MEMORANDUM

Date: 13 September 2021

To: Kyle Roerink, Great Basin Water Network

From: Andy Zdon and Josh Osborne, Roux Associates, Inc.

Subject: **Groundwater impacts of the proposed Pine Valley Water Supply Project, Utah on Nevada groundwater basins with a Focus on Snake Valley, Nevada & Utah**

This technical memorandum related to the proposed Central Iron County Water Conservation District (CICWCD) Pine Valley Water Supply Project (Pine Valley Project) has been prepared by Roux, Inc. (Roux) on behalf of the Great Basin Water Network (GBWN). Although the proposed Pine Valley Project is in Utah, the effects of the project are likely to extend well into Nevada. Although the focus of this technical memorandum is related to the effects of the Pine Valley Project in Nevada, a discussion related to effects of the Pine Valley Project on groundwater flow in Utah is included to provide context for the review of anticipated groundwater-related impacts in Nevada. This memorandum is based on our review of existing literature, Roux's running scenarios on a groundwater flow model developed by the U.S. Geological Survey (USGS), and our field visit of the Pine and Wah Wah Valleys area during 2020. We did not conduct a field inspection of Snake Valley for the purposes of this memorandum.

The locations of eastern Nevada groundwater basins including Snake Valley, and the Pine Valley Project are presented on Figure 1. CICWCD's proposed Pine Valley Project in Utah proposes to export approximately 15,000 acre-feet per year (afy) of groundwater from the southern portion of Pine Valley, a part of the headwaters of the Great Salt Lake Desert groundwater flow system. The Pine Valley Project is not a stand-alone project, but is the first phase of the proposed, multi-basin West Desert Water Supply and Conservation Project (Figure 2). The West Desert Project area lies within the headwaters of the Great Salt Lake Desert Flow System (GSLDFS; for Pine and Snake/Hamlin Valleys), and in the case of Wah Wah Valley, in the Sevier Lake Flow System (Figure 3). CICWCD has obtained groundwater rights in Pine Valley (15,000 acre-feet per year) and Wah Wah Valley (11,000 acre-feet per year). CICWCD currently has groundwater right applications for Hamlin Valley (10,000 acre-feet per year).

Groundwater-dependent ecosystems in the area range from large springs such as Wah Wah Spring (in Wah Wah Valley, Utah) to small springs and wet meadows. Many springs in the region are relatively small springs that individually may not appear to be significant components of the overall area groundwater budget, but individually and collectively are important ecological resources and can be relied upon for human uses. Additionally, springs in Snake Valley provide habitat for the Least Chub. This species of small spring dwelling fish has been declining since the 1940s and presently can only be found in springs in Snake Valley (Wheeler and Fridell, 2008).

The proximity of the proposed Pine Valley Project to Snake Valley is likely to result in lasting water-resource impacts in the area. A reduced groundwater budget in Snake Valley resulting from induced underflow from Snake Valley toward Pine Valley is likely. Additionally, the changes to the groundwater system from the proposed Pine Valley Project, would likely affect springs in Nevada potentially including those in Great Basin National Park. Further, more distant springs such as those at Fish Springs National Wildlife Refuge (in Fish Springs Flat groundwater basin in Utah) also are likely to be affected over time by changes in hydraulic gradients and gradient-directions caused by the groundwater capture from the proposed Pine Valley Project.

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Based on our review of investigations by other researchers including the U.S. Geological Survey, and work conducted by agencies prior to the development of the proposed Pine Valley Project as presented on the U.S. Bureau of Land Management's ePlanning website for this project (U.S. Bureau of Land Management, 2021), we are not convinced that the proposed project as currently designed can provide the volume of water for the period envisioned by CICWCD. This is demonstrated by existing groundwater modeling results (Brooks, 2017), wellfield design and other factors. These potential deficiencies will also be discussed in this report. In order to potentially capture the volume of water envisioned by the project, the project would likely require a well field that is more widely distributed, throughout Pine Valley but based on existing public data and analyses, has not be evaluated. However, if the project does proceed as designed and does produce those volumes of water (~15,000 afy), or even less, the effects of the Pine Valley Project on Snake Valley and surrounding groundwater basins in Nevada would likely be substantial and have not been reliably evaluated at this time, particularly because of substantial, wide-ranging data gaps related to aquifer and flow system characteristics, and the nature and extent of groundwater-dependent ecosystems.

What is a spring and what are they like in this area?

Springs are places where groundwater reaches the ground surface, discharging as surface flow. By nature of their character, springs are highly sensitive to changes in groundwater level. For some springs, the reduction of less than one foot of groundwater elevation can result in the difference between surface water flow being present or absent. Some springs are small, seasonal, locally perched, features where last year's rainfall that soaked into the ground has hit a barrier to its downhill flow path, forcing that water back to the ground surface. The discharge from these local springs is gravity driven. Other springs are tied to deeper and more distant groundwater flow paths that may extend well beyond the boundaries of the local watershed. Because these flow paths are deeper, they are generally not affected by seasonal rainfall or changes in air temperature, they usually have more consistent flow, and if the flow paths are sufficiently deep, they are characterized by warmer groundwater discharge temperatures that remain relatively consistent over time. These springs will commonly have discharges that are anomalously large for their limited watershed and local precipitation. These latter springs rise to the surface under pressure. Figure 4 depicts the relationships between these two different types of springs within a typical flow system context.

How Groundwater Capture Can Impact Springs

In the GSLDFS and surrounding area, the primary risk to springs is the potential impacts due to proposed regional pumping. As described earlier, the proximity of the proposed Pine Valley Project pumping to springs and neighboring basin-fill aquifers is likely to have a deleterious effect. In Snake Valley and Great Basin National Park, these effects may result in changes to hydraulic gradients and gradient-directions, and reductions in spring flow.

Barlow and Leake (2012) present four common misconceptions regarding surface water depletion (such as a reduction of spring flow) due to groundwater pumping:

- Total development of groundwater resources from an aquifer system is "safe" or "sustainable" at rates up to the average rate of recharge;
- Depletion of spring flow is dependent on the rate and direction of water movement in the aquifer (i.e., is the spring upgradient or downgradient);
- Depletion of spring flow will stop when pumping ceases; and,

- Pumping groundwater exclusively below a confining layer will eliminate the possibility of depletion of surface water connected to the overlying groundwater system.

Additionally, Bredehoeft (2002, 2007) and Alley, et.al. (1999) point out the invalidity of the myth that pumping at the estimated groundwater recharge results in practical, sustainable groundwater development. Indeed, the sustainability of pumping is based on the capture (induced inflows and decreased discharges including spring flow) that is a response to groundwater pumping.

Other risks to springs may well arise from the Pine Valley Project but are impossible to evaluate because many of the springs in the region have not been evaluated for their connectedness to basin-fill aquifers. Although a subset of key springs was analyzed in Snake Valley by Gardner (2014) and in the Pine Valley area (Gardner, et.al., 2020), the spring set is not comprehensive, and to our knowledge, there has been no comprehensive regional analysis of springs in this area comparable to the analysis of springs in the Mojave Desert that the U.S. Bureau of Land Management (BLM) commissioned several years ago. Such investigations are not without precedent as shown by that BLM-commissioned comprehensive spring survey for the Mojave (Andy Zdon & Associates, 2016).

Characteristics of Snake Valley and the Great Salt Lake Desert Flow System

The Snake Valley basin (including Hamlin Valley) and surrounding area is in the western parts of Iron, Beaver, Millard, Juab, and Tooele Counties, Utah, and in northeastern Lincoln and eastern White Pine Counties, Nevada, within the Basin and Range geomorphic province. Snake Valley is part of an approximately 135-mile long, continuous north-trending depression, the approximate southern one-third of which is also known as Hamlin Valley. The Basin and Range region (also referred to as the Great Basin) is characterized by basins of internal drainage with considerable topographic relief, alternating between narrow faulted mountain chains and flat arid valleys or basins. The ranges generally trend north-northwest parallel to the regional structural regime. The geology of the Snake Valley area consists primarily of a succession of late Precambrian to early Mesozoic sedimentary rocks up to 33,000 feet thick, along with metamorphic rocks of Jurassic, Cretaceous, and Tertiary age (Kirby and Hurlow, 2005). Carbonate rocks making up the middle and upper portions of the succession are part of a regionally extensive aquifer system covering much of the eastern and southern Great Basin. Within that broad regional aquifer system, Snake Valley is within the GSLDFS, extending from eastern Nevada and western Utah, northward toward the Great Salt Lake Desert (Figure 3).

The Snake Valley area, including surrounding groundwater basins in eastern Nevada, is covered by coalescing alluvial fans forming broad slopes between the surrounding mountains and the valley floor. Coarse-grained deposits (primarily sand and gravel) within the basin fill are responsible for transmitting the greatest quantities of groundwater in the Snake Valley drainage basin, although where present, carbonate rocks may also transmit substantial groundwater. The basin fill is generally unconsolidated, moderately to well-sorted sand, gravel, silt and clay. As the valley floor is reached, the sorting of the alluvial sediments will increase, serving to increase the permeability of the sediments at the base of the alluvial fans. On the other hand, with increased depth, groundwater production can be expected to decrease as deposits lithify and porosity decreases, ultimately reducing permeability as strata is buried and ages (Kirby and Hurlow, 2005). Within the basin fill, the fine-grained (clay and silt) deposits that largely comprise former lakebed deposits and that underly much of the alluvial deposits may serve as aquitards. Aquitards are low permeability geologic units that inhibit groundwater flow and can serve as confining units.

The regional gradient of the groundwater flow system is toward the north (Brooks, 2017; and Kirby and Hurlow, 2005). As described earlier, Snake Valley is within the headwaters of the GSLDFS. The GSLDFS covers approximately 2,600 square miles of western Utah. No perennial streams originate in this area, and runoff only reaches valley floors during and immediately after intense storms or periods of rapid snowmelt (Gates and Kreuer, 1981).

Groundwater is present throughout the GSLDFS within the unconsolidated basin fill and consolidated rocks, and varies in quality from fresh water to brine. Much of the groundwater budget is poorly known, but the annual groundwater recharge from precipitation and underflow from other basins in Nevada to the southern portion of the GSLDFS in Utah has been estimated at a combined 84,000 acre-feet per year (Gates and Kreuer, 1981). As described earlier, CICWCD has been granted rights in Pine Valley and neighboring Wah Wah Valley to the east, and has applied for groundwater rights in Hamlin Valley (southern end of Snake Valley). The combined volume of water of those groundwater rights (in Pine and Wah Wah Valleys) account for approximately 30% of the total groundwater inflow to the southern GSLDFS in Utah and Nevada inclusive of Snake, Pine, Wah Wah Valleys along with other valleys in White Pine County, Nevada and Millard and Juab Counties in Utah.

Fish Springs, the largest spring complex in the GSLDFS is likely primarily derived from underflow from Tule Valley toward Fish Springs Flat. Groundwater in Tule Valley itself is derived from underflow from Pine Valley, Wah Wah Valley, and the Sevier Lake Desert (Gardner, 2014, Brooks, 2017). An isotopic investigation of groundwater movement from Snake Valley toward Fish Springs, identified that a relatively small portion (if any) of the discharge from Fish Springs was derived from Snake Valley (Gardner, 2014). The implications of that condition are that additional production in Snake Valley, or induced underflow from Snake Valley toward Pine Valley would result in reductions in other Snake Valley discharges such as spring flow and evapotranspiration and could induce underflow from surrounding valleys (such as Spring Valley and others) thereby impacting the groundwater budgets for those basins and likely impact groundwater flow to Fish Springs. Additionally, although groundwater from Snake Valley does not appear to be reaching Fish Springs, Fish Springs does receive groundwater from Pine Valley and therefore would likely be directly impacted by Pine Valley Project pumping.

As part of Roux's review of the proposed Pine Valley Project, we reviewed the Great Basin Carbonate and Alluvial Aquifer groundwater flow model (GBCAAM; Brooks, 2017). Figure 5 presents groundwater flow directions as estimated by the GBCAAM under non-pumping conditions and as can be seen, groundwater from Snake Valley generally moves north. Due to the interconnectedness of groundwater flow in the basins within the GSLDFS, changes in the groundwater budgets of upgradient basins, such as Pine and Wah Wah Valleys, will have a domino effect on the groundwater basins down- and cross-gradient, although the timing of those changes is unclear.

In the case of Snake Valley, the majority of discharge from the basin occurs via evapotranspiration (~80,000 afy; Kirby and Hurlow, 2005 and Gardner, 2014). Additionally, groundwater is discharged from agricultural pumping in the area (~14,500 afy). Induced underflow from Snake Valley to Pine Valley caused by the Pine Valley Project would serve as a new stress on the Snake Valley groundwater system and would come at the expense of spring discharge and evapotranspiration, or induced underflow from surrounding basins as described earlier.

Sustainability of Groundwater Systems

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 (groundwater discharge both directly in-basin or through underflow to surrounding basins) exceeds inflow (groundwater recharge in basin plus contributions from surrounding basins), there is a negative change in 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. Where they occur, long-term groundwater level declines are a clear indication that outflow has been exceeding inflow for an extended period. It should also be noted that in many areas, the recovery of groundwater levels following groundwater being removed from storage can take much 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.

Furthermore, under predevelopment conditions, a groundwater system is in equilibrium where inflow equals outflow. Groundwater pumping such as that proposed by CICWCD causes a disruption in this equilibrium, and recharge amounts, and other biological and hydrologic conditions can change. More often, discharge amounts and patterns are impacted. This includes the loss of phreatophytic vegetation (vegetation whose water requirements are met by roots tapping groundwater such as in the area of springs) and reduction or elimination of spring flow. All pumped water must be supplied by one or more of the following:

- Decreases in groundwater storage (lowered groundwater levels);
- Increased or induced recharge or underflow from surrounding basins (e.g., from Snake Valley); and/or,
- Decreased discharge either in the form of reduced subsurface outflow or decreases in natural forms of discharge such as evapotranspiration, spring flow or river base flow (such as would occur at Tule Spring and elsewhere in Sevier Desert areas with shallow groundwater).

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. This area of groundwater drawdown is referred to as a cone of depression. 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 discharge evolve over time. The timing of that evolution in natural discharge change can be difficult to predict.

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 (capture) described above. The amount of groundwater "available" for a future groundwater development project is therefore dependent on what these long-term changes are, and how these changes affect the water resources and groundwater-dependent environmental resources of the area.

Hydrologic Analysis

We reviewed numerous technical documents related to the proposed Pine Valley Project and the hydrogeology of the surrounding region including Snake Valley. Highlights from those studies are discussed below.

Use of the GBCAAS Model

As described earlier, the USGS' GBCAAS Model was used by Roux to estimate local and regional hydrological responses to the proposed pumping scheme in Pine and Wah Wah Valleys. The GBCAAS Model is a regional groundwater model that encompasses alluvial, carbonate, and volcanic aquifer systems across Utah and portions of Nevada, California, and Idaho (Brooks, 2017). The initial release of the model simulated only steady-state flow conditions. The current version of the model, GBCAASv3.0, includes transient groundwater flow capabilities (specific storage and specific yield parameterizations have been added), has been recalibrated, and only employs local grid refinement in a portion of the model domain that covers an area unrelated to Pine Valley. The model includes both a calibration version – used to represent historic data sets – and a projection version that included new pumping in Pine and Wah Wah Valleys and reduced pumping in Parowan Valley.

Pine Valley and surrounding groundwater budgets

Bredehoeft, in his landmark papers (Bredehoeft, 2002; Bredehoeft, 2007; and Bredehoeft and Durbin, 2009), described the myth that pumping at the estimated groundwater recharge rate for a basin results in a sustainable groundwater development scheme. Indeed, the sustainability of groundwater development will be the ability of the groundwater development to capture the discharge from the groundwater basin. In Pine Valley that would translate to the sustainability of the proposed Pine Valley Project being reliant on the ability for the project to reduce groundwater underflow to downgradient basins, capture groundwater underflow from surrounding basins (e.g., Snake Valley) and reductions in spring discharge (the two principal discharge components of the groundwater budget). With respect to timing of discharge capture, Bredehoeft and Durbin (2009) write, “Large ground water systems, where a new equilibrium can be reached and in which the pumping is a long distance from boundaries where capture can occur, take long times to reach a new equilibrium. Some systems are so large that the new equilibrium will take a millennium or more to reach a new steady-state condition. These large systems pose a challenge to the water manager, especially when the water manager is committed to attempting to reach a new equilibrium state in which water levels will stabilize and the system can be maintained indefinitely.”

Ultimately, the groundwater developed from Pine Valley (and potentially Hamlin and Wah Wah Valleys) will be derived by reducing underflow to downgradient groundwater basins in Beaver, Millard, Juab, and Toole Counties in Utah and White Pine and Lincoln Counties in Nevada for the groundwater system to reach a new equilibrium condition. Additionally, beyond the impacts of the Pine Valley Project on Snake Valley in White Pine County, Nevada, if Hamlin Valley is developed by CICWCD, which is planned as part of CICWCD's broader West Desert Water Project, that would have direct, additive impacts to the downgradient portion of Snake Valley in Nevada. Ultimately, a reduction of underflow toward the downgradient portion of the Great Salt Lake Desert flow system could also affect the Great Salt Lake flow system as well, which could affect the Great Salt Lake itself. The timing of those likely irreversible changes could take a long time, but on the other hand they could come sooner.

The U.S. Geological Survey (Brooks, 2017) used the GBCAAS groundwater model to evaluate the effects of the proposed pumping in Pine Valley, along with pumping in Wah Wah Valley (in volumes similar to the water rights held by CICWCD), and reductions in pumping of more than 20,000 acre-feet per year in Parowan Valley, Utah (we have no knowledge of such reductions being proposed). The results of that analysis are reflected in the drawdown prediction presented in Figure 6. Table 1 summarizes the results of that simulation for groundwater basins in Nevada. As described earlier, the timing of the growth of the cone of depression from project pumping is uncertain given the paucity of aquifer data in the vast area affected. Therefore, the 1,000-year scenario is used to estimate the long-term equilibrium condition of Nevada groundwater basins from project pumping. It is important to recognize that the 1,000-scenario results could be attained in a much shorter timeframe. As can be seen, the groundwater level changes predicted by the U.S. Geological Survey in Nevada groundwater basins is substantial in Snake Valley, Spring Valley and surrounding groundwater basins in White Pine and Lincoln Counties.

Supplemental to the U.S. Geological Survey's analyses above, as part of our review we looked at the changes in subsurface flow that would occur as a result of project pumping, predicted by the GBCAAS Model (Brooks, 2017). Roux also looked at drawdown that would continue after pumping ceases. CICWCD's water rights applications for the Pine Valley Project and the larger West Desert Project make it clear that these projects are intended to serve as a permanent water supply for CICWCD's service area, particularly with Iron County's growth projects, and therefore it is not realistic to assume, or limit analysis to only a 50-year pumping period. Further, there is substantial uncertainty related to the timing of the pumping effects, so considering what the groundwater system would look like when the GSLDFS reaches a new equilibrium is of importance.

The primary source of underflow toward Pine Valley as the cone of depression from the proposed well-field pumping grows over the course of the project's projected long-term pumping, and even as the cone of depression recovers if the project is eventually shut down, is from a marked increase in underflow from neighboring Snake Valley (Figure 7). That induced underflow from Snake Valley would no longer be available as underflow northward down Snake Valley. As Gardner (2014) posited that very little if any groundwater from Snake Valley exits the valley toward Fish Springs as that groundwater is largely consumed by downgradient spring flow, evapotranspiration, and human use within Snake Valley, it follows that the reduced down-valley underflow in Snake Valley due to capture from Pine Valley pumping would affect downgradient spring flow, groundwater-dependent vegetation, and existing groundwater users. Ultimately, the induced underflow from Snake Valley due to the Pine Valley Project must be made up from other sources for Snake Valley groundwater basin to adjust to this new stress. Figure 7 presents the results of that pumping scenario and before and after underflow estimates. Figure 8 presents the flow field associated with pumping in Pine Valley after the groundwater system stabilizes (1,000 years), minus the baseline flow field (without pumping), in other words the net flow changes to the system. One can see the impact of pumping on patterns of groundwater flow, extending north from Pine Valley toward Fish Springs Flat and west from Pine Valley toward Snake Valley and into the Great Basin National Park area. That stress on the Snake Valley groundwater system will then result in similar inducements of underflow from groundwater basins surrounding Snake Valley such as Spring Valley. The before and after Pine Valley Project pumping effects on the Snake Valley groundwater budget and how those changes affect surrounding Nevada groundwater basins are presented in Figure 9.

The full extent of the capture will likely occur long after the proposed 50-year pumping period that has been proposed for the Pine Valley Project. Even assuming the 50-year pumping period is not extended, the cone of depression from that pumping will continue to expand as more distant groundwater is captured to allow recovery of the pumping center. Even after groundwater pumping has ceased, no mechanism to stabilize the groundwater flow system from continued drawdown exists. Drawdown will continue to expand resulting in unabated impacts to springs and human use until the aquifer system can reach a new equilibrium and begin to recover. Realistically, it is unlikely that Pine Valley Project pumping would cease after 50 years, and more likely to be substantially supplemented by additional pumping from Wah Wah Valley and, potentially, Hamlin Valley, considerably adding to the stress on groundwater basins in White Pine County and Lincoln County.

The processes and timing of these changes are made more unclear by Pine Valley having not been subject to significant groundwater development and currently being in a state of equilibrium (Gardner, 2020). Therefore, how the basin reacts to long-term groundwater stresses is not known beyond modeling analyses with the inherent uncertainties described earlier. In the case of the proposed project, the stresses will be substantial based on the following:

- The proposed pumping volume (15,000 acre-feet per year) from the basin-fill aquifer exceeds the USGS estimated recharge to that aquifer (11,000 acre-feet unconsumed recharge that moves to basin-fill aquifer per Gardner, et.al., 2020) by more than 35%;
- The estimated subsurface underflow from Pine Valley to the north likely will decrease toward zero as subsurface underflow is the principal groundwater discharge from the Pine Valley basin-fill aquifer available for capture;
- Decreased subsurface underflow affects down-basin discharge points such as those in Tule Valley and the Fish Springs area;
- Underflow from cross gradient basin-fill aquifers, including Snake Valley, and basins contributing flow toward Snake Valley such as Spring Valley, will increase towards Pine Valley as the regional groundwater gradient is interrupted by the extraction of groundwater in Pine Valley potentially creating a groundwater budget deficit for ecological resources and human-users.

As described earlier, the groundwater budget of Snake Valley is threatened by the Pine Valley Project as the likely changes in groundwater gradient of Pine Valley will redirect the groundwater gradient of at least a portion of Snake Valley. The groundwater budget of Snake Valley consists predominantly of evapotranspiration with lesser amounts of spring flow and underflow toward Tule Valley and Deep Creek Valley (Figure 9). Recharge of the Snake Valley basin-fill is predominantly supplied by precipitation in the Snake Range (Gardner and Heilweil, 2014) along with groundwater underflow from Spring Valley to the west.

Our analysis using the USGS GBCAAS Model solely simulating proposed Pine Valley Project pumping indicates that extraction of groundwater and alteration of the groundwater gradient associated with the Pine Valley project will affect the underflow of groundwater from Snake Valley, and ultimately, Spring Valley to the west along with other surrounding valleys. Absent potential future pumping in Wah Wah and Hamlin Valleys, the change in underflow from the southern portion of Spring Valley into Snake Valley under Pine Valley Project pumping almost doubles from 612 afy to 1,054 afy and an increase of 223 afy from the northern portion of Spring Valley. As described before, considering the modeling uncertainties described earlier, the specific volumes could vary substantially. Ultimately, the Pine Valley Project is estimated to affect Spring Valley, Nevada, before a new groundwater system equilibrium is reached (Figure 9 and Table 1). We have not simulated the additional effects that pumping from the Hamlin Valley phase of the West Desert Water Project would have on the groundwater systems in Nevada. However, Brooks (2017) does simulate the additive effects of pumping in Wah Wah and Pine Valleys (see Table 1). Additionally, results of Roux's use of the GBCAAS model indicates that the underflow from Snake Valley to Pine Valley increases more than an order of magnitude as the basins reach a new equilibrium (Figure 7).

Drawdown

When evaluating the model-predicted drawdowns for a pumping program or wellfield, generally the estimated well field drawdown is not representative of drawdown that would be measured in individual wells. The estimated drawdown is the representative drawdown for the model cell. Therefore, drawdown as measured in a specific pumping well would be considerably more than that modeled, irrespective of well efficiency issues.

As estimated by the U.S. Geological Survey (Brooks, 2017), the drawdown estimated from pumping in the Pine Valley and Wah Wah Valley areas is substantial (Figure 9, Table 1). Based on our simulation using the USGS-developed GBCAAS model of pumping solely in the Pine Valley wellfield area, the GBCAAS model predicts approximately 600 feet of drawdown in the wellfield area.

A review of the drawdown predicted in Brooks (2017) for pumping similar to that proposed under the Pine Valley Project in Pine Valley, and in Wah Wah Valley similar to the amount of the CICWCD water rights granted, (Table 1) indicates that it would take approximately 1,000 years of pumping at those rates and conditions for the groundwater system to begin to reach a new equilibrium. Again, the timing of those impacts is subject to modeling error and uncertainties due to the sparsity of data in the area of the model domain. Nonetheless, this is indicative of the magnitude of stress the proposed pumping would put on the aquifer system.

The partial review of groundwater-dependent ecosystems including springs in Pine Valley, Wah Wah Valley and basins that are downgradient from those valleys, along with consideration of springs in Snake Valley that could be affected by declining groundwater levels (see Elliott, et al., 2006), and the predicted drawdowns (Brooks, 2017) demonstrate that the Pine Valley Project will give rise to considerable risk to important ecological and human uses.

Uncertainty

Future impact analyses for the Pine Valley Project should recognize these uncertainties that are also inherent in the GBCAAS Model including:

- The estimated evapotranspiration assumed in the flow system to derive a recharge estimate has an estimated error bounds of plus or minus 35% (Brooks, 2017; Gardner, et al., 2020), and therefore recharge estimates are subject to similar error bounds;
- The estimates described above could underestimate the amount and extent of drawdown as the transmissivity (the measure of the ability of the aquifer to yield water) of the basin-fill aquifer is simulated to not decrease over time even though the parameter is dependent on the saturated thickness of the aquifer (Brooks, 2017) and the fact that groundwater recharge could be overestimated;
- Absence of hydraulic testing in this largely undeveloped region affects predicted timing of pumping effects;
- Aquifers are modeled as confined and transmissivity is not simulated to decrease with groundwater level decline (Brooks, 2017);
- Storage properties are considered uncalibrated outside of Parowan Valley (Brooks, 2017);
- Faults not simulated could act as barriers to groundwater flow providing greater uncertainty to model results;
- Over-generalizing the areas with similar hydraulic characteristics in the models resulting from limited data may affect the model simulations; and,
- Modeling based on an incomplete review of springs in the Great Salt Lake Desert Flow system including isotopic analyses.

Feasibility

Based on our review, it is likely that modifications to the well field design including expanding the well field area and number of wells will be needed. These likely changes to the ultimate well field are not evaluated by the U.S. Geological Survey modeling, nor was Roux able to simulate those changes as we have no information available as to what those changes would be. This is based on the following:

- Modeled drawdowns less than what would be measured in a specific pumping well as the drawdown is representative of conditions in the model cell containing the well and an area of approximately 25 acres;

- Drawdown in a specific pumping well would be expected to be greater than modeled because the model assumes aquifer transmissivity remains constant even though declining groundwater levels would cause transmissivity to decrease;
- The model does not consider the additional in-well drawdown that would result from well inefficiency.

When these three factors are considered together, given the projected drawdowns predicted for pumping in the Pine and Wah Wah Valleys in the GBCAAS Model, there is insufficient information or data to allow an informed determination to be made as to whether there is sufficient aquifer thickness to support the proposed project without substantial changes to project design. Changes to the well field area (e.g. if expanded to cover all of Pine Valley) would substantially alter the extent of groundwater impacts and cause additional impacts to groundwater resources in Nevada, not identified in the current analysis.

Conclusions

Based on the discussion provided above, the following is a summary of our conclusions relating to the proposed Pine Valley Project:

1. CICWCD proposes to pump up to 15,000 acre-feet per year of groundwater from Pine Valley, the first phase of CICWCD's larger planned West Desert Water Supply and Conservation Project.

2. The proximity of the proposed Pine Valley Project to existing groundwater dependent environmental resources and human uses in neighboring Snake Valley (and the surrounding valleys) could result in lasting water resource impacts to those areas including reductions in spring flow and reduced evapotranspiration.

3. Distant springs such as those in Snake Valley that support Least Chub and/or Fish Springs National Wildlife Refuge could be affected by changes in hydraulic gradients and gradient directions caused by Pine Valley Project pumping;

4. The proposed pumping of 15,000 acre-feet per year in Pine Valley exceeds the USGS estimated volume (11,000 acre-feet per year) of groundwater estimated to recharge the alluvial aquifer of Pine Valley and move northward as underflow.

6. Pumping more than the estimated groundwater recharge would result in continued groundwater decline long after project pumping ceases;

7. The spring analysis for the affected region (related to connectivity with basin fill aquifers) is incomplete;

8. The primary source of captured groundwater feeding groundwater recovery after pumping ceases in Pine Valley is induced underflow from Snake Valley, and subsequently other basins such as Spring Valley, with additional induced underflow from Escalante Desert as a secondary source.

9. As groundwater sourced in Snake Valley is generally discharged through spring flow, evapotranspiration and human usage, induced underflow toward Pine Valley would reduce the available water in Snake Valley which is already largely used in-valley.

10. As drawdown and groundwater capture will continue long after pumping ceases, groundwater management to avoid substantial impacts will be impracticable, as once pumping ceases it will not be possible to adjust groundwater management to ameliorate the expanding drawdown until the system reaches its own equilibrium.

11. Based on the uncertainties that remain foundational to the environmental analysis, it is likely that the Pine Valley Project will cause harmful impacts to ecological and human uses in Pine Valley and surrounding valleys in the Great Salt Lake Desert flow system.

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Attachments

Figure 1 – Site Location Map

Figure 2 – West Desert Water Project Site Plan

Figure 3 – Great Salt Lake Desert and Wah Wah Groundwater Flow Systems

Figure 4 – Typical Flow System with Local and Regional Springs

Figure 5 – Non-Pumping Flow Vectors of the Great Salt Lake Desert Flow System

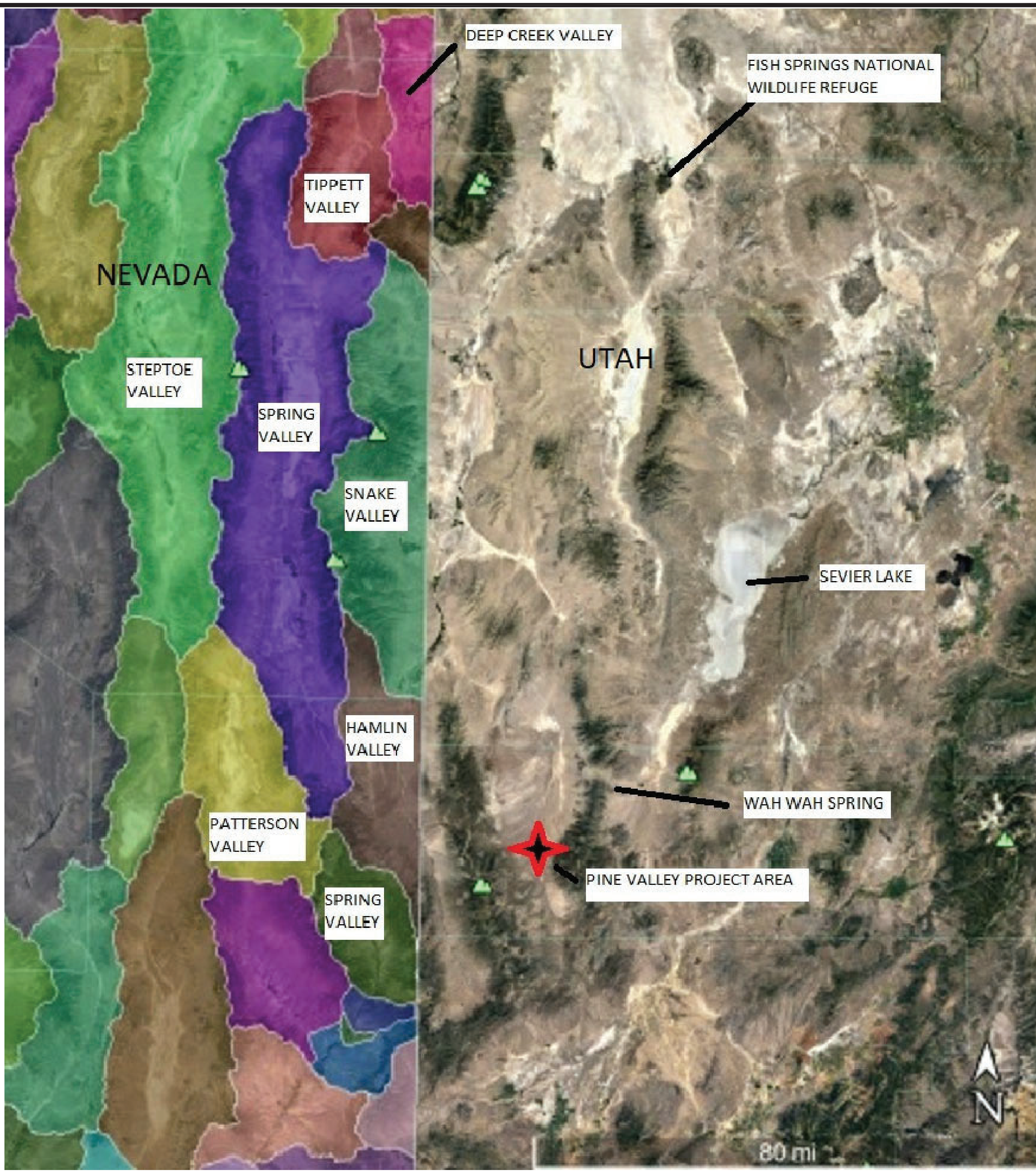
Figure 6 – Snake, Pine and Wah Wah Valley Drawdown—GBCAAS Model

Figure 7 – Change in Subsurface Underflow—Pine Valley Pumping

Figure 8 – Flow Field

Figure 9 – Snake Valley Water Budget—With and Without Pine Valley Pumping

Table 1 – Groundwater-level declines on Nevada and Utah groundwater basins due to future pumping in Pine and Wah Wah Valleys, Utah as predicted by USGS GBAACS Model (Brooks, 2017)



Title: **SITE LOCATION MAP**

Prepared for: GREAT BASIN WATER NETWORK

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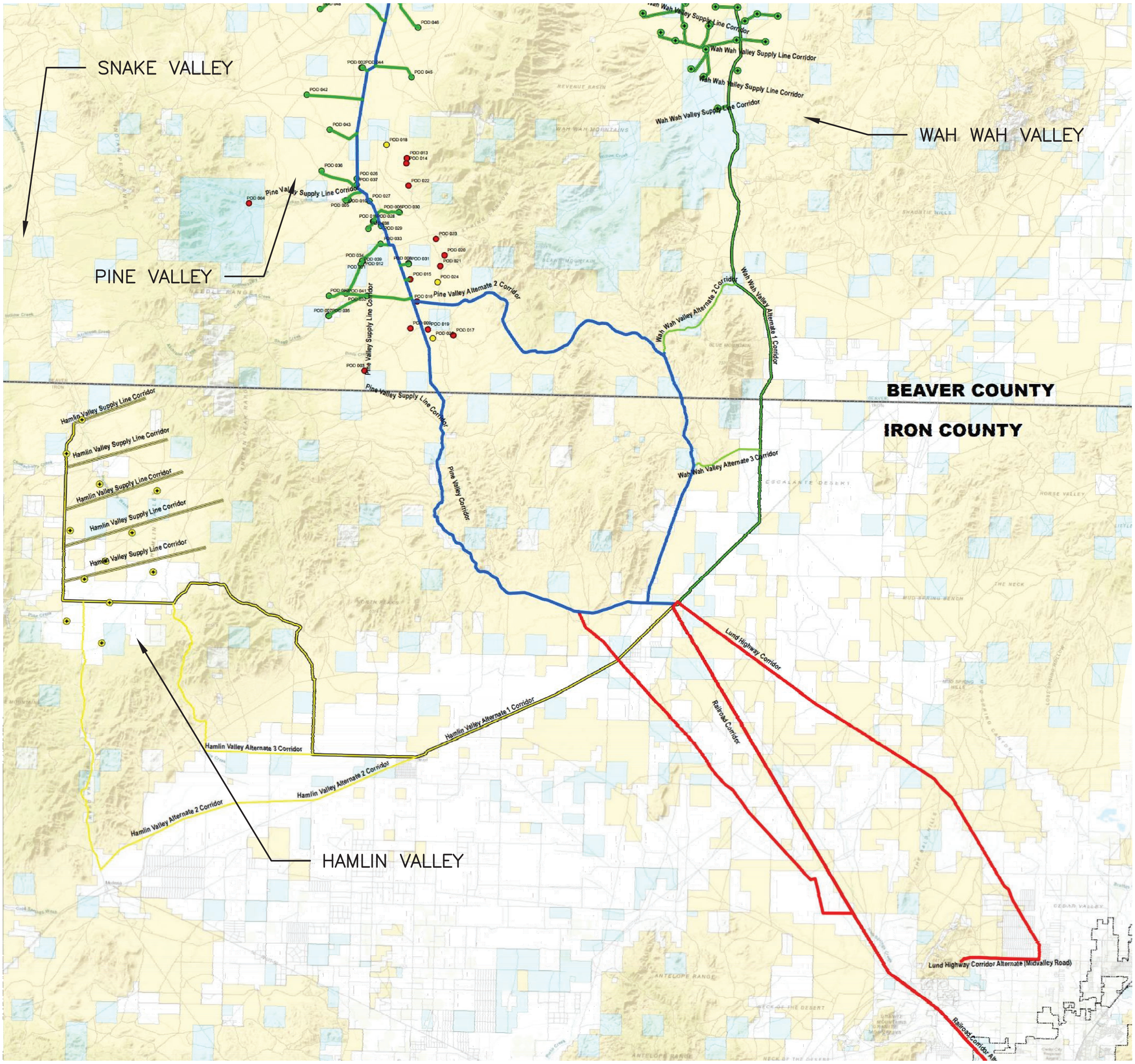

Title:

WEST DESERT WATER PROJECT SITE PLAN

ADAPTED FROM CICWCD (2018)

Prepared for:

GREAT BASIN WATER NETWORK

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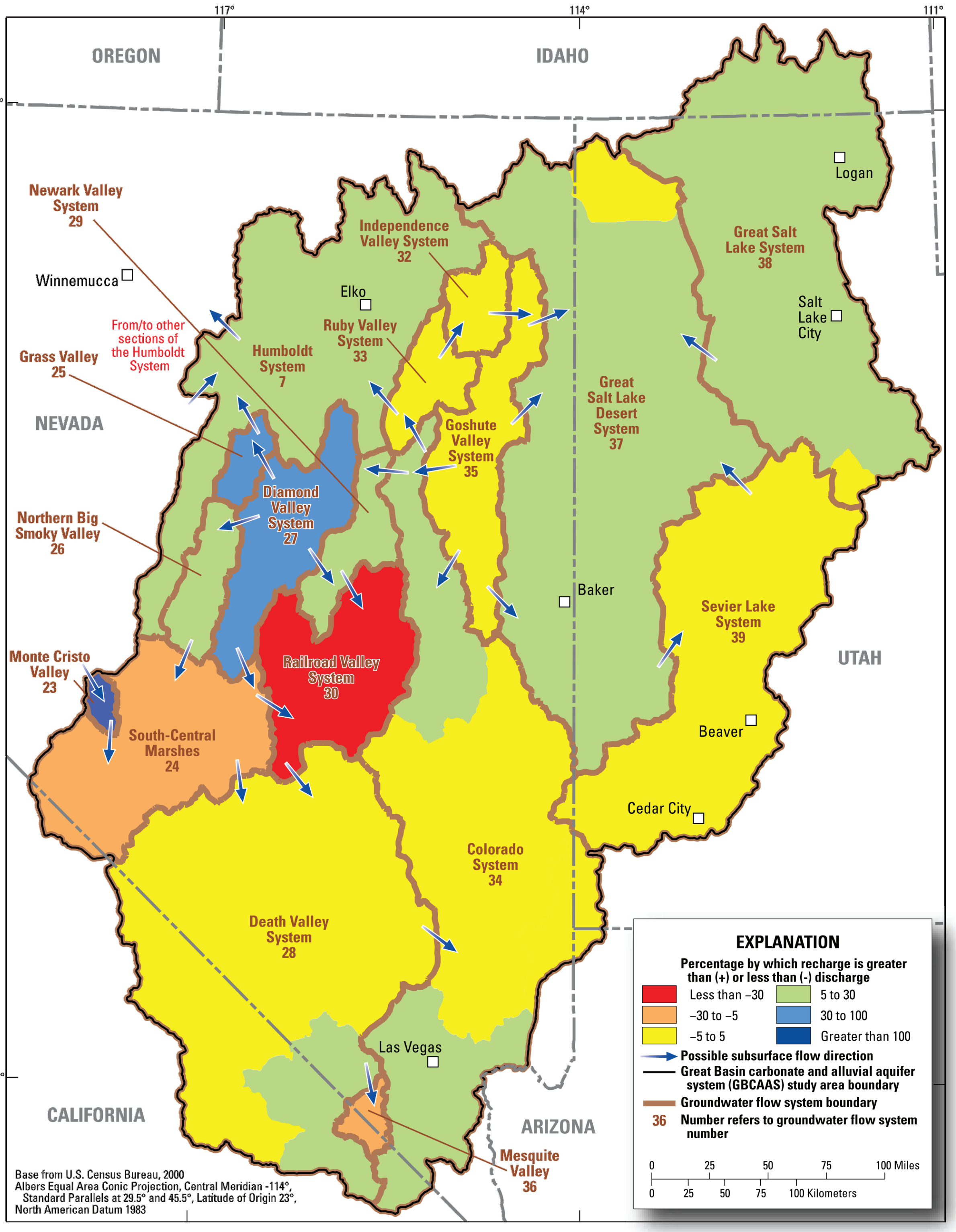

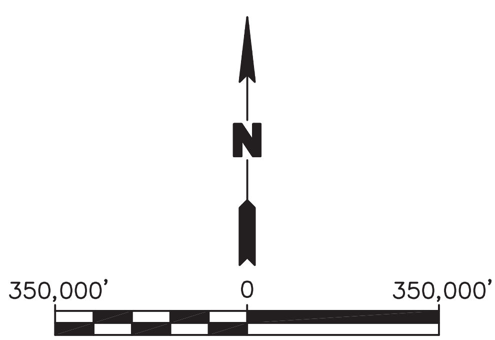

Title:

GREAT SALT LAKE DESERT AND WAH WAH GROUNDWATER FLOW SYSTEMS

FROM HEILWEIL AND BROOKS, 2011

Prepared for:

GREAT BASIN WATER NETWORK

ROUX

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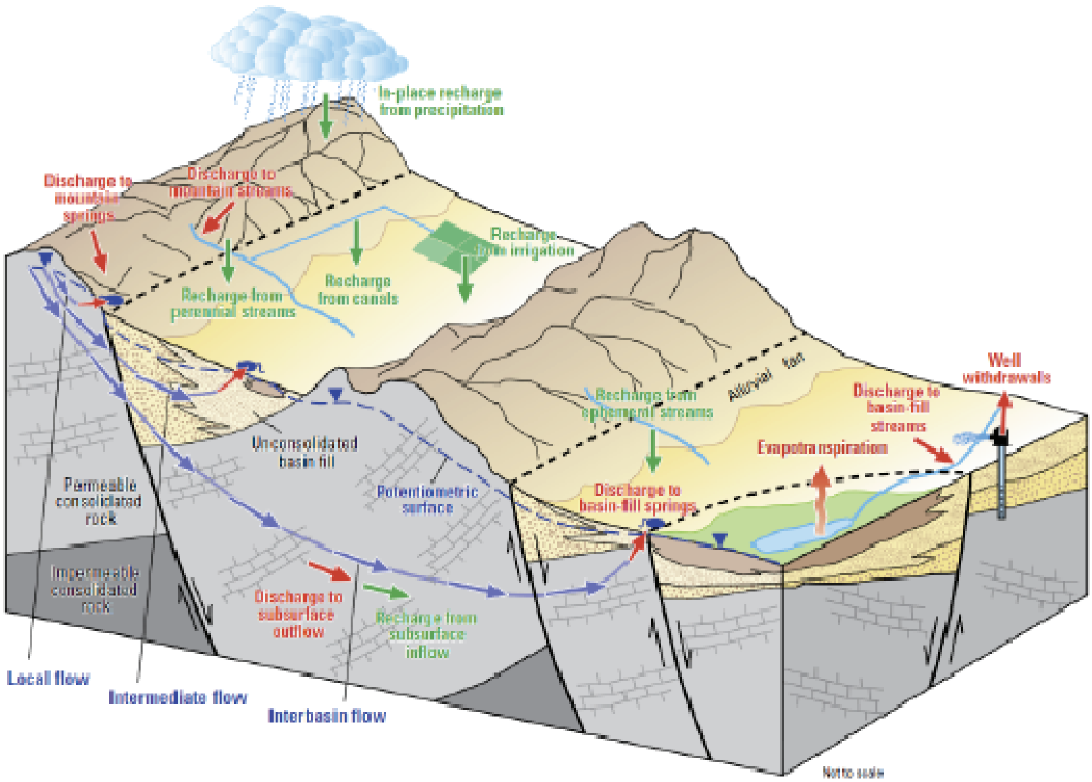
Groundwater Budget Components



Recharge is water inflow to groundwater system:

From precipitation, streams, irrigation, and subsurface inflows.

Storage change:

Change in amount of water in aquifer; change in water level.

Discharge is water outflow from groundwater system:

Streams and Springs.

Pumping and subsurface outflow.

Evapotranspiration includes evaporation from soil and transpiration from groundwater dependent vegetation.

Title: **TYPICAL FLOW SYSTEM WITH LOCAL AND REGIONAL SPRINGS**

FROM ALLANDER AND BERGER, 2017

Prepared for: GREAT BASIN WATER NETWORK

ROUX

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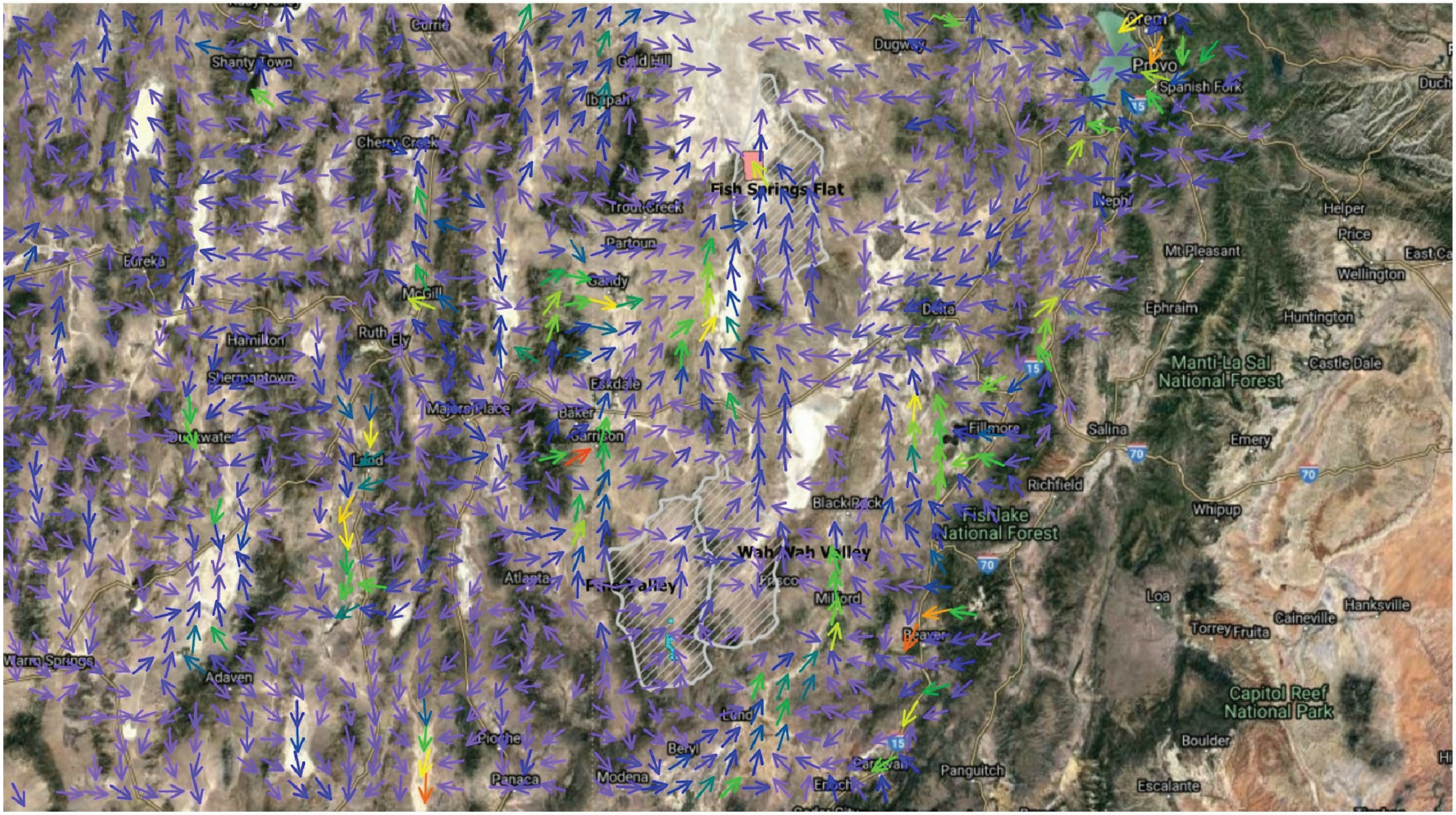

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Title:

NON-PUMPING FLOW VECTORS OF THE GREAT SALT LAKE DESERT FLOW SYSTEM

FROM BROOKS, 2017

Prepared for:

GREAT BASIN WATER NETWORK

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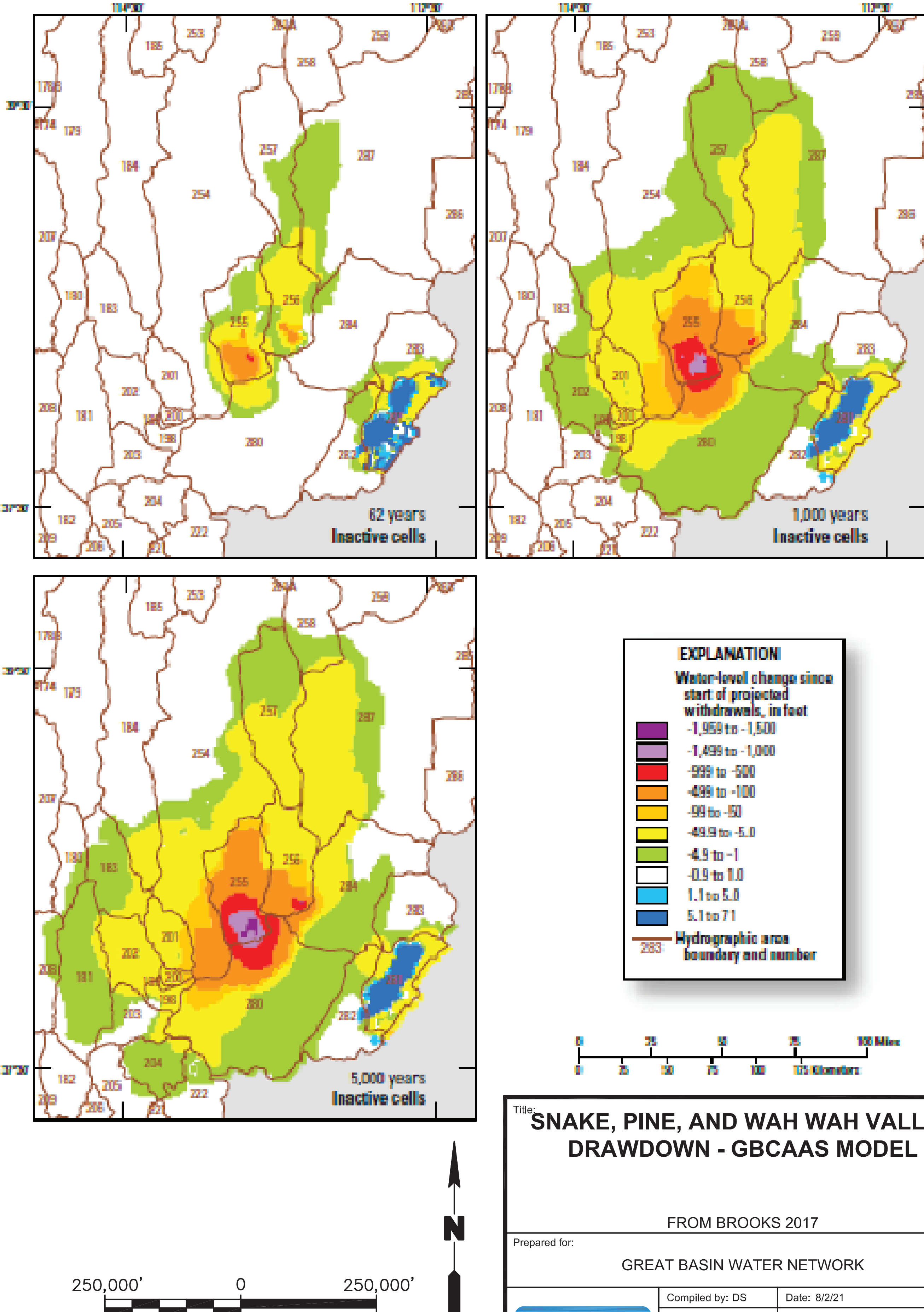

Title: **SNAKE, PINE, AND WAH WAH VALLEY DRAWDOWN - GBCAAS MODEL**

FROM BROOKS 2017

Prepared for:

GREAT BASIN WATER NETWORK

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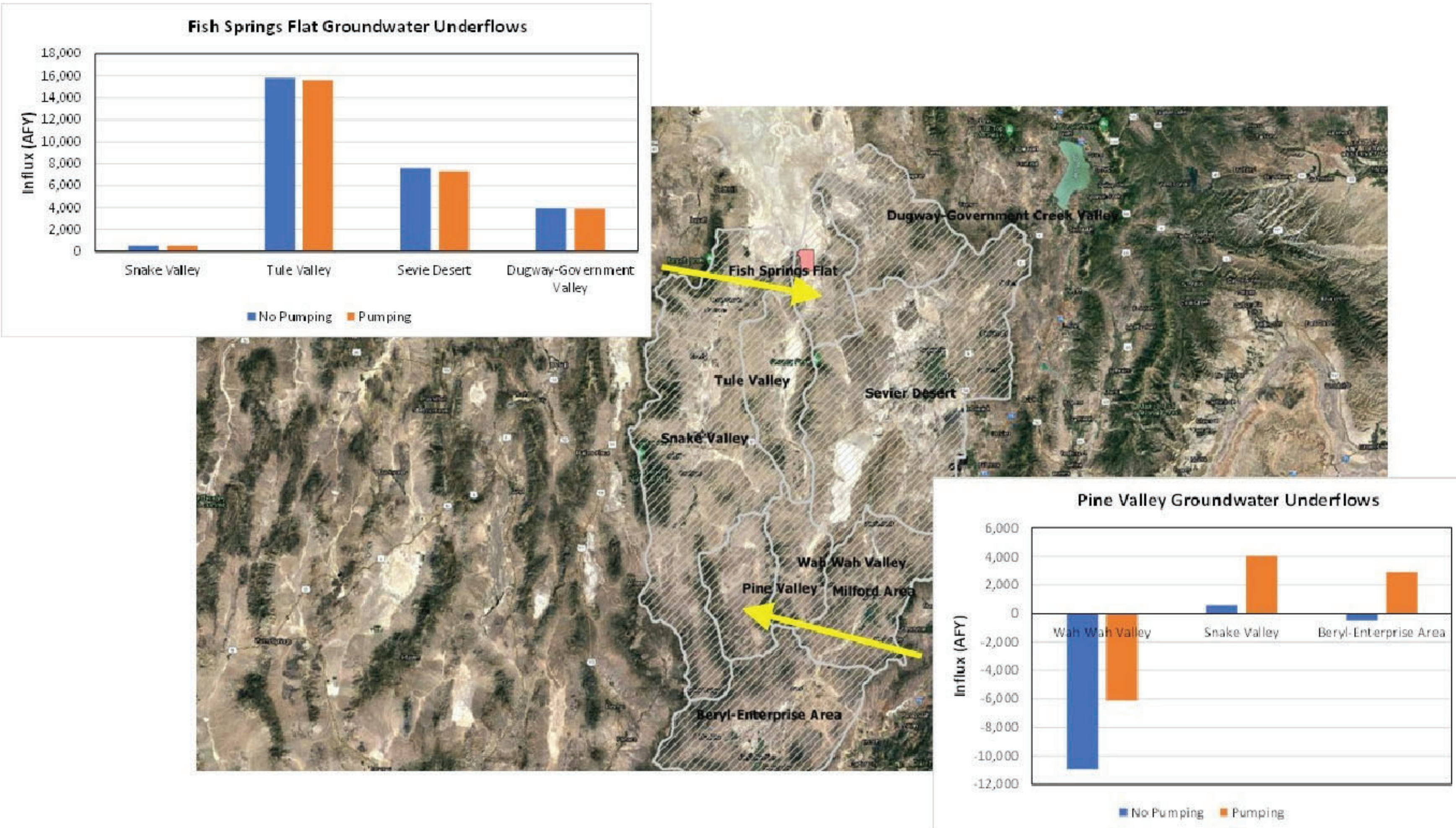

Title:

CHANGE IN SUBSURFACE UNDERFLOW - PINE VALLEY PUMPING

Prepared for:

GREAT BASIN WATER NETWORK

ROUX

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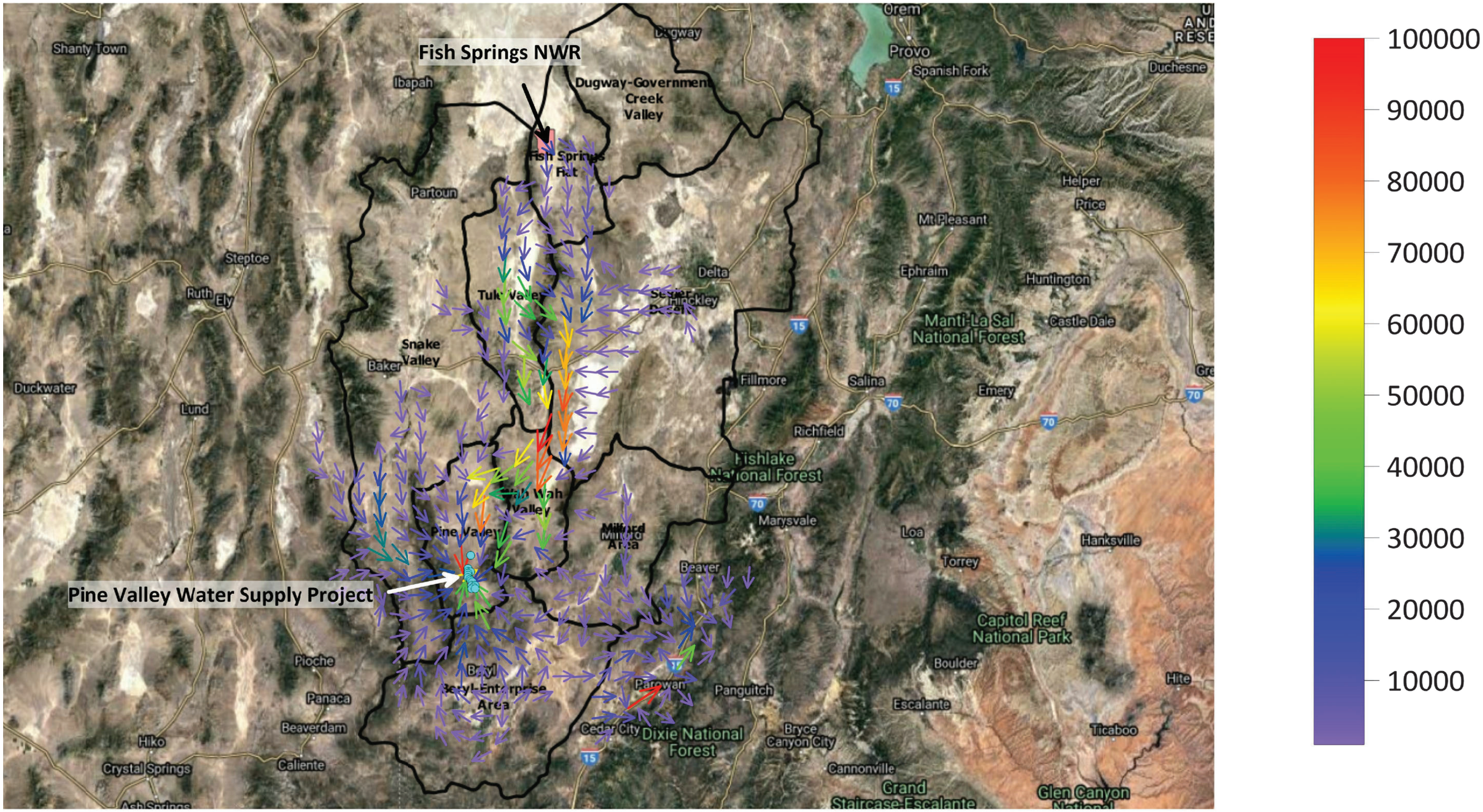

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Title:

FLOW FIELD

Prepared for:

GREAT BASIN WATER NETWORK

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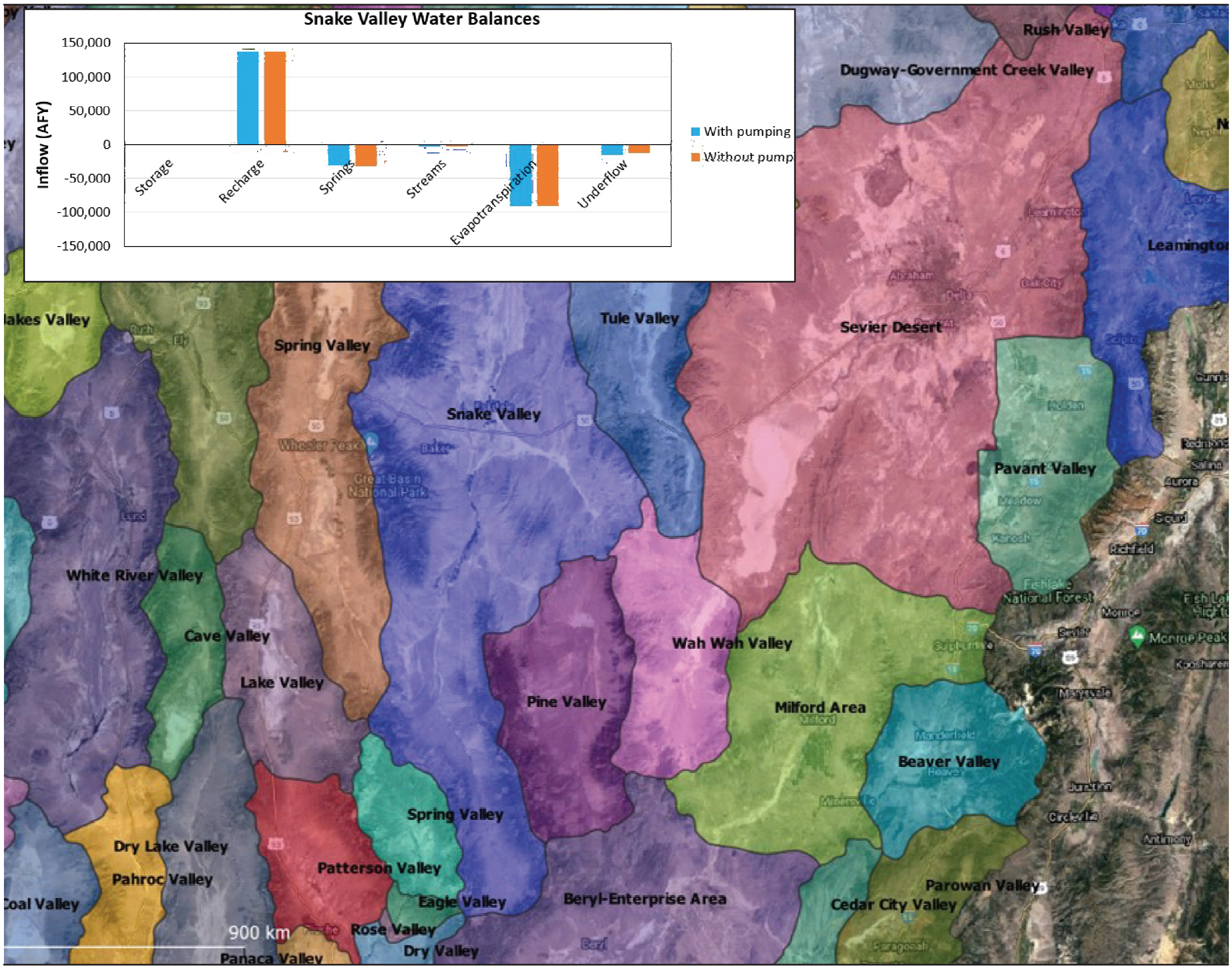

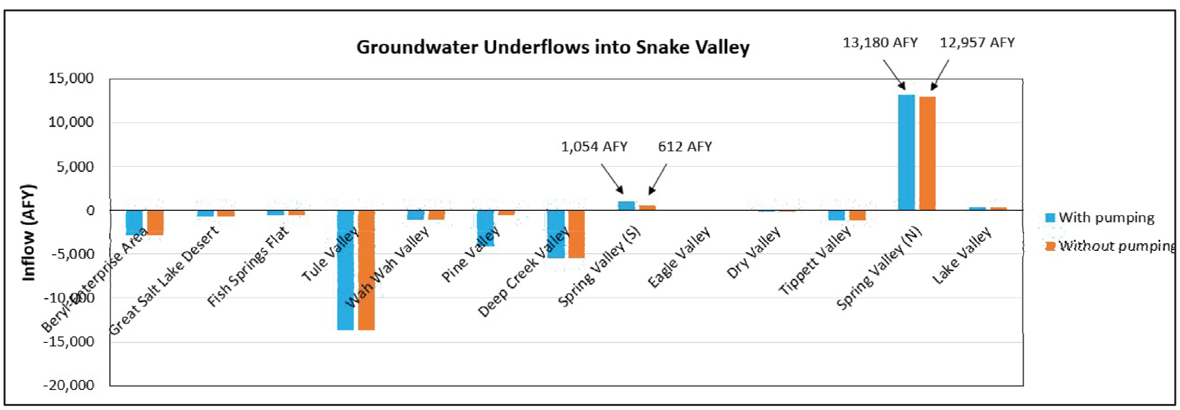

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Title: **SNAKE VALLEY WATER BUDGET - WITH AND WITHOUT PINE VALLEY PUMPING**			
Prepared for: GREAT BASIN WATER NETWORK			
ROUX	Compiled by: DS	Date: 8/2/21	FIGURE
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Table 1. Groundwater-level declines on Nevada and Utah groundwater basins due to future pumping in Pine and Wah Wah Valleys, Utah as predicted by USGS GBAACS Model (Brooks, 2017)

Basin/ Hydrographic Unit No.	Basin Name	County	Short-term Affects (1)	Long-term Effects (2)	Comments
181	Dry Lake Valley, Nevada	Lincoln	<1 ft of drawdown	Up to 4.9 ft of drawdown	Long-term effects along eastern margin of basin
183	Lake Valley, Nevada	Lincoln, White Pine	<1 ft of drawdown	1-49.9 ft of drawdown	Long-term effects - easLotern third of basin with maximum drawdown along eastern margin of basin.
184	Spring Valley, Nevada	White Pine, Lincoln	<1 ft of drawdown	1-49.9 ft of drawdown	Long-term effects - southern portion of basin along margin with Snake Valley; maximum drawdown along eastern margin of basin.
198	Dry Valley, Nevada	Lincoln	<1 ft of drawdown	1 to 49.9 ft of drawdown	Up to 49.9 ft of drawdown most of basin, greater drawdown in northernmost corner of basin.
199	Rose Valley, Nevada	Lincoln	<1 ft of drawdown	5 to 49.9 ft of drawdown	Most of basin with greater drawdown to the north.
200	Eagle Valley, Nevada	Lincoln	<1 ft of drawdown	5 to 49.9 ft of drawdown	Throughout basin
201	Spring Valley, Nevada	Lincoln	<1 ft of drawdown	5 to 49.9 ft of drawdown	Throughout basin
202	Patterson Valley, Nevada	Lincoln	<1 ft of drawdown	1 to 49.9 ft of drawdown	Up to 5 ft of drawdown through most of basin with greater drawdown to the eastern margin with Basin 201.
203	Panaca Valley, Nevada	Lincoln	<1 ft of drawdown	Up to 4.9 ft of drawdown	Northern and southeastern portions of basin.
204	Clover Valley, Nevada	Lincoln	<1 ft of drawdown	Up to 4.9 ft of drawdown	Northeastern tip of basin.
254	Snake & Hamlin Valleys, Nevada-Utah	Lincoln, White Pine, Iron, Beaver, Millard, Juab, Tooele	1-49.9 ft of drawdown	1-100 ft of drawdown	Short-term effect along eastern margin of Snake Valley (boundary with Pine Valley); Long-term effects southern half of basin.
255	Pine Valley, Utah	Iron, Beaver, Millard	Up to 1,000 ft of drawdown	Up to greater than 1,000 ft of drawdown	Maximum drawdowns at pumping center, Short-term drawdowns of 1 to 500 ft through most of basin; long-term drawdowns of 5 to 500 ft through most of valley.
256	Wah Wah Valley, Utah	Iron, Beaver, Millard	Up to 500 ft of drawdown	5 to 500 feet of drawdown	Throughout basin
257	Tule Valley, Utah	Beaver	Up to 49 ft of drawdown	Up to 49 ft of drawdown	Short-term effect along southeastern portion of basin with greater margin at southernmost tip of basin; long-term effects throughout basin with 5 to 49 ft of drawdown in southern half of basin.
258	Fish Springs Flat, Utah	Juab, Tooele	<1 ft of drawdown	Up to 4.9 ft of drawdown	Long-term effects on southern tip of basin.
280	Beryl-Enterprise Area, Utah	Iron	1 to 49.9 ft of drawdown	Up to 999 ft of drawdown	Short-term drawdown to the north, long-term drawdown throughout basin with maximums along northern border with Pine Valley (proximity to simulated pumping center)
281	Parowan Valley, Utah	Iron	5 to 49.9 ft of drawdown	5 to 49.9 ft of drawdown	Short-term drawdown from local pumping effects unrelated to Pine and Wah Wah Valley pumping; long-term drawdown stable as drawdown merges with drawdown from pumping in Pine and Wah Wah Valley.
282	Cedar City Valley, Utah	Iron	Up to 49.9 ft of drawdown	Up to 49.9 ft of drawdown	Short-term drawdown from local pumping effects unrelated to Pine and Wah Wah Valley pumping; long-term drawdown deepens as drawdown merges with drawdown from pumping in Pine and Wah Wah Valley.
283	Beaver Valley, Utah	Beaver	Up to 49.9 ft of drawdown	Up to 49.9 ft of drawdown	Along southern margin of basin due to local pumping
284	Milford Area, Utah	Beaver	Up to 4.9 ft of drawdown	1 to 49.9 ft of drawdown	Short-term effects along northwestern border of basin; long-term effects across western third of basin with maximum drawdown along northwestern border.
287	Sevier Desert, Utah	Millard	1 to 49.9 ft of drawdown	1 to 49.9 ft of drawdown	Short-term effects along western margin of basin with maximum drawdown along southwestern corner of basin; long-term effect across western third of basin.