Volume 3

Groundwater Evapotranspiration Estimates 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
cfs	cubic feet per second
Coop	Cooperative Observer
DRI	Desert Research Institute
ET	Evapotranspiration
ft	foot (feet)
ft^2	square feet
GIS	Geographic Information System
GISMO	Geographical Information Systems Management Office
GPS	Global Positioning System
LVVWD	Las Vegas Valley Water District
NDVI	Normalized Difference Vegetation Index
NLCD	National Land Cover Data
PET	Potential Evapotranspiration
SNWA	Southern Nevada Water Authority
USGS	U.S. Geological Survey
W_Y	Water Yield

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1.0 INTRODUCTION

This report describes the evapotranspiration (ET) estimates and associated data for estimating discharge applied in the groundwater development model. The U.S. Geological Survey (USGS) in cooperation with the Nevada State Engineer's Office were first to complete water resource budgets in eastern Nevada during the 1940s through the 1970s. These estimates are compiled as Reconnaissance Series Reports, Water Resource Bulletins and Water Supply Papers. The ET estimates, or the discharge component of a water resource budget, at the time, were based on previous investigations that date back to as early as 1912. Although, the basis of the estimates date back to the first part of the 20th century, they still remain an important source of historical information on groundwater use in Nevada and are frequently referenced.

1.1 Objectives

The purpose of this report is to describe the datasets applied within the groundwater development model and not necessarily how the datasets were applied in the model. There is, however, some analysis involved in evaluating and describing each dataset. The objective of this report is to (1) evaluate the ET estimates as reported in the USGS Reconnaissance Series Reports for basins within the groundwater model area, (2) describe the methodology for delineating the phreatophytic areas within the model and the application of the appropriate ET volumes to the delineated areas, (3) describe extinction depths for different types of vegetation/land cover and discuss the justification for application of the appropriate extinction depths within the model, (4) describe the data and analysis used in estimating potential evapotranspiration (PET), and (5) discuss the results and limitations of the data and techniques described in this report.

1.2 General Approach

Evapotranspiration is the process whereby water is returned to the atmosphere through evaporation from soil, wet plant surfaces, open water bodies, and transpiration from plants. The type of plants that are of most concern are termed phreatophytes. Phreatophytes were first defined by Meinzer (1927) as:

> *"plants that habitually grow where they can send their roots down to the water table or the capillary fringe immediately overlying the water table and are then able to obtain a perennial and secure supply of water".*

Phreatophytes also act as natural hydraulic pumps increasing the potential to use groundwater through the process of ET. Different phreatophytic species, however, use the available water at different rates. There are a variety of parameters that can determine a plant's ET rate, such as vegetation type, density, soil characteristics, depth to water, and climatic conditions.

The USGS began estimating ET in eastern and southern Nevada nearly 50 years ago. The water use rates applied to phreatophytic areas in these studies were based on evapotranspiration tank research relating to vegetation type, density, and depth to water by numerous scientists in the USGS, notably Lee (1912), Blaney et al. (1930, 1938), White (1932), Young and Blaney (1942), Gatewood et al. (1950), and Robinson (1970).

2.0 GROUNDWATER EVAPOTRANSPIRATION ESTIMATES

This section describes the sources of ET estimates, the analysis for determining the groundwater discharge for each basin, and the results.

2.1 Data Sources and Limitations

The estimates of ET in acre-feet per year (afy) used in the groundwater development model are reported in two sources:

- USGS Reconnaissance Series Reports, as listed in Table 2-1.
- Scott et al. (1971)

Table 2-1
USGS Reconnaissance Series Reports for Basins Within the Model Area

Valley and Hydrographic Basin Number	Report Reference[a]	Author and Year Published
Steptoe – 179	R-42	Eakin et al. (1967)
Spring - 184	R-33	Rush and Kazmi (1965)
Hamlin - 196	R-34	Hood and Rush (1965)
Snake - 195	R-34	Hood and Rush (1965)
Pleasant - 194	R-34	Hood and Rush (1965)
Tippett - 185	R-56	Harrill (1971)
Cave Valley - 180	R-13	Eakin (1962)
Dry Lake Valley - 181	R-16	Eakin (1963)
Lake – 183	R-24	Rush and Eakin (1963)

[a]R = Reconnaissance Series Report Number

There are limitations in the ET estimates as reported by the USGS in the Reconnaissance Series Reports. The most obvious limitation relates to the methodology used in estimating ET and the lack of more recent technology at the time the Reconnaissance work was taking place, such as the use of micrometerological stations to consider climatic conditions.

The data reported in Scott et al. (1971) is essentially a summary of all the USGS Reconnaissance work and even lists the Reconnaissance Reports as the source of data. In many basins, however, the ET estimates as reported in Scott et al. (1971) do not match the values reported in the appropriate Reconnaissance Report. Table 2-2 illustrates these discrepancies.

Table 2-2
Comparison of Reconnaissance ET Estimates and ET Estimates as Reported in Scott et al. (1971)

Valley and Hydrographic Basin Number	Reconnaissance ET Estimate (afy)	Scott et al. (1971) ET Estimate (afy)
Steptoe – 179	70,000	70,000
Spring - 184	70,000	70,000
Hamlin - 196	see Snake	400
Snake - 195	80,000[a]	11,000
Pleasant - 194	see Snake	minor
Tippett - 185	0	0
Cave Valley - 180	“a few hundred"	200
Dry Lake Valley - 181	"a very small amount"	minor
Lake – 183	8,500	8,500

[a]The Reconnaissance Report ET estimate for Snake Valley includes Hamlin and Pleasant Valleys. It does not separate out each valley.

2.2 Data Analysis

Estimating groundwater discharge for purposes of model input consisted of reviewing the appropriate Reconnaissance Report for a particular basin as well as the ET estimates provided in Scott et al. (1971). In a few cases, the ET estimates didn’t always coincide between the two sources (see Table 2-2). For the purposes of this study Snake, Hamlin, and Pleasant are combined into one basin, as is the case in Reconnaissance Report 34 (Hood and Rush, 1965). Therefore, the Reconnaissance Report estimate is the estimate applied to the model. In the case of Hamlin and Cave Valley, the Scott et al. (1971) estimate was accepted because it reported a tangible number that could be inputted into the model as opposed to “a few hundred acre-feet” as cited in Reconnaissance Report 13 (Eakin, 1962).

Once each estimate was compiled, each basin was further evaluated for any possible agricultural, mining, or municipal activities that might have been occurring when the Reconnaissance studies were taking place. The Reconnaissance work does not necessarily represent steady-state conditions. To have a more accurate estimate of discharge to apply to the model, groundwater pumping that was occurring at the time of the Reconnaissance studies was considered and added to the total ET estimate in order to truly represent predevelopment conditions. These volumes of annual pumpage were adjusted to account for consumptive use. It is assumed that agricultural lands displaced phreatophytic areas that would otherwise be contributing to groundwater ET under steady-state or predevelopment conditions. This is not an uncommon assumption, but it is difficult to determine how much water is being consumptively used or how much is being recycled back to the groundwater system. Harrill (1986) assumes that an average of approximately 25 percent of water from agricultural pumping, 70 percent of domestic pumping, and 50 percent of the public and commercial pumpage is being recycled back to the groundwater system. Brothers et al. (1993) assume the same for agriculture and public supply (municipal and domestic). For purposes of this study, it is assumed that 25 percent of the groundwater being pumped is returned to the groundwater system from all types of pumping: agriculture, mining, and municipal. Therefore, 75 percent is being consumptively used. This is a more conservative estimate than the literature cites. Therefore, in basins where groundwater pumping occurred, the pumping estimates as reported in the Reconnaissance Reports were adjusted by 75 percent to represent consumptive use and added to the ET estimate in order to calculate a total groundwater discharge estimate that reflected predevelopment conditions. If groundwater pumping was less than 1,000 acre-feet, it was not considered relevant and therefore, not included in total groundwater discharge calculation.

2.3 Results

Table 2-3 lists the total ET estimates, the source of the ET estimate, the Reconnaissance Report or Scott et al. (1971), the reported amount of groundwater pumping taking place at the time of the Reconnaissance work, the adjusted groundwater pumping estimate, and the adjusted groundwater evapotranspiration estimate applied in the groundwater development model.

2.3.1 Steptoe Valley

Both Scott et al. (1971) and Reconnaissance Report 42 (Eakin et al., 1967) report 70,000 afy for ET from phreatophytes. Eakin et al. (1967, p. 38) further report that 1,200 afy, 3,000 afy, and 3,843 afy of water is being used for municipal supply, agriculture, and mining activities, respectively. It is difficult to discern the amount of water being used for mining purposes. It was assumed that any water originating from springs was essentially originating from groundwater. Therefore, the 3,843 afy is a combined total of the 5 cubic feet per second (cfs) from McGill Springs and .3 cfs from Lackawanna Springs. The total adjusted groundwater discharge estimate for Steptoe Valley is 76,032 afy.

2.3.2 Spring Valley

Both Scott et al. (1971) and Reconnaissance Report 33 (Rush and Kazmi, 1965) report 70,000 afy for ET from phreatophytes. An additional 1,200 afy is reported by Rush and Kazmi (1965, p. 24) as discharge from wells. This is a rough estimate because as Rush and Kazmi (1965) state, irrigation wells were used only when the amount of streamflow was insufficient to meet the needs for irrigation and at the time of the Reconnaissance work in Spring Valley, only one well was being used for irrigation purposes. The total adjusted groundwater discharge estimate for Spring Valley is 70,900 afy.

Table 2-3
Summary of Total Groundwater Discharge Estimates

Basin Name	ET Estimate (afy)	Source[a]	Amount of Pumping (afy)	Adjusted Pumping Estimate (afy)	Addl. Recharge from Runoff (afy)	Adjusted ET (afy)
Steptoe Valley - 179	70,000	R - 42, Scott et al. (1971)	8,043	6032.25	0	76,032
Spring Valley -184	70,000	R - 33, Scott et al. (1971)	1,200	900	0	70,900
"Big Snake" Hamlin - 196 Snake - 195 Pleasant- 194	80,000	R - 34	7,000	5250	2,700	87,950
Tippett Valley - 185	0	R - 56, Scott et al. (1971)	0	0	0	0
Cave Valley - 180	200	Scott et al. (1971)	0	0	0	200
Dry Lake Valley - 181	0	R - 16, Scott et al. (1971)	0	0	0	0
Lake Valley - 183	8,500	R - 24, Scott et al. (1971)	2,000	1500	0	10,000

[a]R = Reconnaissance Report
The ET estimates were consistent among reports when both sources are listed.

2.3.3 Snake Valley

Hood and Rush (1965) in Reconnaissance Report 34 estimate ET from phreatophytes to be 80,000 afy. This is a combined total for Snake, Hamlin and Pleasant Valleys. Hood and Rush (1965, p. 33) further report that 7,000 afy were being pumped for irrigation purposes. In addition, 2,700 afy was also incorporated into the ET estimate to account for additional recharge from runoff. This estimate is listed in Reconnaissance Report 34 (Hood and Rush, 1965, Table 5) but seems unaccounted for when the recharge values are totaled. Because the 2,700 afy was added to the recharge estimate (Volume 2, SNWA, 2006) it must be added to the ET estimate for water budgeting purposes. The total adjusted groundwater discharge estimate for Snake Valley is 87,950 afy.

2.3.4 Tippett Valley

Both Scott et al. (1971) and Reconnaissance Report 56 (Harrill, 1971) report zero ET for Tippett Valley. In addition, Harrill (1971) reports minor irrigation activities (less than 10 acre-feet) or other uses. Therefore, the total adjusted groundwater discharge estimate for Tippett Valley equals zero.

2.3.5 Cave Valley

Reconnaissance Report 13 (Eakin, 1962) reports "a few hundred acre-feet" of ET from groundwater in Cave Valley. Scott et al. (1971) on the other hand determined that "a few hundred acre-feet" to be approximately 200 afy. Limited groundwater pumping (less than 100 acre-feet) was reported in Eakin (1962). The total adjusted groundwater discharge estimate for Cave Valley is 200 afy.

2.3.6 Dry Lake Valley

Both Scott et al. (1971) and Reconnaissance Report 16 (Eakin, 1963) report zero ET for Dry Lake Valley. In addition, (Eakin, 1963) reports minor irrigation activities or other uses (less than 100 acre-feet). Therefore, the total adjusted groundwater discharge estimate for Dry Lake Valley equals zero.

2.3.7 Lake Valley

Both Scott et al. (1971) and Reconnaissance Report 24 (Rush and Eakin, 1963) report 8,500 afy of ET from groundwater. In addition, 2,000 afy of pumping was reported by Rush and Eakin (1963). Therefore, the total adjusted groundwater discharge estimate for Lake Valley is 10,000 afy.

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3.0 DELINEATION OF AREAS OF EVAPOTRANSPIRATION

3.1 Objective

The objective of this section is to describe the data and methodology for delineating areas of ET depicting current conditions and steady-state conditions.

3.2 Data Sources and Limitations

The vegetation maps, imagery, and photography used to delineate areas of evapotranspiration include:

- USGS Reconnaissance Series Reports vegetation maps
- Nichols (2000)
- Las Vegas Valley Water District (LVVWD et al., 1994; LVVWD, 2001)
- Southwest Regional Gap Analysis (USGS, 2004)
- National Land Cover Data (NLCD, 1992)
- Landsat 7 Thematic Mapper imagery (2002, 25-meter pixel resolution)
- USGS Digital Orthophoto Quarter Quads (1999, 1-meter pixel resolution)
- Clark County Geographical Information Systems Management Office (GISMO) biannual aerial coverage update (September, 2005, 1-ft pixel resolution)

Many of the vegetation maps created during the Reconnaissance work illustrate conditions representative of the year the data was being collected. Many of the maps are 40 years old and do not reflect current conditions. Furthermore, the Reconnaissance work does not necessarily reflect predevelopment conditions. Some agricultural activities were occurring in many of the basins at the time of the Reconnaissance studies. Digitally and spatially rectified satellite imagery and aerial photography were obviously not available at the time of the Reconnaissance work in the subject basins. With the advent of these “snapshots in time” incorporated with other geographical information systems (GIS) layers and technology, combined with the accuracy of global positioning systems (GPS), more detailed maps can be and have been created.

There are also limitations in the satellite imagery and aerial photography used in evaluating the current conditions of phreatophytic communities within a basin. Using satellite imagery over large areas introduces limitations related to the weather conditions at the moment the satellite is flying overhead. In order for satellite imagery to be effective in determining conditions on the ground, there must be minimal cloud cover. An additional limitation in satellite imagery and aerial photography involves pixel size. Landsat 7 images have a 25-meter pixel resolution. Plants of interest for this study generally have a width of 1-2 meters on the ground. Most vegetation therefore gets lost within medium resolution imagery, especially in areas of low plant density and high soil reflectance.

3.3 Delineation of Areas of Evapotranspiration Under Current Conditions

The distribution of ET areas under current conditions for each valley is based on a compilation of earlier work by the USGS in the Reconnaissance Series, Nichols (2000), LVVWD et al. (1994), and LVVWD (2001). Occasionally the Southwest Regional Gap Analysis Project data (USGS, 2004) and the National Land Cover Data (NLCD, 1992) were used if there was great uncertainty over the location of a boundary. The ET boundaries of Spring, Snake, Steptoe, Lake, and Hamlin Valleys were field checked during the summer of 2004 by the Southern Nevada Water Authority (SNWA) and modified, as needed, using highly accurate GPS equipment. Cave Valley was field checked in 2003, and no significant phreatophytic communities were evident in Dry Lake Valley; therefore, it was not visited for purposes of this study. Tippett Valley was not analyzed as part of the current condition ET analysis.

Discrepancies in the boundary of the phreatophyte areas between this study and previous studies were attributed, in part, to the lack of high-accuracy technologies and the use of small-scale maps. The extents of the boundaries defined for this study differed from Nichols (2000) boundaries in that newer technologies were used to refine the phreatophytic areas. Also, there were definite historical land use changes between the studies as well as the omission of some agricultural land by Nichols in the southeastern portion of Spring Valley.

In basins with considerably large areas of phreatophytes, such as Spring, Steptoe, and Snake, transects of 300 feet (ft) in length were run at multiple sites throughout each valley in order to gather percent cover and density estimates of the vegetation community. Percent cover was estimated as the fraction of the line that is covered by each species, and density estimates were calculated using strip transects as described in Barbour, Burk and Pitts (1987). Each transect was extended out to 5 ft on both sides of the transect, providing a total area of 3,000 square feet (ft^2). Density of a particular species was defined as the amount of plants per 3,000 ft^2. Estimating these parameters helped define distinct plant assemblages and, when combined with remote sensing techniques, can assist in further defining phreatophytic boundaries across the landscape.

Areas of ET were then classified using the normalized difference vegetation index (NDVI) (Qi et al., 1994) and Landsat 7 Thematic Mapper 2002 satellite imagery. Vegetation indices, such as NDVI, are a type of remote sensing algorithm used to assist in estimating the amount of ET from phreatophytes. These tools, or technologies, are particularly helpful in regional geographic studies because of the large spatial distribution of targeted plants in the landscape. Remotely sensed data images provide a mechanism for measuring the relationships between cover type and spectral reflectance. The NDVI is one of the most common vegetation indices used to estimate plant cover and is based on the red and near-infrared bands of the electromagnetic spectrum. For purposes of further defining current conditions, the areas of ET are classified among the following six categories: open water, bare soil/low vegetation, phreatophyte/medium vegetation, wetland/meadow, agriculture, and playa. The areas of ET within each basin included in the groundwater development model are shown on Figure 3-1.

An assessment was completed to evaluate the accuracy of the land classification using accepted protocols as outlined in Congalton and Green (1999). A total of 249 randomly selected points representing each classification were field checked. This assessment returned an overall accuracy of 88 percent. This value is above the generally accepted value of 85 percent as established by Anderson et al. (1976).

3.4 Delineation of Areas of Evapotranspiration Under Predevelopment Conditions

A steady-state map was created from the current condition map. The model requires areas of non-meadow, meadow, and playa to be delineated. It is difficult to delineate areas of meadow and non-meadow from the Reconnaissance maps. In addition, the Reconnaissance work isn't necessarily representative of steady-state conditions. There were areas that had been developed for agricultural, mining, and municipal purposes in some of the valleys. Since a classification had already been completed under current conditions using satellite imagery, it was decided that creating a steady-state map from the current condition map would be appropriate.

The first assumption in creating a steady-state map was in the determination of where agricultural land had displaced what otherwise would be phreatophytes prior to development. It is assumed that the majority of water being used for agricultural purposes originated within areas that would have otherwise consisted of phreatophytic species prior to development. This seems an appropriate assumption for a model of this scale. To make a determination of these areas a detailed review of historical aerial photography and an evaluation of drainage areas was required for each basin. Agricultural land that occurred on the current condition map was treated in two ways. First, if it was determined that the agricultural area displaced phreatophytes based on natural drainage areas within an area, it was reclassified to represent the land use surrounding the area, in most cases wetland/meadow. Second, if it was determined that the agricultural area did not displace phreatophytes, it was removed entirely. It was assumed that these agricultural areas were not likely present under steady-state conditions.

In addition, all playa areas represented on the current condition map were changed to reflect discharging playa areas as documented in the Reconnaissance Reports. These changes were particular to Spring Valley and Snake Valley. The Reconnaissance Report for Spring Valley reports two playas totaling 11,600 acres (Rush and Kazmi, 1965). The Snake Valley Reconnaissance Report describes a series of playas from Trout Creek southward to Bishop Springs totaling 3,200 acres (Hood and Rush, 1965). In addition, 60,000 acres were added to include the Great Salt Lake Playa (the portion that occurs in Snake Valley) as delineated in the Reconnaissance work (Hood and Rush,

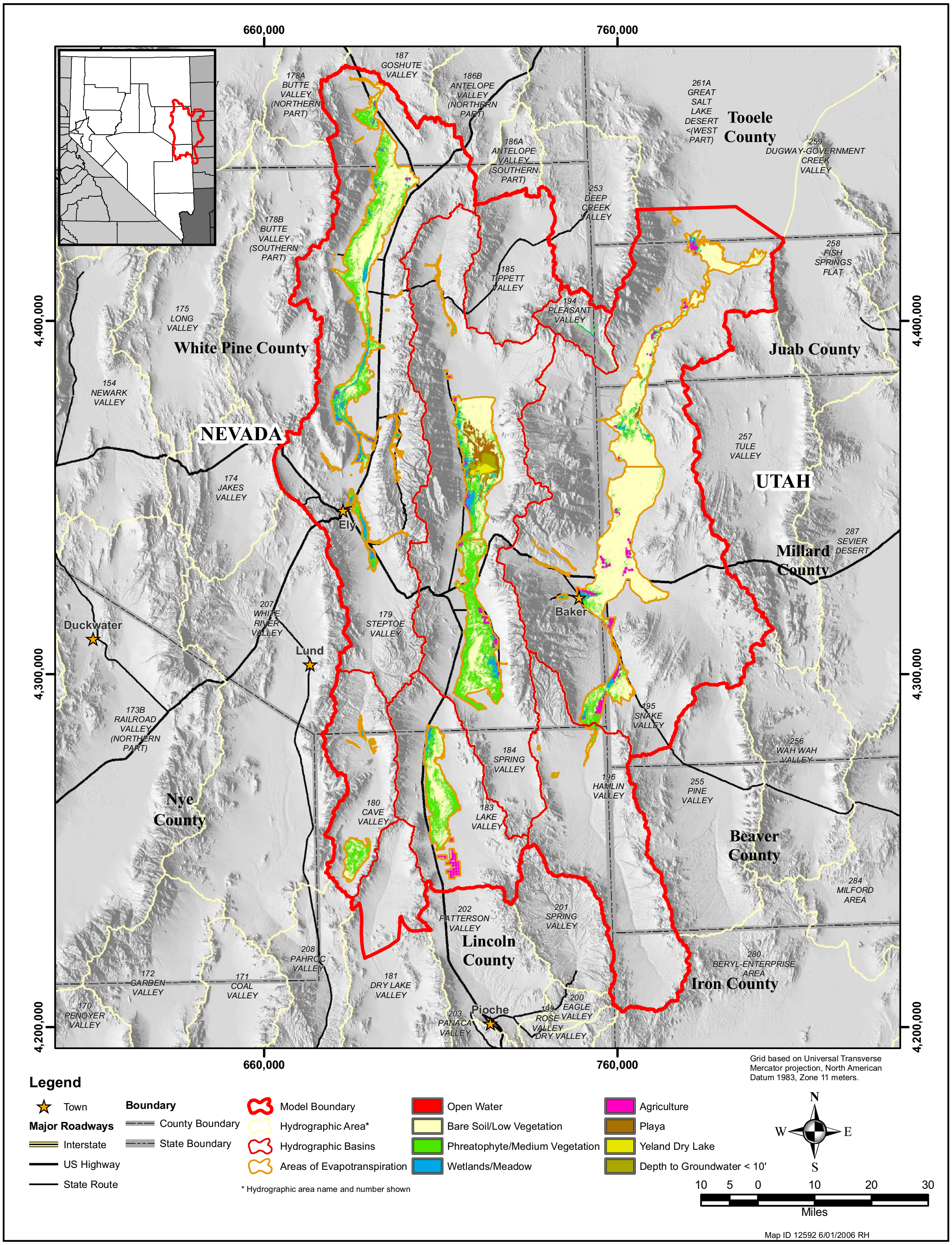

Figure 3-1
Current Conditions for the Basins of Interest

1965). The Reconnaissance Report for Cave Valley defines a playa but does not identify it as a discharging playa (Eakin, 1962), and it was not added in the steady-state map. An inherent challenge in all GIS applications is attempting to create polygons of the exact acreage. Therefore, the acreages reflected on the steady-state map do not exactly match one-to-one with the Reconnaissance maps. Polygons were created as accurately as possible to reflect the acreages reported in the Reconnaissance Reports.

The last step in creating the steady-state map involved regrouping, or collapsing, categories. For modeling purposes, the land use classes were regrouped to depict only three categories; wetland/meadow, non-meadow, and playa. It seems obvious to reclassify areas of open water and wetland/meadow to areas of meadow because of the existence of a shallow groundwater table and free-standing water in these areas. Playa remained playa, and everything else (bare soil/low vegetation and phreatophyte/medium vegetation) became non-meadow. The regrouping is listed in Table 3-1, and Figure 3-2 illustrates the steady-state conditions for the basins within the groundwater development model area.

Table 3-1
Description of New Reclassification Scheme for Steady-State Map

Current Condition Classification	Steady-State Classification	Acreage
Open Water	Wetland/Meadow	99,343
Wetland/Meadow		
Bare Soil/Low Vegetation	Non-Meadow	525,379
Phreatophyte/Medium Vegetation		
Playa	Playa	75,897
Agriculture	Not included	Not included

3.5 Limitations in Delineating Areas of Evapotranspiration

There are limitations associated with delineating areas of ET under current conditions and steady-state conditions. The first relates to the creation of the current condition map. Ground truthing of areas of ET within the study area was conducted during the summer of 2004; however, the classification of the ET areas was determined from 2002 Landsat imagery because the 2004 imagery was not yet available. It is possible that vegetation communities and boundaries could change, especially due to drought, in a two-year span; however, such changes would be minimal. Another important variable in developing the current condition map pertains to the NDVI analysis used in determining the land classification scheme. Landsat scenes, with minimal cloud cover, within the months of June and July were chosen in order to represent maximum plant growth during the height of the growing season. This approach, thereby, is only considering one day in the life of a plant.

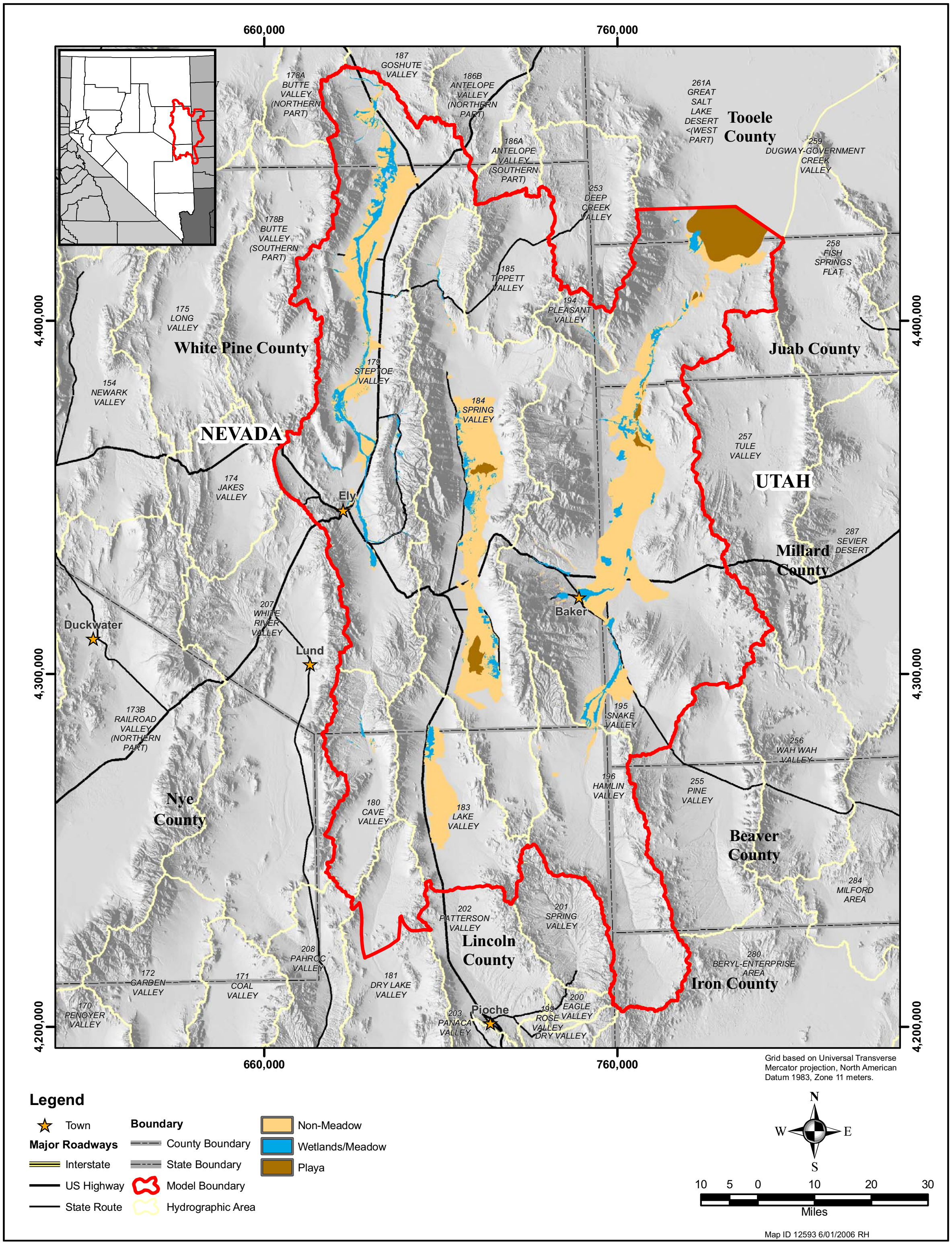

Figure 3-2
Steady-State Conditions for the Basins of Interest

An obvious limitation in creating a steady-state map is the lack of historical imagery. Because historical steady-state imagery is non-existent, creation of a map representing steady-state conditions is solely based on subjective interpretations.

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4.0 POTENTIAL EVAPOTRANSPIRATION

4.1 Objectives

Potential evapotranspiration (PET) is a measure of the ET that would occur if there is no control on the water supply (Fetter, 2001, p. 554). It represents the environmental demand for ET, and therefore, ET should equal PET if there is a sufficient water supply. The objective of this section is to describe the data and analysis used to estimate PET within the basins of interest.

4.2 Data Sources and Limitations

The SNWA funded the Desert Research Institute (DRI) to estimate PET at several sites in Nevada and Utah using Remote Automatic Weather Stations operated by the U.S. Departments of Agriculture and Interior and cooperative observer (Coop) sites, which are used by the National Weather Service for data collection (McCurdy and Albright, 2004). Each type of site is equipped with different instrumentation; therefore, a variety of techniques were used by DRI to calculate PET.

The PET estimates completed by DRI (McCurdy and Albright, 2004) are compiled on a monthly, annual, and average annual basis for several types of weather stations located throughout Nevada and Utah (Figure 4-1). For purposes of this study, these estimates were further reduced to include only the PET calculated for the Coop sites in which the Hargreaves equation (Hargreaves and Samani, 1985) was used. Table 4-1 lists the Coop stations further analyzed for calculating PET within the basins of interest as reported in McCurdy and Albright (2004).

Limitations in the PET data include period of record for many of the stations. A few of the stations had missing data and were therefore not included in the analysis. The Coop stations in which the Hargreaves equation was used were selected as the stations for further analysis because of the large number of stations with an extended period of record. Many stations have record of 40 or more years of data collection.

4.3 Calculation of Potential Evapotranspiration

For purposes of calculating PET in each basin of interest, elevation, latitude and average annual PET over multiple years of data collection were regressed for each one of the Coop sites investigated by DRI. A multiple linear regression was then developed and used to extrapolate long-term average PET estimates within each basin of interest. A multiple linear regression equation was developed in order to evaluate the influences of latitude and elevation on PET.

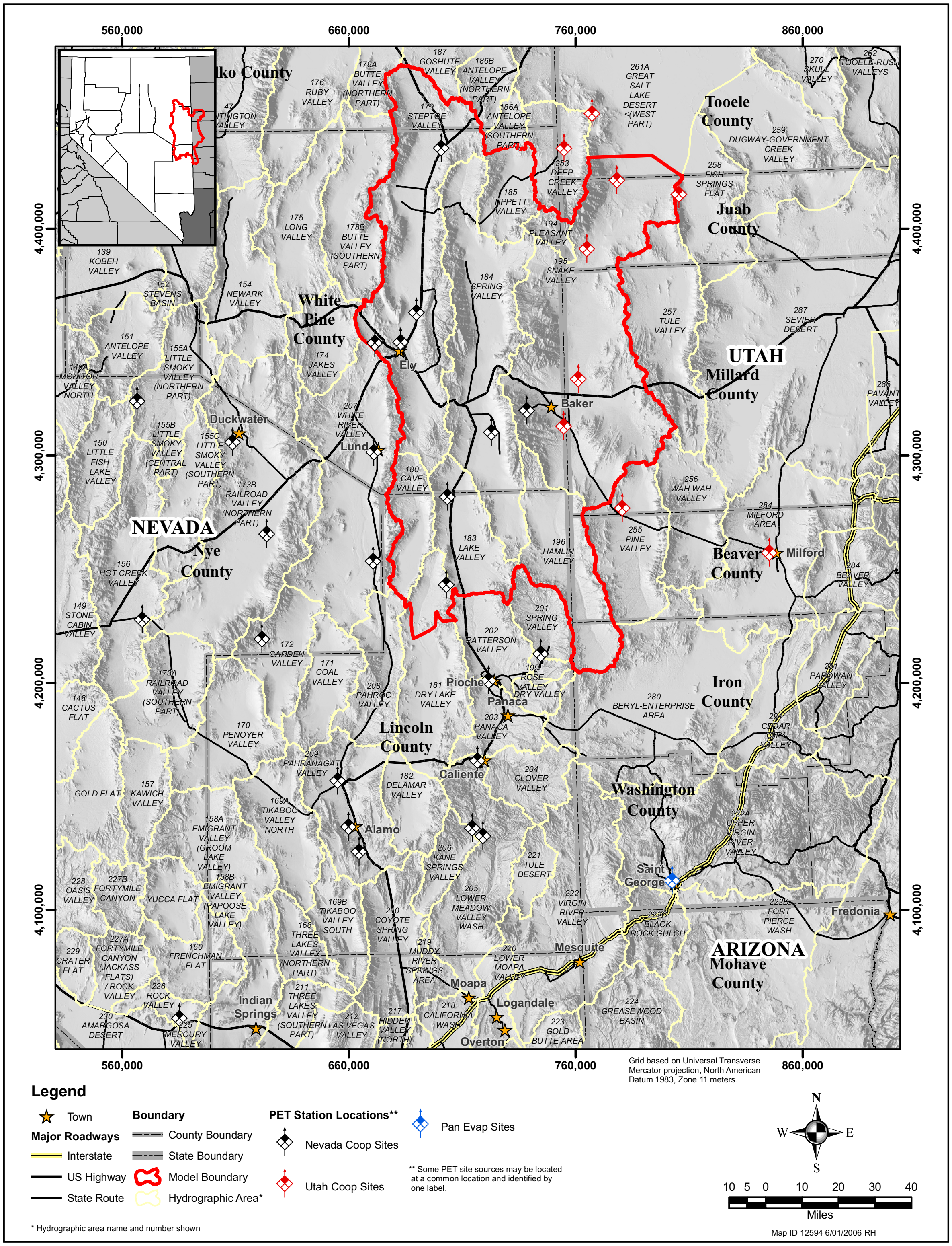

Figure 4-1
PET Station Locations

Table 4-1
Estimated PET by the Hargreaves Method for Coop Sites
(McCurdy and Albright, 2004)

Site Name	Latitude (degrees, minutes)	Longitude (degrees, minutes)	Elevation (ft)	Years of Data Collection	Avg Annual PET (in.)
Adaven	38.07	115.35	6,250	1928-1982	47.57
Alamo	37.22	115.1	3,500	1948-1962	63.64
Blue Eagle	38.32	115.33	4,780	1978-2004	52.95
Boulder City	35.59	114.51	2,520	1931-2004	56.86
Caliente	37.37	114.31	4,400	1931-2004	57.02
Desert Rock	36.37	116.01	3,300	1996-2004	58.09
Duckwater	38.54	115.43	5,400	1966-2003	47.98
Elgin	37.21	114.33	3,420	1985-2004	59.65
Elgin 3SE	37.19	114.3	3,300	1965-1985	56.2
Ely WBO	39.17	114.51	6,250	1897-2004	45.57
Geyser Ranch	38.4	114.38	6,020	1948-2002	48.21
Great Basin	39	114.13	6,830	1948-2004	42.33
Hiko	37.33	115.13	3,940	1989-2004	55.71
Lages	40.03	114.37	5,960	1984-2004	47.58
Lake Valley	38.19	114.39	6,350	1971-1998	41.47
Lund	38.51	115.00	5,570	1957-2004	49.31
McGill	39.24	114.46	6,350	1914-2004	43.75
Pahranagat	37.16	115.07	3,400	1964-2004	59.61
Pahrump	36.12	115.59	2,670	1948-2004	62.51
Pioche	37.56	114.27	6,120	1948-2004	45.22
Reese River O'toole	39.04	117.25	6,550	1972-2004	44.74
Ruth	39.17	114.59	6,830	1958-2004	43.27
Shoshone 5N	38.55	114.24	5,930	1988-2004	49.84
Silverpeak	37.4	117.35	4,260	1967-2004	55.63
Snowball Ranch	39.04	116.12	7,160	1966-2002	42.61
Spring Valley State P.	38.02	114.11	5,950	1974-2004	48.22
Sunnyside	38.25	115.01	5,300	1965-2004	52.31
Twin Springs Fallini	38.12	116.11	5,300	1985-2004	52.02
Callao	39.54	113.43	4,330	1962-2004	48.59
Desert Exp.	38.36	113.45	5,250	1950-1984	50.93
Eskdale	39.07	113.57	4,980	1966-2004	51.39
Fish Springs	39.5	113.24	4,340	1960-2004	49.14
Garrison	38.56	114.02	5,260	1951-1990	50.79
Gold Hill	40.1	113.5	5,250	1966-1990	44.72
Ibapah	40.02	113.59	5,280	1948-2004	51.87
Milford	38.24	113.01	5,010	1906-2004	49.85
Partoun	39.38	115.53	4,780	1950-2004	56.11
St. George	37.07	113.34	2,760	1892-2004	71.47
Currant Hwy[a]	38.48	115.21	6,240	1963-1977	not reported
Ely 6NE[a]	not reported	not reported	not reported	1999-2004	51.5
Fallon Exp. Station[a]	not reported	not reported	not reported	1903-2004	51.36

[a]Sites with missing data (not used in calculations)

The equation is Avg Annual PET (all years) = 104.353 - 0.829 (Lat in decimal degrees) - 0.00419 (Elevation in ft) R-Sq = 80 percent.

The average altitude and latitude for each basin was then derived from 1:24,000, 30-meter digital elevation models. The larger basins such as Steptoe, Snake and Spring were divided into subareas for determining average PET because of the geographical and potential climatic extremes within each basin. Table 4-2 lists the average longitude, latitude, altitude, and PET for each basin in the model.

Table 4-2
Long-Term Average Annual PET

Basin	Longitude (-) decimal degrees NAD83	Latitude decimal degrees NAD83	Mid Altitude (ft)	PET (in.)	PET (ft)
Steptoe: North	114.72	40.03	5,860	46.65	3.89
South	114.82	39.39	6,100	46.16	3.85
Spring: North	114.54	39.79	6,270	45.10	3.76
Central	114.42	39.38	5,550	48.46	4.04
South	114.45	38.93	5,750	47.99	4.00
Hamlin: North	114.10	38.63	5,610	48.83	4.07
South	114.27	38.63	6,050	46.99	3.92
West	114.22	38.66	5,700	48.43	4.04
Snake: North	113.85	39.67	4,720	51.70	4.31
South	114.05	39.01	5,160	50.40	4.20
Pleasant	114.03	39.65	5,850	46.97	3.91
Tippett	114.34	39.84	5,640	47.69	3.97
Cave: North	114.84	38.68	6,530	44.95	3.75
South	114.87	38.36	5,980	47.53	3.96
Lake	114.59	38.50	5,920	47.66	3.97

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