MEMORANDUM

ROUX

Date: May 2, 2024

To: Mason Voehl - Amargosa Conservancy

From: Andy Zdon, P.G., CEG, C.Hg.

Subject: **Preliminary Review - Beatty Area Mine Dewatering**
Amargosa Desert, Oasis Valley and Crater Flat Hydrographic Basins, Nevada

Several proposed mining operations and their associated groundwater pumping projects are situated in the upper Amargosa watershed, specifically in the Amargosa Desert, Oasis Valley, and Crater Flat hydrographic basins. While these operations are in the development phase, the number of them, and the associated potential cumulative impacts on the Amargosa River and feeder springs has raised concerns. Pumping for dewatering and mine operations can have substantial effects on local hydrology, particularly in arid regions such as in the Beatty, Nevada area. On behalf of Amargosa Conservancy, Roux Associates, Inc. (Roux) has modeled multiple scenarios related to potential minerals extraction related groundwater pumping in the Beatty area. This, to obtain a preliminary conceptualization of potential effects to groundwater-dependent ecosystems in the area.

For the purposes of considering the perennial yield and existing underground (groundwater) rights, in this technical memorandum (memo), the Crater Flat, Oasis Valley, and Amargosa Valley hydrographic basins have been lumped with other basins (inclusive of basins #225 through #230) in the surrounding area. These other basins include Mercury Valley, Rock Valley, Fortymile-Jackass Flat, and Fortymile Buckboard Mesa, respectively. The combined estimated perennial yield of these basins is 24,000-acre feet per year (afy), while the committed groundwater rights represent 25,635 afy, indicating an over-allocated area (Nevada Department of Water Resources, 2024).

Numerous regional springs are present in the Oasis Valley basin, a spring is present (Specie Spring) approximately three miles west of the proposed pumping area in the Crater Flat Hydrographic Basin, and Amargosa Desert is the site of Ash Meadows National Wildlife Refuge and its numerous springs, and Devil's Hole. The Amargosa River has perennial flow in segments throughout the Oasis Valley basin.

BACKGROUND

The volume of groundwater in storage is an important aspect of the groundwater system. Changes in storage are identified in the field by changes in groundwater levels. A fundamental groundwater equation and the basis for evaluations of groundwater budgets (inflow vs. outflow estimates) is:

Inflow – Outflow = Change in Storage

When outflow exceeds inflow, there is a negative change of groundwater in storage and groundwater levels can be expected to decline. When inflow exceeds outflow, the reverse is true. When the system is in equilibrium, water levels will generally remain relatively constant despite short-term fluctuations. For the purposes of this evaluation we have evaluated changes to the system based on existing conditions. Long-term groundwater level declines are an indication that outflow is exceeding inflow for an extended

4165.0001S.100/MR

period of time. It should also be noted that in many areas, the recovery of groundwater levels following groundwater being removed from storage can take longer than the period it took to decline, depending on the volume removed from storage, groundwater recharge, precipitation trends and the geology of the basin. As will be described further in this memorandum, this aspect of recovery is also observed in the analysis herein.

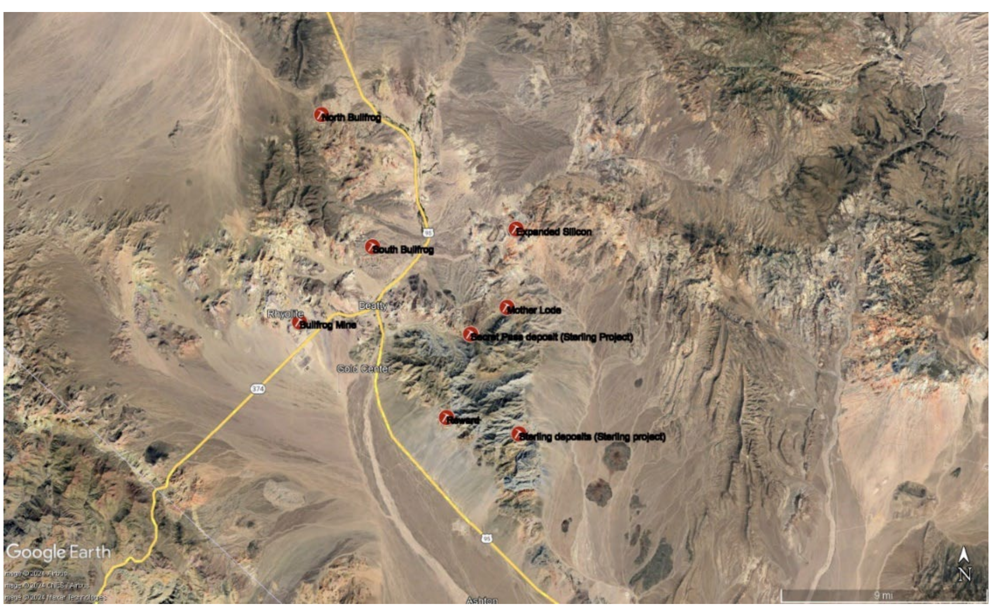
When a groundwater system is in equilibrium where inflow equals outflow, groundwater levels will be stable. Groundwater pumping would cause a disruption in this equilibrium, and recharge amounts and other biological/hydrologic conditions can change. More often, discharge amounts and patterns are impacted.

Regardless of the amount of groundwater pumped, there will always be groundwater drawdown (and the removal of water from storage) in the vicinity of pumping wells, a necessity to induce the flow of groundwater to said wells. For most groundwater systems, the change in storage in response to pumping is a transient phenomenon that occurs as the system readjusts to the pumping stress. The relative contributions of changes in storage, increases in recharge, and decreases in natural discharges evolve over time. If the system can come to a new equilibrium (i.e., a combination of increased recharge and/or decreased discharge), the storage decreases will stop, and inflow will again equal outflow with the changes to the inflow/outflow components described above.

APPROACH

In order to evaluate the effects that pumping for dewatering and other operations from the several potential gold mines could have over an extended period of time, Roux used the U.S. Geological Survey's Death Valley Regional Flow System Model 3 (DV3) developed by Halford and Jackson (2020). The model currently provides the most robust tool for evaluating groundwater changes in the Amargosa Desert area. Given the construction of the DV3 model, the use of the model will provide results (e.g., drawdown) that are relative to existing conditions and water fluxes are not absolute values but changes from "predevelopment" conditions. The distribution of the proposed test mines are provided on Figure 1 below.

Figure 1. Distribution of Local Mines and Proposed Operations



Roux used the DV3 model as developed and made no structural changes to the model. All pumping was assumed to occur in Model Layer #2, as Model Layer #1 is absent in the area. Model Layer #2 is approximately 400 feet thick near the mine locations. Pumping was assumed to continue for 15 years, followed by 15 years of recovery for all scenarios. The selected test locations were assumed to be at the North and South Bullfrog Mines, Bullfrog Mine, and Expanded Silicon Mine (see Table 1 below). Model hydraulic conductivities near the Mother Load and Secret Pass mine locations were too low to support the minimum per-mine trial dewatering rate of 250 afy, so those locations were not simulated. Additionally, the Reward and Sterling deposit locations were not requested by Amargosa Conservancy to be included in this analysis.

Table 1. Simulated Groundwater Extraction Points

Mine	x (NAD83 UTM Zone 11 meters)	y (NAD83 UTM Zone 11 meters)	Scenario 1 (AFY)	Scenario 2 (AFY)	Scenario 3 (AFY)
North Bullfrog	517837.8759	4098126.77	250	250	3,000
South Bullfrog	523351.6706	4088955.246	250	1,000	3,000
Bullfrog	516291.4123	4083583.756	250	250	3,000
Expanded Silicon	530584.6478	4090607.493	250	1,000	3,000

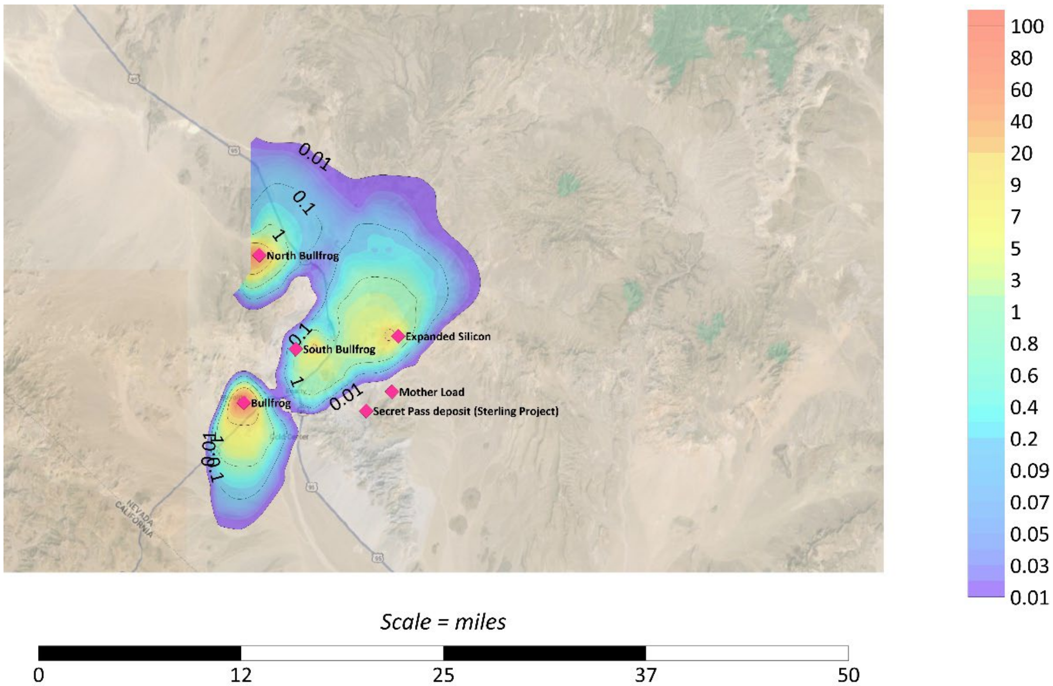
At the four remaining locations (North and South Bullfrog, Bullfrog, and Expanded Silicon), Roux assumed a trial dewatering depth to about 100 feet. This is important for reconciling the pumping rates with the model hydraulic conductivities in the context of the current grid spacing. In general, at the four remaining mine testing locations, transmissivities are too low to support even a 250 afy pumping rate when modeled as points in the x-y plane (i.e., as individual wells). Instead, the coarse grid spacing (in some cases up to about 5,000 feet on the side in the east-west direction), when used with a single well placed within these cells, implies a sort of dewatering drainage system across the finite-sized grid cell. This conceptualization should still produce a reasonable model of the groundwater head perturbation away from the pumped grid cell. Of note is that the North Bullfrog Mine location is close to the edge of the model and hence grid boundary effects may be present.

The dewatering simulations of the North Bullfrog Mine and Bullfrog Mine locations were able to result in the 100 feet of dewatering with about 250 afy of discharge (this is for both Scenarios 1 and 2, attached). For the South Bullfrog Mine and Expanded Silicon Mine locations, Roux moved the pumping location by one grid cell (see white arrows on grid-vs-log hydraulic conductivity figure) into more permeable material to allow evaluation of a higher pumping rate (1,000 afy each, as opposed to 250 afy each). Scenarios 2 and 1 refer to these variations, respectively. Scenario 3 was added as a maximum discharge rate scenario.

DRAWDOWN AND RECOVERY

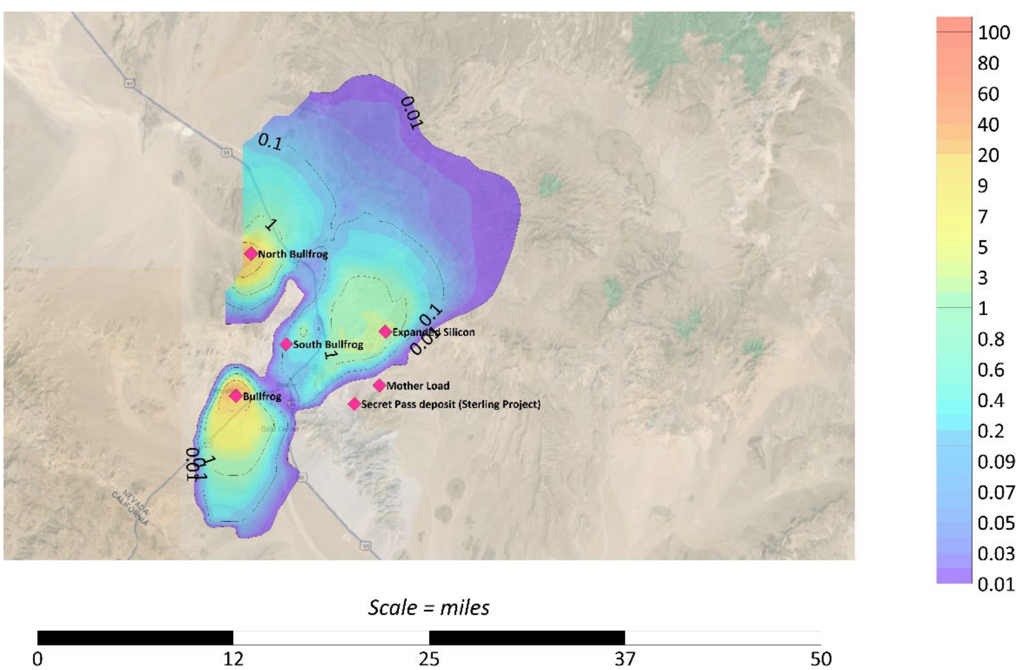
As estimated by DV3, the drawdown from the combined pumping are presented in the figures below (Figures 2 through 7). Scenario 1, which assumed a minimal pumping of 250 afy for 15 years from the four test mine locations, resulted in a cone of depression as presented in Figure 2. As seen on Figure 2, the four individual cones of depression coalesce into a regional cone that extends into the northern Amargosa Desert hydrographic basin on the south and into the Sarcobatus Flat hydrographic basin to the northwest (beyond the model grid). The cone of depression is cut off at the model grid boundary.

Figure 2 – Drawdown for Scenario 1 – Pumping 15 Years



Following 15 years of recovery at the Scenario 1 pumping rates, residual drawdown is shown on Figure 3 below.

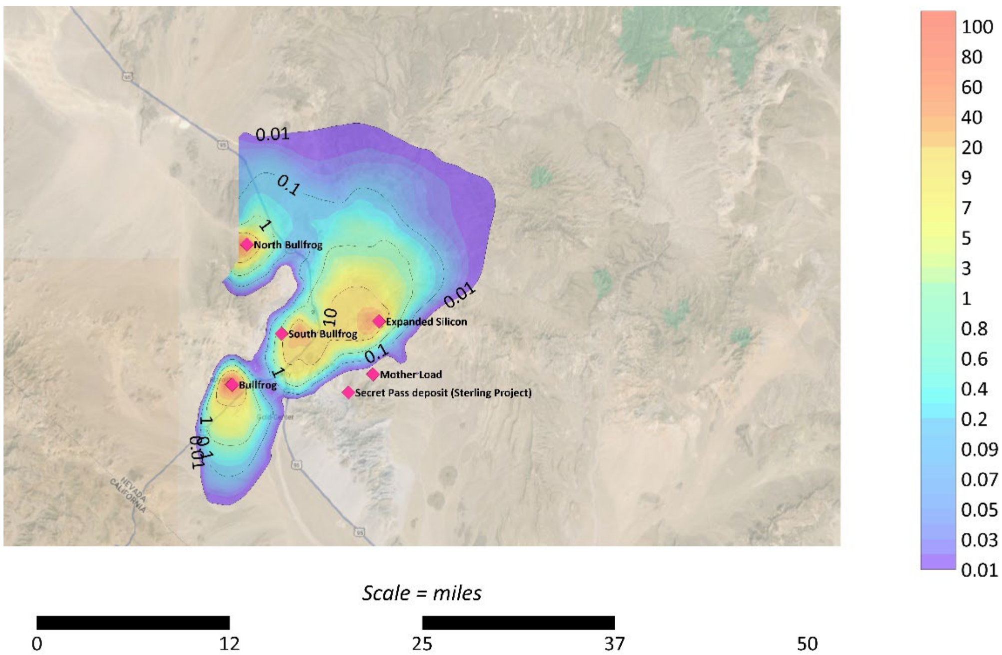
Figure 3. Residual Drawdown following 15 years of Recovery for Scenario 1 (



As can be seen, following 15 years of recovery, although varying degrees of drawdown recovery are observed, the footprint of the regional cone of depression continues to expand, primarily northeastward toward upper the Oasis Valley hydrographic basin. This is a common relationship for groundwater recovery following pumping projects in arid and semi-arid terrains.

Scenario 2, which assumed a pumping of 250 afy for 15 years from the North Bullfrog and Bullfrog Mines, and 1,000 afy for 15 years from the South Bullfrog and Expanded Silicon Mines. As seen on Figure 4, the four individual cones of depression coalesce into a regional cone that is more expansive and of greater magnitude of drawdown than that seen for Scenario 1.

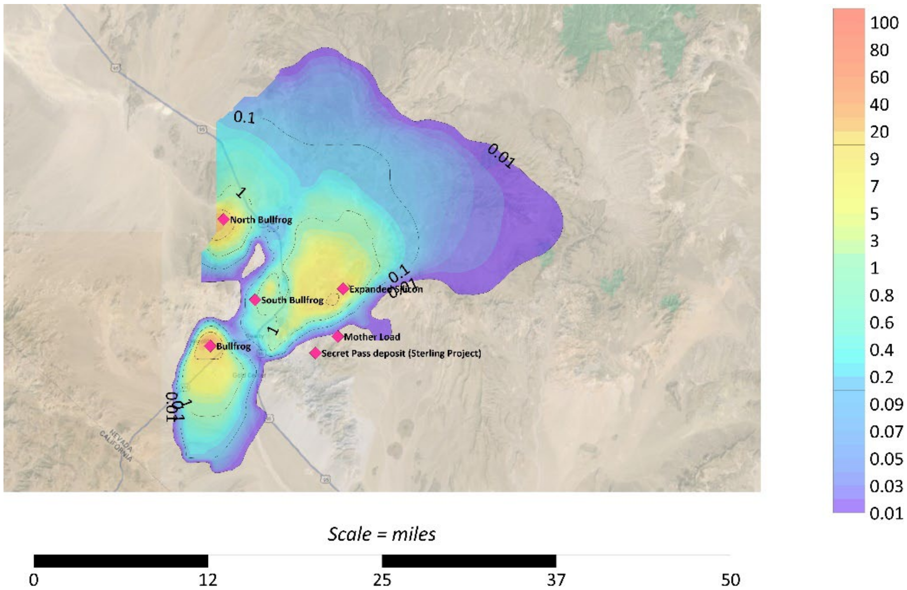
Figure 4. Drawdown for Scenario 2 – Pumping 15 Years



Approximately 80 to 100 feet of drawdown occurs around each of the test location extraction points, and drawdowns of more than 10 feet can be observed along the course of the Amargosa River in the Oasis Valley hydrographic basin. More on the ramification of flow in the Amargosa River will be discussed later in this memo, in the Discussion Section below.

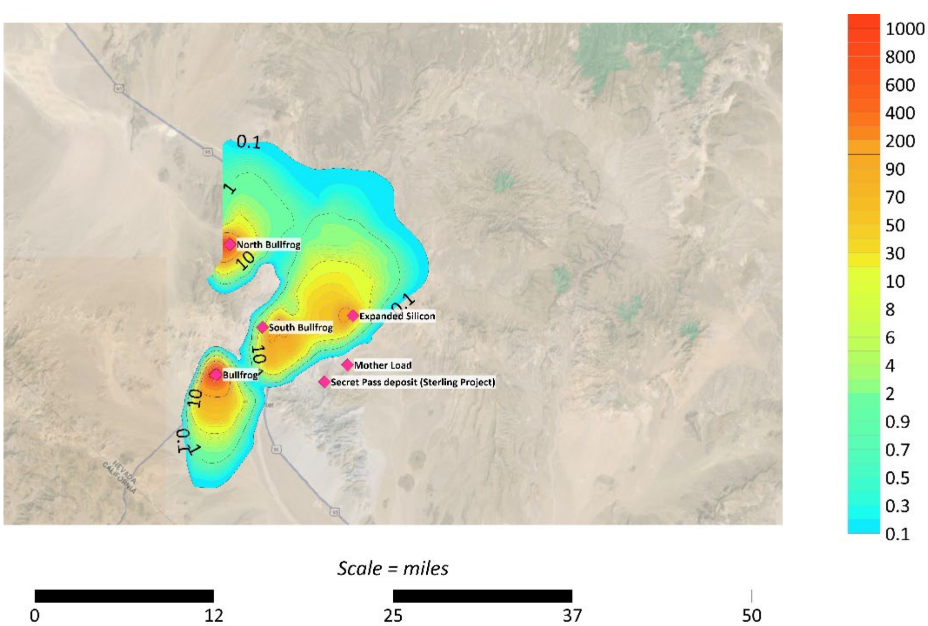
Following 15 years of recovery after Scenario 2 pumping, similar to Scenario 1 (although varying degrees of drawdown recovery is observed), the footprint of the regional cone of depression continues to expand, primarily northeastward toward upper Oasis Valley hydrographic basin.

Figure 5. Residual drawdown after 15 years of recovery – Scenario 2



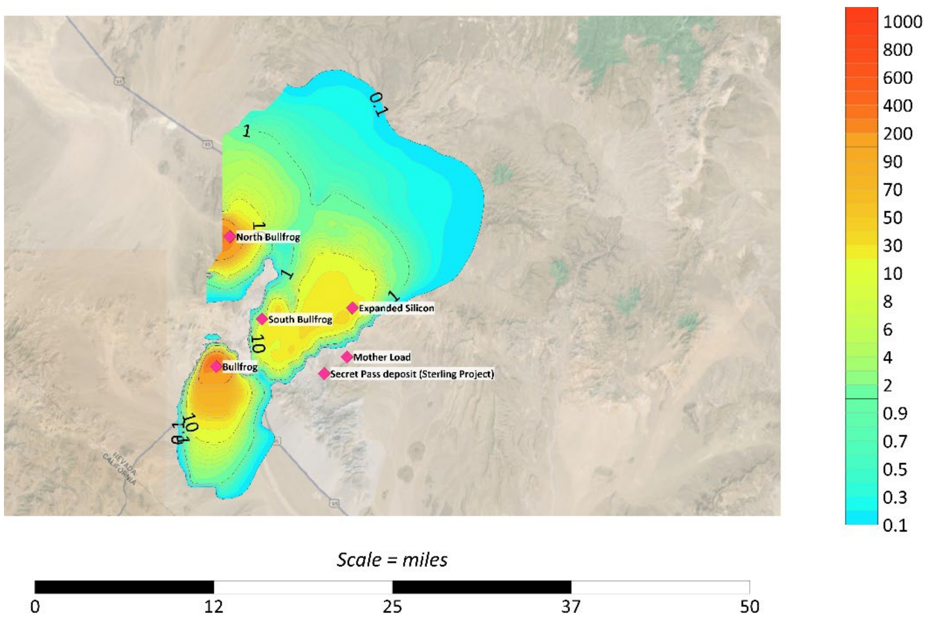
For Scenario 3, Roux assumed a larger scale of pumping with 3,000 afy of discharge from each of the four extraction test locations for 15 years. As would be expected, the drawdown associated with this scenario is substantially greater than for Scenarios 1 and 2 (Figure 6). In this case, 10 to 50 feet of drawdown is simulated along the Amargosa River corridor between the South Bullfrog and Expanded Silicon Mines. The regional cone of depression is more expansive and of substantially greater magnitude in this scenario, as would be expected. Note that the minimum contour is different than in the figures for Scenarios 1 and 2.

Figure 6. Drawdown for Scenario 3 – Pumping 15 Years



Following 15 years of recovery after Scenario 3 pumping, the footprint of the regional cone of depression continues to expand (although varying degrees of drawdown recovery is observed), primarily northeastward toward upper the Oasis Valley hydrographic basin. Also, 10 feet or more of residual drawdown remains along significant reaches of the Amargosa River.

Figure 7. Residual Drawdown following 15 Years of Recovery – Scenario 3



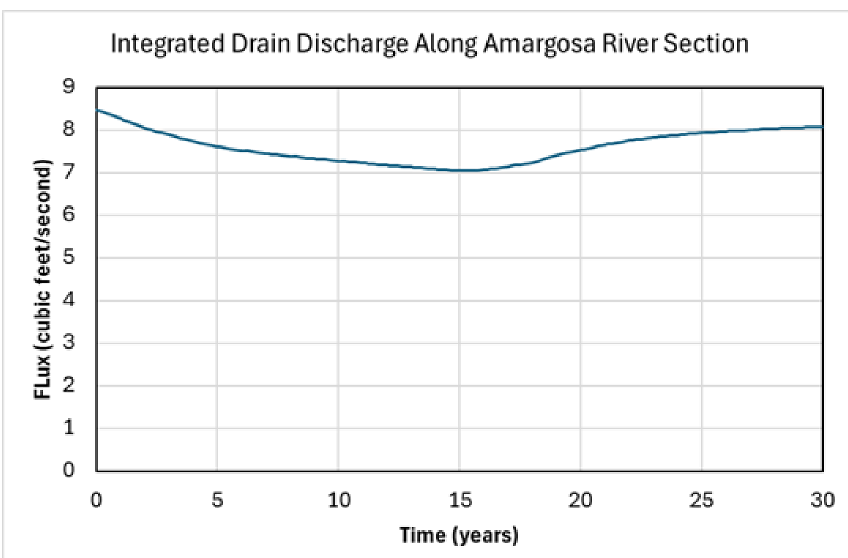
DISCUSSION

The principal concern related to the potential groundwater extraction pumping projects, due to existing and planned mining operations in the Beatty area, are impacts to springs and particularly the "gaining" reaches of the Amargosa River. As observed in each of the scenarios, groundwater drawdown is observed throughout much of Oasis Valley hydrographic basin, with substantial drawdown observed along the trace of the Amargosa River. This indicates that reductions in spring flow and Amargosa River flow would likely be substantial under these scenarios, affecting the extent of surface water along the Amargosa River, and reducing spring flows. Locations of springs in the area of the cone of depression are presented on the following page (Figure 8).

In order to consider the Oasis Valley hydrograph basin and the Amargosa River in a more granular fashion, Roux developed the following graph (Figure 9), which illustrates the discharge via the drain package from cells lining the Amargosa River in the Beatty area for Scenario 2. Roux converted the drain discharges into cubic feet per second (cfs) as it makes it easier to consider stream flow. The discharges are not flow rates in the Amargosa River, but rather the total flux through the drain cells lining the part of the river from the narrows below Beatty, and upstream.

Figure 8. Study Area Springs and Wells

Figure 9. Integrated Drain Discharge – Scenario 2



As can be seen, the flux decreases over the 15-year pumping period, with recovery (but not full recovery) during the 15 years after pumping ceases. This represents about a 17% reduction in the integrated discharge to the Amargosa River at the end of 15 years. The specific fate of where that lost water would have gone otherwise (e.g., riparian evapotranspiration, downstream flow) is not able to be determined, although the water is most likely resulting in reductions of both evapotranspiration and underflow toward Amargosa Desert hydrographic basin.

The drawdown figures (Figures 2 through 7) provided in the memo also indicate that the bedrock narrows along the Amargosa River below Beatty appear to limit drawdown extending southward into the Amargosa Valley, as a result of pumping from the North and South Bullfrog Mines and Expanded Silicon Mine test locations. This results in considerable risk to both springs and the Amargosa River within the Oasis Valley hydrographic basin, particularly as it relates to the continued expansion of the regional cone of depression after pumping ceases. As shown in the figures, the expansion of the regional cone of depression over time, including during recovery is generally northeast and east from the Amargosa River, the direction of many springs (Figure 8). Once pumping ceases, the extent to which the regional cone of depression expands and its magnitude is not controllable, it may continue to affect these ecological resources for decades longer than the amount of time the pumping (i.e., groundwater discharge) occurred.

REFERENCES

Halford, K.J., and Jackson, T.R., 2020, Groundwater characterization and effects of pumping in the Death Valley regional groundwater flow system, Nevada, and California, with special reference to Devils Hole: U.S. Geological Survey Professional Paper 1863, 178 p., https://doi.org/10.3133/pp1863

Nevada Department of Water Resources, 2024. Amargosa Desert Hydrographic Area Summary https://water.nv.gov/DisplayHydrographicGeneralReport.aspx?basin=230