CPB Exh 25

# Aquaveo Response to June 30, 2017 SNWA Exhibits Related to Spring Valley dated August 11, 2017, authored by Dr. Normal L. Jones and Dr. Alan L. Mayo.

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Submitted to:
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# 1 Executive Summary

The objective of this report is to respond to the material submitted on June 30, 2017 by the Southern Nevada Water Authority (SNWA) in response to the remand ruling issued by Judge Estes of the Seventh District Court (Estes 2013). We analyzed the SNWA submissions on behalf of Corporation of the Presiding Bishop (CPB) of The Church of Jesus Christ of Latter-day Saints, which owns Cleveland Ranch and the associated water rights and is protesting portions of the SNWA's proposed Groundwater Development Project (GDP). Of the four directives outlined in the remand ruling, Directives 2 & 3 are directly applicable to the CPB protest:

2) A recalculation of water available for appropriation from Spring Valley assuring that the basin will reach equilibrium between discharge and recharge in a reasonable time
3) Define standards, thresholds, and triggers so that mitigation of unreasonable effects from pumping of water are neither arbitrary nor capricious in Spring Valley…

We have reviewed the SNWA submissions related to these two directives and our responses can be summarized as follows.

## 1.1 Directive 2 – Recalculation of Water Available and Equilibrium in Spring Valley

In response to Directive #2, the SNWA submitted a set of files associated with groundwater model simulations and an accompanying report (Burns et al. 2017). The report describes an updated version of the Central Carbonate-Rock Province (CCRP) model used by the SNWA in 2011 to analyze conflicts with senior water rights.

Burns et al. (2017) argue that it would be inappropriate to use the CCRP computer model, "*or any other model*," to quantify the water available for appropriation in Spring Valley." Rather, they argue that the GDP should be approved at the full appropriation levels and the actual perennial yield should be determined at a later time based on field observations. This blanket rejection of computer modeling flies in the face of long established groundwater modeling science and practice. Such an approach would not protect senior water rights holders or future water users in Spring Valley and it ignores a specific directive in the remand ruling to provide evidence that the proposed well system can achieve equilibrium at some reduced rate and in a reasonable time. The burden of proof on this issue lies squarely with the SNWA.

In spite of arguing that models cannot be used to evaluate ET capture and equilibrium, Burns et al. (2017) present an updated version of the CCRP model and use it to analyze a hypothetical well system with 101 wells distributed throughout the ET discharge zones in Spring Valley. This hypothetical system approaches full ET capture within 200 years while purportedly withdrawing 1-3% of the recoverable storage. This scenario does not satisfy the directive in the remand ruling because it features a set of wells substantially different from the 15 wells specified in the permit applications. So dramatic a change in the applications would require a whole new application process. The current applications are for a specific set of wells in specific locations and must be evaluated solely on that basis.

We used the updated CCRP model submitted by the SNWA experts but restored the wells in Spring Valley to include only the 15 wells specifically described in the SNWA applications. We used this model to repeat the long-term simulations described in our June 30, 2017 report, with only minor differences in the outcomes. Once again, the ET capture plateaus at 75% after several centuries, a significant amount of water is drawn from adjacent basins, and the system is in a state of perpetual groundwater mining. At 200 years, only 69% of the ET is captured and 43-77% of entire recoverable storage in Spring Valley is mined, with no end in sight.

In response to the directive in the remand ruling to recalculate the "*water available for appropriation from Spring Valley assuring that the basin will reach equilibrium between discharge and recharge in a reasonable time,*" we took the updated CCRP model provided by the SNWA experts and performed a fractional pumping analysis with ten simulations pumping at 10%, 20%, 30%, etc. up to 100% of the full 61K AFA (acre-ft annually) value. For each of these solutions we analyzed the flow budget to determine if and when the appropriate level of ET is captured, resulting in equilibrium. However, none of the systems approached a state of equilibrium. Regardless of the fractional pumping rate, all systems resulted in groundwater mining and a net withdrawal of water from adjacent basins. This confirms our analysis that the proposed well system is fundamentally flawed due to the spatial distribution of the wells. They are not sufficiently situated near the ET discharge zones and will never be able to reach equilibrium at any pumping rate. This alone should result in full denial of the applications.

## 1.2 Directive 3 – Define Standards, Thresholds, and Triggers for Mitigation in Spring Valley

Thresholds and triggers are the key element of the proposed SNWA 3M plan because they establish critical monitoring levels when action needs to be taken. The SNWA baseline monitoring period includes 11 years of data starting in 2006. SNWA contends that this is adequate to account for drought periods because it includes data for both wet and dry periods. However, the baseline period is inadequate when viewed in the context of long-term climate and the measured water level responses since monitoring began. The 11 years of SNWA data have been analyzed relative to long-term climate using the Palmer Hydrologic Drought Index (PHDI). The problem of using short-term historical records of well water levels and spring discharge rates for baseline calculations and to calculate triggers and thresholds is further compounded for the Cleveland Ranch area because the baseline period for the designated monitoring wells begins in 2011, which corresponds to an overall drought episode.

The unwritten but underpinning assumption in the 3M plan is that lowered water levels and reduced creek, spring and well discharge fluxes would recover if SNWA groundwater pumping were curtailed. The problem is that the SNWA GDP relies on groundwater mining where steady state or equilibrium conditions will not be achieved between groundwater extraction and groundwater recharge. In most cases once a trigger is activated and an investigation is undertaken water levels will continue to decline regardless of any mitigation action by SNWA. Because the SNWA GDP is largely a groundwater mining project, pumping will result in unrecoverable declines in the groundwater water surface in Spring Valley. Such declines will damage senior well water rights, permanently dry up springs and harm vegetation communities.

The SNWA 3M plan is not based on an understanding of groundwater flow relationships between shallow and deep groundwater systems or on an understanding of how these systems impact spring discharges. Instead the 3M plan is simply "Let's pump water, see what happens, and then attempt to fix it".

# 2 Introduction

The Southern Nevada Water Authority (SNWA) filed applications to appropriate groundwater from Spring, Cave, Dry Lake, and Delamar valleys as part of the Clark, Lincoln, and White Pine Counties Groundwater Development Project (GDP) (SNWA 2012). In 2012, the Nevada State Engineer (NSE) issued a ruling on the applications and all but four of the proposed wells were approved. The decision was appealed by protestants, including Corporation of the Presiding Bishop of The Church of Jesus Christ of Latter-day Saints (CPB) which owns Cleveland Ranch, a cattle ranch in Spring Valley with senior water rights that are threatened by the project. In 2013, the NSE ruling was remanded by Judge Estes of the Seventh District Court (Estes 2013). The remand ruling cited the following four directives to the NSE (pg 23):

1. The addition of Millard and Juab counties, Utah in the mitigation plan so far as water basins in Utah are affected by pumping of water from Spring Valley Basin, Nevada;
2. **A recalculation of water available for appropriation from Spring Valley assuring that the basin will reach equilibrium between discharge and recharge in a reasonable time;**
3. **Define standards, thresholds, and triggers so that mitigation of unreasonable effects from pumping of water are neither arbitrary nor capricious in Spring Valley, Cave Valley, Dry Lake Valley, and Delamar Valley, and;**
4. Recalculate the appropriations from Cave Valley, Dry Lake and Delamar Valley to avoid over appropriations or conflicts with down-gradient, existing water rights.

Directives 2 & 3 are applicable to CPB.

On June 30th, 2017, the SNWA, CPB, and other interested parties submitted new documents and evidence in response the issues raised by the Court in the remand ruling. We submitted a technical report focused on Directives 2 & 3, arguing that the proposed project is fundamentally flawed and would never reach equilibrium in Spring Valley at the pumping rates approved by the NSE, thus resulting in perpetual groundwater mining (Jones and Mayo 2017). We also argued that due to the long time frame required for the groundwater system in Spring Valley to respond to the pumping, it would be difficult, if not impossible with any monitor, manage, and mitigation plan to separate impacts from the GDP from natural variations in water levels in the aquifer.

The SNWA submitted a set of documents on June 30, 2017 addressing issues 1-4 in the remand ruling. The objective of this document is to provide a technical response to the SNWA submittals related to Directives 2 & 3. In Chapter 3, we respond to the SNWA submittals related to Directive #2 – perennial yield and equilibrium in Spring Valley. In Chapter 4, we respond to Directive #3 – the SNWA 3M plan for Spring Valley. In Chapter 5, we summarize our conclusions.

# 3 Perennial Yield and Equilibrium in Spring Valley

Before reviewing the SNWA submittals related to perennial yield and equilibrium, it is helpful to review the District Court remand ruling in more detail. In the 2012 ruling, the NSE argued that there is no requirement that the SNWA wells capture an amount of evapotranspiration (ET) equivalent to the combined pumping rate of the wells (King 2012). The Court disagreed with this statement, and referenced the NSE's own definition of perennial yield (Estes 2013):

> *"Perennial yield is ultimately limited to the maximum amount of storage that can be salvaged for beneficial use." (pg 12)*

If the ET is not captured, the system cannot come to equilibrium and the aquifer is in a state of perpetual groundwater mining, which is against Nevada policy and per the Court, is:

> *"...unfair to following generations of Nevadans, and is not in the public interest" (pg 13).*

The NSE also argued that there is no requirement for the system to reach equilibrium within a specific period of time. The Court responded that without evidence that the system will eventually reach equilibrium, it is reasonable to assume that equilibrium will never be reached. Accordingly, the Court issued a simple directive in the remand ruling:

> *"This finding of the court requires that this matter be remanded to the State Engineer for an award less than the calculated E.T. for Spring Valley Nevada, and that the amended award has some prospect of reaching equilibrium in the reservoir." (pg 13)*

In the technical report that we authored and submitted on July 30, 2017, we showed that there is an overwhelming consensus in the scientific literature going back as early as 1915 that one cannot determine the perennial yield of a basin using a simple water balance. The perennial yield is dependent on how much discharge (ET in this case) can actually be captured by a well system and that, in many cases, the hydraulic conditions and the spatial distribution of the wells may be such that achieving equilibrium is impossible. The scientific literature also indicates that the best way to determine the actual perennial yield for a proposed system and determine whether or not the system will come to equilibrium is through long-term computer simulations. Accordingly, we used the SNWA's own computer model to demonstrate that the proposed pumping system is configured in such a way that it will never reach equilibrium. The ET capture plateaus at ~75% and the remaining shortage is pulled from storage (groundwater mining) and by drawing water from adjacent basins.

On June 30, 2017, the SNWA submitted a set of model files and an accompanying report describing an updated computer model and a corresponding set of simulations done in response to the question of ET capture, perennial yield, and equilibrium (Burns et al. 2017). Surprisingly, the model was not used to demonstrate that the 15 wells in Spring Valley will ever reach equilibrium, in spite of specific instructions to provide such evidence in the remand ruling. Rather, they argue that their model (or any model) should NOT be used to analyze flow budget and equilibrium issues. Instead, they present a simulation representing a hypothetical set of 101 wells that does in fact reach equilibrium in a 200-yr simulation. In the following sections, we respond to the main points raised in the model report and we also present a set of simulations we have conducted using the new SNWA groundwater model using the appropriate set of 15 wells.

## 3.1 Determination of Perennial Yield

In the introduction to the modeling report (page 1-4), Burns et al. (2017) repeat the arguments made in 2011 and 2012 by the SNWA and the NSE that there is no requirement for ET capture, nor is there a need to demonstrate equilibrium. This line of reasoning is contrary to Nevada law, was rejected by the Court in the remand ruling, and is simply illogical. Long-established Nevada policy and numerous statements and rulings by the NSE forbid perpetual groundwater mining. The flow budget calculations at the foundation of the applications for the GDP are based on excess water currently being lost to ET. The only way to avoid groundwater mining is for the drawdown caused by pumping to reduce ET discharge by an amount equal to the approved pumping rate (61K AFA), thereby resulting in equilibrium. It is logically inconsistent to prohibit groundwater mining on the one hand, and then on the other hand deny that equilibrium is necessary.

On pages 1.4-1.6, the SNWA authors go on to argue that they should not be expected to use a groundwater model to analyze the actual perennial yield for Spring Valley, nor should <u>any</u> groundwater model be used to reduce the appropriation to a sustainable amount. Rather, they argue that full appropriation should be approved, and the actual perennial yield should be determined based on field observations and a corresponding limitation applied "during or after the staged development process." First, this response ignores the simple and direct request made by the Court in the remand ruling to recalculate the appropriation and demonstrate equilibrium. The burden of proof on this issue should rest squarely with the SNWA. Second, such an approach is not protective to senior water rights holders and future water users in Nevada because once the multi-billion dollar project is constructed, there would be enormous pressure to pump the full allocation in order to justify the expenditure. Furthermore, in our technical report submitted on June 30, 2017, we showed that the scientific literature on groundwater sustainability overwhelmingly supports the practice of using groundwater models to perform short- and long-term simulations of aquifers with the objective of answering questions related to equilibrium (Jones and Mayo 2017). A flow budget analysis is one of the most fundamental and least uncertain uses of a groundwater model because a flow budget does not represent a prediction at a specific location at a specific point in time. Rather, it is a summative process that aggregates the simulation results over the entire computational grid over long spans of time. The SNWA's rejection of the long-established practice of using computer models as a means of determining sustainable yield seems to disregard the legislative policy expressed in NRS 533.024(1)(c): *"To encourage the State Engineer to consider the best available science in rendering decisions concerning the available surface and underground sources of water in Nevada."*

Burns et al. (2017) also argued that the Central Carbonate-Rock Province (CCRP) model should not be used to simulate ET capture and quantify the amount of water available for appropriation due to model uncertainty. Ironically, the authors then proceed to use the model to demonstrate ET capture with a different, hypothetical set of wells. If the model can be used to demonstrate successful ET capture with a hypothetical set of wells, why did the authors not share what the CCRP model predicts with the actual well field as described in the applications?

The CCRP model was used extensively by the US Bureau of Land Management to analyze the long-term impacts of the SNWA pumping project at part of the studies for the Environmental Impact Statement (BLM 2012a; BLM 2012b). From the EIS:

> *"Although there are inherent uncertainties and limitations associated with results of a regional groundwater flow model over a broad region with complex hydrogeologic conditions, the calibrated CCRP model is a reasonable tool for estimating probable regional-scale drawdown patterns and trends over time, resulting from the various pumping alternatives that were evaluated. When combined with the baseline information of water resources in the study area, the simulated drawdowns, **flow estimates, and water budget estimates** provide reasonable and relevant results for analyzing the probable regional-scale effects and comparing alternatives for this programmatic level analysis (BLM 2012b)." [our emphasis]*

As part of this study, the BLM used the CCRP model to evaluate predicted ET capture on individual basins at time frames up to 200 years after full build out. A sample graphic from the EIS report illustrating the results of the flow budget analysis specific to Spring Valley is shown in Figure 3-1.

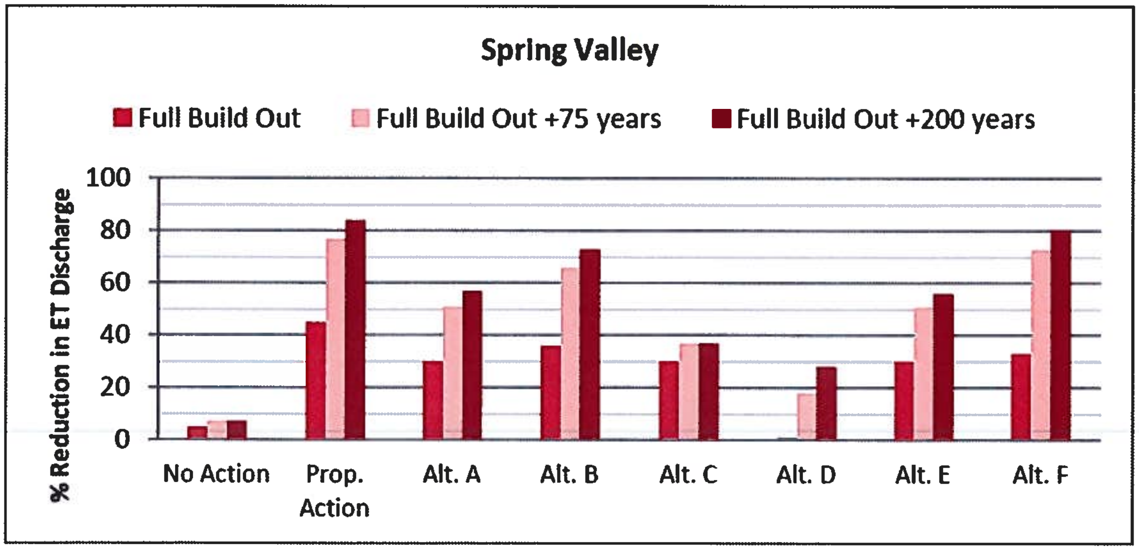


**Figure 3-1 ET Capture Analysis for Spring Valley Conducted by the BLM Using the CCRP Model (BLM 2012b).**

Furthermore, "predictive uncertainty" is not a valid reason to reject modeling completely. No one would argue that models don't include some degree of uncertainty. By definition, models are a simplification of reality. However, there are a number of systematic approaches for dealing with model uncertainty that are routinely used in groundwater modeling studies. These methods typically involve assigning estimates of uncertainty to the model input parameters in the form of standard deviations or Gaussian distributions and then running an ensemble of hundreds or thousands of equally probable simulations to determine the sensitivity of the model predictions on the parameter variations (Capilla et al. 1997; Capilla et al. 1998; Dagan 1982; Dagan 2002; Dagan and Neuman 2005; Delhomme 1979; Desbarats 1998; Freeze 1975; Gelhar 1986; Gómez-Hernández and Wen 1998; Gómez-Hernánez et al. 1997; Højberg and Refsgaard 2005; Mugunthan and Shoemaker 2006; Neuman 2004; Refsgaard et al. 2012; Woodbury et al. 1995; Yeh 1986). This process can be further refined by techniques such as "Null Space Monte Carlo Analysis" that incorporate field observations (water levels, discharges to streams/springs, etc.) with the stochastic process to emphasize or give extra weight to model results that most closely fit field-observed data (Herckenrath et al. 2011; Tonkin and Doherty 2009; Tonkin et al. 2007). Indeed, such techniques are so common that it would be impossible to fully cite them here. A significant percentage of journal articles and presentations at technical conferences on groundwater modeling are dedicated to this fundamental process and it is the focus of several textbooks (Anderson et al. 2015; Bierkens et al. 2006; Dagan and Neuman 2005; Rubin 2003; Zhang 2001). However, no attempt was made by the SNWA authors to systematically assess uncertainty in the model predictions.

The remand ruling was issued in 2013 (Estes 2013). The SNWA experts have had four years to update and improve the groundwater model and to quantify the model uncertainty. They appear to have spent a great deal of time and effort updating the monitor, manage, and mitigate plan, but have done almost nothing with the groundwater model. We believe the reason they are reluctant to see the model used to assess ET capture and equilibrium is because the model predictions indicate that the pumping system is fundamentally flawed, as we will demonstrate in Section 3.4.

## 3.2 ET-Capture vs. Well Locations

In Chapter 2 or their report, Burns et al. (2017) describe the modeling approach they used in updating the CCRP model and performing a set of simulations. On page 2-2, they state:

> *"The permitted maximum volume of project pumping in Spring Valley is limited to 61,127 afy, not the 91,000 afy that was simulated in the CCRP model scenario. This volume is significantly less than the total quantity of ET discharge estimated by the NSE for Spring Valley (84,100 afy). Due to this imbalance, effective capture of the ET discharge by a pumping rate of 61,127 afy in Spring Valley is impossible because the permitted volume of pumping is less than the volume of ET discharge."*

This statement is a straw man argument because they are not being asked to capture the complete ET discharge of 84,100 afy. The remand ruling makes no such condition. Rather, the ruling simply asks for evidence that the system will come to equilibrium. This is accomplished when the ET capture balances the pumping rate of 61,127 afy. The authors continue:

> *"Also, given the same well locations, reducing the amount of water SNWA is allowed to pump would not ensure that the reduced appropriation would be fully captured from the ET discharge area. To the contrary, ET capture would decrease and be further delayed."*

As a general rule, this statement is false. If this were true, the only pumping systems that could potentially reach equilibrium are ones that result in complete capture of the entire available ET in a basin. If that were the case, almost all applications would be denied on the basis of groundwater mining and non-equilibrium conditions. There are countless well systems with pumping rates less than the total available discharge that are able to reach equilibrium. In fact, later in the report, the SNWA authors demonstrate with the subsequent "ET capture scenario" simulation that equilibrium can in fact be achieved with a pumping rate that is a fraction of the total ET in a basin. The factor that makes equilibrium problematic with the 15 SNWA wells in Spring Valley is not the appropriated pumping rate, it is the spatial distribution of the wells in the valley.

The issue of the well locations is referenced by Burns et al. in the same chapter. Referencing the SNWA model presented as evidence in 2011, the SNWA authors state (pg. 2-1):

> *"In addition, in the simulation scenario the Court relied upon, the SNWA wells were located outside the ET discharge area in Spring Valley to delay ET capture and allow for greater time for the vegetation communities to transition and adapt to changing conditions.'"*

And again, in reference to the 2011 SNWA model on page 2-2:

> *"The objective of the scenario used in the CCRP model was to minimize '...the pumping effects at (1) PODs associated with senior water rights and (2) areas containing sensitive or listed species and/or their groundwater-related habitat."*
>
> *"In the scenario used in the CCRP model, the SNWA project wells were deliberately placed outside of the ET discharge area to ensure that the objective stated above would be satisfied. 'This distribution reflects the adaptive management strategies that SNWA plans to utilize in managing the resource by redistributing pumping to minimize effects."*

These statements imply that the well locations are not fixed and can be placed anywhere in the valley, in any number and spatial configuration, and that they just didn't think to select locations where ET capture would occur. Indeed, the authors then go on to describe a new scenario (simulation) that is designed to achieve ET capture. This simulation features 101 wells distributed in the center of the valley in the ET zones. The bulk of the rest of the report is dedicated to describing the results of this "ET Capture Scenario", which does in fact approach equilibrium after 200 years.

The problem with this approach is that the ET Capture Scenario is not applicable to the groundwater withdrawal applications in question. The locations used for the 15 SNWA wells in the 2011 simulation are the locations specified in the official applications. Our understanding is that the wells must be evaluated at precisely those locations. Whether or not the SNWA plans to eventually move the well locations is irrelevant because they are applying for permission to pump from the 15 designated locations and upon approval there will be no legal requirement for them to move the wells. It would be patently unfair to the senior water rights holders for the GDP to be approved based on an analysis of a completely different system.

Taken collectively, the statements about the well locations and the fact that they performed a simulation with a different set of well locations is a tacit admission by the SNWA that the 15 wells they have applied for in Spring Valley will never achieve ET capture or reach equilibrium.

This can be verified by redoing an ET capture simulation using their model with the wells in the correct locations.

## 3.3 Simulation Result with the Proper Set of Wells

The model simulations reported by Burns et al. (2017) were performed using the same CCRP model used by SNWA experts in 2011 (Watrus and Drici 2011), but with a set of updates. The primary updates made to the model are as follows:

a) The pumping rate was reduced from 91,000 AFA to 61,127 AFA to match the appropriation levels approved by the NSE in 2012.
b) The ET discharge was increased from 75,000 AFA to 84,100 AFA to match the updated ET estimate provided by the NSE in 2012. This was accomplished by iteratively increasing the recharge until the ET discharge reached the target amount.
c) The baseline simulation was updated to include water rights purchased by the SNWA in recent years that were not included in the 2011 model.

In our June 30, 2017 submittal, we presented a set of simulations analyzing ET capture and time to equilibrium using an updated version of the same 2011 CCRP model used by the SNWA (Jones and Mayo 2017). We also made modification (a) listed above (reduced pumping rate to 61K AFA). However, we did not make updates (b) & (c). We acknowledge that these two updates are appropriate and result in a more accurate simulation.

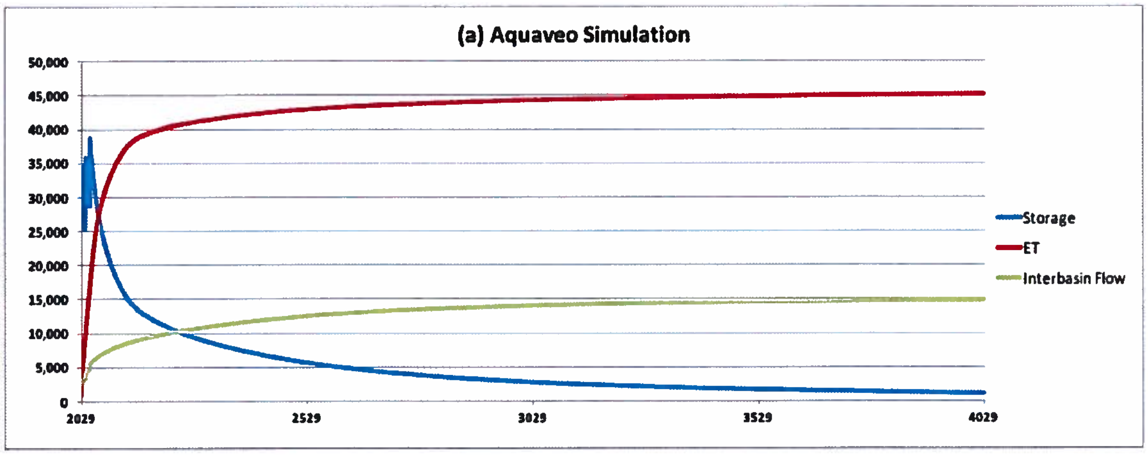
As mentioned in the previous section, the ET Capture Scenario described by Burns et al. (2017) is based on an irrelevant well system. In order to investigate the question of ET capture and equilibrium as specified by the remand ruling, we took the updated CCRP model submitted by Burns et al. on June 30, 2017 and performed a set of simulations with the 15 wells situated in the proper locations.

### 3.3.1 Comparison with Aquaveo Simulation

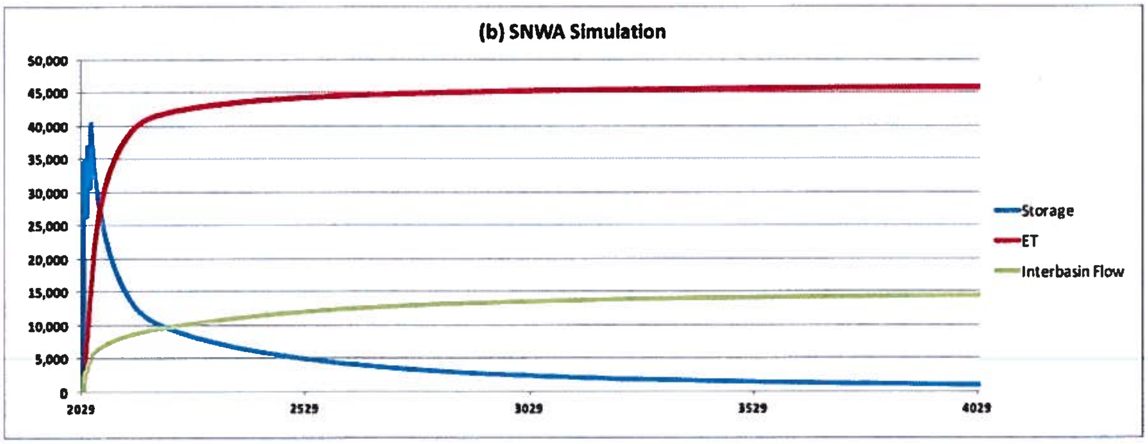
We first performed a set of simulations to reproduce the analyses we reported in our June 30, 2017 submittal. We anticipated some differences in the results due to adjustments (b) and (c) described above, but the differences were small and did not change our conclusions. To avoid confusion, we use the following designations to differentiate the two models in the following paragraphs:

> **Aquaveo Model**: CCRP model that we submitted on June 30, 2017 and described in our technical report (Jones and Mayo 2017).
>
> **SNWA Model**: CCRP model submitted by SNWA experts on June 30, 2017 (Burns et al. 2017)

We first performed a 2000-yr predictive simulation to determine when or if the well system would reach equilibrium pumping at the full allocated rate of 61K AFA. We did one simulation without the 15 wells to create baseline conditions and then ran a second simulation with the 15 wells using the same staged pumping schedule used by Burns et al. (2017). We then calculated the net change in the flow budget by taking the flow budget values from the predictive simulation and subtracting the flow budget values from the baseline simulation. The resulting net flow budget values are illustrated in Figure 3-2. The three flow budget categories are storage, ET, and interbasin flow. These three categories sum to the total pumping rate (61K AFA). As can be seen, there is little difference between the Aquaveo and SNWA simulations. In both cases, the net change in ET plateaus at ~45K AFA, well short of the 61K AFA required for full ET capture and equilibrium. After 2000 years of pumping, the shortfall in the flow budget is made up by withdrawal from storage (groundwater mining) and by a net change of 15K AFA in interbasin flow (from adjacent valleys to Spring Valley).



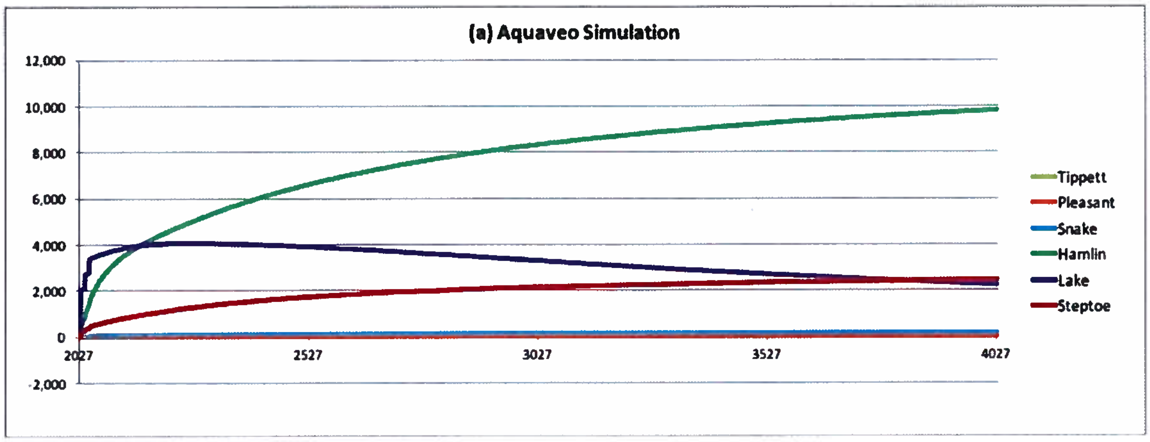
**(a) Aquaveo Simulation**



**(b) SNWA Simulation**

**Figure 3-2 Net Change in Flow Budget [AFA] for (a) Aquaveo Simulation and (b) SNWA Simulation.**

The breakdown of interbasin flow is illustrated in Figure 3-3. In both simulations, the net change for Tippett, Pleasant, and Snake valleys is near zero so the three lines on the chart corresponding to these valleys overlap at the bottom. Hamlin, Lake, and Steptoe valley all experience a net change of flow towards Spring Valley due to the pumping. While the total net interbasin flow is ~15K AFA for each simulation, the SNWA simulation shows a slightly smaller value for Hamlin Valley, and a slightly larger value for Lake Valley. In both cases, the net inflow from Hamlin Valley continues to rise with time.



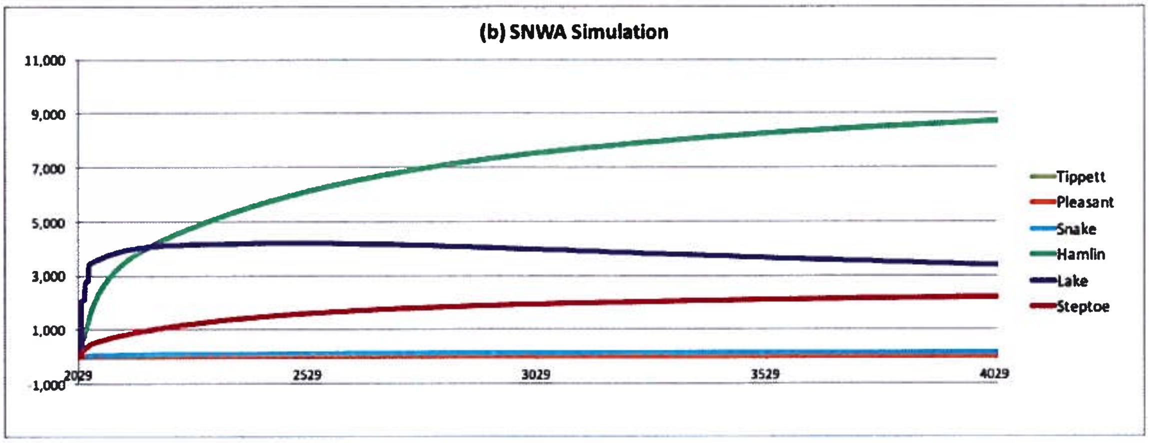


**Figure 3-3 Net Change in Interbasin Flow [AFA] for (a) Aquaveo Simulation and (b) SNWA Simulation.**

### 3.3.2 Results at 200 Years

The time range for the 2000-year simulation is far beyond any reasonable water resource planning and management horizon. This time range was selected simply to determine if the system would ever reach equilibrium. Since the 2011 version of the CCRP model developed by the SNWA used a 200-yr time range and since Judge Estes referenced this time range in the remand ruling, it is helpful to analyze the output from the SNWA model over this range. The net change in flow budget for the 2017 SNWA model is shown in Figure 3-4:

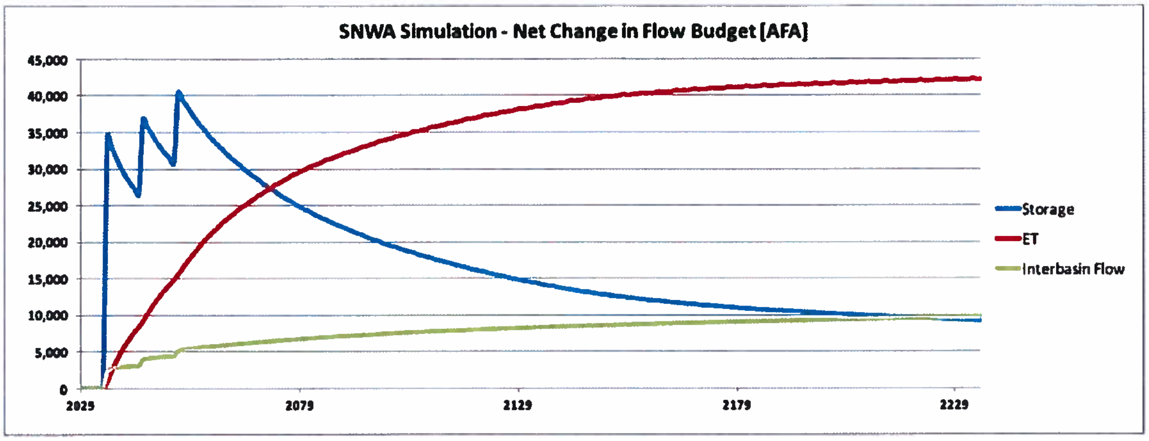


**Figure 3-4 Net Change in Flow Budget [AFA] for the 2017 SNWA Simulation for the First 200 Years of Pumping.**

We also examined and tabulated the flow budget from the updated SNWA model at the same points in time used in the (Burns et al. 2017) report:

- 2051 – the start of full production
- 2126 – 75 years after the start of full production
- 2151 – 100 years after the start of full production
- 2251 – 200 years after the start of full production

The results are shown in Table 3-1. Compare to Table 5-3 in the Burns et al. (2017) report. At 75, 100, and 200 years after pumping, the ET capture is at 62%, 65%, and 69%, respectively, well short of equilibrium conditions. These percentages are found by dividing the ET capture in AFA by the total pumping rate (61K AFA). Again, as long as ET capture is less than 100%, groundwater mining and net withdrawal from adjacent basins will occur in order to satisfy the deficit.

**Table 3-1 Net Change in Flow Budget for SNWA Model at Selected Points in Time.**

| Year | Time | ET Capture [AFA] | ET Capture [%] | Storage [AFA] | Interbasin Flow [AFA] |
|---|---|---|---|---|---|
| 2051 | Full Build-Out | 15602 | 26% | 40315 | 5168 |
| 2126 | +75 Years | 37711 | 62% | 15155 | 8218 |
| 2151 | +100 Years | 39818 | 65% | 12543 | 8703 |
| 2251 | +200 Years | 42338 | 69% | 8787 | 9959 |

### 3.3.3 Storage Depletion

In presenting the results of the ET Capture simulation with 101 hypothetical wells, Burns et al. (2017) presented the cumulative water withdrawn from groundwater storage simulated by the CCRP model and compared this to the total amount of recoverable storage in the basin. The total recoverable storage was found by taking the top 100 ft of the aquifer and multiplying it by the area of the middle of Spring Valley to get an aquifer volume and then multiplying that number by the specific yield (i.e. fraction of volume that drains water) of the aquifer to estimate the total available water in the pore space of the aquifer. The calculations are described in Appendix B of the Burns et al. (2017) report. Since the specific yield has a range of values, they estimated the total recoverable storage as 4.8-8.6 MAF (million acre-feet).

As a point of clarification, the storage values shown above in Figure 3-2, Figure 3-4, and Table 3-1 are the net change in storage for the year in question. The cumulative storage represents the total volume of groundwater withdrawn up to that date and is found by summing each of the yearly values prior to the selected date. This water is lost forever and essentially represents mined groundwater.

Using the updated 2017 SNWA model with the 15 wells in the proper locations, we calculated the cumulative groundwater mined from storage at selected points in time (Table 3-2). The "Min" fraction was found by dividing the mined storage by 8.6 MAF estimate, and the "Max" fraction was found by dividing the mined storage by the 4.8 MAF estimate. As can be seen, the SNWA model predicts that 43-77% of the recoverable storage will be mined after 200 years of pumping, with no end in sight.

**Table 3-2 Total Mined Storage at Selected Points in Time.**

| Year | Time | Total Mined Storage [AF] | Total Mined Storage [MAF] | Fraction (Min) [%] | Fraction (Max) [%] |
|---|---|---|---|---|---|
| 2051 | Full Build-Out | 547774 | 0.55 | 6% | 11% |
| 2126 | +75 Years | 2309133 | 2.31 | 27% | 48% |
| 2151 | +100 Years | 2651478 | 2.65 | 31% | 55% |
| 2251 | +200 Years | 3678921 | 3.68 | 43% | 77% |

## 3.4 Recalculation of Water Available for Appropriation

The District Court remand ruling included the following directive:

> *A recalculation of water available for appropriation from Spring Valley assuring that the basin will reach equilibrium between discharge and recharge in a reasonable time*

Having established that the system will never reach equilibrium pumping at the full rate, we used the 2017 SNWA model to determine if there is a reduced appropriation rate that would result in complete ET capture and thereby achieve an equilibrium condition. To accomplish this, we took the SNWA model, and proportionally reduced the pumping rate to 90%, 80%, 70%, etc. down to 10% of the 61K AFA value and ran a simulation using each of these values. The objective was to plot ET capture vs fractional pumping to facilitate finding a fractional rate at which ET capture is accomplished. In each of these cases, complete ET capture occurs when the net change in ET is equivalent to the fractional pumping rate. The pumping rates associated with each fraction are shown in Table 3-3.

**Table 3-3 Pumping Rates Used in Fractional Pumping Analysis.**

| Fraction | Total Pumping [AFA] |
|---|---|
| 10% | 6,108 |
| 20% | 12,217 |
| 30% | 18,326 |
| 40% | 24,501 |
| 50% | 30,543 |
| 60% | 36,651 |
| 70% | 42,760 |
| 80% | 48,868 |
| 90% | 54,977 |
| 100% | 61,085 |

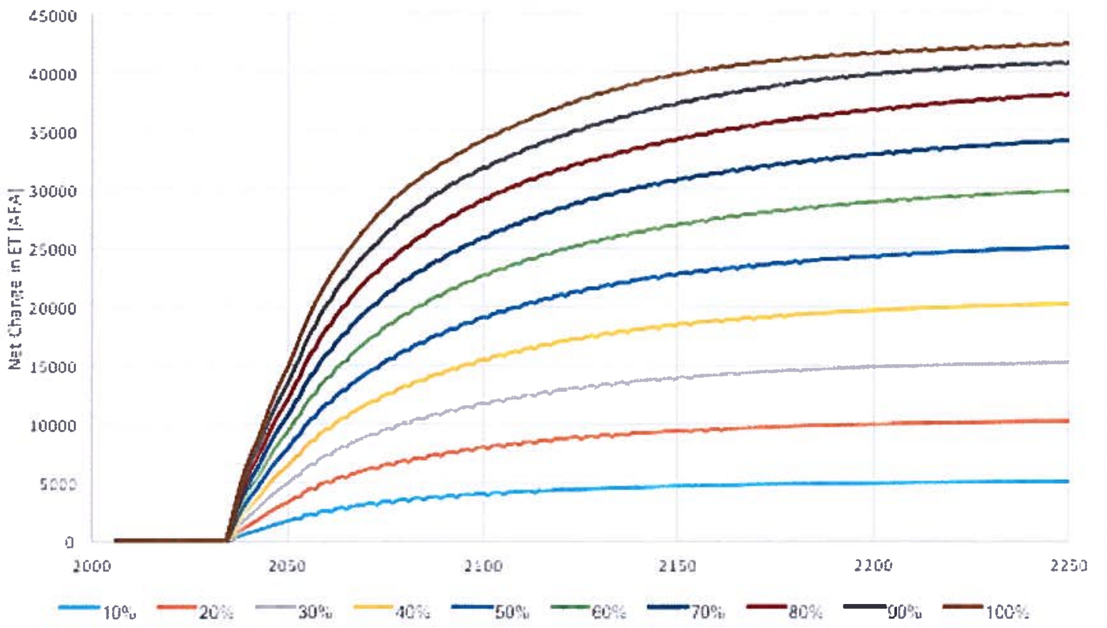
After running the simulations, we subtracted the baseline values from the results of each simulation and analyzed the corresponding flow budgets. The net change in ET capture vs. time up to 200 yrs after full build-out is shown in Figure 3-5(a). While this graph is helpful, one must compare the ET capture values for each simulation with the fractional pumping rate using the values in Table 3-3 to determine if any of these simulations achieve equilibrium. We did this for all of net change in ET values for each simulation to generate a ET capture percentage chart, shown in Figure 3-5(b). ***The results show that even after 200 years of pumping, none of the simulations with fractional pumping approach full ET capture.*** In other words, no matter how much the pumping is reduced, none of the fractional pumping scenarios reach equilibrium.

After 200 years of pumping, the ET capture percentage rates for the fractional pumping scenarios range from 69% to 83%. The 69% capture value corresponds to the full pumping scenario and matches the ET capture percentage show in the last row of Table 3-1, while the 83% capture value corresponds to the case with a fractional pumping rate equal to 10%. The curves in the chart are tightly grouped indicating that changing the fractional pumping rate has little impact on the ET capture.

To better understand why none of the simulations approach equilibrium, we examined the other components of the flow budget. The net change in storage for the fractional simulations is shown in Figure 3-6. After 200 years of full pumping, the water mined from storage represents 3-14% of the total flow budget. This partially explains the deficit. The remaining balance comes from interbasin flow.

The net change in interbasin flow values for the fractional pumping simulations are shown in Figure 3-7. After full pumping begins, the interbasin flow rapidly shifts to pull water from adjacent valleys, regardless of the fractional pumping rate. After 200 years of full pumping, the interbasin flow ranges from 14-16% for all fractional scenarios. Once again, the tight grouping of the percentage-based curves in Figure 3-7(b) indicates that changing the pumping rate has little impact on the outcome.

(a) ET Capture vs. Time - Fractional Pumping



(b) ET Capture (%) vs. Time - Fractional Pumping

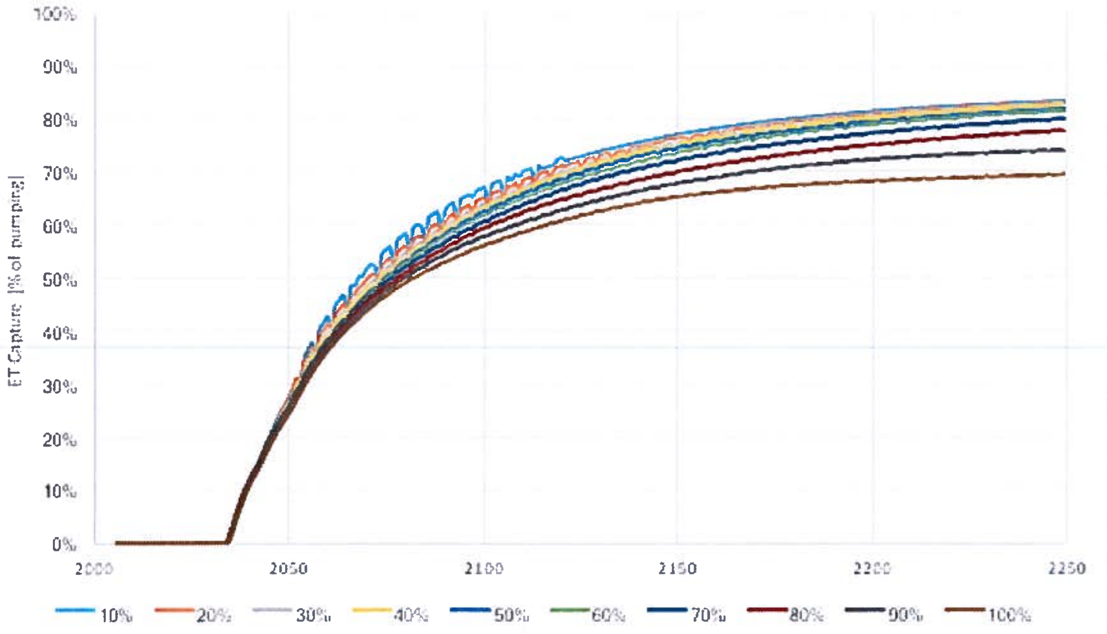
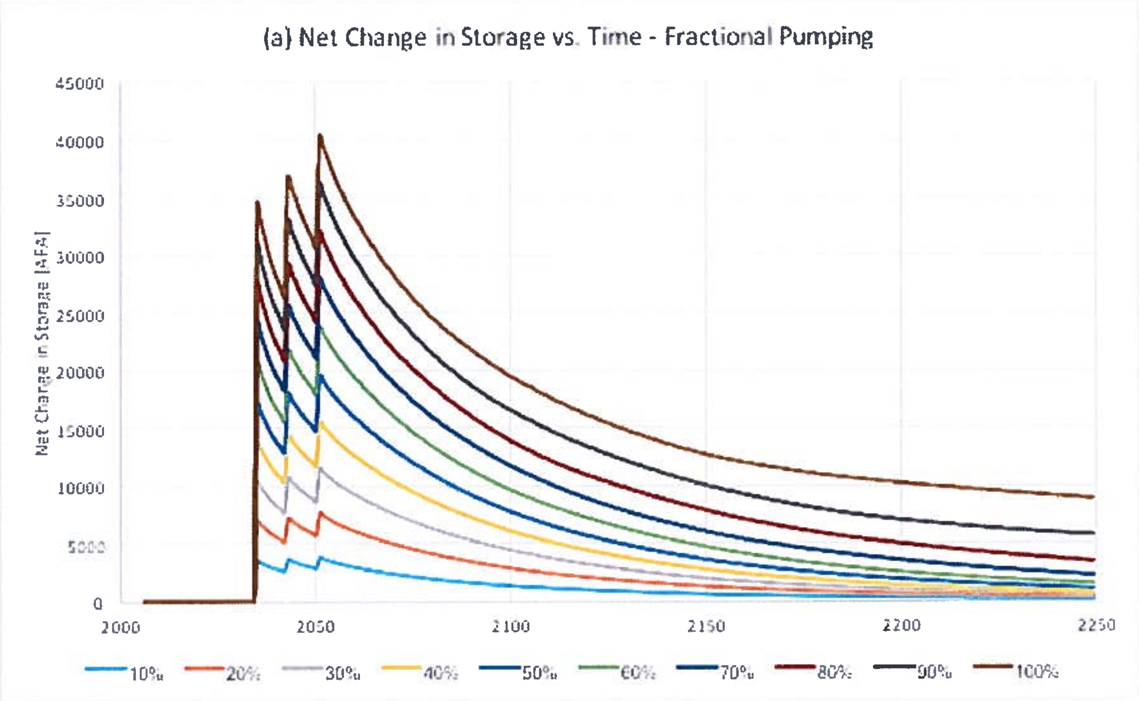
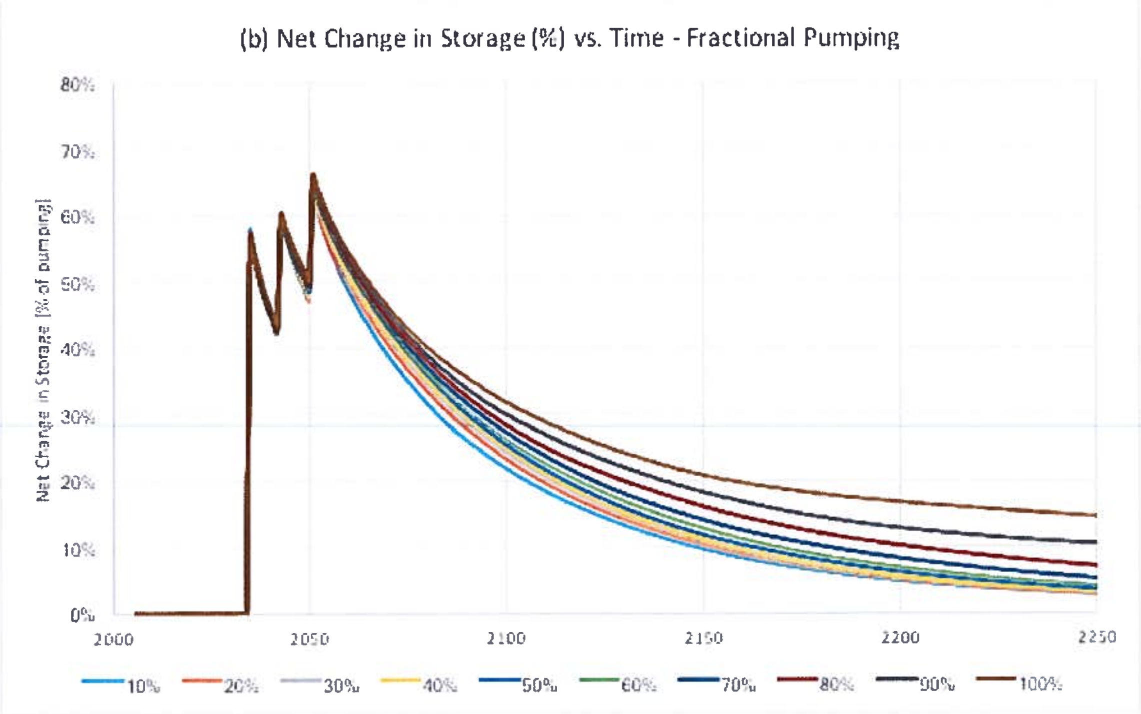


**Figure 3-5 ET Capture vs. Time for Fractional Pumping Analysis with 2017 SNWA Model Expressed as (a) Actual Values in AFA and (b) Percentage of Corresponding Fractional Pumping Rate.**

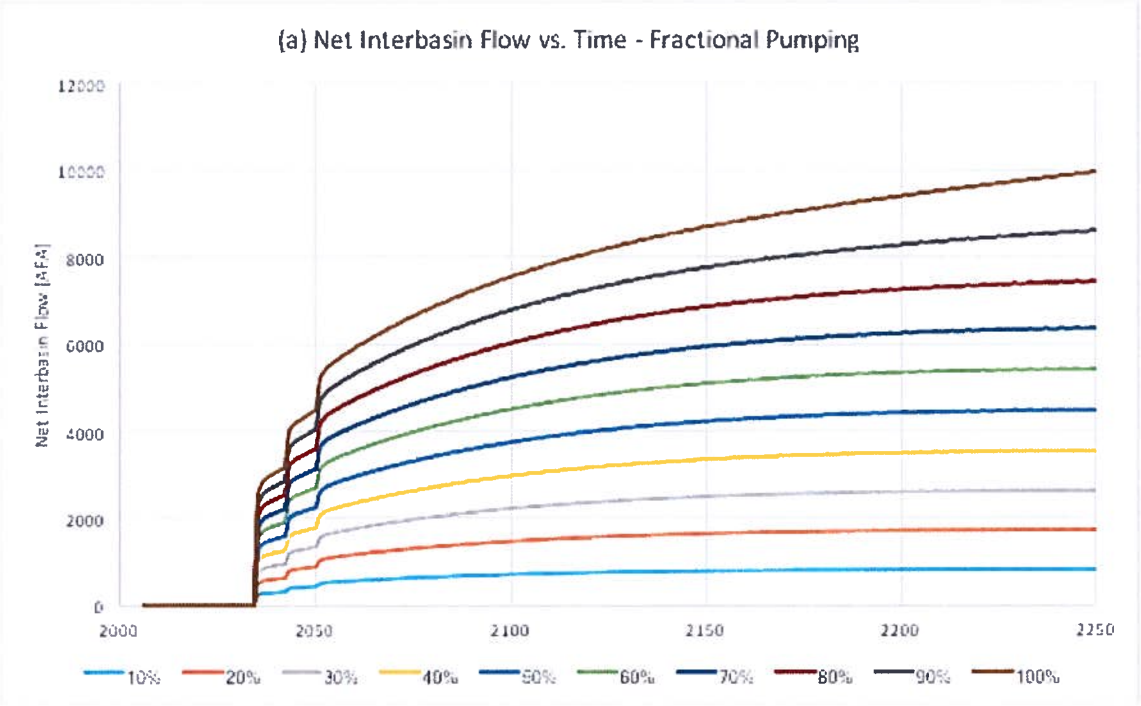


(a) Net Change in Storage vs. Time - Fractional Pumping

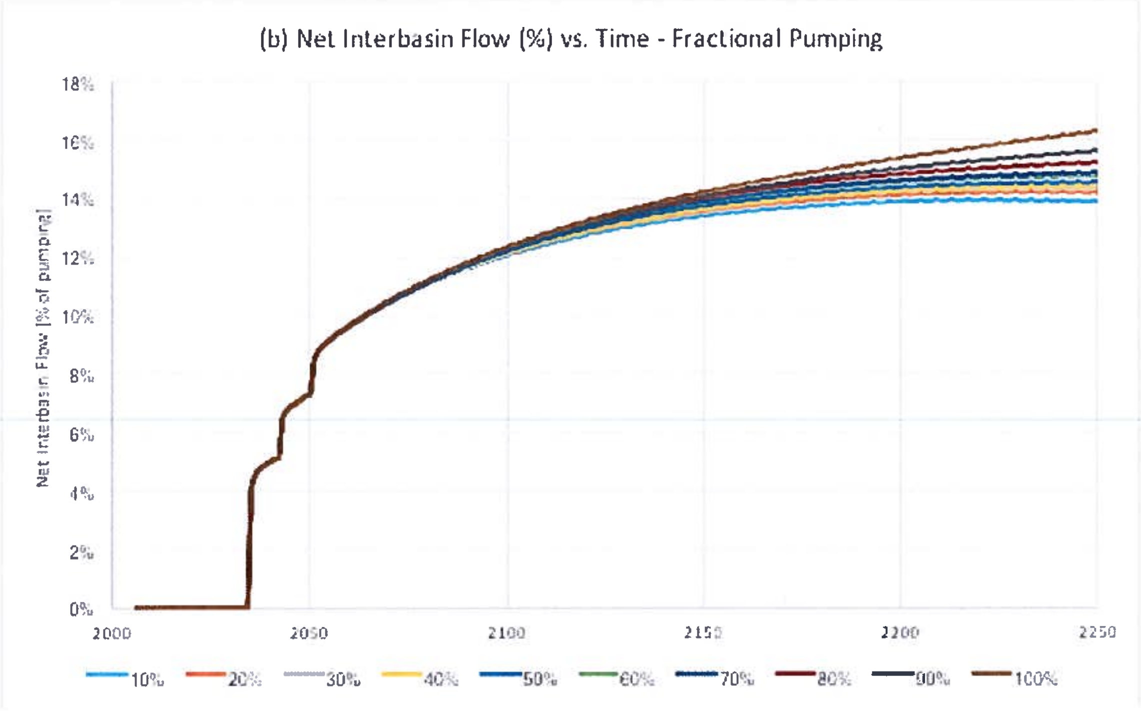


(b) Net Change in Storage (%) vs. Time - Fractional Pumping

**Figure 3-6** **Net Change in Storage vs. Time for Fractional Pumping Analysis with 2017 SNWA Model Expressed as (a) Actual Values in AFA and (b) Percentage of Corresponding Fractional Pumping Rate.**



(a) Net Interbasin Flow vs. Time - Fractional Pumping



(b) Net Interbasin Flow (%) vs. Time - Fractional Pumping

**Figure 3-7 Net Change in Interbasin Flow vs. Time for Fractional Pumping Analysis with 2017 SNWA Model Expressed as (a) Actual Values in AFA and (b) Percentage of Corresponding Fractional Pumping Rate.**

Since the net change in interbasin flow is a significant part of the flow budget dynamics, it is important to look closely at this outcome to see if it makes sense from a conceptual point of view. Over the long term, the largest change in interbasin flow predicted by the CCRP model is between Spring Valley and Hamlin Valley. The baseline scenario associated with the 2017 version of the SNWA CCRP model simulates a net outflow of 6750 AFA from Spring Valley to Hamlin Valley. Various estimates of the net outflow have been made over years by groundwater experts. Rush and Kazmi (1965) estimated the net outflow at 4000 AFA. Nichols (2000) estimated a value of 8000-12000 AFA. The Basin and Range Regional Carbonate-rock Aquifer System (BARCAS) study put the number as high as 33,000 AFA (Welch et al. 2008). More recent estimates put it at 5600 AFA (Halford and Plume 2011) and 6000-11000 AFA (Prudic et al. 2015). In the 2012 ruling, the NSE reviewed testimony and evidence regarding the Spring Valley to Hamlin Valley outflow and concluded that the outflow rate is 4000 – 12000 AFA (King 2012). Thus, the 6750 AFA value simulated by the baseline CCRP model is consistent with most independent estimates. Furthermore, the NSE stated the following in the 2012 ruling:

> *"The Applicant's expert witnesses argue that the groundwater-flow model should not be used to determine interbasin flow, but the State Engineer finds that such estimates are at least as reliable as Darcy flux calculations in this area given the paucity of available head and hydraulic property data." (pg 84)*

Finally, the net change in interbasin flow from adjacent basins toward Spring Valley predicted by the CCRP model makes sense in terms of groundwater hydraulics at a simple conceptual level. The spatial relationship of the wells to the active ET zones (as simulated by the CCRP model) and adjacent valleys is illustrated in Figure 3-8[†]. The southern end of Spring Valley is narrow and the wells in this region lower the water table to create an aggregate cone of depression that changes the hydraulic gradient between Spring Valley and adjacent valleys, thus altering the net interbasin flow.

The change in discharge to adjacent valleys is especially problematic given that the State Engineer specifically stated the following in the 2012 ruling (King 2012):

> *"Basin boundary flows are not a component of the perennial yield of Spring Valley. Any outflow to Snake Valley and/or Hamlin Valley is reserved for those basins."*

Unfortunately, both the CCRP model and basic groundwater hydraulics indicate that the interbasin flow will change in a manner that will harm water users in adjacent valleys and inhibit equilibrium conditions in Spring Valley.

Figure 3-8 highlights another fundamental flaw in the well system design. The ET zone in the southern end of the valley comprises 30% of the total ET discharge prior to pumping. The northern zone comprises the remaining 70%. The Cleveland Ranch lies directly between the

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[†] A similar graphic was included in our June 30, 2017 technical report as Figure 5-5 (Jones and Mayo 2017). We have made two changes to the figure: 1) The figure in the June 30, 2017 report inadvertently included the four wells in the Cleve Creek alluvial fan. The four wells have been removed in this figure. 2) In the June 30, 2017 version, the ET zones were based on our estimate. In this version, the active ET zones represent the model grid cells from the SNWA CCRP model that are actively discharging ET in the baseline simulation. The active ET cells closely align with our prior estimate.

SNWA wells and the large northern ET zone. Even if the aggregate cone of depression from the wells were to somehow extend into the northern zone to capture the ET and achieve equilibrium, it could only do so by dewatering the aquifer below the Cleveland Ranch, doing irreparable harm to CPB water rights.

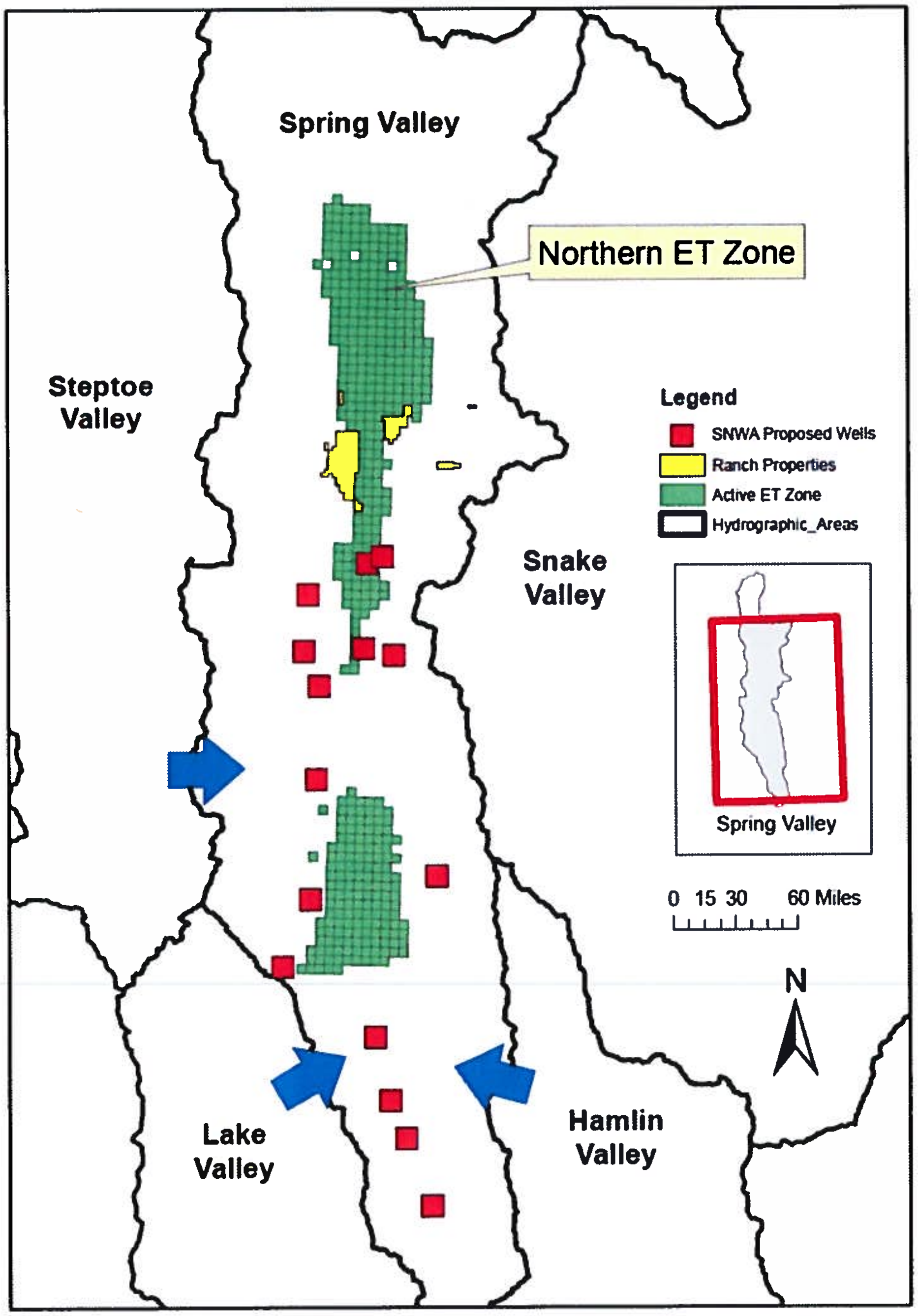


**Figure 3-8** Spatial Distribution of Proposed Wells Relative to Ranch Properties and ET Zones. Net Change in Interbasin Flow Indicated by Block Arrows.

In summary, the SNWA well system is fundamentally flawed due to the spatial distribution of the wells. The wells are located in the central and southern ends of the valley and are not situated inside the ET discharge zones, much of which is in the northern end of the valley. Accordingly, water is mined from storage and pulled from adjacent valleys regardless of the pumping rate. Therefore, there is no reduced appropriation rate that achieves equilibrium and thereby satisfies the directive in the remand ruling. Given this fatal flaw, the only recourse that would protect senior water rights holders and future generations of Spring Valley water users is to reject the applications.

# 4 The SNWA 3M Plan for Spring Valley

In response to Directive #3 in the District Court remand ruling, the SNWA submitted an updated monitor, manage, and mitigate (3M) plan. In this section, we respond to the SNWA submittals describing this new plan.

## 4.1 Thresholds and Triggers

SNWA defines *thresholds* as specific conditions in hydrologic or environmental resources, that when crossed, require mitigation action (Marshall et al. 2017; SNWA 2017). SNWA defines a *trigger* as a quantitative hydrologic or environmental parameter value that prompts action. Two types of triggers are proposed. The primary investigation trigger is a decrease in the measured parameter (such as water level or spring flow) that is collected after SNWA GDP pumping begins. The trigger requires six continuous years of data that are below the 99.7 percent lower control limit using the seasonally adjusted linear regression method (SLAR) for the baseline data collected prior to SNWA GDP pumping. Mitigation thresholds are also based on baseline data.

### 4.1.1 Baseline Conditions

The SNWA baseline monitoring period includes 11 years of data starting in 2006. SNWA contends that this is adequate to account for drought periods because it includes data for both wet and dry periods. However, the baseline period is inadequate when viewed in the context of long-term climate and the measured water level responses since monitoring began.

The Palmer Hydrologic Drought Index (PHDI) is a useful tool for evaluating the meaning of well water level changes and spring discharge hydrographs because it provides a drought and wet cycle framework (NOAA 2017; Palmer 1965). The PHDI measures hydrological impacts of drought (reservoir levels, groundwater levels, etc.) which take longer to develop and longer to recover. This long-term drought index was developed to quantify these hydrological effects. In addition to PHDI data, NOAA publishes data for several other climatic indices such as the Palmer Drought Severity Index (PDSI), Palmer Z-Index, (PDZX), and the Modified Palmer Drought Severity Index (PMDI). Each of these indices has results similar to the PHDI for southern Nevada.

The 1900 to 2016 PHDI data (i.e., 117 years of data) for southern Nevada have been plotted on Figure 4-1a and the 1960-2016 data are on Figure 4-1b. The index rates wet and dry episodes as ranging from neutral to extreme. Between 1900 and 2016 there have been several episodes of overall increasing moisture and decreasing moisture (Figure 4-1a). The baseline period proposed by SNWA, which starts in 2006 coincides with an overall dry period. Although there have been brief times since 2006 when the index approached moderately moist, the index average during the baseline period has been -1.37 which is well below neutral and approaches moderate drought (Figure 4-1b).

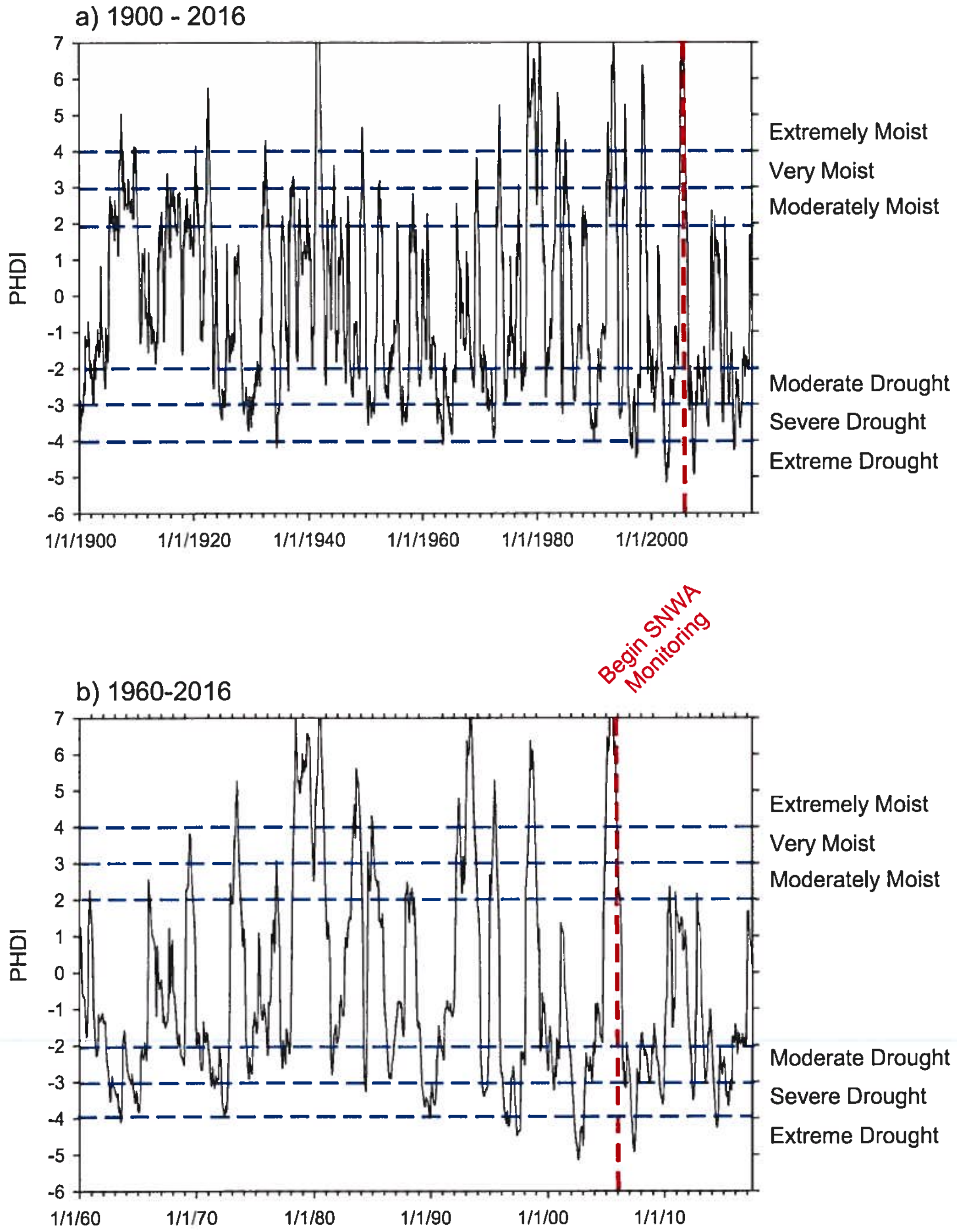


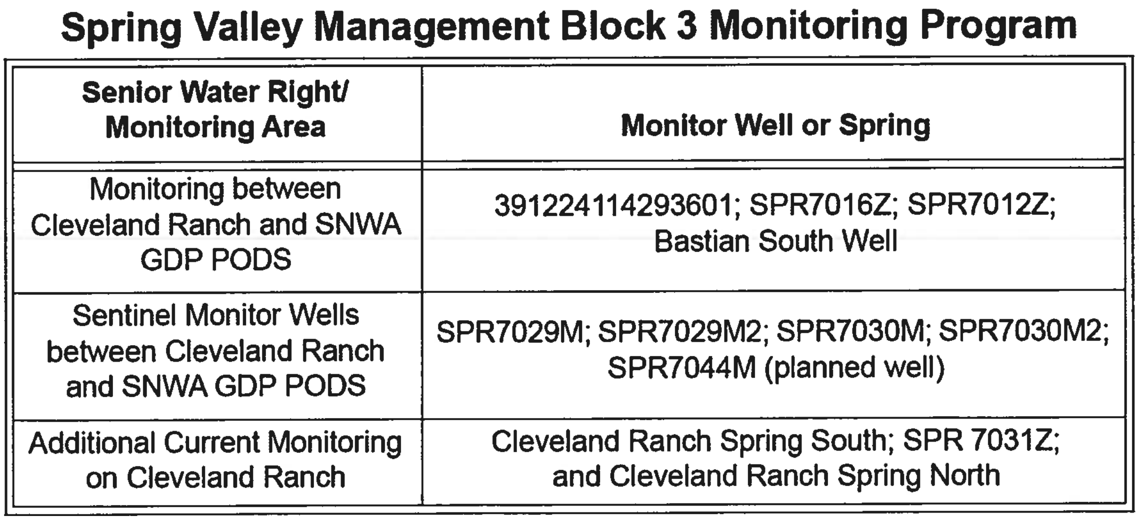
**Figure 4-1** **Plot of the PHDI showing episodes of wet and drought conditions: a) 1900 to 2017, b) 1960-2017. SNWA monitoring began in 2006 (red dashed line) during which time drought conditions were common.**

The problem of the SNWA time frame for establishing baseline triggers and thresholds using only 11 years of data that start in 2006 is further compounded by the fact that SNWA proposes to extrapolate as little as three years of data for SLAR calculations. Clearly there are numerous three to ten-year intervals in the PHDI since 1900 that are downward trending and correspond to drought conditions. It is important to keep in mind that the time frame for the SNWA GDP is considerably longer than the 117 years of PHDI data and it is reasonable to expect similar wet and dry episodes.

The problem of using short-term historical records of well water levels and spring discharge rates for baseline calculations and to calculate triggers and thresholds is further compounded for the Cleveland Ranch area because the baseline period for the designated monitoring wells (Table 4-1) begins in 2011, which corresponds to an overall drought episode (Figure 4-1b). Because of the short baseline time frame and the drought conditions it is not surprising that the proposed SLAR calculated well triggers for the Cleveland Ranch area have a continuous decline (Figure 4-2). It is interesting to note that the declining water levels in the monitoring wells were arrested in 2016, which corresponds with an increase in precipitation. But that is not reflected in the projected continued decline in the projected SLAR lower control limit.

Because of the limited time frame data available, when calculating SLAR lower control limits and thresholds it will not be possible to distinguish between natural declines in water levels and spring discharge rates versus declines caused SNWA pumping. SLARs based on what has been an essentially dry episode since 2011 for the Cleveland Ranch monitoring wells and since 2006 for other wells and springs means that the slope of the SLARs will be negative and any natural recovery in water levels or spring discharges associated with wetter times can be easily masked by SNWA pumping induced declines.

**Table 4-1 SNWA proposed Spring Valley Management Program for Block 3 (After Marshall, 2017).**



**Spring Valley Management Block 3 Monitoring Program**

| Senior Water Right/ Monitoring Area | Monitor Well or Spring |
|---|---|
| Monitoring between Cleveland Ranch and SNWA GDP PODS | 391224114293601; SPR7016Z; SPR7012Z; Bastian South Well |
| Sentinel Monitor Wells between Cleveland Ranch and SNWA GDP PODS | SPR7029M; SPR7029M2; SPR7030M; SPR7030M2; SPR7044M (planned well) |
| Additional Current Monitoring on Cleveland Ranch | Cleveland Ranch Spring South; SPR 7031Z; and Cleveland Ranch Spring North |

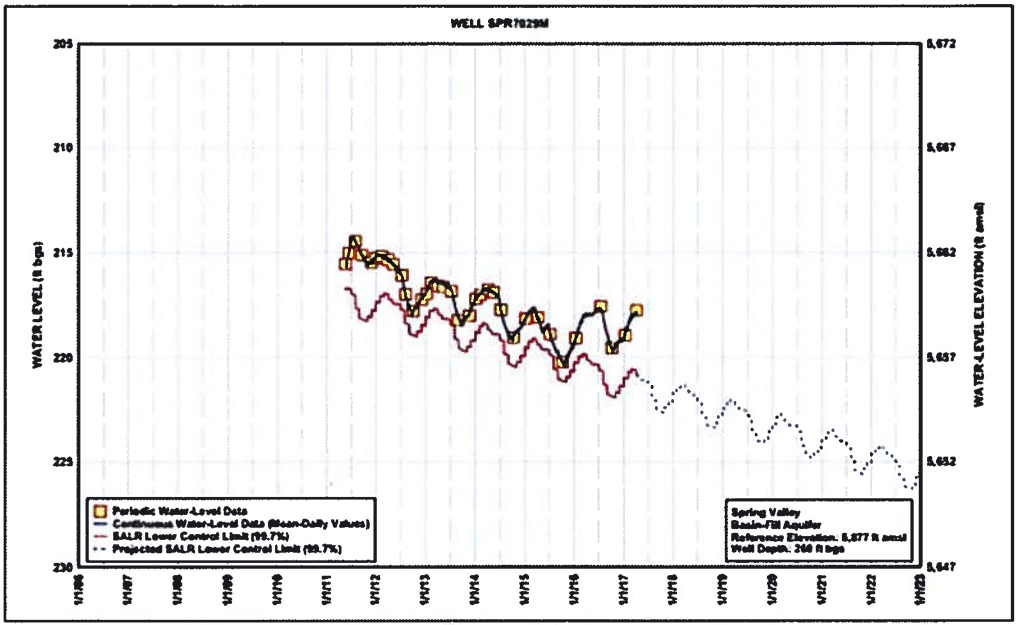


**Figure 6-13**
**SPR7029M - Trigger**

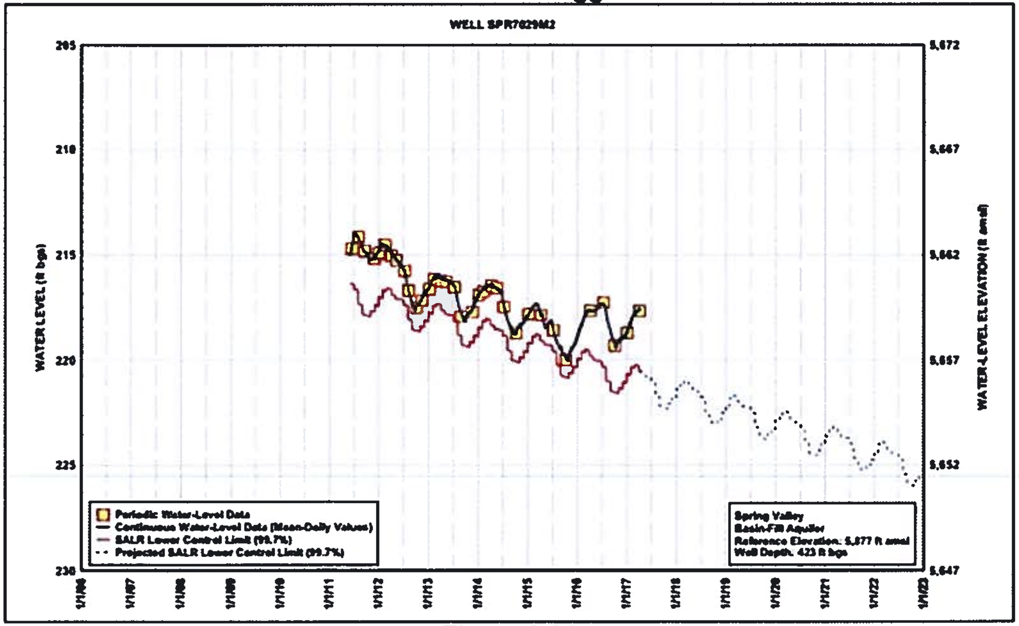


**Figure 6-14**
**SPR7029M2 - Trigger**

**Figure 4-2 SNWA proposed trigger for two sentinel wells in the vicinity of the Cleveland Ranch (after Marshall, 2017). The declines in water levels correspond to a generally decline in PHDI values.**

The pitfalls of using drawdown triggers described above were highlighted in a recent article by (Currell 2016). In his paper "Drawdown triggers: a misguided strategy for protection groundwater-fed streams and springs" published in Groundwater, the publication of the National Groundwater Association, Curell restated the concept described by C. V. Theis (Theis 1940) that water pumped for a groundwater development is always balanced by a combination of three possible sources:

1) An increase in recharge (e.g., incorporation of rejected recharge).
2) A decrease in discharge (e.g., reduced flux to spring, streams, and/or evapotranspiration).
3) Depletion of water in storage (e.g., manifested as declining groundwater levels).

Point 1 above does not apply to Nevada as the precipitation is too meager. However, points 2 and 3 are directly applicable to Spring Valley because the pumping will result in decreased discharge from springs and the depletion of water in storage.

### 4.1.2 Trigger and Threshold Modifications and Investigations

The 3M plan envisions modifying thresholds, triggers and mitigations in light of new data acquisition. The plan does not provide for stakeholder notification or involvement in such modifications and thus gives SNWA carte blanche when designing and implementing such modifications. This means SNWA may undertake actions in the future that harm stakeholders without stakeholders having the opportunity to protect their interest.

SNWA will require six months of data outside of the trigger range before activating an investigation trigger. Once activated SNWA will investigate to determine the cause, condition and significance of the divergence. The 3M plan does not include a provision for limiting the time for the investigation. Without such a provision SNWA could investigate an excursion for years, before coming to a conclusion or taking other actions. During this time, substantial harm could be done to senior water rights and sensitive environmental resources.

## 4.2 Flow Communication between of Spring Valley Shallow and Deep Groundwater Systems

The SNWA 3M plan calls for the construction of a single new groundwater monitoring well pair (SPR7041M and SPR7041) intended to test the vertical groundwater gradient in the vicinity of the Swamp Cedar ACEC area. This is an insufficient number of paired wells in the vicinity of Cleveland Ranch as previous isotopic sampling (Jones and Mayo 2011) demonstrates that at the distal end of the groundwater flow systems in the vicinity of Cleveland Ranch there is upwelling of deeper groundwater into the shallow groundwater systems (Table 4-2).

**Table 4-2 Summary of northern Spring Valley groundwater age data from the vicinity of Cleveland and Rogers Ranches.**

| Sample ID | BYU lab # | Sampling Date | pH | $^{14}$C [pmc] | +/- | $\delta^{13}$C | +/- | $^{3}$H [TU] | +/- | HCO3$^-$ [mg/L] | Fontes calculated 14C age [years] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bastian Creek Spring | 9232 | 7/19/11 | 8.01 | 44.39 | 0.15 | -7.87 | 0.04 | | | 184 | 1200 |
| Irrigation Well | 9234 | 7/19/11 | 8.11 | 37.56 | 0.13 | -8.22 | 0.04 | 3.9 | 0.2 | 186 | 2500 |
| Stephens Creek | 9236 | 7/19/11 | | | | | | 11.1 | 0.4 | | |
| Big Resevoir Spring (#1/2) | 9237 | 7/20/11 | 7.93 | 77.12 | 0.22 | -13.90 | 0.04 | | | 131 | modern |
| Millick Spring | 9238 | 7/20/11 | 7.92 | 44.94 | 0.14 | -8.63 | 0.04 | 2.0 | 0.1 | 270 | 1200 |
| Negro Creek Spring | 9239 | 7/19/11 | | | | | | 9.1 | 0.1 | | |

The Cleveland Ranch flowing-artesian well contains ~37.6 pmc and 3.9 tritium units (TU), which means the water has mixed recharge sources, both modern and older groundwater recharge. The old component of recharge is appreciably older than the calculated Fontes $^{14}$C age of 2,500 years and the tritium content is a mixture of pre-atmospheric nuclear testing groundwater and more recent recharge water. Because the well is screened from about 100 feet to about 600 feet below ground surface, it is likely that the well acquires modern groundwater near the surface and older groundwater deeper in the alluvial fan. The fact that the well is a flowing artesian well indicates that the well penetrates a confining layer, and that there are at least two groundwater systems in the alluvial fan within 700 feet of the ground surface. The significance of the two groundwater systems with different groundwater travel times is that deeper alluvial fan groundwater is not rapidly replenished by annual groundwater recharge; whereas, the overlying shallow alluvial system has an active hydrodynamic communication with surface water and annual recharge events. Because the carbonate aquifer underlies the alluvium, the carbonate groundwater would be older than the deeper alluvial groundwater. The importance of this to groundwater extraction by deep alluvial fan and carbonate aquifer wells is that shallow alluvial fan groundwater will be readily replenished by annual recharge events, whereas the replenishment of the deeper groundwater will require hundreds to thousands of years.

The carbon-14 ages and tritium contents of the Bastian Creek spring and the Millick spring (Table 4-2) suggest that these spring discharges are also supported by younger shallow and older deep groundwater. The fact that shallow and deep groundwater is found supporting springs on opposite sides of Spring Valley indicates that deep groundwater discharges into shallow groundwater is common in Spring Valley.

Because the SNWA GDP calls for the production wells to be screened in both the alluvial and deeper portion of the groundwater system, the cones of depression from the production wells will impact both the shallow and deep groundwater systems. What this means is that the production wells may quickly impact the spring discharge fluxes that are supported by the shallowest groundwater and will continue to impact the springs as the deeper groundwater system(s) are dewatered.

## 4.3 3M Plan

The unwritten but underpinning assumption in the 3M plan is that lowered water levels and reduced creek, spring, and well discharge fluxes would recover if SNWA groundwater pumping were curtailed. The problem is that the SNWA GDP relies on groundwater mining where steady state or equilibrium conditions will not be achieved between groundwater extraction and groundwater recharge. The 15 SNWA wells are located in a relatively dry portion of Spring Valley. Pumping will lower the water table and there is not enough natural recharge in the well area to restore the water table to is original level. This has been demonstrated by long-term simulations using the SNWA's own groundwater models as described in Section 3.3.

There are fundamental differences in the response of groundwater systems to transient stress (e.g., groundwater pumping) between groundwater systems that are undergoing groundwater mining and groundwater systems that reach equilibrium between groundwater recharge and discharge (i.e., natural plus anthropogenic). *The SNWA GDP will not reach equilibrium during the operation of the GDP and thus will be largely based on groundwater mining.* Of interest here are the long-term effects that groundwater extraction will have on the water table. Changes in water table elevations can impact both well production and spring discharges. The effects on both equilibrium and groundwater mining on the long term water surface are described below.

The effect of pumping from an aquifer that has recharge and discharge in equilibrium is shown in Figure 4-3. During pumping, the cone of depression continues to grow with continued pumping. Because the surface area of the cone increases with time, the rate of drawdown decreases with time. After the well is turned off the water surface recovers to near or complete pre-pumping conditions because the volume of water removed, as represented by the volume of the cone of depression, is replaced by recharge water.

The post-pumping result of groundwater mining on the water surface is a lowered water surface (Figure 4-4). The lowered water surface occurs because there is no or very limited natural recharge to replace the volume of water lost during pumping and this replacement water is derived from water in storage. This volume of replacement water is the volume of the cone of depression adjusted for effective porosity. The net effect of post pumping is that water in storage flows to replace the cone of depression and the overall water surface is lowered.

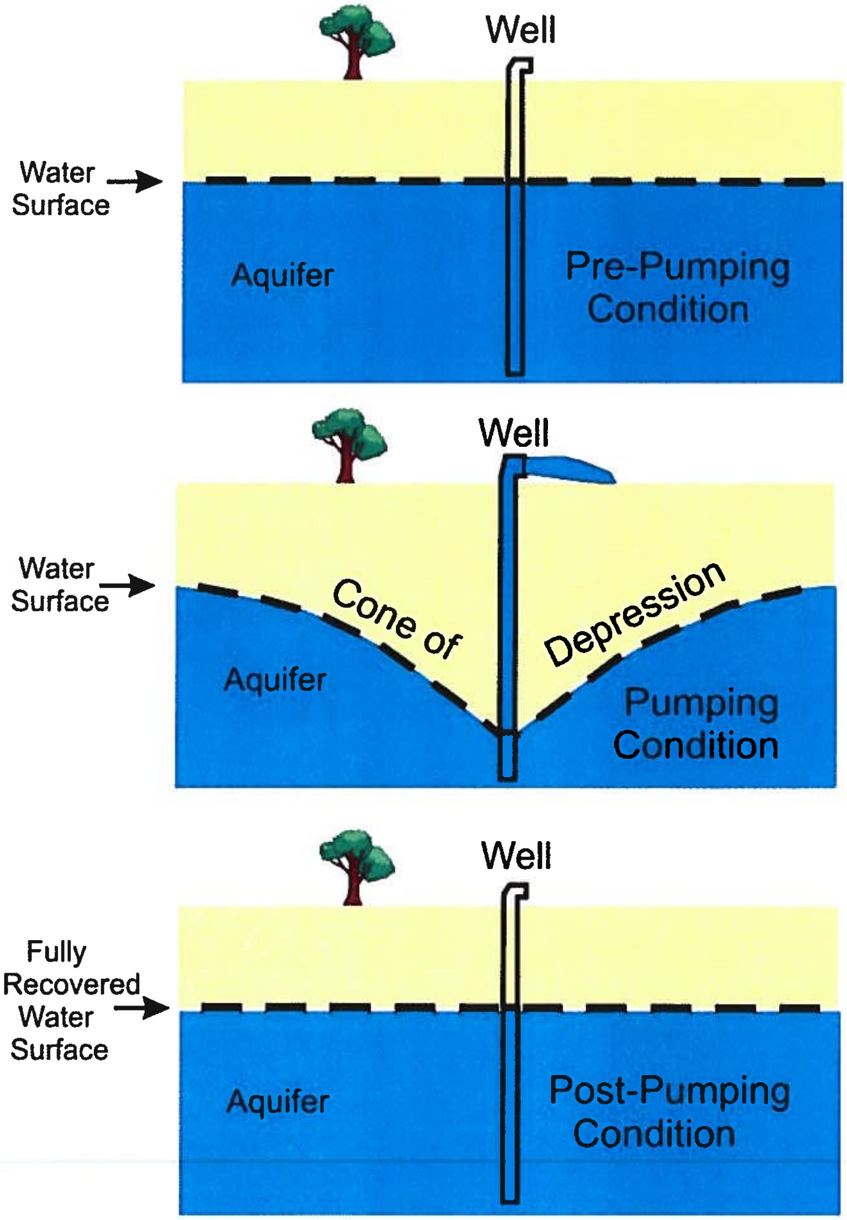


**Figure 4-3** **Effects of groundwater pumping on a groundwater system that has recharge and discharge in equilibrium.**

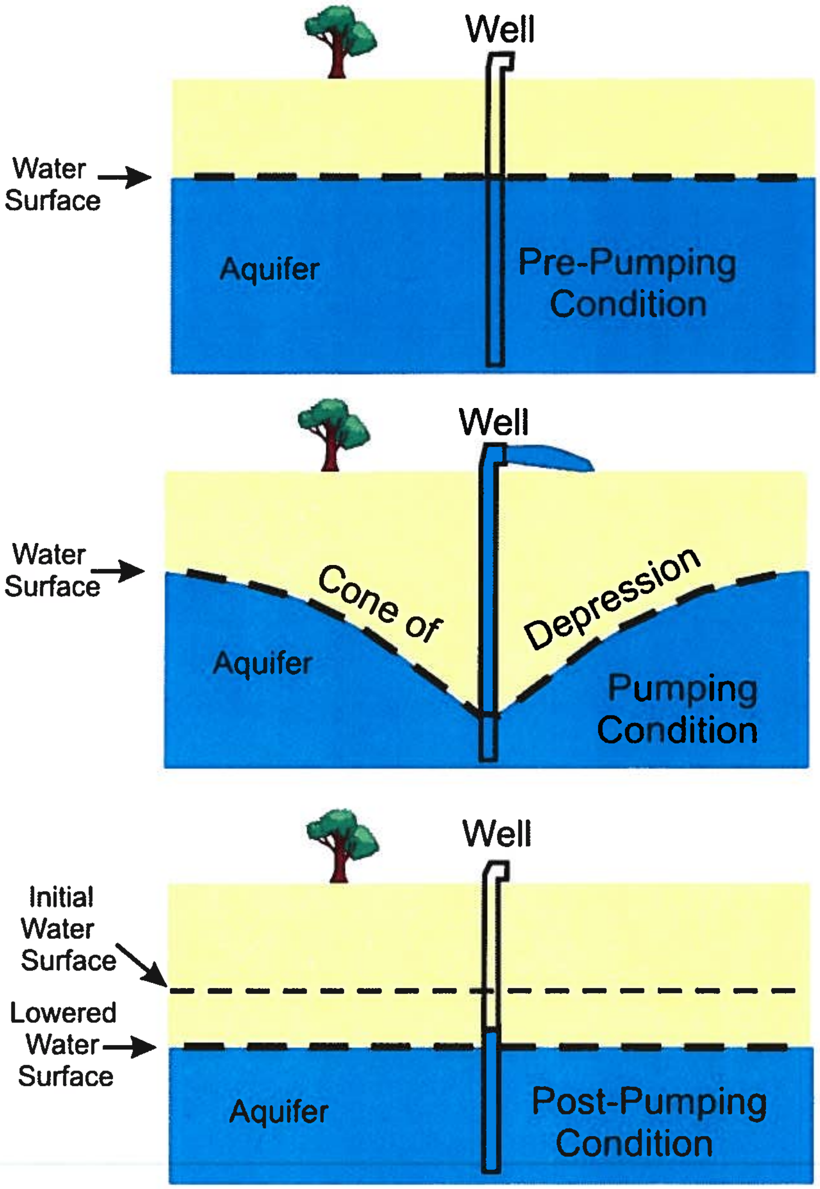


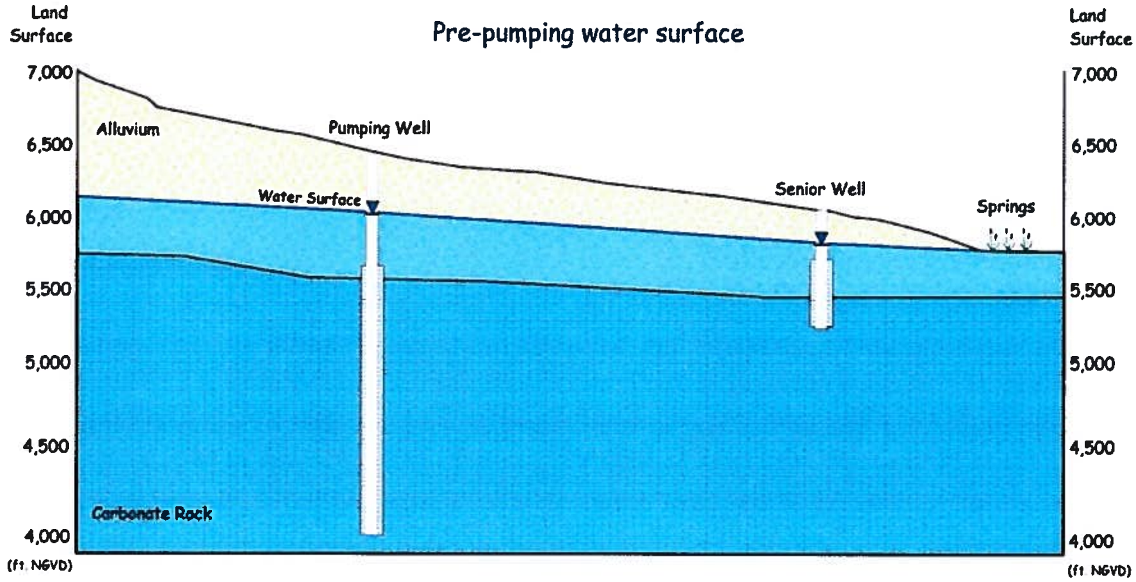
**Figure 4-4** **Effects of groundwater pumping on a groundwater system when groundwater mining occurs. After the well is turned off the volume of water depleted by the cone of depression is not replaced by an inflow of recharge water, but is replaced by an overall lowering of the water surface.**

The effects of groundwater mining on existing wells and spring senior water rights in Spring Valley are illustrated via a series of generalized cross-sections in Figure 4-5. The cross-sections are not to scale and are not intended to represent a specific well or location in Spring Valley. Prior to SNWA pumping, groundwater flow is toward springs and seeps at the distal end of the groundwater flow path (Figure 4-5a). In many locations, the groundwater surface will be slightly below ground surface and the shallow upwelling groundwater supports plant communities including the grove of swamp cedars.

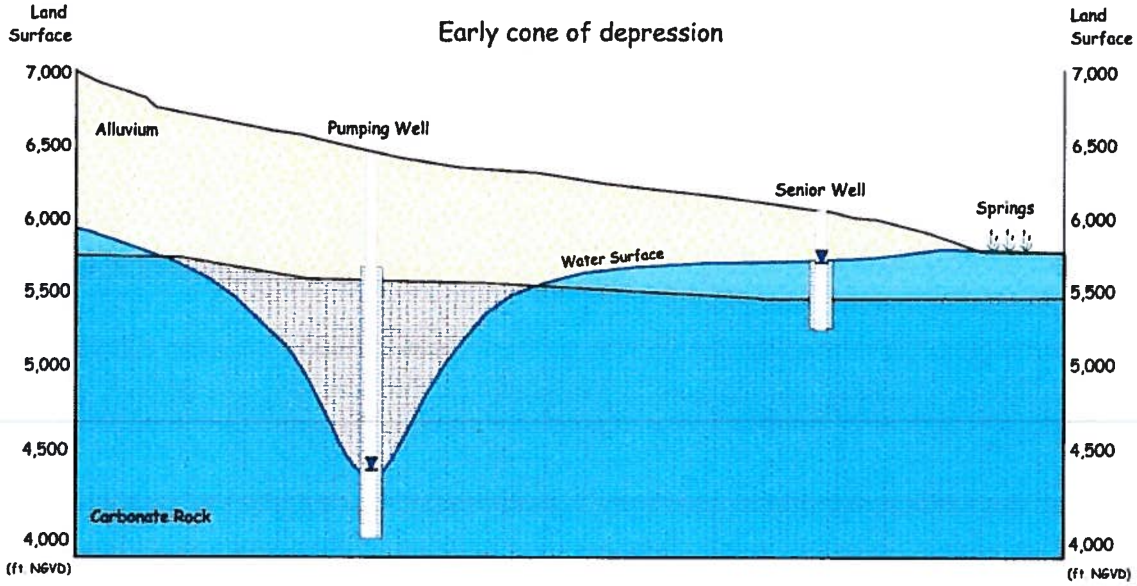
During the early stages of SNWA groundwater pumping the cone of depression is greatest in the vicinity of the pumping well and the springs and vegetation are not yet impacted in Figure 4-5b. In the figure, water in the senior water rights well or sentinel well is slightly lowered and SNWA triggers an investigation. In some locations, the springs and sensitive vegetation are closer to the pumping well than are sentinel wells and the first noticeable impact may be to the springs or vegetation. As pumping of the SNWA well continues, the senior water rights well and the spring in Figure 4-5c have been impacted and the SNWA well is about to be permanently turned off. After the SNWA well has been turned off the level of the water surface recovers. Because the SNWA GDP is mostly a groundwater mining project the water surface will be permanently lowered and the spring or sensitive vegetation will not recover (Figure 4-5d).

The idea that SNWA groundwater mining will result in an unrecoverable decline in the groundwater water surface in Spring Valley is predicated on the fact that there is limited natural groundwater recharge. There is however, an alternative potential source of replacement water for dewatered cones of depression. This source is underflow (i.e., interbasin flow) from adjacent groundwater basins. The SNWA groundwater model predicts that considerable groundwater extracted from the southern portion of Spring Valley will be from interbasin flow. To the extent that this occurs, the permanent lowering of the water surface may be somewhat mitigated at the expense of using groundwater underflow from adjacent basins (i.e., interbasin flow).

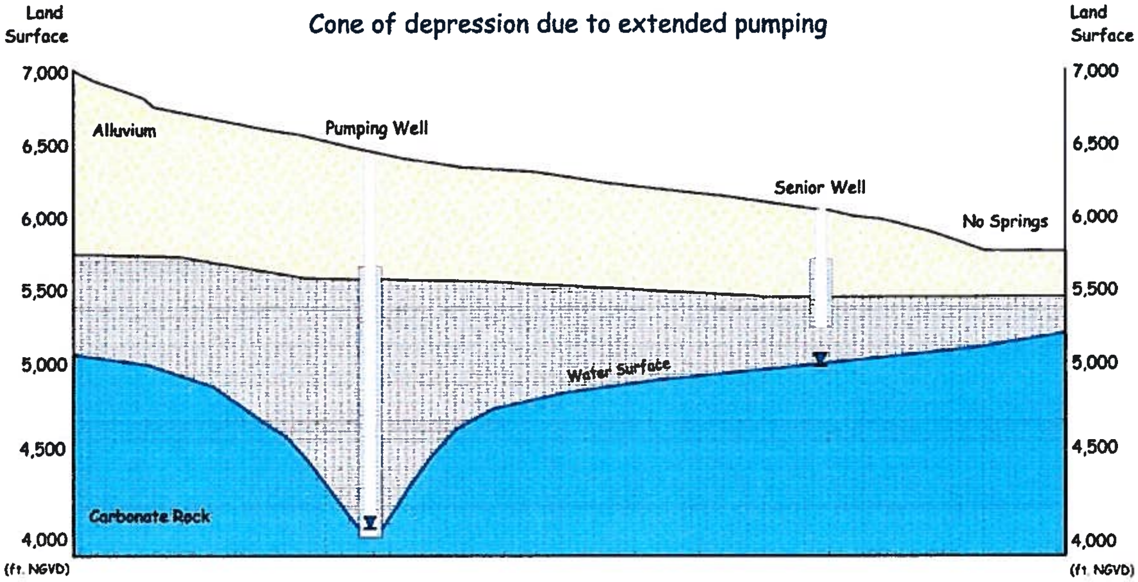
An added problem with the threshold and trigger approach in the SNWA 3M plan is that once a trigger is activated, the studies undertaken, and mitigation begins, the path to irreparable damage is likely set in motion and no mitigation action short of supplying replacement water in perpetuity will be effective. In the case of Spring Valley wells and springs, once a trigger is activated even shutting down the offending well likely result in the permanent loss or curtailment of spring discharge and groundwater well extraction capabilities, because the water surface will not return to pre-extraction conditions.



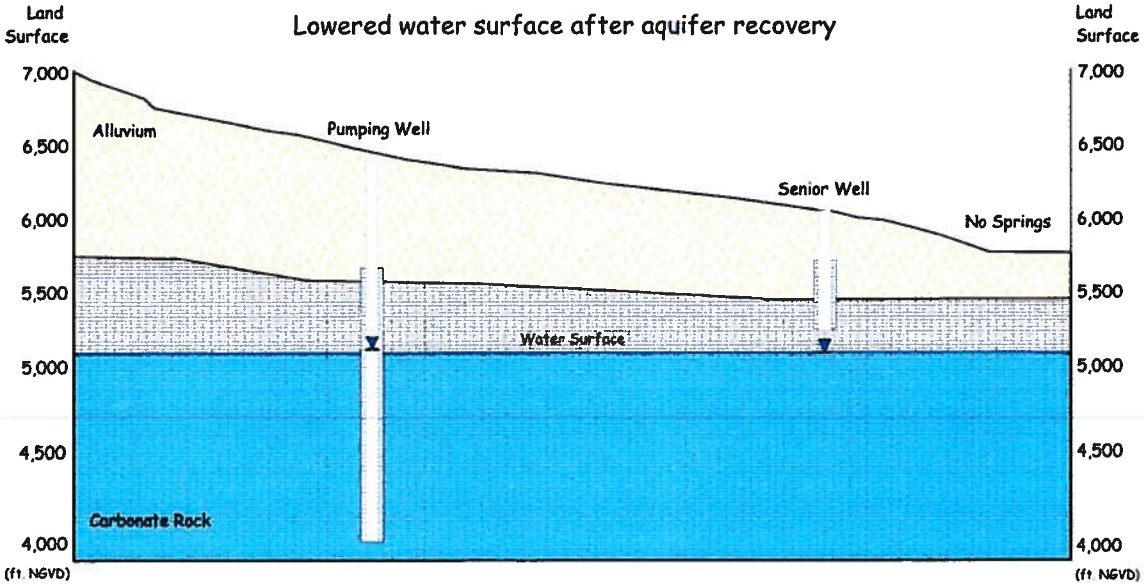
(a) Generalized representation of the groundwater surface and discharge to springs in Spring Valley prior to SNWA groundwater pumping. Both the alluvium and underlying carbonate rock contain groundwater systems. The SNWA pumping well will draw water from both systems.



(b) Generalized representation of the cone of depression associated with SNWA pumping during the early part of the SNWA extraction program. The cone of depression is greatest in the vicinity of the pumping well and the spring is not yet impacted. Water in the senior water rights well is slightly lowered and an investigation is triggered.



(c) Generalized representation of the cone of depression after extended pumping. The senior water rights well and the spring have been impacted and the SNWA well and the SNWA investigation concludes that the well must be permanently turned off.



(d) Generalized representation of the water surface after the SNWA well has been turned off and the water level has recovered. The water surface has been permanently lowered because most of the extracted groundwater was from storage (i.e., groundwater mining). The spring or vegetation based on shallow groundwater will not recover.

Figure 4-5 Impact of SNWA Wells on Senior Water Rights.

## 4.4 Modeling Triggers and Baseline Conditions

Since the court ruling in 2013 SNWA has had several years to evaluate the potential impacts of the GDP project on existing water rights. Inherent in the SNWA 3M plan is the fact that SNWA has not undertaken the studies necessary to adequately understand the shallow and deep groundwater systems, the interrelationships between the systems, between the systems and surface water resources (streams, spring, and seeps), and the impact that the GDP project will have on these resources. This lack of understanding is evident because:

1. The 3M plan calls for the setting of triggers with as little as three years of baseline data. Because the SNWA 3M plan is based on the erroneous assumption that adequate annual groundwater recharge will occur in a reasonable number of years, the short three-year time frame cannot provide the necessary information regarding the effects of wet and dry periods on triggers.

2. The detailed guidance in the 3M plan on how SNWA will investigate lowered water levels and declines in spring discharges makes it clear SNWA does not have a clear or scientific understanding of how groundwater mining will impact the individual senior water rights. Instead the SNWA 3M plan is simply "Let's pump water, see what happens, and then attempt to fix it".

Evapotranspiration (ET) capture is the underlying premise of the SNWA GDP and water rights applications. ET capture cannot be accomplished without doing damage to plant communities and senior water rights. Except for evaporation from spring discharges and ponded surface water, the plant communities are the primary mechanisms for ET. The SNWA 3M plan says in effect, "We will monitor and take action if the impacts become too severe." Unfortunately, because the SNWA GDP is a largely a groundwater mining plan, when the impacts are observed it will likely be too late for mitigation.

SNWA has developed a regional groundwater flow model that includes Spring Valley. Groundwater models are the best way to test various pumping scenarios to predict the potential impacts of groundwater extraction. SNWA experts argue that the existing CCRP model is not suitable for impact testing at specific locations, but there is no technical reason that prevented SNWA from developing such a model during the several years that have passed since the District Court remand ruling. The results of such a model could have been used to develop reasonable threshold and triggers and to determine if the 3M plan would be able to produce water while simultaneously safeguarding senior water rights. This omission puts senior water rights holders at risk.

# 5 Conclusions

Based on our analysis, we offer the following conclusions:

1. The "ET Capture Scenario" submitted by the SNWA experts features a set of wells fundamentally different from the 15 wells described in the groundwater withdrawal permit applications, and is therefore irrelevant.
2. In presenting the ET Capture Scenario as an alternative analysis, the SNWA experts are effectively conceding that the 15 wells in Spring Valley are not situated in locations that would result in ET capture and equilibrium.
3. When used with the proper set of 15 wells in Spring Valley, the updated CCRP model submitted by the SNWA experts results in the same outcomes as the CCRP model we submitted on June 30, 2017. In both cases, the well system never achieves ET capture, never reaches equilibrium, and results in perpetual groundwater mining and a net reduction of interbasin flow reserved for adjacent basins.
4. A fractional pumping analysis demonstrates that the proposed well system is fundamentally flawed and will never achieve ET capture, regardless of what pumping rate is used. This is because the proposed wells are situated in locations where it is physically impossible to capture ET discharge and thereby achieve equilibrium. In other words, the proposed GDP is largely a groundwater mining plan with contributions from interbasin flow.
5. The proposed data for establishing baseline conditions and action triggers in the SNWA 3M plan is inadequate and cannot accommodate well known long-term trends in wet and dry climatic cycles.
6. The SNWA 3M plan is not based on an understanding of groundwater flow relationships between shallow and deep groundwater systems or on an understanding of how these systems impact spring discharges. Instead the 3M plan is simply, "Let's pump water, see what happens, and then attempt to fix it."
7. Implementation of the proposed SNWA GDP and the proposed 3M plan will cause irreparable damage to existing water rights in Spring Valley. The 3M plan does not recognize the fact that the SNWA GDP is largely based on groundwater mining and as such the groundwater levels and spring fluxes will not recover after the proposed mitigation measures are enacted.
8. As part of developing the 3M plan, SNWA should have constructed a groundwater flow model that could be used to predict the impact that different pumping schemes will have on senior water rights at specific locations, and then used that model to test the feasibility of the 3M plan and its effectiveness at protecting senior water rights. This omission puts senior water rights holders at risk.

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