Volume 7

Boundary Fluxes and Predevelopment Steady-State Water Budget for the Spring Valley Model

Presentation to the Office of the Nevada State Engineer

Prepared by

SOUTHERN NEVADA WATER AUTHORITY

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LIST OF ACRONYMS AND ABBREVIATIONS

afy	acre-feet per year
ET	Evapotranspiration
ft	foot (feet)
ft/day	feet per day
ft^2/day	square feet per day
ft/ft	feet per foot
gpd/ft	gallons per day per feet
HA	Hydrographic Area
i	Hydraulic Gradient
K	Hydraulic conductivity
L	Unit of length
NWIS	National Water Information System
Q	Flow rate
RMU	Regional Model Units
T	Transmissivity
t	Unit of time
W	Flow width

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1.0 INTRODUCTION

This report provides estimates of the groundwater fluxes at the boundary of the Spring Valley groundwater flow model (Durbin, 2006) and the pre-development groundwater budget for the model area.

1.1 Boundary Fluxes, Groundwater Budget, and Their Roles

Boundary fluxes represent the rate of groundwater flow at the boundaries of a given flow domain. Estimates of boundary fluxes are essential to an accurate inventory of water resources of a given groundwater basin. They also constitute an important component of the basin groundwater budget and, therefore, are an important part of a numerical flow model. They may be input to a numerical model as specified fluxes, or they can be used as calibration targets if other types of boundary conditions are used.

Under pre-development conditions, a water budget includes several components grouped into inflows and outflows to the system. Inflow components include precipitation recharge, interbasin inflow from adjacent basins, and surface water flow and stream recharge, if perennial surface water that is in hydraulic communication with the flow system exists. Outflow components include groundwater evapotranspiration (ET), interbasin outflow to adjacent basins, and surface water evaporation if surface water is present. Under steady-state conditions, the system inflows equal the system outflows. However, in reality, an attempt is made to estimate each component of the water budget independently. The components are then brought together to form the water budget. Because of uncertainties in the available data and estimation methods, the inflows do not match the outflows exactly. Generally, the estimates are considered adequate if the difference is within 10 percent of the total budget.

1.2 Purpose and Scope

The purpose of the analysis described in this report is to compile or estimate the interbasin fluxes for all basins located within the model area and summarize the water budget for the flow domain of Spring Valley. The water budget used to construct the numerical groundwater flow model for Spring Valley is primarily based on the U.S. Geological Survey (USGS) Reconnaissance Reports. No new information is used unless necessary to estimate missing components of the budget. Specific objectives are as follows:

- Compile reported individual water budget components.
- Estimate unreported water budget components.
- Derive an overall water budget for the model area.

The extent of the study area is limited to the basins located within the model area (Figure 1-1). The scope includes a literature survey and integration techniques to estimate transmissivities along a vertical cross-section and Darcy's law to estimate the boundary fluxes. The water budgets used are based on Reconnaissance Reports published in the 1960s and summarized in the Water Planning Report No. 3 (Scott et al., 1971). The literature survey is limited to these documents.

1.3 General Approach

The general approach consists of the following steps:

- Conduct a literature review of the water budgets including boundary fluxes for basins located with the model boundary and limited to the USGS Reconnaissance Reports and the Water Planning Report No. 3 published by the Nevada Division of Water Resources (Scott et al., 1971).

- Compile available water budgets and boundary flux estimates and related information for each basin within the model area.

- Estimate boundary fluxes where missing for each basin within the model area.

- Extract model boundary fluxes for use in the Spring Valley groundwater flow model.

- Summarize water budget for model area.

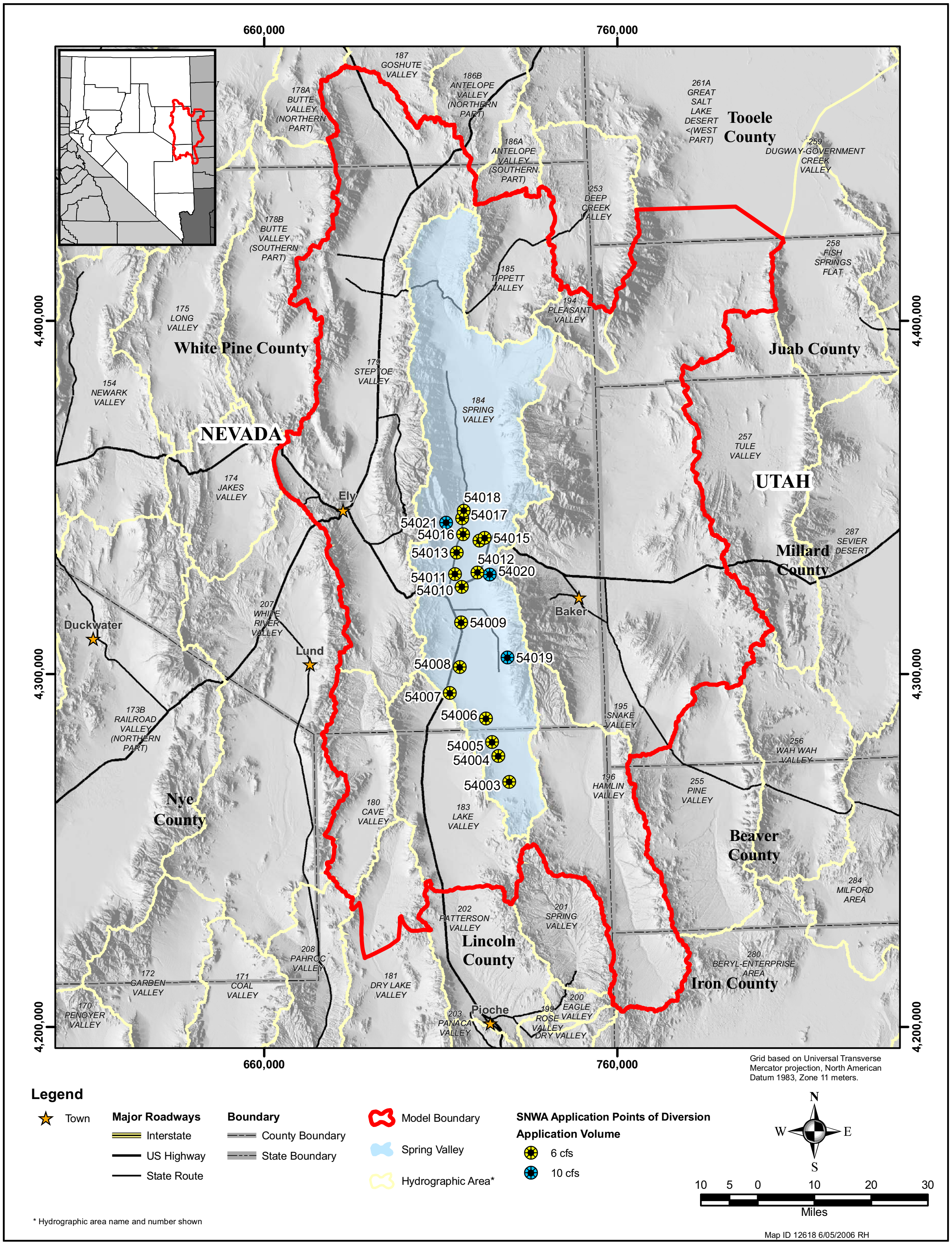

Figure 1-1
Location of Spring Valley Model Area

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2.0 AVAILABLE DATA

This section describes the main data types, methods of measurement, available data sources, and quality evaluation.

2.1 Main Data Types

To summarize the water budget for a given basin, the following data types are needed:

- Estimate of the mountain-block recharge
- Estimate of the recharge from runoff
- Estimate of perennial stream flow where necessary
- Estimate of surface water evaporation where necessary
- Estimates of ET
- Estimates of subsurface fluxes across the basin boundary.

A description of interbasin flow includes (1) estimates of subsurface inflow to a given basin and (2) estimates of subsurface outflow from a given basin. The types of data needed to fully describe interbasin flow are as follows:

- Estimates of boundary flux
- Location of basin boundary where the flux occurs
- Regional Model Units (RMUs) present along the basin boundary through which the flux occurs.

2.2 Methods of Measurements

Methods of measurement or estimation of the first two components of the budget, recharge and ET, are discussed in detail in the Spring Valley Data Report (SNWA, 2006c). Estimates of stream flow are described in the Section 4.0 of the Water Resources Assessment for Spring Valley (SNWA, 2006a). Thus, only methods for estimation of interbasin flow are discussed in this section.

Fluxes across basin boundaries may not be measured directly. They are usually estimated using one of the following five methods:

Method 1: If sufficient information exists, interbasin flow may separately be estimated using Darcy's law, which requires knowledge of the length of the portion of the boundary through which the flow occurs, the transmissivity of the corresponding hydrogeologic units, and the horizontal hydraulic gradient across the boundary. A description of Darcy's law and its history is provided by Freeze and Cherry (1979, pp. 15 to 18) in their book titled *Groundwater*.

Method 2: Interbasin flow may be estimated as a residual quantity if all other components of the groundwater budget of a given basin are known.

Method 3: Interbasin flow for basins located within the area of a numerical groundwater flow model may be derived through model calibration.

Method 4: Interbasin flow may also be estimated as the amount of contributing precipitation recharge for certain basins.

Method 5: If all other components of the budgets have reasonable estimates, interbasin flow may be calculated as the residual quantity.

2.3 Description of Available Data Sources

As stated in Section 1.0, the only sources of existing estimates of basin water budgets and interbasin flow used in this report are the Nevada Water Report No. 3 (Scott et al., 1971) and the Reconnaissance Reports. Although more recent estimates may be available, they were not used in this study.

A list of reconnaissance reports containing data relevant to this data analysis activity follows:

- Reconnaissance Report No. 42 for Steptoe Valley (Eakin et al., 1967, pp. 17 to 35)
- Reconnaissance Report No. 33 for Spring Valley (Rush and Kazmi, 1965, pp. 12 to 26)
- Reconnaissance Report No. 34 for Big Snake Valley (includes Hamlin and Pleasant Valleys - 254) (Hood and Rush, 1965, pp. 14 to 27)
- Reconnaissance Report No. 56 for Tippett Valley (Harrill, 1971, pp. 17 to 19)
- Reconnaissance Report No. 24 for Lake Valley, Nevada (Rush and Eakin, 1963, pp. 9 to 16)
- Reconnaissance Report No.13 for Cave Valley, Nevada (Eakin, 1962)
- Reconnaissance Report No. 16 for Dry Lake and Delamar Valleys, Nevada (Eakin, 1963)

Only information compiled during this project was used to generate estimates of interbasin flow that were not available from the Reconnaissance Reports or Scott et al. (1971). Project documents containing relevant information are as follows:

- The report describing the Water Resource Assessment for Spring Valley for its description of streams (SNWA, 2006a)
- The report describing the Geologic and Hydrogeologic Framework for the Spring Valley Area (SNWA, 2006b)
- The report describing the estimates of groundwater evapotranspiration used for the Spring Valley Data Report (SNWA, 2006c)
- The report describing the derivation of a spatial distribution of areal recharge for the Spring Valley Data Report (SNWA, 2006c)

2.4 Data Quality Evaluation

As stated before, the main sources of data are the Reconnaissance Reports. As their name indicates, these documents report the results of studies made at the reconnaissance level only. These studies were conducted quickly without detailed field work or data analysis. Their objective was to assess the quantities of water resources available for development at that time. Additional notable limitations in selected reports are as follows:

- Reconnaissance Report No. 33 for Spring Valley - 184 (Rush and Kazmi, 1965):

The perennial yield of the groundwater flow system is dependent on the capture of surface water that is lost to evaporation under predevelopment conditions. However, the relationship between groundwater and surface water is not very clear as the section on surface water was prepared by a separate author and was loosely tied to the rest of the report. Also, records of streamflow are not provided for all perennial streams.

- Reconnaissance Report No. 42 for Steptoe Valley - 179 (Eakin et al., 1967):

No estimates of interbasin flow through the carbonate aquifer are provided because the water budget was estimated for the basin-fill aquifer system only.

- Reconnaissance Report No. 34 for Big Snake Valley (includes Hamlin and Pleasant Valleys - 254) (Hood and Rush, 1965):

As for Steptoe Valley, no estimates of interbasin flow through the carbonate aquifer are provided because the water budget was estimated for the basin-fill aquifer system only.

These limitations were resolved during this study. Streamflow in Spring Valley was estimated during the water assessment activities (SNWA, 2006a). Also as stated in Section 1.0, one of the specific objectives of the analysis described in this report is to estimate unreported components of the budget, including interbasin flow.

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3.0 DATA ANALYSIS METHODOLOGY

The data analysis methodology includes three steps: (1) compilation of reported basin water budgets, (2) estimation of individual basin interbasin flow, and (3) derivation of model boundary fluxes and model water budget.

3.1 Compilation of Reported Basin Water Budgets

The methodology consists primarily of compiling water budget data from the Water for Nevada Report No. 3 (Scott et al., 1971) and the relevant Reconnaissance Reports for each of the basins of the model area. Most of the needed information is included in these reports. In some instances, where groundwater budgets reported in the Reconnaissance Report cover the basin fill aquifer only, additional estimates had to be made.

3.2 Estimation of Individual Basin Interbasin Flow

Interbasin flow was estimated for the following cases:

- For two of the basins, Steptoe Valley and Snake Valley, estimates of interbasin flow through the carbonate aquifer were not made because the water budgets were only estimated for the basin fill aquifer. Interbasin flow estimates for these basins were made using Method 1 introduced in Section 2.0 and discussed in more detail in this section.

- For Dry Lake Valley, only a portion of the basin was included in the model area. Thus, estimates of the recharge and subsurface outflow for the portion of this valley that is part of the model area were needed. Interbasin flow estimates for this basin were made using Method 4 also introduced in Section 2.0 and discussed in more detail in this section.

Method Used for Steptoe and Snake Valleys

The process used to estimate the missing interbasin flow components of the water budget is a combination of Methods 1 and 5 listed in Section 2.0.

Method 1 is based on Darcy's law which is of the form:

$$Q = TWi \tag{3-1}$$

where,

Q = Flow rate (L^3/t) (L = unit of length, t = unit of time)
T = transmissivity (L^2/t)
W = Flow width (L)
i = Hydraulic gradient (L/L)

Thus, to calculate the flow rate across a basin boundary, the following information is required:

- Estimated transmissivity of the RMU along boundary
- Approximate flow width
- Average hydraulic gradient in the RMU along boundary.

Estimates of transmissivity were made using the relationships of hydraulic conductivity (K) with depth and the depths of the saturated media along the boundary (SNWA, 2006b).

The relationships of K versus depth developed for selected RMUs have the following form:

$$\log_{10}(K) = \log_{10}(K_0) + a_1 z + a_2 z^2 \quad \text{for} \quad z < -\frac{a_1}{2a_2} \qquad (3\text{-}2)$$

and

$$\log_{10}(K) = \log_{10}(K_0) - \frac{a_1^2}{4a_2} \quad \text{for} \quad z \geq -\frac{a_1}{2a_2} \qquad (3\text{-}3)$$

where:

K = the hydraulic conductivity at depth z [Lt^{-1}],
K_0 = the hydraulic conductivity at depth z equals zero [Lt^{-1}],
z = the depth below the land surface [L],
a_1 = a coefficient [L^{-1}], and
a_2 = a coefficient [L^{-2}].

These relationships were developed using the available well and aquifer testing data. Note that the quantity $\log_{10}(K_0)$ represents the intercept of the fitted function also denoted as a_0.

The transmissivity was estimated as follows:

- Depending on the flow width across the boundary of interest, one or more points were selected on the boundary.

- The corresponding stack of RMUs occurring at these points within the framework model were extracted. The thicknesses of the RMUs were recorded starting from the land surface.

- Estimates of hydraulic conductivities were made for discrete intervals of the saturated portion of the RMUs present using the appropriate relationship of K versus depth.

- Each hydraulic conductivity was multiplied by the thickness of the corresponding interval.

- The resulting transmissivities were summed up to produce an estimate of the transmissivity of the saturated RMU column at the boundary of interest.

The horizontal hydraulic gradient was estimated by selecting two wells with known water levels located on each side of the boundary. The hydraulic gradient was calculated as the ratio of the difference in hydraulic heads to the distance between the two wells. The interbasin flow was estimated using Darcy's law (Method 1). However, given that the other components of the budget are fixed and given the uncertainties in the parameters in Darcy's equation, the flow width was adjusted until the flow estimate approximated the budget residual.

Method Used for Dry Lake Valley

Using Method 2, interbasin flow may also be equated to the amount of recharge infiltrating through the capture area located upgradient from the place of underflow, if groundwater does not discharge from that area by other means such as ET. The method is particularly useful for estimating subsurface outflow from partial valleys where the only discharge is by underflow.

3.3 Estimating Model Boundary Fluxes and Model Water Budget

Once the water budgets for each of the basins of the model area are known, the interbasin flow along the boundary of the model and the overall water budget for the study area can be easily defined. Boundary fluxes between the outer basins and the basins that are adjacent to them on the outside of the model area constitute the model boundary fluxes. To obtain the overall model water budgets, the recharge estimates and ET estimates of all model area basins are totaled. The model boundary fluxes are grouped into inflows and outflows. Any surface water components of the budget are also included.

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4.0 DATA ANALYSIS

The results of the analysis of the water budget components and interbasin flow are presented in this section. The results are presented by basin.

4.1 Reported Individual Basin Water Budgets

The reconnaissance reports listed in Section 2.3 and Scott et al. (1971) contain estimates of most of the water budget components including estimates of subsurface inflow and outflow for the flow system of all basins located within the Spring Valley model area. All components of the water budgets are as reported, except for perennial streamflow in Spring Valley and the groundwater evapotranspiration estimates. Reported groundwater ET values were adjusted to predevelopment steady-state conditions as described by SNWA (2006c). The water budget of each valley is presented and discussed in the following subsections.

Spring Valley (Hydrographic Area [HA] 184)

The estimated predevelopment steady-state groundwater budget for Spring Valley is shown in Table 4-1.

Table 4-1
Predevelopment Steady-State Water Budget for Spring Valley in Acre-Feet per Year (afy)

Component	Value	Source
Mountain Block Recharge	65,000	Rush and Kazmi (1965)
Subsurface Inflow from Tippett Valley	2,000	Scott et al. (1971)
Perennial Stream Flow	47,000	SNWA (2006a)
Total Inflow in afy	**114,000**	**-**
Adjusted Groundwater Evapotranspiration	71,000	SNWA (2006c)
Subsurface Outflow to Hamlin Valley (Big Snake Valley)	4,000	Rush and Kazmi (1965)
Playa Evaporation (Potential Additional Recharge)	37,000	SNWA (2006a)
Total Outflow in afy	**112,000**	**-**
Imbalance	(2,000)	-

As explained in the Reconnaissance Report (Rush and Kazmi, 1965, pgs. 24 to 25), the natural recharge under predevelopment steady-state conditions is portioned into mountain block recharge (65,000 afy) and recharge through the alluvial apron (10,000 afy) via infiltration through the perennial stream beds. The 10,000 afy of recharge through the streambeds is included in the estimate of perennial streamflow (47,000 afy). This estimate was obtained by combining streamflow measurements reported in the Reconnaissance Report (Rush and Kazmi, 1965) and more recent measurements as explained in the Water Resources Assessment Report for Spring Valley (SNWA, 2006a). The remainder of the perennial streamflow (37,500 afy) is assumed to flow down to the playas and evaporate into the atmosphere. The estimate of ET provided in the Reconnaissance Report (Rush and Kazmi, 1965) (70,000 afy) was adjusted to predevelopment steady-state conditions as explained in Volume 3 of Spring Valley Data Report (SNWA, 2006c). Scott et al. (1971) report subsurface inflow to Spring Valley from Tippett Valley. The inflow rate is 2,000 afy. Both the Reconnaissance Report (Rush and Kazmi, 1965) and Scott et al. (1971) report subsurface outflow from Spring Valley. Subsurface outflow from southeastern Spring Valley to Hamlin Valley (Big Snake Valley) occurs through the carbonates of the Snake Range. According to Rush and Kazmi (1965), the outflow was estimated using Darcy's law and the following information:

- Approximate flow width of 4 miles
- Average hydraulic gradient in the valley fill of 20 feet (ft) per mile
- Estimated transmissivity of the valley fill of 50,000 gallons per day per foot (gpd/ft)

Water levels at wells located on each side of the boundary were used to estimate the horizontal hydraulic gradient. The estimated subsurface outflow is 4,000 afy. This underflow value is similar to the 3,500 afy estimate of recharge occurring in the Spring Valley south of the groundwater divide (Rush and Kazmi, 1965; Scott et al., 1971). A limitation to this estimate, stated by Rush and Kazmi (1965), is that the interbasin flow occurs through the carbonate aquifer but the valley fill aquifer characteristics were used to estimate the underflow. This naturally introduces additional uncertainties into the reported values. However, given that the objective of this analysis is to estimate water budgets that are consistent with the Reconnaissance Reports without using new information unless necessary, this estimate of underflow is left as is.

Big Snake Valley (HA 254)

This valley includes Snake Valley (HA 195), Hamlin Valley (HA 196), and Pleasant Valley (HA 194). The estimated predevelopment steady-state groundwater budget for Spring Valley is shown in Table 4-2. As noted before, the ET value provided in the Reconnaissance Report and Scott et al. (1971) was adjusted to predevelopment conditions as explained in Volume 3 of the Spring Valley Data Report (SNWA, 2006c).

Both the Reconnaissance Report (Hood and Rush, 1965) and Scott et al. (1971) report subsurface inflow and outflow from the basin fill aquifer only. The inflow is 0 afy, and the outflow is 10,000 afy to the state of Utah in the north. No estimates of subsurface fluxes through the carbonate aquifer were provided.

Table 4-2
Predevelopment Steady-State Budget for Big Snake Valley in Acre-Feet per Year

Component	Value
Maxey-Eakin Recharge	100,000
Additional Recharge from Runoff	2,700
Total Natural Recharge	102,700
Subsurface Inflow from Spring Valley	4,000
Total Inflow	106,700
Subsurface Outflow to Great Salt Lake Desert	10,000
Subsurface Outflow to Tule Valley, Utah through the Carbonate Aquifer	NR
Total Subsurface Outflow	NR
Adjusted Evapotranspiration	88,000
Total Outflow	NR

NR = Not Reported

Source: Hood and Rush (1965) and SNWA (2006c, Volume 3)

Steptoe Valley (HA 179)

The estimated predevelopment steady-state groundwater budget for Steptoe Valley is shown in Table 4-3. As noted before, the ET value provided in the Reconnaissance Report and Scott et al. (1971) was adjusted to predevelopment conditions as explained in Volume 3 of the Spring Valley Data Report (SNWA, 2006c).

Table 4-3
Predevelopment Steady-State Budget for Steptoe Valley in Acre-Feet per Year

Component	
Maxey-Eakin Recharge	85,000
Subsurface Inflow	-
Total Natural Recharge	85,000
Subsurface Outflow to Goshute Valley through Basin Fill	1,000
Subsurface Outflow to Goshute Valley, through the Carbonate aquifer	NR
Total Subsurface Outflow	NR
Adjusted Evapotranspiration	76,032
Total Outflow in afy	NR

NR = Not Reported

Source: Eakin et al. (1967) and SNWA (2006c, Volume 3)

Both the Reconnaissance Report (Eakin et al., 1967) and Scott et al. (1971) report subsurface inflow and outflow from the basin fill aquifer only. The inflow is 0 afy, and the outflow is 1,000 afy to Goshute Valley. No estimates of subsurface fluxes through the carbonate aquifer were provided in either of the reports.

Tippett Valley, Lake Valley, Cave Valley, and North Dry Lake Valley

The estimated predevelopment steady-state groundwater budgets for all other valleys of the model area are shown in Table 4-4. As reported in Volume 3 of the Spring Valley Data Report (SNWA, 2006c) the ET values for Tippett Valley and Dry Lake Valley are zero by Scott et al. (1971). Thus, no adjustment for predevelopment conditions was necessary for these valleys.

Only the northern portion of Dry Lake Valley is included within the model area. This portion of the valley was selected because it is often referred to as a separate HA known as Muleshoe Valley. It is separated from south Dry Lake Valley by mountains.

Considering that only the northern portion of this valley is included within the model area, a groundwater budget for that portion of the valley is also included in Table 4-4.

Table 4-4
Predevelopment Steady-State Water Budgets in Acre-Feet per Year for Tippett Valley, Lake Valley, Cave Valley, and North Dry Lake Valley

Basin Name	Tippett Valley	Lake Valley	Cave Valley	N. Dry Lake Valley
Maxey-Eakin Recharge	6,900	13,000	14,000	1,730
Subsurface Inflow	-	-	-	-
Total Inflow	6,900	13,000	14,000	1,730
Subsurface Outflow through Basin Fill		3,000		
To		Patterson Valley		
Subsurface Outflow through Carbonate Aquifer	7,000		14,000	1,730
To	Goshute Valley		White River Valley	S. Dry Lake
Total Subsurface Outflow	7,000	3,000	14,000	1,730
Adjusted Evapotranspiration	-	10,000	200	-
Total Outflow	7,000	13,000	14,200	1,730
Imbalance	100	-	200	-

Sources: Eakin (1962), Eakin (1963), Harrill (1971), Rush and Eakin (1963), Scott et al. (1971), SNWA (2006c)

4.2 Estimating Interbasin Flow for Individual Basins

As discussed in the previous section, interbasin flow out of three of the basins of the Spring Valley model area must be estimated.

Steptoe Valley

Groundwater flow from Steptoe Valley to Goshute Valley was estimated using Method 1 described in Section 2.2. This method uses Darcy's law to calculate flow across a vertical face of the flow system. The method requires a flow width, a transmissivity, and the horizontal hydraulic gradient across the boundary. The flow width is usually estimated from a hydraulic head map of the aquifer through which underflow occurs. Due to a limited number of carbonate wells, no hydraulic head map is available from the carbonate aquifer. The length of the flow width is therefore uncertain and was adjusted until a reasonable flow that fits the overall budget was obtained. The horizontal hydraulic gradient was calculated using data from two wells located in Steptoe Valley and Goshute Valley (Figure 4-1). The well location and water-level measurement for well 179 N28 E64 05AA 1 were obtained from the NDWR Well Log Database (NDWR, 2004). The well location and water-level measurement for well 187 N29 E64 15ABDA 1 were obtained from NWIS (USGS, 2005). The transmissivity of the saturated thickness through which the outflow occurs was estimated using the relationship of K with depth developed for the carbonate aquifers using the available hydraulic property data (Durbin, 2006). The equation parameters for the carbonate aquifer are a_0 = 2.00E+00, a_1 = -7.00E-04 ft^{-1}, and a_2 = 4.00E-08 ft^{-2} (Durbin, 2006). The RMU column used in these calculations was extracted from the hydrogeologic framework model (Durbin, 2006) at a point located on the hydrographic basin boundary between Steptoe Valley and Goshute Valley (Figure 4-1).

This method of estimating T requires RMU depths, which were obtained from the hydrogeologic framework model (Durbin, 2006) and an estimate of the depth-to-water at the boundary. The calculations of T are shown in Table 4-5. Interval calculations are made starting at the top of the saturated column. The depth-to-water at the RMU sampling point of 162 ft was derived from the average hydraulic head between the two wells (5,877 ft) used to estimate the horizontal hydraulic gradient (Figure 4-1). The total transmissivity is equal to 3,247 square feet per day (ft^2/day) or 24,286 gpd/ft. The horizontal hydraulic gradient across this boundary is 0.0051 feet per foot (ft/ft). The flow width is estimated to be 8.5 miles or 44,880 ft. The flux is then calculated by multiplying the total transmissivity expressed in gpd/ft by the flow width in feet and by the gradient in ft/ft. The resulting flow rate value is divided by 325,851 and multiplied by 365 for conversion to afy. The resulting estimated flux across the carbonate rocks is approximately 6,000 afy.

Snake Valley

There is uncertainty as to the location of the underflow through the carbonate aquifer from Snake Valley to Utah. Unfortunately, hydraulic head data in the carbonate aquifer are insufficient to identify the location of outflow. Based on previous studies such as Harrill et. al (1988) and Brothers et al. (1993), flow is across the western boundary of Snake Valley to Tule Valley in Utah (Figure 4-2).

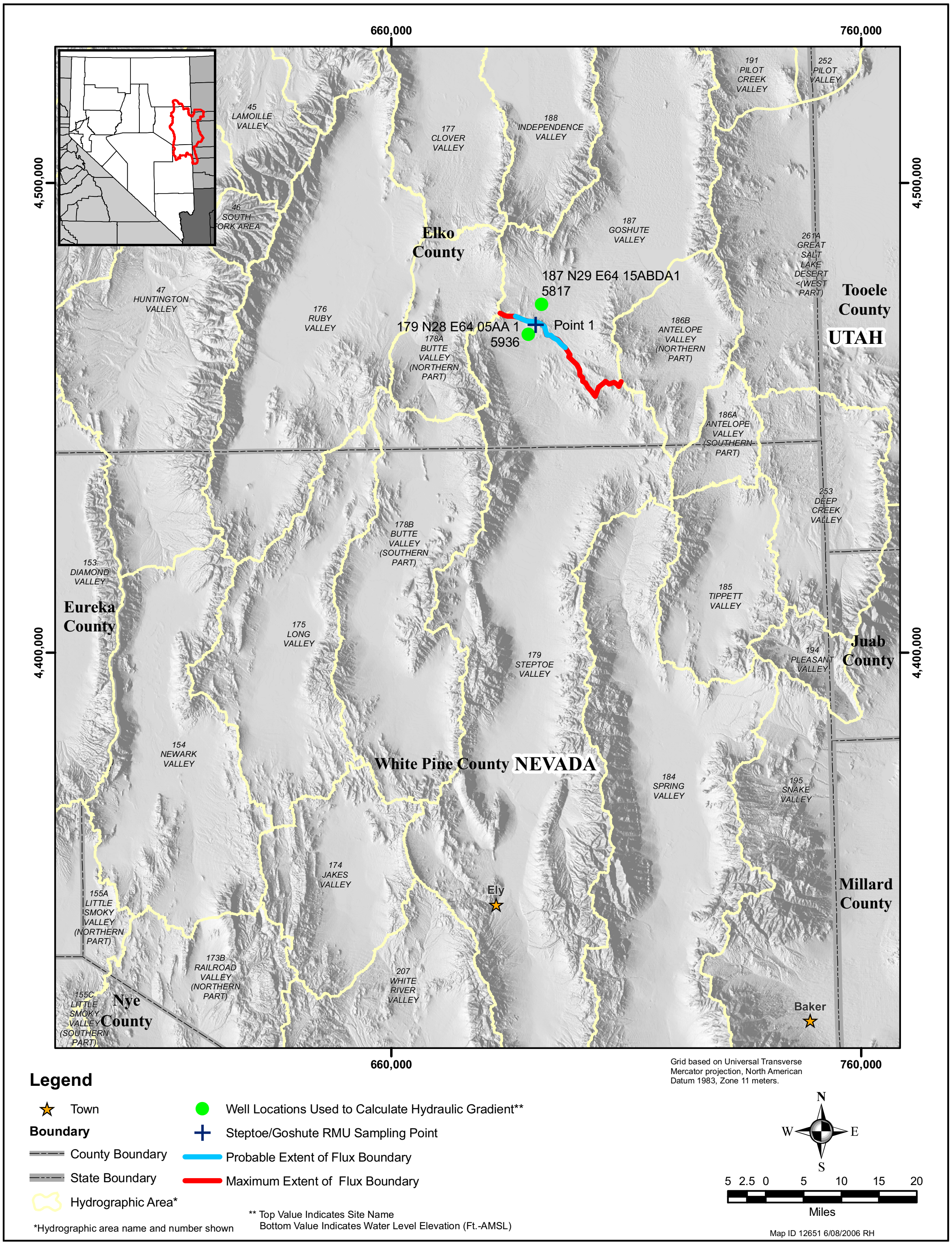

Figure 4-1
Location of Data Used to Estimate Unreported Subsurface Boundary Fluxes for Steptoe Valley

Table 4-5
Calculation of Transmissivity of Carbonate Aquifers at Boundary Between Steptoe Valley and Goshute Valley

Depth (ft)	K (ft/day)	T (ft^2/day)
0	---	---
200	---	---
500	---	---
1,000	---	---
1,500	---	---
2,000	---	---
2,398	---	---
2,600	2.82	569.84
2,650	2.67	133.31
2,750	2.39	238.51
2,800	2.26	112.87
2,850	2.14	106.87
2,900	2.02	101.24
2,950	1.92	95.96
3,000	1.82	90.99
3,050	1.73	86.31
3,250	1.40	280.89
3,500	1.10	274.12
4,000	0.69	345.92
4,500	0.46	228.54
5,000	0.32	158.11
6,000	0.17	173.78
7,000	0.11	114.82
8,000	0.09	91.20
8,500	0.09	43.55
	Total	**3,247**

Note: Depth in bold is estimated depth to water for the RMU model sampling point.

Groundwater flow from Snake Valley to Tule Valley was also estimated using Method 1 described in Section 2.2. The horizontal hydraulic gradient was calculated using data from two wells located in Snake Valley and Tule Valley. Both well locations were originally obtained from the NWIS database (USGS, 2005). The depth-to-water measurement for well (C-17-18)26ab-1 was obtained from Ertec (1981). The depth-to-water measurement for well (C-17-15)17acc-1 was obtained from the NWIS database (USGS, 2005). The transmissivity of the saturated thickness through which the outflow

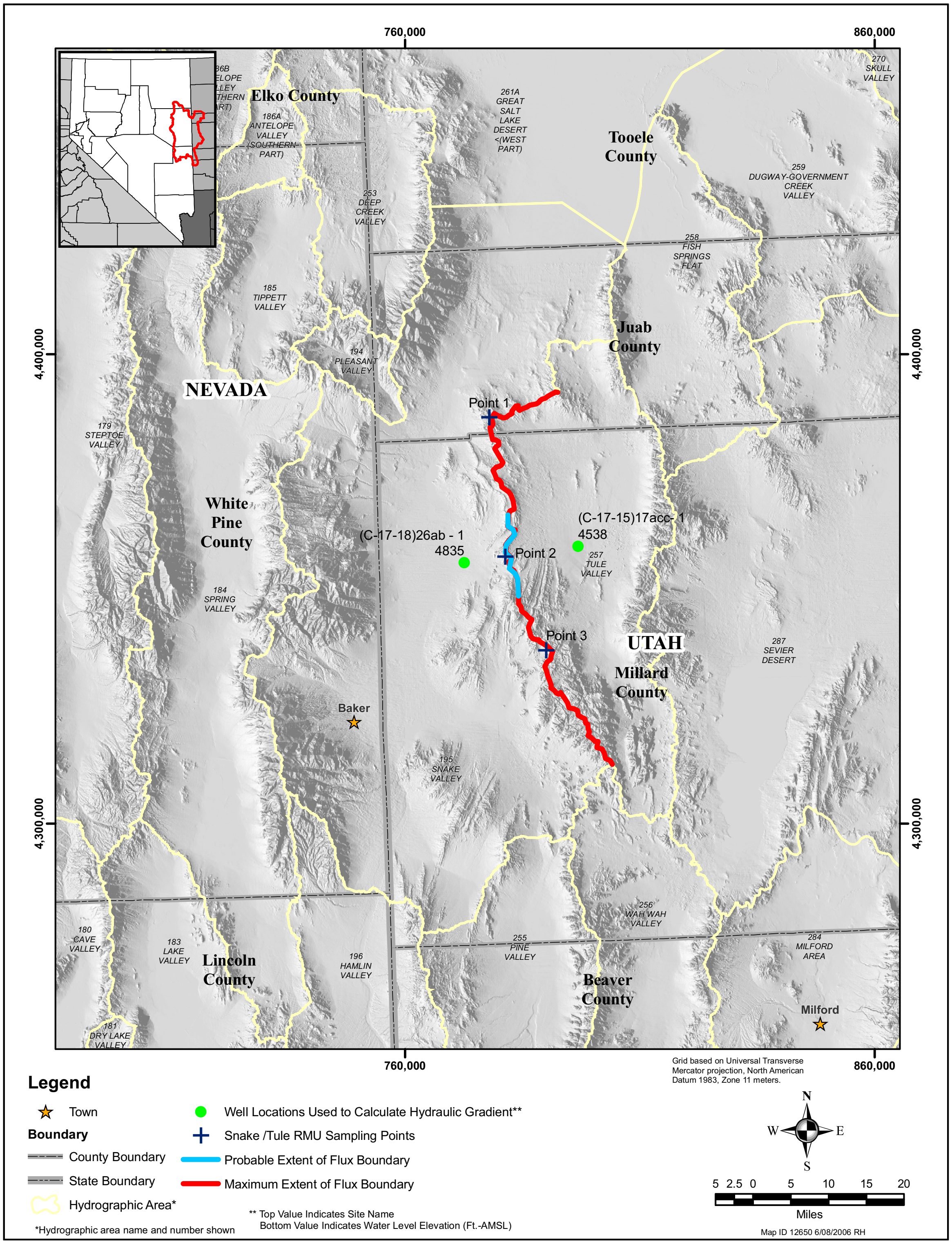

Figure 4-2
Location of Data Used to Estimate Unreported Subsurface Boundary Fluxes for Snake Valley

occurs was estimated using the relationship of K with depth for the carbonate aquifers using the available hydraulic property data and the hydrogeologic framework model (Durbin, 2006). This method of estimating T requires RMU depths, which were obtained from the hydrogeologic framework (Durbin, 2006) at three points located along the boundary between Snake Valley and Tule Valley (Figure 4-2). The depth-to-water at these three points was estimated using the points respective land surface elevations and an estimate of the hydraulic head at this location based on the available data (Figure 4-2). Again, the length of the flow width could not be estimated independently. It was adjusted to obtain a reasonable underflow rate to fit the reported components of the budget.

The calculations of T are shown in Table 4-6. Interval calculations are made starting at the top of the saturated column at the top of the carbonate RMUs. For inch interval, K is calculated and multiplied by the interval thickness, which is the difference between the depth value located in the same row as the K value minus the depth in the previous row. The interval transmissivities are summed up to yield a total transmissivity of 2,950 ft^2/d or 33,236 gpd/ft. Based on the available water level data, the horizontal hydraulic gradient across this boundary is 0.0037 ft/ft. The flow width is estimated to be 14 miles or 73,920 ft. The resulting estimate of flux across the carbonate rocks is approximately 10,000 afy.

North Dry Lake Valley

Considering that the groundwater budget of the full basin has only two components: recharge from precipitation and underflow to the south, the northern portion of the valley will have a similar budget.

Under steady-state conditions, the two components must be equal. It is also known that flow is north to south in this valley. Thus, the underflow out of northern Dry Lake Valley flows into South Dry Lake Valley and is equal to the amount of precipitation recharge in northern Dry Lake. This amount was apportioned from the reported total recharge of the valley reported as 5,000 afy by Scott et, al. (1971) using the recharge grid described in the data analysis report documenting areal recharge (SNWA, 2006c, Volume 2). The resulting amount is 1,730 afy.

Table 4-6
Calculation of Transmissivity of Carbonate Aquifers at Boundary Between Snake Valley and Tule Valley

Depth (ft)	Point 1		Point 2		Point 3	
	K (ft/day)	T (ft^2/day)	K (ft/day)	T (ft^2/day)	K (ft/day)	T (ft^2/day)
0	100	---	100	---	100	---
250	67.22	---	67.22	---	67.22	---
500	45.71	---	45.71	---	45.71	---
1,000	21.88	---	21.88	---	21.88	---
1,264	15.1	---	15.1	---	15.1	---
1,500	10.96	---	10.96	2,587.69	10.96	---
1,917	6.38	---	6.38	2,662.14	6.38	---
1,956	6.08	---	6.08	237.08	6.08	237.08
2,362	3.71	1,507.61	3.71	1,507.61	3.71	1,507.61
2,500	3.16	436.39	3.16	436.39	3.16	436.39
3,000	1.82	909.85	1.82	909.85	1.82	909.85
4,000	0.69	691.83	0.69	691.83	0.69	691.83
5,000	0.32	316.23	0.32	316.23	0.32	316.23
6,000	0.17	173.78	0.17	173.78	0.17	173.78
7,000	0.11	114.82	0.11	114.82	0.11	114.82
8,000	0.09	91.2	0.09	91.2	0.09	91.2
8,500	0.09	43.55	0.09	43.55	0.09	43.55
Transmissivity		4,285.25		4,522.34		4,522.34

Note: Depths in bold are estimated depths to water for the three RMU model sampling points.

5.0 MODEL BOUNDARY FLUXES AND GROUNDWATER BUDGET

The model boundary fluxes, overall model water budget, and associated uncertainties are discussed in this section.

5.1 Model Boundary Fluxes and Groundwater Budget

The reported water budgets for each of the basins and additional estimates of subsurface fluxes described in Section 4.0 were used to derive boundary fluxes and an overall water budget for the Spring Valley model area. This was accomplished by adding each component of the budget for all basins located in the model area, except for the interbasin flow values. For interbasin flow, only interbasin flow that occurs along the boundary of the model was considered. Estimates of these fluxes were renamed "boundary fluxes" and are shown in Figure 5-1; and the overall water budget is presented in Table 5-1. In the flow model, streamflow and streambed infiltration will be explicitly simulated. As shown in Table 5-1, the total streamflow is estimated to be 47,000 afy. The streambed infiltration was estimated to be 10,000 afy by Rush and Kazmi (1965).

5.2 Water Budget Uncertainty

In general, uncertainty exists in each component of the water budget. The most reliable components of the budget are usually the ET and the streamflow rates. However, keeping in mind that the objective of this analysis is not to derive the best estimate of the water budget using all available information, a detailed uncertainty analysis is not warranted. Rather, the sole objective of this analysis is to estimate a complete pre-development water budget for the Spring Valley model that is consistent with that used by the Reconnaissance Reports. The budget includes all components reported by Scott et al. (1971) or the Reconnaissance Reports. Budget components were estimated as part of this analysis only if they were not available from these documents. Consequently, the only uncertainty is the total uncertainty in the estimated predevelopment total budget. The total uncertainty in the pre-development water budget is represented by the imbalance listed as 6,600 afy in Table 5-1. This imbalance represents less than 2 percent of the total inflow estimate. In the numerical flow model, the precipitation recharge and the boundary fluxes are specified and invariant. The 6,600 afy amount of uncertainty should, therefore, be allocated between the ET and streambed recharge components of the water budget.

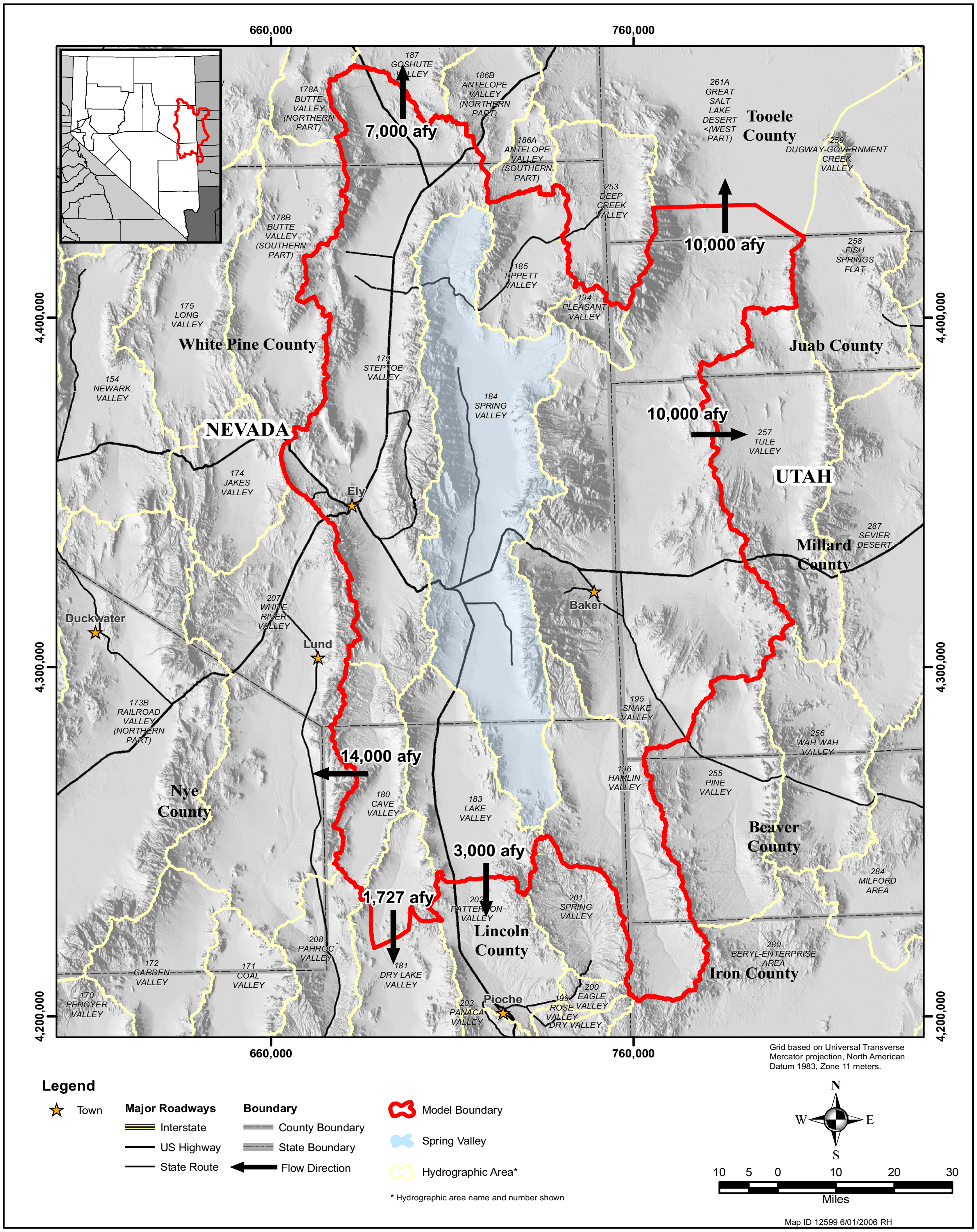

Figure 5-1
Subsurface Boundary Fluxes at Spring Valley Model Boundary

Table 5-1
Water Budget for the Spring Valley Model Domain

Budget Component	Rate (afy)
Mountain-block recharge	284,922
Additional Recharge through Valley Fill in Snake Valley	2,700
Perennial Streamflow in Spring Valley	47,000
Total Inflow	**334,622**
Groundwater Evapotranspiration	
Spring Valley	71,000
Steptoe Valley	76,032
Cave Valley	200
Lake Valley	10,000
Snake Valley	88,000
Boundary Fluxes	
Steptoe Valley	7,000
Lake Valley	3,000
Cave Valley	14,000
Snake Valley	20,000
Dry Lake Valley	1,730
Surface Water Evaporation	
Spring Valley playa	37,000
Total Outflow	**327,962**
Budget Imbalance	**6,660**

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