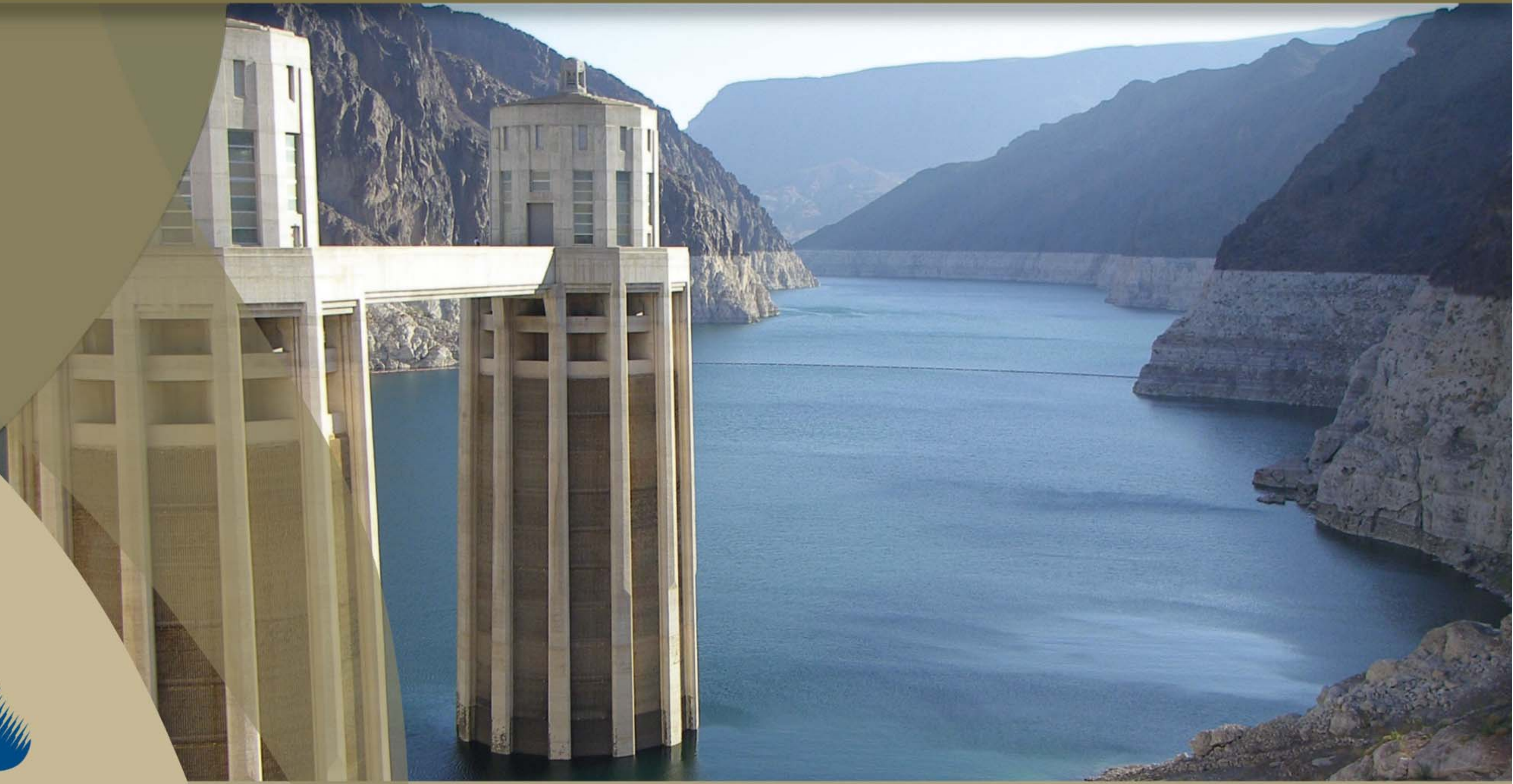
Spring, Cave, Dry Lake and Delamar Valleys



SOUTHERN NEVADA
WATER AUTHORITY

Presentation for
Myers Cross
Spring Valley Part 1

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Statement of Qualifications

Tom Myers is a researcher and consultant in hydrogeology and water resources. Tom specializes in groundwater modeling, hydrogeology, environmental forensics, regulatory compliance, water rights, NEPA analysis, and environmental and water policy. He focuses on mining and water resource development issues, coal-bed methane development and groundwater contamination.

With a Ph.D. and M.S. in hydrology/hydrogeology and more than 28 years experience as a consultant, government planner, academic researcher, teacher and advocate for environmental responsibility and good science, Tom brings a strong technical, regulatory, and public relations background to his work. His work includes major hydrology studies for federal government, hydrogeologic assessments for county governments, expert and evidence reports for use in litigation and administrative hearings, expert witnessing for private industry and nonprofit groups, and testimony to Congress and National Academy of Science. Tom has testified as an expert before the Nevada State Engineer and State Environmental Commission. He has provided evidentiary testimony before federal court in Billings MT.

Because of his experience as a watchdog of government agencies and different industries, Tom has a unique background from which he draws on as a consultant. For example, he has worked to locate the source of pollution from many mines or to determine the cause of drawdown at private wells. He combines a strong technical background with a working knowledge of state environmental and federal NEPA, BLM mining, water law and Clean Water Act regulations which enables him to work with attorneys and conservation groups.

Tom's experience and training uniquely qualifies him to provide diverse and affordable services to clients ranging from nonprofit conservation groups to law firms, industry and governments in many areas of hydrogeology and environmental and water policy. His client base includes nonprofit conservation groups, Native American tribes, the federal government and private industry.

Client List

NON-PROFIT ORGANIZATIONS	***GOVERNMENTAL ENTITIES***
Natural Resources Defense Council	Pima County, AZ
Great Basin Resource Watch	White Pine County, NV
Greater Yellowstone Coalition	Town of Indian Springs, NV
Great Basin Water Network	
Defenders of Wildlife	***PRIVATE INDUSTRY***
Center for Biological Diversity	Yonkee and Toner, LLC, Sheridan WY
McCloud Watershed Council	Public Resource Associates, Reno, NV
Catskill Mountain Keepers	Kuipers and Associates, Butte, MT

INTRODUCTION

The Southern Nevada Water Authority (SNWA) proposes to develop 91,200 af/y of groundwater in Spring Valley of eastern Nevada. This report was prepared on behalf of the Great Basin Water Network, the Confederated Tribes of the Goshute Reservation, and a coalition of protestants to those water right applications. This report assembles evidence supporting the conclusion that pumping the proposed amount of groundwater, or even a substantial portion of that amount, will cause substantial drawdown and detrimental effects to the groundwater levels, spring discharge, wetland evapotranspiration (ET), and water rights in Spring and adjoining valleys.

SNWA filed applications for 19 water rights within Spring Valley (basin 184) in 1989 along with other applications for water rights in many other eastern Nevada basins. SNWA also filed six water rights applications in Cave Valley, Dry Lake Valley, and Delamar Valley, to which GBWN and the same coalition also are protestants. I have prepared a separate evidence report concerning the effects of pumping in those valleys.

SNWA's Spring Valley applications number from 54003 to 54021. All are considered as "ready for action protested" (RFP).

Figure 1 shows the general layout of Spring, Snake, Tippett and surrounding valleys and SNWA's applications. Applications 54003 through 54018 are for 6 cfs and the remaining three applications are for 10 cfs, also referred to as "underground basin in Spring Valley" or "underground rock aquifer in Spring Valley", respectively. This report analyzes pumping the applications as proposed and at two lower pumping rates, 60,000 and 30,000 af/y to provide a range of impacts for evaluation.

This evidence report presents both overarching and hydrogeologically particularized conclusions about the likely effects of the proposed action. These conclusions are drawn from two sources – the conceptual model (Myers 2011a) and the numerical model of Spring Valley (Myers, 2011b). The first, overarching, conclusion is that the amount of water applied for exceeds the conceptual flow model of Spring Valley, meaning that the request exceeds the perennial yield based on the recharge and discharge within the valley. Pumping SNWA's applications will cause a continuing drawdown of the groundwater table and draw water from or prevent groundwater from reaching adjacent valleys.

The second set of conclusions is presented through the simulation of the impacts caused by actually pumping these applications in the scenarios described using the numerical groundwater model of Spring and Snake Valleys, and adjoining areas, developed over the past few years (Myers, 2011b). I based the numerical model on the conceptual model developed in Myers (2011a).

The remainder of this evidence report refers to Myers (2011a) and Myers (2011b) as Part A and Part B, respectively.

Figure 8, clipped from a USGS report (Eakin et al, 1976), shows the general types of flow system that occur in the Great Basin. The figures show the carbonate bedrock at depth underlying the basin fill in the valleys. Recharge enters the bedrock and basin fill. From right to left, the recharge either discharges to vegetation and to downstream, discharges mostly to downgradient basins, discharges only to in-basin vegetation and phreatophytes, or is isolated with no carbonate rock, no interbasin flow and only in-basin recharge discharging to in-basin playas and phreatophytes. All of the basins in this study are like the first one described (the rightmost basin in Figure 8), although Spring Valley had once been considered most like the undrained, closed basin of the far left only with some carbonate basin rock. Prior to the BARCASS study (Welch et al, 2008), Spring Valley had been considered to be almost totally without interbasin flow, excepting a small amount through the southeast portion to Hamlin or Snake Valley. Now, it is accepted, and utilized in this study, that interbasin flow leaves Steptoe Valley and enters Spring Valley either directly or by passing through Lake Valley (Welch et al, 2008).

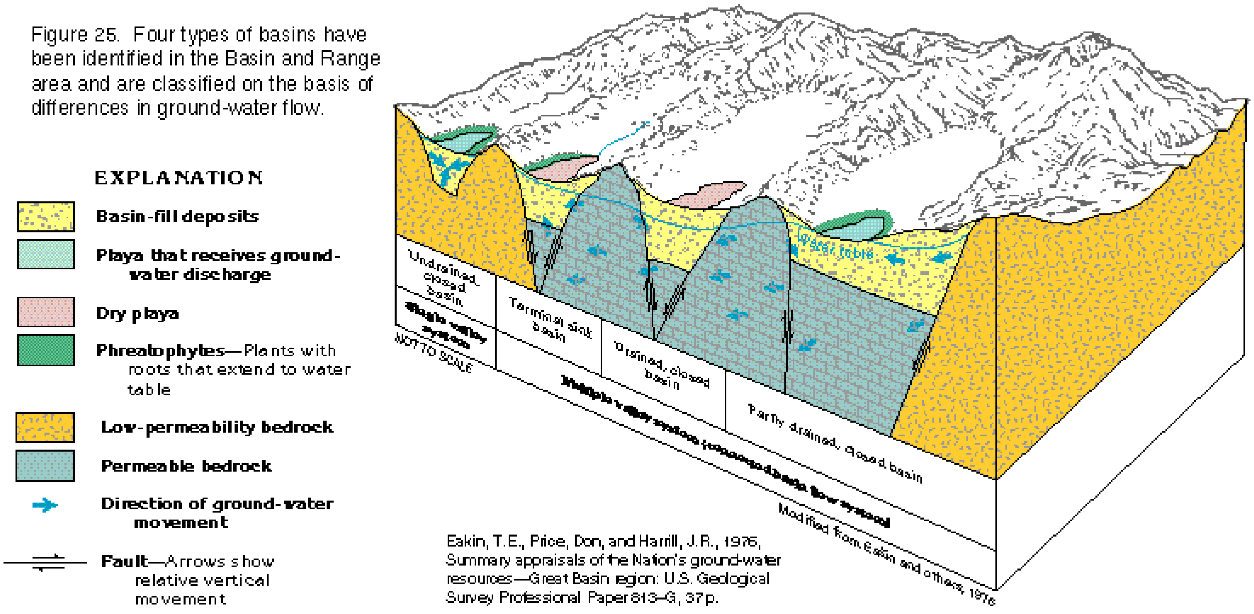


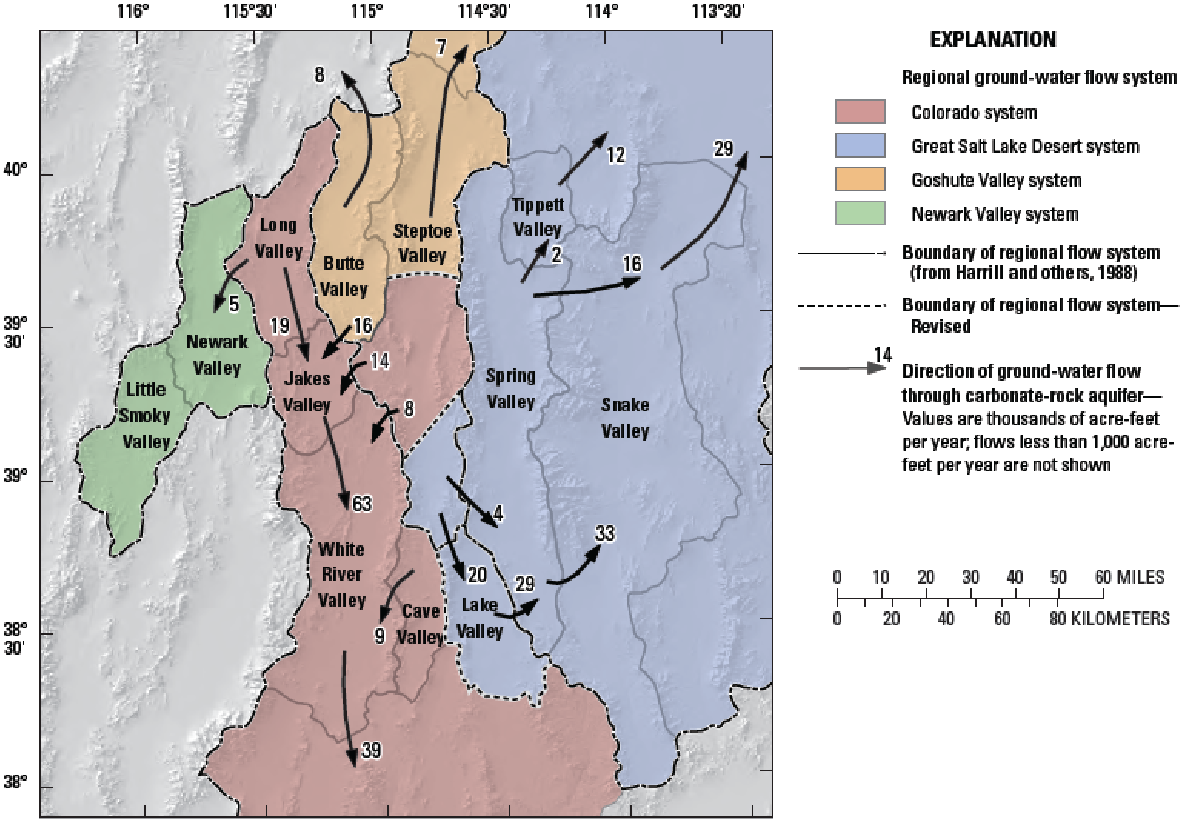
Figure 25. Four types of basins have been identified in the Basin and Range area and are classified on the basis of differences in ground-water flow.

Eakin, T.E., Price, Don, and Harrill, J.R., 1976, Summary appraisals of the Nation's ground-water resources—Great Basin region: U.S. Geological Survey Professional Paper 813–G, 37 p.

Figure 8: Generalized conceptual flow model from Eakin et al, 1976.

Hydrogeology

The Snake/Spring Valley study area includes several high elevation fault/block mountain ranges separated by deep basins filled with basin fill. Fractured carbonate rock and basin fill forms most of the aquifers in the area; locally, there are fractured volcanic rock aquifers. This study based the hydrogeology on classifications published in BARCAS (Welch et al, 2008, Sweetkind et al, 2008, Belcher et al, 2001) (Table 1 and Figure 9).



Shaded relief base from 1:250,000-scale National Elevation Data; sun illumination from northwest at 30 degrees above horizon.
1:1,000,000 scale watershed boundaries from USGS digital data.
Universal Transverse Mercator Projection, Zone 11, NAD83

Figure 2: Figure 41 from BARCAS (Welch et al, 2008) showing the calculated interbasin flow rates (kaf/y).

Chapter A: Introduction

By Victor M. Heilweil, Donald S. Sweetkind, and David D. Susong

This study assesses groundwater resources in the complex Great Basin carbonate and alluvial aquifer system (GBCAAS). Located within the Basin and Range Physiographic Province, the Great Basin carbonate and alluvial aquifer system covers an area of approximately 110,000 mi^2 (fig. A–1), predominantly in eastern Nevada and western Utah. The study area encompasses the Basin and Range carbonate-rock aquifers and Southern Nevada volcanic-rock aquifers and includes a large portion of the Basin and Range basin-fill aquifers (Reilly and others, 2008, fig. 2). The aquifer system generally comprises aquifers and confining units in unconsolidated basin fill and volcanic deposits in the basins, and carbonate and other bedrock in the mountain ranges separating the basins. These same bedrock units often underlie the basins. The aquifers are, in some areas, hydraulically connected between basins. Harrill and Prudic (1998) note that because of this connectivity, the aquifers of the eastern Great Basin "collectively constitute a significant regional ground-water resource." Some mountain ranges in the study area, however, consist of less permeable rock that may impede groundwater flow between basins.

The GBCAAS study area is experiencing rapid population growth and has some of the highest per capita water use in the Nation, resulting in increasing demand for groundwater. The U.S. Census Bureau (2005) found that Nevada and Utah were among the fastest growing states in the United States, with a projected increase in population of more than 50 percent between 2000 and 2030. Growing urban areas include Las Vegas in the southern part of the study area and the Wasatch Front (extending from Cache County to Iron County, Utah) along the eastern margin of the study area (fig. A–1). A 1990 comparison of water use by states found that Utah and Nevada had per capita water uses of 308 and 344 gallons per person per day, respectively (Bergquist, 1994). These rates are the highest in the United States and nearly twice the national average of 185 gallons per person per day. The alluvial aquifers of the GBCAAS are considered part of the Basin and Range basin-fill aquifer system—the fourth most heavily pumped regional aquifer in the United States (Reilly and others, 2008). The combination of rapid population growth, high water use, and arid climate has led to an increased dependence upon groundwater resources during the past 60 years (Gates, 2004) and predictions of future water shortages (U.S. Water News, June 2005). Severe groundwater depletion, along with declining groundwater levels and spring discharge, has occurred in several basins within the study area (Hurlow and Burke, 2008; L. Konikow, U.S. Geological Survey, written commun., 2009).

Because of its regional extent and large reliance upon groundwater resources as water supplies for urban populations, agriculture, and native habitats, the GBCAAS was selected for assessment by the U.S. Geological Survey National Water Census Initiative to evaluate the nation's groundwater availability. Groundwater availability includes an understanding of the groundwater-budget components, along with other considerations such as water quality, regulations, and socioeconomic factors that control its demand and use (Reilly and others, 2008, p. 3). Within the context of the national groundwater availability assessment, the goals of regional assessments (such as the GBCAAS) are the development of (1) water budgets for the aquifer system (recharge and discharge components); (2) current estimates and historic trends in groundwater use, storage, recharge, and discharge; (3) numerical modeling tools to provide a regional context for groundwater availability and for future projections of groundwater availability; (4) regional estimates of important hydrologic variables (e.g. aquifer properties); (5) evaluation of existing groundwater monitoring networks; and (6) new approaches for regional groundwater resources analysis (Reilly and others, 2008, p. 37).

Purpose and Scope

The purpose of this report is to present an updated conceptual model of the GBCAAS for evaluating regional groundwater availability. The report provides an update to the previous Regional Aquifer-System Analysis (RASA) conceptual model (Prudic and others, 1995), integrating newer findings from several recent basin-scale studies, the Death Valley Regional Flow System (DVRFS) study (Belcher, 2004), and the Basin and Range Carbonate Aquifer System (BARCAS) study (Welch and others, 2007). Specifically, this report addresses objectives 1, 2, and 4 of the national groundwater availability assessment described in the previous section. This conceptual model includes the delineation of hydrogeologic units on the basis of lithology and hydraulic properties, construction of a detailed three-dimensional hydrogeologic framework, development of a potentiometric-surface map of the aquifer system, an evaluation of interbasin

Table A7–1. Predevelopment and recent (2000) groundwater-budget estimates for each hydrographic area within the Great Basin carbonate and alluvial aquifer system study area.—Continued

[All values in acre-feet per year rounded to two significant figures. Estimated error in recharge values is ±50 percent. Estimated error in discharge values is ±30 percent. Values in blue are for predevelopment conditions. Values in red are for recent (2000) conditions. Decrease in natural discharge and/or storage: calculated as the difference of well withdrawals and recharge from unconsumed irrigation and public supply water from well withdrawals. Minimum decrease in groundwater storage: calculated as the difference of the decrease in natural discharge and/or change in storage and groundwater discharge under predevelopment conditions, if the difference is greater than zero. Abbreviations: HA, hydrographic area; #, number; —, no estimate]

HA #	HA name	Groundwater recharge for pre-development conditions	Recharge from unconsumed irrigation and public supply water from well withdrawals (2000)	Groundwater recharge for recent (2000) conditions	Groundwater discharge for pre-development conditions	Well withdrawals (2000)	Decrease in natural discharge and/or storage (net well withdrawals) (2000)	Minimum decrease in groundwater storage (2000)	Groundwater discharge for recent (2000) conditions
Flow System 34: Colorado System—Continued									
Virgin River Valley Subarea									
221	Tule Desert	4,200	6.0	4,200	0	20	14	—	6
222	Virgin River Valley	34,000	12,000	46,000	39,000	40,000	28,000	—	51,000
Flow System 35: Goshute Valley System									
178B	Butte Valley-Southern Part	21,000	810	22,000	12,000	2,700	1,900	—	13,000
179	Steptoe Valley	86,000	1,900	88,000	110,000	6,400	4,500	—	110,000
187	Goshute Valley	20,000	720	21,000	6,600	2,400	1,700	—	7,300
Flow System 36: Mesquite Valley									
163	Mesquite Valley	1,900	3,900	5,800	2,200	13,000	9,100	—	6,100
Flow System 37: Great Salt Lake Desert System									
184	Spring Valley	110,000	1,300	110,000	82,000	4,300	3,000	—	83,000
185	Tippett Valley	14,000	6.0	14,000	2,000	20	14	—	2,000
186A	Antelope Valley-Southern Part	3,300	11	3,300	210	38	27	—	220
186B	Antelope Valley-Northern Part	10,000	25	10,000	100	82	57	—	120
189A	Thousand Springs Valley-Herrell-Brush Creek	6,100	0	6,100	2,000	0	0	—	2,000
189B	Thousand Springs Valley-Toano-Rock Spring	14,000	0	14,000	1,600	0	0	—	1,600
189C	Thousand Springs Valley-Rocky Butte Area	9,000	0	9,000	1,200	0	0	—	1,200
189D	Thousand Springs Valley-Montello-Crittenden	18,000	1,200	19,000	15,000	4,100	2,900	—	16,000
191	Pilot Creek Valley	4,800	90	4,900	5,400	300	210	—	5,500
251	Grouse Creek Valley	13,000	1,200	14,000	13,000	4,100	2,900	—	14,000
252	Pilot Valley	1,600	0	1,600	7,400	0	0	—	7,400
253	Deep Creek Valley	17,000	180	17,000	18,000	600	420	—	18,000
254	Snake Valley	160,000	3,300	160,000	130,000	11,000	7,700	—	130,000
255	Pine Valley	27,000	0	27,000	0	0	0	—	0
256	Wah Wah Valley	6,000	0	6,000	1,500	0	0	—	1,500
257	Tule Valley	13,000	0	13,000	38,000	0	0	—	38,000
258	Fish Springs Flat	1,600	0	1,600	34,000	0	0	—	34,000
259	Dugway-Government Creek Valley	13,000	570	14,000	6,100	1,900	1,300	—	6,700
260A	Park Valley-West Park Valley	4,400	0	4,400	5,300	0	0	—	5,300
261A	Great Salt Lake Desert-West Part	29,000	0	29,000	74,000	0	0	—	74,000
Flow System 38: Great Salt Lake System									
260B	Park Valley-East Park Valley	3,800	780	4,600	12,000	2,600	1,800	—	13,000
261B	Great Salt Lake Desert-East Part	200	0	200	7,400	0	0	—	7,400

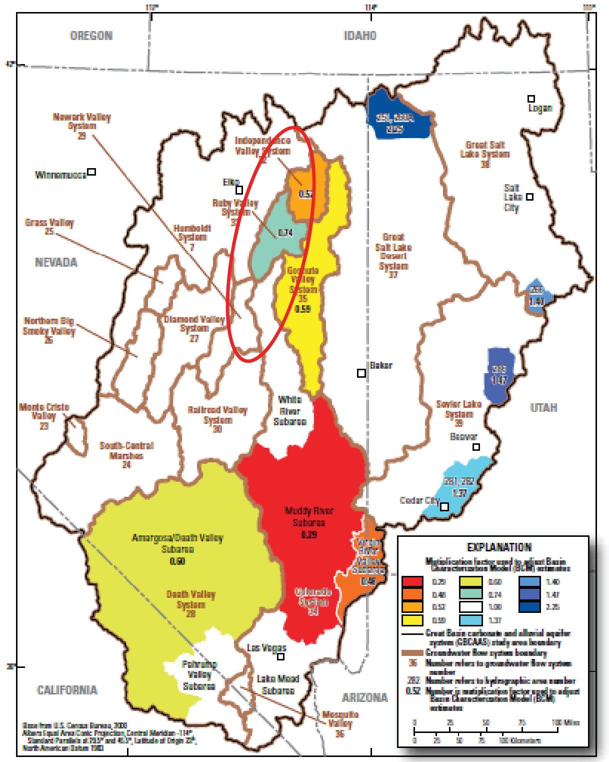
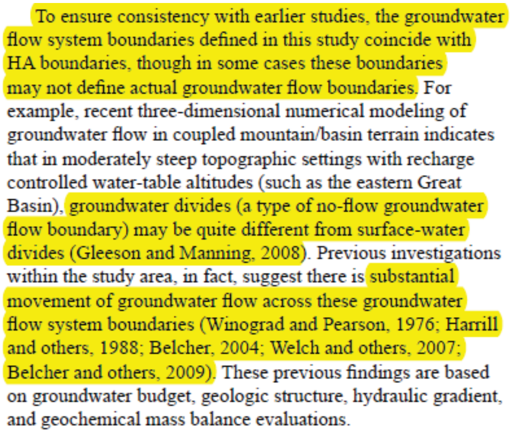
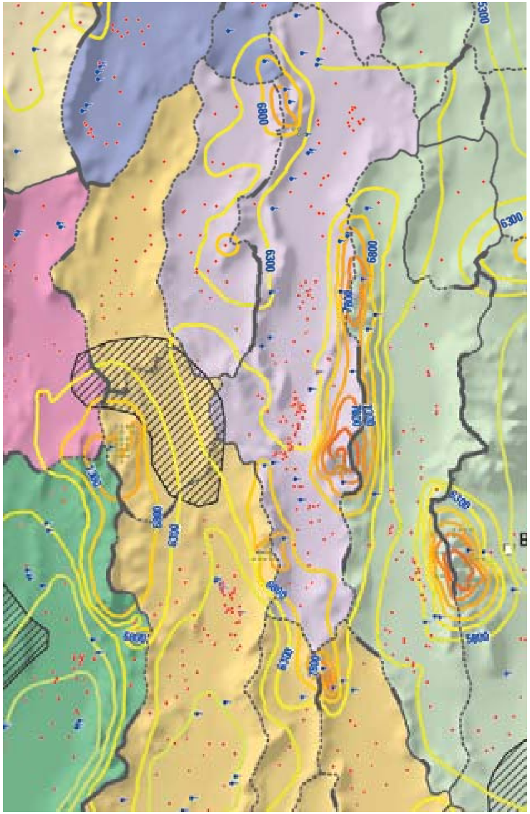


Figure D–8. Multiplication factors used for adjusting Basin Characterization Model (BCM) in-place recharge and runoff for the Great Basin carbonate and alluvial aquifer system study area.



To ensure consistency with earlier studies, the groundwater flow system boundaries defined in this study coincide with HA boundaries, though in some cases these boundaries may not define actual groundwater flow boundaries. For example, recent three-dimensional numerical modeling of groundwater flow in coupled mountain/basin terrain indicates that in moderately steep topographic settings with recharge controlled water-table altitudes (such as the eastern Great Basin), groundwater divides (a type of no-flow groundwater flow boundary) may be quite different from surface-water divides (Gleeson and Manning, 2008). Previous investigations within the study area, in fact, suggest there is substantial movement of groundwater flow across these groundwater flow system boundaries (Winograd and Pearson, 1976; Harrill and others, 1988; Belcher, 2004; Welch and others, 2007; Belcher and others, 2009). These previous findings are based on groundwater budget, geologic structure, hydraulic gradient, and geochemical mass balance evaluations.

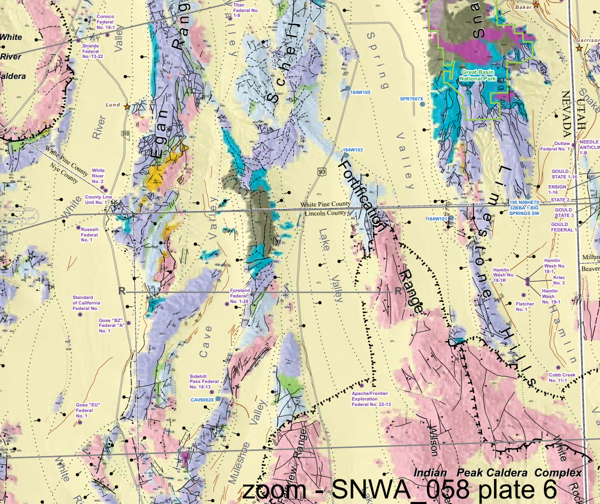
Mil Exh 40, p 54



Mil Exh 44, Plate 2

Some of these springs in the mountains may intercept a portion of the in-place recharge in the mountain block and prevent it from infiltrating to deeper layers and becoming part of a longer flow path discharging to the basin fill. On the basis of hydraulic gradients and the high likelihood of hydraulic connections across HA boundaries (pl. 2), it is possible that subsurface outflow from the Independence Valley (32), Ruby Valley (33), and Goshute Valley (35) groundwater flow systems occurs to the Great Salt Lake Desert groundwater flow system (37), along with lesser potential for flow to the Humboldt (7) and Colorado (34) groundwater flow systems. These possible subsurface outflows, however, are not quantified in the current study because of inherent water-budget uncertainties. The Basin and Range carbonate-rock aquifer system (BARCAS) study (Welch and others, 2007) required subsurface outflow from the Goshute Valley groundwater flow system (35) of 77,000 acre-ft/yr to the Ruby Valley (33), Colorado (34), and Great Salt Lake Desert (37) groundwater flow systems in order to balance the budget. The definition of the BARCAS study area was based, in part, on political boundaries rather than complete groundwater flow systems. The current study evaluated groundwater budgets for entire groundwater flow systems, and it was determined that the groundwater flow systems surrounding the Independence Valley (32), Ruby Valley (33), and Goshute Valley (35) groundwater flow systems do not require subsurface outflow to balance estimated predevelopment discharge. In order to balance the water budgets for these three groundwater flow systems in the current study, BCM in-place recharge and runoff were decreased using multiplication factors of 0.52, 0.74, and 0.59, for the Independence Valley (32), Ruby Valley (33), and Goshute Valley (35) groundwater flow systems, respectively (Auxiliary 3A and fig. D–8).

Mil Exh 41, p 91



zoom - SNWA_058 plate 6

to the north from Tippett or Deep Creek Valley to Antelope Valley or from Snake Valley to the Great Salt Lake Desert basin.

Geology controls flow across the boundaries of the study area. As outlined by Welch et al (2008, p 33), there is either continuous permeable rock, substantial impermeable rock blocking the flow, the system is uncertain, or both factors are present. Figure 15 in Welch et al (2008) provides a map describing the boundaries of the flow system considered in that report; the following paragraphs expand the description as pertains to the Spring/Snake Valley flow system.

The potential inflow to Spring Valley is interbasin flow from Steptoe Valley. Welch et al (2008) estimated that recharge substantially exceed GW discharge within Steptoe Valley, so they estimated interbasin flow from Steptoe Valley to many adjacent valleys to balance the flows. The estimate for flow to Spring Valley was 4000 af/y. Flow from Lake to Spring Valley was estimated at 29,000 af/y, but this mostly originated in Steptoe Valley. Steptoe Valley would therefore be the head of both the Great Salt Lake and White River Flow systems (Eakin, 1966).

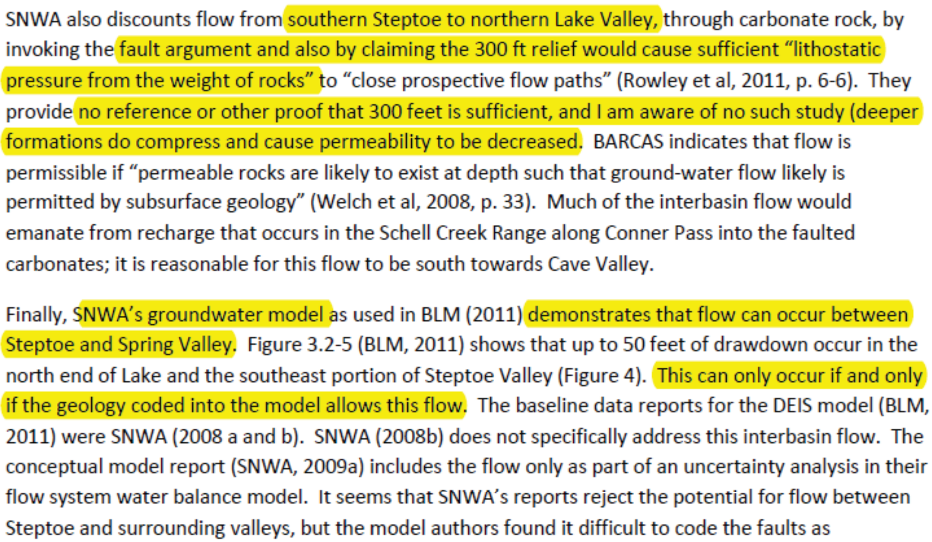
Sedimentary rock, primarily of carbonate composition, forms most of the mountain ranges along the east boundary of Snake Valley (Watt and Ponce, 2007). The Confusion Range, bounding the northeast portion of Snake Valley (Figure 1), consists of significant amounts of limestone (Figure 9) which permits interbasin flow from the Snake Range to the valleys to the east, including Fish Springs Flat (Welch et al, 2008; Kirby and Harlow, 2005).

Volcanic rock bounds the south end of Snake and Spring Valley; although not impermeable, groundwater flow would likely be limited to localized systems. This may impede interbasin flow between Snake and Wah-Wah Valley. The southernmost portion of Snake Valley may be a subbasin relatively isolated from the remainder of the valley due to volcanic rock (Welch et al, 2008, p. 36). Volcanic portions of the Fortification Range bound southwest Spring Valley and may impede flow between Spring and parts of Lake Valley. Northwest of the Fortification Range along Lake Valley summit, there is carbonate rock (UCU) through which the postulated interbasin flow would occur, but with a "thin Chainman shale" layer which may slow or prevent flow through that region (Welch et al, 2008).

About a third of the Schell Creek Range, from Hwy 50 to Lake Valley summit, consists of carbonate rock but with a detachment fault which may impede flow. As described in BARCASS:

> *Ground-water flow is possible, but uncertain, across HA boundaries identified as having permeable carbonate rocks (LCU or UCU) overlying a shallow detachment fault. All these segments are associated with detachment faults in the Cherry Creek, Egan, Grant, Snake, and* ***Schell Creek Ranges*** *where the lower plate beneath the detachment faults may not be exposed but whose presence in the shallow subsurface reasonably is inferred. In these areas, the upper plate consists of highly faulted carbonate rocks that may have enhanced permeability caused by the structural disruption*. (Flint et al, 2008, p. 36)

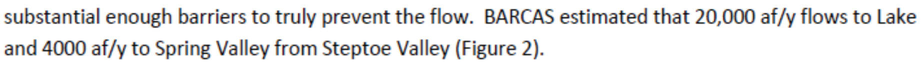
GBWN Exh
103, p 9



SNWA also discounts flow from southern Steptoe to northern Lake Valley, through carbonate rock, by invoking the fault argument and also by claiming the 300 ft relief would cause sufficient "lithostatic pressure from the weight of rocks" to "close prospective flow paths" (Rowley et al, 2011, p. 6-6). They provide no reference or other proof that 300 feet is sufficient, and I am aware of no such study (deeper formations do compress and cause permeability to be decreased. BARCAS indicates that flow is permissible if "permeable rocks are likely to exist at depth such that ground-water flow likely is permitted by subsurface geology" (Welch et al, 2008, p. 33). Much of the interbasin flow would emanate from recharge that occurs in the Schell Creek Range along Conner Pass into the faulted carbonates; it is reasonable for this flow to be south towards Cave Valley.

Finally, SNWA's groundwater model as used in BLM (2011) demonstrates that flow can occur between Steptoe and Spring Valley. Figure 3.2-5 (BLM, 2011) shows that up to 50 feet of drawdown occur in the north end of Lake and the southeast portion of Steptoe Valley (Figure 4). This can only occur if and only if the geology coded into the model allows this flow. The baseline data reports for the DEIS model (BLM, 2011) were SNWA (2008 a and b). SNWA (2008b) does not specifically address this interbasin flow. The conceptual model report (SNWA, 2009a) includes the flow only as part of an uncertainty analysis in their flow system water balance model. It seems that SNWA's reports reject the potential for flow between Steptoe and surrounding valleys, but the model authors found it difficult to code the faults as

GBWN Exh
103, p 10



substantial enough barriers to truly prevent the flow. BARCAS estimated that 20,000 af/y flows to Lake and 4000 af/y to Spring Valley from Steptoe Valley (Figure 2).

GBWN
Exh 103,
Figure 18,
p 34

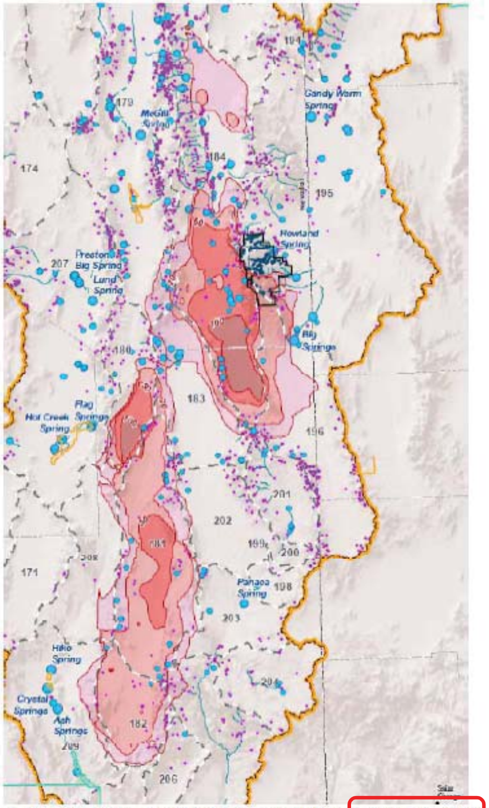
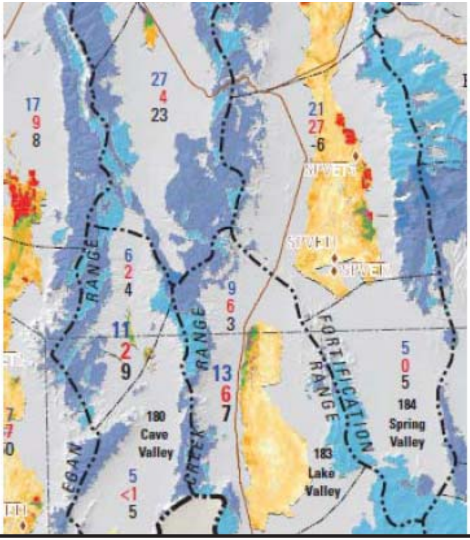


Figure 18: Snapshot from DEIS (BLM, 2011) Figure 3.3.2-29 showing drawdown for Alt E after 200 years.

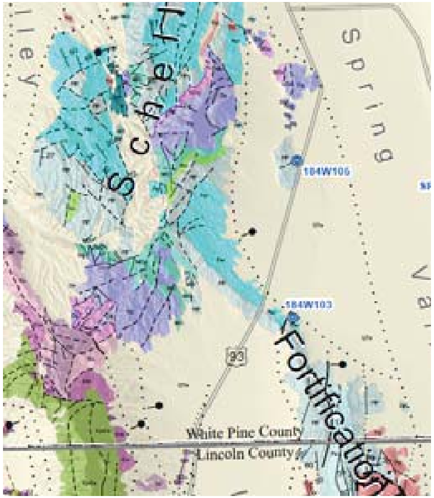
GBWN Exh 103, p 10

SNWA rejects flow into Spring Valley from Lake Valley by invoking the geology argument, even though the rock is mostly carbonate. With range front faults on both sides of the Schell Creek Range in this area, but no springs along the fault, it is necessary for the groundwater to flow into the adjoining valleys. The BARCAS estimate for flow from Lake into Spring Valleys is 29,000 af/y, which includes Steptoe Valley inflow and local Lake Valley recharge. A simple water balance argument indicates that flow must occur to the south and east from Steptoe Valley. There is little in-basin discharge (GWET) in southern Steptoe Valley, but significant recharge Figure 5). Although nothing may prevent northward flow from this area, most of the recharge is in the far south end, so the pathway for some of the recharge would be southward into Lake Valley. The argument for the flow going from Lake into Spring Valleys relies in part on the presence of discharge downgradient in Spring Valley (27,000 af/y in nearby Spring v 6000 af/y in Lake Valley). In the absence of any countervailing evidence, SNWA's rejection of any interbasin flow from Lake Valley to Spring Valley seems arbitrary and unsound.

GBWN Exh 103, Fig 5



SNWA Exh 58, Pl 1



GBWN
Exh 2

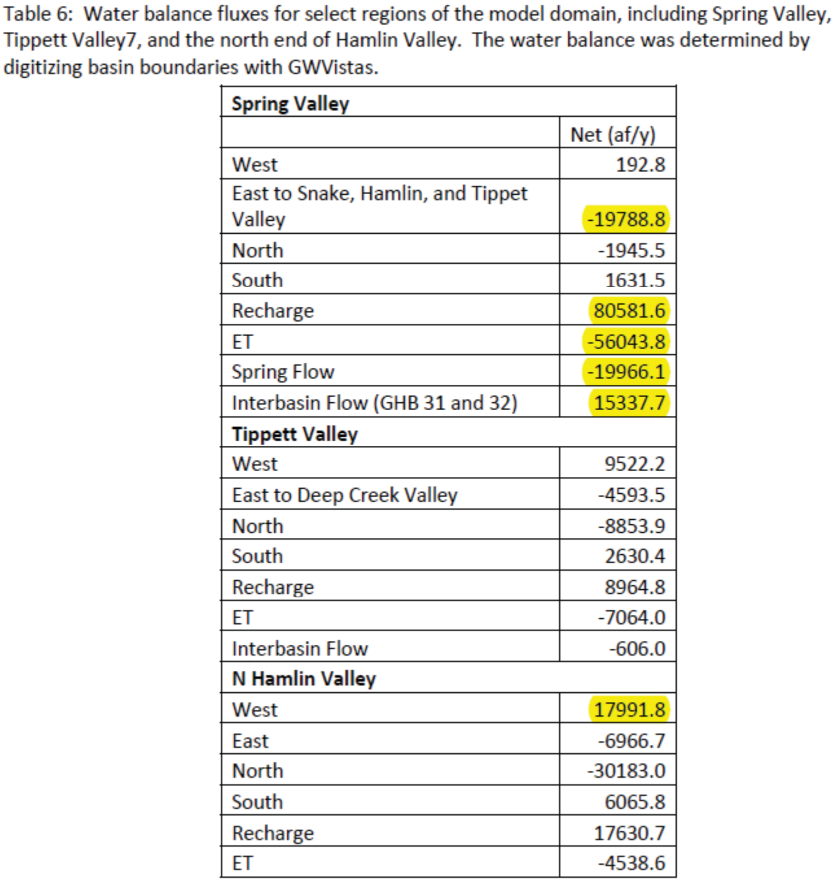


Table 6: Water balance fluxes for select regions of the model domain, including Spring Valley, Tippett Valley7, and the north end of Hamlin Valley. The water balance was determined by digitizing basin boundaries with GWVistas.

Spring Valley	
	Net (af/y)
West	192.8
East to Snake, Hamlin, and Tippet Valley	-19788.8
North	-1945.5
South	1631.5
Recharge	80581.6
ET	-56043.8
Spring Flow	-19966.1
Interbasin Flow (GHB 31 and 32)	15337.7
Tippett Valley	
West	9522.2
East to Deep Creek Valley	-4593.5
North	-8853.9
South	2630.4
Recharge	8964.8
ET	-7064.0
Interbasin Flow	-606.0
N Hamlin Valley	
West	17991.8
East	-6966.7
North	-30183.0
South	6065.8
Recharge	17630.7
ET	-4538.6

SNWA Exh 404

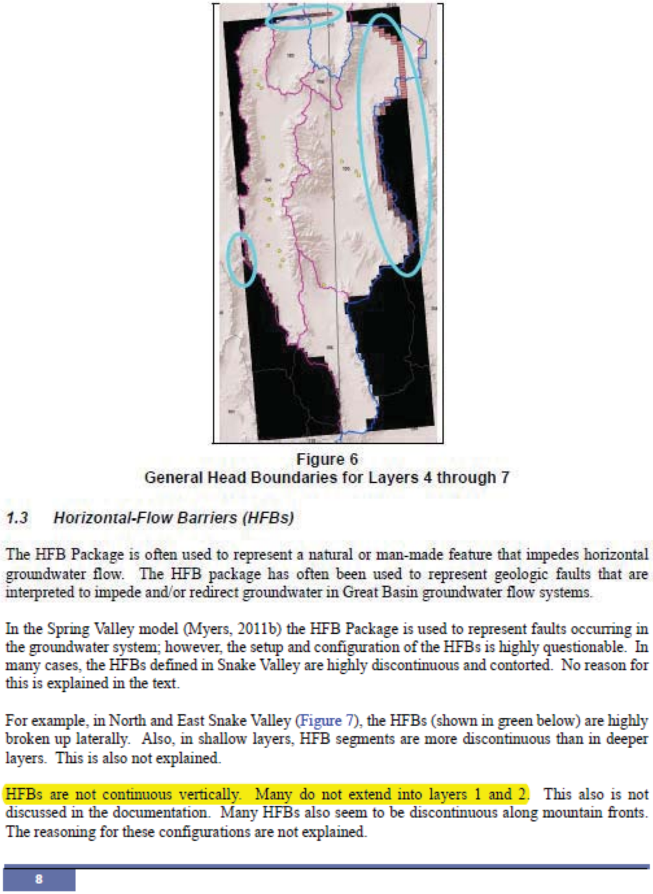


Figure 6
General Head Boundaries for Layers 4 through 7

1.3 Horizontal-Flow Barriers (HFBs)

The HFB Package is often used to represent a natural or man-made feature that impedes horizontal groundwater flow. The HFB package has often been used to represent geologic faults that are interpreted to impede and/or redirect groundwater in Great Basin groundwater flow systems.

In the Spring Valley model (Myers, 2011b) the HFB Package is used to represent faults occurring in the groundwater system; however, the setup and configuration of the HFBs is highly questionable. In many cases, the HFBs defined in Snake Valley are highly discontinuous and contorted. No reason for this is explained in the text.

For example, in North and East Snake Valley (Figure 7), the HFBs (shown in green below) are highly broken up laterally. Also, in shallow layers, HFB segments are more discontinuous than in deeper layers. This is also not explained.

HFBs are not continuous vertically. Many do not extend into layers 1 and 2. This also is not discussed in the documentation. Many HFBs also seem to be discontinuous along mountain fronts. The reasoning for these configurations are not explained.

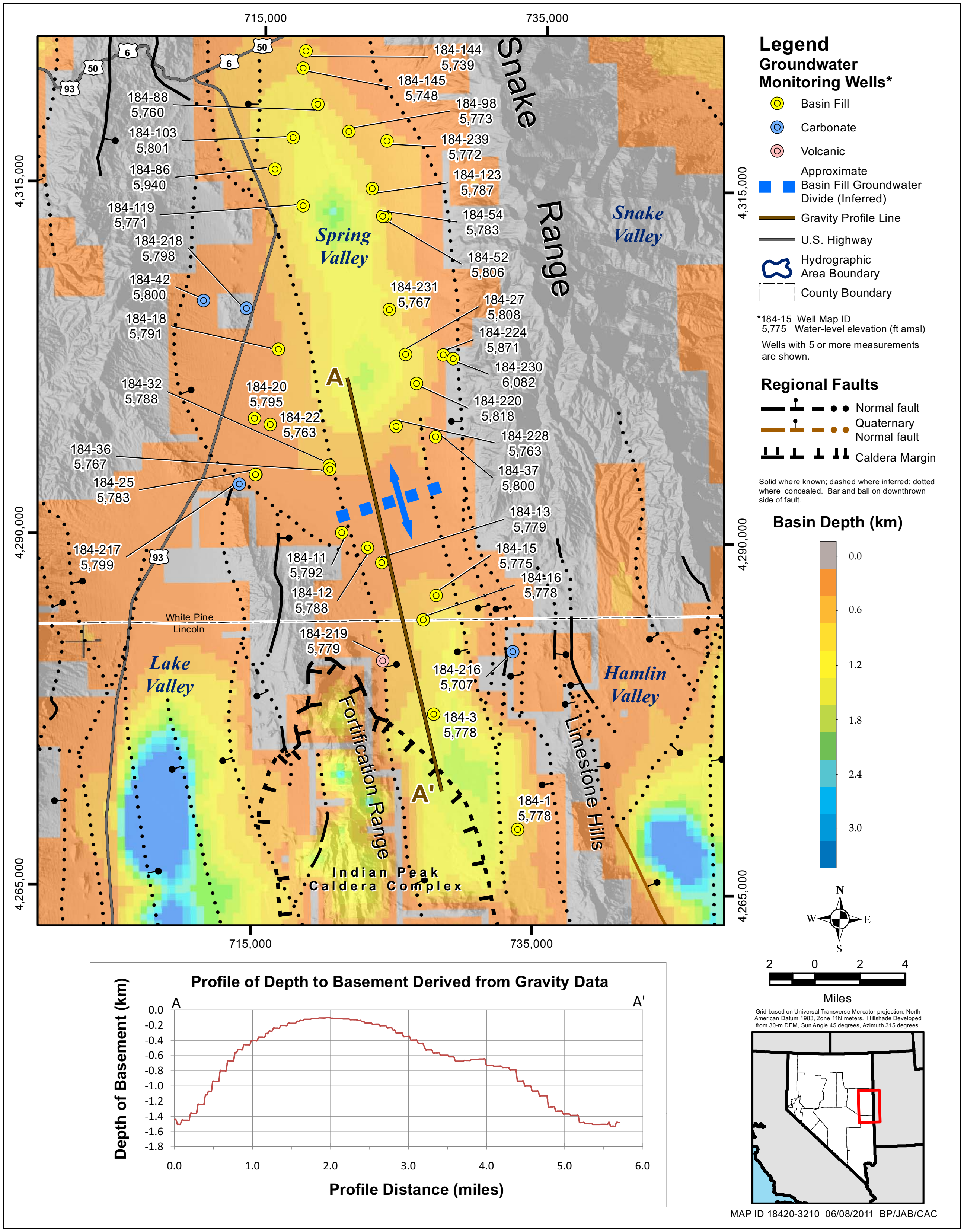
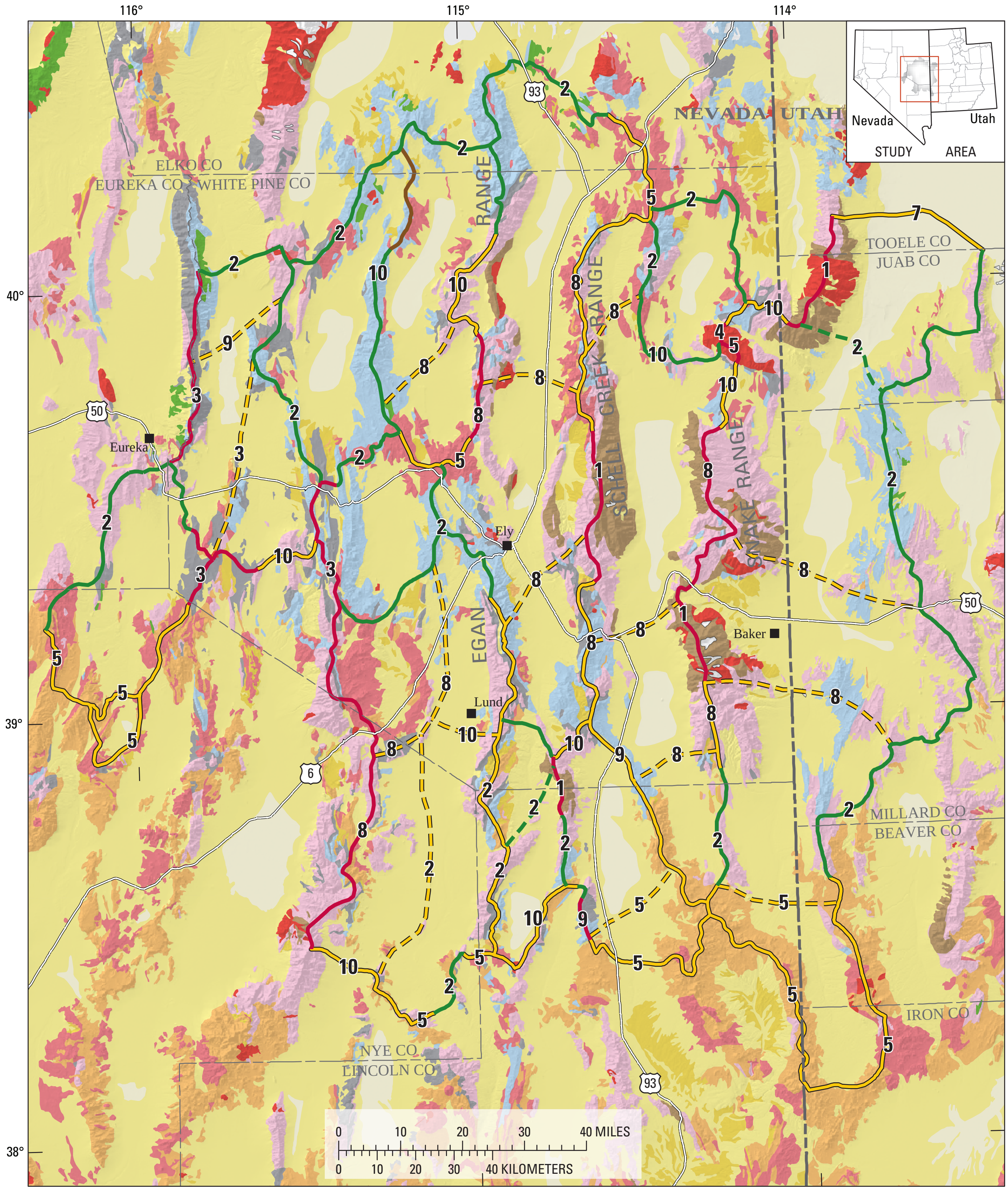


Figure 8-1
Depth to Pre-Cenozoic Basement in Southern Spring Valley and Vicinity



Base from U.S. Geological Survey 1:100,000-scale digital data, 1979–-84.
1:1,000,000 scale watershed boundaries from U.S. Geological Survey digital data.
Universal Transverse Mercator Projection, Zone 11, NAD83.

Figure 15. Characterized hydrographic area boundaries and surface geology, Basin and Range carbonate-rock aquifer system study area, Nevada and Utah.

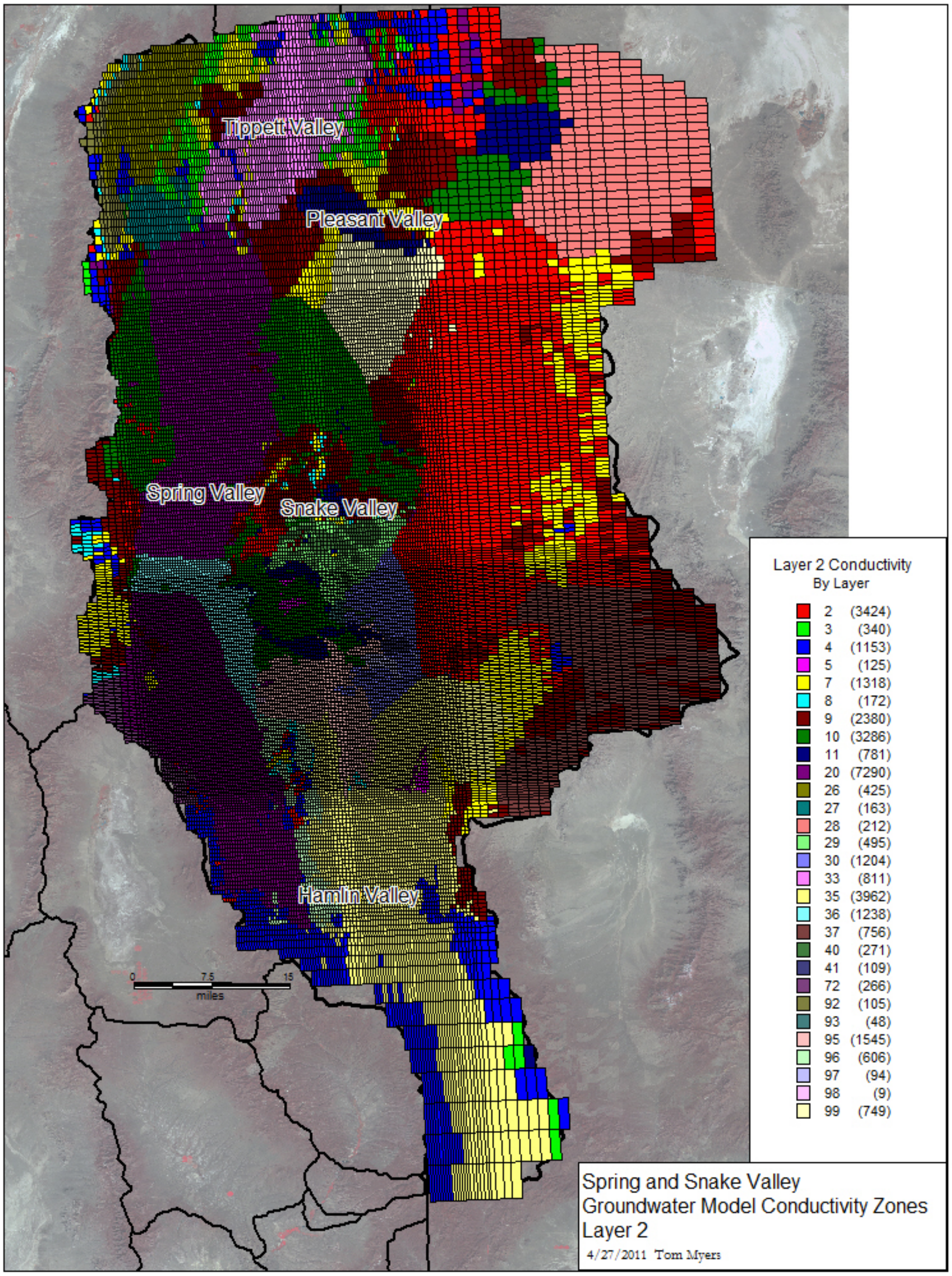
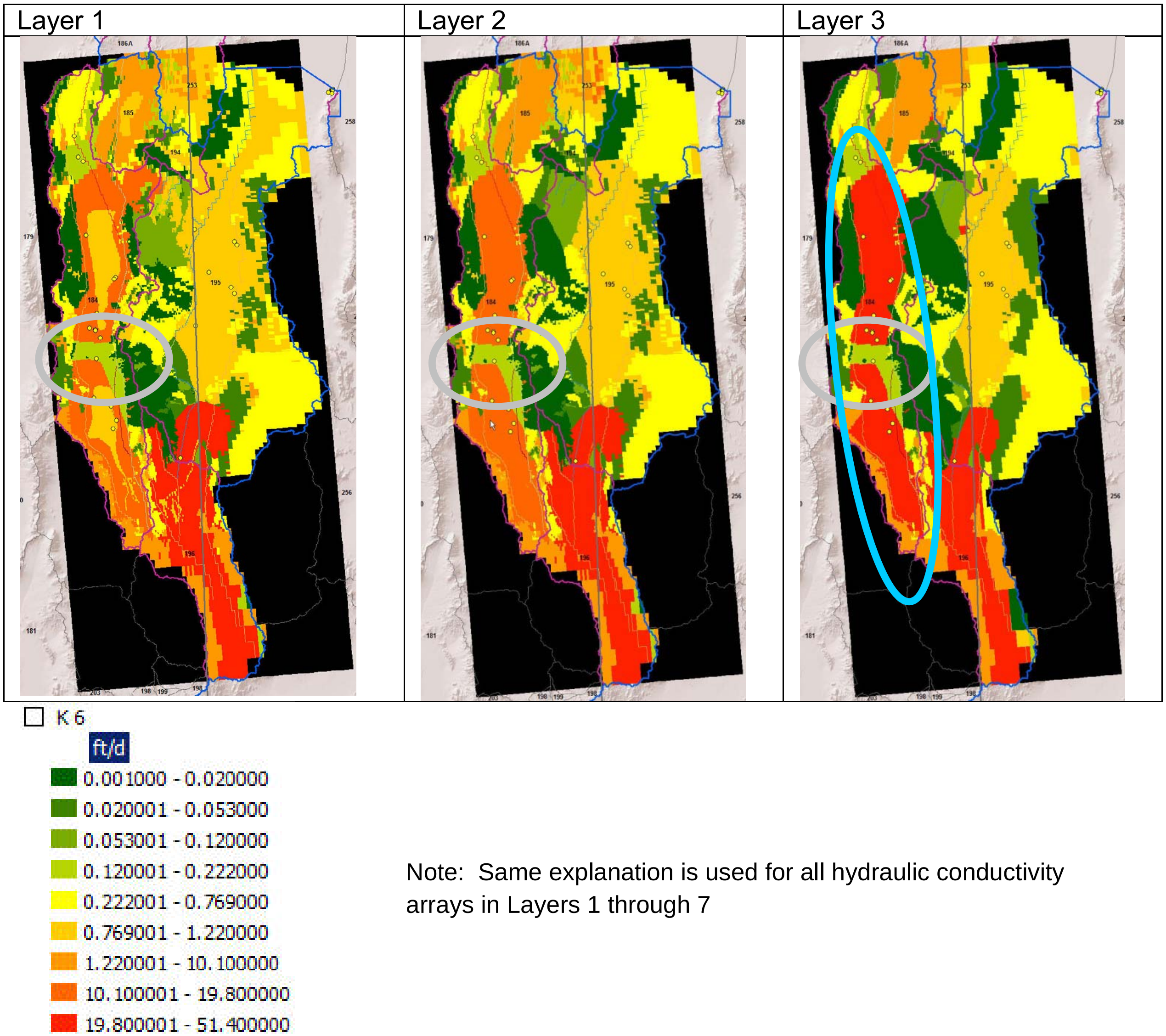


Figure 4: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 2.

1.1 Hydraulic Conductivity and Transmissivity Distributions

A series of highly interpretive hydrogeologic features are clearly present in the hydraulic conductivity and transmissivity distributions incorporated into the model. The justification for incorporating these features is rarely if ever provided in the Myers (2011b) report. These features are not adequately associated with known hydrogeologic units or structures.



Note: Same explanation is used for all hydraulic conductivity arrays in Layers 1 through 7

Figure 1
Hydraulic Conductivity Distribution in Layers 1, 2, and 3

In Figure 1 (above), various unusual hydrogeologic features are apparent, including:

1. A small-K (hydraulic conductivity) unit separating north and south Spring Valley (circled in Gray) has been placed into the Myers model in Layers 1, 2, and 3. This east-west trending unit forces the model to simulate a groundwater divide between north and south Spring Valley

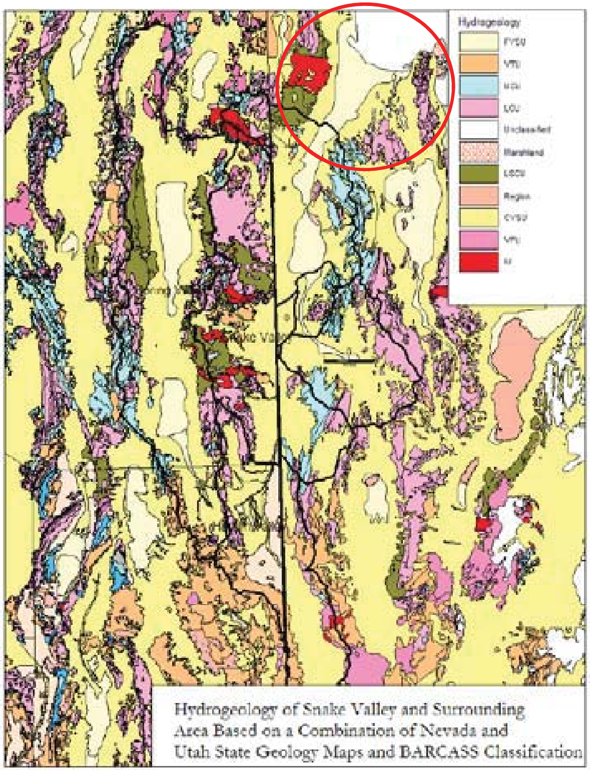
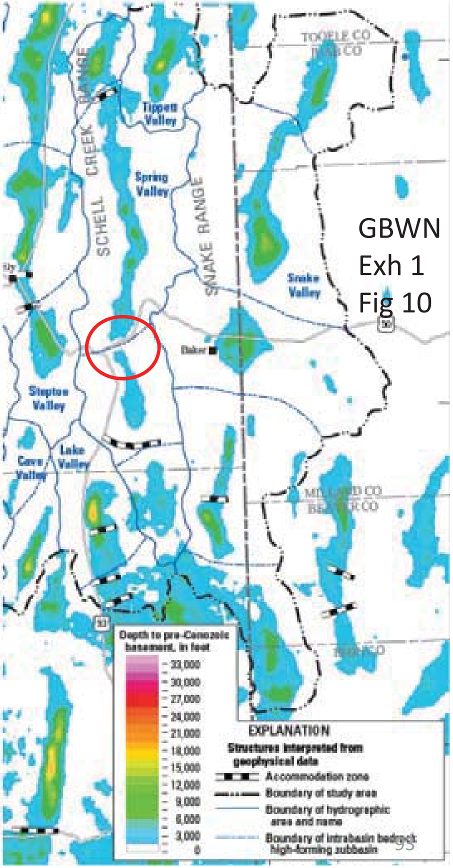


Figure 9: Hydrogeology of Spring and Snake Valley study area. See Table 1 for a description of the hydrogeology. Geology base prepared from Crafford (2007) and Hintze et al (2000).



GBWN
Exh 1
Fig 10

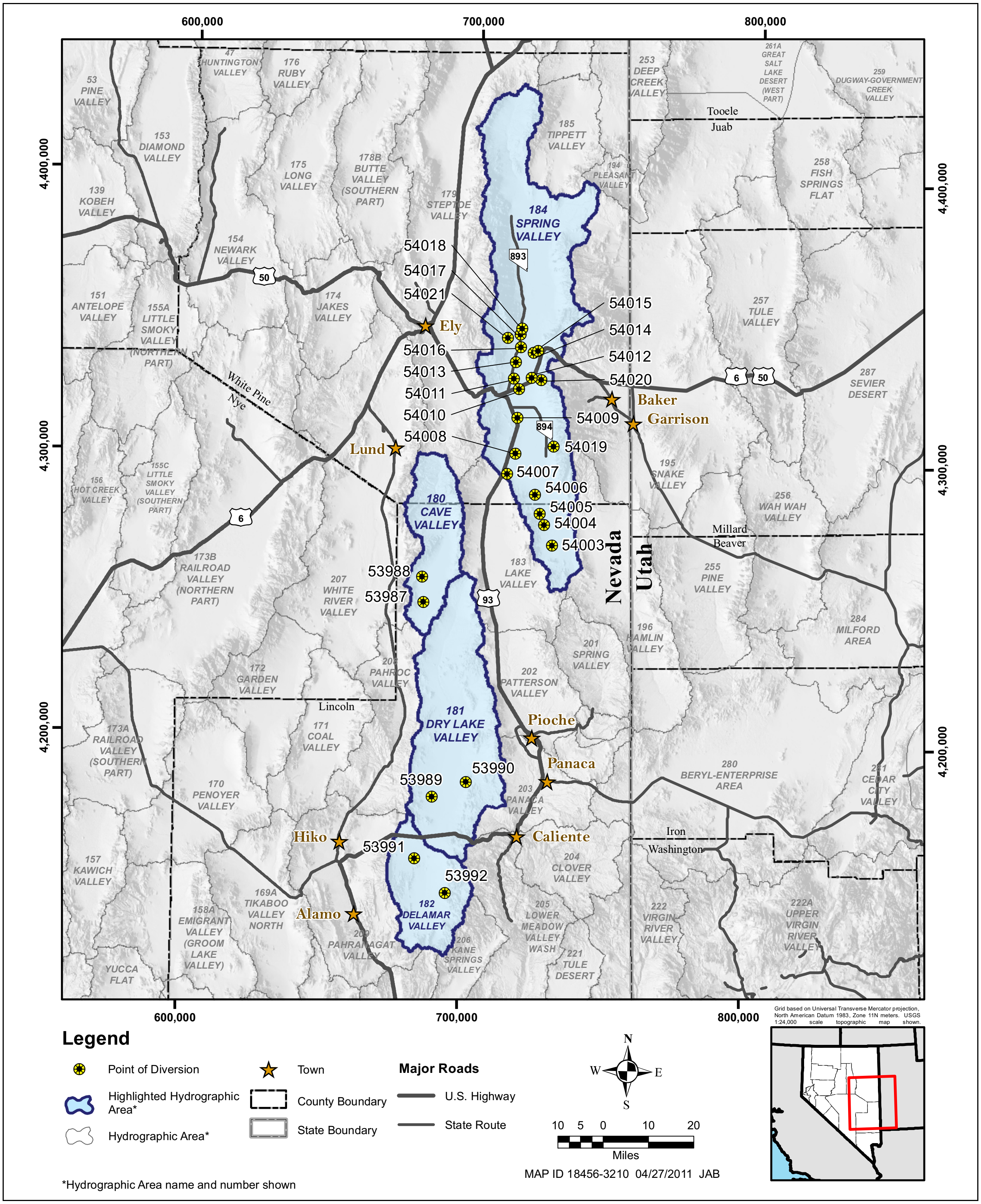
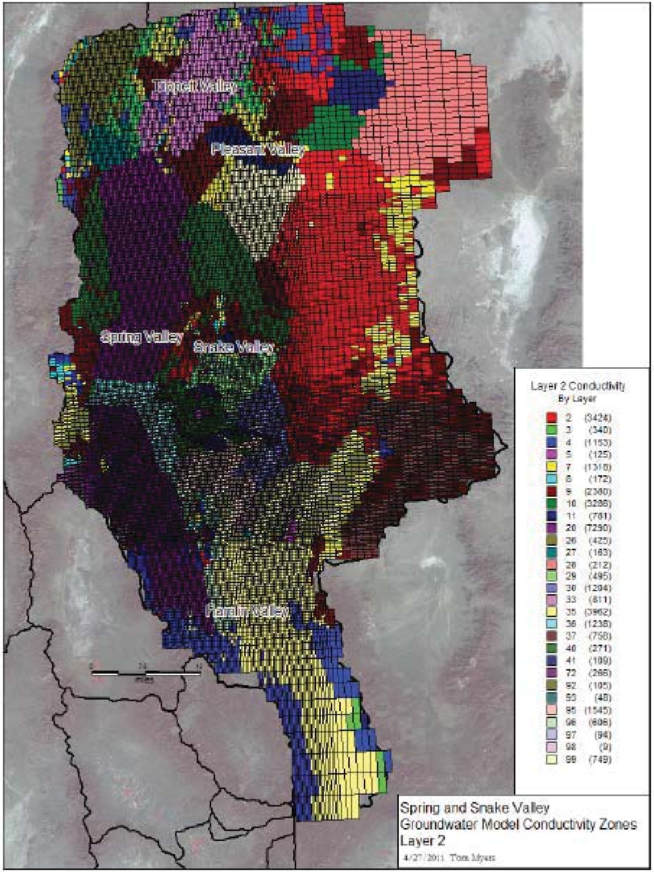


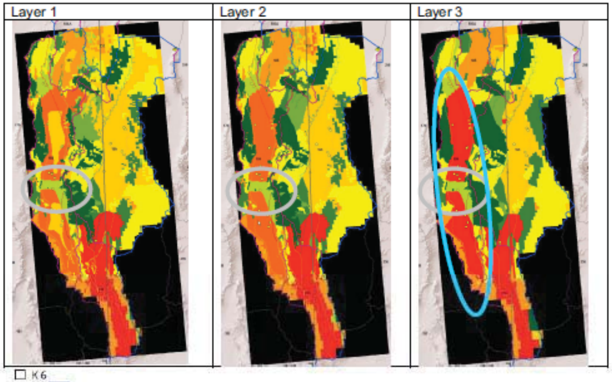
Figure 1-1
Location of Application Points of Diversion in Spring, Cave, Dry Lake, and Delamar Valleys

GBWN Exh
2, Fig 4



Spring and Snake Valley
Groundwater Model Conductivity Zones
Layer 2

4/27/2011 Tom Myers



Note: Same explanation is used for all hydr
arrays in Layers 1 through 7

Figure 1
Hydraulic Conductivity Distribution in Layers 1, 2,

SNWA Exh 404

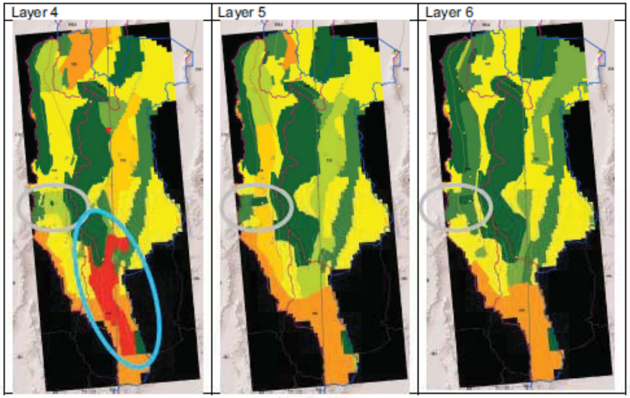


Figure 2
Hydraulic Conductivity Distribution in Layers 4, 5, and 6

This boundary is highly important to this flow system because of the potential for inflow from Steptoe Valley.

Impermeable bedrock forms the core and prevents interbasin flow between Steptoe and Spring Valleys through the central third of the Schell Creek Range. The north end of the Schell Creek Range has carbonate rock but also substantial faulting. There is a gradient of about 200 feet in 15 miles (0.0025) through carbonate rock between Steptoe and northern Spring Valley (Welch et al, 2008, Plate 3). A recharge-induced divide in the northern Schell Creek range would prevent flow between the valleys. Interbasin flow in this area is uncertain.

Volcanic flow dominates the outcrops in the north end of Tippetts and Spring Valley, although there is basin fill on the northwest boundary of Tippetts Valley. The project boundary at the north end of Deep Creek Valley is alluvium underlain by volcanic or siliceous rock, which suggests that interbasin flow would occur through upper layers but not at depth.

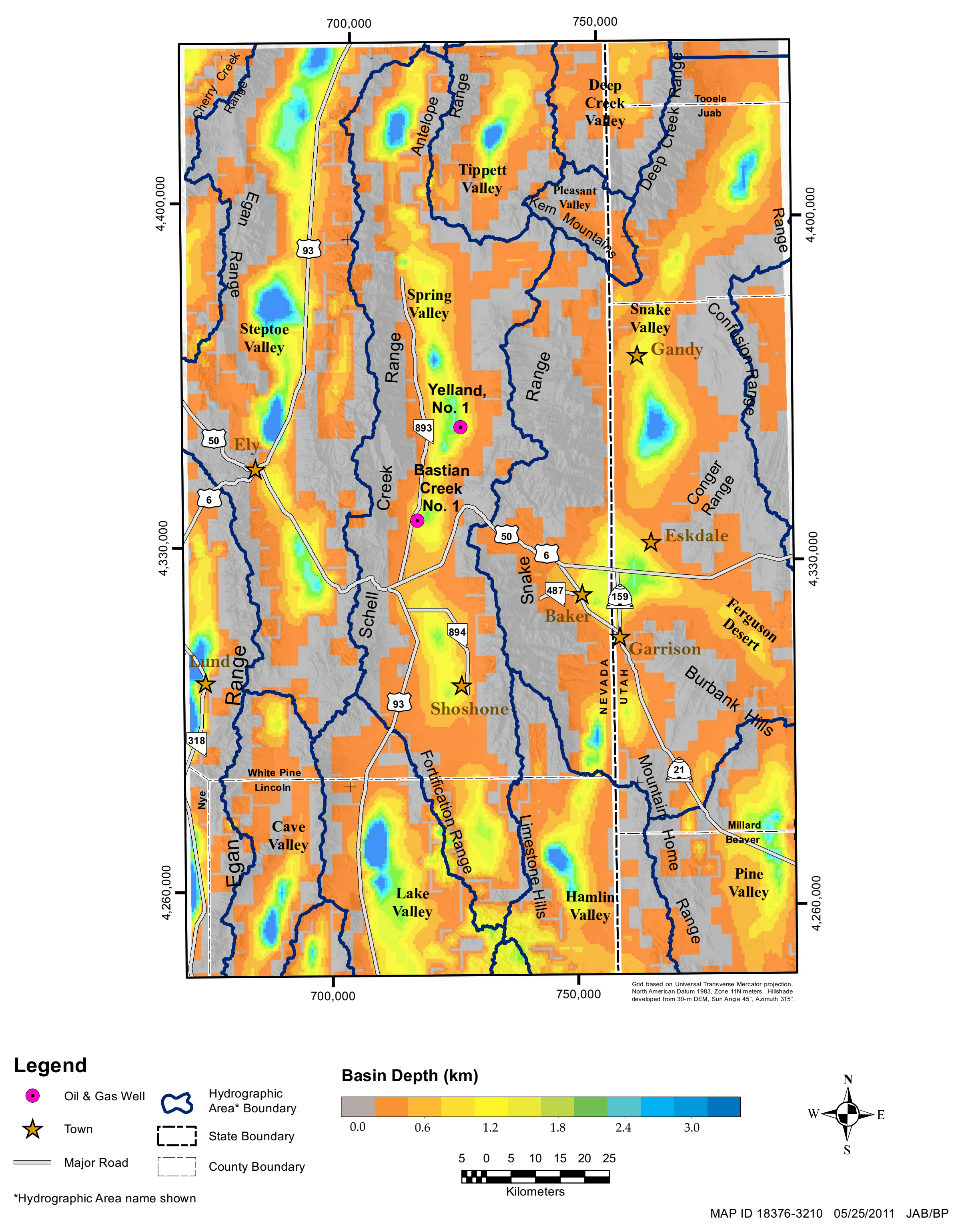
The north end of Snake Valley opens to the broad open basin and playa of the Great Salt Lake. Carbonate rock bounds the east side of Snake Valley, and the gradient indicates that flow occurs in that direction and contribute to discharge from Fish Springs. The BARCAS estimate for flow from Snake Valley to these two areas is 29,000 af/y.

Interbasin Flow between Project Subbasins

The north end of the study area contains both the highest and lowest elevation basin areas. The north end of Spring Valley is as high as 6500 feet; east of that is Tippett Valley at about 5500 ft amsl, Deep Creek Valley at 5000 ft amsl, and northern Snake Valley as low as 4200 ft amsl. Groundwater does not flow directly along that profile, however, due to geology. Interbasin flow is primarily from Spring Valley to Tippett and Snake Valley, with flow from Tippett to Deep Creek and possible further east to Snake Valley.

The ridge between the north end of Spring Valley and Tippets Valley is primarily carbonate rock, which would allow flow between the basins; the degree and role of fracturing or impeding faults is uncertain; there are also zones with volcanic flow units. Interbasin flow between Tippett and Deep Creek Valley is complicated by mixtures of carbonate and volcanic rock. North of the Kern Mountains, the boundary between Tippett and Deep Creek Valley is carbonate, but further north it is volcanic and siliceous.

Potential flow between Spring and Snake Valleys is an important factor because development in one basin could affect resources in the adjoining basin, but geology makes estimating the impacts complicated. Prior to BARCAS, most studies had identified only small amounts of interbasin flow between these valleys; one estimate was 4000 af/y through the Limestone Hills region (Hood and Rush, 1965). Groundwater gradients show a general trend for flow from Spring to Snake Valley.



Grid based on Universal Transverse Mercator projection, North American Datum 1983, Zone 11N meters. Hillshade developed from 30-m DEM, Sun Angle 45°, Azimuth 315°.

MAP ID 18376-3210 05/25/2011 JAB/BP

Figure 5-5
Depth to Pre-Cenozoic Basement in Spring and Snake Valleys and Vicinity, Nevada and Utah

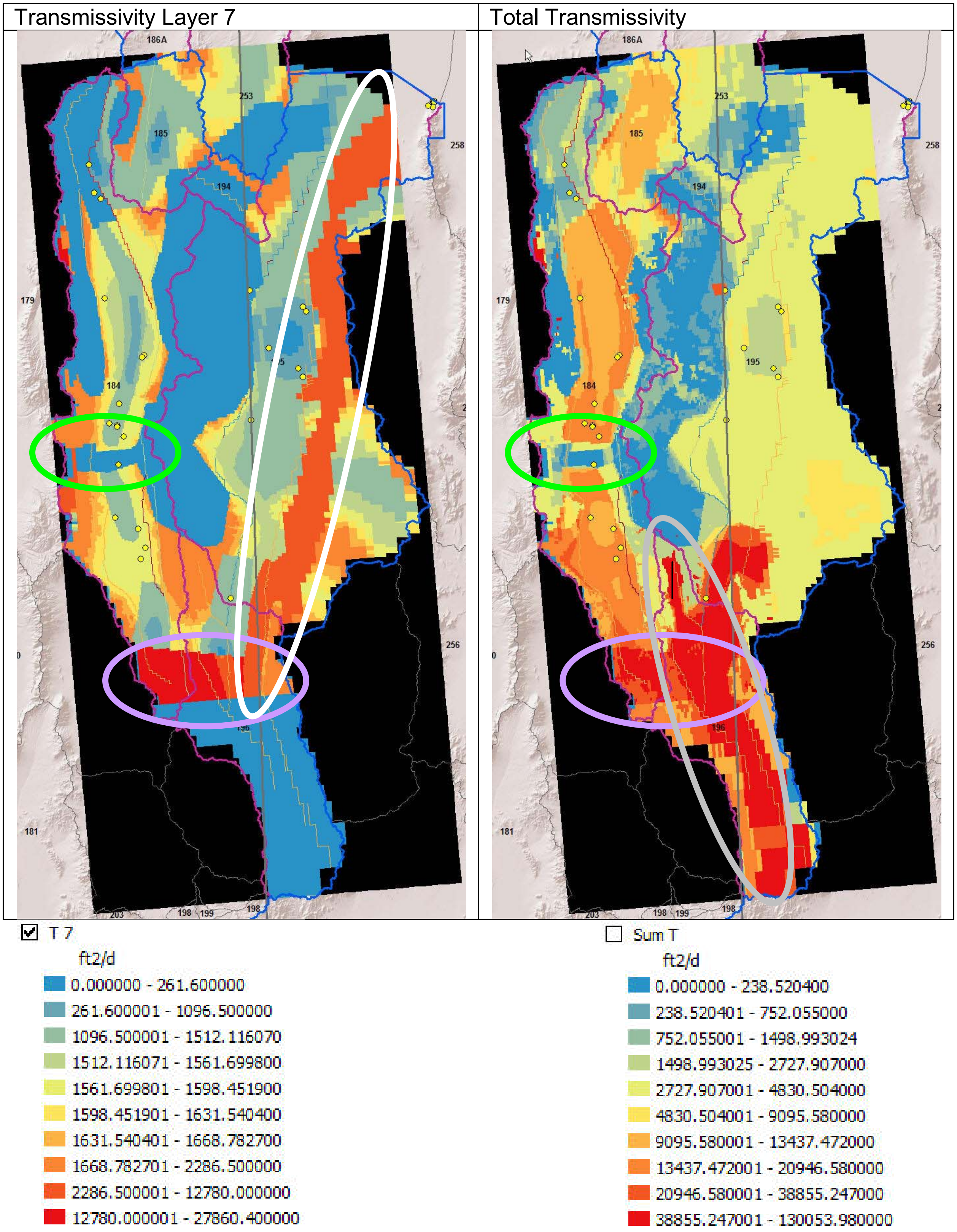


Figure 4
Transmissivity Distribution for Layer 7 and for the Total Model Thickness

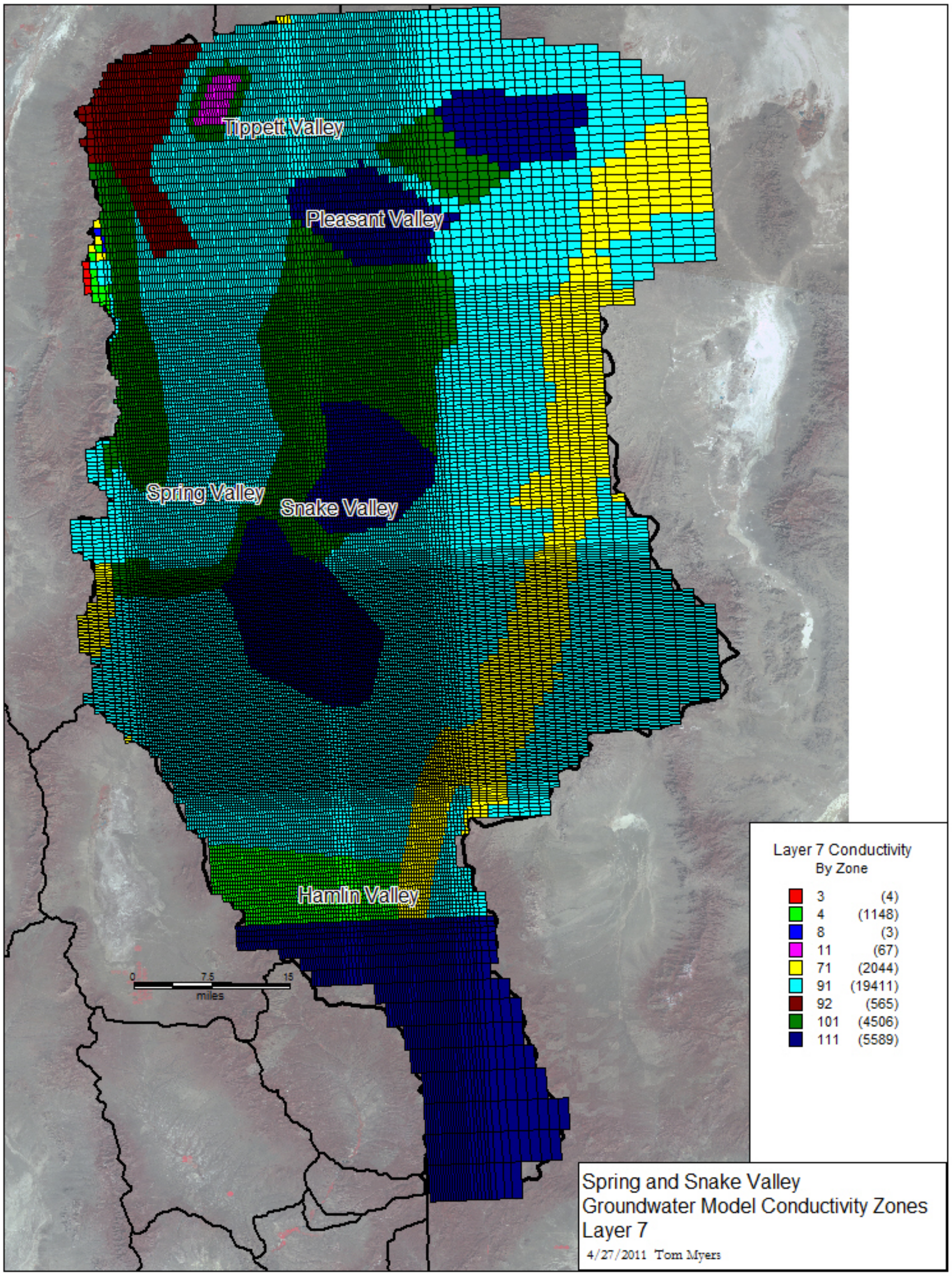


Figure 9: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 7.

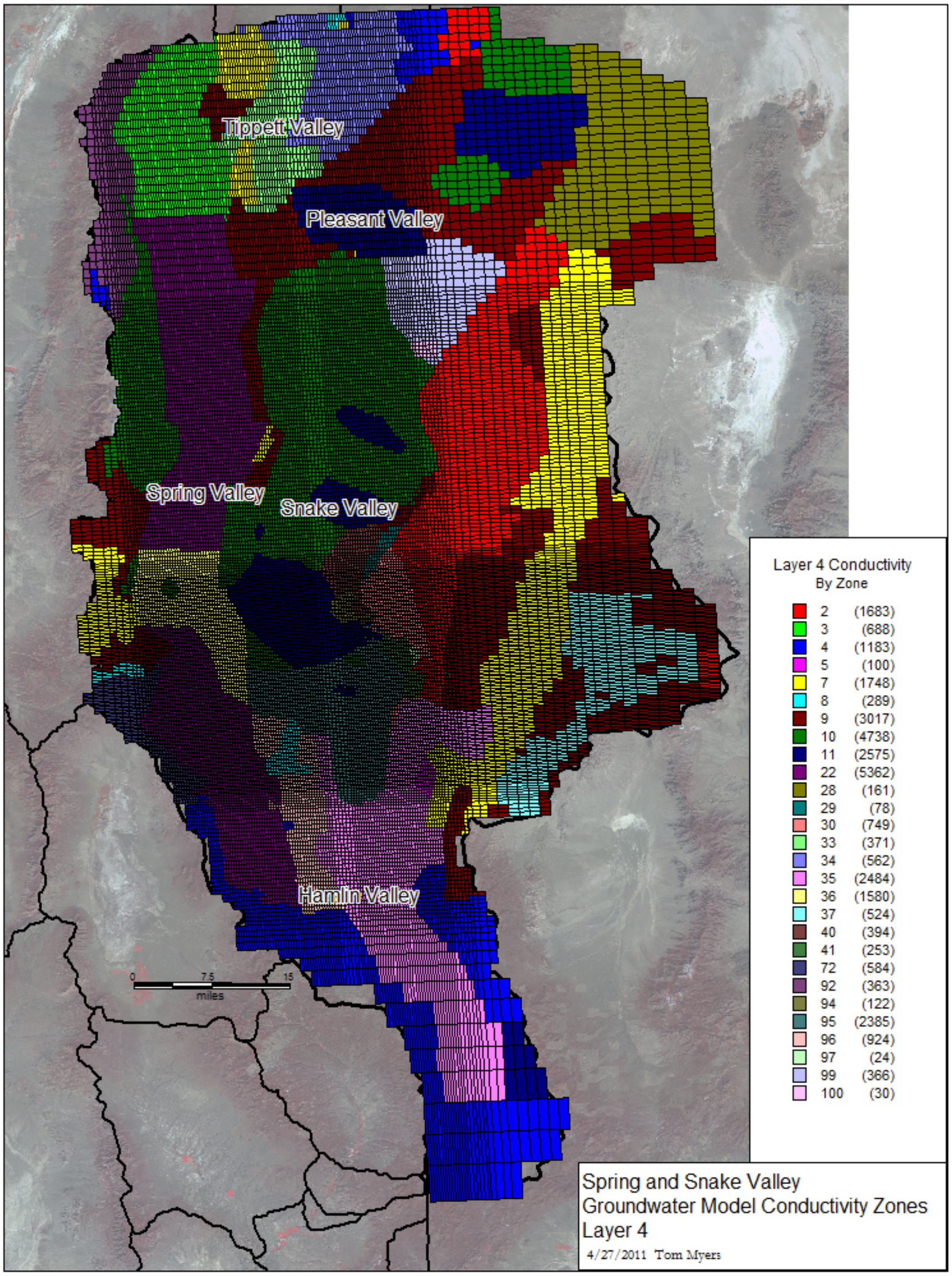


Figure 6: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 4.

Table 2: Calibrated conductivity (ft/d) by parameter zone.

		Initial Conductivity (ft/d)		Calibrated Conductivity (ft/d)		
Parameter Zone	General Hydrogeologic Zone	Kh	Kv	Kx	Ky	Kz
1	FYSU	19		1.22	1.22	0.1
2	CYSU	10		1.16	1.16	0.02
20	CYSU			19.8	19.8	2
21	CYSU			34.7	34.7	1
22	CYSU			0.501	0.501	0.25
23	CYSU			1.2	1.2	0.01
24	CYSU			0.5	0.5	0.15
25	CYSU			0.03	0.03	0.003
26	CYSU			0.745	0.48	0.004
27	CYSU			0.2	0.2	0.02
28	CYSU			0.767	0.767	0.4
29	CYSU			0.492	0.492	0.002
30	CYSU			0.053	0.053	0.02
31	CYSU			0.173	0.173	0.02
32	CYSU			20	20	1
33	CYSU			10.1	10.1	1
34	CYSU			2.65	2.65	0.2
35	CYSU			51.4	51.4	3
36	CYSU			0.222	0.222	0.02
37	CYSU			0.769	0.769	0.2
3	OSU	.4	.04	0.183	0.183	0.01
4	VFU	2.0	.2	2.13	2.13	1.5
40	VFU			0.457	0.457	1
41	VFU			0.108	0.108	0.004
5	VTU	37	3.7	0.08	0.08	0.008
6	MSU	.004	.0004	0.004	0.004	0.0004
7	UCU	3	.3	0.0301	0.0301	0.3
71	UCU			0.269	0.269	0.02
72	UCU			4.89	4.89	0.02
8	USCU	.1	.01	0.1	0.1	0.01
9	LCU	4	.4	0.397	0.397	0.05

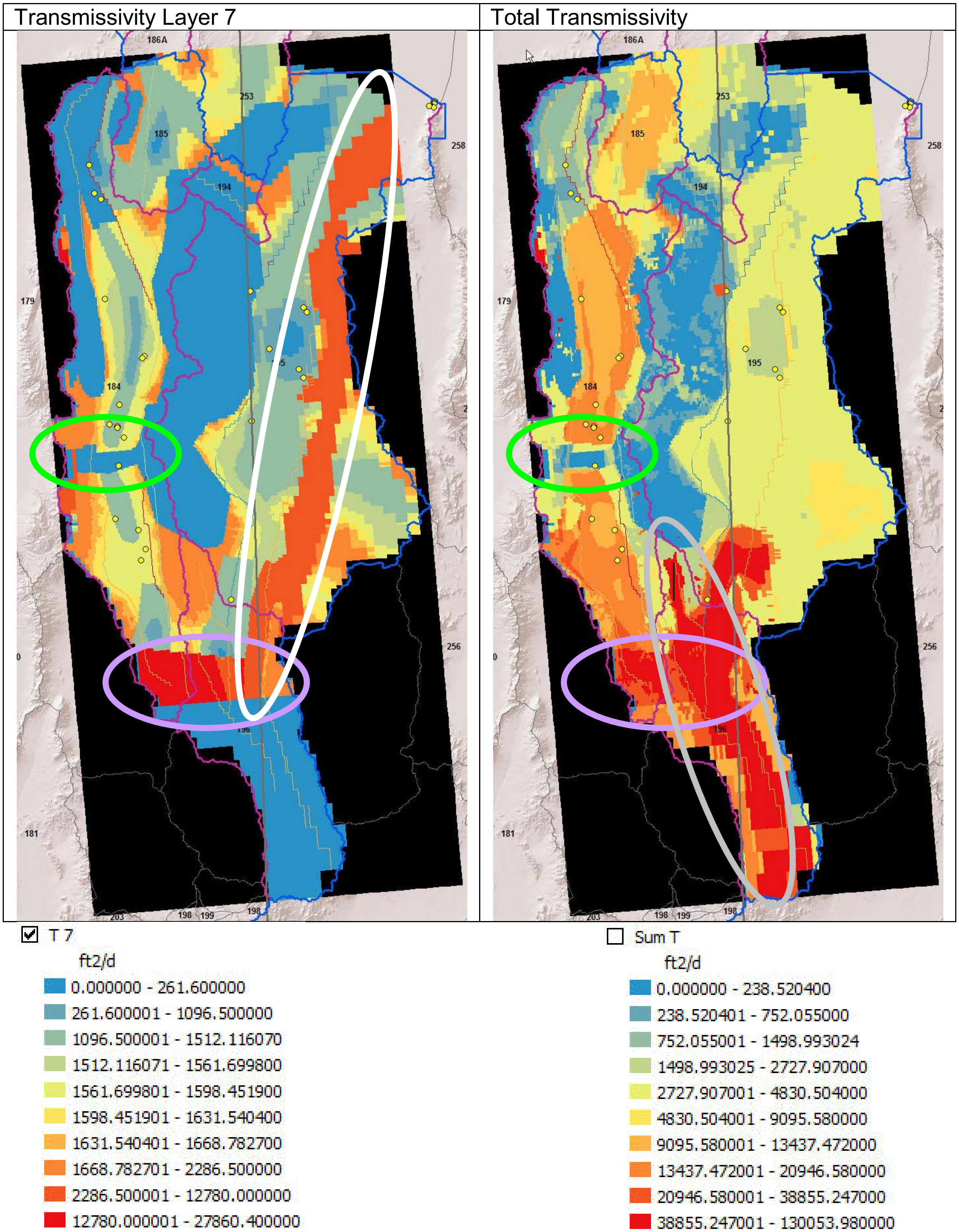


Figure 4
Transmissivity Distribution for Layer 7 and for the Total Model Thickness

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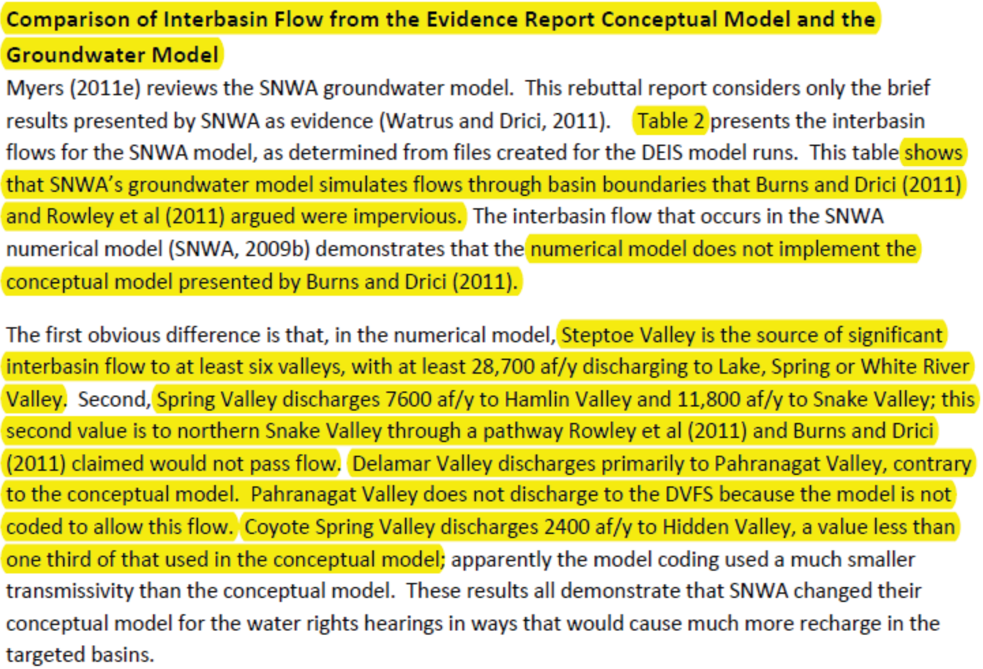
103, p 27



Comparison of Interbasin Flow from the Evidence Report Conceptual Model and the Groundwater Model

Myers (2011e) reviews the SNWA groundwater model. This rebuttal report considers only the brief results presented by SNWA as evidence (Watrus and Drici, 2011). Table 2 presents the interbasin flows for the SNWA model, as determined from files created for the DEIS model runs. This table shows that SNWA's groundwater model simulates flows through basin boundaries that Burns and Drici (2011) and Rowley et al (2011) argued were impervious. The interbasin flow that occurs in the SNWA numerical model (SNWA, 2009b) demonstrates that the numerical model does not implement the conceptual model presented by Burns and Drici (2011).

The first obvious difference is that, in the numerical model, Steptoe Valley is the source of significant interbasin flow to at least six valleys, with at least 28,700 af/y discharging to Lake, Spring or White River Valley. Second, Spring Valley discharges 7600 af/y to Hamlin Valley and 11,800 af/y to Snake Valley; this second value is to northern Snake Valley through a pathway Rowley et al (2011) and Burns and Drici (2011) claimed would not pass flow. Delamar Valley discharges primarily to Pahranagat Valley, contrary to the conceptual model. Pahranagat Valley does not discharge to the DVFS because the model is not coded to allow this flow. Coyote Spring Valley discharges 2400 af/y to Hidden Valley, a value less than one third of that used in the conceptual model; apparently the model coding used a much smaller transmissivity than the conceptual model. These results all demonstrate that SNWA changed their conceptual model for the water rights hearings in ways that would cause much more recharge in the targeted basins.

SNWA Exh 404, p 4

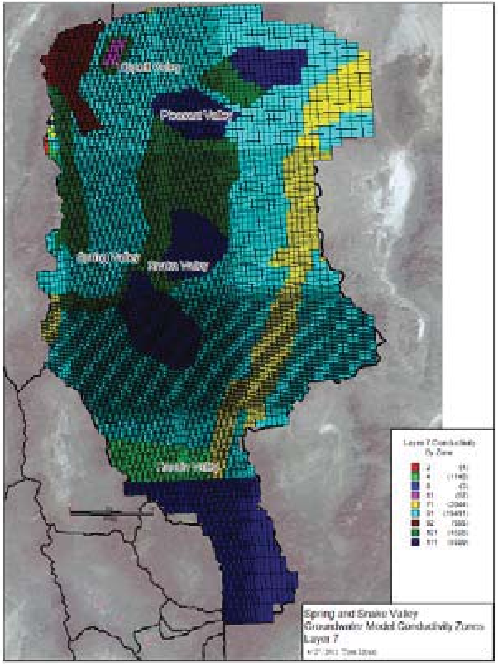


Figure 9: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 7.

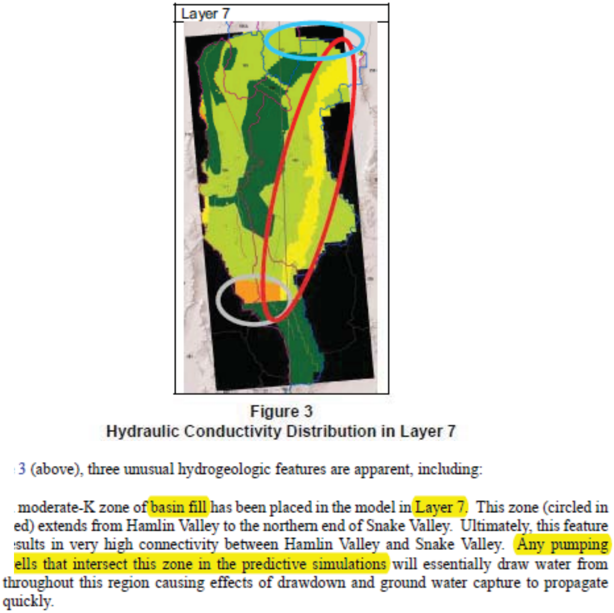


Figure 3
Hydraulic Conductivity Distribution in Layer 7

3 (above), three unusual hydrogeologic features are apparent, including:

moderate-K zone of basin fill has been placed in the model in Layer 7. This zone (circled in ed) extends from Hamlin Valley to the northern end of Snake Valley. Ultimately, this feature sults in very high connectivity between Hamlin Valley and Snake Valley. Any pumping ells that intersect this zone in the predictive simulations will essentially draw water from throughout this region causing effects of drawdown and ground water capture to propagate quickly.

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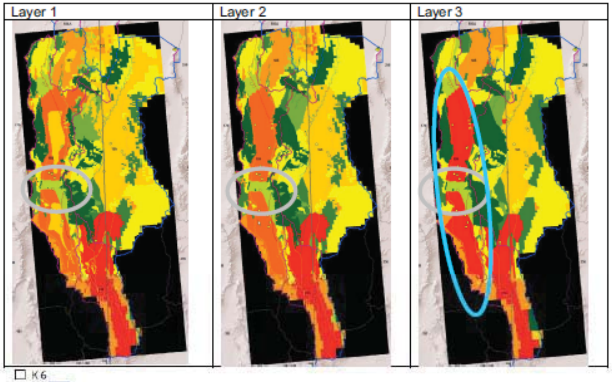


☐ K 6

ft/d	
🟩	0.001000 - 0.020000
🟩	0.020001 - 0.053000
🟩	0.053001 - 0.120000
🟩	0.120001 - 0.222000
🟨	0.222001 - 0.769000
🟨	0.769001 - 1.220000
🟧	1.220001 - 10.100000
🟧	10.100001 - 19.800000
🟥	19.800001 - 51.400000

Note: Same explanation is used for all hydr
arrays in Layers 1 through 7

Figure 1
Hydraulic Conductivity Distribution in Layers 1, 2,

SNWA Exh 404

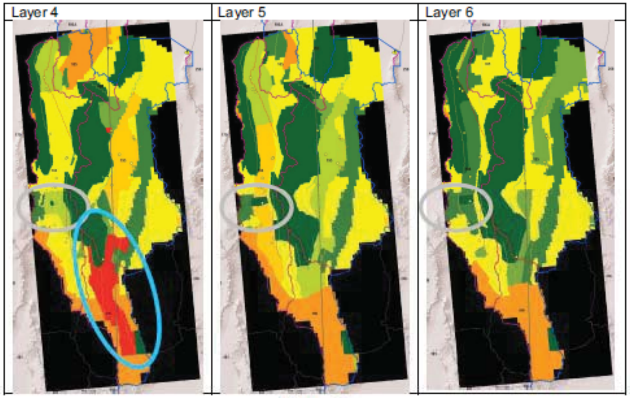


Figure 2
Hydraulic Conductivity Distribution in Layers 4, 5, and 6

precipitation or dilution to account for the minor TDS differences. Plausible NETPATH models that evolve carbonate bedrock water to Big Springs require the precipitation of calcite, exsolution of CO_2 and the dissolution of dolomite (Figure 24). Computed $\delta^{13}C$ values are comparable to observed values (Table 6).

USGS MX (Hamblin Valley South) well is located near Big Springs and has a similar solute composition. The chemical evolution of carbonate bedrock water to USGS MX (Hamblin Valley South) well results in ion exchange, the precipitation of calcite and the dissolution of CO_2 gas, gypsum and halite (Figure 24). Computed $\delta^{13}C$ values are comparable to observed values (Table 6).

Groundwater models that use Monte Neva Hot Spring from Steptoe Valley as a geothermal analogue do not result in plausible NETPATH models to Big Springs or USGS MX (Hamblin Valley South) well. Geochemical modeling suggests that local flow paths alone can account for the water discharging at Big Springs and USGS MX (Hamblin Valley South) well.

Suggested Interbasin Flow Paths

Interbasin flow has been used as a mechanism to explain water budget imbalances in Spring and Snake Valleys that in some cases represent a significant portion (~25%) of the water budget (Table 1). The area south of the Snake Range near the Limestone Hills has been repeatedly suggested as an interbasin flow path between southern Spring and Snake Valleys (Figure 3). In recent studies the area north of the Snake Range has also been identified as an interbasin flow path from northern Spring

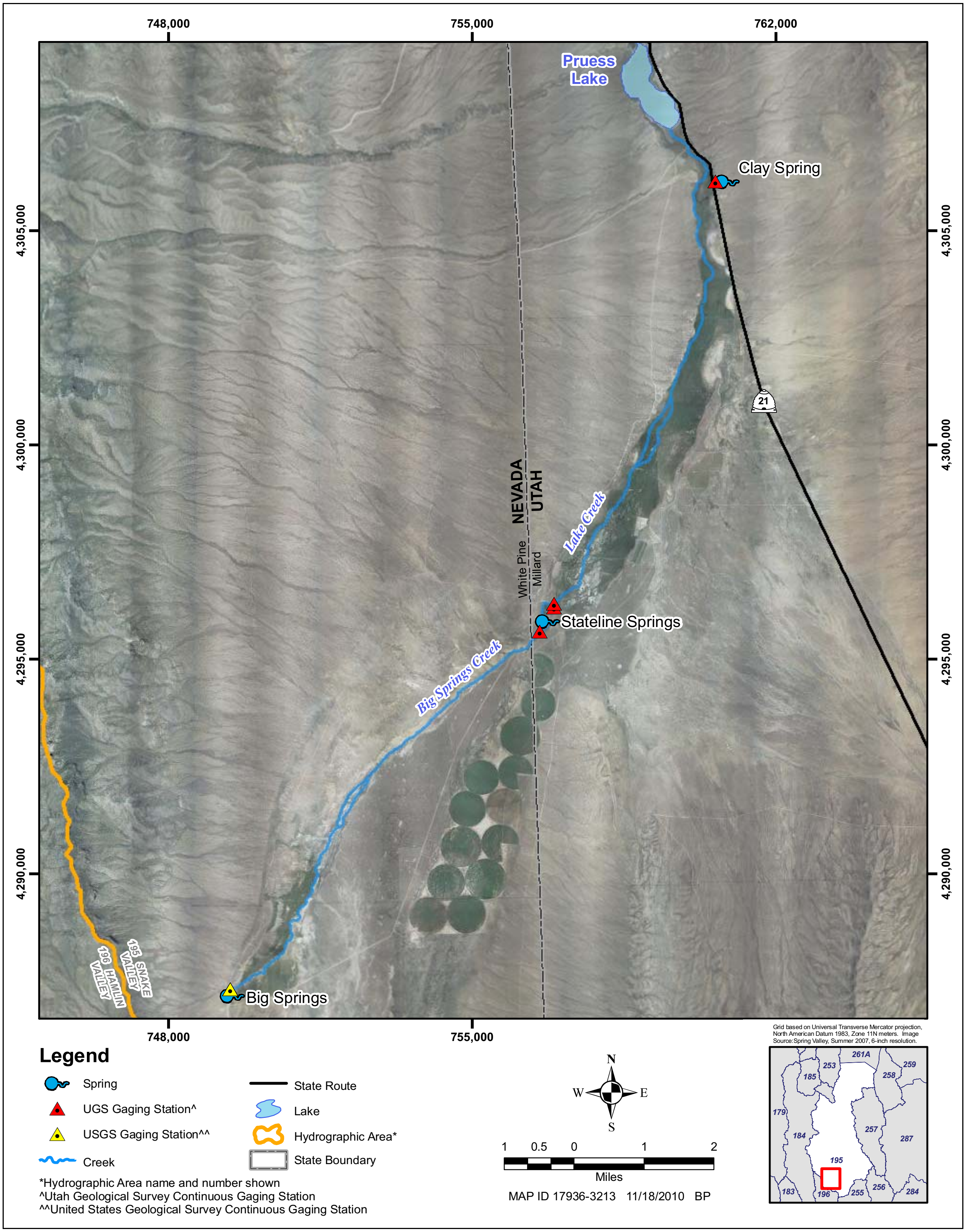
SiO_2; calcium and magnesium exchange for sodium; and precipitation of calcite. The contribution of mountain recharge to valley ground water in southern Spring Valley ranged from 60 to 80 percent; the contribution of central Spring Valley ground water to southern Spring Valley ground water ranged from 20 to 40 percent. Very little carbon isotopic exchange (0 to 0.5 mmol/L) was needed to adjust DIC isotopic concentrations for carbon isotopic exchange with carbon containing minerals along the flowpaths. The resulting travel times for this flowpath ranged from less than 1,000 to 6,000 years (Table 19). Approximate ground-water velocities from central to southern Spring Valley ranged from 10 to 200 ft/yr (Table 19).

Water-rock reaction models of ground-water flow from the southern part of northern Spring Valley to the northern part of northern Spring Valley (Table 18, #68) required the dissolution of feldspar or SiO_2; dissolution of gypsum, dolomite, and small amounts of NaCl; precipitation of clay, zeolite or SiO_2; calcium and magnesium exchange for sodium; and precipitation of calcite. The contribution of mountain recharge to valley ground water in northern Spring Valley ranged from 40 to 100 percent; the contribution of central Spring Valley ground water to northern Spring Valley ground water ranged from 0 to 60 percent. The wide range in contribution of mountain recharge versus central Spring Valley ground water to northern Spring Valley ground water illustrates the sometimes nonuniqueness of water-rock reaction modeling. This nonuniqueness for this flowpath may be indicative of the lack of representative ground-water chemistry and isotopic data in northern Spring Valley. No carbon isotopic exchange was needed to adjust DIC isotopic concentrations for carbon isotopic exchange with carbon containing minerals along the flowpath. The resulting travel times for this flowpath ranged from less than 1,000 to 3,000 years (Table 19). Approximate ground-water velocities for this flowpath ranged from 40 to 150 ft/yr (Table 19).

Interbasin Flowpaths

Spring Valley to Snake Valley

Water-rock reaction modeling scenarios considered two different southern Snake Valley ground-waters, Hyde Well (Table 19 and Figure 33, #263, 57 pmc) and Big Springs (Table 19 and Figure 33, #240, 31 pmc). Water-rock reaction models of ground-water flow from southern Spring Valley to southern Snake Valley required the dissolution of feldspar, dolomite, gypsum, and small amounts of NaCl; precipitation of clay or zeolite; calcium and magnesium exchange for sodium; uptake or loss of CO_2 gas; dissolution or precipitation of SiO_2; and dissolution or precipitation of calcite. The contribution of mountain recharge to southern Snake Valley ranged from zero to 100 percent; correspondingly, the contribution of southern Spring Valley ground water to southern Snake Valley ranged from 0 to 100 percent. However, qualitatively, the models with 78 to 100 percent mountain recharge produced “better” carbon isotope matches to observed Snake Valley ground-water isotopic values. Minimal carbon isotopic exchange (zero to 0.1 mmol/L) was needed to adjust DIC isotopic concentrations for carbon isotopic exchange with carbon containing minerals along the flowpath. The resulting travel times for this flowpath ranged from less than 1,000 to 6,000 years (Table 19). Ground-water flow velocities are approximately 20 to 100 ft/yr.



Grid based on Universal Transverse Mercator projection, North American Datum 1983, Zone 11N meters. Image Source:Spring Valley, Summer 2007, 6-inch resolution.

Figure 9
Big Springs Synoptic-Discharge Measurement Study Area, Snake Valley

Big Springs' flows have been monitored since 2005 in two gages near the upstream end of the channel (Figure 33). The sum of the two gages has averaged 10 cfs with a standard deviation of 0.6 cfs since 10/1/2005. However, the flow rate has apparently decreased about 1 cfs since 2008. Also apparent is a decrease in the flow variability since then. Primarily it is the North gage which has had a decrease in variability. The flow rate in the North Channel also decreased about 0.7 cfs while the flow rate in the South Channel decreased about 0.3 cfs.

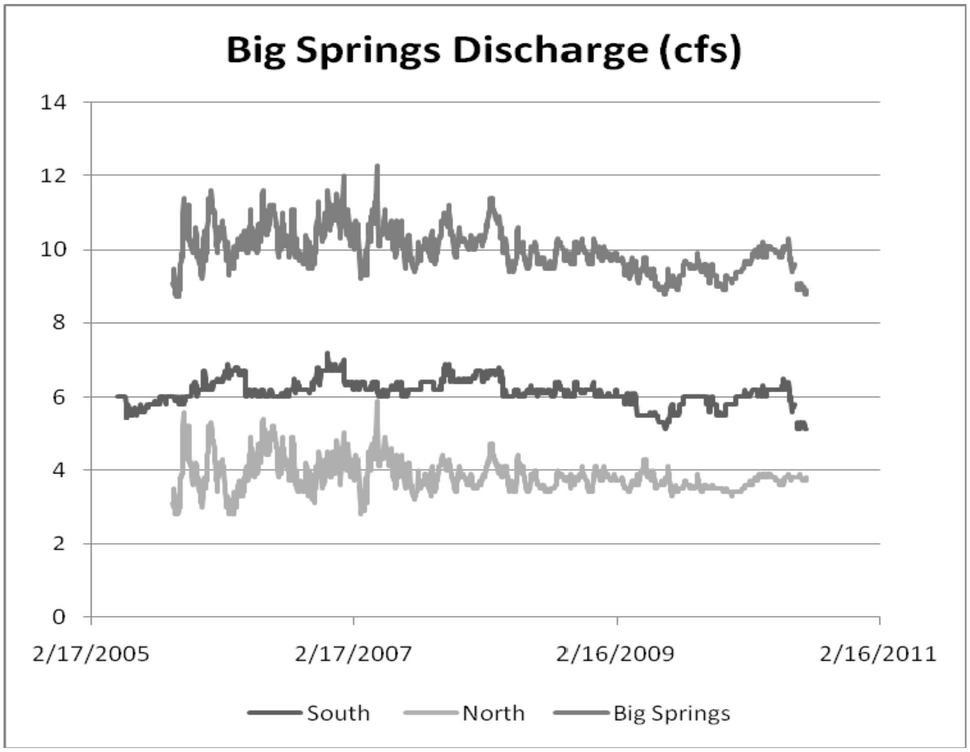


Figure 33: Flow rate hydrograph for Big Springs. USGS gages 10243224 and 102432241, South and North Channel.

There is significant uncertainty about the source of water discharging from Big Springs. There appear to be two carbonate sources of flow to the springs, from interbasin flow from Spring Valley through the Limestone Mountains or the carbonate rock that mantles the south half of the Snake Range. The general dip of this rock would combine the carbonate pathways at the springs, which also coincide with a range-front fault east of the Snake Range.

The decreased flow from the springs since 2008 may reflect ongoing development in the area, just as pumping near Baker has decreased groundwater levels as documented above. Several new irrigation pivots have developed west of the springs since about 2005 (personal communication, Dean Baker, 2006, and field observations by this author).

Stateline Springs are also a significant source of groundwater discharge downstream from Big Springs, measured at about 3700 gpm (8.2 cfs), which is close to the discharge from Big

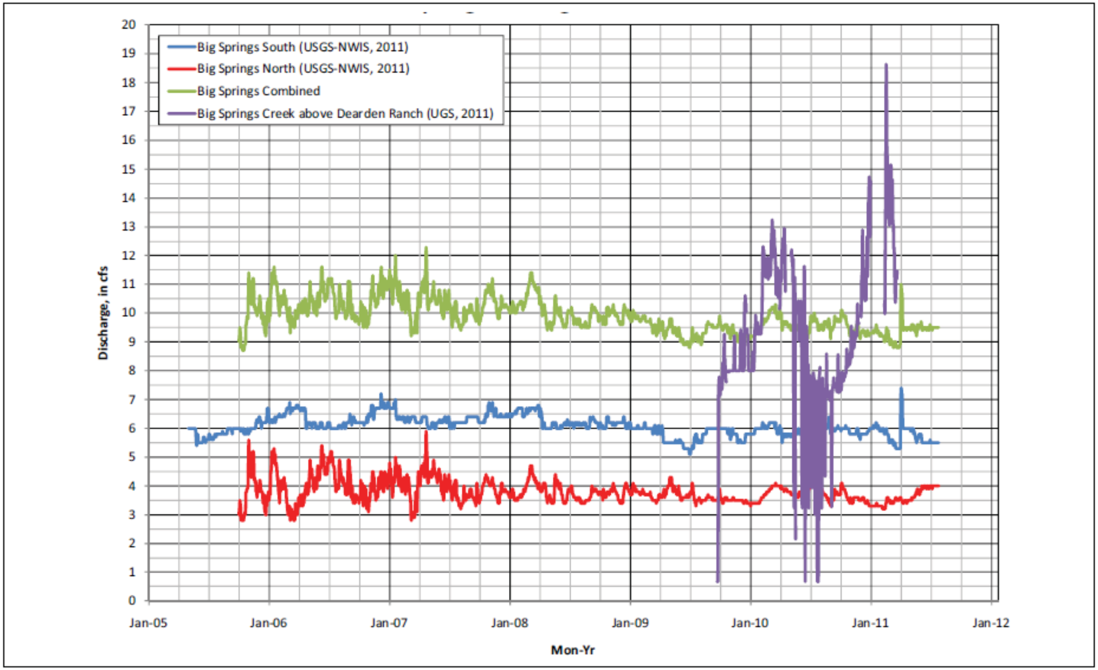


Figure 2
Spring Discharge 2005-2011

SNWA Exh 426

Table 1: Guidelines for effective modeling (Hill and Tiedeman, 2007), and this models utilization of them.

Guideline	Discussion
1: Apply the principle of parsimony	"Start simple and add complexity as warranted by the hydrology and hydrogeology, the inability of the model to reproduce observations, and the complexity that can be supported by the available observations." See text.
2: Use a broad range of system information to constrain the problem	Spatial and temporal structure has been identified using the hydrogeologic conceptual model described in Part A. Initial parameters were as broad as possible. Features were added only when necessary to cause the simulation to emulate observations. Primarily this was subdividing parameter zones, adding and altering fault boundaries, and adding interbasin flow boundaries. Geographic Information Systems were used extensively to describe precipitation and geologic patterns to estimate recharge.
3. Maintain a well-posed, comprehensive regression problem.	When developing parameter zones, it was desirable to only create zones for which the model would be sensitive – that is zones which affect the model results (affect the calibration statistics). This was not possible in all areas, especially the mountains, where there are few observations. In this case, the parameters were set based of subjective judgment.
4. Include many kinds of data as observations	Only head observations were used in the regression. The model was constrained, made unique, by targeting the water balance in whole and in specific reaches, meaning springs and interbasin flow.
5. Use prior information carefully	All parameters were initially set based on previous observations. During calibration, they were also constrained by observed parameter ranges from the literature. However, these ranges were

Table 7: Discharge at select boundaries.

			Targeted Flows				
	Boundary Type	Reach #	Inflow (af/y)	Outflow (af/y)	Discharge ft^3/d	simulated (ft^3/d)	Simulated (af/y)
Steptoe In	GHB	32	4000			274737	2302.09
Lake Valley	GHB	31	29,000			1555697	13035.57
Outflow	GHB	21-25		29,000		-3408603	-28561.5
Tippett/Deep Creek Valley	GHB	12				-1755385	-14708.8
Rowland Springs	Drain	14			172000	-11841	-99.2206
Big Springs	Drain	13			443000	-181984	-1524.89
Stateline Spring	Drain	19				-147775	
Gandy Warm Springs	Drain	16			693000	-14915	-124.977
Spring Creek	Drain	11			86000	-20154	-168.872
Caine Spring	Drain	17			100	-2543	-21.3097
Keegan Spring	Drain	3			100	0	0
Millick Springs	Drain	1			75000	-96007	-804.464
Cleve Creek Spring	Drain	4			1100000	-425668	-3566.78
Swallow Springs	Drain	30			110000	-94628	-792.91
East Side Spring Valley	Drain	2				-1858744	-15574.9
Lehman Crk	River	13	5800		950400	33652	281.9783
Baker Crk	River	14				34373	288.0228
Snake Crk	River	15				-9802	-82.1311
Strawberry Crk	River	12			43200	43213	362.0965
Silver Creek	River	11				268452	2249.429

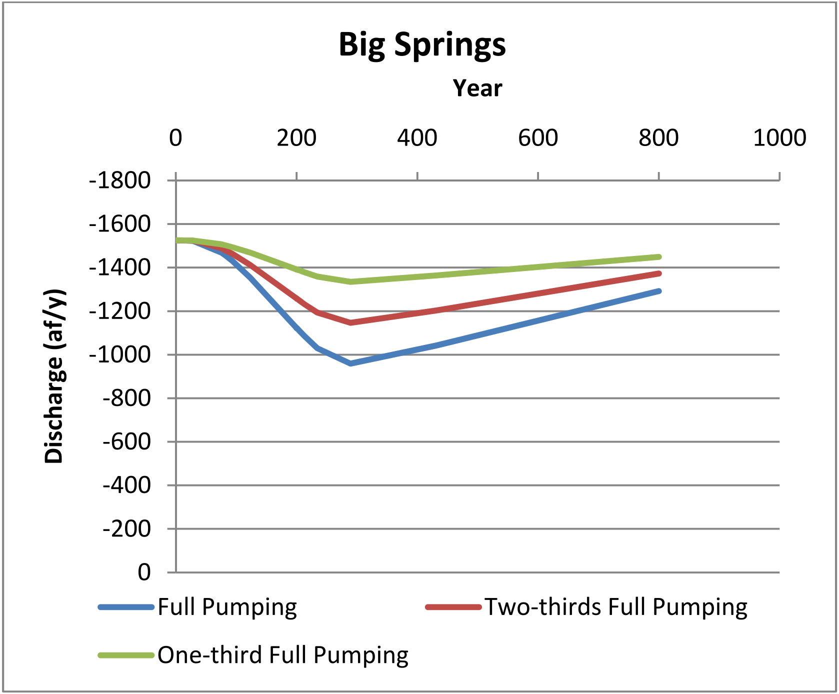


Figure 18: Discharge hydrograph, S Spring Valley Springs, SNWA Original Apps.

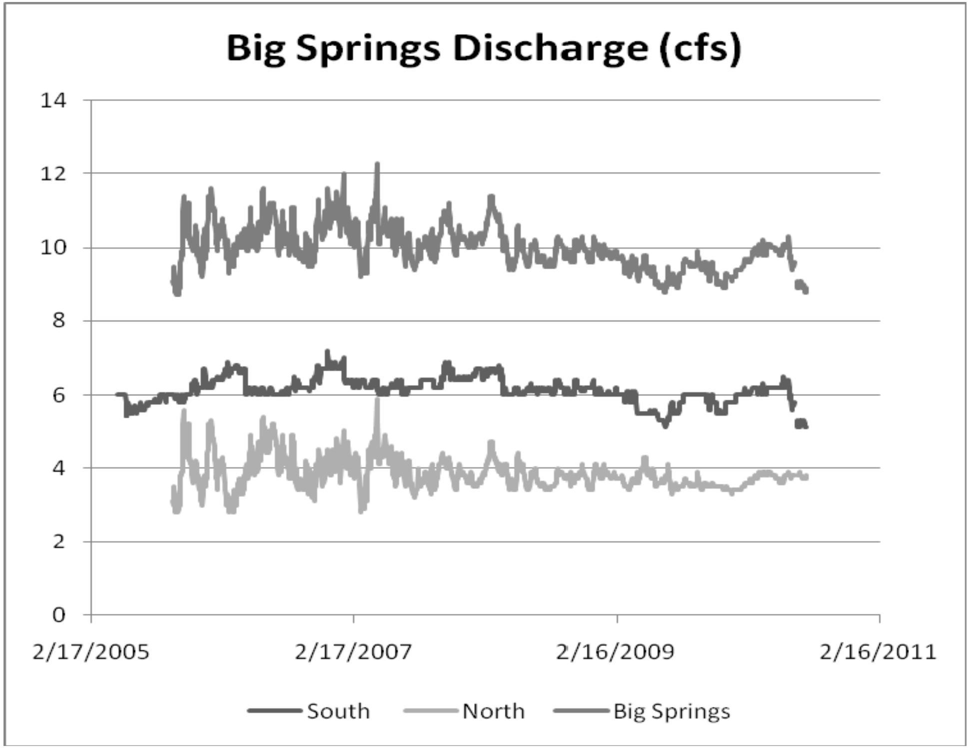
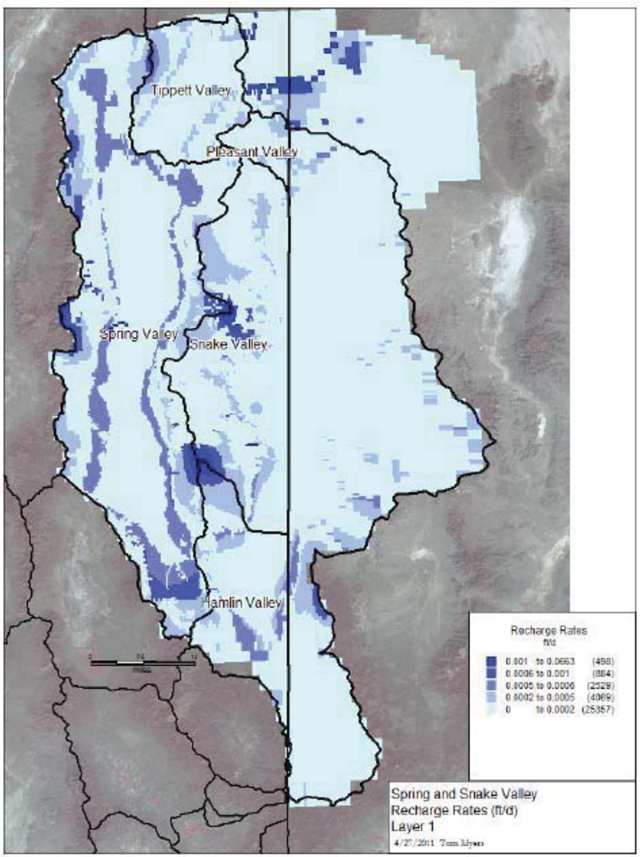


Figure 33: Flow rate hydrograph for Big Springs. USGS gages 10243224 and 102432241, South and North Channel.

GBWN Exh 2,
Fig 11



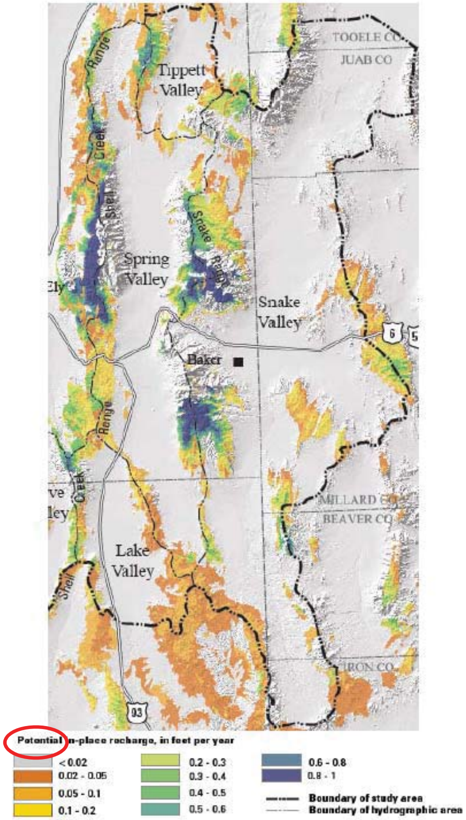


Figure 12: Snapshot of Figure 6 (Flint and Flint, 2007) showing simulated in-place recharge.

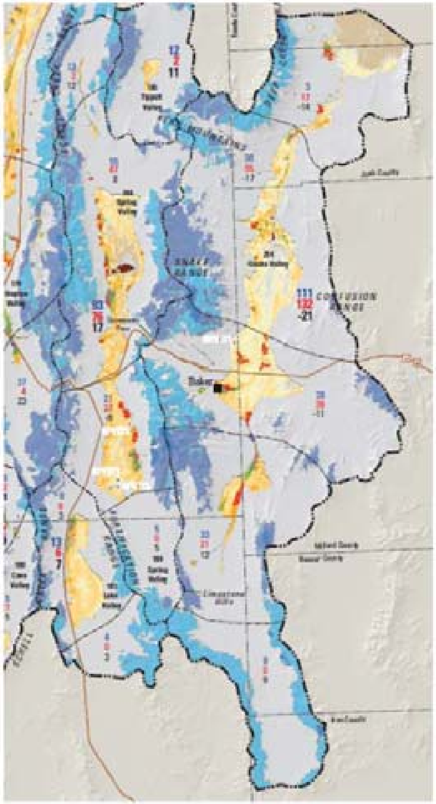


Figure 13: Snapshot of Welch et al (2008), Plate 4, showing distribution of evapotranspiration and locations of in-place recharge or runoff. The ET shading is from about 0.6 ft/y, tan for playa, through yellow (shrubs) to green (marshland) at over 4 ft/y.

GBWN Exh 1

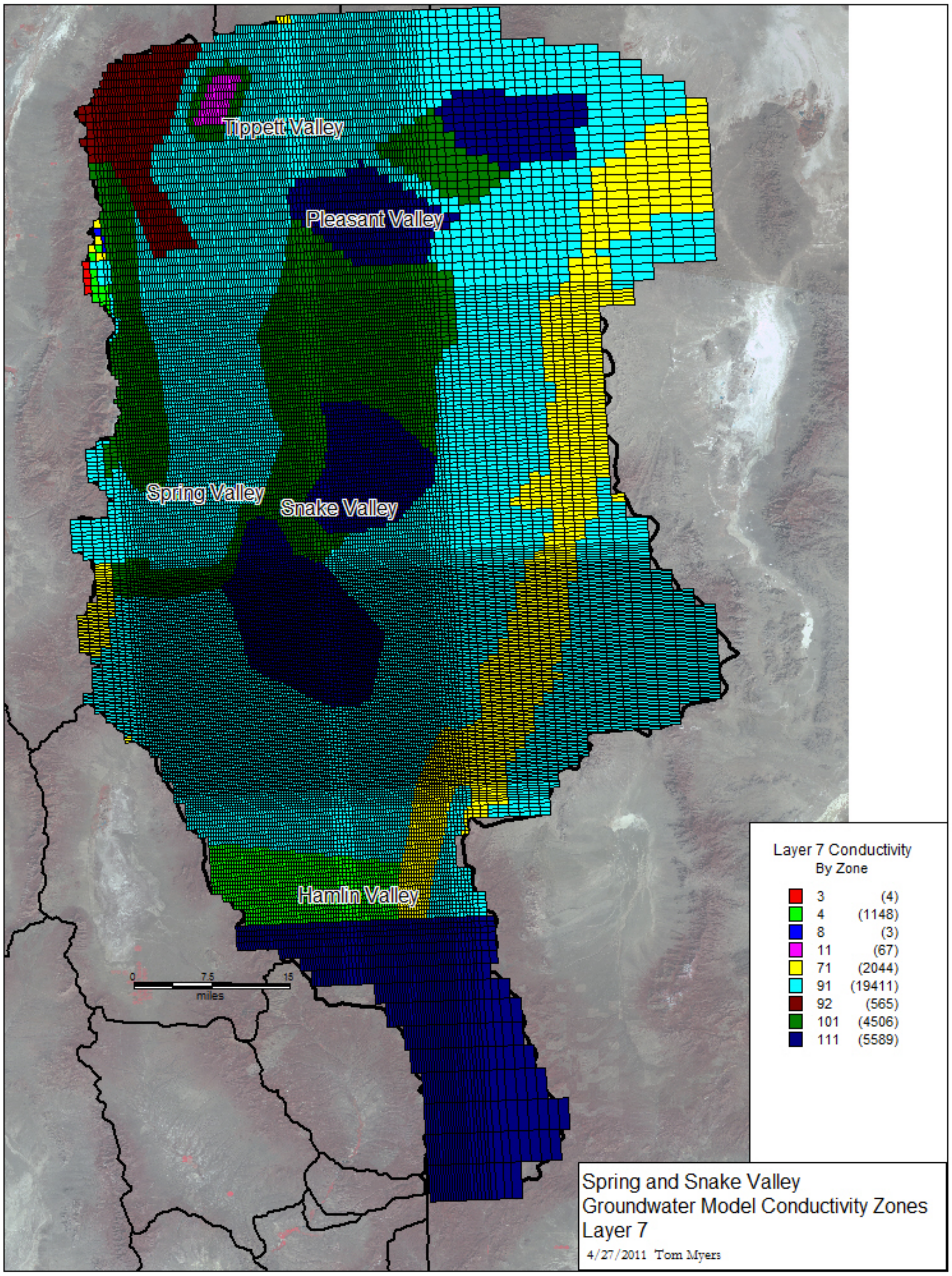
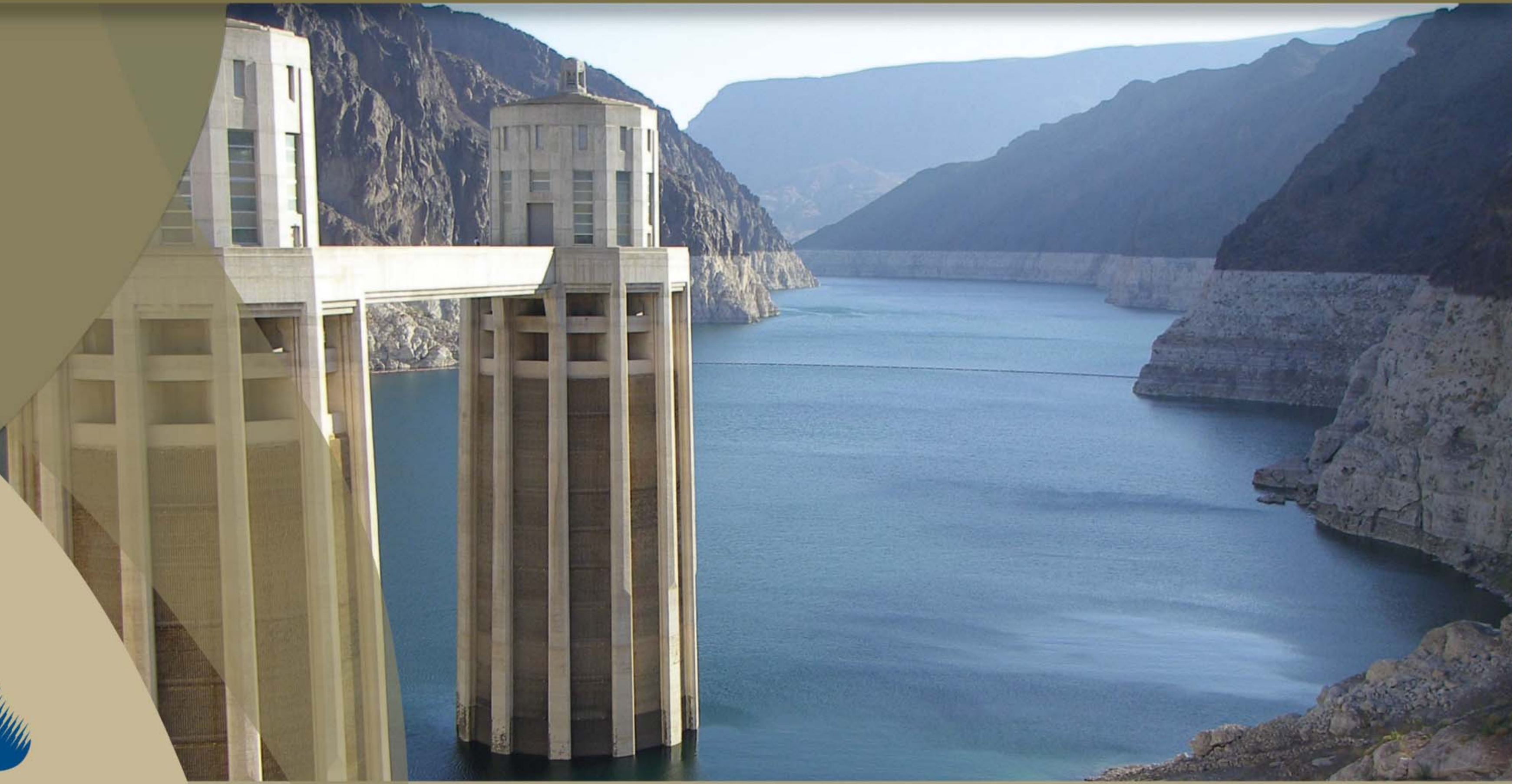


Figure 9: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 7.

Spring, Cave, Dry Lake and Delamar Valleys



SOUTHERN NEVADA
WATER AUTHORITY

Presentation for
Myers Cross
Spring Valley Part 2

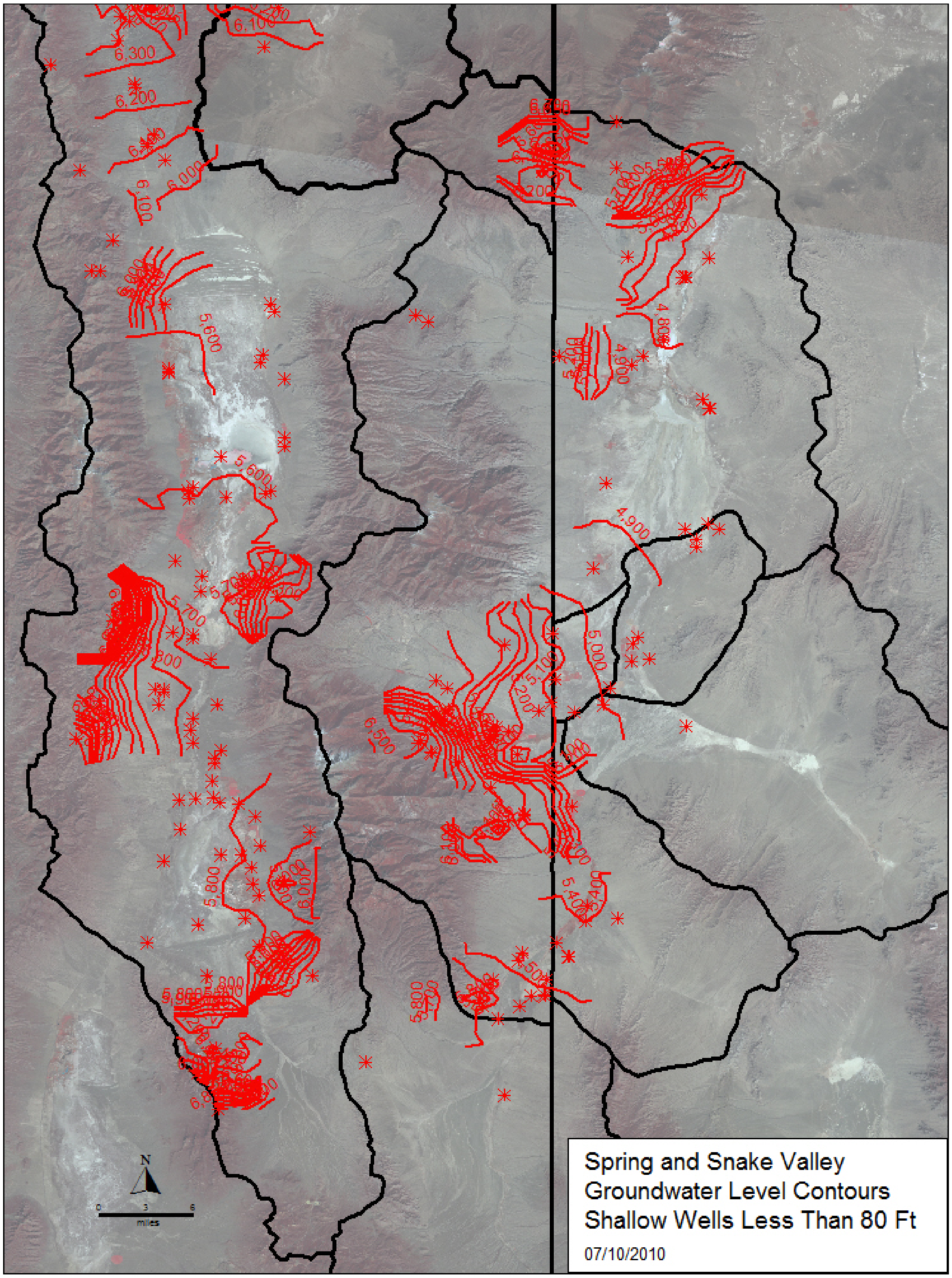


Figure 3: Steady state groundwater contours for shallow wells (<80').

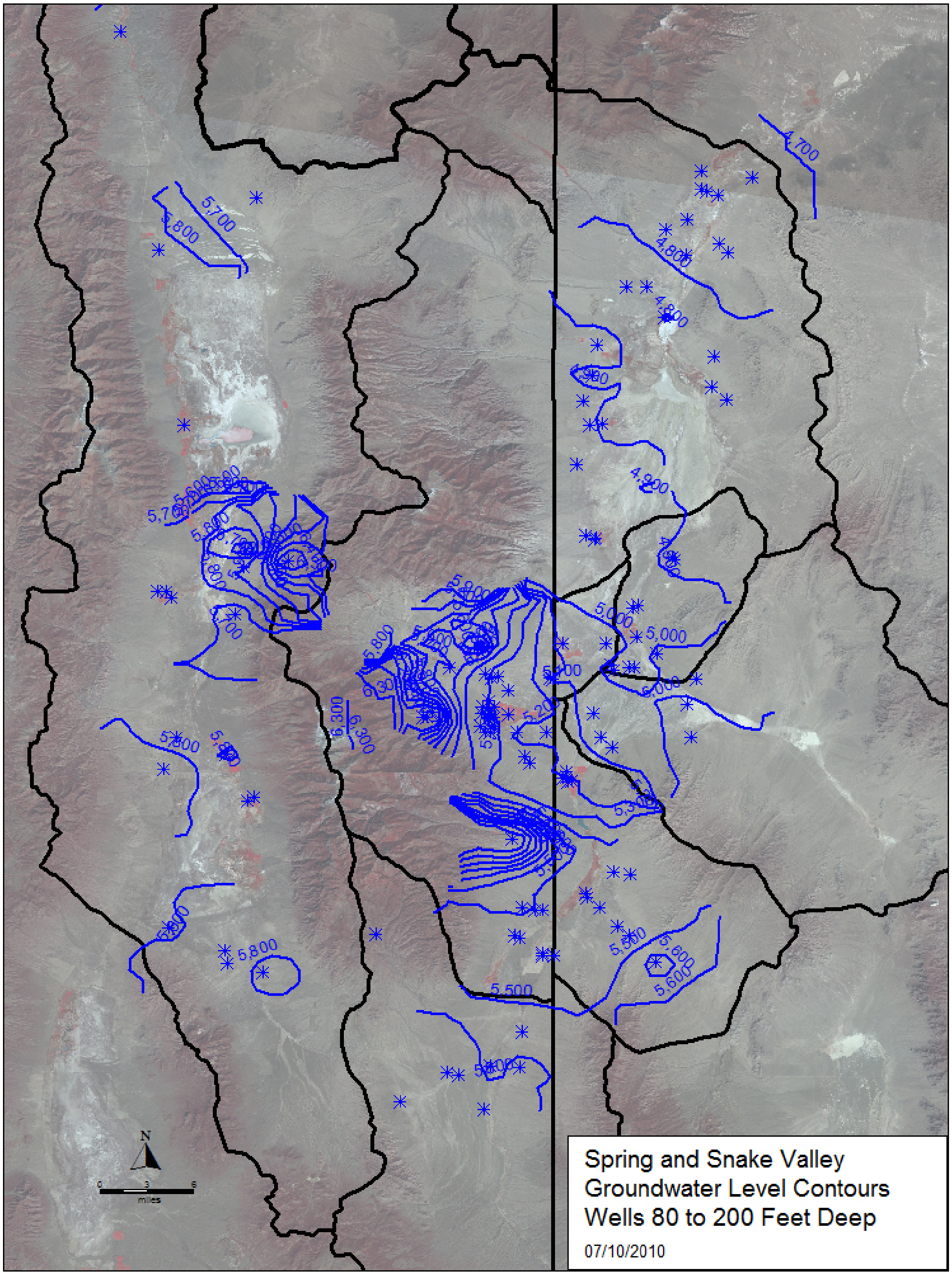


Figure 4: Steady state groundwater contours for intermediate wells (80-200'). White and red targets are SNWA applications.

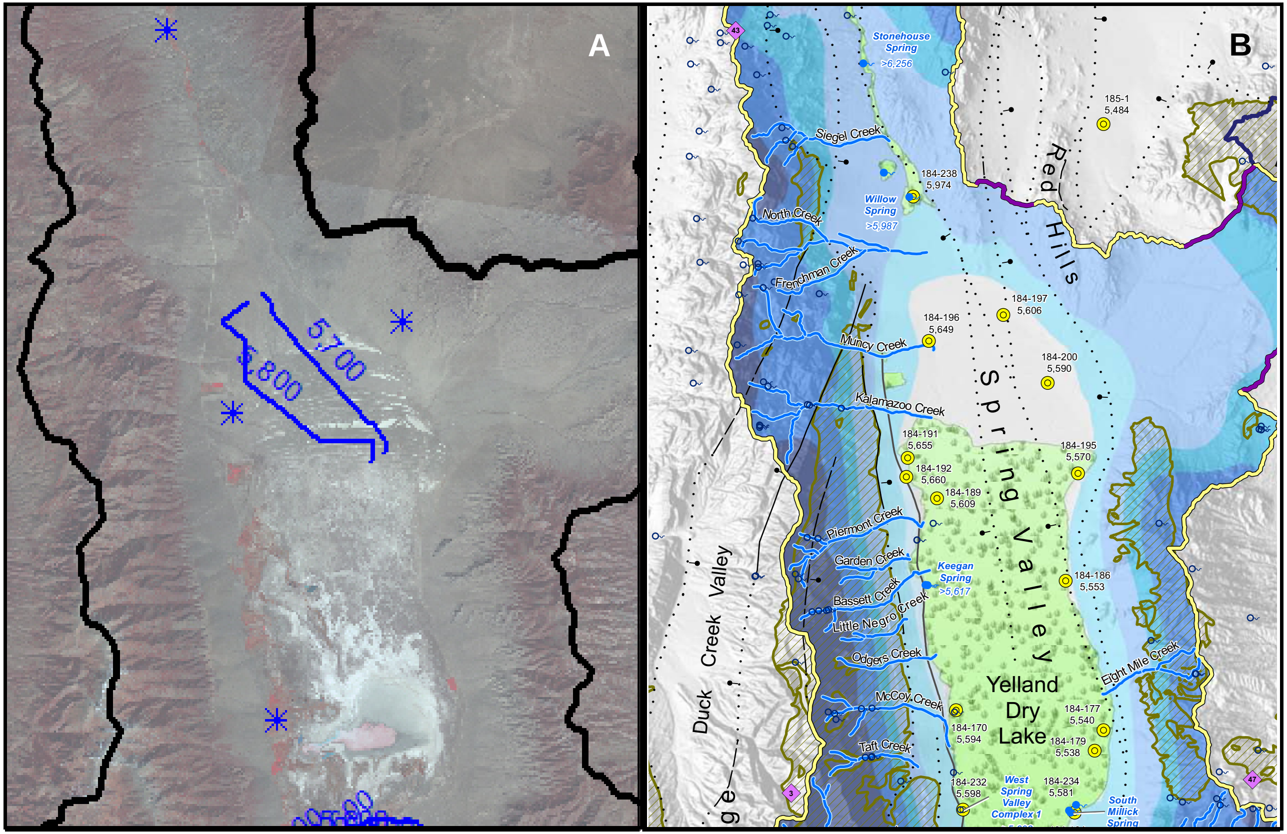


Figure 1
Comparison of Figure 4 from Myers (2011a) and Plate 1 from Burns and Drici (2011)

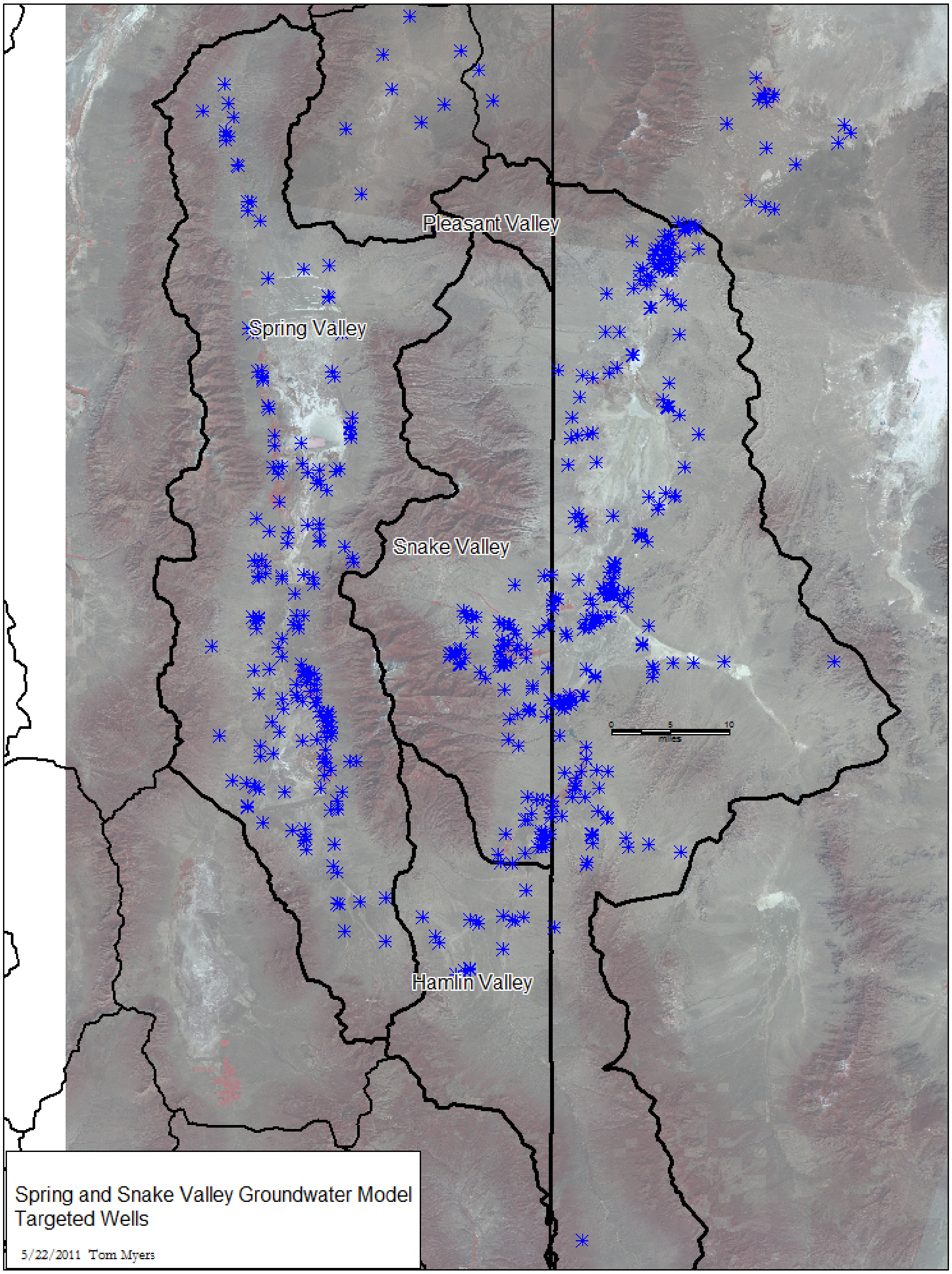


Figure 15: Locations of wells used for steady state calibration.

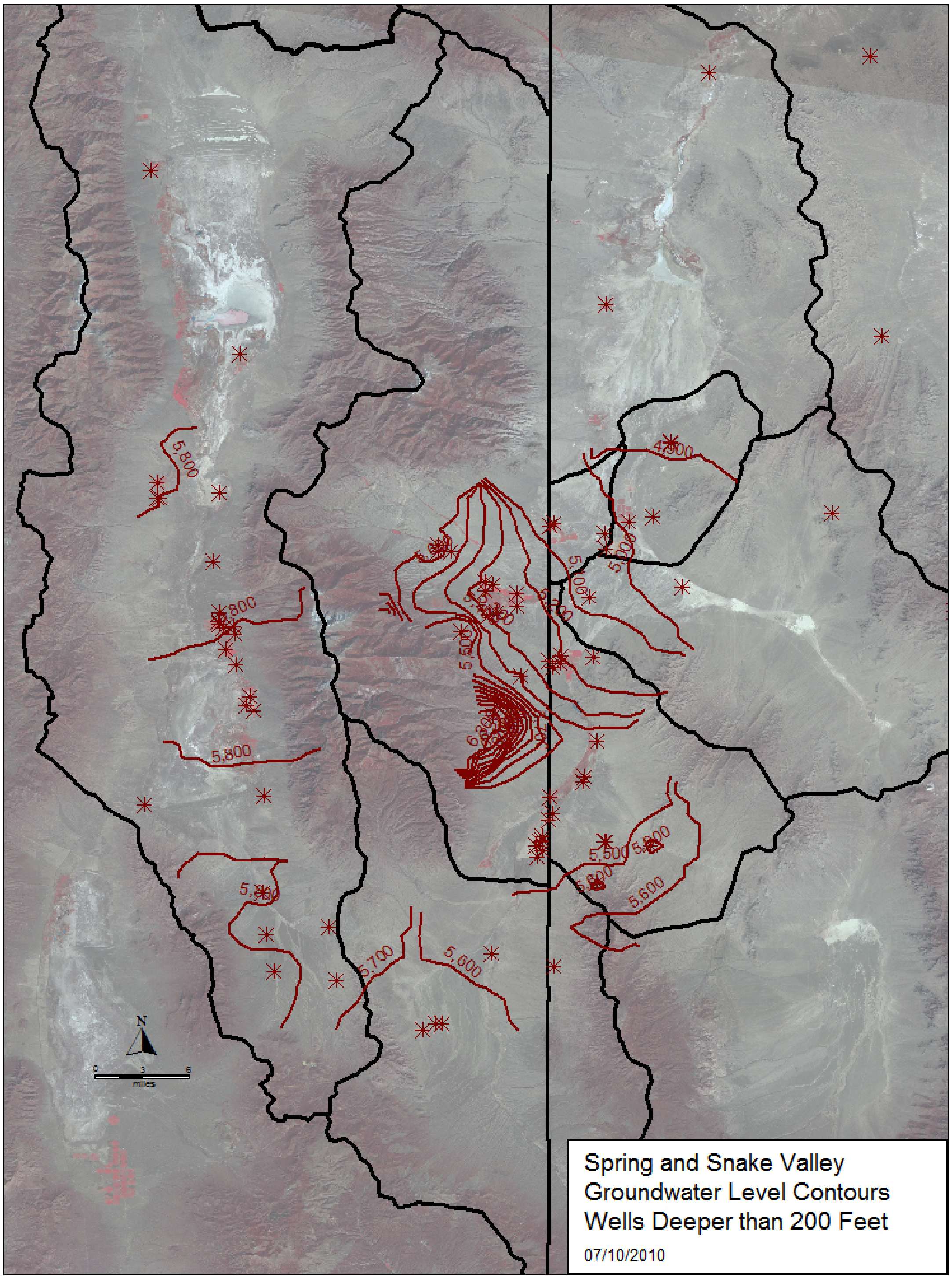


Figure 5: Steady state groundwater contours for deep wells (>200'). White and red targets are SNWA applications.

Do you remember that?

A Yes.

Q Don't you think that 2,000 years is an unreasonable of a timeframe to use?

A I remember Mr. Durbin suggesting that considering that far into the future for effects would -- was reasonable, that you should consider that far, but that for from a planning horizon that he -- he argued that it should be a shorter time interval than 2,000 years.

Q But you certainly agree that the predictive accuracy of the model is less for a 2,000-year timeframe than it is for, say, a 75-year timeframe?

A Well, that was -- in -- in some regards, yes, and in some regards, no.

Q Do you agree that it's not reasonable to presume that pumping would continue 2,000 years?

A I would not make that assumption. I presume that Las Vegas assumes they'll still be here in 2,000 years.

Q And that other water supplies won't be found. That's your assumption, right?

A Northwest territories? I -- I don't know.

Q Okay. Well, wouldn't you agree that if these applications are for approved, it's far more likely that the pumping will occur for 75 years than it is for 2,000

years?

A I -- I suppose -- yeah -- yes.

Q So don't you think that the hundred-year runs of your model are far more useful to the State Engineer considering these applications than the 2,000-year runs?

A No, I don't.

Q Okay. Now, is there a level of predicted drawdowns that these models would arrive at, that you believe is acceptable, given the inherent model error?

A A level of predicted drawdowns that I think is acceptable? I -- a drawdown is acceptable if it's removing a reasonable amount of transitional storage. If the system comes to steady state within a reasonable amount of time, that is a drawdown which I think is acceptable.

Q So if there's any drawdowns outside these basins, that's unacceptable in your view?

A If it interferes with springs and other water rights, I -- I believe that it would be -- it becomes more unacceptable, the more springs and water rights it interferes with.

Q When you worked for Great Basin Mine Watch, you were Executive Director there, right?

A That's correct.

Q In that capacity, you were opposed to the water permits that were issued for the Post Betsy Mine, correct?

In the north, the Kern Mountains have impermeable intrusive rock which likely prevents flow, but just south there is potentially flow through Pleasant Valley from Spring to Snake Valley. The northern portion of the Snake Range, north of Hwy 50, has substantial carbonate rock but detachment faults which may prevent interbasin flow; this faulting may also direct recharge in that carbonate rock to flow north – towards Gandy Warm Springs (Flint et al, 2008, Plate 1). The northern half of the South Snake Range, just south of Hwy 50, is impermeable due to intrusive and siliciclastic bedrock. The southern half is carbonate with a detachment fault on the east (Elliot et al, 2006) which may enhance the permeability. The west half of Hamlin Valley, a portion of Snake Valley, has substantial amounts of carbonate rock, and the fault just east of the Snake Range may direct flow from this carbonate towards Big Springs. In other words, flow to Big Springs may result from interbasin flow through the Limestone Hills and carbonate flow from the south Snake Range. In summary, the best potential for interbasin flow from Spring to Snake Valleys is through the southwest third of Snake Valley and through Pleasant Valley.

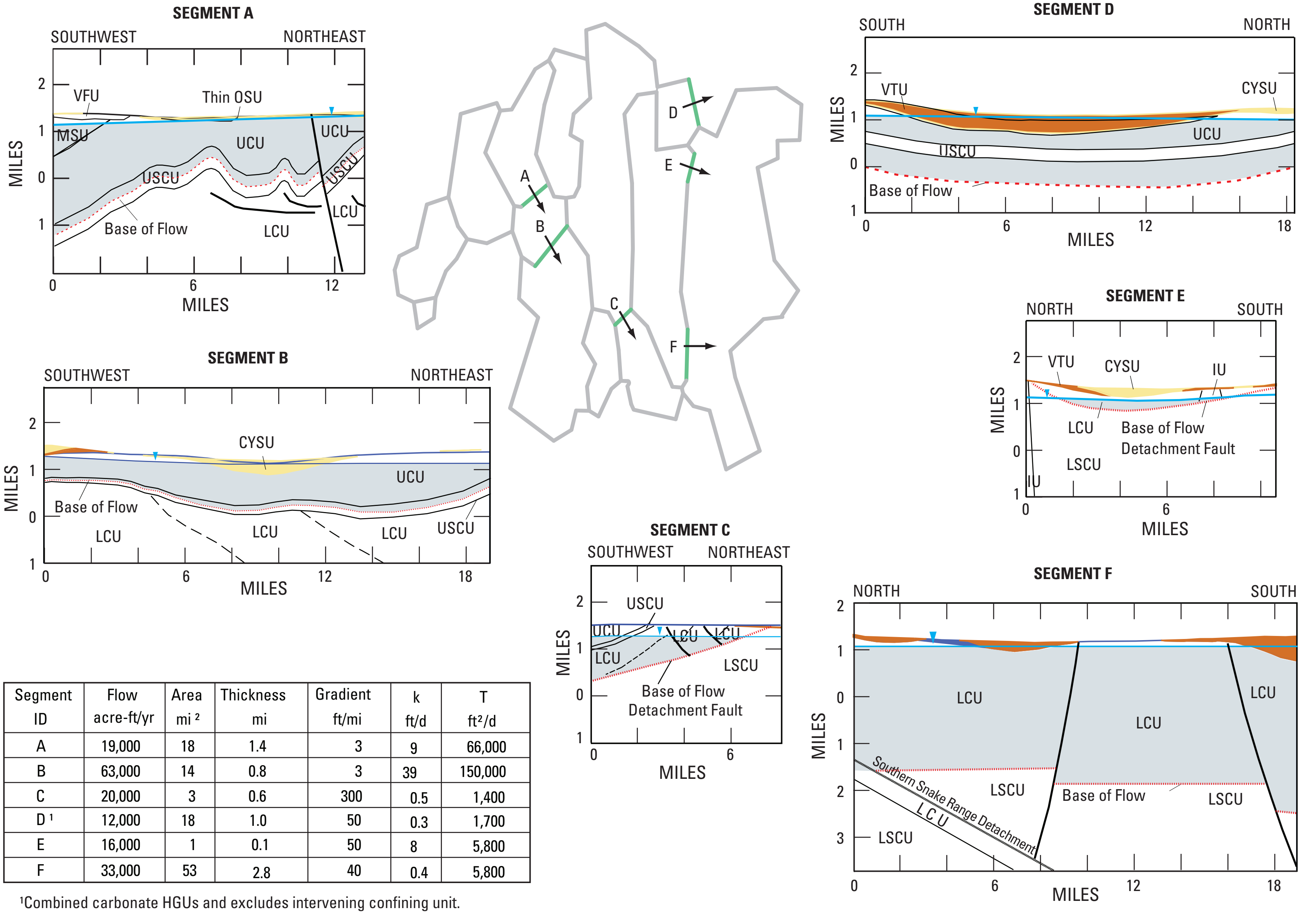
The estimated flux rate between valleys is very uncertain. The flux depends on the water balance of Spring Valley – whether there is more recharge and interbasin flow to Spring Valley than GWET. BARCAS estimates that 33,000 af/y discharges to Snake Valley through the southern end and 16,000 af/y through Pleasant Valley or through carbonates in the Kern Mountains. There is also 2000 af/y discharging to Tippett Valley, based on BARCAS. Thus, interbasin flow discharging from Spring Valley totals about 51,000 af/y (Welch et al, 2008), which depends almost totally on inflow from Steptoe Valley (most of the inflow from Lake Valley originates in Steptoe Valley).

The total recharge estimate for the study area was 194,000 af/y, based on average values from other studies. Interbasin inflow originating in Steptoe Valley could be as much as 33,000 af/y. The outflow to the north from Tippett and Deep Creek Valley is about 12,000 af/y, and to the Great Salt Lake and Fish Spring Flat is about 29,000 af/y. The BARCAS GWET estimate is 209,000 af/y. The flux values just presented have a residual of about 23,000 af/y, which is a good estimate of the uncertainties in the overall water balance for the study area.

Conceptual Models of springs and Streams

The previous section has generally described the flow through the four study area valleys.; it has provided a good conceptual model of that valleywide flow. However, each stream and spring is a detailed manifestation of that flow. They are important recharge and/or discharge points within the overall model. Local-scale geology may control each of these points. This section describes briefly some of the flow details, including geology and measured flows for individual points. Some of the streams and springs are perennial and flow measurements provide estimates of secondary recharge. Figure 14 locates many springs and perennial streams in the study area.

Zoom SNWA 258 Plate 1



Segment ID	Flow acre-ft/yr	Area mi²	Thickness mi	Gradient ft/mi	k ft/d	T ft²/d
A	19,000	18	1.4	3	9	66,000
B	63,000	14	0.8	3	39	150,000
C	20,000	3	0.6	300	0.5	1,400
D[1]	12,000	18	1.0	50	0.3	1,700
E	16,000	1	0.1	50	8	5,800
F	33,000	53	2.8	40	0.4	5,800

[1] Combined carbonate HGUs and excludes intervening confining unit.

Figure 42. Cross sections used to estimate transmissivities of hydrogeologic units.

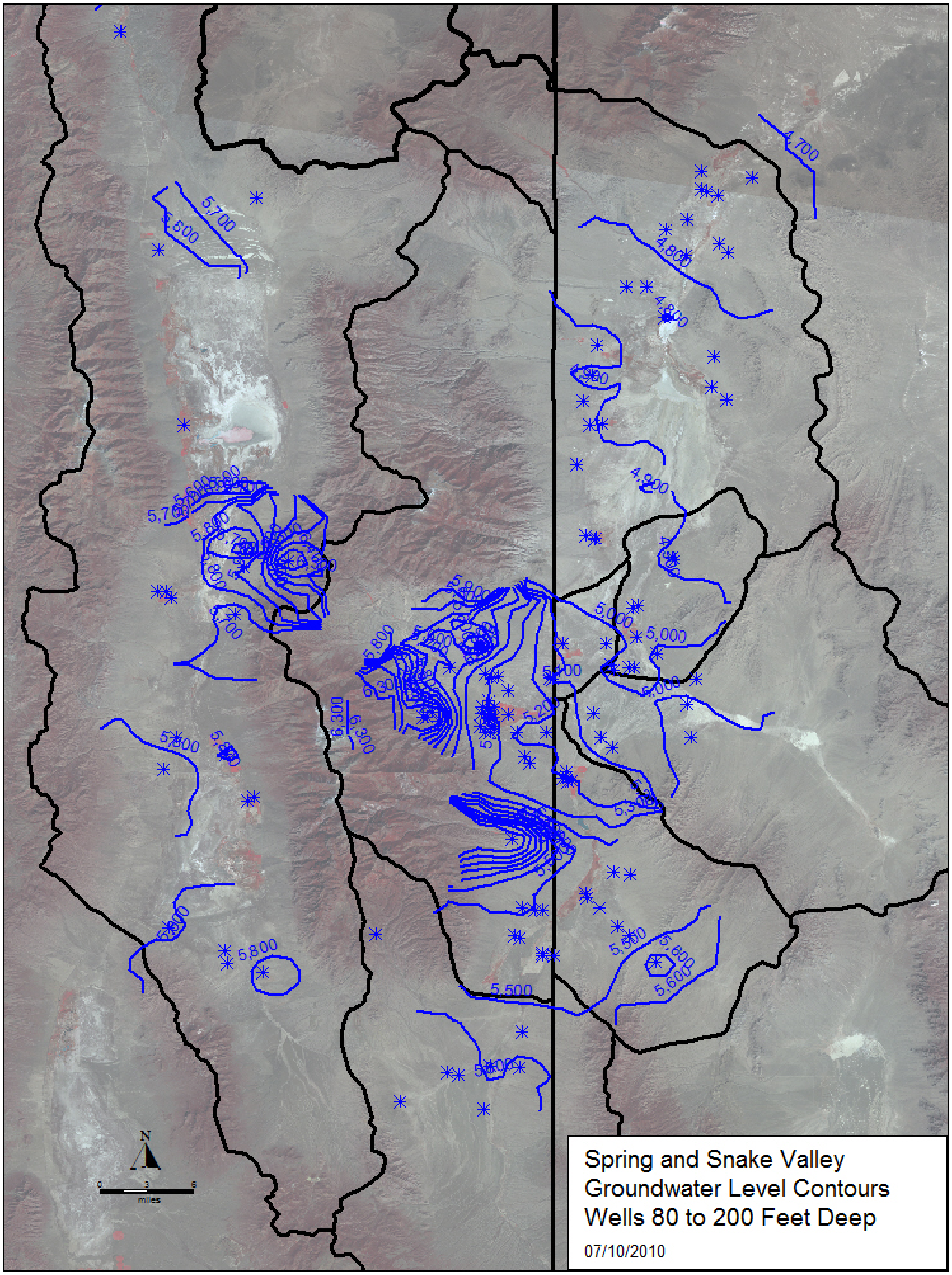


Figure 4: Steady state groundwater contours for intermediate wells (80-200'). White and red targets are SNWA applications.

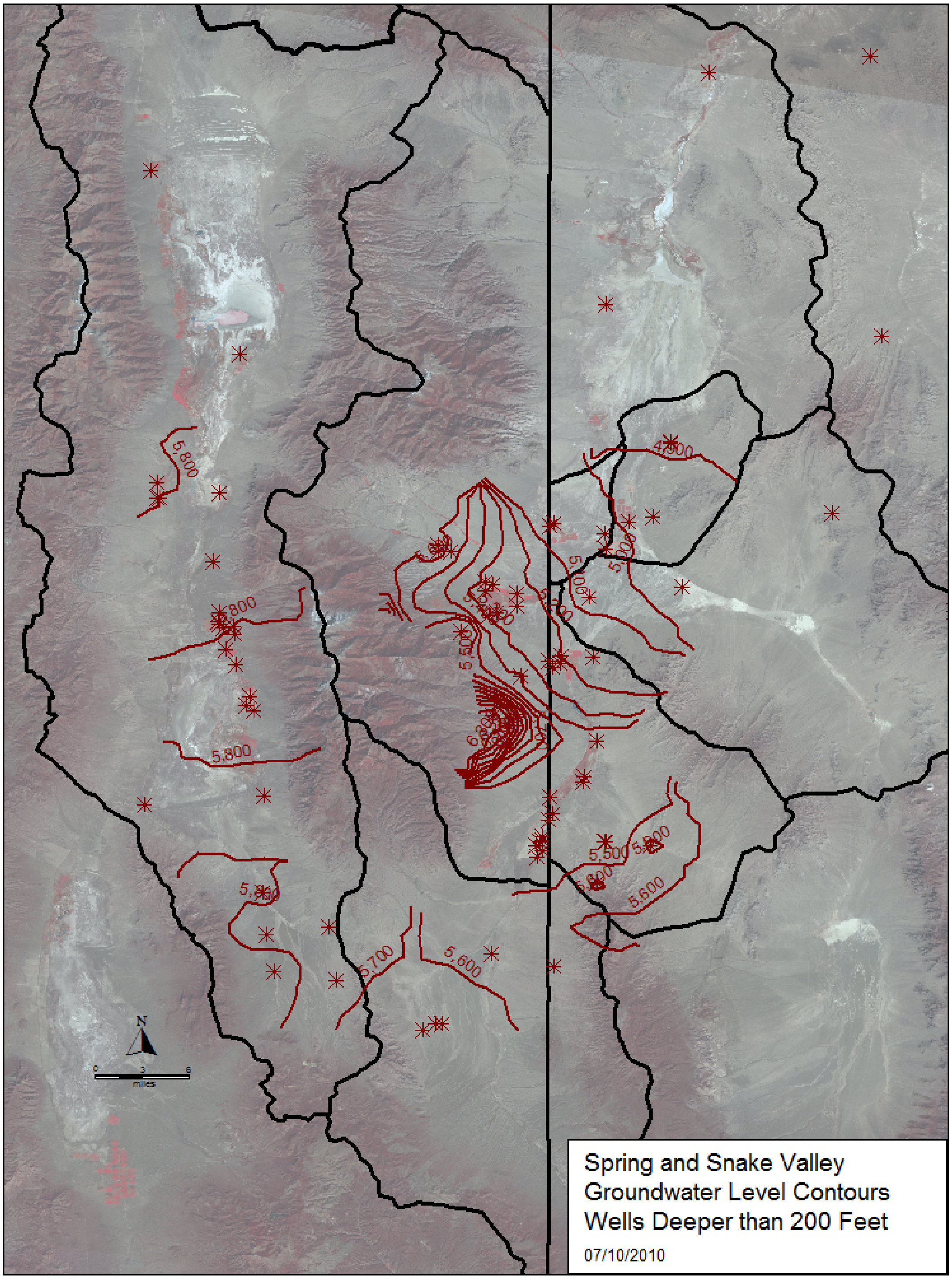


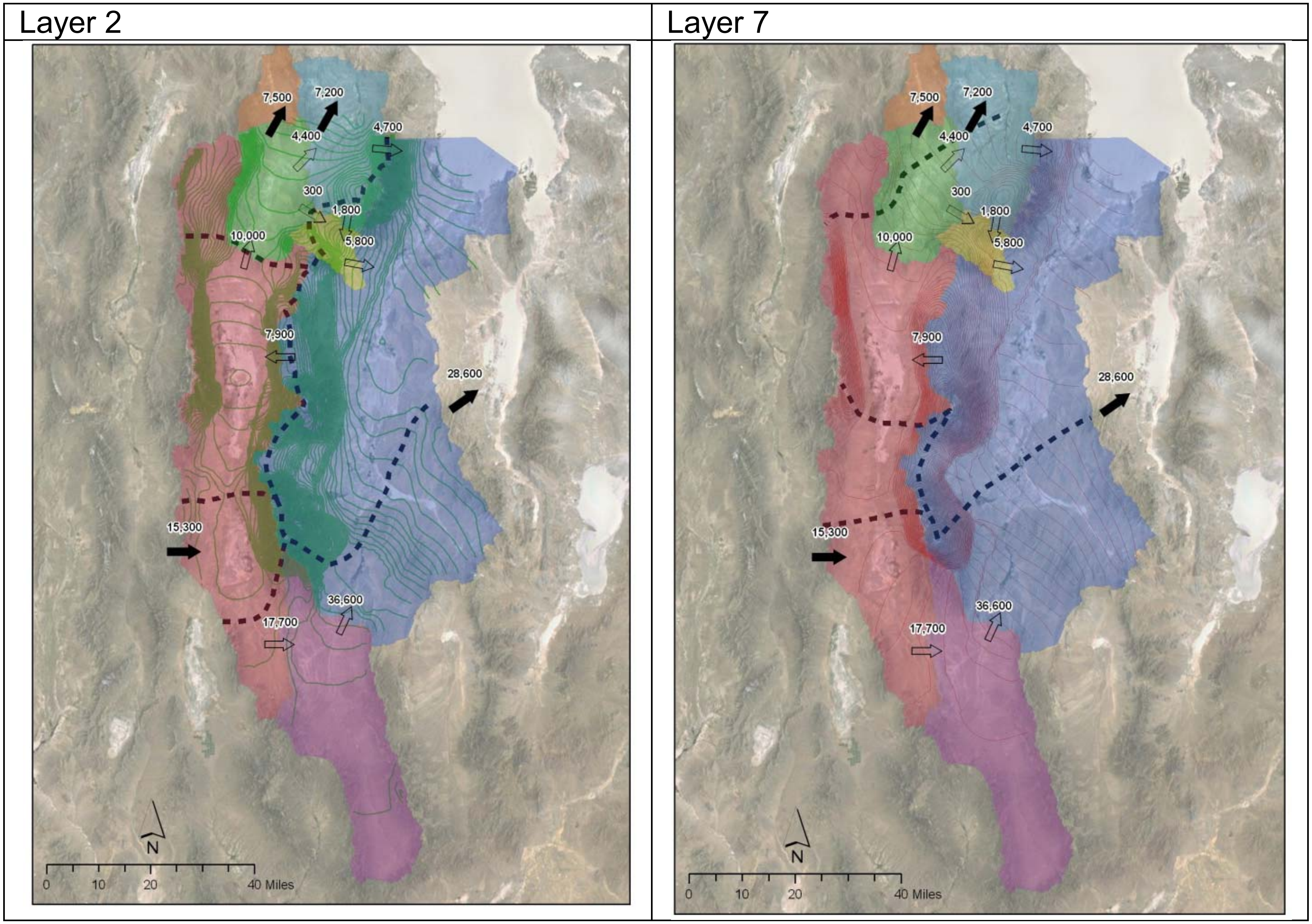
Figure 5: Steady state groundwater contours for deep wells (>200'). White and red targets are SNWA applications.

factors suggest that the use of Elderidge well to represent interbasin flow water is incorrect: first, the solute data does not properly charge balance, and second, water level elevations do not suggest eastward groundwater flow in the basin-fill other than the obvious elevation differences between Spring and Snake Valleys (Figure 5a).

In order to fully address the complications of choosing an initial water in northern Spring Valley a more complete understanding of the mechanism of interbasin flow from northern Spring Valley to Snake Valley is needed. Assuming that Elderidge well does represent the solute composition of interbasin flow water, the mean composition of Cluster 9 samples, which appear to have a similar solute chemistry, were used as substitutes for Elderidge well because the charge balances are acceptable.

The direct chemical evolution of groundwater from Spring Valley (Cluster 9) to Gandy Spring is not plausible because of the abundant ^{3}H at Gandy spring and similar ^{14}C activities at initial and final waters. Thus, realistic models must include component of modern recharge.

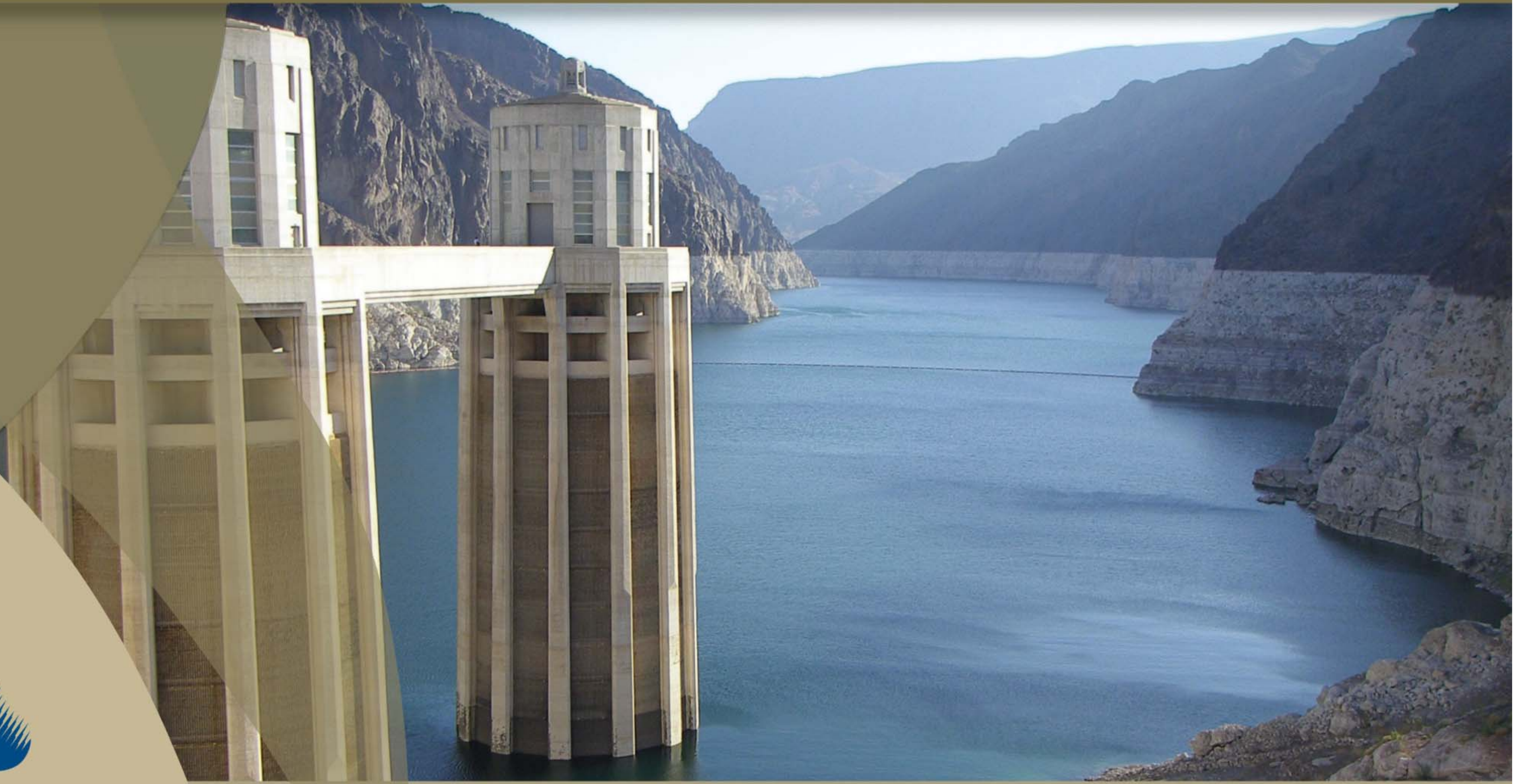
Modern recharge mixing options along the flow path include carbonate bedrock water and siliciclastic water because of these prominent bedrock types in Snake Range and Kern Mountains. NETPATH did not calculate plausible models with $\delta^{13}C$ as a constraint for any combination of modern recharge components and initial waters. The evolution of initial waters in Spring Valley (Cluster 9) and carbonate bedrock springs results in ion exchange and the dissolution of CO_2 gas, dolomite, gypsum and halite (Figure 23). $\delta^{13}C$ values computed by NETPATH are depleted (-10.11 ‰) compared to the observed range of -4.33 to -7.0 ‰ (Table 6). All models



Note: Interbasin flow represents flow across a hydrographic area boundary for the entire model thickness.

Figure 8
Flow Regions Based on Simulated Water Levels for Layers 2 and 7

Spring, Cave, Dry Lake and Delamar Valleys



SOUTHERN NEVADA
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Myers Cross
Spring Valley Part 3

Table A4–1. Current study groundwater-recharge estimates for predevelopment conditions and ranges of previously reported estimates of groundwater recharge for each hydrographic area within the Great Basin carbonate and alluvial aquifer system study area.—Continued

[All values in acre-feet per year rounded to two significant figures. Estimated error in all current study values is ±50 percent. Previously reported total groundwater recharge minimum and maximum: totals adjusted to exclude reported recharge by subsurface inflow (unadjusted estimates are presented in Auxiliary 3G). Abbreviations: HA, hydrographic area; #, number; —, no estimate]

HA #	HA name	Current study groundwater recharge estimates					Previously reported estimates	
		In-place recharge	Runoff	Mountain stream baseflow	Imported surface water	Total groundwater recharge	Total groundwater recharge (minimum)	Total groundwater recharge (maximum)
	Flow System 37: Great Salt Lake Desert System							
184	Spring Valley	99,000	9,000	48	—	110,000	33,000	100,000
185	Tippett Valley	13,000	680	0	—	14,000	5,100	12,000
186A	Antelope Valley-Southern Part	3,100	240	0	—	3,300	800	3,800
186B	Antelope Valley-Northern Part	10,000	380	0	—	10,000	2,400	10,000
189A	Thousand Springs Valley-Herrell-Brush Creek	5,300	730	26	—	6,100	1,700	7,100
189B	Thousand Springs Valley-Toano-Rock Spring	13,000	990	0	—	14,000	4,200	22,000
189C	Thousand Springs Valley-Rocky Butte Area	8,900	140	0	—	9,000	1,100	5,800
189D	Thousand Springs Valley-Montello-Crittenden	17,000	840	0	—	18,000	2,600	13,000
191	Pilot Creek Valley	4,600	250	0	—	4,800	1,800	7,400
251	Grouse Creek Valley	8,300	4,800	290	—	13,000	14,000	14,000
252	Pilot Valley	1,400	180	0	—	1,600	3,400	3,400
253	Deep Creek Valley	16,000	1,100	0	—	17,000	17,000	17,000
254	Snake Valley	150,000	6,900	280	—	160,000	99,000	120,000
255	Pine Valley	26,000	950	0	—	27,000	21,000	21,000
256	Wah Wah Valley	5,500	460	0	—	6,000	7,000	7,000
257	Tule Valley	13,000	310	0	—	13,000	7,600	7,600
258	Fish Springs Flat	1,500	140	0	—	1,600	4,000	4,000
259	Dugway-Government Creek Valley	11,000	1,800	0	—	13,000	7,000	7,000
260A	Park Valley-West Park Valley	4,300	130	0	—	4,400	—	—
261A	Great Salt Lake Desert-West Part	28,000	600	0	—	29,000	94,000	97,000
	Flow System 38: Great Salt Lake System							
260B	Park Valley-East Park Valley	1,600	1,900	330	—	3,800	—	—
261B	Great Salt Lake Desert-East Part	140	55	0	—	200	—	—
262	Tooele Valley	39,000	4,200	2,300	—	46,000	52,000	100,000
263	Rush Valley	66,000	9,300	1,800	—	77,000	34,000	34,000
264	Cedar Valley	27,000	2,000	120	—	29,000	—	—
265	Utah Valley Area	210,000	48,000	33,000	120,000	410,000	280,000	350,000
266	Northern Juab Valley	31,000	6,000	1,000	—	38,000	44,000	44,000
267	Salt Lake Valley	83,000	39,000	10,000	96,000	230,000	360,000	360,000
268	East Shore Area	26,000	42,000	1,900	220,000	290,000	150,000	150,000
269	West Shore Area	330	24	0	—	350	600	600
270	Skull Valley	23,000	2,400	0	—	25,000	40,000	40,000
271	Sink Valley	240	1.8	0	—	240	1,000	1,000
272	Cache Valley	390,000	84,000	57,000	190,000	720,000	210,000	320,000
273	Malad-Lower Bear River Area	90,000	15,000	960	330,000	440,000	380,000	380,000
274	Pocatello Valley	2,100	690	0	—	2,800	—	—

Table 2: Basinwide recharge estimates (kaf/y) for project area basins, from previous studies.

	Snake Valley	Spring Valley	Steptoe Valley	Tippett Valley	Deep Creek
Reconnaissance Reports (Hood and Rush, 1965; Rush and Kazmi, 1965; Eakin et al, 1967; NV Div of Water Resources, 1971)	103	75	85	7	17
Watson et al (1976)		63	75	5	
		33	45	6	
Nichols (2000)		104	132	13	
Epstein (2004), as referenced in Welch et al (2008)		93	101	9	
Dettinger (1989)		62			
Flint and others (2004)	93	67	111	10	12.3
	82	56	94	8	11.4
Brothers et al (1993 and 1994), as referenced in Welch et al (2008)	110	72			
Flint and Flint (2007); Welch et al (2008)	111	93	154	12	
Average (af/y)	**99.8**	**71.8**	**99.6**	**8.8**	**13.6**

Table 5.--Estimated average annual precipitation and ground-water recharge in the Snake Valley area, Nevada and Utah

Precipitation zone (feet)	Area (acres)	Estimated annual precipitation				Estimated recharge from precipitation	
		Range (inches)	Average[1] (inches)	Average (feet)	Average (acre-feet)	Percentage of precipitation	(acre-feet per year)
Above 9,000	83,900	>18	20	1.67	140,000	21	29,400
8,000 to 9,000	127,000	16-18	17	1.42	180,000	14	25,200
7,000 to 8,000	240,000	13-16	14.5	1.21	290,000	8	23,200
6,000 to 7,000	601,000	11-13	12	1	331,000 a 270,000	5 a 1	16,600 2,700
5,000 to 6,000	767,000	8-11	9.5	.79	606,000	1	6,100
below 5,000	412,000	<8	6	.5	206,000	0	0
Total (rounded)	2,230,000				2,000,000		100,000
Estimated ground-water underflow from southern Spring Valley to northern Hamlin Valley.							+4,000
Estimated average annual recharge from all sources, in the Snake Valley area (rounded).							105,000

1. Based on general relation shown by 20 stations listed in table 1.

a. In Hamlin Valley, 1 percent of 270,000 acre-feet used for zone, because most of that area is alluvium.

Table 3. Estimated average annual precipitation, runoff, and recharge for 1895–2006, by subbasin, Basin and Range carbonate-rock aquifer system, Nevada and Utah.

[All values multiplied by 1,000 and rounded to nearest 0.5 acre-ft. **Precipitation:** Values based on Parameter-Elevation Regressions on Independent Slopes Model (PRISM; Daly and others, 1994). **Runoff and Recharge:** Values for 1895–2006 estimated from threshold limited power function. Recharge runoff, equals 15 percent of estimated total runoff. Total recharge, equals in-place recharge plus runoff recharge.**Abbreviations**: ft, feet]

Subbasin	Area (acres)	Precipitation (acre-ft)	Runoff (acre-ft)	Recharge (acre-ft)		
				In-place	Runoff recharge	Total
			Butte Valley			
1	317	339	9	29	1	30
2	144	131	4	4	1	5
			Cave Valley			
1	93	103	4	5	1	6
2	131	142	2	5	0	5
			Jakes Valley			
1	253	261	6	15	1	16
			Lake Valley			
1	253	242	8	8	1	9
2	97	138	11	2	2	4
			Little Smoky Valley–northern part			
	372	246	1	4	0	4
			Little Smoky Valley–central part			
	38	22	0	0	0	0
			Long Valley			
1	435	407	8	24	1	25
			Newark Valley			
1	106	98	2	7	0	7
2	194	160	7	4	1	5
3	220	200	3	8	0	8
			Snake Valley			
1	359	259	13	1	2	3
2	710	567	27	34	4	38
3	558	479	35	23	5	28
4	460	467	7	32	1	33
5	283	387	32	4	5	9
			Spring Valley			
1	101	120	6	12	1	13
2	570	618	60	46	9	55
3	253	253	19	18	3	21
4	152	140	6	4	1	5
			Steptoe Valley			
1	600	589	29	59	4	63
2	431	463	31	59	5	64
3	220	251	9	26	1	27
			Tippett Valley			
1	211	209	6	11	1	12
			White River Valley			
1	237	227	10	7	2	9
2	270	216	1	3	0	3
3	199	182	3	16	0	16
4	338	267	2	7	0	7
Total	860 4	8,185	361	476	53	530

Introduction

This report documents the implementation of the conceptual model of groundwater flow in Spring and Snake Valley into a numerical groundwater model. The conceptual model was completed as Myers (2011a). Throughout this report, Myers (2011a) is referred to as Part A.

The conceptual model (Part A) describes the flow directions and rates within and into and from Spring, Tippett, and Snake Valley, Nevada and Utah. The conceptual model accurately represents the flow into, from, and within the model domain (Part A). The general hydrogeologic formations, faults, recharge rates by subbasin, evapotranspiration (ET) rates and locations, flow directions, and interbasin flow estimates are accurate at a basin and subbasin scale. It includes accurate descriptions of the flow at major springs. However, the conceptual model contains significant uncertainties.

The biggest uncertainty comes in the estimate of spring flow and groundwater ET (GWET). For example, GWET is often calculated as the difference between ET rates and annual precipitation at a point; in large phreatophyte areas with low ET, such as much of Snake Valley, an error of half an inch in the annual precipitation estimate can be thousands of acre-feet of difference in the GWET estimate. Adding to this the uncertainty in estimating the area of phreatophyte type, and the estimated GWET from a basin is very uncertain. In Snake Valley, holding all else equal, a decrease in GWET just increases the amount of water discharging to the Great Salt Lake basin (to the northeast of Snake Valley). In Spring Valley, the difference would be the amount discharging from springs to playas or to Tippett or Snake Valley as interbasin flow. Another example is the difference in springs and GWET discharge. Most springs in these valleys support large phreatophyte communities, but are areas of with high water tables. It is very difficult to discern whether the ET from a wetland is from a spring or directly from groundwater. For the purpose of large-scale modeling, it is not relevant.

The purpose of the model is to predict future conditions due to pumping large quantities of water from various parts of the valleys. These predictions rely on a conceptual models and parameterization of numerical models without ever having stressed the aquifers, especially in Spring Valley, at rates remotely similar to the proposed pumping.

Predictions completed with any numerical model of this area provide good estimates of the level of magnitude of impacts to be expected. The model is far more than an interpretative model (Hill and Tiedeman, 2007), but the predictions should be considered accurate, not precise. Accurate because the processes affecting the considered estimates are accurate but not precise because of the uncertainties outlined above.

Part A presents the conceptual model including water balance implemented in this numerical model. It also includes descriptions of the formation properties, including conductivity and thickness.

Table A5–1. Current study groundwater-discharge estimates for predevelopment conditions and ranges of previously reported estimates of groundwater discharge for each hydrographic area within the Great Basin carbonate and alluvial aquifer system study area.—Continued

[All values in acre-feet per year rounded to two significant figures. Estimated error in all current study values is ±30 percent. Previously reported total groundwater discharge minimum and maximum: totals adjusted to exclude groundwater discharge by subsurface outflow (unadjusted estimates are presented in Auxiliary 3P). Abbreviations: HA, hydrographic area; #, number; ETg, groundwater evapotranspiration; —, no estimate]

HA #	HA name	Current study groundwater discharge estimates						Previously reported estimates	
		ETg	Mountain streams	Basin-fill streams/ lakes/ reservoirs	Springs	Adjustment to natural discharge for well withdrawals	Total groundwater discharge	Total groundwater discharge (minimum)	Total groundwater discharge (maximum)
Flow System 37: Great Salt Lake Desert System									
184	Spring Valley	65,000	480	0	17,000	0	82,000	71,000	90,000
185	Tippett Valley	2,000	0	0	0	0	2,000	0	2,900
186A	Antelope Valley-Southern Part	210	0	0	0	0	[13]210	[2,13]0	—
186B	Antelope Valley-Northern Part	100	0	0	0	0	100	[2]100	—
189A	Thousand Springs Valley-Herrell-Brush Creek	1,500	260	0	0	240	2,000	[2]1,800	—
189B	Thousand Springs Valley-Toano-Rock Spring	1,600	0	0	0	0	1,600	[2]1,700	—
189C	Thousand Springs Valley-Rocky Butte Area	1,200	0	0	0	0	1,200	[2]1,200	—
189D	Thousand Springs Valley-Montello-Crittenden	12,000	0	0	2,600	0	15,000	[2]14,000	—
191	Pilot Creek Valley	4,000	0	0	1,400	0	5,400	[2]4,600	—
251	Grouse Creek Valley	11,000	960	0	0	1,400	13,000	[2]13,000	—
252	Pilot Valley	6,900	0	0	480	0	7,400	[2]7,600	—
253	Deep Creek Valley	14,000	0	0	4,400	0	18,000	14,000	17,000
254	Snake Valley	100,000	2,800	0	30,000	0	130,000	82,000	130,000
255	Pine Valley	0	0	0	0	0	[11]0	[11]7,000	[11]7,100
256	Wah Wah Valley	620	0	0	900	0	1,500	1,400	1,500
257	Tule Valley	37,000	0	0	1,000	0	38,000	32,000	40,000
258	Fish Springs Flat	8,000	0	0	26,000	0	34,000	35,000	35,000
259	Dugway-Government Creek Valley	1,000	0	0	5,100	0	[1]6,100	[1]3,800	[1]3,800
260A	Park Valley-West Park Valley	4,100	0	0	1,200	0	5,300	—	—
261A	Great Salt Lake Desert-West Part	56,000	0	0	18,000	0	74,000	[2]83,000	—
Flow System 38: Great Salt Lake System									
260B	Park Valley-East Park Valley	11,000	1,100	0	0	0	12,000	—	—
261B	Great Salt Lake Desert-East Part	7,400	0	0	0	0	7,400	—	—
262	Tooele Valley	17,000	7,800	0	24,000	13,000	62,000	66,000	68,000
263	Rush Valley	27,000	5,900	0	0	3,400	36,000	[2]32,000	—
264	Cedar Valley	0	390	0	3,700	0	4,100	—	—
265	Utah Valley Area	49,000	110,000	81,000	110,000	64,000	410,000	310,000	500,000
266	Northern Juab Valley	4,400	3,400	5,800	13,000	11,000	38,000	[2]41,000	—
267	Salt Lake Valley	60,000	34,000	170,000	20,000	75,000	360,000	[2]360,000	—
268	East Shore Area	8,000	6,200	0	70,000	35,000	120,000	[2]130,000	—
269	West Shore Area	2,400	0	0	4,700	0	7,100	[2]6,800	—
270	Skull Valley	27,000	0	0	4,100	3,500	35,000	[2]35,000	—
271	Sink Valley	0	0	0	0	0	[14]0	[2,14]200	—
272	Cache Valley	63,000	190,000	130,000	130,000	27,000	[1]540,000	[1]280,000	[1]330,000
273	Malad-Lower Bear River Area	130,000	9,600	130,000	86,000	11,000	370,000	[2]370,000	—
274	Pocatello Valley	0	0	0	0	0	0	—	—
275	Blue Creek Valley	700	0	0	7,700	0	8,400	[2]8,500	—

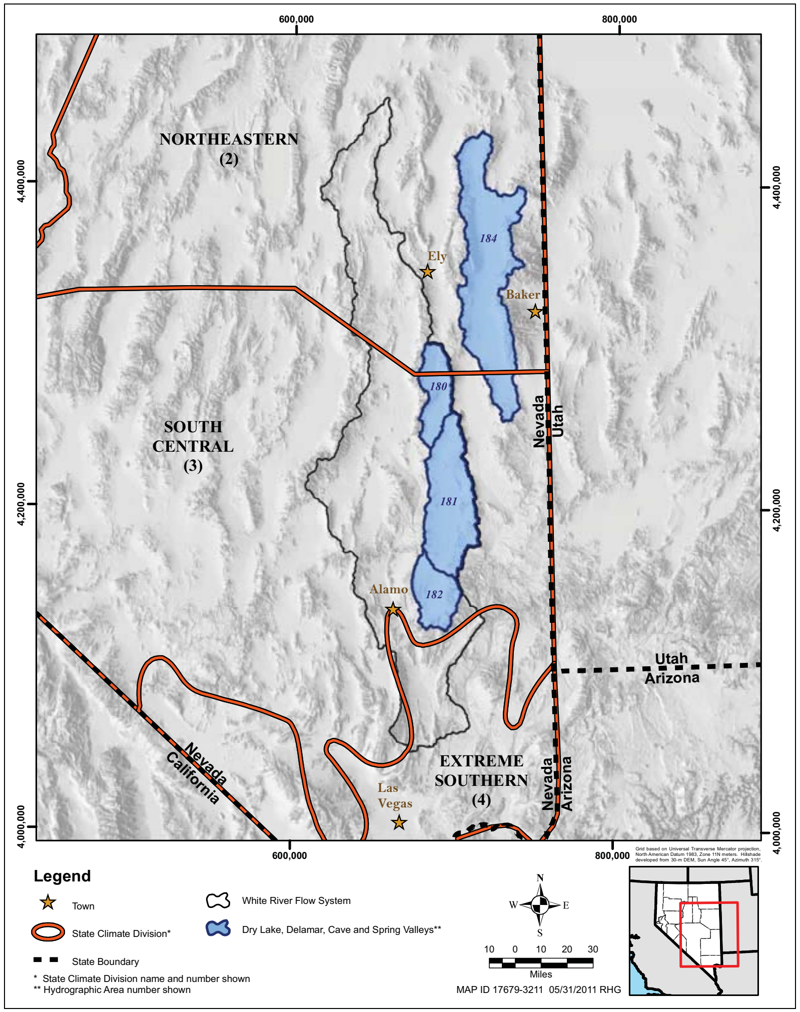
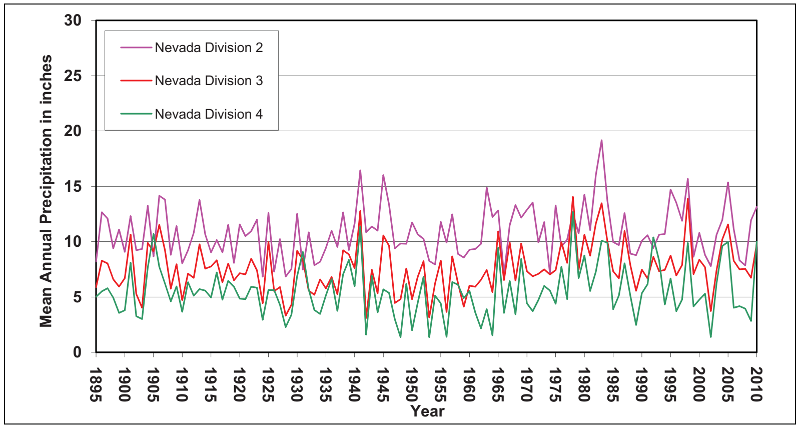


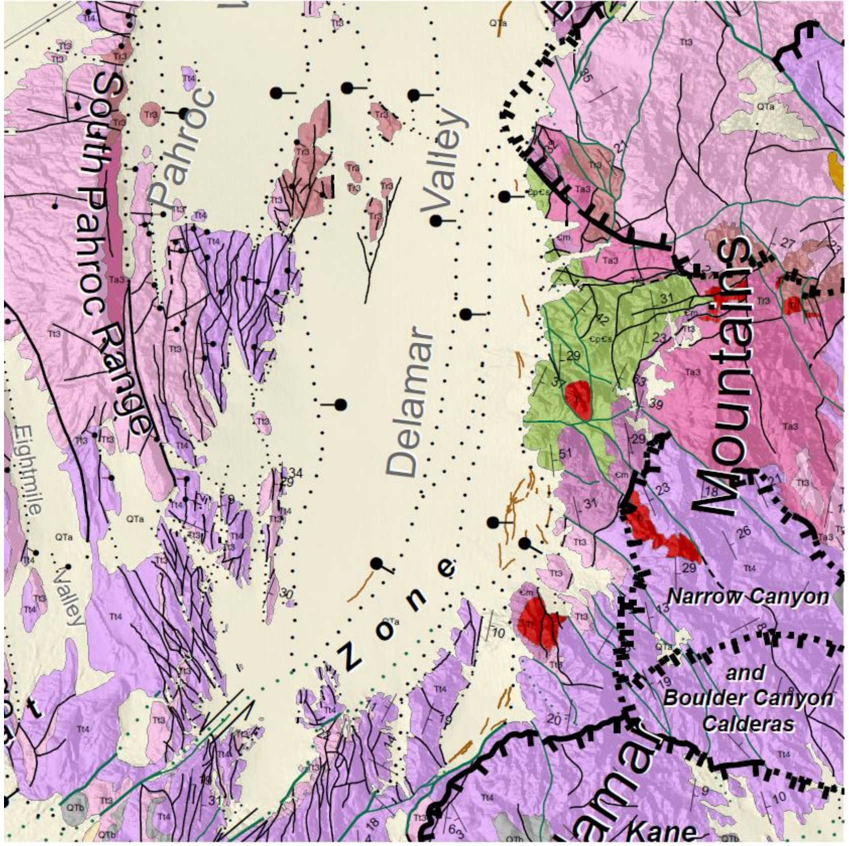
Figure B-8
Location of U.S. Climate Divisions in the Area of Interest



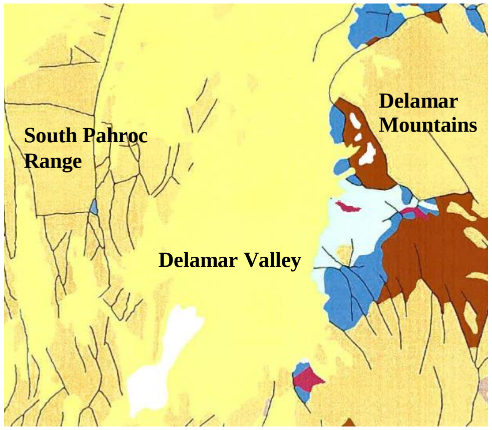
Source: NOAA (2011)

Figure B-9
Historical Precipitation Variability in the Area of Interest

1:250,000 Geology Map of Delamar Valley and Vicinity (Rowley et al. 2011; Plate 1)



1:500,000 Geology Map of Delamar Valley and Vicinity (Stewart, J.H., and Carlson, J.E., 1978)



Shown above are examples of the same area of Nevada that were geologically mapped at two different scales (1:250,000 and 1:500,000). The Rowley et al. 2011 geology map was completed at a 1:250,000 scale and shows greater detail to the geologic structures and units. The 1:250,000 map illustrates interbasin structures (faults within the valley floor) and types of faults (i.e. black normal, brown quaternary, green lateral faults, and caldera boundaries), whereas the 1:500,000 map of Stewart, J.H., and Carlson, J.E., 1978 display fewer structures and does not distinguish the type of structure. The reason that the maps were completed at different scales is the 1:500,000 mapped the entire state of Nevada (which requires less detail), while the 1:250,000 scale map focused on the SNWA project area and provide greater detail to the geologic structures and units.

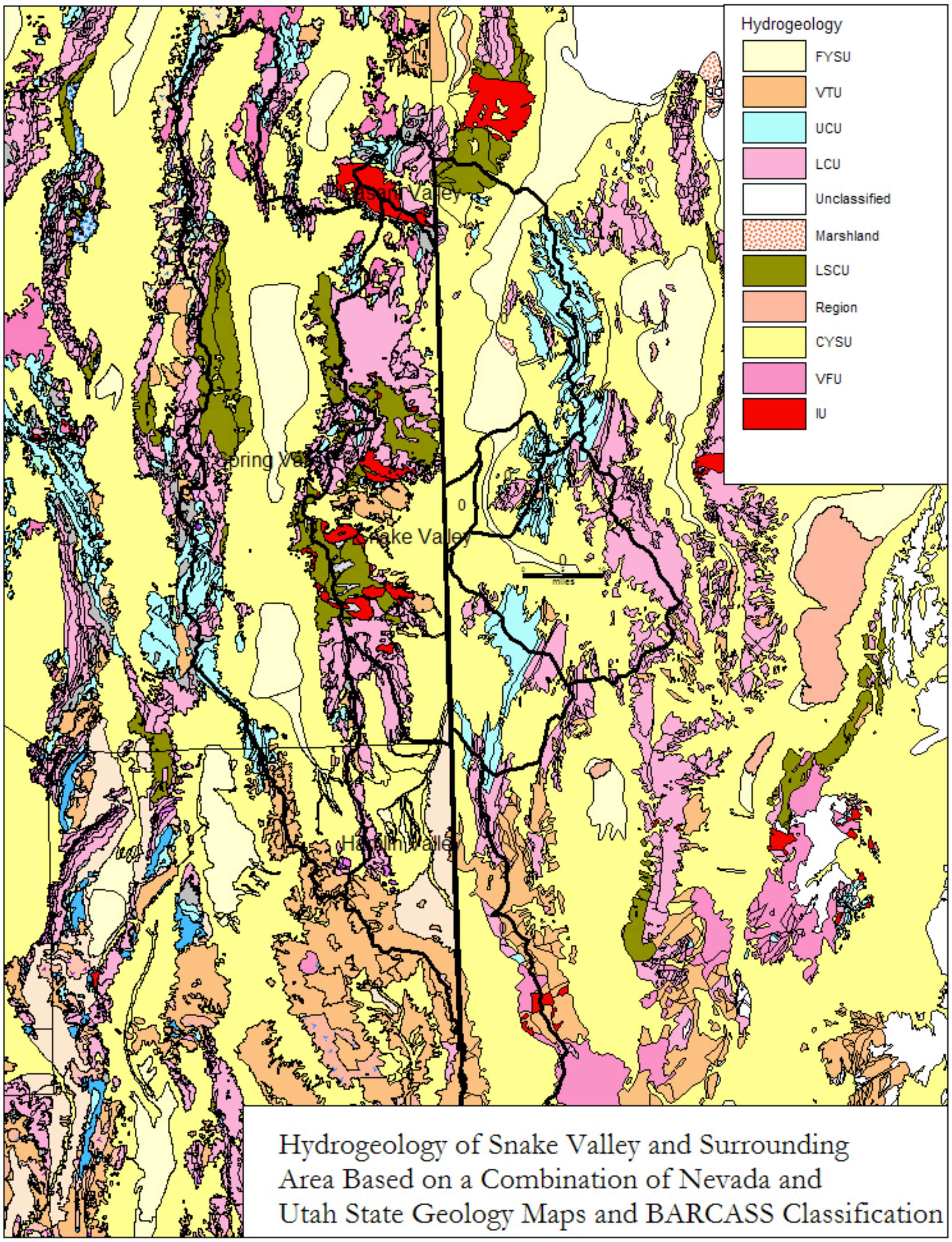


Figure 9: Hydrogeology of Spring and Snake Valley study area. See Table 1 for a description of the hydrogeology. Geology base prepared from Crafford (2007) and Hintze et al (2000).

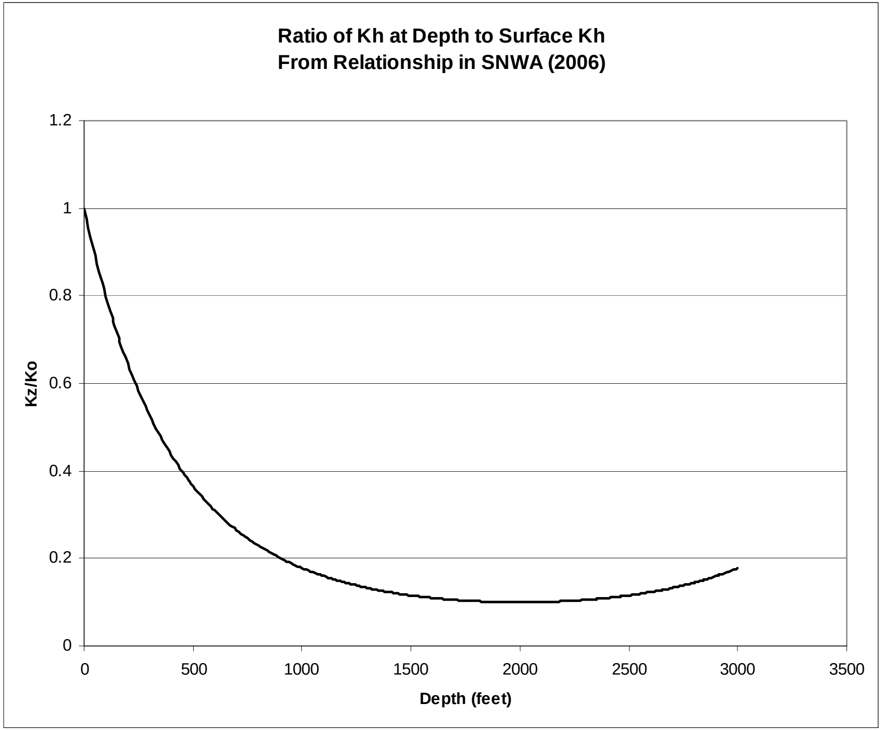


Figure 11: Variation of conductivity with depth for upper valley fill (Durbin, 2006).

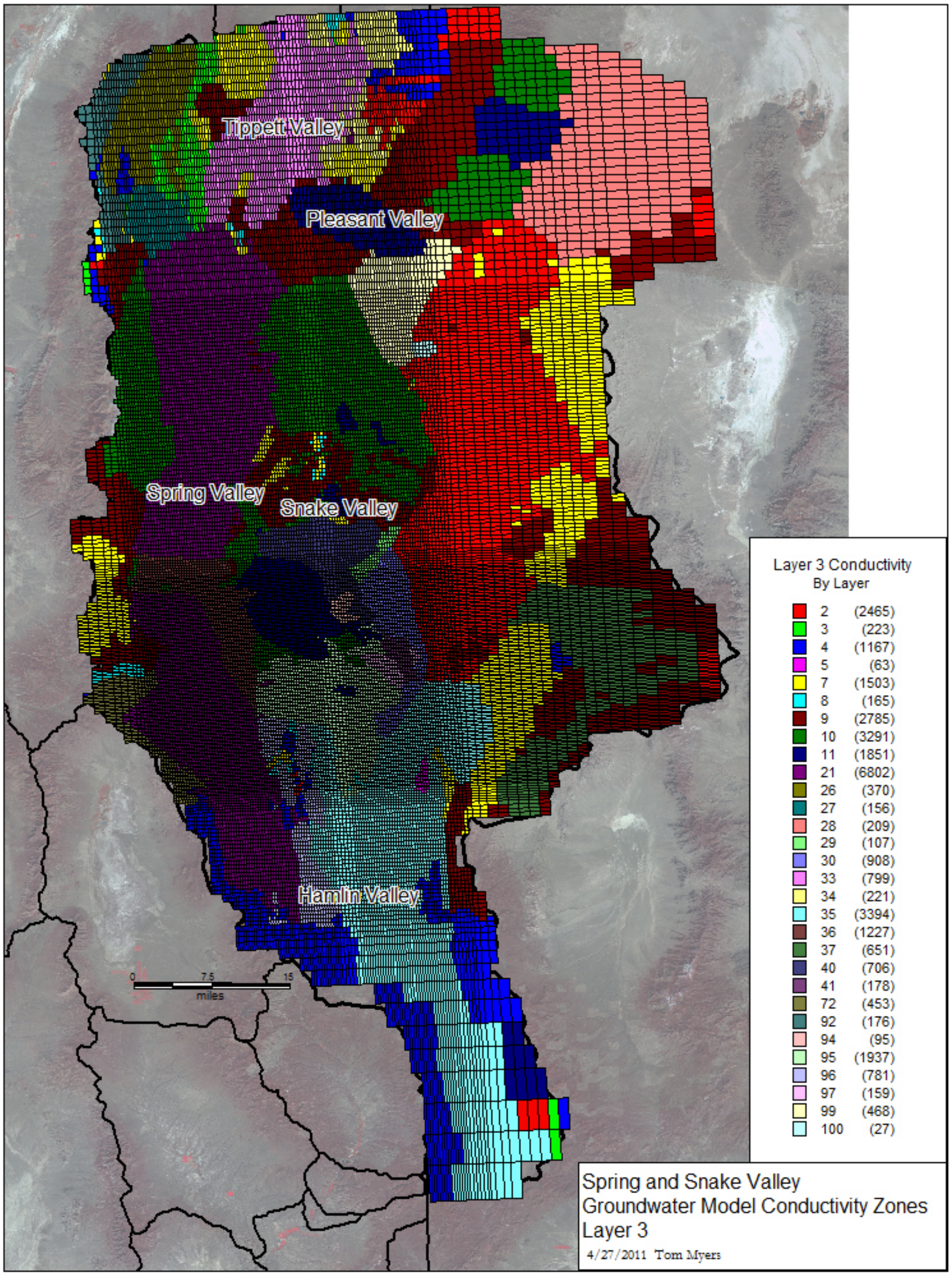
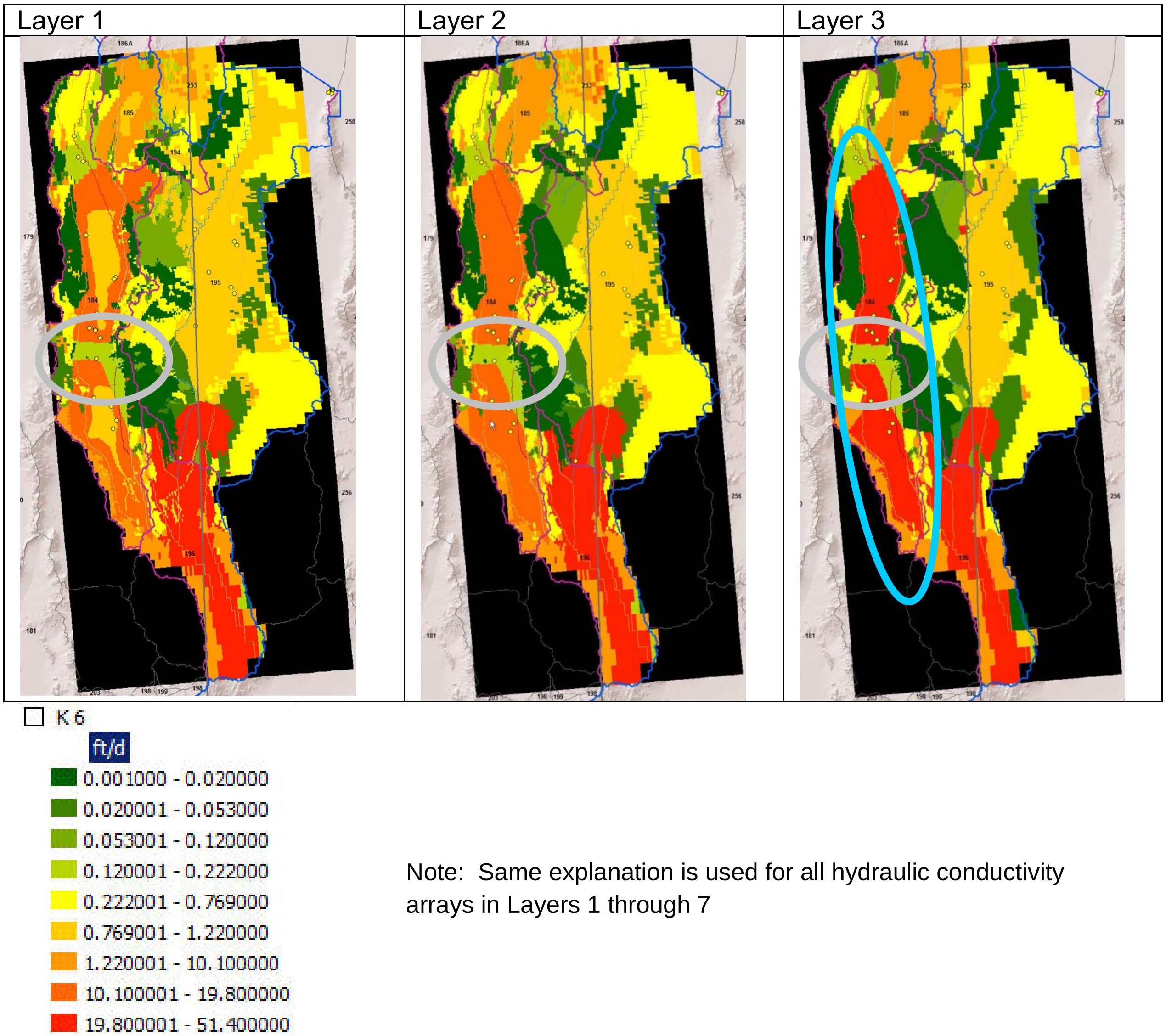


Figure 5: Conductivity parameter zones for the Spring and Snake Valley Groundwater Model, layer 3.

1.1 Hydraulic Conductivity and Transmissivity Distributions

A series of highly interpretive hydrogeologic features are clearly present in the hydraulic conductivity and transmissivity distributions incorporated into the model. The justification for incorporating these features is rarely if ever provided in the Myers (2011b) report. These features are not adequately associated with known hydrogeologic units or structures.



Note: Same explanation is used for all hydraulic conductivity arrays in Layers 1 through 7

Figure 1
Hydraulic Conductivity Distribution in Layers 1, 2, and 3

In Figure 1 (above), various unusual hydrogeologic features are apparent, including:

1. A small-K (hydraulic conductivity) unit separating north and south Spring Valley (circled in Gray) has been placed into the Myers model in Layers 1, 2, and 3. This east-west trending unit forces the model to simulate a groundwater divide between north and south Spring Valley

Guideline 4: Include many kinds of data as observations in the regression

Guideline 4 stresses the importance of using as many kinds of observations as possible. For example, in ground-water flow problems, it is important to augment commonly available hydraulic-head observations with flow observations. The latter serve to constrain solutions much more than the relatively easy to fit hydraulic heads and, therefore, using observations that reflect the rate and(or) direction of ground-water flow tends to promote the development of more accurate models. MODFLOWP supports many types of observations relevant to ground-water flow problems, such as hydraulic heads, temporal changes in hydraulic head, streamflow gains and losses, and advective travel (Hill, 1992; Anderman and Hill, 1997). An advantage of UCODE is that it allows any quantity to be used as an observation for which a simulated equivalent value is printed in any application model output file, or for which a simulated equivalent value can be calculated from the values printed in any application model output file. A detailed analysis of the importance of different types of observations and how to conduct such an analysis is presented by Anderman and others (1996).

In some circumstances, it may appear that guideline 4 could be addressed by using contoured values to increase the number of observations. In a ground-water example, Neuman (1982), Clifton and Neuman (1982), Neuman and Jacobson (1984), and Carrera and Neuman (1986) used kriging to interpolate hydraulic-head measurements to generate hydraulic heads used in the regression. When kriging is used, the associated kriging variances and variogram can be used to calculate the variance-covariance matrix on hydraulic-head observation errors needed to calculate the weighting. The advantage of interpolation methods is that more hydraulic-head values are available for the regression. As shown by Cooley and Sinclair (1976) and noted by Hill (1992), the disadvantage of interpolation methods is that the interpolated hydraulic heads are not based on the physics of ground-water flow, so that interpolated values generally do not respect the underlying processes represented in the model. This problem can be severe if aquifer properties change rapidly because the interpolation method would tend to make the ‘observed’ hydraulic-head distribution unrealistically smooth. Use of interpolated values in the regression procedure produces correlation between the errors, so use of a full weight matrix may be important. These problems are avoided if the observations are used directly in the regression.

Guideline 5: Use prior information carefully

Using prior information allows direct measurements of model input values to be included in the regression. Prior information is treated differently than observations in this work because relevant observations generally can be measured more accurately than model-input values. Indeed, that is the most fundamental characteristic of the problems considered in this work. If the measurements of the model input values were accurate and applicable to the scale of the model, model calibration would be unnecessary or less important. Thus, it is suggested that the generally more accurate observations be emphasized more than the relatively less accurate prior information. Prior information takes on an important, but less central role in the suggested methodology. For problems with more accurate prior information, the prior information might be treated more like the obconfidence intervals on the parameter values (eq. 28).

Guideline 6: Assign weights that reflect measurement errors

The weights are an important part of the regression, and assigning appropriate values can be confusing. The guideline presented here has a solid statistical basis and provides substantial guidance in most circumstances. For regression methods to produce parameter estimates with the smallest possible variance, the weighting needs to be proportional to the inverse of the variance-covariance matrix of the measurement errors (Appendix C). For a diagonal weight matrix, this means that the weights need to be proportional to one divided by the variance of the measurement errors. This definition of the weights results in two consequences that have substantial intuitive appeal: (a) Relatively accurate measurements are weighted more heavily than relatively inaccurate measurements, and (b) although different observations may have different units, weighted quantities have the same units and can, therefore, be summed in equation 1 or 2. Based on this guideline, information independent of the model is used to determine the weights, so that issues related to the weights are less likely to obscure model error or problems related to the data.

For problems with observations of a simgle type and measured with apparently equal error, on average, it generally is easiest to set all weights equal to 1.0, as was done for the Theis problem of figure 2. In this situation, the calculated error variance has the units of the observations.

For problems with more than one kind of observation, as well as prior information on the parameters, it is more convenient to define the weighting to equal the inverse of the variance-covariance matrix of the measurement errors instead of being proportional to it (Hill and others, 1998). This guideline encourages the user to compare the weights used to what the weights should be theoretically. If it is suspected that another weighting is needed to achieve, for example, randomly weighted residuals at optimal parameter values, this can be tested and placed in context relative to the assumed measurement error statistics. In addition, the assumed statistics of the measurement errors can be compared with the fit to the data achieved by the regression to provide a check on the weights used, as discussed under guideline 8.

UCODE and MODFLOWP read statistics from which the variances of the observation errors and then the weights are calculated. The statistics can equal the variance, standard deviation, or coefficient of variation of the measurement error of the observations or prior information. Values for these statistics rarely are known in practice. Although assignment of values for the statistics, therefore, is subjective, in most circumstances the estimated parameter values and calculated statistics are not very sensitive to moderate changes in the weights used. Several examples of using commonly available data to determine weights are described in the following paragraphs. MODFLOWP also allows a full weight matrix, with covariances as well as variances, to be used. The following examplesfocus primarily on determining the more commonly used diagonal weighting, specific yield within what's reasonable, more water is removed from storage and less drawdown occurs, but if I were to decrease the values to be more in line with these other modelers, the drawdown would have been higher.

I want to address complexity a little bit again. This model presents predictions that are consistent with our current understanding of the valley. I'm definitely going to say that extending this to 1,000 years or 22,000 years definitely is making a prediction that's probably not supported by our understanding of it, but I just wanted to bracket some values or provide the State Engineer with some talking points or points of going beyond a certain level.

I'm going to bring up another presentation I've recently seen, one written by Eileen Potter, one might wonder why I would put in the title of her 2006 Darcy lecture, if all models are wrong, some are better than others or something to that effect.

The reason why I bring that up is what she does in this talk is emphasizing more complexity with the model, adding more things if you don't know, if they're not well parameterized, it's just as bad as not sufficient enough complexity. Thus, I'm going to conclude or I'm going to suggest the thought at least that the Southern Nevada Water Authority wants to rely on the complexity of the system to avoid making predictions.

Introduction

This report documents the implementation of the conceptual model of groundwater flow in Spring and Snake Valley into a numerical groundwater model. The conceptual model was completed as Myers (2011a). Throughout this report, Myers (2011a) is referred to as Part A.

The conceptual model (Part A) describes the flow directions and rates within and into and from Spring, Tippett, and Snake Valley, Nevada and Utah. The conceptual model accurately represents the flow into, from, and within the model domain (Part A). The general hydrogeologic formations, faults, recharge rates by subbasin, evapotranspiration (ET) rates and locations, flow directions, and interbasin flow estimates are accurate at a basin and subbasin scale. It includes accurate descriptions of the flow at major springs. However, the conceptual model contains significant uncertainties.

The biggest uncertainty comes in the estimate of spring flow and groundwater ET (GWET). For example, GWET is often calculated as the difference between ET rates and annual precipitation at a point; in large phreatophyte areas with low ET, such as much of Snake Valley, an error of half an inch in the annual precipitation estimate can be thousands of acre-feet of difference in the GWET estimate. Adding to this the uncertainty in estimating the area of phreatophyte type, and the estimated GWET from a basin is very uncertain. In Snake Valley, holding all else equal, a decrease in GWET just increases the amount of water discharging to the Great Salt Lake basin (to the northeast of Snake Valley). In Spring Valley, the difference would be the amount discharging from springs to playas or to Tippett or Snake Valley as interbasin flow. Another example is the difference in springs and GWET discharge. Most springs in these valleys support large phreatophyte communities, but are areas of with high water tables. It is very difficult to discern whether the ET from a wetland is from a spring or directly from groundwater. For the purpose of large-scale modeling, it is not relevant.

The purpose of the model is to predict future conditions due to pumping large quantities of water from various parts of the valleys. These predictions rely on a conceptual models and parameterization of numerical models without ever having stressed the aquifers, especially in Spring Valley, at rates remotely similar to the proposed pumping.

Predictions completed with any numerical model of this area provide good estimates of the level of magnitude of impacts to be expected. The model is far more than an interpretative model (Hill and Tiedeman, 2007), but the predictions should be considered accurate, not precise. Accurate because the processes affecting the considered estimates are accurate but not precise because of the uncertainties outlined above.

Part A presents the conceptual model including water balance implemented in this numerical model. It also includes descriptions of the formation properties, including conductivity and thickness.

INTRODUCTION

The Southern Nevada Water Authority (SNWA) proposes to develop 91,200 af/y of groundwater in Spring Valley of eastern Nevada. This report was prepared on behalf of the Great Basin Water Network, the Confederated Tribes of the Goshute Reservation, and a coalition of protestants to those water right applications. This report assembles evidence supporting the conclusion that pumping the proposed amount of groundwater, or even a substantial portion of that amount, will cause substantial drawdown and detrimental effects to the groundwater levels, spring discharge, wetland evapotranspiration (ET), and water rights in Spring and adjoining valleys.

SNWA filed applications for 19 water rights within Spring Valley (basin 184) in 1989 along with other applications for water rights in many other eastern Nevada basins. SNWA also filed six water rights applications in Cave Valley, Dry Lake Valley, and Delamar Valley, to which GBWN and the same coalition also are protestants. I have prepared a separate evidence report concerning the effects of pumping in those valleys.

SNWA's Spring Valley applications number from 54003 to 54021. All are considered as "ready for action protested" (RFP).

Figure 1 shows the general layout of Spring, Snake, Tippett and surrounding valleys and SNWA's applications. Applications 54003 through 54018 are for 6 cfs and the remaining three applications are for 10 cfs, also referred to as "underground basin in Spring Valley" or "underground rock aquifer in Spring Valley", respectively. This report analyzes pumping the applications as proposed and at two lower pumping rates, 60,000 and 30,000 af/y to provide a range of impacts for evaluation.

This evidence report presents both overarching and hydrogeologically particularized conclusions about the likely effects of the proposed action. These conclusions are drawn from two sources – the conceptual model (Myers 2011a) and the numerical model of Spring Valley (Myers, 2011b). The first, overarching, conclusion is that the amount of water applied for exceeds the conceptual flow model of Spring Valley, meaning that the request exceeds the perennial yield based on the recharge and discharge within the valley. Pumping SNWA's applications will cause a continuing drawdown of the groundwater table and draw water from or prevent groundwater from reaching adjacent valleys.

The second set of conclusions is presented through the simulation of the impacts caused by actually pumping these applications in the scenarios described using the numerical groundwater model of Spring and Snake Valleys, and adjoining areas, developed over the past few years (Myers, 2011b). I based the numerical model on the conceptual model developed in Myers (2011a).

The remainder of this evidence report refers to Myers (2011a) and Myers (2011b) as Part A and Part B, respectively.

The NSE currently specifies perennial yield in Spring Valley to be 80,000 af/y (NSE web page, http://water.nv.gov/data/underground/printableSummary.cfm?basin=184&CFID=653613&CFTOKEN=25781569, downloaded 5/17/11, reproduced in Appendix A).

EFFECTS OF SNWA WATER RIGHTS APPLICATIONS ON WATER BALANCE

SNWA's water right applications sum to approximately 91,200 af/y. Any amount granted would be diverted from the valley and is therefore an effective consumptive use to Spring Valley.

Recharge estimates for Spring Valley average about 72,000 af/y (Part A). The ten individual estimates vary around the mean by about plus/minus 30,000 af/y. Three of the most recent estimates, based on the basin characterization method and made by the same hydrologists (Flint et al, 2004; Flint and Flint, 2007), were 56,000, 67,000, and 93,000 af/y. The variation reflected different assumptions of climate record and the model cell size. Considering that the same method yielded such a range of estimates, it is very unlikely that any estimate could be considered as most accurate, especially in light of the effects that climate change may have on groundwater recharge. Even if the historic period could provide a stationary record for recharge, the future will deviate from that record. Because of all the uncertainties in these estimates, the average from Part A, 72,000 af/y, is a good estimate of recharge for comparison.

Discharge from the valley may be more easily estimated, because it is based on phreatophyte areas that can be measured and ET rates that can be estimated. Any given estimate, however, reflects conditions at the time the areas are measured. Wetland and phreatophyte areas, ET rates, and the proportion of ET satisfied by precipitation would vary annually. The point is that estimates of GWET are highly dependent on antecedent conditions, as Myers (2006b) argued in rebuttal for the first Spring Valley hearing. Based on that preamble, the BARCAS estimate of 75,600 af/y for Spring Valley is an acceptable middle-of-the-road estimate (Part A).

The average recharge and discharge for Spring Valley could be considered within measurement error of being the same value. SNWA's total applied-for water rights exceed the average recharge and discharge by 27 and 20 percent, respectively.

BARCAS was the first study to estimate substantial amounts of interbasin inflow to Spring Valley from Steptoe and Lake Valley, about 33,000 af/y, and from Spring Valley to Snake Valley, about 49,000 af/y. These estimates are much higher than any previous estimates, and essentially depend on very high recharge estimates in Steptoe Valley (Welch et al, 2008). They are also higher than simulated in steady state using the groundwater model in Part B.

Irrigation underground rights total 18,908 af/y and mining and milling rights total 1,361 af/y; total underground (UG) permitted and certificated rights total 11,414 and 10,262 af/y, respectively, as of May 17, 2011 (see Appendix A for a summary from the NSE Web page). Total UG certificated and permitted water rights exceed 25 percent of the NSE perennial yield and 28 percent of the BARCAS ET discharge estimate. The basin has significant underground water rights development. The difference

Scenarios 2 and 3: Pumping Less Water from the Application

The full application amount for Spring Valley totals approximately 91,200 af/y, which exceeds the recharge to and discharge from the valley. As will be discussed in Results below, this pumping rate pulls water from adjoining valleys and causes excessive drawdown. Therefore, I chose two lower pumping rates to consider the effects of pumping less water from Spring Valley. These new scenarios pumped from the same points of diversion and model layers, but the total from the valley was reduced to 60,000 and 30,000 af/y, respectively, or two-thirds and one-third of the original amount. Each well pumping rate was reduced proportionally.

Results

I present the results of simulating the scenarios with drawdown maps, monitoring well hydrographs, and flux hydrographs for boundaries around the model domain below. The drawdown maps present contours at the 1-, 5-, 10-, 20-, 50-, 100-, 500-, 1000-, and 2000-foot levels. The 2000-ft drawdowns occur near two wells and exceed the layer thickness, as described above.

One-foot contours show the total reach of these proposals. Some argue that one-foot (anything less than 10 feet) drawdown is within the seasonal variability and measurement accuracy of the wells and therefore should not be considered. Both points are correct, however the smaller drawdowns merely superimpose on top of the natural variability. A phreatic spring by definition is one for which the water table is at the ground surface. Lowering the water table by a foot turns a flowing spring into a mud hole. Lowering the water table by a foot even with natural variability increases the time that the spring is dry. The one-foot drawdown therefore provides a more complete rendition of the springs which could be affected.

Three of the applications caused drawdown to below the layer bottoms. This is due to the relatively low conductivity – calibrated values that are too low to actually pump 6 or 10 cfs on a sustained basis. In the simulation, the cells remain active, and the wells continue to remove water from the model domain, because the layer was simulated as confined. The reality is that SNWA would not be able to pump this amount from these three locations. Although this amount of pumping yields inaccurate predictions at the well, the excessive drawdown would limit the extent of drawdown predicted through the remainder of the valley because the volume of the actual cone simulated within the model is larger near the well than would in reality occur. This release from storage would satisfy pumping requirements that otherwise would be drawn further from the well. Although it is probably not substantial, the model is conservative in favor of SNWA in that it slightly underpredicts the extent of drawdown due to pumping the full application amount.

Drawdown hydrographs show the amount that water levels or potentiometric surfaces drop from the initial water level as a result of pumping without regard to the actual water level. The initial water level is a baseline and drawdown should be considered as a difference from the pre-pumping condition rather than an exact water level prediction. A similar point applies to the flux hydrographs. The starting flux is that resulting from steady state calibration, which accurately but not precisely

Table 6: Water balance fluxes for select regions of the model domain, including Spring Valley, Tippett Valley7, and the north end of Hamlin Valley. The water balance was determined by digitizing basin boundaries with GWVistas.

Spring Valley	
	Net (af/y)
West	192.8
East to Snake, Hamlin, and Tippet Valley	-19788.8
North	-1945.5
South	1631.5
Recharge	80581.6
ET	-56043.8
Spring Flow	-19966.1
Interbasin Flow (GHB 31 and 32)	15337.7
Tippett Valley	
West	9522.2
East to Deep Creek Valley	-4593.5
North	-8853.9
South	2630.4
Recharge	8964.8
ET	-7064.0
Interbasin Flow	-606.0
N Hamlin Valley	
West	17991.8
East	-6966.7
North	-30183.0
South	6065.8
Recharge	17630.7
ET	-4538.6

Cleve Creek

Cleve Creek discharges onto Spring Valley from the Schell Creek Range (Figure 14). It has intermittent flow records dating from 1914. The highest daily flow was 280 cfs in May 1984. Seasonal peaks occur every year, however, with daily peaks exceeding 50 cfs during most years. The average flow in both May and June is 23.1 cfs for the period of record and the long-term mean and median is 10.7 and 7.7 cfs. During dry to average conditions, the flow percolates into the alluvial fan before reaching the playa east of the gage, but during wet periods much water reaches the playa (personal observations in 1995, 2004, 2005, 2006, 2009, and 2010). The springs at the base of the fan discharge large flows which is likely percolation from Cleve Creek. The median flow, 5500 af/y, represents the percolation into the fan. This is secondary recharge of stream baseflow. Based on the stratified lithology in the area, flow in the fan may be partly perched, therefore it cannot be assumed that the water table approaches the ground surface.

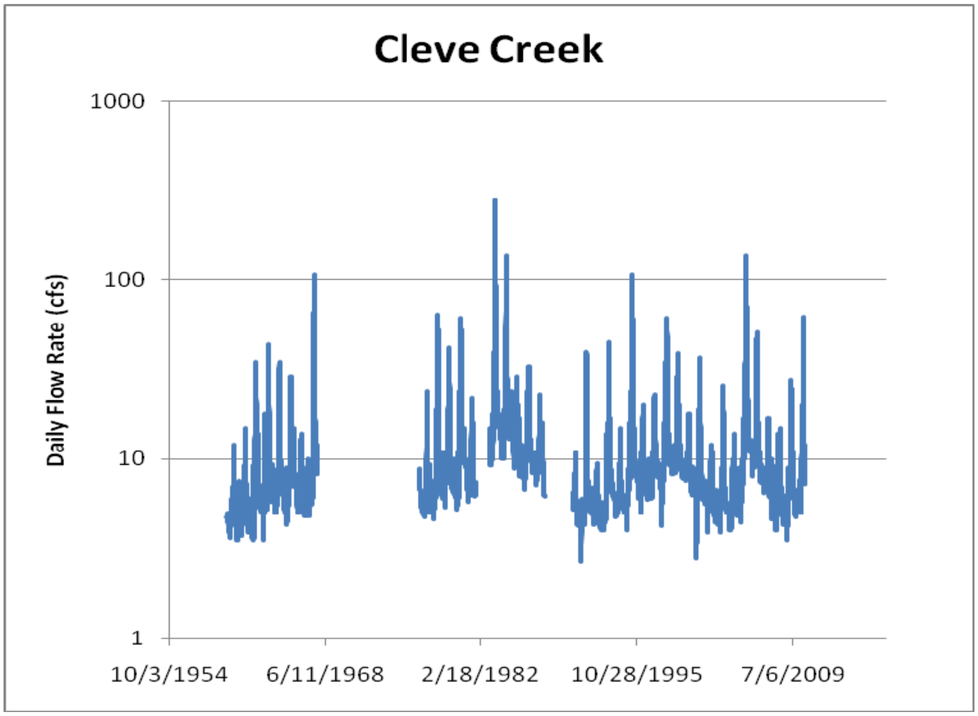


Figure 29: Daily flows at the Cleve Creek gage, USGS #10243700, since 1956.

Spring Discharge

Spring Valley lives up to its name, having many springs discharging at the base of alluvial fans into the adjacent playas. As noted above, these springs and/or seeps may provide much of the water that evapotranspires from the playas and other wetlands in the base of the valley. The published inventories of springs (Welch et al, 2008; BioWest, 2006; Pupacko et al, 1989) vary greatly, with variable estimates of flows. The largest springs are in Snake Valley, including Gandy Warm, Big, and Stateline Springs (Figure 30), although the mass of springs discharging at

It is also useful to compare the targeted flux for various springs and streams and other flux boundaries with the simulated values (Table 7). Simulated and targeted interbasin flows, such as outflow to the GSL and inflow from Steptoe and Lake Valley, match well. The flow from Lake and Steptoe Valley was from BARCAS (Welch et al, 2008) and only treated as a guideline. A few springs have large residuals, but they are misleading. The most difficult springs to simulate are Gandy Warm and Rowland Springs. The residual at Gandy Warm Springs is misleading because there is substantial ET near the spring. The boundary for Rowland Spring is very near Lehman and Baker Creek so that overall the fluxes are accurate. At Big Springs, there is also substantial ET nearby and discharge from nearby Stateline Springs. Cleve Creek Springs is simulated at about half the targeted value, but because the target was based on a water right rather than measurements, the residual is acceptable. Swallow Springs, Millick Springs, and Strawberry Creek are simulated very accurately.

Table 7: Discharge at select boundaries.

			Targeted Flows				
	Boundary Type	Reach #	Inflow (af/y)	Outflow (af/y)	Discharge ft^3/d	simulated (ft^3/d)	Simulated (af/y)
Steptoe In	GHB	32	4000			274737	2302.09
Lake Valley	GHB	31	29,000			1555697	13035.57
Outflow	GHB	21-25		29,000		-3408603	-28561.5
Tippett/Deep Creek Valley	GHB	12				-1755385	-14708.8
Rowland Springs	Drain	14			172000	-11841	-99.2206
Big Springs	Drain	13			443000	-181984	-1524.89
Stateline Spring	Drain	19				-147775	
Gandy Warm Springs	Drain	16			693000	-14915	-124.977
Spring Creek	Drain	11			86000	-20154	-168.872
Caine Spring	Drain	17			100	-2543	-21.3097
Keegan Spring	Drain	3			100	0	0
Millick Springs	Drain	1			75000	-96007	-804.464
Cleve Creek Spring	Drain	4			1100000	-425668	-3566.78
Swallow Springs	Drain	30			110000	-94628	-792.91
East Side Spring Valley	Drain	2				-1858744	-15574.9
Lehman Crk	River	13	5800		950400	33652	281.9783
Baker Crk	River	14				34373	288.0228
Snake Crk	River	15				-9802	-82.1311
Strawberry Crk	River	12			43200	43213	362.0965
Silver Creek	River	11				268452	2249.429

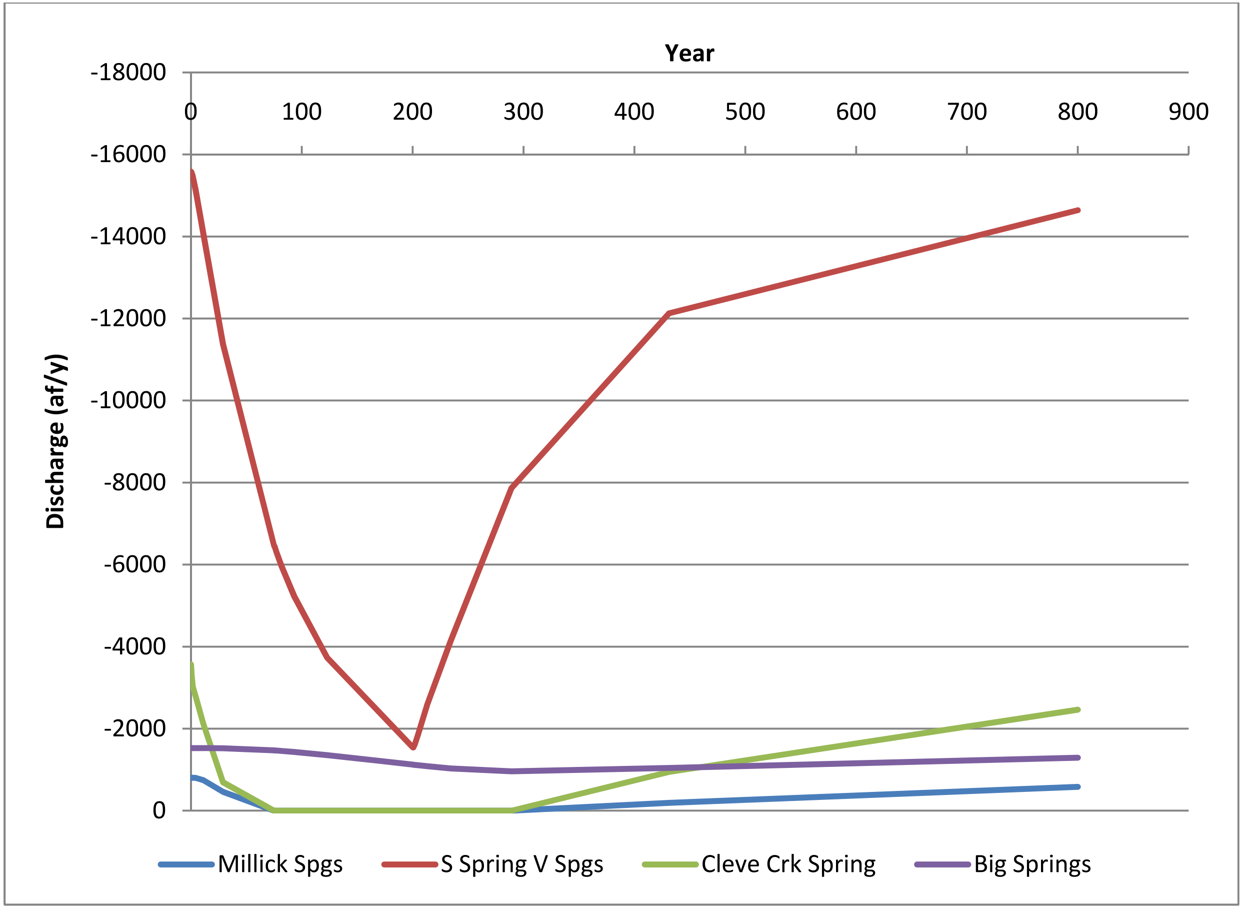


Figure 8: Flux hydrograph for four simulated springs.

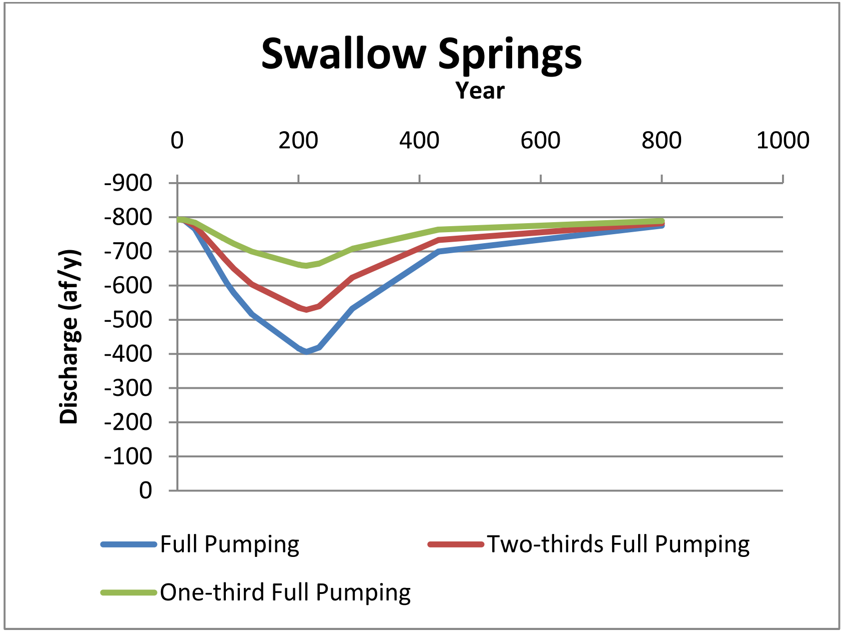


Figure 17: Discharge hydrograph, S Spring Valley Springs, SNWA Original Apps.

Spring, Cave, Dry Lake and Delamar Valleys

SOUTHERN NEVADA
WATER AUTHORITY

Presentation for
Myers Cross
DDC Valleys Part 2

Considering the locations of the original applications, it is difficult not to conclude that the applications were located to draw water from Steptoe Valley. They are located near the carbonate boundaries between the valleys (Welch et al, 2007) where interbasin flow would have been expected even in 1989.

Conclusion

The three pumping scenarios considered herein and in Myers (2011c) demonstrate that no water should be exported from Spring Valley. The system does not come to equilibrium for thousands of years, even when pumping at only a third of the application amount. Distributing the wells around the valley differently from the applications changes the proportion of water removed from storage and captured from wetlands and springs, but all scenarios cause unreasonable, environmentally unsound, detrimental impacts to the Valley. The NSE should deny the applications due to potential damages to environmental resources and water rights within Spring Valley and in adjacent valleys.

References

(BLM) U.S. Bureau of Land Management, 2011. Clark, Lincoln, and White Pine Counties Groundwater Development Project Draft Environmental Impact Statement. Reno, NV.

Myers, T., 2011a. Hydrogeology of Spring Valley and Surrounding Areas, Part A: Conceptual Flow Model. Presented to the Nevada State Engineer on behalf of Great Basin Water Network and the Federated Tribes of the Goshute Indians.

Myers, T., 2011b. Hydrogeology of Spring Valley and Surrounding Areas, Part B: Groundwater Model of Snake Valley and Surrounding Area. Presented to the Nevada State Engineer on behalf of Great Basin Water Network and the Federated Tribes of the Goshute Indians.

Myers, T., 2011c. Hydrogeology of Spring Valley and Surrounding Areas, PART C: IMPACTS OF PUMPING UNDERGROUND WATER RIGHT APPLICATIONS #54003 THROUGH 54021. Presented to the Nevada State Engineer on behalf of Great Basin Water Network and the Federated Tribes of the Goshute Indians.

Myers, T., 2011d. Rebuttal Report: Part 1, Review of Evidence Reports Submitted by Southern Nevada Water Authority in Support of Water Rights Applications for Spring, Cave, Dry Lake, and Delamar Valleys. Presented to the Nevada State Engineer on behalf of Great Basin Water Network and the Federated Tribes of the Goshute Indians.

(SNWA) Southern Nevada Water Authority, 2010. Simulation of Groundwater Development Scenarios Using the Transient Numerical Model of Groundwater Flow for the Central Carbonate-Rock Province: Clark, Lincoln, and White Pine Counties Groundwater Development Project. Prepared in Cooperation with the Bureau of Land Management.

STATE OF NEVADA

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

DIVISION OF WATER RESOURCES

BEFORE SUSAN JOSEPH-TAYLOR, HEARING OFFICER

IN RE:

APPLICATIONS 53987 THROUGH 53992, INCLUSIVE, AND 54003 THROUGH 54030, INCLUSIVE, FILED BY THE LAS VEGAS VALLEY WATER DISTRICT TO APPROPRIATE THE UNDERGROUND WATERS OF DELAMAR VALLEY (182), DRY LAKE VALLEY (181), CAVE VALLEY (184), AND SNAKE VALLEY (195) HYDROGRAPHIC BASINS, LINCOLN and WHITE PINE COUNTIES, NEVADA.
____/

VOLUME IX

TRANSCRIPT OF PROCEEDINGS

PUBLIC HEARING

THURSDAY, SEPTEMBER 21, 2006

Reported by:

CAPITOL REPORTERS
Certified Shorthand Reporters
BY: MARY E. CAMERON, CCR, RPR
Nevada CCR #98
410 East John Street, Ste. A
Carson City, Nevada 89706
(775) 882-5322

that the drawdown in the valley will be significant, extensive and commence very quickly".

Q. Would you agree, Dr. Myers, that if in fact the amount of water that the Southern Nevada Water Authority would be withdrawing is below the perennial yield, at or below the perennial yield, that we would not see the kind of drawdowns you predict here?

A. It depends upon how far below the perennial yield, but if Southern Nevada Water Authority develops the perennial yield, eventually you reach an equilibrium, outflow equals inflow. It was a long time before equilibrium is reached in my model, but that's a basic precept of hydrology.

Q. I want to get an answer to that question, Dr. Myers, and I'm not sure you answered it. There's a statement here that if you pump at or above perennial yield you'll experience these drawdowns. I'm trying to have you tell us if you pump at or below the perennial yield, let's assume it's below, will you see this, the same kinds of drawdowns that you predicted in your model?

A. If you pump at below the perennial yield the drawdown would be less than predicted. If I developed a model with a smaller amount of pumpage there would be less drawdown, absolutely.

Q. Would you turn to page 15 in Exhibit 3001, please? I'm sorry, I don't think that's the right exhibit.

BEFORE THE STATE ENGINEER, STATE OF NEVADA

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

DIVISION OF WATER RESOURCES

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IN THE MATTER OF HEARING RE
APPLICATIONS 53987-53992

VOLUME VI

RE CAVE VALLEY, DRY LAKE VALLEY,
DELAMAR VALLEY HYDROGRAPHIC
BASINS, LINCOLN COUNTY, NEVADA
_______________________________________/

Pages 1097 - 1309

TRANSCRIPT OF PROCEEDINGS

PUBLIC HEARING

MONDAY, FEBRUARY 11, 2008

REPORTED BY:

CAPITOL REPORTERS
Certified Shorthand Reporters
BY: CARRIE HEWERDINE, RDR
Nevada CCR #820
410 E. John Street, Ste. A
Carson City, Nevada 89706

Q Do you think it's appropriate to diverge from all prior flow understandings in the White River Flow System and -- and offer the theory that 17,000 acre-feet flows in from Steptoe Valley to White River Valley, based upon one carbonate control?

A The -- their estimate of 17,000 is based on a great deal more than one carbonate control well. The -- the contours are based on -- it's strictly the contours that are reflected by that one well, if that's what it is.

Q In your report, which is Exhibit 1101 -- I'll be referring to that in all of my questions. Do you have a copy of that?

A Yes.

Q In your report you describe perennial yield, and my question is: Do you agree that the State Engineer in Nevada has used the perennial yield concept to limit the amount of water that can be used in hydrographic basins?

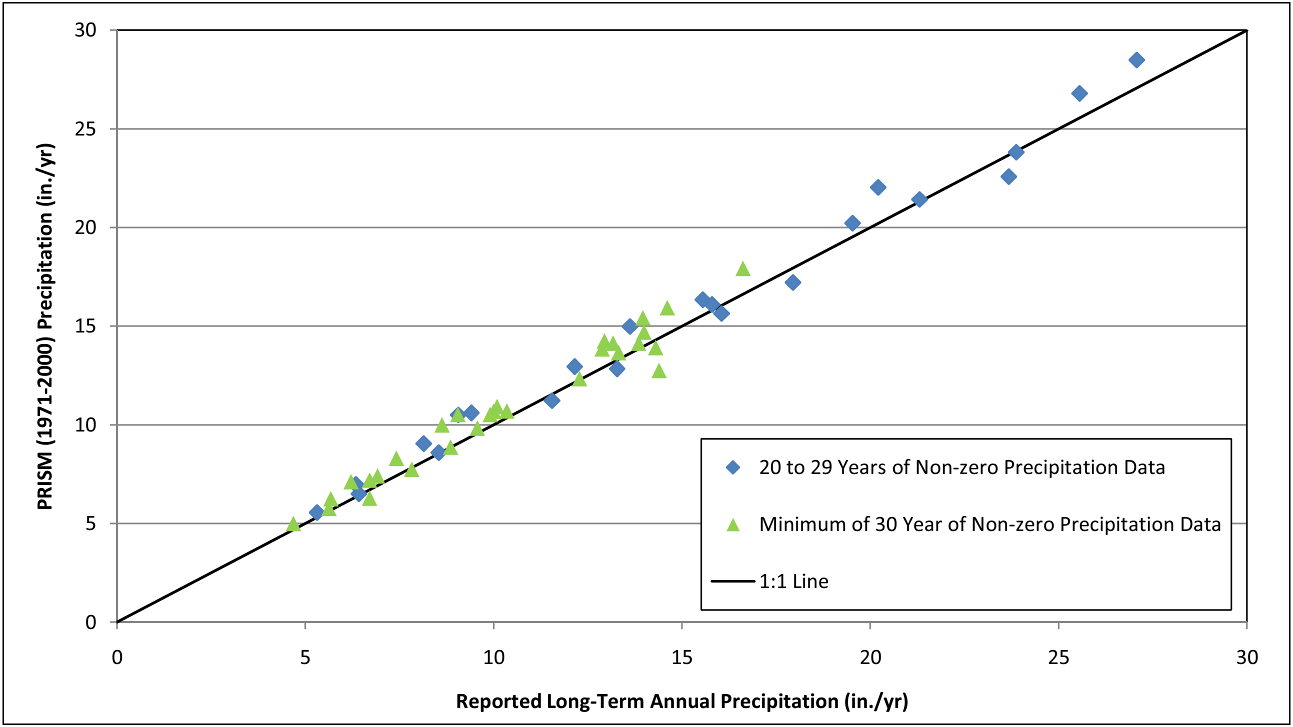
A (No audible response).

Q Do you agree with that statement?

A Yes.

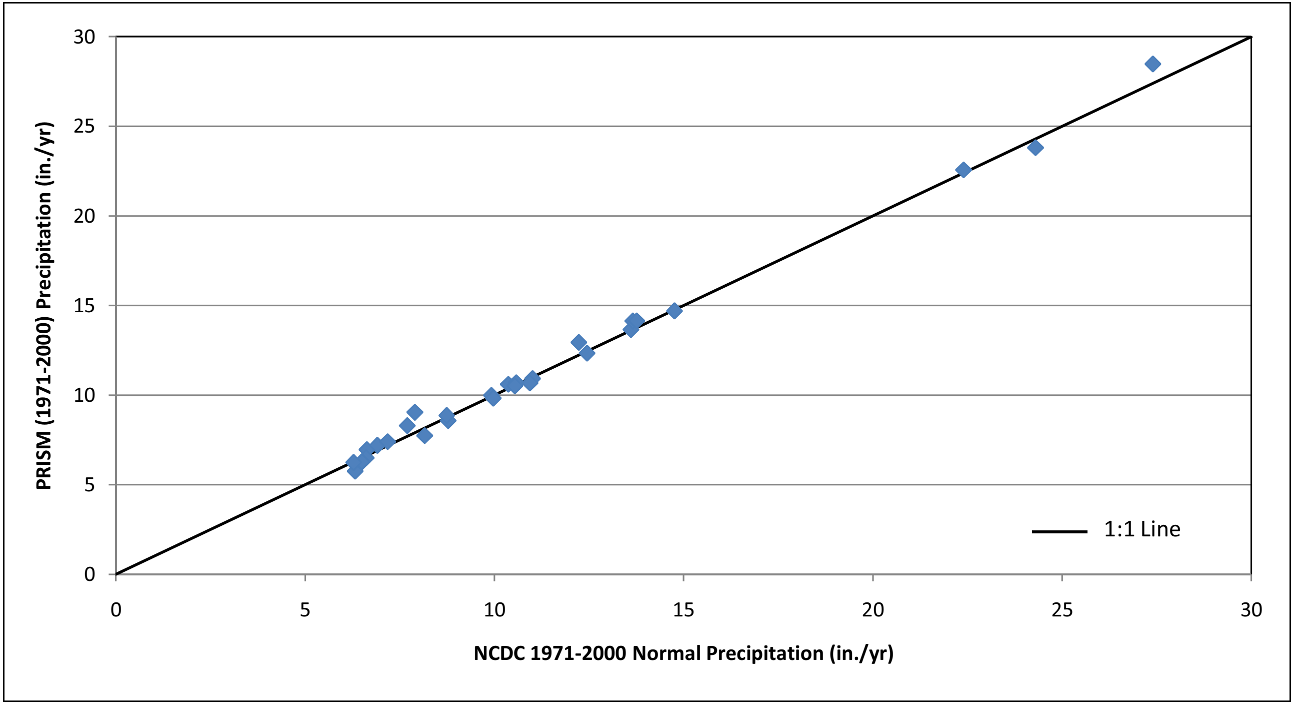
Q Do you believe -- or do you agree with the statement that within the perennial yield concept there is an allowance for the development of some portion of transitional storage?

A Oh, absolutely.



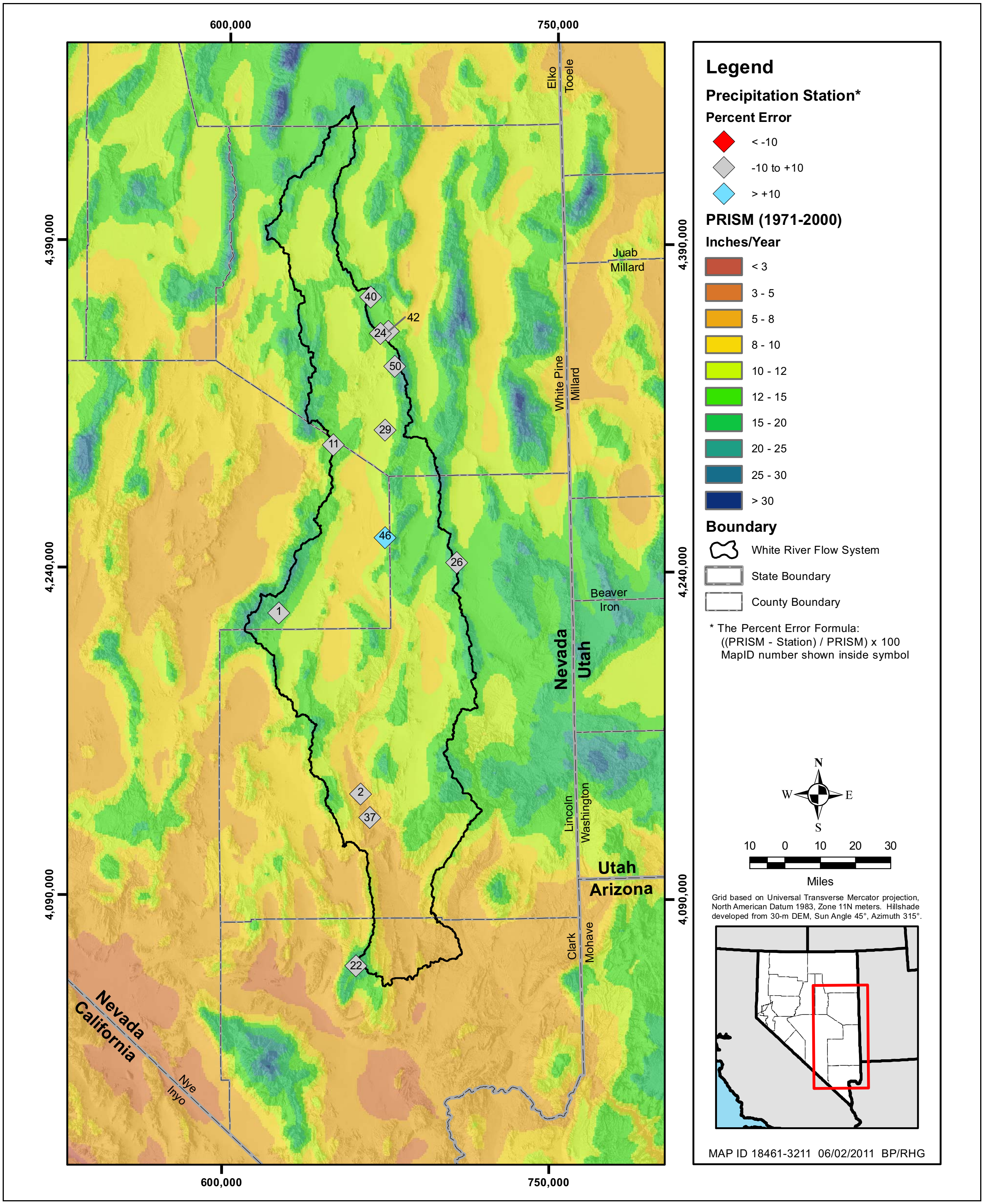
Note: See Table B-1 for precipitation values for selected stations.

Figure B-5
Comparison of 800-m PRISM Precipitation Values
to Period-of-Record Mean Station Values within Area of Interest



Note: See Table B-1 for names of “normal” precipitation stations.

Figure B-4
Comparison of 800-m PRISM Precipitation Values to Normal Station Precipitation Values within Area of Interest



Note: See Table B-1 for precipitation values at the selected stations.

Figure B-7
Percent Error between 800-m PRISM and Period-of-Record Average for Precipitation Stations Located in White River Flow System's Potential Recharge Areas

Table B-1
Precipitation Station Data Set Used in Evaluation of 800-m PRISM Distribution
(Page 1 of 2)

Map ID	Station Name	Location[a]		Source	Elevation (ft amsl)	Period-of-Record									NCDC Normals (1971-2000) Annual Average (in.)	800-m PRISM 1971-2000
		UTM Northing (m)	UTM Easting (m)			Start	End	Duration	Years of Non-zero Precipitation	Annual Average (in.)	Annual Minimum (in.)	Annual Maximum (in.)	Standard Deviation (in.)	Standard Error of the Mean (Percent of Average)		
1	Adaven	4,219,708	624,186	WRCC	6,250	1914	1982	69	50	12.94	4.42	23.64	4.13	4.51	---	14.25
2	Alamo	4,137,126	662,343	WRCC	3,480[b]	1921	1962	42	20	6.34	1.23	11.16	2.93	10.33	---	6.98
3	Berry Creek	4,354,989	705,169	NRCS (SNOTEL)	9,100	1976	2010	35	28	27.54	17.20	39.30	5.83	4.00	27.4	28.48
4	Blue Eagle Ranch Hank	4,264,579	626,889	WRCC	4,780	1978	2010	33	27	8.54	4.41	15.11	2.96	6.67	8.78	8.59
5	Boulder City	3,983,875	694,163	WRCC	2,500	1931	2004	74	63	5.63	0.67	13.36	2.69	6.02	6.32	5.76
6	Caliente	4,166,217	719,251	WRCC	4,400	1903	2010	108	67	8.63	1.84	18.73	3.22	4.56	9.92	9.99
7	Callao	4,421,802	781,034	WRCC	4,342	1902	2010	109	67	5.68	0.94	10.59	2.04	4.39	6.28	6.25
8	Cave Mountain	4,337,545	706,107	USGS	10,650	1983	2009	27	26	20.21	12.00	32.16	5.11	4.96	---	22.03
9	Cherry Creek Range	4,443,653	680,593	USGS	9,700	1983	2009	27	26	15.55	7.75	26.25	4.63	5.84	---	16.33
10	Connors Pass	4,323,532	703,651	NDWR	7,740	1953	2010	58	51	13.96	3.40	23.94	4.01	4.02	---	15.40
11	Current Creek NDWR	4,297,077	648,450	NDWR	6,830	1953	2010	58	53	12.88	6.00	24.49	3.86	4.12	---	13.86
12	Desert Exp Range	4,277,401	783,035	WRCC	5,249	1950	1984	35	33	6.22	2.40	10.68	2.12	5.93	---	7.13
13	Ely WBO	4,351,755	685,692	WRCC	6,262	1893	2010	118	79	9.57	4.22	16.16	2.85	3.35	9.97	9.83
14	Enterprise	4,163,891	790,106	WRCC	5,320	1905	2010	106	51	13.99	5.08	28.61	4.65	4.65	14.76	14.70
15	Enterprise Beryl Jct	4,185,535	794,591	WRCC	5,150	1940	2008	69	43	10.35	5.65	16.53	2.42	3.57	10.58	10.70
16	Eskdale	4,333,158	763,441	WRCC	4,980	1966	2010	45	29	6.34	3.18	12.57	2.32	6.80	6.63	6.97
17	Fish Springs Refuge	4,416,211	808,238	WRCC	4,357	1960	2010	51	42	7.83	3.89	12.64	2.26	4.45	8.16	7.75
18	Garrison	4,313,564	757,154	WRCC	5,260	1903	1990	88	30	7.42	4.35	14.69	2.37	5.83	7.70	8.30
19	Geyser Ranch	4,282,623	705,658	WRCC	6,020	1904	2002	99	20	9.06	1.65	19.04	4.00	9.87	---	10.50
20	Gold Hill UT	4,451,066	769,671	WRCC	5,250	1966	1990	25	15	11.55	5.29	22.08	4.56	10.19	---	11.22
21	Great Basin NP	4,321,069	740,678	WRCC	6,850	1948	2010	63	54	13.32	7.37	21.20	3.19	3.26	13.61	13.66
22	Hayford Peak USGS	4,058,445	660,853	USGS	9,840	1985	2009	25	24	15.80	6.50	38.25	7.61	9.83	---	16.09
23	Ibapah	4,436,297	756,954	WRCC	5,279	1903	2010	108	47	9.91	3.20	16.41	2.87	4.22	10.54	10.52
24	Kimberly	4,348,213	669,663	WRCC	7,234	1928	1958	31	25	13.28	6.86	19.95	3.57	5.38	---	12.84
25	Lages	4,437,512	703,405	WRCC	5,960	1984	2010	27	23	8.14	4.10	13.20	2.29	5.87	7.90	9.05
26	Lake Valley Steward	4,243,564	705,447	WRCC	6,350	1971	1998	28	20	16.05	9.39	28.29	5.15	7.17	---	15.63
27	Little Grassy	4,153,894	778,503	NRCS (SNOTEL)	6,100	1985	2010	26	25	24.73	9.60	45.50	9.13	7.38	24.30	23.81

Table 6 : Water budget accounting for the study area basins under pre-development conditions. All flows are in af/y.

	Recharge	Interbasin Inflow	GW Discharge	Interbasin outflow	To
Garden/Coal Valley	12000		0	12000	Pahranagat
Cave Valley	14000		1200	12800	White River
Dry Lake	5000		0	5000	Delamar
Delamar	1000	5000	0	6000	Pahranagat
White River Valley	38000	75800	76700	37100	Pahroc
Pahroc Valley	2200	37100	0	39300	Pahranagat
Pahranagat Valley	1800	57300	25000	34100	Coyote Springs
Coyote Spring/Kane Springs Valley	6000	34100	0	40100	Muddy Springs
48 kaf/y inflow from Steptoe and Jakes Valley, Welch et al (2008)					

GBWN_Exh_004

Table 7: Water rights in White River Valley. Data from Nevada State Engineer's online database, 2007.

Stream	**Number**	**Duty (af/y)**
CER	26	24643
PER	1	152
VST	7	16306
Subtotal	34	41102
Spring		
CER	74	16149
DEC	12	102
RES	1	
PER	11	3596
VST	24	2755
Subtotal	122	22602
Underground		
CER	122	25354
PER	37	11103
VST	1	0
Subtotal	160	36457
UG total adj for Sup		23255
Total	316	86959

Table 8: Water rights summary for Paharanagat Valley. Data from Nevada State Engineer's online database, 2007.

Pahranagat Valley Water Rights Summary		
Stream	Number	Duty (af/y)
CER	3	761
VST	1	184
Subtotal	4	946
Lake		
CER	2	2127
VST	5	0
Subtotal	7	2127
Spring		
CER	21	5646
DEC	17	14535
RES	2	4
VST	4	1278
Subtotal	44	21463
Underground		
CER	41	9886
PER	24	3088
VST	5	48
Subtotal	70	13022
Total	118	35430

Table 9: Water budget for the White River Flow System with existing groundwater use. All units af/y.

	Recharge	Interbasin Inflow	GW Discharge	Groundwater Use	Interbasin outflow	To
Garden/Coal Valley**	12000		0	421	11579	Pahranagat
Cave Valley	14000		1200	35.4	12765	White River
Dry Lake	5000		0	57	4943	Delamar
Delamar	1000	4943	0	7.4	5936	Pahranagat
White River Valley*	38000	75765	76700	8776	28289	Pahroc
Pahroc Valley	2200	28289	0	30	30459	Pahranagat
Pahranagat Valley	1800	47973	25000	8692	16081	Coyote Springs
Coyote Spring/Kane Springs Valley	6000	16081	0		22081	Muddy Springs

* - 48 kaf/y inflow from Steptoe and Jakes Valley, Welch et al (2008)

** - Groundwater use is sum of 388 af/y in Garden and 33 af/y in Coal Valley

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