United States Department of the Interior
U.S. GEOLOGICAL SURVEY
Utah Water Science Center
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NV State Engineer's Spring Valley Water Rights Hearing
Expert Testimony Written Report
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This document discusses the opinions that I plan to present at the NV State Engineer's Spring Valley Water Rights hearing on October 31, 2011. For a statement of my qualifications as an expert witness on the foregoing, please see my attached curriculum vitae.

Opinion #1: Groundwater in Spring Valley (Hydrographic Area 184) is a finite resource and the proposed 91,224 acre-ft/yr of well withdrawals by SNWA approaches or exceeds previously published estimates of total groundwater discharge from Spring Valley. This proposed pumping, therefore, would capture most, if not all, of current groundwater discharge from Spring Valley, including springflow, groundwater evapotranspiration (ET_g), and well withdrawals. This level of pumping would also likely capture groundwater from adjacent hydraulically-connected valleys, particularly in situations where parts of those valleys are closer than more-distant parts of Spring Valley to the proposed pumping centers.

Rationale, data, and supporting documentation for Opinion #1:

1. Previously published groundwater budget estimates for Spring Valley range from 75,000 and 130,000 acre-ft of discharge annually (Rush and Kazmi, 1965; Brothers and others, 1994; Nichols, 2000; Welch and others, 2007).

2. A recently published pre-development Spring Valley total groundwater discharge estimate (excluding subsurface outflow) is 82,000 ± 25,000 acre-ft (Heilweil and Brooks, 2011), with the following individual pre-development groundwater component estimates:
   - Discharge to ET_g: 65,000 acre-ft/yr
   - Discharge to mountain streams: 500 acre-ft/yr
   - Discharge to springs: 17,000 acre-ft/yr

   (Recent (2000) well withdrawals from Spring Valley published in Heilweil and Brooks (2011) are about 4,000 acre-ft/yr.)

3. Groundwater hydraulics has shown that the source of water derived from wells is essentially capture of other forms of groundwater discharge (Theis, 1957);

4. But groundwater conceptual modeling shows that the ultimate hydrologic effects of development in a basin depend on the hydraulic properties and boundaries of the aquifer, not the quantities of natural recharge and discharge; the amount of water available for withdrawal by wells depends on the extent of hydrologic effects that can be tolerated (Bredoheft and others, 1982)

Exhibits:

1. Various tables and figures, Heilweil and Brooks, 2011

2. Theis, 1957
3. Bredohoeft and others, 1982

Opinion #2: Published potentiometric maps, 3-D hydrogeologic frameworks, transmissivity values from calibrated groundwater flow models, and estimates of interbasin groundwater flow all indicate a subsurface hydraulic connection having substantial transmissivity between Spring Valley and Snake Valley (Hydrographic Area 254).

Rationale, data, and supporting documentation for Opinion #2:

1. Published regional groundwater studies indicate that Spring and Snake Valleys are part of the larger "Great Salt Lake Desert" groundwater flow system (Harrill and others, 1988; Harrill and Prudic, 1998; Heilweil and Brooks, 2011)
2. Published equipotentials (lines of equal groundwater levels) on potentiometric maps suggest there is hydraulic potential for groundwater flow from Spring to Snake Valleys (Thomas and others, 1986; Wilson, 2007; Heilweil and Brooks, 2011, plate 2).
3. Published geologic surface maps and cross sections show the likely existence of a continuous permeable carbonate aquifer under the southern parts of Spring and Snake Valleys (Plume and Carlton, 1988; Plume, 1996, plate 2; Welch and others, 2007, fig. 15; Southern Nevada Water Authority, 2009, plates 2 and 3)
4. Published hydrogeologic maps and 3-D geologic frameworks indicate a high likelihood of hydraulic connection (flow permitted by subsurface geology) between southern parts of Spring and Snake Valleys (Harrill and others, 1988, sheet 2; Welch and others, 2007, fig. 15; Southern Nevada Water Authority, 2009, fig H-1, table H-1; Heilweil and Brooks, 2011, plate 2).
5. Published groundwater budget estimates of interbasin groundwater flow from southern Spring to southern Snake Valley range from 4,000 and 33,000 acre-ft/yr (Hood and Rush, 1965; Rush and Kazmi, 1965; Scott and others, 1971; Gates and Kruer, 1981; Harrill and others, 1988; Brothers and others, 1994; Nichols, 2000; Welch and others, 2007).
6. The RASA regional steady-state numerical groundwater flow model indicates groundwater flow from southern Spring Valley to southern Snake Valley occurs (Prudic and others, 1995).
7. Published values of transmissivity from aquifer tests conducted in carbonate rocks in southeastern Spring and southwestern Snake Valleys range from 4,000 to 10,000 ft^2/d (Dong and Halford, 2010; Halford, 2010).
8. A calibrated steady-state groundwater flow model of Spring and Snake Valleys (Halford and Plume, 2011) similarly indicated substantial transmissivity (up to 10,000 ft^2/d) along the southern part of the HA divide between Spring and Snake Valleys. Predictive transient simulations resulted in up to 30 ft of groundwater-level decline in the carbonate aquifer (layer 4) of Spring Valley after 300 years of pumping 40,000 acre-ft/yr from Snake Valley.
9. A regional steady-state numerical groundwater flow model currently being developed by the USGS and including the Great Salt Lake Desert groundwater flow system also indicates groundwater flow from southern Spring Valley to southern Snake Valley (Brooks, oral commun., 2011).

Exhibits:

1. Plate 2, Harrill and others, 1988
2. Figure 15, Harrill and Prudic, 1998
3. Plate 2, Heilweil and Brooks, 2011
4. Various figures and tables, Heilweil and Brooks, 2011
5. Plates 1 and 2, Thomas and others, 1986
6. Plate 1, Wilson, 2007

7. Hydrologic Atlas Map, Plume and Carlton, 1988
8. Plate 2, Plume, 1996
9. Various figures and tables, Welch and others, 2007
10. Prudic and others, 1995
11. Various figures, Halford and Plume, 2011
12. Dong and Halford, 2010
13. Halford, 2010

Opinion #3: The 91,224 acre-ft per year of increased well withdrawals proposed by SNWA for Spring Valley would initially cause groundwater level declines and depletion of groundwater storage. Ultimately, however, these withdrawals would likely cause a reduction in or a reversal of subsurface groundwater flow from Spring Valley to Snake Valley, a reduction in spring flow and groundwater evapotranspiration (ETg) in Snake Valley, and (or) a reduction in groundwater availability to current water users in Snake Valley.

Rationale, data, and supporting documentation for Opinion #3:

1. A new potentiometric map based on a March 2010 mass water-level inventory (Gardner and Plume, in press) shows a prominent groundwater divide in southern Spring Valley and occurrence of subsurface from Spring to Snake; such a divide is not a stationary boundary - increasing well withdrawals by 91,000 acre-ft/yr in southern Spring Valley would likely move this groundwater divide closer to or even beyond (east of) the Spring/Snake surface-water divide and capture groundwater from or heading to Snake Valley.
2. Several published transient numerical groundwater flow models indicate potential water-level declines in Snake Valley and reduced subsurface flow from Spring to Snake Valley with increased well withdrawals in Spring Valley:

- Schaefer and Harrill (1995) simulate more than 100 ft of groundwater declines in both the shallow layer (predominantly representing basin fill) and the deep layer (predominantly representing the carbonate-rock aquifer) in parts of Snake Valley with 50,000 acre-ft/yr withdrawals from Spring Valley and 25,000 acre-ft/y withdrawals from Snake Valley (final steady-state simulation). The affects caused by withdrawals in Spring Valley alone was simulated.
- Southern Nevada Water Authority's (2010) numerical groundwater flow model (alternative "B") indicates that after 200 years of pumping of 91,224 acre-ft/yr from Spring Valley and 50,700 acre-ft/yr from Snake Valley, over 100 ft of groundwater decline would occur in parts of Snake Valley, a reduction in ETg of 25,000 acre-ft/yr, and a 2,700 acre-ft/yr reduction at Big Springs. The affects caused by withdrawals in Spring Valley alone was simulated.

Exhibits:

1. Plate 1, Gardner and Plume, in press
2. Figure 10, Shaefer and Harrill, 1995
3. Plate 2, Figure 4.3, Table 4.2, Southern Nevada Water Authority, 2010

Opinion #4: Continued and expanded monitoring of groundwater levels and spring discharge in both Spring and Snake Valleys is necessary for evaluating potential effects of increased well withdrawals, including:

A. The need to implement the Stipulated Agreement Monitoring, Management, and Mitigation Plans

Rationale, data, and supporting documentation for Opinion #4A:

1. The hydrologic data collection proposed in the Stipulated Agreement monitoring plan will provide baseline data for evaluating potential impacts of pumping on groundwater resources in Spring Valley and the NV part of Snake Valley

-and -

B. The need to expand the groundwater monitoring program to include eastern part of Snake Valley and other hydraulically connected basins.

Rationale, data, and supporting documentation for Opinion #4B:

1. The Snake Valley groundwater system is an aquifer shared by both Nevada and Utah (Welch and others, 2007; Halford and Plume, 2011, Heilweil and Brooks, 2011).
2. Potential effects of Spring Valley withdrawals on groundwater resources in Snake Valley are not adequately addressed by the Stipulated Agreement, which does not include monitoring in the eastern part of Snake Valley (Utah) or other hydraulically connected basins.

Exhibits:

1. Plate 2, Heilweil and Brooks, 2011
2. Various figures and tables, Heilweil and Brooks, 2011
3. Various figures and tables, Welch and others, 2007
4. Various figures, Halford and Plume, 2011

Supporting Documentation

Bredehoeft, J.D., Papadopulos, S.S., and Cooper Jr., H.H., 1982, Groundwater: The water budget myth, *in* Scientific Basis of Water-Resources Management, ed. National Research Council (U.S.), Geophysical Study Committee, Washington, D.C., National Academy Press, p. 51-57

Brothers, K., Buqo, T.S., Bernholtz, A.J., and Tracy, J.V., 1994, Hydrology and steady state ground-water model of Spring Valley, Lincoln and White Pine Counties, Nevada: Las Vegas Valley Water District, Cooperative Water Project, Series Report No. 13, 69 p.

Dong, W., and Halford, K.J., 2010, Analysis of multiple-well aquifer test of carbonate-rock aquifer, southeastern Spring Valley, HA 184, near Great Basin National Park, NV: U.S. Geological Survey Memorandum, 13 p., accessed on 08/24/2011 at: http://nevada.usgs.gov/water/AquiferTests/spring_valley.cfm?studyname=spring_valley

Gardner, P.M., Masbruch, M.D., Plume, R.W., and Buto, S.G., (in press) Regional potentiometric surface map of the Great Basin carbonate and alluvial aquifer system in Snake Valley and surrounding areas, Juab, Millard, and Beaver Counties, Utah and White Pine and Lincoln Counties, Nevada: U.S. Geological Survey Scientific Investigations Map 2011-XXXX.

Gates, J.S., and Kruer, S.A., 1981, Hydrologic reconnaissance of the southern Great Salt Lake Desert and summary of the hydrology of west-central Utah: Utah Department of Natural Resources Technical Publication 71, 55 p.

Halford, K.J., 2010, Analysis of BS-SW single-well aquifer test of carbonate-rock aquifer, southwestern Snake Valley, HA 195, near Great Basin National Park, NV: U.S. Geological Survey Memorandum, 5 p., accessed on 08/24/2011 at: http://nevada.usgs.gov/water/AquiferTests/2010_BigSprings-SW/Report/00_BigSprings-SW-SnakeV_%20AquiferTestReport.v2.pdf

Halford, K.J., and Plume, R.W., 2011, Potential effects of groundwater pumping on water levels, phreatophytes, and spring discharges in Spring and Snake Valleys, White Pine County, Nevada, and adjacent areas in Nevada and Utah: U.S. Geological Survey Scientific Investigations Report 2011-5032, 52 p.

Harrill, J.R., Gates, J.S., and Thomas, J.M., 1988, Major ground-water flow systems in the Great Basin region of Nevada, Utah, and adjacent States, U.S. Geological Survey Hydrologic Investigations Atlas HA-694-C, scale 1:1,000,000, 2 sheets.

Harrill, J.R., and Prudic, D.E., 1998, Aquifer systems in the Great Basin region of Nevada, Utah, and adjacent States—A summary report: U.S. Geological Survey Professional Paper 1409-A, 66 p.

Heilweil, V.M., and Brooks, L.E., eds., 2011, Conceptual model of the Great Basin Carbonate and Alluvial Aquifer System: U.S. Geological Survey Scientific Investigations Report 2010-5193, XX p.

Hood, J.W., and Rush, F.E., 1965, Water-resources appraisal of the Snake Valley area, Utah and Nevada: Nevada Department of Conservation and Natural Resources, Water Resources-Reconnaissance Report 34, 43 p.

Nichols, W.D., 2000, Regional ground-water evapotranspiration and ground-water budgets, Great Basin, Nevada: U.S. Geological Survey Professional Paper 1628, 82 p.

Plume, R.W., and Carlton, S.M., 1988, Hydrogeology of the Great Basin region of Nevada, Utah, and adjacent states: U.S. Geological Survey Hydrologic Investigations Atlas HA-694-A, 1 pl.

Plume, R.W., 1996, Hydrogeologic framework of the Great Basin region of Nevada, Utah, and adjacent States: U.S. Geological Survey Professional Paper 1409-B, 64 p.

Prudic, D.E., Harrill, J.R., and Burbey, T.J., 1995, Conceptual evaluation of regional ground-water flow in the carbonate-rock province of the Great Basin, Nevada, Utah, and adjacent States: U.S. Geological Survey Professional Paper 1409-D, 102 p.

Rush, F.E., and Kazmi, S.A.T., 1965, Water resources appraisal of Spring Valley, White Pine and Lincoln Counties, Nevada: Nevada Department of Conservation and Natural Resources, Water Resources-Reconnaissance Report 33, 39 p.

Schaefer, D.H., and Harrill, J.R., 1995, Simulated effects of proposed ground-water pumping in 17 basins of east-central and southern Nevada: U.S. Geological Survey Water-Resources Investigations Report 95-4173, 71 p.

Scott, B.R., Smales, T.J., Rush, F.E., and Van Denburgh, A.S., 1971, Water for Nevada: Nevada Department of Conservation and Natural Resources, Water Planning Report No. 3, 87 p.

Southern Nevada Water Authority, 2009, Conceptual model of groundwater flow for the Central Carbonate-Rock Province—Clark, Lincoln,and White Pine Counties Groundwater Development Project: Southern Nevada Water Authority, Las Vegas, Nevada, 416 p.

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. Southern Nevada Water Authority, Las Vegas, Nevada, 97 p.

Theis, C.V., 1957, The source of water derived from wells: essential factors controlling the response of an aquifer to development: U.S. Geological Survey Ground Water Notes – Hydraulics, no. 34, 16 p.

Thomas, J.M., Mason, J.L., and Crabtree, J.D., 1986, Ground-water levels in the Great Basin region of Nevada, Utah, and adjacent States: U.S. Geological Survey Hydrologic Investigations Atlas HA-694-B, 2 sheets.

Welch, A.H., Bright, D.J., and Knochenmus, L.A., eds., 2007, Water Resources of the Basin and Range carbonate-rock aquifer system, White Pine County, Nevada, and adjacent areas in Nevada and Utah: U.S. Geological Survey Scientific Investigations Report 2007-5261, 96 p.

Wilson, J.W., 2007, Water-Level Maps of the Carbonate-Rock and Basin-Fill Aquifers in the Basin and Range Carbonate-Rock Aquifer System, White Pine County, Nevada, and Adjacent Areas in Nevada and Utah: U.S. Geological Survey Scientific Investigations Report 2007-5089, 10 p., 2 pls.

Signed:

Victor M. Heilweil

August 24th, 2011

Dr. Victor M. Heilweil

Education

B.S., Geology, Duke University, 1984

M.E. Geotechnical Engineering, University of Utah, 1989

Ph.D. Hydrogeology, University of Utah, 2003

Professional Experience

Research Hydrologist, U.S. Geological Survey, Salt Lake City, UT, 2005-present

Groundwater Specialist, U.S. Geological Survey, Salt Lake City, UT, 2002-present

Hydrologist, U.S. Geological Survey, Salt Lake City, UT, 1988 - 2005

Short description

Vic Heilweil is a Research Hydrologist and the Ground Water Specialist for the USGS Utah Water Science Center. He is currently the senior scientist on several local to regional-scale groundwater studies, with research focused on both natural and managed aquifer recharge to permeable bedrock in arid settings of the western US and abroad. Specialties include applying both dissolved-gas and isotopic tracers, along with multiphase modeling, for evaluating groundwater flow paths, travel times, and water budgets. He currently serves as treasurer for the U.S. National Chapter of the International Association of Hydrogeologists and is an Adjunct Professor at the University of Utah.

Selected Publications

Heilweil, V.M., and Brooks, L.E., eds., 2011, *Conceptual model of the Great Basin Carbonate and Alluvial Aquifer System,* U.S. Geological Survey Scientific Investigations Report 2010-5193, 188 p., 2 pls.

Heilweil VM, Marston TM, 2011, *Assessment of managed aquifer recharge at Sand Hollow Reservoir, Washington County, Utah, Updated to conditions in 2010*, US Geological Survey Scientific Investigations Report (in press).

Heilweil VM, Watt DE, 2011, *Trench infiltration for enhancing artificial recharge to fractured sandstone*, Hydrological Processes, 25 (1), 141-151.

Heilweil VM, Solomon DK, Gingerich SB, Verstraeten IM, 2009, *Oxygen, hydrogen, and helium isotopes for investigating groundwater systems of the Cape Verde Islands, West Africa*, Hydrogeology Journal, 17 (5), 1157-1174.

Heilweil VM, Solomon DK, Ortiz G, 2009, *Silt and gas accumulation beneath an artificial recharge spreading basin, southwest Utah, USA*, Boletín Geológical y Minero, 120 (2) 185-195.

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Heilweil VM, Susong DD, and Cram JC, 2007, *Reservoir infiltration to fractured sandstone at Sand Hollow, southwestern Utah, USA, in* Fox, P., ed., *Management of Aquifer Recharge for Sustainability, Acacia Publications,* Phoenix, Arizona, 475-483.

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Heilweil VM, Solomon DK, Gardner, PM, 2007, *Infiltration and recharge at Sand Hollow, an upland bedrock basin in southwestern Utah*, *in* Stonestrom, Constantz, Ferré, and Leake, S.A., eds., Ground-water recharge in the arid and semiarid southwestern United States: U.S. Geological Survey Professional Paper 1703-I, 221-251.

Heilweil VM, Susong DD, 2007, *Assessment of artificial recharge at Sand Hollow Reservoir, Washington County, Utah, Updated to conditions through 2006*, U.S. Geological Survey Scientific Investigations Report 2007-5023, 74 p.

Heilweil VM, Hsieh PA, 2006, *Determining anisotropic transmissivity using a simplified Papadopulos Method*, Ground Water, 44(5), 749-753.

Heilweil VM, Solomon DK, Gardner PM, 2006, *Borehole environmental tracers to evaluate net infiltration and recharge through desert bedrock*, Vadose Zone, 5, 98-120.

Heilweil VM, Susong DD, Gardner, PM, Watt DE, 2005, *Pre- and post-reservoir ground-water conditions and assessment of artificial recharge at Sand Hollow, Washington County, Utah, 1995-2005*, U.S. Geological Survey Scientific Investigations Report 2005-5185, 74 p.

Heilweil VM, Solomon DK, Ellett KM, Perkins KS, 2004, *Gas-partitioning tracer test to quantify trapped gas during recharge*, Ground Water, 42 (4), 589-600.

Heilweil VM, Solomon DK, 2004, *Millimeter- to kilometer-scale variations in vadose-zone bedrock solutes: Implications for estimating recharge in arid settings*, *in* Phillips, Scanlon, Hogan, eds., Groundwater Recharge in a Desert Environment: The Southwestern US, Water Sci. and Appl. 9, Am. Geophys. Union, Wash, D.C., 49-67.

Recent Invited Talks

Heilweil VM, 2011, *The Great Basin Carbonate and Alluvial Aquifer System*, Great Basin Water Forum, Ely, Nevada, USA

Heilweil VM, 2011, *Managed aquifer recharge to fractured sandstone*, National Water Research Institute Managed Aquifer Recharge Symposium, Irvine, California, USA

Heilweil VM, 2011, *Evaluation of trapped gas clogging during spreading basin recharge*, National Water Research Institute Managed Aquifer Recharge Symposium, Irvine, California, USA

Heilweil VM, 2009, *Managed aquifer recharge to fractured sandstone*, International Workshop: Artificial Recharge of Groundwater Management, Palma de Mallorca, Spain

Heilweil VM and Suflita M, 2009, *Managed aquifer recharge: Concepts and considerations*, Utah Water Users Workshop, St. George, Utah, USA

Heilweil VM, 2009, *Managed aquifer recharge to permeable bedrock: A case study of the Navajo Sandstone of the western United States*, Joint IAH/IAHS International Conference, Hyderabad, India

Heilweil VM, 2008, *A multiple tracer approach for tracking the movement of artificial recharge through desert sandstone*, Geological Society of America National Meeting, Houston, Texas, USA