Appendix F

Technical Memorandum

October 9, 2011

To: Great Basin Water Network

From: Tom Myers, Ph.D., Hydrologic Consultant

Subject: Review of the SNWA Pipeline Draft Environmental Impact Statement

The Bureau of Land Management (BLM) released the Clark, Lincoln, and White Pine Counties Groundwater Development Project Draft Environmental Impact Statement (DEIS)(BLM 2011) in early June 2011. The memorandum has five primary sections reviewing the DEIS and supporting documents. First is a Summary and Conclusion of the overall memorandum. The next three sections review the actual DEIS (BLM 2009), the Conceptual Model Report (SNWA 2009a), and the SNWA Numerical Model (SNWA 2009b, 2010a, 2010b), respectively. Additionally, the fifth section is an analysis of the DEIS proposed action and a reduced pumping option for Spring and Snake Valleys using the Myers (2011a and 2011b) numerical groundwater model.

Summary and Conclusions

This DEIS has highlighted the potentially devastating impacts that will occur to the environment of eastern Nevada and far western Utah if the pipeline project is developed and SNWA pumps groundwater at up to the full application amount. These impacts are obvious even though the models used for the BLM's DEIS are fraught with errors and assumptions which bias the model to underpredict the impacts.

A major deficiency with the DEIS is that it limits impacts to those which occur within the 10-foot drawdown cone, although major impacts can occur with less drawdown, including dried springs and wetlands and effective loss of water rights for wells that depend on a few productive zones. A second major deficiency is the DEIS considers impacts for only 200 years into the future. Groundwater model simulations do not reach equilibrium within that time frame, therefore the impacts will continue to increase after 200 years. Unless there are guarantees that the pumping will cease in 200 years, the DEIS must consider the impacts of pumping until equilibrium is reached. Based on the Myers model simulations, equilibrium requires at least 10,000 years.

The groundwater model used to simulate the impacts of this project has many problems and is inappropriate for analyzing the impacts of this project. For one, it is too coarse to simulate such significant drawdown; the model cells are too large and the model layers too thick. Drawdown amounts at the wells are grossly underestimated as a result. The model is poorly conceptualized as evidenced by the fact that model simulations do not converge without the modelers having set all layers as confined. The model poorly simulates the area water balance and does not even attempt to simulate most springs. It has also placed fault barriers and conductive zones so as to minimize the predicted impacts to important spring.

The DEIS model shows that groundwater drawdown would exceed 1000 feet at the application points of diversion and the extent of drawdown would cover hundreds of square miles, drying springs and wetlands over most of that area. The distributed pumping option analyzed as the proposed action in the DEIS, would expand the extent of drawdown and dry even more springs and wetlands. The proposed action would impact 18 nearby basins, not just the five targeted for pumping. Steptoe Valley would experience drawdown up to 50 feet in its southern end and have significant amounts of water drawn toward Spring Valley.

Draft Environmental Impact Statement

The DEIS considers the impacts of the Southern Nevada Water Authority (SNWA) developing a right-of-way for its water rights applications in Snake, Spring, Cave, Dry Lake, and Delamar Valleys. This technical memorandum reviews exclusively the aspects of the DEIS that deal with pumping the groundwater. The DEIS review includes consideration of the alternatives, DEIS hydrogeology, and predicted impacts.

The DEIS fails to consider a range of pumping options that would involve pumping different amounts of water. The DEIS considers pumping the full application amount for the five valleys, at the original application points of diversion (PODs) and at distributed pumping locations. Just one alternative (A) considers a reduced pumping amount, although another alternative considers intermittently pumping the full application amount. Considering the distributed pumping layout with a much reduced pumping rate would provide a comparison of the marginal impacts of increasing the pumping from low rates to much higher rates.

Inadequacy of Ten-Foot Drawdown Analysis

The BLM presents impacts only to the ten-foot drawdown level, for reasons described in chapter 3 (p. 3.3-87). They do this even though they acknowledge that lesser drawdowns could cause additional impacts that they are ignoring. "Drawdowns of less than 10 feet could reduce flows in perennial springs or streams that are controlled by discharge from the regional groundwater flow system, which in turn could potentially cause declines in the diversity and abundance of associate riparian flora and fauna that may only be able to tolerate water declines on the order of a few feet" (*Id.*). BLM has acknowledged that the use of 10-foot drawdowns for their analysis is a failure to disclose all potential impacts from the pumping project.

BLM makes several excuses for limiting the analysis to the 10-foot drawdown. First, the "BLM does not believe that it is reasonable or appropriate to use the regional model to quantify changes in groundwater elevation" (*Id.*) because of the model's regional scale and "unavoidable uncertainty associated with the model predictions" (*Id.*). They could have developed a more detailed model for the targeted valleys, such as Myers (2011a and 2011b). Even so, understanding that predictions are uncertain is much better than just ignoring the impacts.

The point about uncertainty in the predictions is irrelevant. If the model has been objectively constructed, each contour line represents an expected value for that contour value. In the absence of obvious model bias, model error should be normally distributed (Hill et al 1998). There is just as much chance that the contour is underestimated as overestimated. All predictions should be treated as though there is a confidence band around them. If the BLM has concerns about the uncertainty, they should require the modeler to put confidence bands around the contour estimates.

Second, the BLM is concerned that 10 feet is similar to the magnitude of natural variation. Seasonal variation in water levels at any point may exceed the predicted drawdown, but a constant drawdown would cause a new median level around which the natural changes would fluctuate. Where seasonal variability causes springs or wetlands to dry, the additional drawdown may cause them to be dry longer. The DEIS fails to disclose the impacts to those resources that have a significant natural variability.

Third, the BLM justifies its use of 10-foot drawdown by mentioning other DEISs in which it used similar reasoning. The fact that the BLM did it wrong in the past is not a justification for doing it wrong in this project. This is particularly important because the area between the predicted 10-foot and 1-foot drawdown may be hundreds of square miles.

The following are reasons to include lesser drawdowns.

- Springs can be dried even if the water table is lowered less than 10 feet. Not identifying the springs between 10-ft and 1-ft of drawdown is a failure to present potential impacts of the proposed project.
- Lowered water tables can dry or significantly change the wetland ecosystem types. The same argument as for springs can be made for wetlands. A wetland that is naturally stressed could be killed with just a few feet of drawdown.
- Less than 10 feet of drawdown can affect wells with a productive zone near the top of the screens.

Halford and Plume (2011) presented drawdown contours as low as 0.3 ft, without making a detailed uncertainty analysis. They did mention the uncertainty in the placement of a contour as being equal in magnitude as the length of a side of a cell.

Inadequacy of Limiting the Analysis to 200 Years

The DEIS considers the alternatives for only 200 years, which is a failure to disclose all the potential impacts of granting this right-of-way and allowing the concomitant pumping. This is an insufficient time period because the groundwater systems do not even approach equilibrium within 200 years. Equilibrium would occur at the time that the pumping essentially ceases to remove groundwater from storage. It is the time at which the pumping has captured an equivalent amount of natural discharge, meaning wetlands evapotranspiration (ET) and spring discharge. At this point the drawdown will have reached its maximum extent and the impacts caused by the project will be at a maximum. The DEIS does not identify these potential impacts.

Predicted water levels for various wells, for example, well 184 N11E6713B1 USBLM (DEIS, Figure 3.3.2-7), begin to decrease by the time of full build-out, but in the long-term trend almost linearly downward. Two hundred years after full build-out, the water levels are decreasing almost as rapidly as just a few years after full build-out. This demonstrates clearly that the impact will continue to worsen far beyond the time period as presented in the DEIS.

The 200-year time frame is arbitrary. The BLM in Nevada commonly analyzes the effects of open pit mines that will take more than 200 years to fill with groundwater, thereby forming a pit lake[1]. Longer analyses are necessary even though the predictions become more uncertain. The choice the BLM leaves the reader is between uncertain predictions and no predictions at all. The issues regarding uncertainty beyond 200 years are similar to those discussed and rejected above regarding the use of a 10-foot drawdown cone. The uncertainty could be considered with a stochastic analysis wherein they present the drawdown contours and hydrographs with a confidence band.

Unless there is a viable plan for ending the project after 200 years, the analysis should consider a much longer pumping period.

Alternatives Analysis

The BLM presented impacts of its various alternatives and the No Action alternative as a series of drawdown maps and hydrographs of water levels and fluxes. The impacts of the project alternatives are the difference in the drawdown caused by the sum of the No Action and project alternatives and the No Action alternative. Although not stated in the DEIS, this assumes that drawdowns for No Action and the projects is additive.

The No Action alternative assumes that too many existing rights will be developed in the future. For example, No Action includes the future development of water for a power plant in Steptoe Valley, SNWA developing the 8000 af/y it has on the ranches it owns in Spring Valley, and the water rights to be transferred from Lake Valley to Coyote Springs (DEIS, chapter 2, Figure 2.2-1). The impacts caused by these projects may not occur; if SNWA is not granted water rights in Spring Valley, it may not develop the other rights it has purchased. **The BLM should develop a No Action alternative that includes only existing pumping. The other options should be considered reasonably foreseeable future actions.**

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[1] Examples of such pit lakes are Betze/Post, Gold Quarry, and Twin Creeks.

The impacts of the action alternatives should be determined without pumping the No Action alternatives simultaneously. This would remove the potential nonlinearities which could skew the estimates of the with-project impacts. Predicted impact would be estimated with certainty that they are not potentially due to existing pumping.

The DEIS ignores too many applications that should be considered a reasonably foreseeable future action. Applications listed as APP, RFA, or RFP in 11 basins total almost 488,000 af/y (Table 5). BLM did not adequately justify its decision regarding which to consider as reasonably foreseeable. The BLM should include more of the potential future uses, especially since some are owned by credible entities including SNWA, Vidler, and Lincoln County.

Table 1: Total duty for pending applications in eleven basins within the study area.

Basin	Basin	Duty	Comment
210	Coyote	202268	The duty was determined by converting the proposed
205	L Meadow V	14632	
204	Clover	14479	
203	Panaca	3552	
202	Patterson	54364	Includes Vidler/Lincoln Cty from 1989 and various
195	Snake V	61598	Does not include NPS instream flow application or 1977
184	Spring V	100645	Includes many irrigation applications, including many by
183	Lake V	0	Valley has many change apps for moving water to Coyote
182	Cave V	0	The database includes SNWA's applications as RFP, not as
181	Dry Lake V	2388	The database includes SNWA's applications as RFP, not as
180	Delamar V	33018	The database includes SNWA's applications as RFP, not as
	TOTAL	486944	
The duty includes applications listed as APP, RFA, or RFP; application, ready for action, or ready for action protested.			

Drawdown Effects

The DEIS presents many maps and figures showing drawdown for the various alternatives. **Even though SNWA's analysis underestimates the drawdown, the results presented in the DEIS show that any of the alternatives will cause massive drawdown and dry up much of the valleys within the 200-year analysis period.**

Alterative B, pumping the original application amounts at the original locations cause the deepest drawdowns within the targeted valleys. The drawdowns, which exceed 1000 feet at the wells, are excessive. The drawdown results from the aquifers not being able to provide 6 or 10 cfs at an original application point. The proposed action, a distributed pumping option, which would pump from 800 to 1000 gpm from as many as five times as many wells, cause a more widespread drawdown that is not as deep at specific well points.

DEIS Table 3.3.2-6 tabulates the devastation that would be caused by the proposed action. At full build-out, and 75- and 200-years after full build-out, drawdown will affect 7, 16, and 18 basins, respectively; the proposed action clearly affects much more than the target basins. It will also affect 6, 80, and 112 miles of perennial streams and 25, 145, and 212 surface water rights, respectively. Well over a hundred springs could be affected.

DEIS Table 3.3.2-6 also demonstrates how pumping the proposal will dry up Spring Valley. At full build-out, and 75- and 200-years after full build-out, the percent reduction in ET and spring discharge is 45, 77, and 84 percent, respectively. The similar values for Snake Valley are 0, 28, and 33 percent, respectively. The Snake Valley full build-out reduction is 0 because project pumping in Snake Valley only begins at full build-out. Big Springs would be dry within 75 years of full build-out. Numerous springs in Spring Valley will be substantially dried (DEIS, Table 3.3.2-7).

Predicted drawdown reaches the model boundary at Pine Valley (DEIS, p. 3.3-110). This demonstrates the BLM made an error in establishing the boundaries for the numerical groundwater model.

The maps and tables present the best estimates from the calibrated model (SNWA 2009b). Although the model has many errors and great uncertainty, if it has been calibrated objectively, the estimates may be considered an expected value (Hill et al 1998). This is similar to determining the mean where the observations around the mean are the variability but the mean may be an expected value. In general, the estimates should not be considered conservative. Drawdown and springflow reductions are as likely to have been underestimated as overestimated.

One model simplification likely causes an underestimate in the extent of drawdown. That is the assumption that groundwater flow is Darcian and that the aquifers are a homogeneous porous media. If the pumping affects a fracture or other preferential flow zone, it could draw water from much further away than the porous media simulation allows.

Monitoring and Mitigation

The primary interest of this review is the monitoring and mitigation as applied to the groundwater development activities (BLM, 2011, p. 3.3-97). The DEIS proposes most of the monitoring and mitigation as part of the stipulated agreement, for Spring Valley and Delamar, Dry Lake, and Cave Valleys (BLM, 2011, p. 3.3-113) (included in the DEIS Appendix C).

The stipulated agreements do not include Snake Valley. There is no interstate agreement regarding Snake Valley. **The DEIS provides no basis for monitoring or mitigation in Snake Valley.**

The stipulated agreements are intended to only protect "federal" resources, including water rights or the national park. **These stipulations are a poor basis for monitoring and mitigation for this entire project**. They do not contain mitigations for other water rights.

The DEIS presents a circular monitoring and mitigation discussion regarding the stipulate agreements and the BLM's authority. Basically, the M&M plan purportedly would allow "SNWA and the BLM to identify, avoid, minimize, and mitigate adverse effects associated with the proposed pumping in all five hydrographic basins" (DEIS, p. 3.3-116). It would "address uncertainties in predicting potential effects of SNWA's groundwater production on water dependent resources and water rights holders". The impacts could be far worse than predicted, but the DEIS does not present a plan for avoiding even the predicted impacts, such as drying up 84 percent of the discharges from Spring Valley or completely drying Big Springs, so it is unclear why the DEIS focuses on uncertainties. This could be due to the stipulated agreements occurring before the DEIS modeling predicted the valleys would be dried by the pumping.

The monitoring sites shown on Figures 3.3.2-9 and -10 may or may not be adequate – it is impossible to know until the actual location of the pumping wells is known. These monitoring wells were located based on the stipulated agreement, but until the actual well locations are known, the value of these monitoring wells is unknown. The monitoring wells specified in the stipulated agreements were based in part on the location of the original applications, which are the PODs for which the stipulated agreements were developed. However, the proposed action places pumping wells across the basins far from the current PODs, so the monitoring well sites may not be in the best locations. Adaptive management must assure that new monitoring sites be established prior to pumping by a sufficient time period to establish a baseline.

The DEIS fails by not describing the "groundwater-dependent, early warning thresholds" (DEIS, p. 3.3-116). In the appendix, they indicate that it is necessary to collect baseline data "before specific early warning thresholds can be identified" (DEIS, p. A-49). This is simply not correct because **they should use the DEIS model to establish thresholds.** In establishing thresholds and monitoring, **BLM must consider the "time to full capture" problem.** Once a monitoring well indicates that impacts are occurring, it may be too late to stop or mitigate them. Drawdown cones expand even after pumping ceases. The BLM admits as much on p. 3.3-120, where it claims that "specific adaptive management measures ... may not successfully mitigate long-term impacts to surface water resources" and a "long-term reduction in surface discharge" is likely to occur. BLM considers this an unavoidable adverse impact.

Having established early warning thresholds based on the DEIS modeling, the monitoring sites would be established as long as possible before the pumping commences. Data collection at the sites would establish the range of natural variability before any pumping effects could occur. This is essential to understanding whether a change is project induced.

The DEIS lists five adaptive management actions to reduce observed or predicted impacts, including geographic redistribution of the groundwater withdrawals, reduction or cessation, augmentation of water supplies using surface and groundwater sources, conducting recharge to offset local groundwater drawdown, and cloud seeding. These actions had been listed in the stipulated agreements. **Reducing or ceasing the pumping or significant changes in**

its location are the only potentially effective adaptive management actions. Augmentation and recharge should not be relied upon because both require additional water – using them merely transfers the impact elsewhere in the valley. There is no unused water in any of the valleys, including surface water that may reach the playas in wet years because the moisture holds together the playa soils. Cloud seeding is unproven technology which, if it works, must actually reduce precipitation somewhere downgradient.

At various points, the DEIS notes that the BLM will require the implementation of mitigation measures, which could include the cessation of pumping. "**If the BLM determines those early warning thresholds have been reached** as a result of the SNWA's groundwater withdrawal; (sic) one or more adaptive management measures may be implemented" (DEIS, p. 3.3-116, emphasis added). "If the BLM determines that SNWA groundwater withdrawals have likely caused or contributed to the adverse effect, BLM will require that one or more adaptive management measures be taken" (DEIS, App E, p. A-54). The BLM should state its authority for requiring mitigation measures that will reduce the amount of water pumped from the project, because elsewhere the BLM maintains that the NSE establishes the amount of water that may be pumped from a water right, not the BLM. Also, these statements do not purport with the stipulated agreements which indicate a technical review team will consider whether the pumping has damaged resources.

The DEIS should specify an M&M plan that protects the resources in the project area. It should do so as best it can with current data and update the plan as new data and modeling becomes available. The following a basic steps that should be used:

- Identify resources to protect
- Define what it means to protect them
- Use existing modeling to establish monitoring sites
- Use existing modeling to establish triggers or early-warning thresholds.
- Use existing modeling to specify the mitigation that could be used – moving the pumping wells or reducing the amount being pumped. Predict if/when resources will be impacted.
- Every five years, use the monitoring data to verify and validate the model. if the data shows the model was poorly conceptualized, it should be reconstructed. If the data shows the basic model structure is adequate, the new data should be used to recalibrate the model.
- Use updated model and repeat # 3, 4, and 5.
- Continue through the life of the project

Several additional M&M factors should be considered in the DEIS. One, the DEIS states the groundwater model "identified areas of uncertainty with regard to geologic and hydraulic characteristics" (DEIS, p. 3.3-120). These areas should be specified in the DEIS. The additional studies suggested (*Id.*) should be completed prior to finalizing the EIS.

Second, the DEIS specifies that SNWA will develop a "groundwater flow system numerical model ... specific to Snake Valley" (DEIS, p. 3.3-121). This indicates the BLM has no confidence in the results of the CCRP model used for this DEIS - an admission that the DEIS is insufficient at presenting the potential impacts of this project.

Third, as part of mitigation GW-WR-5, the DEIS notes that the pumping will likely affect Shoshone Ponds, and also specifies that deepened or new wells to replace the existing source shall draw water from the same aquifer. This may not be possible if the source is a layer of highly conductive gravel with artesian pressure related to recharge uphill on the fan above the ponds.

Miscellaneous DEIS Comments

The maps throughout the DEIS should show Indian reservations along with the FWS, NPS, and state lands.

The DEIS should not cite the Spring Valley or the Cave, Dry Lake, and Delamar state engineer rulings for the perennial yield in those valleys (DEIS, p. 3.3-66, Table 3.3.1-20). These rulings have been rescinded by court ruling and the perennial yield values will be reconsidered. It is more appropriate to use previous PY estimates for this purpose.

The DEIS considers the risks to springs based on being within a ten-foot drawdown cone and on their susceptibility. The DEIS inappropriately downplays the risk to valley margin springs (DEIS, p. 3.3-89) by considering them to have just a moderate risk due to a lack of understanding of their hydrologic control. The BLM should complete more site-specific study of these springs. Springs that are controlled by normal faults are likely connected to the regional water table but a spring near recharge zone at the top of the fan may be perched. The simple classification used in the DEIS may downplay the importance of or risk to certain springs.

Similarly, the DEIS should not specify flow reductions that would be important in modeled springs (DEIS 3.3-92). It should simply provide hydrographs of spring/stream flow so that the reader can assess the potential impacts. The DEIS correctly claims these estimates are uncertain, but uncertainty cuts both ways. Spring flow is just as likely to be decreased more than simulated as it is to be affected less.

The problems highlighted in the DEIS with modeling Big Springs (DEIS, p. 3.3-93) are disturbing. The placement of a flow barrier east of the springs allowed the model to simulate the spring reasonably accurately, but the BLM requested the fault be moved west of the springs so that it would not limit the drawdown. Geologic mapping shows dual faults – a normal fault west of the springs and two of them just east of springs. The coarseness of the model discretization makes it difficult to simulate both faults because they are only one model cell apart. Another solution to the BLM's problem with the fault protecting the spring from Snake Valley pumping would be to have higher conductance on the fault to the north. A relatively impermeable HFB may be necessary at the spring, but faults are not homogeneous along their length.

Review of Conceptual Model

A conceptual model is a description of flow paths through an aquifer or flow system, from the point of recharge to the point of discharge. This section reviews the conceptual model used as a basis for the DEIS and the numerical model (SNWA 2009a).

Water Budget Comments

SNWA estimated recharge using a water budget method wherein they set basinwide recharge equal to the measured discharge and interbasin flow from the flow system. The method they used was similar to the original Maxey-Eakin method, but they estimated new coefficients to be used with new precipitation estimate. They effectively determined a proportion of the total annual average rainfall in the basin that would become recharge. The method balanced flows among basins within individual flow systems, so that recharge equaled discharge by flow system – Goshute Valley, Great Salt Lake, Meadow Valley Wash, or White River. The estimates led to basin recharge estimates that exceeded the original reconnaissance report recharge estimates, as shown in the following table.

Table 2: Comparison of annual recharge amounts (af/y) for flow systems considered in the CMR and various reconnaissance reports.

Flow System	Goshute Valley	Great Salt Lake	Meadow V Wash	White River
SNWA Study	116,373	237,911	54,227	159,579
Recon Reports	100,000	181,900	35,900	104,500

SNWA's estimates lie near the upper range of the other estimates, as may be seen in Tables 9-2, I-5, or I-6 (SNWA 2009a). The primary reason the recharge estimates are high compared with all estimates is that the groundwater discharge estimates have increased substantially because the groundwater evapotranspiration (GWET) rates have increased, from earlier studies. This is because the system recharge must equal system discharge, and system discharge depends on spring flow and GWET estimates. Basically, increasing the discharge estimates requires that more of the estimated precipitation becomes recharge; it also means that there is more discharge for their pumping to capture.

SNWA's description of the method, however, indicated they really do not understand their own estimate. Their map of recharge does not account for geology:

> It must be noted that this spatial distribution only accounts for variation of recharge rates with altitude. It does not explicitly account for the geology of the units through which precipitation infiltrates to recharge the flow system, and it does not explicitly

distribute the recharge from runoff to the actual locations where it occurs. The quantity of recharge from infiltration is, however, implicitly included in the recharge estimated using the groundwater-balance method. (CMR, page 9-10)

While SNWA acknowledges the map is inaccurate, their explanation is partly wrong. The map accounts for the variation of recharge with precipitation which, while correlating with altitude, is not the same as varying with altitude. It does not account for geology, as they correctly state. The method merely describes a means of determining recharge in each basin based on the precipitation bands (volume of precipitation between two depths, such as 12 and 16 inches). It is based on balancing overall flow system recharge with flow system discharge considering only the precipitation variation around the flow system. The recharge estimate includes both mountain block and mountain front recharge. These differ due to geology because high elevation precipitation may recharge where it falls on carbonate outcrops or run off from other bedrock outcrops and recharge at the mountain front.

The recharge estimates are incorrect because the groundwater discharge estimates are incorrect. SNWA used various methods to estimate the ET rates by phreatophyte type, and compiled a range of potential estimates from the literature – in fact, the CMR and appendices actually summarize almost every method and estimated rate available in the literature. Their final choice apparently is the BARCASS estimates for the basins within White Pine County.

ET rates (regardless of whether the source is ground or surface water) vary within a fairly narrow range, typically within 20%. SNWA's GWET estimates are wrong because of how they allocate the source water to accommodate that ET – groundwater, precipitation, surface runon, or unsaturated zone water.

> Groundwater ET emanating exclusively from the saturated zone is difficult, if not impossible, to measure separately. ET rates derived from field data (using ET towers) represent the total ET rates from the plants and the soils under and around the plants. The measured ET rates may include several sources of water: groundwater and soil moisture uptake by the plants, groundwater and soil moisture lost by evaporation, and water on the plant leaves lost by evaporation. The following simplifying assumption is usually made to derive mean annual groundwater ET rates: **all sources of water, other than groundwater, can be attributed to the mean annual precipitation**. Estimates of groundwater ET rates can then be obtained by **subtracting the local mean annual precipitation rate from the measured annual ET rate**. (CMR, page 7-6, emphases added)

SNWA acknowledges the various sources but makes the "simplifying assumption" that precipitation can represent all sources other than groundwater. Most precipitation at a site with GWET does satisfy the ET demands because wetland sites are usually flat and have little runoff – most precipitation infiltrates or ponds on the surface. SNWA's assumption ignores the following sources of water:

- Surface runon from offsite: Surrounding wetland areas are upland areas that usually have more topographic gradient than the much flatter wetland. Water runs off of that area and onto the wetland area thus satisfying more of the ET demands. If just 10% of the annual precipitation runs onto adjoining wetlands, because the surrounding upland may be larger, it could satisfy a much larger portion of the ET demand.
- Surface runoff from the mountains: Most wetland areas lie in the low portions of valleys, such as the playas and surrounding moist wetlands in Spring Valley. Most of the streams that discharge from the mountains infiltrate at the mountain front and contribute to basinwide recharge. During wet years, however, the streams flow to the valley bottoms and become another source of surface water to the wetlands, as evidenced by the playa lakes that form throughout the Great Basin.
- Mountain front springs contribute water to low-lying wetlands. An example is the regional springs in White River Valley which, predevelopment, satisfied ET demands in the wetlands below the springs.
- Lateral unsaturated zone flow: Water that infiltrates the ground surface adjacent to the wetlands will flow both vertically and laterally, and some will reach the unsaturated zone beneath the wetland areas.

Simply stated, SNWA modeled GWET as equal to the predicted ET minus predicted onsite precipitation (SNWA 2009a, pages 3-4 and 7-6) therefore estimated GWET depends on precipitation. SNWA used PRISM to estimate precipitation around the study area after rejecting other estimation methods. PRISM overestimates annual precipitation at most stations (Figure 6-4), as acknowledged and discussed by SNWA. "The comparison shows that the PRISM distribution slightly **overestimated** the period-of-record mean precipitation values for most stations" (CMR, page 6-5). Jeton et al (2005) substantially agree – **PRISM overestimates precipitation**. Yet, SNWA chose to use it for this study, claiming it would be a conservative estimate. "As precipitation is subtracted from ET to obtain groundwater ET, the larger estimates of precipitation derived from the PRISM grid will lead to smaller estimates of groundwater ET and, therefore, smaller recharge estimates. This demonstrates that the use of the PRISM precipitation distribution leads to **conservative estimates of recharge** and is appropriate in this study" (CMR, page 6-5, emphasis added).

The argument is conservative only if the other sources of water to satisfy ET listed above are ignored because they still overestimate GWET and recharge. This is understood by understanding the process through which precipitation becomes recharge (Wilson and Guan, 2004), as simulated with the BCM (Flint and Flint, 2007; Flint et al, 2004). The BCM estimates recharge using a water balance of the soil moisture zone in areas that are not wetlands; the method calculates infiltration and runoff. The infiltration either evapotranspires or becomes recharge; the runoff either recharges further downstream, at the mountain front, for example, or discharges to the playa. Up to **85% of runoff that does not become recharge goes to satisfying the ET from the wetland areas (Flint et al 2004)**. Nothing in SNWA's basinwide recharge estimate accounts for the proportion of precipitation that runs off and satisfies the ET demand – in fact, the method as used by SNWA does not require that the precipitation pass through the groundwater at all before it satisfies ET.

A consideration of how much the CMR GWET estimates, by flow system, exceed the recon report estimates (Scott et al in CMR Table 6-1) demonstrates the potential for additional water in the basins to make up some of the ET demands. PRISM estimated precipitation as being substantially more than the recon reports in all of the flow systems with Meadow Valley Wash being by far the largest difference (Table 3).

Table 3: Percent additional precipitation estimated in the CMR as compared with Recon Reports.

Flow System	% Increase Over Recon Estimates
Goshute Valley	9.4
Great Salt Lake	17.0
Meadow Valley Wash	59.1
White River	41.7

Much of the overestimated precipitation occurs in Hamlin Valley; the overestimate was so great that SNWA had to manually lower the recharge estimate they made for the basin (see the NMR section review below). Halford and Plume (2011) also noted this problem.

Miscellaneous Comments on the Conceptual Model

Spring Types: The difference between regional and intermediate springs appears to be arbitrary, with Gandy Warm and Big Springs considered intermediate. The basis is location in the basin, temperature, flow rate and its variability, hydrogeologic setting, and geochemistry. Regional springs are warm and constant, but the actual bounds were not specified. With respect to modeling, the difference is not important.

Interbasin Flows to Adjoining Flow Systems: SNWA estimated interbasin flows from the model domain to surrounding flow systems based on a probability distribution of material properties and gradient over the boundary. They assumed the gradient across the boundary equaled the gradient between mid-basin wells – "Because carbonate wells are scarce, water levels in the central parts of the basins were assumed to represent regional potentiometric levels, i.e., carbonate aquifer is connected to alluvial aquifers (CMR, 8-4)". This is an unfounded assumption. The gradient could be estimated using bedrock contours estimated in BARCASS or in chapter 5 of the CMR. The estimates are not well supported by the analysis, but are within the same orders of magnitude as should be expected (Welch et al, 2008).

Depth-decay relations: SNWA estimated a conductivity/depth relationship to justify lowering the conductivity at depth, but the regression relationships barely justify it. CMR Figures C-9, C-10, and C-11 show the R^2 for Log K v depth regressions are 0.16, 0.27, and 0.43 for LC, LVF, and UVF, respectively; from the figures it is also apparent the relations would not be as good as they are, such as it is, except for a few very deep values. This spurious correlation may artificially increase the confidence in the relations.

Groundwater Contour Map: The SNWA GW contour map includes both basin fill and carbonate water levels (CMR, Figure 5-2). This may imply a substantial connection. Also they do not show any flow into Fish Springs Flat or Tule Valley, although their geologic analysis properly notes the presence of carbonate rock. BARCASS had treated the mountains on the east side of Snake Valley as a potential flow pathway.

Review of SNWA CCRP Model

The DEIS used the Central Carbonate Rock Province (CCRP) model to simulate the proposed action and alternatives. This section reviews some of the details of that model, and shows that it is insufficient for NEPA analysis and may bias the simulations to minimize the predicted impacts.

The model calibration was not based on stresses similar to that expected in the future, which far exceed anything observed to date. **The model will be used to predict drawdown that goes far beyond any drawdown observed to date so the model parameters are not representative of likely future conditions.**

The SNWA model is too coarse, both horizontally and vertically, to use for predicting the impacts due to this proposed groundwater development. SNWA's model cells are **all 3281 ft square. D'Agnese (2011, p. 2) pointed out that the simulation of drawdown at a pumping well improves with improved discretization but SNWA failed to implement it in their modeling effort.**

The model layers are too thick and simulate too much of the deeper aquifer layers. The CCRP model layer thickness varies from 328 to 984 feet over layers 2 through 5, from 328 to 6562 feet for layer 1, and 984 ft or thicker for layers 7 through 11; the total model thickness varies but the bottom is about 10,000 feet below sea level so at the center of Spring Valley, thickness would be about 16,000 ft. Halford and Plume (2011) generally did not simulate an overall model thickness more than 4000 ft because they expected little deep circulation. The lower half of the CCRP model is wasted.

SNWA's model is poorly conceptualized as demonstrated by the convergence problems they could only solve by simulating all layers as confined, including layer 1 (SNWA, 2009, p. 4-2, 4-4). SNWA set the top of layer 1 to coincide with the top of the water table so that the layer had a constant transmissivity and did not change the layer type during transient simulation. This means that layer-1 transmissivity remains constant through the simulation even though the thickness is significantly decreasing. There are areas where the simulated drawdown exceeds 328 feet, so the layer should go dry; SNWA's assumption would maintain the transmissivity and flow even when simulating heads below the bottom of the layer.

SNWA attempts to fix the problem by setting storage coefficients to represent specific yields. The valley fill storage is set at 0.015, which is higher than it should for specific storage but lower than a specific yield; this is the value for the upper six layers. The model will therefore release more water for a given drawdown than it would had a proper specific storage had been used. The combination of high specific storage and unchanging transmissivity would cause the model **to underestimate the drawdowns.** This will dampen the predicted effect of pumping and decrease the predicted drawdown.

Convergence problems during steady state simulations are typically caused by an inaccurate representation of the flow system. In this case, the model cell size may be too big to accurately simulate the details of flow in the upper layers. The model very precisely inputs the perceived geology (depths to formations and thicknesses) over a coarse grid. This requires detailed calculations in the HUF2 package and elsewhere to set the parameter values for each cell; this could cause rapid changes between cells, as formations pinch out, which also causes instability in the water balance calculations for these cells. Either the use of smaller grid cells or specifying the model layers with hydrogeologic units could obviate this problem.

SNWA's model calibration is biased to look better than it actually is. SNWA presented unweighted residuals, in Figure 6-9 (SNWA, 2009), which shows extreme bias in the distribution of residuals. In the area of Dry Lake and Pahroc Valleys, six residuals are between -440 and -220; five more are between -200 and -50 (Figure 1). Just east of Dry Lake Valley, in a trend that looks very much like the PRISM precipitation overestimates in Patterson, Lake, and Cave Valleys, are at least ten residuals from 200 to 955 and another ten from 20 to 200 (Figure 1). The CCRP model ranges from gross overestimation of head in Dry Lake/Pahroc Valleys (simulated exceeds observed in a negative residual) to gross underestimation of heads 10 to 20 miles to the east.

SNWA's numerical model report addresses the residual problem between Patterson and Dry Lake Valley (SNWA, 2009, p 5-8). They used two low-K horizontal flow barriers (HFBs) to force the head to drop over 1000 feet between the valleys, but just were unable to do this which resulted in the high residuals. (The steady state model simulates 1600 af/y from Patterson to Dry Lake Valley). This should have caused SNWA to reconsider the overall conceptual model for the area. Their model simulates too much recharge in Dry Lake Valley, most specifically in the mountains on the east side of the valley between Dry Lake and Patterson Valleys; this extra recharge increases the head on each side of the fault and topographic divide so that the model cannot simulate sufficient head drop between valleys.

SNWA emphasizes the value of using "weighted" observations to calibrate the model. Weighting attempts to account for the accuracy of the observation measurement and may be based on many things, from the method of determining the ground surface elevation or the depths to water to the seasonal variability of a series of measurements (from which a variance for the observed values can be determined). Ultimately, setting a "weight" is as fraught with uncertainty as the observation itself. Halford and Plume (2011) set weights based on the source of the observations, but described weighting individual observations as a "fool's errand" because model-discretization error "typically dominates measurement error". In other words,

SNWA's use of weighted observations should not increase the perception of accuracy in the model.

Two other obvious problems are the high positive residuals in north Spring Valley and along the mountain front in Snake Valley (Figure 1). The model does not accurately simulate the water table in the higher elevations along the boundary of the valleys. There should be little confidence in the simulated drawdown in these areas, potentially biasing the predicted results.

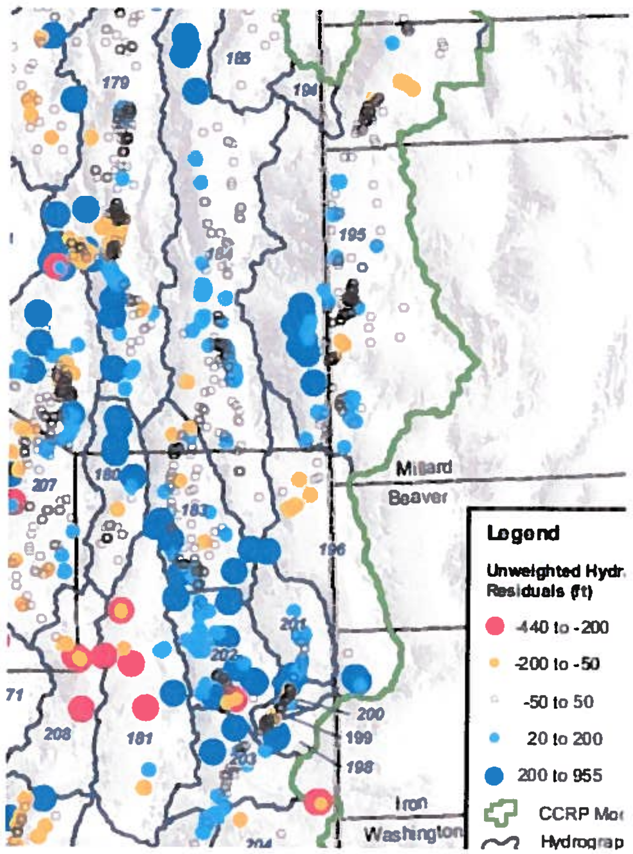


Figure 1: Snapshot from Figure 6-9 (SNWA, 2009) showing unweighted residuals.

The SNWA model handles faults in a way that may be biased because there is very little data to support their ultimate parameter choices. The following sections describe some of the problems.

Pahranagat and Coyote Spring Valleys

The Pahranagat shear zone causes a head drop of about 700 feet across one model cell, as represented by the blue in the hydrogeology at column 62 (Figure 2); this is modeled with a series of HFBs. Further east (right) in column 72 is a conductive fault in LC3 (lower carbonate rock). The conductivity (K) in the fault ranges from 17 to 62 ft/d, over 3281 feet, while the surrounding LC3 cells have K about 0.5 ft/d. The high K fault runs north/south through Coyote Spring Valley to just south of the Pahranagat Shear zone (Figure 3); the fault is shown on Figure 3 just east of the highway; it ends approximately where it intersects the shear zone. Based on K, this fault zone would transport vastly more groundwater than the surrounding rock.

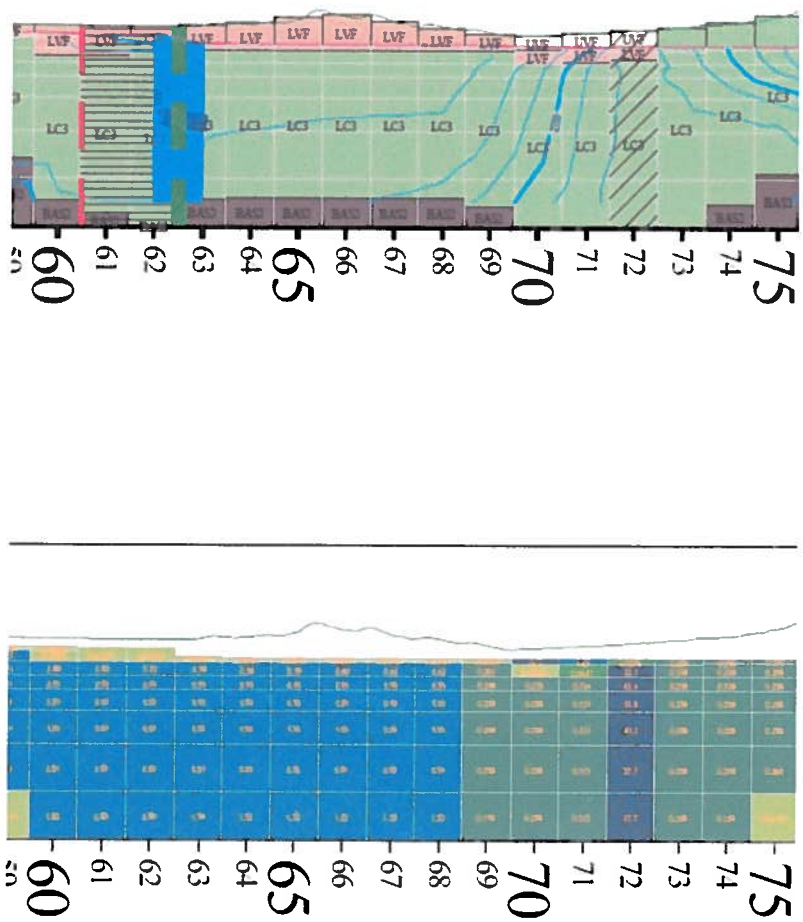


Figure 2: Snapshot of hydrogeology and calibrated K, model row 359. This section crosses Pahranagat and Coyote Spring Valley. (file xs_rum_rows-rev2-7o-map-hd-kh-s-1lay-ucth814-1-4748.pdf). The blue in the upper figure is a cluster of contours.

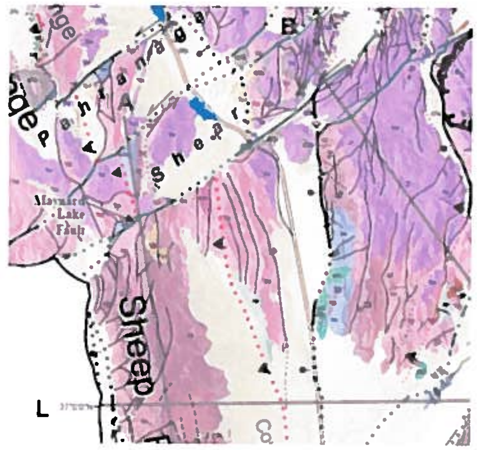


Figure 3: Snapshot from Plate 2, Rowley et al (2011).

The source of the Pahranagat springs in SNWA's model is a highly conductive fault running down the middle of Pahranagat Valley. This fault gathers and transports groundwater from the north and west; K in the carbonate rock ranges to 30 ft/d for one or two column widths. The Pahranagat shear zone is simulated with a series of HFBs which prevent much of the flow from passing and also force groundwater to the surface to form the springs. Flow from the east to the central part of Pahranagat Valley is blocked by a normal fault that bounds the east side of the valley. The head drop across the HFB is about 300 feet (row 336); some flow occurs during steady state conditions but the HFB would be slow to respond to upgradient pumping. SNWA protects the Pahranagat Springs with an HFB that has not been proven on the ground.

Further south, three faults converge in Coyote Spring Valley which allows groundwater to move to the Muddy River Springs area through a zone of very high K LC3 rock. Figure 4 shows two of the faults and high K zones right of the faults; Figure 5 shows the convergence of these faults and the fault on the east which impedes the flow causing it to surface at the springs. Figure 6 shows the three faults north of the springs near their convergence into the broad high K LC3 material. These figures demonstrate how a model simplifies complex geology but the problem with this is the broad zones with very high K cover as much as 20 model rows by 15 columns, or about 300 square kilometers. There is no geologic evidence for such a broad fractured zone in this area. Such a zone may bias the results for this area. The springs probably discharge from a narrow highly conductive fracture zone which could be drained sooner by pumping than would a 300 square km, 10,000 feet thick zone, with high K.

SNWA should use different storage coefficients for the high K zones. Clearly, highly fractured areas would have different storage properties than unfractured media.

SNWA added a constant head boundary between Pahranagat and Tickaboo Valleys to "allow some of the discharge to flow out of the model area" which was necessary because "discharge by groundwater ET from Pahranagat Valley tended to be larger than expected"

(SNWA, 2009, p. 5-13). In other words, they needed a release valve even though the Death Valley Flow System (DVFS) analyses had not included such an outflow. **The reason a "release valve" was needed was, once again, that SNWA estimated far too much recharge in the WRFS, mostly in Dry Lake and Delamar Valleys.**

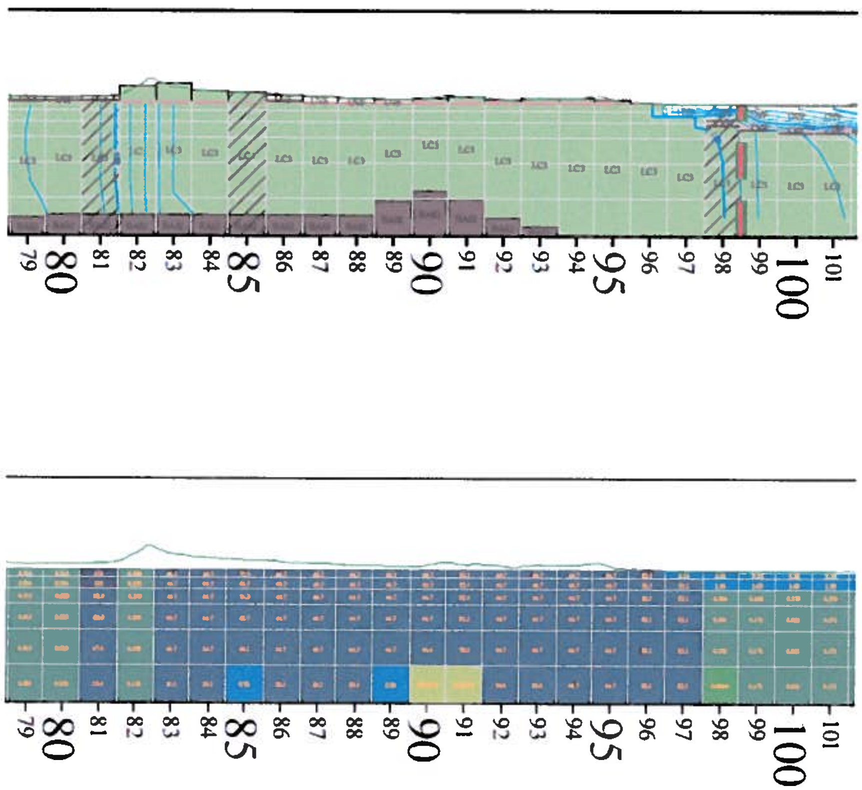


Figure 4: Hydrogeology and K values for row 407. (file xs_rum_rows-rev2-7o-map-hd-kh-s-1lay-ucth814-1-4748.pdf)

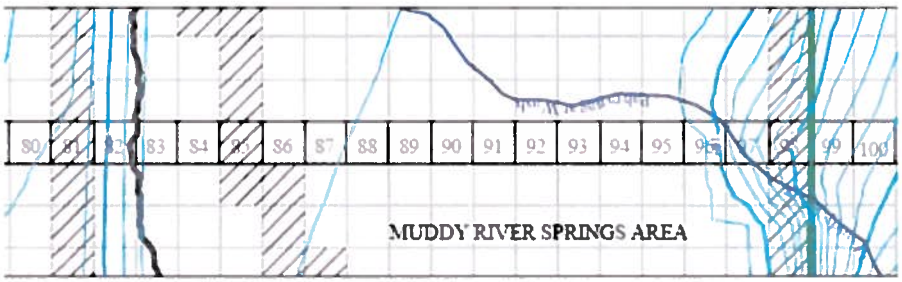


Figure 5: Model area near row 407 showing faults. (file xs_rum_rows-rev2-7o-map-hd-kh-s-1lay-ucth814-1-4748.pdf)

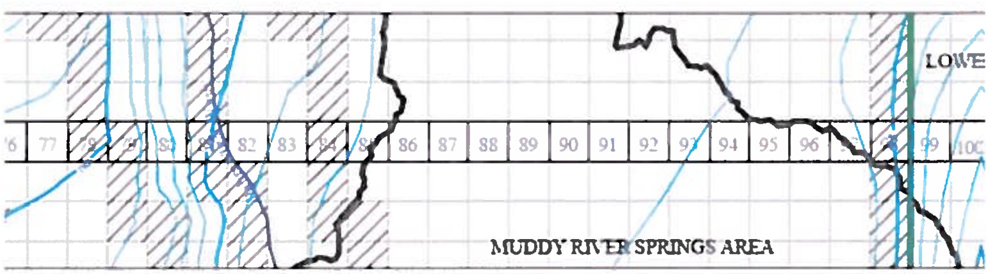


Figure 6: Model area near row 397 showing the collection of faults, all with high K but also the cells to the east have high K. (file xs_rum_rows-rev2-7o-map-hd-kh-s-1lay-ucth814-1-4748.pdf)

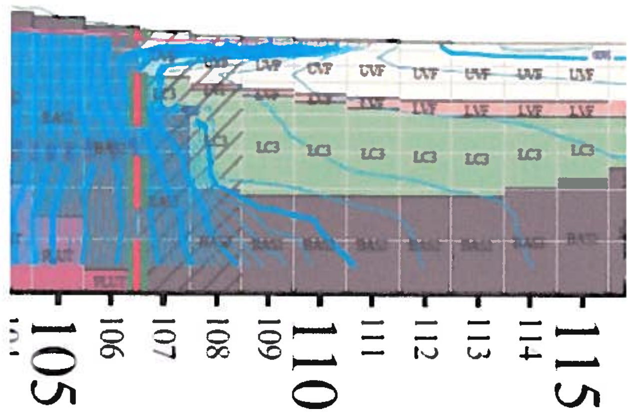
Spring Valley

The CCRP model simulates Spring Valley with faults on each side, but only the normal fault on the west side affects the flow (Figure 7). An HFB runs between the bedrock and fill, causing a significant head drop. The bedrock is all low K, therefore the flow into the fill is probably low; the northern portion of Spring Valley has mostly mountainfront recharge. The east side fault shows as large displacement, but the K is not significantly different from the surrounding rock.

The carbonate rock that underlies northern Spring Valley extends into Tippett Valley, under the Antelope Range. The K under Tippet Valley is almost two orders of magnitude higher, and the normal faults along the boundaries of Tippet Valley have high K.

SNWA simulates the fill in Spring Valley as high to very high K. The primary feature is that the fill is modeled as a bowl, with high K fill surrounded by bedrock. SNWA models specific storage in lower layers of the fill, 5000 ft bgs, as 0.015. This imparts a huge bias on the predicted results because much more water is released for a unit drop in head than is realistic. Anderson and Woessner (1992, Table 3.4) specified a range of specific storage values ranging from 0.02 to 0.000049 m^{-1} for material ranging from clay through dense sandy gravel; the high range is for plastic clay, not the type of material found in Spring Valley. Halford and Plume (2011) used a specific storage of $2x10^{-6}$ ft^{-1} for their layers 2 through 4. These references support the use of a lower specific storage than was used by SNWA (2009). **SNWA's choice would improperly minimize the predicted drawdown by causing the model to release more water to pumping for a given drawdown than is realistic.** It biases the drawdown prediction to be much lower than would occur in reality.

SNWA (2009, p 3-2) notes that measured storage properties may not convert to model scale storage properties. This is similar to the scale issues for K as discussed by authors such as Schulz-Makuch et al (1999). It is reasonable that storage coefficients would increase with scale as the volume under consideration includes more connected fractures, but the issue with SNWA's choices in the previous paragraph refers to fill for which porous-media flow is more predominant and scale issues much less important.



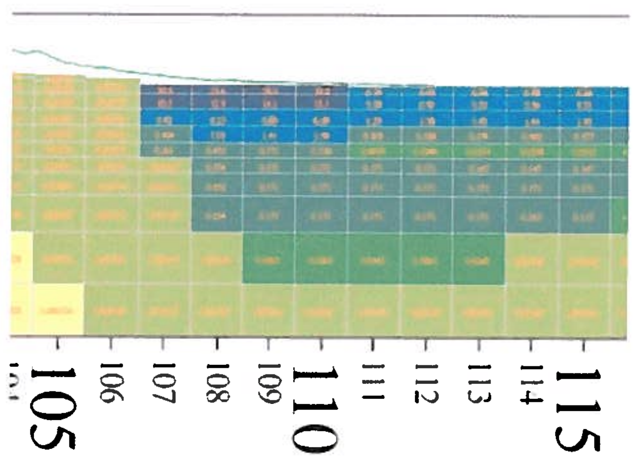


Figure 7: Snapshot of portion of row 128 in center of Spring Valley showing hydrogeology (upper) and K (lower). (file xs_rum_rows-rev2-7o-map-hd-kh-s-1lay-ucth814-1-4748.pdf)

Steptoe to Spring Valley

Groundwater contours along row 160 show a gradient through carbonate rock from Steptoe to Spring Valley (Figure 8). The model includes an HFB, but no mounding of contours. This is an example of how the CCRP model allows flow from Steptoe to Spring Valley, in contradiction to their geology models. Figure 9 and 10 demonstrate how a groundwater level contour map can show a divide while there is clearly flow at depth.

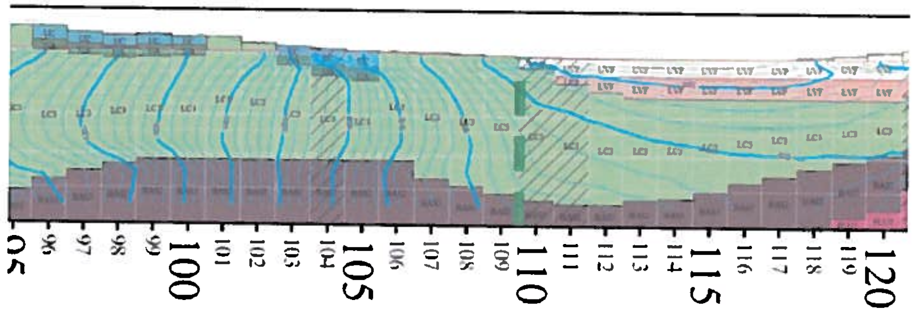


Figure 8: Snapshot of row 160 showing hydrogeology from Steptoe Valley (left) to Spring Valley. (file xs_rum_rows-rev2-7o-map-hd-kh-s-1lay-ucth814-1-4748.pdf)

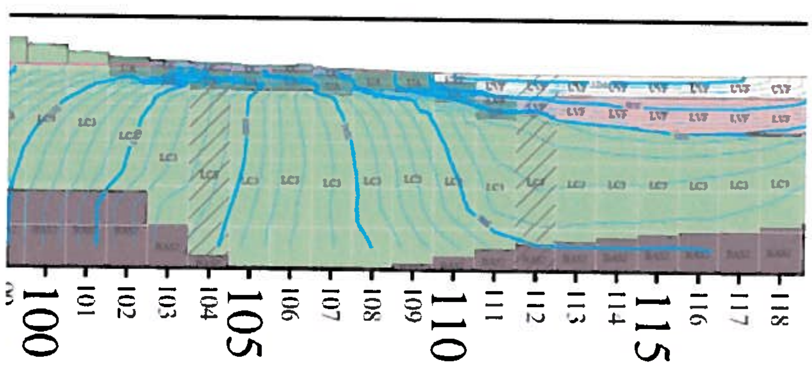


Figure 9: Snapshot of Row 166 showing hydrogeology from Steptoe Valley (left) to Spring Valley. (file xs_rum_rows-rev2-7o-map-hd-kh-s-1lay-ucth814-1-4748.pdf)

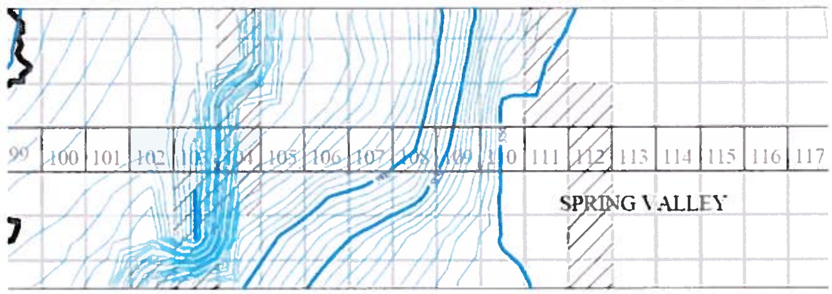


Figure 10: Snapshot of Row 166 showing groundwater contours from Steptoe Valley (left) to Spring Valley. (file xs_rum_rows-rev2-7o-map-hd-kh-s-1lay-ucth814-1-4748.pdf)

The source of Big Springs, in the model, appears to be a large expanse of carbonate rock that has K very near 0.413 ft/d. The carbonate rock extends through the thickness of the model meaning the upgradient transmissivity is very high. A fault forces groundwater to surface.

Gandy Warm Spring

The simulated flow from Gandy Warm Spring is approximately one-third of the targeted flow (NMR, page 5-5), which is likely an error in the conceptual flow model. However, the simulated discharge overall from Snake Valley is within 4% of the targeted value. The valleywide discharge does not require the discharge from Gandy Warm Springs. The problem is that discharge which should be discharging from the springs is actually simulated as discharging from elsewhere in the valley, where it can be captured by the proposed pumping and *decrease the predicted impacts of pumping*. The error in simulating the spring is likely that SNWA treats the spring as intermediate rather than regional (CMR page 7-41), described as follows:

> Gandy Warm Springs is located on the western edge of Snake Valley in the northern portion of the study area (Plate 1). It discharges water from alluvial materials approximately 1.6 mi west of a normal fault. The spring was selected for inclusion in the conceptual model because of its large discharge. The average spring discharge is approximately 17 cfs. (CMR, page 7-41)

SNWA misses the two most likely sources of water to the spring: the substantial carbonate rock on the northeast side of the Snake Range southwest of the spring and interbasin flow from Spring Valley. A fault diverts flow from the Snake range. SNWA discounts the idea that interbasin flow from Spring Valley could support the spring (NMR, page 5-6). This is curious because the model simulates 11,800 af/y of interbasin flow to just north of Snake Valley which is of the same order of magnitude as the approximately 16,000 af/y estimated for this region in BARCASS (Welch et al, 2008, Figure 41). If even a third of that amount combined with carbonate recharge in the northeast portion of the Snake Range, the Gandy Warm Springs flow could be accurately reproduced.

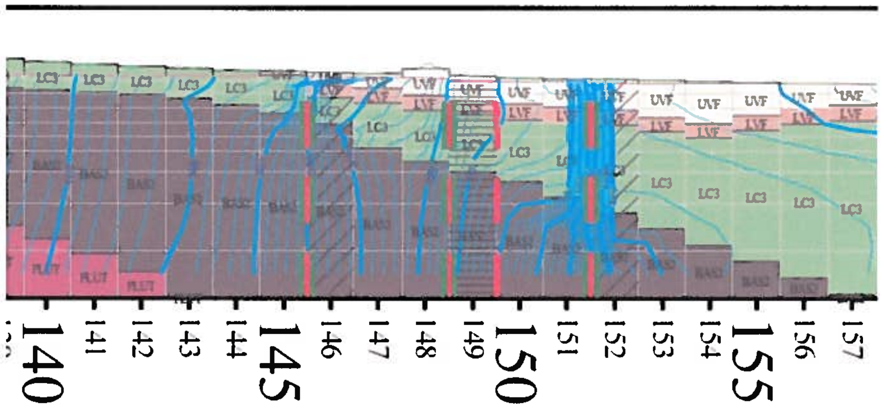


Figure 11: Snapshot for Row 100 showing groundwater contours and hydrogeologic formations near Gandy Warm Springs, near column 148.

Recharge Redistribution

The recharge estimates used in SNWA's numerical model are not the same as in SNWA's conceptual model, which had estimated recharge by basin. SNWA somewhat reshuffled the recharge distribution during numerical model calibration so that the recharge can meet the discharges specified from the model (SNWA, 2009, p. 4-62 – 4-64). In other words, SNWA started the process over during their numerical model calibration but did not constrain the estimates by basin. This explains the differences in recharge by basin and difference in interbasin flow for the numerical model as compared to the conceptual model.

The PRISM precipitation estimates also caused too much interbasin flow from Hamlin to Snake Valley (SNWA, 2009, p. 3-3). This was due to the PRISM precipitation estimate for that area being much too high. Halford and Plume (2011) found similar problems.

Shingle Pass

The model conceptualization of Shingle Pass is as complicated as any in the model, with several formations including carbonate rock and several faults (Figure 12). The faults within Cave Valley are simulated with HFBs which prevent flow from leaving Cave Valley. The mountain front faults on the east side of White River Valley have very high K, being high displacement faults. The high K zones extending north and south along the west side of the Egan Range capture and transmit substantial recharge from the mountains to the springs. However, SNWA does not include an HFB on these faults which would force water to surface in to the springs. Thus, the model is biased so that Cave Valley flow does not support the springs in two ways – HFBs within Cave Valley prevent flow from reaching White River Valley and high K faults along the east side of WRV bring water from the north to the springs rather than from the east.

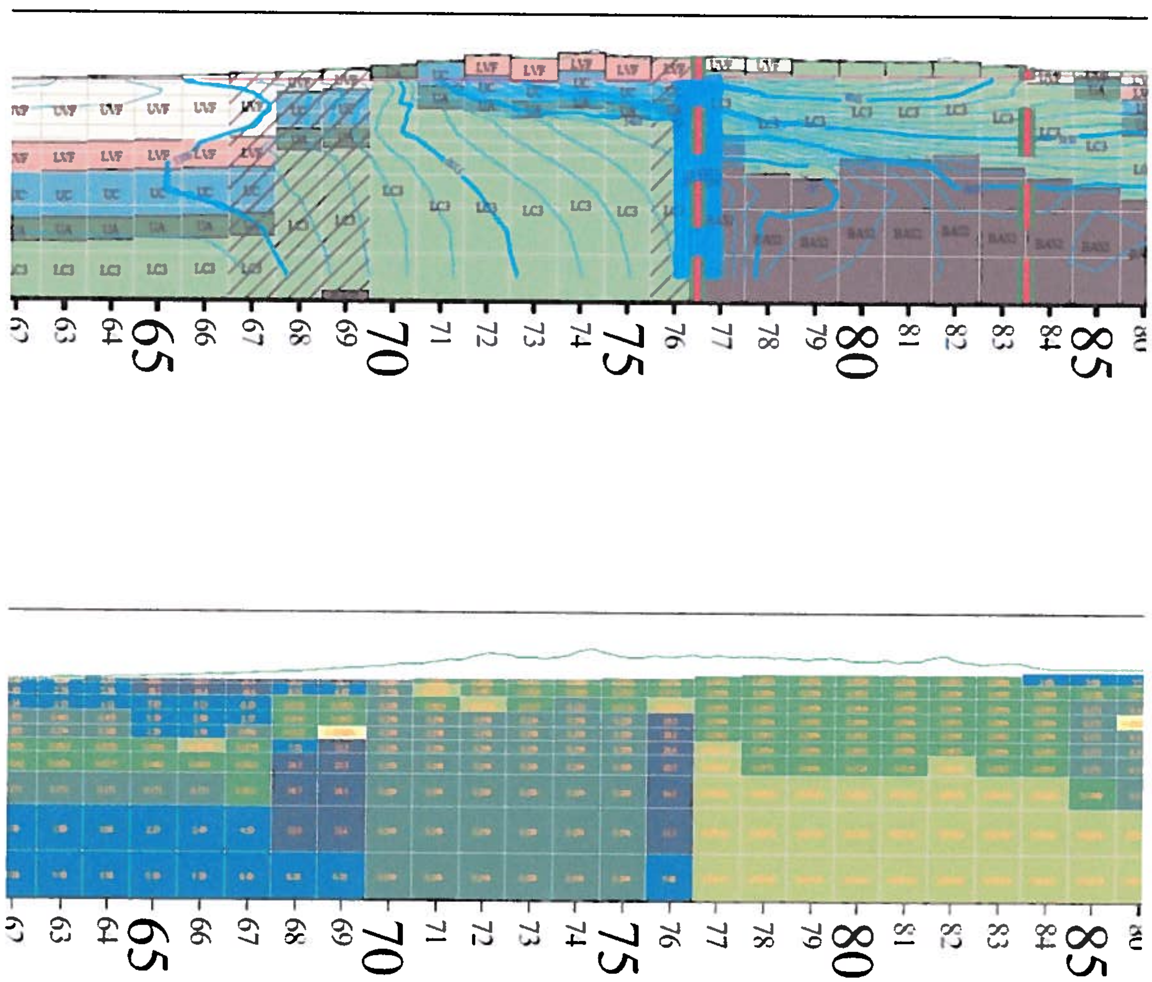


Figure 12: Snapshot of row 202 showing hydrogeology (top) and K values near Shingle Pass. (file xs_rum_rows-rev2-7o-map-hd-kh-s-1lay-ucth814-1-4748.pdf)

Combining Inappropriate Formations in One Cell

The HUF2 routine (SNWA, 2009, p. 4-6) inappropriately combines grossly different media into one cell. "Although the HUF Package allows model layers to be defined independently of hydrogeologic units, **careful definition of the model layers** is important to represent properly the flow through the simulated area. Specifying model-layer boundaries that coincide with or are parallel to hydrogeologic-unit boundaries is helpful" (Anderman and Hill, 2000, emphasis added). If the HUF or HUF2 package combines significantly different hydrogeologic units, the cell properties may be an average of significantly different flow types. SNWA does not carefully define the model layers by combining formations in one cell, which results in an average K which is a meaningless number.

The east front of the Snake Range, near Baker, is a great example of inappropriately averaging formations in one cell. As may be seen (Figure 13), on column 149, the model averages UVF and LC3 properties. In column 150, the model averages LVF and LC3 properties. Considering the conductivity values by cell, the model combined values that differ by more than an order of magnitude (Figure 14). Also, the model would not allow continuous flow among columns within the LC3 unit under Snake Valley because the unit does not match in adjacent cells (Figure 13). This forces the groundwater to follow unrealistic pathways. It would essentially force water in the LC3 unit in column 149 to flow into the LVF unit in column 150.

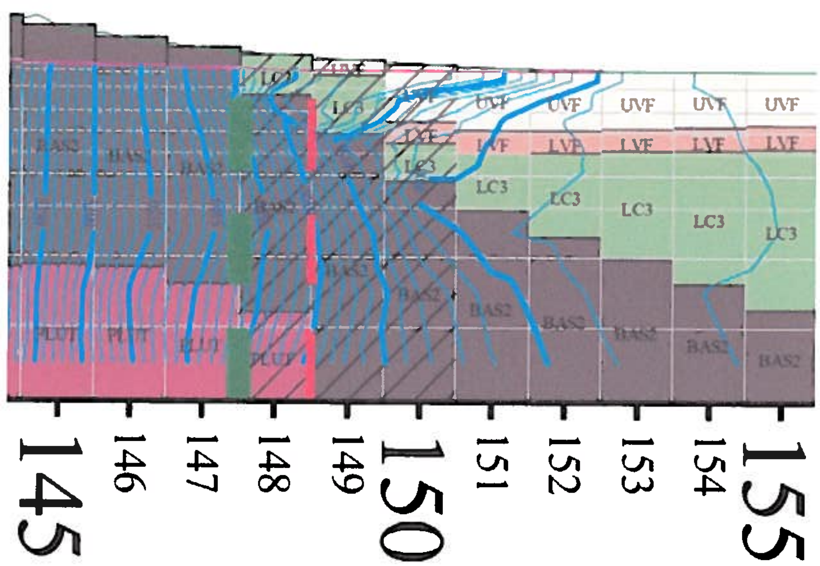


Figure 13: Portion of model row 126 near the east side of the Snake Range near Baker. White lines are cells, blue lines are groundwater head contours. Other colors represent hydrogeologic units as labeled.

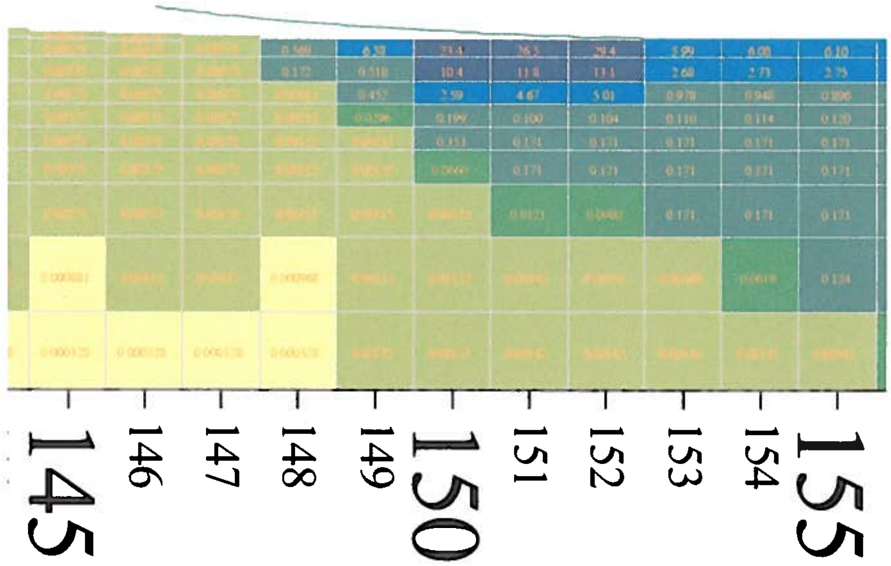


Figure 14: Portion of model row 126 near the east side of the Snake Range near Baker showing the average horizontal hydraulic conductivity values.

Forcing the flow into the valley fill, as just described, would **minimize predicted drawdowns from the model**. This is because the model pumps primarily from the valley fill units where the storage coefficient is much higher than in the carbonate units. The HUF2 package, as used by SNWA in this model, forces a connection so that water flow into the LVF where it supplies SNWA's wells, in the model, and may significantly bias the model to underestimate drawdown in these locations.

The numerical model simulated flow from Fish Springs Flat into Snake Valley (SNWA, 2009, p. 5-13). This goes against most other reports, which SNWA cites, showing that because of the high discharge from the springs there must be inflow from elsewhere.

SNWA did not do any verification modeling for this model, although they have data to do so with. They should use 2005-2010 data to verify for a model and DEIS being released now, in 2011.

Conclusion

The DEIS used a regional groundwater flow model to make predictions of drawdown to be expected from pumping the No Action and action alternatives in Snake, Spring, Cave, Dry Lake, and Delamar Valley. It is inappropriate for use in predicting detailed drawdown impacts due to pumping the alternatives for many reasons documented in this report, including the following:

1. The model cells are too coarse for detailed drawdown predictions.

2. The model layers are too thick and the model domain extends much deeper than necessary for simulating the details of pumping their applications.
3. SNWA simulated all layers, including layer 1, as confined. This assumption biases the simulation to underpredict drawdown in Spring Valley because it does not adjust the transmissivity as the water table lowers.
4. The conceptual model used for the numerical model is substantially different from the conceptual model used to develop the numerical model.
5. The numerical model structure was far too complex for the quantity and quality of hydrologic data used to calibrate it.
6. The model relies on faults to control the flow even though there is little collaborating hydrologic data.
7. In many areas, the model is poorly conceptualized which allows the model to protect certain resources and to transmit too much water to certain areas.

Simulation of Proposed Action with Myers Spring/Snake Valley Groundwater Model

The review of the SNWA CCRP model has shown that it is too coarse to make sufficiently accurate predictions for the study area. To provide an alternative tool for considering the impacts in Spring and Snake Valley, I ran the Myers (2011a) model to consider two alternatives. The first is the DEIS proposed action and the second is similar to the reduced pumping option, with the Snake Valley pumping reduced to 36,000 af/y for the entire valley and in Spring Valley reduced to one-third its proposed value. This is less pumping in Spring Valley than the reduced pumping option in the DEIS to better bracket the impacts and to determine whether the drawdown extent differs substantially even for much reduced pumping.

Simulations were run exactly as in Myers (2011b). Three stress periods, 75, 125, and 10,000 years long were used to simulate impacts up to 200 years and to allow the system to come to equilibrium at up to 10,200 years, if that is possible. Figure 15 shows the pumping locations, as for the DEIS, for each scenario; the difference between scenarios is the pumping rates. Pumping was drawn from model layers 4 and 5, 400 to 2000 ft bgs. Wells were not targeted to specific formations, however, as was done in the DEIS (BLM, 2011, p. 3.3-97) because water rights' applications do not limit the pumping to a given formation.

Starting the pumping in each valley at the same time allows better comparisons of predicted drawdown between valleys. The DEIS simulation included pumping in some valleys during the construction period; the DEIS drawdown maps show the results of much less pumping in Snake Valley than in Spring Valley. Nothing legally binds SNWA to pumping schedules as analyzed in the DEIS which means they could begin pumping the full amount from each valley as soon as any water rights are granted.

Also, the pumping includes only the project, so there is no confusion with ongoing pumping in the valleys – the drawdowns and changes in fluxes reported are due simply to pumping SNWA's proposals.

Results

Drawdown maps for the two scenarios are presented for two different model layers, 2 and 5, at two different times, 75 and 200 years after pumping begins (Figures 15 through 22). Flux values for the proposed action are shown in Figures 23 through 25 and for the reduced pumping option in Figures 24 to 26. Appendix A contains hydrographs for various monitoring points (Figure 15) for layers 2 and 5 for both pumping scenarios. Layer 2 is for 80 to 200 ft bgs and layer 5 is from 800 to 2000 ft bgs. Differences in water level at a point between the layers represent a vertical gradient.

Drawdown predicted with the Myers model for the proposed action is similar in extent to that predicted by the DEIS, with several exceptions (Figures 15 through 18). First, the drawdown of course clusters around the pumping wells. However, the Myers model simulates numerous areas near those wells with drawdown in excess of 200 feet whereas the DEIS simulation does not (BLM, 2011, Figure 3.3.2-5). Only for pumping the full amount from the original locations does the DEIS predict drawdown near the wells to exceed 200 feet (BLM, 2011, Figure 3.3.2-18). There are even some small areas with drawdown exceeding 500 feet in layer 5 after 200 years (Figure 18).

The SNWA model may underestimate drawdown at the wells because it simulates pumping to occur from 400 to 2000 ft bgs; a longer screen length may spread the impacts over a thicker aquifer section for modeling. This may bias the results because such long screens may not be feasible. Also, the SNWA model simulates all layers as confined, with specific storage too high. Such simulation maintains a constant transmissivity as the water level lowers which may minimize drawdown at the wells.

The Myers model also predicts more drawdown in the middle of the north half of Spring Valley (Figures 15 through 18); the DEIS modeled drawdown did not exceed 10 feet under a broad section of the playa even after 200 years. The DEIS probably underestimated discharge reductions in this area. The reasons for the difference are probably SNWA's specific storage values being too high (releasing more water for a unit head drop).

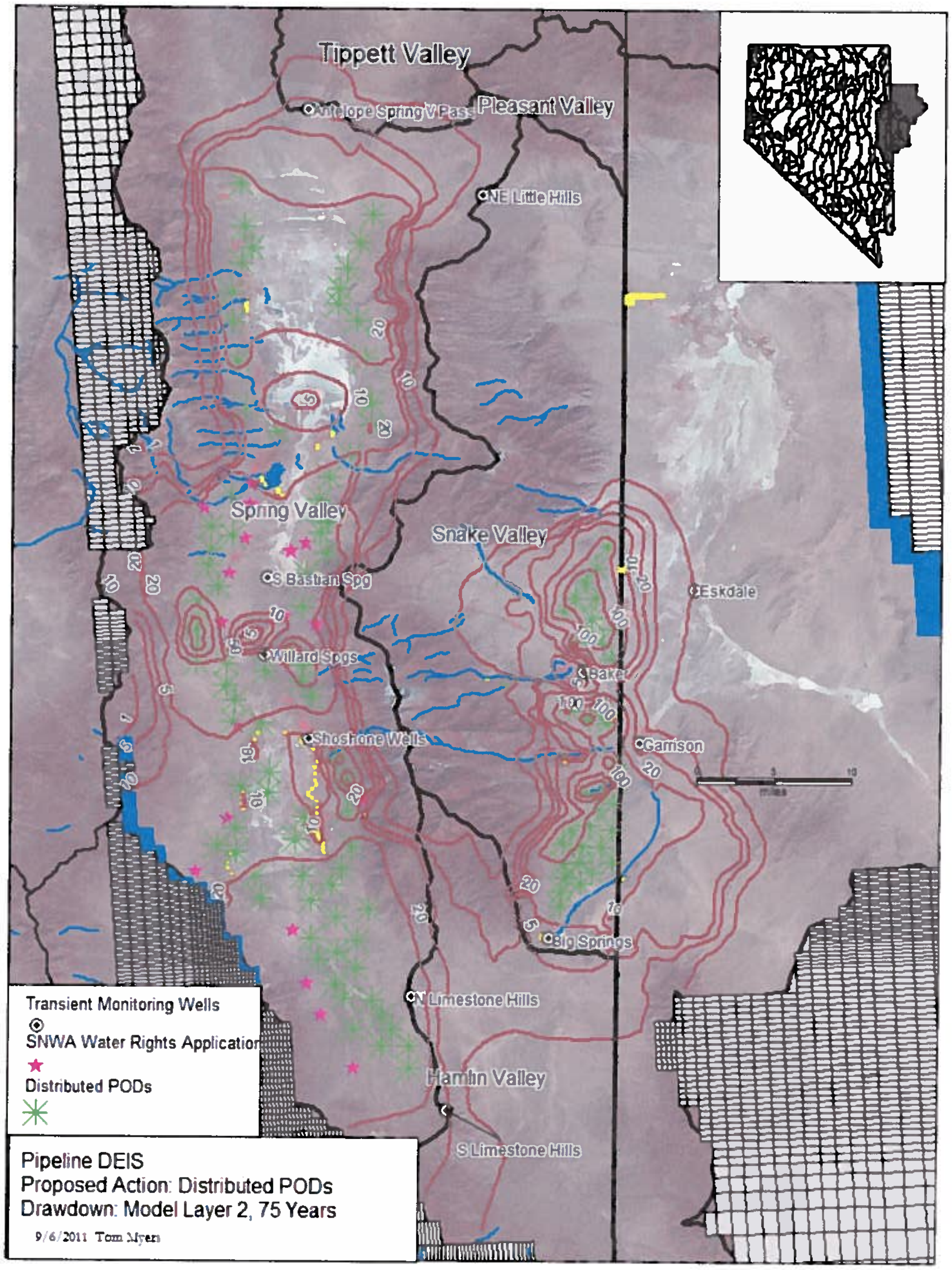


Figure 15: Drawdown for simulation of DEIS proposed action in model layer 2 after 75 years of pumping. The figure also shows pumping and monitoring well locations and the general outline of boundaries in the Myers (2011) model.

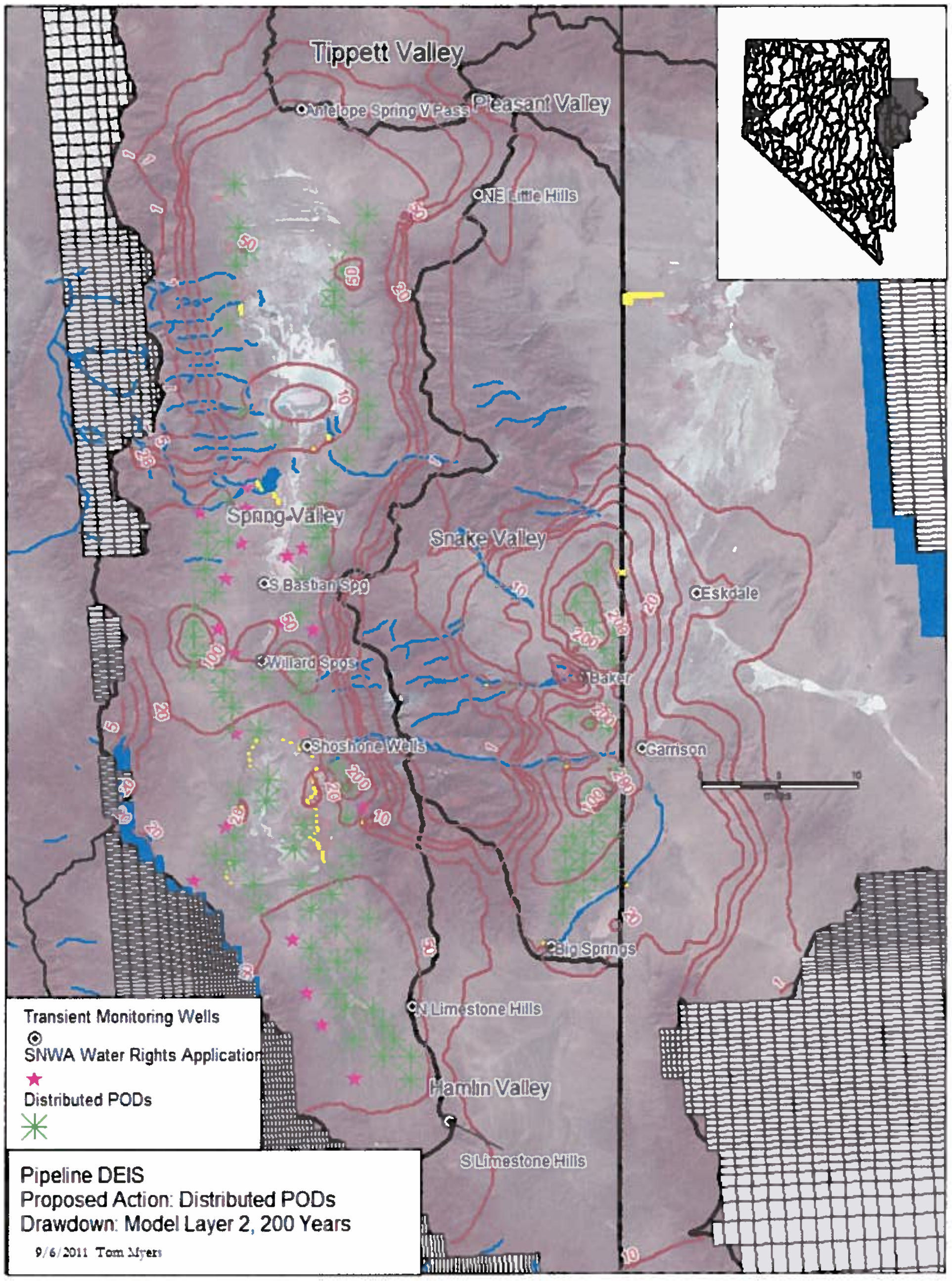


Figure 16: Drawdown for simulation of DEIS proposed action in model layer 2 after 200 years of pumping. The figure also shows pumping and monitoring well locations and the general outline of boundaries in the Myers (2011) model.

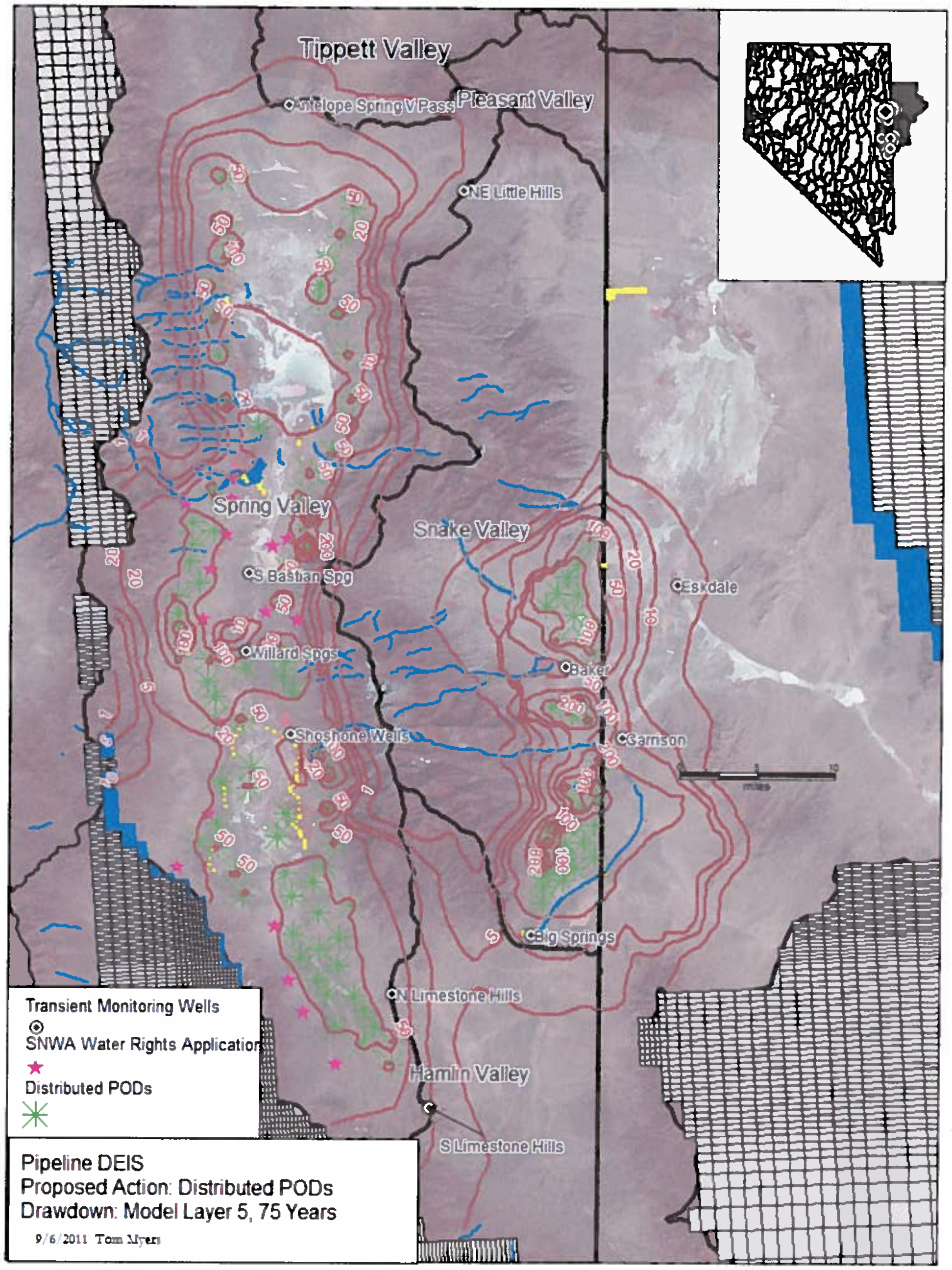


Figure 17: Drawdown for simulation of DEIS proposed action in model layer 5 after 75 years of pumping. The figure also shows pumping and monitoring well locations and the general outline of boundaries in the Myers (2011) model.

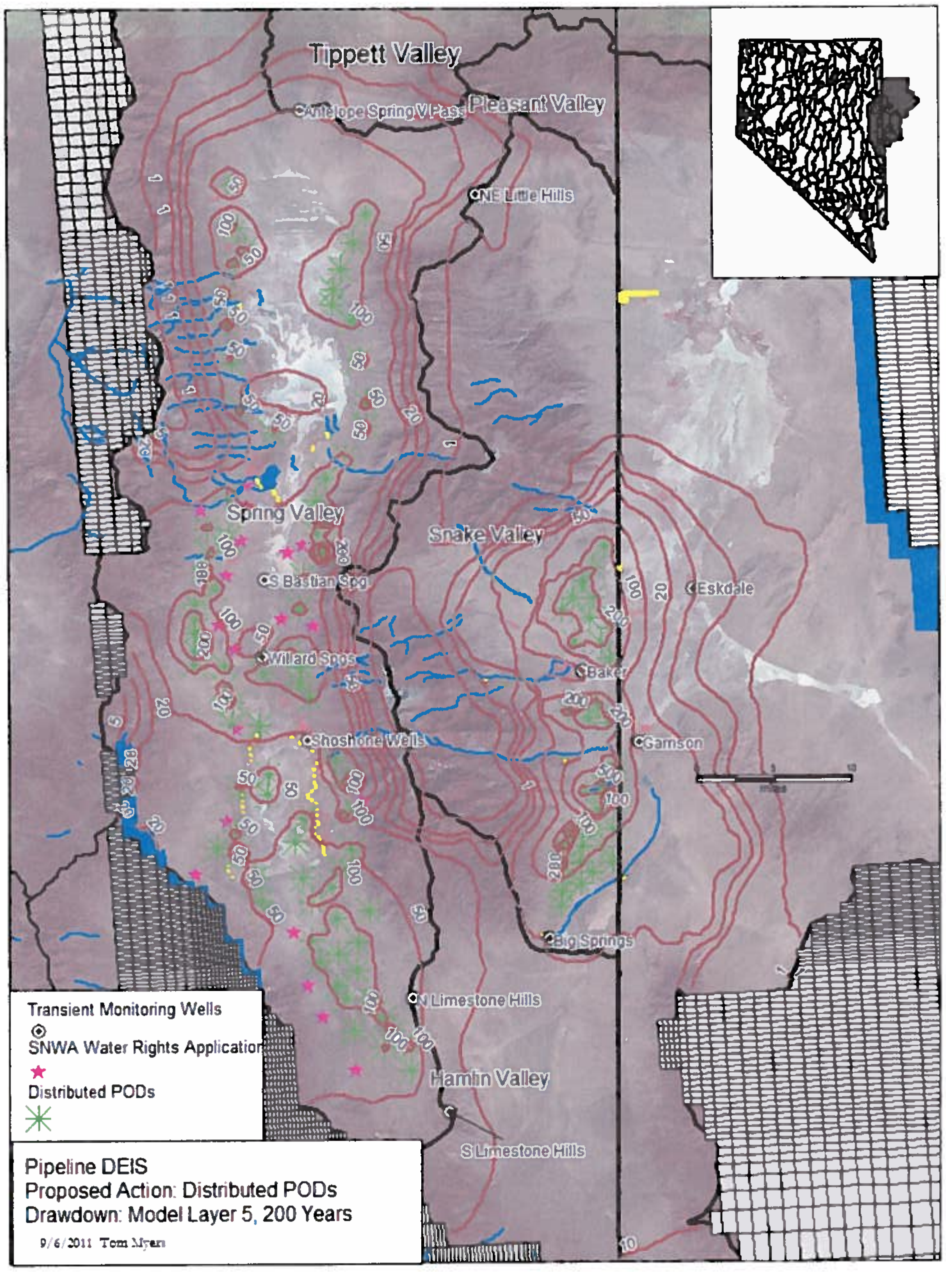


Figure 18: Drawdown for simulation of DEIS proposed action in model layer 5 after 200 years of pumping. The figure also shows pumping and monitoring well locations and the general outline of boundaries in the Myers (2011) model.

Pumping the DEIS proposed action causes most of the simulated spring flows to approach zero within 200 years (Figure 23). For example, Spring Creek and Millick Springs dry in 30 years, Big Springs in 80 years, Stateline Springs in 11 years, and discharge to Cleve Creek ceases in 120 years (Figure 24); Swallow Springs are relatively protected by the mountain-front normal fault. Flow from Steptoe Valley to Spring Valley increased by 3000 af/y within 200 years and by 10,000 af/y after 10,200 years.

The system does not come to equilibrium for over 10,000 years. Even at 10,000 years, approximately 1140 af/y continues to be removed from storage; the cumulative amount up to this time is about 100 million af. Over the 10,000 years, the total natural discharge, the sum of ET and springs, reduced from about 163,000 to 38,000 af/y, for a reduction of approximately 125,000 af/y. Total pumping is approximately 142,000 af/y, so the pumping has captured about 90 percent of its total from natural discharge. As noted, some groundwater continues to be removed from storage; the remainder is changes in flow across the model boundaries, so the pumping in Spring and Snake Valley will ultimately affect surrounding valleys with up to 17,000 af/y being drawn from or prevented from flow to those valleys.

The drawdown for reduced pumping option is nearly as extensive as the proposed action, but not as deep (Figures 19 through 22). This is due to the bounds in the model. The central and northern Schell Creek Range and the central two-thirds of the Snake Range are mostly impermeable – pumping quickly draws water from the available aquifer to those boundaries. The 1- through 10-foot drawdown contours near these boundaries are very similar between scenarios. The proposed action has deeper drawdown toward the middle of the valleys as compared to the reduced pumping scenario. Another difference is that the drawdown does not extend as far north into Tippet Valley as quickly.

Although the drawdown extents are similar, the reduced pumping option reduces the various fluxes proportional to the difference in pumping rates (Figures 26 through 28). The reduced option does not avoid impacts because even this option captures most of its pumping from discharge. Wetlands and springs will have reduced flow, but will continue to discharge groundwater. The lesser discharge is due to the decreased drawdown, but then the drawdown is less because less discharge must be captured to offset the pumping.

However, even after 10,200 years, the system has not reached equilibrium for reduced pumping, meaning that the pumping has not totally captured an equivalent amount of discharge. The change in storage flux is about 860 af/y, with a total of 39 million af being removed from storage in 10,200 years. The difference in cumulative storage between the options reflects the different drawdown depths.

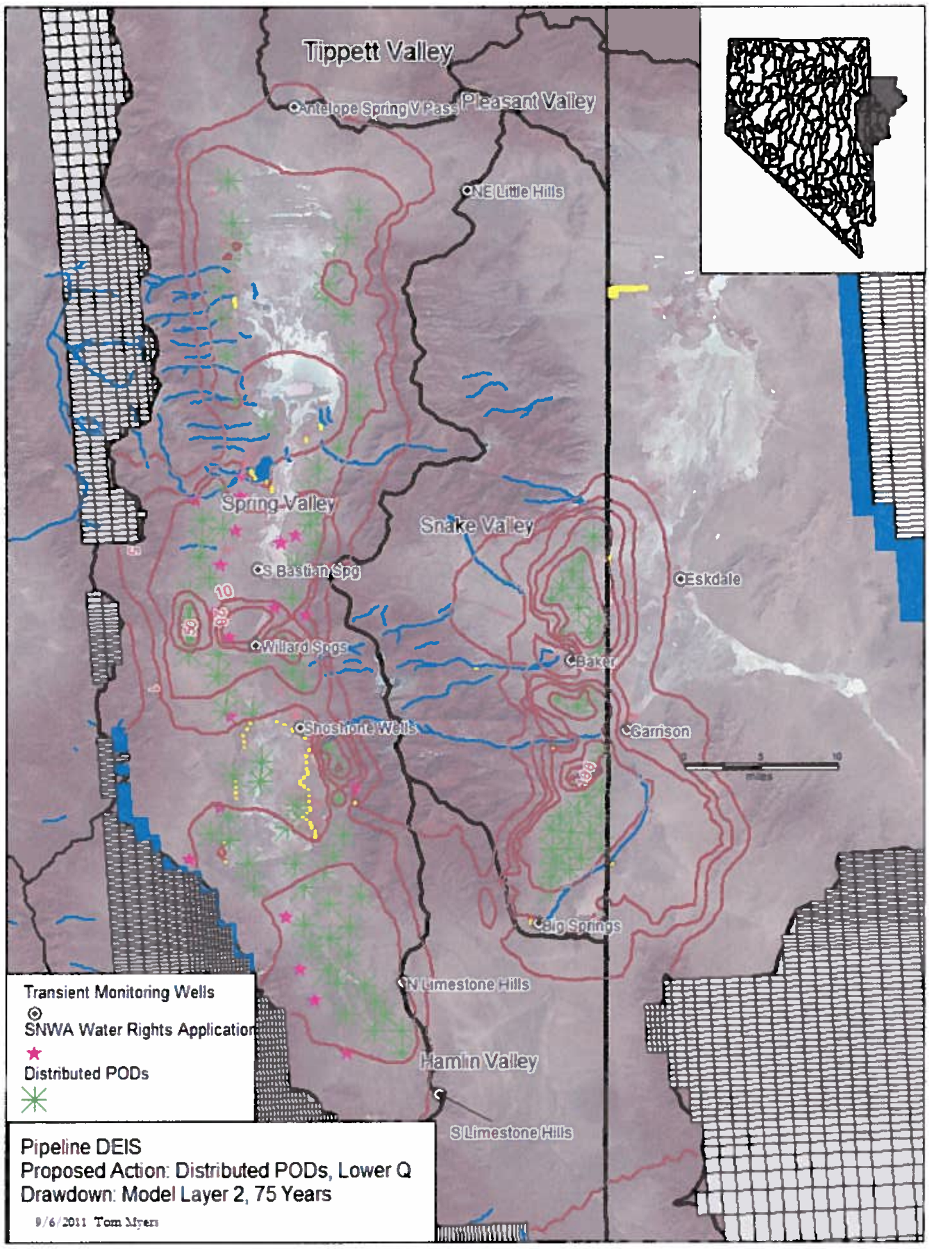


Figure 19: Drawdown for simulation of DEIS proposed action with reduced rates in model layer 2 after 75 years of pumping. The figure also shows pumping and monitoring well locations and the general outline of boundaries in the Myers (2011) model.

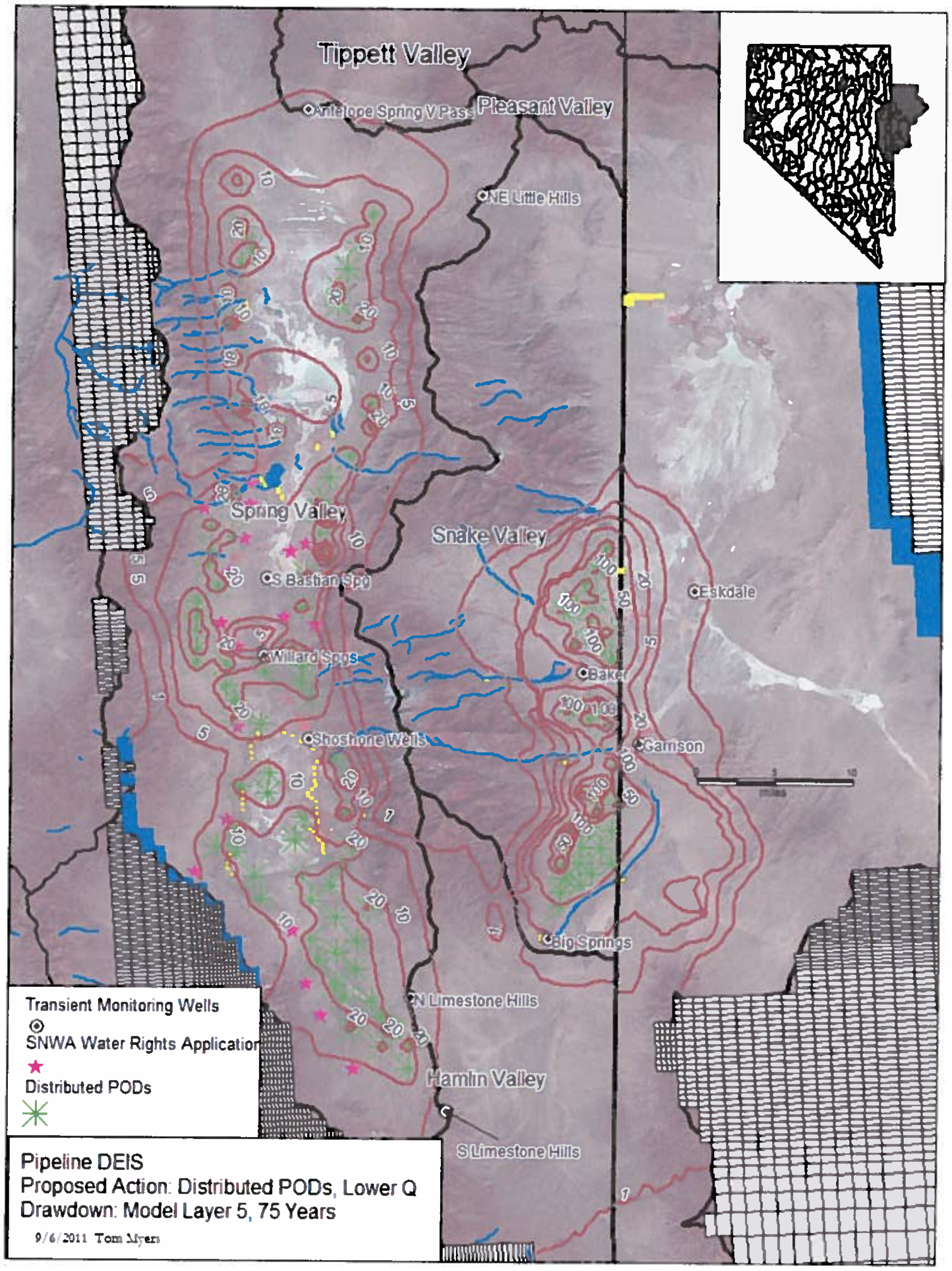


Figure 20: Drawdown for simulation of DEIS proposed action with reduced rates in model layer 5 after 75 years of pumping. The figure also shows pumping and monitoring well locations and the general outline of boundaries in the Myers (2011) model.

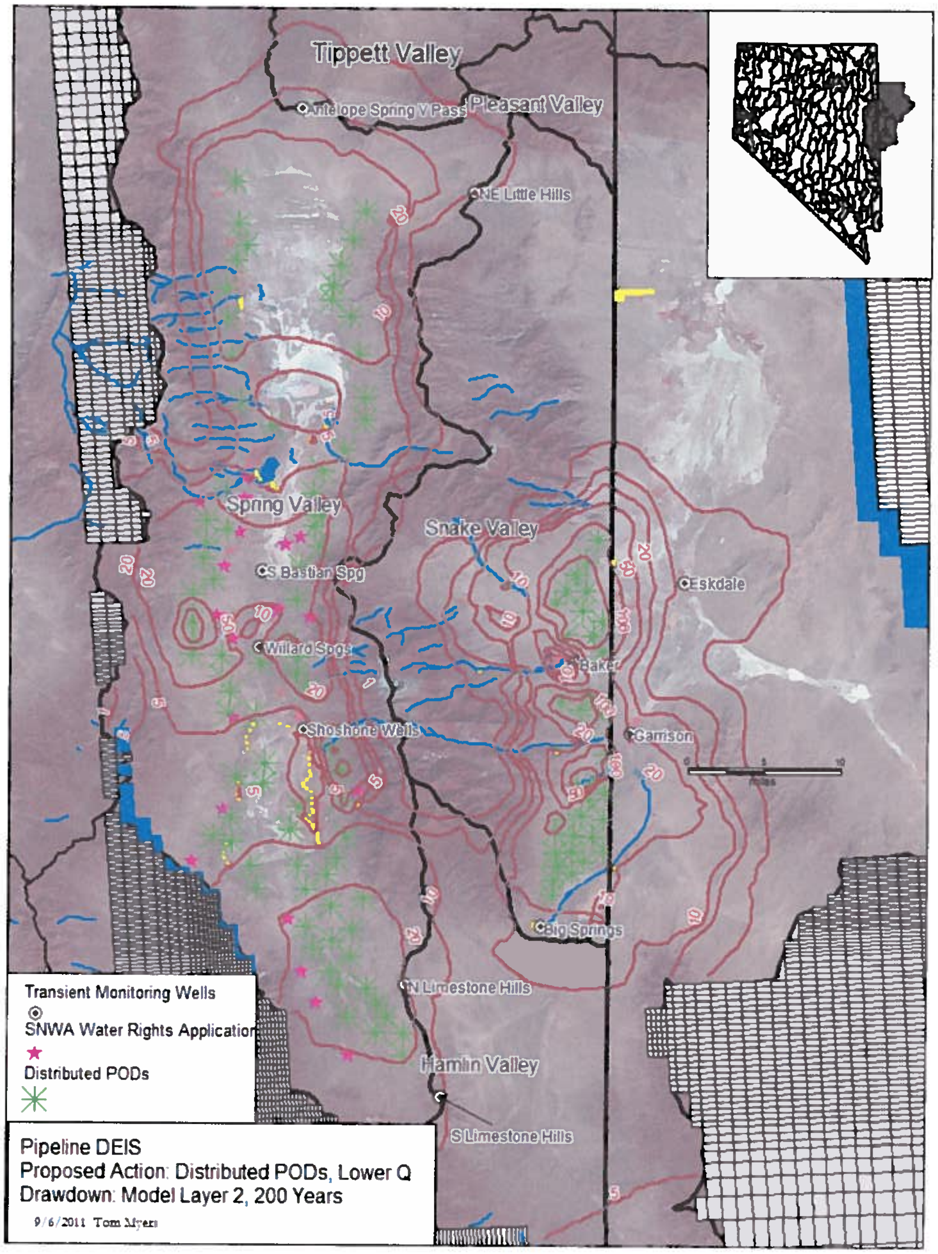


Figure 21: Drawdown for simulation of DEIS proposed action with reduced rates in model layer 2 after 200 years of pumping. The figure also shows pumping and monitoring well locations and the general outline of boundaries in the Myers (2011) model.

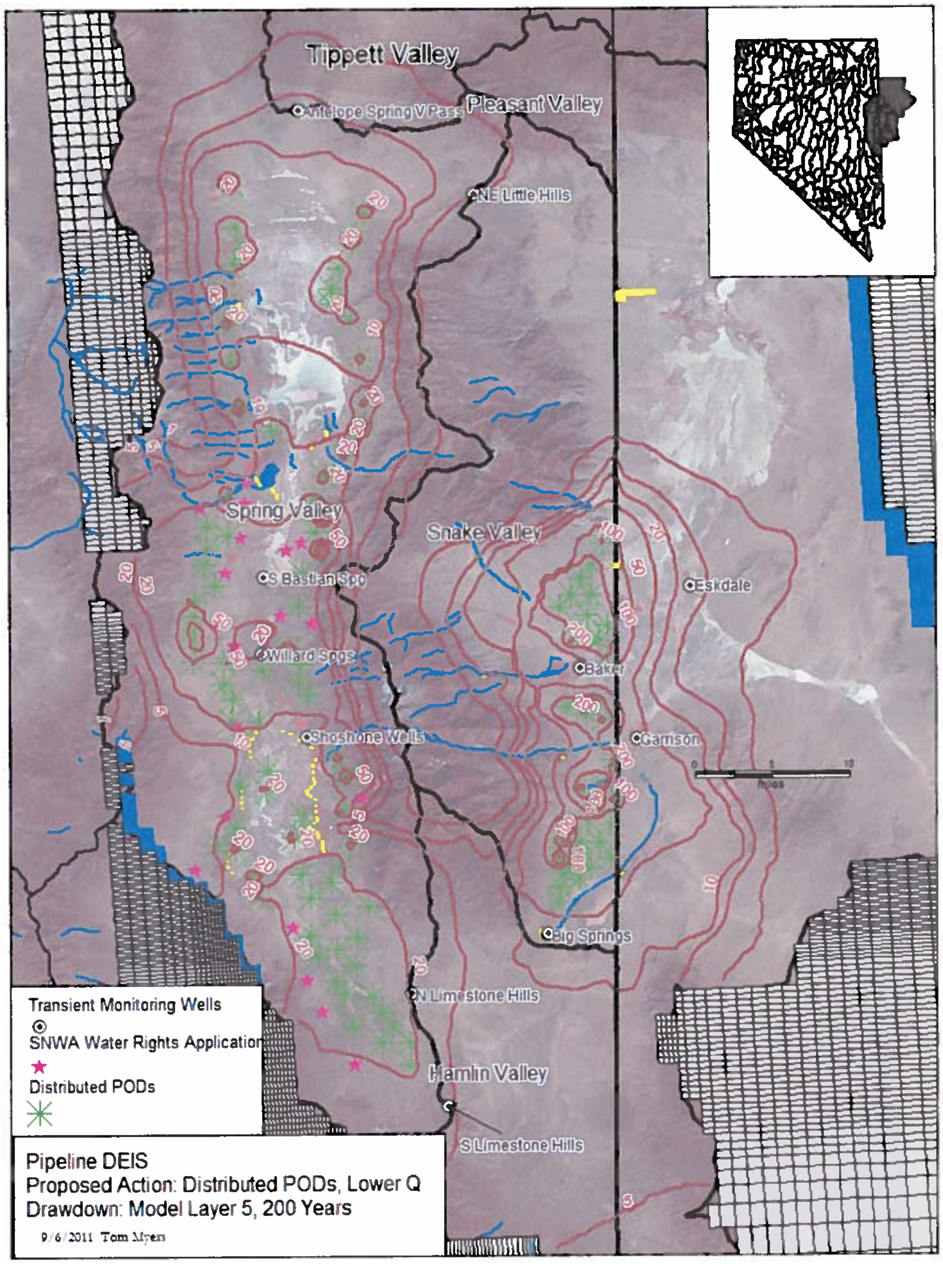


Figure 22: Drawdown for simulation of DEIS proposed action with reduced rates in model layer 5 after 200 years of pumping. The figure also shows pumping and monitoring well locations and the general outline of boundaries in the Myers (2011) model.

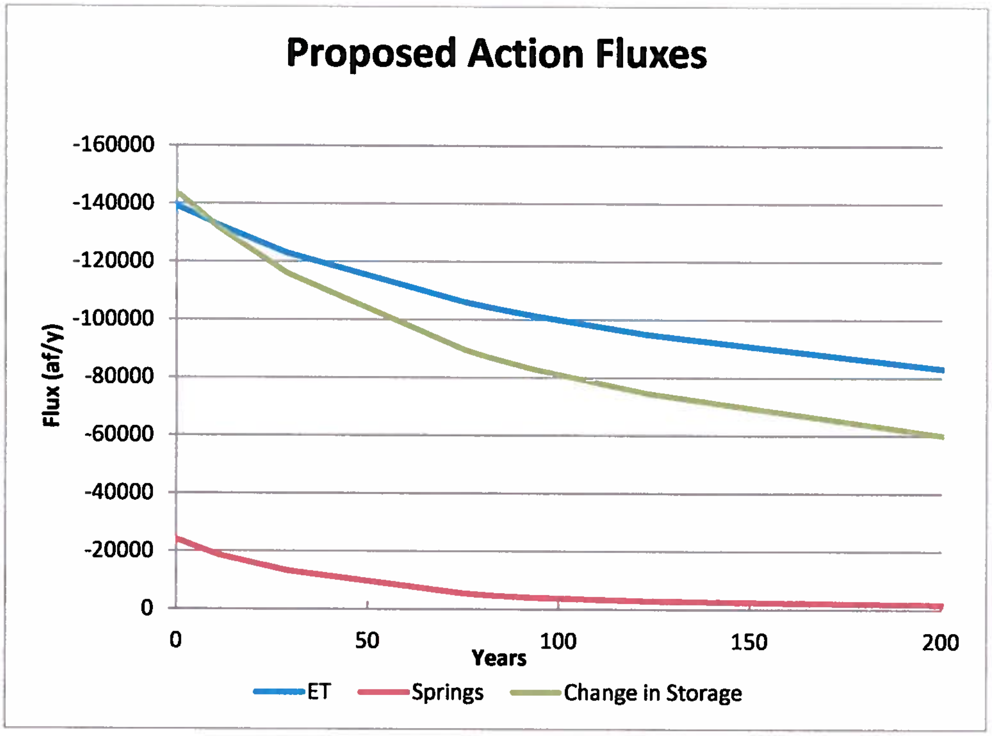


Figure 23: Simulated proposed action flux values.

The area most affected by pumping the reduced amount varies from the area most affected for pumping the full application amount. Some of the springs that dried quickly for the proposed action do not dry at all with reduced pumping – these include Millick Springs and the discharge to Cleve Creek. Pumping significantly affects the Snake Valley springs, with the time to complete drying just being increased due to reduced pumpage. The differences between the impacts to Spring and Snake Valleys reflects the fact that the pumping in Snake Valley was only reduced to 36,000 from 50,000 af/y but the pumping in Spring Valley was reduced to one-third of its original rate.

The monitoring well hydrographs (Appendix A) reveal much about the different responses to pumping around the model domain. Some areas initially have higher head in layer 5 than in layer 2; this represents an upward gradient. The Baker monitoring site demonstrates this clearly with about a 60-foot head drop between layers 5 and 2; this reflects the sub-irrigated pastures near Baker and the circulation of recharge in the carbonate in the Snake Range and at the head of the alluvial fans. Although the gradient varies, similar upward gradients occur at Garrison, both Swamp Cedar sites, Shoshone Wells, South Spring Valley Playa, Minerva, and barely at Big Springs. Pumping reduces or eliminates the vertical upward gradient, as is apparent at Baker and Shoshone Springs, which suggests the subirrigated meadows will eventually be dried and the well at Shoshone Wells will no longer be artesian.

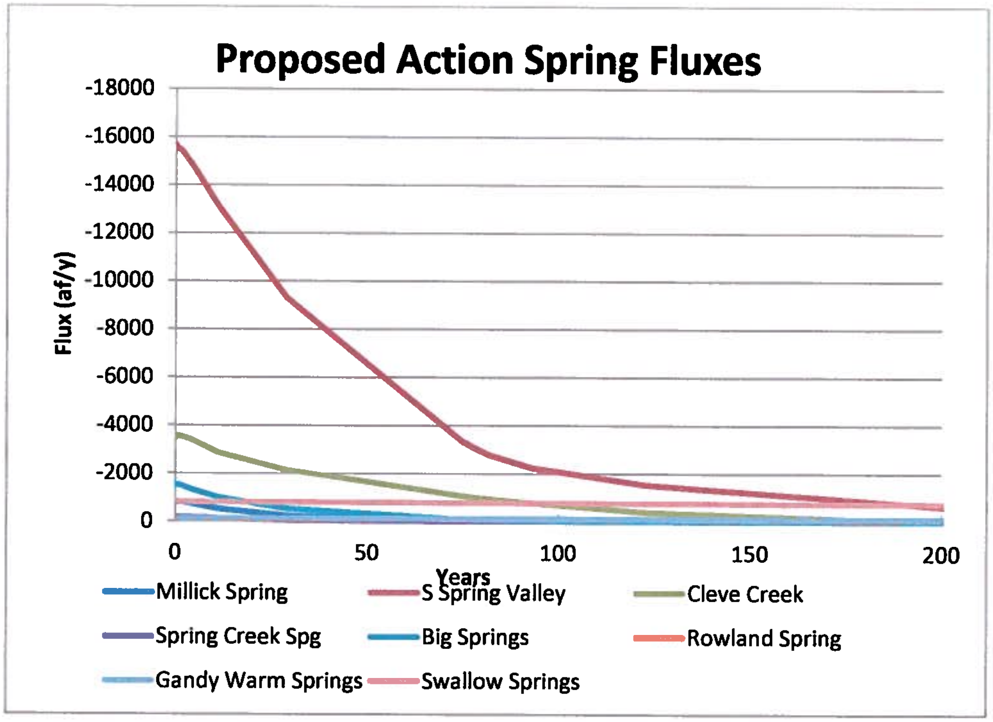


Figure 24: Simulated proposed action spring fluxes.

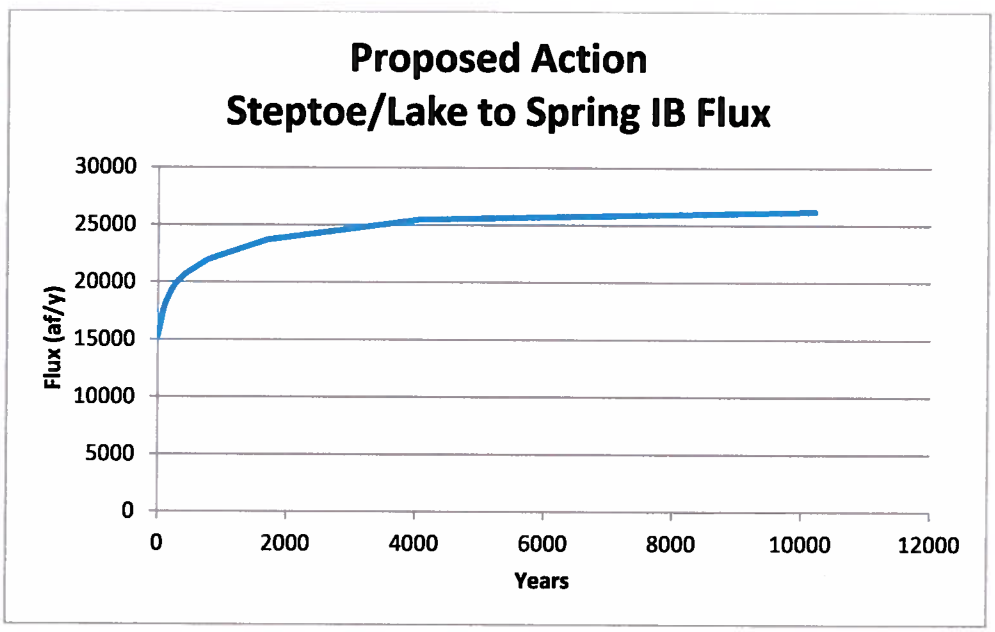


Figure 25: Simulated proposed action flux for interbasin flow from Steptoe to Spring Valley.

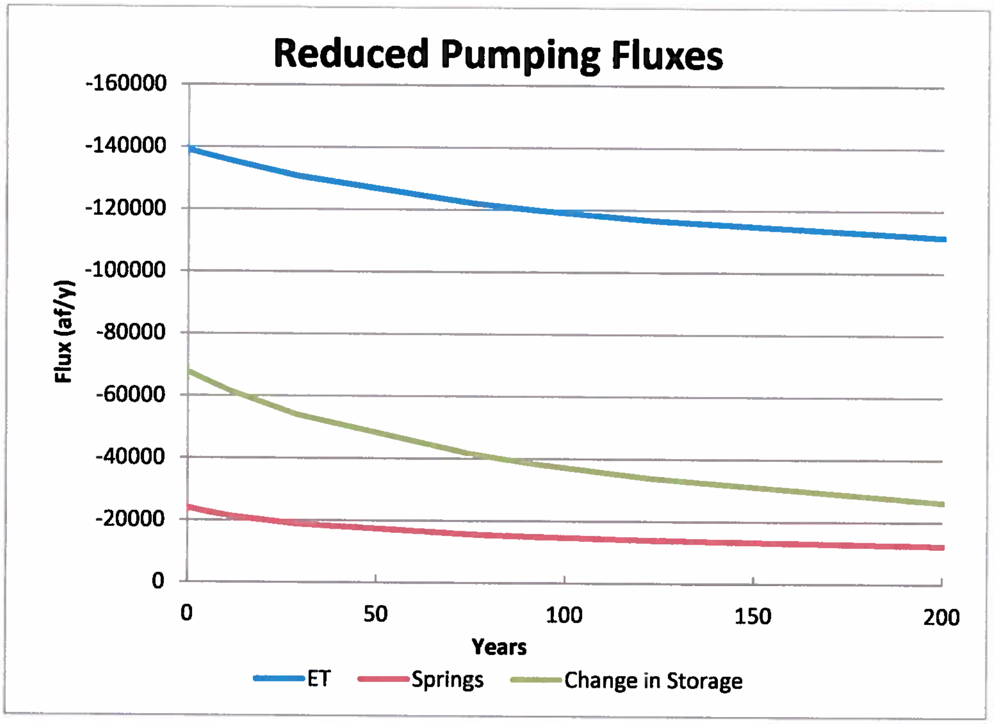


Figure 26: Simulated reduced pumping scenario fluxes.

Areas near the base of the mountains, such as Shingle Creek and Stonehouse Spring, naturally have a downward gradient. Pumping effects do not reach Stonehouse Spring for more than 200 years, but when they do, they lower the potentiometric surface in layer 5 more than in layer 2. This could increase the downward fluxes and induce recharge if any streams intersect the water table.

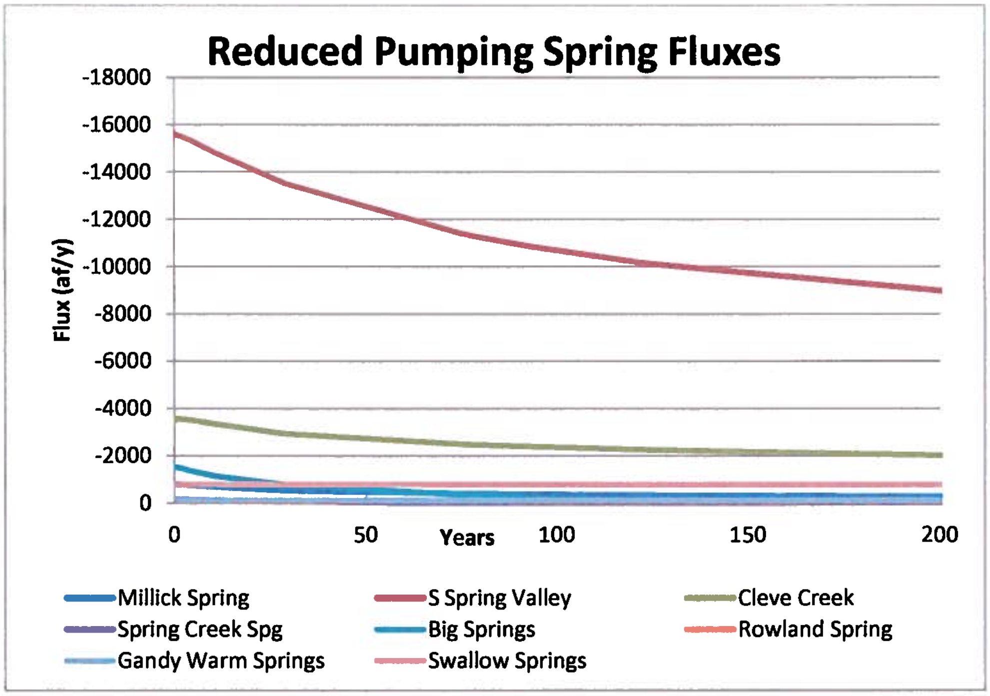


Figure 27: Simulated reduced pumping option spring fluxes.

Another obvious point from the monitoring well hydrographs is that the system is still undergoing significant change at 200 years. This may be seen by comparing the 10,200-year hydrographs with the 200 –year hydrographs. In the long-term, the drawdown will overwhelm the vertical gradient. After a few hundred years, the head level for both layers will be similar with the differences due to pumping scenario. Less drawdown at any point occurs with the reduced pumping option.

Drawdown at points near the center of the valley for the DEIS proposed action exceeds that caused by the reduced pumping option by much more than three times. At some of these points, the hydrographs suggest equilibrium has been established after several hundred years for the reduced pumping option while drawdown from the proposed action just continues to increase. The difference is that the proposed action draws the water table below the extinction depth for the ET zones; once that occurs, there is no more discharge to capture at the point. Continued water table lowering does not decrease the discharge, so at that point the system cannot come into equilibrium. The water table will continue to lower so that the drawdown extent can increase to capture more discharge. In Spring Valley, drawdown can only extend north or south to capture other discharges. This is why the water table continues to deepen after the ET discharge has ceased.

The Center South Spring playa site is a good example: the proposed action causes the water table to draw down indefinitely and completely eliminates the upward gradient; the reduced pumping option allows the upward gradient to continue.

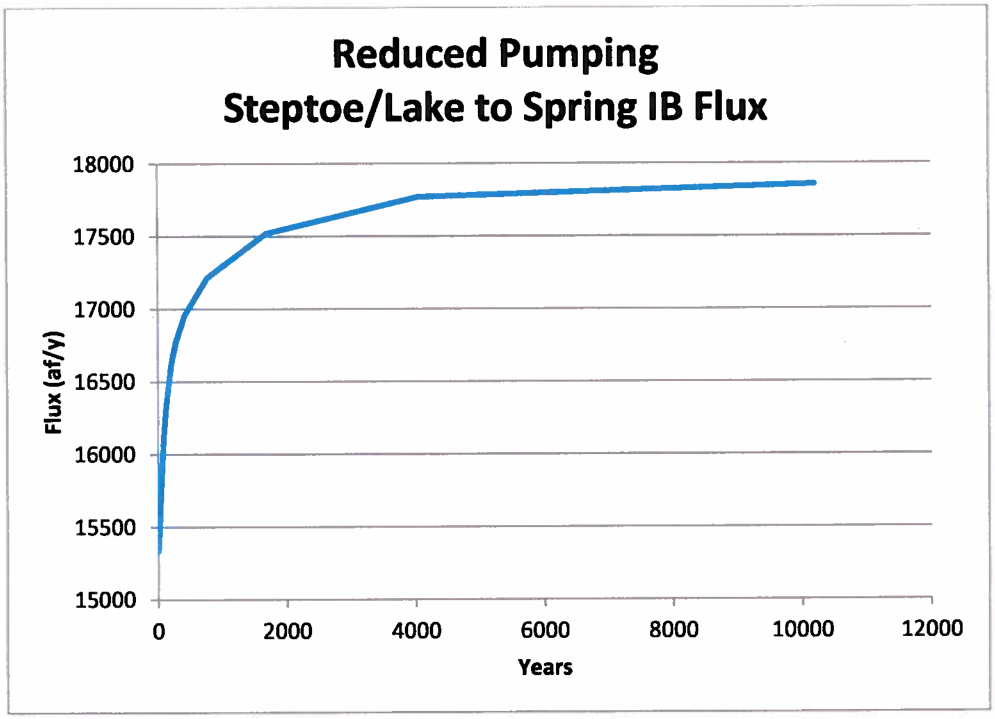


Figure 28: Simulated reduced pumping option interbasin flow from Steptoe/Lake Valleys to Spring Valley.

Summary of Alternatives Simulations

Pumping either the DEIS proposed action or the reduced pumping scenario would cause widespread drawdown around both Spring and Snake Valleys. With time, either option draws groundwater from surrounding valleys, causing drawdown and intercepting discharge there. The DEIS proposed action will cause very substantial drawdown near the centers of pumping. The groundwater system does not come into equilibrium for more than 10,000 years.

Reducing the pumping rate to one-third of the full application amount, or about 30,000 af/y, allows the system to almost come to equilibrium with a some wetland ET discharge and spring flow continuing. Although the valley resources would be severely damaged, they would at least still remain while the proposed action would almost completely dry the valley.

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Presentedto the Nevada State Engineer on behalf of Great Basin Water Network and the Confederated Tribes of the Goshute Reservation. Available at Nevada State Engineer's web site, currently (9/7/11), http://water.nv.gov/hearings/upcoming/springetal/exhibits.cfm.

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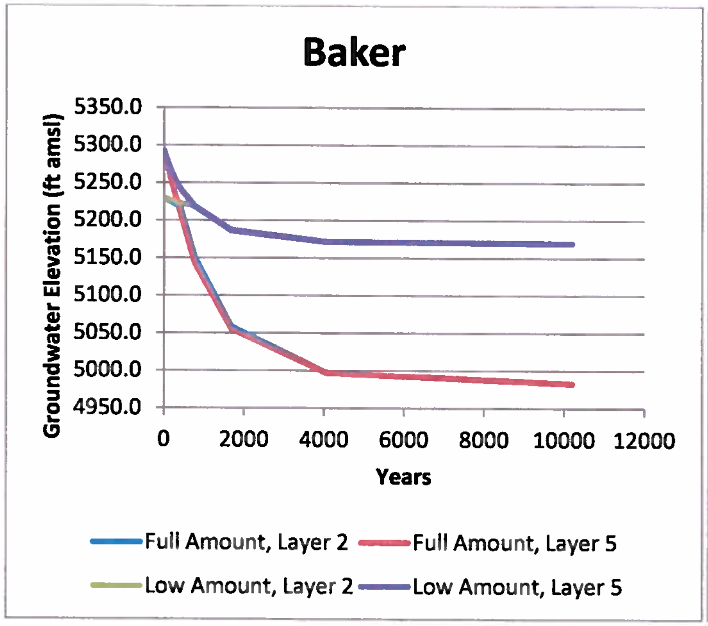
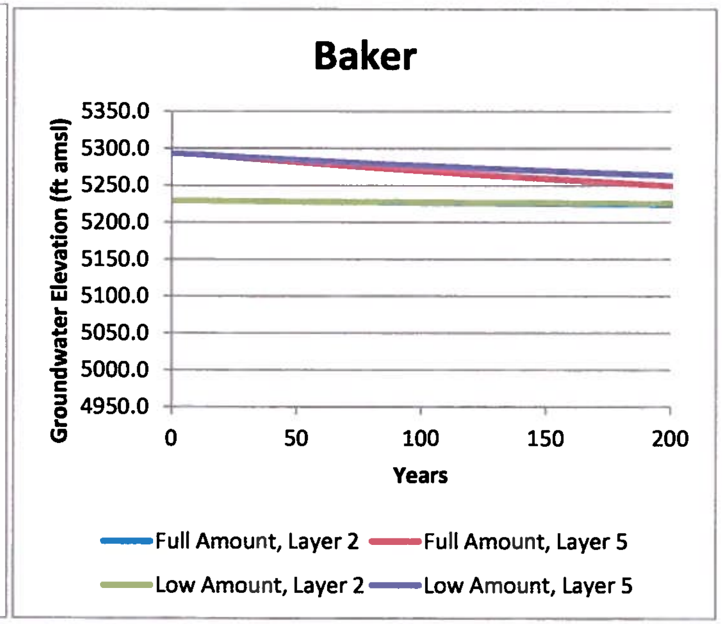
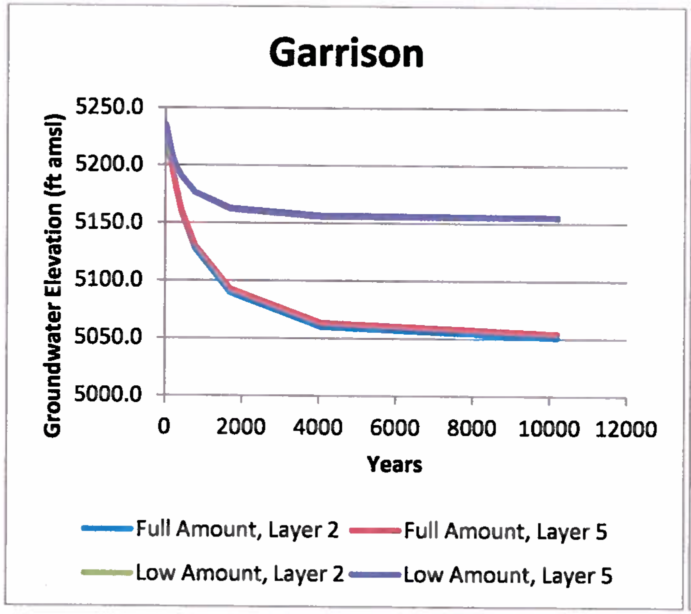
APPENDIX 1: GROUNDWATER LEVELS AT SELECT MONITORING POINTS.

EACH PAGE PRESENTS HYDROGRAPHS FOR 10,200 YEARS AND FOR 200 YEARS.



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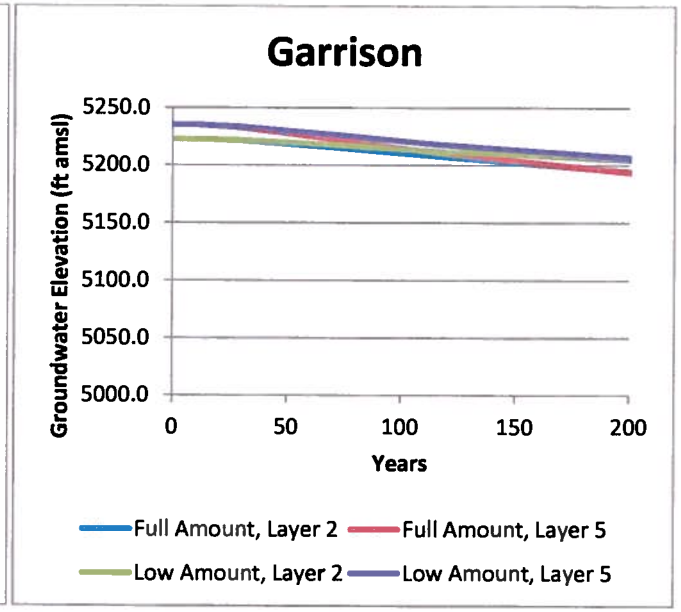
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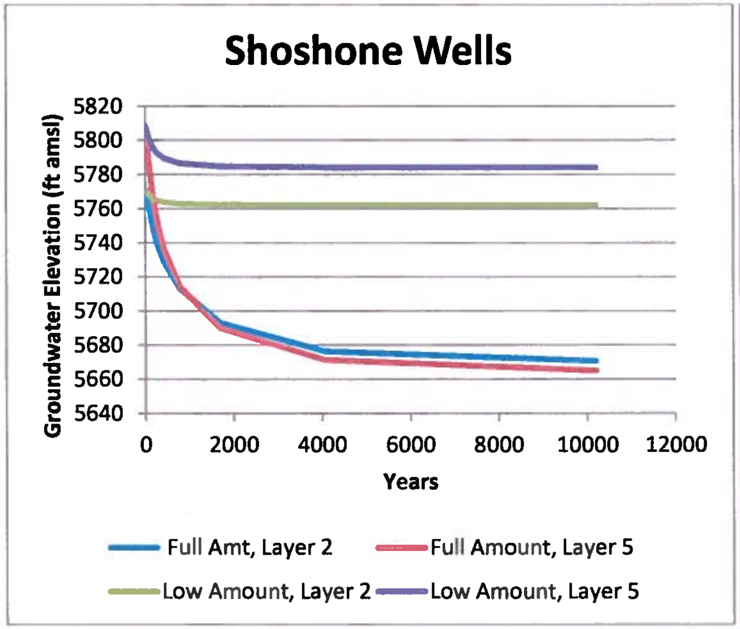
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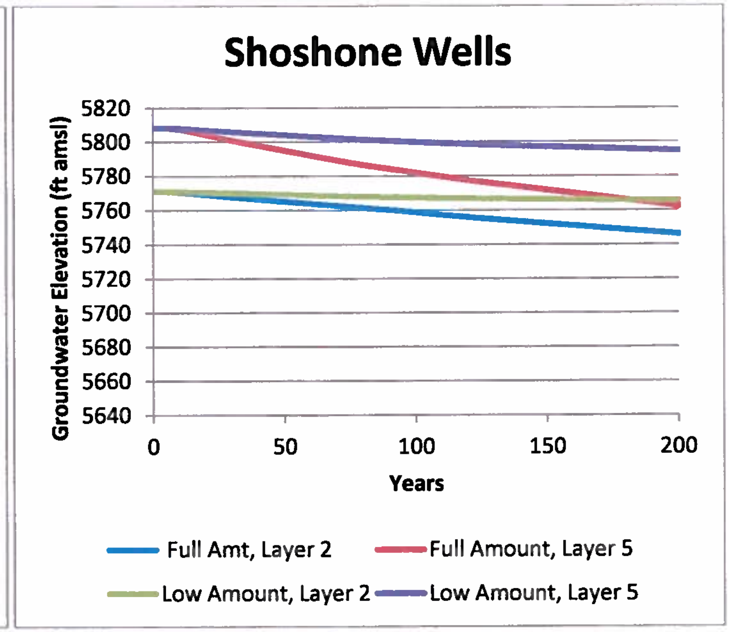
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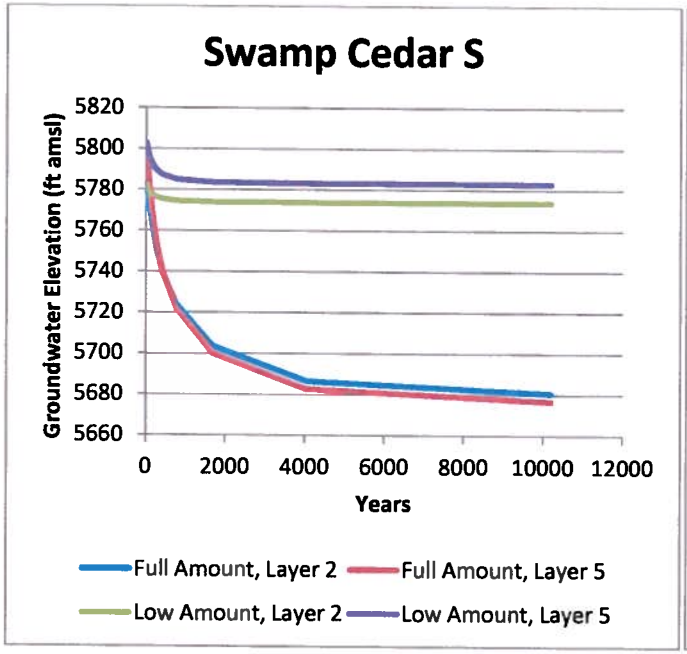
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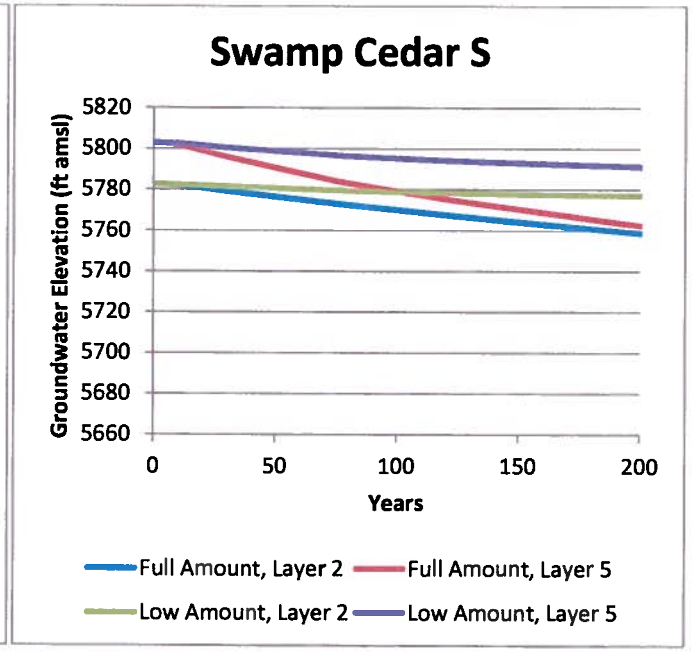
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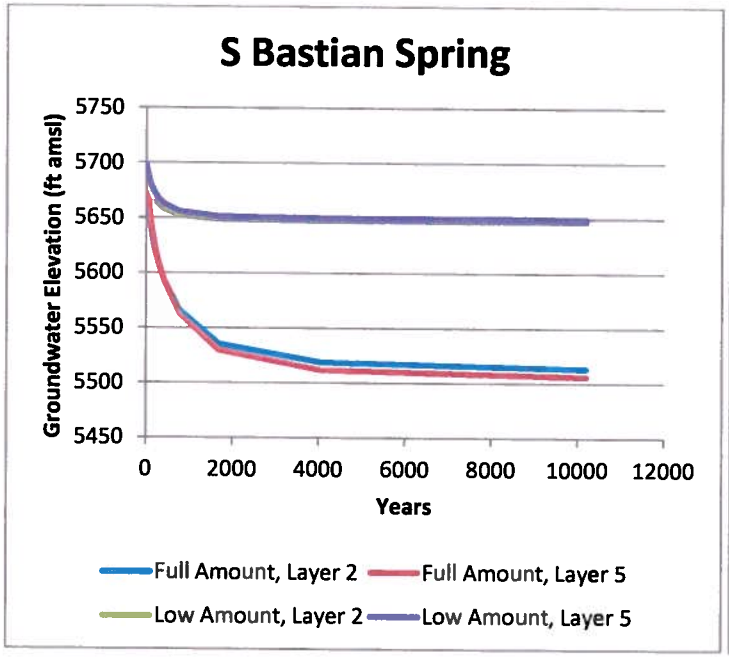
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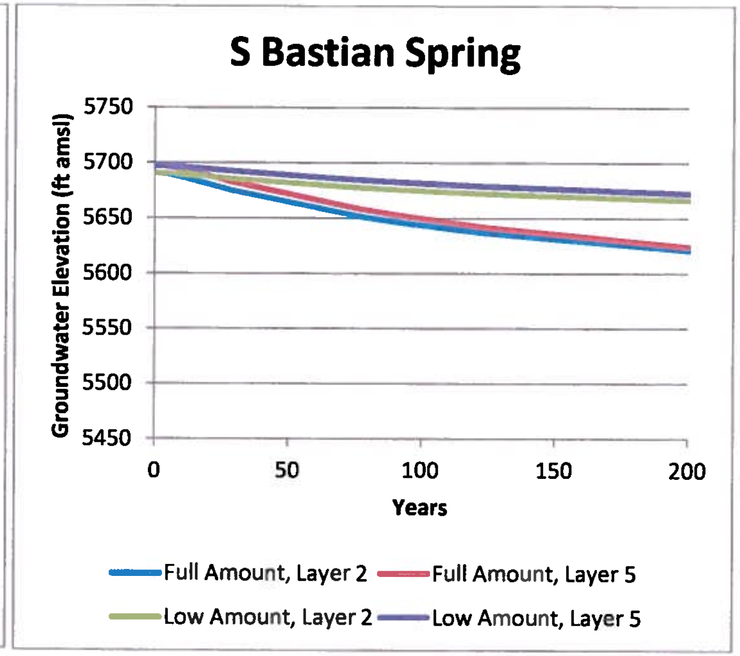
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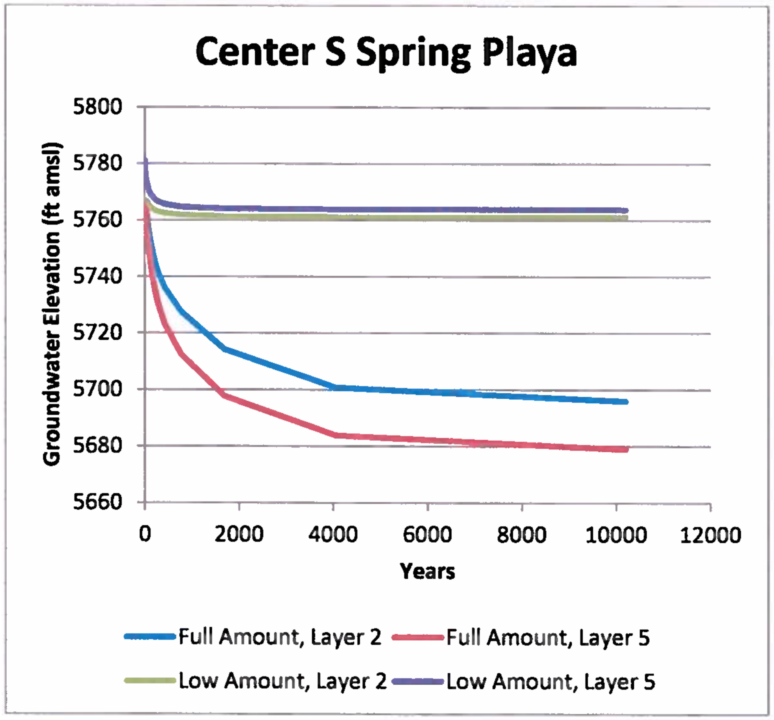
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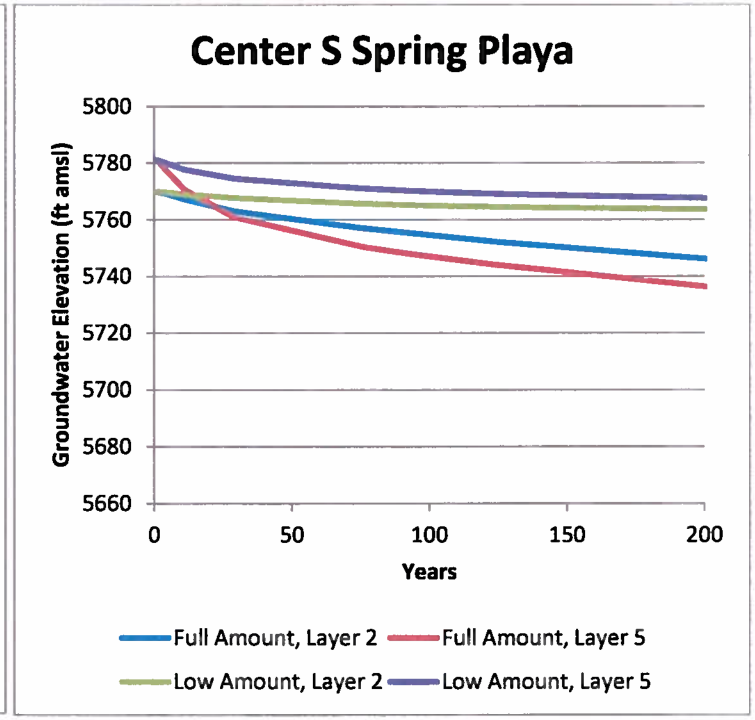
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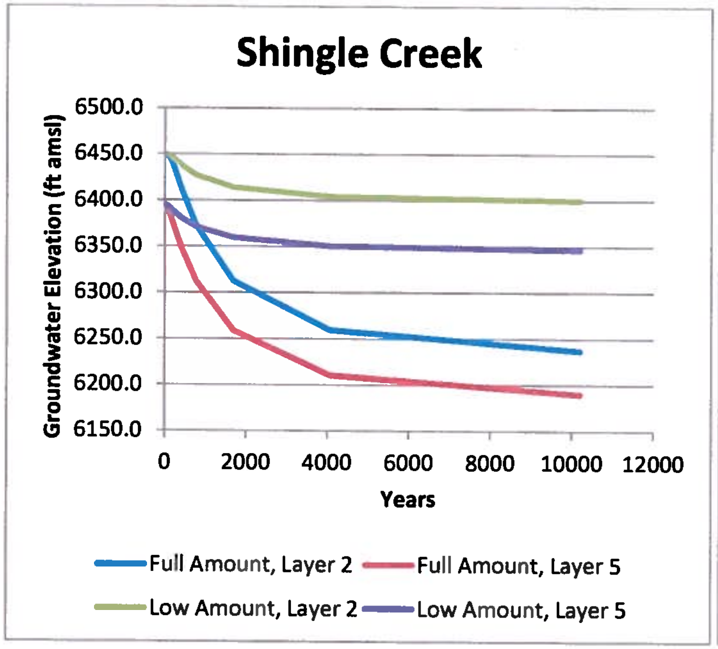
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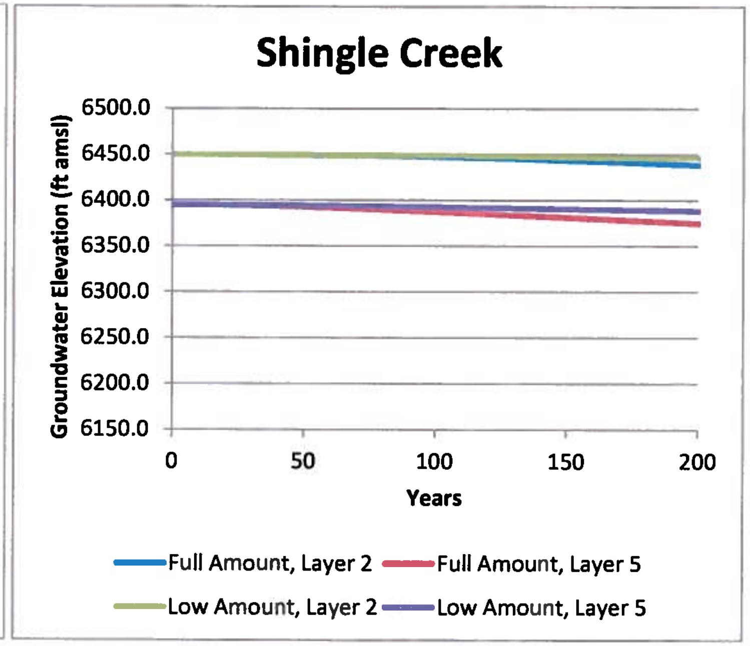
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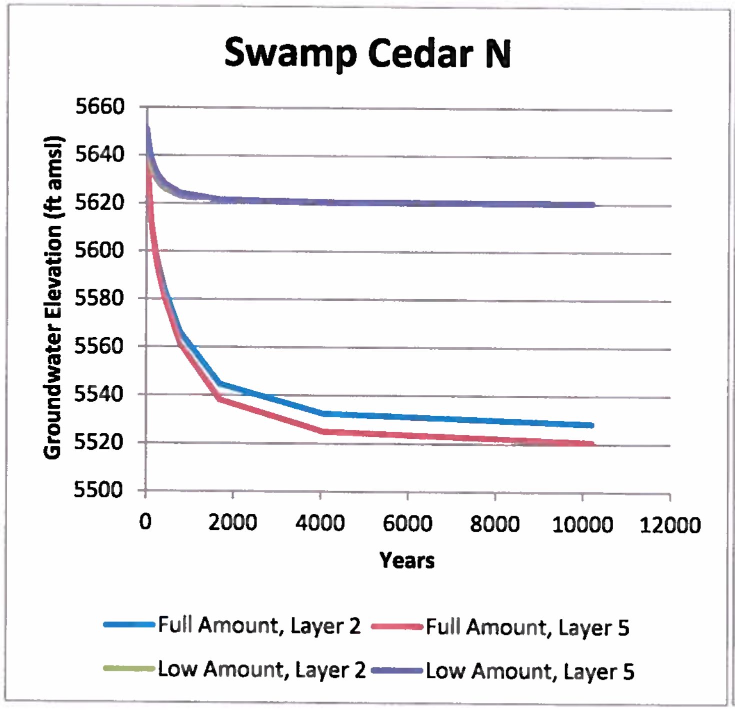
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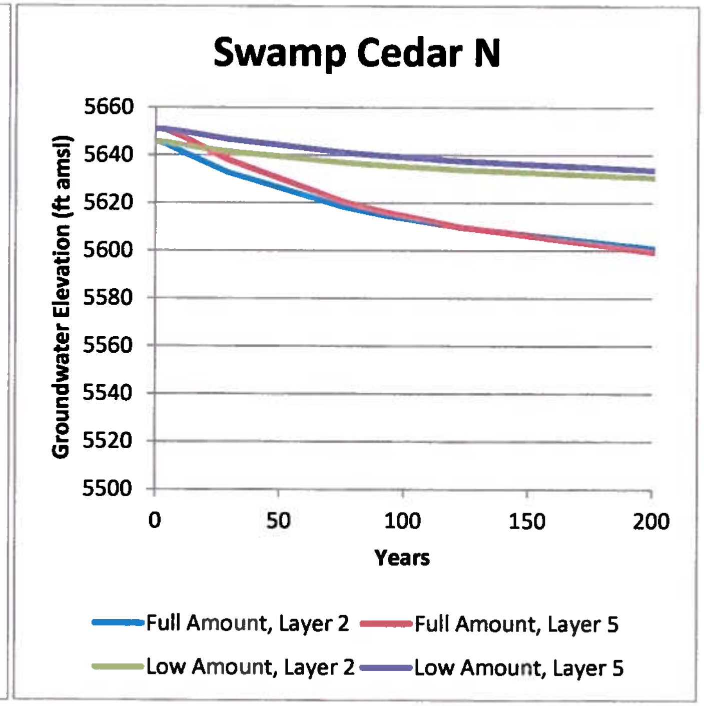
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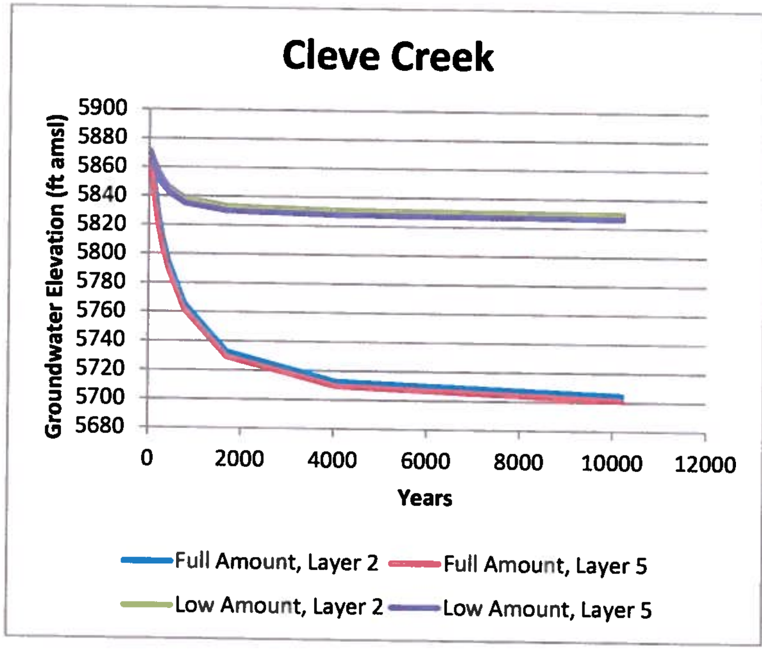
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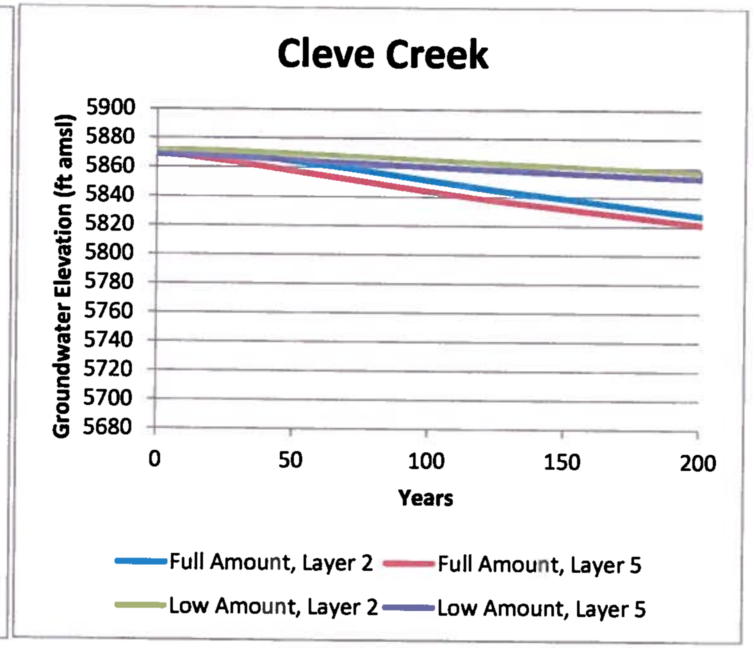
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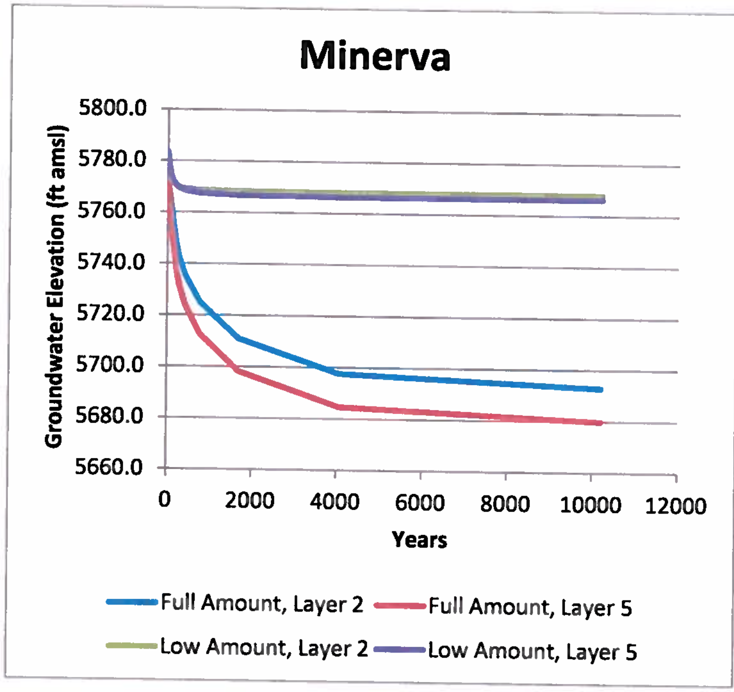
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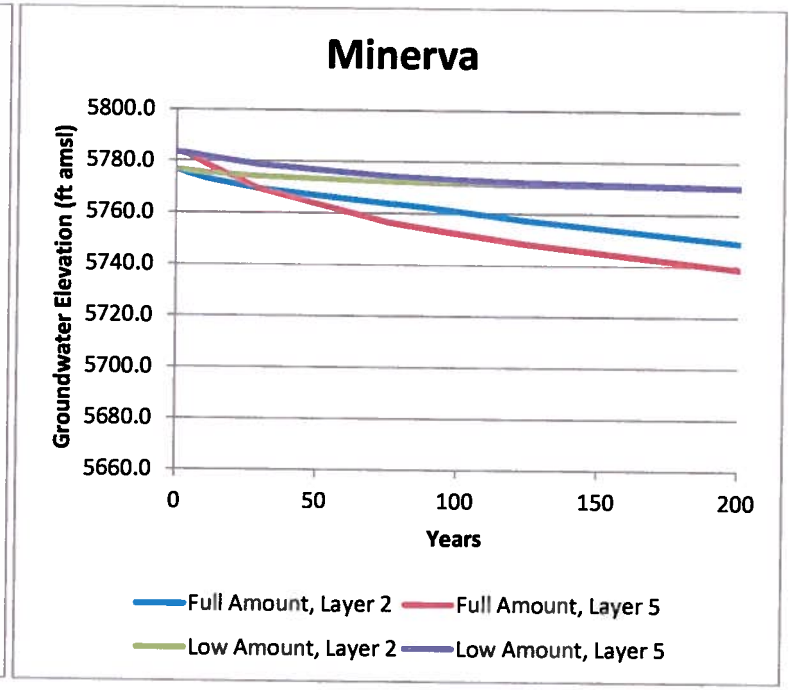
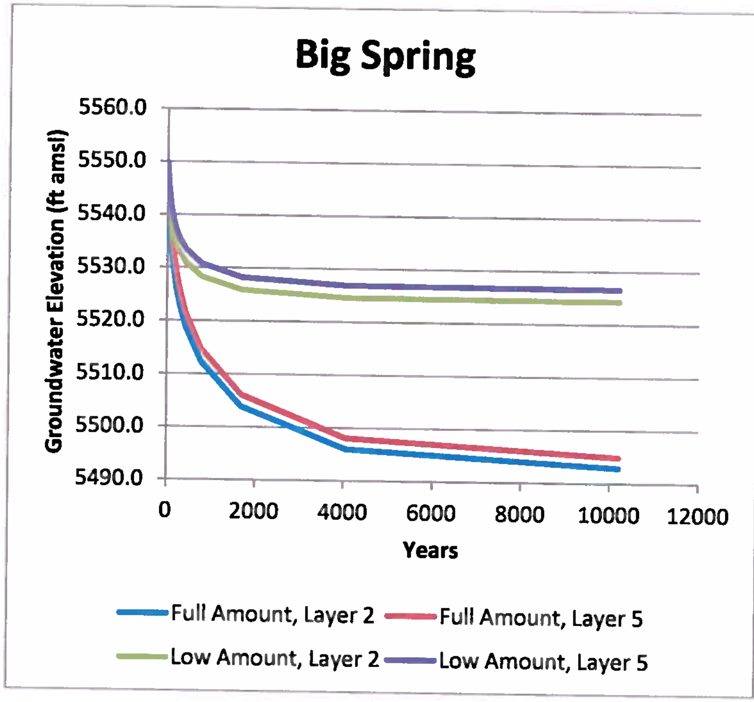
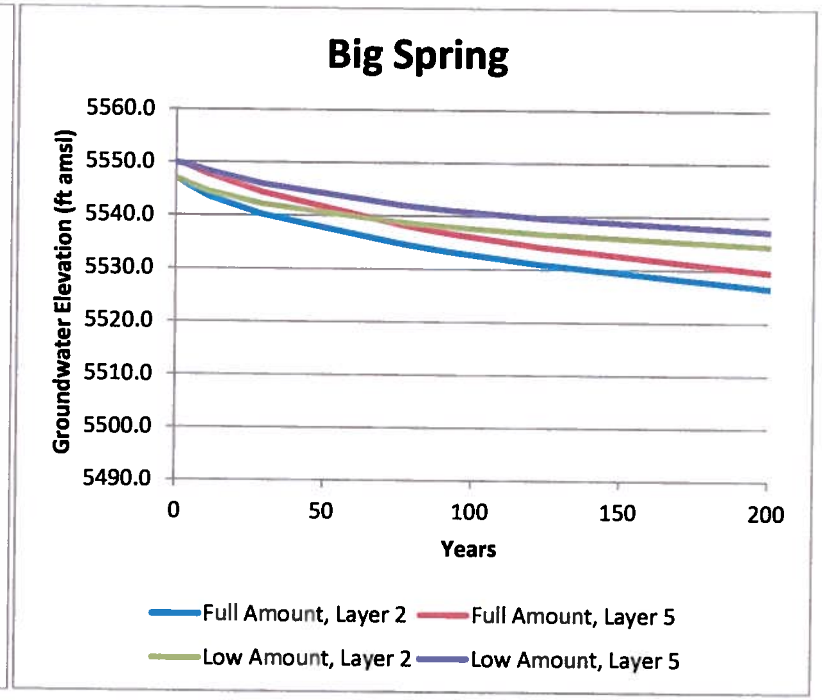
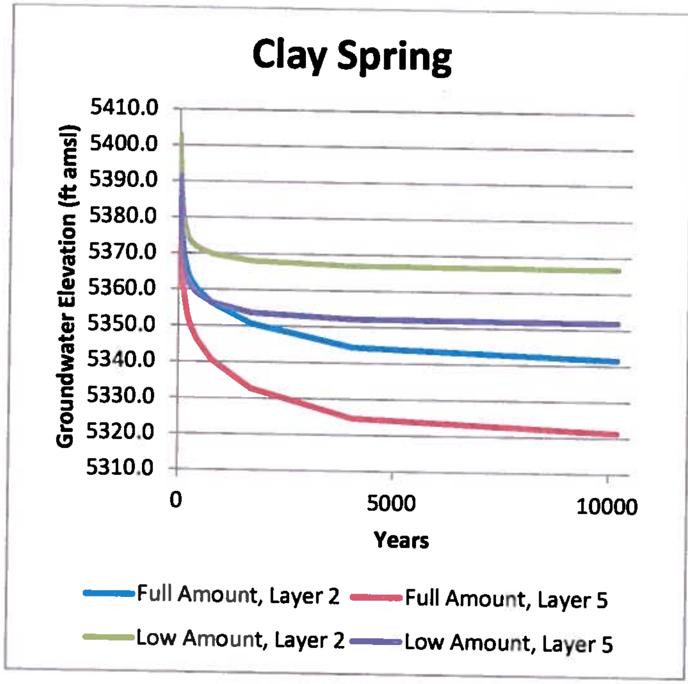
Low Amount, Layer 2
Low Amount, Layer 5

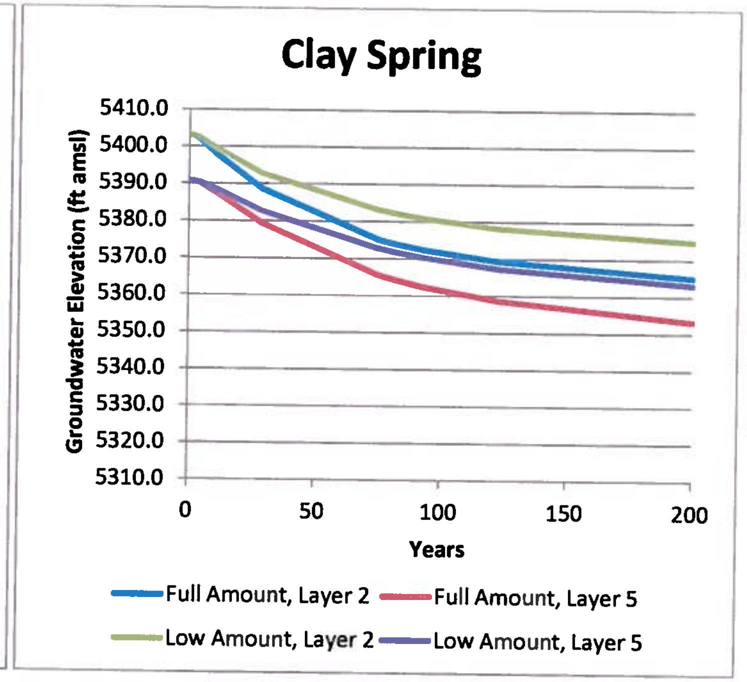

Minerva
Groundwater Elevation (ft amsl)
5800.0
5780.0
5760.0
5740.0
5720.0
5700.0
5680.0
5660.0
0
50
100
150
200
Years
Full Amount, Layer 2
Full Amount, Layer 5
Low Amount, Layer 2
Low Amount, Layer 5

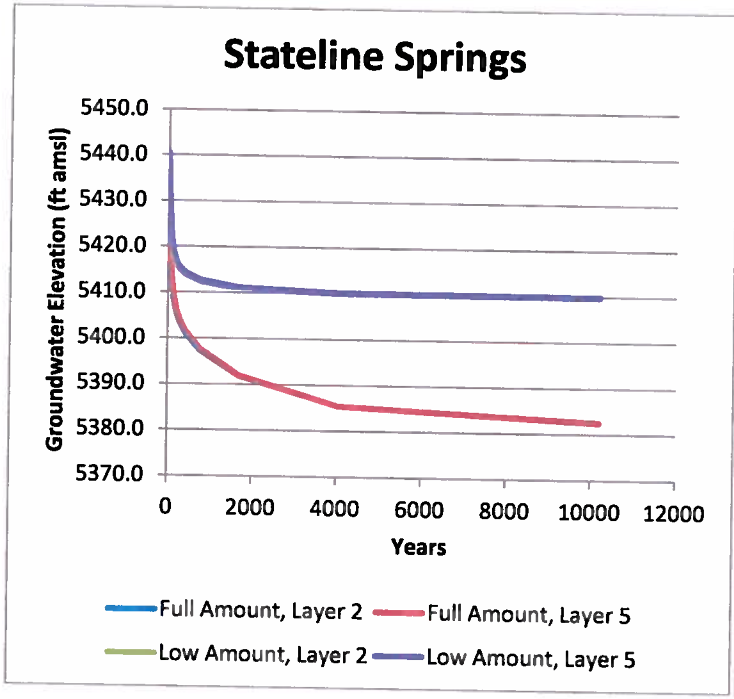
x

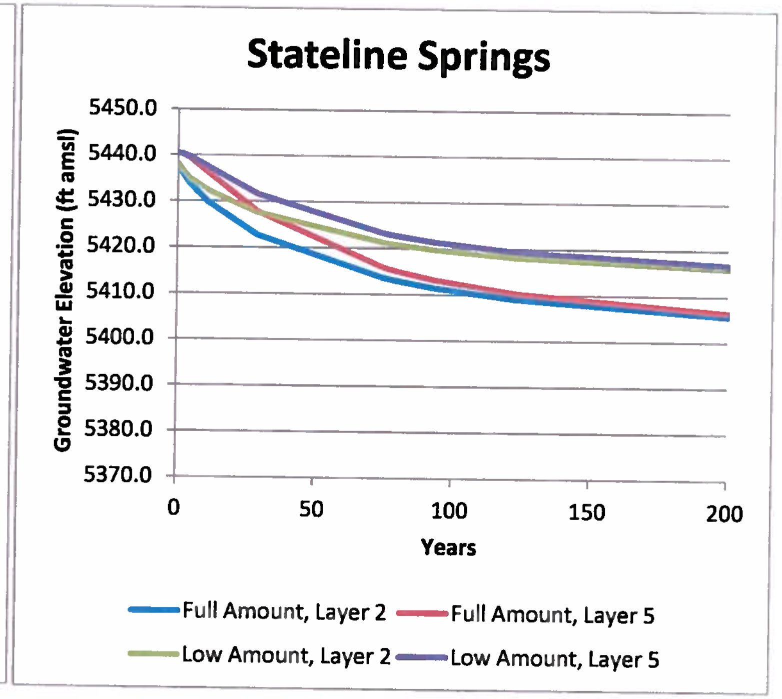

Big Spring
Groundwater Elevation (ft amsl)
5560.0
5550.0
5540.0
5530.0
5520.0
5510.0
5500.0
5490.0
0
2000
4000
6000
8000
10000
12000
Years
Full Amount, Layer 2
Full Amount, Layer 5
Low Amount, Layer 2
Low Amount, Layer 5

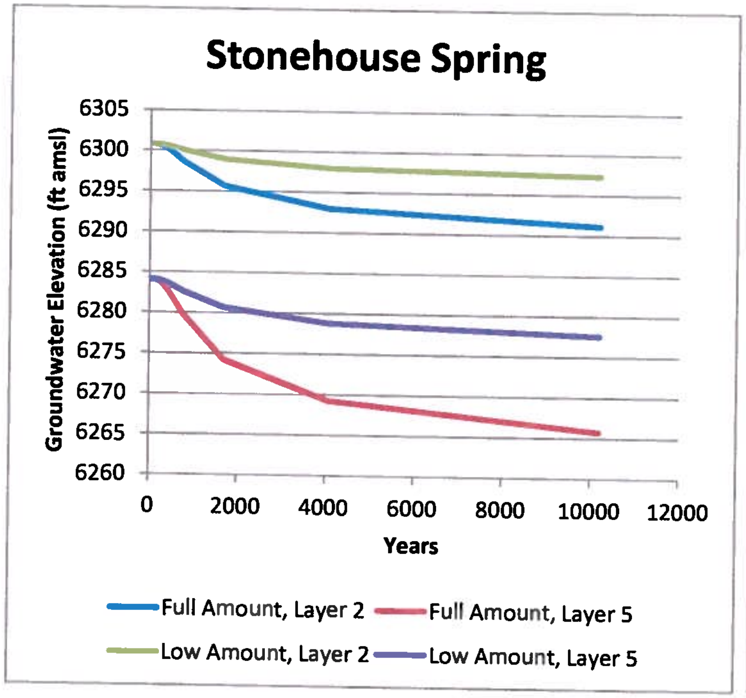

Big Spring
Groundwater Elevation (ft amsl)
5560.0
5550.0
5540.0
5530.0
5520.0
5510.0
5500.0
5490.0
0
50
100
150
200
Years
Full Amount, Layer 2
Full Amount, Layer 5
Low Amount, Layer 2
Low Amount, Layer 5

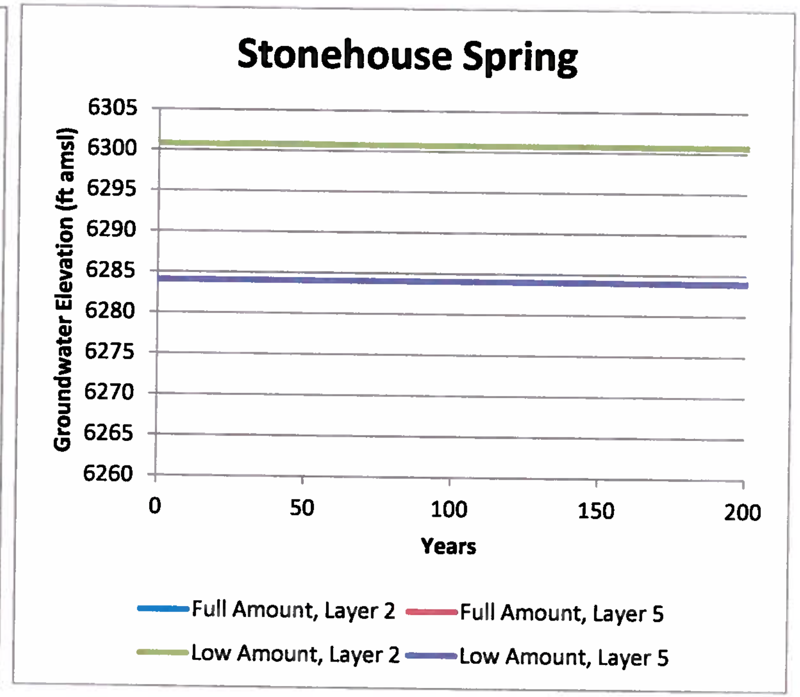

Clay Spring
Groundwater Elevation (ft amsl)
5410.0
5400.0
5390.0
5380.0
5370.0
5360.0
5350.0
5340.0
5330.0
5320.0
5310.0
0
5000
10000
Years
Full Amount, Layer 2
Full Amount, Layer 5
Low Amount, Layer 2
Low Amount, Layer 5


Clay Spring
Groundwater Elevation (ft amsl)
5410.0
5400.0
5390.0
5380.0
5370.0
5360.0
5350.0
5340.0
5330.0
5320.0
5310.0
0
50
100
150
200
Years
Full Amount, Layer 2
Full Amount, Layer 5
Low Amount, Layer 2
Low Amount, Layer 5


Stateline Springs
Groundwater Elevation (ft amsl)
5450.0
5440.0
5430.0
5420.0
5410.0
5400.0
5390.0
5380.0
5370.0
0
2000
4000
6000
8000
10000
12000
Years
Full Amount, Layer 2
Full Amount, Layer 5
Low Amount, Layer 2
Low Amount, Layer 5


Stateline Springs
Groundwater Elevation (ft amsl)
5450.0
5440.0
5430.0
5420.0
5410.0
5400.0
5390.0
5380.0
5370.0
0
50
100
150
200
Years
Full Amount, Layer 2
Full Amount, Layer 5
Low Amount, Layer 2
Low Amount, Layer 5


Stonehouse Spring
Groundwater Elevation (ft amsl)
6305
6300
6295
6290
6285
6280
6275
6270
6265
6260
0
2000
4000
6000
8000
10000
12000
Years
Full Amount, Layer 2
Full Amount, Layer 5
Low Amount, Layer 2
Low Amount, Layer 5


Stonehouse Spring
Groundwater Elevation (ft amsl)
6305
6300
6295
6290
6285
6280
6275
6270
6265
6260
0
50
100
150
200
Years
Full Amount, Layer 2
Full Amount, Layer 5
Low Amount, Layer 2
Low Amount, Layer 5