2368-00029

University of Nevada, Reno

A Water Resource Investigation using GIS and Remote Sensing Methods, Washoe Valley, Washoe County, Nevada

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Hydrology

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December, 2003

Abstract

Population growth and the trading of water rights have brought renewed interest in available water resources in Washoe Valley, a hydrographic area located in west central Nevada. The purpose of this project is to develop a Geographic Information System (GIS) based water budget for Washoe Valley. With the use of satellite imagery and GIS processing, new estimates of mean-annual water-yield, open-water evaporation, evapotranspiration, ground-water discharge from phreatophytic vegetation, and domestic consumption are calculated. To calculate the water-budget, the Washoe Valley hydrographic area is subdivided into mountain-block and valley-floor areas where water budget components are identified and estimated on each landform, and then combined to calculate the overall water-budget for the hydrographic area. The distribution of precipitation was acquired from a precipitation map at 4 inch contour intervals, derived from local long-term precipitation measurements and vegetation patterns. Water-yield and runoff estimates were derived from geophysical tools, chloride-balance methods and simple least squares regression analysis. Estimates of domestic consumption, and evapotranspiration of precipitation and groundwater were based on vegetation distributions, and micrometeorological and regionalized remote sensing methods. When compared to water-budgets developed for Washoe Valley in 1967 and 1984, results from this study indicate more inflow from mountain-block areas, and more outflow from the valley-floor area. By integrating updated water-budget estimates in a GIS, this study provides spatially referenced information, which can be used in ground-water modeling efforts and provide a more refined planning tool for future water resource issues.

Acknowledgements

With a week left to graduate as an undergraduate in Environmental Sciences from the University of Nevada, Reno, my former boss and former Water Planning Manager for the Washoe County Department of Water Resources, Leonard Crowe, said "Well, now that you are getting your license to learn, what are you going to do now?" Knowing that I couldn't maintain my status as an intern if I wasn't in school, I responded by asking him if I could take on the Washoe Valley basin assessment project as my primary duty. We worked out some logistics and the next thing I knew I was delineating the hydrographic boundary of Washoe Valley on a topographic map and back to school the next semester, this time as a graduate student in Hydrologic Sciences program. Leonard Crowe has been a major part of my success, including getting me hooked on hydrology and making this thesis project possible. For that I thank him dearly.

I would like to acknowledge Gail Prokish at the Washoe County Department of Water Resources for her tireless support, willingness to assist me with the installation of instrumentation, and teaching me how to use Geographic Information Systems. Also, thanks to Mike Widmer and Keith Weaver at Washoe County Department of Water Resources for their priceless advise and support on the Washoe Valley project when I moved from Reno. I would also like to thank everyone else at Washoe County Department of Water Resources that has helped me on this project.

I would like to thank Dave Berger at the U. S. Geological Survey in Carson City for being a mentor, assisting me in the field, and offering endless support and advice. Much of this thesis project would not have been possible without Dave Berger's research in Eagle Valley. I would also like to thank my advisor, Dr. Greg Pohll for taking me on as a student and introducing me to new and innovative ideas. Also, I give acknowledgements to my committee members Dr. James Carr and Dr. Scott Tyler, and Sam Miller, Hydrologic Sciences program manager, for they have been very supportive during this research.

Finally, I would like to thank my family, and my parents, Ron and Sharon Huntington. I owe everything to my parents for giving me the opportunity to leave Las Vegas and move to Reno to attend college. Without that offer, none of what I have accomplished would have been possible. Love, understanding, support, and patience have provided me the ability to build my mental and spiritual strengths, take on challenges in life, and to be successful at them. This thesis is dedicated to you.

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Chapter 1: Introduction

Population growth and the trading of water rights have brought renewed interest in available water resources in Washoe Valley (Figure 1). From July to September 2000, five streamflow gaging stations and two weather stations were installed in Washoe Valley (Figure 2). The overall objective for the assessment is to provide a scientific evaluation of surface-water and ground-water resources, and to determine the effects of all major water uses in the basin such as increases or decreases in evapotranspiration, runoff, and lake stage, on the quantity and beneficial use of the basins' water resources.

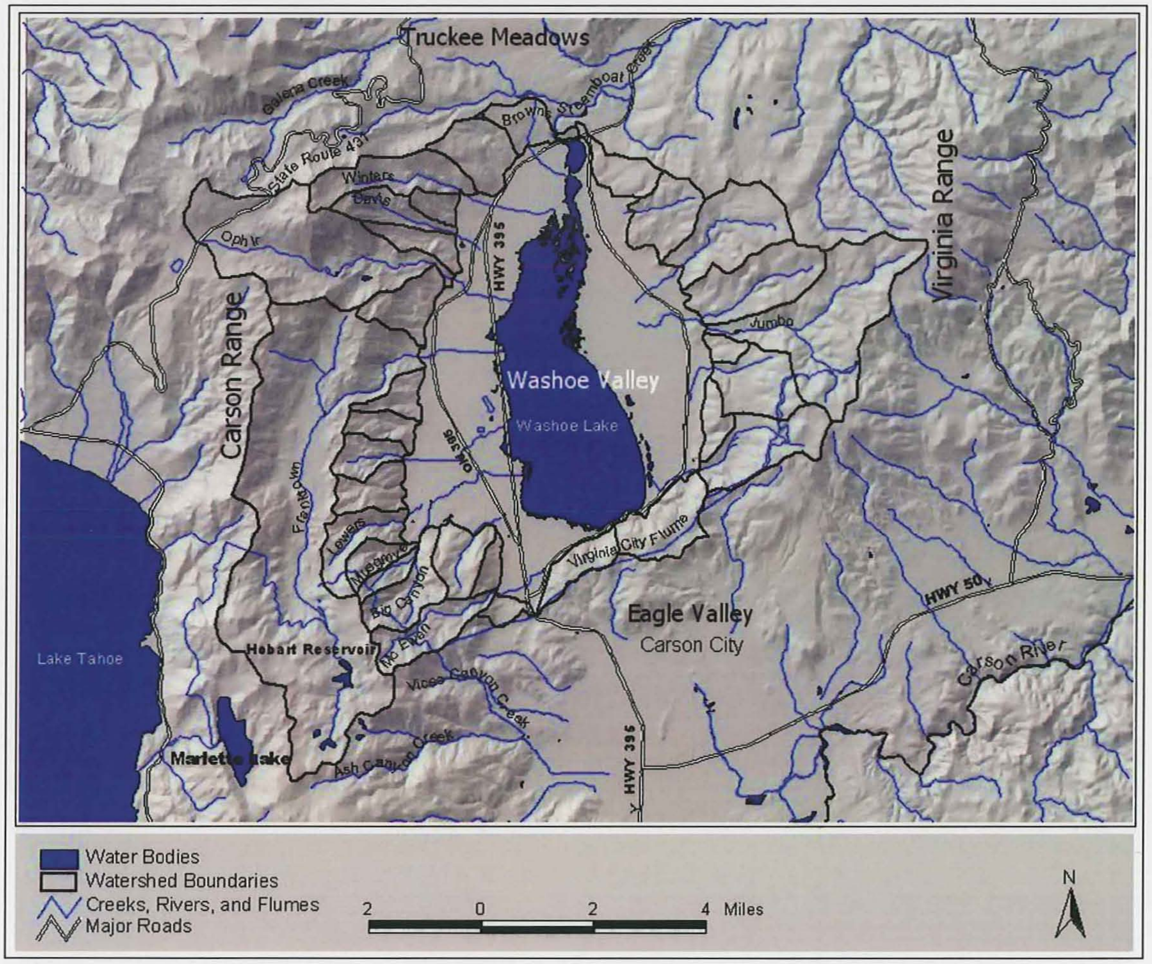


Figure 1. Washoe Valley hydrographic area and delineated watersheds tributary to the valley floor.

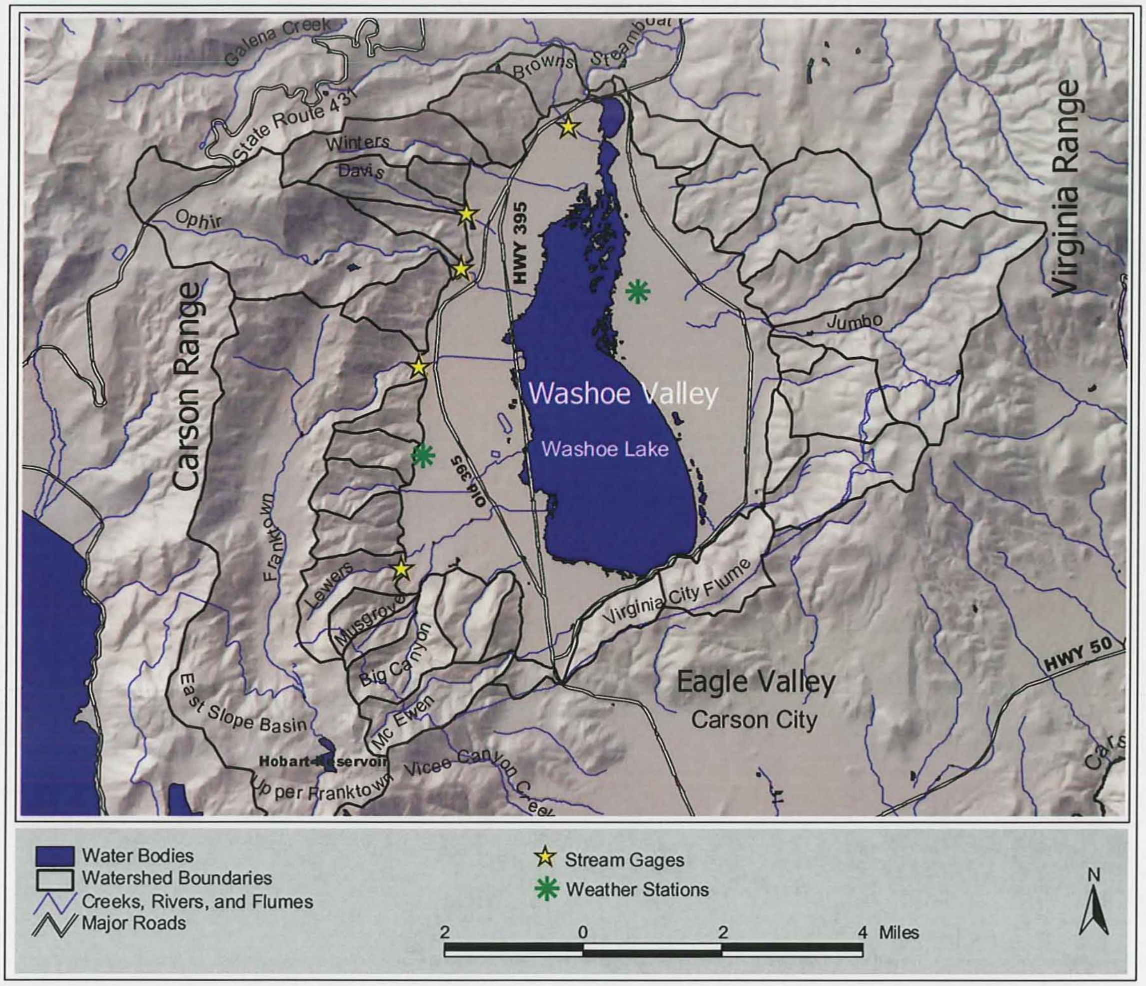


Figure 2. Locations of instrumentation, which includes five stream gages and two weather stations.

As an initial attempt for investigating water resources it is often necessary to analyze the water-budget, in which quantities of inflow and outflow to and from a hydrographic area (HA) are assessed. A water-budget for a particular HA is a simplified accounting of the hydrologic cycle. It is a quantification of water moving from surface-water, ground-water, and vegetation to the atmosphere and back to the earth in the form of precipitation. For the Washoe Valley HA, a simple mean-annual water-budget can be written as inflow equaling outflow, where inflow consists of precipitation, surface-water inflow, subsurface inflow, and imports. Outflow consists of open-water evaporation, evapotranspiration, surface-water outflow, subsurface outflow, and domestic consumption.

Purpose and Scope

The purpose of this report is to present an updated Geographic Information System (GIS) based water-budget for Washoe Valley. With the use of satellite imagery and GIS processing, new estimates of inflow and outflow are calculated, which include water-yield, open-water evaporation, evapotranspiration, ground-water discharge from phreatophyte plants, and domestic consumption.

With only approximately three years of runoff and evapotranspiration (ET) data collected in Washoe Valley, mean-annual inflow and outflow cannot be directly estimated from these data. In an effort to estimate updated mean-annual water-budget components, regional relations from recent studies (Nichols, 2000; Shevenell, 1996; Maurer and Berger, 1997) completed in adjacent basins with similar geology, vegetation, and climate, are applied to the Washoe Valley HA and compared to 1) estimates from earlier studies (Rush, 1967; Arteaga, 1984; Widmer, 1997) and 2) runoff and ET data collected in Washoe Valley from 2000-2003. By integrating updated water-budget estimates in a GIS, this study provides spatially referenced information, which can be used in ground-water modeling efforts and provide a more refined planning tool for future water resource issues.

Previous Studies

Water-budgets for Washoe Valley have been previously estimated by Widmer (1997), Arteaga (1984) and Rush (1967). Inflow and outflow components of water-budgets from previous studies are out of date due to new available methodologies and newly acquired data. Rush (1967) previously estimated ground-water recharge using the Maxey-Eakin method (Maxey and Eakin, 1949), an empirical relation between precipitation and recharge. Some researchers (Nichols, 2000) have revised older empirical relations between precipitation and recharge by using micrometeorological methods, however like the Maxey-Eakin method, the Nichols method provides a reconnaissance level, basin-wide estimate of ground-water recharge. Arteaga (1984) applied a mean-annual precipitation water-yield relation to estimate inflow from tributaries to Washoe Valley, where water-yield equals surface-water runoff plus subsurface flow. The precipitation water-yield relation applied by Arteaga (1984) was developed using mean-annual surface-water runoff data from tributaries to Eagle Valley, an adjacent basin to Washoe Valley with similar geologic, vegetation, and climate characteristics. The precipitation water-yield relation applied by Arteaga (1984) in Washoe Valley is not conceptually correct because subsurface flow from tributaries to Washoe Valley was considered negligible, based on assumptions of impermeable bedrock properties at the mountain-front. In an effort to construct a ground-water model for Washoe Valley and simulate mountain-front recharge Widmer (1997) used estimates of runoff from Arteaga (1984) and assumed that approximately 25 percent of runoff contributed to mountain-front recharge. The U.S. Geological Survey with the cooperation of the Carson Utilities Department began investigations in 1994 to refine water-budget components for the adjacent Eagle Valley HA. The investigations used physically based measurements of aquifer properties to estimate subsurface flow beneath several stream channels at the mountain-front. Mauer and others (1996) found that the weathered bedrock beneath stream channels at the mountain-front of Eagle Valley was permeable, and that total water-yield was greater than runoff alone. The relevance of previous work in Eagle Valley (Mauer and others, 1996) to Washoe Valley is that past estimates of inflow at the mountain-front have been underestimated and are updated in this study. Previous estimates of outflow components are also out of date due to changes in land use, new available methods to estimate ET from vegetated areas (Shevenell, 1996; Nichols, 2000), and a larger period of record of surface-water outflow for Steamboat Creek, all of which are analyzed and updated in this study.

Chapter 2: Description of Washoe Valley and Approach of Constructing the Water Budget

Physiographic Setting

Washoe Valley is located approximately fifteen miles south of Reno and five miles north of Carson City, Nevada. The Washoe Valley HA is a product of the tectonic extension of Basin and Range physiography that has been ongoing regionally since mid-Tertiary time (Tabor and others, 1983). The HA encompasses 81 square miles and is situated between the Carson Range to the west and the Virginia range to the east (Figure 1). The horst and graben faulting in the Washoe Valley HA have resulted in a topographic relief of 5000-9700 feet, and 5000-8400 feet for the Carson and Virginia Ranges respectively. The Carson Range is mainly comprised of hornblende-biotite granodiorite that was emplaced as part of the Sierra Nevada batholith (Tabor and Ellen, 1976). The Virginia Range is composed of granodiorite, andesitic volcanics, and metasediments (Trexler, 1977). The valley-floor is relatively flat with coalescing alluvial fans extending out from the mountain fronts. The lithology of the valley-floor is mainly comprised of Quaternary undifferentiated sediments of lake, alluvial, talus and playa deposits (Tabor and others, 1983).

Hydrographic Setting

The primary hydrologic feature of the Washoe Valley HA is Washoe Lake, covering approximately 5177 acres during mean-annual lake stage of 5027 feet. During periods of high lake stage Washoe Lake enlarges northward and joins with Little Washoe

Lake. Under mean-annual conditions the area between the two adjoining lakes is open to the atmosphere in which phreatophyte and riparian vegetation dominate the floodplain. The stage of Washoe and Little Washoe Lake can be considered a reflection of the water table. Ground-water and surface-water flows towards Little Washoe Lake, which drains into Steamboat Creek and flows northward through the Truckee Meadows and into the Truckee River. Washoe Lake receives water by surface-water and subsurface flow from adjacent mountains, from infiltration of streams as they flow across alluvial fans and the valley-floor, precipitation on the lake surface, and possibly by infiltration of precipitation falling on the valley-floor.

Winter regional frontal systems from the Pacific Ocean are the primary source of precipitation. Precipitation producing air masses generally move eastward across Washoe Valley with the predominate jet stream. Mean-annual precipitation that falls on the Carson Range varies between 10 inches on the valley-floor, to 52 inches on Slide Mountain (Klieforth and others, 1983). Mean-annual precipitation that falls on the Virginia Range varies from 10 inches on the valley-floor, to 24 inches at the highest peak tributary to Jumbo Creek, Mt. Bullion. High amounts of precipitation falling on the Carson range can be attributed to orographic effects. As air masses rise on the western side of the Carson Range, cooling occurs and causes the release of moisture in the form of precipitation. The overall effect is an increase of precipitation with increasing elevation. However, a rain-shadow effect occurs as air masses travel across Washoe Valley and toward the Virginia Range. As an air mass moves past the Carson Range and drops in elevation, it warms and causes precipitation to decrease. If sufficient moisture is available within air masses, it is then released as it rises in elevation and cools over the

Virginia Range. Because of the loss of moisture from air masses traveling across the Carson Range, the orographic effect is less on the Virginia Range than the Carson Range.

As a result of heavy precipitation on the Carson Range, several intermittent and perennial creeks flow from the mountain front. The majority of the runoff flowing to the valley-floor originates from the Carson Range, primarily from Ophir Creek and Franktown Creek (Figure1). Other perennial creeks flowing from the Carson Range include Big Canyon Creek, Musgrove Creek, Lewers Creek and Winters Creek. The runoff derived from the Virginia Range is primarily from Jumbo Creek and flows only during spring snow melt and occasional summer rain showers. Diversions exist on Ophir, Franktown, Winters, Davis, Lewers, Big Canyon, and McEwen Creeks, and are used by local ranchers to irrigate lands west of Washoe Lake. Irrigated lands are mostly native pasture and cover about 3,859 acres of the valley-floor. During the irrigation season nearly all surface runoff is diverted and applied to pasturelands by flood irrigation. Most of the water is lost to percolation past the root zone, plant consumption, and evapotranspiration. Runoff from irrigated areas is probably significant during periods of above average annual precipitation due to increases in irrigation and the presence of shallow ground-water below irrigated areas.

Approach

The approach used for estimating the water-budget for Washoe Valley is largely taken from earlier work in developing water-budgets for HAs in Nevada (Eakin and others, 1965; Eakin and Lamke, 1966; Berger, 1997; Berger, 2000) and is viewed as an accounting procedure tracking the movement of water throughout different landforms and budget components (Figure 3). In defining the hydrologic system and identifying water-budget components on each landform, the Washoe Valley HA is subdivided into valley-floor, alluvial-fan, and mountain-block areas. Water-budget components for each landform and vegetation type are recognized and estimated individually, and then combine to estimate the water-budget for the entire Washoe Valley HA. Some budget components are estimated by newly developed methods, while other components are estimated as residuals from mass-balance calculations.

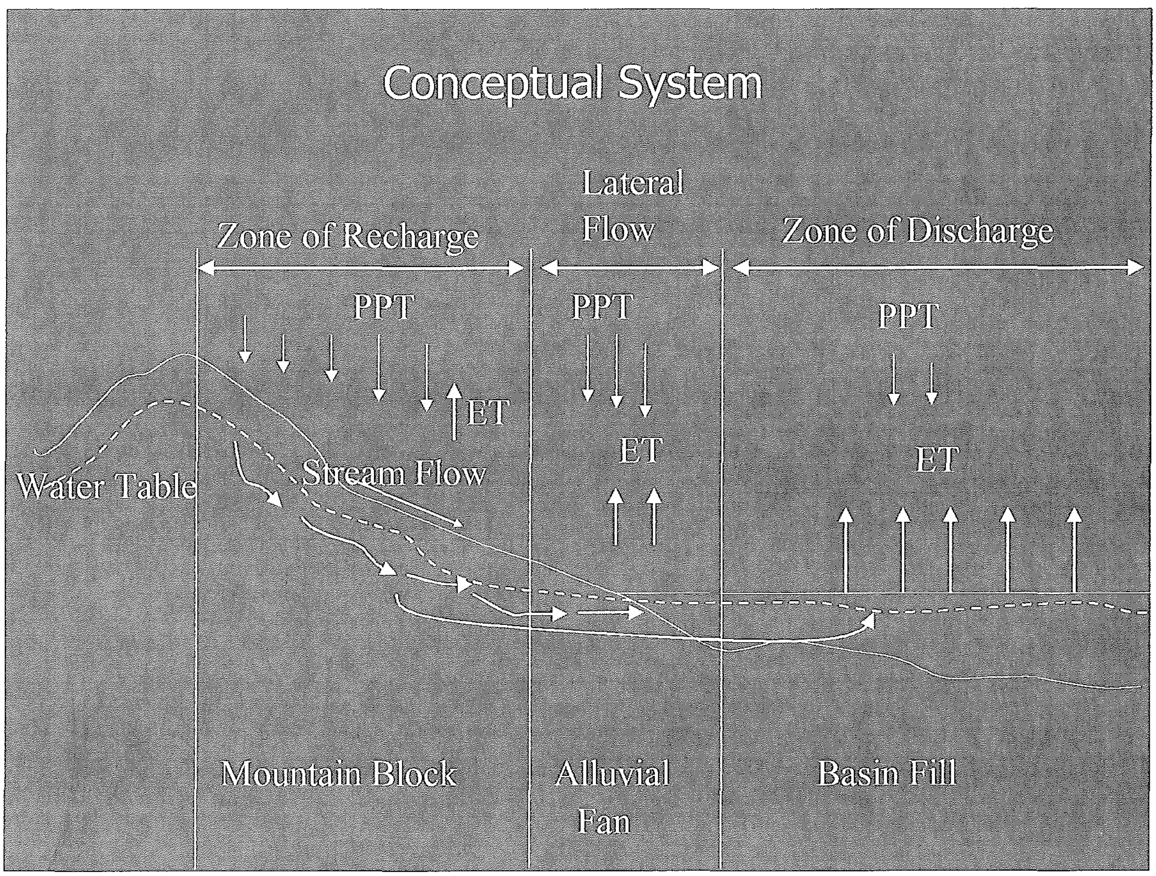


Figure 3. Conceptualization of hydrologic flow paths for the development of the water budget. Abbreviations PPT and ET stand for precipitation and evapotranspiration, respectively.

Conceptualization of Hydrologic Processes

The geomorphic processes within a HA create landforms that often correspond to different trends in ground-water and surface-water flow (Harrill and Prudic, 1998). Delineating landforms provide insight in understanding important hydrologic processes and relative magnitudes of water-budget components. For example, figure 3 illustrates that mountain-block zones typically represent the area of recharge, alluvial-fan zones represent the area of lateral flow, and the valley-floor represents areas of ground-water discharge (Mifflin, 1968). The magnitude and spatial distribution of water-budget components are influenced by climate, geology, geomorphology, vegetation, and anthropogenic affects.

Mountain Block

Precipitation is the principle inflow component to Washoe Valley and is mainly in the form of snow with occasional summer convective storms. Because the majority of precipitation falls on the mountain-block areas in the form of snow, the potential for ground-water recharge, and runoff is the greatest in these areas. Nearly all water entering Washoe Valley is derived from mountain-block areas in the form of runoff and subsurface flow, where runoff is defined as precipitation that eventually appears in streams.

Alluvial Fan

Alluvial-fan areas develop along the margin between the mountain-block and valley-floor. On the west side of Washoe Valley alluvial fans are generally short and steep, and are primarily pasture and croplands, in which significant evapotranspiration, ground-water recharge, and runoff occurs from flood irrigation practices. On the east side of Washoe Valley alluvial fans are longer, which gently slope toward the valley-floor, and are native shrub lands. Runoff generated from alluvial-fan and valley-floor areas in part, is a function of the intensity, duration, and distribution of precipitation, permeability of the surface sediments, temperature, and vegetation type (Berger, 2000). Because of the bedrock composition from adjacent mountain-block areas, sediments on the alluvial-fan surface are typically course grained, in which the majority of runoff derived from the mountain-block probably infiltrates before reaching Washoe Lake. Gravity and electromagnetic airborne surveys (Peterson, 1993; Dighem, 1994) concluded that sediments are generally coarsest along the western margins and in the north central portion of the basin, and are finest in the east and southeast, and near the northern margins. Coarse sediments are thought to represent strongly weathered granodiorite and thick alluvial deposits, where the fine sediments are thought to represent alluvial deposits of volcanic origin (Widmer, 1997). Recharge from precipitation that falls on alluvial fans could be large due to the fact that the majority of precipitation occurs between December and May, promoting episodic recharge.

Valley Floor

Although recharge may occur for a short period of time, the valley-floor area of Washoe Valley is believed to be the primary zone of discharge on an annual basis. Open-water evaporation from Washoe Lake is the primary zone of outflow, however, discharge of ground-water from evaporation from bare soil, and transpiration from phreatophytic shrubs is large due to the shallow water-table. Evapotranspiration from irrigated pasture and croplands is also a major outflow component of the water-budget and is analyzed by considering the water requirements of specific vegetation.

Developing the Water Budget and GIS Data Base

Budget components are estimated for each landform from direct estimation and by difference, by assuming that the system is in steady-state and that the annual net change in ground-water storage is negligible. For a steady-state system the water-budget can be derived on each landform where inflow equals outflow (Table 1). This steady-state approach is used to for the development and estimation of budget components for Washoe Valley.

A GIS is used to develop the water-budget for Washoe Valley. A GIS is an organized collection of computer hardware, software, and geographic data designed to efficiently capture, store, update, manipulate, analyze, and display geographically referenced information (ESRI, 1997). The most common type of geo-datasets used in GIS systems is vector, raster, and geo-referenced digital imagery. Vector data is geographic data of lines, polygons, and points, whereas raster data is cellular based information in the form of pixels, with each pixel representing a unique attribute. Geo-referenced imagery is also used to develop and create vector and raster datasets.

Management of data and processing procedures used to delineate the Washoe Valley HA, watersheds, landforms, irrigated lands, native vegetation, soil units, open-waters, and residential irrigated areas, was facilitated using a GIS. Rates of evaporation from open-water and evapotranspiration from vegetation on the valley-floor are also incorporated in a GIS to give managers the ability to alter the water-budget as land uses change over time.

Table 1. Mean-annual water-budget components for Washoe Valley, Nevada.

	Inflow	=	Outflow
Mountain-block	$P_{mb} + SW_{in}$	=	$RO_{mb} + SB_{mb} + ET_{mb} + SW_{exp}$
Valley-floor	$P_{vf} + RO_{mb}, + SB_{mb} + SW_{in}$	=	$SW_{out} + ET_{ph} + ET_{xe} + ET_{irr} + E_{ow} + DC$

Combined Inflow $P_{mb} + P_{vf} + SW_{in}$

Combined Outflow $SW_{out} + ET_{mb} + ET_{ph} + ET_{xe} + ET_{irr} + E_{ow} + DC$

Budget components for the mountain-block

Inflow

- P_{mb}, precipitation on mountain-block
- SW_{in}, surface-water imports

Outflow

- RO_{mb}, runoff from mountain-block
- SB_{mb}, subsurface flow from mountain-block
- ET_{mb}, sublimation and evapotranspiration of soil moisture and precipitation from mountain-block
- SW_{exp}, surface-water exports

Budget components for valley-floor

Inflow

- P_{vf}, precipitation on valley-floor
- RO_{mb}, runoff from mountain-block
- SB_{af}, subsurface flow from mountain-block
- SW_{in}, surface-water imports

Outflow

-SW_{out}, outflow to Steamboat Creek
-ET_{ph}, sublimation and evapotranspiration of ground-water and precipitation from phreatophyte shrubs and bare soil
-ET_{xe}, sublimations and evapotranspiration of soil moisture and precipitation from xerophyte shrubs
-ET_{irr}, evapotranspiration from irrigated lands
-E_{ow}, evaporation from open-waters
-DC, domestic consumption

Combined water-budget for Washoe Valley HA

Inflow

-P_{mb}, precipitation on mountain-block
-P_{af}, precipitation on alluvial-fan
-P_{vf}, precipitation on valley-floor
-SW_{in}, surface-water imports

Outflow

-SW_{tot}, total surface-water outflow
-ET_{mb}, sublimation and evapotranspiration from mountain-block
-ET_{irr}, evapotranspiration from irrigated lands
-ET_{ph}, sublimation and evapotranspiration of ground-water and precipitation from phreatophyte shrubs and bare soil
-ET_{xe}, sublimation and evapotranspiration of soil moisture and precipitation from xerophyte shrubs
-E_{ow}, evaporation from open-waters
-DC, domestic consumption

Chapter 3: Methods

Landform Delineation

The Natural Resource Conservation Service (NRCS), SURRGO GIS soils database (USDA-NRCS, 1994) was used to delineate landforms into mountain-block, alluvial-fan, and valley-floor areas. The delineation of these areas was performed by using ArcView© GIS, selecting the "landform" attribute item, and querying for classifications of "upland" (mountain-block),"alluvial terrace / pediment" (alluvial-fan), and "floodplain" (valley-floor) landforms. After landforms of mountain-block, alluvial-

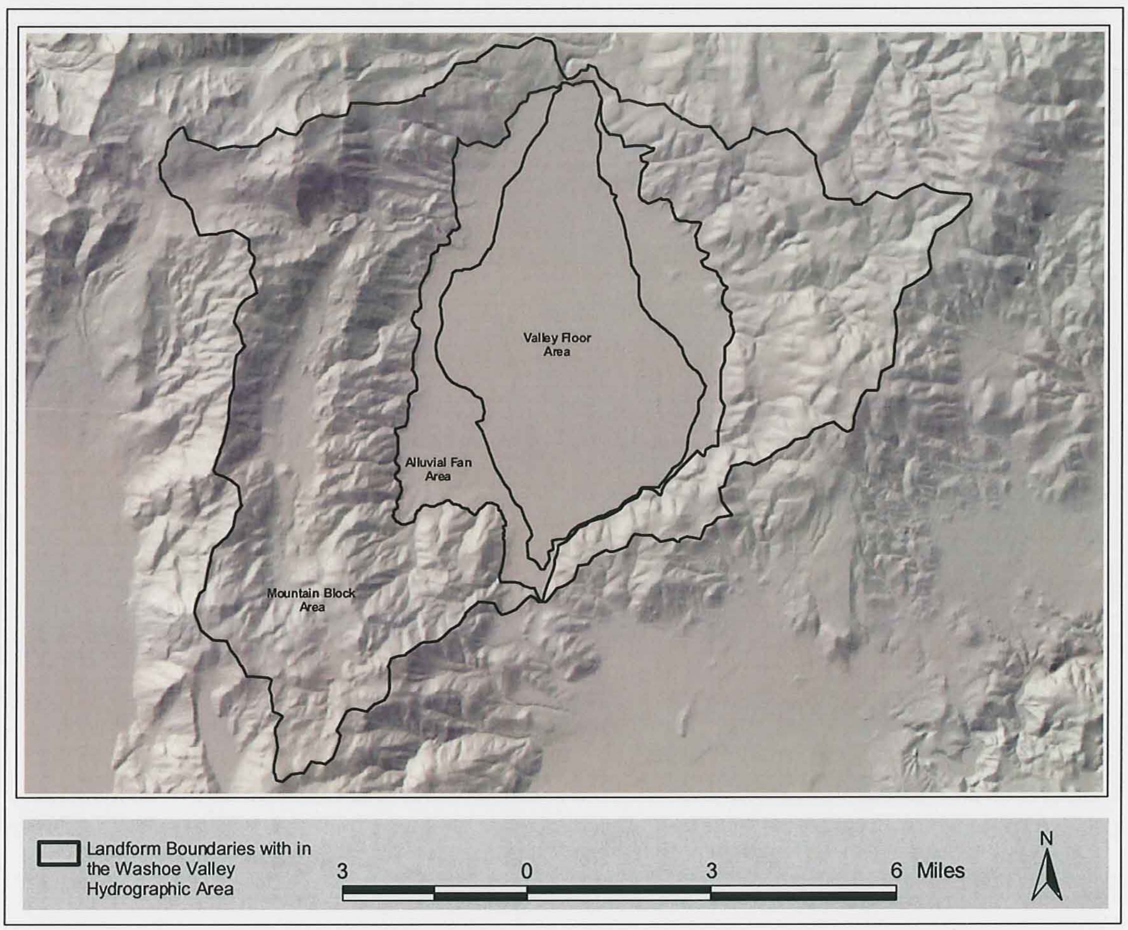


Figure 4. Landform delineation derived from the NRCS GIS soils database.

fan, and valley-floor areas were selected by the queries, selected shapes were merged to obtain boundaries between the mountain-block, alluvial-fan and valley-floor (Figure 4). To simplify the water-budget, the boundary between alluvial-fan and valley-floor areas was deleted creating one boundary between the mountain-block area and the valley-floor (Figure 5).

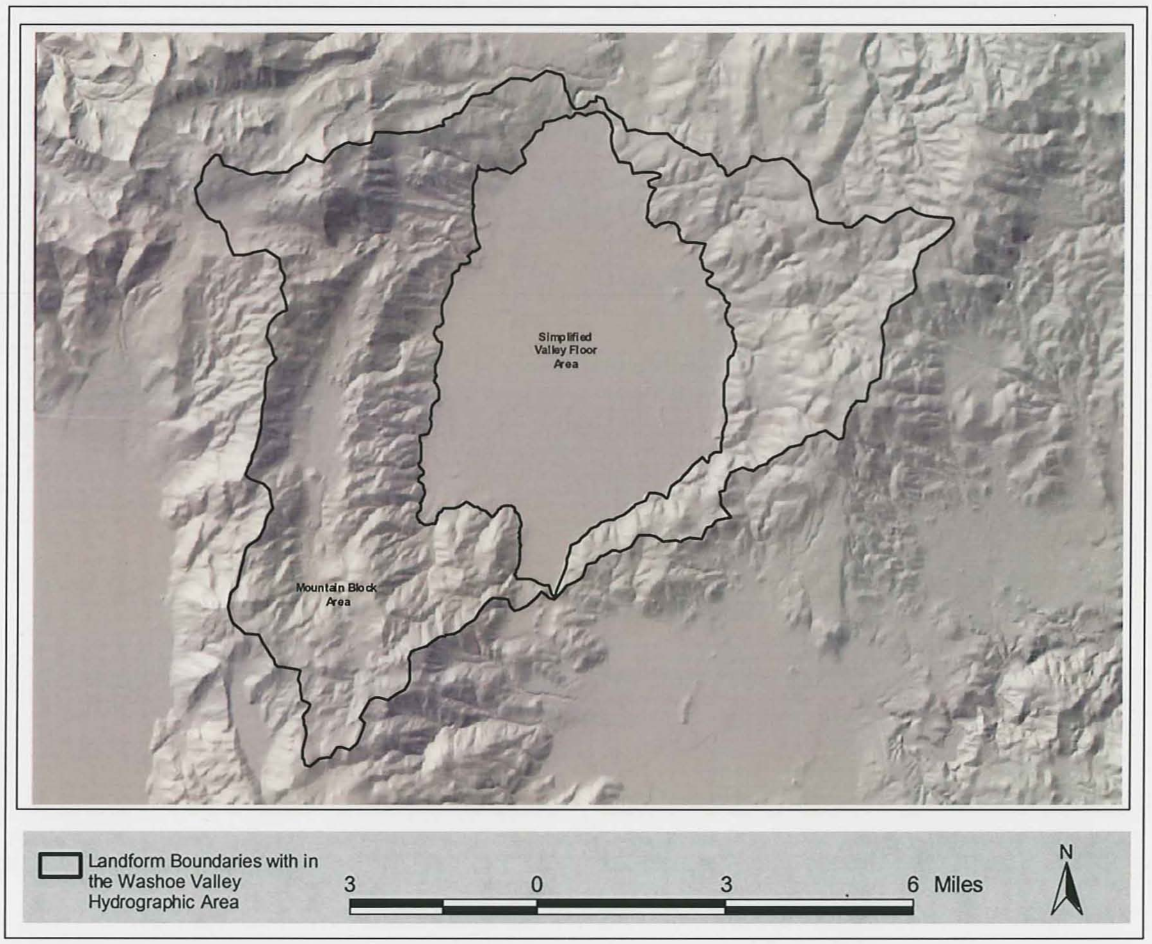


Figure 5. Simplified landform delineation, where alluvial-fan areas were combined with the valley-floor.

The simplification of not analyzing water-budget terms derived on the alluvial-fan areas was made because estimates of transmissions losses from diversion flow, tail-water runoff from flood irrigation, and recharge from flood irrigation are not estimated directly in this study. Crude estimates of these budget components could be derived if irrigation companies would make surface-water diversion data available, but are unwilling to do so.

Watershed Delineation

In order to assess the water-budget of Washoe Valley, it was required that watersheds of Washoe Valley, Eagle Valley, Carson Valley and the Truckee Meadows be delineated. Delineated watersheds of the previously mentioned HAs are used in calculations and estimations of mean-annual precipitation, water-yield, runoff, subsurface flow and, ET. Instead of delineating the watershed boundaries by hand with the use of a topographic map, numerous processes were performed in a GIS. First, a 30-meter resolution seamless elevation grid was clipped from a larger National Elevation Dataset (NED). After the elevation grid was clipped to the proper extent of Washoe Valley, Eagle Valley, and the Truckee Meadows, an extension named "Watershed Delineator Extension" (Environmental Systems Research Institute, Inc., 1997) was activated in ArcView© GIS. The Watershed Delineator Extension (Environmental Systems Research Institute, Inc., 1997), uses the elevation grid to create pre-processing grids of filled sinks, flow direction, flow accumulation and streams, in which it creates watershed boundaries from these grids at user defined outlet points. Locations of watershed outlet points were defined at mountain front stream gages by importing latitude and longitudinal coordinates into ArcView© GIS. Watershed boundaries created from gage locations include Davis Creek, Franktown Creek, Ophir Creek, Lewers Creek, and Jumbo Creek. Digital watershed boundaries located in Eagle Valley and the Truckee Meadows were obtained from the USGS water-resources division in Carson City. To create boundaries for ungaged watersheds, outlet points were defined at the mountain front of each watershed. Once all the watersheds of interest were delineated and edited, attributes of unique identification numbers, watershed names, and calculated areas were assigned.

Vegetation Delineation

Vegetation that occurs on alluvial-fan and valley-floor areas of Washoe Valley include, wetlands, irrigated pasturelands, phreatophytes, and xerophytes. The hydrologic settings in these areas primarily control the diversity of plant communities. In order to estimate the volume of water used by various plant communities of Washoe Valley, the aerial extent of the communities were defined and multiplied by respective rates of ET. For purposes of this study, the most aerially extensive habitats were grouped by general plant communities and by the source of water consumed by ET. Classification of generalized plant communities include xerophyte shrubs, phreatophyte shrubs, pasture and crop lands, and turf grass. It is assumed that xerophyte shrubs receive water from soil moisture derived from precipitation, phreatophytes shrubs receive water from shallow ground-water and soil moisture derived from precipitation, pasturelands receive water from surface-water irrigation and precipitation, and turf grass receives water from precipitation and ground-water pumping.

It is important to accurately estimate the mean-annual lake area due to its resulting effect on the aerial extent of vegetation at its shorelines. Changes in the type of plant community occur with increasing distance from Washoe Lake as soils become drier and depth to ground-water increases. Seasonally flooded areas occupy a large amount of the valley-floor between Washoe Lake and Little Washoe Lake. During prolonged dry periods wetland plants and phreatophytic vegetation such as salt grass sparsely colonize the seasonally flooded areas. Along the western margin of Washoe Lake bare soil and phreatophytic vegetation transition to pasturelands, and xerophytes as land surface altitudes increases toward the Carson Range. Likewise, bare soil and phreatophyte communities that transition to residential areas and xerophyte communities dominate the eastern margin of Washoe Lake. The extent of phreatophyte communities is much larger along the eastern margin of Washoe Lake due to the absence of pasturelands. In contrast, as a result of grazing and harvest practices the boundaries between phreatophytes, pasturelands, and xerophytes along the western margin of Washoe Lake are very distinct. Distinct boundaries also exist between boundaries of pasturelands, and turf grass, as well as between boundaries of xerophytes and turf grass. The largest amount of turf grass is associated with a golf course located at the southwest end of Washoe Valley. Turf grass is also present in residential areas along the western and eastern margin of Washoe Lake

Once identified, general plant community boundaries were estimated from the NRCS GIS soils database, digital ortho-photography (DOP) and Landsat TM imagery acquired June 15, 2000 and August 19, 2000, respectively. On August 19, 2000, Washoe Lake was at it's mean-annual lake stage of 5027 feet (1963-2001), therefore Landsat TM imagery acquired on this date provided the ability to delineate what is assumed to be the mean-annual boundary between vegetation communities and the lake (Figure 6). Boundaries along the western margin of Washoe Lake between xerophytes, and pasturelands, were easily distinguished because of distinct color contrasts in the DOP and Landsat TM image. Along the eastern and northeastern margin of Washoe Lake, boundaries between plant communities of phreatophytes and xerophytes were much harder to distinguish by only using DOP's and Landsat TM imagery. Therefore, attributes of a digital soils map created by the Natural Resource Conservation Service (USDA-NRCS, 1994) were used in a GIS to delineate soil groups that contain phreatophyte vegetation.

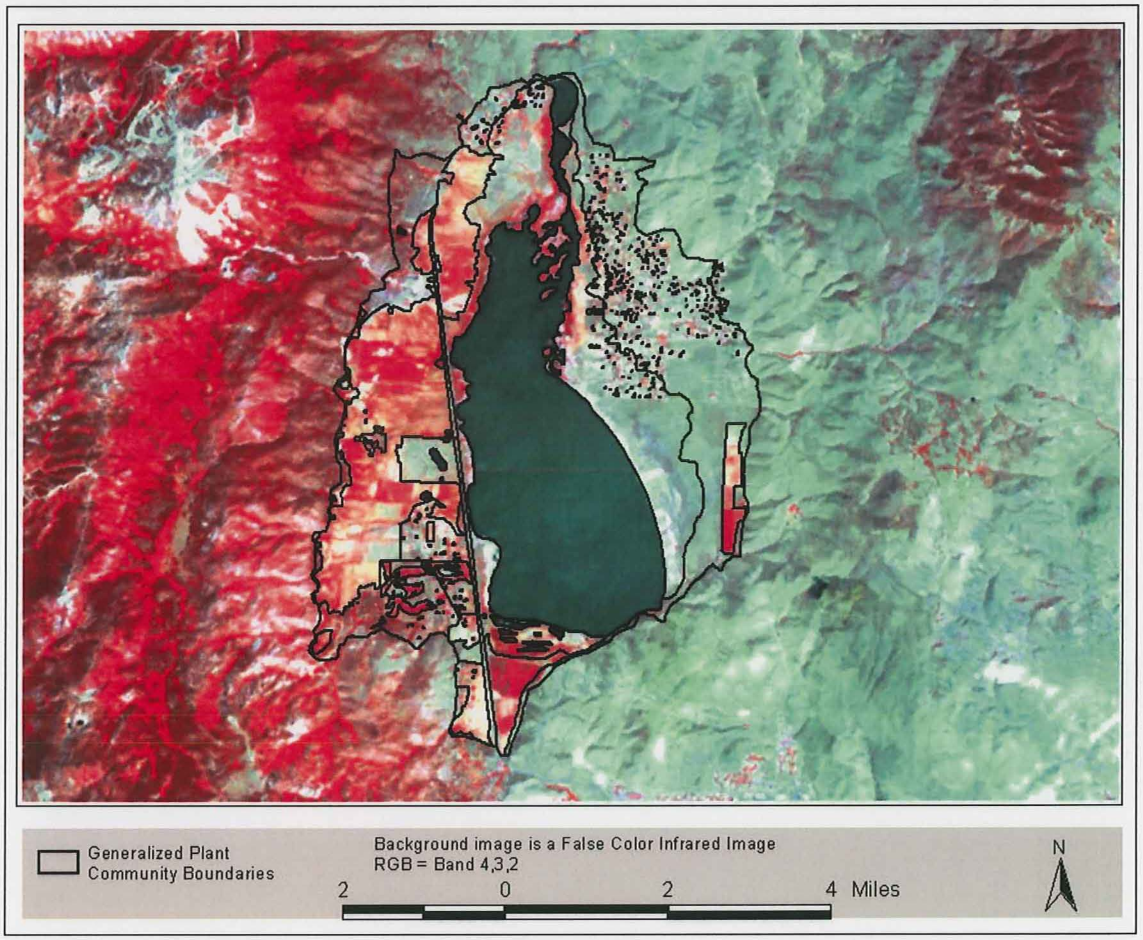


Figure 6. Delineated vegetation boundaries overlaid on a false color infrared Landsat TM image acquired on August 19, 2000 during mean-annual lake stage of 5027 feet.

The NRCS soil attribute item named "common vegetation" was queried in the GIS, in which polygons were selected that contained phreatophyte vegetation of greasewood (*Sarcobatus vermiculatus*), rabbitbrush (*Chrysothamnus nauseosus*), and big sagebrush (*Artemisia tridentate*). Once preliminary boundaries were determined from remotely sensed data, field investigations were performed in which salt grass, greasewood, and big sagebrush were used as indicators of areas of ground-water discharge. The locations of the boundary between phreatophyte and xerophyte communities were collected during field surveys by using a Trimble Geo Explorer 3 GPS unit. Boundaries were manually digitized in the GIS by using field verifications, and visual and numeric interpretation of the DOP and the near-infrared Landsat image. This methodology was also used to delineate plant-community boundaries between xerophytes, and pasturelands, as well as turf grass and xerophytes. Attributes of area, and plant type were then assigned to each polygon, in which polygons were assumed to represent the current spatial distribution of plant communities present in Washoe Valley (Figure 7).

INFLOW

Mean Annual Precipitation

There are many methods of regionalizing precipitation measurements but few have been able to adequately explain the complex variations in precipitation that occur in mountainous regions (Daly and others, 1994). Since precipitation is the primary inflow component of many water-budgets, it is important to analyze various precipitation maps for a given study area. In deciding which precipitation map to use calculating the water-budget, a comparison was made between a locally derived precipitation map of Klieforth, (1983) from the Desert Research Institute (DRI), and a map derived from a precipitation

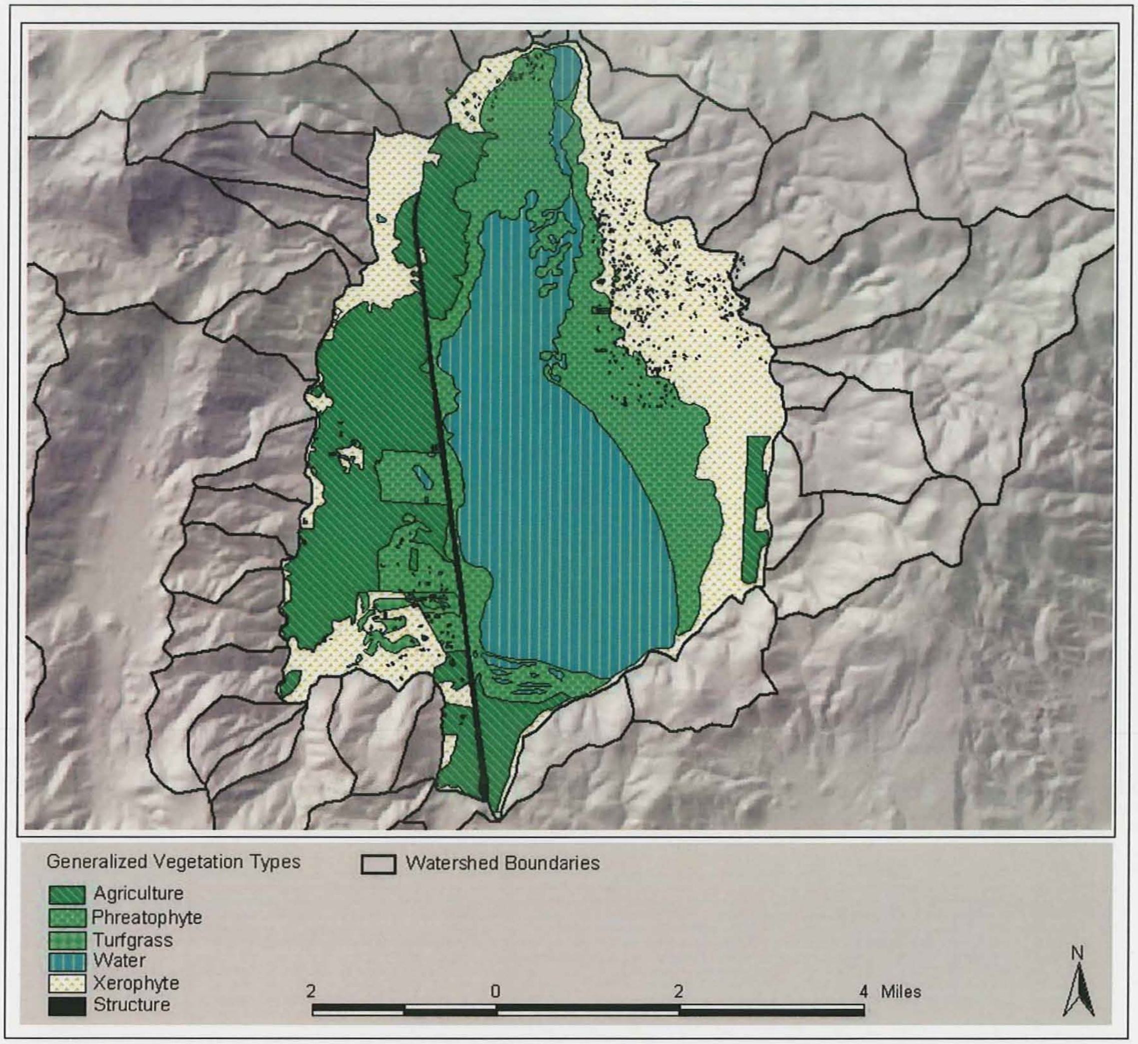


Figure 7. Generalized vegetation classification derived from Landsat TM imagery, one foot resolution aerial photography, and NRCS GIS soils database.

model, called PRISM or "Parameter-elevation Regressions on Independent Slopes Model" (Daly and others, 1994), which also uses local measurements of precipitation. The locally derived precipitation map, which was used in this study "is based on annual precipitation averages from DRI sites for the period of 1969-1979, long-term averages of varying periods, historical averages for sites no longer in existence, and shorter-term measurements of several years (Klieforth and others, 1983)." Klieforth found that when isohyetal lines were drawn and overlaid on topography maps, the data suggested a strong correlation existed between precipitation and altitude. Therefore, isohyetal lines were drawn on mylar, using topographic contours as principle guidelines, while using measurements of snow water content and annual precipitation in the Mt. Rose area. Special consideration in the analysis was given to personal knowledge of the terrain features, storm winds, snowdrift patterns and vegetation types (Klieforth and others, 1983). In order to transform isohyetal lines into a digital form, Washoe County Department of Water Resources digitized, georeferenced, and attributed the isohyetal lines from the 1:24,000 mylar (Washoe County Department of Water Resources written communication, 1999). The digital precipitation map was then clipped in the GIS to the Washoe Valley HA to calculate the volume of precipitation and compare it to the statistically derived PRISM precipitation volume discussed later in this section.

The PRISM model uses regional precipitation data collected from 1961-1990 to regionalize point precipitation measurements by considering local topography and orographic affects. PRISM considers orographic regimes in a GIS by creating a relationship between precipitation and elevation that varies from one slope face to another, depending on location and orientation. Together these slope faces are a mosaic of smoothed topographic facets resulting in variations in orographic regimes (Daily and others, 1994). In operation, for each digital elevation model (DEM) cell, PRISM develops a weighted precipitation-elevation regression function from nearby stations, and predicts precipitation at the DEM elevation. In the regression, greater weight is given to stations with location, elevation, and topographic positioning similar to that of the DEM grid cell. By using many localized facet specific precipitation-elevation relationships rather than a single domain wide relationship, PRISM continually adjusts to accommodate local and regional changes in orographic regime with minimal loss of predictive capability (Daly and others, 1994).

For comparison purposes, figure 8 illustrates the DRI precipitation map and the PRISM map for Washoe Valley, respectively. Notice that the DRI precipitation map estimates higher mean-annual precipitation in high elevations when compared to the PRISM map. To further illustrate the differences, the volume of mean-annual precipitation that falls within the HA of Washoe Valley is 104,672 acre-feet using the local precipitation map, and 68,315 acre-feet, using the PRISM precipitation map. This difference of 36,357 acre-ft is large, and is primarily due to the scale at which PRISM model was derived. PRISM does not simulate mean-annual precipitation well where anomalously high precipitation falls in high elevations such as Mt Rose, NV and Mt Hood, OR (Taylor, 2003 Oregon State Climatologist, verbal communication). This is due to the fact that PRISM grid precipitation estimates are originally derived from digital elevation model cells of 4-kilometer resolution. Area weighted averaging of elevation over 4 kilometers in an area such as Washoe Valley and Mt Rose weights the lower altitudes higher, due to the larger area and therefore under predicts precipitation at the higher altitude. A panel of state climatologists from several western states, plus additional experts, critically reviewed PRISM methods and maps of precipitation, and concluded that maps equaled or exceeded the quality of the best manually prepared maps available (Daly and others, 1994). However, since the DRI precipitation map was based on an extensive network of gages in and around the study area, and analyzed at a scale

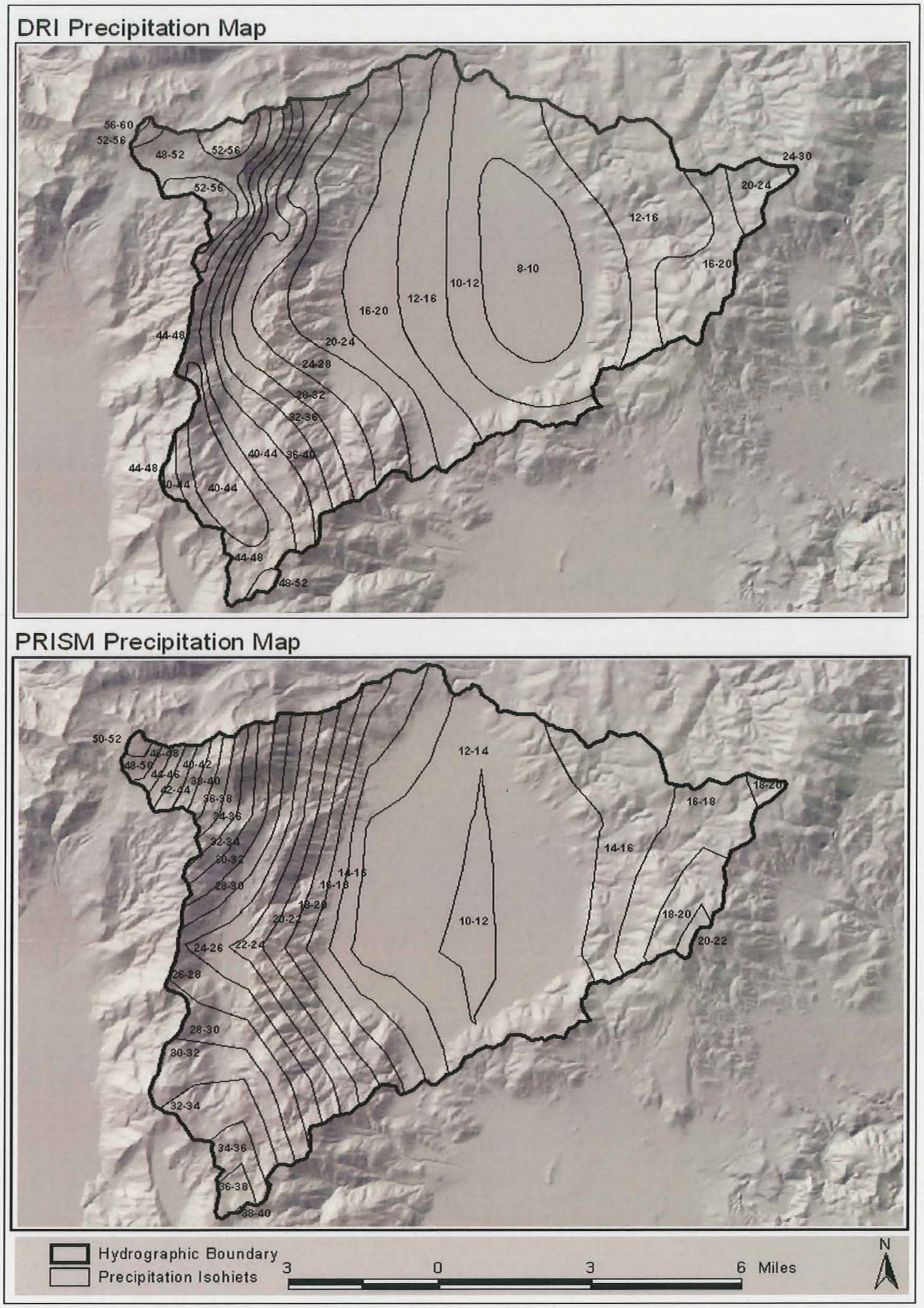


Figure 8. Comparison between DRI and PRISM precipitation maps. Depths are in inches per year. Notice large differences between maps in high elevation areas.

appropriate to be applied to Washoe Valley, it was decided that for this study applying the DRI precipitation map would be most appropriate.

Calculation of Precipitation Volumes and Area Weighted Averages

To develop mean-annual precipitation estimates in the GIS, the DRI precipitation map was intersected with watersheds and valley-floor boundaries of Washoe Valley to calculate estimates of area weighted mean-annual precipitation (Figure 9).

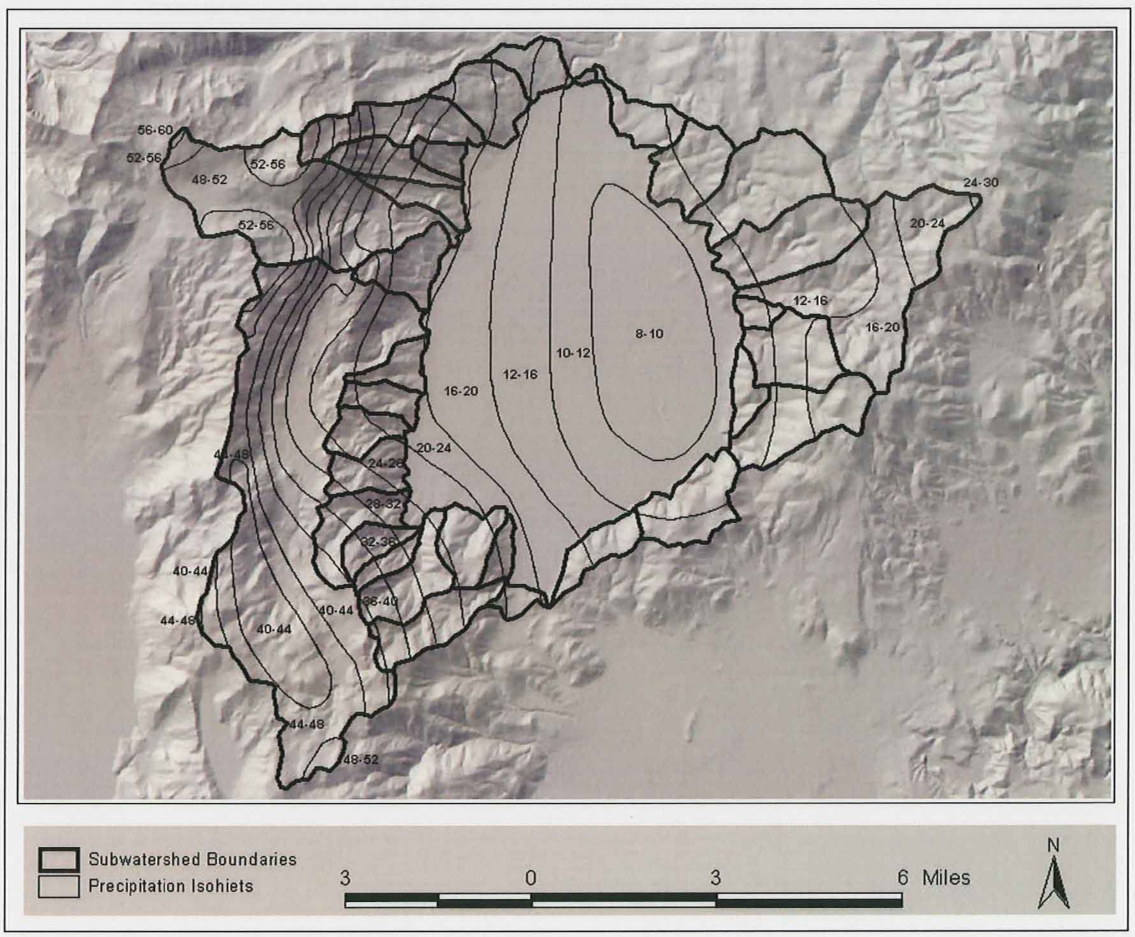


Figure 9. Intersected precipitation isohyets in which polygons were attributed with the mean of the depth of precipitation (inches per year) between upper and lower contours.

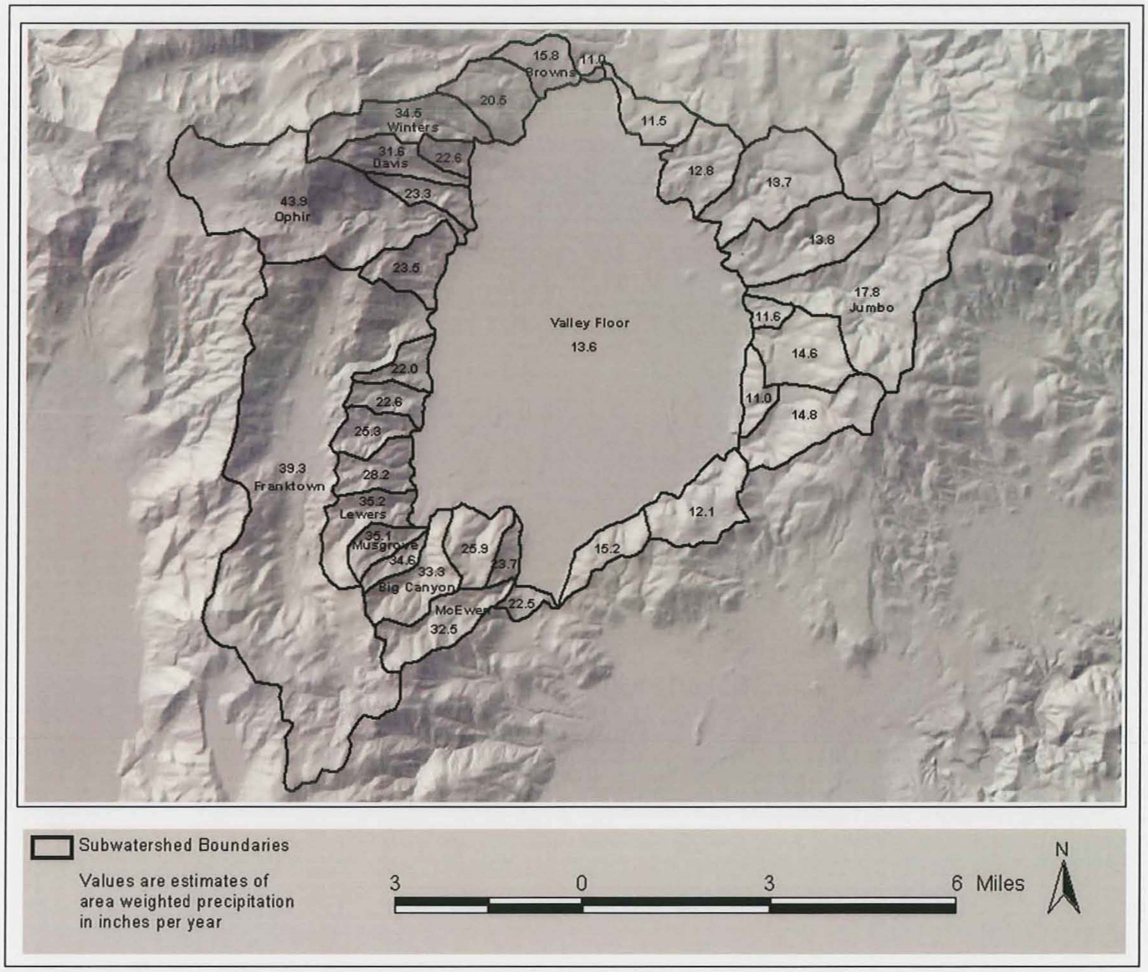


Figure 10. Area weighted mean-annual precipitation estimates for watersheds and valley-floor area.

Before the DRI precipitation map was intersected to watershed and valley-floor boundaries, isohyetal lines of equal mean-annual precipitation were converted into polygons and attributed with the depth of area weighted mean-annual precipitation, area, and watershed name (Figure 10). Area weighted mean-annual precipitation depths were calculated by taking the sum of the mid-range value between isohyetal lines, multiplied by the area between the isohyets, and dividing by the total area of each watershed. This is calculated in the GIS by applying

$$\Sigma\ (P_i * A_i) / A_{sw} \qquad \text{Eq. 1}$$

to each watershed and precipitation polygon where, P_i is the average depth of mean-annual precipitation between two isohyets, in inches, A_i is the area of the polygon that is encompassed by the upper and lower isohyets, in acres, and A_{sw} is the total watershed area, in acres.

Estimation of Runoff and Water Yield

To develop a regional relationship between precipitation and runoff, and precipitation and water-yield, which could be applied to the eastern slopes of the Carson Range and western slopes of the Virginia range, several watersheds and streams adjacent to Washoe Valley were analyzed. Watersheds and streams adjacent to Washoe Valley that were chosen to be included in the analysis were based on availability of long-term runoff data, and available estimates of area weighted mean-annual precipitation. Several studies have estimated mean-annual runoff and mean-annual area weighted precipitation for watersheds adjacent to Washoe Valley (Widmer, 2000; Maurer and Berger, 1997; Katzer, 1984; Arteaga and Nichols, 1984). Precipitation estimates in these studies were derived from historical averages and precipitation measurements collected and maintained by DRI from 1968-1982, the same periods of record in which precipitation contours were derived for this study. Runoff estimates in previous studies were derived from historical averages, and synthetic averages generated for runoff gages with missing periods of record. Figure 11 illustrates adjacent watersheds analyzed used for developing a precipitation-runoff relationship for Washoe Valley.

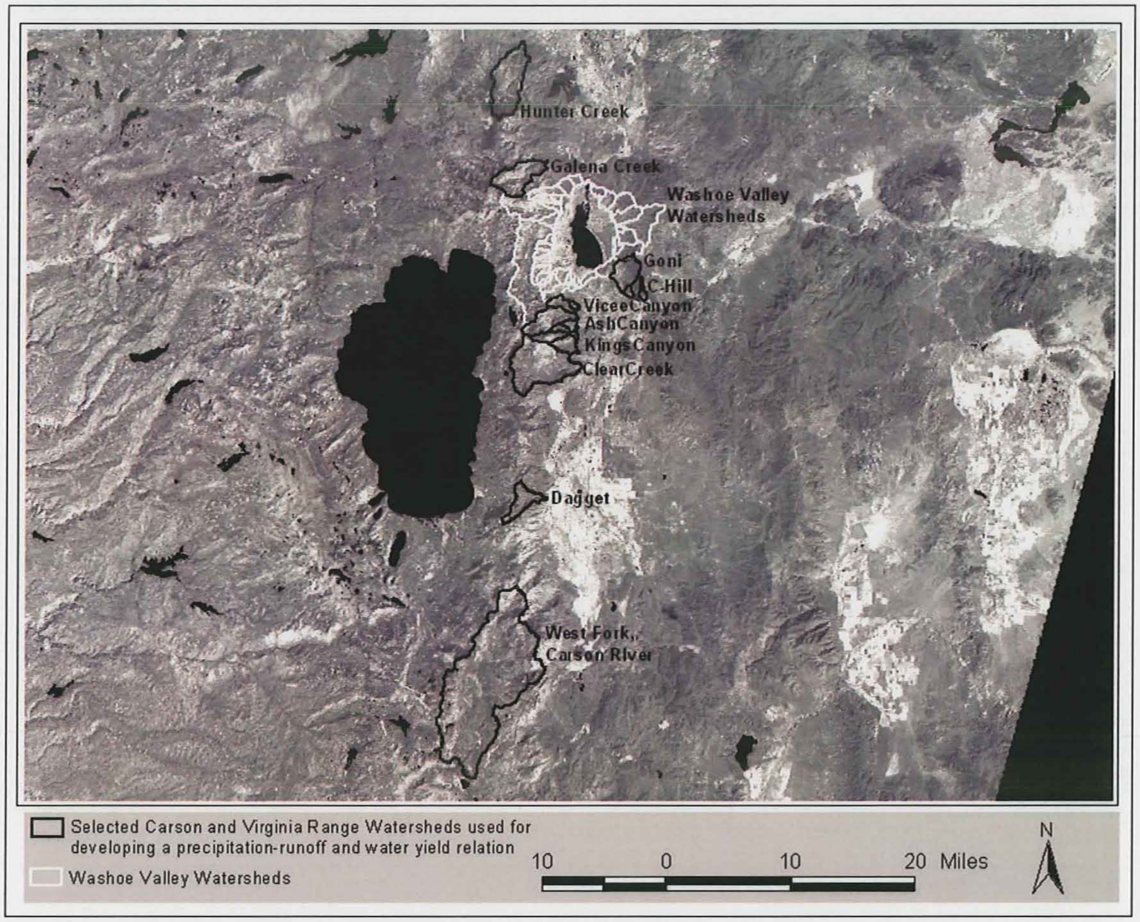


Figure 11. Near-infrared Landsat TM image overlaid by selected watersheds used to derive the precipitation-runoff and water-yield relation used in this study.

Estimates of mean-annual runoff from eight watersheds tributary to Eagle Valley, are the results of a study by Maurer and Berger, (1997), and were used to develop a regional relationship between mean-annual precipitation and runoff which could be applied to watersheds in the region. Maurer and Berger, 1997 measured runoff at gaging stations located at the mountain front of Kings Canyon, Ash Canyon, Vicee Canyon, and Clear Creek of Eagle Valley, and adjusted measurements of runoff on the basis of long term measured runoff at the West Fork of the Carson River, Woodfords, California. The measured runoff for the period of record was divided by the ratio of: a) mean-annual runoff of the West Fork Carson River at Woodfords Calif., for the period of record of each gaged watershed to b) the long term mean-annual runoff recorded for the West Fork Carson River at Woodfords (Maurer and Berger, 1997), (period of record from 1900-1907, 1910-11, and 1938-95).

Statistically derived estimates of mean-annual runoff for Upper Galena Creek, and Hunter Creek used in this study were calculated by Widmer (2000). The periods of record used for generating synthetic daily steam flow estimates for Upper Galena Creek and Hunter Creek are from 1986-1997, and 1962-1971, 1978-1985, 1987-1993 respectively. Regression equations were used to generate synthetic runoff estimates for missing periods of record for both Galena Creek and Hunter Creek. Widmer (2000) assumed that the hydrograph data for both creeks follow a normal distribution, where Hunter Creek was used to generate a record for Upper Galena Creek (1962-1986), and Upper Galena Creek was used to generate a record for Hunter Creek (1986, 1994-1998). To include the period of record for water years 1972-1977, which were extreme drought periods, Widmer (2000) analyzed a 38 year continuous record of stream-flow on Blackwood Creek, an east facing drainage above the west shore of Lake Tahoe. To generate synthetic estimates of flow while accounting for extreme drought periods of 1972-1977, a dimensionless unit hydrograph representing percentages of flow above or below the average annual flow for Blackwood Creek was applied, to the dimensionless unit hydrographs of Hunter and Upper Galena Creeks. Ultimately, synthetic estimates of mean-annual runoff from Upper Galena and Hunter Creek represent a 38-year average between 1962 and 1999.

Several studies have developed relationships used to estimate mean-annual runoff from mean-annual precipitation in west-central Nevada (Berger, 2000; Maurer and Berger, 1997; Katzer and others, 1984; Arteaga and Nichols, 1984; Arteaga and Durbin, 1979). However, to estimate runoff from mountain-block areas of Washoe Valley it was required that a function be derived from watersheds that are located on both the Virginia and Carson Range, which receive a wide range of mean-annual precipitation, and have stream-flow records or estimates that represent mean-annual conditions. Table 2 lists watersheds that were chosen to be used in this study to derive a relationship between area weighted mean-annual precipitation and mean-annual runoff estimates from watersheds adjacent to Washoe Valley. In developing the relationship, a least-squares power regression analysis was performed between mean-annual surface runoff from 12 eastern sierra watersheds (dependent variable), and DRI area weighted mean-annual precipitation (independent variable). The regression analysis showed a strong correlation with a coefficient of determination (R^2) of 0.97 (figure 12). The equation that best approximates the relation of mean-annual runoff to mean-annual precipitation is:

Table 2. Area weighted precipitation, mean-annual runoff and water-yield from adjacent watersheds used to construct precipitation-runoff and water-yield relation.

Watershed	Area (acres)	Precipitation (inches)	Runoff (inches)	Water Yield (inches)
Centennial Park	389	11.4	0.3	1.1
C-Hill	944	12.8	0.5	1.1
Goni	3048	14.0	0.6	1.5
Northwestern KingsCanyon	558	15.6	1.2	3.0
Vicee Canyon	1255	21.2	1.9	5.3
Kings Canyon	3263	24.3	4.4	9.7
Clear Creek	9876	27.9	4.9	6.3
Ash Canyon	3377	29.6	9.2	10.5
Galena Creek	4570	49.5	24.3	-
West Carson River	41874	47.0	22.8	-
Hunter Creek	7285	40.5	10.7	-
Dagget Creek	2469	29.0	6.5	-

$$RO_{mb} = 0.00031 * P_{mb}^{2.91} \qquad \text{Eq. 2}$$

where, RO_{mb} is mean-annual surface runoff from mountain-block areas, in inches per year, and P_{mb} equals the area weighted mean-annual precipitation that occurs on the mountain-block, in inches per year.

Water-yield is the total amount of water, both surface-water and subsurface-water, that exits at the mountain front of a watershed. However, in a past study (Arteaga and Nichols, 1984) subsurface flow estimates have not been included when developing precipitation water-yield relationships. Arteaga and Nichols (1984) justified considering subsurface flow as a negligible term in the water-budget, by assuming that the weathered bedrock at the mountain front is impermeable. Mauer and others (1996) showed that weathered bedrock at the mountain front of watersheds in Eagle Valley had a wide range of permeability, and concluded that water-yield should not neglect subsurface flow at the mountain front.

To estimate water-yield in Washoe Valley a regression function was derived between the area weighted mean-annual precipitation, and water-yield from eight adjacent watersheds in Eagle Valley. Mauer and others (1996), estimated subsurface flow below eight instrumented mountain front streambeds in Eagle Valley by using borehole geophysical logs, slug tests, and Darcy's Law and chloride-balance methods. As part of a later study in Eagle Valley, Maurer and Berger, 1997 estimated water-yield by adding subsurface flow to the mean-annual runoff from respective watersheds. Least-squares regression analysis of mean-annual water-yield (dependent variable), and the area weighted precipitation (independent variable) from eight Eagle Valley watersheds, showed a strong correlation with a coefficient of determination (R^2) of 0.92. Mauer and Berger, 1997 determined that equation that best approximated the range in mean-annual water-yield to mean-annual precipitation for eight instrumented watersheds in Eagle Valley is:

$$Y_{mb} = 0.00266 * P_{mb}^{\ 2.453} \qquad \text{Eq. 3}$$

where, Y_{mb} equals mean-annual water-yield from mountain-block areas, in inches per year, and P_{mb} equals the area weighted mean-annual precipitation that occurs on the mountain-block, in inches per year.

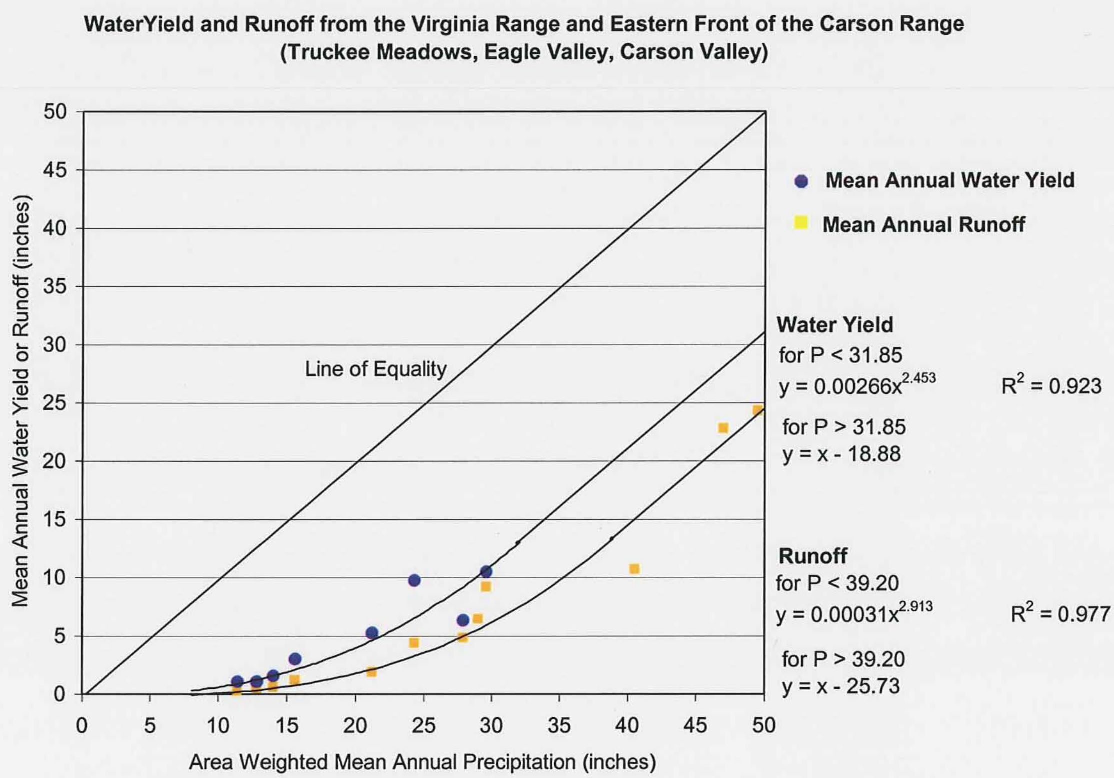


Figure 12. Power and linear regression functions between precipitation, and runoff and water-yield for watersheds shown in table 2.

A linear model was used to estimate runoff and water-yield from mountain-block areas of Washoe Valley that receive more than 31.8 and 39.2 inches of mean-annual. Linear segments were fit to the modeled regression lines where the slopes between two modeled points equaled 1 (Figure 12). The physical justification for this is that a unit increase in mean-annual water-yield and runoff cannot be more that a unit increase in mean-annual precipitation when analyzing a watershed at the mountain front. The linear equation used for estimating mean-annual water-yield for watersheds in the Washoe Valley HA that receive more than 31.8 inches of precipitation is:

$$Y_{mb} = P_{mb} - 18.88 \qquad \text{Eq. 4}$$

where, Y_{mb} equals mean-annual water-yield, in inches per year, and P_{mb} equals the area weighted mean-annual precipitation, in inches per year. The linear equation used for estimating mean-annual runoff for sub watershed in the Washoe Valley HA that receive more than 38.8 inches of precipitation is:

$$RO_{mb} = P_{mb} - 25.53 \qquad \text{Eq. 5}$$

where, RO_{mb} equals mean-annual runoff, in inches per year, and P_{mb} equals the area weighted mean-annual precipitation, in inches per year.

To calculate the depth of runoff and water-yield, regression equations were applied to the depth of mean-annual precipitation for each watershed in Washoe Valley. The calculated depth of runoff and water-yield was then multiplied by the respective watershed area and integrated into the GIS for displaying the volume of runoff and water-yield from mountain-block areas.

Imports

The total volume of imported water into Washoe Valley is largely unknown. Water is diverted from Third Creek in the Tahoe Meadows area, and from Galena Creek. Water diverted from Third Creek is the primary import, and is transferred into Ophir Creek near Tahoe Meadows. At Price Lake, which is at the base of Slide Mountain and exists due to a small dam on Ophir Creek, the same volume of water is diverted from Third Creek and is again transferred into Franktown Creek where it is then used for irrigation in Washoe Valley. Diversion volumes are collected by the Franktown Irrigation Company, and are unwilling to provide estimates of imported water into Price Lake.

A stream gage was installed on Browns Creek during the summer of 2000 to estimate the volume of imported water from Galena Creek. The period of record available for Browns Creek is from October 2000 to April 2003. There are several months of missing records due to equipment malfunction and vandalism, however for water year 2001 the period of record is complete. Results for the 2001 water year indicate that discharge is estimated to equal 914 acre-feet.

Rush (1967) and Arteaga (1984) estimated total imports into Washoe Valley to equal 4,000 acre-feet per year. Rush did not provide information on how this estimate was derived, nor did Arteaga (1984). With no other option, this estimate provided by Rush (1967) and Arteaga (1984) of 4,000 acre-feet per year was used in this study as the total import volume into Washoe Valley.

OUTFLOW

Valley Floor Area

As in most basin and range settings, the valley-floor area of Washoe Valley is considered the primary outflow area. Conceptually, surface and ground-water flow terminates at the valley-floor where it contributes to the ground-water reservoir, and is subsequently evaporated or transpired from open-water and vegetated areas. To quantify the total outflow from the valley-floor area of Washoe Valley, water-budget components of mean-annual precipitation, ET from areas of phreatophyte vegetation, ET from crop and pasture lands, open-water evaporation, surface-water outflow into Steamboat Creek, domestic consumption and exports, were analyzed separately.

ET from Phreatophyte Vegetation

Phreatophyte plants are those that are able to obtain their water supply from the saturated zone (Wilson and Moore, 1998). Several studies have shown that ET by phreatophyte shrubs and grasses, and evaporation from bare soil are principal mechanisms of ground-water discharge from the valleys of the Great basin (Berger, 2001; Nichols, 2000; Laczniak and others, 1996; Nichols, 1994). From a simple water-balance, ground-water discharge from phreatophyte areas can be defined as total measured ET minus total measured precipitation.

The valley-floor of Washoe Valley contains many phreatophyte communities of saltgrass (*Distichlis spicata*), greasewood (*Sarcobatus vermiculatus*), rabbitbrush (*Chrysothamnus nauseosus*), and big sagebrush (*Artemisia tridentate*). Phreatophyte communities located in Washoe Valley exist because of shallow ground-water and frequent fluctuations of lake stage. Several studies have correlated phreatophyte communities to shallow ground-water depths. Blaney and others (1933) found that saltgrass, which is the principal phreatophyte of the salt-desert community, commonly grows where the depth to ground-water is less than 8 feet to as much as 12 feet deep. Rabbitbrush grows where the depth to water is less than about 35 feet (Robinson, 1958). Greasewood commonly occurs where the depth to ground-water ranges from about 5 feet to 35 feet (Nichols, 2000). Big sagebrush is commonly believed to be a xerophyte, however under conditions of shallow ground-water it is considered a phreatophyte (Mozingo, 1987). Nichols (1994) found such a strong correlation between the depth to ground-water and ground-water ET from phreatophytes, that he proposed a linear function with an extinction depth to estimate ground-water ET from phreatophytes. However, developing an accurate spatial distribution of the depth to ground-water is not easily achieved. Realizing this fact, Nichols (2000) developed a regionalized remote sensing and energy balance approach that relates ground-water ET to vegetative conditions rather than depth to ground-water.

To estimate ground-water ET from phreatophyte shrubs and bare soil in Washoe Valley, functions developed by Nichols (2000), and Qi and others (1994), were applied to the delineated phreatophyte area using a three-step approach. First, vegetation indices are calculated from remotely sensed data acquired by the Landsat thematic mapper (TM) satellite (Qi and others, 1994). Second, plant cover estimates were determined from functions that relate vegetation indices to plant cover (Qi and others, 1994; Nichols

2000). Finally, a functional relation between plant cover and ground-water ET from phreatophyte plants was applied (Nichols, 2000).

Calculation of Vegetation Indices

Many vegetation indices have been developed for characterizing biophysical parameters of vegetation by using remotely sensed data, (Rouse and others, 1973, Asrar and others, 1984; Huete, 1988; Wiegand and others, 1991; Jackson, 1991; Qi, and others 1994). Indices of vegetation are functions of plant density and the total green leaf area of plants, which can be determined from the Landsat TM satellite (Nichols, 2000). The Landsat TM satellite contains a thematic mapper (TM) radiometer that measures visible and non-visible radiation in seven wavelength bands, which range from 0.45 to 12.5 mm (micrometers). Healthy green vegetation generally reflects 40%-50% of the incident near-infrared (NIR) energy, with the chlorophyll in the plants absorbing approximately 80%-90% of the incident energy in the visible part of the spectrum (Jensen, 1983). The wavelength bands used to calculate vegetation indices for this study are bands 3 and 4, which are the reflectance of red wavelengths at 0.63 – 0.69 μm (band 3) and reflectance of non-visible near infrared (NIR) wavelengths at 0.76 – 0.90 μm (band 4), respectively.

Images used in this study for calculating vegetation indices and therefore ground-water ET, were acquired on June 28, 1984, August 26, 1993, and May 31, 2000, and were chosen based on their availability at no cost. Precipitation records collected at the Mt Rose Ski Resort showed that cumulative precipitation for 1984, 1993 and 2000, were 114%, 126% and 83% of normal, respectively. Since the average cumulative precipitation from 1984, 1993, and 2000 was 108% of normal, it was decided that spatially distributed estimates of mean-annual ground-water ET would be calculated from images acquired on June 28, 1984, August 26, 1993, and May 31, 2000, and are assumed to represent mean-annual conditions.

Two of the most common vegetation indices are the normalized difference vegetation index, which is calculated as

$$NDVI = \rho_{NIR} - \rho_{red} / \rho_{NIR} + \rho_{red} , \qquad \text{Eq. 6}$$

and the perpendicular vegetation index (PVI), which is calculated as

$$PVI = a\rho_{NIR} - b\rho_{red}, \qquad \text{Eq. 7}$$

where ρ_{ι} is the percent reflectance in the red and near infrared (NIR) bands, and a and b are soil line parameters (Qi, and others, 1994). However, problems exist when applying the NDVI and PVI in arid environments because of external factor effects, such as soils background variations (Huete, 1989). Qi and others (1994) proposed that a modified soil-adjusted vegetation index (MSAVI) that included a variable soil-adjustment factor was the most appropriate for quantifying vegetation conditions in arid environments. The MSAVI is calculated as

$$MSAVI = ((\rho_{NIR} - \rho_{red}) / (\rho_{NIR} + \rho_{red}) + L) (1+L) \qquad \text{Eq. 8}$$

where L is the soil adjustment factor and is given by

$$L = 1 - 2g(NDVI)(WDVI). \qquad \text{Eq. 9}$$

where g is the slope of the soil line and is determined as the ratio of rNIR to rred for bare soil. WDVI is the weighted difference vegetation index and is calculated by

$$WDVI = \rho_{NIR} - g\rho_{red} \qquad \text{Eq. 10}$$

where g is the slope of the soil line, and is equal to 1.06 (Qi and others, 1994). These indices provide regional plant cover information that is appropriate for use in the plant cover-phreatophyte ground-water ET relations (Nichols, 2000).

To calculate the MSAVI for Washoe Valley, Landsat TM images of NIR reflectance (band 4) and red reflectance (band 3) from June 28, 1984, August 26, 1993, and May 31, 2000, were converted into grids, in which NDVI, WDVI, L, and MSAVI were calculated for each grid cell or pixel using Arc/Grid©.

Plant Cover and Bare Soil

Few studies have been completed that correlate MSAVI to plant cover. However, Qi and others (1994) developed a relation between plant cover and MSAVI for 20 percent to 97 percent plant cover. The linear relation shown by Qi and others (1994) is

$$Cp = -0.0177 + 1.1308(MSAVI). \qquad \text{Eq. 11}$$

However, plant cover conditions in Nevada and the Great Basin are typically less than 20 percent (Nichols, 2000). In an effort to develop a relation between MSAVI and plant cover in areas of sparse vegetation, Nichols (2000) developed a relation based from field measurements and calculated MSAVI that is best described by a logarithmic equation ($R^2 = 0.84$) of

$$Cp = 0.5130 + 0.1910 \ln(MSAVI). \qquad \text{Eq. 12}$$

By applying results from past studies in Nevada and the Great Basin, plant cover and bare soil in Washoe Valley was approximated by applying equation 12 to MSAVI grid cells with values less than 0.16. For MSAVI grid cell values greater than 0.16, equation 11 was applied. The resulting plant cover values for individual cells were then grouped into 8 categories between 0 and 70 percent, in which a color legend was applied to each grid to view the spatial variation of plant cover (Figure 13).

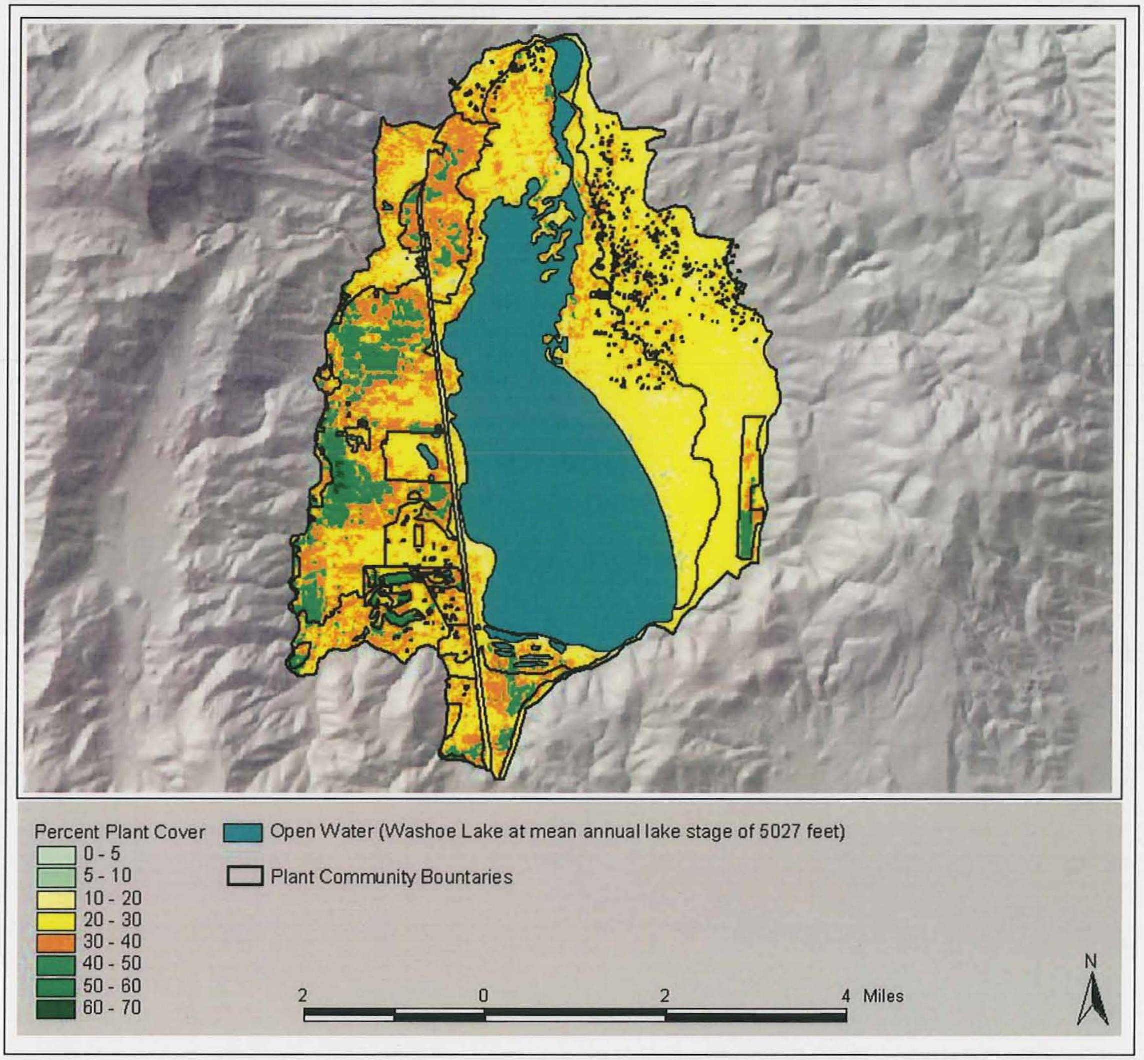


Figure 13. Regional percent plant cover, derived from the modified soil adjusted vegetation index (MSAVI) overlaid by vegetation boundaries.

Ground Water Discharge and Total ET

A functional relation exists between phreatophyte shrub density, shrub leaf area index, and the depth to ground-water (Nichols, 1994). To develop a relation between plant cover and ground-water ET energy budget studies were performed using micrometeorological instruments at four sites across Nevada (Nichols, 1994; Nichols and others, 1997), and seven sites in Owens Valley California (Duell, 1990). Precipitation that occurred during the study periods was subtracted from measured ET to estimate ground-water discharge. Nichols (2000) found that a least-squares regression analysis indicated that there was a strong correlation between plant cover and ground-water ET which was described by,

$$ET = \exp[a + (b/Cp) + c \ln(Cp)] \qquad \text{Eq. 13}$$

where Cp is plant cover and a, b, and c are constants that are defined by the time period of analysis. Seasonal and mean-annual constants are shown in Table 3.

Table 3. Coefficients proposed by Nichols (2000) for estimating ground-water ET from phreatophyte vegetation.

Data Set	Coefficients			
	a	b	c	R^2
May-September, feet per day	-4.13	-0.199	-0.263	0.973
October-April, feet per day	-5.82	-0.203	-0.483	0.842
Annual, feet per day	-4.77	-0.214	-0.358	0.975
Annual, feet	1.13	-0.215	-0.363	0.975

To estimate the rate of ground-water discharge from phreatophyte areas on the valley-floor area of Washoe Valley, equation 13 was applied to average plant cover grid cells using Arc/Grid©. The calculated ground-water ET grids included non-phreatophyte communities, therefore to restrict the analysis only to phreatophyte communities the ground-water ET grid was clipped to phreatophyte boundaries (Figure 14). Spatially distributed volumes of ground-water ET were calculated by multiplying the rate by the area of each cell of 0.22 acres (900 square meters).

Precipitation that falls on phreatophyte areas of the valley-floor is considered to be transpired by plants and evaporated from bare soil. Total ET from phreatophyte areas on the valley-floor is therefore defined as the sum of precipitation and ground-water

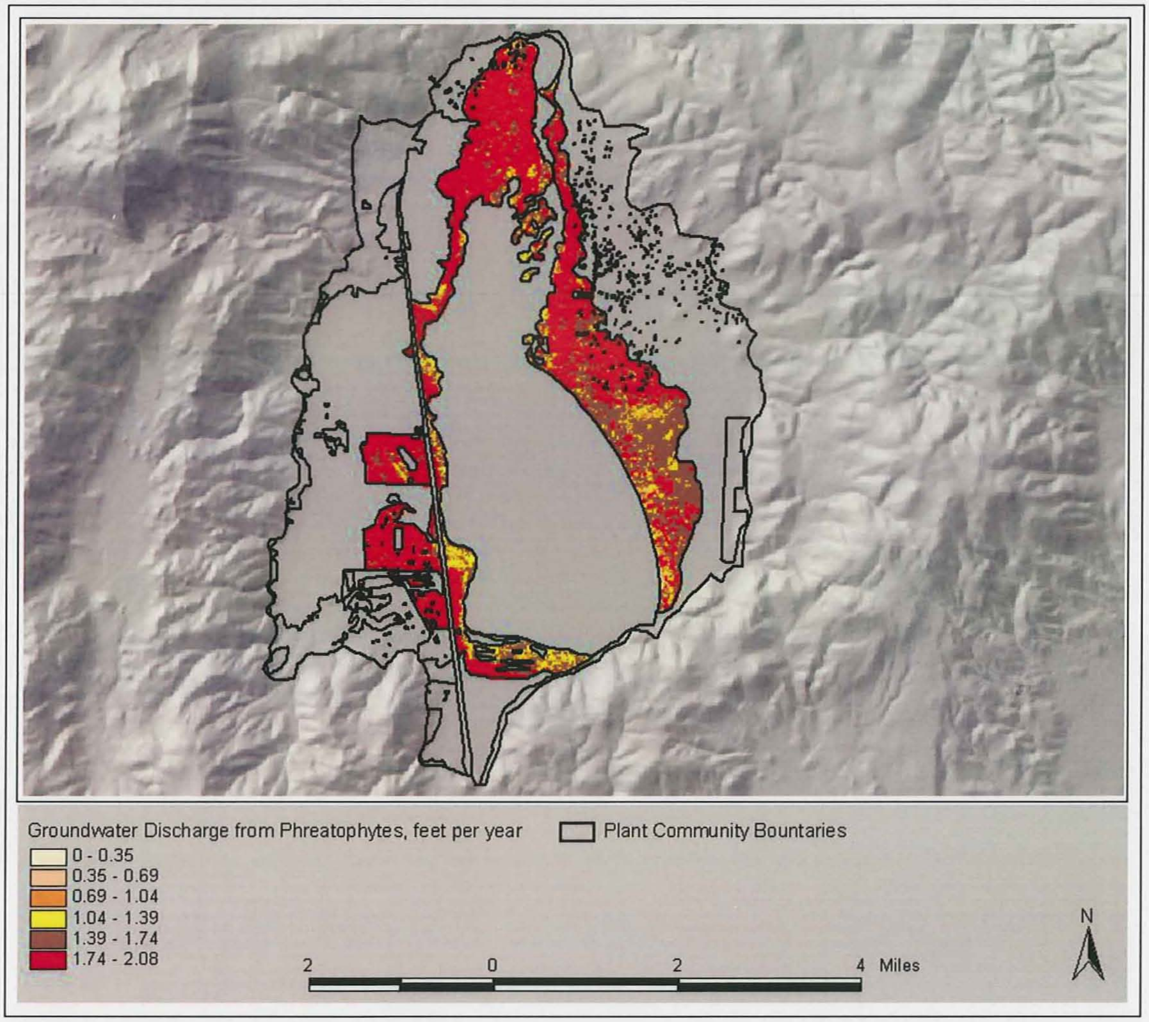


Figure 14. Regionalized ground-water discharge from phreatophyte areas.

discharge. This was calculated by adding the depth of mean-annual precipitation to respective grid cell values of ground-water discharge (Figure 15).

Potential and Actual ET from Pasturelands

Potential ET (PET) refers to ET from a reference crop that is actively growing, completely shading the ground, not short on water, and is not limited by soil moisture

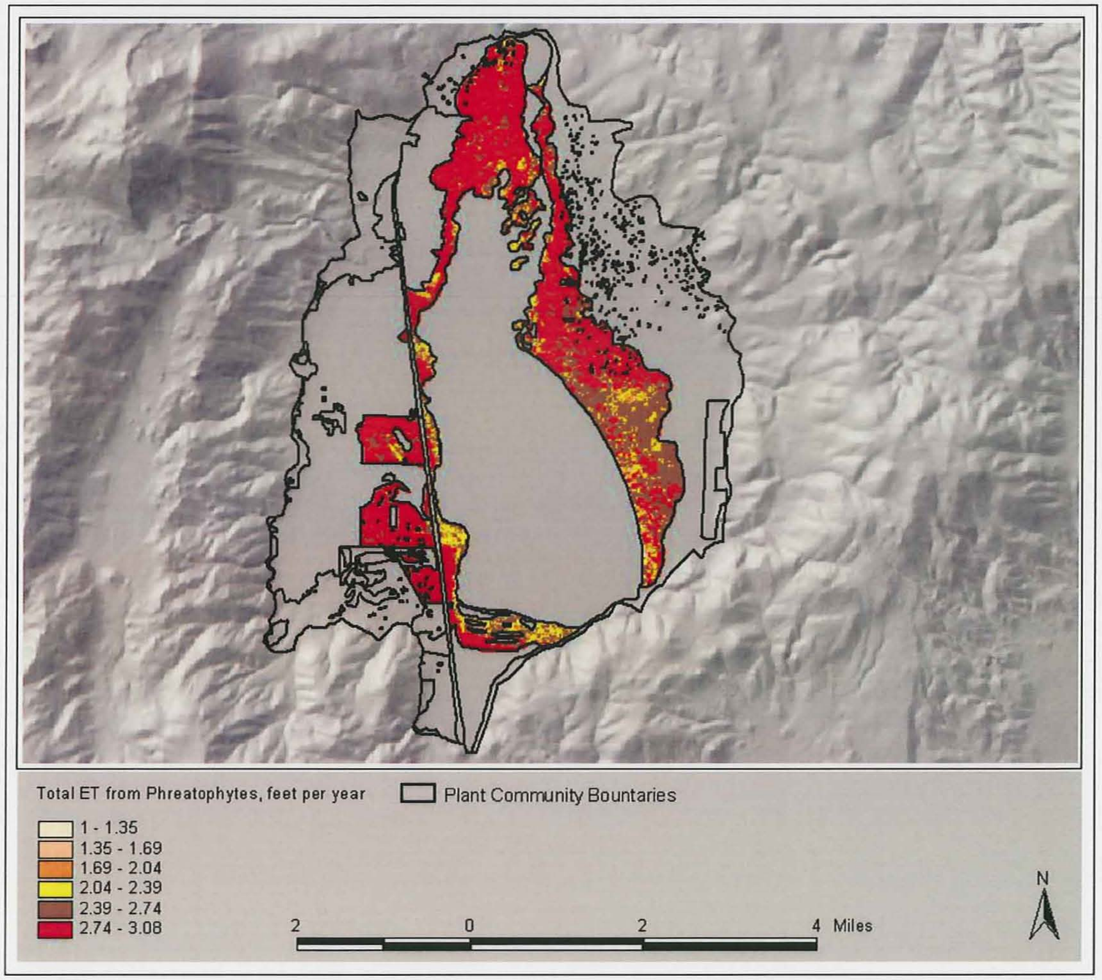


Figure 15. Total ET from phreatophyte areas, which includes ET of precipitation.

content (Dingmen, 2002). Reference crops are typically considered to be alfalfa and short grass. Many methods have been developed to estimate potential ET and can be grouped into three categories: the theoretical approach, based on the physics of the ET process; the analytical approach, based on the balance of energy or water amounts; and the empirical approach, based on the regional relation between the measured ET and the climatic conditions.

Several studies have shown that one theoretical approach known as the Penman-Monteith method for estimating potential ET, models actual ET (AET) from reference crops the best (Campbell Scientific, Inc., 1999). The Penman-Monteith method includes more of the factors that influence crop water loss than other equations, such as measurements of absorbed radiant energy, wind, and atmospheric vapor deficits. The Penman-Monteith equation can be written as:

$$ET_o = (\Delta(R_n - G) / \lambda(\Delta + \gamma^*)) + ((\gamma^* M_W(e_a - e_d) / R\Theta r_v(\Delta + \gamma^*)) \qquad \text{Eq. 14}$$

where

ET_o = Potential ET kg m^{-2} s^{-1} or mm s^{-1}

R_n = Net radiation (kW m^{-2})

G = Soil heat flux density (kW m^{-2})

M_w = Molecular mass of water (0.018 Kg mol^{-1})

R = Gas constant (8.31 x 10^{-3} kJ mol^{-1} K^{-1})

Θ = Kelvin temperature (293 K)

e_a-e_d = Vapor pressure deficit of the air (kPa)

λ = Latent heat of vaporization of water (2450 kJ kg^{-1})

r_v = Canopy plus boundary layer resistance for vapor (s m^{-1})

Δ = Slope of the saturation vapor pressure function (Pa degree C^{-1})

γ^* = Apparent psychrometer constant (Pa degree C^{-1}).

Details on the derivation of this equation can be found in Monteith and Unsworth (1990). Weather stations located in Washoe Valley were pre-programmed with the Penman-Monteith equation, in which PET is averaged and stored in the CR10x Campbell Scientific data loggers every hour. Weather stations are instrumented to measure air temperature, relative humidity, incident solar radiation, and wind speed, however several conversions and assumptions are needed to convert these measurements to parameters used in the Penman-Monteith equation. Conversions and assumptions used in the calculation of the Penman-Monteith follow the recommendations suggested by Smith (1991), and have been recommended as standards for use throughout the world by the Food and Agriculture Organization of the United Nations. Weather stations in Washoe Valley are useful because they provide locally derived potential ET estimates, however the period of record for both stations is only from September 1, 2000 to present, and do not represent mean-annual conditions. Therefore, a regional estimate of mean-annual PET taken from a study by Shevenell (1996), was applied to pasturelands and turf grass in Washoe Valley.

Shevenell (1996) developed an empirical method that could be used to estimate regional mean-annual potential ET for the state of Nevada. Few weather stations in Nevada acquire data such as relative humidity, incident solar radiation, and wind speed from which potential ET can be estimated. Since temperature is a function of vapor deficit and solar radiation reaching the surface of the earth, Shevenell (1996), used a less rigorous method derived in Nevada, (Behnke and Maxey, 1969) to estimate potential ET based only on average monthly temperature and solar radiation. With limited data needed for more rigorous calculation of potential ET, Behnke and Maxey (1969) found that the expression that best estimates potential ET in Nevada could be written as

$$ET_0 = (T^0C/1.9) \times (L_0/L^2) \qquad \text{Eq. 15}$$

where L_0 is the mean monthly ratio between total and vertical radiation for one year (R/R_v), L is the monthly value of R/R_v, and T^0C /1.9 is the simulated wet bulb depression empirically derived by Behnke and Maxey (1969). The vertical component of radiation (Rv) on a clear day is given by

$$Rv = R\sin(h) \qquad \text{Eq. 16}$$

where R equals total radiation. The angular distance of the sun above the horizon, sin(h), is expressed as

$$\sin(h) = \sin(\phi)\sin(d) + \cos(\phi)\cos(d)\cos(t) \qquad \text{Eq. 17}$$

where f is the latitude of the observation location, d equals the declination or angular distance of the sun above or below the equator, and t = the hour angle, which is the angle between the meridian plane through the observation location and the meridian plane through the sun (Sevenell, 1996). Values for ϕ, t, and d used in the analysis by Shevenell, (1996) were obtained from the weather station locations and the Astronomical Almanac.

To calculate mean-annual potential ET, Shevenell (1996) acquired mean monthly temperature data from 124 weather stations in Nevada through 1994, all with more than

10 years of temperature data in which the latitude of each station was then used to calculate R/Rv (L) for each month and applied to equation 15. To regionalize calculated mean-annual potential ET, a linear regression analyses was performed between station elevations and mean-annual calculated potential ET for 5 different regions. Shevenell, (1996) only published monthly regression equations for region 3, which includes Washoe Valley, and are shown in Table 4.

Month	Slope	Intercept	R^2	Elevation (meters)
January	0	0	0	
February	-0.021	42.073	0.801	less than or equal to 1951
March	-0.054	125.184	0.852	less than or equal to 2287
April	-0.073	208.504	0.799	less than or equal to 2838
May	-0.082	300.185	0.822	less than or equal to 3655
June	-0.074	350.836	0.728	less than or equal to 3850
July	-0.071	407.096	0.599	less than or equal to 3850
August	-0.054	320.344	0.566	less than or equal to 3850
September	-0.046	335.708	0.587	less than or equal to 3850
October	-0.032	123.972	0.611	less than or equal to 3850
November	-0.018	44.313	0.58	less than or equal to 2454
December	-0.011	16.272	0.146	less than or equal to 1418

For elevations greater than listed PET is assumed to equal zero (Shevenell, 1996)

Table 4. Regression equations and associated elevations for calculating spatially distributed, monthly PET. Modified from Shevenell (1996).

Shevenell (1996) applied equations shown in Table 4, to a 1-kilometer resolution digital elevation model in order to regionalize monthly and mean-annual ET estimates. Since ET is a function of solar radiation then aspect must be taken into consideration when regionalizing ET measures. To produce potential ET contours that reflect variations with aspect, Shevenell, (1996), calculated slope grids from the DEM (digital elevation model), in which the potential ET grids were multiplied by aspect weighting factors. For example if potential ET cells were located on northern aspects indicated by the DEM, cells of potential ET were multiplied by a weighting factor of 0.90. In contrast, if elevations of the DEM indicate a southward aspect, a weighting factor of 1.10 was multiplied by cells of potential ET. Shevenell, 1996, contoured mean monthly and annual potential ET grids at 13-inch (30 centimeter) intervals using Arc/Info 6.1 (Figure 16). Although some monthly correlations were poor, mean-annual potential ET showed a good correlation ($R^2 = 0.97$) to observed mean-annual pan evaporation data within region 3.

Given that potential ET refers to ET from a reference crop or short grass surface, crop coefficients for irrigated pasturelands were applied. A crop coefficient is defined as the ratio of the actual ET of a particular crop, to the potential ET. Crop coefficients used in this study for vegetation types of turf grass, pasture grass and hay were taken from a report by the American Society of Civil Engineers (Allen and others, 1990). Typically the method to estimate AET from irrigated areas is simply to multiply crop coefficients by PET estimates and assume that the rate is constant over the irrigated area. After applying a crop coefficient of 0.69 for pasture grass and hay, the rate of AET for pasturelands in Washoe Valley is estimated to equal 3.43 feet per year. However, since PET refers to ET from a reference crop that is actively growing, completely shading the ground, and not short on water, it would not be practical to apply the AET estimate of 3.43 feet per year to the entire area of pastureland. Given Washoe Valley's arid environment, current flood irrigation practices, and large variability in seasonal runoff, assumptions inherent in the PET estimate are not satisfied for the entire area of pastureland. It is evident that vegetative conditions diminish with distance from flood irrigation sources as shown in figure 6. Because of the relationship between plant

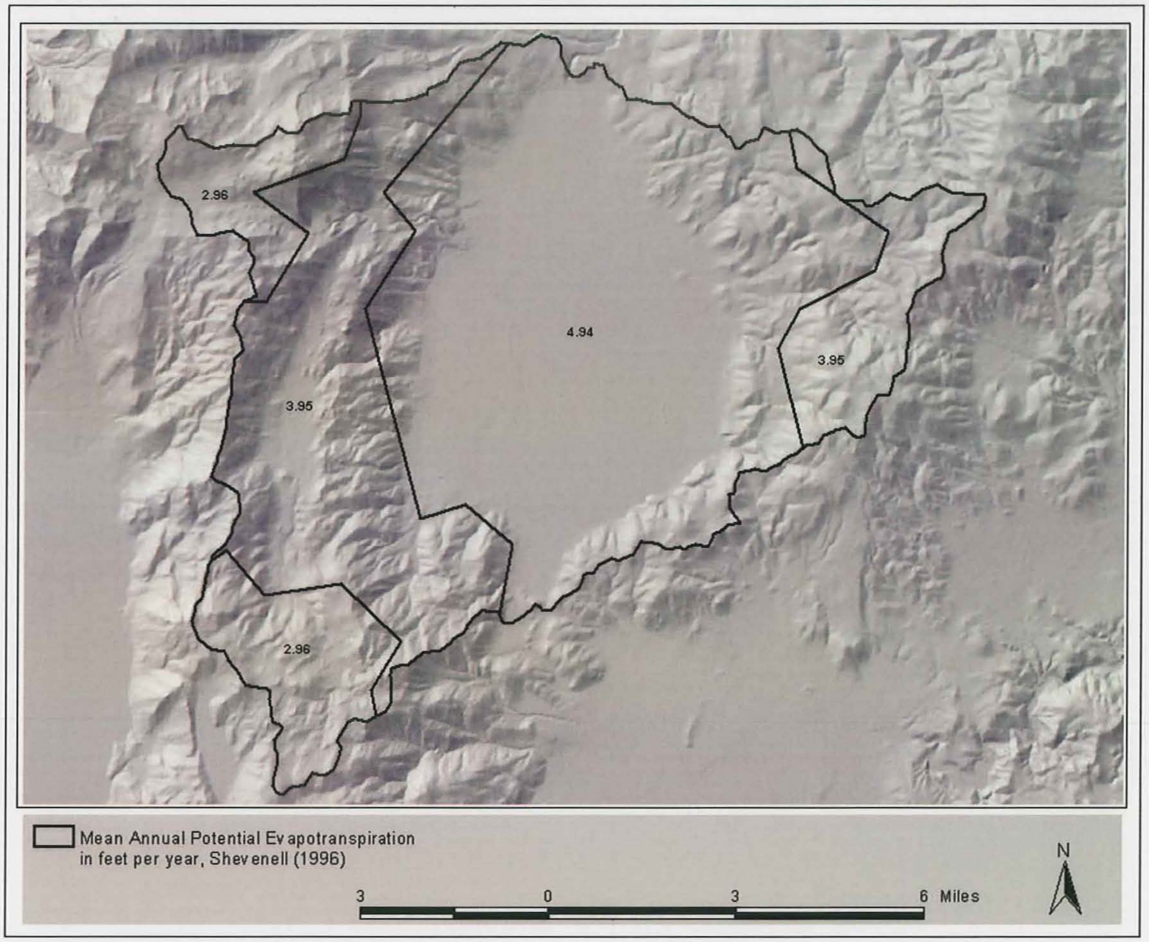


Figure 16. Spatially distributed PET estimates derived by Shevenell (1996).

cover and water availability in Washoe Valley, estimates of plant cover derived using remote sensing methods discussed earlier, were used to adjust the AET estimate of 3.42 feet per year. A linear function was derived by assuming that AET of 3.43 feet per year correlates with the maximum value of plant cover of 0.66, and the area weighted mean-annual precipitation for pasturelands of 1.49 feet per year correlates with the minimum value of plant cover of 0.06.

The adjustment of AET was accomplished in the GIS by applying a linear function of,

$$AET = 3.2497\ (Cp) + 1.2885 \qquad \text{Eq. 18}$$

to each plant cover grid cell with in pasturelands, where AET equals the actual evapotranspiration, in feet per year, and Cp is equal to the average plant cover derived

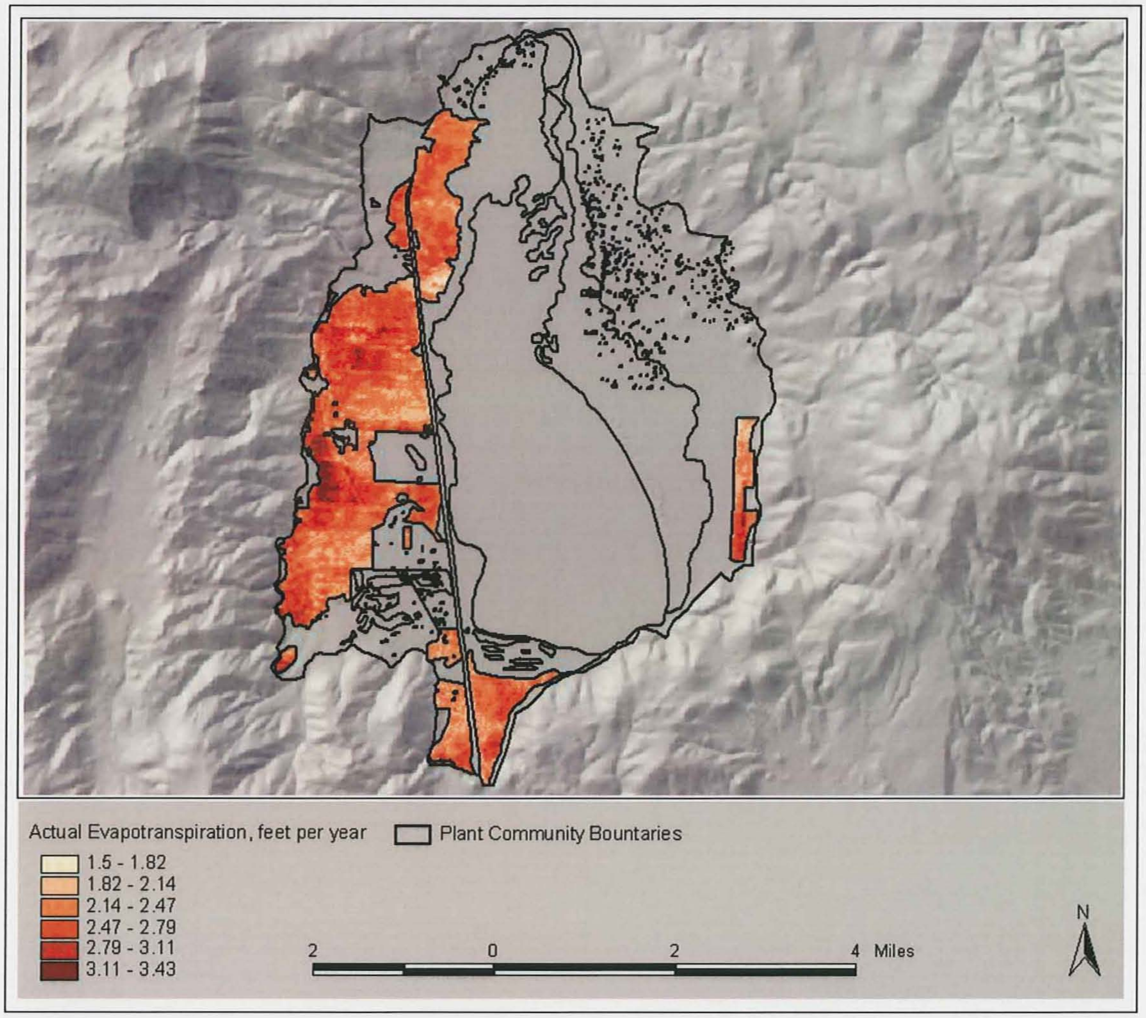


Figure 17. Regional AET from pasturelands estimated by applying a linear function between AET and percent plant cover.

from images acquired on June 28, 1984, August 26, 1993, and August 19, 2000. Figure 17 illustrates spatially distributed AET estimates for pasturelands of Washoe Valley.

ET from Xerophytes

Xerophytes are plants that have adapted to dry environmental conditions by developing mechanisms to store available water and prevent water loss. Xerophytes commonly occur in upland areas where depth to ground-water is too great to support phreatophytes communities. In these areas the source of water for ET is soil moisture derived from precipitation. Xerophytes that commonly occur on mountain-block, alluvial-fan, and valley-floor areas of Washoe Valley include, antelope bitterbrush *(Purshia tridentata)*, low sagebrush (*Artemisia arbuscula)*, bottleneck squirrel tail (*sitanion hystrix*), black sagebrush (*Artemisia nova*) and green rabbitbrush (*Chrysothamnus viscidiflorus*).

Little is known about rooting depth, distribution and root water uptake from xerophyte vegetation (Hendrickx and Walker, 1997). Previous studies have used crop coefficients to provide a means of relating AET to standard references such as PET and pan evaporation. Crop coefficients have been used extensively for irrigated agriculture but only limitedly on rangelands with xerophyte vegetation (Wight, 1982). Researchers that have developed xerophyte crop coefficients (Wight and others, 1986; Wight, 1990), estimated AET by using lysimeter measured ET for conditions where evaporation was minimal and water was nonlimiting for transpiration. Since these studies do not consider water as a limiting factor for transpiration, it would not be appropriate to apply rangeland crop coefficients to xerophyte or rangeland plant communities that experience water limiting conditions.

Few researchers have measured AET from xerophyte communities under natural water limiting conditions. Loeltz and others (1949) estimated mean-annual consumptive use by xerophyte vegetation in Paradise Valley, Nevada to be 0.75ft/yr, which equaled cumulative precipitation for the study period. Estimates of water-yield from watersheds tributary to Eagle Valley (Maurer and Berger, 1997) show similar estimates of consumptive use, ranging from 0.67 to 1.04 feet per year for low altitude watersheds with xerophyte vegetation like that on alluvial-fan and mountain-block areas of Washoe Valley. A recent study (Berger, 2001) measured actual ET from several plant communities in Ruby Valley, Nevada using the Bowen-ratio method, which is based on characteristics of the energy budget and is considered an accurate method for estimating actual ET. For the 2000 water year, actual ET from xerophyte vegetation in Ruby Valley, Nevada was estimated to be 0.99 feet per year using the Bowen-ratio method (Berger 2001). Precipitation for the 2000 water year was 0.65 feet, and was measured at the Ruby Valley refuge headquarters several miles away at a lower elevation because of vandalism problems at the study area.

After analyzing previous studies, all of which conclude that xerophyte communities in lower elevations consume all or nearly all available water from precipitation, it is assumed that ET from xerophytes on the valley-floor in Washoe Valley equals the mean area weighted precipitation for xerophytes of 1.15 feet per year (Figure 18). This ET estimate should be considered as a maximum rate of ET from xerophytes. To calculate the volume of ET from xerophytes communities on the valley-floor of

Washoe Valley, the ET rate of 1.15 feet per year was attributed in the GIS and multiplied by the xerophyte area of 4728 acres.

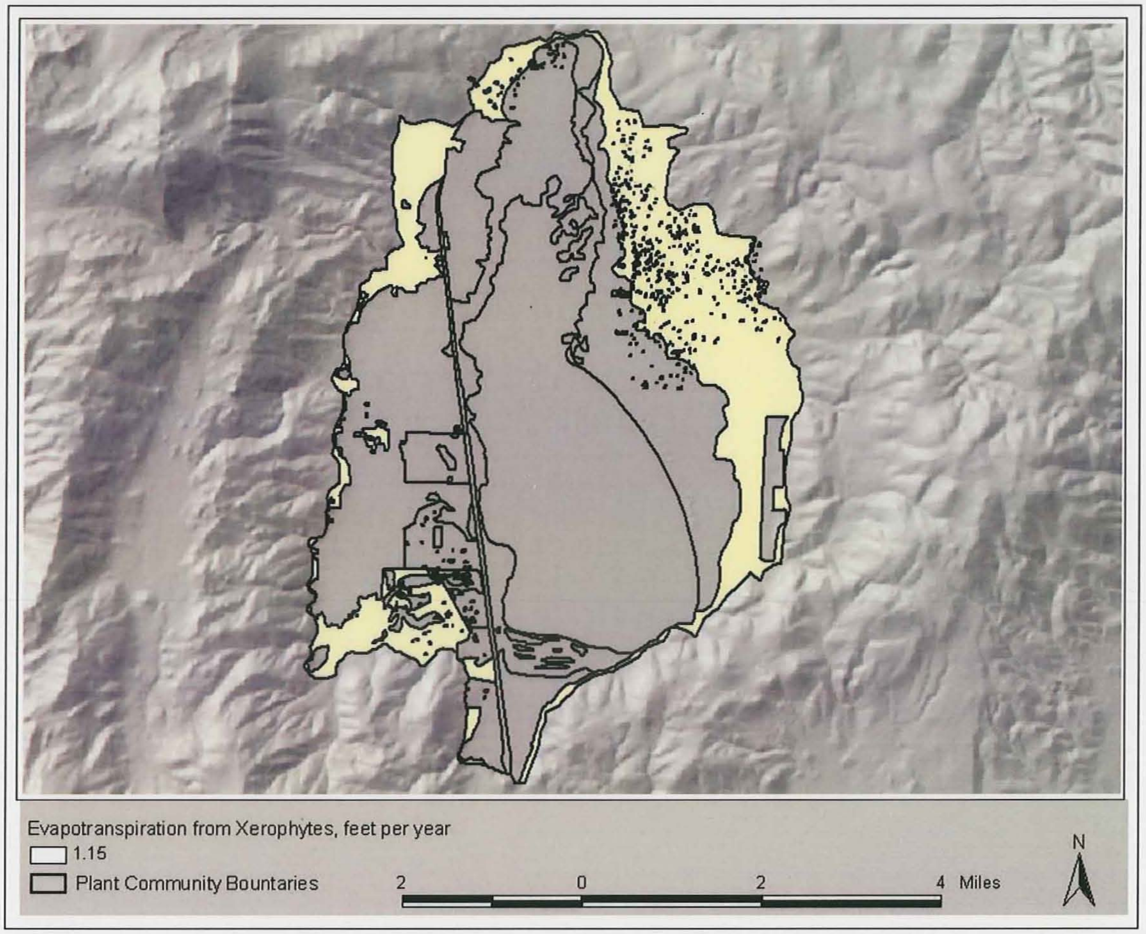


Figure 18. Evapotranspiration from xerophyte communities and is assumed to equal mean-annual precipitation.

Evaporation from Open-water Bodies

For shallow water bodies in semi-arid environments, water-advected heat and change in heat storage is significant in the energy balance, and depends on the area, volume, and residence time relative to the time period of the analysis (Dingman, 2002). Because of these non-meteorologic factors in the energy balance, it is not generally possible to develop equations for predicting the evaporation for a particular lake from meteorologic data alone. Analogous to PET, hydrometerologists have developed a concept of free-water evaporation in order to create general methods for estimating evaporation from surface-water bodies. Free-water evaporation is defined as evaporation that would occur from an open-water surface in the absence of advection and changes in heat storage (Chow, 1964). Many researchers have developed climatic correction factors to adjust mapped or computed free water evaporation to account for the advection and heat storage effects in a water body. Dorenbos and Pruitt, 1977 found that free-water evaporation was very similar to PET, and developed regional climatic correction factors that could be used to adjust PET estimates. This method of applying a climatic correction factor was used to estimate open-water evaporation in Washoe Valley, in which the PET rate of 4.94 feet per year, derived by Shevenell, 1996 was applied the following equation of

$$E_{sw} = (c)(PET) \qquad \text{Eq. 19}$$

(Doorenbos and Pruitt, 1977) where, E_{sw}, equals open-water evaporation, in feet per year, and c equals the climatic correction factor. Doorenbos and Pruitt (1977) suggest a climatic correction factor of 0.98 for semi-arid environments with moderate winds. To calculate the mean-annual volume of evaporation from open-water bodies, mean-annual lake area of 5,177 acres, plus water bodies of 95 acres was multiplied by the evaporation rate of 4.84 feet per year.

Surface Water Outflow

Surface-water leaves the Washoe Valley HA via Steamboat Creek, which is tributary to the Truckee River. In 1863 a small wooden dam was build at the head of Steamboat Creek just north of U.S. Highway 395 (Rush, 1967). In 1889 the wooden dam was replaced by a concrete structure that still exists today. The purpose of the dam is to regulate water release and storage for downstream irrigation in Pleasant Valley and the Truckee Meadows. Outflow from Little Washoe Lake into Steamboat Creek has been measured since 1966. Outflow data acquired from the Federal Water Master for the period of 1966 to 2001 indicates that mean-annual outflow into Steamboat Creek is 13,643 acre-feet per year (appendix 21).

Domestic Consumption

Currently, ground-water is the only source of water available for domestic use in Washoe Valley, in which residences receive and discharge water through well and septic systems. Due to this fact, the primary loss of water from domestic use is ET from irrigated vegetation within residential areas. Plant communities in residential areas consist mostly of xerophyte shrubs, however there is a significant amount of turf grass, including a 160 acre golf course. To estimate the area of turf grass with in residential areas, one-foot resolution aerial photography acquired in June of 2000 (Triathlon Inc., 2000), was used as a background image in the GIS to digitize polygons around turf grass. Polygons were digitized at a 1:500 scale in ArcView© using the ESRI digitizer extension (Figure 19). To estimate the rate of AET from turf grass a crop coefficient of 0.70 (Allen and others, 1990) was multiplied by the PET estimate of 4.94 feet per year, derived from

Shevenell, 1996. Polygons were then assigned attributes of calculated area, and the calculated AET rate of 3.45 feet per year. The volume of ET or ground-water consumption from domestic use was calculated in the GIS by multiplying the turf grass area of 266 acres by the depth of AET.

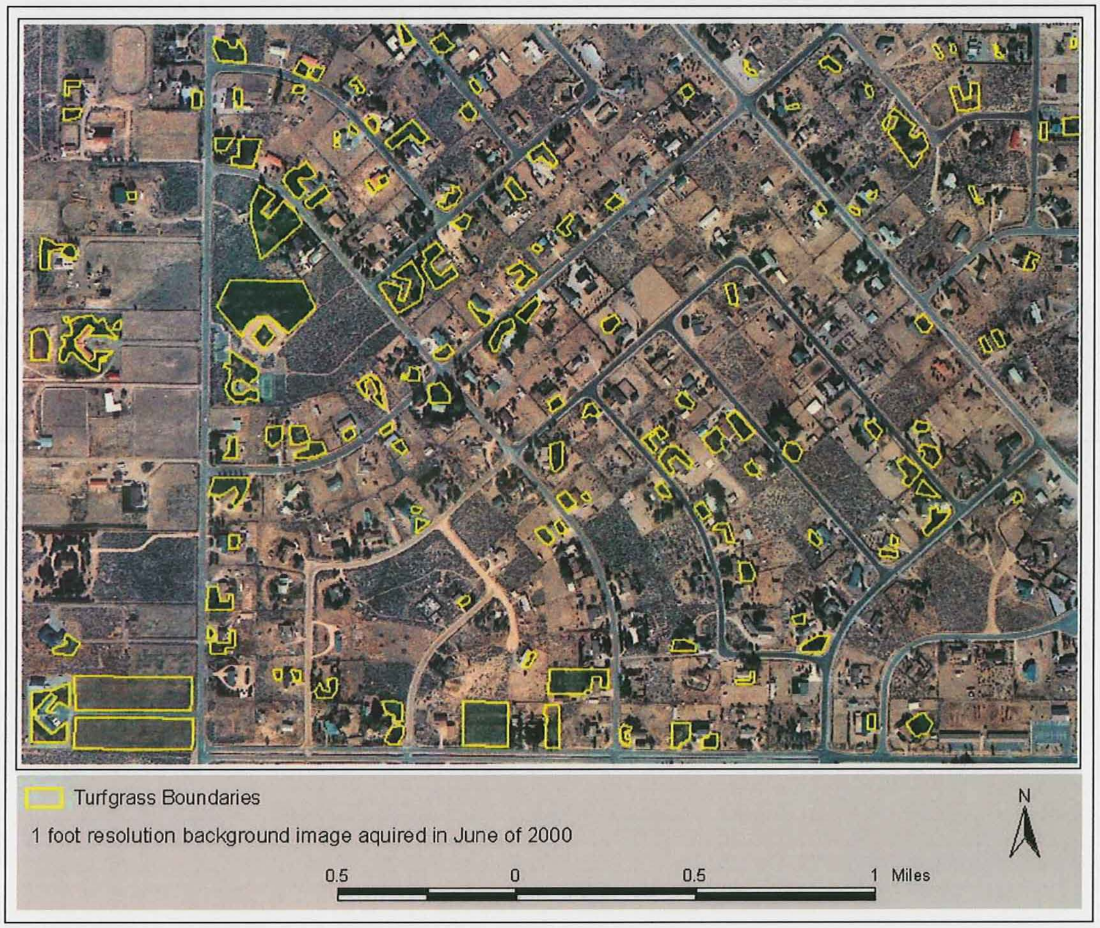


Figure 19. Turf grass boundaries used for estimating domestic consumption by multiplying the AET rate by the total acreage of turf grass.

<u>Exports</u>

The sole export of water from Washoe Valley is facilitated by the Marlette-Hobart Water Supply System (MHWS), a historical system of impoundments originally developed in the 1870's to transmit water to the Comstock region of Nevada. The

MHWS is currently the sole water delivery system to Virginia City and also provides water to Carson City. The State of Nevada holds several permitted water rights for the MHWS. The total available water for the Upper Franktown and East Slope drainages under the water rights for the MHWS is 7240 acre feet per year (written communication 2003, Carson Water Subconservancy District). However, environmental issues associated with pumping from Marlette Lake, available yield from the East Slope and upper Franktown Creek drainages, and inadequate facilities to store or distribute the full water right volume limits this total.

The East Slope drainage basin consists of upper reaches of several drainages geographically tributary to Franktown Creek below the Red House diversion structure (Figure 20). The basin is defined by the existence of collection systems that intersect several small creeks and transport water through a pipeline that traverses eastward to the Red House diversion structure. The drainage area that contributes to the pipe system is roughly 1.8 miles long, 1.1 miles wide, and comprises about 1,291 acres. The Upper Franktown Creek drainage basin naturally captures waters that discharge to Hobart Reservoir and the Red House diversion structure, and is about 2.6 miles long, 1.3 miles wide, and comprises about 2,054 acres.

The Carson Water Subconservancy District (CWSD) contracted with Brown and Caldwell in 2000 to investigate a phased approach to increase the surface-water volume to Carson City and upgrade the capacity of the existing MWHS System. The study evaluated potential improvements and estimated the available yield for dry, average, and wet conditions from the East Slope and upper Franktown Creek Basin. The USGS established permanent gaging stations on Franktown Creek below Hobart Reservoir in the early 1970s, and has intermittently monitored stream flow in several drainages of the East Slope and Upper Franktown Creek basins. These data were used by Brown and Caldwell to estimate a mean-annual runoff from Upper Franktown and East Slope

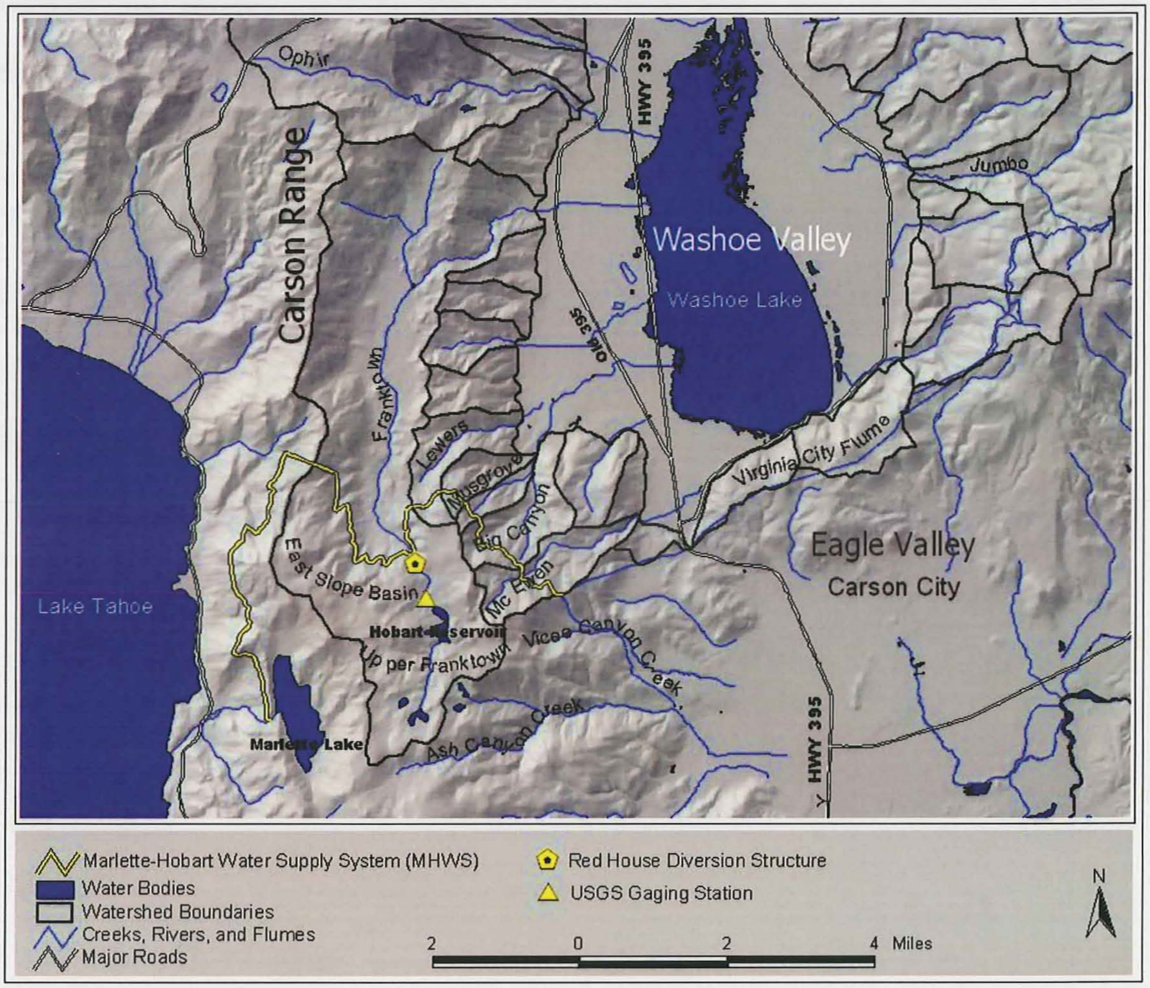


Figure 20. Marlette-Hobart Water Supply System (MHWS), which exports water from creeks tributary to Washoe Valley, to Carson City and Virginia City.

drainages to be 4,262 acre-feet per year, or 45% of the total water right. By analyzing flow records as well as water sales records, the CWSD estimated that 2,718 acre feet per year is actually exported from the Upper Franktown and East Slope drainages to Carson

City and Virginia City (written communication 2003, Carson Water Subconservancy District). This estimate of 2,718 acre-feet per year was used as the total export volume leaving the Washoe Valley HA.

Chapter 4: Results and Discussion of Water Budget Components

The preceding methods applied to the Washoe Valley HA result in a water-budget representing mean-annual conditions where inflow equals outflow, as presented earlier in table 1. For average conditions, annual inflow to the valley floor of Washoe Valley consists of water-yield, plus precipitation that falls on the valley floor and surface of Washoe Lake, and imports from Third Creek and Browns Creek. Outflow consists of evaporation from Washoe Lake, ET from pasturelands, phreatophytes, and xerophyte plant communities, outflow into Steamboat Creek, exports to Carson and Virginia City, and domestic consumption.

In this section the estimates of water-budget components are presented and compared to results from earlier studies (Rush, 1967; Arteaga, 1984; Widmer, 1997) as well as measurement results of runoff and ET acquired in Washoe Valley for the time period of August 2000 through April 2003.

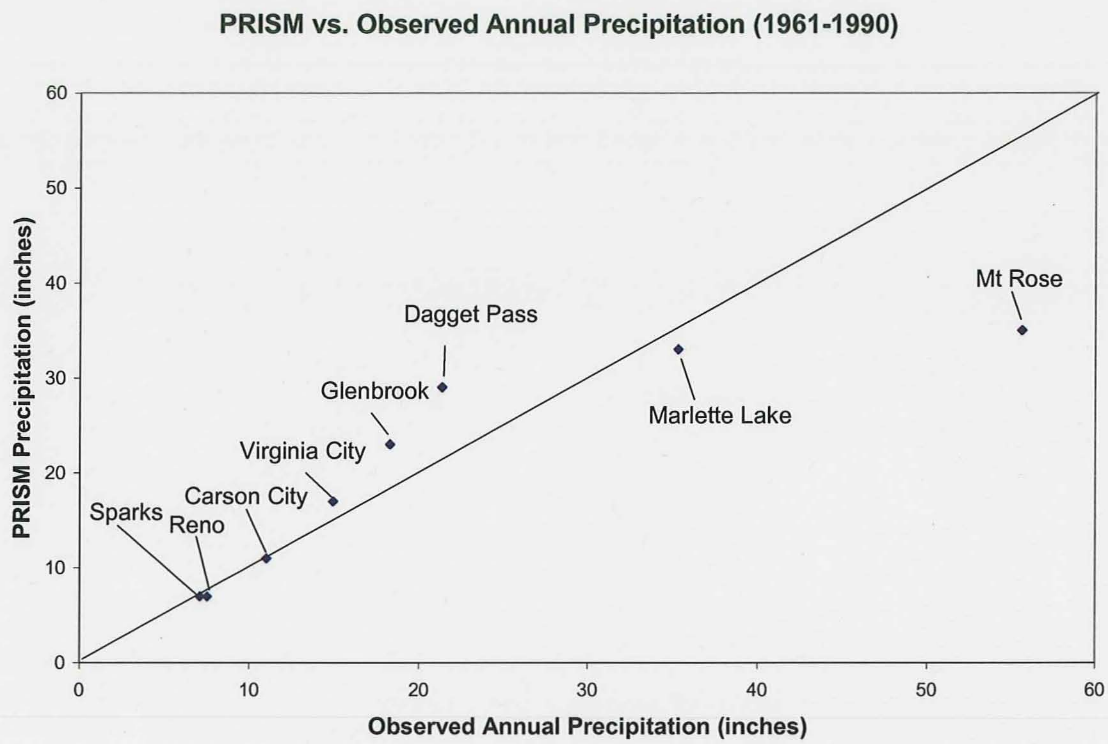
INFLOW

Mean Annual Precipitation

By directly applying the DRI precipitation map to valley floor area of 13,066 acres, and 5,272 acres of open-water, mean-annual inflow from precipitation is estimated as 15,757 and 5,082 acre-feet, respectively. The volume of precipitation for the entire HA of Washoe Valley is estimated to equal 104,730 acre-feet. Arteaga (1984) used the identical DRI precipitation map, and as expected calculated nearly the same volume of mean-annual precipitation that falls within the Washoe Valley HA. Rush (1967) used a precipitation map derived by Hardman (1936), and estimated mean-annual precipitation for the HA to equal 91,000 acre-feet. To quantify the uncertainties associated with the DRI map derived from Klieforth and others (1983), and the PRISM map (Daly and others, 1994) mean-annual precipitation data was acquired from weather stations throughout the area. Respective time periods were used in comparing observed vs. estimated mean-annual precipitation for both DRI and PRISM precipitation maps. Figure 21 illustrates observed verses estimated precipitation showing good correlation of the DRI map to observed precipitation. Some locations were not comparable because the study by Klieforth and others (1983) only analyzed precipitation data for locations that were in the Truckee Meadows HA. Since estimates of water-budget components are heavily dependent on precipitation estimates, understanding uncertainties associated with the precipitation map used is important. Even with good correlation between observed verses estimated DRI precipitation, particularly with the Mt. Rose location, accuracy of the mean-annual spatial distribution of precipitation that falls within Washoe Valley is still somewhat uncertain.

Water Yield, Runoff, and Subsurface Flow from Mountain Block Areas

Water-yield, which is defined as runoff plus subsurface flow at the mountain front, is the primary inflow component to the valley floor of Washoe Valley. The individual predicted water-yields from the 33 watersheds tributary to Washoe Valley are shown in Figure 22. Water-yield estimates were derived by directly applying equations 3 and 4 to the area weighted mean-annual precipitation estimate of each watershed. The



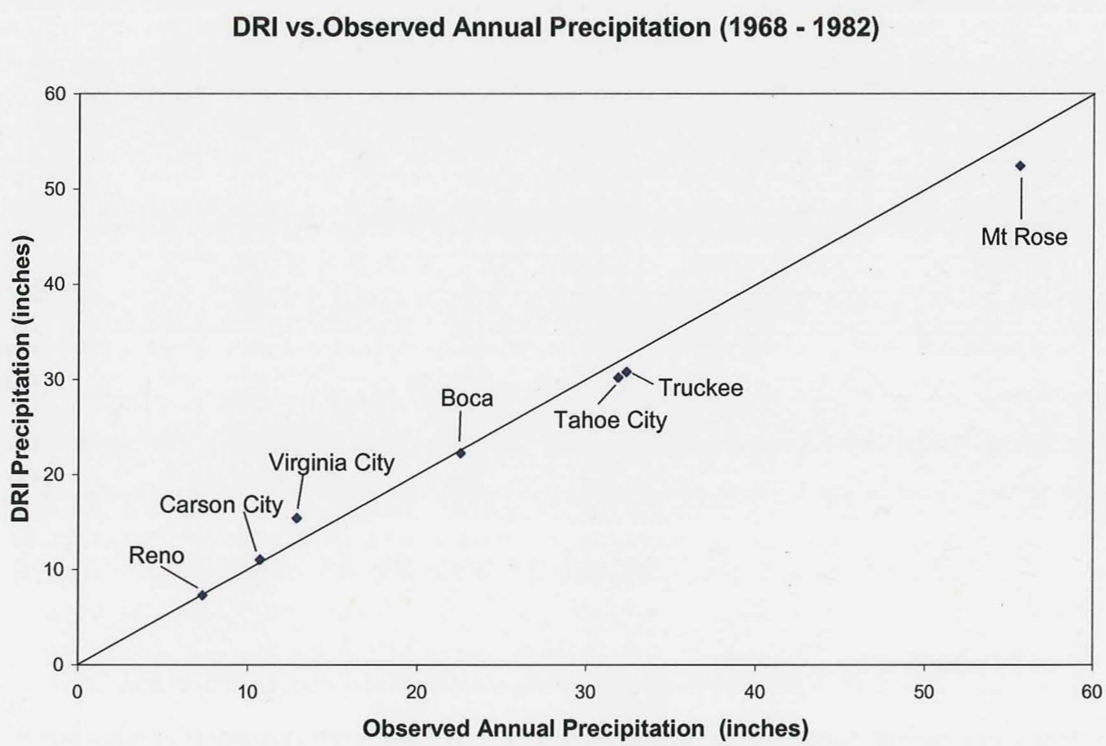


Figure 21. Comparison between estimates from PRISM and DRI precipitation maps and observed precipitation measurements.

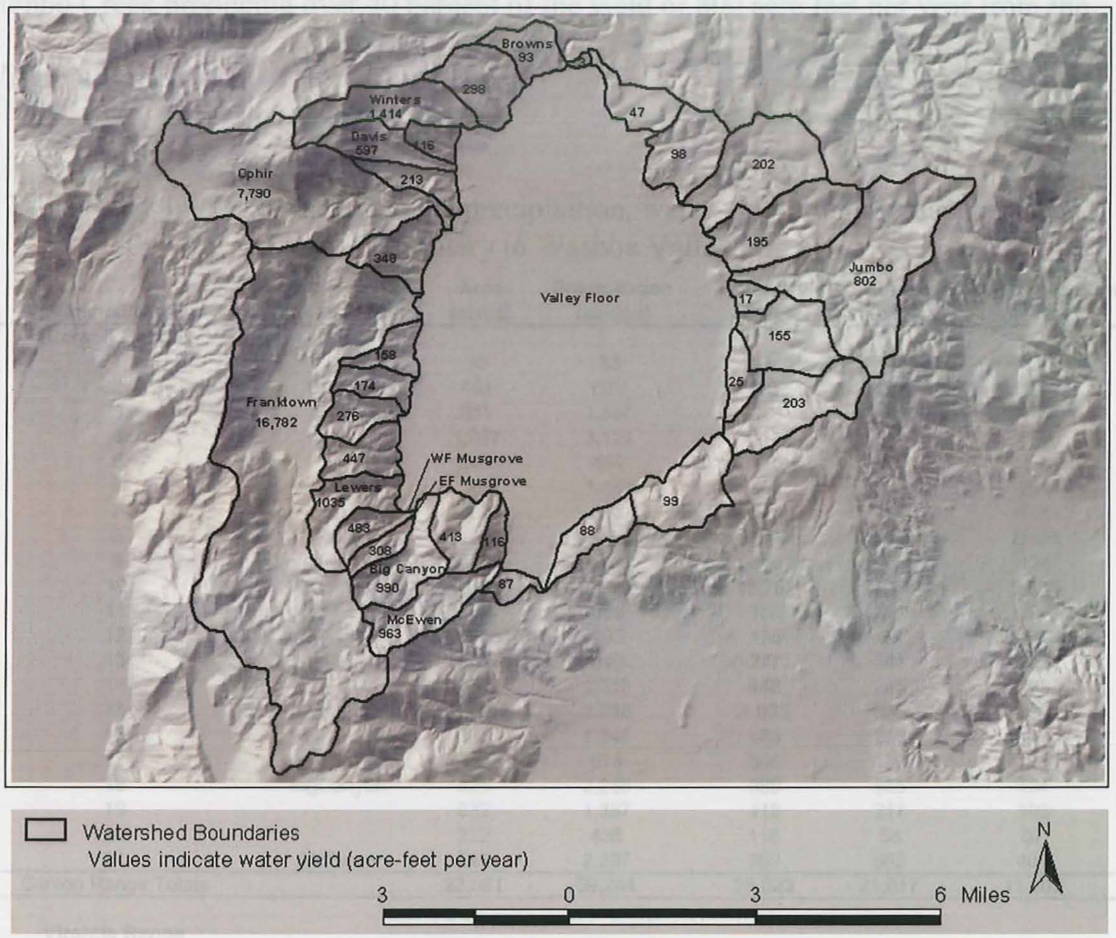


Figure 22. Water-yield estimated for individual watersheds. Water-yield includes runoff plus subsurface flow.

estimated total water-yield from mountain-block areas tributary to Washoe Valley is 35,043 acre-feet. Previous estimates of water-yield by Rush (1967) and Arteaga (1984) were calculated to equal 24,000 acre-feet and 26,000, respectively. The Carson Range produces an estimated mean-annual yield of 33,023 acre-feet, or 94 percent of the total yield to Washoe Valley, with watersheds of Ophir and Franktown Creek consisting of over 74 percent, or 24,500 acre-feet per year of the yield from the Carson Range. The Virginia Range produces an estimated mean-annual yield of 2,021 acre-feet per year with

Jumbo Creek producing over 40 percent of the yield or 800 acre feet per year from the Virginia Range.

Table 5. Estimates of mean-annual precipitation, water-yield, runoff and subsurface flow for watersheds tributary to Washoe Valley.

Watershed Number	Watershed Name	Area (acres)	Precipitation (ac-ft/yr)	Water Yield (ac-ft/yr)	Runoff (ac-ft/yr)	Subsurface Flow (ac-ft/yr)
Carson Range						
1		36	33	3	1	2
2	Browns	481	635	93	39	54
3		811	1,387	298	141	158
4	Winters	1,087	3,124	1,414	856	558
5		249	469	116	57	59
6	Davis	565	1,487	598	344	254
7		423	823	213	107	106
8	Ophir	3,742	13,678	7,790	5,654	2,136
9		679	1,331	349	175	174
10	Franktown	9,869	32,310	16,782	11,149	5,634
11		361	663	158	77	81
12		373	705	175	86	89
13		450	949	277	144	133
14		557	1,310	448	245	203
15	Lewers	759	2,230	1,035	636	399
16	Musgrove	358	1,046	483	296	187
17	Musgrove	235	678	308	187	121
18	BigCanyon	824	2,286	989	585	404
19		632	1,367	413	217	196
20		222	438	116	58	57
21	McEwen	848	2,297	963	562	401
Carson Range Totals		23,561	69,244	33,023	21,617	11,406
Virginia Range						
22		190	356	88	43	44
23		500	634	88	36	52
24		980	991	99	37	63
25		1,238	1,523	203	82	121
26		322	295	26	9	17
27		973	1,185	156	63	93
28		186	180	17	6	11
29	Jumbo	3,108	4,599	802	354	448
30		1,402	1,612	195	77	118
31		1,474	1,689	203	80	123
32		849	906	98	37	61
33		526	504	47	17	30
Virginia Range Totals		11,746	14,475	2,021	841	1,180
Mountain Block Area Totals		70,615	83,719	35,043	22,458	12,586

Runoff from mountain-block areas was calculated by applying equations 2 and 5 to each watershed area weighted mean-annual precipitation estimate. Results indicate that runoff from mountain-block areas of Washoe Valley consists of 64 percent of the water-yield, and 13 percent of mean-annual precipitation that falls on mountain-block areas, which equals nearly 22,500 acre feet per year. Runoff estimated in this study agrees well with previous estimates of 23,000 and 26,000 acre-feet per year (considered water-yield), calculated by Rush (1967) and Arteaga (1984), respectively. The Carson Range produces 96 percent or about 21,500 acre-feet per year of the total runoff. The largest watershed of the Carson Range located in Washoe Valley, named Franktown Creek, is estimated to produce over 50 percent or 11,150 acre-feet of the total runoff from the Carson Range. However, the runoff estimate of 11,150 acre-feet per year is not accurate due to the presence of the Marlette-Hobart Water Supply System (MHWS) as well as diversion structures operated and maintained by the Franktown Irrigation Company. Exports volumes of the MHWS are available and have been estimated at 2,718 acre-feet per year, however diversion volumes of surface-waters below the MHWS are largely unknown.

Differences between water-yield estimates used in this study and estimates from Rush (1967) and Arteaga (1984) are simply due to the fact that subsurface flow at the mountain front was considered negligible. In the semi-arid West, the mountains must be considered as major sources of subsurface flow or "hidden recharge", and when neglected the development of alluvial basin water resources are likely under designed (Feth, 1964). Physically based measurements of mean-annual subsurface flow and measured runoff at the mountain front of Eagle Valley that were used to construct mean-annual precipitation water-yield and runoff regression functions used in this study, have estimated that the Carson and Virginia Range ranges produce yield from 6-11 percent and 21-27 percent of the mean-annual precipitation, respectively (Maurer and Berger, 1997). After applying equations 2-5, estimates of subsurface flow and water-yield from mountain-block areas of Washoe Valley resulted in 7.5 and 21 percent of the mean-annual precipitation, respectively. Estimates of subsurface flow were calculated as the difference between water-yield and runoff. Water-yield, runoff and subsurface flow from mountain-block areas of Washoe Valley are listed in Table 5.

To show the statistical uncertainty between relationships of mean-annual precipitation, and water-yield and runoff, graphs of the 95 percent prediction interval were plotted as upper and lower bounds, shown in Figure 23 and 24. Notice that the upper and lower bounds diverge from the regression line for both water-yield and runoff.

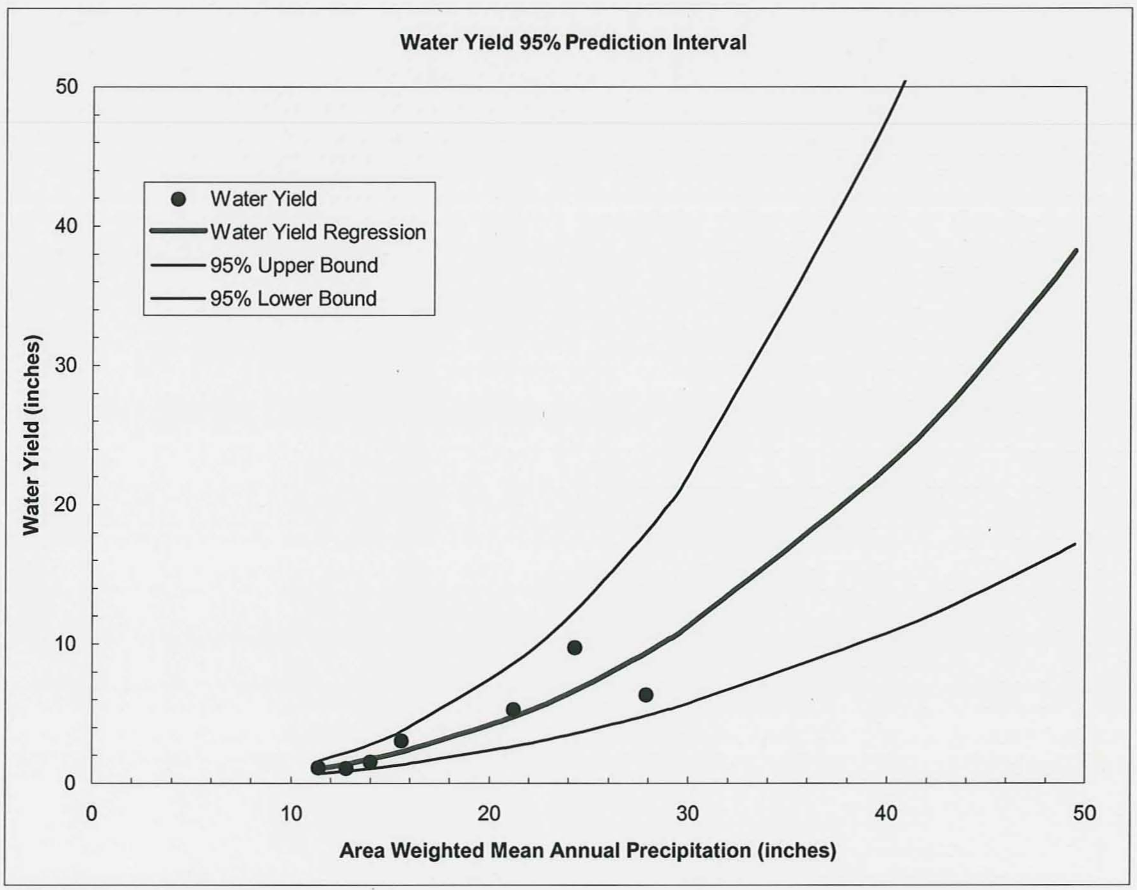


Figure 23. Precipitation water-yield regression with upper and lower 95% prediction intervals. The large divergence is mainly due to the lack of observation points.

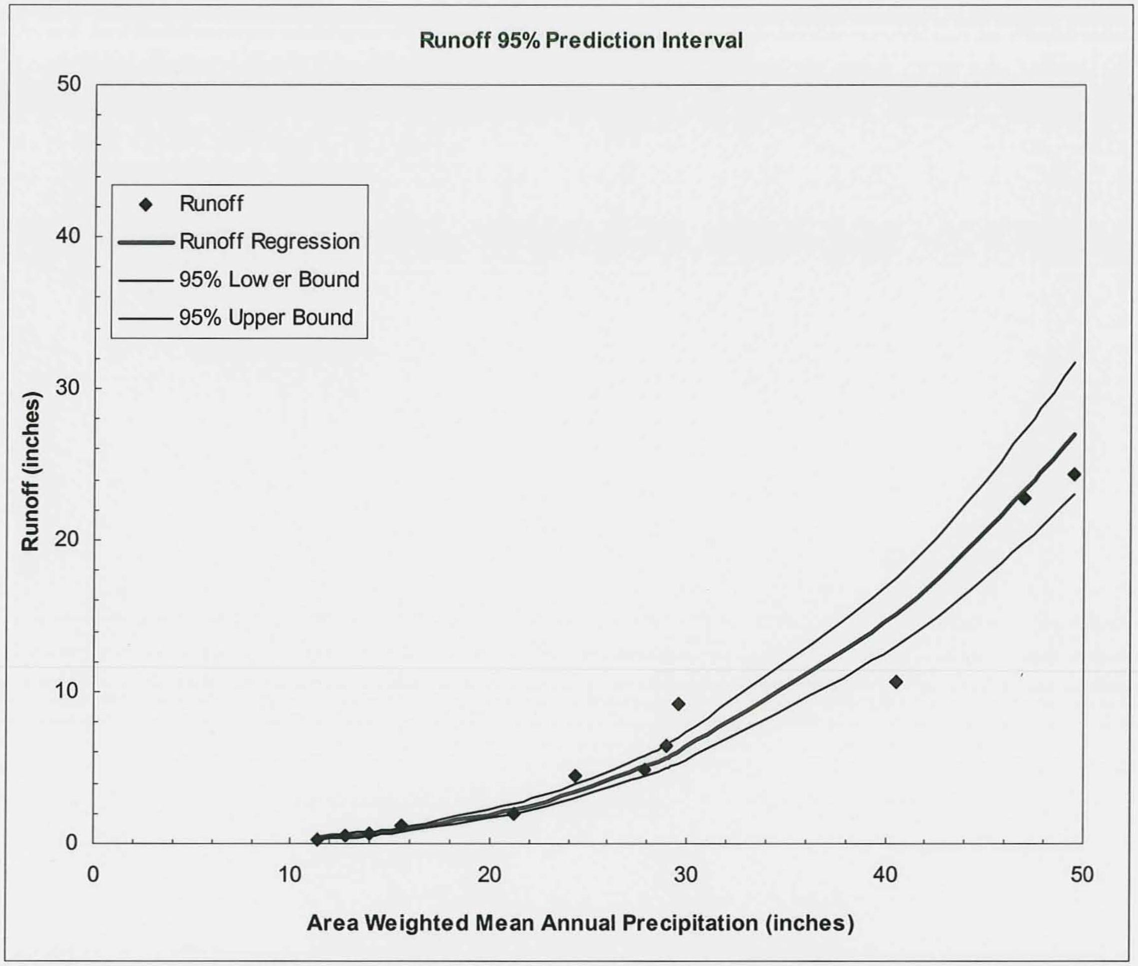


Figure 24. Precipitation-runoff regression with upper and lower 95% prediction intervals. The divergence is less than the water-yield prediction intervals mainly because of four additional observation points.

The divergence is mainly due to the lack of observation points of water-yield and runoff, making the statistical predictability of both components fairly low. As mentioned earlier, water-yield and runoff regression and 95% prediction interval curves are not valid when the slope is larger than one. The physical justification for this is that a unit increase in mean-annual water-yield and runoff cannot be more that a unit increase in mean-annual precipitation because the change in ET approaches zero as the mean-annual precipitation increases. Therefore, to evaluate the predictability when the slopes of the regression and 95% curves are greater than one would not be practical. Regardless of the statistical uncertainty or predictability, an effort was made to check the agreement between measured and estimated runoff from mountain-block areas in Washoe Valley.

As part of this study, Washoe County Department of Water Resources installed five stream gages in Washoe Valley from July to September of 2000. Stream gages were installed at the mountain front of Browns Creek, Davis Creek, Ophir Creek, Franktown Creek and Lewers Creek. By applying rating curves relating the stage to discharge measurements, estimates of average daily discharge were calculated. Average daily discharge estimates from gaged creeks in Washoe Valley are presented in appendix 1-14. Several of the gages are below diversions and therefore cannot be used in the water-budget analysis because diversion volumes are unknown. However, Ophir Creek was chosen to be used as a measure of the uncertainty in estimating runoff because of the absence of significant diversions and the existence of a nearby SNOTEL site at the Mt. Rose Ski Resort. The stream gage on Ophir Creek has collected hourly stage measurements from October 2000 to April 2003. The period of record for the 2002 water year is nearly complete for Ophir Creek and provides a rough estimate of the annual runoff, however it does not represent mean-annual conditions, as the Mt Rose Ski Resort SNOTEL site only measured 84 percent of normal cumulative precipitation for the 2002 water year. During the 2002 water year discharge measurements for 47 days between August 16 and September 31 were not recorded on Ophir Creek due to equipment malfunction. Regardless of missing data, the cumulative discharge from Ophir Creek for the 2002 water year was measured to equal 4,621 acre-feet, or 81 percent of the simulated value derived from the mean-annual precipitation-runoff regression function. The agreement between the percent of normal between measured and simulated runoff from Ophir Creek, and precipitation, gives confidence in the accuracy of the runoff regression function and respective results provided by this study.

The amount of subsurface flow occurring at the mountain front of Washoe Valley is largely unknown and is not easily measurable. Therefore, comparisons between measured and simulated water-yield cannot be analyzed. However, due to similarities of measured runoff in Eagle Valley and Washoe Valley, and given that surface and ground-water interactions are similar for both valleys, it is probable that subsurface flow occurs at the mountain front of Washoe Valley. With no measurements of subsurface flow available for Washoe Valley, it is assumed that the amount of precipitation that contributes to subsurface flow in Washoe Valley is similar to that of Eagle Valley.

Imports

Import volumes into Washoe Valley are primarily from the Third Creek diversion in Tahoe Meadows. A smaller amount is imported into Washoe Valley via Browns Creek. The Franktown Irrigation Company, which owns, operates, and maintains the diversion structure on Third Creek, is unwilling to provide any information on imported water into Ophir Creek. The stream gage on Browns Creek indicates that 914 acre-feet was imported into Washoe Lake during the 2001 water year. As a rough estimate, the import volume estimated by Rush (1967) and Arteaga (1984) of 4,000 acre-feet per year was used in this study as the mean-annual import volume.

OUTFLOW

ET from Mountain Block Areas

By applying water-yield equations 3 and 4 to the area weighted mean-annual precipitation estimate for each watershed ET from mountain-block areas was estimated. Precipitation that is consumed by ET from mountain-block areas was estimated as the difference between the area weighted mean-annual precipitation and water-yield. Total ET from mountain-block areas is estimated to equal 48,676 acre-feet per year (Table 6).

Few researchers have attempted to measure ET in high elevation mountain-block environments due to complexities involving equipment cost, installation, maintenance, and data collection. Due to the absence of alpine research that can provide spatially distributed estimates of ET, no comparisons can be made between estimates derived by water balance residuals, and direct measurements. When comparing estimates of ET from mountain-block areas to other studies it is important to realize that many researchers have neglected to include subsurface flow in water-yield estimates, resulting in over estimates of ET from mountain-block areas. For example, Arteaga (1984) estimated ET from mountain-block areas as the difference between precipitation and runoff (what he calls "water-yield") and estimated that 68% of precipitation is consumed by ET. By including subsurface flow in the analysis such as this study, results indicate that 58% of precipitation is consumed by ET in mountain-block areas of Washoe Valley.

Table 6. Mountain-block ET for individual watersheds estimated as the difference between precipitation and water-yield.

Watershed Number	Watershed Name	Area (acres)	Precipitation (ac-ft/yr)	Water Yield (ac-ft/yr)	ET (ac-ft/yr)
Carson Range					
1		36	33	3	30
2	Browns	481	635	93	541
3		811	1,387	298	1,089
4	Winters	1,087	3,124	1,414	1,710
5		249	469	116	353
6	Davis	565	1,487	598	889
7		423	823	213	610
8	Ophir	3,742	13,678	7,790	5,888
9		679	1,331	349	982
10	Franktown	9,869	32,310	16,782	15,527
11		361	663	158	505
12		373	705	175	530
13		450	949	277	672
14		557	1,310	448	862
15	Lewers	759	2,230	1,035	1,194
16	Musgrove	358	1,046	483	563
17	Musgrove	235	678	308	370
18	BigCanyon	824	2,286	989	1,297
19		632	1,367	413	954
20		222	438	116	322
21	McEwen	848	2,297	963	1,335
Carson Range Totals		23,561	69,244	33,023	36,221
Virginia Range					
22		190	356	88	269
23		500	634	88	546
24		980	991	99	892
25		1,238	1,523	203	1,320
26		322	295	26	269
27		973	1,185	156	1,030
28		186	180	17	163
29	Jumbo	3,108	4,599	802	3,798
30		1,402	1,612	195	1,417
31		1,474	1,689	203	1,486
32		849	906	98	808
33		526	504	47	457
Virginia Range Totals		11,746	14,475	2,021	12,455
Mountain Block Area Totals		70,615	83,719	35,043	48,676

ET from Pasturelands

By directly applying equation 18, which assumes a linear relationship between plant cover to actual evapotranspiration (AET or potential evapotranspiration multiplied by a crop coefficient for pasturelands of 0.69) to 3,859 acres of pastureland, 9,335 acre-feet or 13% or of total outflow is consumed from these areas. As with all budget components consisting of ET, the volume of outflow is dependent on the rate of ET and the area in which the ET rate is applied. Studies by Rush (1967), Arteaga (1984) and Widmer (1997) have estimated ET from pasturelands and are compared to results from this study in Table 7.

In order to make comparisons of the area and rate of ET from crop and pasture areas, which in this study is referred to as pasturelands, area weighted estimates of ET were calculated for previous studies. There are significant differences between this study and previous studies in both the rate of ET and the extent of pasturelands. The main reasons for these differences are due to the methods used to calculate ET, and time period in which pasturelands were delineated. Rush (1967) did not analyze ET from pasturelands directly, instead he estimated the volume of diversion flow from creeks tributary to Washoe Lake used for irrigation, and well pumpage used for irrigation. By adding the pumpage and diversion volumes proposed by Rush (1967), and dividing

Table 7. Estimates of crop and pastureland ET from studies in Washoe Valley

Study	Acres of Crop and Pasturelands	Evapotranspiration Rate (feet per year)	Volume of ET from Pasturelands (acre-feet)
This Study	3,859	2.41[a]	9,335
Rush (1967)	4,800	1.75[b]	8,424
Arteaga (1984)	2,410	3.58[c]	8,627
Widmer (1997)	4,800	3.23[d]	15,550

a) Rate is an area weighted average derived from the 30 meter ET grid for pasturelands.
b) Rate was derived by adding the volume of consumption of surface-water diversions, irrigation by wells and ground-water ET from pasturelands, and dividing by the area of pasturelands.
c) Rate is an area weighted average for areas of crop and pastureland for the west side and east side of Washoe Valley.
d) Rate is an area weighted average for cropland and pasturelands.

by the area of pasturelands, an area weighted ET rate was estimated for comparison purposes. Arteaga (1984) analyzed the extent of crop and pasturelands separately for the west and east side of Washoe Valley and included non-irrigated pasture into a native vegetation classification, therefore the total area and rate of ET of crop and pasturelands cannot be directly compared. Widmer (1997) used areas of crop and pasturelands derived by Rush (1967) and used PET rates developed from local weather data published by Water Research and Development (1987). By applying PET estimates to areas of crop and pasturelands, which were delineated in 1966, the volume of ET estimated by Widmer (1997) seems high. The volume of ET provided by this study has uncertainties, however by using a PET rate derived from long term weather data provided by Shevenell (1996), and realizing that ET is not uniform over the entire extent of pasturelands, a spatially variable estimate of ET that is a function of plant cover, is probably more appropriate.

To analyze the uncertainty of the PET estimated used in this study, PET estimates acquired from weather stations in Washoe Valley are compared to the estimated derived by Shevenell (1996). Two weather stations are located in Washoe Valley located on the west side and east side of Washoe Lake, and have been calculating daily PET from October 1, 2000 to present (Appendix 15-20). However, several equipment problems occurred at both weather stations resulting in missing data. Therefore the water year of 2001 provides the only complete cumulative annual PET estimate available for both weather stations. The west side weather station is located within a pasture at the mountain front of the Carson Range and calculated cumulative PET of 50 inches or 4.1 feet per year. The east side weather station calculated a cumulative PET of 54 inches or 4.5 feet per year. The east side weather station is located near Washoe Lake and provides a better representation of climatic conditions occurring on the valley floor. Due to this fact the PET calculated from the east side weather station is used to compare to the PET estimate provided by Shevenell (1996). The cumulative annual PET calculated from the east side weather station for the 2001 water year does not represent mean-annual conditions, therefore mean-annual air temperature and the mean temperature for 2001 from a weather station in Carson City was analyzed to provide a index of the percent normal PET. The mean-annual air temperature at the Carson City weather station for 49 years is 50.32 degrees Fahrenheit, while the annual temperature for 2001 was equal to 46.96 Fahrenheit or 93 percent of normal. Likewise the cumulative PET estimate from the east side weather station in Washoe Valley equals 90 percent of mean-annual PET derived by Shevenell (1996). The agreement of the percent of normal between air temperature and PET gives confidence in Shevenell's mean-annual PET estimate used in this study.

A more appropriate approach for estimating spatially distributed estimates of AET from pasturelands might be accomplished by applying a model named "SEBAL", which stands for Surface Energy Balance Algorithm for Land. SEBAL is an image processing model comprised of twenty-five computational steps that calculates ET and other energy exchanges at the earth's surface using satellite images measuring visible, near infrared, and thermal infrared radiation (Bastiaanssen and others, 1998). In operation SEBAL uses at least 9 images acquired from the same year, commonly from Landsat 5 and 7 satellites, and calculates ET by generating grids of net surface radiation, soil heat flux, and sensible heat flux to the air. By subtraction the soil heat flux and sensible heat flux from the net radiation at the surface, the residual energy flux (latent heat flux) is assumed to equal ET. Researchers have applied SEBAL to areas of southwest Idaho, in a collaborative effort with the Idaho Department of Water resources to ultimately monitor water right violations and estimate recharge from irrigated agriculture (Allen and others, 2002; Morse and others, 2001; Tasumi, 2000).

SEBAL was not applied to pasturelands in the Washoe Valley area due to the cost of purchasing 9 satellite images yearly. Although somewhat expensive SEBAL provides water resource managers the ability to estimate more appropriate values of recharge and ET at large scales.

Evaporation from Open Water Bodies

Outflow in the form of evaporation from Washoe Lake and other open-water is dependent on the rate of evaporation and open-water surface area, which was estimated to equal 4.94 feet per year from 5,177 and 701 acres, respectively. The method for estimating the rate of evaporation and surface area of open-water is discussed in chapter III. When comparing the estimates of the rate of evaporation, and surface area of Washoe Lake to past studies by Rush (1967) and Arteaga (1984) several differences arise. Table 8 lists estimates of mean-annual surface area, and rate of evaporation used for comparisons. Rush (1967) and Arteaga (1984) both used the same estimate of mean-annual lake stage of 5027 feet, as estimated in this study. However, Rush (1967) and Arteaga (1984) estimated the surface area of Washoe Lake to equal 4,000 and 4,900 acres, respectively. Figure 25 illustrates the generalized land status of the valley floor of Washoe Valley proposed by Rush (1967), where the dashed line represents the mean-annual lake area. Realizing that the mean-annual lake area was a rough estimate, Rush (1972) performed a bathymetric reconnaissance of Big and Little Washoe Lakes and developed a relation between lake stage, area, and volume (Figure 26). Arteaga (1984) estimated the mean-annual lake area to equal 4,900 acres by applying the relation

Table 8. Comparison of open-water evaporation to previous studies

	Washoe Lake Surface Area (acres)	Open-water Surface Area (acres)	Evaporation Rate (feet per year)	Volume of Evaporation from Open-water Bodies
This Study	5,177[a]	701[a]	4.94[a]	26,046
Arteaga (1984)	4,900[b]	-	4.6[b]	23,000
Rush (1967)	4,000	-	3.5[c]	14,000

a) Lake surface area derived from GIS by using satellite imagery acquired during mean-annual lake stage. Open-water areas estimated from GIS by using one-foot resolution aerial photography. Rate derived from adjusting the PET rate to a climatic correction factor of 0.98.
b) Lake surface area derived from a stage/lake area relationship proposed by Rush (1972). It is uncertain if the lake area was modified because the relationship proposed by Rush (1972) estimates more surface area than reported. It is also unclear if open-water areas were considered. Evaporation rate derived from PET data collected in Reno, Nevada.
c) Initially estimated in 1967 prior to a bathymetric reconnaissance in 1972.

between lake stage and area, derived by Rush (1972). Arteagea's estimate of the mean-annual lake area of 4,900 acres, implies a mean-annual lake stage of about 5025 feet according to the relation derived by Rush (1972). However by visually analyzing the graphical relation between lake stage, area, and volume developed by Rush (1972) shown in figure 26, the mean-annual lake area at the time of mean-annual lake stage should equal about 5,300 acres. Regardless of the differences between previous and current estimates, digitizing the lake boundary from a satellite image acquired during the period of mean-annual lake stage, discussed earlier in chapter III, probably gives the best estimate. It is unclear if previous studies by Rush (1967) and Arteaga (1984) included other open-water surfaces in their analysis of total surface area from open-waters.

Evaporation of open-water equal to 4.94 feet per year used in this study is significantly different from past studies. Rush estimated open-water evaporation to equal 3.5 feet per year. This estimate was based on rates determined by Kohler and others (1959) for the United States, and does not account for local climatic and hydrologic conditions such as winds and shallow water. Arteaga estimated open-water evaporation to equal 4.6 feet per year, which was based on PET data collected in Reno, Nevada, derived from a modified Penman equation (Doorenbos and Pruitt, 1977). The difference in the open-water evaporation estimate used in this study to that of the study by Arteaga (1984), might be due to the time period of data acquisition. The period of record used by Arteaga (1984) to estimated mean-annual PET is unclear. The PET estimate used

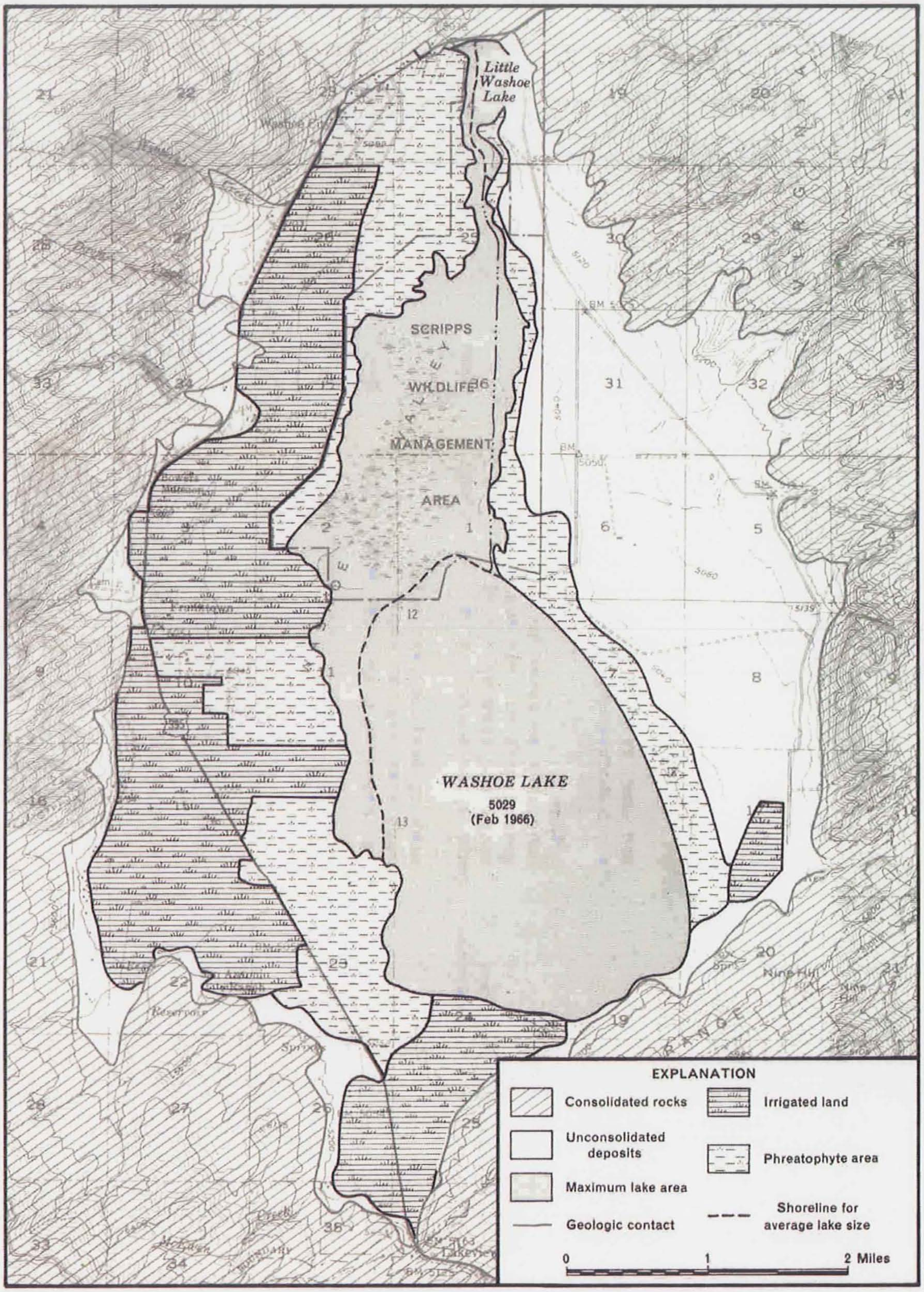


Figure 25. Generalized land status map proposed by Rush (1967). Figure copied from Rush (1967).

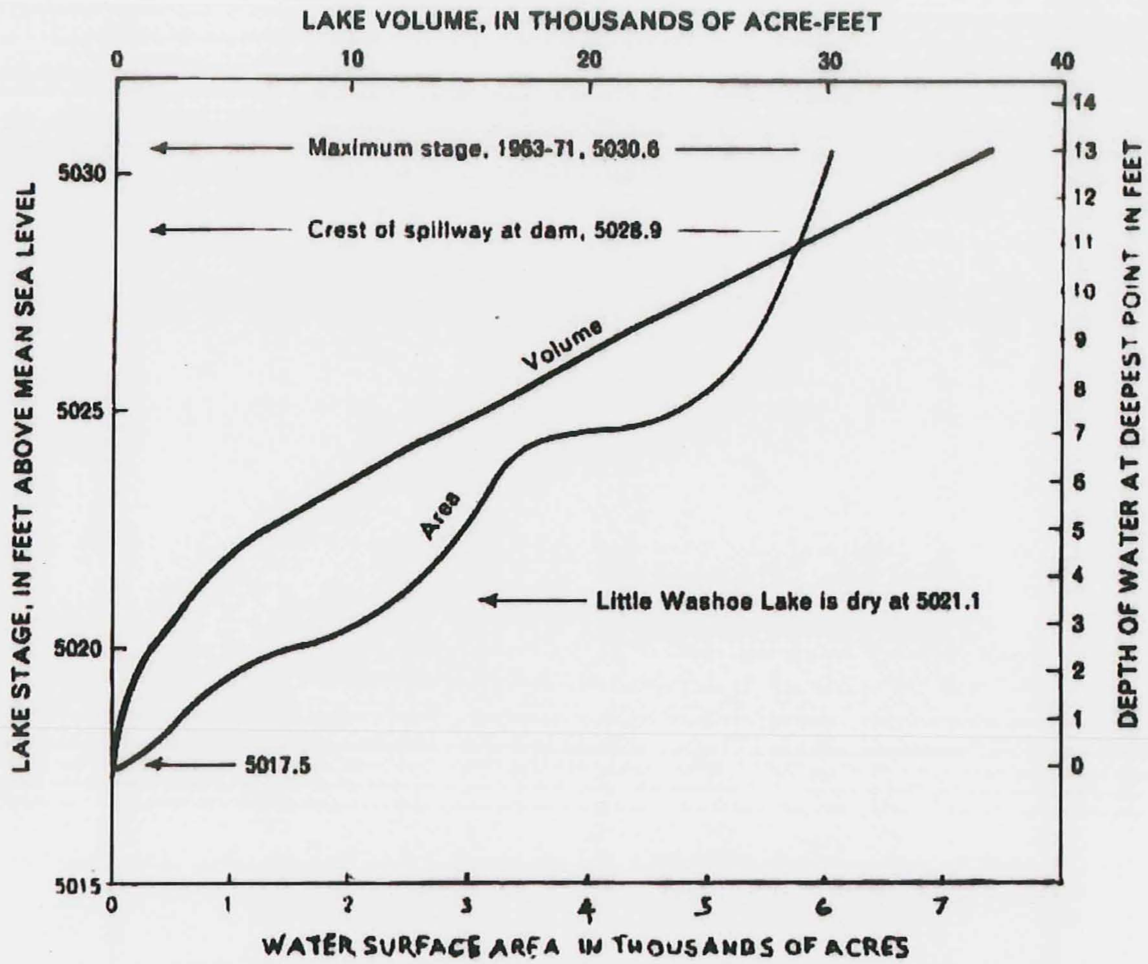


Figure 26. Relation between lake stage, surface area and volume of Big and Little Washoe Lakes (Rush, 1972). Figure modified from Rush (1972).

in this study derived by Shevenell (1996) is probably the most accurate for representing local mean-annual conditions, since it represents conditions for a period of record of at least 10 years and was collected from numerous local weather stations.

ET from Phreatophytes

By applying methods developed by Nichols (2000) for estimating ground-water discharge from phreatophyte areas, and adding 12.9 inches per year of mean-annual precipitation that falls on phreatophyte areas, 11,264 acre-feet per year or 16% of the total outflow is consumed by phreatophytes. Ground-water discharge from phreatophytes is estimated to equal 7,055 acre-feet or 10% of the total outflow. The area weighted ET rate was calculated to equal 2.6 feet per year, while the aerial extent was estimated to equal 4,212 acres. The area weighted rate of ground-water discharge estimated in this study was calculated to equal 1.67 feet per year. When compared to studies by Rush (1967), Arteaga (1984), and Widmer (1997) the aerial extent of phreatophytes and ET rate estimated by this study are significantly different (Table 9).

Table 9. Comparison of ET from phreatophytes to previous studies.

Study	Acres of Phreatophytes	Evapotranspiration Rate (feet per year)	Volume of ET from Phreatophtyes (acre-feet)
This Study	4,212	2.67[a]	11,264
Rush (1967)	3,100	1.7[b]	5,270
Arteaga (1984)	1,080[c]	3.0[c]	3,200
Widmer (1997)	2,400	4.2[d]	10,080

a) Rate includes ET of ground-water and precipitation.
b) Rate of ground-water discharge (does not include ET of precipitation).
c) Considered "wetland areas," however these areas are inundated during mean-annual lake stage, as found in this study. Phreatophytes were not considered in Arteaga's study. It is unclear how the ET rate was determined for wetland areas.
d) Rate includes ET of ground-water and precipitation.

Rush (1967) estimated phreatophyte areas to equal 3,100 acres with a rate of ground-water discharge of 1.7 feet per year. The spatial distribution of phreatophytes estimated by Rush (1967) shown in Figure 25 is very similar to the spatial distribution estimated in this study. However, the extent of phreatophytes along the east shore of Washoe Lake seems to have been under estimated by Rush (1967). The rate of ground-water discharge of 1.7 feet per year provided by Rush (1967) was based on studies by Lee (1912), White (1932), and Young and Blaney (1942). Rush (1967) did not consider ET of precipitation from phreatophyte areas, and is probably the reason for the dissimilarity of total ET from these areas.

Arteaga (1984) did not delineate phreatophyte areas, instead he considered "wetland areas." There are several problems with this approach, the first being that the delineated "wetland areas" are inundated during mean-annual lake stage, and second, that phreatophyte areas were considered xerophytes (Figure 27). It is also unclear how Arteaga (1984) derived the ET rate of 3.0 feet per year for "wetland areas."

Phreatophyte areas considered by Widmer (1997) were determined according to Rush (1967) but modified to equal 2,400 acres. The rate of ET estimated by Widmer (1997) was calculated to equal 4.2 feet per year, with a calculated area weighted ground-water ET rate of 2.9 feet per year. Widmer (1997) assumed that the total ET rate was equal to the average between a typical rate of ET from alfalfa and open-water evaporation. Ground-water ET was calculated as the difference between mean-annual precipitation that falls on phreatophyte areas and the total ET.

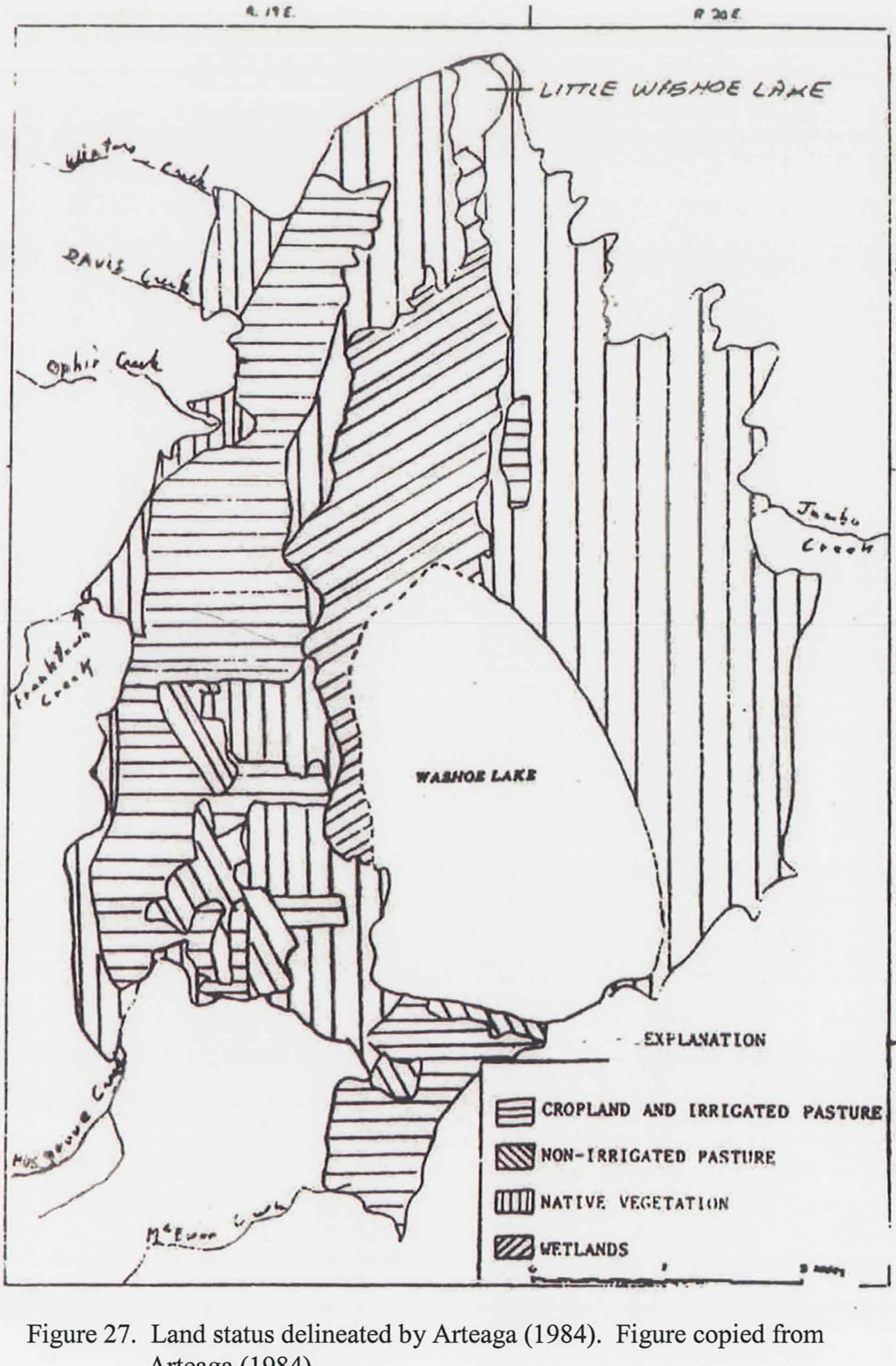


Figure 27. Land status delineated by Arteaga (1984). Figure copied from Arteaga (1984).

Regardless of the differences between ET rates and aerial extent of phreatophytes from previous studies in Washoe Valley, the methods used in this study provide the ability to acquire spatially distributed estimates of ground-water discharge and total ET as a function of vegetative condition instead of single value estimates. Due to similarities in climate, location, and vegetation types between Washoe Valley and field sites in which methods were derived by Nichols (2000), it is believed that the results of ground-water discharge and total ET from phreatophyte areas presented in this study are probably the most reasonable.

ET from Xerophytes

By multiplying the ET rate of 1.15 per year to the xerophyte area of 4,728 acres, it is estimated that xerophyte communities consume 5,437 acre-feet, or 8 percent of the total outflow. Since the rate of ET associated with xerophyte communities is largely dependent on the depth of mean-annual precipitation, estimates of ET from previous studies in Washoe Valley should be similar to ET reported in this study (Table 10).

However, Rush (1967) did not delineate xerophyte communities, and it is unclear if consumption from these areas was considered in the water-budget at all. Arteaga (1984) considered xerophytes, however phreatophyte communities and non-irrigated pasture areas were delineated as xerophytes. Arteaga (1984) estimated that 4,880 acres of xerophytes are located east of Washoe Lake, and consume 1.0 feet per year, and an additional 5,100 acres of xerophytes and non irrigated pasture land are located on the west side of Washoe Lake, which consume 2.0 feet per year. In this study, areas west of

Table 10. Comparison of ET from xerophytes to previous studies.

Study	Acres of Xerophytes	Evapotranspiration Rate (feet per year)	Volume of ET from Xerophytes (acre-feet)
This Study	4,728	1.15[a]	5,437
Rush (1967)	-	-	-
Arteaga (1984)	4,880[b]	1.0[b]	4,880
Widmer (1997)	3,800[c]	1.11[c]	4,218

a) Rate equal to the area weighted mean-annual precipitation that falls on xerophyte areas.
b) Area and rate are only for xerophytes located east of Washoe Lake.
c) Area derived from modifying Rush's figure, and including xerophyte areas. Rate equal to the area weighted mean-annual precipitation that falls on xerophyte areas.

Washoe Lake of non-irrigated pasture were delineated as pasture land, and xerophyte communities were delineated as xerophytes, therefore a direct comparison between the result of ET from Arteaga's study and this one cannot be made. Widmer (1997) estimated the area of xerophytes to equal 3,800 acres, which was apparently estimated by modifying Rush's generalized vegetation map (Figure 25) to include xerophyte vegetation. With an ET rate equal to mean-annual precipitation that falls on xerophyte communities Widmer (1997) estimated total consumption from xerophyte communities to equal 4,218 acre feet per year.

The estimate of ET of precipitation from xerophytes communities provided by this study can be considered a maximum value. An area weighted estimate, derived from a range of ET rates which are spatially distributed would be a more appropriate estimate, however at this time there are no locally derived regionalized remote sensing methods to estimate ET from xerophyte communities in arid environments. Researchers are currently modifying and calibrating SEBAL to estimate ET from xerophyte communities, however extensive fieldwork is needed in order to estimate energy budget components that are calculated using micrometeorological methods.

Surface Water Outflow

By analyzing the period of record between 1966 and 2001, mean-annual surface-water outflow was calculated to equal 13,643 acre-feet per year or 20 percent of the total outflow. Previous investigators have estimated surface-water outflow (Rush, 1967; Arteaga, 1984) into Steamboat Creek, however due a limited period of record analyzed, estimates of outflow are significantly different from this study. Rush (1967) made a rough estimate of outflow equal to 1,000 acre-feet per year, but was calculated from one year of record. Arteaga (1984) estimated outflow equal to 2,300 acre-feet per year but does not mention the period of record analyzed. When analyzed in this study it was found that the mean-annual outflow for the period of record between 1966 and 1981, analyzed by Arteaga (1984), equaled 4,000 acre-feet per year. With higher demand of water from irrigators in Pleasant Valley and the Truckee Meadows, and exceptionally high release events, outflow from little Washoe Lake has substantially increased since 1981. During years of 1983, 1984, and 1986 surface-water outflow into Steamboat Creek was exceptionally high, due to large amounts of precipitation (figure 28). As a result the average surface-water outflow is heavily weighted on these high release years. It also should be noted that about two years of incomplete records exists throughout different months, especially during unregulated flow in fall and winter months (appendix 21).

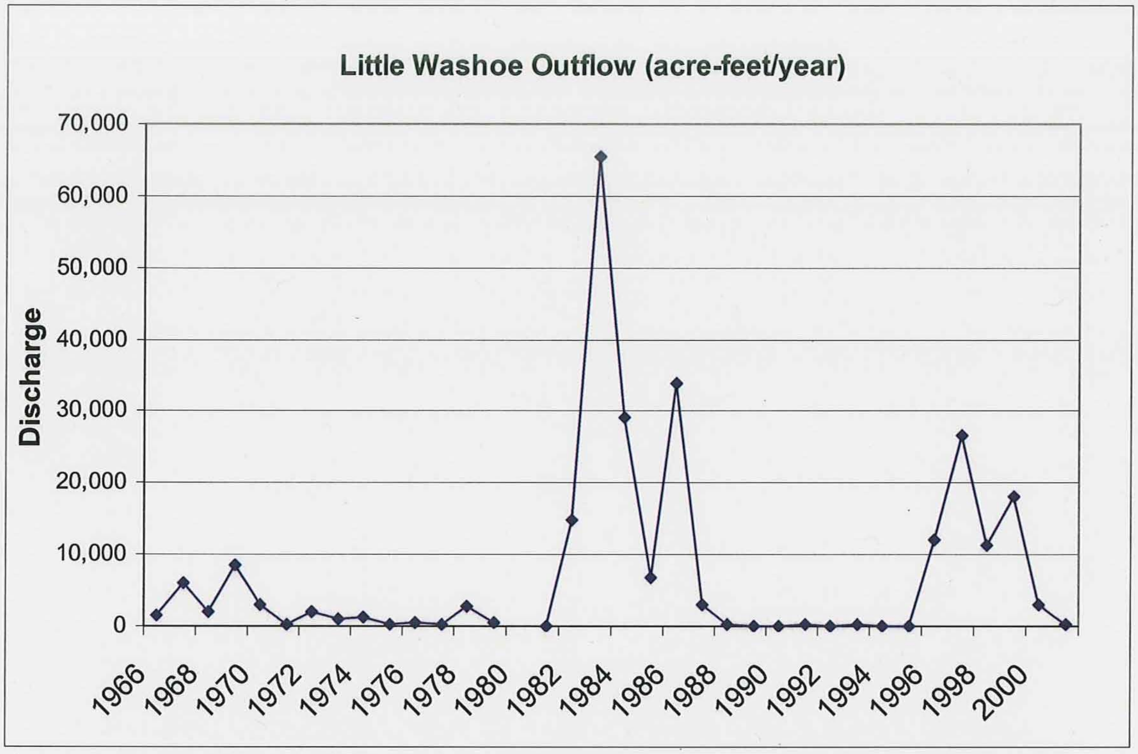


Figure 28. Surface-water outflow into Steamboat Creek from 1966 to 2001. Mean-annual outflow of 13,643 acre-feet per year is heavily weighted by extreme release periods between 1982 and 1985.

Domestic Consumption

By applying a crop coefficient for turf grass of 0.70 (Allen and others, 1990) to the PET estimate derived by Shevenell (1996), domestic consumption of 923 acre-feet per year was estimated by applying the AET rate of 3.46 feet per year to 266 acres of turf grass. Since much of the turf grass in residential areas is not well watered, the rate of domestic consumption calculated in this study is probably a high estimate. The volume of ET and therefore consumption from the golf course, which is well water, is calculated to equal 553 acre-feet per year. Since the aerial extent of turf grass was digitized from aerial photography from 2000, the estimate of domestic consumption is a maximum value and does not represent mean-annual conditions.

Domestic consumption estimates derived by Rush (1967), Arteaga (1984), and Widmer (1997), are significantly different from the estimate provided by this study (Table 11). It is unclear how Rush (1967) derived the estimate of 200 acre-feet per year of domestic consumption. Arteaga (1984) calculated domestic consumption by assuming that pumping rates and recharge proportions estimated for Cold Springs Valley (Van Denburgh, 1981) are similar to Washoe Valley, in which 100 acre-feet per year was estimated. Widmer (1997) estimated domestic consumption as part of a transient state ground-water modeling exercise in which a consumptive use value of 0.25 acre-feet per year, per home was used. After applying 0.25 acre-feet per year, per home, to the average of 812 homes from 1966-1996, domestic consumption was estimated to equal 200 acre-feet per year.

Table 11. Comparison of domestic consumption to previous studies.

Study	Rate of Domestic Consumption acre-feet per year
This Study	923[a]
Rush (1967)	200[b]
Arteaga (1984)	100[c]
Widmer (1997)	200[d]

a) Rate derived by applying AET estimate of 3.46 feet per year to 106 acres of turf grass located within residential areas, and 160 acres of golf course turf grass.
b) It is unclear how Rush derived this estimate.
c) Calculated by assuming pumping rates and recharge proportions estimated for Cold Springs Valley (Van Denburgh, 1981) are similar to Washoe Valley.
d) Rate derived by applying an average domestic consumptive use per home, estimated at 0.25 acre feet per year, to the average number of homes between 1966-1996 calculated as 812.

THE WATER BUDGET

A water-budget for native conditions assumes equilibrium conditions where inflow equals outflow for long-term conditions. Mining, agriculture and residential development have modified native conditions by diverting, importing, and exporting water creating non-equilibrium conditions. The largest modification made to natural conditions was the building of a small dam at the outlet of Little Washoe Lake, which has increased the storage, surface area, and therefore evaporation from Big and Little Washoe Lakes. Another significant modification to natural conditions is the practice of irrigation and subsequent increase in ET from the valley floor. By including the effects of modifications made to the natural system, such as increases in ET from pasturelands, outflow into Steamboat Creek, and domestic pumping, one can formulate a mean-annual water-budget and analyze the magnitude of non-equilibrium conditions. Unfortunately, errors in individual budget components exist, so it is not possible to analyze steady-state or non-equilibrium conditions. However, since the magnitude of non-equilibrium conditions is probably small compared to the total budget, the imbalance of the budget primarily reflects the cumulative error in the estimation of individual water-budget components.

By combining individual water-budget components shown in table 1, total inflow into the valley floor area of Washoe Valley was calculated to equal 59,900 acre-feet per year, with outflow equaling 69,400 acre-feet per year (Table 12). The closure in the water-budget is about 86 percent. Inflow from mountain-block areas was estimated to equal 35,000 acre-feet per year, while precipitation and imports to the valley floor equaled 24,800 acre-feet per year. Outflow from open-water was estimated as 26,000 acre-feet per year, with ET from the valley floor equaling 27,000 acre-feet per year. Surface-water outflow was estimated to equal 13,600 acre-feet per year. Rush (1967) estimated total inflow to the valley floor to equal 33,000 acre feet per year, with outflow equaling 31,000 acre-feet. Arteaga (1984) estimated total inflow and outflow, to and from the valley floor to equal 52,900 and 53,400 acre-feet, respectively. Differences of inflow and outflow volumes from previous studies can be attributed to available measurements of runoff and ET, as well as differences in the methods that were applied to estimate individual budget components.

The most uncertain budget components that are probably responsible for the imbalance in the water-budget are subsurface flow, imports, ET from pasturelands, and evaporation from Washoe Lake. Due to extreme amounts of precipitation, not present in Eagle Valley, subsurface flow into Washoe Valley may exceed 40% of the total yield from mountain-block areas. Current import volumes are unknown, but are likely higher that previously estimated. Estimating ET from pasturelands in Washoe Valley is complex and involves many uncertainties including shallow ground-water influences on ET rates, an assumed relationship between plant cover and ET, and crop coefficients. Evaporation from Washoe Lake could be as high as 5.5 feet per year due to frequent winds and shallow lake conditions.

Table 12. Mean-annual water-budget for Washoe Valley, Nevada.

Budget Summary	**Area (acres)**	**Rate (feet/year)**	**Quantity (acre-feet/year)**
ESTIMATED INFLOW			
Water Yield from mountain block	48,429		
Runoff from mountain block			22,458
Subsurface flow from mountain block			12,586
Precipitation			
Open water	5,273	0.96	5,083
Phreatophytes	4,213	1.00	4,194
Xerophytes	4,728	1.15	5,429
Pasturelands	3,860	1.49	5,745
Turf grass	267	1.47	391
Surface water imports			4,000
		Total Inflow	59,885
	Area (acres)	**Rate (feet/year)**	**Quantity (acre-feet/year)**
ESTIMATED OUTFLOW			
Evapotranspiration			
Phreatophytes	4,213	2.67	11,264
Xerophytes	4,728	1.15	5,438
Pasturelands	3,860	2.41	9,335
Turf grass	267	3.47	924
Open water evaporation	5,273	4.94	26,047
Little Washoe outflow			13,643
Exports			2,718
		Total Outflow	69,368

Inflow	**Outflow**	**% Closure**
59,885	69,368	86

Conclusions

Continued growth of the Truckee Meadows, and Eagle Valley is increasing the demand for development and municipal water supply in Washoe Valley, Nevada. The aquifers beneath the valley-floor of Washoe Valley receive inflow from subsurface flow from adjacent watersheds tributary to the valley-floor, infiltration of stream flow, precipitation and water applied for irrigation on the valley-floor. By using newly derived methods using GIS and remote sensing techniques a water-budget for Washoe Valley, Nevada was constructed for use by water managers. Total estimated mean-annual inflow to the valley-floor of Washoe Valley was 59,900 acre-feet per year. Mean-annual inflow includes 20,800 acre-feet per year of precipitation that falls on the valley-floor, 35,000 acre-feet per year of runoff and subsurface flow, and 4,000 acre-feet per year imported from adjacent hydrographic areas via Third Creek and Browns Creek. Estimates of mean-annual outflow total 69,400 acre-feet per year. Mean-annual outflow includes 27,000 acre feet per year of ET from vegetation on the valley floor, 26,000 acre-feet per year of open water evaporation, 13,600 acre-feet per year (19 cfs) of outflow into Steamboat Creek, and 2,700 acre-feet per year of exported water to Carson City and Virginia City.

Measurements of runoff and ET collected in Washoe Valley from August 2000 to April 2003 provide independent estimates, and show that estimates of water-budget components are reasonable and are probably within 10-20 percent of their actual values. However, volumes of water-budget components can change due to variations in climate and changes in land and water use. The volume of outflow from the valley-floor of Washoe Valley could largely be affected by water management practices and residential development. By increasing residential development and decreasing flood irrigation practices, natural discharge by ET and recharge from irrigation waters will continue to decrease, possibly causing Washoe Lake and the surrounding ground-water table to rise from increases in surface-water inflow.

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Appendix 1

Ophir Creek

Discharge in cubic feet per second, Water Year October 2000 to September 2001

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	3.5	5.9	5.0	3.7	4.0	4.4	8.8	12.0	3.4	2.9	2.5	1.8
2	3.5	5.8	5.0	3.5	4.0	3.7	8.3	8.4	3.7	2.8	2.5	1.8
3	3.5	5.9	5.0	3.5	4.0	3.5	7.3	8.0	4.1	2.9	2.5	1.8
4	3.5	5.7	5.0	3.5	4.0	3.5	6.6	8.3	4.5	3.0	2.5	1.8
5	4.0	5.7	5.0	3.5	4.0	3.5	5.9	9.5	4.7	2.8	2.5	1.8
6	4.2	5.9	5.0	3.5	4.0	3.8	5.9	9.9	4.0	2.7	2.5	1.8
7	4.4	5.5	5.0	3.5	4.0	4.0	5.7	10.1	3.0	2.7	2.5	1.8
8	4.6	5.5	5.0	3.5	4.0	4.0	5.3	10.3	2.9	2.7	2.5	1.8
9	4.6	5.5	5.0	3.3	4.0	3.8	5.1	8.4	2.9	2.8	2.5	1.8
10	5.0	5.0	4.8	3.4	4.0	3.6	5.2	7.3	3.0	2.8	2.5	1.8
11	5.2	4.9	4.5	3.5	4.0	3.5	5.2	7.3	3.4	3.0	2.4	1.8
12	5.5	4.5	4.6	3.5	4.0	3.7	5.0	6.2	3.4	2.9	2.4	1.8
13	5.6	5.1	4.3	3.4	4.0	3.8	5.0	5.7	3.4	2.9	2.4	2.0
14	5.6	5.3	4.3	3.4	4.3	3.8	4.9	5.4	3.6	2.8	2.4	1.9
15	5.3	5.0	4.7	3.5	4.0	3.9	5.0	10.2	3.5	2.7	2.5	1.9
16	5.4	5.0	4.5	3.4	3.9	3.9	5.4	10.5	3.6	2.7	2.5	1.9
17	5.4	5.0	4.5	3.5	3.9	4.3	6.1	8.2	3.6	2.8	2.5	2.0
18	5.4	5.0	3.7	3.5	3.9	5.1	6.8	7.7	3.7	2.8	2.5	2.0
19	5.4	5.0	4.3	3.5	3.9	5.8	6.6	8.9	3.5	2.7	2.4	2.0
20	5.4	5.0	4.6	3.5	3.9	6.0	5.6	6.9	3.3	2.7	2.4	2.0
21	5.6	5.0	4.6	3.5	3.8	6.3	5.5	5.9	3.4	2.9	2.4	2.0
22	5.5	4.7	4.3	3.5	3.7	6.4	5.2	5.4	3.2	2.8	2.5	2.0
23	6.4	4.6	4.2	3.5	3.7	6.7	5.8	5.5	3.3	2.6	2.4	2.0
24	5.6	4.6	4.2	4.1	3.7	6.6	7.5	5.6	3.3	2.5	2.5	2.0
25	5.4	4.6	3.8	4.0	3.7	5.8	9.8	5.0	3.2	2.5	2.4	2.0
26	5.2	4.6	3.7	4.0	3.7	5.8	12.6	4.4	2.8	2.6	2.4	2.0
27	5.8	4.6	3.9	4.0	3.6	7.6	14.0	4.2	2.8	2.5	2.4	2.0
28	6.5	4.6	3.7	4.0	3.6	8.1	12.3	4.0	3.0	2.5	2.5	2.0
29	5.9	4.6	3.5	4.0	-	7.7	11.4	3.8	3.1	2.5	2.3	2.0
30	5.9	4.5	3.6	4.0	-	8.3	13.9	3.6	3.1	2.5	2.0	2.0
31	5.9	-	3.7	4.0	-	-	-	3.6	-	2.5	1.8	-
Mean:	5.1	5.1	4.4	3.6	3.9	5.0	7.3	7.1	3.4	2.7	2.4	1.9
Max:	6.5	5.9	5.0	4.1	4.3	8.3	14.0	12.0	4.7	3.0	2.5	2.0
Min:	3.5	4.5	3.5	3.3	3.6	3.5	4.9	3.6	2.8	2.5	1.8	1.8
Acre-feet:	315	302	271	222	216	299	432	437	203	168	149	112
Annual Acre-feet total:	3126											

Appendix 2

Ophir Creek

Discharge in cubic feet per second, Water Year October 2001 to September 2002

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	2.0	2.8	3.0	3.1	9.0	3.4	6.8	8.1	24.7	8.5	8.3	-
2	2.0	2.7	3.1	3.3	9.0	3.3	7.2	7.8	21.5	8.1	8.4	-
3	2.0	2.6	2.9	3.3	9.0	3.3	7.2	11.3	19.7	8.1	7.0	-
4	2.0	2.6	2.9	3.1	9.0	3.5	7.3	17.3	18.9	8.1	7.0	-
5	2.0	2.6	2.7	3.1	9.0	3.5	8.0	20.5	19.4	8.1	7.0	-
6	2.0	2.4	2.8	3.6	9.0	3.6	7.5	25.4	19.2	8.1	7.0	-
7	2.0	2.4	2.7	3.5	8.6	3.4	6.8	27.0	18.0	8.1	7.0	-
8	2.1	2.4	2.7	3.3	2.1	3.3	7.4	19.8	17.0	8.3	6.8	-
9	2.1	2.4	2.7	3.3	2.0	3.3	8.2	16.4	16.1	8.5	6.7	-
10	2.0	2.4	2.7	3.3	2.0	3.2	6.9	14.7	14.9	8.3	6.6	-
11	2.0	2.9	2.7	3.1	1.9	3.4	7.5	12.2	14.5	8.1	6.6	-
12	2.2	3.3	2.7	3.1	1.9	3.5	9.9	15.3	14.7	8.1	6.6	-
13	2.2	3.0	2.7	3.1	2.0	3.3	12.0	21.2	14.4	8.2	6.5	-
14	2.2	2.9	2.7	3.1	2.2	3.2	15.9	26.6	13.7	8.4	6.4	-
15	2.2	3.0	2.5	2.8	2.4	2.9	17.2	27.1	12.8	8.5	6.6	-
16	2.2	2.9	2.5	2.8	2.6	3.0	11.0	27.7	12.1	8.5	-	-
17	2.2	2.8	2.7	2.8	2.7	3.0	8.1	30.5	12.5	8.8	-	-
18	2.2	2.7	2.7	3.0	2.6	3.0	7.0	38.4	13.1	9.6	-	-
19	2.2	2.7	2.7	2.9	2.4	3.1	6.3	36.0	12.7	9.3	-	-
20	2.2	2.7	2.7	2.9	2.4	3.2	5.4	28.0	12.2	9.0	-	-
21	2.2	3.2	2.8	2.7	2.3	3.2	5.2	22.2	11.7	8.9	-	-
22	2.2	4.4	2.9	2.7	2.4	3.3	5.9	20.1	11.4	8.5	-	-
23	2.3	3.1	2.9	11.6	2.4	3.3	8.7	20.3	11.0	8.5	-	-
24	2.3	4.1	2.9	17.0	2.3	3.3	11.7	22.0	10.3	8.4	-	-
25	2.3	3.1	2.9	17.0	2.3	3.1	13.0	25.9	10.1	8.2	-	-
26	2.2	2.8	2.9	5.4	2.3	3.1	14.6	27.6	9.8	8.2	-	-
27	2.2	2.9	2.9	2.5	2.3	3.3	11.1	27.4	9.6	8.1	-	-
28	2.1	2.8	2.9	3.3	2.9	3.4	9.7	29.4	9.5	8.3	-	-
29	2.1	2.8	2.9	3.1	-	3.6	9.4	30.8	9.3	8.3	-	-
30	2.7	2.9	2.9	8.9	-	4.2	8.7	32.3	9.0	8.3	-	-
31	3.0	-	3.4	9.0	-	5.7	-	28.8	-	8.3	-	-
Mean:	2.2	2.9	2.8	4.7	4.0	3.4	9.0	23.2	14.1	8.4	6.9	-
Max:	3.0	4.4	3.4	17.0	9.0	5.7	17.2	38.4	24.7	9.6	8.4	-
Min:	2.0	2.4	2.5	2.5	1.9	2.9	5.2	7.8	9.0	8.1	6.4	-
Acre-feet:	135	171	173	183	133	208	538	1424	840	517	300	
Annual Acre-feet total:	4621											

Appendix 3

Ophir Creek

Discharge in cubic feet per second, Water Year October 2002 to September 2003

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	-	0.1	9.4	10.2	10.9	9.4	11.7	-	-	-	-	-
2	-	0.2	9.4	10.4	10.7	9.4	11.2	-	-	-	-	-
3	-	0.2	9.4	10.4	10.4	9.4	11.0	-	-	-	-	-
4	-	0.2	9.4	10.6	10.1	9.4	10.6	-	-	-	-	-
5	6.2	0.3	9.4	10.8	10.1	9.4	10.4	-	-	-	-	-
6	4.5	0.3	9.4	10.4	10.3	9.7	10.5	-	-	-	-	-
7	3.6	0.3	9.4	10.5	10.4	9.9	11.0	-	-	-	-	-
8	2.4	0.3	9.4	10.9	10.4	9.9	11.6	-	-	-	-	-
9	2.3	0.2	9.4	10.9	10.4	9.9	12.5	-	-	-	-	-
10	2.3	0.2	9.4	10.9	10.4	10.0	13.3	-	-	-	-	-
11	1.7	0.2	9.4	10.9	10.4	10.4	14.1	-	-	-	-	-
12	1.6	1.1	9.4	10.9	10.4	11.0	13.1	-	-	-	-	-
13	1.8	0.3	10.4	10.9	10.0	11.4	11.8	-	-	-	-	-
14	1.9	0.2	10.9	10.9	9.9	11.5	11.4	-	-	-	-	-
15	1.9	0.2	8.6	10.9	10.3	10.4	11.1	-	-	-	-	-
16	1.7	0.2	9.5	10.9	9.9	10.0	10.9	-	-	-	-	-
17	1.9	0.2	9.3	10.9	9.9	9.9	10.9	-	-	-	-	-
18	1.7	0.4	10.5	10.9	9.9	9.9	10.7	-	-	-	-	-
19	1.3	0.6	10.6	10.9	9.9	9.9	10.9	-	-	-	-	-
20	1.1	1.0	10.7	11.1	9.9	9.9	10.8	-	-	-	-	-
21	1.1	1.5	10.2	11.5	9.9	10.4	10.4	-	-	-	-	-
22	1.7	2.2	10.5	12.8	9.8	10.4	-	-	-	-	-	-
23	0.9	3.2	10.4	11.9	9.9	10.0	-	-	-	-	-	-
24	0.9	4.3	10.4	10.9	9.9	10.1	-	-	-	-	-	-
25	1.1	5.8	10.4	10.9	9.8	11.8	-	-	-	-	-	-
26	1.2	9.5	10.5	11.5	9.6	11.7	-	-	-	-	-	-
27	0.3	9.4	11.1	11.2	9.4	11.0	-	-	-	-	-	-
28	0.5	9.4	10.9	10.9	9.4	10.9	-	-	-	-	-	-
29	0.4	9.4	9.8	10.9	-	11.4	-	-	-	-	-	-
30	0.2	9.4	10.1	10.9	-	12.1	-	-	-	-	-	-
31	0.2	-	10.1	11.4	-	12.9	-	-	-	-	-	-
Mean:	1.7	2.4	9.9	11.0	10.1	10.4	11.4	-	-	-	-	-
Max:	6.2	9.5	11.1	12.8	10.9	12.9	14.1	-	-	-	-	-
Min:	0.2	0.1	8.6	10.2	9.4	9.4	10.4	-	-	-	-	-
Acre-feet:	92	141	610	674	560	642	476					
Annual Acre-feet total:	3195											

Appendix 4

Franktown Creek

Discharge in cubic feet per second, Water Year October 2000 to September 2001

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	-	-	4.5	4.7	4.4	4.9	6.3	9.8	2.8	0.8	1.0	0.7
2	-	-	4.3	4.7	4.5	4.0	5.8	9.2	2.6	1.0	0.9	0.7
3	-	-	4.2	4.7	5.1	4.1	5.5	6.1	2.4	1.0	0.8	0.7
4	-	-	4.1	4.7	5.6	4.0	5.1	6.2	2.2	1.1	0.8	0.7
5	-	-	3.9	4.7	5.4	4.1	5.0	6.2	2.0	1.3	0.8	0.7
6	-	-	3.8	4.7	4.8	4.2	5.0	6.2	2.2	1.2	0.8	0.8
7	-	-	4.0	4.7	4.5	4.8	4.6	6.1	2.6	1.2	0.8	0.8
8	-	-	4.0	4.5	7.5	5.7	5.2	6.0	2.6	1.2	0.8	0.8
9	-	-	4.0	4.4	5.7	5.6	4.9	7.2	2.4	1.0	0.8	0.9
10	-	-	4.0	4.3	4.7	4.7	4.7	7.1	2.1	1.2	0.7	0.9
11	-	-	4.0	4.4	4.7	4.4	4.9	6.3	1.7	1.5	0.7	0.8
12	-	-	4.0	4.4	4.5	4.4	4.9	6.5	1.9	1.1	0.7	0.9
13	-	-	4.0	4.4	4.4	4.7	5.5	6.1	1.9	1.0	0.7	0.9
14	-	4.0	3.4	4.4	4.4	5.0	5.4	5.7	1.7	0.8	0.7	0.9
15	-	4.2	4.1	4.4	4.4	5.1	5.6	6.1	1.5	1.0	0.7	0.9
16	-	4.4	3.9	4.4	4.4	4.7	5.6	6.6	1.3	1.0	0.7	0.9
17	-	4.5	4.2	4.4	4.4	5.3	5.6	5.7	1.1	0.9	0.7	0.9
18	-	4.7	3.2	4.4	4.4	7.3	5.6	5.3	1.0	0.8	0.7	0.9
19	-	4.7	4.5	4.4	4.3	9.7	6.4	3.6	1.1	0.9	0.6	0.9
20	-	4.7	4.2	4.4	4.0	12.4	5.5	3.8	1.3	0.8	0.7	0.9
21	-	4.7	4.0	4.4	4.1	12.8	6.1	4.1	1.0	0.7	0.7	0.9
22	-	4.7	4.0	4.4	4.0	11.9	7.3	4.0	1.1	0.8	0.7	0.9
23	-	4.7	3.9	4.4	4.1	11.0	9.5	4.0	0.9	0.9	0.7	1.0
24	-	4.6	4.0	4.4	4.0	10.7	8.9	3.9	0.8	0.9	0.7	1.2
25	-	4.7	3.2	4.4	4.1	13.9	8.7	3.7	1.0	1.1	0.8	1.5
26	-	4.5	3.8	4.4	4.0	9.5	8.9	3.6	1.8	1.1	0.7	1.4
27	-	4.6	4.2	4.4	4.1	8.1	7.9	3.4	1.5	1.0	0.7	1.2
28	-	4.7	4.4	4.4	4.3	10.3	6.7	3.3	1.1	1.0	0.7	1.1
29	-	4.6	4.4	4.4	-	9.9	5.9	3.3	1.1	1.0	0.7	1.1
30	-	4.5	4.4	4.4	-	7.9	5.7	3.1	0.9	1.1	0.7	1.1
31	-	-	4.5	4.4	-	6.8	-	2.9	-	1.2	0.7	-
Mean:	-	4.6	4.0	4.4	4.6	7.2	6.1	5.3	1.7	1.0	0.7	0.9
Max:	-	4.7	4.5	4.7	7.5	13.9	9.5	9.8	2.8	1.5	1.0	1.5
Min:	-	4.0	3.2	4.3	4.0	4.0	4.6	2.9	0.8	0.7	0.6	0.7
Acre-feet:	-	154	248	273	255	440	362	327	100	63	46	56
Annual Acre-feet total:	2324											

Appendix 5

Franktown Creek

Discharge in cubic feet per second, Water Year October 2001 to September 2002

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	2.3	4.1	6.2	14.4	6.8	13.3	34.4	22.7	13.5	4.6	2.0	1.4
2	2.2	4.3	9.4	15.2	6.8	14.1	72.0	20.3	11.9	4.5	4.4	1.4
3	2.2	3.8	9.8	21.4	6.8	14.8	61.3	22.9	10.7	15.4	1.9	1.4
4	2.3	3.8	9.4	13.0	6.8	13.7	75.7	22.6	16.2	8.8	2.4	1.5
5	2.3	3.8	8.3	11.6	6.8	11.7	82.7	24.7	9.1	4.4	2.5	1.6
6	2.3	4.1	8.2	28.6	6.8	30.0	66.6	24.7	9.2	4.2	1.9	1.7
7	2.4	3.8	9.0	22.7	6.8	19.2	59.6	25.5	8.1	18.7	2.2	1.8
8	2.5	3.7	8.2	17.8	6.8	17.5	63.5	38.2	7.5	3.9	2.2	1.9
9	2.4	3.6	8.0	14.6	6.8	17.4	64.5	21.0	7.7	6.9	2.2	1.9
10	2.3	3.6	7.9	12.8	6.8	15.1	62.5	17.8	7.0	3.2	2.1	1.8
11	2.3	4.8	6.9	11.4	6.8	15.0	65.0	18.3	6.9	3.1	1.9	1.8
12	2.3	5.6	6.8	11.0	6.8	21.0	65.5	16.2	7.3	11.8	2.4	1.8
13	2.5	5.4	6.6	10.1	6.9	21.7	58.3	15.2	7.2	3.3	4.4	1.7
14	2.4	4.5	5.8	9.6	7.3	16.1	73.2	14.8	6.9	3.2	2.0	1.7
15	2.3	4.5	6.4	8.8	7.6	15.1	63.8	14.4	6.6	2.9	1.9	1.6
16	2.3	4.5	6.7	10.7	8.0	15.4	40.0	14.6	6.5	2.7	2.2	1.7
17	2.3	4.5	7.1	10.1	8.0	14.2	31.5	14.4	6.2	3.3	1.8	1.7
18	2.3	4.5	6.8	13.4	7.8	13.9	29.1	15.3	6.1	4.5	1.7	1.9
19	2.3	4.5	6.8	10.8	9.9	15.2	27.7	18.5	6.3	3.9	1.7	1.9
20	2.4	4.5	6.8	10.2	23.2	15.9	29.9	20.6	6.5	3.4	1.8	1.9
21	2.5	6.0	6.8	7.7	19.1	18.2	41.5	17.1	6.2	3.0	1.7	1.9
22	2.6	18.5	6.4	6.8	20.9	16.6	43.4	16.2	6.2	3.0	1.8	1.8
23	2.7	7.2	6.6	7.0	25.0	13.7	37.3	14.4	6.0	3.7	2.2	1.8
24	2.8	35.6	6.7	6.6	18.1	11.7	32.9	15.0	5.7	2.5	2.3	1.8
25	3.0	13.0	7.1	6.4	15.1	10.9	29.3	16.1	5.5	2.3	2.9	1.7
26	4.5	8.1	7.2	6.8	14.1	11.8	34.2	16.4	5.2	2.3	2.2	1.7
27	4.0	7.3	7.4	6.8	13.8	15.4	32.6	14.9	4.8	2.3	2.2	1.8
28	3.8	6.4	7.4	7.3	13.6	19.2	25.1	15.0	4.8	2.2	2.4	1.9
29	3.8	5.9	7.6	7.9	-	24.2	30.5	16.6	4.9	2.1	1.9	2.0
30	5.0	6.3	8.7	8.3	-	27.3	27.9	13.3	16.4	2.0	1.7	2.1
31	5.5	-	18.3	7.0	-	29.8	-	14.1	-	4.9	1.4	-
Mean:	2.8	6.7	7.8	11.5	10.7	17.1	48.7	18.4	7.8	4.7	2.2	1.8
Max:	5.5	35.6	18.3	28.6	25.0	30.0	82.7	38.2	16.4	18.7	4.4	2.1
Min:	2.2	3.6	5.8	6.4	6.8	10.9	25.1	13.3	4.8	2.0	1.4	1.4
Acre-feet:	87	200	241	357	300	529	1461	572	233	147	68	55
Annual Acre-feet total:	4252											

Appendix 6

Franktown Creek

Discharge in cubic feet per second, Water Year October 2002 to September 2003

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	2.3	2.6	4.4	6.1	23.8	7.7	16.7	-	-	-	-	-
2	2.3	3.0	4.4	6.9	17.1	8.6	15.2	-	-	-	-	-
3	2.3	3.8	4.3	7.3	12.9	8.4	14.6	-	-	-	-	-
4	2.5	3.8	4.5	7.5	11.0	8.8	14.0	-	-	-	-	-
5	2.6	3.8	4.5	8.0	10.7	8.8	13.6	-	-	-	-	-
6	2.6	4.1	4.5	7.7	12.5	-	13.5	-	-	-	-	-
7	2.6	5.7	4.3	7.0	12.5	-	16.9	-	-	-	-	-
8	2.6	36.5	3.9	6.9	12.5	9.6	21.9	-	-	-	-	-
9	2.6	14.6	4.5	6.9	12.5	10.0	21.2	-	-	-	-	-
10	2.4	7.2	4.5	6.8	11.6	10.9	18.7	-	-	-	-	-
11	2.5	6.7	4.4	6.9	9.1	12.6	17.8	-	-	-	-	-
12	2.6	7.3	4.5	6.8	8.3	15.6	17.8	-	-	-	-	-
13	2.6	8.7	10.2	7.0	9.2	19.8	15.8	-	-	-	-	-
14	2.7	6.6	17.3	7.3	9.5	21.5	19.4	-	-	-	-	-
15	2.8	5.6	5.0	6.7	9.1	57.4	18.4	-	-	-	-	-
16	3.0	5.3	4.8	6.5	8.2	23.9	17.8	-	-	-	-	-
17	3.1	5.3	4.7	6.3	8.5	14.6	18.1	-	-	-	-	-
18	3.1	5.0	5.3	6.2	9.1	12.1	19.2	-	-	-	-	-
19	3.1	4.9	5.8	6.3	8.6	11.2	22.1	-	-	-	-	-
20	3.1	4.8	5.9	6.5	8.4	12.7	25.1	-	-	-	-	-
21	3.1	4.7	5.5	7.6	8.4	12.7	29.1	-	-	-	-	-
22	3.1	4.9	5.3	11.1	8.5	15.1	22.2	-	-	-	-	-
23	3.2	5.3	5.3	38.4	8.3	26.4	-	-	-	-	-	-
24	3.3	4.9	5.0	33.0	8.6	20.8	-	-	-	-	-	-
25	3.3	4.7	5.8	22.3	8.2	17.0	-	-	-	-	-	-
26	3.3	4.1	5.8	18.0	7.9	42.0	-	-	-	-	-	-
27	3.4	4.0	9.0	39.0	7.8	26.1	-	-	-	-	-	-
28	3.4	4.1	11.2	35.9	7.8	18.8	-	-	-	-	-	-
29	3.4	3.9	7.5	20.0	-	16.0	-	-	-	-	-	-
30	3.4	4.4	7.5	18.2	-	15.7	-	-	-	-	-	-
31	3.5	-	5.9	20.1	-	16.4	-	-	-	-	-	-
Mean:	2.9	6.3	6.0	12.9	10.4	17.3	18.6	-	-	-	-	-
Max:	3.5	36.5	17.3	39.0	23.8	57.4	29.1	-	-	-	-	-
Min:	2.3	2.6	3.9	6.1	7.8	7.7	13.5	-	-	-	-	-
Acre-feet:	90	190	185	401	291	501	409	-	-	-	-	-
Annual Acre-feet total:	2068											

Appendix 7

Lewers Creek

Discharge in cubic feet per second, Water Year October 2001 to September 2002

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	-	-	-	0.64	0.50	0.75	1.65	0.79	0.48	0.17	0.10	0.04
2	-	-	-	0.72	0.54	0.74	1.38	0.76	0.48	0.17	0.10	0.03
3	-	-	-	0.77	0.55	0.74	1.57	0.74	0.41	0.17	0.10	0.03
4	-	-	-	0.64	0.54	0.74	1.96	0.74	0.41	0.17	0.10	0.04
5	-	-	-	0.64	0.54	0.74	2.12	0.71	0.41	0.17	0.10	0.05
6	-	-	-	0.85	0.51	1.04	1.96	0.71	0.41	0.14	0.10	0.06
7	-	-	-	0.76	0.51	0.99	1.85	0.71	0.35	0.14	0.10	0.06
8	-	-	-	0.69	0.50	0.86	1.88	0.70	0.41	0.14	0.10	0.06
9	-	-	-	0.64	0.48	0.85	1.99	0.69	0.41	0.12	0.10	0.06
10	-	-	-	0.64	0.48	0.85	1.88	0.69	0.41	0.12	0.08	0.06
11	-	-	0.48	0.64	0.48	0.89	1.85	0.66	0.41	0.12	0.08	0.06
12	-	-	0.48	0.63	0.48	1.02	1.78	0.64	0.35	0.12	0.08	0.06
13	-	-	0.48	0.64	0.48	0.99	1.64	0.64	0.35	0.14	0.08	0.05
14	-	-	0.49	0.59	0.48	0.96	1.72	0.64	0.35	0.12	0.08	0.05
15	-	-	0.47	0.55	0.48	0.90	1.56	0.64	0.35	0.12	0.08	0.06
16	-	-	0.48	0.54	0.48	0.85	1.24	0.61	0.29	0.12	0.06	0.06
17	-	-	0.51	0.54	0.48	0.85	1.06	0.60	0.29	0.21	0.08	0.06
18	-	-	0.48	0.51	0.48	0.85	0.98	0.57	0.29	0.17	0.08	0.08
19	-	-	0.48	0.54	0.58	0.96	0.96	0.56	0.25	0.14	0.08	0.08
20	-	-	0.48	0.52	0.81	1.03	0.95	0.64	0.25	0.14	0.10	0.08
21	-	-	0.48	0.55	0.80	1.06	1.03	0.64	0.25	0.14	0.10	0.08
22	-	-	0.48	0.52	0.78	1.15	1.06	0.60	0.25	0.14	0.08	0.08
23	-	-	0.48	0.50	0.84	1.13	0.99	0.56	0.25	0.12	0.08	0.08
24	-	-	0.48	0.53	0.74	1.12	0.89	0.55	0.25	0.12	0.06	0.10
25	-	-	0.48	0.51	0.74	1.12	0.85	0.55	0.25	0.12	0.06	0.14
26	-	-	0.48	0.52	0.71	1.15	0.89	0.52	0.21	0.12	0.06	0.17
27	-	-	0.48	0.50	0.73	1.18	0.87	0.51	0.21	0.12	0.05	0.14
28	-	-	0.51	0.48	0.81	1.29	0.84	0.50	0.21	0.10	0.05	0.14
29	-	-	0.55	0.48	-	1.41	0.89	0.48	0.21	0.12	0.04	0.14
30	-	-	0.57	0.48	-	1.51	0.85	0.47	0.17	0.10	0.04	0.14
31	-	-	0.75	0.48	-	1.65	-	0.48	-	0.10	0.04	-
Mean:	-	-	0.50	0.59	0.59	1.01	1.37	0.62	0.32	0.14	0.08	0.08
Max:	-	-	0.75	0.85	0.84	1.65	2.12	0.79	0.48	0.21	0.10	0.17
Min:	-	-	0.47	0.48	0.48	0.74	0.84	0.47	0.17	0.10	0.04	0.03
Acre-feet:	-	-	21	36	33	62	82	38	20	8	5	14
Annual Acre-feet total	318											

Appendix 8

Lewers Creek

Discharge in cubic feet per second, Water Year October 2002 to September 2003

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.14	0.41	0.35	0.35	0.71	0.35	0.65	-	-	-	-	-
2	0.14	0.41	0.35	0.36	0.59	0.35	0.64	-	-	-	-	-
3	0.14	0.41	0.35	0.37	0.55	0.36	0.56	-	-	-	-	-
4	0.14	0.41	0.35	0.39	0.51	0.36	0.55	-	-	-	-	-
5	0.14	0.41	0.35	0.41	0.48	0.37	0.55	-	-	-	-	-
6	0.12	0.41	0.35	0.41	0.48	0.37	0.54	-	-	-	-	-
7	0.14	0.85	0.35	0.41	0.48	0.42	0.55	-	-	-	-	-
8	0.14	1.12	0.35	0.41	0.46	0.41	0.59	-	-	-	-	-
9	0.14	0.41	0.35	0.41	0.41	0.41	0.58	-	-	-	-	-
10	0.14	0.48	0.35	0.41	0.41	0.44	0.58	-	-	-	-	-
11	0.17	0.35	0.35	0.41	0.41	0.49	0.59	-	-	-	-	-
12	0.17	0.41	0.35	0.41	0.41	0.52	0.61	-	-	-	-	-
13	0.17	0.41	0.74	0.41	0.41	0.58	0.66	-	-	-	-	-
14	0.17	0.35	0.48	0.41	0.41	0.57	0.63	-	-	-	-	-
15	0.17	0.35	0.48	0.41	0.41	0.80	0.61	-	-	-	-	-
16	0.17	0.35	0.48	0.41	0.41	0.65	0.61	-	-	-	-	-
17	0.21	0.29	0.48	0.41	0.40	0.59	0.64	-	-	-	-	-
18	0.21	0.41	0.48	0.40	0.38	0.55	0.64	-	-	-	-	-
19	0.21	0.35	0.48	0.40	0.41	0.53	0.66	-	-	-	-	-
20	0.25	0.35	0.48	0.40	0.37	0.54	0.67	-	-	-	-	-
21	0.29	0.35	0.48	0.43	0.36	0.53	0.68	-	-	-	-	-
22	0.35	0.35	0.48	0.48	0.35	0.57	0.64	-	-	-	-	-
23	0.29	0.35	0.41	0.79	0.35	0.68	-	-	-	-	-	-
24	0.29	0.35	0.41	0.73	0.35	0.71	-	-	-	-	-	-
25	0.29	0.35	0.41	0.64	0.36	0.68	-	-	-	-	-	-
26	0.29	0.35	0.64	0.64	0.35	1.03	-	-	-	-	-	-
27	0.35	0.35	0.64	0.94	0.37	0.88	-	-	-	-	-	-
28	0.35	0.35	0.55	0.93	0.35	0.76	-	-	-	-	-	-
29	0.35	0.35	0.48	0.69	-	0.67	-	-	-	-	-	-
30	0.35	0.35	0.55	0.67	-	0.61	-	-	-	-	-	-
31	0.41	-	0.45	0.69	-	0.66	-	-	-	-	-	-
Mean:	0.22	0.41	0.44	0.50	0.42	0.56	0.61	-	-	-	-	-
Max:	0.41	1.12	0.74	0.94	0.71	1.03	0.68	-	-	-	-	-
Min:	0.12	0.29	0.35	0.35	0.35	0.35	0.54	-	-	-	-	-
Acre-feet:	14	24	27	31	24	35	27	-	-	-	-	-
Annual Acre-feet total:	181											

Appendix 9

Davis Creek

Discharge in cubic feet per second, Water Year October 2000 to September 2001

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	-	-	-	-	-	-	0.6	0.5	0.05	0	0	0
2	-	-	-	-	-	-	0.6	0.6	0.05	0	0	0
3	-	-	-	-	-	-	0.6	0.6	0.08	0	0	0
4	-	-	-	-	-	-	0.6	0.6	0.10	0	0	0
5	-	-	-	-	-	-	0.6	0.5	0.08	0	0	0
6	-	-	-	-	-	-	0.6	0.5	0.06	0	0	0
7	-	-	-	-	-	0.6	0.6	0.4	0.04	0	0	0
8	-	-	-	-	-	1.0	0.5	0.4	0.03	0	0	0
9	-	-	-	-	-	1.0	0.5	0.4	0.03	0	0	0
10	-	-	-	-	-	0.9	0.5	0.4	0.02	0	0	0
11	-	-	-	-	-	0.9	0.5	0.4	0.03	0	0	0
12	-	-	-	-	-	0.8	0.5	0.4	0.04	0	0	0
13	-	-	-	-	-	0.8	0.5	0.4	0.05	0	0	0
14	-	-	-	-	-	0.8	0.5	0.4	0.04	0	0	0
15	-	-	-	-	-	0.8	0.4	0.4	0.02	0	0	0
16	-	-	-	-	-	0.8	0.4	0.4	0.02	0	0	0
17	-	-	-	-	-	0.7	0.4	0.3	0.01	0	0	0
18	-	-	-	-	-	0.8	0.4	0.3	0.01	0	0	0
19	-	-	-	-	-	0.9	0.5	0.3	0.01	0	0	0
20	-	-	-	-	-	0.9	0.5	0.2	0.01	0	0	0
21	-	-	-	-	-	0.9	0.7	0.2	0.01	0	0	0
22	-	-	-	-	-	0.9	0.8	0.2	0	0	0	0
23	-	-	-	-	-	0.9	0.7	0.1	0	0	0	0
24	-	-	-	-	-	0.8	0.6	0.1	0	0	0	0
25	-	-	-	-	-	0.8	0.5	0.1	0	0	0	0
26	-	-	-	-	-	0.8	0.5	0.1	0	0	0	0
27	-	-	-	-	-	0.7	0.5	0.1	0	0	0	0
28	-	-	-	-	-	0.7	0.5	0.1	0	0	0	0
29	-	-	-	-	-	0.7	0.5	0.1	0	0	0	0
30	-	-	-	-	-	0.6	0.5	0.1	0	0	0	0
31	-	-	-	-	-	0.6	-	0.1	-	0	0	-
Mean:	-	-	-	-	-	0.8	0.5	0.3	0	0	0	0
Max:	-	-	-	-	-	1.0	0.8	0.6	0.1	0	0	0
Min:	-	-	-	-	-	0.6	0.4	0.1	0.0	0	0	0
Acre-feet:	-	-	-	-	-	40	32	19	2	0	0	0
Annual Acre-feet total:	93											

Appendix 10

Davis Creek

Discharge in cubic feet per second, Water Year October 2001 to September 2002

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	-	1.37	0.24	0.26	0.19	0.34	0.64	0.55	0.19	0	0	0
2	-	1.25	0.24	0.30	0.19	0.34	1.13	0.55	0.19	0	0	0
3	-	1.21	0.24	0.28	0.19	0.34	1.46	0.64	0.23	0	0	0
4	-	1.25	0.24	0.23	0.28	0.34	1.46	0.47	0.16	0	0	0
5	-	1.32	0.24	0.23	0.23	0.34	1.28	0.47	0.13	0	0	0
6	-	0.41	0.24	0.23	0.19	0.74	0.98	0.55	0.13	0	0	0
7	-	0.14	0.24	0.23	0.28	0.47	0.85	0.55	0.13	0	0	0
8	-	0.15	0.24	0.23	0.23	0.47	1.13	0.47	0.13	0	0	0
9	-	0.15	0.24	0.23	0.19	0.40	0.74	0.55	0.13	0	0	0
10	-	0.16	0.24	0.23	0.19	0.40	0.47	0.55	0.13	0	0	0
11	-	0.28	0.24	0.23	0.19	0.47	0.74	0.55	0.13	0	0	0
12	-	0.33	0.16	0.23	0.23	0.64	0.85	0.55	0.10	0	0	0
13	-	0.29	0.16	0.28	0.23	0.47	0.98	0.56	0.10	0	0	0
14	-	0.26	0.16	0.28	0.23	0.47	1.28	0.59	0.08	0	0	0
15	-	0.27	0.14	0.28	0.23	0.28	0.85	0.58	0.08	0	0	0
16	-	0.23	0.13	0.23	0.23	0.40	0.74	0.56	0.08	0	0	0
17	-	0.22	0.15	0.23	0.23	0.40	0.64	0.54	0.08	0	0	0
18	0.02	0.24	0.13	0.23	0.10	0.40	0.64	0.49	0.08	0	0	0
19	0.02	0.26	0.13	0.23	0.40	0.40	0.64	0.43	0.08	0	0	0
20	0.02	0.24	0.13	0.19	0.40	0.40	0.64	0.47	0.05	0	0	0
21	0.02	0.24	0.13	0.19	0.47	0.40	0.64	0.43	0.06	0	0	0
22	0.13	0.24	0.14	0.19	0.64	0.47	0.64	0.40	0.06	0	0	0
23	0.34	0.24	0.14	0.19	0.55	0.40	0.83	0.42	0.05	0	0	0
24	0.53	0.24	0.13	0.19	0.47	0.40	0.64	0.47	0.05	0	0	0
25	0.58	0.24	0.13	0.19	0.47	0.40	0.64	0.45	0.04	0	0	0
26	0.59	0.24	0.14	0.19	0.40	0.40	0.64	0.44	0.02	0	0	0
27	0.62	0.24	0.16	0.19	0.40	0.47	0.64	0.41	0.01	0	0	0
28	0.61	0.24	0.17	0.19	0.40	0.47	0.55	0.37	0.01	0	0	0
29	0.66	0.24	0.23	0.19	-	0.55	0.55	0.35	0.03	0	0	0
30	1.52	0.24	0.25	0.19	-	0.55	0.55	0.31	0.01	0	0	0
31	1.77	-	0.30	0.19	-	0.64	-	0.23	-	0	0	-
Mean:	0.53	0.41	0.19	0.23	0.30	0.44	0.82	0.48	0.09	0	0	0
Max:	1.77	1.37	0.30	0.30	0.64	0.74	1.46	0.64	0.23	0	0	0
Min:	0.02	0.14	0.13	0.19	0.10	0.28	0.47	0.23	0.01	0	0	0
Acre-feet:	15	25	12	14	17	27	49	30	5	0	0	0
Annual Acre-feet total:	193											

Appendix 11

Davis Creek

Discharge in cubic feet per second, Water Year October 2002 to September 2003

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0	0.23	0.40	-	0.70	-	-	-	-	-	-	-
2	0	0.64	0.43	-	0.56	-	-	-	-	-	-	-
3	0	0.34	0.45	-	0.45	-	-	-	-	-	-	-
4	0	0.23	0.41	-	0.37	-	-	-	-	-	-	-
5	0	0.23	0.40	-	0.30	-	-	-	-	-	-	-
6	0	0.23	0.40	-	0.24	-	-	-	-	-	-	-
7	0	1.64	0.40	-	0.17	-	-	-	-	-	-	-
8	0	3.55	0.40	-	0.23	-	-	-	-	-	-	-
9	0	0.05	0.40	-	0.26	-	-	-	-	-	-	-
10	0	0.74	0.40	-	0.20	-	-	-	-	-	-	-
11	0	0.64	0.40	-	0.69	-	-	-	-	-	-	-
12	0	0.64	0.41	-	0.85	-	-	-	-	-	-	-
13	0	0.55	0.70	-	0.90	-	-	-	-	-	-	-
14	0	0.55	0.95	-	0.94	-	-	-	-	-	-	-
15	0	0.47	0.70	-	1.07	-	-	-	-	-	-	-
16	0	0.40	0.67	-	0.90	-	-	-	-	-	-	-
17	0	0.40	0.58	0.63	1.52	-	-	-	-	-	-	-
18	0.01	0.42	0.50	2.54	1.02	-	-	-	-	-	-	-
19	0.01	0.47	0.49	1.43	0.97	-	-	-	-	-	-	-
20	0.01	0.47	-	0.93	-	-	-	-	-	-	-	-
21	0.05	0.45	-	1.18	-	-	-	-	-	-	-	-
22	0.05	0.41	-	0.95	-	-	-	-	-	-	-	-
23	0.05	0.43	-	1.73	-	-	-	-	-	-	-	-
24	0.06	0.40	-	1.63	-	-	-	-	-	-	-	-
25	0.06	0.40	-	2.19	-	-	-	-	-	-	-	-
26	0.08	0.40	-	0.97	-	-	-	-	-	-	-	-
27	0.10	0.40	-	1.49	-	-	-	-	-	-	-	-
28	0.10	0.40	-	1.34	-	-	-	-	-	-	-	-
29	0.10	0.40	-	1.06	-	-	-	-	-	-	-	-
30	0.13	0.40	-	0.68	-	-	-	-	-	-	-	-
31	0.19	-	-	0.69	-	-	-	-	-	-	-	-
Mean:	0.03	0.57	0.50	1.30	0.65	-	-	-	-	-	-	-
Max:	0.19	3.55	0.95	2.54	1.52	-	-	-	-	-	-	-
Min:	0	0.05	0.40	0.63	0.17	-	-	-	-	-	-	-
Acre-feet:	2	34	19	39	24	-	-	-	-	-	-	-
Annual Acre-feet total:	118											

Appendix 12

Browns Creek

Discharge in cubic feet per second, Water Year October 2000 to September 2001

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0	2.5	2.6	2.6	2.0	1.3	3.8	1.7	0	0	0	0
2	0	2.4	2.6	2.6	2.0	0.7	3.4	1.3	0	0	0	0
3	0	2.4	2.6	2.6	2.0	1.0	3.0	0.9	0	0	0	0
4	0	2.4	2.6	2.6	2.0	0.8	3.1	1.0	0	0	0	0
5	0	2.5	3.0	2.6	2.0	0.9	2.9	1.1	0	0	0	0
6	0	2.5	2.6	2.6	1.8	0.8	2.6	1.2	0	0	0	0
7	0	2.6	2.6	2.6	1.7	1.2	2.5	1.2	0	0	0	0
8	0	2.8	2.5	2.6	1.7	2.6	3.4	1.2	0	0	0	0
9	0	2.5	2.5	2.6	1.7	2.5	3.4	0.9	0	0	0	0
10	0	2.9	2.5	2.6	1.7	2.3	3.6	0.8	0	0	0	0
11	0	3.2	3.2	2.6	1.6	2.4	2.6	0.7	0	0	0	0
12	0	4.4	2.5	2.5	1.6	2.6	3.1	0.6	0	0	0	0
13	0	3.7	3.4	3.0	1.7	2.3	2.5	0.6	0	0	0	0
14	0	2.7	2.6	2.0	1.6	2.3	2.5	0.5	0	0	0	0
15	0	2.2	2.7	2.0	1.6	2.4	2.8	0	0	0	0	0
16	0	2.1	3.5	2.0	1.6	2.2	3.0	0	0	0	0	0
17	0	3.0	2.6	2.0	1.6	2.4	3.1	0	0	0	0	0
18	0	2.8	2.6	2.0	1.6	2.8	2.8	0	0	0	0	0
19	0	2.5	2.6	2.0	1.5	3.2	1.0	0	0	0	0	0
20	0	2.5	2.9	2.0	1.3	3.8	0.8	0	0	0	0	0
21	0.8	3.5	2.5	2.0	1.1	3.7	0.8	0	0	0	0	0
22	0.9	2.7	2.5	2.0	0.9	3.9	0.9	0	0	0	0	0
23	0.8	3.7	3.0	2.0	1.1	3.9	0.9	0	0	0	0	0
24	0.5	2.6	2.5	2.0	1.1	3.8	1.0	0	0	0	0	0
25	0.6	2.6	2.6	2.0	0.9	3.6	1.2	0	0	0	0	0
26	2.9	2.5	2.6	2.0	0.8	3.2	1.6	0	0	0	0	0
27	3.0	2.5	2.6	2.0	1.0	3.2	1.6	0	0	0	0	0
28	2.8	2.5	2.6	2.0	1.2	3.9	1.3	0	0	0	0	0
29	2.4	2.5	2.6	2.0	-	3.8	1.2	0	0	0	0	0
30	2.5	2.8	2.6	2.0	-	3.6	1.5	0	0	0	0	0
31	2.4	-	2.6	2.0	-	3.8	-	-	-	0	0	-
Mean:	0.63	2.75	2.69	2.27	1.52	2.60	2.26	0.46	0	0	0	0
Max:	3.02	4.37	3.47	2.99	2.02	3.95	3.85	1.67	0	0	0	0
Min:	0	2.10	2.46	2.02	0.78	0.74	0.80	0	0	0	0	0
Acre-feet:	39	164	165	140	84	160	135	27	0	0	0	0
Annual Acre-feet total:	914											

Appendix 13

Browns Creek

Discharge in cubic feet per second, Water Year October 2001 to September 2002

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0	2.6	-	2.8	2.4	3.2	3.7	0.6	0	0	0	-
2	0	2.5	-	3.1	2.4	3.5	4.2	0.6	0	0	0	-
3	0	2.4	-	2.9	2.4	3.6	4.9	0.6	0	0	0	-
4	0	2.4	-	3.4	2.5	3.6	6.1	0.6	0	0	0	-
5	0	2.4	-	2.8	2.5	2.8	6.2	0.7	0	0	0	-
6	0	2.4	-	3.7	2.5	3.6	5.7	0.8	0	0	0	-
7	0	2.3	-	3.4	2.5	3.6	5.4	0.8	0	0	0	-
8	0	2.3	-	3.2	2.5	3.7	5.7	0.7	0	0	0	-
9	0	2.3	-	3.0	2.5	3.9	5.8	0.6	0	0	0	-
10	0	2.4	-	2.9	2.4	3.0	5.1	0.6	0	0	0	-
11	0	2.7	-	2.9	2.4	3.1	5.2	0.6	0	0	0	-
12	0	2.7	3.2	2.7	1.5	3.1	6.5	0.6	0	0	0	-
13	0	2.5	2.8	2.9	1.1	3.1	6.8	0.6	0	0	0	-
14	0	2.5	3.4	3.4	2.0	2.9	9.3	0.7	0	0	0	-
15	0	2.5	4.6	3.8	2.6	3.4	6.9	0.7	0	0	0	-
16	0.5	2.4	7.2	3.6	2.6	3.3	4.5	0.7	0	0	-	-
17	1.9	2.4	5.7	4.1	2.6	3.9	3.9	0.7	0	0	-	-
18	2.1	2.2	3.7	4.2	2.6	3.5	2.6	0.7	0	0	-	-
19	2.1	2.1	2.6	3.8	2.7	3.8	1.4	0.7	0	0	-	-
20	2.1	2.1	2.6	3.8	3.1	3.0	1.3	0.5	0	0	-	-
21	2.1	2.2	2.9	2.8	3.0	3.0	1.3	0.5	0	0	-	-
22	2.1	3.3	3.1	2.1	3.1	3.0	1.2	0.5	0	0	-	-
23	2.3	2.2	2.8	2.0	3.4	3.0	0.6	0.5	0	0	-	-
24	2.4	3.8	2.8	2.5	3.2	3.0	0.5	0	0	0	-	-
25	2.4	3.0	4.4	2.4	3.2	2.9	0.6	0	0	0	-	-
26	2.4	3.4	3.7	2.0	3.3	2.9	0.8	0	0	0	-	-
27	2.4	-	2.8	2.0	3.0	3.0	0.6	0	0	0	-	-
28	2.4	-	2.9	2.3	3.1	3.3	0.6	0	0	0	-	-
29	2.3	-	2.8	2.7	-	3.5	0.6	0	0	0	-	-
30	2.8	-	2.8	2.4	-	3.8	0.6	0	0	0	-	-
31	2.8	-	3.0	2.4	-	3.8	-	0	-	0	-	-
Mean:	1.1	2.5	3.5	3.0	2.6	3.3	3.6	0.5	0	0	0	-
Max:	2.8	3.8	7.2	4.2	3.4	3.9	9.3	0.8	0	0	0	-
Min:	0	2.1	2.6	2.0	1.1	2.8	0.5	0.0	0	0	0	-
Acre-feet:	69	124	138	183	145	203	215	29	0	0	0	-
Annual Acre-feet total:	1107											

Appendix 14

Browns Creek

Discharge in cubic feet per second, Water Year October 2002 to September 2003

Daily Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	-	-	-	4.6	2.7	1.9	2.3	-	-	-	-	-
2	-	-	-	3.6	2.5	2.0	2.1	-	-	-	-	-
3	-	-	-	2.8	2.0	1.9	2.0	-	-	-	-	-
4	-	-	-	2.8	1.9	2.0	2.4	-	-	-	-	-
5	-	-	-	2.9	2.0	2.0	2.1	-	-	-	-	-
6	-	-	-	3.1	1.6	1.9	2.1	-	-	-	-	-
7	-	-	1.9	3.1	1.4	2.0	2.1	-	-	-	-	-
8	-	-	1.9	3.1	1.4	2.2	2.0	-	-	-	-	-
9	-	-	2.7	2.8	1.3	2.2	2.0	-	-	-	-	-
10	-	-	1.9	2.8	1.2	2.2	2.0	-	-	-	-	-
11	-	-	1.6	2.8	1.5	2.2	2.0	-	-	-	-	-
12	-	-	1.9	2.8	1.4	2.2	2.1	-	-	-	-	-
13	-	-	2.0	2.8	2.0	2.3	2.0	-	-	-	-	-
14	-	-	2.6	2.8	2.0	2.4	2.0	-	-	-	-	-
15	-	-	3.0	2.9	2.0	2.5	1.9	-	-	-	-	-
16	-	-	2.5	2.9	2.0	2.4	2.1	-	-	-	-	-
17	-	-	5.9	2.7	1.8	2.3	2.1	-	-	-	-	-
18	-	-	6.8	2.3	2.1	2.1	2.1	-	-	-	-	-
19	-	-	9.5	2.3	2.0	2.1	2.1	-	-	-	-	-
20	-	-	10.4	2.2	2.0	2.2	2.1	-	-	-	-	-
21	-	-	9.2	2.2	2.0	2.2	2.1	-	-	-	-	-
22	-	-	8.4	2.3	2.0	2.2	2.1	-	-	-	-	-
23	-	-	7.9	3.0	2.3	2.2	-	-	-	-	-	-
24	-	-	8.6	3.0	2.0	2.2	-	-	-	-	-	-
25	-	-	11.4	2.7	2.0	2.2	-	-	-	-	-	-
26	-	-	12.6	2.6	2.0	2.4	-	-	-	-	-	-
27	-	-	7.1	3.0	2.0	2.3	-	-	-	-	-	-
28	-	-	3.2	3.1	1.9	2.2	-	-	-	-	-	-
29	-	-	2.9	2.7	-	2.2	-	-	-	-	-	-
30	-	-	3.3	2.5	-	2.2	-	-	-	-	-	-
31	-	-	3.1	2.5	-	2.3	-	-	-	-	-	-
Mean:	-	-	-	3.0	2.6	3.3	3.6	-	-	-	-	-
Max:	-	-	-	4.2	3.4	3.9	9.3	-	-	-	-	-
Min:	-	-	-	2.0	1.1	2.8	0.5	-	-	-	-	-
Acre-feet:	-	-	263	173	105	134	92	-	-	-	-	-
Annual Acre-feet total:	766											

Appendix 15

West Side Weather Station

Daily Evapotranspiration (inches), Water Year October 2000 to September 2001

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.15	0.04	0.02	0.05	0.04	0.08	0.15	0.27	0.25	0.25	0.22	0.15
2	0.15	0.07	0.04	0.04	0.05	0.06	0.16	0.28	0.26	0.26	0.21	0.15
3	0.17	0.06	0.04	0.04	0.05	0.08	0.20	0.24	0.12	0.25	0.24	0.14
4	0.17	0.07	0.04	0.04	0.07	0.04	0.20	0.28	0.20	0.29	0.23	0.16
5	0.14	0.07	0.05	0.05	0.07	0.06	0.20	0.25	0.18	0.29	0.22	0.16
6	0.14	0.08	0.03	0.05	0.08	0.02	0.16	0.25	0.25	0.30	0.24	0.14
7	0.15	0.05	0.05	0.05	0.11	0.02	0.18	0.23	0.27	0.29	0.23	0.14
8	0.14	0.05	0.03	0.05	0.07	0.04	0.21	0.24	0.26	0.21	0.21	0.15
9	0.14	0.06	0.03	0.04	0.03	0.11	0.20	0.27	0.28	0.24	0.21	0.15
10	0.14	0.05	0.04	0.03	0.05	0.11	0.14	0.27	0.28	0.26	0.22	0.21
11	0.11	0.02	0.03	0.04	0.05	0.02	0.16	0.24	0.18	0.28	0.22	0.19
12	0.08	0.01	0.06	0.02	0.03	0.06	0.20	0.18	0.17	0.26	0.22	0.09
13	0.02	0.02	0.03	0.02	0.02	0.09	0.21	0.22	0.19	0.24	0.22	0.14
14	0.06	0.04	0.02	0.02	0.05	0.10	0.21	0.22	0.17	0.27	0.22	0.17
15	0.09	0.04	0.04	0.03	0.03	0.12	0.22	0.24	0.12	0.27	0.17	0.18
16	0.10	0.03	0.02	0.03	0.06	0.12	0.25	0.27	0.24	0.25	0.20	0.20
17	0.11	0.03	0.05	0.01	0.06	0.10	0.22	0.26	0.18	0.19	0.19	0.16
18	0.12	0.02	0.04	0.02	0.07	0.09	0.22	0.27	0.15	0.26	0.21	0.16
19	0.13	0.04	0.04	0.04	0.05	0.11	0.24	0.22	0.22	0.26	0.19	0.19
20	0.12	0.05	0.04	0.03	0.03	0.13	0.16	0.20	0.25	0.26	0.09	0.18
21	0.11	0.05	0.06	0.03	0.03	0.15	0.22	0.19	0.27	0.27	0.14	0.18
22	0.08	0.05	0.04	0.04	0.03	0.11	0.15	0.20	0.27	0.25	0.17	0.17
23	0.04	0.05	0.02	0.03	0.04	0.12	0.14	0.25	0.25	0.26	0.18	0.18
24	0.08	0.05	0.05	0.05	0.03	0.10	0.22	0.26	0.16	0.26	0.20	0.15
25	0.09	0.03	0.04	0.03	0.05	0.15	0.23	0.28	0.23	0.26	0.16	0.15
26	0.10	0.05	0.02	0.02	0.02	0.14	0.21	0.27	0.23	0.25	0.16	0.14
27	0.07	0.04	0.03	0.03	0.06	0.10	0.23	0.26	0.24	0.26	0.19	0.16
28	0.02	0.02	0.04	0.02	0.04	0.13	0.23	0.27	0.24	0.25	0.18	0.16
29	0.04	0.04	0.03	0.02	-	0.14	0.22	0.25	0.24	0.22	0.18	0.14
30	0.04	0.05	0.04	0.05	-	0.16	0.25	0.28	0.25	0.23	0.17	0.14
31	0.05	-	0.04	0.04	-	0.14	-	0.28	-	0.22	0.18	-
Mean:	0.10	0.04	0.04	0.03	0.05	0.10	0.20	0.25	0.22	0.25	0.19	0.16
Max:	0.17	0.08	0.06	0.05	0.11	0.16	0.25	0.28	0.28	0.30	0.24	0.21
Min:	0.02	0.01	0.02	0.01	0.02	0.02	0.14	0.18	0.12	0.19	0.09	0.09
Monthly Totals	3.16	1.31	1.12	1.04	1.36	2.97	5.99	7.67	6.59	7.89	6.04	4.75
Annual Total:	49.90											

Appendix 16

West Side Weather Station

Daily Evapotranspiration (inches), Water Year October 2001 to September 2002

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.15	0.07	-	-	0.04	0.10	0.17	0.11	0.27	0.27	0.22	0.20
2	0.15	0.07	-	-	0.04	0.07	0.17	0.09	0.13	0.28	0.23	0.22
3	0.15	0.06	-	-	0.05	0.08	0.16	0.16	0.23	0.28	0.23	0.17
4	0.17	0.08	-	-	0.05	0.09	0.18	0.19	0.21	0.23	0.22	0.16
5	0.16	0.08	-	-	0.06	0.10	0.17	0.19	0.23	0.27	0.20	0.18
6	0.12	0.08	-	-	0.06	0.10	0.15	0.19	0.26	0.27	0.22	0.14
7	0.13	0.08	-	-	0.08	0.02	0.12	0.20	0.26	0.25	0.20	0.16
8	0.15	0.07	-	-	0.06	0.04	0.14	0.16	0.25	0.23	0.22	0.17
9	0.10	0.07	-	-	0.06	0.05	0.15	0.17	0.19	0.25	0.22	0.18
10	0.10	0.06	-	-	0.06	0.09	0.11	0.19	0.18	0.28	0.24	0.18
11	0.11	0.06	-	-	0.06	0.06	0.15	0.13	0.20	0.28	0.22	0.19
12	0.10	0.04	-	-	0.06	0.08	0.13	0.16	0.22	0.27	0.23	0.18
13	0.11	0.04	-	-	0.07	0.08	0.16	0.20	0.25	0.21	0.23	0.19
14	0.12	0.05	-	-	0.04	0.06	0.19	0.22	0.26	0.14	0.24	0.20
15	0.11	0.06	-	-	0.04	0.04	0.18	0.18	0.27	0.26	0.24	0.14
16	0.11	0.05	-	-	0.04	0.05	0.06	0.20	0.28	0.26	0.24	0.17
17	0.12	0.06	-	-	0.05	0.05	0.07	0.21	0.28	0.26	0.23	0.15
18	0.13	0.07	-	-	0.02	0.05	0.07	0.22	0.28	0.08	0.24	0.15
19	0.11	0.05	-	-	0.05	0.08	0.05	0.23	0.22	0.11	0.23	0.16
20	0.11	0.04	-	-	0.04	0.12	0.07	0.16	0.23	0.22	0.19	0.17
21	0.13	0.08	-	-	0.05	0.12	0.14	0.09	0.25	0.24	0.20	0.16
22	0.14	0.03	-	0.05	0.09	0.12	0.16	0.13	0.23	0.24	0.20	0.18
23	0.11	0.04	-	0.03	0.12	0.12	0.18	0.17	0.22	0.22	0.21	0.18
24	0.11	0.04	-	0.04	0.08	0.08	0.18	0.18	0.26	0.27	0.21	0.18
25	0.09	0.01	-	0.05	0.09	0.06	0.17	0.21	0.26	0.27	0.22	0.16
26	0.09	0.03	-	0.09	0.08	0.11	0.16	0.22	0.24	0.27	0.19	0.17
27	0.11	0.03	-	0.02	0.08	0.13	0.06	0.22	0.26	0.25	0.18	0.12
28	0.09	0.03	-	0.02	0.08	0.14	0.12	0.18	0.27	0.24	0.20	0.12
29	0.09	-	-	0.02	-	0.15	0.13	0.22	0.27	0.25	0.21	0.12
30	0.10	-	-	0.02	-	0.15	0.07	0.25	0.26	0.24	0.20	0.12
31	0.03	-	-	0.03	-	0.16	-	0.26	-	0.24	0.19	-
Mean:	0.12	0.05	-	0.04	0.06	0.09	0.13	0.18	0.24	0.24	0.22	0.17
Max:	0.17	0.08	0.00	0.09	0.12	0.16	0.19	0.26	0.28	0.28	0.24	0.22
Min:	0.03	0.01	0.00	0.02	0.02	0.02	0.05	0.09	0.13	0.08	0.18	0.12
Monthly Totals	3.58	1.49	0.00	0.38	1.73	2.73	3.99	5.71	7.18	7.41	6.67	4.97
Annual Total:	45.84											

Appendix 17

West Side Weather Station

Daily Evapotranspiration (inches), Water Year October 2002 to September 2003

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.07	0.05	0.05	-	-	-	-	-	-	-	-	-
2	0.10	0.06	0.04	-	-	-	-	-	-	-	-	-
3	0.11	0.06	0.05	-	-	-	-	-	-	-	-	-
4	0.05	0.07	0.05	-	-	-	-	-	-	-	-	-
5	0.11	0.08	0.04	-	-	-	-	-	-	-	-	-
6	0.12	0.08	0.02	-	-	-	-	-	-	-	-	-
7	0.13	0.06	0.04	-	-	-	-	-	-	-	-	-
8	0.13	0.01	0.03	-	-	-	-	-	-	-	-	-
9	0.12	0.05	0.03	-	-	-	-	-	-	-	-	-
10	0.12	0.02	0.03	-	-	-	-	-	-	-	-	-
11	0.11	0.05	0.04	-	-	-	-	-	-	-	-	-
12	0.11	0.07	0.04	-	-	-	-	-	-	-	-	-
13	0.11	0.04	0.02	-	-	-	-	-	-	-	-	-
14	0.11	0.06	0.07	-	-	-	-	-	-	-	-	-
15	0.12	0.04	0.04	-	-	-	-	-	-	-	-	-
16	0.12	0.10	0.01	-	-	-	-	-	-	-	-	-
17	0.12	0.06	0.02	-	-	-	-	-	-	-	-	-
18	0.11	0.05	0.03	-	-	-	-	-	-	-	-	-
19	0.11	0.05	0.02	-	-	-	-	-	-	-	-	-
20	0.11	0.06	0.03	-	-	-	-	-	-	-	-	-
21	0.07	0.04	0.02	-	-	-	-	-	-	-	-	-
22	0.08	0.03	0.01	-	-	-	-	-	-	-	-	-
23	0.07	0.05	0.02	-	-	-	-	-	-	-	-	-
24	0.08	0.04	0.02	-	-	-	-	-	-	-	-	-
25	0.07	0.05	0.02	-	-	-	-	-	-	-	-	-
26	0.08	0.05	0.02	-	-	-	-	-	-	-	-	-
27	0.08	0.05	0.04	-	-	-	-	-	-	-	-	-
28	0.07	0.05	0.05	-	-	-	-	-	-	-	-	-
29	0.07	0.05	0.03	-	-	-	-	-	-	-	-	-
30	0.07	0.03	0.02	-	-	-	-	-	-	-	-	-
31	0.06		0.02	-	-	-	-	-	-	-	-	-
Mean:	0.10	0.05	0.03	-	-	-	-	-	-	-	-	-
Max:	0.13	0.10	0.07	-	-	-	-	-	-	-	-	-
Min:	0.05	0.01	0.01	-	-	-	-	-	-	-	-	-
Monthly Totals	2.97	1.54	0.95	-	-	-	-	-	-	-	-	-
Annual Total:	5.47											

Appendix 18

East Side Weather Station

Daily Evapotranspiration (inches), Water Year October 2000 to September 2001

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.15	0.07	0.04	0.04	0.05	0.08	0.18	0.23	0.29	0.31	0.26	0.24
2	0.17	0.06	0.04	0.04	0.05	0.04	0.12	0.17	0.26	0.31	0.29	0.25
3	0.17	0.07	0.04	0.04	0.07	0.06	0.11	0.18	0.22	0.19	0.30	0.23
4	0.14	0.07	0.05	0.05	0.07	0.02	0.09	0.21	0.24	0.21	0.31	0.24
5	0.14	0.08	0.03	0.05	0.08	0.02	0.12	0.23	0.23	0.23	0.27	0.24
6	0.15	0.05	0.05	0.05	0.11	0.04	0.05	0.23	0.27	0.20	0.28	0.18
7	0.14	0.05	0.03	0.05	0.07	0.08	0.07	0.24	0.29	0.14	0.28	0.21
8	0.14	0.06	0.03	0.04	0.03	0.11	0.08	0.27	0.30	0.25	0.26	0.20
9	0.14	0.05	0.04	0.03	0.05	0.03	0.08	0.25	0.30	0.20	0.19	0.21
10	0.11	0.02	0.03	0.04	0.05	0.07	0.13	0.24	0.27	0.16	0.28	0.21
11	0.08	0.01	0.06	0.02	0.03	0.10	0.05	0.27	0.21	0.26	0.29	0.11
12	0.02	0.02	0.03	0.02	0.02	0.11	0.12	0.18	0.24	0.27	0.27	0.15
13	0.06	0.04	0.02	0.02	0.05	0.13	0.12	0.24	0.22	0.29	0.29	0.18
14	0.09	0.04	0.04	0.03	0.03	0.13	0.15	0.19	0.28	0.30	0.26	0.18
15	0.10	0.03	0.02	0.03	0.06	0.10	0.19	0.14	0.29	0.28	0.29	0.21
16	0.11	0.03	0.05	0.01	0.06	0.11	0.21	0.24	0.31	0.19	0.29	0.15
17	0.12	0.02	0.04	0.02	0.07	0.11	0.19	0.25	0.29	0.25	0.29	0.17
18	0.13	0.04	0.04	0.04	0.05	0.13	0.17	0.24	0.29	0.26	0.30	0.20
19	0.12	0.05	0.04	0.03	0.03	0.16	0.06	0.26	0.28	0.27	0.28	0.19
20	0.11	0.05	0.06	0.03	0.03	0.12	0.07	0.26	0.27	0.27	0.28	0.20
21	0.08	0.05	0.04	0.04	0.03	0.14	0.08	0.25	0.31	0.27	0.28	0.19
22	0.04	0.05	0.02	0.03	0.04	0.12	0.14	0.25	0.32	0.26	0.27	0.19
23	0.08	0.05	0.05	0.05	0.03	0.16	0.17	0.30	0.30	0.27	0.26	0.16
24	0.09	0.03	0.04	0.03	0.05	0.16	0.19	0.31	0.27	0.27	0.23	0.17
25	0.10	0.05	0.02	0.02	0.02	0.13	0.22	0.26	0.16	0.28	0.22	0.16
26	0.07	0.04	0.03	0.03	0.06	0.15	0.23	0.30	0.22	0.33	0.25	0.17
27	0.02	0.02	0.04	0.02	0.04	0.15	0.23	0.26	0.19	0.33	0.26	0.19
28	0.04	0.04	0.03	0.02	0.08	0.18	0.18	0.27	0.27	0.35	0.23	0.15
29	0.04	0.05	0.04	0.05	-	0.15	0.20	0.26	0.30	0.33	0.25	0.15
30	0.05	0.02	0.04	0.04	-	0.17	0.24	0.26	0.30	0.16	0.24	0.17
31	0.04	-	0.05	0.04	-	0.19	-	0.30	-	0.22	0.23	-
Mean:	0.10	0.04	0.04	0.03	0.05	0.11	0.14	0.24	0.27	0.25	0.23	0.19
Max:	0.17	0.08	0.06	0.05	0.11	0.19	0.24	0.31	0.32	0.35	0.31	0.25
Min:	0.02	0.01	0.02	0.01	0.02	0.02	0.05	0.14	0.16	0.14	0.19	0.11
Monthly Totals	3.04	1.29	1.15	1.04	1.40	3.44	4.24	7.53	7.98	7.89	8.28	5.64
Annual Total:	52.93											

Appendix 19

East Side Weather Station

Daily Evapotranspiration (inches), Water Year October 2001 to September 2002

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.16	0.07	0.02	-	0.02	0.08	0.19	0.11	0.21	0.30	-	-
2	0.16	0.06	0.00	-	0.04	0.08	0.17	0.18	0.24	0.30	-	-
3	0.18	0.09	0.03	-	0.05	0.09	0.19	0.21	0.23	0.33	-	-
4	0.19	0.09	-	-	0.05	0.11	0.18	0.21	0.26	0.29	-	-
5	0.13	0.09	-	-	0.06	0.12	0.16	0.21	0.30	0.29	-	-
6	0.15	0.10	-	-	0.07	0.03	0.14	0.21	0.29	0.28	-	-
7	0.16	0.07	-	-	0.09	0.03	0.16	0.19	0.27	0.30	-	-
8	0.12	0.07	-	-	0.07	0.07	0.14	0.18	0.21	0.28	-	-
9	0.11	0.07	-	-	0.07	0.10	0.11	0.22	0.20	0.29	-	-
10	0.12	0.07	-	-	0.06	0.07	0.17	0.10	0.21	0.30	-	-
11	0.13	0.04	-	-	0.06	0.09	0.17	0.17	0.24	0.28	-	-
12	0.12	0.05	-	-	0.07	0.09	0.17	0.22	0.27	0.23	-	-
13	0.14	0.05	-	-	0.08	0.06	0.21	0.24	0.29	0.15	-	-
14	0.11	0.07	-	0.05	0.03	0.07	0.20	0.20	0.31	0.29	-	-
15	0.11	0.06	-	0.08	0.05	0.05	0.07	0.22	0.31	0.30	-	-
16	0.14	0.07	-	0.04	0.05	0.06	0.07	0.22	0.31	0.29	-	-
17	0.12	0.07	-	0.04	0.05	0.05	0.07	0.25	0.33	0.09	-	-
18	0.12	0.05	-	0.03	0.02	0.08	0.05	0.25	0.27	0.11	-	-
19	0.12	0.05	-	0.04	0.07	0.13	0.07	0.18	0.25	0.23	-	-
20	0.14	0.07	-	0.04	0.05	0.13	0.14	0.10	0.27	0.25	-	-
21	0.15	0.03	-	0.05	0.07	0.13	0.17	0.15	0.26	0.25	-	-
22	0.12	0.05	-	0.06	0.09	0.14	0.20	0.19	0.24	0.29	-	-
23	0.13	0.04	-	0.04	0.13	0.07	0.20	0.20	0.28	0.30	-	-
24	0.10	0.02	-	0.04	0.08	0.06	0.18	0.23	0.28	0.31	-	-
25	0.10	0.04	-	0.05	0.10	0.12	0.18	0.25	0.28	-	-	-
26	0.12	0.03	-	0.10	0.09	0.15	0.07	0.23	0.25	-	-	-
27	0.12	0.03	-	0.03	0.09	0.15	0.11	0.22	0.30	-	-	-
28	0.09	0.02	-	0.03	0.09	0.16	0.14	0.24	0.30	-	-	-
29	0.10	0.02	-	0.02	0.12	0.16	0.07	0.28	0.30	-	-	-
30	0.04	0.04	-	0.01	-	0.18	0.12	0.29	0.31	-	-	-
31	0.09	-	-	0.01	-	0.18	-	0.29	-	-	-	-
Mean:	0.13	0.06	-	0.04	0.07	0.10	0.14	0.21	0.27	0.26	-	-
Max:	0.19	0.10	0.03	0.10	0.13	0.18	0.21	0.29	0.33	0.33	-	-
Min:	0.04	0.02	0.00	0.01	0.02	0.03	0.05	0.10	0.20	0.09	-	-
Monthly Totals	3.88	1.67	0.05	0.76	1.94	3.08	4.26	6.42	8.05	6.31	-	-
Annual Total:	36.42											

Appendix 20

East Side Weather Station

Daily Evapotranspiration (inches), Water Year October 2002 to September 2003

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	-	0.06	0.05	0.02	0.09	0.07	0.06	-	-	-	-	-
2	-	0.07	0.05	0.03	0.06	0.10	0.06	-	-	-	-	-
3	-	0.07	0.05	0.03	0.05	0.06	0.09	-	-	-	-	-
4	-	0.08	0.05	0.04	0.05	0.06	0.06	-	-	-	-	-
5	-	0.09	0.04	0.06	0.05	0.11	0.10	-	-	-	-	-
6	-	0.08	0.03	0.05	0.05	0.13	0.10	-	-	-	-	-
7	-	0.07	0.04	0.04	0.04	0.14	0.14	-	-	-	-	-
8	-	0.02	0.04	0.04	0.06	0.15	0.18	-	-	-	-	-
9	-	0.05	0.04	0.04	0.06	0.12	0.18	-	-	-	-	-
10	-	0.03	0.04	0.02	0.07	0.07	0.17	-	-	-	-	-
11	-	0.06	0.04	0.01	0.08	0.12	0.17	-	-	-	-	-
12	-	0.07	0.05	0.03	0.05	0.14	0.10	-	-	-	-	-
13	-	0.05	0.02	0.06	0.03	0.17	0.03	-	-	-	-	-
14	-	0.06	0.10	0.05	0.06	0.11	0.11	-	-	-	-	-
15	-	0.05	0.03	0.05	0.07	0.06	0.11	-	-	-	-	-
16	-	0.11	0.01	0.05	0.07	0.07	0.07	-	-	-	-	-
17	-	0.07	0.02	0.05	0.06	0.07	0.09	-	-	-	-	-
18	-	0.05	0.02	0.05	0.05	0.11	0.11	-	-	-	-	-
19	0.12	0.06	0.02	0.05	0.07	0.13	0.15	-	-	-	-	-
20	0.12	0.07	0.03	0.05	0.04	0.09	0.12	-	-	-	-	-
21	0.07	0.04	0.02	0.07	0.07	0.11	0.09	-	-	-	-	-
22	0.08	0.04	0.02	0.04	0.08	0.12	0.08	-	-	-	-	-
23	0.07	0.06	0.03	0.06	0.09	0.06	-	-	-	-	-	-
24	0.09	0.05	0.02	0.02	0.09	0.12	-	-	-	-	-	-
25	0.07	0.05	0.02	0.03	0.07	0.12	-	-	-	-	-	-
26	0.08	0.05	0.02	0.06	0.03	0.10	-	-	-	-	-	-
27	0.08	0.05	0.03	0.05	0.08	0.11	-	-	-	-	-	-
28	0.08	0.06	0.05	0.05	0.04	0.12	-	-	-	-	-	-
29	0.09	0.05	0.03	0.05	0.06	0.15	-	-	-	-	-	-
30	0.07	0.03	0.03	0.05	-	0.16	-	-	-	-	-	-
31	0.07	-	0.03	0.06	-	0.17	-	-	-	-	-	-
Mean:	0.09	0.06	-	0.04	0.06	0.11	0.11	-	-	-	-	-
Max:	0.12	0.11	0.10	0.07	0.09	0.17	0.18	-	-	-	-	-
Min:	0.07	0.02	0.01	0.01	0.03	0.06	0.03	-	-	-	-	-
Monthly Totals	1.11	1.70	1.04	1.37	1.76	3.41	2.34	-	-	-	-	-
Annual Total:	12.73											

Appendix 21

Little Washoe Outflow Data from Office of the Water Master - Truckee River System

Monthly Discharge (Acre-feet)

							Month							Blank entries indicate no flow
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total**	* = incomplete record
1966						171	298	287	51				1,598	
1967						811	1,081	1,455	1,688	873	112		6,020	
1968						145	459	593	556	183			1,936	
1969				1,737	1,918	2,219	1,319	422	538	267				
1970				1,142	709	469	124	409	264				3,117	
1971				165	176									
1972							1,209	819					2,028	
1973							721	374					1,095	
1974							203	680	484				1,367	
1975						74	91							
1976					135	104	240						479	
1977				36	228	22							286	
1978					465	1,539	792	14					2,810	
1979						90	44	410					545	
1980														no release year
1981								52	9				60	
1982					834	2,954	2,308	502	136	221	3,173	4,754	14,881	
1983	5,606	5,107	6,358	6,942	6,296	8,688	7,039	4,273	2,570	2,388	3,815	6,405	65,487	
1984	7,212	6,179	5,280	3,762	3,178	2,570	510	212	71	15	15	15	29,018	
1985	53	496	1,294	1,922	1,366	179	428	291	598	61	59	61	6,810	
1986	61	4,087	9,674	7,559	5,336	4,220	1,402	864	493	127	59	15	33,853	
1987	15	145	641	700	314	20	487	416	207	1			2,945	
1988	15	19	17	18	17	33	40	3					162	minor leakage
1989	*	*	1	13	12	11	14	3	6	*	*	*	60	
1990	*	*	*	3	12	15	5			*	*	*	35	leakage and storm runoff only
1991	*	*	*	8	17	34	67	2					128	Washoe Lake dry late summer 1991
1992	*	*	4	3			14	*	*	*	*	*	21	minor leakage
1993	18	17	49	30	31	30	18	9	8				210	
1994	7	16	11										34	
1995	4	6	6	6	6	6	3						37	leakage only, no release in 1995
1996	15	214	2,066	2,759	3,807	2,979	48	82	162	*	*	*	12,132	
1997	*	10,050	8,170	3,297	2,241	1,149	370	311	487	397	33	24	26,529	
1998	24	261	1,371	3,144	2,761	1,954	862	419	298	61	37	45	11,237	
1999	289	3,150	3,440	1,730	1,870	2,660	1,300	1,800	1,210	468	11	19	17,947	
2000	53	82	307	401	425	192	1,029	408	26				2,923	minor leakage
2001	31	27	26	25	19	0	50	2			*	20	200	
Average Monthly Flow	957	1,990	2,277	1,609	1,340	1,191	728	560	493	422	813	1,262		

Average Annual Flow 13,643