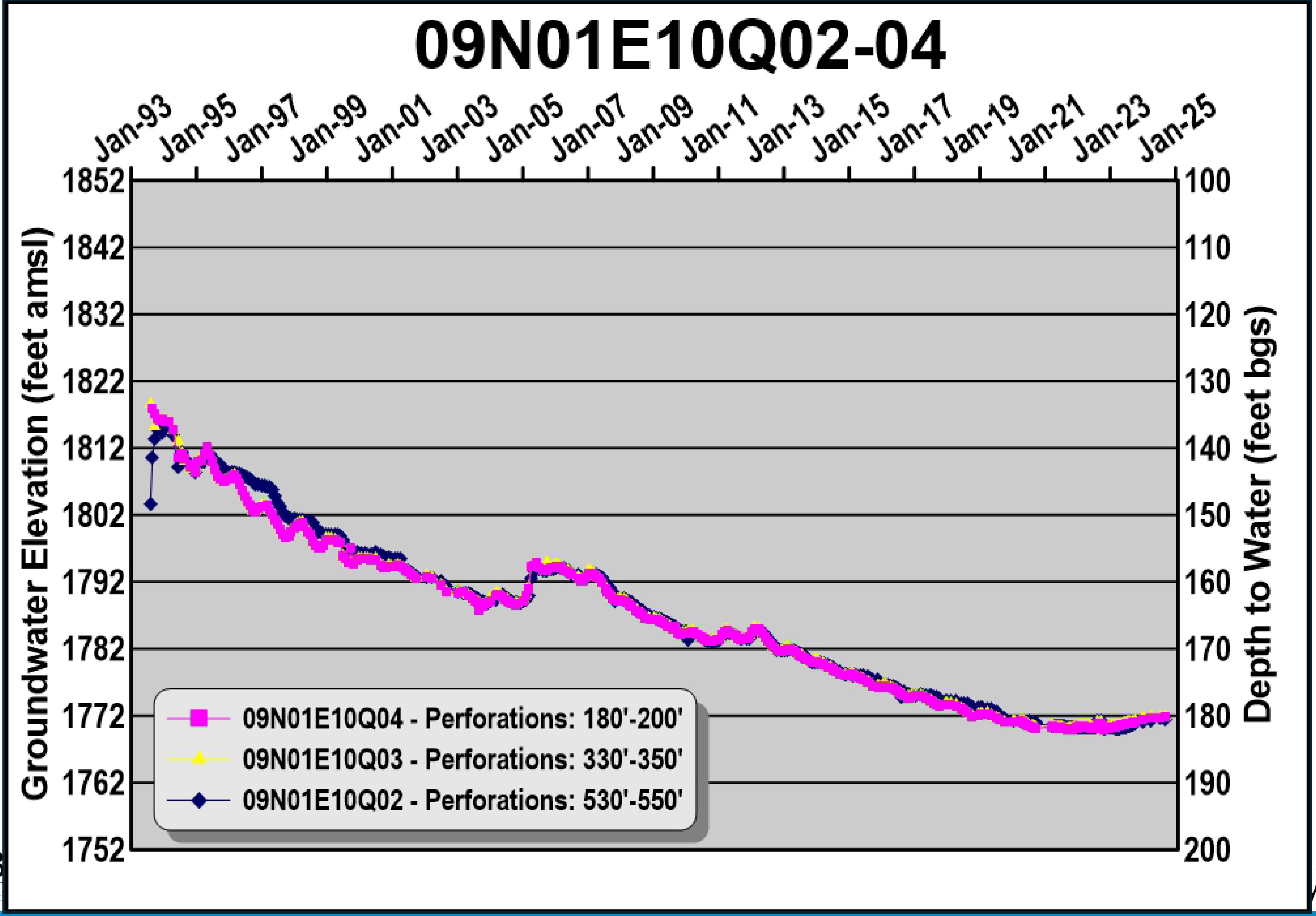
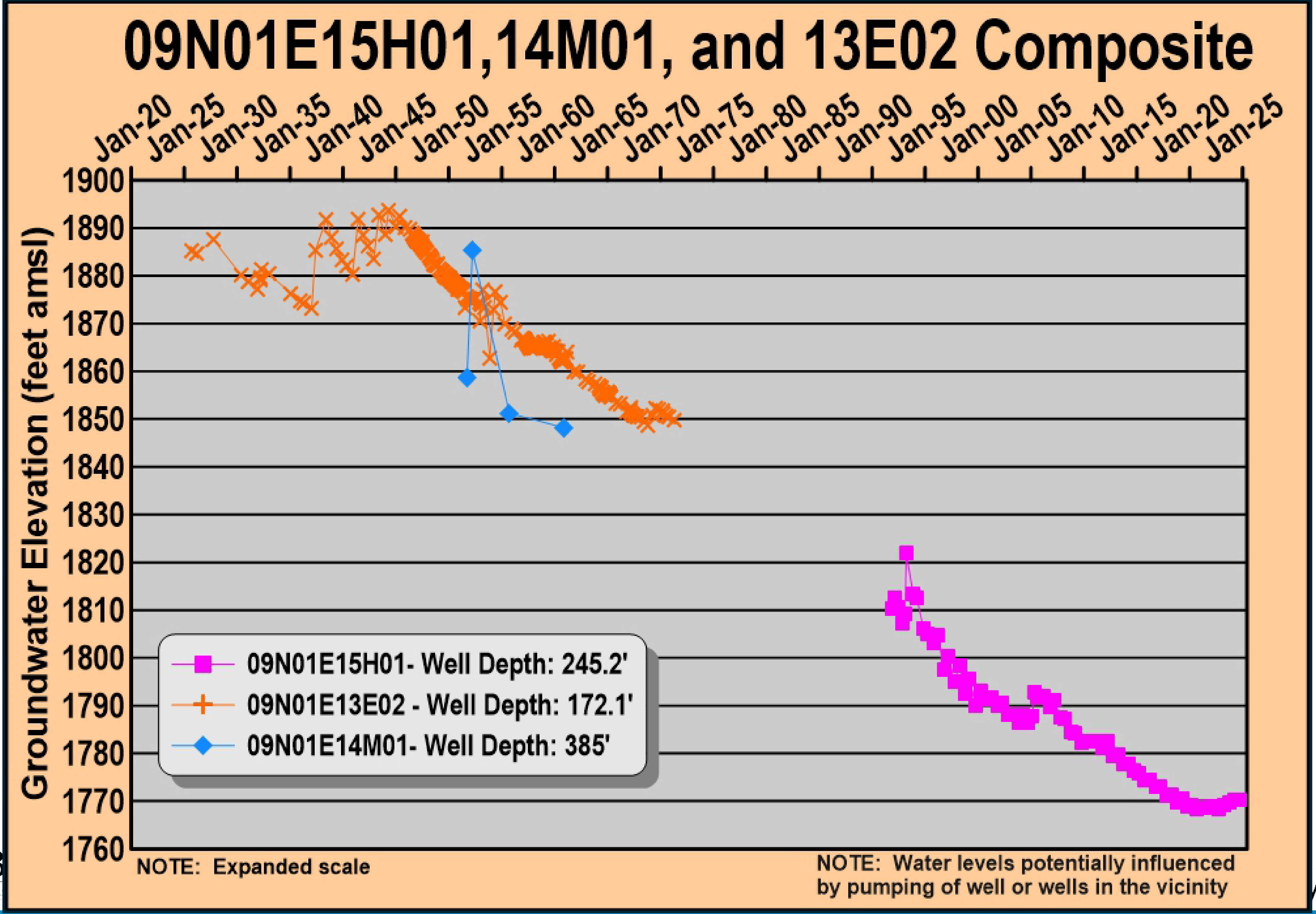
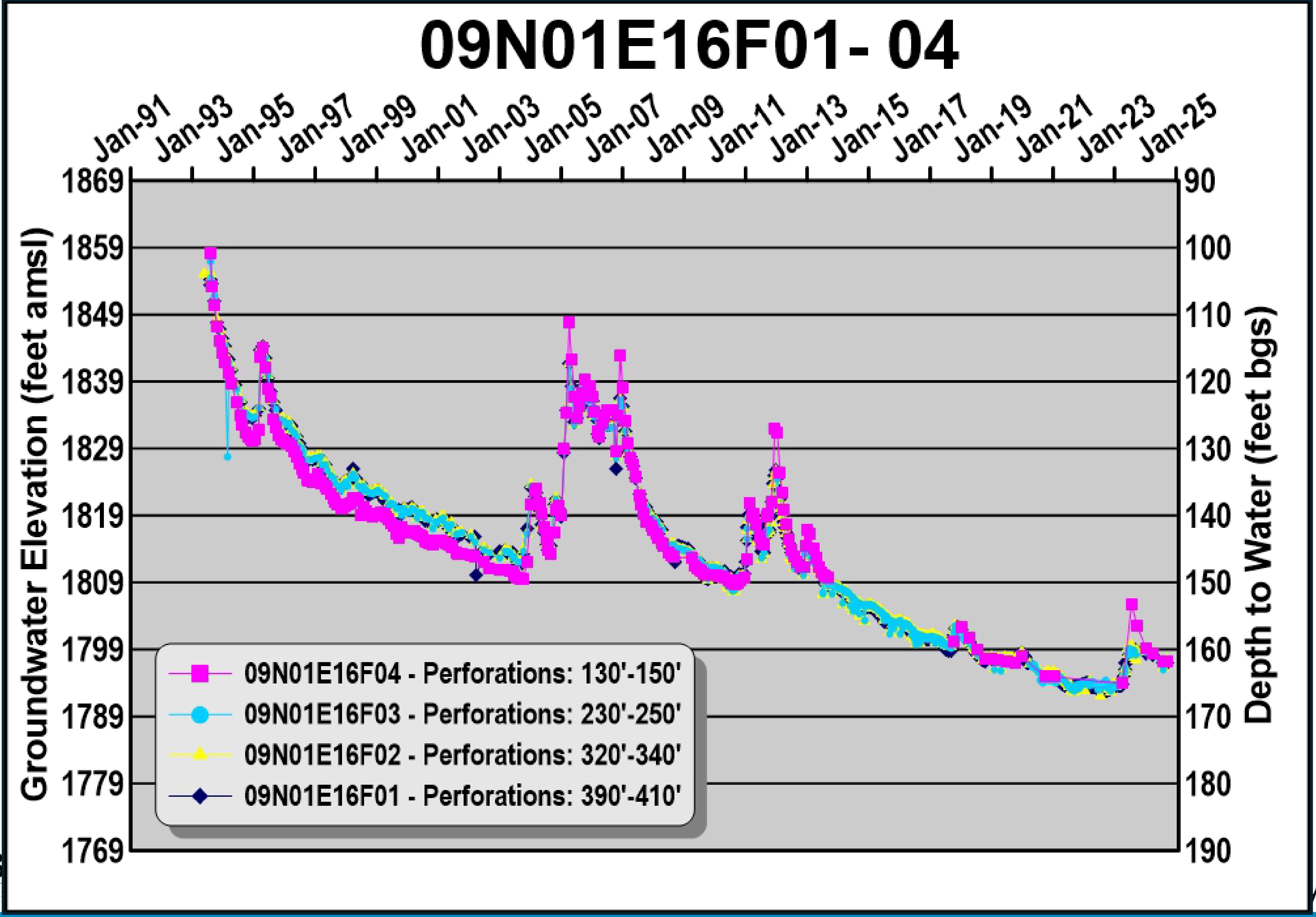
WATERMASTER



09N01E10Q02-04
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
1852
1842
1832
1822
1812
1802
1792
1782
1772
1762
1752
Depth to Water (feet bgs)
100
110
120
130
140
150
160
170
180
190
200
09N01E10Q04 - Perforations: 180'-200'
09N01E10Q03 - Perforations: 330'-350'
09N01E10Q02 - Perforations: 530'-550'


09N01E15H01,14M01, and 13E02 Composite
Jan-20 Jan-25 Jan-30 Jan-35 Jan-40 Jan-45 Jan-50 Jan-55 Jan-60 Jan-65 Jan-70 Jan-75 Jan-80 Jan-85 Jan-90 Jan-95 Jan-00 Jan-05 Jan-10 Jan-15 Jan-20 Jan-25
Groundwater Elevation (feet amsl)
1900 1890 1880 1870 1860 1850 1840 1830 1820 1810 1800 1790 1780 1770 1760
09N01E15H01- Well Depth: 245.2'
09N01E13E02 - Well Depth: 172.1'
09N01E14M01- Well Depth: 385'
NOTE: Expanded scale
NOTE: Water levels potentially influenced by pumping of well or wells in the vicinity



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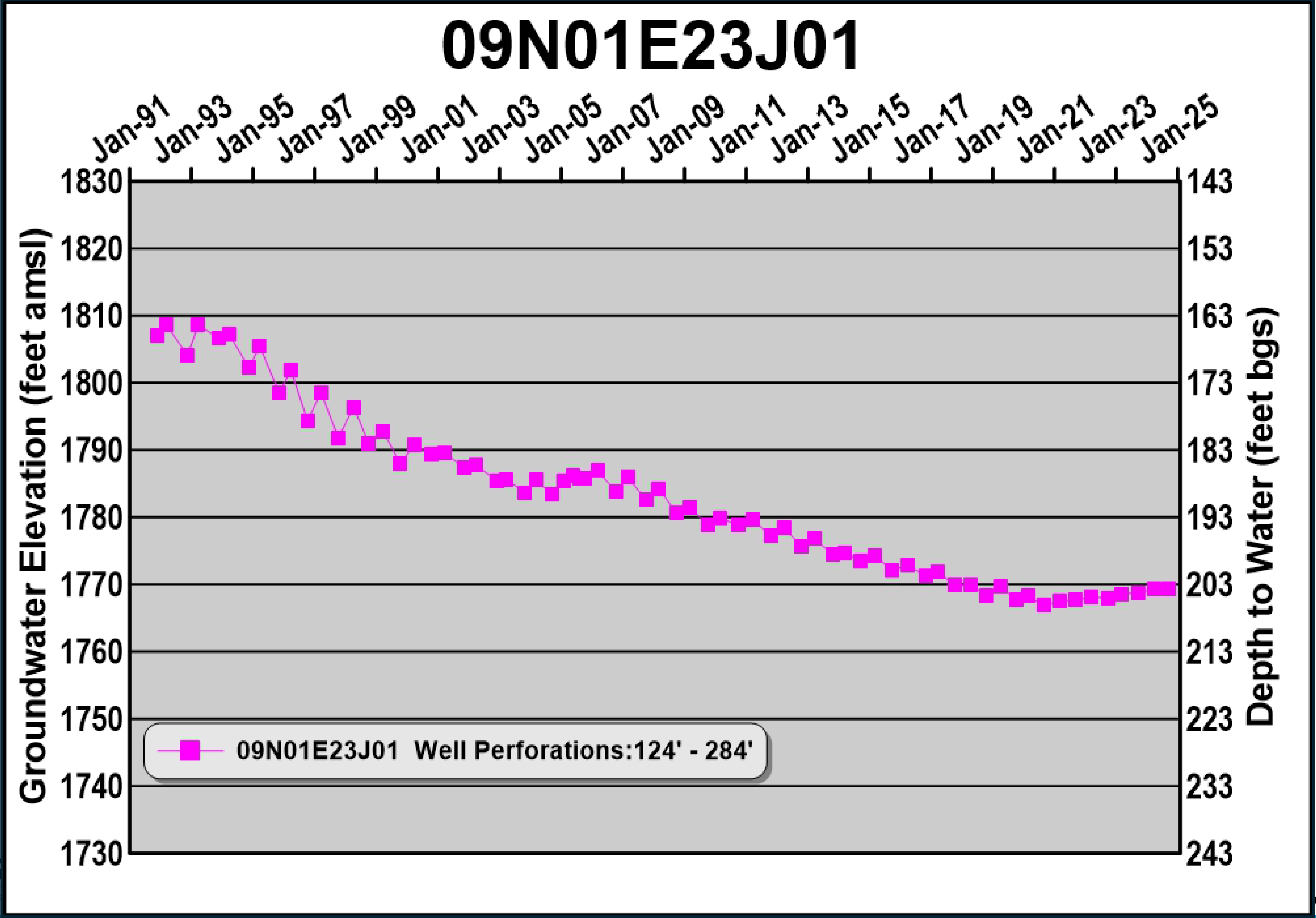
WATERMASTER



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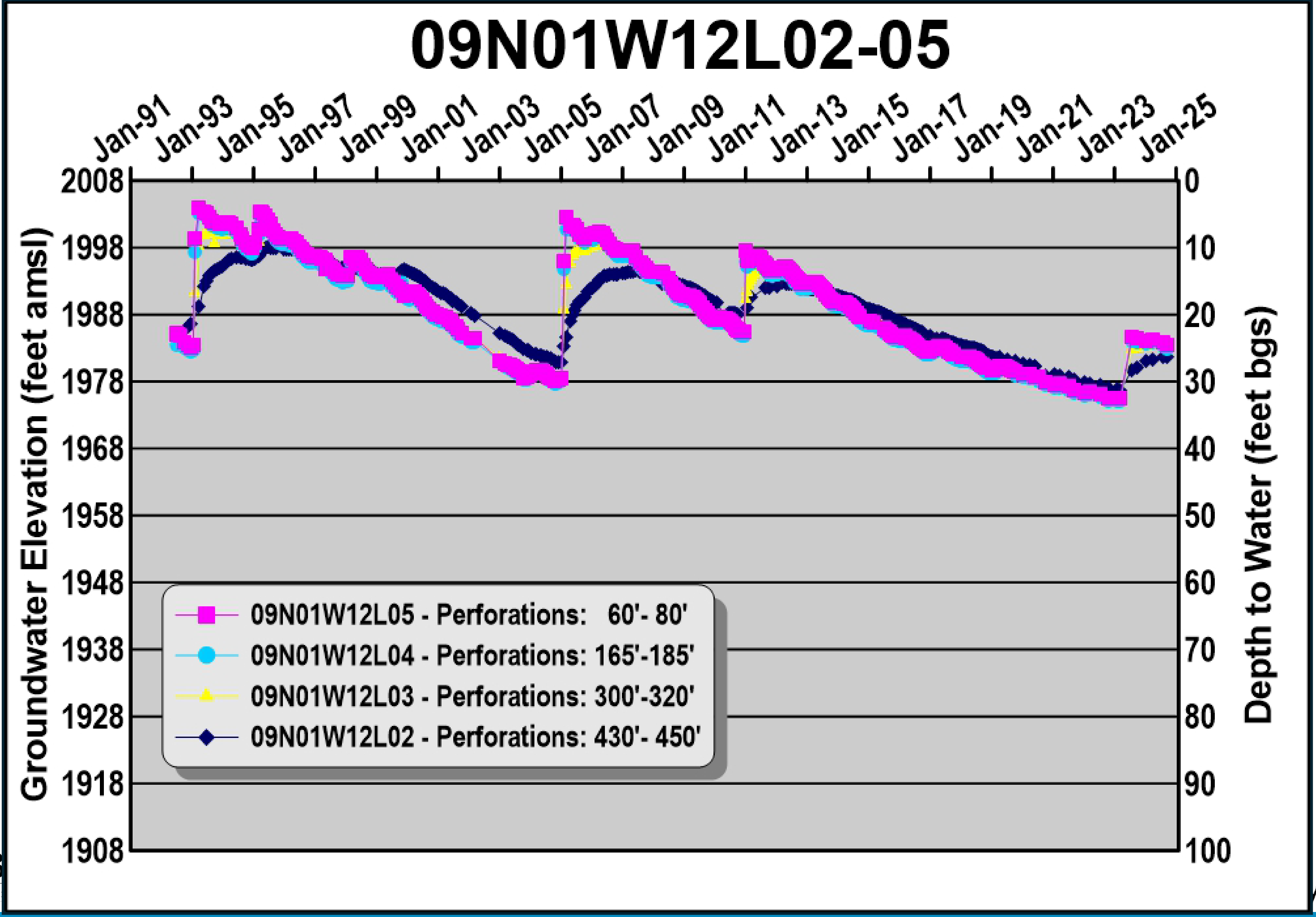
MOJAVE BASIN AREA
WATERMASTER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Jan-05
Jan-07
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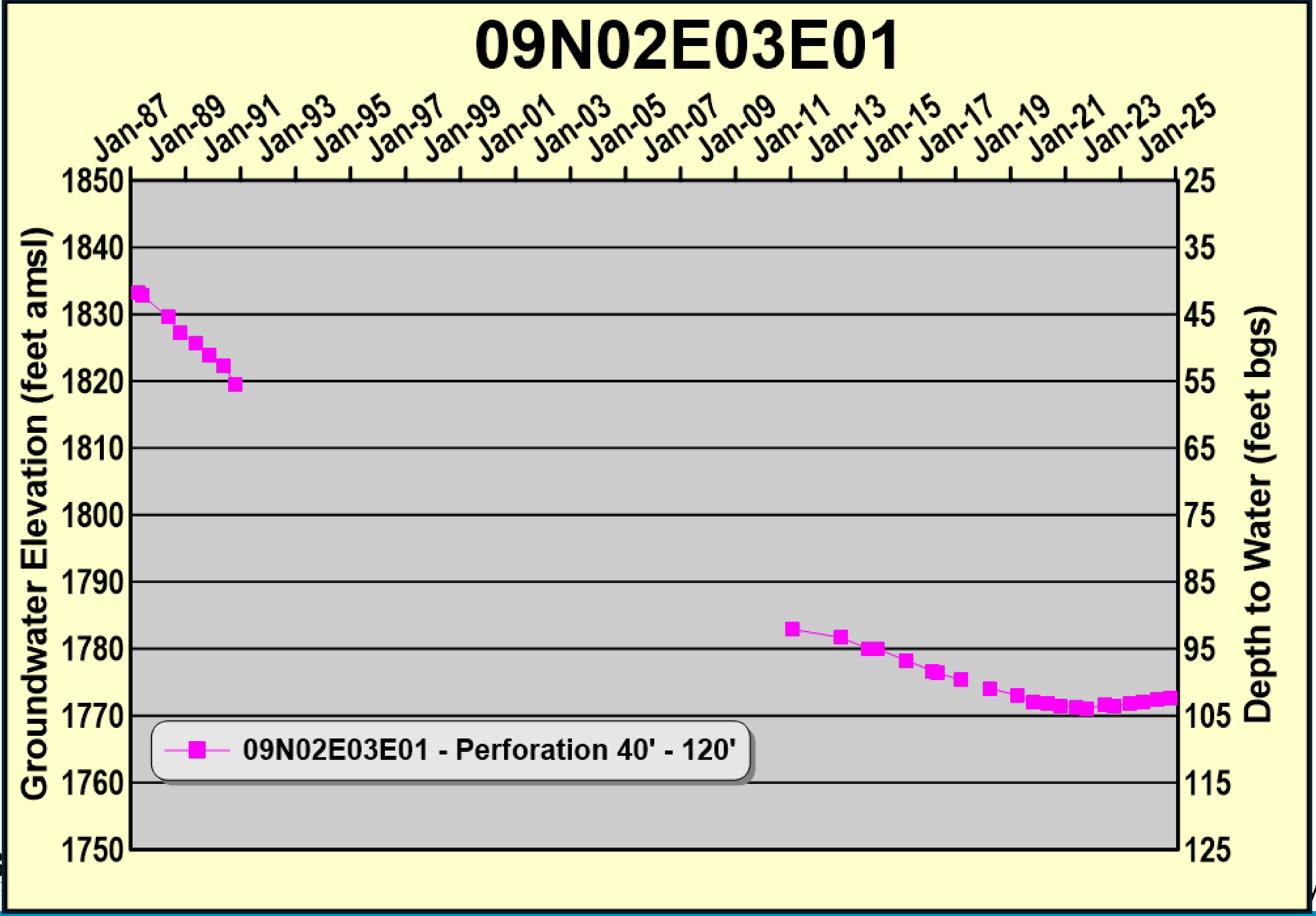
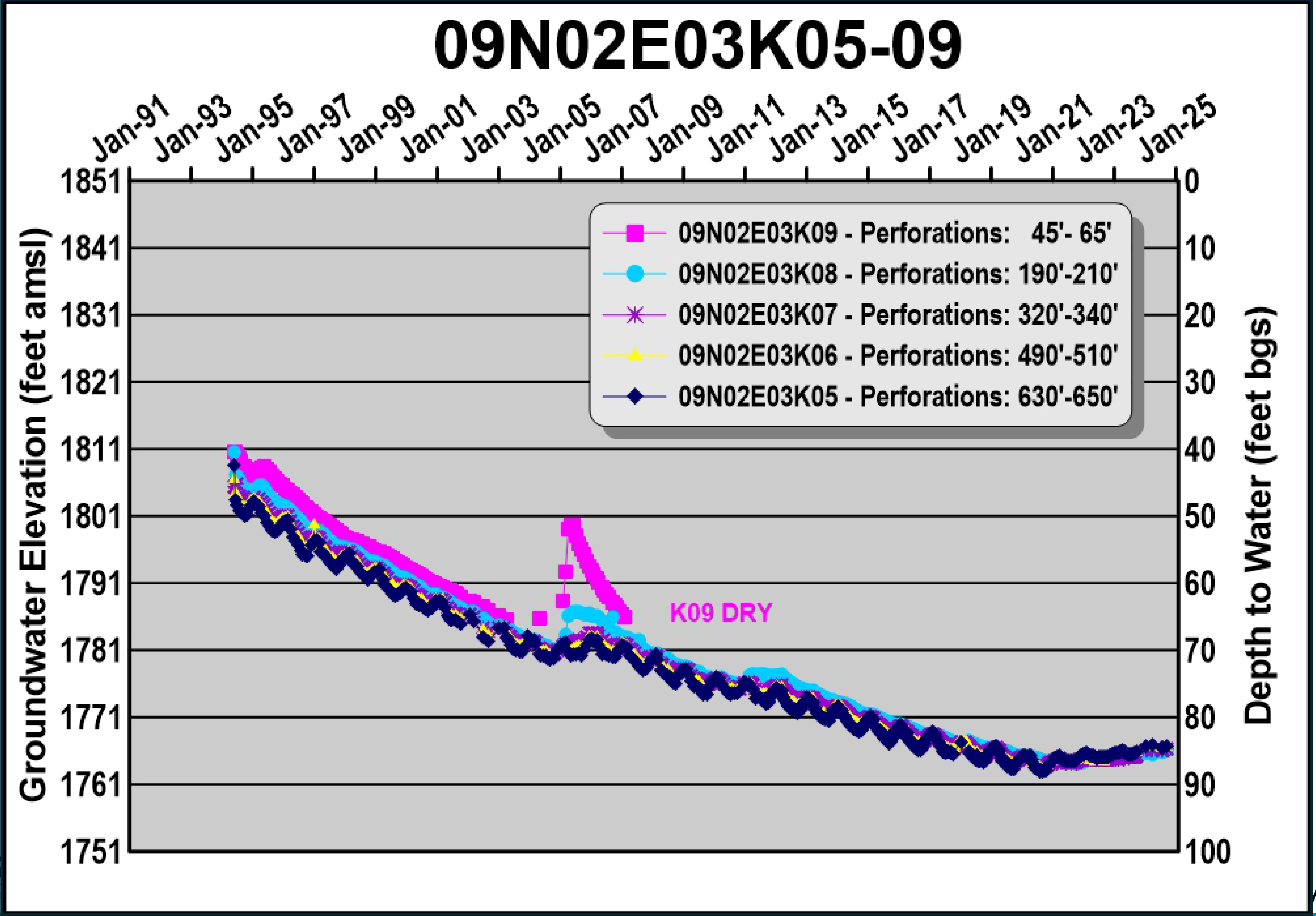
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
2008
1998
1988
1978
1968
1958
1948
1938
1928
1918
1908
Depth to Water (feet bgs)
0
10
20
30
40
50
60
70
80
90
100
09N01W12L05 - Perforations: 60'- 80'
09N01W12L04 - Perforations: 165'-185'
09N01W12L03 - Perforations: 300'-320'
09N01W12L02 - Perforations: 430'- 450'


09N02E03E01
Jan-87
Jan-89
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
1850
1840
1830
1820
1810
1800
1790
1780
1770
1760
1750
Depth to Water (feet bgs)
25
35
45
55
65
75
85
95
105
115
125
09N02E03E01 - Perforation 40' - 120'



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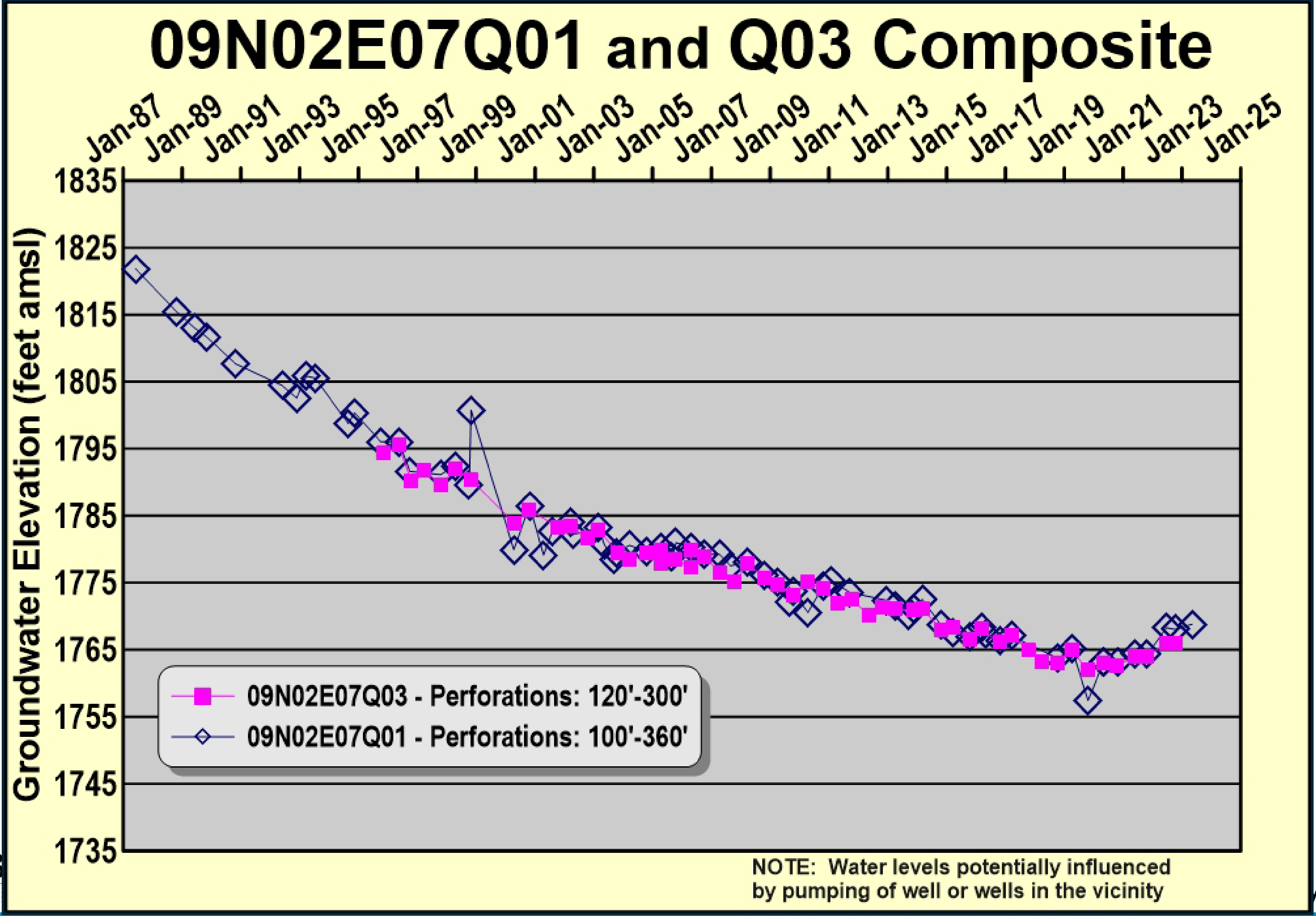
WATERMASTER



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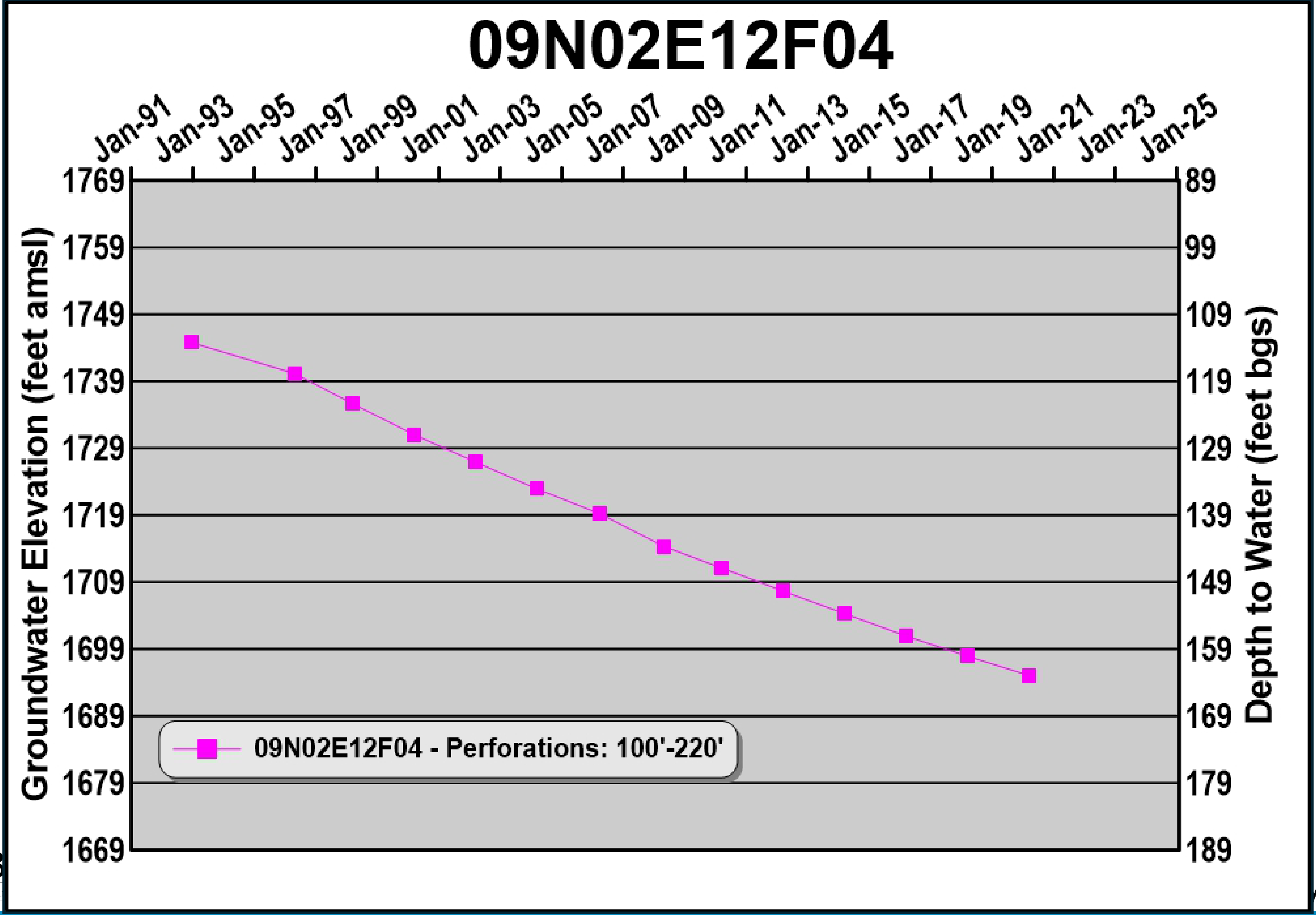
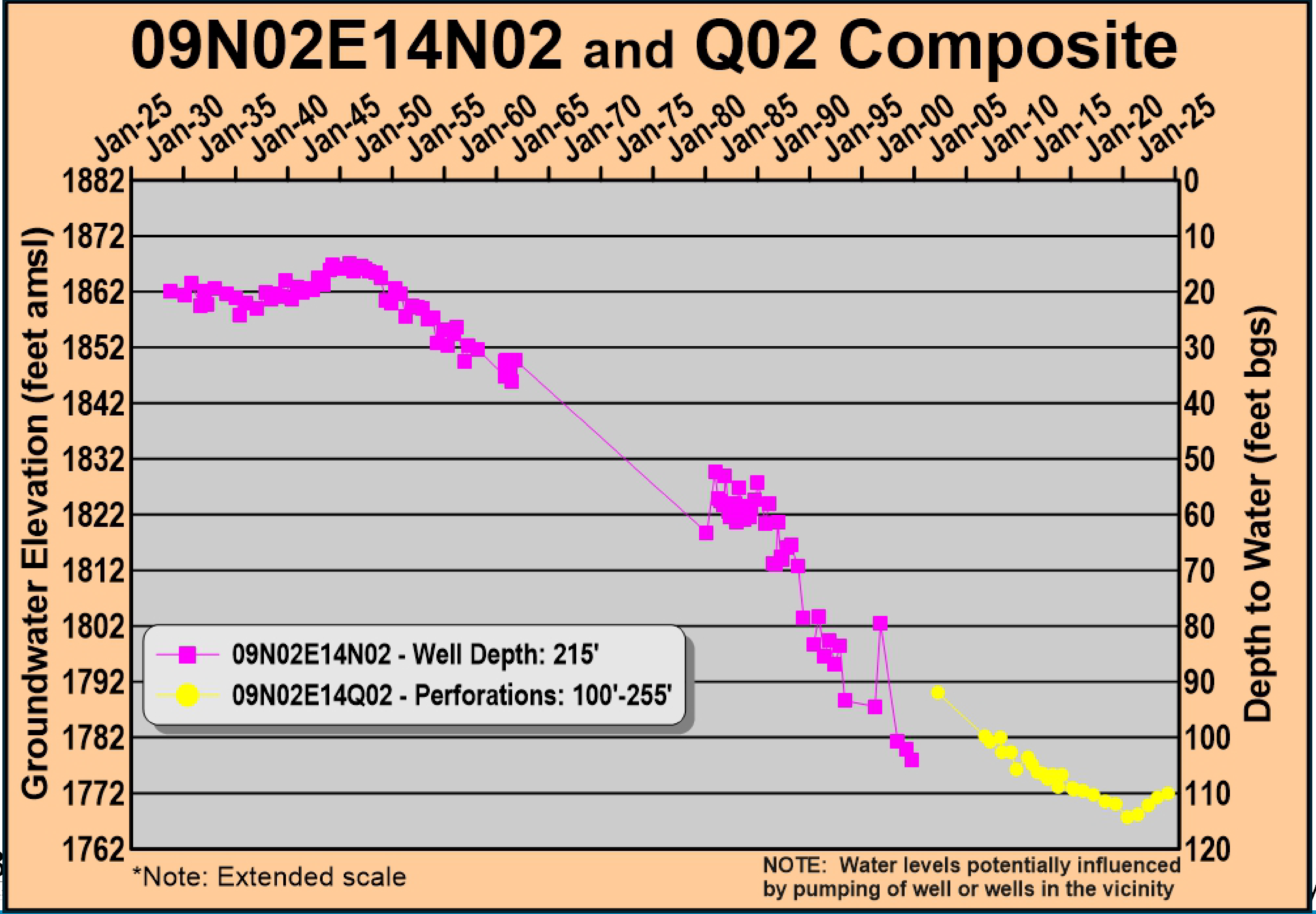
MOJAVE BASIN AREA WATERMASTER


09N02E12F04
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
1769
1759
1749
1739
1729
1719
1709
1699
1689
1679
1669
Depth to Water (feet bgs)
89
99
109
119
129
139
149
159
169
179
189
09N02E12F04 - Perforations: 100'-220'



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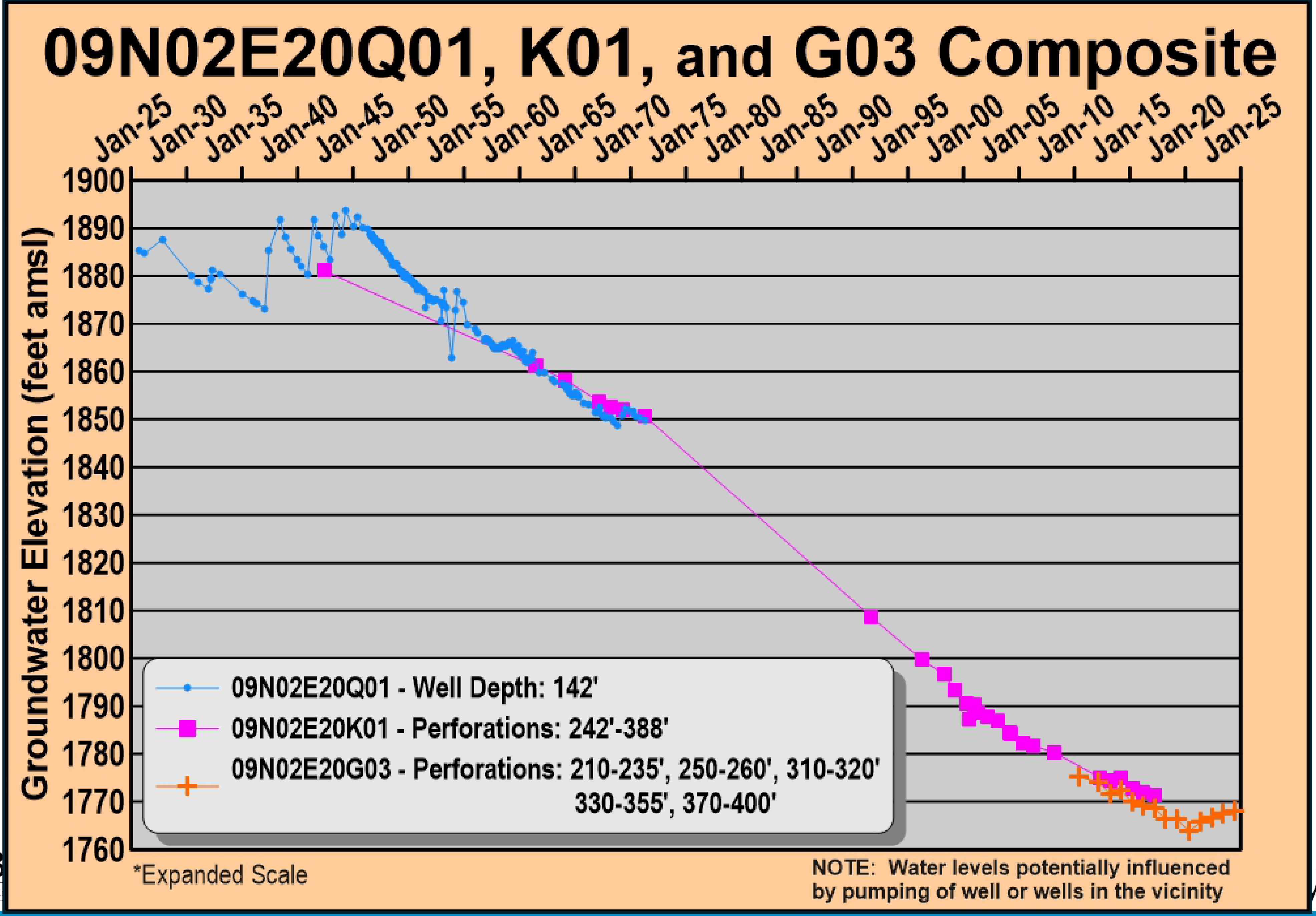

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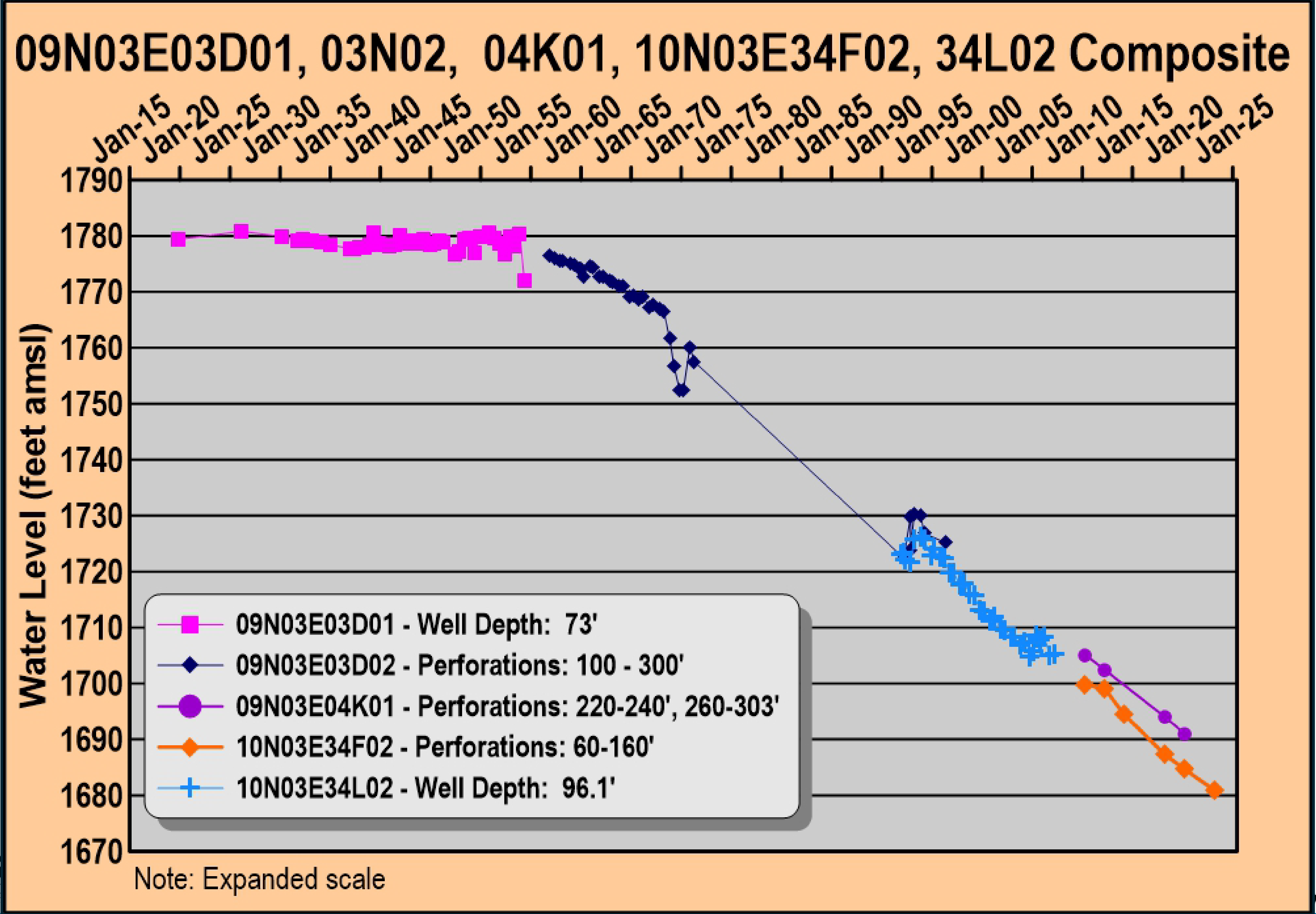
MOJAVE BASIN AREA WATERMASTER



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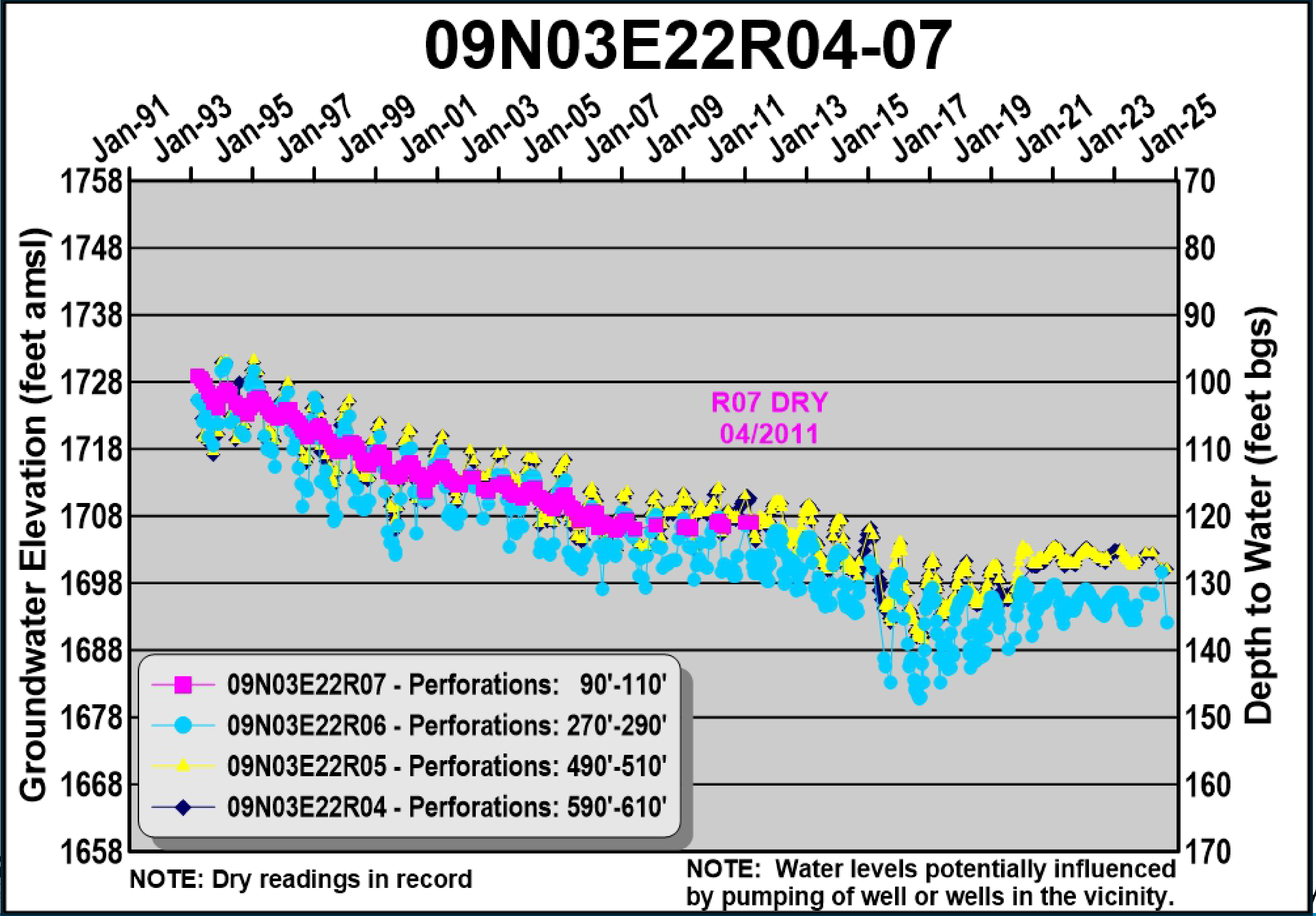
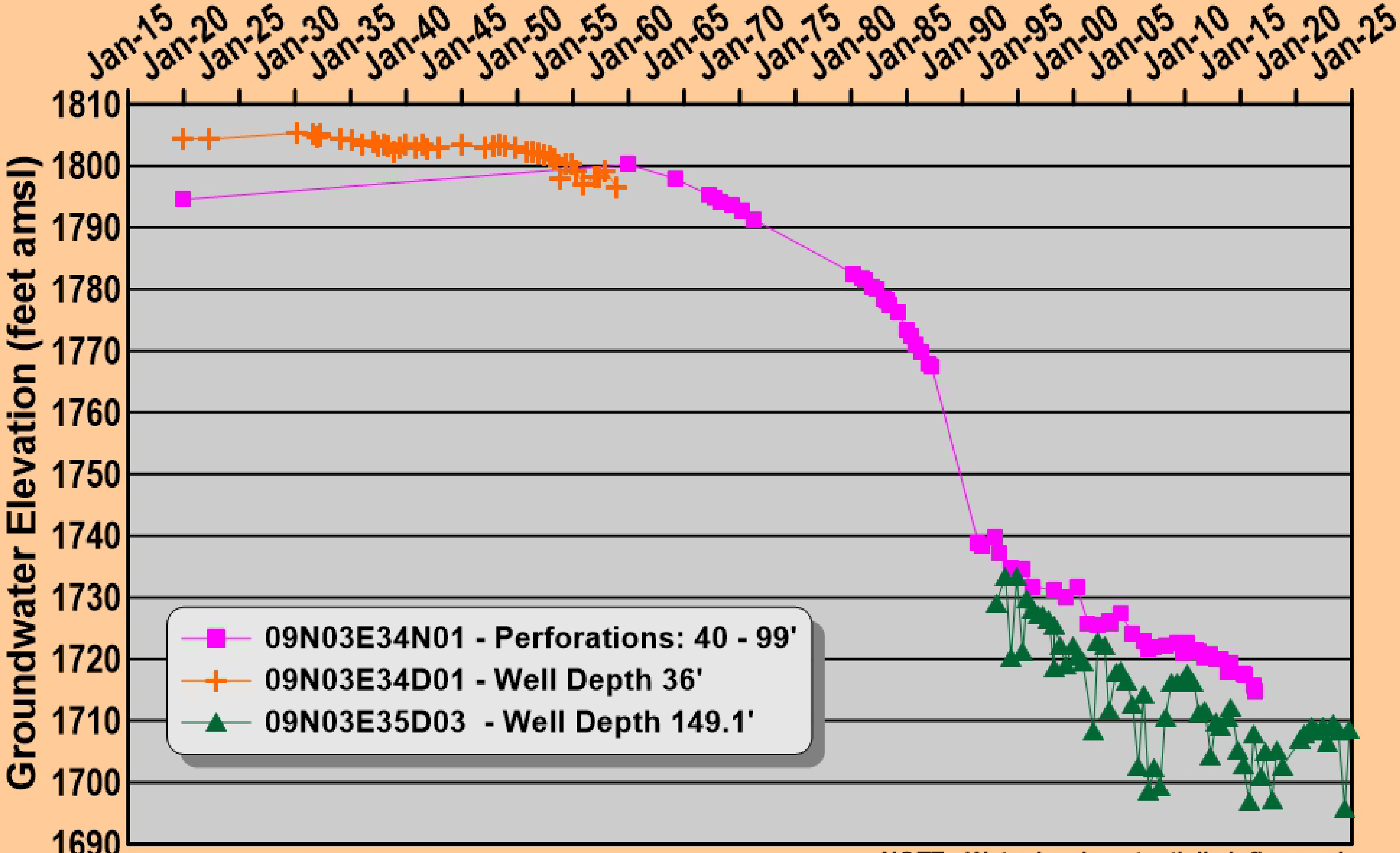
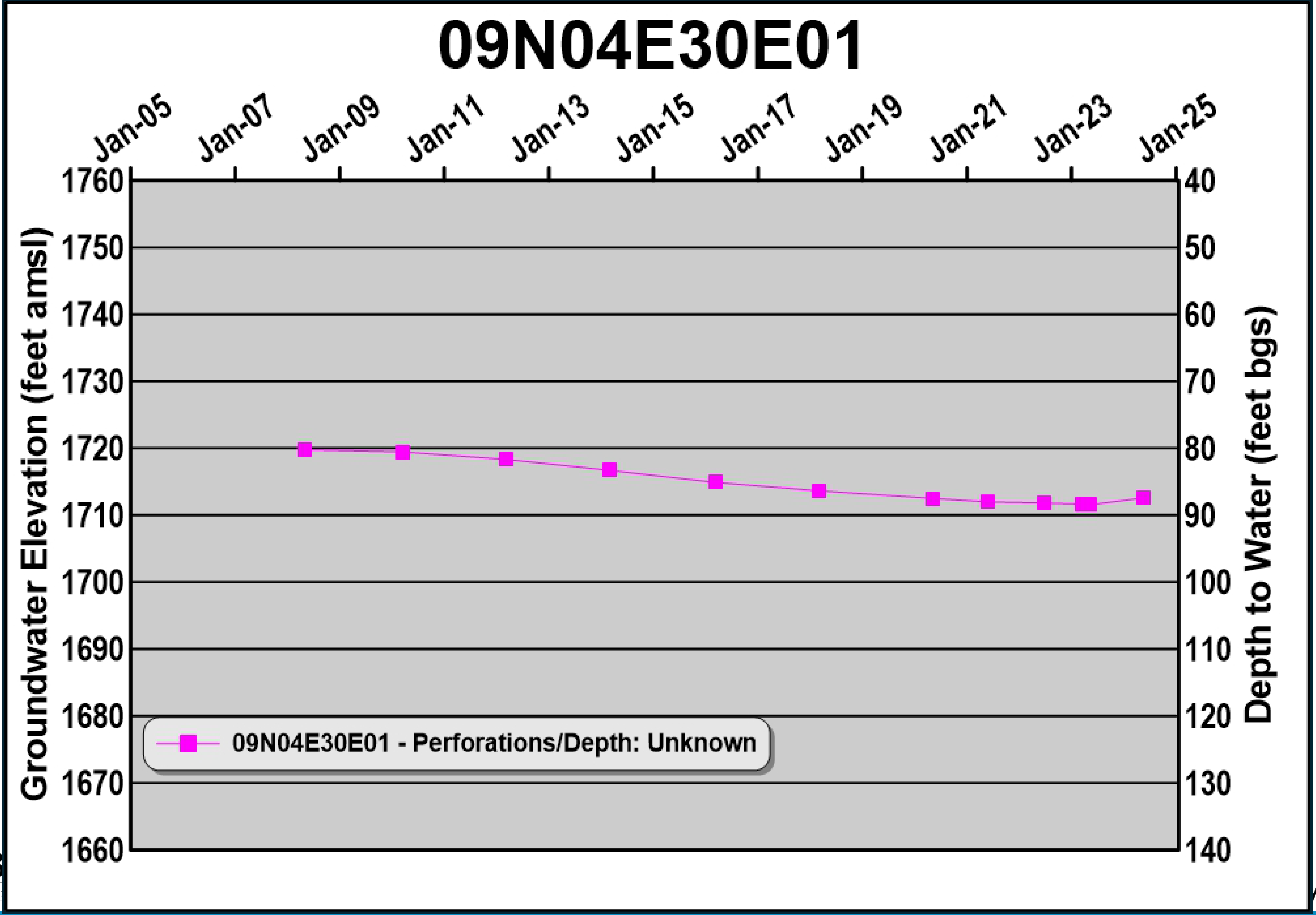

09N03E22R04-07
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
1758
1748
1738
1728
1718
1708
1698
1688
1678
1668
1658
Depth to Water (feet bgs)
70
80
90
100
110
120
130
140
150
160
170
R07 DRY
04/2011
09N03E22R07 - Perforations: 90'-110'
09N03E22R06 - Perforations: 270'-290'
09N03E22R05 - Perforations: 490'-510'
09N03E22R04 - Perforations: 590'-610'
NOTE: Dry readings in record
NOTE: Water levels potentially influenced by pumping of well or wells in the vicinity.

09N03E34D01, N01, and 35D03 Composite



Note: expanded Scale

NOTE: Water levels potentially influenced by pumping of well or wells in the vicinity



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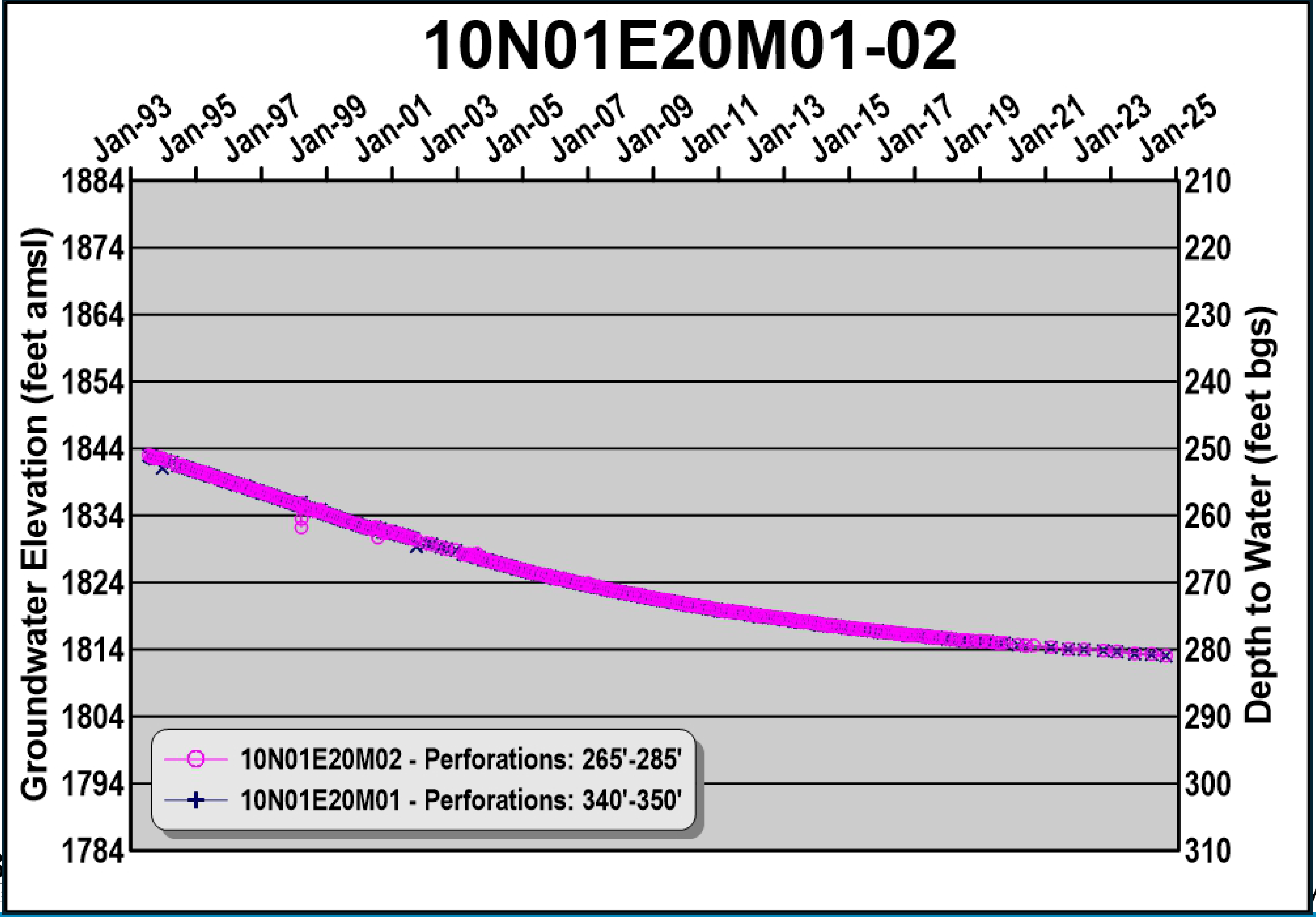
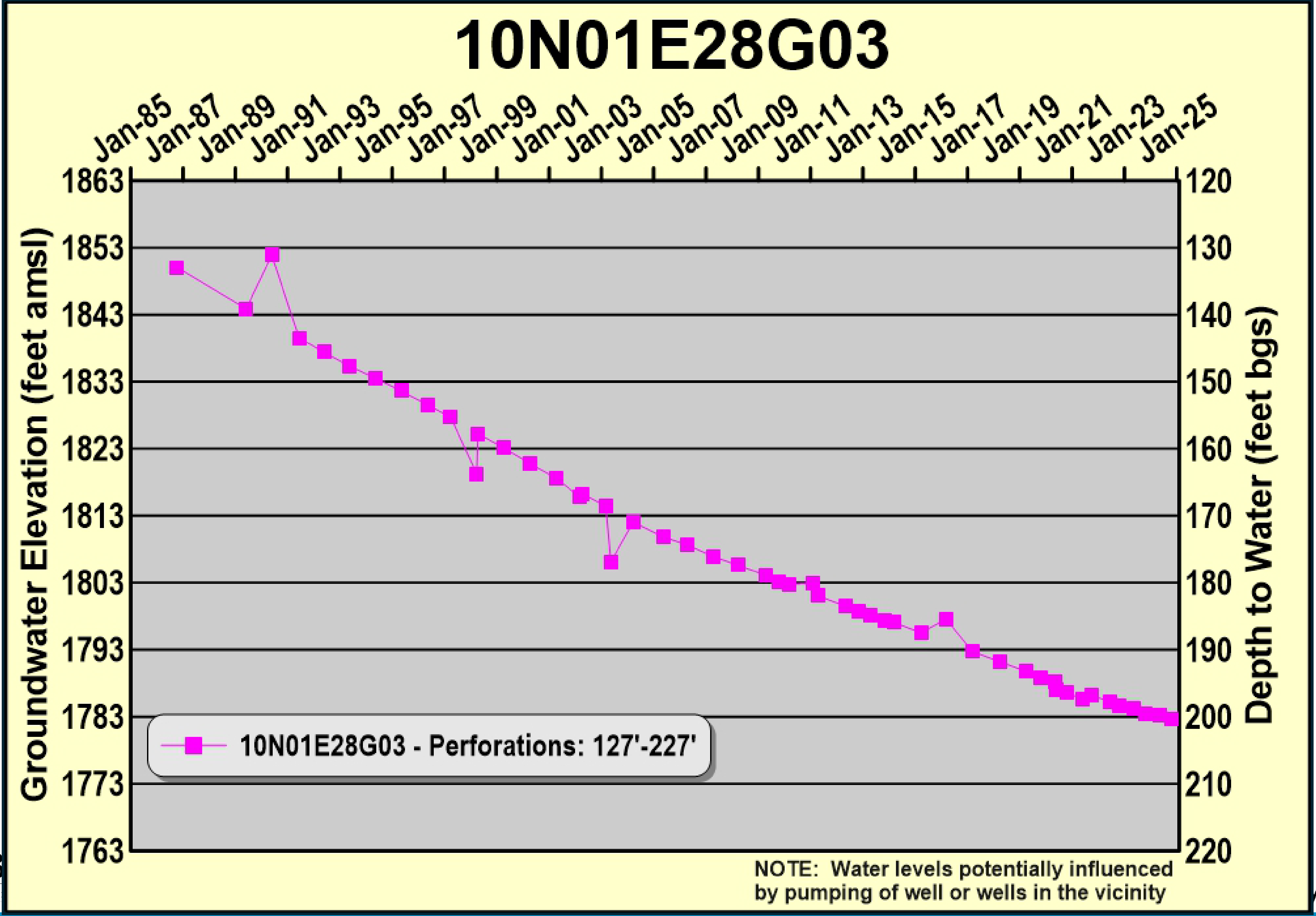
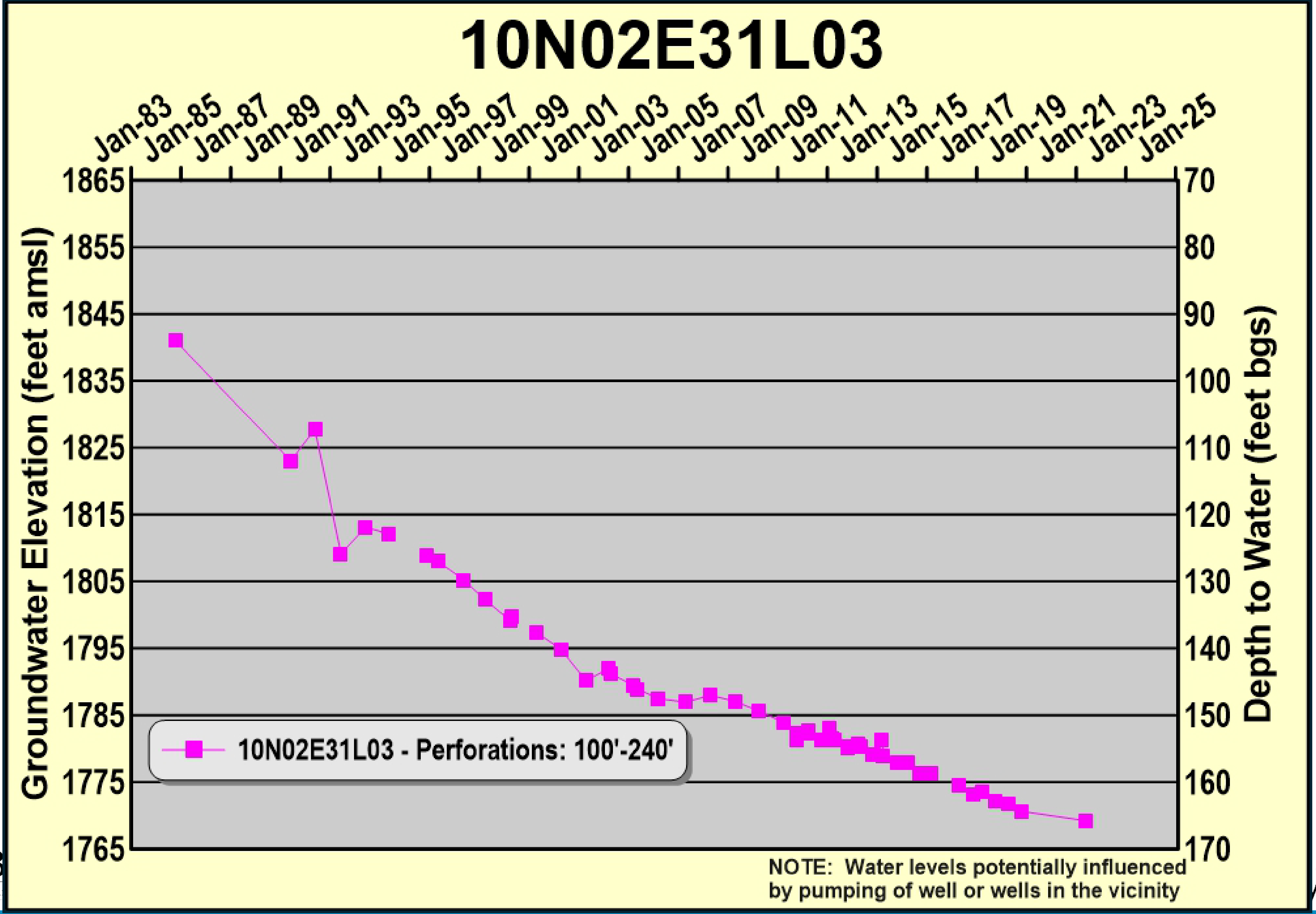
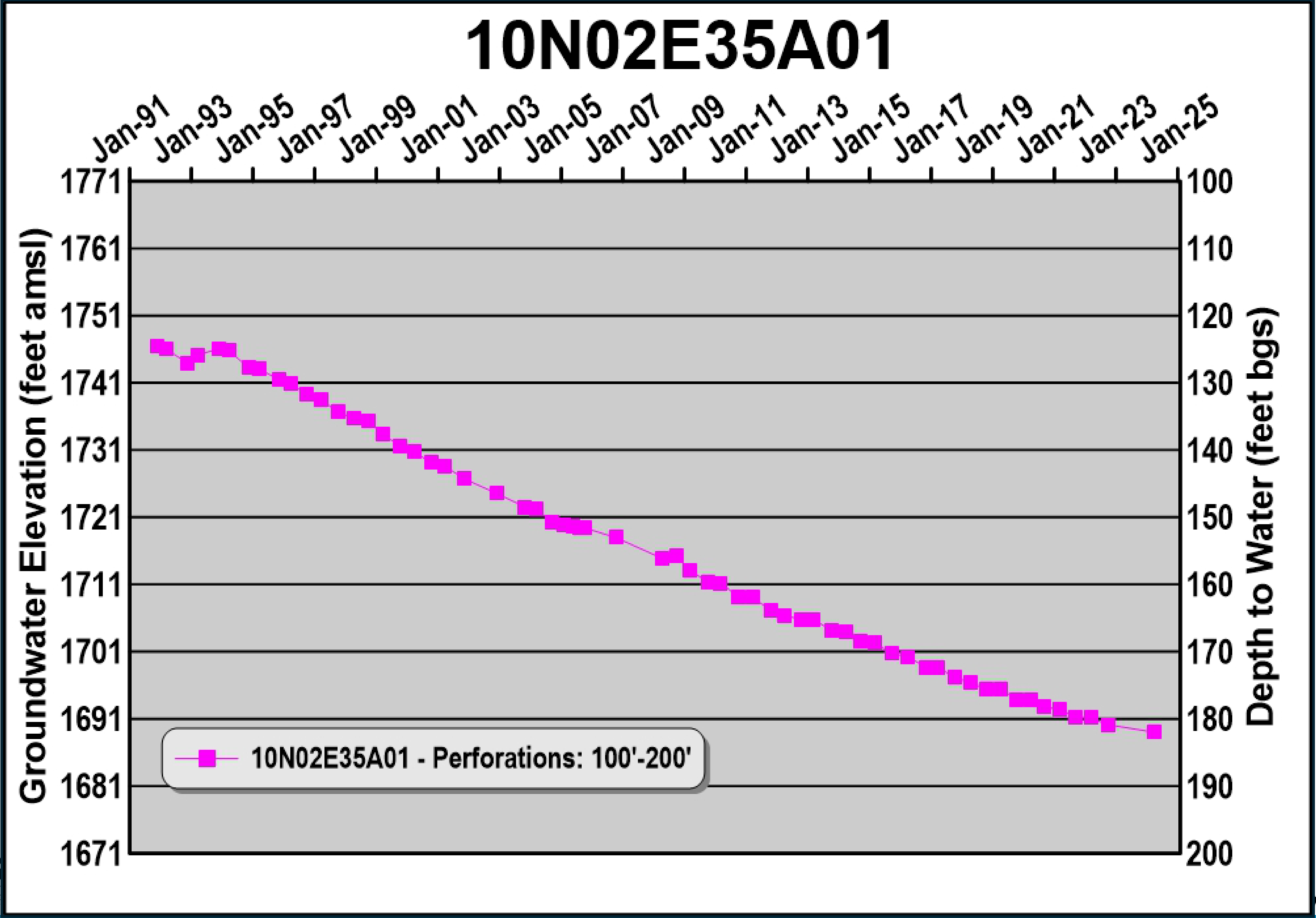
MOJAVE BASIN AREA WATERMASTER

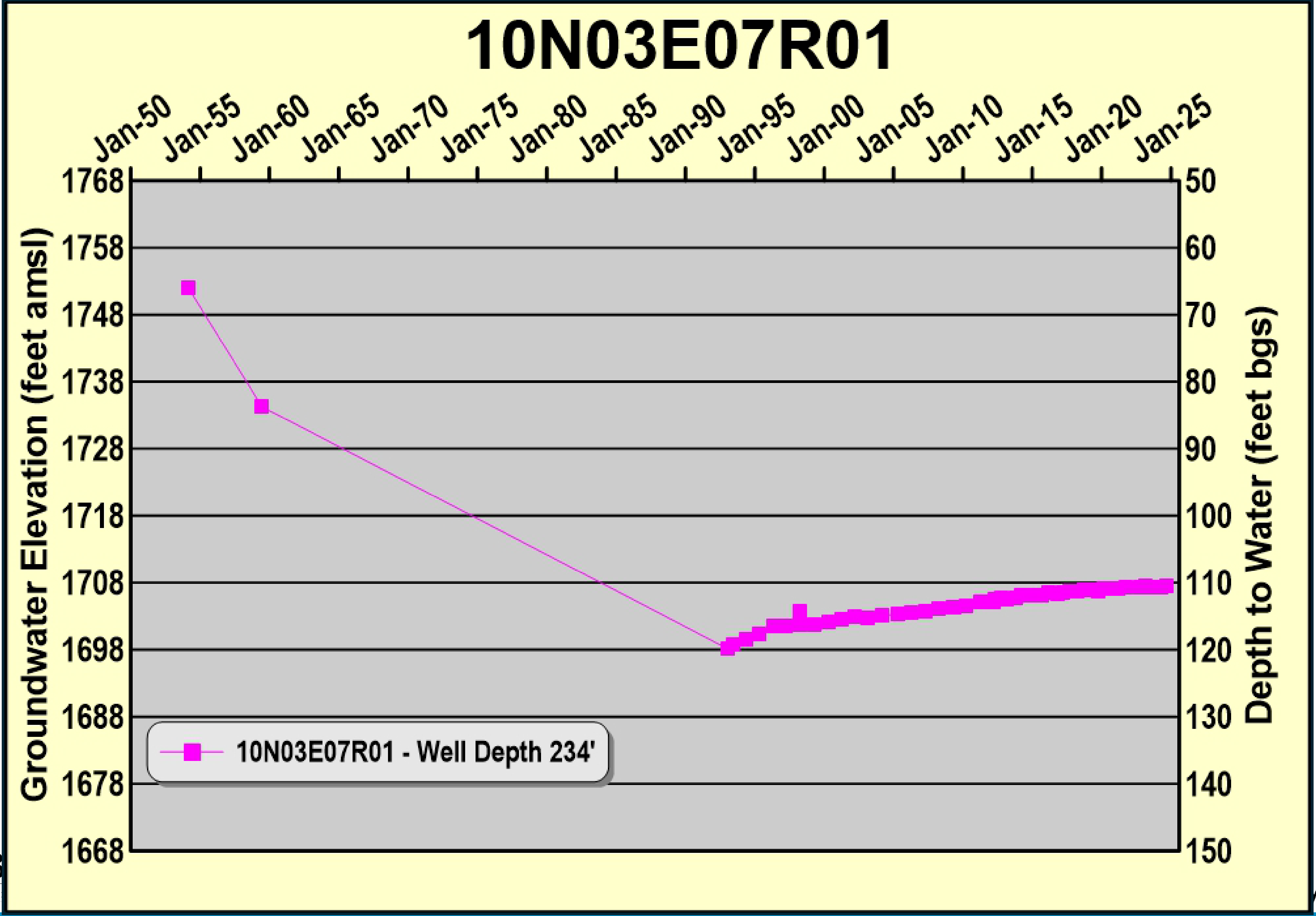

10N01E20M01-02
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
1884
1874
1864
1854
1844
1834
1824
1814
1804
1794
1784
Depth to Water (feet bgs)
210
220
230
240
250
260
270
280
290
300
310
10N01E20M02 - Perforations: 265'-285'
10N01E20M01 - Perforations: 340'-350'

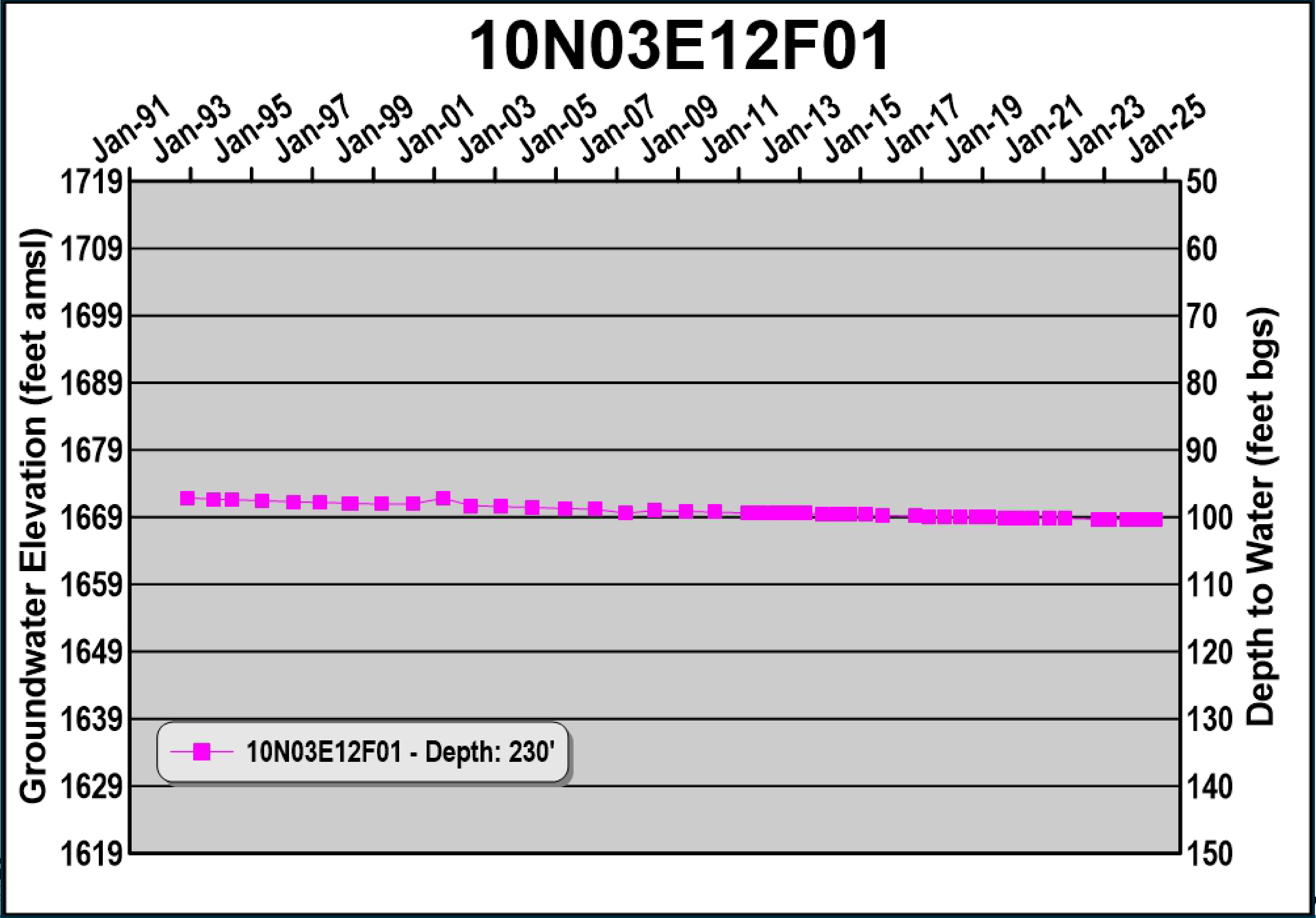


10N01E28G03
Jan-85
Jan-87
Jan-89
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
1863
1853
1843
1833
1823
1813
1803
1793
1783
1773
1763
Depth to Water (feet bgs)
120
130
140
150
160
170
180
190
200
210
220
10N01E28G03 - Perforations: 127'-227'
NOTE: Water levels potentially influenced by pumping of well or wells in the vicinity

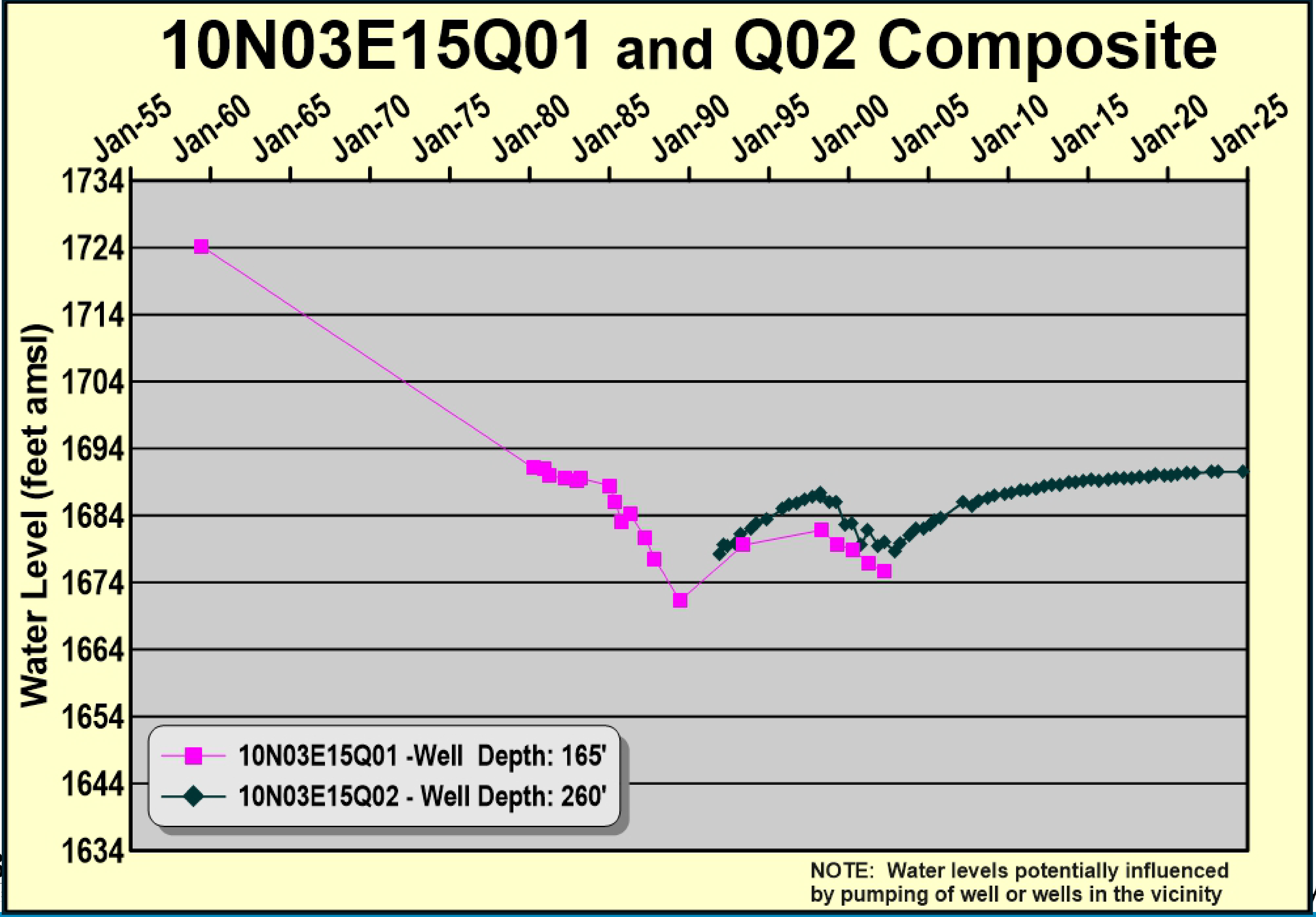

10N02E31L03
Jan-83 Jan-85 Jan-87 Jan-89 Jan-91 Jan-93 Jan-95 Jan-97 Jan-99 Jan-01 Jan-03 Jan-05 Jan-07 Jan-09 Jan-11 Jan-13 Jan-15 Jan-17 Jan-19 Jan-21 Jan-23 Jan-25
Groundwater Elevation (feet amsl)
1865 1855 1845 1835 1825 1815 1805 1795 1785 1775 1765
Depth to Water (feet bgs)
70 80 90 100 110 120 130 140 150 160 170
10N02E31L03 - Perforations: 100'-240'
NOTE: Water levels potentially influenced by pumping of well or wells in the vicinity

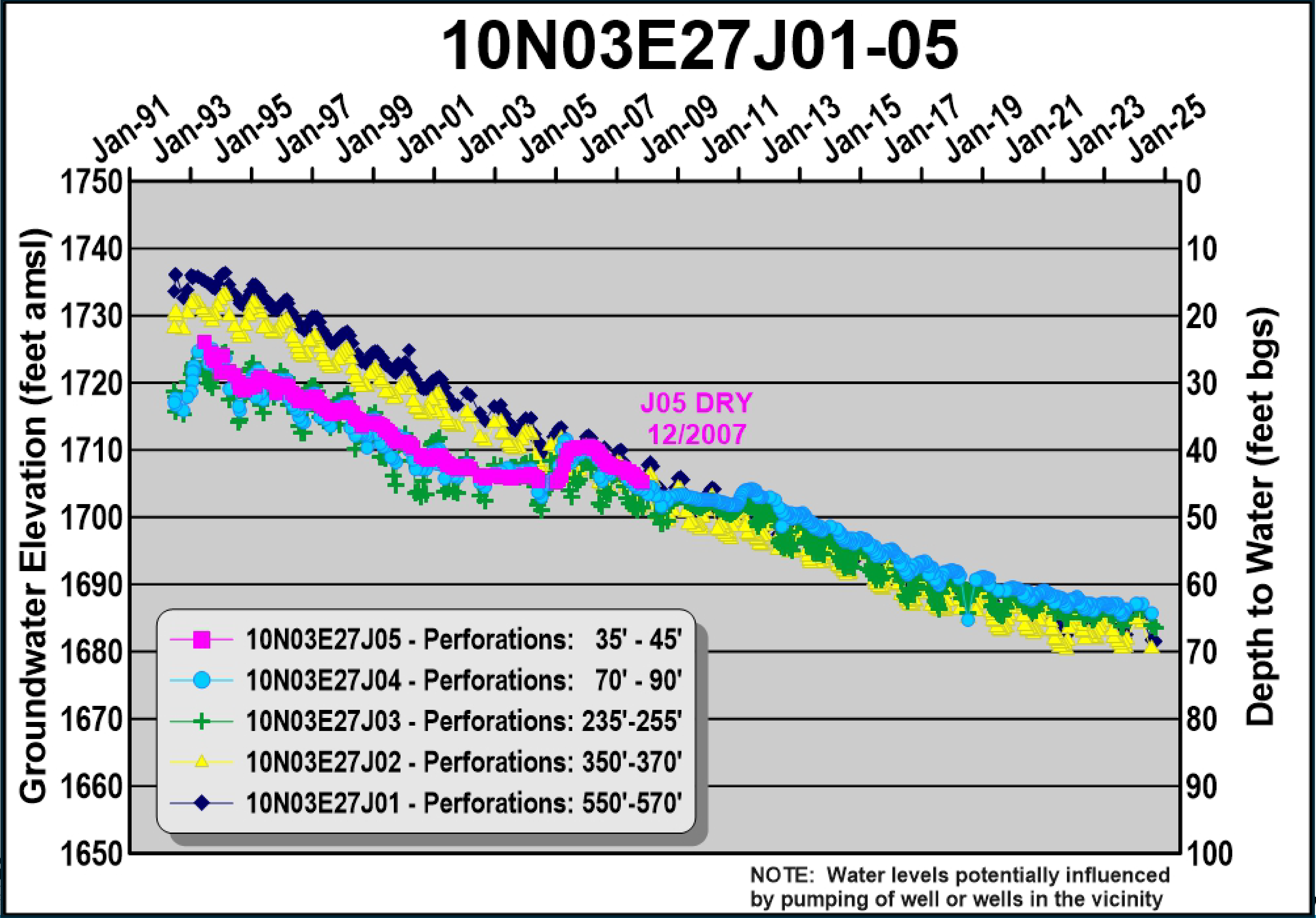

10N02E35A01
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
1771
1761
1751
1741
1731
1721
1711
1701
1691
1681
1671
Depth to Water (feet bgs)
100
110
120
130
140
150
160
170
180
190
200
10N02E35A01 - Perforations: 100'-200'

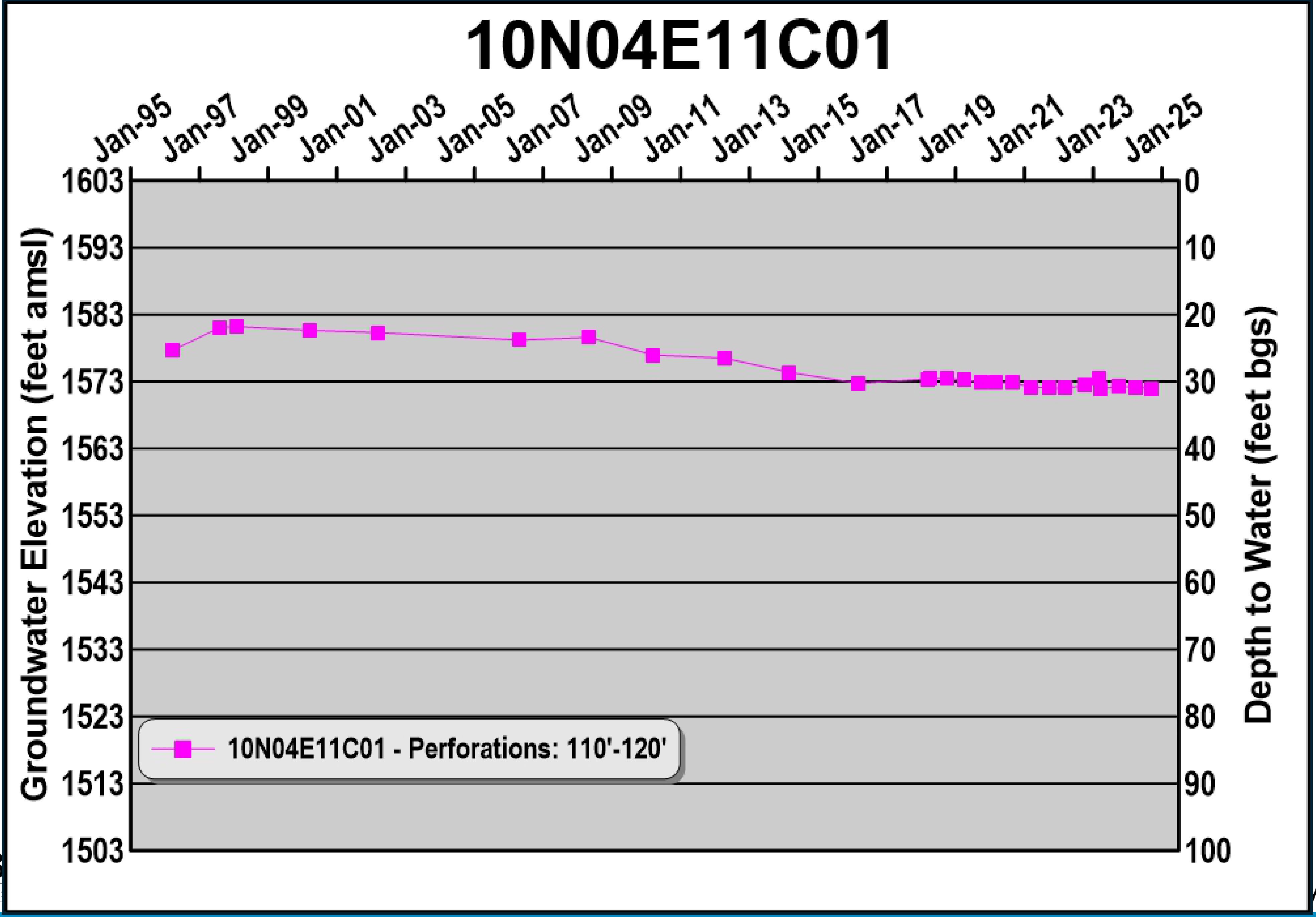

10N03E07R01
Jan-50
Jan-55
Jan-60
Jan-65
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90
Jan-95
Jan-00
Jan-05
Jan-10
Jan-15
Jan-20
Jan-25
Groundwater Elevation (feet amsl)
1768
1758
1748
1738
1728
1718
1708
1698
1688
1678
1668
Depth to Water (feet bgs)
50
60
70
80
90
100
110
120
130
140
150
10N03E07R01 - Well Depth 234'

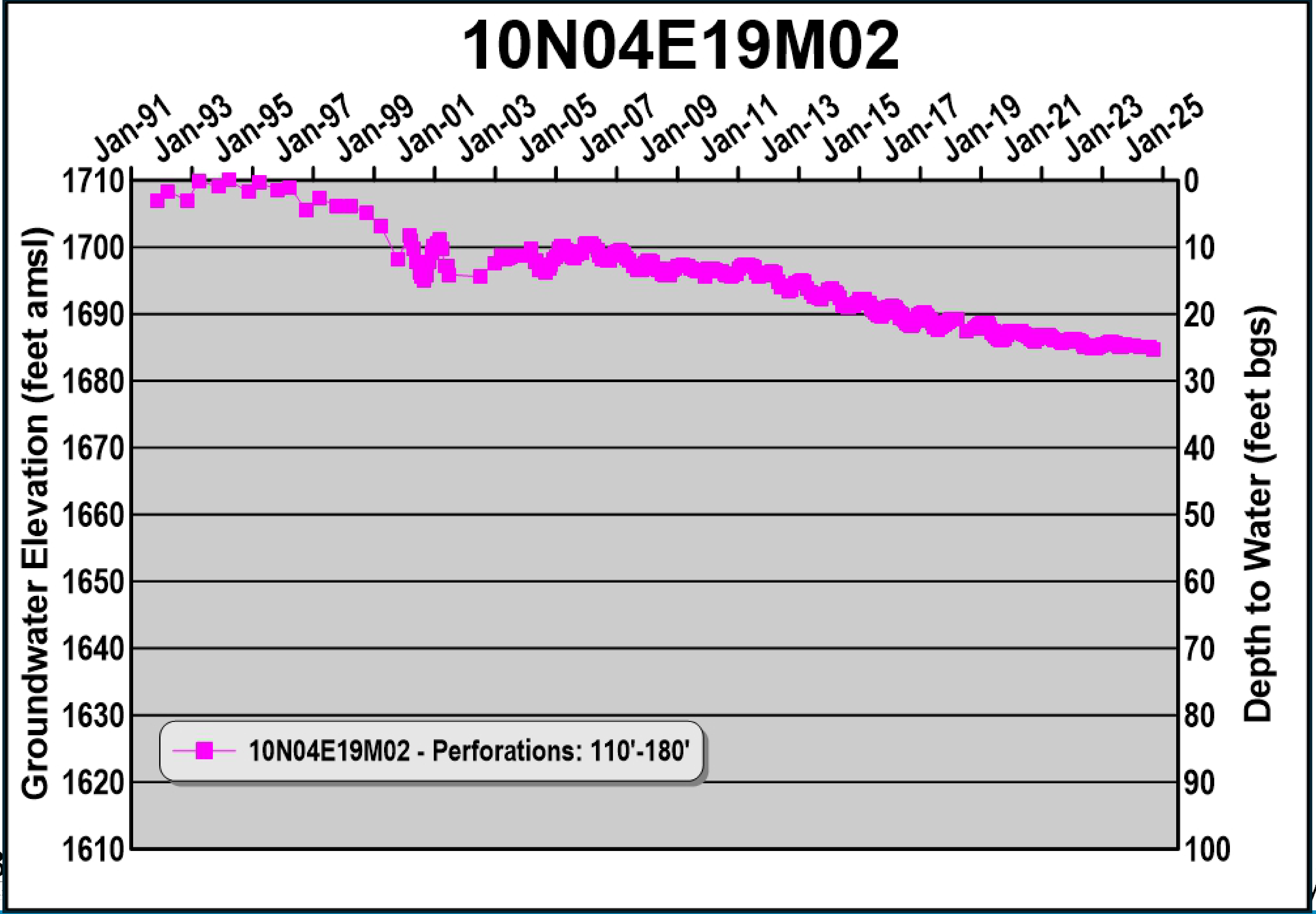


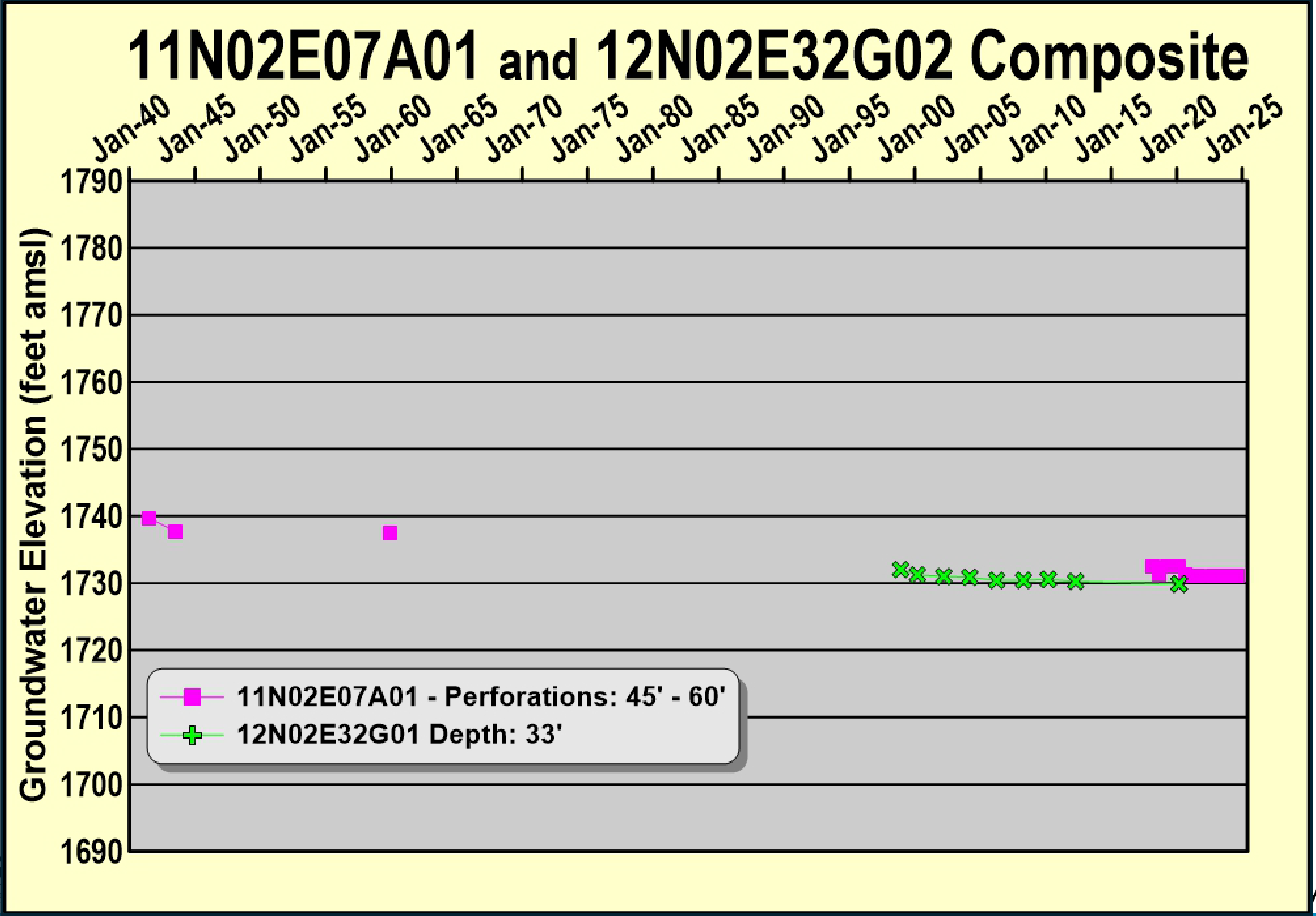
10N03E12F01
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
1719
1709
1699
1689
1679
1669
1659
1649
1639
1629
1619
Depth to Water (feet bgs)
50
60
70
80
90
100
110
120
130
140
150
10N03E12F01 - Depth: 230'

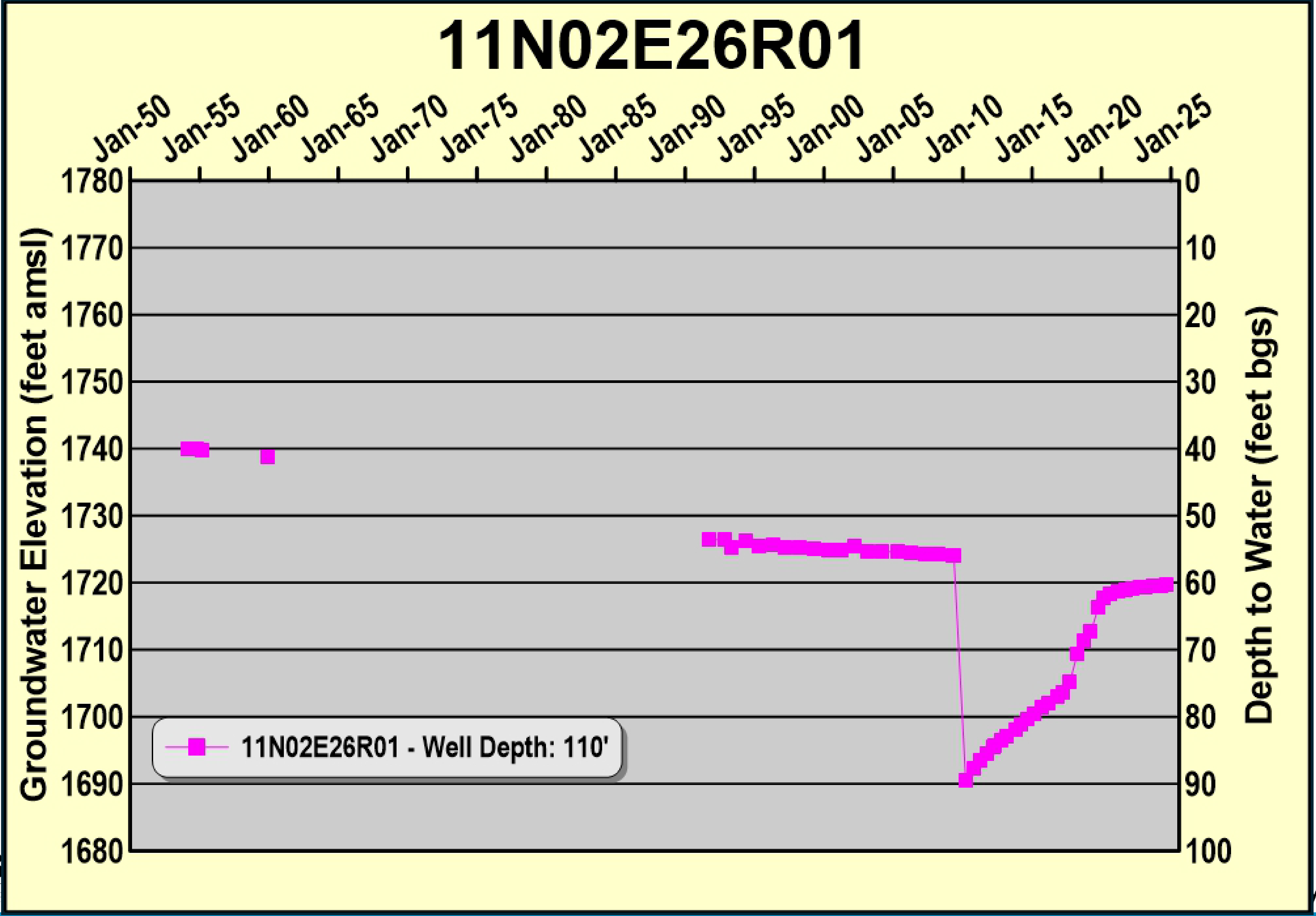

10N03E15Q01 and Q02 Composite
Jan-55
Jan-60
Jan-65
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90
Jan-95
Jan-00
Jan-05
Jan-10
Jan-15
Jan-20
Jan-25
1734
1724
1714
1704
1694
1684
1674
1664
1654
1644
1634
Water Level (feet amsl)
10N03E15Q01 -Well Depth: 165'
10N03E15Q02 - Well Depth: 260'
NOTE: Water levels potentially influenced by pumping of well or wells in the vicinity


10N03E27J01-05
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
1750
1740
1730
1720
1710
1700
1690
1680
1670
1660
1650
Depth to Water (feet bgs)
0
10
20
30
40
50
60
70
80
90
100
J05 DRY
12/2007
10N03E27J05 - Perforations: 35' - 45'
10N03E27J04 - Perforations: 70' - 90'
10N03E27J03 - Perforations: 235'-255'
10N03E27J02 - Perforations: 350'-370'
10N03E27J01 - Perforations: 550'-570'
NOTE: Water levels potentially influenced by pumping of well or wells in the vicinity


10N04E11C01
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
1603
1593
1583
1573
1563
1553
1543
1533
1523
1513
1503
Depth to Water (feet bgs)
0
10
20
30
40
50
60
70
80
90
100
10N04E11C01 - Perforations: 110'-120'


10N04E19M02
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Groundwater Elevation (feet amsl)
1710
1700
1690
1680
1670
1660
1650
1640
1630
1620
1610
Depth to Water (feet bgs)
0
10
20
30
40
50
60
70
80
90
100
10N04E19M02 - Perforations: 110'-180'


11N02E07A01 and 12N02E32G02 Composite
Jan-40
Jan-45
Jan-50
Jan-55
Jan-60
Jan-65
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90
Jan-95
Jan-00
Jan-05
Jan-10
Jan-15
Jan-20
Jan-25
Groundwater Elevation (feet amsl)
1790
1780
1770
1760
1750
1740
1730
1720
1710
1700
1690
11N02E07A01 - Perforations: 45' - 60'
12N02E32G01 Depth: 33'



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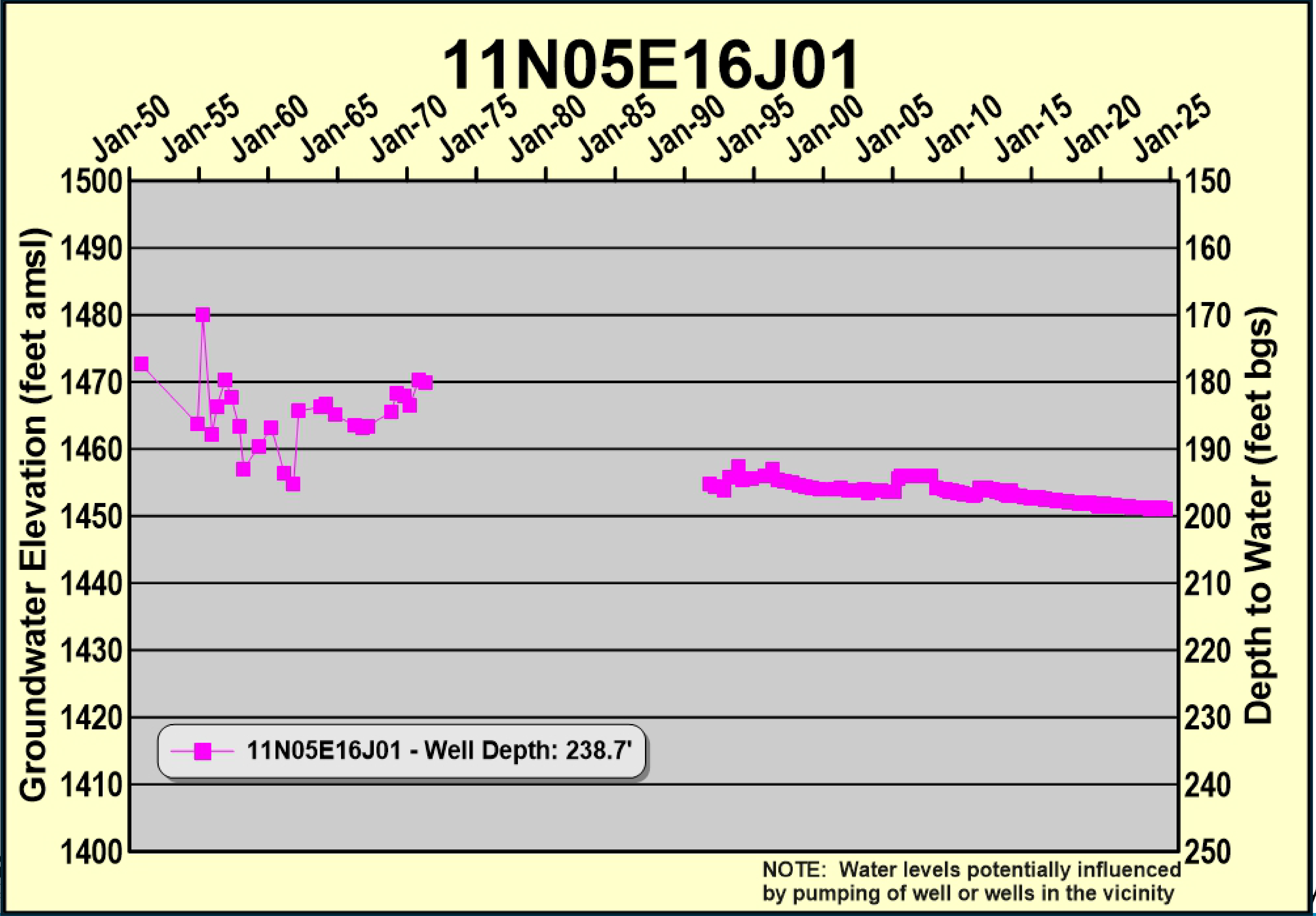
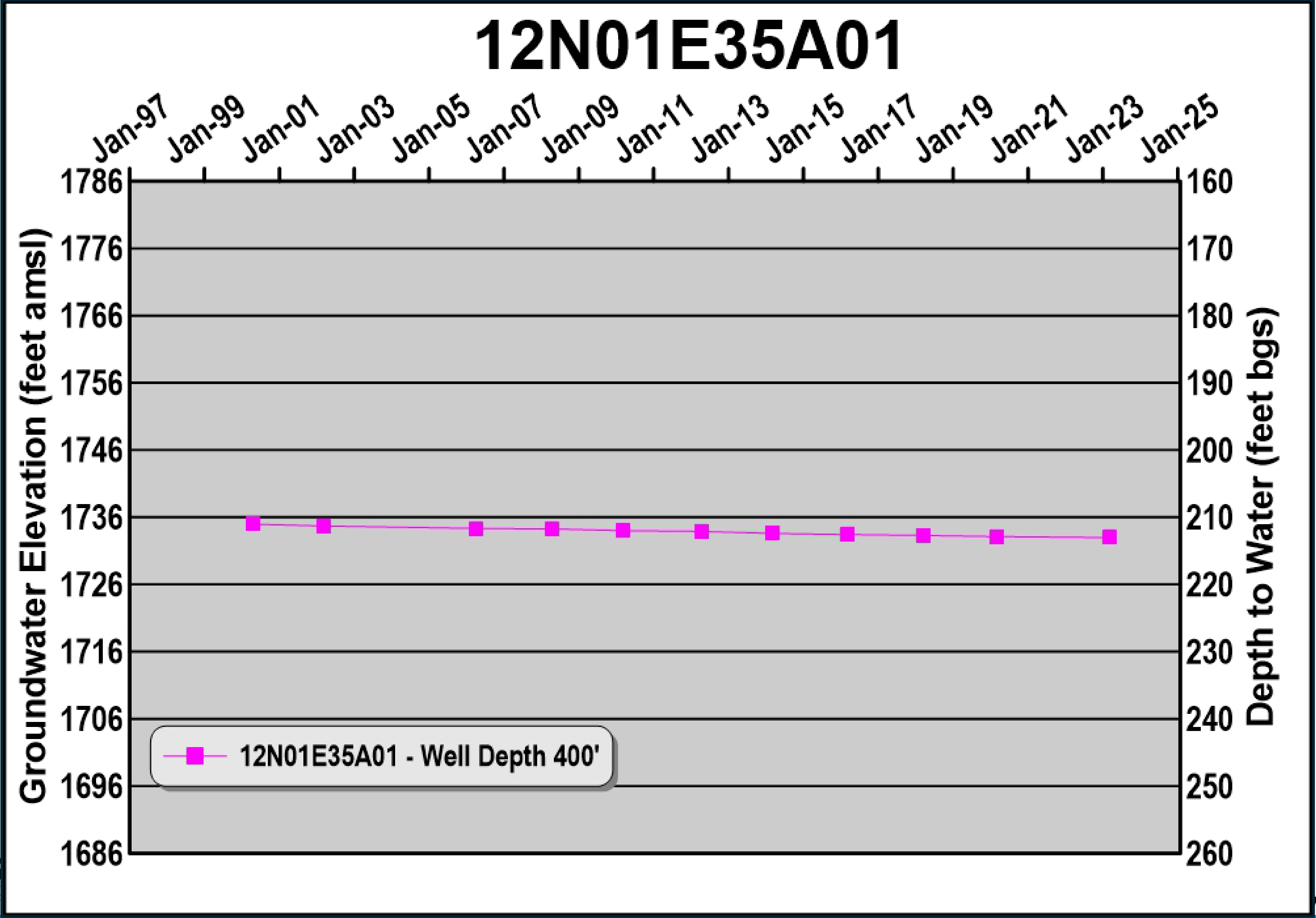

11N05E16J01
Jan-50
Jan-55
Jan-60
Jan-65
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90
Jan-95
Jan-00
Jan-05
Jan-10
Jan-15
Jan-20
Jan-25
Groundwater Elevation (feet amsl)
1500
1490
1480
1470
1460
1450
1440
1430
1420
1410
1400
Depth to Water (feet bgs)
150
160
170
180
190
200
210
220
230
240
250
11N05E16J01 - Well Depth: 238.7'
NOTE: Water levels potentially influenced by pumping of well or wells in the vicinity



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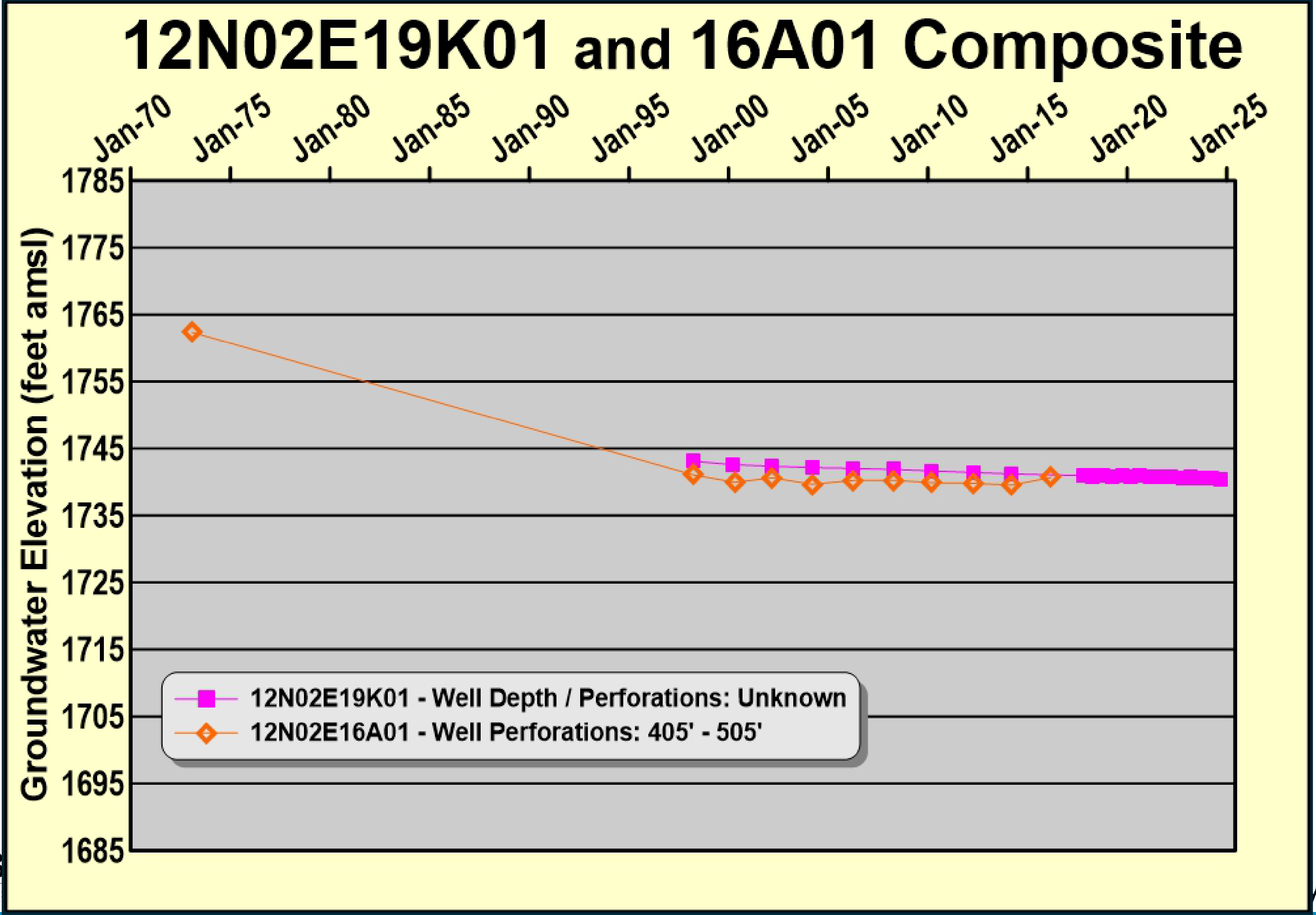

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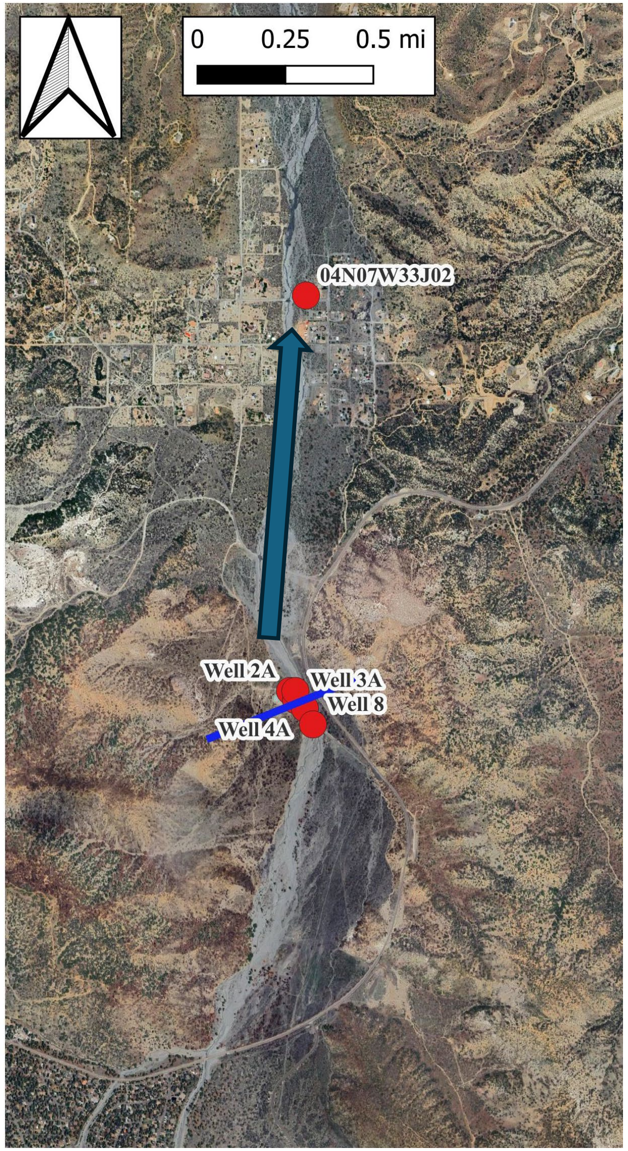
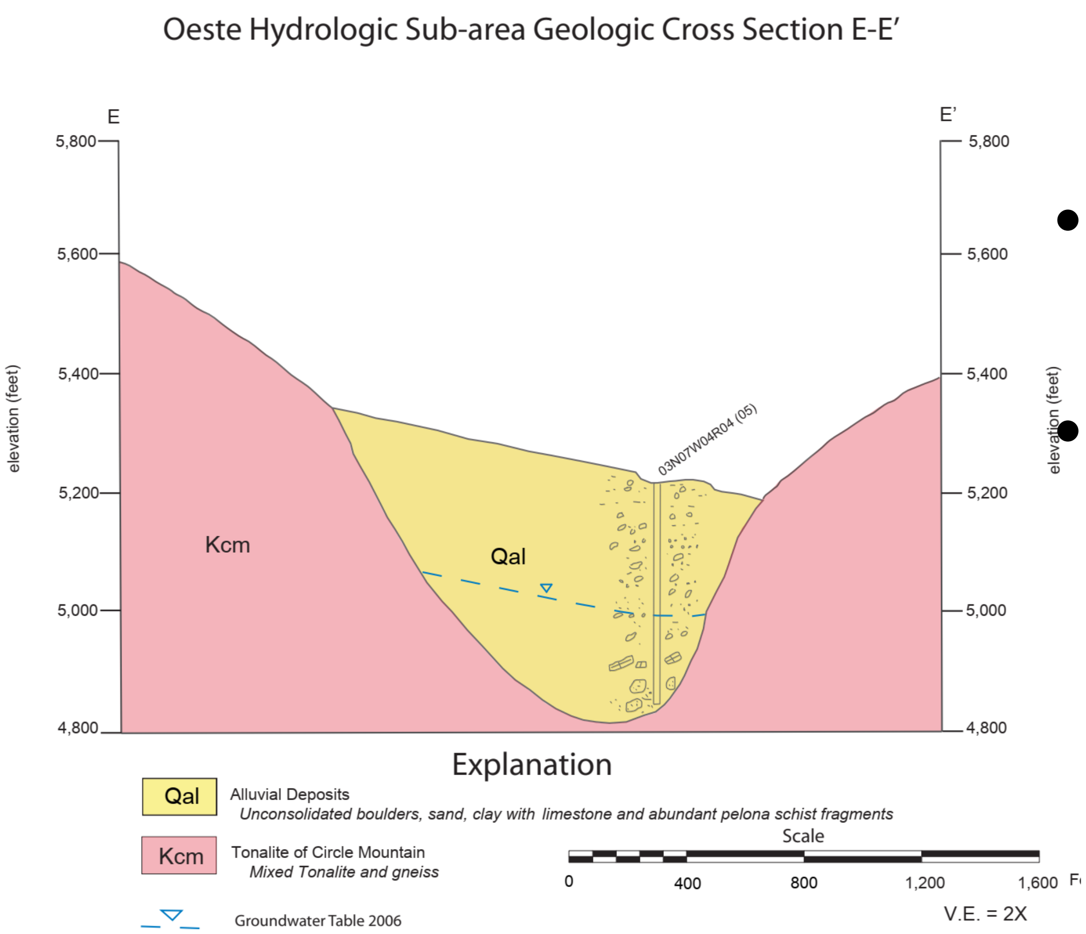
WATERMASTER

EXHIBIT 9

Model Update: Sheep Creek underflow Inflow





- Estimated 536 AFY from Sheep Creek
- More Geophysics being conducted

EXHIBIT 10

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

MEMORANDUM

To: Mojave Basin Area Watermaster

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

Date: April 16, 2025

Re: **Review of Subsurface Flow at the Alto-Centro Subarea Boundary Mojave Basin Area**

This memorandum presents a review of previous studies performed to estimate the annual subsurface flow across the Alto-Centro Subarea boundary. In addition, groundwater data reviewed were used to calculate the annual flow across the Helendale fault, which generally defines the subarea boundary. This review relied on existing maps and data; field investigation or well testing were not performed. The sources reviewed are listed in the References.

Hydrogeologic Setting of the Alto Transition Zone - Centro Boundary (Helendale Fault)

The setting of the area reviewed is shown on the attached geologic map from a study of the Helendale fault by the U.S. Geological Survey (USGS; Stamos and others, 2003, Figure 2). Groundwater flow through the shallow (Floodplain) and deeper alluvial (Regional) aquifers has been evaluated at the Alto Transition Zone (TZ) - Centro Subarea boundary in several prior studies. These prior studies have generally concluded that the Helendale fault, which generally defines the Alto-Centro subarea boundary, does not impede groundwater flow in the shallow Floodplain aquifer. In California Department of Water Resources Bulletin 84 (DWR; 1967), analysis of groundwater levels concluded that the Helendale fault impedes groundwater flow in the deeper, older alluvium (i.e., Regional aquifer), but not within the recent channel deposits of the Mojave River. The study also noted that upstream of the fault, rising water (i.e., an upward gradient) contributes to the Mojave River, while downstream, this condition is reversed.

A 1971 study by Hardt (USGS) also noted that water levels in wells adjacent to the Mojave River near the Helendale fault indicated that the fault impeded flow in the deeper, older alluvium (Regional aquifer), but not within the overlying Mojave River deposits (Floodplain aquifer). Since most pumping and development is from the shallow river deposits of the Floodplain aquifer, Hardt concluded that ground-water movement was little affected by the Helendale fault. Hardt also noted that the fault acts as a barrier in the older alluvium (Regional aquifer) and causes water to move upward to the land surface on the south (upstream) side of the fault, which in part accounts for the abundance of phreatophytes upstream of the fault.

Review of well hydrographs prepared by Mojave Water Agency and U.S. Geological Survey for various years generally indicate that water levels in most wells through the Alto TZ remained stable or rose slightly since the early 1990s, indicating that groundwater storage within the Transition Zone has remained relatively stable or has increased slightly. Hydrographs show a period from about 2000 to 2005 when water levels in wells upstream and south of the fault steadily declined up to about seven feet, but rebounded after a large storm event in 2005. Overall, gradients have remained relatively constant.

In the electric analog model of the Mojave basin, Hardt (1971) developed values for transmissivity (the flow through a vertical strip through the aquifer one foot wide) of the Floodplain aquifer, based on an empirical relationship between specific capacity of a well (the pumping yield per foot of drawdown) and transmissivity. This was obtained mainly by estimating transmissivity of the materials from information on well drillers reports. Hardt notes that the values of transmissivity developed by this method are approximate, and dependent on factors such as the accuracy of the drillers descriptions and estimates of well yield, in addition to construction (efficiency) of the well. Transmissivity developed by this method was about 100,000 gallons per day (gpd) per foot in the channel deposits (i.e., Floodplain aquifer), and much lower, about 5,000 to 25,000 gpd per foot in the adjacent and underlying older alluvium (Regional aquifer). The transmissivity estimates developed by Hardt (1971) have subsequently been used or cited in subsequent studies by USGS and by private consultants.

In 2003, the USGS released a report of the geohydrologic study of the Helendale fault (Stamos and others, 2003). In that study, multi-point wells (piezometers) were installed in four locations near the fault. The USGS performed a well pumping test in one of the wells (8N/4W-20Q12) and monitored the response in the piezometers. The USGS also performed single well (slug) tests to estimate aquifer transmissivity. The pumping test yielded a calculated transmissivity 1,346 gpd per foot for the Floodplain aquifer, much lower than the transmissivities estimated by Hardt (1971) or Stamos and others (2001). However, the USGS concluded that the tested well may have been located in less permeable materials that were not representative of the overall Floodplain aquifer. The single well (slug) test data also did not agree well with prior studies or well test and so were used only as a relative comparison between the wells for the study.

In a 2013 study of the Centro and Baja subareas, Todd Engineers also used the relationship between specific capacity and transmissivity to estimate transmissivities from well logs. They assumed unconfined aquifer conditions and used a conversion factor of 1,500 to estimate a range of 50,000 to 100,000 gpd/ft for the Floodplain aquifer. The estimates assumed an aquifer thickness of 150 feet, similar to the conditions at the subarea boundary.

Prior Estimates of Subsurface Flow Across the Alto-Centro Subarea Boundary

Early investigations of the Mojave River Groundwater Basin by Department of Water Resources, (DWR; Weber, 1967) estimated groundwater flow from the upper Mojave Basin (Alto, Este, Oeste) to the middle Mojave at 2,000 acre-feet per year (AFY). The subsurface flows across the subarea boundary were calculated using a form of Darcy's equation. In this equation, the flow across the boundary in gallons per day Q = TIW; where W is the width of aquifer at the basin boundary in feet; T (transmissivity) is the hydraulic conductivity of the aquifer material times the saturated thickness of the aquifer, expressed in gallons per day per foot of aquifer width; and I is the slope of the groundwater surface (i.e., the gradient).

In a 2001 groundwater model by USGS (Stamos and others), Hardt's 1971 transmissivity data were used as initial input to the model and subsequently adjusted during model calibration. From the 2001 USGS groundwater model simulation, flow across the Helendale fault was calculated to range from 2,444 AFY in 1930 to 720 AFY in 1994, with an average of 1,566 AFY over that period. However, the same report cites an estimate by Gregory Mendez of the USGS that as much as 5,000 to 6,000 AFY of groundwater may actually flow through the Floodplain aquifer across the fault, with an additional 1,200 AFY in the deeper Regional Aquifer.

In a 2003 study of the Transition Zone hydrogeology by URS Corporation, the prior estimates of flow by Weber (1987) at 2,000 AFY and USGS (2001) of 1,556 AFY were presented, as well as an independent calculation of flow across the Helendale fault, using previously developed transmissivity values. In their study, URS estimated that average flow across the Helendale fault, using 1998 water levels, was about 3,358 AFY in the Floodplain Aquifer and about 1,220 in the deeper Regional Aquifer across the Helendale fault.

Updated Estimate of Flow Across Alto TZ-Centro Boundary

As part of the current review, we also performed an estimate of groundwater flow across the Helendale fault. Our analysis used water levels and gradients calculated from USGS regional water table maps and MWA hydrographs (see attached 2025 hydrograph map) for the period from 2006 to 2016, and the cross-sectional area of the Floodplain aquifer measured from Cross Section A-A' (see attached) in the 2003 USGS Helendale fault study (Stamos and others, 2003). In addition, we used MWA monitoring data from 2024 to evaluate recent conditions. We compared Floodplain aquifer thickness shown on the USGS cross section (denoted by symbols Qra and Qya) to unpublished cross sections we prepared (Wagner & Bonsignore, 2024) as part of MWA's groundwater model update and found good agreement. Additionally, a transmissivity of 100,000 gpd per foot was used, based on information presented in Hardt (1971) and was divided by an aquifer thickness of 150 feet to obtain a hydraulic conductivity (k) of 666 gallons/day or equivalently, 89 ft/day.

Gradients were estimated from measurements taken from relatively small-scale USGS regional water table maps and so are considered approximate. From the period of 2006 to 2016, water levels near the cross section varied from about 2,391 to 2,396 feet and gradients in the vicinity of the USGS cross section generally ranged from about 0.0024 to 0.0043. The results of our analysis are shown in the following table:

Subsurface Flows at USGS Cross Section A-A’ (Stamos and others, 2003; see attachments)

Year	Groundwater Elevation Near Fault (Well Number)	Measurement Date	Average Gradient	Wells and Elevations Used for Gradient Calculation/Distance	Flow through Section, AFY
2006	2,395 (20Q11)	4/21/2006	0.0043	6N1(2,463) – 29E6(2,401) 2.69 mi.	3,411
2010	2,394 (19G4)	3/29/2010	0.0041	6N1(2,459) - 29E6 (2,401)/ 2.69 mi.	3,253
2012	2,396 (19G4)	3/13/2012	0.0029	6N1(2,444) - 29E6 (2,402)/ 2.69 mi.	2,301
2014	2,392 (20Q13)	3/3/2014	0.0030	6F7 (2,438) – 29E6 (2,402)/ 2.27 mi.	2,380
2016	2,391 (20Q13)	3/8/2016	0.0031	6F7 (2,438)- 29E6 (2,401)/ 2.27 mi.	2,459
2018	2,390 (20Q11)	Annual Averages	0.0041	6F7 (2,434) - 29E6 (2,385) / 2.27 mi.	3,253
2020	2,391 (20Q11)		0.0042	6F7 (2,436)- 29E6 (2,386) / 2.27 mi.	3,332
2022	2,390 (20Q11)		0.0042	6F7(2,436) - 29E6 (2,386) / 2.27 mi.	3,332
2024	2,392 (20Q11)		0.0041	6F7 (2,437) - 29E6 (2,388)/ 2.27 mi.	3,253
Averages	2,393		0.0038		2,997

Note: Water level data from 2006 – 2016 from USGS; data from 2018 – 2024 are from MWA. Gradient calculations for 2018 to 2024 were based on average water levels for the year.

The subsurface flow analysis performed above indicates that flow through the Helendale fault has exceeded 2,000 AFY for the period reviewed. While our analysis relied primarily on water-table maps by USGS published through 2016 and MWA well monitoring data from 2018 to 2024, water levels in wells south and upstream of the fault (Alto TZ) have only changed slightly over time. Since water levels and gradients have been small over time, changes in flow through the subarea boundary are also expected to be small.

Discussion and Conclusions

As previously discussed, calculation of flow using Darcy’s Law requires three inputs; cross sectional area, gradient, and permeability/transmissivity. Of these, cross sectional area and gradient can be determined or calculated from well data and water levels. In the analysis, we calculated the area of the saturated Floodplain aquifer using the USGS cross section and an average groundwater elevation of about 2,393 feet. This was the approximate average water level during the period analyzed, although variations in water levels might introduce a few percent of error into the calculations.

Somewhat more difficult to measure is transmissivity, which was obtained from the references reviewed and was based on the approximate relationship between the pumping yield and drawdown observed in newly completed wells, often during initial development. Ideally, transmissivity data would be obtained by controlled, constant-rate pumping tests in several locations, in wells that fully penetrate the aquifer (i.e., at least 150 feet deep in this area). However, without these types of tests, the use of specific capacity data to estimate transmissivity is a broadly accepted method in hydrogeologic studies and is a typical method used in development of groundwater models.

As shown above, the calculated subsurface flow has averaged about 2,997 acre feet per year at Helendale Fault and has been as high as 3,411 acre feet and as low as 2,301 acre feet. The average is at nearly 3,000 acre feet per year, which is about 50% higher than the 2,000 acre feet per year assumed for the Judgement. Additionally, MWA monitoring data for well 08N04W20Q11, located just upstream of the Helendale fault indicates that water levels are little changed since 2018.

Attachments

Geologic Map and Explanation Sheet from Stamos and others, USGS, 2003 (Figure 2)
Cross Section A-A' from Stamos and others, USGS, 2003 (Figure 3)
Alto Subarea Transition Zone Hydrographs 2025 – MWA

References

Albert A. Webb Associates, 2000, Consumptive Water Use Study and Update of Production Safe Yield Calculations for the Mojave Basin Area: Unpublished report to the Mojave Basin Area Watermaster, dated February 16, 2000, 234p.

Hardt, W.F., 1971, Hydrologic Analysis of Mojave River Basin, California, Using Electric Analog Model: U.S. Geological Survey Open File Report 72-157, 91p.

Mojave Water Agency, 2025, Alto Subarea Transition Zone Hydrographs 2025: unpublished well hydrograph maps prepared by Mojave Water Agency staff.

Richard C. Slade & Associates LLC, 2011, Review of Subsurface Data for Northern Transition Zone, Mojave Water Agency: Unpublished Technical Memorandum to Mojave Water Agency, dated May 31, 2011, 44p.

Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F., 2001, Simulation of Ground-Water Flow in the Mojave River Basin, California: U.S. Geological Survey Water-Resources Investigations Report 01-4002, Version 3, 137p., with illustrations.

Stamos, C.L., Cox, B.F., Izbicki, J.A., and Mendez, G.O., 2003, Geologic Setting, Geohydrology and Ground-Water Quality near the Helendale Fault in the Mojave River Basin, San Bernardino County, California: U.S. Geological Survey Water-Resources Investigations Report 03-4069, 53p.

Todd Engineers with Kennedy/Jenks Consultants, 2013, Final Report, Conceptual Hydrogeological Model and Assessment of Water Supply and Demand for the Centro and Baja Management Subareas, Mojave River Groundwater Basin: Unpublished report to the Mojave Water Agency, dated July 2013, 291p. with Appendices.

URS Corporation, 2003, Mojave River Transition Zone Recharge Project, Phase I Report, Transition Zone Hydrogeology: Unpublished report to the Mojave Water Agency, dated March 13, 2003, 112 p., with tables and illustrations.

U.S. Geological Survey, 1996-2016, Regional Water Table in the Mojave River and Morongo Groundwater Basins, Southwestern Mojave Desert, California: Scientific Investigations Maps/Reports prepared by various authors, scale 1:170,000.

Wagner & Bonsignore Consulting Engineers, 2024, Draft geologic cross sections and explanatory text for the Baja and Centro Subareas, Mojave River Groundwater Basin: unpublished consultants report to Mojave Water Agency, 18 sheets (cross sections) and 18p (text).

Weber, E.M. (Supervising Geologist), 1967, Mojave River Groundwater Basins Investigation: California Department of Water Resources, Bulletin 84, 196p, with figures and tables.

Figures from Stamos and others, 2003, USGS Water-Resources Investigations Report 03-4069

Geologic Setting, Geohydrology, and Ground-Water Quality near the Helendale Fault in the Mojave River Basin, San Bernardino County, California

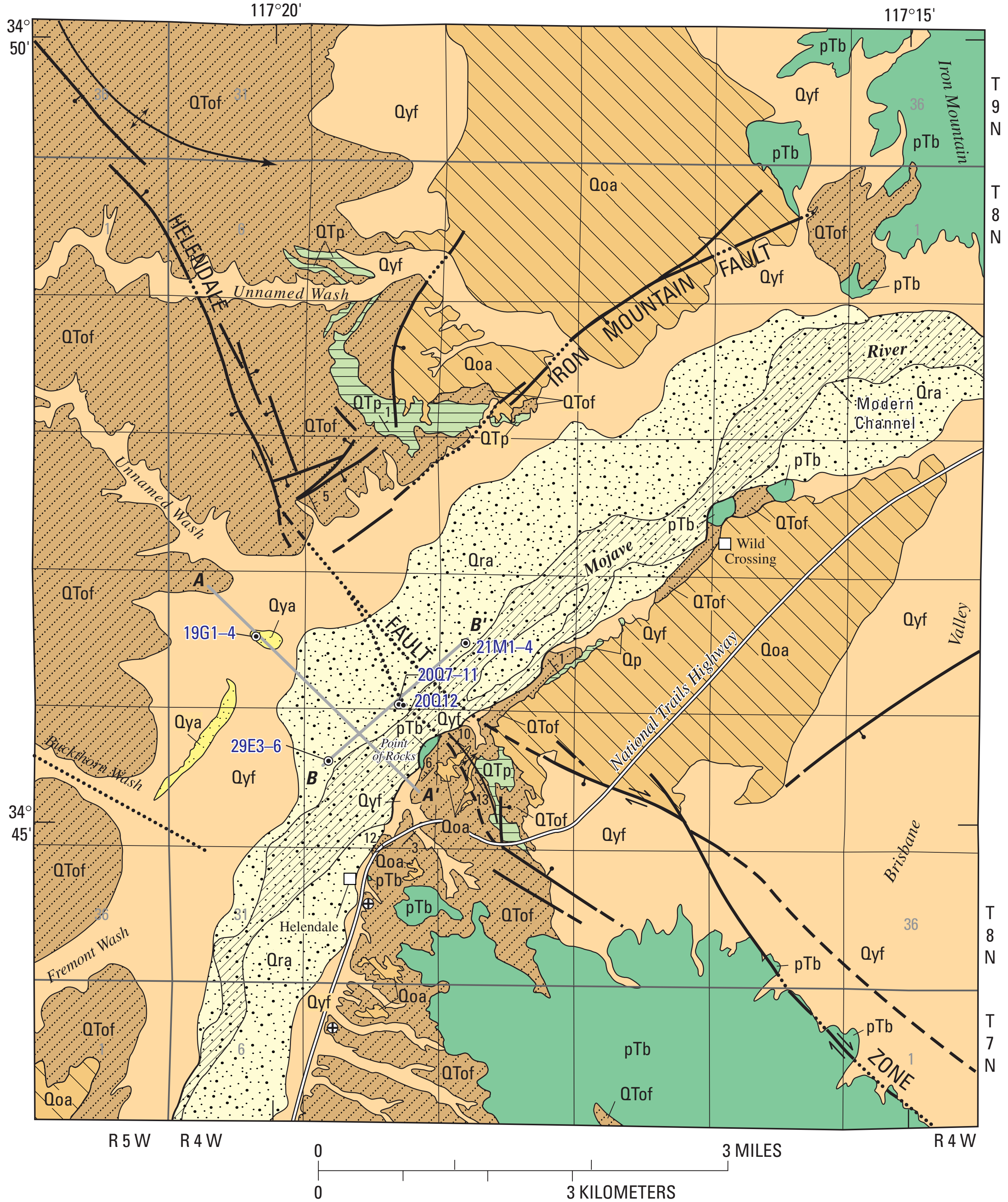


Figure 2. Surface geology, line of cross sections *A–A′* and *B–B′*, and location of the multiple-well monitoring sites near Helendale, San Bernardino County, California.

Reference: Stamos and others, USGS, 2003

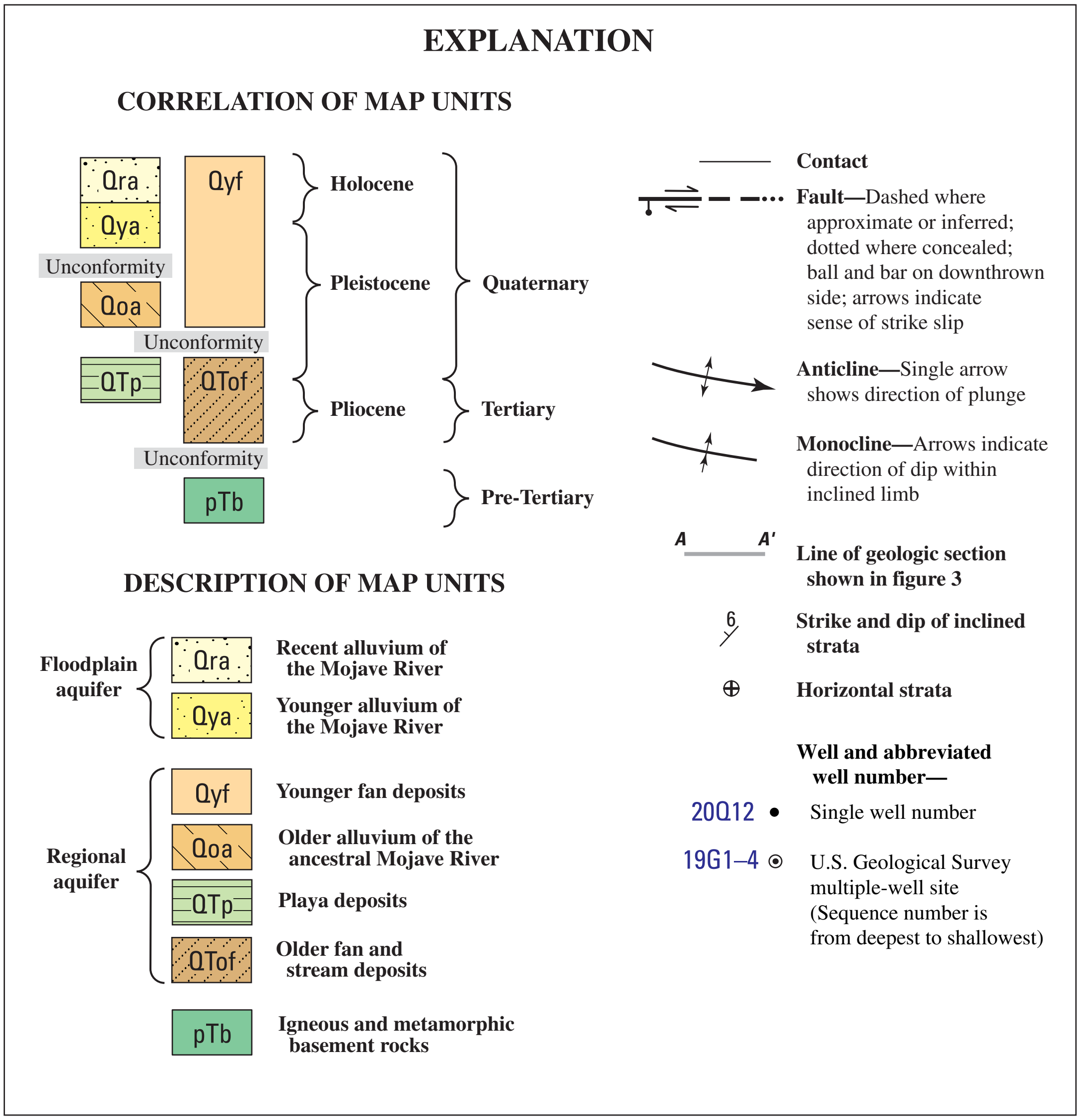


Figure 2.—Continued.

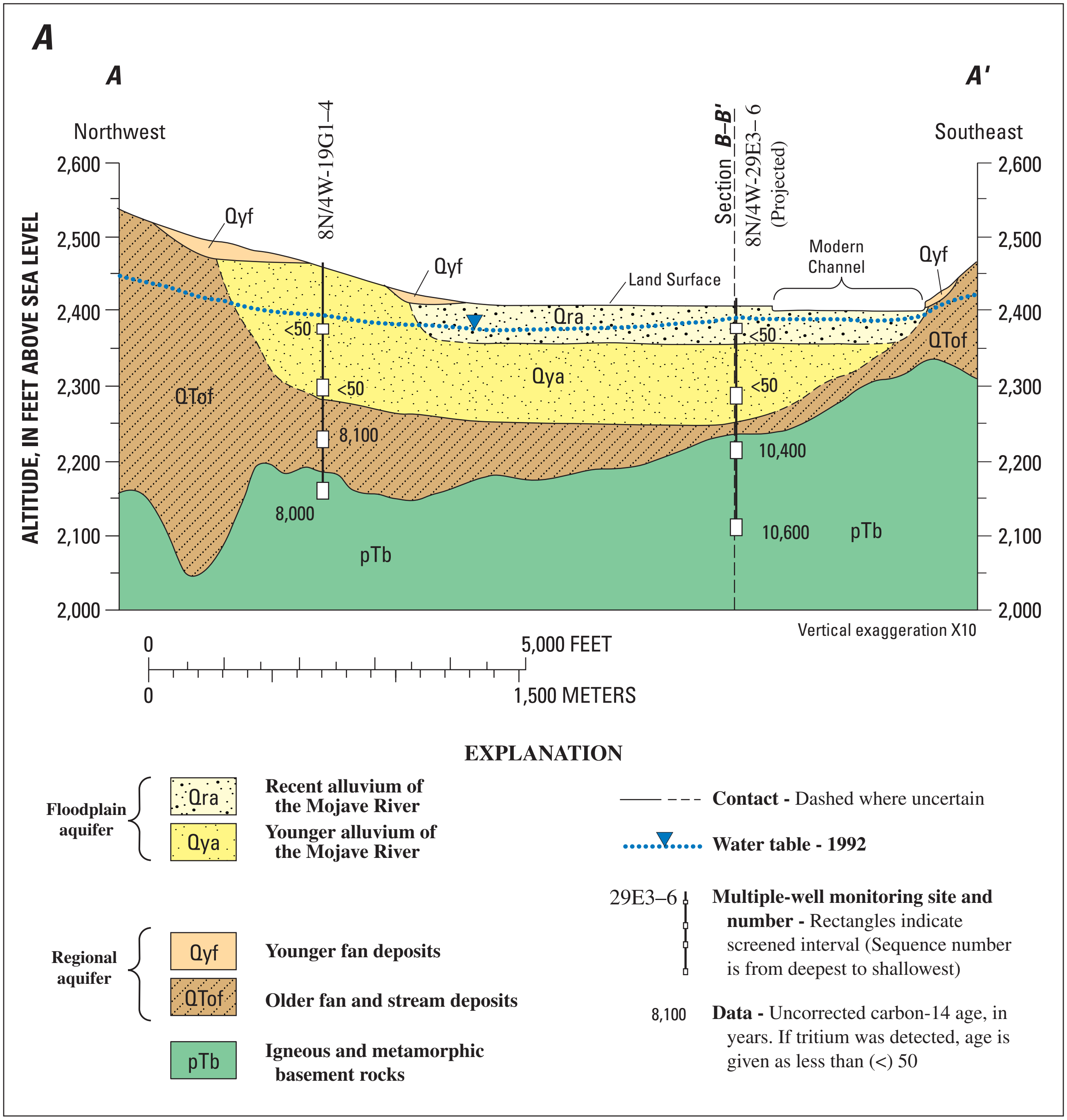
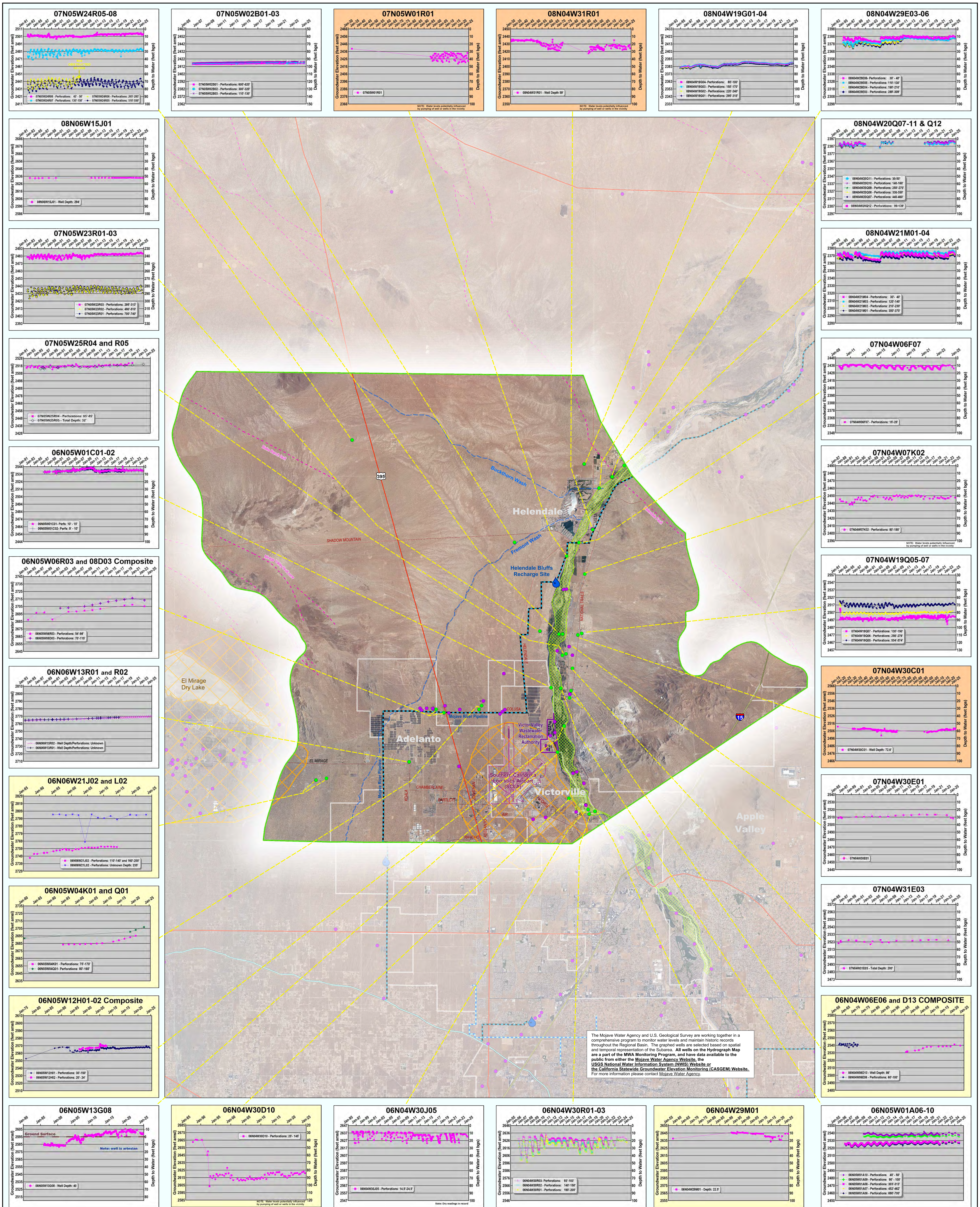


Figure 3. Geologic cross sections near Helendale, San Bernardino County, California, (*A*) cross section *A–A′*, and (*B*) cross section *B–B′*.

Mojave Water Agency, 2025

Alto Subarea Transition Zone Hydrographs 2025



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 2025

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

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