Treasure Valley Hydrologic Project
Research Report

1996 WATER BUDGET
FOR THE
TREASURE VALLEY AQUIFER SYSTEM

prepared by

Scott M. Urban
Idaho Department of Water Resources

and

Christian R. Petrich
Idaho Water Resources Research Institute
University of Idaho

January, 1998

(Revised July, 1998)

This report presents a water budget for the Treasure Valley aquifer system for the calendar year 1996. The water budget provides an estimate of the current balance between total aquifer withdrawals and discharge, aquifer recharge, and changes in aquifer storage. Specific objectives for this water budget were to (1) define major water budget components, (2) estimate inflows and outflows for the Treasure Valley aquifer systems, (3) describe, where possible, the spatial characteristics of the water budget data, (4) create, where possible, GIS coverages of the water budget data, and (5) create input files (e.g., recharge, withdrawals and ET) for the Treasure Valley ground water flow model.

Inflows to the Treasure Valley aquifer system include (1) seepage from canals, (2) seepage from rivers and streams, (3) seepage from Lake Lowell, (4) underflow, (5) infiltration of precipitation and surface water, and (6) seepage from rural domestic septic systems. Outflows include (1) municipal withdrawals, (2) industrial withdrawals, (3) irrigation withdrawals, (4) rural domestic withdrawals, (5) stock withdrawals, (6) discharge to canals, drains and rivers and (7) evapotranspiration.

Total inflow is estimated at 1,035,000 acre-feet, while total outflow is estimated at 999,000 acre-feet. The net difference shows an apparent increase in aquifer storage of 36,000 acre-feet. This difference is less than five percent of the total recharge or discharge, and is well within the estimated margin of error of 20 percent for some of the individual water budget component estimates. At this time, the condition of ground water surplus cannot be confirmed because of the error margin associated with some water budget components. The overall error associated with individual water budget component estimates and water level evaluations is expected to decrease as more information becomes available.

The largest source of ground water recharge appears to be seepage from the canal system, followed by seepage from flood irrigation and precipitation. The aggregate discharge to the Boise and Snake Rivers (through canals, drains, or to the rivers directly) is far greater than all withdrawals combined. On a valley-wide basis, the volume of ground water pumped during the year represents approximately 20 percent of the total ground water recharge for 1996.

Primary pumping areas and primary recharge areas do not coincide throughout the valley. The primary recharge areas are those with extensive canals and/or flood irrigation, while the greatest withdrawals occur in areas that are not flood irrigated. For example, agricultural irrigation withdrawals (non-supplemental) are concentrated in areas where surface water irrigation is unavailable, and municipal withdrawals are concentrated near the urban areas of Boise, Nampa, Caldwell, and Meridian. As a result, withdrawals may exceed recharge in local areas within the Treasure Valley, resulting in local water level declines. Water level increases were noted in areas where recharge was sufficient to offset local withdrawals.

The aggregate nature of the water budget masks the temporal characteristics of ground water recharge, withdrawals, and natural discharge. Infiltration from the surface water distribution system and irrigation occurs primarily in the summer. The actual aquifer recharge from irrigation activities lags the infiltration, so that water levels may be rising months after irrigation has ceased. Also, municipal withdrawals vary throughout the year, and is greatest during the summer irrigation season.

A cursory analysis of the change in aquifer storage was conducted using water level measurements made during March 1996 and March 1997. The difference between water levels indicated a positive net change in storage of about 20,000 acre-feet during this period.

ACKNOWLEDGEMENTS

This water budget was developed as part of the Treasure Valley Hydrologic Project. The first phase of the Treasure Valley Hydrologic Project was funded by the Idaho State Legislature ($300,000), United Water Idaho, Inc. ($201,000), and the Idaho Water Resource Board/U.S. Bureau of Reclamation ($15,000). In addition, in-kind services were provided by United Water Idaho, Inc. ($102,200) and the U.S. Geological Survey ($66,150).

The authors wish to acknowledge the assistance of IDWR staff (including Hal Anderson, Steve Baker, Shane Bendixsen, Linda Davis, Karl Dreher, Wayne Haas, Sheryl Howe, John Lindgren, Tony Morse, Bill Ondrechen, David Palmer, Bob Sutter, and Mike Verdun) in the completion of this report. The authors also acknowledge contributions made by the TVHP Technical Advisory Committee. Special thanks are extended to those individuals and communities that provided municipal pumping data: Gary Shoemaker and Wally Hammons of the City of Caldwell; Norman Revels, City of Eagle; Jim Taylor, City of Kuna; Gary Smith, City of Meridian; Bob Schmillen, City of Middleton; Tony Chavez, City of Nampa; Keith Stokes, South County Water Company, and Ed Squires, United Water Idaho.

DISCLAIMER

Some of the values and estimates provided in this report are changing on the basis of new information. For the latest estimates, please contact Scott Urban, Idaho Department of Water Resources (email: surban@idwr.state.id.us, or telephone: 208-327-5441).

Table of Contents

List of Figures

List of Tables

1. Introduction

Water budgets have been used throughout the western United States to help

provides an estimate of the current balance between total aquifer withdrawals and discharge, aquifer recharge, and changes in aquifer storage.

This report presents a water budget for the Treasure Valley aquifer system for the calendar year 1996. The water budget includes estimates of recharge to the Treasure Valley aquifer system, and estimates of ground water discharge. The report outlines specific water budget components, and provides estimates of aquifer recharge and discharge rates. The water budget also provides data for the development of a numerical ground water flow model for the Treasure Valley aquifer system. Aquifer recharge and ground water pumping rates are model inputs. The water budget also provides a basis for model calibration (simulated recharge and discharge rates should correspond with observed rates).

The report concludes with a discussion of the water budget findings and a list of recommendations for improving the water budget.

1.1. Purpose

The purpose of the Treasure Valley water budget is to estimate recharge to and discharge from the Treasure Valley aquifers. Specific objectives for this water budget were to:

1. Define major water budget components.
2. Estimate inflows and outflows for the Treasure Valley aquifer systems.
3. Describe, where possible, the spatial characteristics of the water budget data.
4. Create, where possible, GIS coverages of the water budget data.
5. Create input files (e.g., recharge, withdrawals and ET) for the Treasure Valley ground water flow model.

1.2. Background

This section provides a review of water budgets for arid regions within the western United States. This review of water budget methods, applications, and results was conducted to help define Treasure Valley water budget components. Selected results from these water budgets are shown for the purpose of comparison. Results from these water budgets do not necessarily reflect conditions within the Treasure Valley.

Water budgets have been compiled for many areas, including Utah's Ogden Valley (Thomas, 1963), Las Vegas Valley (Patt, 1987), the Uinta Basin of Utah (Holmes, 1985) the Coconino Aquifer in Arizona (Mann, 1979), and California's San Joaquin Valley (Gronberg and Belitz, 1992). Newton (1991) and Kjelstrom (1995) prepared water budgets for the western Snake River Plain, which includes the Treasure Valley area. Garabedian (1992) completed a water budget for the eastern Snake River Plain. Newton's (1991) water budget was prepared in conjunction with a ground water model of the western Snake River Plain. However, the range of uncertainty associated with the water budget was large because some of the component values could not be well defined (Newton, 1991). For example, the amount of irrigation water that returns to canals and drains was not measured. As a result, the amount of return flow attributed to ground water discharge could not be defined.

Irrigation with surface water is intensive in the Boise and Payette River valleys, and along the Snake River. Newton (1991) estimated that 80 percent of ground water recharge resulted from surface water irrigation. Precipitation was shown to be a source of recharge, though on average only about two percent of total annual precipitation was estimated to become ground water recharge for the western Snake River Plain. Recharge from precipitation on irrigated land was assumed to be equivalent to the average annual precipitation. Nearly 83 percent of ground water discharge was estimated to be to rivers and drains; the remainder was pumping withdrawals. Power-consumption records were used to estimate that about 300,000 acre-feet of ground water were pumped to irrigate about 130,000 acres on the western plain. The mean application rate was estimated to be about 2.2 feet/acre (Newton, 1991).

Kjelstrom (1995) reported that changes in ground water storage were the net result of 100 successive years of irrigation on the entire Snake River Plain. During the 1930 to 1972 time period, ground water storage increased about 3 million acre-feet. From 1972 to 1980 storage generally decreased. Furthermore, from 1930 to 1980 several short-term cycles of gains and losses are evident. Kjelstrom attributed some cycles to periods of above- and below-normal precipitation. Sources of recharge, in order of decreasing magnitude, were infiltration of surface water irrigation, and infiltration of precipitation. According to Kjelstrom (1995), precipitation for the western Snake River Plain contributes an average of about 0.03 feet/acre of aquifer recharge per year. Most ground water discharge is to rivers and drains, primarily during the irrigation season (Kjelstrom, 1995).

Garabedian (1992) developed a numerical model for the eastern Snake River Plain. Ground water withdrawals were shown to be an important discharge component of the water budget. Withdrawals were estimated at about 1.8 million acre-feet for 1980 by using power billings for irrigation pumps. Some pumped water was returned to the aquifer from canal loss and field seepage. Therefore, withdrawals estimated from power-consumption was compared with estimated consumptive irrigation requirements, and the smaller of the two estimates was used to determine net ground water withdrawals. For 1980, net ground water withdrawals were estimated at about 1.1 million acre-feet, or about two-thirds of total withdrawals as estimated from power data (Garabedian, 1992).

1.3. Physiography and Climate

This water budget focuses on the Treasure Valley of southwestern Idaho. The project area is shown in Figure 1. The term “Treasure Valley” refers to the lower Boise River watershed area. The lower Boise River begins where the Boise River exits the mountains near the Lucky Peak Reservoir. From Lucky Peak Reservoir the lower Boise River flows about 64 (river) miles northwestward through the Treasure Valley to its confluence with the Snake River. The valley is bounded to the northwest by the Boise Foothills. Topography within the valley can be described as generally flat, with some rolling hills within the southern-most portion of the area. The project area extends to the southwest to the Snake River. This area was included in the study because some ground water originating in the lower Boise River area discharges to the Snake River.

Precipitation in the Treasure Valley ranges from about 8 to 14 inches per year, with a 30-year average of about 11 inches per year. Figure 2 is a precipitation map of the Treasure Valley; Figure 3 shows the mean monthly precipitation at seven sites. About 50 percent of the precipitation falls during the non-irrigation season. The average precipitation in the southern portion of the valley is about 10 inches per year (based on Kuna and Deer Flat data; Molnau and Winters, 1988). The average precipitation for flood-irrigated lands during 1996 was 12.8 inches (based upon data for Deer Flat Dam, Boise, Caldwell and Parma; NOAA, 1996) The mean annual temperature for the valley is about 51 degrees.

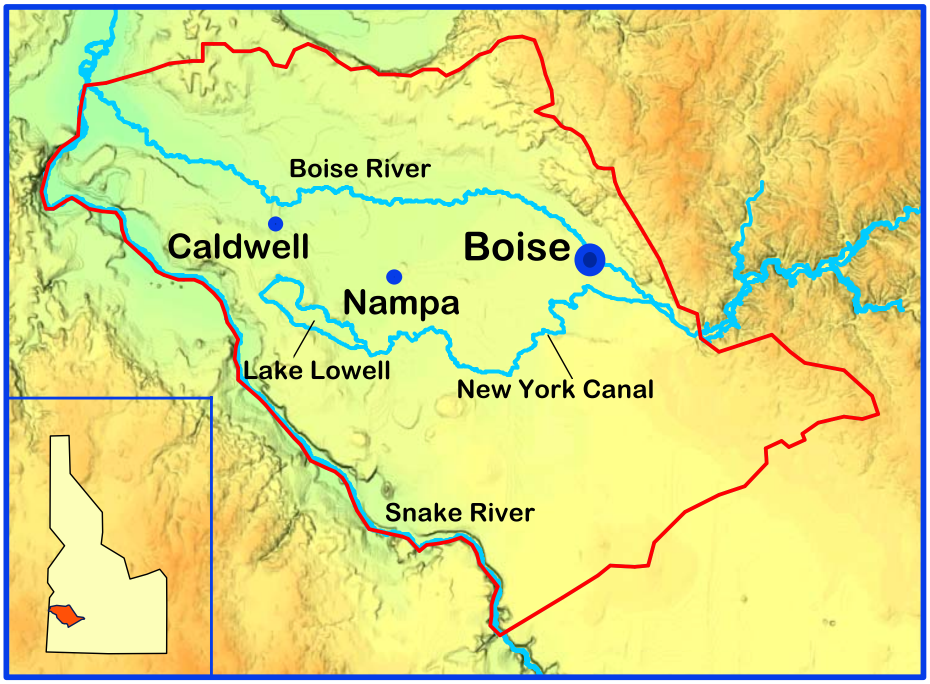


Figure 1: Project Area.

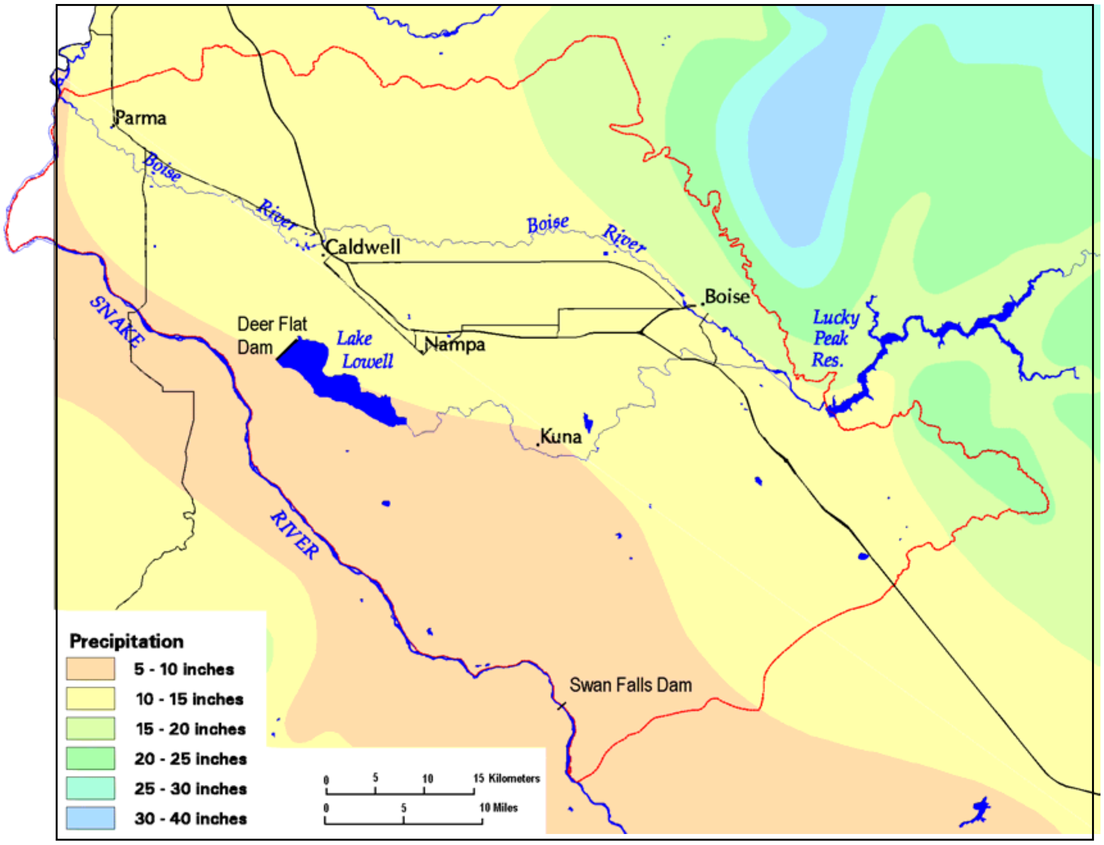


Figure 2: Precipitation map of the Treasure Valley.

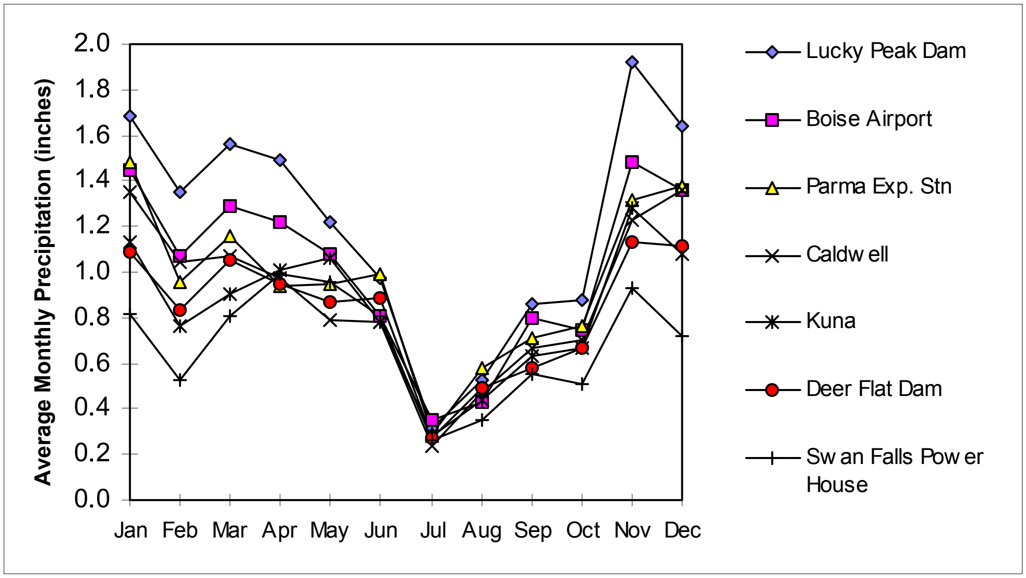


Figure 3: Average monthly precipitation for 1961-1990.

1.4. Water Budget Area and Time Frame

The water budget area corresponds with that of the Treasure Valley Hydrologic Project area (Figure 1). Water budgets can be constructed for an entire aquifer system, for individual aquifers, or both. The Treasure Valley contains a deep regional aquifer system (typically confined, with depths ranging from about 50 to 1500 feet) and shallow aquifer system (typically unconfined, generally less than about 150 feet in depth). The shallow system may contain local perched aquifers. The Phase I water budget focuses on the entire Treasure Valley aquifer system as a whole for several reasons.

First, pumping withdrawal data have not yet been differentiated on the basis of source aquifer. Although most municipal withdrawals occur from the deeper regional aquifer, and most rural domestic wells extend into the shallow system, there are numerous exceptions. Irrigation withdrawals are estimated on the basis of consumptive use (see Section 3.1.3), and are not differentiated between source aquifers.

Second, subsurface flow rates between the shallow and deeper regional aquifer systems have not been quantified. Percolating water from surface sources recharges shallow zones first. Recharge to the deeper regional system depends on local hydraulic gradients and on the hydraulic characteristics of aquifer materials. Recharge to the deep, regional aquifer system occurs in areas with downward hydraulic gradient. Shallow system recharge can occur in areas of regional upward hydraulic gradient, although this "recharge" may quickly discharge into the nearest drain or canal (Figure 4).

Developing water budgets for individual aquifers requires a better understanding of vertical flow between aquifers and pumping data that differentiate between source aquifers. More detailed pumping data will be developed as the Treasure Valley Hydrologic Project progresses. Vertical flow between aquifer systems also will be evaluated with the help of the numerical model.

The time frame selected for this water budget is a one year period corresponding with the 1996 calendar year. This year was the most recent year for which data were available.

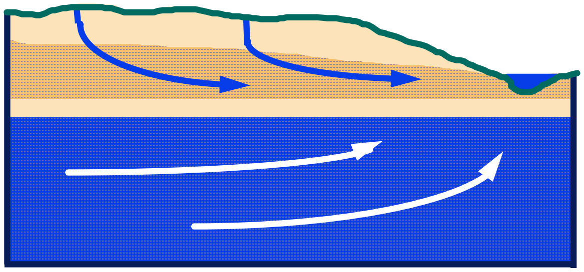


Figure 4: Schematic diagram showing recharge in a regional discharge area.

Water budget development is an iterative process. The data presented in this water budget will be used to help develop the numerical ground water flow model. The model results will be used to advance the water budget development (e.g., the model will be used to evaluate vertical flow between aquifers), and to help prioritize water budget data development efforts.

1.5. Water Budget Components

Water budget components include all significant sources of ground water inflows (recharge) and outflows (discharge) to the Treasure Valley aquifer system. In general,

$Inflows - Outflows = Change\ in\ Aquifer\ Storage$ (Eqn 1)

Ground water recharge is defined (Driscoll, 1986) as the amount of water added to the saturated zone (again, depending on the location within the valley, percolating water may recharge the deep regional aquifer or it may move horizontally in very shallow saturated zones, discharging into nearby canals or drains). Ground water discharge is the sum total of water leaving the saturated zone and can be in the form of aquifer discharge into canals, drains, or rivers, evapotranspiration, and withdrawals from wells.

Inflows into the Treasure Valley aquifer system (Figure 5) include (1) seepage from canals, (2) seepage from rivers and streams, (3) seepage from Lake Lowell, (4) underflow, (5) infiltration of precipitation and surface water used for irrigation, and (6) seepage from rural domestic septic systems. Outflows include (1) municipal withdrawals, (2) industrial withdrawals, (3) irrigation, (4) rural domestic withdrawals, (5) stock withdrawals, (6) evapotranspiration, and (7) discharge to drains and rivers. These inflows and outflows are related as shown in the following equation:

$$\begin{aligned}&R_C + R_R + R_L + I_U + R_P + R_{FI} + R_{SI} + R_S\\&-P_M - P_{MI} - P_{IN} - P_{IR} - P_R - P_S - D_R - D_C - ET \quad \text{(Eqn. 2)}\\&= \Delta S_{(S+R)}\end{aligned}$$

where

R_C = recharge from canal seepage
R_R = the recharge from river seepage
R_L = the recharge from Lake Lowell seepage
I_U = subsurface inflow (underflow)
R_P = recharge from precipitation
R_{FI} = recharge from agricultural flood irrigation
R_{SI} = recharge from agricultural sprinkler irrigation
R_S = recharge from rural domestic septic systems
P_M = municipal domestic and commercial withdrawals
P_{MI} = municipal irrigation withdrawals
P_{IN} = industrial withdrawals
P_{IR} = agricultural irrigation withdrawals
P_R = rural domestic withdrawals
P_S = withdrawals for stock watering
D_R = discharge to rivers
D_C = discharge to canals
ET = loss to evapotranpsiration
$\Delta S_{(S+R)}$ = aggregate change in aquifer storage for the shallow and regional aquifers.

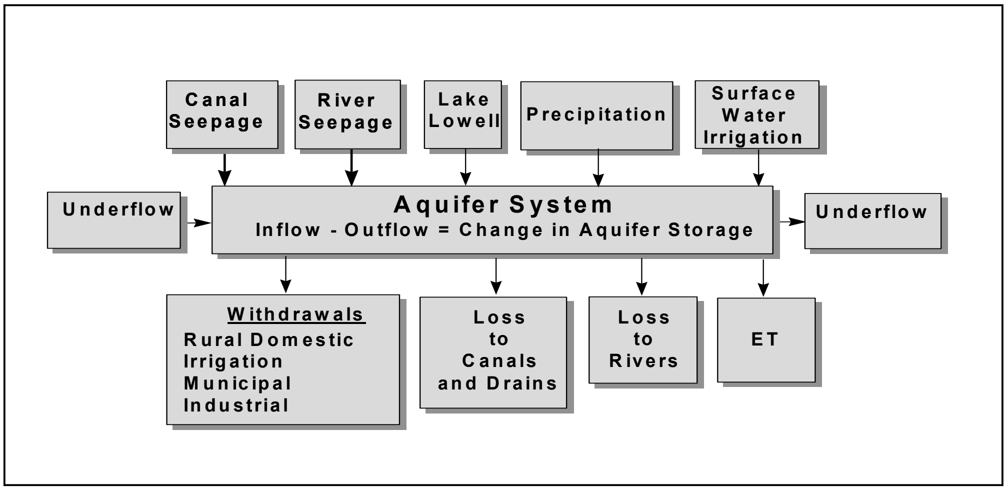


Figure 5: Generalized water budget schematic .

Equation 2 describes water budget components for the Treasure Valley ground water system as a whole. The Treasure Valley covers a large area (over 1,500 square miles), and aggregate values for the water budget components may mask some of the spatial characteristics of individual water budget components. For instance, recharge and withdrawal areas may not coincide, resulting in local changes in aquifer storage. The spatial distribution of inflows and outflows are also important to the numerical ground water flow model. The spatial distribution of individual water budget components is therefore provided whenever possible.

Water budget data are being stored and processed using Geographical Information System (GIS) software. Locational data for the water budget components can be maintained at the collection scale. Water budget data therefore can be compiled for different areas at different scales.

The following sections provide a discussion of individual water budget components. Included are descriptions of analysis methods and preliminary water budget results.

1.6. Units

Data provided in this report are generally presented in the form of acre-feet per year (acre-feet/yr) or cubic feet per second (cfs). Managers of surface water supplies commonly use acre-feet when evaluating water volumes stored in reservoirs, or when describing volumes allotted for irrigation. The unit of cubic feet per second is commonly used to describe flows in rivers and canals, and is also used in water rights to specify the permitted rate of ground water withdrawals. It is important to note that all flow rates presented in this report are average annual rates, even though some flows are seasonal in nature.

2. Estimates of Inflows

The primary inflows to the Treasure Valley aquifer system include (1) seepage from canals; (2) seepage from rivers and streams; (3) seepage from Lake Lowell; (4) underflow; (5) infiltration from precipitation and irrigation and (6) seepage from septic systems. Estimates of inflows from these sources are presented in the following sections.

2.1. Canal seepage

There are about 1,170 miles of major irrigation canals throughout the Treasure Valley (D. Palmer, IDWR, personal communication, 1997), and seepage from these is known to occur. These large and intermediate canals are shown in Figure 6. In addition to these larger canals, many miles of small canals and ditches exist within the valley. However, most of these smaller canals have not been mapped, and as a result the total length and spatial distribution of such canals is unknown. Because the length and location of the smaller canals is unknown, estimates of seepage from these canals is not provided in this water budget. Rather, this water budget provides an estimate of total canal seepage, and assigns the total seepage to the large and intermediate sized canals which have been located spatially.

The total canal seepage was estimated using the following relationship:

$$C_{seep} = T_{div} - Evap - ET - LL_{loss} + LL_{dS} - F_A \qquad \text{(Eqn. 3)}$$

where

C_{seep} = total canal seepage

T_{div} = total amount of water diverted to the valley

$Evap$ = direct evaporation from the canal surface

ET = evapotranspiration from phreatophytes along the canals

LL_{loss} = amount of water lost from Lake Lowell (seepage plus evaporation)

LL_{dS} = change in storage at Lake Lowell

F_A = average amount of water delivered to the fields

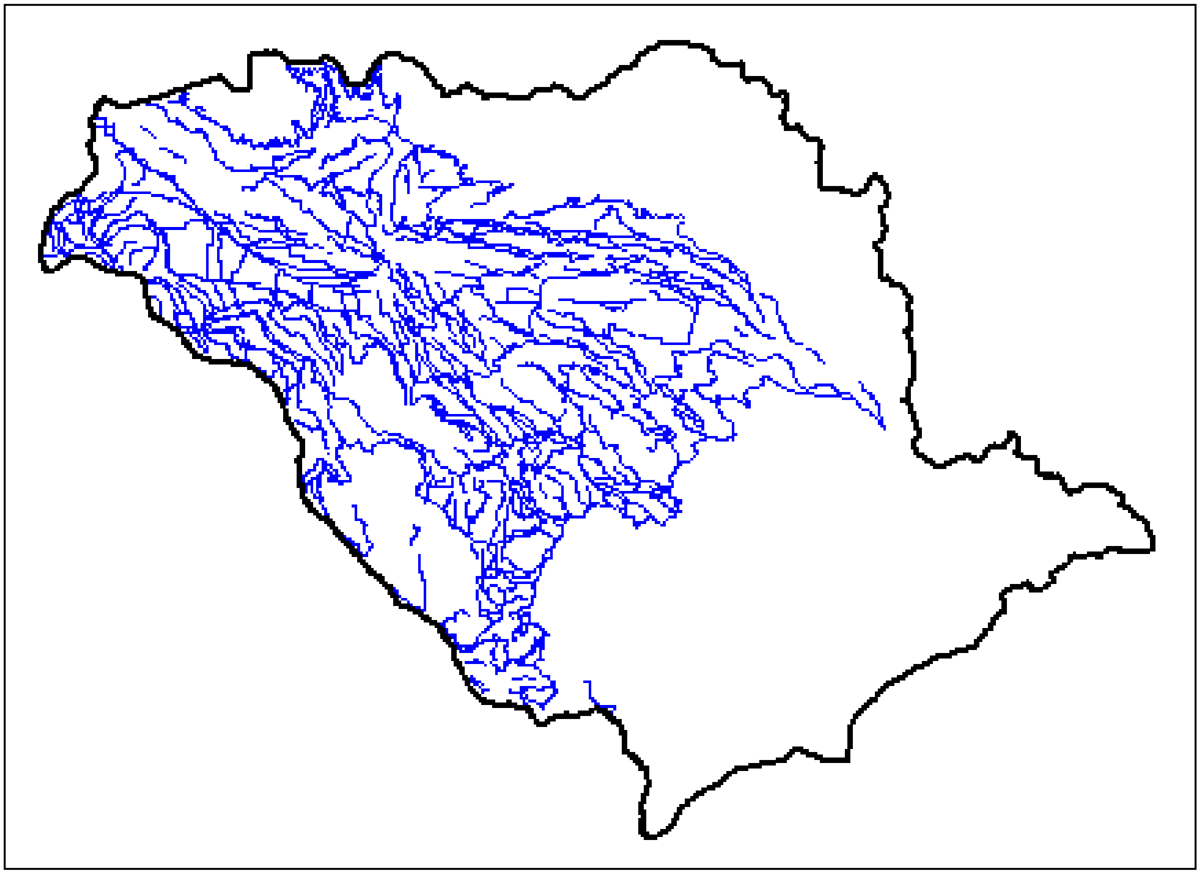


Figure 6: Distribution of major and intermediate canals and drains

It was assumed that none of the diverted water passes directly to the Boise or Snake Rivers (i.e., it was assumed that return flow to the river system consists only of runoff from the fields and ground water discharge to canals, drains and the rivers).

The total 1996 diversion (T_{div}) for all irrigation districts within the Treasure Valley was about 1,741,200 acre-feet during the irrigation season (April 15 through October 15; Note: all water volumes presented in this report are averaged over a one year period). About 1,381,000 acre-feet were diverted to the Boise Project and other districts from the Boise River (USGS, 1997), while about 360,200 acre-feet were diverted from the Payette River to irrigate farmland within the Black Canyon Irrigation District (USBR, 1997). Total flood irrigated area was estimated to be about 252,000 acres (IDWR GIS data, 1997).

Evaporation from canals (*Evap*) was estimated with the following assumptions: (1) total length of the canal system (major canals only) is about 1,170 miles (IDWR, 1996); (2) average canal width is 10 feet, and (3) evaporation rate is about 33 inches/year (see Section 2.3 for further discussion). Based upon these assumptions, about 3,600 acre-feet of canal water may be lost as evaporation. This is less than one percent of the total diversion of 1,741,200 acre-feet.

Evapotranspiration (*ET*) from phreatophytes along the canals was estimated based upon the following assumptions: (1) total canal length is about 1,170 miles; (2) average vegetated width is about 5 feet along each side of the canal, and (3) evapotranspiration is about 2.4 feet/year (see Section 2.5 for further discussion). Based upon these assumptions evapotranspiration from phreatophytes along the canals was estimated to be about 3,600 acre-feet, which is less than one percent of the total diversion.

Water loss data (USGS, 1997) for Lake Lowell (Ll_{loss}) showed a total loss of about 46,300 acre-feet (evaporation plus seepage). Change in storage at Lake Lowell (LL_{dS}) was estimated at 32,600 acre-feet (USGS, 1997). This is the amount of water diverted from Lake Lowell during the 1996 irrigation season.

The average amount of water delivered to the fields (F_A) was estimated to be about 4.3 feet/acre (refer to Section 2.5 for additional discussion). Assuming a total flood irrigated area of 252,000 acres, this is about 1,083,600 acre-feet.

Using these estimates, Treasure Valley canal seepage was estimated as follows:

$$\begin{aligned} C_{seep} &= T_{div} - Evap - ET - LL_{loss} + LL_{dS} - F_A \\ &= 1{,}741{,}200 - 3{,}600 - 3{,}600 - 46{,}300 + 32{,}600 - 1{,}083{,}600 \\ &= 636{,}700 \text{ acre-feet/year} \end{aligned}$$

This result shows canal seepage represents about 37 percent of the total 1996 diversion of 1,741,200 acre-feet. This estimate was then compared to conveyance loss data from the Boise Project Board of Control and the Black Canyon Irrigation District.

The Boise Project is an irrigation operations entity comprised of five irrigation districts: Big Bend, Boise-Kuna, Nampa and Meridian, New York, and Wilder. These districts comprise approximately 48 percent of Treasure Valley flood irrigated acreage (about 137,700 acres). The Black Canyon Irrigation District irrigated about 45,300 acres of land within the northern portion of the valley (north and west of the City of Caldwell).

According to Board of Control annual reports (IDWR files), the average conveyance loss during the 1985-1990 period was about 49 percent of the amount diverted to the Boise Project area. About 3 percent of the conveyance loss was attributed to losses from Lake Lowell, while an additional 1 percent is lost through direct evaporation and evapotranspiration along the canals. Using these estimates, conveyance loss attributed to canal seepage was estimated to be about 45 percent of the total diversion. The Black Canyon Irrigation District reported canal seepage losses of about 33 percent of the diversion for 1992 (USBR, 1997).

In addition to the above estimates, seepage measurements were taken by the USGS in 42 canal reaches throughout the Treasure Valley during the beginning and end of the 1996 irrigation season (Petrich and Urban, 1997). These data appear to be influenced by local hydraulic factors and do not necessarily reflect regional seepage patterns.

The USGS also measured seepage in the New York Canal during March, 1997 (Petrich and Urban, 1997). The New York canal lost approximately 12 percent of the flow between the Boise River and Lake Lowell when approximately 430 cfs were being diverted at Diversion Dam. At a diversion rate of 870 cfs the canal lost approximately 17 percent of its flow over the same reach. Causes for the flow loss include channel loss (seepage) and evaporation. Evaporation at the March measurement time is considered to be minimal, so most of the loss was attributed to channel loss. These seepage tests were of relatively short duration, and it is possible that the measured seepage rate would decrease over time as the local soils became saturated, and as shallow ground water levels rise in response to the seepage. For the purpose of this water budget, it was assumed that under equilibrium conditions New York Canal seepage was approximately 13 percent of the total 1996 diversion during the irrigation season.

In conclusion, canal seepage rates will vary throughout the valley, depending on soil type and elevation of the water table. For the purpose of this water budget, total canal seepage for the valley was estimated to be about 636,700 acre-feet, or about 37 percent of the total diversion to the valley. Assuming a total canal length of 1,170 miles (major and intermediate canals only), canal seepage occurs at an average rate of about 0.75 cfs/mile.

2.2. Recharge from Rivers and Streams

Additional sources of aquifer recharge include seepage from the Boise River and from small streams and drainages located within the Boise Foothills. Other streams within the valley are ephemeral in nature and are thought to contribute very little ground water recharge. Many serve as drains where they pass through flood-irrigated lands (B. Ondrechen, IDWR, personal communication, 1997).

Streams draining the Boise Foothills either discharge to the Boise River or provide seepage into the ground which then enters the valley as underflow. Recharge within the Boise Foothills was treated as a source of underflow and is discussed further in Section 2.4 below.

The Boise River loses water to the aquifer system from the Lucky Peak Reservoir to Capitol Bridge reach (about 11 miles), while it gains water from the aquifer along the Capitol Bridge to Parma reach (based on stream gage data; USGS, 1996). Reach gain data indicate an annual average loss of about 15,000 acre-feet/yr along the Lucky Peak to Capitol Bridge reach during 1958-1996, a period of time reflecting a wide variety of river flow conditions following the construction of Lucky Peak Dam (B. Sutter, IDWR, personal communication, 1996). Data for 1996 suggests the Boise River lost about 15,500 acre-feet to the aquifer system along the Lucky Peak to Capitol Bridge reach (USGS, 1997).

2.3. Recharge from Lake Lowell

Lake Lowell is a 9,800-acre reservoir located in the southwest portion of the valley. Data for 1996 were not available at the time of this report. However, total loss during 1995 was about 46,000 acre-feet (IDWR data), including evaporative losses from the lake surface. About 26,900 acre-feet are lost to evaporation each year, assuming a total surface area of 9,800 acres and a mean evaporative loss of 33 inches/year (Dion, 1972). Net recharge to the shallow aquifer for 1995 was therefore estimated to be about 19,000 acre-feet. This value was used for the 1996 water budget.

2.4. Subsurface Inflow (Underflow)

Subsurface inflow (or underflow) is defined as the ground water which flows across the water budget boundary and can include both horizontal and vertical components of flow. There appears to be no evidence (on the basis of regional ground water contours -- Newton, 1991) of ground water flow across the northern boundary (the watershed divide between the Payette and Boise Rivers) or underneath the Snake River. There is potential underflow across the northeast water budget boundary, and across the east and southeast boundaries.

The magnitude of underflow across the northeast boundary was estimated by assuming all precipitation within the Boise Foothills, less evapotranspiration and stream discharge, seeps into the rocks and sediments and ultimately flows across the northeastern boundary as ground water. The net precipitation was estimated using water yield maps (Rosa, 1968) and total drainage area (B. Ondrechen, IDWR, 1996). These maps correct for ET, thus allowing an estimate of water available for recharge and runoff. The total drainage area bounded by the valley floor and the hydrographic divide was estimated at 55.4 mi^2 . This area includes Stuart Gulch, Crane Creek, Hulls Gulch, Freestone Creek, Cottonwood Creek, Warm Springs Creek, Squaw Creek, Maynard Gulch, Highland Creek, and other unnamed tributaries between Highland Creek and Lucky Peak Reservoir. Based on this approach, the average annual amount of water available for runoff and ground water recharge was estimated to be 7,600 ac-ft/year (2.6 area inches). Less than 1 area inch of recharge is estimated for the foothills area west of Stuart Gulch.

Total stream discharge from the Foothills was estimated using published data to be about 4 cfs (e.g., USGS, 1956). Total underflow across the northern and northeast boundaries was therefore estimated to be about 4,300 acre-feet.

The underflow across the eastern and southeastern project boundaries also appears to be very small. Ground water level maps drawn from the spring 1996 and fall 1996 mass ground water level measurements indicate ground water flow lines somewhat parallel to the southeastern project boundary, indicating no-flow boundary conditions (see Petrich ad Urban, 1997). Simulated ground water contours in deeper zones (Newton, 1991) also indicate minimal ground water flow across the southeastern project boundary. Newton's model (1991) was run to evaluate the possible magnitude of underflow across the southeastern project boundary. Calculations using transmissivity and head-difference values between rows 30 and 31 of layer 2 (which extends from 500 to 4,500 feet below ground surface) in the Western Snake River Plain model (Newton, 1991) result in an estimate of approximately 5 cfs in the form of underflow across the eastern boundary. Proposed additional monitoring wells in southeast Ada County may help confirm these observations.

In summary, total underflow (as recharge) for the valley was estimated to be about 8,000 acre-feet. This represents less than 1 percent of the total aquifer recharge.

2.5. Recharge from Precipitation and Surface Water Irrigation

It is generally recognized that flood irrigation can be a significant source of recharge to Treasure Valley aquifers. Development of an extensive canal system, beginning in the 1880's, and associated irrigation using diverted surface water raised ground water levels in the shallow aquifers several tens of feet and has significantly increased the amount of water held in storage (Dion, 1972). This section presents estimates of ground water recharge from precipitation and irrigation for several Treasure Valley land use types.

Precipitation and surface water irrigation are addressed together because precipitation and applied surface water jointly meet consumptive demands and a portion of each source may become aquifer recharge. For example, most of the precipitation is lost to evapotranspiration in a low precipitation area. In an irrigated area, some of the soil moisture requirement is met by irrigation but some is also met by precipitation (especially in the spring and early summer months). Similarly, some precipitation may infiltrate to become aquifer recharge, and any excess water applied during the irrigation season may also become recharge.

The following sections provide estimates of ground water recharge for flood-irrigated lands using surface water (Section 2.5.1), sprinkle-irrigated lands using surface water, fallow land, rangeland, residential lands, and public lands such as parks and greenways (Section 2.5.2).

2.5.1. Recharge from Flood Irrigation and Precipitation

Recharge was estimated using the following relationship:

$R_{FI} = F_A + P - ET - R_{off} - F_c$ (Eqn. 4)

where

R_{FI} = recharge from flood irrigation

F_A = amount of surface water applied

P = precipitation

ET = crop evapotranspiration

$Evap$ = evaporation from bare soils

$Roff$ = total runoff (incudes runoff from flood irrigation and precipitation, and municipal discharges to the river)

Water application rates vary within the Treasure Valley depending upon water availability, crop demand, and the efficiency of the irrigation district. The Boise Project, which includes most of the southern portion of the Treasure Valley, delivered an average of 2.5 feet of water per acre to the fields during the 1985-1990 time period. The Black Canyon irrigation district (located in the northern portion of the valley) delivered about 5.2 feet per acre to fields during 1992 (USBR, 1997). Other districts within the valley delivered an undefined amount of water. According to Newton (1991), the USBR reported that farm delivery requirements for the Boise River valley averaged about 3.8 feet/acre. Lindgren (1982) evaluated average irrigation diversions for 29 subareas within the Treasure Valley. Net application ranged from less than 2 feet/acre to more than 8 feet/acre. The average was 4.3 feet/acre.

The actual amount diverted throughout the valley varies; the actual amount applied to a specific tract of land depends on crop demand and water availability. For this water budget, it was assumed that an average of 4.3 feet/acre was applied to 252,000 acres of flood irrigated lands during 1996 (1,083,600 acre feet). It was also assumed that all precipitation, less ET, evaporation during the non-irrigation season, and direct runoff was available for recharge where land is used for flood irrigation because soil-moisture conditions are otherwise satisfied throughout much of the growing season (Newton, 1991). The mean annual precipitation for flood irrigated land within the valley was about 12.8 inches (Section 1.3). This results in about 268,800 acre-feet of precipitation over a flood-irrigated area of 252,000 acres.

Much of the total potential recharge from precipitation is lost to evapotranspiration (ET). ET data for the Treasure Valley area are calculated for a variety of crops using the Kimberly-Penman equation which incorporates variables representing local conditions (USBR, 1995). These variables include measured values for solar radiation, air temperature, relative humidity and wind conditions. These variables are used to develop coefficients which are updated yearly using water consumption data provided by local farmers. As a result, these data are considered by many to be most representative for this area (B. Ondrechen, IDWR, personal communication, 1996).

Typical crop rotations for 1995 (Idaho Agricultural Statistics Service, 1996) were examined and assumed to be relatively unchanged for 1996. Crop rotations and corresponding ET data are summarized in Table 1. Because crop types vary spatially, and ET varies by crop, a weighted average for ET was developed. This average takes into account the average crop acreage and ET for each crop type. As shown in Table 1, this approach resulted in a weighted average of about 29.1 inches (2.4 acre-feet/acre). This weighted average represented the average amount of water transpired for each acre of cropland within the Treasure Valley. Using this value, and a flood irrigated area of

252,000 acres, total crop ET (consumptive use) was estimated to be 604,800 acre-feet/yr.

Table 1: Estimates of irrigated acreage and consumptive use for 1995

Crop	1995 Crop Acreages[1]		Total Acreage[1]	Percent of Acreage in Normal Rotation	Average Consumptive Use for 1988-1994[2] (inches/acre)
	Ada County	Canyon County			
Alfalfa Hay	26,400	33,500	59,900	23	38.8
Alfalfa Seed	1,900	18,100	20,000	8	29.9
Barley	2,300	13,900	16,200	6	24.3
Corn	4,900	22,800	17,700	10	25.7
Dry Beans	1,900	15,700	17,600	7	19.2
Mint	5,000	7,100	12,100	5	24.7
Oats	1,200	3,400	4,600	2	24.3
Onions	0	5,000	5,000	2	27.4
Potatoes	600	11,000	11,600	4	25.6
Sugar Beets	5,200	25,300	30,500	12	31.8
Wheat	7,300	49,700	57,000	22	24.3
TOTAL:	56,700	205,500	262,200	101	
				Weighted Average:	**29.1**

Notes: 1) 1995 crop acreages from Idaho Agricultural Statistics Service (July 1996) EXCEPT data for alfalfa seed, mint and onions, which are 1992 values from USDA 1992 Census of Agriculture. For comparison, land use data for 1994 (IDWR, 1997) show about 258,370 acres of actively irrigated land in organized irrigation districts within the water budget area.

2) Consumptive use data from Agricultural Water Use Summary, 1988-1994 (USBR, 1995). Consumptive use for alfalfa seed computed as 77 percent of alfalfa hay (Brockway and Allen, 1983)

Data for evaporation from bare soils during the non-irrigation season (*Evap*) were not available for the valley, so this parameter was estimated using monthly values for reference ET (AgriMet data, USBR, 1997) and early season crop coefficients. During the early months of the growing season crops such as peas and potatoes have relatively little foliage, so most of the reported ET is from direct evaporation from the soils (B. Ondrechen, IDWR, personal communication, 1997). The early season crop coefficients for these plants suggested bare soil evaporation was about 25 percent of the reference ET. The total reference ET for the October- March period was about 10.2 inches during the 1996 calendar year (AgriMet data, USBR, 1997). Using a crop coefficient of 25 percent, bare soil evaporation during the non-irrigation season was estimated to be about 2.5 inches. This is equivalent to about 52,000 acre-feet of evaporation over a 252,000 acre area.

Run off of flood irrigation water and precipitation was estimated from reach gain data for the Boise River using the following relationship:

$$R_{off} = R_{gain} - GW_{disch} \quad \text{(Eqn. 5)}$$

where

R_{off} = total runoff (flood irrigation and precipitation runoff) R_{gain} = total gain

Gw_{disch} = estimated ground water discharge

Reach gains represent the aggregate inflow along a particular reach, and include groundwater discharge, and runoff from fields. Runoff is comprised of excess precipitation and surface water applied to the fields. Reach gains are determined using stream flow measurements at discrete points along the reach. For this estimate Boise River stream flow data for Parma and the Glenwood Bridge were used.

Reach gain data for the Boise River showed a total gain of about 903,000 acre-feet during 1996. About 523,200 acre-feet of ground water were discharged to the Boise River during 1996, either directly, or through streams and canals (refer to Section 3.2). Based upon these estimates, total runoff to the Boise River was estimated to be about 379,800 acre-feet during 1996.

Reach gain data were not available for the Snake River for the year 1996. However, drain flow data from major canals and drains were available for 1992 and showed about 14,000 acre-feet of return flow to the Snake River (Section 3.2.3). This amount was assumed to represent total runoff (surface water plus precipitation) from the Treasure Valley to the Snake River during 1996.

Total runoff from the Treasure Valley was therefore estimated to be about 393,800 acre-feet for the year 1996. Spread over 252,000 acres of flood irrigated land, this is equivalent to about 19 inches of runoff per acre. The actual amount of runoff may vary throughout the valley, ranging from about 3 to 30 inches per acre, depending on crop and soil type, water availability and method of application (T. Stieber, University of Idaho College of Agriculture, personal communication, 1997).

For comparison, an average of 11 inches/year of runoff per acre was reported by the Natural Resource Conservation Service (NRCS) for farmlands within the Treasure Valley. The NRCS estimate is based on preliminary results from a computer model ("EPIC") that simulates field erosion. This preliminary estimate was thought to be a representative average for the valley; actual values vary depending upon soil types and field slopes (David Ferguson, NRCS, personal communication, 1997).

Based upon the above estimates, the net recharge to flood-irrigated land was estimated as follows:

$$
\begin{aligned}
R_{FI} &= F_A + P - ET - Evap - R_{off} \\
&= 1{,}083{,}600 + 268{,}800 - 604{,}800 - 52{,}000 - 393{,}800 \\
&= 301{,}800 \text{ acre-feet/yr} \\
&= 1.2 \text{ feet/acre of flood irrigated land}
\end{aligned}
$$

It was assumed that the estimated recharge is distributed proportionately over flood irrigated areas. This assumption, and the estimated recharge value will be reviewed as more data become available.

2.5.2. Recharge from Precipitation for Other Land Uses

This section presents estimates of ground water recharge from precipitation and irrigation for non-flood irrigated areas. Specifically, this subsection presents estimates of recharge from (1) sprinkler-irrigated land; (2) fallow lands; (3) rangeland; (4) residential land, and (5) public lands. Except where specifically noted otherwise, it was assumed that most of these lands use ground water for irrigation purposes.

Previous investigations in the Western Snake River Plain (WSRP) provided estimates of recharge from precipitation. Kjelstrom (1995) assumed an average of 0.03 feet/year for the WSRP. Newton (1991) estimated that the total average to all lands within the WSRP was two percent of the average annual precipitation (about 0.02

feet/year assuming an average precipitation of 10 inches/year). In developing this estimate, Newton assumed that no recharge occurs through non-irrigated lands if precipitation is less than 9 inches (i.e., ET from native vegetation exceeds precipitation

Recharge rates from precipitation were estimated on the basis of 1986 and 1994 land use data (IDWR). Recharge sources by land use included precipitation and, where applicable, irrigation practices. Recharge rates were estimated for individual land use types. The rates were approximated based upon recharge estimates from Newton (1991), Kjelstrom (1995), Drost, et. al.(1997), and communications with IDWR staff. Actual recharge rates vary widely throughout the study area, and depend on variables such as soil type, vegetative cover, and water application.

Table 3 provides a summary of estimated recharge rates. These rates represent an approximation of potential recharge based upon major land use classifications. For lands occupied by buildings, pavement, and irrigable lawn (such as residential lands, public lands, and recreational lands), it was assumed that 50 percent of the land was not irrigable. Given these assumptions, it was estimated that precipitation contributes about 47,900 acre-feet of recharge to Treasure Valley aquifers for non-flood irrigated land uses.

Table 2: Recharge from precipitation by land use.

Land Use	Recharge Rate[1] (feet/year)	Total Acreage[2]	Recharge from Precipitation (acre-feet/yr)
Arid/Barren Lands	.02	483,800	9,700
Residential[3]	.25	57,200	14,300
Public/Recreation[3]	.25	7,900	2,000
Farmland, Sprinkle Irrigated (ground water)	.20	42,300	4,200
Farmland, Sprinkle Irrigated (surface water)	.45	58,700	17,600
Dairy/Feedlot	.02	4,300	100
Industrial/Commercial	0.0	17,200	0
			TOTAL: 47,900

Notes: 1. Recharge rates are estimated values based on previous investigations (eg., Newton, 1991, Kjelstrom, 1995, and Drost, et. al., 1997) and communications with IDWR staff. Additional recharge estimates from precipitation on flood irrigated land are provided in Section 2.5.1.

2. Acreages from 1986 and 1994 GIS land use coverage (IDWR, 1995, 1997).

3. "Residential" includes rural dwellings, farmsteads, old urban and new subdivisions. "Public" includes parks, colleges, hospitals, schools, etc. "Recreation" includes golf courses, race tracks, campgrounds, stadiums, etc. Recharge rate for these land uses was estimated to be about 0.5 feet/year, but was reduced to 0.25 feet/year to correct for assumption that about 50 percent of these lands are not irrigable.

2.6. Recharge from Rural Domestic Septic Systems

Recharge from septic systems can be significant in some regions, particularly where water use is high and where rural housing is relatively dense. It was assumed that all septic discharge becomes ground water recharge This recharge was estimated using census data for numbers of rural dwellings and an estimated per-capita discharge rate.

House count data were obtained using census tract data (Bureau of Census, 1992). This GIS database provided an approximate spatial distribution of houses in the

Treasure Valley, and showed approximately 28,700 rural domestic houses existed within the Treasure Valley during 1990 (Note: the Treasure Valley includes all lands within Ada and Canyon counties, and portions of Elmore and Payette counties). Similar GIS census tract data were not available for 1995 or 1996. However, county census data showed the number of rural houses in Ada and Canyon counties increased from a total of 22,775 to 27,000 from 1990 to 1995. This represents an increase of about 20 percent. To provide an approximation of the spatial distribution of rural domestic houses within the entire Treasure Valley during 1995, the 1990 GIS estimate was increased by 20 percent, resulting in about 34,400 rural domestic houses.

The U.S. Environmental Protection Agency reported typical septic discharge to be about 45 gallons per day per person (EPA, 1980). Assuming three persons per household (Idaho State Department of Commerce, 1996), and 34,400 houses, total recharge from septic systems during 1996 was estimated to be about 1.7 billion gallons, or about 5,200 acre-feet.

3. Estimates of Ground Water Discharge

3.1. Ground Water Withdrawal

Ground water withdrawals are comprised of water that is pumped or flows under artesian pressure from municipal, industrial, agricultural and rural domestic water supply wells. The category includes water that is withdrawn from a variety of depths and aquifers. The following sections describe how withdrawal data were obtained, and provide estimates of 1996 withdrawals. With the exception of industrial withdrawals all estimates refer to a total volume of ground water withdrawn, and do not necessarily reflect consumptive use (i.e., water permanently removed from the system). For many land uses some of the ground water withdrawn seeps into the ground as recharge (e.g., irrigated and rural domestic lands; refer to Sections 2.5 and 2.6). For industrial land uses it was assumed that the estimated withdrawal was a measure of consumptive use (i.e., no subsequent aquifer recharge occurs).

3.1.1. Municipal Withdrawal

Municipal wells in the Treasure Valley supply water to a large number of domestic and commercial users. Domestic use refers to water used for individual homes, while commercial use refers to water used by restaurants, industries, apartment complexes, miscellaneous businesses, etc. In addition to these uses, water pumped by municipalities is used to irrigate public lands such as parks and golf courses. This section provides estimates of withdrawals for each of these uses. Not included are geothermal withdrawals for heating purposes. Geothermal water is withdrawn from an aquifer system which is below and largely isolated from the aquifer systems considered in the Treasure Valley Hydrologic Project.

<u>Domestic and Commercial Withdrawal</u>

Data for municipal ground water withdrawals were obtained from United Water Idaho, and the cities of Caldwell, Eagle, Kuna, Meridian, Middleton, Nampa and South County Water Company. The City of Kuna’s two wells supply nearly all water for the city's commercial, in-house domestic, and domestic irrigation uses (J. Taylor, City of Kuna, personal communication, 1996).

Municipal pumping rates for areas where actual data were not available were estimated on a per capita basis. Data from the city of Kuna were used to estimate per capita pumping rates because user population was well known, and these pumping data represent both commercial and domestic uses. Based on 1995 population and water use data, the citizens of Kuna use about 230 gallons per day per person (gpd/person). This was the same value reported by Goodell (1988) for nonindustrial public-supply for Ada and Canyon counties during 1980. Table 3 compares Kuna withdrawals with other suppliers from which actual withdrawal data were obtained.

Table 3: Summary of selected municipal water consumption for 1995

City	1995[1] Population	Average Commercial and Domestic Water Use for 1995[1,2] (gallons/day/person)		
		October-April	May-September	Annual
Boise[3]	146,000	150	370	240
Caldwell[4]	24,000	110	230	160
Kuna[5]	2,400	120	380	230
Nampa[4]	35,300	130	160	140

Notes: 1. 1996 census data unavailable at time of report.

2. Does not include municipal irrigation of public lands, or self-supplied industrial/commercial use.

3. Assumes United Water Idaho serves a population equivilent to the city of Boise. Assumes domestic irrigation is supplied by United Water Idaho.

4. Does not include domestic irrigation from municipal irrigation wells.

5. Domestic irrigation provided by municipal wells.

Municipal withdrawal was then estimated for municipalities in the study area which did not have actual data by using the average consumption for Kuna (i.e., 230 gpd/person) and 1995 census data. Figure 7 summarizes municipal water use for 1996. Total municipal use (less municipal irrigation) for 1996 was estimated to be about 66,100 acre-feet. For comparison, municipal withdrawal for 1980 (Goodell, 1988) was about 51,300 acre-feet.

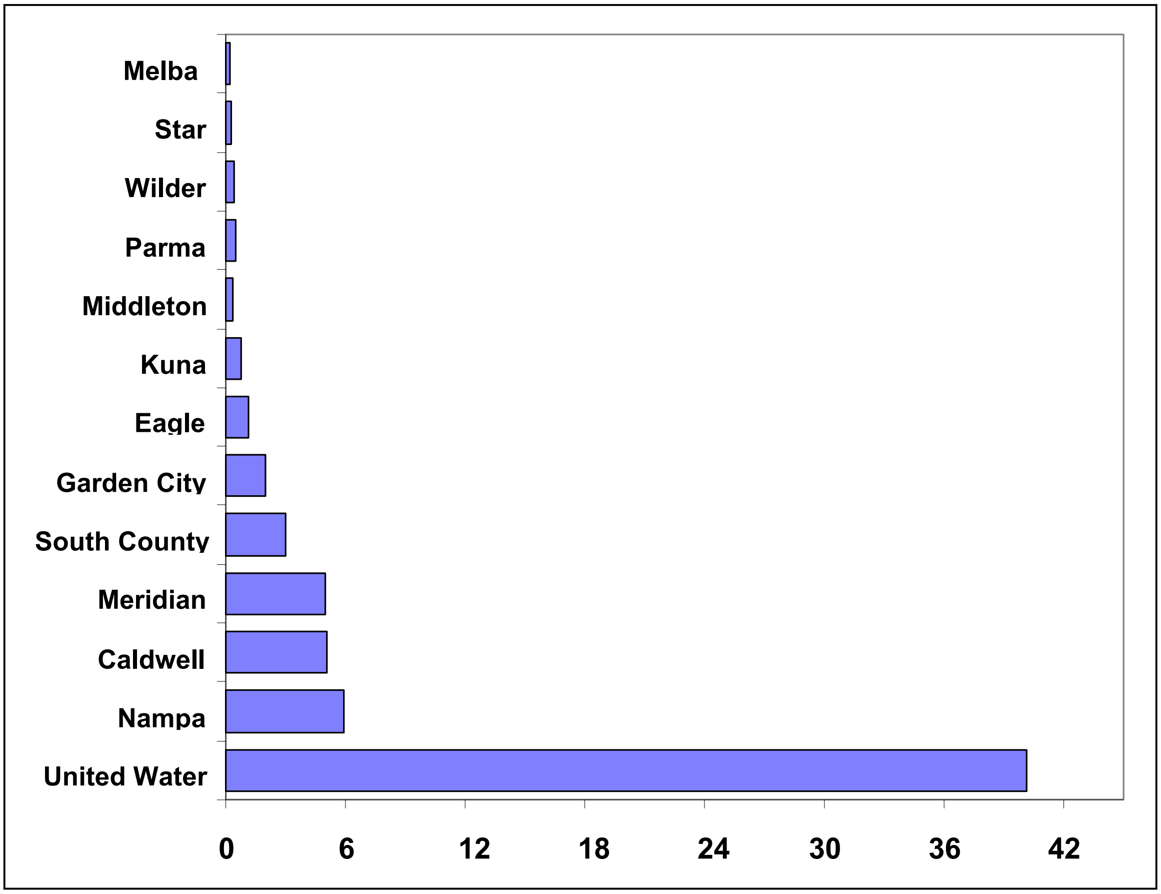


Figure 7: Municipal water use for 1996 (thousands of acre-feet)

Municipal Irrigation of Public Lands

Most municipalities also use ground water to irrigate public areas such as parks, public golf courses, etc. The City of Nampa utilizes a dual-supply system, where culinary and irrigation water are supplied by two different distribution systems. Nampa used about 11,600 acre-feet for municipal irrigation of public and private lands from canals and irrigation wells during 1996 (T. Chavez, City of Nampa, personal communication, 1996).

The City of Boise irrigates about 435 acres of city parks and greenways using ground water and an additional 240 acres using surface water (L. Cody, personal communication, 1996). Most of Boise's irrigation wells lack flow meters, so estimates of ground water withdrawals for irrigating public lands were made using total acreage and evapotranspiration (ET) data. A weather station located at Ann Morrison Park provided daily ET values which were used to estimate lawn irrigation requirements. For 1995, total ET was estimated to be about 31 inches (2.6 feet). A minimum of 1,130 acre-feet were required to meet this demand. Assuming an irrigation efficiency of about 80 percent (T. Scanlan, Scanlan Engineering, personal communication, 1997), approximately 3.5 feet of water were required per acre. Total ground water withdrawal by the City of Boise for municipal irrigation was estimated to be about 1,500 acre-feet.

Total municipal irrigation of public lands throughout the valley was estimated using land use data (IDWR, 1997). These data show that the total area for public lands was about 7,900 acres (this includes public lands within the City of Boise). As discussed in Section 2.5, it was assumed that approximately 50 percent of public lands were not irrigable, resulting in a revised irrigated acreage of about 3,950 acres. Assuming that 3.5 feet of water were applied (based on the above estimate for the City of Boise), total use of ground water for municipal irrigation was estimated to be about 13,800 acre-feet. However, some of this public land was irrigated with surface water. The City of Boise irrigated about 35 percent of its public lands with surface water, while the City of Nampa obtained about 24 percent of its irrigation water from surface sources. It was therefore assumed that 30 percent of the total municipal irrigation demand is satisfied with surface water sources.

In conclusion, it was assumed that about 70 percent of public lands are irrigated with ground water, resulting in about 9,700 acre-feet of ground water withdrawal.

3.1.2. Self-Supplied Industrial

Industrial ground water use is difficult to quantify because many industries rely on different water sources, such as a combination of municipal supply and self-supplied water. Also, municipal suppliers usually do not distinguish between commercial and industrial use, i.e., the commercial category includes small businesses, multi-family housing, and industrial facilities.

Industrial withdrawal was estimated from water use coefficients (USGS, 1997b) because actual pumping data were not available for most Treasure Valley industries. Water use coefficients relate average industrial water use, without regard to region or specific water conservation efforts, to the total number of employees for each industry. Actual water use for a specific industry may vary within a region depending on plant efficiency and/or the type of water conservation programs used (Burt, 1983). Goodell (1988) used this approach to estimate self-supplied industrial ground water withdrawal for 1980, and showed self-supplied industrial use was about 14,900 acre-feet for Canyon county and about 700 acre-feet for Ada county, or a total of about 15,600 acre-feet.

To estimate current self-supplied industrial withdrawal for the Treasure Valley, census data for industrial populations were obtained for 1995 (Idaho Department of Employment, 1997; 1996 data unavailable at time of report preparation). Industrial water use coefficients were obtained for industries typically found in the Treasure Valley (USGS, 1997b), assuming the majority of Treasure Valley industries are self-supplied.

Most industries within the Treasure Valley do not record or report water use. However, Micron Technology, Inc. of Boise provided estimates for 1995 water use and employee census. This allowed a water use coefficient to be calculated for the largest industrial employer in the Treasure Valley. In 1995, Micron employed about 7,000 people and used about 2,650 acre-feet of water at its southeast Boise semiconductor facility. This resulted in a water use coefficient of about 340 gpd/employee (gallons per day per employee). However, about 960 acre-feet of the total was used were purchased from United Water Idaho (M. Maupin, USGS, personal communication, 1997). Using this latter value yielded a water use coefficient of about 215 gpd/employee for the amount of water self-supplied by Micron (the balance of 960 acre-feet was included under total municipal withdrawal; refer to Section 3.1.1). Table 4 provides a summary of industry census data and water use coefficients.

Table 4: Summary of self-supplied industrial ground water withdrawal

Industry[1]	Numbers of Employees (1995)[1]		Water Use Coefficient[2]	Self-Supplied Industrial Withdrawal by County (acre-feet/yr)		Total Self-Supplied Industrial Withdrawal
	Ada County	Canyon County	gpd/person	Ada	Canyon	acre-feet/year
Agriculture[3]	400	3,000	15	10	50	60
Construction	10,300	2,500	390	4,480	1,070	5,550
Food Processing	2,400	3,900	1,287	3,470	5,710	9,180
Manufacturing[4]	10,000	4,700	204	2,240	1,070	3,310
Micron Technology[5]	7,000	0	215	1,690	0	1,690
Wood Products[6]	2,300	1,400	240	630	360	990
TOTAL:	32,400	15,500		12,520	8,260	20,780

Notes:

1. Industry categories and 1995 employee census data from Idaho Dept. of Employment, Research and Analysis, except for Micron Technology, Inc, which supplied its own population and water use data for 1995.

2. Typical daily industrial water consumption (gallons/day/employee). Data from USGS WEB site: http://h20.er.usgs.gov/public/wateruse. Exception for Micron Technology, which supplied specific water use and population estimates for 1995.

3. Agriculture category refers to amount of water personally consumed by the employee; does not include irrigation water, livestock water, or other agricultural uses. Rate of 15 gpd/person obtained from Idaho Water Law Handbook, 1988, Appendix IV;value for “day camps, no lunch served.”

4. Manufacturing category includes electronics industries (except Micron Technology, Inc. of Boise, which is considered separately).

5. This rate reflects the amount of water pumped from Micron wells only; an additional 123 gpd/employee was purchased from United Water Idaho.

6. Wood products category includes lumber and wood industries, such as lumber, plywood, and cabinet making. It does not include pulp and paper industries.

Approximately 12,500 acre-feet of self-supplied industrial ground water were self-supplied by industries in Ada County during 1995 (Table 5). About 8,300 acre-feet of self-supplied ground water were used by industries in Canyon County. Total self-supplied industrial ground water use for 1995 was estimated to be about 20,800 acre-feet based upon employee census data.

As discussed above, this approach assumes all major industries are self-supplied, except for Micron Technology. The estimates of industrial withdrawal presented above may be higher than actual because some industries purchase an undefined amount of ground water from municipal suppliers. Also, with the exception of Micron Technology, the industrial water use estimates may contain some error because national water use coefficients were used which may not accurately reflect local conditions (Burt, 1983). Despite these potential errors, total industrial ground water use is small relative to other water budget components, and any errors are small in comparison with other water budget components.

3.1.3. Irrigation Withdrawals

A significant portion of Treasure Valley agricultural lands are irrigated with ground water. Approximately 42,300 acres of farmland (primarily in the southern portion of the valley) utilize ground water exclusively (IDWR, 1997). In addition, many of the irrigators dependent on surface water supplies use supplemental irrigation wells during periods of drought.

There are three methods commonly used to estimate ground water pumping for irrigation wells (Collins, 1984; Frenzel, 1984; Bowman and Wilson, 1987; Morgan, 1988; Van Metre and Seevers, 1991). These methods include (1) direct readings from flow meters; (2) power billing records for the pump, and (3) consumptive use data and irrigated acreage. These methods are discussed below.

First, direct readings from flow meters require that a significant number of irrigation wells are fitted with totalizing flow meters. At this time, most wells within the Treasure Valley area are not metered.

Second, power consumption data are commonly used to estimate ground water withdrawal using the following relationship (Goodell, 1988):

$$Q = \frac{kWh}{K \times TH} \quad \text{(Eqn. 6)}$$

where$Q$ = total volume of water pumped (acre-feet/yr)
kWh = total power consumed in a year (kilowatt-hours)
K = number of kilowatt-hours required to lift 1 acre-foot of water 1 foot (kilowatt-hours/acre-feet-foot)
TH = total head, or pumping lift (feet)

Power consumption, as an indication of ground water pumping, is best suited to areas where pumping lifts are fairly constant throughout an irrigation season and where data are available for individual irrigation wells (Bowman and Wilson, 1987, Frenzel, 1984). Power billing data are available for Treasure Valley irrigation wells, but measurements of head are not available at this time. Consequently, errors in estimates of total head could be a major source of error with respect to calculating ground water use (Morgan, 1988).

The third approach is to use consumptive use and irrigated acreage data to estimate ground water withdrawals. This latter approach was used for the 1996 Treasure Valley water budget because of the limitations associated with the first and second approaches. Estimates of ground water withdrawal on a per-acre basis were obtained by multiplying the irrigated acreage by the average per-acre consumptive use for the valley. A consumptive use value of 29.1 inches/acre was used as described in Section 2.5.

The following assumptions were made in estimating agricultural ground water irrigation:

1. Because water pumping costs are high relative to flood irrigation costs, farmers will not over apply ground water used for irrigation.
2. With the exception of runoff, all precipitation goes into soil storage and is available to the crop.
3. The mean annual precipitation for areas irrigated with ground water was about 10 inches.
4. Topography in areas irrigated with ground water is relatively flat, and the soils are generally well-drained. Therefore runoff from the fields was probably very low, and was estimated to be about 1 inch per acre (B. Ondrechen, IDWR, 1996).
5. The amount of ground water withdrawn was estimated to be equivalent to the total consumptive use (ET), less the net precipitation.

The average ET throughout the valley was estimated in Section 2.5 to be about 29.1 inches/acre, while the effective precipitation was estimated to be about 9 inches. Based upon these estimates, the amount of ground water required to meet crop consumptive use was estimated to be about 20 inches/acre (1.7 feet/acre). Multiplying this value by 42,300 acres (the total ground water irrigated acreage) resulted in about 71,900 acre-feet of ground water withdrawn for agricultural irrigation.

Pumpage from supplemental irrigation wells was not addressed in this Phase I water budget. Supplemental wells are frequently used by surface water irrigators during times when surface water supplies run short (such as during a drought period). Supplemental pumping was not addressed because it was judged to be relatively small in 1996 given that surface water supplies were available throughout the growing season.

3.1.4. Rural Domestic Withdrawals

Rural domestic withdrawal refers to ground water used by rural residences located outside the boundaries of municipal distribution systems. This section describes estimates made for domestic use only; stock water use was described in Section 1.3.5.

Goodell (1988) assumed the average per-capita rural domestic use was about 98 gpd/person for a total rural population of 51,800 in 1980. The rural domestic ground water use for 1980 was therefore estimated to be about 5,600 acre-feet for Ada and Canyon counties. The 98 gpd/person value used by Goodell was reported to be the average per-capita rural domestic use for 17 western states.

For the 1996 Treasure Valley water budget rural domestic ground water use was estimated using census data for numbers of rural dwellings and occupants, and an assumed per capita consumption rate. House count data were obtained using 1990 using census tract data (Bureau of the Census, 1992). This GIS database provided an approximate spatial distribution of houses and therefore ground water withdrawal (a more recent GIS database was not available). From this data set the total number of rural domestic homes was estimated to be about 28,700 for the study area in 1990. As described in Section 2.6, 1995 census data were used to extrapolate a spatially distributed estimate for 1995. Results suggest that there were about 34,400 rural domestic houses in the Treasure Valley in 1995, and it was assumed that each house had its own well. According to census records (Idaho Department of Commerce, 1996), each house is occupied by an average of 3 people. Total rural domestic population was therefore estimated to be about 103,20o.

In general, many rural houses occupy larger lot sizes (0.5 to 5 acres) than in urban areas. As a result, per capita water use may be higher in rural areas. However, many rural residences within the Treasure Valley have access to surface water supplies which can be used for lawn and pasture irrigation, thus reducing overall ground water use during the irrigation season. As a result, overall per capita ground water use was assumed to be the same as for urban domestic use (230 gpd/person).

Based on the above, total rural domestic ground water withdrawal was estimated to be about 26,600 acre-feet during 1996.

3.1.5. Livestock

Stock water refers to water used by livestock such as cattle, horses, etc. Goodell (1988) reported 1980 stock ground water use in Ada and Canyon counties to be about 2,100 acre-feet/yr, with an additional 900 acre-feet of surface water being used, or a total of about 3,000 acre-feet. This estimate was made using reported livestock populations and typical daily per animal water use.

Revised estimates of ground water consumption for stock watering were made for the 1996 Treasure Valley water budget using animal inventories (Table 5) as provided by the 1992 Census of Agriculture (U.S. Dept. of Commerce, 1994) and typical daily water consumption values (Idaho Water Law Handbook, 1988). Data for 1996 were not available. This estimate was restricted to those animals using relatively large amounts of water (i.e., small animals were not included). It is not known how much surface water was used to augment stock ground water withdrawal during 1992. However, estimates previously provided by Goodell (1988) suggest about 30 percent of total stock demand is satisfied using surface water sources. Total stock water consumption for Ada and Canyon counties for 1992 was estimated to be about 3.4 million gallons per day (about 3,800 acre-feet/yr). Assuming ground water comprises 70 percent of this total, it was estimated that ground water use was about 2,600 acre-feet.

Table 5: Estimated stock water use

Animal	**1992 Census**		**Daily Water Consumption**	**Total Consumption (surface and ground water)**	
	Ada	Canyon	(gallons)	(gal./day)	(acre-feet/yr)
Cattle/Calves	73,400	130,790	12	2,457,500	2,750
Dairy	9,430	14,010	35	820,600	920
Horses	2,910	2,840	12	69,000	70
Sheep	1,940	16,130	2	36,100	40
			TOTAL:	3,383,200	3,780

3.1.6. Summary of Ground Water Withdrawal

In summary, total ground water withdrawal for 1996 was estimated to be about 197,700 acre-feet. Table 6 provides a summary of withdrawal estimates. Agricultural irrigation represents the largest amount of water pumped, followed by municipal uses.

Irrigation withdrawal is concentrated primarily within the southwestern portion of the valley.

Table 6: Summary of Treasure Valley Ground Water Withdrawal for 1996

Ground Water Withdrawal	Estimated Withdrawal for 1996	
	acre-feet	Percent of Total
Domestic and Industrial Withdrawal	66,100	34
Municipal Irrigation	9,700	5
Self-Supplied Industrial	20,800	11
Agricultural Irrigation	71,900	37
Rural Domestic Withdrawal	26,600	12
Stock Watering	2,600	1
TOTAL:	197,700	

Municipal withdrawal is concentrated in urban areas. The amount of water withdrawn for industrial use was considered to represent consumptive use (volume of water removed from the aquifer system). The volume estimates associated with the remaining water use classifications do not represent consumptive use because some ground water recharge was assumed to occur (from excess water applied for irrigation on these lands; refer to Section 2.5).

3.2. Discharge to Rivers and Drains

Discharge to rivers and drains refers to ground water that exits the valley by discharging into canals, drains and rivers. According to Lindholm (1993), 83 percent of discharge from the western Snake River Plain is to rivers and drains, with the remaining 17 percent discharged via wells. Most discharge in the Treasure Valley occurs to the Boise River during the irrigation season. The principal discharge area along the Boise River is the reach between the cities of Middleton and Parma (Kjelstrom, 1995). This reach represents the lower half of the valley, and it is along this reach that most of the drains (from the valley’s extensive irrigation system) discharge to the river. Additional ground water discharge occurs to the Snake River between Murphy and Nyssa. The following sections provide estimates of ground water discharge to these reaches.

3.2.1. Previous Estimates

Newton (1991) estimated ground water discharge to the Boise River to be about 460,000 acre-feet for the year 1980. This estimate was based on river gain data for the non-irrigation season (October to April), and assumes all canal and drain flow to the river during this period was due to ground water discharge.

Thomas and Dion (1974) estimated ground water discharge directly to the Boise River to be about 3 cfs/mile (about 104,200 acre-feet) during 1971. This was determined by measuring river discharge at select points at a time when there were no releases from Lucky Peak Reservoir. Increases in river flow were attributed to ground water discharge.

Ground water discharge to the Snake River was estimated by Newton (1991) to be about 350,000 acre-feet for the year 1980 over the 101 mile reach between Murphy and Weiser. Gain measurements for the Snake River typically fall within the assumed 5 percent margin of error for gage measurements (Newton 1991), and as a result should be used with caution.

3.2.2. Boise River

For this water budget, ground water discharge to the Boise River was estimated by determining the mean monthly gain during the non-irrigation season, and assuming the same discharge rate occurs during the irrigation season. With the exception of runoff from precipitation, it was assumed that this gain was from ground water discharge to canals and drains, and ground water discharge directly to the river. Total gain during the non-irrigation season (October 15, 1995 through April 15, 1996) was estimated at 283,500 acre-feet, or an average of 47,175 acre-feet/month (data from USGS, 1996). However, about 3,600 acre-feet/month of the winter gain is from storm water and wastewater discharges from the cities of Boise, Caldwell, Meridian and Nampa (DEQ, 1997). Subtracting this amount from the mean monthly gain results in about 43,600 acre-feet/month of ground water discharge. Assuming this same rate of ground water discharge occurs during the irrigation season, a total of about 523,200 acre-feet of ground water were discharged during 1996.

There are potential sources of error with this estimate. For example, the ground water discharge is not constant throughout the year. The discharge rate may be less than the average winter flow at the start of the irrigation season, and peak at an above-average value following the end of the irrigation season.

3.2.3. Snake River

Some ground water from the Treasure Valley also discharges to the Snake River. Reach gain data (USGS) for the 68 mile Murphy to Nyssa reach were examined to provide an updated estimate. This reach was coincident with much of the Treasure Valley Hydrologic Project's southwestern boundary. Because the Snake River received discharge from sources outside the Treasure Valley, ground water discharge was estimated by subtracting estimates of these additional discharge sources from the total reach gain. The balance was assumed to represent ground water discharge and direct return flow from drains leaving the Treasure Valley project area. This approach was taken because data were not available for most drains along this reach.

Reach gain data for the Snake River were not available for 1995 or 1996, so the mean annual gain for the years 1976-1992 was used (period of record). The mean gain for the Murphy to Nyssa reach was estimated to be about 540,800 acre-feet. Of this total, about 250,000 acre-feet/yr was attributed to sources located south and west of the Snake River (e.g., the Owyhee River drainage, an area outside of the Treasure Valley Hydrologic Project; IDWR data). Subtracting this amount resulted in a net gain of about 290,800 acre-feet.

Discharge from drains was estimated using 1992 data from the Boise Project Board of Control. These data showed drain discharge was about 14,000 acre-feet. This amount was assumed to represent surface water runoff only. Subtracting this runoff amount from 290,800 acre-feet resulted in about 276,800 acre-feet of ground water discharge.

In summary, ground water discharge to the Boise River was estimated to be about 523,200 acre-feet, while discharge to the Snake River was estimated to be

290,800 acre-feet. Total estimated ground water discharge to rivers and drains during 1996 was about 814,000 acre-feet.

Table 7: Ground Water Discharge to Rivers and Drains

Estimated Ground Water Discharge, 1996	
Reach	**Acre-feet**
Boise River	
Lucky Peak to Boise	NA[1]
Boise to Parma	523,200
Snake River	
Murphy to Nyssa	276,800
TOTAL:	814,000

Notes: 1. Not applicable because river discharges to aquifer along this reach.

3.3. Underflow

With the exception of ground water discharge to major rivers (Section 3.2), there appears to be no evidence of significant subsurface ground water flow leaving the project area. Based upon ground water contours for the region (Newton, 1990), the Snake River appears to be a major ground water divide along the downgradient southern and western project boundaries. Underflow from the project area is therefore considered to be negligible.

4. Spatial Distribution of Recharge and Pumping

The water budget results presented in the preceding sections focus on the Treasure Valley aquifer system as a whole. These aggregate values do not describe the spatial distribution of the water budget components. This section provides three maps describing the general spatial distribution of recharge to and withdrawals from the Treasure Valley aquifer system, as currently defined by the Treasure Valley water budget.

Maps shown in this section were created by kriging spatial data and interpolating the results to a grid with a one-mile cell size. This grid is the same that currently is being used for the development of a Treasure Valley ground water flow model (Petrich, 1997).

4.1. Recharge

The estimated spatial distribution of ground water recharge in the Treasure Valley is presented in Figure 9. Recharge is concentrated in areas receiving flood irrigation and containing canals.

Some of the recharge is shown in areas of ground water discharge. Infiltration to shallow, local ground water flow systems may result in discharge to nearby canals and/or drains. The map does not distinguish between recharge entering local and regional ground water flow systems.

The spatial distribution of ground water recharge reflects the methods used for estimating recharge. For instance, recharge associated with flood irrigated agriculture was estimated on the basis of land use; the spatial distribution of flood irrigation is therefore based on the estimated spatial distribution of flood irrigated lands. Similarly, the recharge associated with canal seepage is distributed on the basis of aggregate canal length per unit area. The greatest canal seepage is therefore in areas having the greatest concentration of canals. A better method of distributing canal seepage throughout the canal system is not available because of the current lack of seepage data for individual canals (with the exception of the New York Canal).

Figure 9 shows significant recharge along the New York Canal. The New York canal seepage estimate was based on measurements made during March, 1997 (Petrich and Urban, 1997). The New York Canal was assumed to be leaking at a rate of 13% of the average irrigation season flow (refer to Section 2.1). This amount was subtracted from the general canal seepage estimate and was distributed evenly along the length of the New York Canal.

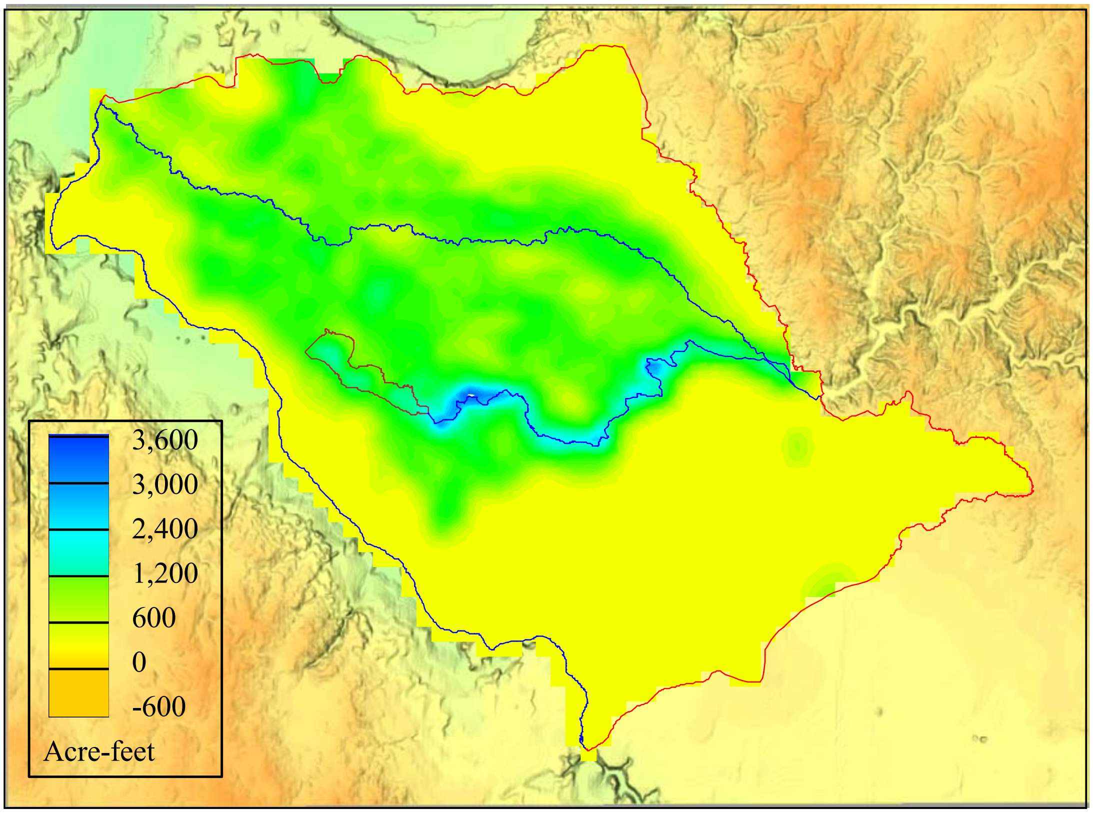


Figure 9: Estimated spatial distribution of 1996 ground water recharge.

4.2. Discharge

Ground water discharge from the Treasure Valley aquifer system consists of discharges to canals, drains, and rivers, and ground water pumping. Discharges to canals, drains, and rivers were estimated on the basis of river gains along Boise and Snake River reaches (Section 3.2). Ground water withdrawals were estimated for various water uses (municipal, irrigation, industrial, etc.).

The spatial distribution of ground water discharge to canals and drains cannot be determined using the aggregate reach gain measurements along the Boise and Snake Rivers. The spatial distribution of discharge to canals and drains will be made using the numerical ground water flow model currently under development.

The approximate spatial distribution of ground water withdrawals in the Treasure Valley is shown in Figure 10. The pumping distribution shows concentrated pumping in urban areas surrounding Boise, Nampa, and Caldwell, and in areas of significant irrigation use (e.g., south and southeast of Lake Lowell).

The distribution of ground water use shown in Figure 10 does not distinguish between source aquifers. Most rural domestic and some irrigation pumping occurs from shallow aquifers; most of the municipal pumping occurs from deep, regional aquifers. The vertical distribution of pumping will be estimated during the second phase of the Treasure Valley Hydrologic Project.

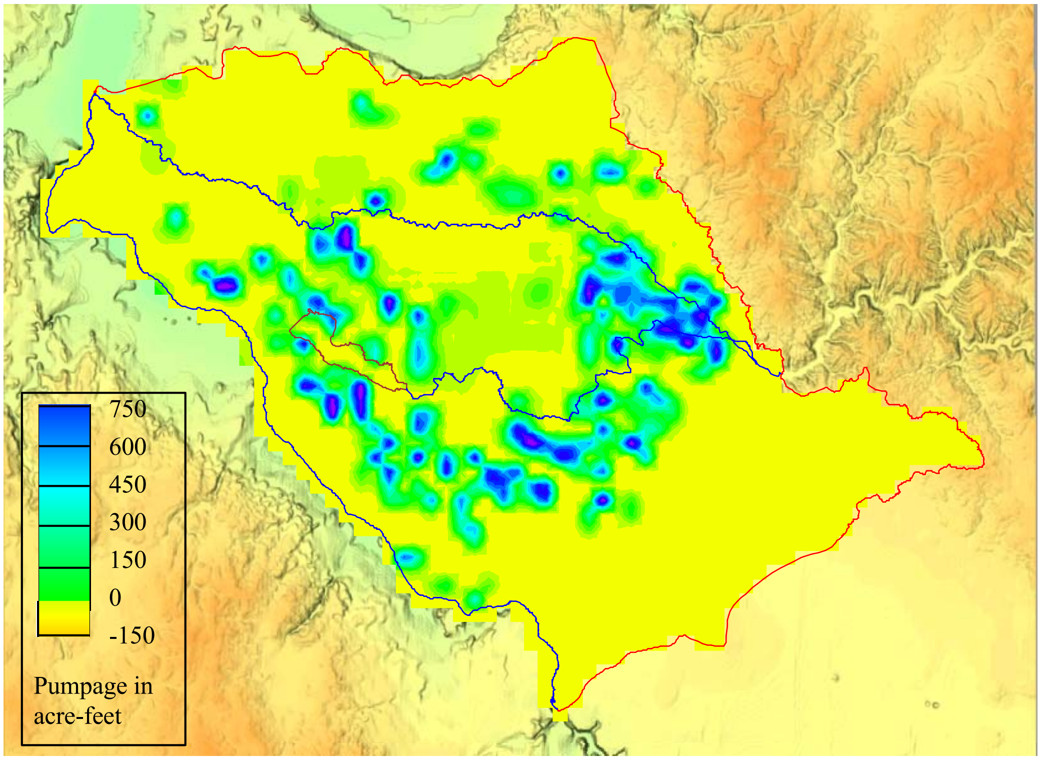


Figure 10: Estimated spatial distribution of 1996 withdrawals

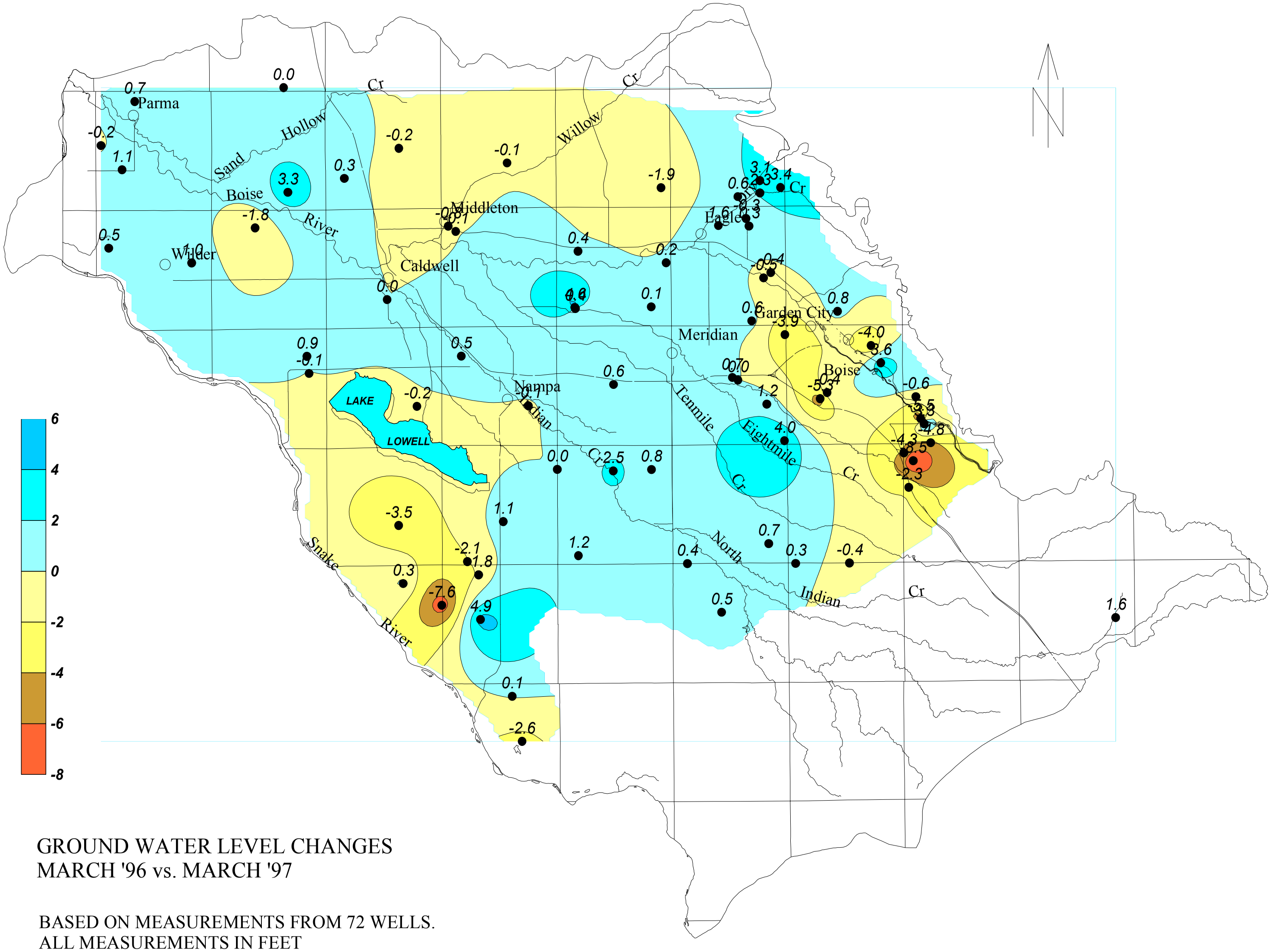
5. Change in Aquifer Storage

A difference between net recharge and net discharge implies a change in aquifer storage. A net increase in aquifer storage of about 36,000 acre feet was estimated on the basis of water budget results. For comparison, a change in regional ground water storage was estimated using water level data.

Water level measurements were compared from 72 Treasure Valley wells taken in March 1996 and March 1997. These measurements were part of monthly measurements in 74 Treasure Valley wells (Petrich and Urban, 1997). Mass measurement water levels (measured from over 300 Treasure Valley wells) were not used for these calculations because a second spring mass measurement will not be conducted until March, 1998. The 72 water level measurements were taken from wells completed at deep and shallow depths, and from wells that may have been influenced by recent pumping. The time period of March, 1996 to March, 1997 does not fully coincide with that of the water budget (which was prepared for the 1996 calendar year; TVHP water level measurements did not begin until March 1996).

Water levels from the March 1996 measurement were subtracted from the March 1997 measurement, and a surface map was prepared (using Surfer™) from the individual difference values (Figure 12). This method will produce similar values as subtracting one surface from another, and is legitimate if the measurement points are the same (Davis, 1986). It was assumed that the increase in storage occurred in the uppermost aquifer, and that this aquifer zone had an effective porosity of 0.30.

An increase in aquifer storage of approximately 20,000 acre feet was estimated using the 1996 and 1997 water level measurements. This was a preliminary estimate because it was based on water levels taken from a variety of wells (some of the water levels may have been influenced by pumping) completed in different aquifer zones. Estimates of changes in aquifers storage based on water level measurements will be refined during the second phase of the Treasure Valley Hydrologic Project.



GROUND WATER LEVEL CHANGES
MARCH '96 vs. MARCH '97

BASED ON MEASUREMENTS FROM 72 WELLS.
ALL MEASUREMENTS IN FEET

Figure 11: Ground water level change map created by comparing water level elevations for March, 1996 and March, 1997.

6. Summary and Conclusions

This section summarizes results presented in previous sections, and provides a discussion of those results. Conclusions drawn from the water budget data are summarized at the end of this section.

This water budget provides an initial regional accounting of inflows and outflows to the Treasure Valley aquifer system. Results from this Phase I water budget are summarized in Table 8 and in Figure 12. The largest source of ground water recharge was seepage from the canal system, followed by flood irrigation and precipitation. The aggregate discharge to the Boise and Snake Rivers (through canals, drains, or to the rivers themselves) is far greater than all withdrawals combined. On a valley-wide basis, ground water withdrawals represent approximately 20 percent of the total ground water recharge.

There are error ranges associated with all of the water budget estimates. Sources of error include all of the measurements and estimation methods for each water budget component. The impact of a relatively small error in a large component can have a significant impact on the water budget balance. For example, seepage from the canal system appears to be the largest recharge component, but the actual magnitude and the distribution of the leakage has not yet been well defined. Similarly, the aquifer discharge to the Snake and Boise Rivers and to Treasure Valley canals and drains is the largest discharge mechanism, and a small error in this estimate could have a significant effect on the overall water budget. The error associated with individual water budget component estimates is expected to decrease as more information becomes available.

The water budget addresses the Treasure Valley aquifer system as a whole. However, the aquifer system clearly consists of a series of shallow and regional aquifers interconnected to varying degrees. This water budget does not take into account ground water flow between different aquifer zones. A numerical ground water flow model (currently under development) will be used to help quantify inter-aquifer flows, results from which will be used to refine the water budget.

Pumping data will be associated with individual aquifer zones as these data become available.

Table 8: Phase I water budget summary.

Sources of Recharge and Discharge	**Estimated Recharge/Discharge for 1996**	
	acre-feet	Percent of Total
RECHARGE[1]		
Canal Seepage	637,000	61
Seepage from Rivers and Streams	16,000	1
Seepage from Lake Lowell	19,000	2
Underflow	8,000	1
Flood Irrigation and Precipitation[2]	302,000	30
Recharge by Other Land Uses[3]	48,000	4
Rural Domestic Septic Systems	5,000	<1
TOTAL RECHARGE[1]	1,035,000	
Domestic and Industrial Withdrawals	66,000	6
Municipal Irrigation	10,000	1
Self-Supplied Industrial	21,000	2
Agricultural Irrigation	72,000	7
Rural Domestic Withdrawals	27,000	2
Stock Watering	3,000	<1
Discharge to Rivers and Drains	800,000	81
TOTAL DISCHARGE:	999,000	
NET DIFFERENCE[4]:	+36,000	

1. See text for explanations; values shown in this table are rounded to the nearest 1,000 acre-feet.
2. Includes recharge from precipitation and irrigation on flood-irrigated lands only.
3. Includes recharge from precipitation by land use; does not include flood-irrigated land.
4. Because of the error associated with the individual water budget components, a positive net difference does not necessarily indicate a positive change in aquifer storage.

The aggregate nature of the water budget masks the temporal characteristics of ground water recharge, withdrawals, and natural discharge. Infiltration from the surface water distribution system and irrigation occurs primarily in the summer. The actual recharge from irrigation activities lags the infiltration so that water levels may be rising months after irrigation has ceased. Also, municipal ground water use varies throughout the year, and is greatest during the summer irrigation season.

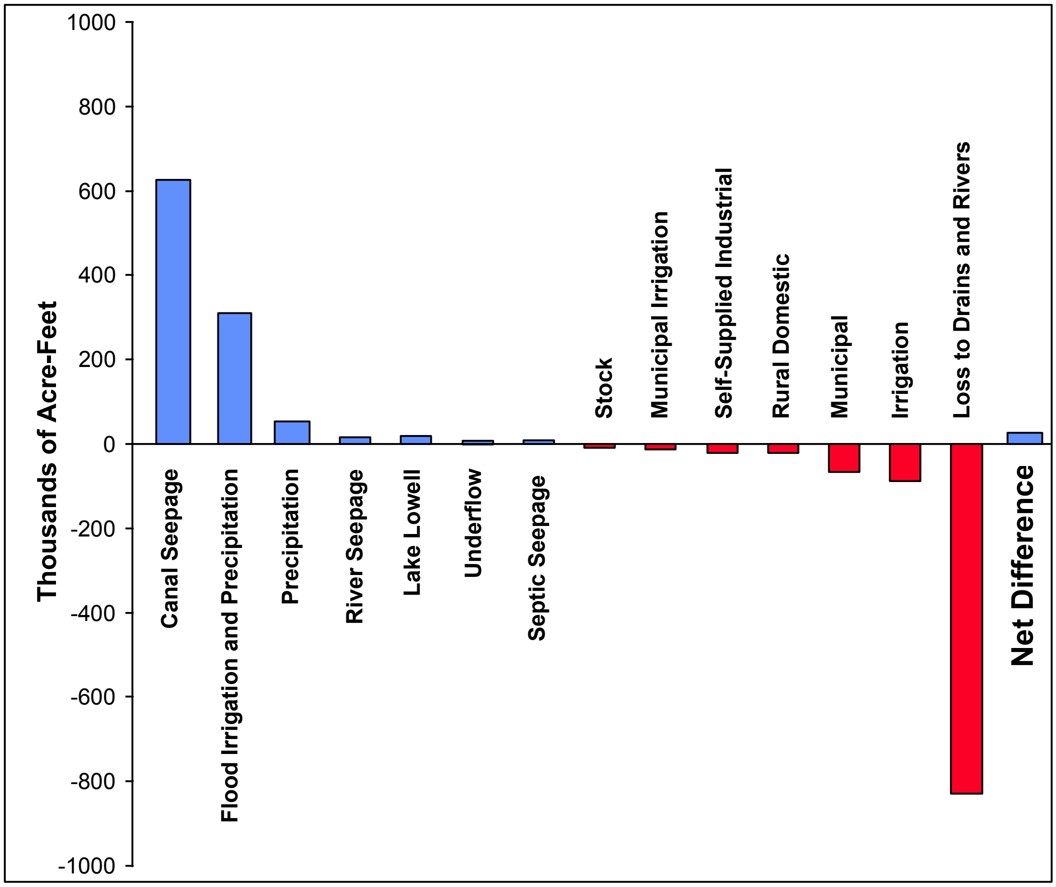


Figure 12: Graph showing 1996 water budget components

The total estimated ground water recharge exceeded the estimated discharge by approximately 36,000 acre-feet during 1996. However, this positive net difference is less than five percent of the total recharge or discharge, and is considered to be within the margin of error for the individual water budget component estimates. As a result, this net difference does not indicate conclusively that a condition of ground water surplus existed during the 1996 calendar year.

For comparison, a change in aquifer storage of approximately 20,000 acre feet was estimated on the basis of 72 water level measurements taken in March 1996 and March 1997. The error associated with this estimate is high because of the small number of wells, the vertical distribution of the screened well openings, potential pumping influences, and lack of actual data for effective porosity or specific yield. At this time, the condition of ground water surplus cannot be confirmed because of limited water level measurements and the error margin associated with some water budget components.

Several general conclusions can be drawn from this water budget. These are:

1. The largest components of aquifer recharge are seepage from the canal system and infiltration associated with irrigated agriculture.
2. Seepage to rivers, drains, and canals is the largest source of discharge from the Treasure Valley aquifer system.
3. Overall, total aquifer recharge to the Treasure Valley appears to exceed aquifer discharge. However, the net difference is well within the error range of the large water budget components, and the system as a whole is considered to be in equilibrium. At this time, the condition of ground water surplus cannot be confirmed because of limited water level measurements and the error margin associated with some water budget components.
4. Recharge to the Treasure Valley aquifer system is significantly influenced by land use (by the location of irrigation activities).
5. Evaluating water budgets for individual portions of the Treasure Valley aquifer system requires quantification of vertical and horizontal ground water movement between aquifer zones and the categorization of pumping data by aquifer zone.

7. Recommendations

The following recommendations are made on the basis of the Phase I water budget results:

1. Collect additional diversion and return flow data for all of the canal systems in the Treasure Valley to better define canal losses and gains. Some of these data are currently being developed by the USBR. Additional data will be obtained during Phase 2 of the Treasure Valley Hydrologic Project.
2. Measure seepage and gains in more intermediate-sized canals. These measurements should be conducted over longer reaches, with diversion and return flow measurements made along the measured reaches.
3. Evaluate the dynamics of canal seepage. This evaluation might be done by measuring directly the hydraulic conductivity of canal bottom sediments, installing piezometers near selected canal reaches and monitoring infiltration, or other means.
4. Obtain pumping data from Treasure Valley communities from which pumping data had been unavailable to reduce errors in estimating water use.
5. Separate pumping data by aquifer zone. The water budget could then be differentiated between shallow and regional portions of the aquifer system.
6. Evaluate withdrawals from irrigation wells by installing flow meters in selected wells (on a voluntary basis) and evaluating withdrawals data with electrical records, lift data, and crop type data.
7. Evaluate the impact of supplemental irrigation wells during typical normal and dry water years. This could be done by installing flow meters in selected wells (on a voluntary basis) in different parts of the valley, and evaluating withdrawals on acreage and crop-type basis.
8. Evaluate vertical ground water movement between aquifer zones through the installation of multi-level piezometers, the identification and monitoring of nearby wells completed at different depths, and the use of a numerical model.
9. The estimated recharge rates presented for some land use classifications may not reflect actual conditions. For example, the net recharge from domestic lawn irrigation may be much higher than 0.25 feet/year in some areas, depending on soil type and efficiency of the irrigation system. In general, actual measurements of recharge rates for major land use classifications would improve the overall estimate of aquifer recharge.

8. References

Bigelow, B.B., S.A. Goodell, and G.D. Newton, 1986. Water Withdrawn for Irrigation in 1980 on the Snake River Plain, Idaho and Eastern Oregon. U.S. Geological Survey Hydrologic Investigations Atlas HA-690, scale 1:1,000,000, 2 sheets.

Bowman, J.A. and S.D. Wilson, 1987. Estimating Irrigation Withdrawals: Lessons in the Variability of Individual Well Withdrawals. Illinois State Water Survey. In: Proceedings of the NWWA FOCUS Conference on Midwestern Ground Water Issues. National Water Well Association, Dublin, OH. p. 81-91.

Brockway, C.E. and R.G. Allen, 1983. Estimating Consumptive Irrigation Requirements for Crops in Idaho. Research Technical Completion Report, Idaho Water Resources Institute, University of Idaho, 183 pp.

Bureau of Census, 1992. Census data.

Burt, R.J., 1983. Problems in estimating self-supplied industrial water use by indirect methods - - the California example. U.S. Geological Survey Water Resources Investigations Report 83-4276.

Canter, Larry W. and Robert C. Knox, 1985. Septic Tank System Effects on Ground Water Quality. Lewis Publishers, 336 pp.

Classen, Hans C., Michael M. Reddy and Douglas R. Halm, 1986. Use of the Chloride Ion in Determining Hydrologic-Basin Water Budgets -- A 3-Year Case Study in the San Juan Mountains, Colorado, U.S.A. Journal of Hydrology, 85:49-71.

Collins, C.A., 1984. Ground-Water Withdrawals from the Columbia Plateau Regional Aquifer System. Oregon, 1984. U.S. Geological Survey Water-Resources Investigations Report 86-4211.

Davis, John C., 1986. Statistics and Data Analysis in Geology. John Wiley and Sons.

DEQ, 1997. Miscellaneous waste water and storm water discharge data provided by State of Idaho, Department of Environmental Quality, Southwest Region.

Dion, N.P., 1972. Some Effects on Land Use Changes on the Shallow Ground Water System in the Boise-Nampa Area, Idaho. Idaho Department of Water Administration Water Information Bulletin No. 26.

Driscoll, Fletcher G., 1986. Ground Water and Wells. Johnson Filtration Systems Inc.

E.P.A., 1980. Design Manual, Onsite Wastewater Treatment and Disposal Systems. U.S. Environmental Protection Agency.

Fetter, C.W., 1988. Applied Hydrogeology. Merrill Publishing Company.

Frenzel, Steven A., 1985. Comparison of Methods for Estimating Ground-Water Withdrawals for Irrigation. Ground Water, Vol. 23, No. 2, p. 220-226.

Garabedian, S.P., 1992. Hydrology and Digital Simulation of the Regional Aquifer System, Eastern Snake River Plain, Idaho. U.S. Geological Survey Professional Paper 1408-F.

Goodell, S.A., 1988. Water Use on the Snake River Plain, Idaho and Eastern Oregon. U.S. Geological Survey Professional Paper 1408-E.

Gronberg, Jo Ann M. and Kenneth Belitz, 1992. Estimation of a Water Budget for the Central Part of the Western San Joaquin Valley, California. U.S. Geological Survey, Water-Resources Investigations Report 91-4192, Regional Aquifer-System Analysis.

Hill, Bradley M., 1996. Use of a Numerical Model for Management of Shallow Ground-Water Levels in the Yuma, Arizona Area. Ground Water, Vol. 34, No. 3, May-June 1996, p. 397-404

Holmes, Walter F., 1985. Water Budget and Ground-Water Occurrence in the Uinta Basin of Utah. In: Geology and Energy Resources, Uinta Basin of Utah, M. Dane Picard, Editor. Utah Geological Association. pp. 271-275.

Idaho Agricultural Statistics Service, 1996. Miscellaneous data.

Idaho Department of Commerce, 1996. Miscellaneous census data.

Idaho Department of Employment, 1997. Miscellaneous census data.

Idaho Department of Water Resources, 1995. Map and GIS database: General Land Use for Ada and Canyon Counties. Based upon 1986 NAPP photography. 1:100,000 scale.

Idaho Department of Water Resources, 1997. Map and GIS database: Boise Valley Project, Land Use and Land Cover, 1994. Based on 1:12,000 scale CIR photography. Map scale: 1:100,000.

Johnson, Gary S., Charles E. Brockway, and Ann Coiner, 1985. Evaluation of Methods for Estimation of Aquifer Recharge from Precipitation on Semi-Arid Lands. Research Technical Completion Report, Idaho Water Resources Institute, University of Idaho, 24 pp.

Kjelstrom, L.C., 1995. Streamflow Gains and Losses in the Snake River and Ground-Water Budgets for the Snake River Plain, Idaho and Eastern Oregon. U.S. Geological Survey Professional Paper 1408-C.

Lindholm, G.F., 1993. Summary of the Snake River Plain Regional Aquifer-System Analysis in Idaho and Eastern Oregon. U.S. Geological Survey Open File Report 91-98.

Mann, Larry J., 1979. Water Budget and Mathematical Model of the Coconino Aquifer, Southern Navajo County, Arizona. U.S. Geological Survey Open-File Report 79-348.

Molnau, Myron and Francis M. Winters, Jr. 1988. Mean annual precipitation map for Idaho. Idaho Water Resources Research Institute Research Technical Completion Report.

Morgan, David S., 1988. Geohydrology and Numerical Model Analysis of Ground-Water Flow in the Goose Lake Basin, Oregon and California. U.S. Geological Survey Water-Resources Investigations Report 87-4058.

Newton, Garth D., 1991. Geohydrology of the Regional Aquifer System, Western Snake River Plain, Southwestern Idaho. U.S. Geological Survey Professional Paper 1408-G.

NOAA, 1996. Climatological data, Idaho. National Oceanic and Atmospheric Administration.

Patt, Ralph O., 1978. Las Vegas Valley Water Budget, Relationship of Distribution, Consumptive Use, and Recharge to Shallow Ground Water. U.S. Environmental Protection Agency, EPA-600/2-78-159. 61 pp.

Petrich, C., and S. Urban, 1997. Summary of Phase I Well_Log Modifications, Water Level Measurements, and Canal Seepage Measurements, Treasure Valley Hydrologic Project. Idaho Department of Water Resources.

Petrich, C. 1997. Progress Report on the Development of the Treasure Valley Ground Water Flow Model. Research report by the Idaho Water Resources Research Institute for the Idaho Department of Water Resources.

Rosa, J. Marvin, 1968. Water-yield maps for Idaho. ARS 41-141. United States Department of Agriculture.

Sutter, R.J., and G.L. Corey, 1970. Consumptive Irrigation Requirements for Crops in Idaho: Moscow, University of Idaho Experimental Station Bulletin 516, 97 pp.

Thomas, C.A., and N.P. Dion, 1974. Characteristics of Streamflow and Ground-Water Conditions in the Boise River Valley, Idaho. U.S. Geological Survey Water Resources Investigations 38-74, 56 pp.

Thomas, Harold E., 1963. A Water Budget for the Artesian Aquifer in Ogden Valley, Weber County, Utah. In: Methods of Collecting and Interpreting Ground-Water Data. U.S. Geological Survey Water Supply Paper 1544-H, p H63-H97.

U.S. Bureau of Reclamation, 1995. Agricultural Crop Water Use Summary, 1988-1994, Pacific Northwest Region, Historical Summation of Evapotranspiration Data from AgriMet. 25 pp.

U.S. Bureau of Reclamation, 1996. A description of BOR system operation of the Boise and Payette Rivers.

U.S. Bureau of Reclamation, 1997. Miscellaneous canal diversion data.

U.S. Department of Commerce, 1994. 1992 Census of Agriculture, Part 12 Idaho.

U.S.G.S., 1956. Compilation of records of Surface Waters of the U.S. through September, 1950. Part 13 Snake River Basin.

U.S.G.S., 1996. Water resources data, Idaho, water year 1996.

U.S.G.S., 1997a. Preliminary water resources data.

U.S.G.S., 1997b. U.S. Geological Survey internet WEB site providing industrial water use coefficients. Site located at: http://h20.er.usgs.gov/public/wateruse.

Van Metre, Peter and Paul Seevers, 1991. Use of landsat imagery to estimate ground-water withdrawals for irrigation on the Columbia Plateau in Eastern Washington, 1985. U.S. Geological Survey Water Resources Investigations Report 89-4157. 38 pp.

Costs associated with this publication are available from the Idaho Department of Water Resources in accordance with Section 60-202, *Idaho Code*. IDWR-25404-50-1/98.