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Numerical Model Simulations of Potential Changes in Water Levels and Capture of Natural Discharge From Groundwater Withdrawals in Snake Valley and Adjacent Areas, Utah and Nevada

Open-File Report 2019–1083

U.S. Department of the Interior
U.S. Geological Survey

Cover photo: View across Snake Valley, looking west toward the southern Snake Range, Utah and Nevada. Photograph by Melissa Masbruch, U.S. Geological Survey, March 2010.

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DAVID BERNHARDT, Secretary

U.S. Geological Survey
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Contents

Figures

Tables

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Abbreviations

BLM	Bureau of Land Management
GBCAAS	Great Basin carbonate and alluvial aquifer system
NPS	National Park Service
NVDWR	Nevada Division of Water Resources
POD(s)	Point(s) of diversion
SNWA	Southern Nevada Water Authority
USGS	U.S. Geological Survey
UTDWR	Utah Division of Water Rights

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Abstract

The National Park Service (NPS) and the Bureau of Land Management (BLM) are concerned about cumulative effects of groundwater development on groundwater-dependent resources managed by, and other groundwater resources of interest to, these agencies in Snake Valley and adjacent areas, Utah and Nevada. Of particular concern to the NPS and BLM are withdrawals from all existing approved, perfected, certified, permitted, and vested groundwater rights in Snake Valley totaling about 55,272 acre-feet per year (acre-ft/yr), and from several senior water-right applications filed by the Southern Nevada Water Authority (SNWA) totaling 50,680 acre-ft/yr.

An existing groundwater-flow model of the eastern Great Basin was used to investigate where potential drawdown and capture of natural discharge is likely to result from potential groundwater withdrawals from existing groundwater rights in Snake Valley, and from groundwater withdrawals proposed in several applications filed by the SNWA. To evaluate the potential effects of the existing and proposed SNWA groundwater withdrawals, 11 withdrawal scenarios were simulated. All scenarios were run as steady state to estimate the ultimate long-term effects of the simulated withdrawals. This assessment provides a general understanding of the relative susceptibility of the groundwater resources of interest to the NPS and BLM, and the groundwater system in general, to existing and future groundwater development in the study area.

At the NPS and BLM groundwater resource sites of interest, simulated drawdown resulting from withdrawals based on existing approved, perfected, certified, permitted, and vested groundwater rights within Snake Valley ranged between 0 and 159 feet (ft) without accounting for irrigation return flow, and between 0 and 123 ft with accounting for irrigation return flow. With the addition of proposed SNWA withdrawals of 35,000 acre-ft/yr (equal to the Unallocated Groundwater portion allotted to Nevada in a draft interstate agreement), simulated drawdowns at the NPS and BLM sites of interest increased to range between 0 and 2,074 ft without irrigation return flow, and between 0 and 2,002 ft with irrigation return flow. With the addition of the proposed SNWA withdrawals of an amount equal to the full application amounts (50,680 acre-ft/yr), simulated drawdowns at the NPS and BLM sites of interest increased to range between 1 and 3,119 ft without irrigation return flow, and between 1 and 3,044 ft with irrigation return flow.

At the NPS and BLM groundwater resource sites of interest, simulated capture of natural discharge resulting from withdrawals based on existing groundwater rights in Snake Valley, both with and without irrigation return flow, ranged between 0 and 100 percent; simulated capture of 100 percent occurred at four sites. With the addition of proposed SNWA withdrawals of an amount equal to the Unallocated Groundwater portion allotted to Nevada in the draft interstate agreement, simulated capture of 100 percent occurred at nine additional sites without irrigation return flow, and at eight additional sites with irrigation return flow. With the addition of the proposed SNWA withdrawals of an amount equal to the full application amounts, simulated capture of 100 percent occurred at 11 additional sites without irrigation return flow, and at 9 additional sites with irrigation return flow.

The large simulated drawdowns produced in the scenarios that include large portions or all of the proposed SNWA withdrawals indicate that the groundwater system may not be able to support the amount of withdrawals from the proposed points of diversion (PODs) in the current SNWA water-right applications. Therefore, four additional scenarios were simulated where the withdrawal rates at the SNWA PODs were constrained by not allowing drawdowns to be deeper than the assumed depth of the PODs (about 2,000 ft).

In the constrained scenarios, total withdrawals at the SNWA PODs were reduced to about 48 percent of the Unallocated Groundwater portion allotted to Nevada (35,000 acre-ft/yr reduced to 16,817 acre-ft/yr or 16,914 acre-ft/yr, without or with irrigation return flow, respectively), and about 44 percent of the full application amounts (50,680 acre-ft/yr reduced to 22,048 acre-ft/yr or 22,165 acre-ft/yr, without or with irrigation return flow, respectively). This indicates that the SNWA may need to add more PODs, or PODs in different locations, in order to withdraw large portions or all of the groundwater that has been applied for.

At the NPS and BLM groundwater resource sites of interest, simulated drawdown resulting from the addition of the constrained SNWA withdrawals applied to the Unallocated Groundwater amount ranged between 0 and 290 ft without irrigation return flow, and between 0 and 252 ft with irrigation return flow. With the addition of the constrained SNWA withdrawals applied to the full application amounts, simulated drawdowns at the NPS and BLM sites of interest ranged between 0 and 358 ft without irrigation return flow, and between 0 and 313 ft with irrigation return flow.

At the NPS and BLM groundwater resource sites of interest, with the addition of the constrained SNWA withdrawals applied to the Unallocated Groundwater amount, simulated capture of 100 percent of the natural discharge occurred at five additional sites without irrigation return flow, and at two additional sites with irrigation return flow (in addition to the four captured from existing water rights both with and without irrigation return flow). With the addition of the constrained SNWA withdrawals applied to the full application amounts, simulated capture of 100 percent occurred at six additional sites both with and without irrigation return flow.

Introduction

Snake Valley is a sparsely populated basin along the Utah–Nevada border in the eastern part of the Great Basin Physiographic Province (Fenneman, 1931). The groundwater system in the study area consists of water in unconsolidated deposits in the basins and in consolidated rock underlying the basins and in the adjacent mountain blocks. The consolidated-rock and basin-fill aquifers are well connected hydraulically (Gardner and others, 2011; Sweetkind and others, 2011), with most of the recharge occurring in the consolidated-rock mountain blocks and most of the discharge occurring from the lower altitude basin-fill deposits. For a complete description of the hydrogeology of the Snake Valley area, more detail can be found in Gardner and others (2011); Heilweil and Brooks (2011); and Masbruch and others (2014).

The National Park Service (NPS) and the Bureau of Land Management (BLM) are concerned about cumulative effects of groundwater development on groundwater-dependent resources managed by, and other groundwater resources of interest to, these agencies in Snake Valley and adjacent areas (fig. 1). The NPS and BLM have identified more than 40 sites, including wells, springs or spring complexes, and mountain streams that may be impacted by groundwater development in the area (fig. 2 and table 1). The groundwater resources of concern support multiple uses, including habitat for sensitive threatened and endangered species, water and habitat for other wildlife species, recreational use, livestock use, and use by wild horses and burros. Using an existing numerical groundwater-flow model of the eastern Great Basin (fig. 1; Brooks and others, 2014; Brooks, 2017a,b; Stolp and others, 2017), the U.S. Geological Survey (USGS) has simulated the potential effects of withdrawals based on existing water rights and other water-right applications on the groundwater resources of interest to the NPS and BLM.

Of particular concern to the NPS and BLM are the potential effects of withdrawals from all approved, perfected, certified, permitted, and vested groundwater rights in Snake Valley, and from several water-right applications filed by the Southern Nevada Water Authority (SNWA). In 1989, SNWA filed nine applications for new groundwater rights within the Nevada portion of Snake Valley totaling approximately 50,680 acre-feet per year (acre-ft/yr). These water-right applications have not yet been approved and await a hearing by the Nevada State Engineer. Additionally, Public Law 108-424 (also known as the Lincoln County Conservation, Recreation, and Development Act) signed in 2004 requires, in part, that the states of Nevada and Utah must reach an agreement regarding the division of water resources for any groundwater basins located within both states prior to any potential transbasin diversions. An interstate agreement was drafted in 2009 (available at https://waterrights.utah.gov/snakeValleyAgreement/agreement.pdf, accessed on June 20, 2019; the State of Utah, however, chose not to sign the agreement, leaving this legal issue unresolved at this time.

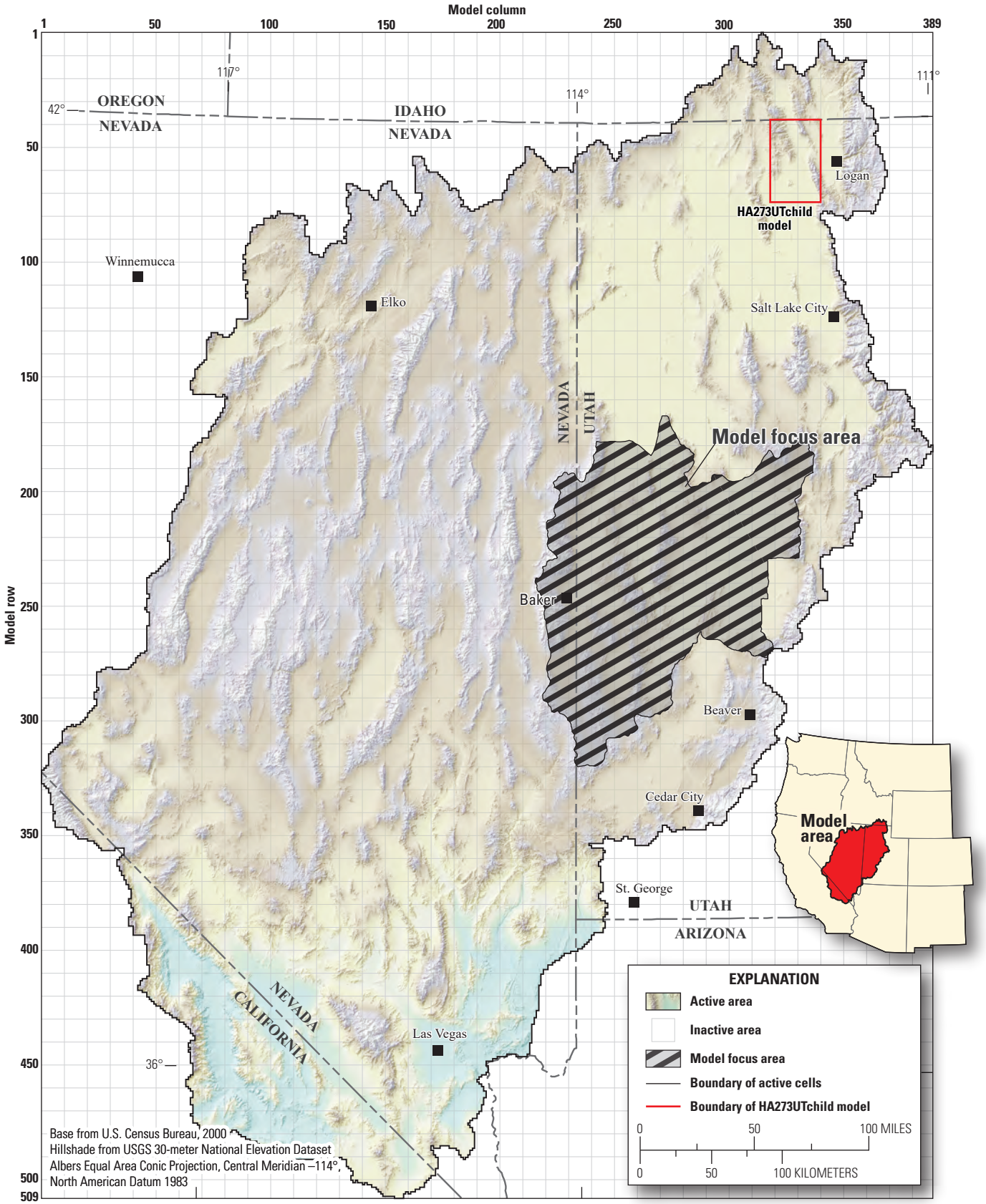

Figure 1. Location of model grid, model focus area, and child model, Great Basin carbonate and alluvial aquifer system groundwater model.

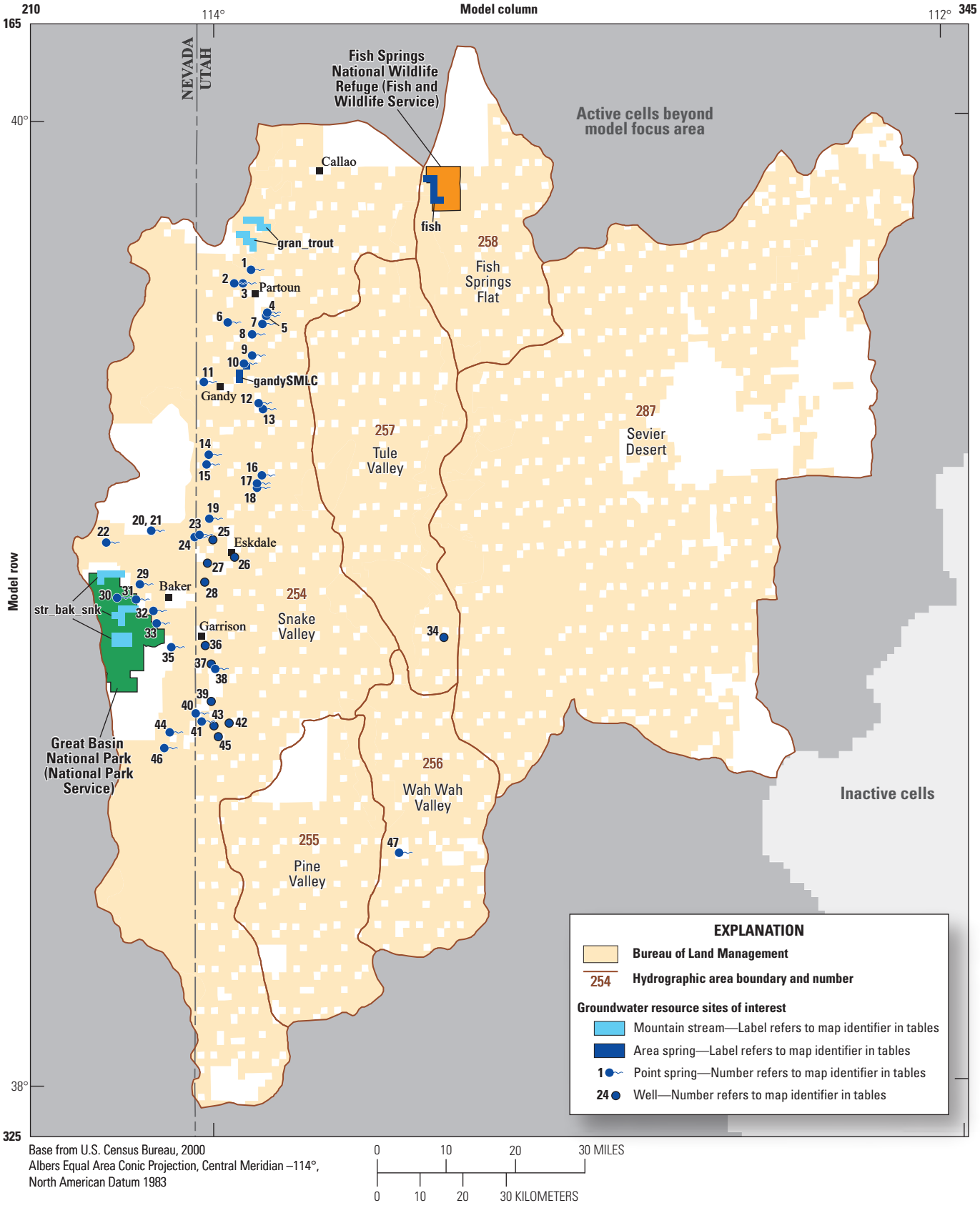

Figure 2. Groundwater resource sites of interest to the National Park Service and Bureau of Land Management, and land-management areas of Department of the Interior agencies, model focus (Snake Valley) area, Utah and Nevada.

Table 1. Summary of the National Park Service and Bureau of Land Management groundwater resource sites of interest in the model focus (Snake Valley) area, Utah and Nevada.

[Figure 2 shows the location of the sites. Water-right number: Water-right numbers are preceded by state abbreviation. Latitude and longitude are referenced to the North American Datum of 1983 (NAD83). **Abbreviations**: ID, identifier; USGS, U.S. Geological Survey; UT, Utah; NV, Nevada; N/A, not applicable]

Map ID	Site name	Water-right number	Latitude (decimal degrees)	Longitude (decimal degrees)	USGS site number
1	Partoun Spring	UT 18-540	39.692	–113.893	394131113533301
2	South Seeps	UT 18-597	39.664	–113.941	393949113562301
3	Lime Spring	UT 18-594	39.664	–113.917	393949113550001
4	Snake Valley North Spring Complex	UT 18-701	39.603	–113.850	N/A
5	Snake Valley South Spring Complex	UT 18-702	39.596	–113.853	N/A
6	Coyote Spring	UT 18-596	39.584	–113.958	393501113572701
7	Miller Spring[1]	UT 18-253	39.580	–113.864	393449113515201
8	Leland Harris Spring Complex	unknown	39.559	–113.892	N/A
9	Gandy Salt Marsh Seep	UT 18-579	39.515	–113.893	N/A
10	Springs feeding Gandy Salt Marsh Lake	UT 18-537	39.498	–113.914	392952113544801
gandySMLC	Gandy Salt Marsh Lake Spring Complex	UT 18-575	N/A[2]	N/A[2]	N/A
11	Gandy Warm Springs[1]	UT 18-584, 18-585, 18-623	39.460	–114.038	392737114021201
12	Foote Reservoir Spring[1]	UT 18-711, 18-255	39.415	–113.875	392455113522601
13	Twin Springs[1]	UT 18-476, 18-486	39.404	–113.864	392413113515001/ 392411113514301
14	Briggs Spring	UT 18-604	39.309	–114.010	N/A
15	Phil Spring	UT 18-742	39.289	–114.017	N/A
16	North Knoll Spring	UT 18-535	39.266	–113.866	391557113515601
17	Middle Knoll Spring	UT 18-491	39.249	–113.879	391457113524101
18	Knoll Spring	UT 18-84	39.241	–113.879	391426113524401
19	Unnamed Spring 1	unknown	39.176	–114.009	N/A
20	Unnamed Spring 2	unknown	39.151	–114.166	N/A
21	Unnamed Spring 3	unknown	39.150	–114.167	N/A
22	Want Spring	NV R05275	39.127	–114.289	N/A
23	Kane Spring	UT 18-406	39.143	–114.036	N/A
24	Caine Spring	unknown	39.138	–114.049	390818114025501
25	Eskdale Well	UT 18-304	39.133	–114.002	390758114000701
26	West Buckskin Well	UT 18-555	39.097	–113.942	390549113562901
27	Flowing Well 2	UT 18-719	39.084	–114.016	390503114005901
28	Shell Baker Creek Well	UT 18-168	39.045	–114.024	390243114012201
29	Unnamed Spring 4	unknown	39.040	–114.197	N/A
30	Upper Lehman Spring[1]	unknown	39.012	–114.259	390042114152601
31	Rowland Springs[1]	NV V10164	39.009	–114.208	10243265
32	Kious Spring	unknown	38.985	–114.160	385911114093101
33	Mahogany Spring	unknown	38.959	–114.152	N/A
34	Ibex Well	UT 18-356	38.928	–113.377	385542113223601
35	Spring Creek Spring[1]	unknown	38.909	–114.113	385433114063901
36	Diversion from Lake Creek 1	UT 18-620	38.913	–114.022	N/A
37	Diversion from Lake Creek 2	UT 18-621	38.875	–114.006	N/A
38	Clay Spring[1]	unknown	38.866	–113.993	385156113593701

Table 1. Summary of the National Park Service and Bureau of Land Management groundwater resource sites of interest in the model focus (Snake Valley) area, Utah and Nevada.—Continued

[Figure 2 shows the location of the sites. Water-right number: Water-right numbers are preceded by state abbreviation. Latitude and longitude are referenced to the North American Datum of 1983 (NAD83). **Abbreviations**: ID, identifier; USGS, U.S. Geological Survey; UT, Utah; NV, Nevada; N/A, not applicable]

Map ID	Site name	Water-right number	Latitude (decimal degrees)	Longitude (decimal degrees)	USGS site number
39	Davies Well 1	UT 18-497	38.798	–114.006	N/A
40	Dearden Spring Group[1]	UT 18-684	38.773	–114.046	384621114024601
41	Needle Point Spring	UT 18-571	38.756	–114.030	N/A
42	Davies Well 2	UT 18-203	38.753	–113.958	384510113573001
43	Needle Point Well	UT 18-678	38.747	–113.998	384449113595401
44	Unnamed Spring 5	NV R05271	38.734	–114.116	N/A
45	Cove Well	UT 18-673	38.724	–113.987	384327113591401
46	Big Springs[1]	unknown	38.699	–114.132	384158114075201
47	Wah Wah Springs[1]	UT 69-1, 69-107, 69-108, 69-19, 69-33	38.484	–113.498	382901113295101
fish	Fish Springs[1]	UT 18-215, 18-66, 18-51	N/A[2]	N/A[2]	N/A
gran_trout	Granite Creek[1]	UT 18-552	N/A[2]	N/A[2]	N/A
	Trout Creek[1]	UT 18-565	N/A[2]	N/A[2]	N/A
str_bak_snk	Strawberry Creek[1]	unknown	N/A[2]	N/A[2]	N/A
	Baker Creek[1]	NV V01066	N/A[2]	N/A[2]	N/A
	Snake Creek[1]	UT 18-11, 18-12, 18-249, 18-250, 18-251, 18-257; NV C3863	N/A[2]	N/A[2]	N/A

[1]Spring discharge or groundwater discharge to streams explicitly simulated in model.

[2]These sites are not located at a single point and, therefore, cannot be represented by a single latitude and longitude.

In the draft interstate agreement, the available annual groundwater supply in Snake Valley was assumed to be 132,000 acre-ft/yr, which was the amount of groundwater annually consumed by evapotranspiration in Snake Valley, as determined by the Basin and Range carbonate aquifer study (Welch and others, 2007). This consumptive amount was to be divided equally between the two states. The agreement identified three categories in which the available annual groundwater supply was to be divided, as follows:

1. Allocated Groundwater—Groundwater that was set aside solely for the satisfaction of existing water rights in Snake Valley and at Fish Springs National Wildlife Refuge with a priority date before October 17, 1989. Recognition of unrecorded diligence claims also shall be accounted for as Allocated Groundwater. Under the draft agreement, Allocated Groundwater amounts were divided as follows: Utah=55,000 acre-ft/yr; Nevada=12,000 acre-ft/yr.

2. Unallocated Groundwater—Groundwater available for additional appropriation by the two states in accordance with the laws of their respective jurisdictions. Water rights with a priority date on or after October 17, 1989, fall into this category. Under the draft agreement, Unallocated Groundwater amounts were divided as follows: Utah=6,000 acre-ft/yr; Nevada=35,000 acre-ft/yr.

3. Reserved Groundwater—Groundwater for which the states may grant appropriations when and if reliable data are gathered indicating that additional groundwater can be safely and sustainably withdrawn from Snake Valley without unreasonably impacting other water-rights holders. Under the draft agreement, Reserved Groundwater amounts were divided as follows: Utah=5,000 acre-ft/yr; Nevada=19,000 acre-ft/yr.

Based on a summary of available online water-right data for Snake Valley provided by the Nevada State Engineer and the Utah State Engineer, the combined diversion amount of Allocated and Unallocated Groundwater (specifically, approved, perfected, certified, permitted, and vested groundwater rights) reported by Nevada (as of February 2018) was about 13,551 acre-ft/yr, while the combined diversion amount of Allocated and Unallocated Groundwater reported by Utah (as of July 2018) was about 41,721 acre-ft/yr (excluding the amount recognized for Fish Springs National Wildlife Refuge).

Purpose and Scope

An existing numerical groundwater-flow model of the eastern Great Basin (Brooks and others, 2014; Brooks, 2017a,b; Stolp and others, 2017) was used to investigate where potential drawdown and capture of natural discharge is likely to result from potential groundwater withdrawals from existing approved, perfected, certified, permitted, and vested groundwater rights in Snake Valley (categorized as Allocated and Unallocated Groundwater), and from withdrawals proposed in nine senior applications filed by the SNWA (categorized as Unallocated and Reserved Groundwater). Figure 1 shows the location of the model focus area and model grid used in the simulations. This report presents results from 11 simulations with differing groundwater withdrawal scenarios. Limitations in time and funding precluded the collection of additional data or recalibration of the model to transient conditions. This assessment provides a general understanding of the relative susceptibility of the groundwater resources of interest to the NPS and BLM, and the groundwater system in general, to existing and future groundwater development in the study area.

Potential Effects of Groundwater Withdrawals

Description of Numerical Groundwater-Flow Model

The pre-existing eastern Great Basin groundwater-flow model was constructed using MODFLOW-2005 and MODFLOW-LGR, and has undergone two revisions; it now consists of a parent model and a child model. The parent model covers the study focus (Snake Valley) area (fig. 1), and was used for the simulations presented in this report. During the most recent revision (GBCAAS v. 3.0; Brooks, 2017a,b) the parent model was updated and recalibrated to steady-state conditions in southwestern Utah and Snake Valley using new data (water levels and groundwater evapotranspiration estimates) that were collected in Snake, Pine, Wah Wah, and Tule Valleys, and the Sevier Desert. The model was also updated and recalibrated to represent transient conditions in Parowan Valley.

The first stress period of the pre-existing parent model simulates steady-state pre-development (or pre-pumping) conditions in the study focus area. Only the first stress period from the model was used for the simulations in this report because the model may not accurately represent transient conditions outside of Parowan Valley (Brooks, 2017a). Although the top of the groundwater system is unconfined, all model layers were designated as confined for numerical stability. Simulating layer 1 as confined is a reasonable approximation if the top of the model is close to the simulated water levels in layer 1. During calibration, the top of the model was adjusted to be close to the altitude of simulated water levels (Brooks, 2017a). The model incorporates the unconsolidated basin fill and consolidated rock into a hydraulically connected system, where most recharge occurs on the consolidated rock in the mountains, and most discharge occurs as groundwater evapotranspiration in the basins. Groundwater recharge from precipitation is simulated across the top of the model. Groundwater discharge is simulated to evapotranspiration, and to selected springs and mountain streams using head-dependent boundary packages.

To simulate the potential withdrawals based on existing Allocated and Unallocated groundwater rights and SNWA applications in Snake Valley (fig. 3 and tables 2 and 3), and to allow for analysis of the potential effects of these withdrawals on NPS and BLM managed water rights and other sites of interest, several model input files were modified or added, including input to the Well and Multi-Node Well Packages, to account for withdrawals associated with the existing water rights and future proposed groundwater withdrawals from the SNWA applications. Because only the parent model was used, it was converted to run with MODFLOW-2005. Modifications to the MODFLOW and ZONEBUDGET input files for the GBCAAS v. 3.0 parent model are summarized below.

- MODFLOW-2005 Name File: Updated names and locations of input and output files.
- MODFLOW-2005 Discretization Package: Changed number of stress periods to 1 to simulate only the first (steady-state) stress period.
- MODFLOW-2005 Hydrogeologic-Unit Flow (HUF) Package: Removed specific yield and specific storage parameters. Because only the first stress period, which is a steady-state stress period, is being simulated, the model will not run and gives an error if there are specific yield and specific storage parameters defined in the HUF Package.
- MODFLOW-2005 Starting Heads File: Set starting heads equal to ending heads from first steady-state stress period.
- MODFLOW-2005 Well Package: Added withdrawals from existing Allocated and Unallocated water rights and proposed SNWA applications in Snake Valley. This file is unique for each simulation scenario (see the "Description of Simulated Scenarios and Results" section for amounts and locations of well withdrawals used for each scenario).
- MODFLOW-2005 Multi-Node Well Package: Added withdrawals from SNWA applications, but allowed the withdrawals to be constrained by drawdown at the SNWA PODs.
- MODFLOW-2005 Head Observation Package: Updated to include NPS and BLM groundwater resource sites of interest.
- ZONEBUDGET Zone File: Updated to include NPS and BLM groundwater resource sites of interest.
- ZONEBUDGET Main Input File: Updated names and locations of input and output files.

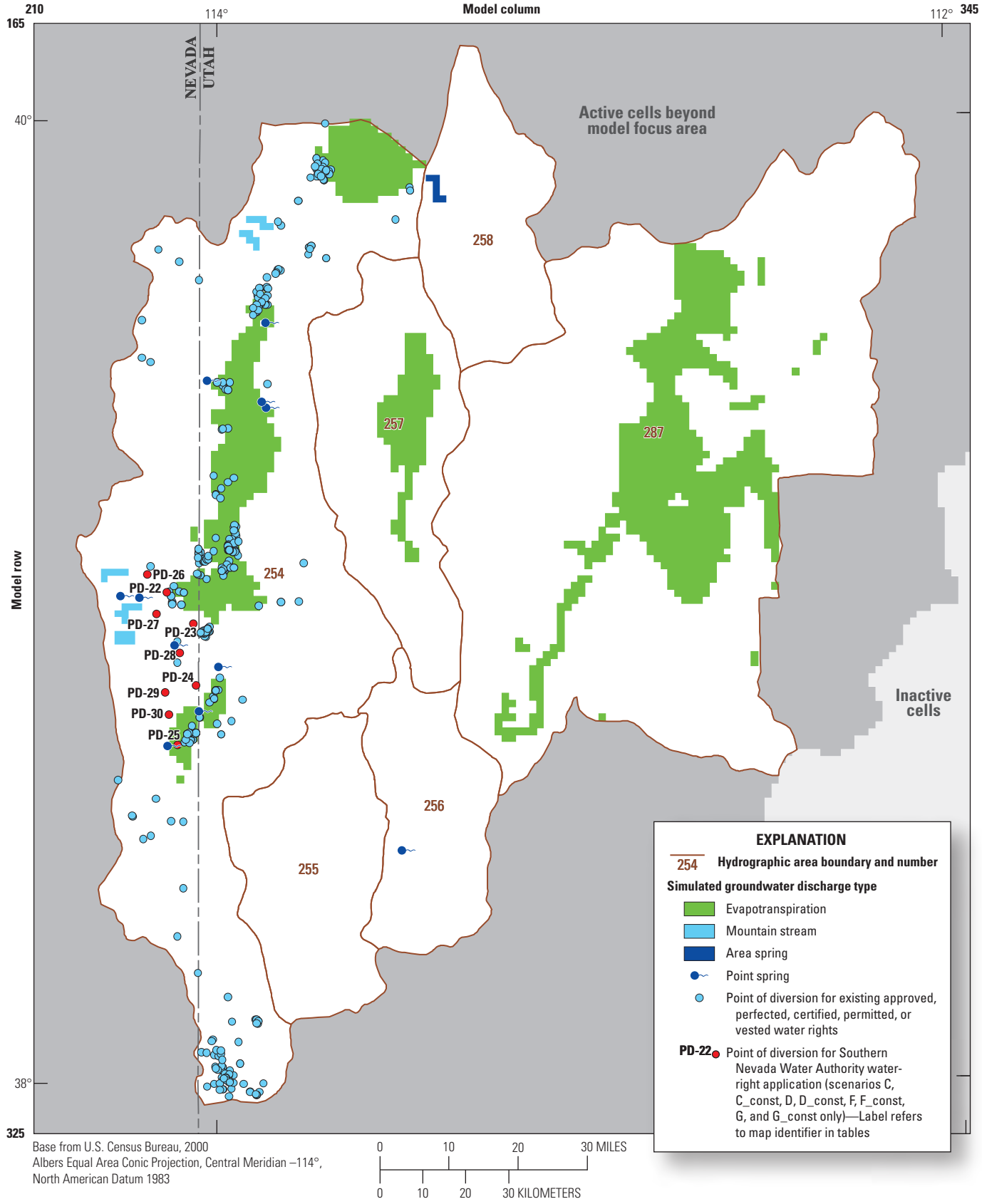

Figure 3. Locations or areas of simulated natural groundwater discharge types and locations of simulated groundwater withdrawal sites, model focus (Snake Valley) area, Utah and Nevada.

Table 2. Withdrawal amounts used to simulate existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley, Utah and Nevada.

[Figure 3 shows the location of the sites. Simulated withdrawals are rounded to the nearest acre-foot or, if below 1 acre-foot, rounded to the nearest tenth of an acre-foot. Priority date is in 4-digit year, 2-digit month, and 2-digit day format. Water-right numbers in red indicate water rights that have a priority date after October 17, 1989 (junior to Southern Nevada Water Authority water-right applications priority date). **Abbreviations**: YYYYMMDD, year month day; acre-ft/yr, acre-feet per year; UTDWR, Utah Division of Water Rights; NVDWR, Nevada Division of Water Resources; NS, not simulated]

Agency	Water-right number	Status	Priority date (YYYYMMDD)	Points of diversion[1]	Simulated withdrawals, Scenarios B, C, C_const, D, and D_const (acre-ft/yr)	Simulated withdrawals, Scenarios E, F, F_const, G, and G_const (acre-ft/yr)
UTDWR	18-127	Perfected	19590415	1	147	126
UTDWR	18-129	Certified	19490805	1	322	277
UTDWR	18-130	Certified	19490514	1	14	12
UTDWR	18-133	Certified	19490912	1	503	433
UTDWR	18-136	Certified	19500508	1	1	0.9
UTDWR	18-137	Certified	19500922	1	503	433
UTDWR	18-138	Perfected	19500922	1	1	0.9
UTDWR	18-139	Perfected	19500922	1	6	5
UTDWR	18-140	Certified	19530529	1	396	341
UTDWR	18-141	Perfected	19510406	1	0.5	0.4
UTDWR	18-142	Certified	19570819	1	1,216	1,046
UTDWR	18-143	Perfected	19511006	1	0.5	0.4
UTDWR	18-145	Certified	19571112	1	23	20
UTDWR	18-147	Perfected	19530305	1	3	3
UTDWR	18-148	Perfected	19530511	1	0.5	0.4
UTDWR	18-150	Perfected	19531014	1	0.5	0.4
UTDWR	18-151	Perfected	19540119	1	0.5	0.4
UTDWR	18-155	Perfected	19540920	1	6	5
UTDWR	18-156	Certified	19550111	2	17 17	15 15
UTDWR	18-158	Certified	19820416	2	257 257	221 221
UTDWR	18-159	Certified	19591109	3	159 159 159	137 137 137
UTDWR	18-161	Certified	19550111	2	254 254	218 218
UTDWR	18-162	Certified	19550111	2	254 254	218 218
UTDWR	18-163	Certified	19550111	3	316 316 316	272 272 272
UTDWR	18-168	Certified	19550626	1	8	7
UTDWR	18-169	Perfected	19550919	1	5	4
UTDWR	18-170	Perfected	19551128	1	4	3
UTDWR	18-175	Perfected	19560507	1	5	4
UTDWR	18-176	Perfected	19560717	1	1	0.9
UTDWR	18-177	Perfected	19560905	1	5	4
UTDWR	18-178	Perfected	19560905	1	5	4
UTDWR	18-179	Perfected	19561117	1	8	7
UTDWR	18-180	Perfected	19570103	1	7	6
UTDWR	18-181	Perfected	19570103	1	8	7

Table 2. Withdrawal amounts used to simulate existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley, Utah and Nevada.—Continued

[Figure 3 shows the location of the sites. Simulated withdrawals are rounded to the nearest acre-foot or, if below 1 acre-foot, rounded to the nearest tenth of an acre-foot. Priority date is in 4-digit year, 2-digit month, and 2-digit day format. Water-right numbers in red indicate water rights that have a priority date after October 17, 1989 (junior to Southern Nevada Water Authority water-right applications priority date). **Abbreviations**: YYYYMMDD, year month day; acre-ft/yr, acre-feet per year; UTDWR, Utah Division of Water Rights; NVDWR, Nevada Division of Water Resources; NS, not simulated]

Agency	Water-right number	Status	Priority date (YYYYMMDD)	Points of diversion[1]	Simulated withdrawals, Scenarios B, C, C_const, D, and D_const (acre-ft/yr)	Simulated withdrawals, Scenarios E, F, F_const, G, and G_const (acre-ft/yr)
UTDWR	18-182	Perfected	19570103	1	8	7
UTDWR	18-183	Perfected	19570307	1	4	3
UTDWR	18-184	Certified	19670606	1	367	316
UTDWR	18-185	Certified	19570606	1	423	364
UTDWR	18-190	Perfected	19571003	1	2	2
UTDWR	18-191	Perfected	19571003	1	2	2
UTDWR	18-192	Perfected	19571003	1	2	2
UTDWR	18-193	Perfected	19571003	1	2	2
UTDWR	18-194	Perfected	19571003	1	2	2
UTDWR	18-195	Perfected	19571228	1	7	6
UTDWR	18-196	Perfected	19580125	1	3	3
UTDWR	18-197	Perfected	19580206	1	11	9
UTDWR	18-199	Perfected	19580723	1	0.5	0.4
UTDWR	18-202	Certified	19580823	1	5	4
UTDWR	18-203	Perfected	19580823	1	3	3
UTDWR	18-210	Certified	19561119	1	368	316
UTDWR	18-211	Certified	19600104	7	177 177 177 177 177 177 177	152 152 152 152 152 152 152
UTDWR	18-212	Perfected	19600226	4	322 322 322 322	277 277 277 277
UTDWR	18-213	Perfected	19650203	1	4	3
UTDWR	18-216	Certified	19760228	2	332 332	286 286
UTDWR	18-218	Certified	19690217	1	480	413
UTDWR	18-219	Certified	19610712	2	371 371	319 319
UTDWR	18-223	Perfected	19711031	1	1,309	1,126
UTDWR	18-224	Certified	19610814	1	9	8
UTDWR	18-225	Certified	19620721	1	NS[2]	NS[2]
UTDWR	18-228	Certified	19620830	1	41	35
UTDWR	18-230	Perfected	19630227	1	123	106
UTDWR	18-232	Certified	19630830	4	42 42 42 42	36 36 36 36

Table 2. Withdrawal amounts used to simulate existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley, Utah and Nevada.—Continued

[Figure 3 shows the location of the sites. Simulated withdrawals are rounded to the nearest acre-foot or, if below 1 acre-foot, rounded to the nearest tenth of an acre-foot. Priority date is in 4-digit year, 2-digit month, and 2-digit day format. Water-right numbers in red indicate water rights that have a priority date after October 17, 1989 (junior to Southern Nevada Water Authority water-right applications priority date). **Abbreviations**: YYYYMMDD, year month day; acre-ft/yr, acre-feet per year; UTDWR, Utah Division of Water Rights; NVDWR, Nevada Division of Water Resources; NS, not simulated]

Agency	Water-right number	Status	Priority date (YYYYMMDD)	Points of diversion[1]	Simulated withdrawals, Scenarios B, C, C_const, D, and D_const (acre-ft/yr)	Simulated withdrawals, Scenarios E, F, F_const, G, and G_const (acre-ft/yr)
UTDWR	18-235	Perfected	19640429	1	3	3
UTDWR	18-240	Perfected	19720919	5	0.4	0.3
					0.4	0.3
					0.4	0.3
					0.4	0.3
					0.4	0.3
UTDWR	18-259	Perfected	192806	1	NS[3]	NS[3]
UTDWR	18-260	Perfected	19340718	1	NS[3]	NS[3]
UTDWR	18-261	Perfected	19340723	1	NS[3]	NS[3]
UTDWR	18-262	Perfected	19300317	1	NS[3]	NS[3]
UTDWR	18-263	Perfected	19220930	1	NS[3]	NS[3]
UTDWR	18-265	Perfected	1925	1	NS[3]	NS[3]
UTDWR	18-266	Perfected	190106	1	NS[3]	NS[3]
UTDWR	18-267	Perfected	190107	1	NS[3]	NS[3]
UTDWR	18-268	Perfected	19360318	1	NS[3]	NS[3]
UTDWR	18-269	Perfected	1890	1	NS[3]	NS[3]
UTDWR	18-270	Perfected	193408	1	NS[3]	NS[3]
UTDWR	18-271	Perfected	192305	1	NS[3]	NS[3]
UTDWR	18-272	Perfected	192305	1	NS[3]	NS[3]
UTDWR	18-273	Perfected	1896	1	NS[3]	NS[3]
UTDWR	18-274	Perfected	1896	1	NS[3]	NS[3]
UTDWR	18-280	Perfected	19200401	1	NS[3]	NS[3]
UTDWR	18-290	Perfected	1925	1	NS[3]	NS[3]
UTDWR	18-292	Perfected	1935	1	NS[3]	NS[3]
UTDWR	18-294	Perfected	1935	1	NS[3]	NS[3]
UTDWR	18-296	Certified	19660218	1	456	392
UTDWR	18-301	Perfected	1915	1	NS[3]	NS[3]
UTDWR	18-302	Certified	19571016	3	147	126
					147	126
					147	126
UTDWR	18-303	Perfected	19671031	1	2	2
UTDWR	18-304	Certified	19671113	1	22	19
UTDWR	18-305	Certified	19710204	2	405	348
					405	348
UTDWR	18-307	Certified	19680308	1	5	4
UTDWR	18-308	Certified	19680419	1	9	8
UTDWR	18-316	Certified	19690905	1	764	657
UTDWR	18-317	Perfected	19691023	1	11	9
UTDWR	18-319	Perfected	1909	1	NS[3]	NS[3]
UTDWR	18-325	Perfected	19700320	1	11	9
UTDWR	18-327	Perfected	19700427	1	5	4

Table 2. Withdrawal amounts used to simulate existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley, Utah and Nevada.—Continued

[Figure 3 shows the location of the sites. Simulated withdrawals are rounded to the nearest acre-foot or, if below 1 acre-foot, rounded to the nearest tenth of an acre-foot. Priority date is in 4-digit year, 2-digit month, and 2-digit day format. Water-right numbers in red indicate water rights that have a priority date after October 17, 1989 (junior to Southern Nevada Water Authority water-right applications priority date). **Abbreviations**: YYYYMMDD, year month day; acre-ft/yr, acre-feet per year; UTDWR, Utah Division of Water Rights; NVDWR, Nevada Division of Water Resources; NS, not simulated]

Agency	Water-right number	Status	Priority date (YYYYMMDD)	Points of diversion[1]	Simulated withdrawals, Scenarios B, C, C_const, D, and D_const (acre-ft/yr)	Simulated withdrawals, Scenarios E, F, F_const, G, and G_const (acre-ft/yr)
UTDWR	18-332	Perfected	19710308	2	326	280
					326	280
UTDWR	18-335	Perfected	19710730	1	26	22
UTDWR	18-336	Perfected	19710927	1	41	35
UTDWR	18-339	Perfected	19720223	1	16	14
UTDWR	18-344	Perfected	19730220	2	202	174
					202	174
UTDWR	18-345	Perfected	19730220	1	29	25
UTDWR	18-346	Perfected	19730220	2	200	172
					200	172
UTDWR	18-357	Certified	19740207	1	2	2
UTDWR	18-359	Perfected	19740418	1	173	149
UTDWR	18-360	Certified	19820617	1	76	65
UTDWR	18-362	Perfected	19740806	1	2	2
UTDWR	18-365	Perfected	19740822	1	16	14
UTDWR	18-368	Perfected	19741205	1	2	2
UTDWR	18-371	Perfected	19741220	1	27	23
UTDWR	18-373	Perfected	19750227	1	2	2
UTDWR	18-374	Perfected	19750409	1	1	0.9
UTDWR	18-376	Certified	19750501	1	20	17
UTDWR	18-379	Perfected	19760429	1	647	556
UTDWR	18-381	Perfected	19760716	4	221	190
					221	190
					221	190
					221	190
UTDWR	18-383	Perfected	1925	1	NS[3]	NS[3]
UTDWR	18-395	Certified	19770822	1	59	51
UTDWR	18-4	Perfected	1917	1	30	26
UTDWR	18-401	Certified	19780621	1	598	514
UTDWR	18-404	Certified	19781219	1	300	258
UTDWR	18-413	Perfected	19790516	1	123	106
UTDWR	18-415	Perfected	19790524	1	3	3
UTDWR	18-420	Certified	19791109	1	393	338
UTDWR	18-421	Certified	19791109	1	304	261
UTDWR	18-423	Perfected	19800214	1	6	5
UTDWR	18-424	Perfected	1920	1	NS[3]	NS[3]
UTDWR	18-427	Perfected	19800721	1	1	0.9
UTDWR	18-460	Perfected	19811117	1	29	25
UTDWR	18-461	Perfected	19811117	1	662	569
UTDWR	18-462	Perfected	19750501	1	505	434
UTDWR	18-463	Certified	19811124	1	11	9
UTDWR	18-472	Perfected	19820611	1	2	2

Table 2. Withdrawal amounts used to simulate existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley, Utah and Nevada.—Continued

[Figure 3 shows the location of the sites. Simulated withdrawals are rounded to the nearest acre-foot or, if below 1 acre-foot, rounded to the nearest tenth of an acre-foot. Priority date is in 4-digit year, 2-digit month, and 2-digit day format. Water-right numbers in red indicate water rights that have a priority date after October 17, 1989 (junior to Southern Nevada Water Authority water-right applications priority date). **Abbreviations**: YYYYMMDD, year month day; acre-ft/yr, acre-feet per year; UTDWR, Utah Division of Water Rights; NVDWR, Nevada Division of Water Resources; NS, not simulated]

Agency	Water-right number	Status	Priority date (YYYYMMDD)	Points of diversion[1]	Simulated withdrawals, Scenarios B, C, C_const, D, and D_const (acre-ft/yr)	Simulated withdrawals, Scenarios E, F, F_const, G, and G_const (acre-ft/yr)
UTDWR	18-487	Certified	19821001	1	1	0.9
UTDWR	18-490	Certified	19821020	1	18	15
UTDWR	18-493	Certified	19821020	1	NS[4]	NS[4]
UTDWR	18-497	Certified	19830429	1	12	10
UTDWR	18-5	Perfected	1904	1	8	7
UTDWR	18-509	Perfected	19840106	1	26	22
UTDWR	18-530	Certified	19850715	1	348	299
UTDWR	18-554	Certified	19851219	1	41	35
UTDWR	18-555	Certified	19851223	1	1	0.9
UTDWR	18-557	Certified	19860122	1	13	11
UTDWR	18-590	Certified	19880520	1	465	400
UTDWR	18-592	Perfected	1928	1	NS[2]	NS[2]
UTDWR	18-6	Perfected	1928	1	NS[2]	NS[2]
UTDWR	18-600	Certified	19891027	1	152	131
UTDWR	18-613	Certified	19910226	1	296	255
UTDWR	18-614	Certified	19910311	1	41	35
UTDWR	18-625	Certified	19920117	2	42 42	36 36
UTDWR	18-630	Certified	19920601	1	1	0.9
UTDWR	18-631	Certified	19920710	1	654	562
UTDWR	18-634	Certified	19920806	1	1	0.9
UTDWR	18-647	Certified	20041022	1	641	551
UTDWR	18-648	Certified	19960816	1	22	19
UTDWR	18-650	Certified	19970414	1	4	3
UTDWR	18-654	Certified	19970709	1	1	0.9
UTDWR	18-659	Certified	20000121	1	54	46
UTDWR	18-660	Certified	20000302	1	2	2
UTDWR	18-663	Certified	20110802	1	2	2
UTDWR	18-667	Certified	20010206	1	400	344
UTDWR	18-671	Certified	20011009	1	2	2
UTDWR	18-676	Certified	20020624	1	0.4	0.3
UTDWR	18-678	Certified	20020813	1	13	11
UTDWR	18-680	Certified	20030519	1	9	8
UTDWR	18-683	Certified	20030703	1	5	4
UTDWR	18-69	Certified	19390926	1	1	0.9
UTDWR	18-690	Certified	20050721	1	544	468
UTDWR	18-692	Certified	20050721	1	45	39
UTDWR	18-70	Certified	19400725	1	60	52
UTDWR	18-700	Certified	20051221	1	0.5	0.4
UTDWR	18-706	Certified	19920710	1	243	209
UTDWR	18-707	Certified	19710204	2	494 494	425 425

Table 2. Withdrawal amounts used to simulate existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley, Utah and Nevada.—Continued

[Figure 3 shows the location of the sites. Simulated withdrawals are rounded to the nearest acre-foot or, if below 1 acre-foot, rounded to the nearest tenth of an acre-foot. Priority date is in 4-digit year, 2-digit month, and 2-digit day format. Water-right numbers in red indicate water rights that have a priority date after October 17, 1989 (junior to Southern Nevada Water Authority water-right applications priority date). **Abbreviations**: YYYYMMDD, year month day; acre-ft/yr, acre-feet per year; UTDWR, Utah Division of Water Rights; NVDWR, Nevada Division of Water Resources; NS, not simulated]

Agency	Water-right number	Status	Priority date (YYYYMMDD)	Points of diversion[1]	Simulated withdrawals, Scenarios B, C, C_const, D, and D_const (acre-ft/yr)	Simulated withdrawals, Scenarios E, F, F_const, G, and G_const (acre-ft/yr)
UTDWR	18-709	Certified	19460715	1	165	142
UTDWR	18-714	Certified	20130103	1	5	4
UTDWR	18-716	Certified	20071121	1	1	0.9
UTDWR	18-717	Perfected	19561221	1	NS[4]	NS[4]
UTDWR	18-72	Certified	19561221	1	12	10
UTDWR	18-721	Certified	20080820	4	100 100 100 100	86 86 86 86
UTDWR	18-732	Certified	20090804	1	2	2
UTDWR	18-733	Certified	20090901	1	406	349
UTDWR	18-738	Certified	20100816	1	155	133
UTDWR	18-749	Certified	20131223	2	245 245	211 211
UTDWR	18-750	Certified	20140107	1	358	308
UTDWR	18-763	Certified	19550111	2	169 169	145 145
UTDWR	18-769	Certified	19460814	1	400	344
UTDWR	18-78	Perfected	19440424	1	0.5	0.4
UTDWR	18-81	Perfected	19450217	1	313	269
UTDWR	18-82	Perfected	19450615	1	11	9
UTDWR	18-83	Perfected	19450803	1	11	9
UTDWR	18-85	Certified	19460309	1	241	207
UTDWR	18-86	Certified	19460309	1	354	304
UTDWR	18-87	Certified	19460309	1	291	250
UTDWR	18-88	Certified	19460501	1	313	269
UTDWR	18-89	Certified	19460320	1	NS[2]	NS[2]
UTDWR	18-90	Perfected	19460531	1	0.5	0.4
UTDWR	18-91	Certified	19460715	1	14	12
UTDWR	18-92	Certified	19460814	1	NS[5]	NS[5]
UTDWR	18-95	Perfected	19470818	1	0.5	0.4
UTDWR	18-96	Certified	19471110	1	221	190
UTDWR	19-125	Perfected	19690205	1	11	9
UTDWR	19-17	Certified	19530120	1	36	31
UTDWR	19-21	Certified	19630511	1	2	2
UTDWR	19-28	Perfected	1899	1	NS[3]	NS[3]
UTDWR	19-286	Perfected	19691113	1	1	0.9
UTDWR	19-310	Perfected	19760813	1	3	3
UTDWR	19-323	Perfected	1930	1	4	3
UTDWR	19-328	Perfected	1930	1	2	2
UTDWR	19-341	Certified	1930	1	6	5

Table 2. Withdrawal amounts used to simulate existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley, Utah and Nevada.—Continued

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Agency	Water-right number	Status	Priority date (YYYYMMDD)	Points of diversion[1]	Simulated withdrawals, Scenarios B, C, C_const, D, and D_const (acre-ft/yr)	Simulated withdrawals, Scenarios E, F, F_const, G, and G_const (acre-ft/yr)
UTDWR	19-342	Certified	19881208	1	10	9
UTDWR	19-343	Certified	19890519	1	1	0.9
UTDWR	19-344	Certified	19891016	1	4	3
UTDWR	19-350	Certified	19750815	1	1	0.9
UTDWR	19-351	Certified	19870202	1	0.4	0.3
UTDWR	19-356	Certified	19980304	1	2	2
UTDWR	19-358	Certified	19980303	1	1	0.9
UTDWR	19-362	Certified	19980624	1	2	2
UTDWR	19-364	Certified	19980708	1	2	2
UTDWR	19-368	Certified	19981002	2	1 1	0.9 0.9
UTDWR	19-376	Certified	20011120	1	0.3	0
UTDWR	19-377	Certified	20011127	1	1	0.9
UTDWR	19-379	Certified	20020509	1	2	2
UTDWR	19-380	Certified	20020625	1	2	2
UTDWR	19-384	Certified	20030821	1	1	0.9
UTDWR	19-385	Certified	20031016	1	2	2
UTDWR	19-386	Certified	20031106	1	2	2
UTDWR	19-389	Perfected	1930	1	15	13
UTDWR	19-39	Perfected	1886	1	0.3	0.3
UTDWR	19-398	Perfected	1930	1	3	3
UTDWR	19-400	Certified	20061030	1	2	2
UTDWR	19-404	Certified	20070330	1	2	2
UTDWR	19-405	Certified	20070509	1	1	0.9
UTDWR	19-407	Certified	20070828	1	2	2
UTDWR	19-413	Certified	20081002	1	2	2
UTDWR	19-417	Certified	20090630	2	1 1	0.9 0.9
UTDWR	19-418	Certified	20091208	1	2	2
UTDWR	19-420	Perfected	1930	1	4	3
UTDWR	19-422	Certified	20101104	1	0.3	0.3
UTDWR	19-423	Certified	20110126	1	0.3	0.3
UTDWR	19-425	Certified	20120404	1	2	2
UTDWR	19-430	Perfected	1930	1	1	0.9
UTDWR	19-431	Certified	20130711	1	2	2
UTDWR	19-76	Perfected	1930	1	17	15
UTDWR	19-77	Perfected	1930	1	38	33
UTDWR	19-78	Perfected	1930	1	20	17
UTDWR	19-91	Perfected	19690205	1	637	548
UTDWR	18-348	Approved	19751103	1	121	104

Table 2. Withdrawal amounts used to simulate existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley, Utah and Nevada.—Continued

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Agency	Water-right number	Status	Priority date (YYYYMMDD)	Points of diversion[1]	Simulated withdrawals, Scenarios B, C, C_const, D, and D_const (acre-ft/yr)	Simulated withdrawals, Scenarios E, F, F_const, G, and G_const (acre-ft/yr)
UTDWR	18-386	Approved	19770307	1	1,061	912
UTDWR	18-501	Approved	19830720	3	119	102
					119	102
					119	102
UTDWR	18-582	Approved	19870512	5	95	82
					95	82
					95	82
					95	82
					95	82
UTDWR	18-612	Approved	19830720	3	223	192
					223	192
					223	192
UTDWR	18-638	Approved	20140227	1	16	14
UTDWR	18-655	Approved	20160401	1	400	344
UTDWR	18-658	Approved	19991213	1	562	483
UTDWR	18-668	Approved	20150414	1	339	292
UTDWR	18-669	Approved	20010504	2	3	3
					3	3
UTDWR	18-670	Approved	20010504	1	57	49
UTDWR	18-672	Approved	20160429	7	57	49
					57	49
					57	49
					57	49
					57	49
					57	49
					57	49
					57	49
UTDWR	18-673	Approved	20020425	1	19	16
UTDWR	18-675	Approved	20110224	1	39	34
UTDWR	18-679	Approved	20030212	1	404	347
UTDWR	18-682	Approved	20030702	1	4	3
UTDWR	18-685	Approved	20050404	1	70	60
UTDWR	18-699	Approved	20050804	1	43	37
UTDWR	18-710	Approved	20170420	1	1	0.9
UTDWR	18-713	Approved	20070417	1	6	5
UTDWR	18-715	Approved	20071108	1	7	6
UTDWR	18-718	Approved	20080208	1	4	3
UTDWR	18-720	Approved	20080703	1	114	98
UTDWR	18-723	Approved	20090115	1	2	2
UTDWR	18-724	Approved	20090121	1	10	9
UTDWR	18-727	Approved	20090427	1	24	21
UTDWR	18-734	Approved	20100208	1	5	4

Table 2. Withdrawal amounts used to simulate existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley, Utah and Nevada.—Continued

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Agency	Water-right number	Status	Priority date (YYYYMMDD)	Points of diversion[1]	Simulated withdrawals, Scenarios B, C, C_const, D, and D_const (acre-ft/yr)	Simulated withdrawals, Scenarios E, F, F_const, G, and G_const (acre-ft/yr)
UTDWR	18-737	Approved	20100427	1	480	413
UTDWR	18-740	Approved	20110412	1	2	2
UTDWR	18-741	Approved	20110830	2	178	153
					178	153
UTDWR	18-743	Approved	20120306	1	480	413
UTDWR	18-745	Approved	20130905	1	4	3
UTDWR	18-748	Approved	20131010	1	4	3
UTDWR	18-751	Approved	19920710	2	294	253
					294	253
UTDWR	18-755	Approved	20140731	2	166	143
					166	143
UTDWR	18-756	Approved	20141120	1	321	276
UTDWR	18-757	Approved	20150202	1	10	9
UTDWR	18-758	Approved	20150403	1	99	85
UTDWR	18-759	Approved	20150414	1	144	124
UTDWR	18-760	Approved	20150716	1	29	25
UTDWR	18-762	Approved	19870512	5	13	11
					13	11
					13	11
					13	11
					13	11
UTDWR	18-765	Approved	20160927	3	183	157
					183	157
					183	157
UTDWR	18-766	Approved	20161229	1	1	0.9
UTDWR	19-395	Approved	20120103	1	0.5	0.4
UTDWR	19-402	Approved	20061030	1	2	2
UTDWR	19-406	Approved	20070820	1	2	2
UTDWR	19-409	Approved	20080528	2	1	0.9
					1	0.9
UTDWR	19-414	Approved	20081022	1	2	2
UTDWR	19-415	Approved	20081110	1	2	2
UTDWR	19-424	Approved	20161003	1	0.5	0.4
UTDWR	19-429	Approved	20130605	1	2	2
UTDWR	19-432	Approved	20140128	1	2	2
UTDWR	19-433	Approved	20140321	1	2	2
UTDWR	19-434	Approved	20140331	1	0.5	0.4
UTDWR	19-436	Approved	20140428	1	2	2
UTDWR	19-437	Approved	20140609	1	2	2
UTDWR	19-438	Approved	20140915	2	1	0.9
					1	0.9

Table 2. Withdrawal amounts used to simulate existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley, Utah and Nevada.—Continued

[Figure 3 shows the location of the sites. Simulated withdrawals are rounded to the nearest acre-foot or, if below 1 acre-foot, rounded to the nearest tenth of an acre-foot. Priority date is in 4-digit year, 2-digit month, and 2-digit day format. Water-right numbers in red indicate water rights that have a priority date after October 17, 1989 (junior to Southern Nevada Water Authority water-right applications priority date). **Abbreviations**: YYYYMMDD, year month day; acre-ft/yr, acre-feet per year; UTDWR, Utah Division of Water Rights; NVDWR, Nevada Division of Water Resources; NS, not simulated]

Agency	Water-right number	Status	Priority date (YYYYMMDD)	Points of diversion[1]	Simulated withdrawals, Scenarios B, C, C_const, D, and D_const (acre-ft/yr)	Simulated withdrawals, Scenarios E, F, F_const, G, and G_const (acre-ft/yr)
UTDWR	19-439	Approved	20150203	1	2	2
UTDWR	19-440	Approved	20150407	1	2	2
UTDWR	19-441	Approved	20150903	1	2	2
UTDWR	19-443	Approved	20151130	1	0.5	0.4
UTDWR	19-444	Approved	20161207	1	2	2
UTDWR	19-446	Approved	20170522	1	2	2
UTDWR	19-447	Approved	20170621	1	2	2
NVDWR	11022	Certified	19431029	1	9	8
NVDWR	12932	Certified	19490527	2	33 33	28 28
NVDWR	13640	Certified	19510219	1	242	208
NVDWR	15213	Certified	19530620	1	682	587
NVDWR	15555	Certified	19540315	1	2	2
NVDWR	19740	Certified	19610410	1	1,816	1,562
NVDWR	20321	Certified	19620226	1	273	235
NVDWR	2284	Certified	19111212	1	6	5
NVDWR	23580	Certified	19670103	1	30	26
NVDWR	24022	Certified	19670801	1	4	3
NVDWR	27079	Certified	19721017	1	55	47
NVDWR	28366	Certified	19740604	1	703	605
NVDWR	35845	Certified	19780906	1	3	3
NVDWR	43169	Certified	19920219	1	11	9
NVDWR	44153	Certified	19810709	1	9	8
NVDWR	45497	Certified	19820402	1	87	75
NVDWR	45498	Certified	19820402	1	87	75
NVDWR	45499	Certified	19820402	1	87	75
NVDWR	45500	Certified	19820402	1	86	74
NVDWR	52488	Certified	19880909	1	0.1	0.1
NVDWR	60121	Certified	19880805	1	33	28
NVDWR	64888	Certified	19990305	1	9	8
NVDWR	64975	Permitted	20030721	1	18	15
NVDWR	68304	Permitted	19820405	1	360	310
NVDWR	68305	Permitted	19820405	1	360	310
NVDWR	69873	Permitted	19820405	1	1,415	1,217
NVDWR	69874	Permitted	19820405	1	2,445	2,103
NVDWR	69875	Permitted	19820405	1	11	9
NVDWR	7241	Certified	19241030	1	9	8
NVDWR	74644	Certified	19820405	1	285	245
NVDWR	75386	Certified	20070226	1	0.1	0.1
NVDWR	77343	Permitted	20080826	1	320	275
NVDWR	78800	Permitted	19950705	1	90	77

Table 2. Withdrawal amounts used to simulate existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley, Utah and Nevada.—Continued

[Figure 3 shows the location of the sites. Simulated withdrawals are rounded to the nearest acre-foot or, if below 1 acre-foot, rounded to the nearest tenth of an acre-foot. Priority date is in 4-digit year, 2-digit month, and 2-digit day format. Water-right numbers in red indicate water rights that have a priority date after October 17, 1989 (junior to Southern Nevada Water Authority water-right applications priority date). **Abbreviations**: YYYYMMDD, year month day; acre-ft/yr, acre-feet per year; UTDWR, Utah Division of Water Rights; NVDWR, Nevada Division of Water Resources; NS, not simulated]

Agency	Water-right number	Status	Priority date (YYYYMMDD)	Points of diversion[1]	Simulated withdrawals, Scenarios B, C, C_const, D, and D_const (acre-ft/yr)	Simulated withdrawals, Scenarios E, F, F_const, G, and G_const (acre-ft/yr)
NVDWR	78803	Permitted	19950705	1	102	88
NVDWR	78804	Permitted	19950705	1	102	88
NVDWR	78805	Permitted	19950705	1	102	88
NVDWR	78806	Permitted	19950705	1	102	88
NVDWR	78807	Permitted	19950705	1	102	88
NVDWR	78810	Permitted	19950705	1	120	103
NVDWR	84145	Permitted	19720522	1	263	226
NVDWR	84147	Permitted	19860410	1	159	137
NVDWR	84148	Permitted	19860410	1	99	85
NVDWR	84149	Permitted	19860410	1	81	70
NVDWR	84150	Permitted	19860410	1	141	121
NVDWR	84151	Permitted	19860410	1	300	258
NVDWR	84152	Permitted	19950705	1	60	52
NVDWR	84154	Permitted	19950705	1	84	72
NVDWR	84155	Permitted	19950705	1	36	31
NVDWR	84157	Permitted	19950705	1	120	103
NVDWR	84158	Permitted	19950705	1	90	77
NVDWR	84159	Permitted	19950705	1	90	77
NVDWR	84160	Permitted	19950705	1	24	21
NVDWR	84161	Permitted	19950705	1	66	57
NVDWR	84162	Permitted	19950705	1	90	77
NVDWR	84163	Permitted	19950705	1	105	90
NVDWR	84164	Permitted	19950705	1	105	90
NVDWR	84165	Permitted	19950705	1	120	103
NVDWR	84166	Permitted	19950705	1	120	103
NVDWR	84167	Permitted	19950705	1	120	103
NVDWR	84168	Permitted	19950705	1	120	103
NVDWR	85537	Permitted	20151021	1	18	15
NVDWR	86518T	Permitted	19340101	1	80	69
NVDWR	86519T	Permitted	19340101	1	80	69
NVDWR	86520T	Permitted	19340101	1	80	69
NVDWR	86561	Permitted	19950705	1	60	52
NVDWR	86562	Permitted	19950705	1	60	52
NVDWR	86563	Permitted	19950705	1	60	52
NVDWR	86564	Permitted	19950705	1	90	77
NVDWR	86565	Permitted	19950705	1	90	77
NVDWR	86566	Permitted	19950705	1	90	77
NVDWR	86567	Permitted	19860410	1	81	70
NVDWR	86568	Permitted	19860410	1	99	85
NVDWR	9981	Certified	19360417	1	7	6

Table 2. Withdrawal amounts used to simulate existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley, Utah and Nevada.—Continued

[Figure 3 shows the location of the sites. Simulated withdrawals are rounded to the nearest acre-foot or, if below 1 acre-foot, rounded to the nearest tenth of an acre-foot. Priority date is in 4-digit year, 2-digit month, and 2-digit day format. Water-right numbers in red indicate water rights that have a priority date after October 17, 1989 (junior to Southern Nevada Water Authority water-right applications priority date). **Abbreviations**: YYYYMMDD, year month day; acre-ft/yr, acre-feet per year; UTDWR, Utah Division of Water Rights; NVDWR, Nevada Division of Water Resources; NS, not simulated]

Agency	Water-right number	Status	Priority date (YYYYMMDD)	Points of diversion[1]	Simulated withdrawals, Scenarios B, C, C_const, D, and D_const (acre-ft/yr)	Simulated withdrawals, Scenarios E, F, F_const, G, and G_const (acre-ft/yr)
NVDWR	V02198	Vested	18990301	1	10	9
NVDWR	V02199	Vested	18990301	1	10	9
NVDWR	V04568	Vested	19700101	1	NS[3]	NS[3]
NVDWR	V09745	Vested	19340101	1	NS[3]	NS[3]
				Total:	**55,272**	**47,534**

[1]For water rights with more than one point of diversion, simulated withdrawals are split evenly among the points of diversion.

[2]Well listed as abandoned; did not simulate.

[3]Only instantaneous diversion rate is given; total diversion rates are unknown.

[4]Total diversion rate listed as 0 acre-ft/yr; did not simulate

[5]Total diversion rate listed as negative value; did not simulate.

Table 3. Withdrawal amounts used to simulate Southern Nevada Water Authority groundwater applications in Snake Valley, Utah and Nevada.

[Figure 3 shows location of sites. Simulated withdrawals for Scenarios C and F represent Unallocated amount for Nevada under the draft interstate agreement (35,000 acre-feet per year); simulated withdrawals for Scenarios C_const and F_const are the constrained withdrawals that applied to the Unallocated simulations. Simulated withdrawals for Scenarios D and G represent the full application amount (35,000 acre-feet per year for Unallocated amount, and an additional 15,680 acre-feet per year from Reserved amount for Nevada under the draft interstate agreement); simulated withdrawals for Scenarios D_const and G_const are the constrained withdrawals that applied to the full application simulations. **Abbreviations**: ID, identifier; acre-ft/yr, acre-feet per year; NVDWR, Nevada Division of Water Resources]

Map ID	Agency	Application number	Simulated withdrawals, Scenarios C and F (acre-ft/yr)	Simulated withdrawals, Scenario C_ const (acre-ft/yr)	Simulated withdrawals, Scenario F_ const (acre-ft/yr)	Simulated withdrawals, Scenarios D and G (acre-ft/yr)	Simulated withdrawals, Scenario D_ const (acre-ft/yr)	Simulated withdrawals, Scenario G_ const (acre-ft/yr)
PD-22	NVDWR	54022	3,000	3,000	3,000	4,344	4,344	4,344
PD-23	NVDWR	54023	3,000	3,000	3,000	4,344	4,344	4,344
PD-24	NVDWR	54024	3,000	3,000	3,000	4,344	4,344	4,344
PD-25	NVDWR	54025	3,000	3,000	3,000	4,344	4,344	4,344
PD-26	NVDWR	54026	5,000	892	930	7,240	832	875
PD-27	NVDWR	54027	5,000	412	419	7,240	401	410
PD-28	NVDWR	54028	5,000	3,075	3,122	7,240	3,011	3,069
PD-29	NVDWR	54029	5,000	220	224	7,240	213	218
PD-30	NVDWR	54030	3,000	218	219	4,344	215	217
		Total:	**35,000**	**16,817**	**16,914**	**50,680**	**22,048**	**22,165**

Model files, including additional model details and datasets are also available in an associated data release at https://doi.org/10.5066/P9LQDQGM.

Description of Simulated Scenarios and Results

To investigate the potential effects of withdrawals based on existing Allocated and Unallocated groundwater rights and SNWA applications, 11 withdrawal scenarios were simulated. All scenarios were run as steady state to estimate the ultimate long-term effects of the simulated withdrawals.

Scenarios B, C, C_const, D, and D_const do not include recharge from irrigation return flow, whereas Scenarios E, F, F_const, G, and G_const do include this process. Both groups of scenarios are presented because of the high uncertainty in irrigation return flow estimates, which are dependent on a number of factors including irrigation type (flood, line sprinkler, central pivot, etc.), local soil properties, crop type, and rate of irrigation. Because of the dampening effects that irrigation return flows have on drawdown and capture of natural discharge, Scenarios B, C, C_const, D, and D_const represent the maximum effects that the simulated withdrawals would have on the groundwater system.

Although some of the springs identified by the NPS and BLM are not explicitly simulated in the model, the model could simulate natural groundwater discharge as evapotranspiration in the model cells containing these springs. Assuming that some part of this evapotranspiration is related to spring flow, the amount of discharge captured from these cells is also likely to affect spring flow. Because the spring orifice could be discharging only a portion of the total groundwater discharge from the model cell, however, the percentage of simulated natural groundwater capture cannot be directly translated to a percentage of reduction in spring flow. Additionally, the model could continue to show that well withdrawals capture groundwater discharge from the model cell even when the hydraulic gradient and groundwater levels decline to the point where spring flow through the orifice ceases. The model would continue to simulate capture of transpiration from phreatophytes up to an extinction depth of about 40 feet (ft) that is simulated in the model; this depth may extend much deeper into the subsurface than the spring orifice.

In Scenarios B, C, D, E, F, and G, constraints were not applied to the groundwater withdrawal rates to investigate if the groundwater system could support the total volume of withdrawals from both the existing water rights and future proposed SNWA applications. Scenarions C, D, F, and G, which included withdrawals from the SNWA PODs, however, produced extremely large drawdowns, especially near the SNWA PODs. Therefore, in four additional scenarios (C_const, D_const, F_const, and G_const) withdrawal rates at the SNWA PODs were constrained by not allowing drawdowns to be deeper than the assumed depth of the PODs (about 2,000 ft). In the constrained scenarios, total withdrawals at the SNWA PODs were reduced to about 48 percent of the Unallocated amount (35,000 acre-ft/yr reduced to 16,817 acre-ft/yr or 16,914 acre-ft/yr, without or with irrigation return flow, respectively), and to about 44 percent of the full application (Unallocated plus Reserved) amount (50,680 acre-ft/yr reduced to 22,048 acre-ft/yr or 22,165 acre-ft/yr, without or with irrigation return flow, respectively) for Nevada under the draft interstate agreement.

Scenario A: Pre-Development Conditions

Scenario A simulates pre-development (or pre-pumping) conditions, and is the baseline to which all other scenarios are compared. Simulated water-level altitudes and groundwater discharge for Scenario A at the NPS and BLM groundwater resource sites of interest, and at the SNWA PODs, are summarized in tables 4–9.

Table 4. Simulated water-level altitudes and drawdowns for scenarios without irrigation return flow at the National Park Service and Bureau of Land Management groundwater resource sites of interest in the model focus (Snake Valley) area, Utah and Nevada.

[Refer to figures 2 and 4–8 for location of sites. Values rounded to nearest foot. **Abbreviation**: ID, identifier]

Map ID	Site name	Scenario					
		A	B	C	C_const	D	D_const
		Simulated water-level altitude (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)
1	Partoun Spring	4,847	74	75	75	77	75
2	South Seeps	5,026	95	97	95	98	96
3	Lime Spring	4,813	79	81	80	82	80
4	Snake Valley North Spring Complex	4,700	53	55	54	56	54
5	Snake Valley South Spring Complex	4,705	43	44	43	45	43
6	Coyote Spring	5,022	30	32	30	34	31
7	Miller Spring	4,732	34	36	35	37	35
8	Leland Harris Spring Complex	4,753	15	16	15	16	16
9	Gandy Salt Marsh Seep	4,753	2	2	2	2	2
10	Springs feeding Gandy Salt Marsh Lake	4,772	2	2	2	3	2
gandySMLC	Gandy Salt Marsh Lake Spring Complex[1]	4,776	2	2	2	3	2
11	Gandy Warm Springs	5,159	2	2	2	3	2
12	Foote Reservoir Spring	4,803	2	5	3	8	4
13	Twin Springs	4,802	3	5	3	8	4
14	Briggs Spring	4,867	4	11	6	18	7
15	Phil Spring	4,872	6	14	8	23	9
16	North Knoll Spring	4,820	3	10	5	20	6
17	Middle Knoll Spring	4,827	4	15	6	28	8
18	Knoll Spring	4,829	4	17	7	32	9
19	Unnamed Spring 1	4,905	67	168	94	258	112
20	Unnamed Spring 2	6,328	38	222	87	344	108
21	Unnamed Spring 3	6,310	39	229	89	354	110
22	Want Spring	6,540	18	152	51	231	61
23	Kane Spring	4,943	124	302	172	458	205
24	Caine Spring	4,960	128	317	179	480	214
25	Eskdale Well	4,931	125	307	174	466	208
26	West Buckskin Well	4,937	152	332	200	491	234
27	Flowing Well 2	4,971	159	370	216	554	255
28	Shell Baker Creek Well	5,046	29	290	97	524	148
29	Unnamed Spring 4	5,492	70	914	290	1,416	358
30	Upper Lehman Spring	7,863	4	80	20	156	25
31	Rowland Springs	6,328	22	441	107	814	139
32	Kious Spring	5,687	47	2,074	268	3,119	325
33	Mahogany Spring	6,163	25	1,296	181	2,006	219
34	Ibex Well	4,471	1	4	1	7	2
35	Spring Creek Spring	5,885	14	430	123	756	163
36	Diversion from Lake Creek 1	5,212	43	308	119	550	168
37	Diversion from Lake Creek 2	5,305	32	265	98	498	140

Table 4. Simulated water-level altitudes and drawdowns for scenarios without irrigation return flow at the National Park Service and Bureau of Land Management groundwater resource sites of interest in the model focus (Snake Valley) area, Utah and Nevada.—Continued

[Refer to figures 2 and 4–8 for location of sites. Values rounded to nearest foot. **Abbreviation**: ID, identifier]

Map ID	Site name	Scenario					
		A	B	C	C_const	D	D_const
		Simulated water-level altitude (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)
38	Clay Spring	5,359	20	219	69	447	99
39	Davies Well 1	5,429	22	182	48	406	67
40	Dearden Spring Group	5,436	8	161	30	384	48
41	Needle Point Spring	5,442	21	177	46	400	64
42	Davies Well 2	5,455	19	181	49	398	70
43	Needle Point Well	5,436	18	176	44	399	63
44	Unnamed Spring 5	5,532	26	169	50	388	63
45	Cove Well	5,466	24	181	51	399	71
46	Big Springs	5,576	7	127	18	327	35
47	Wah Wah Springs	5,560	0	0	0	1	0
str	Strawberry Creek[2]	6,834	3	30	9	46	11
bak	Baker Creek[2]	6,653	11	389	68	753	88
snk	Snake Creek[2]	6,332	11	437	111	763	146

[1]Drawdown at center of spring complex.

[2]Drawdown where creek crosses Great Basin National Park boundary.

Table 5. Simulated water-level altitudes and drawdowns for scenarios with irrigation return flow at the National Park Service and Bureau of Land Management groundwater resource sites of interest in the model focus (Snake Valley) area, Utah and Nevada.

[Refer to figures 2 and 9–13 for location of sites. Values rounded to nearest foot. **Abbreviation**: ID, identifier]

Map ID	Site name	Scenario					
		A	E	F	F_const	G	G_const
		Simulated water-level altitude (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)
1	Partoun Spring	4,847	59	60	59	61	59
2	South Seeps	5,026	76	78	77	79	77
3	Lime Spring	4,813	62	63	63	64	63
4	Snake Valley North Spring Complex	4,700	38	38	38	40	38
5	Snake Valley South Spring Complex	4,705	27	28	28	30	28
6	Coyote Spring	5,022	23	24	23	26	23
7	Miller Spring	4,732	21	22	21	23	22
8	Leland Harris Spring Complex	4,753	11	11	11	11	11
9	Gandy Salt Marsh Seep	4,753	1	2	1	2	1
10	Springs feeding Gandy Salt Marsh Lake	4,772	2	2	2	2	2
gandySMLC	Gandy Salt Marsh Lake Spring Complex[1]	4,776	2	2	2	2	2
11	Gandy Warm Springs	5,159	1	2	1	2	1
12	Foote Reservoir Spring	4,803	2	4	2	6	3
13	Twin Springs	4,802	2	4	3	7	3

Table 5. Simulated water-level altitudes and drawdowns for scenarios with irrigation return flow at the National Park Service and Bureau of Land Management groundwater resource sites of interest in the model focus (Snake Valley) area, Utah and Nevada.—Continued

[Refer to figures 2 and 9–13 for location of sites. Values rounded to nearest foot. **Abbreviation**: ID, identifier]

Map ID	Site name	Scenario					
		A	E	F	F_const	G	G_const
		Simulated water-level altitude (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)
14	Briggs Spring	4,867	3	8	4	14	5
15	Phil Spring	4,872	5	10	6	18	7
16	North Knoll Spring	4,820	2	7	3	15	4
17	Middle Knoll Spring	4,827	3	9	4	21	5
18	Knoll Spring	4,829	3	11	4	24	5
19	Unnamed Spring 1	4,905	48	123	62	211	77
20	Unnamed Spring 2	6,328	29	191	68	312	86
21	Unnamed Spring 3	6,310	30	197	70	322	88
22	Want Spring	6,540	14	137	43	216	52
23	Kane Spring	4,943	92	226	118	379	145
24	Caine Spring	4,960	96	239	123	399	152
25	Eskdale Well	4,931	92	228	117	385	146
26	West Buckskin Well	4,937	118	251	142	408	171
27	Flowing Well 2	4,971	123	281	152	463	185
28	Shell Baker Creek Well	5,046	18	208	48	440	91
29	Unnamed Spring 4	5,492	56	839	252	1,339	313
30	Upper Lehman Spring	7,863	3	71	16	130	21
31	Rowland Springs	6,328	17	384	90	751	118
32	Kious Spring	5,687	38	2,002	233	3,044	284
33	Mahogany Spring	6,163	19	1,233	153	1,938	185
34	Ibex Well	4,471	0	2	1	6	1
35	Spring Creek Spring	5,885	11	365	92	687	126
36	Diversion from Lake Creek 1	5,212	34	233	80	473	121
37	Diversion from Lake Creek 2	5,305	26	197	69	427	104
38	Clay Spring	5,359	15	154	48	379	74
39	Davies Well 1	5,429	18	119	37	340	51
40	Dearden Spring Group	5,436	7	99	18	319	32
41	Needle Point Spring	5,442	18	114	34	334	48
42	Davies Well 2	5,455	16	120	37	335	53
43	Needle Point Well	5,436	15	114	32	334	47
44	Unnamed Spring 5	5,532	22	112	44	328	54
45	Cove Well	5,466	20	120	39	335	54
46	Big Springs	5,576	6	74	13	271	24
47	Wah Wah Springs	5,560	0	0	0	1	0
str	Strawberry Creek[2]	6,834	2	28	8	44	10
bak	Baker Creek[2]	6,653	8	339	56	695	74
snk	Snake Creek[2]	6,332	9	379	86	700	114

[1]Drawdown at center of spring complex.

[2]Drawdown where creek crosses Great Basin National Park boundary.

Table 6. Simulated capture of natural discharge for scenarios without irrigation return flow at the National Park Service and Bureau of Land Management groundwater resource sites of interest in the model focus (Snake Valley) area, Utah and Nevada.

[Refer to figures 2 and 4–8 for location of sites. **Abbreviations**: ID, identifier; acre-ft/yr, acre-feet per year; ETg, groundwater evapotranspiration; N/A, not applicable]

Map ID	Site name	Simulated groundwater discharge type	Scenario					
			A	B	C	C_const	D	D_const
			Simulated natural discharge (acre-ft/yr)	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge
1	Partoun Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
2	South Seeps	None	N/A	N/A	N/A	N/A	N/A	N/A
3	Lime Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
4	Snake Valley North Spring Complex	ETg	46	100	100	100	100	100
5	Snake Valley South Spring Complex	ETg	100	100	100	100	100	100
6	Coyote Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
7	Miller Spring	Spring	261	100	100	100	100	100
8	Leland Harris Spring Complex	ETg	201	93	96	94	99	95
9	Gandy Salt Marsh Seep	ETg	115	23	25	23	27	23
10 and gandySMLC	Springs feeding Gandy Salt Marsh Lake and Gandy Salt Marsh Lake Spring Complex	ETg	623	7	9	7	12	8
11	Gandy Warm Springs	Spring	11,607	7	10	8	13	8
12	Foote Reservoir Spring	Spring	0	0	0	0	0	0
13	Twin Springs	Spring	3,640	24	55	32	87	38
14	Briggs Spring	ETg	149	30	69	39	100	46
15	Phil Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
16	North Knoll Spring	ETg	91	33	100	49	100	63
17	Middle Knoll Spring	ETg	39	85	100	100	100	100
18	Knoll Spring	ETg	41	93	100	100	100	100
19	Unnamed Spring 1	None	N/A	N/A	N/A	N/A	N/A	N/A
20 and 21	Unnamed Spring 2 and Unnamed Spring 3	None	N/A	N/A	N/A	N/A	N/A	N/A
22	Want Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
23	Kane Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
24	Caine Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
29	Unnamed Spring 4	None	N/A	N/A	N/A	N/A	N/A	N/A
30	Upper Lehman Spring	Spring	1,447	1	55	10	100	13
31	Rowland Springs	Spring	1,489	8	100	36	100	45
32	Kious Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
33	Mahogany Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
35	Spring Creek Spring	Spring	1,877	26	100	100	100	100
36	Diversion from Lake Creek 1	None	N/A	N/A	N/A	N/A	N/A	N/A
37	Diversion from Lake Creek 2	None	N/A	N/A	N/A	N/A	N/A	N/A
38	Clay Spring	Spring	281	100	100	100	100	100

Table 6. Simulated capture of natural discharge for scenarios without irrigation return flow at the National Park Service and Bureau of Land Management groundwater resource sites of interest in the model focus (Snake Valley) area, Utah and Nevada.—Continued

[Refer to figures 2 and 4–8 for location of sites. **Abbreviations**: ID, identifier; acre-ft/yr, acre-feet per year; ETg, groundwater evapotranspiration; N/A, not applicable]

Map ID	Site name	Simulated groundwater discharge type	Scenario					
			A	B	C	C_const	D	D_const
			Simulated natural discharge (acre-ft/yr)	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge
40	Dearden Spring Group	Spring	4,626	81	100	100	100	100
41	Needle Point Spring	ETg	152	55	100	100	100	100
44	Unnamed Spring 5	ETg	180	0	100	25	100	56
46	Big Springs	Spring	7,063	46	100	99	100	100
47	Wah Wah Springs	Spring	748	3	12	5	23	6
fish	Fish Springs	Spring	23,042	3	5	4	6	4
gran_trout	Granite and Trout Creeks	Stream	1,143	4	4	4	4	4
str_bak_snk	Strawberry, Baker, and Snake Creeks	Stream	1,635	2	42	14	62	16

Table 7. Simulated capture of natural discharge for scenarios with irrigation return flow at the National Park Service and Bureau of Land Management groundwater resource sites of interest in the model focus (Snake Valley) area, Utah and Nevada.

[Refer to figures 2 and 9–13 for location of sites. **Abbreviations**: ID, identifier; acre-ft/yr, acre-feet per year; ETg, groundwater evapotranspiration; N/A, not applicable]

Map ID	Site name	Simulated groundwater discharge type	Scenario					
			A	E	F	F_const	G	G_const
			Simulated natural discharge (acre-ft/yr)	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge
1	Partoun Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
2	South Seeps	None	N/A	N/A	N/A	N/A	N/A	N/A
3	Lime Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
4	Snake Valley North Spring Complex	ETg	46	100	100	100	100	100
5	Snake Valley South Spring Complex	ETg	100	100	100	100	100	100
6	Coyote Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
7	Miller Spring	Spring	261	100	100	100	100	100
8	Leland Harris Spring Complex	ETg	201	65	67	66	70	66
9	Gandy Salt Marsh Seep	ETg	115	17	18	17	20	17
10 and gandySMLC	Springs feeding Gandy Salt Marsh Lake and Gandy Salt Marsh Lake Spring Complex	ETg	623	5	7	6	9	6
11	Gandy Warm Springs	Spring	11,607	5	8	6	11	6
12	Foote Reservoir Spring	Spring	0	0	0	0	0	0

Table 7. Simulated capture of natural discharge for scenarios with irrigation return flow at the National Park Service and Bureau of Land Management groundwater resource sites of interest in the model focus (Snake Valley) area, Utah and Nevada.—Continued

[Refer to figures 2 and 9–13 for location of sites. **Abbreviations**: ID, identifier; acre-ft/yr, acre-feet per year; ETg, groundwater evapotranspiration; N/A, not applicable]

Map ID	Site name	Simulated groundwater discharge type	Scenario					
			A	E	F	F_const	G	G_const
			Simulated natural discharge (acre-ft/yr)	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge	Percent capture of simulated natural discharge
13	Twin Springs	Spring	3,640	19	41	23	71	27
14	Briggs Spring	ETg	149	22	50	27	89	32
15	Phil Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
16	North Knoll Spring	ETg	91	23	71	31	100	40
17	Middle Knoll Spring	ETg	39	59	100	79	100	100
18	Knoll Spring	ETg	41	63	100	88	100	100
19	Unnamed Spring 1	None	N/A	N/A	N/A	N/A	N/A	N/A
20 and 21	Unnamed Spring 2 and Unnamed Spring 3	None	N/A	N/A	N/A	N/A	N/A	N/A
22	Want Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
23	Kane Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
24	Caine Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
29	Unnamed Spring 4	None	N/A	N/A	N/A	N/A	N/A	N/A
30	Upper Lehman Spring	Spring	1,447	1	48	8	96	10
31	Rowland Springs	Spring	1,489	7	100	30	100	38
32	Kious Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
33	Mahogany Spring	None	N/A	N/A	N/A	N/A	N/A	N/A
35	Spring Creek Spring	Spring	1,877	21	100	100	100	100
36	Diversion from Lake Creek 1	None	N/A	N/A	N/A	N/A	N/A	N/A
37	Diversion from Lake Creek 2	None	N/A	N/A	N/A	N/A	N/A	N/A
38	Clay Spring	Spring	281	100	100	100	100	100
40	Dearden Spring Group	Spring	4,626	69	100	100	100	100
41	Needle Point Spring	ETg	152	46	100	94	100	100
44	Unnamed Spring 5	ETg	180	0	100	11	100	34
46	Big Springs	Spring	7,063	39	100	86	100	100
47	Wah Wah Springs	Spring	748	3	8	4	20	5
fish	Fish Springs	Spring	23,042	3	4	3	5	3
gran_trout	Granite and Trout Creeks	Stream	1,143	3	3	3	3	3
str_bak_snk	Strawberry, Baker, and Snake Creeks	Stream	1,635	2	38	11	60	14

Table 8. Simulated water-level altitudes and drawdowns for scenarios without irrigation return flow at the proposed point of diversion sites for the Southern Nevada Water Authority water-right applications in Snake Valley, Utah and Nevada.

[Refer to figure 3 for location of sites. Values rounded to nearest foot. **Abbreviation**: ID, identifier]

Map ID	Scenario					
	A	B	C	C_const	D	D_const
	Simulated water-level altitude (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)
PD-22	5,212	214	913	483	1,347	593
PD-23	5,139	42	325	124	573	181
PD-24	5,415	26	482	129	822	183
PD-25	5,560	28	176	60	389	81
PD-26	5,419	73	2,648	434	3,912	486
PD-27	5,881	34	4,761	389	7,019	429
PD-28	6,013	17	1,928	403	2,919	435
PD-29	6,236	17	3,366	203	5,002	224
PD-30	5,836	20	2,314	183	3,484	200

Table 9. Simulated water-level altitudes and drawdowns for scenarios with irrigation return flow at the proposed point of diversion sites for the Southern Nevada Water Authority water-right applications in Snake Valley, Utah and Nevada.

[Refer to figure 3 for location of sites. Values rounded to nearest foot. **Abbreviation**: ID, identifier]

Map ID	Scenario					
	A	E	F	F_const	G	G_const
	Simulated water-level altitude (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)	Simulated drawdown (feet)
PD-22	5,212	180	812	420	1,242	522
PD-23	5,139	33	245	79	491	127
PD-24	5,415	21	418	110	756	158
PD-25	5,560	24	120	53	329	68
PD-26	5,419	58	2,574	401	3,835	448
PD-27	5,881	27	4,694	361	6,947	396
PD-28	6,013	13	1,865	379	2,853	405
PD-29	6,236	14	3,310	191	4,943	208
PD-30	5,836	17	2,259	176	3,426	188

Scenario B: Withdrawals Based on Existing Approved, Perfected, Certified, Permitted, and Vested Groundwater Rights

Scenario B simulates the potential effects of groundwater withdrawals based on existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley. Groundwater withdrawals were simulated using the Well Package (Harbaugh, 2005), which simulates a specified-flux boundary in each cell in which it is assigned. Data required for the Well Package are the withdrawal rates in each model layer. The distribution of withdrawals among the layers for each of the water rights was determined by multiplying the total withdrawal rate by the proportion of the open interval in that layer. For example, if 75 percent of the open interval was in layer 1 and 25 percent of the open interval was in layer 2, the withdrawal rate applied in layer 1 would be 75 percent of the total withdrawal for the well, with the remaining 25 percent of the withdrawal assigned to layer 2. The Well Package places the location of the withdrawal in the middle of each model layer(s) in which the well exists.

Not all of the existing water rights are currently associated with an existing well. For some of the newer water rights, a well may not have yet been drilled. Additionally, well logs for some of the older water rights could not be found. To distribute the water-rights withdrawals among the model layers, the open intervals for existing wells or proposed PODs for these water rights were determined by the following: (1) using the depth to the top and bottom of the open interval reported on a well log associated with the water right; (2) if no open interval information was reported on an associated well log, but total depth of the well or POD was reported on the well log or water right, it was assumed that the open interval was from land surface to the reported total depth of the well or POD; (3) if no open interval or total depth information for a well or POD associated with the water right was reported, it was assumed that either the well or POD associated with the water right had a similar open interval or total depth of other wells in the area or, if no other wells in the area had depth or open interval information, the well or POD was assumed to have an open interval that extended from the water table to the middle of model layer 1.

The total simulated withdrawals for these water rights (based on the amount reported as the total water right) are about 55,272 acre-ft/yr. Locations and amounts of simulated withdrawals used in Scenario B are summarized in table 2 and on figure 3. Results for Scenario B are summarized in tables 4, 6, and 8, and on figure 4.

Simulated drawdowns at the NPS and BLM sites of interest from the Scenario B withdrawals range between 0 and 159 ft compared to pre-development conditions. The largest drawdowns occurred at Flowing Well 2 (site 27). Other sites that showed simulated drawdowns of greater than 100 ft include Kane Spring (site 23); Caine Spring (site 24); Eskdale Well (site 25); and West Buckskin Well (site 26). Figure 4 shows the distribution of simulated drawdowns across the model focus area. Simulated drawdowns across the model focus area for Scenario B ranged between 0 and 647 ft.

Simulated capture of natural discharge at the NPS and BLM sites of interest from the Scenario B withdrawals ranged between 0 and 100 percent compared to pre-development conditions. At four sites, the withdrawals capture 100 percent of the total natural discharge simulated for that model cell. These sites included Snake Valley North Spring Complex (site 4); Snake Valley South Spring Complex (site 5); Miller Spring (site 7); and Clay Spring (site 38).

Scenario C: Withdrawals Based on Existing Groundwater Rights Plus Proposed Southern Nevada Water Authority Withdrawals (Unallocated Amount)

Scenario C simulates the potential effects of withdrawals based on existing groundwater rights in Snake Valley (Scenario B), plus a large portion of the proposed withdrawals from senior water-right applications filed by the SNWA. Simulated withdrawals for the SNWA applications are 35,000 acre-ft/yr, based on the full Unallocated amount proposed for Nevada in the draft interstate agreement. No data exist about the open intervals of these PODs. To distribute the withdrawals proportionately across the model layers, it was assumed that the SNWA PODS had an open interval extending from the water table to 2,000 ft below the water table or, in the case of POD PD-26 (fig. 3), to the bottom of the lower carbonate aquifer unit (about 1,277 ft below the water table at this POD). The depth of 2,000 ft was chosen because (1) this put the bottom of most of the PODs in the lower carbonate aquifer unit, which is a highly transmissive unit within the groundwater system, and (2) given lift and other infrastructure considerations, it is highly unlikely that wells would be drilled much deeper than this. Because the Well Package assigns discharge (or well withdrawals) to the middle of the model layer, and because the deeper layers in the model are generally thicker than the shallower layers, the simulated discharge (or well withdrawals) may be from a depth greater than the assumed bottom of the open interval at some of the PODs. However, constraints were not applied to the groundwater withdrawal rates (that is, limiting the rates so that drawdown at the POD did not exceed the assumed depth of the bottom of the open interval) to investigate if the groundwater system could support the volume of withdrawals in the existing water rights and SNWA applications. Locations and amounts of simulated withdrawals used in Scenario C are summarized in tables 2 and 3 and on figure 3. Results for Scenario C are summarized in tables 4, 6, and 8, and on figure 5.

Simulated drawdowns at the NPS and BLM sites of interest from the Scenario C withdrawals ranged between 0 and 2,074 ft compared to pre-development conditions. The largest drawdowns occurred at Kious Spring (site 32).

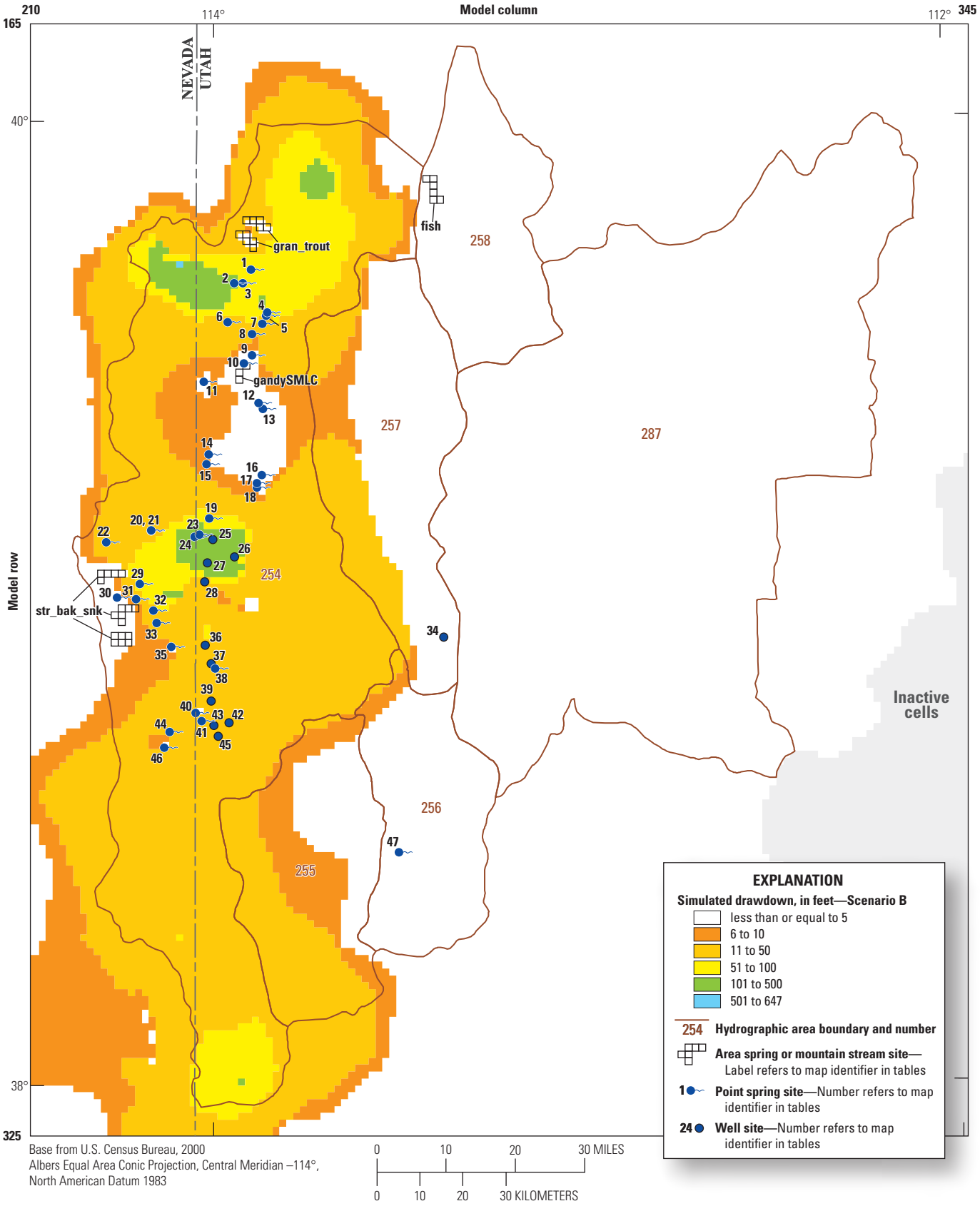

Figure 4. Groundwater resource sites of interest to the National Park Service and Bureau of Land Management, and simulated drawdown from groundwater withdrawals under Scenario B, model focus (Snake Valley) area, Utah and Nevada.

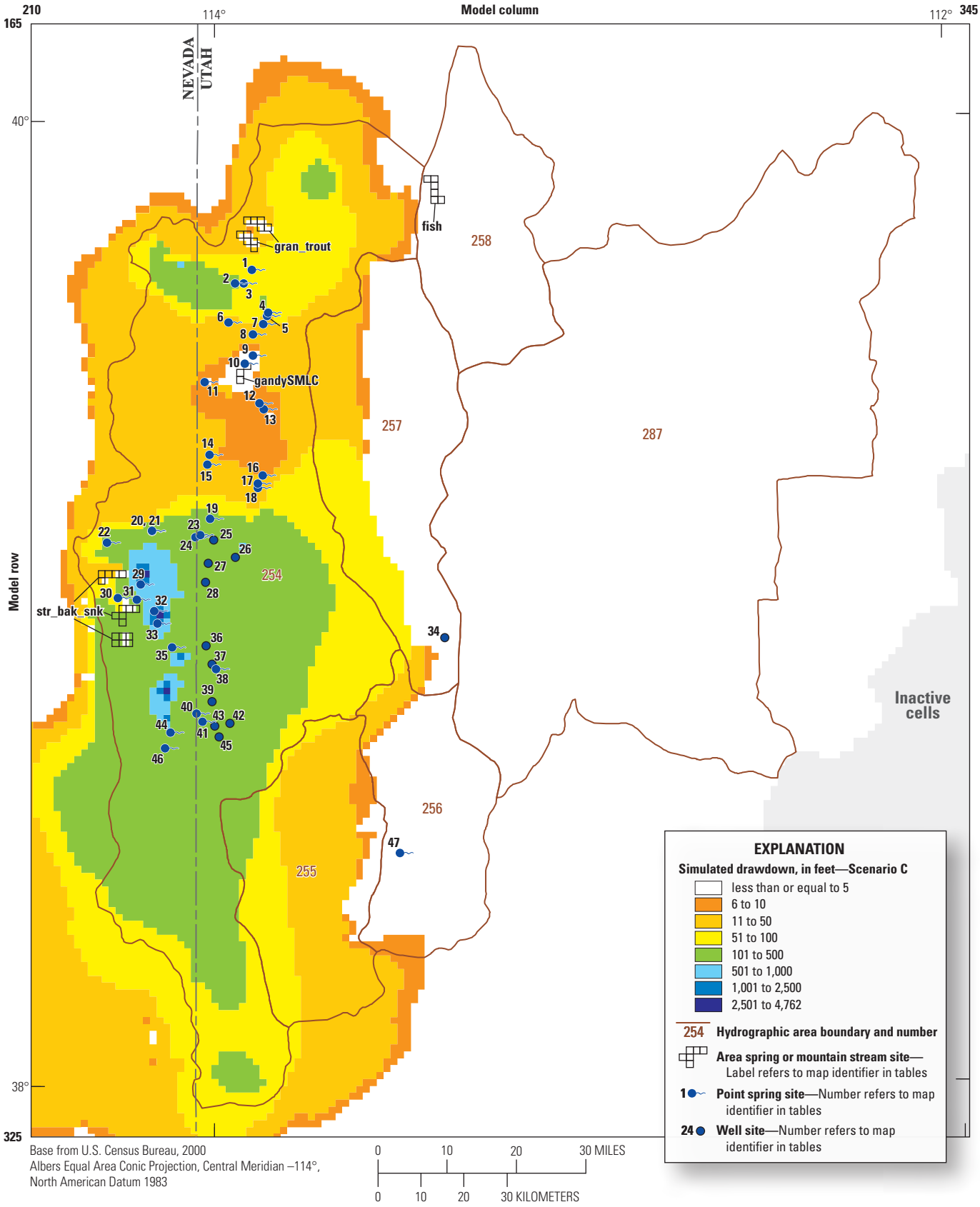

Figure 5. Groundwater resource sites of interest to the National Park Service and Bureau of Land Management, and simulated drawdown from groundwater withdrawals under Scenario C, model focus (Snake Valley) area, Utah and Nevada.

Mahogany Spring (site 33) also showed simulated drawdowns of greater than 1,000 ft. Simulated drawdowns of greater than 100 ft occurred at 28 sites. Figure 5 shows the distribution of simulated drawdowns across the model focus area. Simulated drawdowns across the model focus area for Scenario C ranged between 0 and 4,762 ft.

Simulated drawdowns at the SNWA PODs were also calculated, and ranged between 176 and 4,761 ft compared to pre-development conditions. The largest drawdowns occurred at POD PD-27, which is in an area where the low-permeability non-carbonate confining unit (siliciclastic rock) extends from land surface to the total depth of the model. Drawdowns are greater than 1,000 ft at five of the nine SNWA PODs. Additionally, simulated drawdowns at PODs PD-26, PD-27, PD-29, and PD-30 are greater than the assumed depths of these PODs, indicating that they may not be able to sustain the proposed withdrawal rates. The large simulated drawdowns produced in this scenario indicate that the groundwater system may not be able to support the volume of withdrawals from many of the proposed PODs in the current SNWA water-right applications.

Simulated capture of natural discharge at the NPS and BLM sites of interest from the Scenario C withdrawals ranged between 0 and 100 percent compared to pre-development conditions. In addition to the four sites where withdrawals from Scenario B captured 100 percent of the total natural discharge simulated for that model cell, withdrawals from Scenario C captured 100 percent of the simulated discharge at nine additional sites (model cells). These included North Knoll Spring (site 16); Middle Knoll Spring (site 17); Knoll Spring (site 18); Rowland Springs (site 31); Spring Creek Spring (site 35); Dearden Spring Group (site 40); Needle Point Spring (site 41); Unnamed Spring 5 (site 44); and Big Springs (site 46).

Scenario C_const: Withdrawals Based on Existing Groundwater Rights Plus Constrained (From Unallocated Amount) Southern Nevada Water Authority Withdrawals

Scenario C_const simulates the potential effects of withdrawals based on existing groundwater rights in Snake Valley (Scenario B), plus a large portion of the proposed withdrawals from water-right applications filed by the SNWA. It is highly unlikely that the SNWA wells would be drilled deeper than about 2,000 ft given lift and other infrastructure considerations; therefore, the extremely large drawdowns produced by the SNWA withdrawals simulated in Scenario C are also highly unlikely. To simulate drawdowns and capture that might more realistically occur throughout the groundwater system, the withdrawals from the SNWA PODs in this scenario were constrained such that the drawdown could not exceed the assumed depth of the PODs. To apply constraints on the withdrawal rates for the SNWA PODs, the Multi-Node Well (MNW2) Package (Konikow and others, 2009) was utilized to simulate withdrawals from the SNWA PODs. The MNW2 Package takes as input the desired withdrawal rate, and the option to limit that withdrawal rate if the head at the well drops below a specified value. For this scenario, desired withdrawal rates for the PODs were the same as those simulated in Scenario C (table 3), totaling 35,000 acre-ft/yr, which is equivalent to Nevada's allotment of Unallocated Groundwater in the draft interstate agreement. The assumed depths of the PODs (2,000 ft except for POD PD-26, which was assumed to be about 1,277 ft below the water table) were applied as the limiting drawdown factor. The model automatically calculates the constrained withdrawal rates that honor the drawdown limitations. The constrained rates computed for this scenario resulted in simulated withdrawals from the SNWA PODs totaling only 16,817 acre-ft/yr, or about 48 percent of the desired amount of 35,000 acre-ft/yr (table 3). Withdrawal rates at PODs PD-22, PD-23, PD-24, and PD-25 did not need to be constrained. Withdrawal rates were most highly constrained at PODs PD-26 (simulated withdrawals were only 18 percent of desired amount), PD-27 (simulated withdrawals were only 8 percent of desired amount), PD-29 (simulated withdrawals were only 4 percent of desired amount), and PD-30 (simulated withdrawals were only 7 percent of desired amount). This constrained analysis still indicates that the SNWA may need to add more PODs, or PODs in different locations, in order to withdraw large portions of the total amount of groundwater that has been applied for. Locations and amounts of simulated withdrawals used in Scenario C_const are summarized in tables 2 and 3 and on figure 3. Results for Scenario C_const are summarized in tables 4, 6, and 8, and on figure 6.

Simulated drawdowns at the NPS and BLM sites of interest from the Scenario C_const withdrawals ranged between 0 and 290 ft compared to pre-development conditions. The largest drawdowns occurred at Unnamed Spring 4 (site 29). Simulated drawdowns of greater than 100 ft occurred at 12 sites. Figure 6 shows the distribution of simulated drawdowns across the model focus area. Simulated drawdowns across the model focus area for Scenario C_const ranged between 0 and 648 ft.

Simulated drawdowns at the SNWA PODs were also calculated and ranged between 60 and 483 ft compared to pre-development conditions. The largest drawdown occurred at PD-22, which was one of the wells in which the withdrawal rate did not need to be constrained.

Simulated capture of natural discharge at the NPS and BLM sites of interest from the Scenario C_const withdrawals ranged between 0 and 100 percent compared to pre-development conditions. In addition to the four sites where withdrawals from Scenario B captured 100 percent of the total natural discharge simulated for that model cell, withdrawals from Scenario C_const captured 100 percent of the simulated discharge at five additional sites (model cells). These included Middle Knoll Spring (site 17); Knoll Spring (site 18); Spring Creek Spring (site 35); Dearden Spring Group (site 40); and Needle Point Spring (site 41).

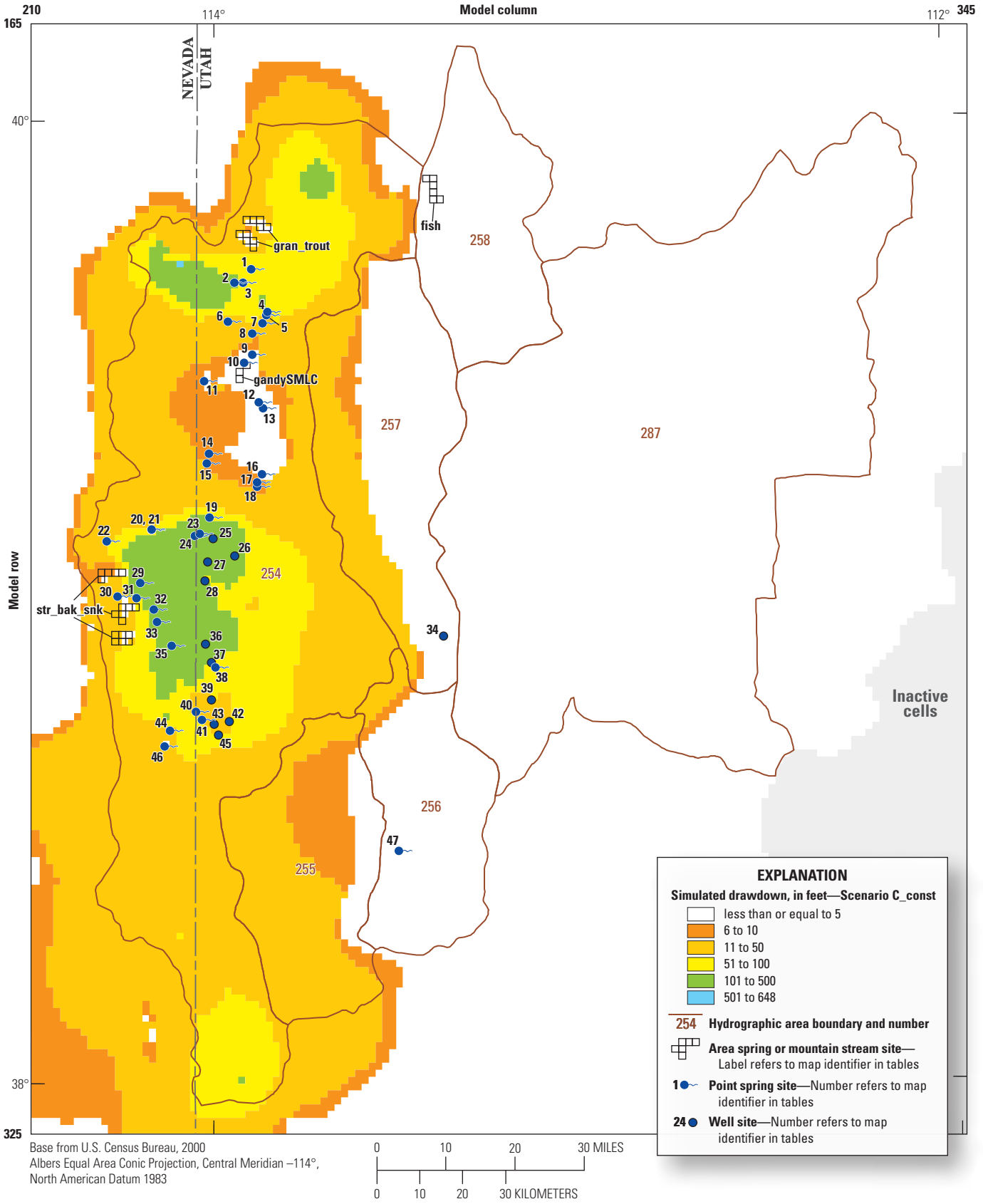

Figure 6. Groundwater resource sites of interest to the National Park Service and Bureau of Land Management, and simulated drawdown from groundwater withdrawals under Scenario C_const, model focus (Snake Valley) area, Utah and Nevada.

Scenario D: Withdrawals Based on Existing Groundwater Rights Plus Proposed Southern Nevada Water Authority Withdrawals (Full Application Amount)

Scenario D simulates the potential effects of withdrawals based on existing groundwater rights in Snake Valley (Scenario B), plus withdrawals from water-right applications filed by the SNWA at the full application amount. Simulated withdrawals for the senior SNWA applications are 50,680 acre-ft/yr, based on the total amount reported on each application; therefore, these withdrawals represent 35,000 acre-ft/yr of the Unallocated Groundwater plus an additional 15,680 acre-ft/yr of the Reserved Groundwater allotted to Nevada in the draft interstate agreement. Locations and amounts of simulated withdrawals used in Scenario D are summarized in tables 2 and 3 and on figure 3. Results for Scenario D are summarized in tables 4, 6, and 8, and on figure 7.

Simulated drawdowns at the NPS and BLM sites of interest from the Scenario D withdrawals ranged between 1 and 3,119 ft compared to pre-development conditions. Similar to Scenario C, the largest drawdowns occurred at Kious Spring (site 32). Other sites that showed simulated drawdowns of greater than 1,000 ft included Unnamed Spring 4 (site 29) and Mahogany Spring (site 33). Simulated drawdowns of greater than 100 ft occurred at 29 sites. Figure 7 shows the distribution of simulated drawdowns across the model focus area. Simulated drawdowns across the model focus area for Scenario D ranged between 0 and 7,020 ft.

Simulated drawdowns at the SNWA PODs were also calculated, and ranged between 389 and 7,019 ft compared to pre-development conditions. The largest drawdowns occurred at POD PD-27, which is not surprising given that this POD would be in a low-permeability unit. Drawdowns are greater than 1,000 ft at six of the nine SNWA PODs. Additionally, simulated drawdowns at PODs PD-26, PD-27, PD-28, PD-29, and PD-30 are greater than the depth of these PODs, indicating that they may not be able to sustain the proposed withdrawal rates. The large simulated drawdowns produced in this scenario continues to indicate that the groundwater system may not be able to support the volume of withdrawals from many of the proposed PODs in the current SNWA water-right applications.

Simulated capture of natural discharge at the NPS and BLM sites of interest from the Scenario D withdrawals ranged between 0 and 100 percent compared to pre-development conditions. In addition to the four sites where withdrawals from Scenario B captured 100 percent of the total natural discharge simulated for that model cell, withdrawals from Scenario D captured 100 percent of the simulated discharge at 11 additional sites (model cells). These included the same sites as in Scenario C, plus Briggs Spring (site 14) and Upper Lehman Spring (site 30).

Scenario D_const: Withdrawals Based on Existing Groundwater Rights Plus Constrained (From Full Application Amount) Southern Nevada Water Authority Withdrawals

Scenario D_const simulates the potential effects of withdrawals based on existing groundwater rights in Snake Valley (Scenario B), plus a large portion of the proposed withdrawals from senior water-right applications filed by the SNWA. It is highly unlikely that wells would be drilled deeper than about 2,000 ft given lift and other infrastructure considerations; therefore, the extremely large drawdowns produced by the SNWA withdrawals in Scenario D are also highly unlikely. To simulate drawdowns and capture that might more realistically occur throughout the groundwater system, the withdrawals from the SNWA PODs in this scenario were constrained such that the drawdown could not exceed the assumed depth of the PODs. For this scenario, desired withdrawal rates for the PODs were the same as those simulated in Scenario D, totaling 50,680 acre-ft/yr (table 3), and the assumed depths of the PODs (2,000 ft except for POD PD-26, which was assumed to be about 1,277 ft below the water table) were applied as the limiting drawdown factor. The constrained rates computed for this scenario resulted in simulated withdrawals from the SNWA PODs totaling only 22,048 acre-ft/yr, or about 44 percent of the desired amount of 50,680 acre-ft/yr (table 3). Withdrawal rates at PODs PD-22, PD-23, PD-24, and PD-25 did not need to be constrained. Withdrawal rates were most highly constrained at PODs PD-26 (simulated withdrawals were only 11 percent of desired amount), PD-27 (simulated withdrawals were only 6 percent of desired amount), PD-29 (simulated withdrawals were only 3 percent of desired amount), and PD-30 (simulated withdrawals were only 5 percent of desired amount). This constrained analysis continues to indicate that the SNWA may need to add more PODs, or PODs in different locations, in order to withdraw the total amount of groundwater that has been applied for. Locations and amounts of simulated withdrawals used in Scenario D_const are summarized in tables 2 and 3 and on figure 3. Results for Scenario D_const are summarized in tables 4, 6, and 8, and on figure 8.

Simulated drawdowns at the NPS and BLM sites of interest from the Scenario D_const withdrawals ranged between 0 and 358 ft compared to pre-development conditions. Similar to Scenario C_const, the largest drawdowns occurred at Unnamed Spring 4 (site 29). Simulated drawdowns of greater than 300 ft occurred at Kious Spring (site 32). Simulated drawdowns of greater than 100 ft occurred at 17 sites. Figure 8 shows the distribution of simulated drawdowns across the model focus area. Simulated drawdowns across the model focus area for Scenario D_const ranged between 0 and 649 ft.

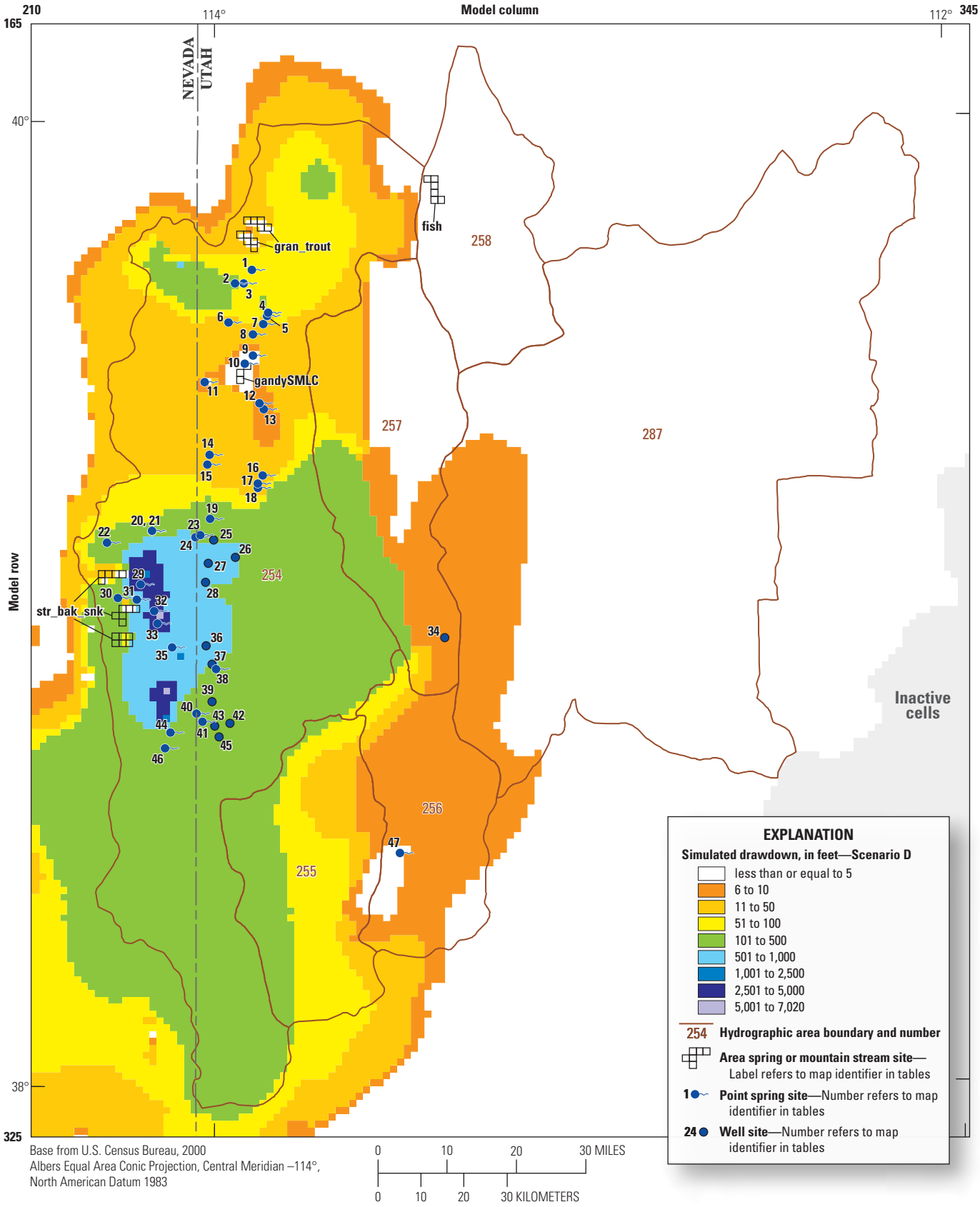

Figure 7. Groundwater resource sites of interest to the National Park Service and Bureau of Land Management, and simulated drawdown from groundwater withdrawals under Scenario D, model focus (Snake Valley) area, Utah and Nevada.

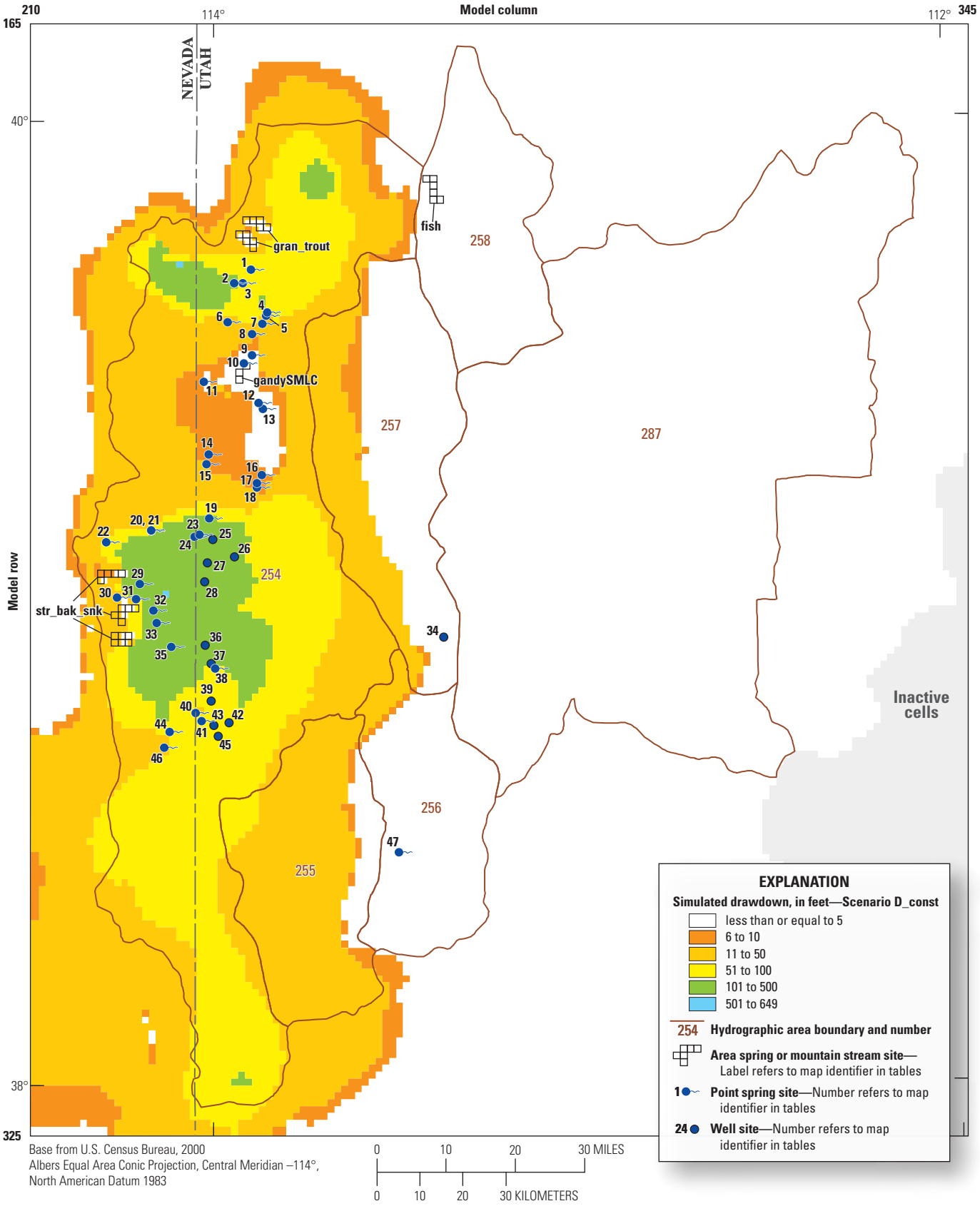

Figure 8. Groundwater resource sites of interest to the National Park Service and Bureau of Land Management, and simulated drawdown from groundwater withdrawals under Scenario D_const, model focus (Snake Valley) area, Utah and Nevada.

Simulated drawdowns at the SNWA PODs were also calculated and ranged between 81 and 593 ft compared to pre-development conditions. Similar to Scenario C_const, the largest drawdown occurred at PD-22, which was one of the wells in which the withdrawal rate did not need to be constrained.

Simulated capture of natural discharge at the NPS and BLM sites of interest from the Scenario D_const withdrawals ranged between 0 and 100 percent compared to pre-development conditions. In addition to the four sites where withdrawals from Scenario B captured 100 percent of the total natural discharge simulated for that model cell, withdrawals from Scenario D_const captured 100 percent of the simulated discharge at six additional sites (model cells). These included Middle Knoll Spring (site 17); Knoll Spring (site 18); Spring Creek Spring (site 35); Dearden Spring Group (site 40); Needle Point Spring (site 41); and Big Springs (site 46).

Scenario E: Withdrawals Based on Existing Groundwater Rights With Irrigation Return Flow

Scenario E simulates the potential effects of groundwater withdrawals based on existing approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights within Snake Valley with irrigation return flow included in the simulation. This scenario assumes that some of the groundwater that is applied for irrigation is not consumed by crops and may infiltrate back into the subsurface and become recharge to the groundwater system. Irrigation return flow is dependent on a number of factors, including irrigation type (flood, line sprinkler, central pivot, etc.), local soil properties, crop type, and rate of irrigation. Irrigation return flow studies in the Milford area, Utah (Susong, 1995) and the Amargosa Desert, California (Stonestrom and others, 2003) show that recharge from irrigation on sprinkler-irrigated fields is between 8 and 14 percent, and 8 and 16 percent of the applied irrigation, respectively. The Milford area is relatively close to, and climatologically similar to, the Snake Valley area. Because most of the fields in Snake Valley are sprinkler irrigated, it was assumed that irrigation return flow was also 14 percent. It was beyond the scope of the current study to simulate this recharge over the fields where irrigation is applied; instead, the irrigation return flow was simulated by reducing the amount of groundwater withdrawals by 14 percent. This reduction was applied to all simulated withdrawals from the existing approved, perfected, certified, permitted, and vested groundwater rights in Snake Valley. The total simulated withdrawals for these water rights, therefore, were reduced to 47,534 acre-ft/yr. Locations and amounts of simulated withdrawals used in Scenario E are summarized in table 2 and on figure 3. Results for Scenario E are summarized in tables 5, 7, and 9, and on figure 9.

Simulated drawdowns at the NPS and BLM sites of interest from the Scenario E withdrawals ranged between 0 and 123 ft compared to pre-development conditions, slightly less than Scenario B, as expected. The largest drawdowns occurred at Flowing Well 2 (site 27). Other sites that showed simulated drawdowns of greater than 50 ft include Partoun Spring (site 1); South Seeps (site 2); Lime Spring (site 3); Kane Spring (site 23); Caine Spring (site 24); Eskdale Well (site 25); West Buckskin Well (site 26); and Unnamed Spring 4 (site 29). Figure 9 shows the distribution of simulated drawdowns across the model focus area. Simulated drawdowns across the model focus area for Scenario E ranged between 0 and 555 ft.

Simulated capture of natural discharge at the NPS and BLM sites of interest from the Scenario E withdrawals ranged between 0 and 100 percent compared to pre-development conditions. The withdrawals captured 100 percent of the total natural discharge simulated for that model cell at the same four sites as in Scenario B, namely, Snake Valley North Spring Complex (site 4); Snake Valley South Spring Complex (site 5); Miller Spring (site 7); and Clay Spring (site 38).

Scenario F: Withdrawals Based on Existing Groundwater Rights With Irrigation Return Flow Plus Proposed Southern Nevada Water Authority Withdrawals (Unallocated Amount)

Scenario F simulates the potential effects of withdrawals based on existing groundwater rights with irrigation return flow in Snake Valley (Scenario E), plus a large portion of the withdrawals from senior water-right applications filed by the SNWA, equivalent to Nevada's allotment of Unallocated Groundwater in the draft interstate agreement (35,000 acre-ft/yr). The simulated withdrawals for the SNWA PODs were not reduced to account for irrigation return flow because, unlike the majority of the other water rights in Snake Valley, these groundwater withdrawals will be exported out of the valley and, therefore, no return flow would occur that could potentially become recharge to the groundwater system. Additionally, constraints were not applied to the groundwater withdrawal rates for the SNWA PODs (that is, limiting the rates so that drawdown at the POD did not exceed the assumed depth of the bottom of the open interval) to investigate if the groundwater system could support the volume of withdrawals in the existing water rights and SNWA applications. Locations and amounts of simulated withdrawals used in Scenario F are summarized in tables 2 and 3 and on figure 3. Results for Scenario F are summarized in tables 5, 7, and 9, and on figure 10.

Simulated drawdowns at the NPS and BLM sites of interest from the Scenario F withdrawals ranged between 0 and 2,002 ft compared to pre-development conditions. Similar to Scenario C, the largest drawdowns occurred at Kious Spring (site 32), and simulated drawdowns at Mahogany Spring (site 33) still exceeded 1,000 ft. Simulated drawdowns of greater than 100 ft also occurred at 26 sites. Figure 10 shows the distribution of simulated drawdowns across the model focus area. Simulated drawdowns across the model focus area for Scenario F ranged between 0 and 4,694 ft.

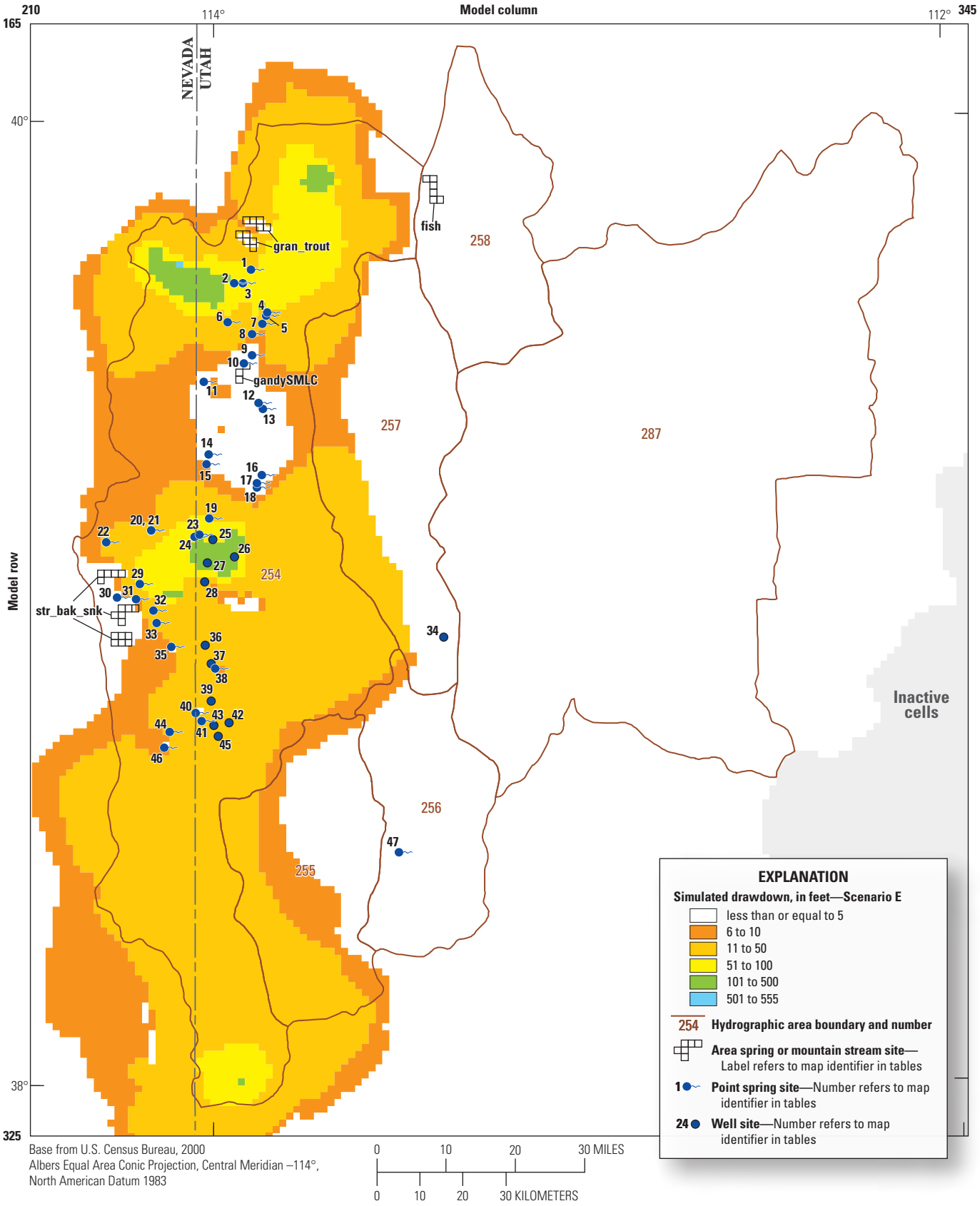

Figure 9. Groundwater resource sites of interest to the National Park Service and Bureau of Land Management, and simulated drawdown from groundwater withdrawals under Scenario E, model focus (Snake Valley) area, Utah and Nevada.

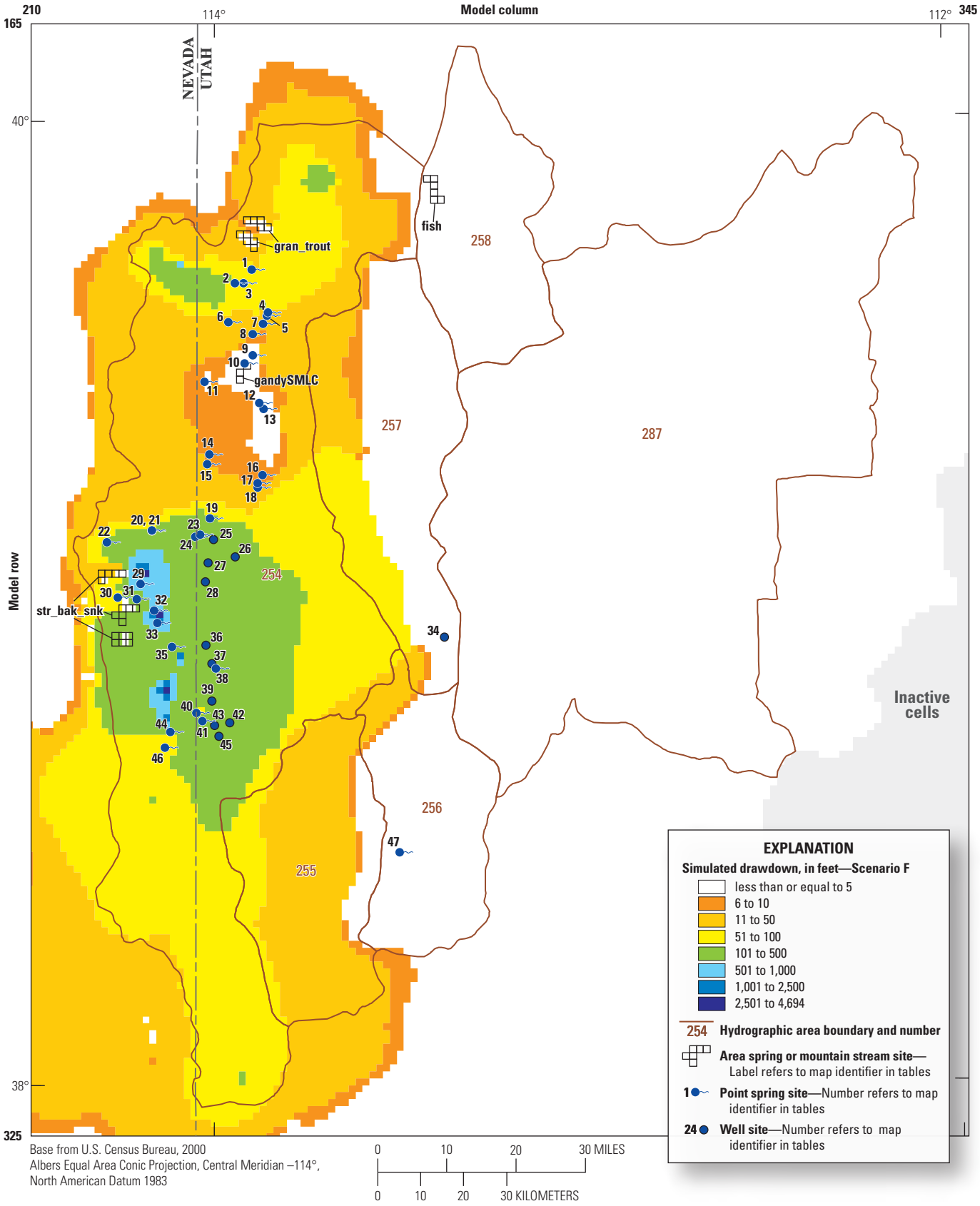

Figure 10. Groundwater resource sites of interest to the National Park Service and Bureau of Land Management, and simulated drawdown from groundwater withdrawals under Scenario F, model focus (Snake Valley) area, Utah and Nevada.

Simulated drawdowns at the SNWA PODs were slightly less than for Scenario C, and ranged between 120 and 4,694 ft compared to pre-development conditions, with the largest drawdowns still occurring at POD PD-27. Drawdowns were still greater than 1,000 ft at five of the nine SNWA PODs. Additionally, simulated drawdowns at PODs PD-26, PD-27, PD-29, and PD-30 are greater than the depth of these PODs, indicating that they may not be able to sustain the proposed withdrawal rates. The large simulated drawdowns produced in this scenario continue to indicate that the groundwater system may not be able to support the volume of withdrawals from many of the proposed PODs in the current SNWA water-right applications.

Simulated capture of natural discharge at the NPS and BLM sites of interest from the Scenario F withdrawals ranged between 0 and 100 percent compared to pre-development conditions. In addition to the four sites where withdrawals from Scenario E captured 100 percent of the total natural discharge simulated for that model cell, withdrawals from Scenario F captured 100 percent of the simulated discharge at eight additional sites (model cells). These included Middle Knoll Spring (site 17); Knoll Spring (site 18); Rowland Springs (site 31); Spring Creek Spring (site 35); Dearden Spring Group (site 40); Needle Point Spring (site 41); Unnamed Spring 5 (site 44); and Big Springs (site 46).

Scenario F_const: Withdrawals Based on Existing Groundwater Rights With Irrigation Return Flow Plus Constrained (From Unallocated Amount) Southern Nevada Water Authority Withdrawals

Scenario F_const simulates the potential effects of withdrawals based on existing groundwater rights with irrigation return flow in Snake Valley (Scenario E), plus a large portion of the withdrawals from senior water-right applications filed by the SNWA. It is highly unlikely that wells would be drilled deeper than about 2,000 ft given lift and other infrastructure considerations; therefore, the extremely large drawdowns produced by the SNWA withdrawals in Scenario F are also highly unlikely. To simulate drawdowns and capture that might more realistically occur throughout the groundwater system, the withdrawals from the SNWA PODs in this scenario were constrained such that the drawdown could not exceed the assumed depth of the PODs. For this scenario, desired withdrawal rates for the PODs were the same as those simulated in Scenario F (table 3), totaling 35,000 acre-ft/yr and equivalent to Nevada's allotment of Unallocated Groundwater in the draft interstate agreement. The assumed depths of the PODs (2,000 ft except for PD-26, which was assumed to be about 1,277 ft below the water table) were applied as the limiting drawdown factor. The model automatically calculates the constrained rates that honor the drawdown limitations. The constrained rates computed for this scenario resulted in simulated withdrawals from the SNWA PODs totaling only 16,914 acre-ft/yr, or about 48 percent of the desired amount of 35,000 acre-ft/yr (table 3). Withdrawal rates at PODs PD-22, PD-23, PD-24, and PD-25 did not need to be constrained. Withdrawal rates were most highly constrained at PODs PD-26 (simulated withdrawals were only 19 percent of desired amount), PD-27 (simulated withdrawals were only 8 percent of desired amount), PD-29 (simulated withdrawals were only 4 percent of desired amount), and PD-30 (simulated withdrawals were only 7 percent of desired amount). This continues to indicate that the SNWA may need to add more PODs, or PODs in different locations, in order to withdraw large portions of the total amount of groundwater that has been applied for. Similar to Scenario F, the simulated withdrawals for the SNWA PODs were not reduced to account for irrigation return flow because, unlike the majority of the other water rights in Snake Valley, these groundwater withdrawals will be exported out of the valley and, therefore, no return flow would occur that could potentially become recharge to the groundwater system. Locations and amounts of simulated withdrawals used in Scenario F_const are summarized in tables 2 and 3 and on figure 3. Results for Scenario F_const are summarized in tables 5, 7, and 9, and on figure 11.

Simulated drawdowns at the NPS and BLM sites of interest from the Scenario F_const withdrawals ranged between 0 and 252 ft compared to pre-development conditions. Similar to Scenarios C_const and D_const, the largest drawdowns occurred at Unnamed Spring 4 (site 29). Simulated drawdowns of greater than 100 ft occurred at eight sites. Figure 11 shows the distribution of simulated drawdowns across the model focus area. Simulated drawdowns across the model focus area for Scenario F_const ranged between 0 and 556 ft.

Simulated drawdowns at the SNWA PODs were also calculated and ranged between 53 and 420 ft compared to predevelopment conditions. Similar to Scenarios C_const and D_const, the largest drawdown occurred at POD PD-22, which was one of the PODs in which the withdrawal rate did not need to be constrained.

Simulated capture of natural discharge at the NPS and BLM sites of interest from the Scenario F_const withdrawals ranged between 0 and 100 percent compared to pre-development conditions. In addition to the four sites where withdrawals from Scenario E captured 100 percent of the total natural discharge simulated for that model cell, withdrawals from Scenario F_const captured 100 percent of the simulated discharge at two additional sites. These included Spring Creek Spring (site 35) and Dearden Spring Group (site 40).

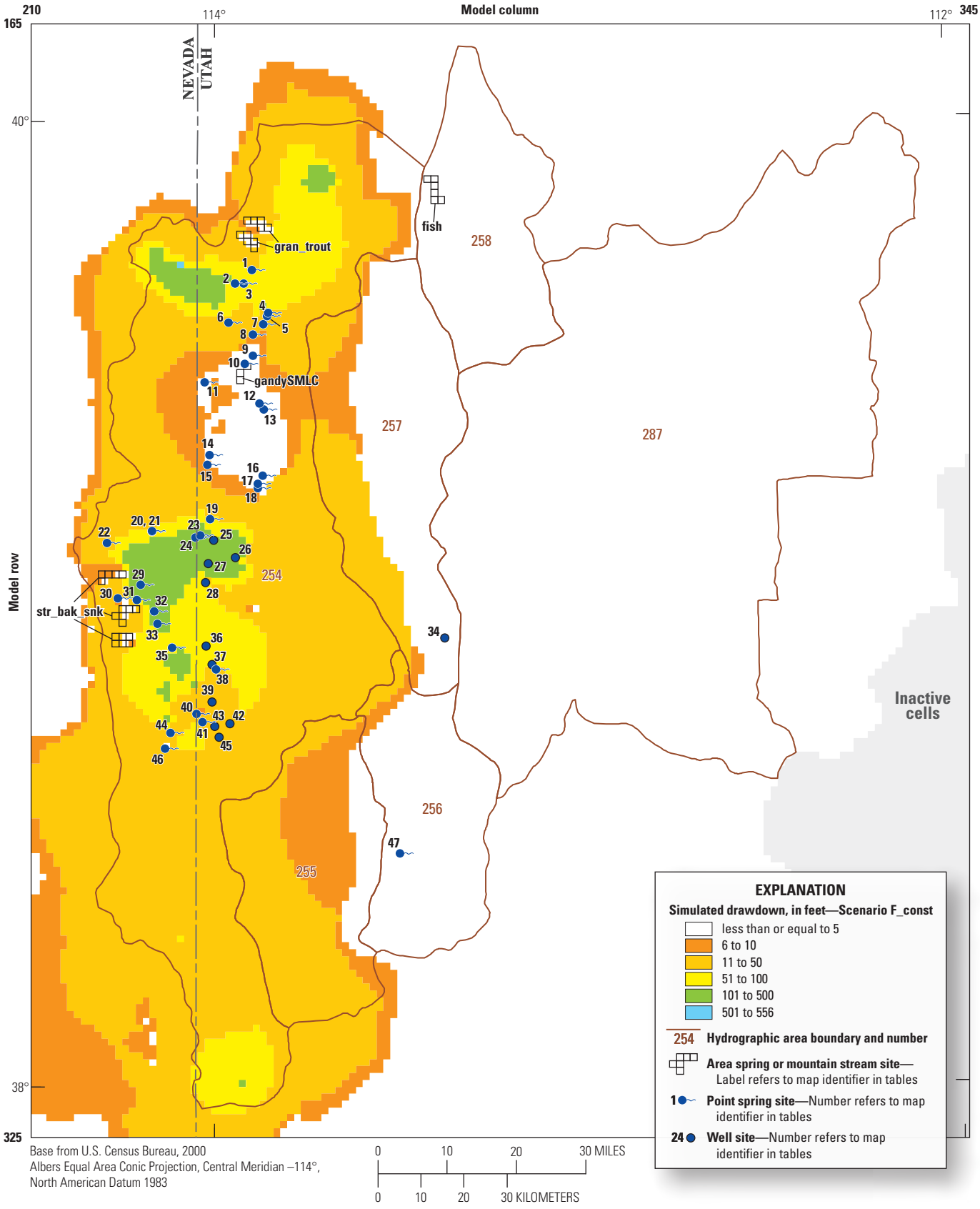

Figure 11. Groundwater resource sites of interest to the National Park Service and Bureau of Land Management, and simulated drawdown from groundwater withdrawals under Scenario F_const, model focus (Snake Valley) area, Utah and Nevada.

Scenario G: Withdrawals Based on Existing Groundwater Rights With Irrigation Return Flow Plus Proposed Southern Nevada Water Authority Withdrawals (Full Application Amount)

Scenario G simulates the potential effects of withdrawals based on existing groundwater rights with irrigation return flow in Snake Valley (Scenario E), plus withdrawals from water-right applications filed by the SNWA at the full application amount. Simulated withdrawals for the SNWA applications are 50,680 acre-ft/yr, based on the total amount reported on each application; therefore, these withdrawals represent 35,000 acre-ft/yr of the Unallocated Groundwater plus an additional 15,680 acre-ft/yr of Reserved Groundwater amounts allotted to Nevada in the draft interstate agreement. Similar to Scenarios F and F_const, the simulated withdrawals for the SNWA PODs were not reduced to account for irrigation return flow because, unlike the majority of the other water rights in Snake Valley, these groundwater withdrawals will be exported out of the valley and, therefore, no return flow would occur that could potentially become recharge to the groundwater system. Additionally, constraints were not applied to the groundwater withdrawal rates for the SNWA PODs (that is, limiting the rates so that drawdown at the POD did not exceed the assumed depth of the bottom of the open interval) to investigate if the groundwater system could support the volume of withdrawals in the existing water rights and SNWA applications. Locations and amounts of simulated withdrawals used in Scenario G are summarized in tables 2 and 3 and on figure 3. Results for Scenario G are summarized in tables 5, 7, and 9, and on figure 12.

Simulated drawdowns at the NPS and BLM sites of interest from the Scenario G withdrawals ranged between 1 and 3,044 ft compared to pre-development conditions. Similar to Scenario D, the largest drawdowns occurred at Kious Spring (site 32), and simulated drawdowns at Unnamed Spring 4 (site 29) and Mahogany Spring (site 33) still exceeded 1,000 ft. Simulated drawdowns of greater than 100 ft also occurred at the same 29 sites as in Scenario D. Figure 12 shows the distribution of simulated drawdowns across the model focus area. Simulated drawdowns across the model focus area for Scenario G ranged between 0 and 6,948 ft.

Simulated drawdowns at the SNWA PODs were slightly less than for Scenario D, and ranged between 329 and 6,947 ft compared to pre-development conditions, with the largest drawdowns still occurring at POD PD-27. Drawdowns were still greater than 1,000 ft at six of the nine SNWA PODs. Additionally, simulated drawdowns at PODs PD-26, PD-27, PD-28, PD-29, and PD-30 are greater than the depth of these PODs, indicating that they may not be able to sustain the proposed withdrawal rates. The large simulated drawdowns produced in this scenario continue to indicate that the groundwater system may not be able to support the volume of withdrawals from many of the proposed PODs in the current SNWA water-right applications.

Simulated capture of natural discharge at the NPS and BLM sites of interest from the Scenario G withdrawals ranged between 0 and 100 percent compared to pre-development conditions. In addition to the four sites where withdrawals from Scenario E captured 100 percent of the total natural discharge simulated for that model cell, withdrawals from Scenario G captured 100 percent of the simulated discharge at nine additional sites (model cells). These included the same sites as in Scenario F plus North Knoll Spring (site 16).

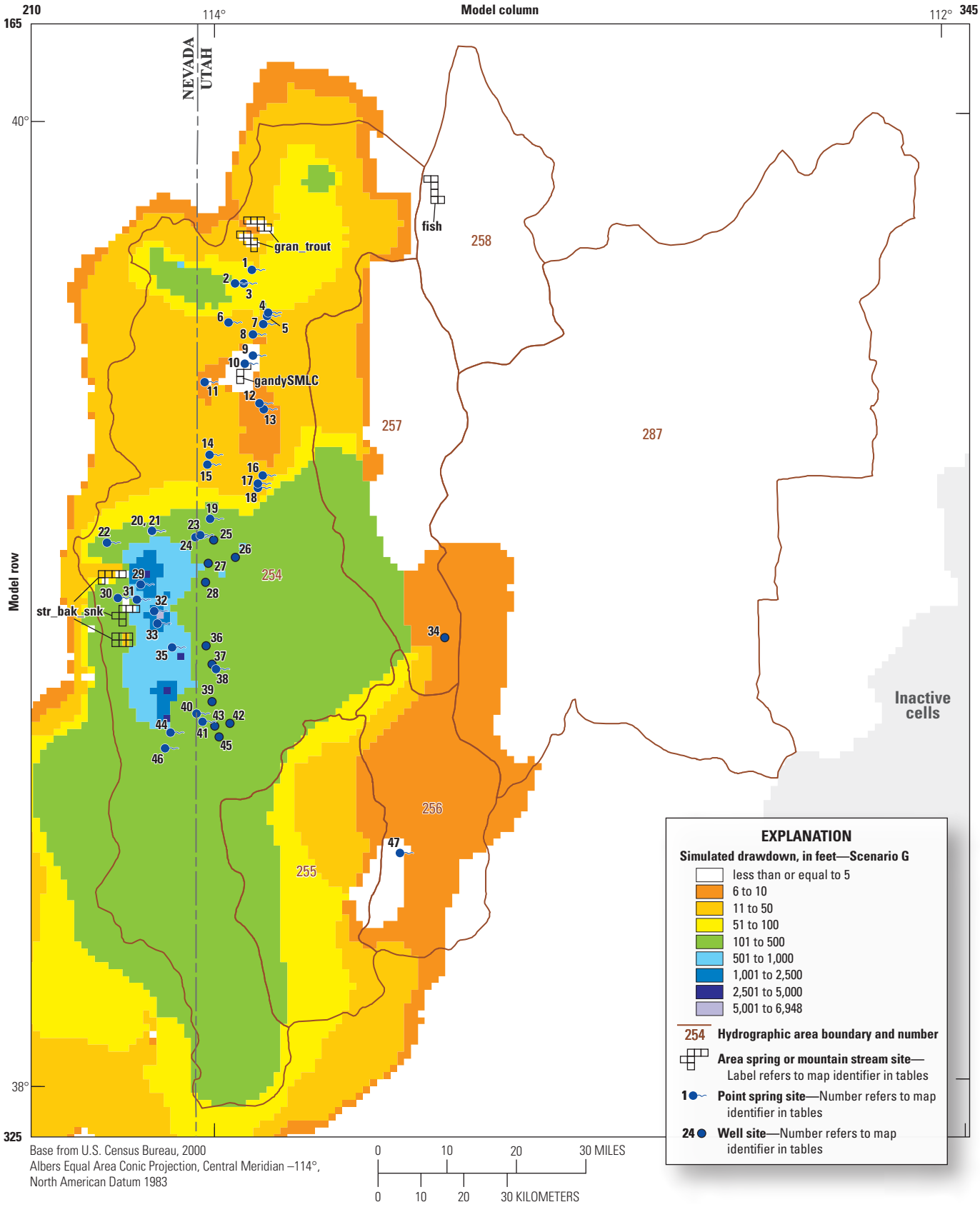

Figure 12. Groundwater resource sites of interest to the National Park Service and Bureau of Land Management, and simulated drawdown from groundwater withdrawals under Scenario G, model focus (Snake Valley) area, Utah and Nevada.

Scenario G_const: Withdrawals Based on Existing Groundwater Rights With Irrigation Return Flow Plus Constrained (From Full Application Amount) Southern Nevada Water Authority Withdrawals

Scenario G_const simulates the potential effects of withdrawals based on existing groundwater rights with irrigation return flow in Snake Valley (Scenario E), plus a large portion of the proposed withdrawals from senior water-right applications filed by the SNWA. It is highly unlikely that wells would be drilled deeper than about 2,000 ft given lift and other infrastructure considerations; therefore, the extremely large drawdowns produced by the SNWA withdrawals in Scenario G are also highly unlikely. To simulate drawdowns and capture that might more realistically occur throughout the groundwater system, the withdrawals from the SNWA PODs in this scenario were constrained such that the drawdown could not exceed the assumed depth of the PODs. For this scenario, desired withdrawal rates for the PODs were the same as those simulated in Scenario G, totaling 50,680 acre-ft/yr (table 3), and the assumed depths of the PODs (2,000 ft except for PD-26, which was assumed to be about 1,277 ft below the water table) were applied as the limiting drawdown factor. The model automatically calculates the constrained rates that honor the drawdown limitations. The constrained rates computed for this scenario resulted in simulated withdrawals from the SNWA PODs totaling only 22,165 acre-ft/yr, or about 44 percent of the desired amount of 50,680 acre-ft/yr (table 3). Withdrawal rates at PODs PD-22, PD-23, PD-24, and PD-25 did not need to be constrained. Withdrawal rates were most highly constrained at PODs PD-26 (simulated withdrawals were only 12 percent of desired amount), PD-27 (simulated withdrawals were only 6 percent of desired amount), PD-29 (simulated withdrawals were only 3 percent of desired amount), and PD-30 (simulated withdrawals were only 5 percent of desired amount). This continues to indicate that the SNWA may need to add more PODs, or PODs in different locations, in order to withdraw the total amount of groundwater that has been applied for. Similar to Scenarios F, F_const, and G, the simulated withdrawals for the SNWA PODs were not reduced to account for irrigation return flow because, unlike the majority of the other water rights in Snake Valley, these groundwater withdrawals will be exported out of the valley and, therefore, no return flow would occur that could potentially become recharge to the groundwater system. Locations and amounts of simulated withdrawals used in Scenario G_const are summarized in tables 2 and 3 and on figure 3. Results for Scenario G_const are summarized in tables 5, 7, and 9, and on figure 13.

Simulated drawdowns at the NPS and BLM sites of interest from the Scenario G_const withdrawals ranged between 0 and 313 ft compared to pre-development conditions. Similar to Scenarios C_const, D_const, and F_const, the largest drawdowns occurred at Unnamed Spring 4 (site 29). Simulated drawdowns of greater than 100 ft occurred at 13 sites. Figure 13 shows the distribution of simulated drawdowns across the model focus area. Simulated drawdowns across the model focus area for Scenario G_const ranged between 0 and 556 ft.

Simulated drawdowns at the SNWA PODs were also calculated and ranged between 68 and 522 ft compared to pre-development conditions. Similar to Scenarios C_const, D_const, and F_const, the largest drawdown occurred at POD PD-22, which was one of the wells in which the withdrawal rate did not need to be constrained.

Simulated capture of natural discharge at the NPS and BLM sites of interest from the Scenario G_const withdrawals ranged between 0 and 100 percent compared to pre-development conditions. In addition to the four sites where withdrawals from Scenario E captured 100 percent of the total natural discharge simulated for that model cell, withdrawals from Scenario G_const captured 100 percent of the simulated discharge at six additional sites (model cells). These included Middle Knoll Spring (site 17); Knoll Spring (site 18); Spring Creek Spring (site 35); Dearden Spring Group (site 40); Needle Point Spring (site 41); and Big Springs (site 46).

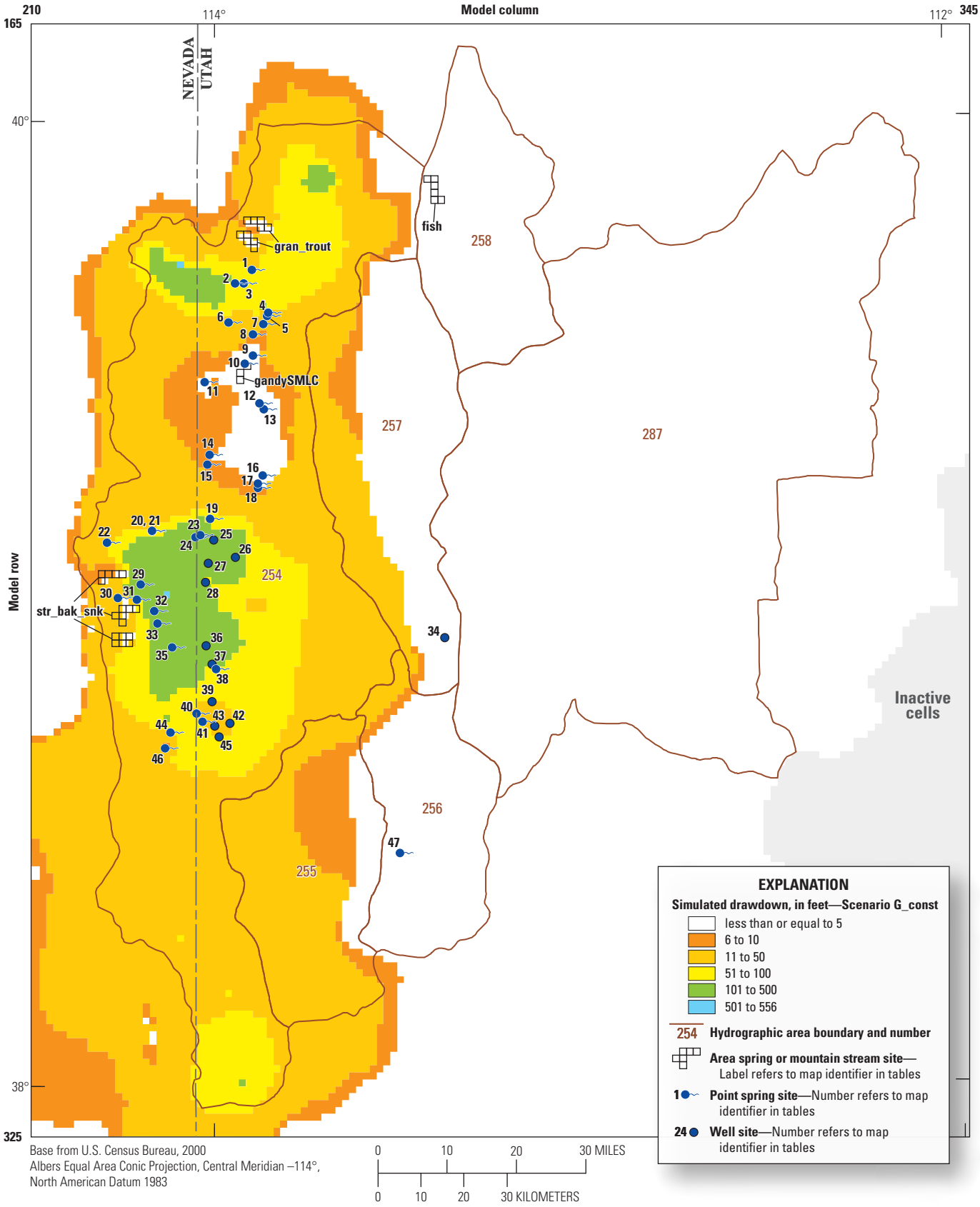

Figure 13. Groundwater resource sites of interest to the National Park Service and Bureau of Land Management, and simulated drawdown from groundwater withdrawals under Scenario G_const, model focus (Snake Valley) area, Utah and Nevada.

Model Limitations

The GBCAAS v. 3.0 parent groundwater model was constructed to simulate regional-scale groundwater flow; thus, it can be used to answer questions regarding groundwater flow issues at this scale. All groundwater-flow models are based on a limited amount of data and, thus, are necessarily simplifications of natural systems. When creating a model of a large region it is necessary to make more simplifications than when creating models of smaller regions. Model limitations are a consequence of uncertainty in three basic aspects of the model, including inadequacies, inaccuracies, or simplifications in (1) observations used in model calibration, (2) representation of geologic complexity in the hydrogeologic framework, and (3) representation of the groundwater system in the model, specifically recharge and discharge boundaries. It is important to understand how these characteristics limit the use of the model. These limitations are described in Brooks and others (2014, p. 84–85), and summarized in Brooks (2017a, p. 60).

A detailed sensitivity analysis was performed for the original calibrated steady-state model (GBCAAS v. 1.0, Brooks and others, 2014) that was used as the first stress period for the GBCAAS v. 3.0 parent model (Brooks, 2017a,b), and the model described in this report. The sensitivity analysis showed that the model observations were highly sensitive to several parameters representing horizontal hydraulic conductivity (especially in the basin-fill and volcanic hydrogeologic units), recharge rates, and evapotranspiration rates. A small change in any one of these parameters could potentially cause a significant change in either simulated drawdown or capture estimates. The model represents hydraulic properties that appear reasonable on the basis of water levels and discharge estimates, but may not be unique. Different combinations of model input parameters may result in an equally reasonable fit to the observed data. For a complete description of the sensitivity analysis, refer to Brooks and others (2014, p. 38–64, and figs. 20–22).

Because several of the springs of interest are not explicitly simulated in the model, there is uncertainty in the estimate of groundwater capture from these springs. The model does simulate natural discharge as evapotranspiration in some of the model cells containing these springs. Assuming that some part of the evapotranspiration is related to spring flow, the amount of discharge potentially captured from these cells also is likely to affect spring flow. Because the spring orifice could be discharging only a small percentage of the total groundwater discharge from the model cell, however, the percentage of simulated natural groundwater capture cannot be directly translated to a percentage of reduction in spring flow. Additionally, the model could continue to show that well withdrawals are capturing groundwater discharge from the model cell even when the hydraulic gradient and groundwater levels decline to the point where spring flow through the orifice ceases. The model would continue to simulate capture of transpiration from phreatophytes, which can have roots much deeper than the spring orifice. Because these springs are not explicitly simulated in the model, it is impossible to determine how much of the potentially captured groundwater is coming from the springs compared to how much is coming from evapotranspiration. Additionally, different types of springs respond differently to changing groundwater levels caused by well withdrawals. Springs that are sourced near the water table could be very sensitive to groundwater-level change, whereas springs that are sourced deeper in the system might not be as sensitive.

It is difficult to assess the extent of the limitations on use and interpretation of results because of the lack of discharge data for several of the spring sites. With limited information about spring flow, it is difficult to accurately quantify the effects of proposed groundwater withdrawals on some of the springs of interest to the NPS and BLM.

Appropriate Uses of the Model

The GBCAAS v. 3.0 parent model is a regional model designed to test the conceptual groundwater budget in the model focus area of southwestern Utah (Brooks, 2017a), and was used as a tool to estimate effects of existing and proposed withdrawals in Snake Valley. Despite the stated limitations, the modeling effort represents the best available scientific information for predicting the response of the groundwater system to groundwater withdrawals. The modeling demonstrated that groundwater withdrawals could affect groundwater levels and discharge at almost all of the NPS and BLM groundwater resource sites of interest. A more exact determination of how these resources might be affected could be made by physically monitoring water levels or discharge (for example, spring flow) while a long-term aquifer test was in progress. Monitoring of discharge, nearby water levels, or both, is important for long-term assessment and management of these water resources.

Summary

The National Park Service (NPS) and the Bureau of Land Management (BLM) are concerned about cumulative effects of groundwater development on groundwater-dependent resources managed by, and other groundwater resources of interest to, these agencies in Snake Valley and adjacent areas, Utah and Nevada. The groundwater resources of concern include groundwater discharge sites that support multiple uses. Of particular concern to the NPS and BLM are withdrawals from existing approved, perfected, certified, permitted, and vested groundwater rights in Snake Valley, and from several senior water-right applications filed by the Southern Nevada Water Authority (SNWA). Existing groundwater-rights in Snake Valley total about 55,272 acre-feet per year (acre-ft/yr). Water-right applications filed by the SNWA total 50,680 acre-ft/yr.

This report presents results from 11 numerical model simulations with differing groundwater withdrawal scenarios. An existing numerical groundwater-flow model of the eastern Great Basin was used to investigate where potential drawdown and capture of natural discharge is likely to result from potential groundwater withdrawals from existing approved, perfected, certified, permitted, and vested groundwater rights in Snake Valley, and from groundwater withdrawals proposed in nine senior applications filed by the SNWA. Eleven withdrawal scenarios were simulated. All scenarios were run as steady state to estimate the potential ultimate long-term effects of the simulated withdrawals. This assessment provides a general understanding of the relative susceptibility of the groundwater resources of interest to the NPS and BLM, and the groundwater system in general, to existing and future groundwater development in the study area.

At the NPS and BLM groundwater resource sites of interest, simulated drawdown resulting from withdrawals based on existing approved, perfected, certified, permitted, and vested groundwater rights (Allocated and Unallocated) within Snake Valley ranged between 0 and 159 feet (ft) without irrigation return flow (Scenario B), and between 0 and 123 ft with irrigation return flow (assumed to be 14 percent of the simulated withdrawal rate; Scenario E). With the addition of the SNWA withdrawals at an amount equal to the Unallocated Groundwater portion allotted to Nevada in the draft interstate agreement (35,000 acre-ft/yr), simulated drawdowns at the NPS and BLM sites of interest increased to range between 0 and 2,074 ft without irrigation return flow (Scenario C), and between 0 and 2,002 ft with irrigation return flow (Scenario F). With the addition of the SNWA withdrawals at an amount equal to the full application amounts (50,680 acre-ft/yr), simulated drawdowns at the NPS and BLM sites of interest increased to range between 1 and 3,119 ft without irrigation return flow (Scenario D), and between 1 and 3,044 ft with irrigation return flow (Scenario G).

At the NPS and BLM groundwater resource sites of interest, simulated capture of natural discharge resulting from the existing Allocated and Unallocated groundwater rights within Snake Valley both with and without irrigation return flow (Scenarios B and E, respectively) ranged between 0 and 100 percent; simulated capture of 100 percent occurred at four sites. With the addition of the SNWA withdrawals at an amount equal to the Unallocated Groundwater portion allotted to Nevada in the interstate agreement (35,000 acre-ft/yr), simulated capture of 100 percent occurred at nine additional sites without irrigation return flow (Scenario C), and at eight additional sites with irrigation return flow (Scenario F). With the addition of the SNWA withdrawals at an amount equal to the full application amounts (50,680 acre-ft/yr), simulated capture of 100 percent occurred at 11 additional sites without irrigation return flow (Scenario D), and at 9 additional sites with irrigation return flow (Scenario G).

Simulations C, D, F, and G (which included proposed withdrawals from the SNWA points of diversion [PODs]) produced extremely large drawdowns, especially near the SNWA PODs. Therefore, four additional scenarios were run (Scenarios C_const, D_const, F_const, and G_const) where the withdrawal rates at the SNWA PODs were constrained by not allowing drawdowns to be deeper than the assumed depth of the PODs (about 2,000 ft). In the constrained scenarios, withdrawals at the SNWA PODs were reduced to about 48 percent of the Unallocated amount (35,000 acre-ft/yr reduced to 16,817 acre-ft/yr or 16,914 acre-ft/yr, without and with irrigation return flow, respectively), and about 44 percent of the full application amounts (50,680 acre-ft/yr reduced to 22,048 acre-ft/yr or 22,165 acre-ft/yr, without and with irrigation return flow, respectively). This indicates that the SNWA may need to add more PODs, or PODs in different locations, in order to withdraw the total amount of groundwater that has been applied for.

At the NPS and BLM groundwater resource sites of interest, simulated drawdown resulting from the addition of the constrained SNWA withdrawals applied to the Unallocated Groundwater amount ranged between 0 and 290 ft without irrigation return flow (Scenario C_const), and between 0 and 252 ft with irrigation return flow (Scenario F_const). With the addition of the constrained SNWA withdrawals applied to the full application amounts, simulated drawdowns at the NPS and BLM sites of interest ranged between 0 and 358 ft without irrigation return flow (Scenario D_const), and between 0 and 313 ft with irrigation return flow (Scenario G_const).

At the NPS and BLM groundwater resource sites of interest, with the addition of the constrained SNWA withdrawals applied to the Unallocated Groundwater amount, simulated capture of 100 percent of the natural discharge occurred at five additional sites (in addition to the four captured at 100 percent in Scenario B) without irrigation return flow (Scenario C_const), and at two additional sites (in addition to the four captured at 100 percent in Scenario E) with irrigation return flow (Scenario F_const). With the addition of the constrained SNWA withdrawals applied to the full application amounts, simulated capture of 100 percent occurred at six additional sites (in addition to the four captured at 100 percent in Scenarios B and E) both without and with irrigation return flow (Scenarios D_const and G_const, respectively).

The GBCAAS v. 3.0 parent groundwater model was constructed to simulate regional-scale groundwater flow; thus, it can be used to answer questions regarding groundwater flow issues at this scale. All groundwater-flow models are based on a limited amount of data and, thus, are necessarily simplifications of natural systems. Despite its limitations, the modeling effort represents the best available scientific information for predicting the response of the groundwater system to groundwater withdrawals. The modeling demonstrated that both the existing and proposed groundwater withdrawals could affect groundwater levels and discharge at almost all of the NPS and BLM groundwater resource sites of interest. A more exact determination of how these resources might be affected could be made by physically monitoring water levels or groundwater discharge (for example, spring flow) while a long-term aquifer test was in progress. Monitoring of discharge, nearby water levels, or both, is important for long-term assessment and management of these water resources.

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