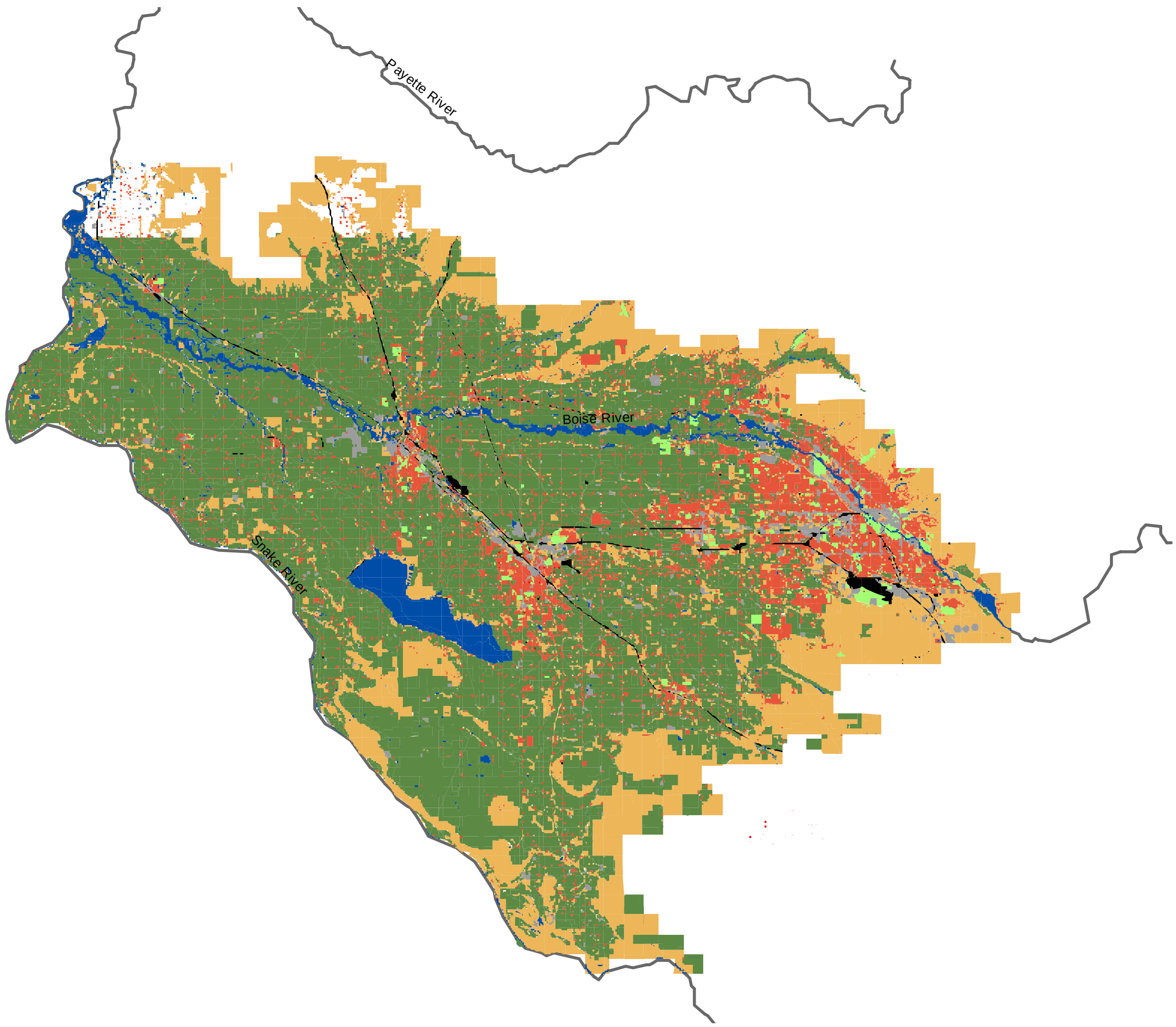
A Distributed Parameter Water Budget Data Base for the Lower Boise Valley



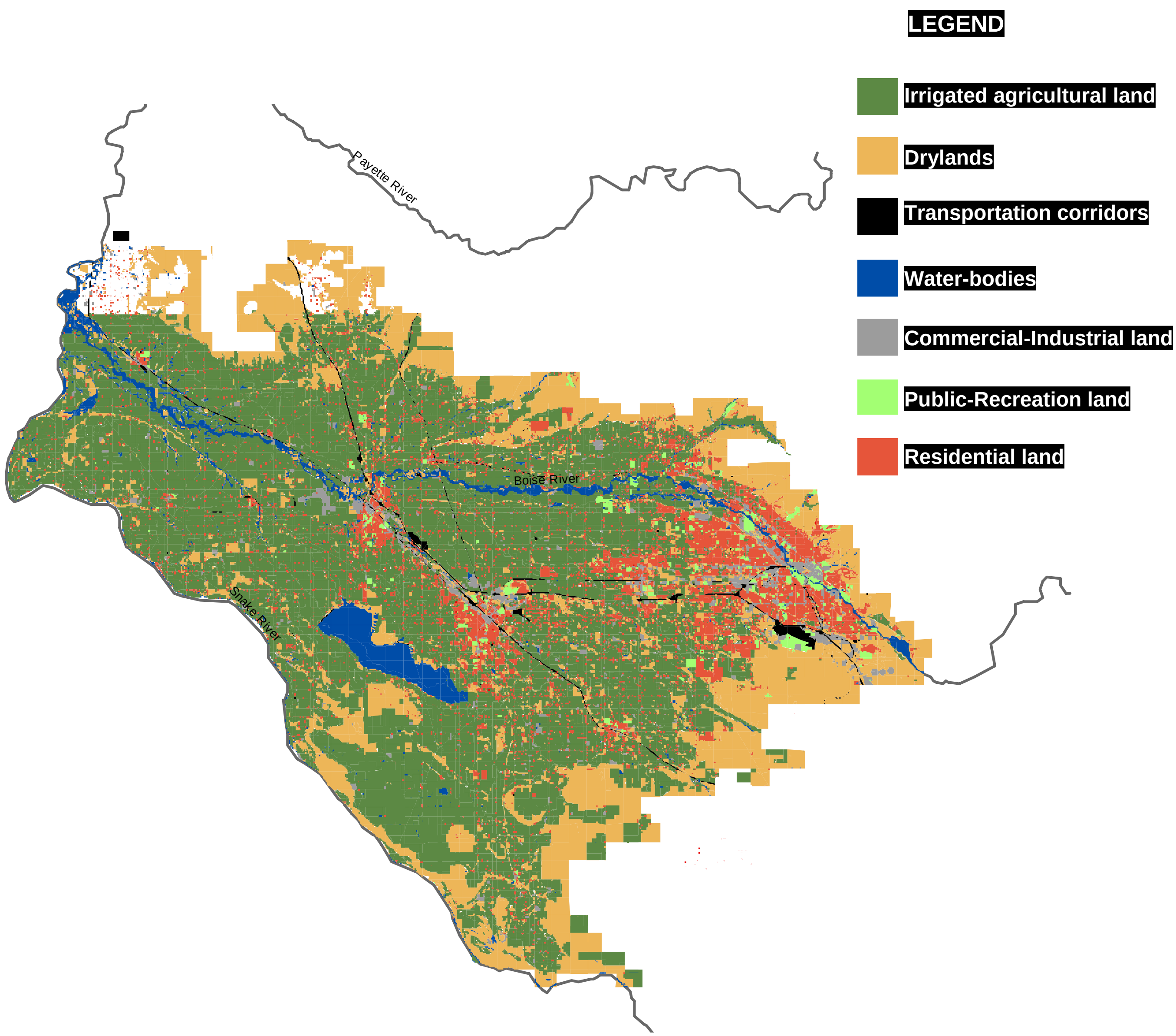
U.S. Bureau of Reclamation
Pacific Northwest Region
River and Reservoir Operations Group
Boise, Idaho

Idaho Department of Water Resources
Planning Bureau
Boise, Idaho

Revised January 2008

On The Cover

Seven Land Uses in the Boise Valley. This map is an example of the layers of information available in this summary of *A Distributed Parameter Water Budget Data Base for the Lower Boise Valley*.



A DISTRIBUTED PARAMETER WATER BUDGET DATA BASE FOR THE LOWER BOISE VALLEY

JANUARY 2008

THIS REVISION SUPERSEDES THE REPORT

A DISTRIBUTED PARAMETER WATER BUDGET DATA BASE FOR THE BOISE VALLEY

(SEPTEMBER 2006 AND JANUARY 2007)

U.S. BUREAU OF RECLAMATION

PACIFIC NORTHWEST REGION

RIVER AND RESERVOIR OPERATIONS GROUP

BOISE, IDAHO

AND

IDAHO DEPARTMENT OF WATER RESOURCES

PLANNING BUREAU

BOISE, IDAHO

CONTRIBUTORS

RD Schmidt, Bureau of Reclamation, Pacific Northwest Regional Office, Boise, ID

Zena Cook, Idaho Department of Water Resources, Boise, ID

Darrel Dyke, Bureau of Reclamation, LaGrande Field Office, LaGrande, OR

Sudhir Goyal, Idaho Department of Water Resources, Boise, ID

Mary McGown, Idaho Department of Water Resources, Boise, ID

Karl Tarbet, Bureau of Reclamation, Pacific Northwest Regional Office, Boise, ID

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GLOSSARY

Term	Meaning	Eq.
∆ AqStor	change in aquifer (groundwater) storage due to irrigation activities	2-1, 2-3, 2-15
∆ LowStor	change in Lake Lowell reservoir storage	3-3
AreaDrnRet	individual area drain return	2-10
AreaFrmDel	farm delivery for individual drainage areas	2-10
AreaIrrET	evapotranspiration (ET) on surface-water irrigated agricultural lands for individual drainage areas	2-10
BaseFlo	base flow discharge (of groundwater) to the main channels of a river reach	2-1, 2-3, 2-15, 3-2
CanET	canal evapotranspiration (ET)	2-8
CanLoss	canal seepage plus canal evapotranspiration (ET)	2-5
CanSeep	canal seepage losses	2-2, 2-3, 2-14
ETDry	evapotranspiration (ET) rates on dry lands	3-1
GwDrnRet	the groundwater component of net drain return to rivers	2-3, 2-12, 2-13
GwIrrET	evapotranspiration (ET) on groundwater irrigated agricultural lands	2-8, 2-9
GwPmpAg	groundwater withdrawals on groundwater-irrigated agricultural lands	2-3, 2-9, 2-14
GwPmpRcp	consumptively used groundwater withdrawals on residential, commercial and public lands	4-1
GwPrecip	precipitation on groundwater irrigated agricultural lands	2-9
InfilRcp	infiltration rate of 0.25 acre-feet per acre on RCP lands	4-1
kaf	thousand [kilo] acre-feet	—
LowDrnRet	drain returns to Lake Lowell	3-3
LowET	Lake Lowell evapotranspiration (ET)	2-8, 3-3
LowGain	net groundwater gain by Lake Lowell	2-2, 2-3, 2-5, 3-3

Term	Meaning	Eq.
LowIn	Diversions into Lake Lowell	3-3
LowOut	Diversion out of Lake Lowell	3-3
NetDrnRet	surface-water and groundwater components of net drain return to rivers	2-1, 2-11, 2-12, 3-2
NetFrmDel	Net farm delivery to irrigated agricultural lands (excluding re-diversions)	2-6
NetRec/DisAg	Net groundwater recharge-discharge on irrigated agricultural lands	2-14, 2-15
NetRec/DisDry	Net groundwater recharge-discharge on dry lands	3-1
NetRec/DisLL	Net groundwater recharge-discharge on Lake Lowell (same as LowGain)	3-3
NetRec/DisRcp	Net groundwater recharge-discharge on residential, commercial and public lands	4-1
NetRec/DisRv	Net groundwater recharge-discharge on river channels and riparian wetlands (same as base flow)	3-2
NetRivDivr	net diversions from Boise, Payette and Snake Rivers (excluding re-diversions)	2-1, 2-2, 2-4, 2-5
OnFrmInfl	on-farm infiltration on irrigated agricultural lands	2-2, 2-3, 2-13, 2-14
PrecipAg	precipitation on irrigated agricultural lands	2-1, 2-2, 2-13
PrecipDry	precipitation on dry lands and water-bodies	3-1
ReDrnRet	re-diverted drain returns between drainage areas	2-7, 2-11
ReIrrRet	re-diverted drain returns between irrigation districts	2-7, 2-11
SurfDrnRet	the surface-water component of net drain return to rivers	2-2, 2-12, 2-13
SurfETAg	evapotranspiration (ET) on surface-water irrigated agricultural lands, plus canal ET and Lake Lowell ET	2-2
SurfIrrET	evapotranspiration (ET) on surface-water irrigated agricultural lands	2-8, 2-13
TotalDrnRet	total drain returns	2-11
TotalETAg	total agricultural lands evapotranspiration (ET) -- (surface-water irrigated ET, farm ET, canal ET, and Lake Lowell ET)	2-1, 2-8

Term	Meaning	Eq.
TotalFrmDel	total farm delivery to irrigated agricultural lands	2-5, 2-6, 2-13
TotalRchDivr	total diversion from Boise, Snake, and Payette Rivers (including re-diversions)	2-4; 3-2
TotalRchDrnRet	total drain return to a river reach	3-2
TotalRchGn/Los	total river reach gain or loss measured at upstream and downstream gages	3-2
TotalReDrnRet	total re-diverted drain return (between and within drainage areas)	2-4, 2-5, 2-7
TotalRivRchGn	total river reach gain from tributaries	3-2

1. BACKGROUND

1.1. PURPOSE AND NEED

A water budget describes and accounts for inflows, outflows, and storage changes in an aquifer system or drainage basin. Water budgets are generally described as either distributed-parameter or lumped-parameter budgets. Distributed-parameter budgets provide details of the spatial distribution of individual water budget components; lumped-parameter budgets aggregate inflows, outflows, and storage changes together for an entire aquifer system or drainage basin.

The *Lower Boise Valley Distributed-Parameter Water Budget* is a geographic information system (GIS) database containing details of the spatial and temporal distribution of groundwater and surface-water usage in the "lower" Boise River valley, the area downstream from Lucky Peak Dam. The water budget database is a product of the Boise Valley Water-Use Planning Study, a collaboration of the Bureau of Reclamation (Reclamation) and the Idaho Department of Water Resources (IDWR). An earlier Boise Valley Water-Use Planning Study report addressed the impacts of future land-use changes on demands for surface-water and groundwater resources in the Boise Valley (Cook, Urban et al. 2003).

The Lower Boise Valley distributed-parameter water budget was developed in order to provide more detailed budget data for use in sub-regional scale hydrologic modeling of the Boise Valley. The current budget contains average monthly and average annual estimates for seventeen different water budget components. The spatial resolution of these components varies, but is generally adequate for hydrologic modeling at a modeling scale that identifies individual irrigation districts, drainage areas, and urban centers.

The current water budget is divided into three main parts that are aligned with three broad land-use categories in the Lower Boise Valley — irrigated agricultural lands; residential, commercial, and public-recreation lands; and dry lands and water-bodies. A 1994 classification of Boise Valley land-uses (IDWR 1995b; IDWR 1996) is used for all three categories. The *irrigated agricultural lands* budget is based on water-use data for the period 1967-1997, and the *residential, commercial, and public-recreation lands* budget is based on DCMI (domestic, commercial, municipal, and industrial) water-use data for the period 1995-2001.

One of the main reasons for developing sub-regional hydrologic models in the Lower Boise Valley is to investigate the impacts of future land-use changes on groundwater resources. However, the current water budget is reflective of land-uses that existed prior to 2001. The problem of using current budget data in hydrologic models of a future (different) land-use distribution is overcome (at least partly) by representing all budget components in units that are independent of current land-use acreages. All of the components in the GIS budget database have units of acre-feet per acre (that is, feet). The per-acre average monthly and average annual budget components are associated with the 1994 Boise Valley land-use classification and in the future could be associated with a different classification of agricultural, residential, and urban lands.

Although *irrigated agricultural lands* budget components are based on a 1994 land-use classification, irrigation district records show relatively little change in total irrigated acreage since 1967 (the year after the completion of Lucky Peak Dam and Reservoir). The year-to-year increases and decreases of a few thousand acres are seemingly unrelated to urbanization and appear to reflect more the circumstances of the agricultural economy. Expansion into once non-irrigated land would also explain why there has been little net change in irrigated acreage between 1967 and 1997.

A section of this report compares *irrigated agricultural lands* budget estimates to those of the previously developed Treasure Valley Hydrologic Project (TVHP) budget (Urban 2004). The TVHP budget produced aggregate (valley-wide) estimates of aquifer withdrawals, aquifer recharge, and change in aquifer storage for the year 1996, that were incorporated into the (regional-scale) Treasure Valley Hydrologic Model (Petrich 2004b). While the TVHP water budget is a distributed-parameter water budget, it is not a geospatial database. For the most part the TVHP budget does not have the spatial resolution needed for sub-regional scale hydrologic modeling.

The scope of this report is limited to meeting two basic objectives. The first is to describe the procedures and assumptions used in developing the budget components in each budget category; the second is to summarize the magnitude and distribution of the major components of each category. As such, the report is essentially a summary of the GIS water budget database contained on the companion CD (Attachment C). While this report presents a brief summary of every budget component on the CD, it does not include a full description of the spatial distribution of every component. The full spatial distribution of average monthly and average annual values for all seventeen budget components in the GIS database can be displayed by joining one or more data tables to spatial data layers representing the three Boise Valley land-use categories. Attachment A of this report describes the attributes of data tables that are used in making these table joins. Attachment B of the PDF version of this document provides full-page versions of the “thumbnail” figures in Section 5 which show spatially distributed budget components.

1.2. GIS DATABASE ORGANIZATION

As noted previously, the spatial distribution of budget components in all three budget categories is applied to a 1994 classification of Boise Valley land-uses. The *irrigated agricultural lands* GIS layer consists of about 371,000 acres, including canals and drains. The *residential, commercial, and public-recreation lands* GIS layer consists of about 85,000 acres; the layer includes industrial lands, recreation lands, and municipal wells. The *dry lands and water-bodies* GIS layer has about 182,000 acres; the layer includes rangelands, barren lands, Lake Lowell, riparian wetlands, and river channels.

The GIS budget data base is contained in a single folder on Attachment C, a CD-ROM. The data base consists of three GIS data layers, one for each of the three budget categories and associated budget tables. The spatial distribution of budget components within the data layers is determined by geographic properties referred to as “feature types.” For example, in the *irrigated agricultural lands* layer, the feature types are irrigation districts, Boise Project Board of Control (BPBOC) divisions, drainage areas, precipitation zones, and gravity/sprinkler classes.

Tables A-9, A-10, and A-11 in Attachment A list the attribute identification names (“ID”) used to identify budget components in the GIS budget layers. There are seventeen GIS budget attributes in the *irrigated agricultural lands* data layer; three in the *dry lands and water-bodies* data layer; and five in the *residential, commercial, and public-recreation lands* data layer. Tables A-9, A-10, and A-11 also identify the fields in each layer table used to join budget components to feature types. Only three budget components are common to the three GIS budget layers — Precipitation, Evapotranspiration (or outdoor consumptive use), and Net Groundwater Recharge-Discharge.

The layer tables in the GIS budget layers were originally developed from Microsoft Excel™ spreadsheets and then exported as data base files. The CD also includes the Excel spreadsheets that were used to develop the GIS database and to calculate average annual and average monthly budget components. The spreadsheet data is split into primary and secondary data sources. The primary data sources are spreadsheets and calculations that have a primary link to GIS budget layers. These files also contain aggregated (valley-wide) statistics for each budget component. The secondary sources are worksheets containing historical data and other records of Boise Valley water use and availability that are (in some cases) linked to the primary worksheets.

The GIS database can be accessed using ArcMap 9.1™ (ESRI 2005). However, the water budget data base on the CD also includes a free MapWindow™ application. MapWindow is basic GIS software that supports limited manipulation, analysis, and viewing of spatial data and associated attributes without requiring the purchase of a complete GIS software package (MapWindow 2005).

MapWindow (in its current version) does not have the capability to join layer tables to feature types. In the GIS database on the CD, the net groundwater recharge-discharge budget component has already been joined to features in each of the three data layers. If MapWindow is being used and other budget components need to be joined to data layers, the joins must be done in Excel before the data layer is opened inside MapWindow.

1.3. DATA SOURCES

The largest and most complex part of the Boise Valley water budget is the *irrigated agricultural lands* budget category. Data used to develop this budget category was compiled largely by Reclamation personnel during 1998 and 1999, from records and data cited here. The sources include the Boise Project Board of Control (BPBOC 1998) and private irrigation districts (I.D.). The latter include Big Bend I.D. (1998); Boise-Kuna I.D. (1999); Black Canyon I.D. (1998); Capital View I.D. (1999); Farmers Coop Ditch Co. (1999); Farmers Union Ditch Co. (1999); Nampa & Meridian I.D. (1999); New York I.D. (1998); Pioneer I.D. (1999); Riverside I.D. (1999); Settlers I.D. (1999); and Wilder I.D. (1998). The data supplied to Reclamation included historical records of diversion, farm delivery, canal losses, drains returns, and reservoir storage.

Other data sources for the *irrigated agricultural lands* budget category include Hydromet (Reclamation 2005c) and U.S. Geologic Survey (USGS 2005) for river flow and reach gains data; Agrimet (Reclamation 2005a), the Farm Service Administration (FSA 1997), and the Soil Conservation Service (SCS 1970) for crop distribution and evapotranspiration (ET) estimates; the U.S. Geologic Survey (USGS 1997) and Reclamation (2004) for drain return and canal seepage estimates; and National Weather Service for precipitation data (NWS 1999).

Data used to describe residential, commercial-industrial, and public-recreation water use in the Boise Valley for the *residential, commercial, and public-recreation lands* budget category came mainly from recent IDWR investigations (Cook, Urban et al. 2003; IDWR 2003a; IDWR 2003b; and IDWR 2005). Additional estimates of outdoor consumptive use came from IDWR investigations of ET rates on residential, commercial-industrial, and public-recreation lands (Kramber 2002) and from United Water Idaho, Inc. records of groundwater withdrawal (UWI 2001).

Data used in the *dry lands and water-bodies* budget category to estimate precipitation and ET on dry lands came from the National Weather Service and from earlier TVHP estimates (Urban 2004). Estimates of ET and seepage gains and losses from Lake Lowell and the Boise River are based on calculations which use BPCOC and irrigation district records of diversions, drain returns, and reservoir storage, and on Hydromet data from gaging stations on the Boise and Snake Rivers (Reclamation 2005c).

Additional description of data sources and calculation of budget components is included in the following three sections of this report, one of which is devoted to each of the three budget categories.

2. IRRIGATED AGRICULTURAL LANDS WATER BUDGET

The *irrigated agricultural lands* GIS layer includes all surface-water and groundwater irrigated agricultural lands in the Boise Valley, as well as canals and most drains. The Lake Lowell water budget is included in the *irrigated agricultural lands* budget spreadsheets, and it is included in some generalized *irrigated agricultural lands* budget results. However, the details of the Lake Lowell budget (along with the Boise River riparian lands budget) are presented in Section 3, as part of the *dry lands and water-bodies* budget.

Most of the diversion and delivery data used in the *irrigated agricultural lands* budget is based on historical records obtained by Reclamation from BPBOC and private irrigation districts during 1998 and 1999. In some cases, these records extend back to the early 1900s. However, the *irrigated agricultural lands* budget was developed using only those records for the period 1967-1997. The starting year for this period (1967) was chosen because it follows the completion of Lucky Peak Dam and Reservoir. The completion of the reservoir in 1966 was the last major change to the surface-water-supply infrastructure of the Boise Valley (Reclamation 2005a).

The *irrigated agricultural lands* budget components include river diversions, farm delivery, surface-water and groundwater return to drains, re-diverted drain returns, precipitation, evapotranspiration (ET) and groundwater pumping. The spatial distribution of these budget components is determined by geographic feature types that include BPBOC divisions, private irrigation districts, drainage areas, gravity and sprinkler irrigation areas, and precipitation zones. The geographic feature types in the GIS data base are described first, followed by *irrigated agricultural lands* budget summary statistics (1967-1997), and then by maps of the spatial distribution of selected budget components.

2.1. FEDERAL IRRIGATION PROJECTS

The Boise Project furnishes a full irrigation water supply to about 224,000 acres in the Boise Valley (Reclamation 2005a). The Arrowrock and Payette Divisions of the Boise Project were established by Federal law in 1905 and 1922, respectively. The Project holds storage rights on Anderson Ranch, Arrowrock, Lucky Peak, Deadwood and Cascade reservoirs. Figure 2–1 shows the distribution of irrigated lands in the Boise Project which drain directly to either the Boise River or the Snake River. The Arrowrock Division contains BPBOC lands and the Payette Division contains Black Canyon I.D. lands.

The Arrowrock Division irrigates about 176,000 acres that are served through the BPBOC. The BPBOC in turn has five divisions, representing its member irrigation districts — Nampa & Meridian, Boise-Kuna, Wilder, Big Bend, and New York. Lands in the Arrowrock Division are irrigated with storage water diverted from the Boise River and conveyed to Project lands through the New York Canal. The 40-mile-long New York Canal begins at Boise River Diversion Dam (river mile 61) and includes a part of the Indian Creek channel. Water in the New York Canal is diverted into numerous other distribution systems including the Mora Canal, the Deer Flat High Line Canal, and Lake Lowell.

Lake Lowell (originally known as Deer Flat Reservoir) is the principal off-stream storage structure for the Arrowrock Division of the Project and is formed by earthfill dams enclosing a natural depression. Its active storage capacity is about 159,400 acre-feet.[1/]

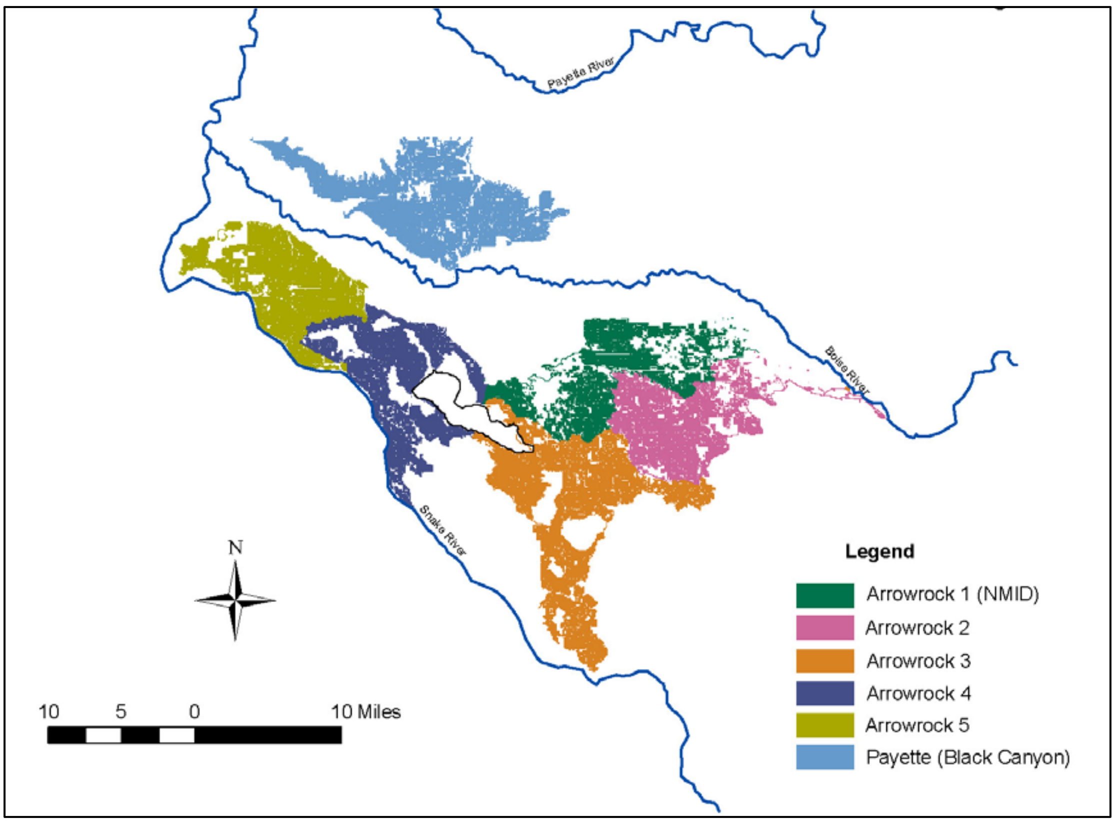

Figure 2–1. *[map]* Boise Project irrigation lands (by division).

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[1] Lake Lowell is currently under a Safety of Dams "restriction" to a total active capacity of about 129,100 acre-feet at elevation 2526 feet. Repairs are projected to be complete by Autumn 2008. Dead storage and inactive capacity are about 13,700 acre-feet.

The Payette Division of the Boise Project irrigates about 95,000 acres and is served by the Black Canyon I.D. Project lands in the Payette Division receive water from the Payette River and from surplus drain returns from the Arrowrock Division (which is pumped across the Boise River near Notus). About 42,000 acres in the Black Canyon I.D. drain to the Boise River, and only these lands are included in this Boise Valley water budget.

2.2. PRIVATE IRRIGATION ENTITIES

Within the Boise Valley but not part of the Boise Project, there are thirty-seven private canal companies and surface-water irrigation districts. These non-Project canal companies and irrigation districts irrigate approximately 172,000 acres. Most of these irrigators have natural flow rights from the Boise River. An additional 20,000 acres are irrigated from non-Project Snake River diversions. Approximately 42,000 acres are located within private groundwater irrigation districts.

Figure 2–2 shows the locations of the private irrigation entities in the Boise Valley. Six of the larger private irrigation districts and ditch companies are identified individually in this figure. They include Capital View I.D., Farmers Cooperative Ditch Co., Farmers Union Ditch Co., Pioneer I.D., Riverside I.D., and Settlers I.D. Thirty other small private irrigation districts and canal companies are aggregated together based on their diversion location along the Boise River. Those that divert

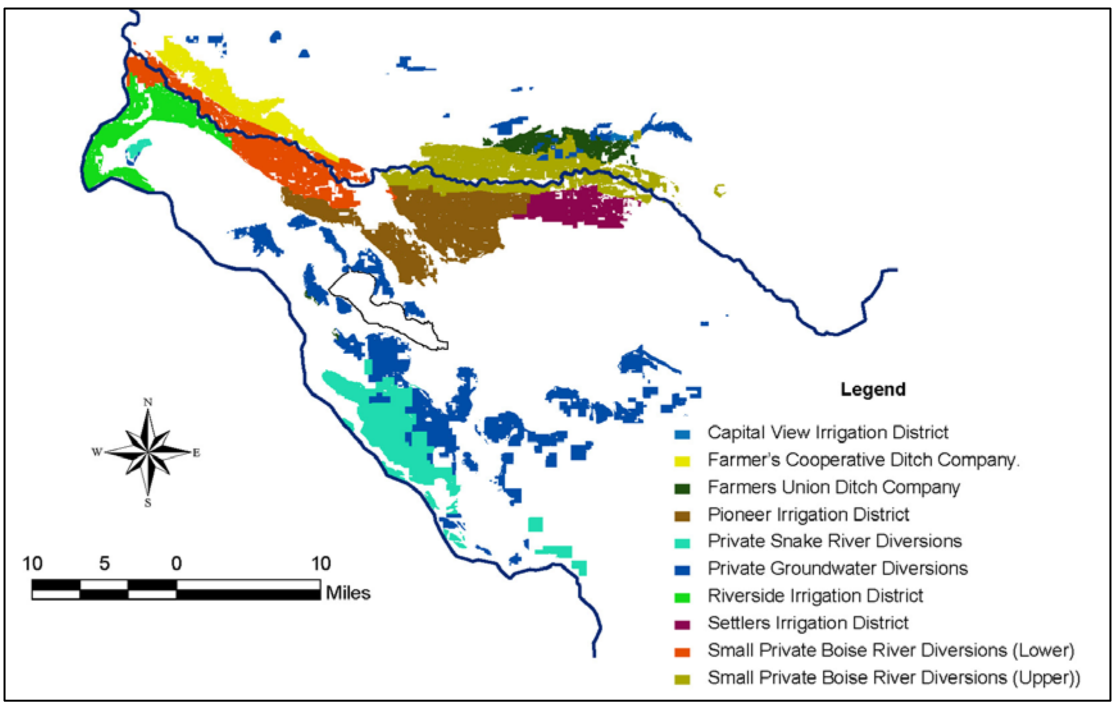

Figure 2–2. *[map]* Irrigated lands in private irrigation districts and canal companies in the Boise Valley.

from the Boise River upstream of Caldwell are collectively termed “small private Boise River Diverters (upper)” or Upper Boise Diverters. Those that divert downstream from Caldwell are termed “small private Boise River Diverters (lower)” or Lower Boise Diverters. In addition, all groundwater irrigators are grouped together as “Private Groundwater Diverters” and all Snake River irrigators are grouped together as “Private Snake River Diverters.”

2.3. DRAINAGE AREAS

Irrigation practices over the last century have significantly altered drainage patterns in the Boise Valley. Natural drainages have been deepened, lengthened, and straightened; new man-made waterways and wasteways have been created. The Boise Valley contains about 1,400 miles of natural drainage features (not counting the Boise and Snake Rivers) and about 460 miles of man-made drainage features (including canals and drains).

A drainage area is the surface-water catchment area associated with a major drainage feature. This could be a natural watercourse such as a river, or a man-made feature into which surface-water is discharged such as a drain, canal or reservoir. Discharge to a major drain results mainly from return flows produced on irrigated lands within the drainage area. However not all drainage-area return flows are discharged directly to rivers. Before reaching either the Boise River or the Snake River, return flows may pass through other drainage areas and other irrigation districts. Along the way, return flows may be intercepted by canals and re-diverted to agricultural lands.

Surface-water catchment areas incorporate residential lands and dry lands, as well as irrigated agricultural lands. However since the vast majority of return flows are generated on surface-water irrigated agricultural lands, only those lands are included in the depiction of drainage areas on subsequent drainage area maps.

Figure 2-3 shows the drainage areas associated with surface-water irrigated agricultural lands in the Boise Valley. This figure shows the distribution of nineteen drainage areas in the Boise Valley and was adapted from a map produced by the Canyon County Soil and Water Conservation District for the Idaho Department of Environmental Quality (IDEQ 2001).

The names of drainage areas refer to the principle receiving point (drain, canal, reservoir, or river) for return flows generated on surface-water irrigated lands within the drainage area. Drainage areas range from 400 acres (the Thurman drainage area) to 42,700 acres (the Riverside Canal drainage area) and average about 18,600 acres. All drain returns are assumed to originate on the gravity-irrigated portion of surface-water irrigated lands within drainage areas. Groundwater irrigated agricultural lands, which are also not included in drainage area acreage calculations, are identified separately in Figure 2-3.

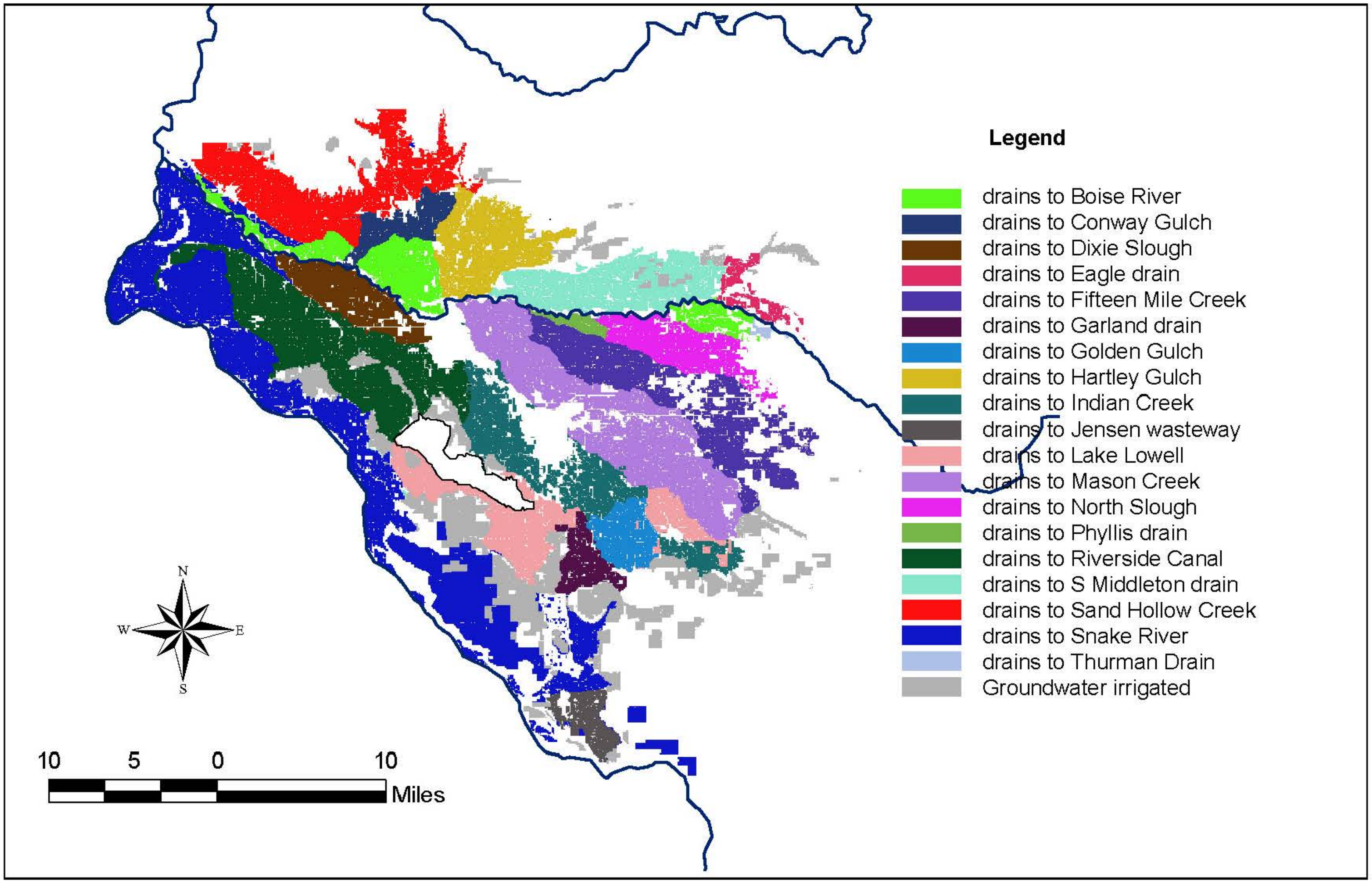

Figure 2–3. ***[map]*** **Drainage areas associated with surface-water irrigated agricultural lands in the Boise Valley.**

Fourteen of the nineteen major drains and wasteways associated with drainage areas in the Boise Valley are monitored throughout the irrigation season. These include Phyllis Wasteway, Willow Creek Wasteway, Five Mile Creek, North and South Middleton Drain, Indian Creek, Mason Creek, Notus-Conway Wasteway, Dixie Slough, Golden Gulch Wasteway, Hartley Gulch, Conway Gulch, Garland Drain, Jensen Wasteway, and Eagle Drain. Returns from the other five drainage areas, which include large areas of irrigated land, are not monitored and must be estimated by other means. Even for drains that are monitored during the irrigation season, irrigation districts do not normally monitor flows during winter months, so the returns that occur during these months must be estimated using other information.

Since all return flows in the Boise Valley ultimately discharge to the Snake River or Boise River, most drainage areas are isolated surface-water catchment features which share a boundary with one of the rivers. Mason Creek, Indian Creek, Fifteen Mile Creek, and Dixie Slough in Figure 2-3 are examples of drainage areas that discharge directly to the Boise River through single or multiple drains.

However, not all Boise Valley drainage areas are isolated surface-water catchment areas. Because drain-flow data in the Boise Valley is relatively sparse, if drain measurements are available from smaller catchment areas within larger catchment areas, then the smaller catchment areas are represented in Figure 2-3 as separate drainage areas. For example, the Dixie Slough, Riverside Canal, Lake Lowell, Garland and Golden Gulch drainage areas are in smaller drainage areas located within one larger surface-water catchment area. Surface-water returns to drains in the Garland drainage area and Golden Gulch drainage area flow into the Lake Lowell drainage area and (if not re-diverted) from there into the Riverside Canal drainage area. Lake Lowell is the receiving point for all drainage from the Lake Lowell drainage area, and the Riverside Canal is the receiving point for all drainage from the Riverside Canal drainage area. Drain return from the Riverside Canal drainage area is split between the Snake River drainage area and the Dixie Slough drainage area.

2.4. PRECIPITATION ZONES

Daily precipitation data for the Boise Valley is obtained from seven National Weather Service recording stations. These are located at Boise, Caldwell, Lake Lowell Dam, Parma, Swan Falls, Nampa, Kuna, and Adrian (Oregon). Precipitation rates in the Boise Valley are distributed spatially, using Thiessen polygons (Maidment 1992). Thiessen polygons are formed by intersecting the perpendicular bisectors of lines drawn between weather station locations. The average monthly precipitation at each station for the period 1967-1997 is assumed to be uniformly distributed over the surrounding polygon. Figure 2–4 shows the distribution of the eight precipitation zones; only irrigated agricultural land-uses are represented in this figure. However, the same zones are used by the spatial distribution of precipitation in the *dry lands and water-bodies* budget category.

2.4 Precipitation zones

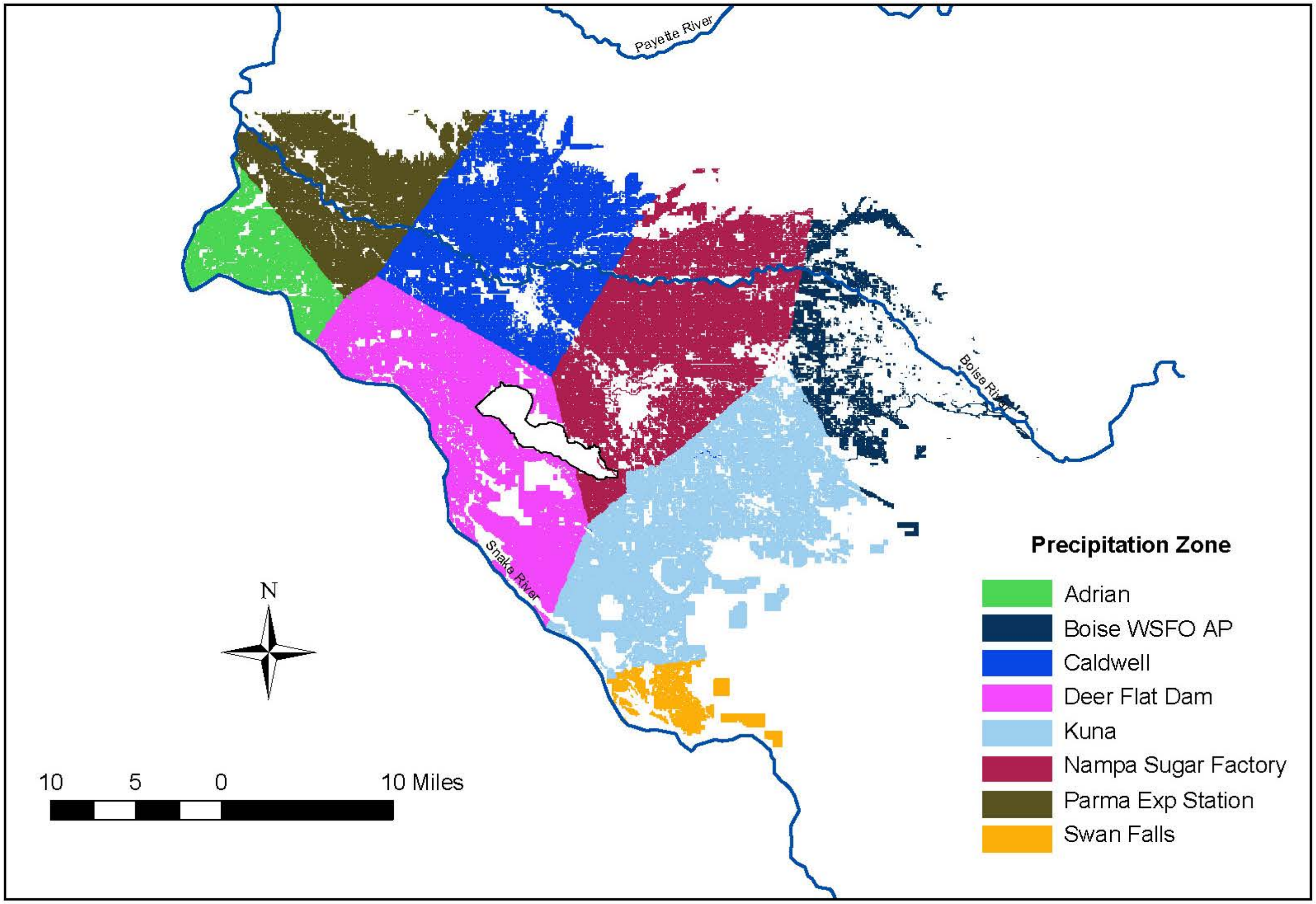

Figure 2–4. ***[map]*** **Irrigated land within precipitation zones in the Boise Valley.**

2.5. LANDS IRRIGATED BY GRAVITY AND SPRINKLER

About 72 percent of agricultural lands in the Boise Valley are irrigated by gravity diversions and about 28 percent by sprinklers (IDWR 1995). Figure 2–5 shows the distribution of approximately 269,000 acres of gravity-irrigated agricultural land and 102,000 acres of sprinkler-irrigated agricultural land in the Boise Valley.

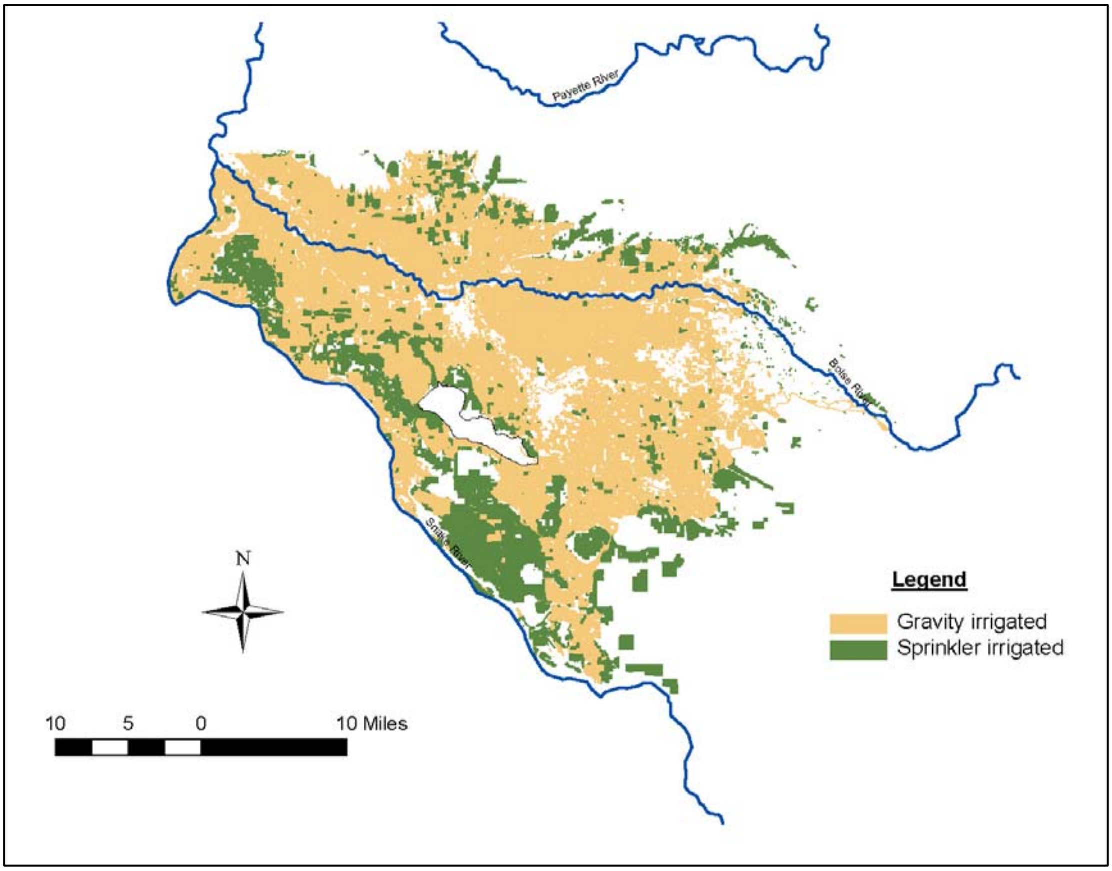

Figure 2–5. *[map]* Gravity and sprinkler irrigated lands in the Boise Valley.

2.6. IRRIGATED AGRICULTURAL LANDS BUDGET EQUATIONS

The following subsections present equations that define the relationships between the various components of the Boise Valley *irrigated agricultural lands* water budget. Some of the equations are applied to average monthly and average annual budget data; others are applied only to average annual data.

The Boise Valley *irrigated agricultural lands* water budget is represented most generally by **Equation 2-1**, which describes the relationship between the principal surface-water and groundwater budget components on an average annual basis. The principal budget components include river diversions, precipitation, ET, drain returns to rivers, base flow to rivers, and change-in-aquifer-storage. The budget components in this expression (including precipitation) pertain only to irrigated agricultural lands.

Equation 2-1. Relationship between major surface-water and groundwater components for irrigated agricultural lands.

Δ AqStor = NetRivDivr + PrecipAg – TotalETAg – NetDrnRet – BaseFlo

where,

Δ AqStor = change in aquifer (groundwater) storage due to irrigation activities

NetRivDivr = net diversions from Boise, Payette and Snake Rivers (excluding re-diversions)

PrecipAg = precipitation on irrigated agricultural lands

TotalETAg = total agricultural lands ET (including farm, canal and Lake Lowell ET)

NetDrnRet = surface-water and groundwater components of net drain return to rivers

BaseFlo = base flow discharge (of groundwater) to the main channels of the Boise and Snake Rivers

The surface-water portion of the *irrigated agricultural lands* budget is made up of components that relate to availability and use of surface-water for irrigation in the

Boise Valley. **Equation 2-2** shows the relationship that exists between seven principal surface-water budget components on an average annual basis.

Equation 2-2. Relationship between seven principal surface-water budget components.

NetRivDivr + PrecipAg + LowGain – CanSeep – OnFrmInfl – SurfETAg – SurfDrnRet = 0

where

NetRivDivr = net diversions from Boise, Payette, and Snake Rivers (excluding re-diversions)

PrecipAg = precipitation on irrigated agricultural lands

LowGain = net groundwater gain by Lake Lowell

CanSeep = canal seepage losses

OnFrmInfl = on-farm infiltration on irrigated agricultural lands

SurfETAg = ET on surface-water irrigated agricultural lands, plus canal ET and Lake Lowell ET

SurfDrnRet = the surface-water component of net drain return to rivers

The groundwater portion of the *irrigated agricultural lands* budget is made up of components that relate to the availability and use of groundwater for irrigation. **Equation 2-3** shows the relationship between seven principal components of the groundwater budget on an average annual basis.

Equation 2-3. Relationship between seven principal groundwater budget components.

Δ AqStor = OnFrmInfl + CanSeep – LowGain – GwPmpAg – GwDrnRet – BaseFlo

where

Δ AqStor = change in aquifer (groundwater) storage due to irrigation activities

OnFrmInfl = on-farm infiltration on irrigated agricultural lands

CanSeep = canal seepage losses

LowGain = net groundwater gain by Lake Lowell

GwPmpAg = groundwater withdrawals on groundwater-irrigated agricultural lands

GwDrnRet = the groundwater component of net drain return to rivers

BaseFlo = base flow discharge (of groundwater) to the main channels of the Boise and Snake Rivers

The spatial distribution of individual budget components in Equations 2-1, 2-2, and 2-3 varies. Imbalances in groundwater and surface-water availability and use exist both spatially and temporally within the Boise Valley. Therefore, these equations are not applicable to individual drainage areas or individual irrigation districts. The equalities in these expressions are preserved only for irrigated lands in the Boise Valley as a whole.

Further, Equations 2-1 and 2-3 incorporate a change-in-aquifer-storage (Δ **AqStor**) budget term that is not appropriate for describing short-term (less than a year) differences in groundwater recharge and discharge. While this budget includes calculations of net monthly groundwater recharge and discharge, it does not distinguish between shallow and deep infiltration. Therefore, short-term (monthly) differences between groundwater recharge and discharge should not be interpreted as changes in aquifer storage.

In general, Equations 2-1, 2-2 and 2-3 describe relationships between budget components that are true only for irrigated lands in the Boise Valley as a whole and only on an average annual basis. In the following sub-sections, the budget components in these equations are defined in terms of other budget attributes. The budget expressions developed in these sub-sections are applicable to both average monthly and average annual budget data.

2.6.1. DIVERSION, FARM DELIVERY AND RE-DIVERTED DRAIN RETURN

Diversion records frequently include a measure of the total diversion that actually is drain return from other irrigation districts. Consequently, it is important to make a distinction between net river diversion and total diversion to an irrigation district. Net river diversion excludes re-diverted drain return. Total diversion includes re-diverted drain return. Without this distinction, water budget statistics based on total diversion would double and even triple count some surface-water diversions.

Equation 2-4 shows the relationship between net (or river) diversion, total diversion, and re-diverted drain return. Both net (river) diversion and total diversion in this expression include diversions to Lake Lowell storage. (Diversions from Lake Lowell storage are not considered re-diversions.)

Equation 2-4. Relationship between net river diversion, total diversion, and re-diverted drain return.

NetRivDivr = TotalDivr – TotalReDrnRet

where

NetRivDivr = net diversions from Boise, Payette and Snake Rivers (excluding re-diversions)

TotalDivr = total diversion from Boise, Snake, and Payette Rivers (including re-diversions)

TotalReDrnRet = total re-diverted drain returns

Total farm delivery is the component of total diversion that reaches the farm after subtracting off canal losses. Total farm delivery includes any re-diverted drain returns delivered to the farm. Like total diversion, total farm delivery will double-count some water that is delivered to farms.

Equation 2-5 shows the relationship between total farm delivery, net river diversion, re-diverted drain return, and canal loss. Since river diversion includes diversions that go to Lake Lowell storage, Lake Lowell gains and losses are also included in the calculation of farm delivery. This budget assumes that all re-diverted drain return is delivered to the farm without additional canal loss.

Equation 2-5. Relationship between total farm delivery, net river diversion, re-diverted drain return, and canal loss.
TotalFrmDel = NetRivDivr + TotalReDrnRet – CanLoss + LowGain where **TotalFrmDel** = total firm delivery to irrigated agricultural lands **NetRivDivr** = net diversions from Boise, Payette and Snake Rivers (excluding re-diversions) **TotalReDrnRet** = total re-diverted drain returns **CanLoss** = canal seepage plus canal ET **LowGain** = net groundwater gain by Lake Lowell

Net farm delivery is analogous to net diversion in that it excludes re-diverted drain returns. **Equation 2-6** shows the relationship between net farm delivery, total farm delivery, and re-diverted drain returns.

Equation 2-6. Relationship between net farm delivery, total farm delivery, and re-diverted drain return.
NetFrmDel = TotalFrmDel – TotalReDrnRet where **NetFrmDel** =net farm delivery to irrigated agricultural lands (excluding re-diversion) **TotalFrmDel** = total farm delivery to irrigated agricultural lands **TotalReDrnRet** = total re-diverted drain returns

The availability of diversion, farm delivery, and re-diversion data for the Boise Valley varies. For some irrigation districts, both farm delivery data and diversion data are available on a monthly basis; for others, only diversion data is available on a monthly basis.

Monthly diversion data is available for seven irrigation districts (Black Canyon, Pioneer, Riverside, Settlers, Farmers Co-op, Farmers Union, and Capital View). Monthly canal diversion records are also available for the small, private, upper Boise

River diverters and lower Boise River diverters. Annual reports from other private irrigation districts generally provide net diversion after accounting for canal losses. In some cases, both monthly and annual diversion and farm delivery data are reported; in other cases, some data are reported annually and some monthly.

Some diversion and farm delivery records acknowledge certain return-flow credits between irrigation districts or BPBOC divisions and others do not. For the five BPBOC divisions (of the Boise Project's Arrowrock Division), monthly records of farm delivery are available along with annual records of drain return credits to other divisions. For Riverside, Pioneer, and Black Canyon irrigation districts, records of total monthly diversion, total farm delivery, or both, are available, as is the component of annual diversion that is re-diverted drain return.

The distribution of farm delivery within irrigation districts varies, depending on whether lands are sprinkler or gravity irrigated. Within irrigation districts that have both sprinkler-irrigated and gravity-irrigated lands, most farm delivery goes to the gravity irrigated lands. In this budget, farm delivery to sprinkler-irrigated lands is assumed to be no more than 15 percent in excess of the net ET demand (that is, the difference between ET and precipitation). The estimate is based on a survey of average ET (1.8 acre-feet per acre) and average diversions (2.1 acre-feet per acre) on sprinkler irrigated lands in the Boise Project (Reclamation 2005b).

2.6.1.1. Re-diverted drain returns within and between drainage areas

The absence of a consistent set of monthly records of diversions, farm delivery, and re-diverted drain returns for all irrigation districts makes it necessary to calculate re-diversions based partly on irrigation district records (of actual re-diverted drain returns) and partly on records of drain returns from up-gradient drainage areas. As a result **TotalReDrnRet** in Equations 2-4, 2-5 and 2-6 has two components: drain returns that are produced in one irrigation district and re-diverted into another, generally within the same drainage area; and drain returns that are produced in one drainage area and re-diverted in another drainage area.

Equation 2-7 shows the total re-diverted drain return component of total farm delivery as the sum of these two components.

Equation 2-7. Total re-diverted drain return, irrigation district, and drainage area components of re-diverted drain return.
TotalReDrnRet = ReIrrRet + ReDrnRet where **TotalReDrnRet** = total re-diverted drain return (between and within drainage areas **ReIrrRet** = drain returns re-diverted within the same drainage area **ReDrnRet** = drain returns re-diverted in different drainage areas

For irrigation districts located within the same drainage area, **ReIrrRet** is most often calculated using actual records of re-diverted drain returns. For irrigation districts located in drainage areas that receive drain returns from irrigation districts in up-gradient drainage areas (including BPBOC divisions), the portion of total diversion and total farm delivery that is re-diverted drain return (**ReDrnRet**) is calculated by tracking drain returns from drainage area to drainage areas.

For instance, net and total diversions to Big Bend, Wilder, and Riverside irrigation districts (which are located in the Riverside Canal drainage area) are calculated by tracking drain returns produced by irrigation districts located in the Lake Lowell drainage area, which is up-gradient from the Riverside canal drainage area. In turn, net and total diversions to irrigation districts in the Lake Lowell drainage area (portions of Boise-Kuna I.D. and Nampa & Meridian I.D.) are calculated by tracking drain returns from the up-gradient Golden Gulch and Garland Drain drainage areas. The re-diverted drain returns from up-gradient drain areas are proportionally distributed among irrigation districts in down-gradient drainage areas based on the relative area of each irrigation districts within the down-gradient drainage area.

As indicated in Equations 2-5 and 2-6, irrigation season drain returns that are discharged to another drainage area become part of the latter's farm delivery. For instance, drain return from the (up-gradient) Lake Lowell drainage area is counted as part of the farm delivery to Wilder I.D. and Big Bend I.D. in the (down-gradient) Riverside Canal drainage area. Similarly, drain return from the Riverside Canal drainage area to the Riverside I.D. (located in the Snake River drainage area) is counted as farm-delivery to this latter district.

2.6.1.2. Re-diverted drain returns by small private Boise River diverters

Small, private Upper Boise River and Lower Boise River diverters also use a high percentage of re-diverted drain returns. For these irrigation districts, the calculation of re-diverted drain returns is based on the proportion of Boise River flows between Glenwood Bridge and Middleton that are return flows. About 35 percent of the flow in the Boise River at Middleton return flow from eight drainage areas (Eagle, North Slough, Phyllis, Fifteen Mile Creek, Mason Creek, South Middleton, Thurman, and Hartley Gulch). Therefore, total farm delivery by Upper Boise River diverters from seven canals (New Dry Creek, Ballentine, Middleton, Middleton Mill, Eureka #1, Little Pioneer, and Canyon County) is estimated to be about 35 percent re-diverted return flow and 65 percent net river diversion.

Farm delivery by Lower Boise River diverters also has a very high percentage of re-diverted return flow. In spite of diversions to the Siebenberg, Eureka #2, and Upper Center Point canals, the average flow at Parma is almost four times what it is at Middleton. This is due to return flows from the Dixie Slough, Indian Creek, and Conway Gulch drainage areas. It is reasonable to assume that the farm deliveries between Middleton and Parma are made up entirely of re-diverted return flow from other drainage areas, thus, net farm delivery by Lower Boise River diverters is zero.

2.6.2. EVAPOTRANSPIRATION (ET)

Estimates of crop ET in the Boise Valley are based on application of the Blaney-Criddle method (Blaney and Criddle 1950). The method was applied in the Boise Valley using historical crop and weather data and a program developed by the Soil Conservation Service (SCS 1970) and modified by Reclamation (Wensman 1997). With the Blaney-Criddle method, the main inputs used to calculate a reference crop ET are daylight hours, temperature, and humidity.

Monthly estimates of ET for the Boise Valley reference crop (alfalfa) were developed using historical temperature and humidity data. Individual crop coefficients were calculated for twenty other crops grown in the Boise Valley. Crop coefficients generated by the model were adjusted so that recent values matched the coefficients derived from Boise Valley Agrimet data (Reclamation 2005b). Only minimal adjustments to the Blaney-Criddle values were needed to achieve this.

Crop distribution records for Boise Project lands are available through 1992. For private irrigation districts, crop distribution data is available from USDA National Agricultural Statistical Service through 1997 (USDA 2005). To obtain a weighted average monthly crop ET for each irrigation district, crop coefficients were multiplied by estimated crop acreage and then divided by total irrigated acreage. Average monthly crop ET for groundwater irrigated lands and for Snake River irrigated lands was calculated in the same manner.

Bare-ground ET during winter months on agricultural lands is based on rangeland ET budget data (described in Subsection 3.1 “Dry lands budget components”). Lake Lowell ET is based on a separate reservoir budget calculation (described in Subsection 3.4 “Lake Lowell gains and losses”). Canal ET is assumed to be 0.2 percent of irrigation district diversion, based on Treasure Valley Hydrologic Project (TVHP) budget estimates (Urban 2004).

Equation 2-8 shows total irrigated agricultural lands ET as the sum of ET on surface-water irrigated and groundwater irrigated lands, canal ET, and Lake Lowell ET.

Equation 2-8. Total irrigated agricultural lands ET as the sum of the ET components.

TotalETAg = SurfIrrET + GwIrrET + CanET + LowET

where

TotalETAg = total agricultural lands ET

SurfIrrET = ET on surface-water irrigated agricultural lands (including surface-water supplied by irrigation districts to dual-use DCMI lands)

GwIrrET = ET on groundwater irrigated agricultural lands

CanET = canal ET

LowET = Lake Lowell ET

Surface-water irrigated lands ET includes ET on those DCMI lands within irrigation district boundaries that are supplied with irrigation water for outdoor use (so-called “dual-use lands”).

Irrigated lands in private groundwater irrigation districts are assumed to use groundwater only. Groundwater-irrigated lands located within surface-water irrigation districts are assumed to use groundwater for supplemental irrigation only. For these lands, it is assumed that during an average year one-half the agricultural lands ET is met using groundwater during three months of the irrigation season: at the beginning (April) and the end (September and October).

2.6.3. GROUNDWATER PUMPING AND SNAKE RIVER DIVERSIONS

Groundwater withdrawal by private groundwater-irrigation districts during the irrigation season is assumed to be the difference between ET and precipitation on these lands. Canal loss and drain return within private groundwater irrigation districts is assumed to be zero. Groundwater withdrawal during winter months is also zero. **Equation 2-9** represents this relationship.

Equation 2-9. Groundwater withdrawal by private groundwater irrigation districts equaling the difference between ET and precipitation.

$$\textbf{GwPmpAg} = \begin{cases} = \textbf{GwIrrET} - \textbf{GwPrecip}\ \textit{[during irrigation season]} \\ = \textbf{0}\ \textit{[during winter months]} \end{cases}$$

where

GwPumpAg = groundwater withdraws on groundwater-irrigated agricultural lands

GwIrrET = ET on groundwater-irrigated agricultural lands

GwPrecip = Precipitation on groundwater-irrigated agricultural lands

Supplemental groundwater withdrawal by surface-water irrigation districts is assumed to be one-half of the agricultural lands ET during April, September, and October.

Snake River diversions are based on calculations of **k** factors (kilowatt hours per acre-foot of water pumped) using records of power consumption and lifts for thirty-four pumps located along the Snake River below Murphy. Power records were obtained by the USGS for the years 1990-1995 and used to calculate total diversions (Maupin 1999). The average estimated diversion during these six years is used in the annual budget. Monthly diversions during the irrigation season on Snake River irrigated lands are assumed to be proportional to monthly ET.

2.6.4. RETURN FLOWS TO DRAINS

The depth to the regional water table in the Boise Valley ranges from several feet to hundreds of feet. However, even in areas where the regional water table is far below the surface, shallow clay lenses can create perched water table conditions during the irrigation season. Such lenses permit the lateral movement of groundwater to drains situated well above the regional water table (Keener 1920; Stevens 1962). For this reason (and as noted previously), the drain return calculations of this budget do not distinguish between groundwater that infiltrates only the shallow subsurface before discharge to a drain and groundwater that infiltrates to the regional water table before discharge to a drain. However, budget calculations do distinguish between the surface-water and groundwater components of drain return.

Regardless of whether they originate as surface-water or groundwater, all drain returns from a drainage area are discharged on the surface (either to a river or to another drainage area). The budget component that represents subsurface groundwater discharge to the Boise or Snake Rivers is described as base flow. (This budget component is described in Section 3.3, Base flow to Boise and Snake Rivers.)

2.6.4.1. Estimating drain return using regression analysis

As noted, not all drainage areas have measured return flows. In cases where drain flow data is unavailable, a regression model is used to estimate average monthly drain return. The regression equation is then used to estimate return flow in unmeasured drainage areas.

Fourteen (of the nineteen) drainage areas in the Boise Valley have irrigation season return-flow measurements associated with them. These fourteen areas contain about 57 percent of the total surface-irrigated land (about 171,000 acres). The measured drainage areas are Hartley (Willow Creek is its main drain), Conway Gulch, South and North Middleton, Lake Lowell, Garland, Jensen Wasteway, Golden Gulch Wasteway, Indian Creek, Dixie Slough, Mason Creek, Fifteen Mile Creek, Phyllis Waste, Eagle, and Thurman.

The five unmeasured drainage areas are Riverside Canal, Sand Hollow Creek, Snake River, Boise River, and North Slough. Surface-water irrigated lands in these areas comprise about 43 percent (about 130,500 acres) of the total surface-water irrigated land in the Boise Valley.

Equation 2-10 is the regression model used to calculate return flow in the unmeasured drainage areas. The three coefficients in this equation were generated by regressing average monthly return flow in measured drainage areas against average monthly farm delivery and average monthly ET on surface-water irrigated lands in measured drainage areas. Since nearly all drainage areas are comprised of more than one irrigation district, drainage area farm delivery and drainage area ET are the weighted averages of farm delivery and surface-water irrigated ET within each drainage area. All variables in Equation 2-10 have units of acre-feet per acre.

Equation 2-10. Regression model calculating return flow for unmeasured individual drain areas.
AreaDrnRet = 0.253 + 0.537 * AreaFrmDel – 0.639 * AreaIrrET where **AreaDrnRet** = drain return for individual drainage areas **AreaFrmDel** = farm delivery for individual drainage areas **AreaIrrET** = ET on surface-water irrigated agricultural lands for individual drainage areas

Equation 2-10 shows that return flow in measured drainage areas correlates positively with farm delivery and negatively with ET, which is expected. As farm delivery increases, both infiltration and drain return would be expected to increase. Reduced farm delivery would be expected to result in reduced infiltration and drain return. On the other hand, as ET increases both infiltration and drain return would be expected to decrease, and reduced ET could be expected to have the opposite effect.

The regression model can also be used to calculate drain returns during winter months. Equation 2-10 contains a constant (**0.253**) so the regression line is not forced through the origin. Forcing the regression line through the origin would be equivalent to forcing return flow to be zero when farm delivery and ET are zero. While return flows are diminished during winter months (when there is no farm delivery), there is ample evidence of year-around flows in many drainage areas due to groundwater discharge to drains. The non-zero intercept in this equation allows the regression model to approximate the average monthly groundwater contribution to return flow during winter months when there is no farm delivery and little ET on irrigated lands.

The $\mathbf{R^2}$ value for Equation 2-10, which indicates how well the regression line fits the measured drain return data, is **0.94**. This means that about 94 percent of the average monthly variability in return flow from measured drains can be explained by farm delivery and ET rates in the associated drainage areas. Although it is a measured drainage area, the Thurman drain area is not included in the regression model because of its very small size (385 acres).

2.6.4.2. Total drain return and net drain return to rivers

As noted previously, some drain returns are re-diverted before reaching either the Boise or the Snake River. **Equation 2-11** represents net drain return to rivers as being the difference between total return and the two components of re-diverted drain return.

Equation 2-11. Net drain return to rivers as the difference between total drain return and re-diverted drain returns.

NetDrnRet = TotalDrnRet – ReDrnRet – ReIrrRet

where

NetDrnRet = surface-water and groundwater components of net drain return to rivers

TotalDrnRet = total drain returns

ReIrrRet = drain returns re-diverted within the same drainage area

ReDrnRet = drain returns re-diverted in different drainage areas

Drain returns are re-diverted (and counted as part of total farm delivery) only during the irrigation season. During winter months, all returns generated within drainage areas are assumed to remain in the drains until they reach either the Boise River or the Snake River.

2.6.4.3. Surface-water and groundwater components of drain return

As noted, net drain return to rivers has surface-water and groundwater components. **Equation 2-12** represents net drain return to rivers as the sum of these two components.

Equation 2-12. Net drain return to rivers as the sum of surface-water and groundwater components.

NetDrnRet = SurfDrnRet + GwDrnRet

where

NetDrnRet = surface-water and groundwater components of net drain return to rivers

SurfDrnRet = the surface-water component of net drain return to rivers

GwDrnRet = the groundwater component of net drain return to rivers

Two assumptions underlie the calculation of surface-water and groundwater components of net drain return to rivers in this budget. First, all drain returns during winter months are assumed to be groundwater. Second, the groundwater component of drain return is assumed to increase over the course of the irrigation season (April-September) at the same rate that it is observed to decrease during winter months (October through March)

Drain returns in the Boise Valley decrease during winter months due to a slow decline in the water table, in the absence of irrigation. On average, February and March are the low points during the year in terms of drain return. The decline ends at the start of the irrigation season in April (or May, depending on the drain) with an abrupt increase in drain return (assumed to be mostly surface return). The groundwater component of drain return also increases during the irrigation season in response to a rising water table.

Therefore, at the start of the irrigation season (April), the groundwater component of drain return is assumed to be the same as the total drain return in March. In other words, the increase in total drain return that occurs in April is assumed to be entirely surface-water return. Since the decreasing trend in groundwater return during winter months is assumed to match the increasing trend during the irrigation season, the groundwater component of drain return in May, is the same as the total drain return in February. In June, it is the same as the total return in January, and so forth through the remainder of the irrigation season.

The surface-water component of drain return is calculated by subtracting the groundwater component from the total (irrigation season) return. Finally, the winter months in which drain returns are assumed to be entirely groundwater varies, depending on when an abrupt increase in drain return is observed at the start of the irrigation season. For some drainage areas, the season is October through March and for others it is November through April.

2.6.4.4. Drain returns during winter months

As noted, drain returns during winter months (October through March) are assumed to be entirely groundwater. Estimates of drain returns during winter months are based mostly on winter-time measurements of drain discharge from six drainage areas to the Boise River made during 1996 and 1997. These are the Eagle, Thurman, Hartley Gulch, Willow Creek, Mason Creek, and Indian Creek drainage areas (CH2M 1998).

For the eight drainage areas where winter drain-return data are not available, returns are assumed to match those of the measured drains in terms of winter-time and irrigation-season percentages. That is, winter-time drain returns are assumed to be 55 percent of irrigation season drain returns, and the monthly distribution of winter-time returns is proportional to the monthly distribution of returns in the six measured drains. For the five drainage areas where the regression model is used to calculate drain return, the regression constant supplies an estimate of winter-time return.

Since no farm deliveries occur during winter months, no re-diversions of drain return occur. Winter-time returns in all drainage areas are assumed to discharge directly to rivers.

2.6.5. ON-FARM INFILTRATION

On-farm infiltration occurs on surface-water irrigated farm lands in cases where farm delivery and precipitation exceed ET and the surface-water component of drain returns. On-farm infiltration on primary groundwater irrigated lands is assumed to be zero. **Equation 2-13** shows on-farm infiltration as the combination of these four previously defined budget components. The groundwater component of drain return is not subtracted from on-farm infiltration in this expression because on-farm infiltration includes all infiltration, whether or not it is discharged to drains later in the year. Note also that total farm delivery in this expression includes all re-diverted drain returns both within and between drainage areas (see Equation 2-6).

Equation 2-13. On-farm infiltration on surface-water irrigated lands.

OnFrmInfl = TotalFrmDel + PrecipAg – SurfIrrET – SurfDrnRet
where
TotalFrmDel = total farm delivery to irrigated agricultural lands
PrecipAg = precipitation on irrigated agricultural lands
SurfIrrET = ET on surface-water irrigated agricultural lands
SurfDrnRet = the surface-water component of net drain return to rivers

On-farm infiltration is typically a positive number, indicating that some of the water being applied to surface-water irrigated farm lands is infiltrating the subsurface and reaching the watertable surface. However, on-farm infiltration may be negative under certain circumstances. Negative on-farm infiltration occurs if the combination of ET on surface-water irrigated lands and the surface-water component of drain return exceed total farm delivery and precipitation.

Recall that the surface-water component of drain return in this budget consists of water that is applied to farm lands and subsequently discharged to drains within the same year. This includes water that infiltrates the shallow subsurface (whether or not it reaches the water table). Negative on-farm infiltration generally occurs in drain areas where the water table is close to the surface, and which receive additional surface and/or subsurface return flow from other drain areas. Negative on farm infiltration in an area can be considered as part of the groundwater component of drain return. It is an indication that the water table is already so high that no additional aquifer storage is possible.

WATER BUDGET EXPRESSIONS USED IN MODELING

It is often useful in the application of numerical groundwater models such as *Modflow* (McDonald and Harbaugh 1988) to have a single parameter which represents the spatial distribution of all (or almost all) groundwater recharge and discharge budget components. Net groundwater recharge-discharge is useful in this regard because it combines the influence of all of the budget components that are likely to be represented in a model by flow-dependent boundary conditions.

Other hydrologic features such as rivers are more likely to be represented in a model by head-dependent boundary conditions. For these boundary conditions, another budget component which describes base flow to rivers is useful for model calibration. The change in aquifer storage component is also a useful model calibration parameter.

2.6.5.1. Net groundwater recharge-discharge

The net groundwater recharge-discharge budget component is useful in models which aggregate the influence of irrigated lands budget components as flow-dependent boundary conditions. Therefore, net groundwater recharge-discharge is defined in **Equation 2-14** to include all of the groundwater recharge and discharge budget components calculated in the *irrigated agricultural lands* budget. (Net groundwater recharge-discharge also includes Lake Lowell gains and losses; these are calculated in the *dry lands and water-bodies* budget.)

Equation 2-14. Net groundwater recharge-discharge on irrigated agricultural lands.

NetRec/DisAg = OnFrmInfl + CanSeep – GwPmpAg – GwDrnRet

where

NetRec/DisAg = Net groundwater recharge-discharge on irrigated agricultural lands

OnFrmInfl = on-farm infiltration on irrigated agricultural lands

CanSeep = canal seepage losses

GwPmpAg = groundwater withdrawals on groundwater-irrigated agricultural lands

GwDrnRet = the groundwater component of net drain return to rivers

Net groundwater recharge occurs (that is, has positive value) on irrigated agricultural land when on-farm infiltration and canal seepage exceed groundwater pumping and the groundwater component of drain return. Net groundwater discharge occurs (that is, has negative values) when groundwater pumping and the groundwater component of drain returns exceed on-farm infiltration and canal seepage.

On a month-by-month basis, net groundwater recharge-discharge in the Boise Valley could be expected to switch back and forth between positive and negative values. During the irrigation season on surface-water irrigated lands, net groundwater recharge-discharge is dominated by the (positive) influence of on-farm infiltration and canal seepage. On these same lands during winter months, it is dominated by the (negative) influence of groundwater return to drains. For groundwater-irrigated lands, the opposite occurs. Net groundwater recharge-discharge is dominated by the (negative) influence of groundwater pumping during the irrigation season. During winter months, it is dominated by the small (positive) influence of precipitation, which is included in on-farm infiltration.

It is not expected that net groundwater recharge would be balanced by net groundwater discharge for individual drainage areas, for individual irrigation districts, or for the Boise Valley as a whole. While the surface-water component of drain return is naturally constrained by drainage area boundaries, drainage areas are not isolated from one another in the subsurface. On-farm infiltration that occurs in an up-gradient drainage area may eventually become part of the groundwater component of drain return in a down-gradient drainage area.

In addition, monthly rates of net groundwater recharge and discharge will tend to overstate actual aquifer recharge and discharge rates. This occurs because not all groundwater recharge reaches the water table before being discharged to drains. Over longer time intervals, these monthly variations in net groundwater recharge and discharge will tend to average out and, on an annual basis, net groundwater recharge-discharge will more closely approximate the actual aquifer recharge-discharge rate.

On an annual basis and for the Boise Valley as a whole, net groundwater recharge and discharge is assumed to be balanced by base flow to rivers and change in aquifer storage. The distribution of groundwater flow between surface-water sources and sinks in the Boise Valley is not directly accounted for in this budget since it would require a groundwater model to calculate it.

2.6.5.2. Base flow to rivers and change in aquifer storage

Base flow to the Boise and Snake Rivers is calculated separately from net groundwater recharge-discharge and is described in Section 3.3. However, net groundwater recharge-discharge and base flow to rivers are both used to calculate change in aquifer storage, which is useful in calibration of steady-state and transient hydrologic models.

As represented in **Equation 2-15**, average annual change in aquifer storage due to irrigation is the difference between net groundwater recharge-discharge on irrigated agricultural lands and base flow to rivers. As noted, change in aquifer storage is a budget parameter that is meaningful only for the Boise Valley as a whole, and only on an annual basis.

Equation 2-15. The change in aquifer storage attributed to irrigation activity as the difference between net groundwater recharge-discharge and base flow to rivers.

Δ AqStor = NetRec/DisAg – BaseFlo

where

Δ AqStor = change in aquifer (groundwater) storage due to irrigation activities

NetRec/DisAg = Net groundwater recharge-discharge on irrigated agricultural lands

BaseFlo = base flow discharge (of groundwater) to the main channels of the Boise and Snake Rivers

2.7. SUMMARY OF IRRIGATED AGRICULTURAL LANDS BUDGET

This section summarizes the major components of the Boise Valley *irrigated agricultural lands* budget. The summaries are presented in the form of bar charts showing average annual and average monthly distributions of diversions, farm delivery, precipitation, ET, groundwater pumping, on-farm infiltration, drain returns, and change in aquifer storage due to irrigation activities. The *irrigated agricultural lands* budget summary describes net values of diversions, farm delivery, and drain return budget components for the Boise Valley as a whole.

2.7.1. ANNUAL BUDGET SUMMARY

The major components of the annual Boise Valley *irrigated agricultural lands* water budget expressed previously in Equation 2-1 are presented in a bar chart form in **Figure 2-6**. Positive numbers on this chart denote the addition of irrigation water to the Boise Valley; negative numbers denote the subtraction of water.

The bar chart shows that total river diversions to the Boise Valley (**RivDivr**) average about 1,786 thousand acre-feet (kaf) per year. On average, about 1,612 kaf is diverted from the Boise River, 79 kaf is diverted from the Payette River, and 95 kaf is diverted from the Snake River. The average annual precipitation on irrigated lands in the Boise Valley (**PrecipAg**) is about 319 kaf per year. Total ET (**TotalETAg**)

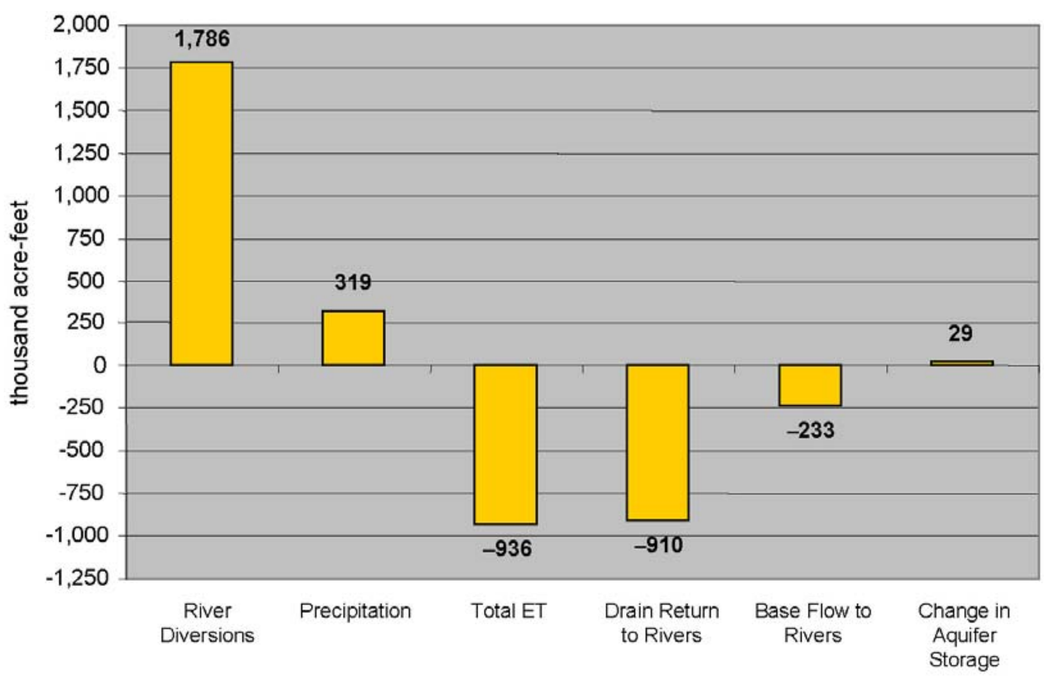

Figure 2–6. Average annual water budget for irrigated agricultural lands.

averages about 936 kaf per year, and includes evapotranspiration on surface-water and groundwater irrigated lands, canal ET (**CanET**), Lake Lowell ET (**LowET**), and ET on dual-use DCMI lands supplied by irrigation districts.

Total drain return to the Boise and Snake Rivers (**TotalDrnRet**) is about 910 kaf per year. Base flow to the main channels of the Boise and Snake Rivers (**BaseFlo**) is about 233 kaf per year. On average, as a result of all irrigation activities, aquifer storage in the Boise Valley (**Δ AqStor**) is increased by about 29 kaf each year.

On average, about 44 percent of combined annual river diversion and precipitation in the Boise Valley is consumptively used on irrigated lands. Another 43 percent is discharged to drains, either on the surface or in the subsurface and eventually discharged (on the surface) to rivers. Of the remaining supply, about 11 percent is discharged (in the subsurface) as base flow to rivers. Less than 2 percent goes into aquifer storage.

2.7.1.1. Annual surface-water budget summary

The major surface-water components of the Boise Valley *irrigated agricultural lands* budget, expressed in Equation 2-2, are presented in bar-chart form in **Figure 2-7**. Positive numbers denote additions to surface-water of the Boise Valley; negative numbers denote subtractions of surface-water.

Diversions from the Payette, Boise, and Snake River (**RivDivr**) average 1,786 kaf acre-feet per year, and precipitation on irrigated lands (**PrecipAg**) averages

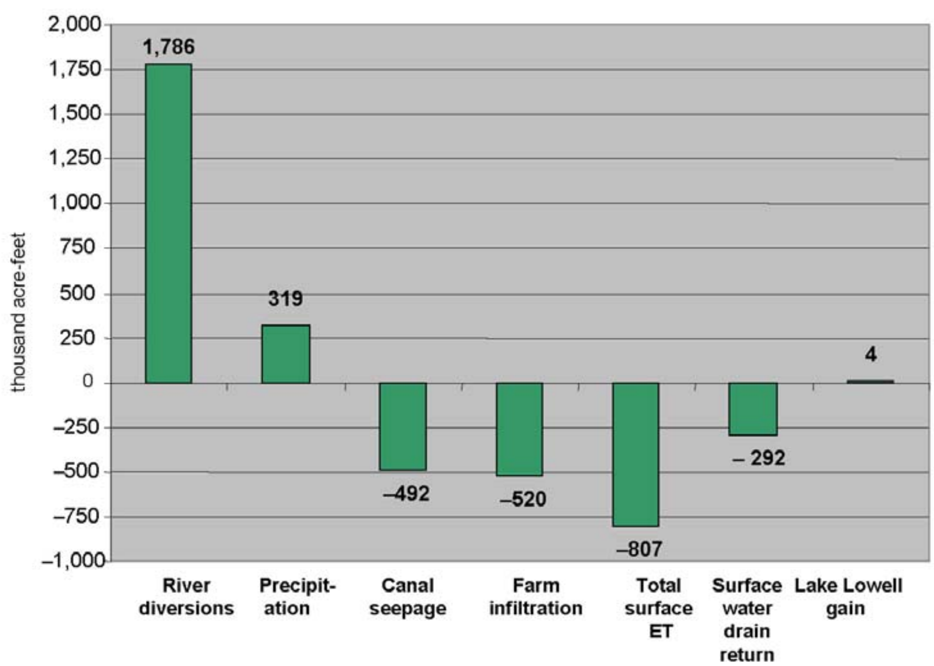

Figure 2–7. Average annual surface-water budget for irrigated agricultural lands.

319 kaf per year. These surface supplies are offset by canal seepage (**CanSeep**) which averages about 492 kaf per year; ET on surface-water irrigated lands, canals, and Lake Lowell (**SurfETAg**), which averages 807 kaf per year; on-farm infiltration (**OnFrmInfl**), which averages 520 kaf per year; and surface-water drain returns to the Boise and Snake Rivers (**SurfDrnRet**), which averages 292 kaf per year. On an annual basis, the net difference between surface-water additions and subtractions is just under 4 kaf per year, which in this budget equation is attributed to a net annual gain or loss from Lake Lowell (**LowGain**).

In an average year, about 38 percent of the total surface-water supply is consumptively used on surface-water irrigated lands (counting canal ET and Lake Lowell ET). About 14 percent of the supply returns to drains as surface runoff, 25 percent infiltrates on-farm fields, and 23 percent seeps from canals.

2.7.1.2. Annual groundwater budget summary

The major groundwater components of the Boise Valley *irrigated agricultural lands* budget, expressed in Equation 2-3, are presented in bar-chart form in **Figure 2-8**. Positive numbers denote groundwater recharge components and negative numbers denote groundwater discharge components. Groundwater recharge on irrigated agricultural lands occurs in the form of on-farm infiltration and canal seepage. Groundwater discharge occurs via groundwater returns to drains, groundwater pumping, Lake Lowell gain, and base flow to rivers.

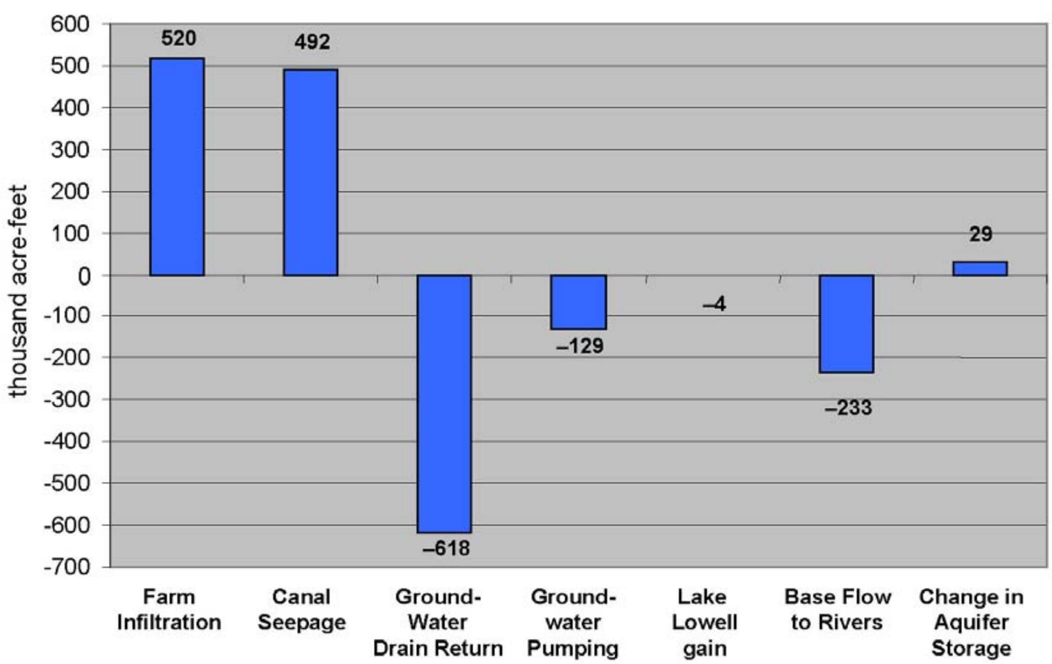

Figure 2–8. Average annual groundwater budget for irrigated agricultural lands.

On an annual basis, on-farm infiltration in the Boise Valley (**OnFrmInfl**) averages about 520 kaf per year. Canal seepage (**CanSeep**) averages about 492 kaf per year. Groundwater drain returns to the Boise and Snake Rivers (**GwDrnRet**) averages about 618 kaf per year. Groundwater pumping to meet ET demand on groundwater irrigated land (**GwPmpAg**) averages about 129 kaf annually, and groundwater gain to Lake Lowell (**LowGain**) is about 4 kaf per year. Base flow to the main channel of the Boise River and to the Snake River (**BaseFlo**) averages 233 kaf per year. On average, about 29 kaf of water goes into aquifer storage (**Δ AqStor**) each year.

Annually, about 51 percent of the total irrigated agricultural land infiltration in the Boise Valley occurs on farms. The other 49 percent occurs as seepage from canals and laterals. About 61 percent of the infiltrated water is discharged to drains and ultimately reaches either the Boise or Snake Rivers within a year. About 13 percent is pumped from the aquifer and consumptively used on groundwater-irrigated lands. About 23 percent is discharged directly to rivers as base flow. Roughly 3 percent of total infiltration and canal seepage goes into aquifer storage on an average annual basis.

Figure 2-9 shows the annual totals for budget components represented in Equation 2-15. This includes net groundwater recharge-discharge on irrigated agricultural lands (**NetRec/DisAg),** base flow to rivers (**BaseFlo**), and change in aquifer storage (**Δ AqStor**) due to irrigation. Net groundwater recharge, which averages about 256 kaf per year, is balanced by base flow discharge to rivers of about 233 kaf per year, and by an increase in aquifer storage of about 29 kaf per year.

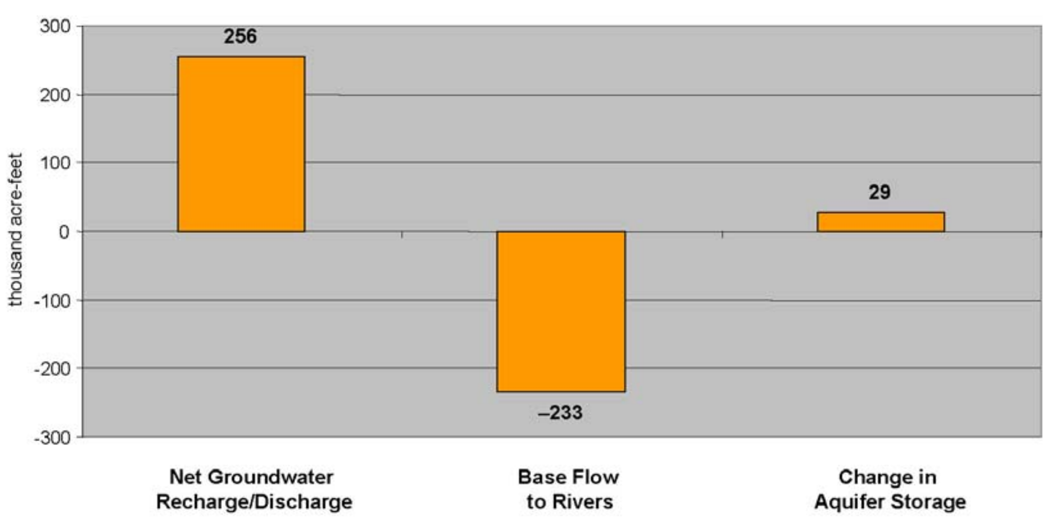

Figure 2–9. Average annual net groundwater recharge-discharge.

2.7.2. MONTHLY BUDGET SUMMARIES

Irrigated agricultural lands budget components vary in magnitude from month to month during an average year. The monthly averages presented on bar charts in the following subsections are ordered from November through October, which corresponds to the irrigation district water year.

2.7.2.1. Diversion and farm delivery

Figure 2-10 shows the average monthly distribution of three related budget components: net river diversion (**NetRivDivr**), net farm delivery (**NetFrmDel**), and canal loss (**CanLoss**). Major river diversions to agricultural lands in the Boise Valley are made only during the irrigation season (April- October). Small river diversions made during winter months are to fill Lake Lowell. On average, net river diversions range from 70 to 367 kaf per month during the irrigation season, increasing steadily during the first three months of the season and decreasing at about the same rate during the last three months. Net farm delivery ranges from 33 to 300 kaf per month and follows a similar trend. Canal loss, which accounts for the difference between net diversion and net farm delivery, ranges between 21 kaf and 99 kaf per month during the irrigation season.

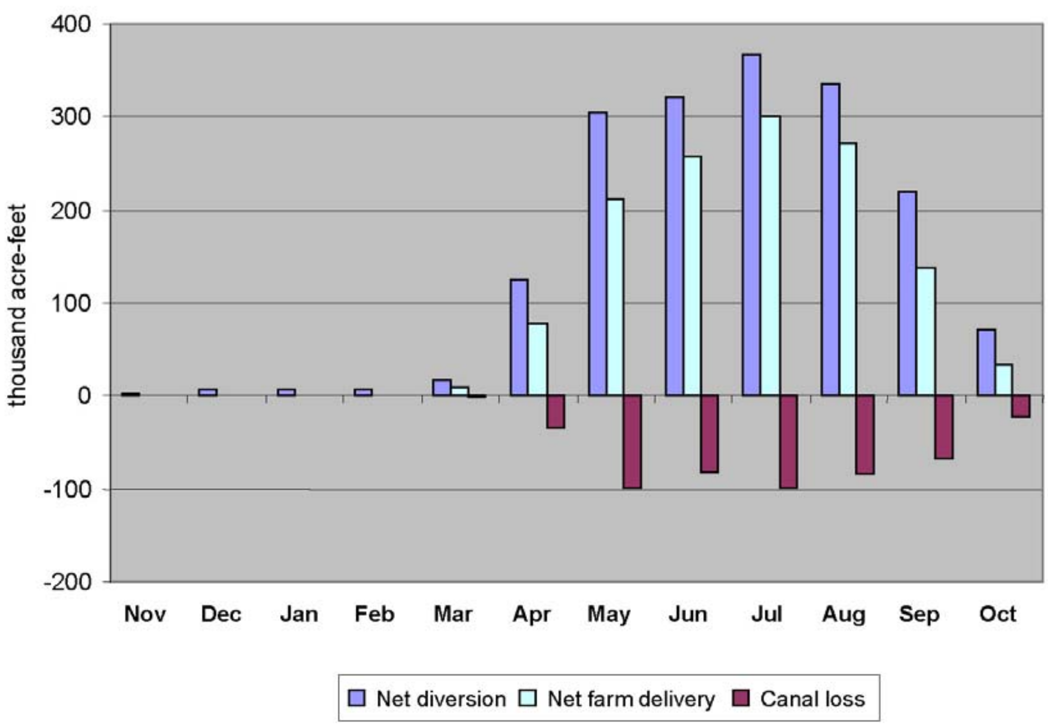

Figure 2–10. Average monthly diversion, farm delivery, and canal loss.

Figure 2-11 presents the average monthly distribution of the two components that make up total farm delivery (**TotalFrmDel**), farm delivery from river diversions (**NetFrmDel**), and farm delivery from re-diverted drain returns (**TotalReDrnRet**).

Over the course of the irrigation season (April-October), total farm delivery ranges from 55 to 365 kaf per month. Farm delivery from river diversions (net farm delivery) ranges from 33 kaf to 300 kaf. Farm delivery from re-diverted drain returns, which ranges from 21 to 65 kaf per month, is a relatively small part of total farm delivery except at the very beginning and end of the season. As a monthly percentage, re-diverted drain return accounts for between 18 percent of total farm delivery in July and 39 percent in October. Over the course of an average year, total farm delivery averages about 1,650 kaf; of this, about 79 percent (1,300 kaf) comes from river diversions directly and 21 percent (about355 kaf) comes from re-diverted drain returns.

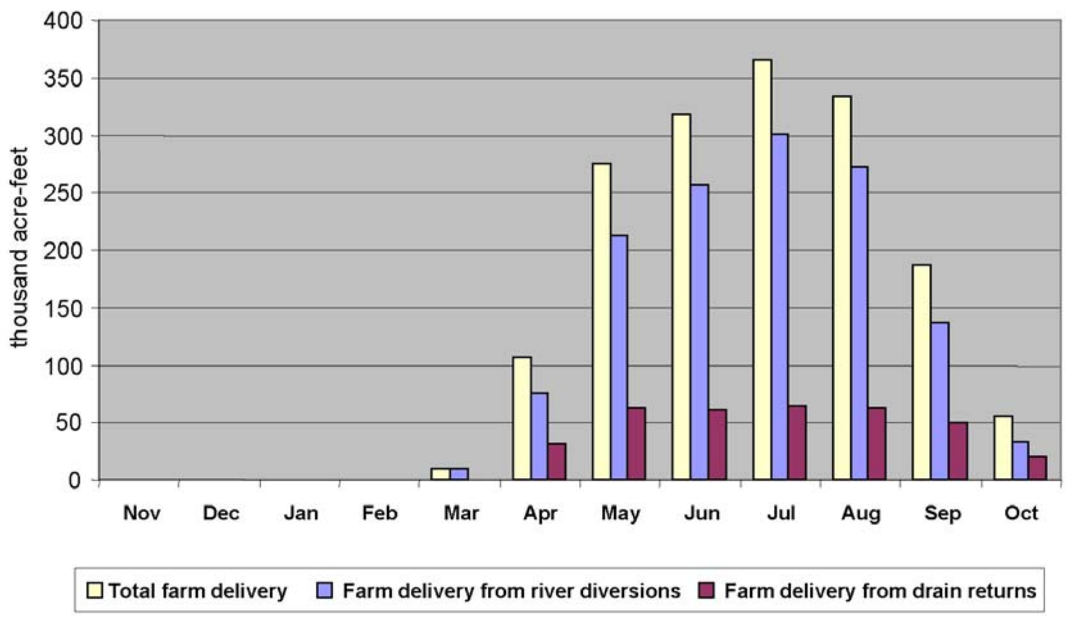

Figure 2–11. Average monthly farm delivery from river diversions and drain returns.

2.7.2.2. Precipitation

Figure 2-12 shows the monthly distribution of precipitation on agricultural lands (**PrecipAg**). On average, precipitation supplies about 416 kaf of water to the Boise Valley each year. Of this amount, about 330 kaf is distributed on irrigated agricultural lands. On average, the three wettest months of the year are November, December, and January; these are followed by February, March, April, and May. The three driest months of the year are July, August, and September. About 38 percent of annual precipitation occurs during the irrigation season, and 62 percent occurs during winter months.

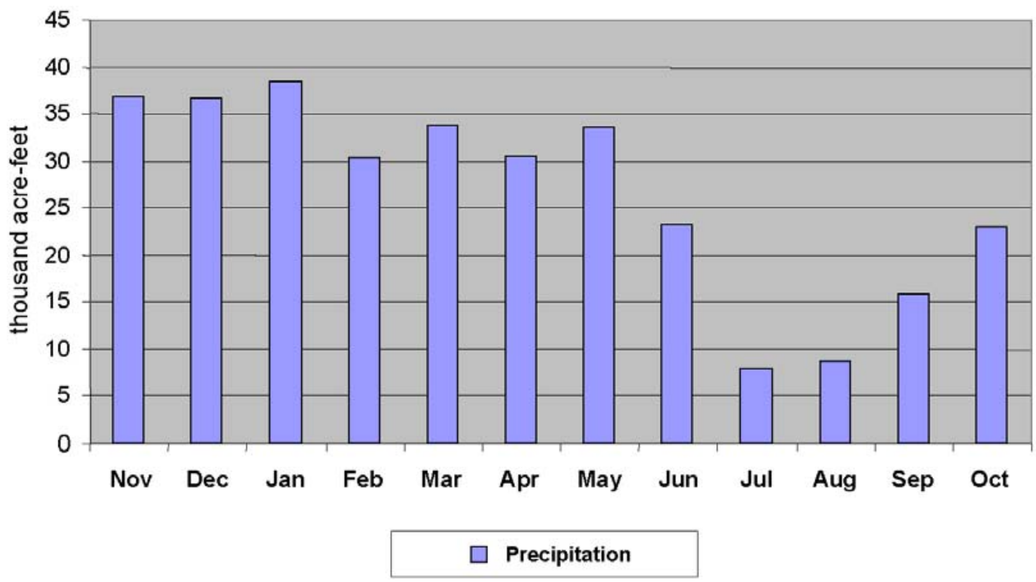

Figure 2–12. Average monthly precipitation on irrigated agricultural lands.

2.7.2.3. Evapotranspiration

Figure 2-13 shows the average monthly distribution of total ET (**TotalETAg**) on irrigated agricultural lands and its three main components: surface-water irrigated lands ET (**SurfIrrET**); groundwater irrigated lands ET (**GwIrrET**); and the combined Canal ET + Lake Lowell ET (**CanET + LowET**).

Like river diversions, irrigated agricultural lands ET increases steadily during the first three months of the irrigation season and decreases during the last three months. Total ET peaks in July at about 228 kaf. Of the total, about 194 kaf is ET on surface-water irrigated lands (including dual use DCMI lands within irrigation district boundaries) and 32 kaf is ET on groundwater irrigated lands. Combined Canal ET + Lake Lowell ET is less then 2 acre-feet per month during the irrigation season. Over the course of a year, about 83 percent of total agricultural lands ET occurs on surface-water irrigated lands, 17 percent occurs on groundwater irrigated lands, and less than 1 percent is from canals and Lake Lowell. Bare (agricultural) ground ET during winter months ranges from 5 to 9 kaf per month. Not surprisingly, 97 percent of irrigated agricultural lands ET in the Boise Valley occurs during the seven-month irrigation season.

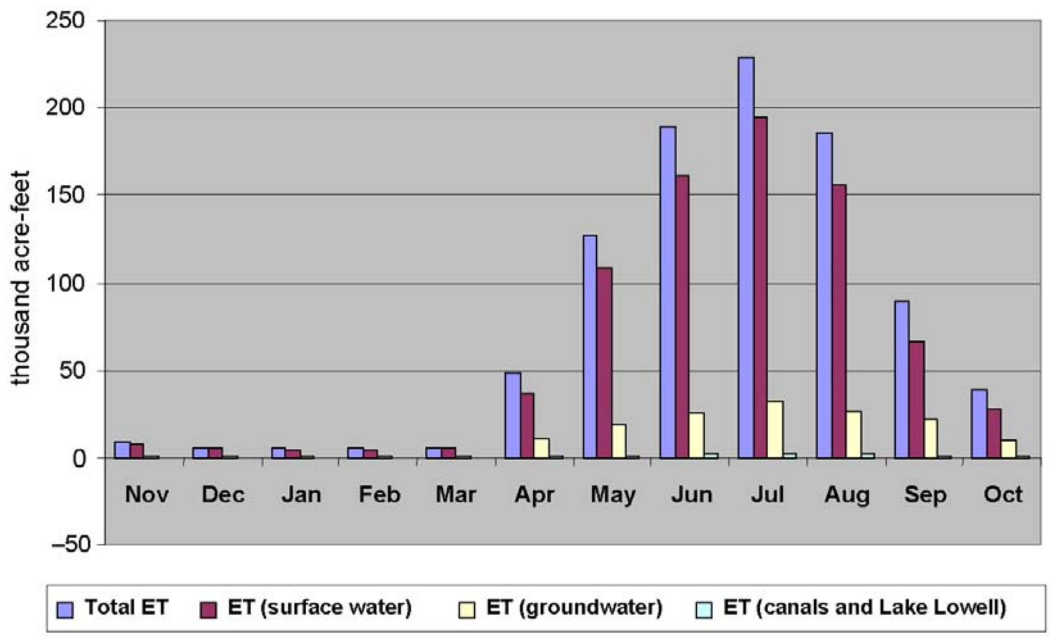

Figure 2–13. Average monthly ET on surface-water and groundwater irrigated lands.

2.7.2.4. Drain return components (net to river and re-diverted)

As noted previously, individual drains may or may not discharge directly to either the Boise River or to the Snake River. Return flows from some drainage areas may be intercepted and re-diverted to irrigate agricultural lands in other drainage areas before reaching a river.

Figure 2-14 shows the monthly distribution of total drain return (**TotalDrnRet**) and its two components, net return to rivers (**NetDrnRet**) and the combined re-diverted returns between irrigation districts plus and re-diverted returns between drainage areas (**ReDrnRet** + **ReIrrRet**). Total drain return increases abruptly at the beginning of the irrigation season and decreases abruptly at the end of the season. During the seven-month irrigation season (April- October), total return ranges from 78 to 173 kaf per month. During the five winter months, it ranges from 49 to 61 kaf per month. About 78 percent of total annual drain return occurs during the irrigation season.

Since no drain returns are re-diverted during winter months, all returns at this time of year are discharged directly to a river. During the irrigation season, between 31 and 65 kaf per month of drain return is re-diverted before reaching a river. Of the total irrigation season return, about 36 percent is re-diverted before reaching a river.

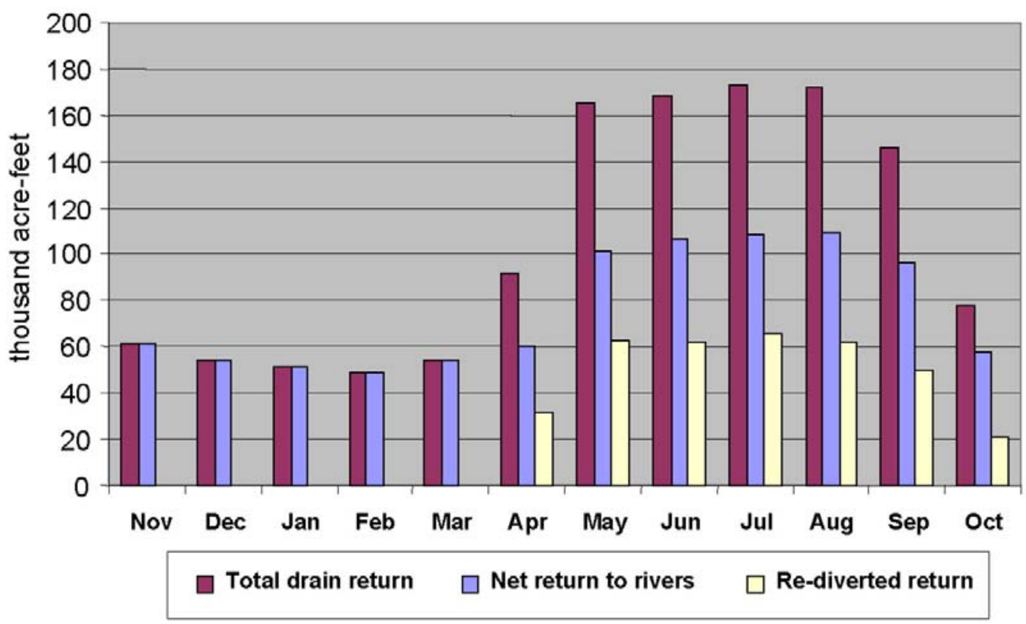

Figure 2–14. Average monthly drain return, net return to rivers, and re-diverted return.

2.7.2.5. Drain return components (surface water and groundwater)

As described previously, all drain return during winter months (either October-March or November-April, depending on the drainage area) is assumed to be groundwater return. The increase in drain return that occurs at the beginning of the irrigation season (April or May) is assumed to be due entirely to an increase in the surface-water component of drain return. During the next five months of the irrigation season, the groundwater component of drain return is assumed to increase at the same rate that it decreased during winter months.

Figure 2-15 shows the average monthly distribution of net drain return to both the Boise and Snake Rivers (**TotalDrnRet**), along with the surface-water (**SurfDrnRet**) and groundwater (**GwDrnRet**) components of drain return. As described, the surface-water component of drain return is zero during winter months. All winter time drain return is groundwater. Groundwater return peaks at about 61 kaf in November, just after the end of the irrigation season, and then gradually declines during the winter months.

The small surface-water return in April, the beginning of the irrigation season, is the difference between the total April return and the total March return. Surface-water return increases in May to 51 kaf and peaks in July at 62 kaf. At the same time groundwater return gradually declines to about 46 kaf in July, the low point of the

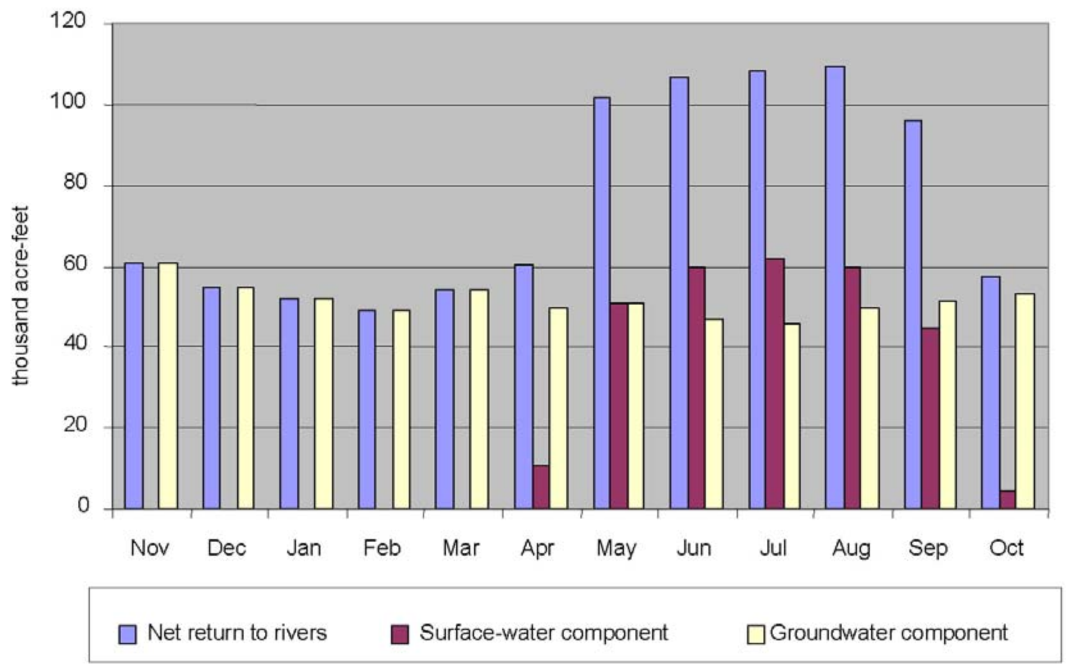

Figure 2–15. Average monthly surface-water and groundwater components of drain return.

year. Groundwater return begins to increase in August just as surface-water return begins to decline. By October surface-water return has dropped to less than 5 kaf.

Groundwater return lags behind surface-water return at the start of the irrigation season by about three months. The lag is a consequence of the method used to split surface-water and groundwater drain returns; hydrologically, it can be attributed to the extra time required for groundwater returns to reach the drains.

In terms of annual percentages, net drain return to rivers is about 68 percent groundwater return and 32 percent surface-water return. About 70 percent of net drain return occurs during the irrigation season (April-October) and 30 percent occurs during the five winter months.

2.7.2.6. Drain return components (Boise River and Snake River)

Figure 2-16 shows the monthly distribution of net drain return to rivers (**NetDrnRet**) and the split between Boise River and Snake River components. Average monthly returns to the Boise River range from 34 kaf to 67 kaf, and average returns to the Snake River range from 15 kaf to 43 kaf. For both rivers, drain returns are lowest during winter months and highest during the irrigation season.

Annually, about 67 percent of total drain return to rivers (607 kaf) is to the Boise River and 33 percent of the total (303 kaf) is to the Snake River. The distribution matches roughly the proportional distribution of acreage draining to each river. (Most of the returns from Farmers Coop Ditch I.D. and Black Canyon I.D. are discharged to the Snake River via the Sand Hollow Creek and drain network.)

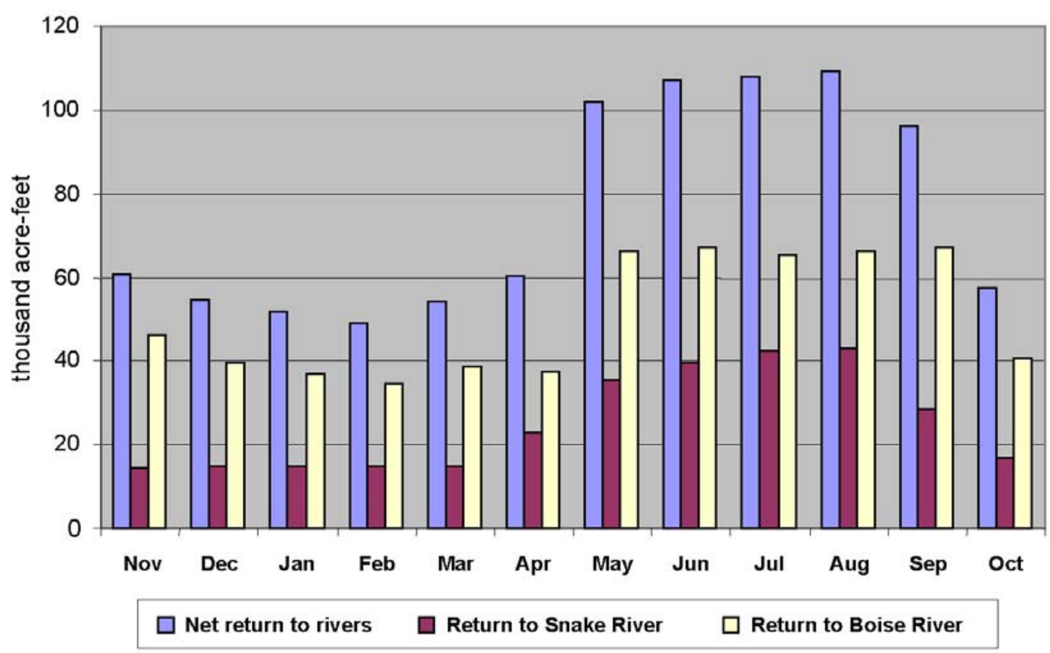

Figure 2–16. Average monthly drain return to Boise River and Snake River.

2.7.2.7. On-farm infiltration

Figure 2-17 shows the average monthly distribution of on-farm infiltration. During the irrigation season, on-farm infiltration (**OnFrmInfl**) occurs whenever farm delivery and precipitation exceed crop ET and surface-water return to drains. During winter months on-farm infiltration occurs whenever precipitation exceeds bare ground ET.

On-farm infiltration during the irrigation season ranges between 41 kaf and 79 kaf per month. Bare ground infiltration during winter months ranges between 24 kaf and 34 kaf month. On-farm infiltration peaks twice during the irrigation season, once in May and again in August. Both peaks are produced by relatively high farm deliveries combined with relatively low ET rates at these times of the year. The somewhat lower on-farm infiltration rates in June and July can be traced to the opposite set of conditions, relatively low farm deliveries compared to ET rates.

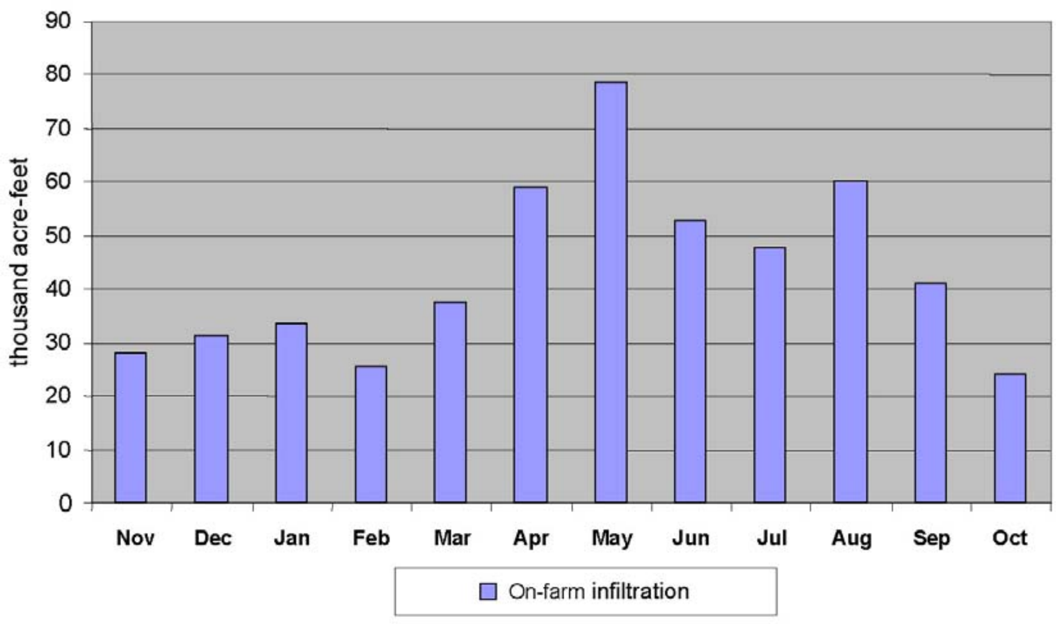

Figure 2–17. Average monthly on-farm infiltration.

2.7.2.8. Net Groundwater Recharge-Discharge

Net groundwater recharge-discharge (**NetRec/DisAg**) on irrigated agricultural lands incorporates canal seepage (**CanSeep**), the groundwater component of drain return (**GwDrnRet**), on-farm infiltration (**OnFrmInfl**), and groundwater pumping (**GwPumpAg**). (Refer to Equations 2-13 and 2-14.)

Figure 2-18 shows the average monthly distribution of net groundwater recharge-discharge on irrigated agricultural lands (**NetRec/DisAg**). Net groundwater recharge-discharge is positive (net recharge) during the irrigation season, and negative (net discharge) during winter months.

Net groundwater recharge peaks in May at 120 kaf; this is due to a combination of high on-farm infiltration and canal seepage combined with limited groundwater pumping and relatively low groundwater return to drains at this time of year. Net recharge drops by almost half in June but remains above 60 kaf per month through August. Net recharge drops again in September by half.

Net groundwater discharge occurs throughout the six winter months (October through March) due to the absence of on-farm infiltration and canal seepage, and a relatively high rate of groundwater return to drains at this time of year. Net groundwater discharge is highest in November (33 kaf) and then gradually diminishes as groundwater return to drains declines over the winter.

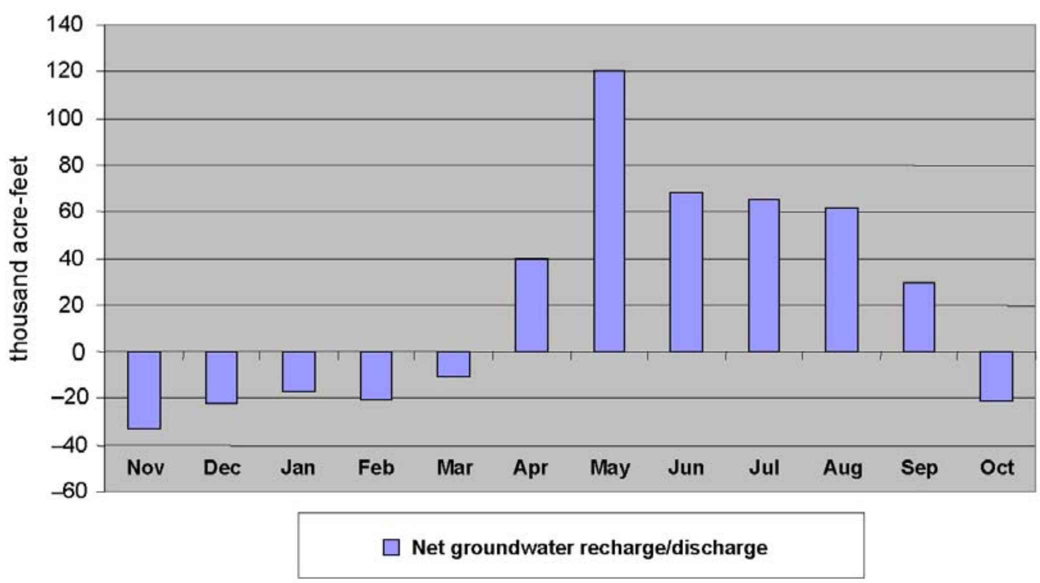

Figure 2–18. Average monthly net groundwater recharge-discharge on irrigated agricultural land.

2.7.3. SPATIAL DISTRIBUTION OF IRRIGATED AGRICULTURAL LANDS BUDGET COMPONENTS

The spatial distribution of budget components in the *irrigated agricultural lands* budget category is presented in the *irrigated agricultural lands* GIS layer. The spatial distribution of budget components depends on the location of agricultural land-use polygons with respect to five geographic properties described as features types (Figures 2-1 through 2-5). **Table 2-1** summarizes the dependencies of each *irrigated agricultural lands* budget component on geographic feature types in the *irrigated agricultural lands* GIS layer. The numbers in the column headings indicate the number of feature objects associated with each feature type (that is, the number of irrigation districts, BPBOC divisions, drainage areas, precipitation zones, and gravity/sprinkler classes).

Table 2-1. Spatial dependencies of *irrigated agricultural lands* budget components.

	Feature types (feature objects); *Source*				
Budget component	**BPBOC division** (5) *Fig. 2-1*	**Irrigation district** *(17)* *Fig. 2-2*	**Drainage area** (20) *Fig. 2-3*	**Precip. zone** (8) *Fig. 2-4*	**Gravity or sprinkler class** (2); *Fig. 2-5*
River diversion	x	x			
Farm delivery	x	x	x		
Canal seepage	x	x			
ET		x			
Groundwater pumping		x		x	
Net drain return[1/]			x		x
Re-diverted drain return	x	x	x		
Precipitation				x	
On-farm infiltration	x	x	x	x	x
Net groundwater recharge-discharge	x	x	x	x	x

1/ Including surface-water and groundwater components of net drain return to rivers

Most *irrigated agricultural lands* budget components are dependent on two or more feature types. Precipitation and ET are the only budget components dependent on a single feature type. On-farm infiltration and net groundwater recharge-discharge depend on all five feature types.

In addition to the ten primary budget components listed in Table 2-1, a further breakdown of ET and re-diverted drain return components produces six additional spatially distributed budget components that are included in the *irrigated agricultural lands* GIS layer:

- ET on surface-water irrigated lands
- farm delivery excluding re-diverted drain returns
- farm delivery from re-diverted drain returns within drainage areas
- farm delivery from re-diverted drain returns between drainage areas
- surface-water components of drain returns
- groundwater components of drain returns.

There are over 27,000 possible combinations of feature objects in Table 2-1. However, there are only 252 unique combinations in the *irrigated agricultural lands* GIS layer, which contains 16,000 land-use polygons. The sizes of the polygons vary; however, none is larger then 640 acres and the average is 36 acres. Each of the land-use polygons in this layer is associated with one of these 252 unique combinations of feature objects.

For each budget component in the *irrigated agricultural lands* GIS layer, thirteen spatial distributions of data can be generated: one average annual value and twelve average monthly values. In all, there are 208 possible spatial representations of *irrigated agricultural lands* budget data. All budget components in the database have units of feet. Multiplying budget table entries by the associated acreage of each land-use polygon yields a budget component having units of acre-feet.

Attachment Table A-9 lists the attribute identifiers for each budget component in the *irrigated agricultural lands* GIS layer. Data tables containing average monthly and average annual values for each budget component are joined to polygons in the *irrigated agricultural lands* GIS layer using a concatenated attribute (CONCAT) in the data table.

2.7.4. Spatial distribution of net groundwater recharge-discharge

Figure 2–19 shows the spatial distribution of the average annual net groundwater recharge-discharge on all lands in the *irrigated agricultural lands* GIS layer.

Gradations of green are lands where net groundwater recharge exceeds net groundwater discharge on an average annual basis (positive value); gradations of red are lands where net groundwater discharge exceeds net groundwater recharge on an average annual basis (negative value). Note that the color gradations do not represent equal intervals of recharge or discharge.

The predominantly green shading indicates that, on an average annual basis, net groundwater recharge is occurring on the majority of irrigated agricultural land in the Boise Valley. This is due mainly to on-farm infiltration and canal seepage during the irrigation season. The net annual recharge rate on most lands is less than one acre-foot per acre. However, net recharge is significantly higher east of Lake Lowell in portions of the Boise-Kuna and New York irrigation districts. Annual groundwater recharge in these areas ranges from one to five acre-feet per acre, mostly because of higher canal seepage rates.

Red shading on agricultural lands located along the Boise River and in areas south of Lake Lowell indicates that net groundwater discharge is occurring in these areas. In the Dixie Slough drainage area (along the lower Boise River), the net discharge ranges from five to ten acre-feet per acre; this is due mainly to the high rate of groundwater return to drains, which discharge to the Boise River at this area. Net groundwater discharge occurring on lands south and east of Lake Lowell is due to extensive groundwater withdrawals for irrigation in this area.

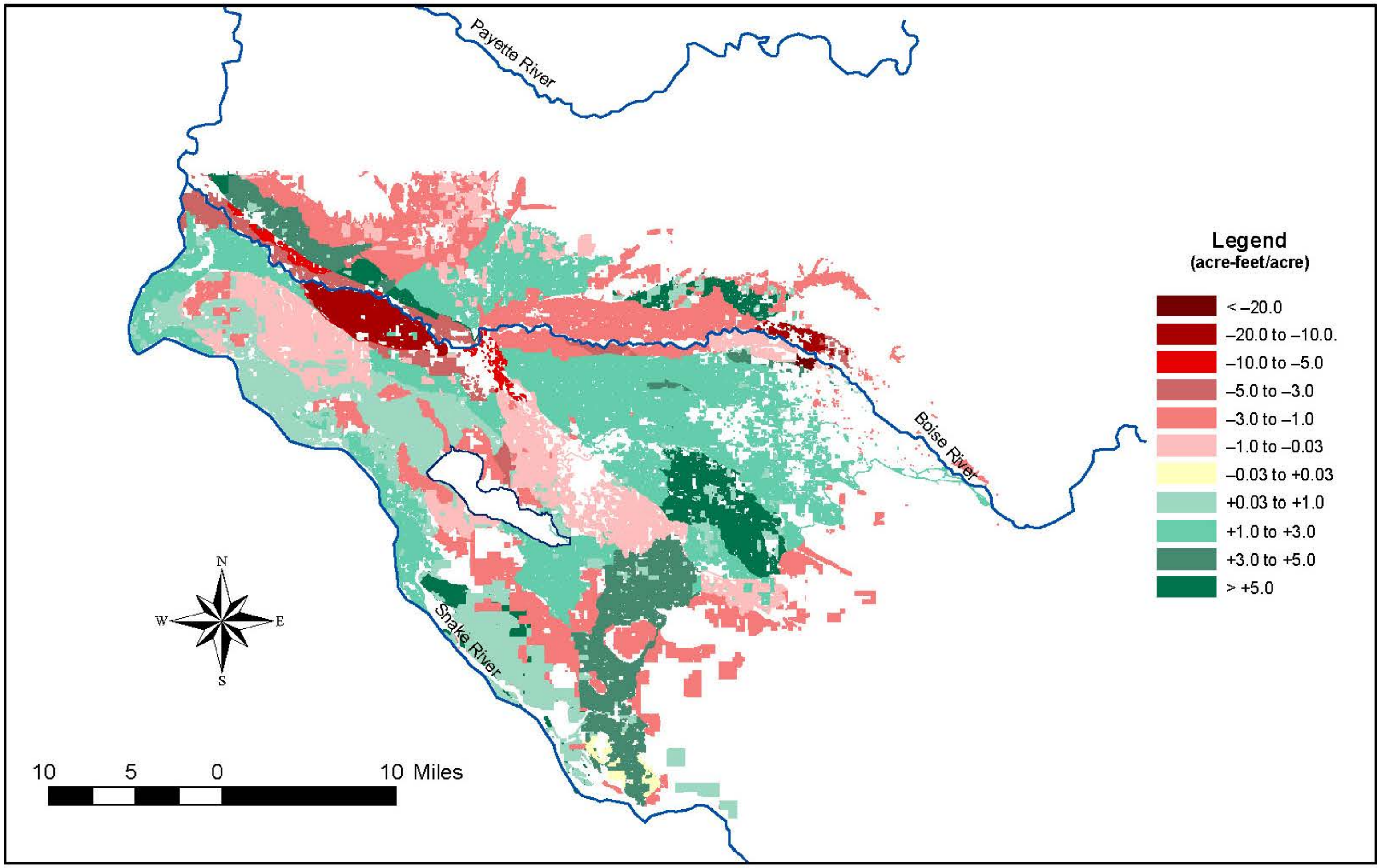

Figure 2–19. ***[map]*** **Spatial distribution of average annual net groundwater recharge-discharge on irrigated agricultural lands.**

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2.8. COMPARISON WITH THE TREASURE VALLEY HYDROLOGIC PROJECT (TVHP) BUDGET

The TVHP water budget produced valley-wide estimates of total aquifer withdrawals, aquifer recharge, and change in aquifer storage for the year 1996 (Urban 2004). **Table 2-2** (third page following) displays average annual components from this distributed parameter water budget (the DP budget) alongside comparable (or nearly comparable) components from the 1996 TVHP budget.

The notes in Table 2-2 indicate that it is not always possible to make direct comparisons between individual components in the two budgets; this is because of differences in the way they were compiled. In particular, the TVHP budget estimates of precipitation, farm delivery, ET, and on-farm infiltration apply to gravity-irrigated lands only. In order to make comparisons, the DP budget components are narrowed to include only these lands.

Budget components in this comparison include total river diversions, farm delivery on gravity-irrigated lands, precipitation on gravity irrigated lands, ET on gravity irrigated lands, canal losses, on-farm infiltration on both gravity-irrigated and sprinkler-irrigated lands, groundwater pumping, Lake Lowell seepage, surface-water drain returns to the Boise and Snake Rivers, and total sub-surface discharge to the Boise and Snake Rivers (which includes base flow and drain returns).

Table 2-2 indicates that diversion, farm delivery, precipitation and ET components in the DP budget are all comparable in magnitude to those of the TVHP budget.

The DP budget estimate of average annual river diversion is 1,786 kaf. The TVHP budget estimate for 1996 was 1,741 kaf. The 45 kaf difference is less than 3 percent of total diversion in the DP water budget. The DP budget estimate of average annual farm delivery on gravity irrigated lands (excluding re-diverted drain returns) is 1,155 kaf. The TVHP budget estimate for 1996 was 1,084 kaf. The 71 kaf difference is about 6 percent of farm delivery in the DP water budget. The DP budget estimate of average annual precipitation on gravity-irrigated lands is 233 kaf. The TVHP budget estimate for 1996 was 231 kaf. The difference is less than 1 percent.

The DP budget also estimate of average annual ET on gravity-irrigated lands is 637 kaf. The TVHP budget estimate for 1996 was 657 kaf. The difference between the two budgets is less than 3 percent. However, comparisons between other budget components show some significant differences. For instance, the DP budget estimate of average annual canal seepage is 492 kaf, while the TVHP budget estimate for 1996 was 637 kaf. The 145 kaf difference is 29 percent of the canal seepage estimate in the

DP budget. There is also a significant difference between the two budgets in on-farm infiltration. The DP budget estimate of average annual on-farm infiltration on gravity-irrigated lands is 454 kaf; the TVHP budget estimate for 1996 was 307 kaf. The 147 kaf difference is 32 percent of the DP budget estimate.

The disparities that exist between the budgets with respect to these two components are significant, but notably they are in opposite directions. The DP budget estimate of canal seepage is 145 kaf lower then the TVHP estimate, and the DP estimate of on-farm infiltration is 147 kaf higher then the TVHP estimate. Most likely, the budget differences are due to how canal seepage and on-farm infiltration are defined (and separated) in the budgets. When the two components are combined, there is less than one percent difference between the two budgets.

There is also a disparity between the two budgets with respect to groundwater pumping. The DP budget estimate of average annual groundwater pumping on primary groundwater acreage was115 kaf, while the TVHP budget estimate for 1996 was 72 kaf. An additional 12 kaf of pumping is estimated to occur on supplemental groundwater acreage in the DP budget. Supplemental groundwater pumping is not included in the TVHP budget.

The disparity in estimates of groundwater pumping is due partly to a difference in acreage. Groundwater irrigated acreage in the DP budget is 4,900 acres greater than in the TVHP budget. The main difference however is in the calculation of irrigation season ET. The TVHP estimate of ET was 2.42 acre-feet per acre, of which 0.75 acre-feet per acre was assumed to be met with precipitation, leaving net groundwater withdrawal of 1.67 acre-feet per acre. The DP budget estimate of ET (based on the Blaney-Criddle method) is 2.87 acre-feet per acre during the irrigation season. Precipitation in the DP budget (during the irrigation season) accounts for just 0.37 acre-feet per acre, leaving a net groundwater withdrawal of 2.49 acre-feet per acre.

Although Lake Lowell gain-loss is a very small component of the budget, there is still a significant difference between the DP budget estimate and the TVHP budget estimate. The TVHP estimate of Lake Lowell seepage of 19 kaf in 1996 is confirmed by historical records for that year. However, historical records also show that lake gains and losses fluctuate considerably from year-to-year. Since 1967, records indicate an average net annual lake gain of just under 4 kaf.

In actuality, given how long the reservoir has been in place, Lake Lowell is likely to be in near equilibrium (on an average annual basis) with the underlying aquifer. Although there are significant seasonal fluctuations in lake gains and losses, these tend to balance out over the course of a year. In fact, the DP budget estimate of a

4 kaf annual gain could be interpreted as simply the error in estimating an expected value of zero. (Section 3.4 “Lake Lowell gains and losses” describes the average seasonal variation in that reservoir.)

With respect to the drain returns budget component, the TVHP budget is, again, compiled somewhat differently from the DP budget. In both budgets, surface-water returns are separated out from subsurface returns. However in the TVHP budget, subsurface returns include both the groundwater component of drain return to rivers and the base flow discharge to rivers. In order to make a direct comparison, these two components are also combined in the DP budget.

In the TVHP budget, the 1996 surface-water component of drain return to the Boise River was estimated to be 337 kaf, and the surface-water component of drain return to the Snake River was estimated to be 14 kaf. Total surface-water return to both rivers was 351 kaf. Subsurface discharge of groundwater to the Boise River was estimated to be 523 kaf, and subsurface discharge to the Snake River was estimated to be 277 kaf. Total subsurface discharge to both rivers was 851 kaf.

In the DP budget, the surface-water component of drain return to the Boise River is estimated to be 226 kaf, and the surface-water component of drain return to the Snake River is estimated to be 67 kaf. Total surface return to both rivers is 293 kaf. Subsurface discharge to the Boise River (which includes both the groundwater component of drain returns and baseflow discharge) is 489 kaf, and subsurface discharge to the Snake River is 362 kaf. Total subsurface discharge to both rivers in the DP budget is 800 kaf.

Total surface-water return in the DP budget exceeds that of the TVHP budget by 58 kaf. On the other hand, total sub-surface discharge in the TVHP budget exceeds that of the DP budget by 51 kaf. While there are some significant differences between the two budgets in terms of the relative distribution of Boise River and Snake River return and terms of surface and sub-surface components of total return, there is only 7 kaf difference in their estimates of combined (surface and sub-surface) return to both rivers. This is less than one percent of the DP budget estimate of total drain return.

Overall, there is relatively close agreement between the two budgets in terms of the main categories of additions and subtractions of surface-water and groundwater from the Boise Valley. In this regard, the TVHP water year (1996) is reasonably close to the average DP water year. The main difference between the two budgets lies in the details of individual budget components. In this regard, the DP water budget has an advantage in that it is based on more detailed irrigated agricultural lands water use and spatial data.

Table 2-2. Comparison of DP budget and TVHP budget components for irrigated agricultural lands.

Item	**Distributed Parameter (DP) Budget** (average 1967-1997)			**TVHP Budget** (1996)	
	Budget Component	**acre-feet**	**DP budget notes**	**acre-feet**	**TVHP budget notes**
1	Net river diversions	1,786,090	excludes re-diverted drain returns	1,741,200	
2	Farm delivery including re-diverted drain returns	1,476,807	gravity irrigated land only	NA	
3	Farm delivery excluding re-diverted drain returns	1,154,760	gravity irrigated land only	1,083,600	gravity irrigated land only
4	Canal seepage	492,284		636,600	
5	Precipitation	232,764	gravity irrigated land only	231,000	gravity irrigated land only
6	Surface-water irrigated land, irrigation season ET	613,787	gravity irrigated land only	604,800	gravity irrigated land only
7	Bare soil ET	22,819	winter months ET	52,000	bare soil ET
8	Surface-water irrigated land ET	636,606	gravity irrigated land only	656,800	gravity irrigated land only
9	Canal ET	3,331		3,600	
10	Lake Lowell ET	5,778		26,900	
11	Lake Lowell gain/loss	3,752	Lake Lowell gain	19,000	Lake Lowell loss
12	Primary irrigation pumping	115,482		71,900	
13	Supplemental irrigation pumping	13,480		NA	
14	Total groundwater pumping for irrigation	128,962		71,900	
15	On-farm infiltration (gravity irrigated)	453,868	gravity irrigated land only	307,000	gravity irrigated land only
16	On-farm infiltration (sprinkler irrigated)	47,753	sprinkler irrigated land only	21,800	sprinkler irrigate land only
17	Total on-farm infiltration	501, 22	sum of items 15 and 16	328,800	sum of items 15 and 16
18	Surface-water component of drain return to Boise River	225,587	excludes Sand Hollow drain area	336,900	
19	Surface-water component of drain return to Snake River	66,872	includes Sand Hollow drain area	14,000	
20	Total surface-water drain return to Boise R. and Snake R.	292,4659	sum of items 18 and 19	350,900	sum of items 18 and 19
21	Groundwater component of drain return to Boise River	381,338		NA	
22	Groundwater component of drain return to Snake River	236,356		NA	
23	Total groundwater drain return to Boise R. and Snake R.	617,694	sum of items 21 and 22	NA	
24	Base flow discharge to Boise River	107,767	Glenwood Bridge to Snake R.	NA	Glenwood Bridge to Snake R.
25	Base flow discharge to Snake River	125,667	Murphy to Nyssa (north and east side only)	NA	Murphy-Nyssa (N. and E. side only)
26	Total subsurface discharge to Boise River	489,105	Glenwood Bridge to Snake R,	523,200	Glenwood Bridge to Snake River
27	Total subsurface discharge to Snake River	362,023	Murphy to Nyssa (north and east side only)	276,800	Murphy-Nyssa (N. and E. side only)
28	Total subsurface discharge to Boise R. and Snake R.	851,128	sum of items 26 and 27	800,000	sum of items 26 and 27
29	Combined surface and subsurface discharge to Boise R. and Snake R.	1,143,587	sum of items 20 and 28	1,150,900	sum of items 20 and 28

3. DRY LANDS AND WATER-BODIES BUDGET

The *dry lands and water-bodies* GIS layer includes six land classes: rangelands, barren lands, idle and abandoned farmlands, transportation corridors, riparian wetlands, and water-bodies. **Figure 3-1** shows the distribution of these land classes in the Boise Valley based on the 1994 land-use coverage (IDWR 1996). Together these land classes comprise about 182,000 acres. About 9 percent (16,700 acres) are idle and abandoned farm land; about 74 percent (135,000 acres) are rangelands or barren lands; about 14 percent (24,800 acres) are wetlands or water-bodies, and about 3 percent (5,500 acres) are transportation corridors. The *dry lands and water-bodies* GIS data layer consists of 7,250 land-use polygons. The polygons vary in size; none is larger then 640 acres, and the average is about 25 acres.

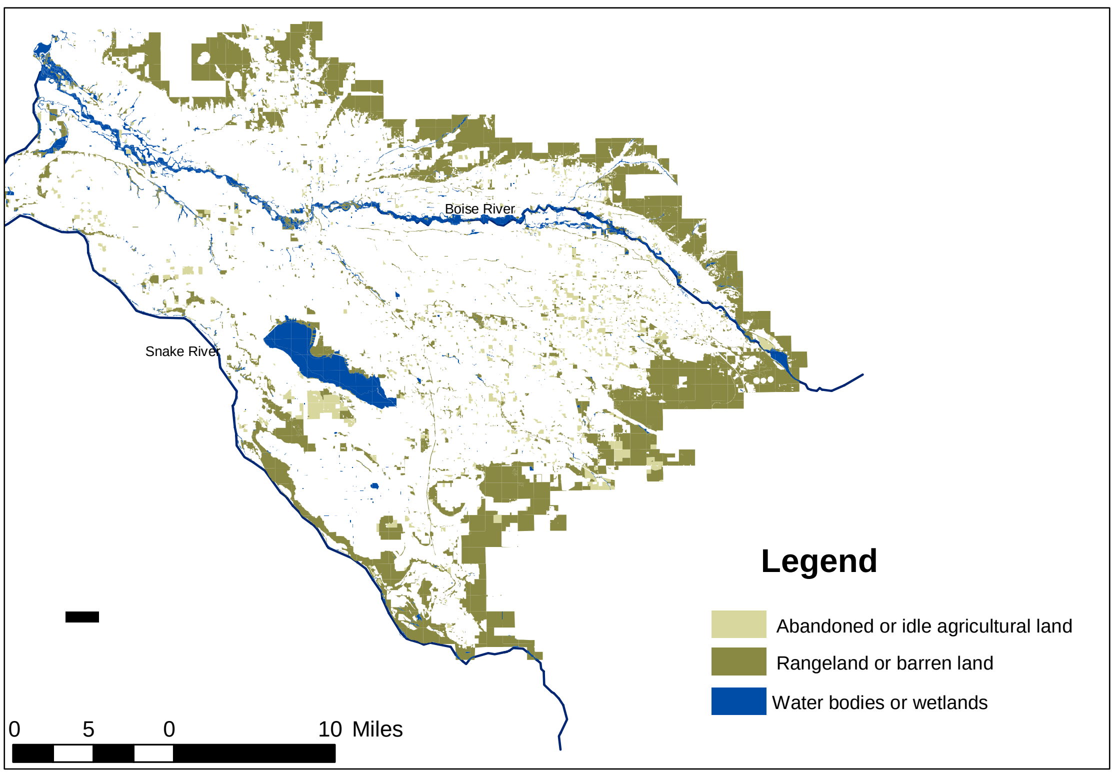

Figure 3–1. ***[map]*** **Lands in the** ***dry lands and water-bodies*** **budget category.**

3.1. DRY LANDS BUDGET COMPONENTS

Dry lands budget components are associated with rangelands, barren lands, idle and abandoned farmlands and transportation corridors. The three dry lands budget components: precipitation (**PrecipDry**), evapotranspiration (**ETDry**), and net groundwater recharge-discharge (**NetRec/DisDry**) are analogous to precipitation, ET and net groundwater recharge-discharge budget components in the *irrigated agricultural lands* budget.

3.1.1. PRECIPITATION

Precipitation on both dry lands and water-bodies (**PrecipDry**) is distributed spatially, based on the same eight Thiessen polygons used to define the distribution of precipitation on irrigated agricultural lands. (See Section 2.4 "Precipitation Zones" and Figure 2-4 "Irrigated land within precipitation zones in the Boise Valley [map]".)

3.1.2. EVAPOTRANSPIRATION

ET estimates for the five classes of dry lands (**ETDry**) are based on Landsat thermal imaging data obtained in the spring and fall of 2000. These data were analyzed to determine ET by the University of Idaho and IDWR using SEBAL[2/] (Morse et al. 2002). **Table 3-1** presents average monthly ET for the four dry lands classes and the two water classes in this budget category. The average monthly ET values in this table are applied during seven summer months (April-October). During the five winter months, ET on all lands in this category is assumed to be 0.007 feet per month, which is the average bare ground ET on agricultural land. (Lake Lowell ET is calculated separately in Subsection 3.4, "Lake Lowell gains and losses.")

[2] "Surface Energy Balance Algorithm for Land." SEBAL is an image-processing model that computes energy balance, heat flux, and land-surface ET. It uses satellite thermal imaging data, wind speed and temperature data, and a reference ET.

Table 3-1. Average seasonal ET on dry lands (April-October).	
Land classification	**Monthly ET** (acre-feet/acre)
Rangeland	0.113
Barren land	0.157
Idle and abandoned agriculture	0.101
Transportation corridors	0.196
Wetland	0.480
Water-bodies (excluding Lake Lowell)	0.433
Source: Morse et al. 2002.	

3.2. DRY LAND NET GROUNDWATER RECHARGE-DISCHARGE

Equation 3-1 is the expression used to calculate net groundwater recharge-discharge on dry lands. Net groundwater recharge-discharge on these lands is simply the difference between precipitation and ET. Canals and drains which have a wetlands land classification are excluded from Equation 3-1, since canal seepage and drain return are included in the *irrigated agricultural lands* budget.

Equation 3-1. Net groundwater recharge-discharge on dry-lands classes.

NetRec/DisDry = PrecipDry – ETDry

where

NetRec/DisDry = Net groundwater recharge-discharge on dry-lands classes

PrecipDry = precipitation on dry lands

ETDry = ET on dry lands

Figure 3-2 shows the average monthly distribution of net groundwater recharge-discharge on dry lands (**NetRec/DisDry)**. Net groundwater recharge occurs on dry lands mainly during winter months and net groundwater discharge occurs mainly during summer months, which is the opposite of irrigated agricultural lands (Figure 2-18 “Average monthly drain return to Boise River and Snake River”).

In terms of absolute magnitude, net groundwater recharge-discharge on dry lands is small compared to that of irrigated agricultural lands. On average, net groundwater recharge-discharge on dry lands never exceeds 15 kaf per month.

Also in contrast to irrigated agricultural lands, groundwater recharge and discharge on dry lands is more-or-less evenly balanced. Over the course of an average year the net difference between recharge and discharge is less then 6 kaf.

Finally, as noted previously, monthly groundwater recharge-discharge does not equate to aquifer recharge-discharge. On dry lands in particular, nearly all of the groundwater recharge that occurs during winter months is consumptively used by vegetation during summer months.

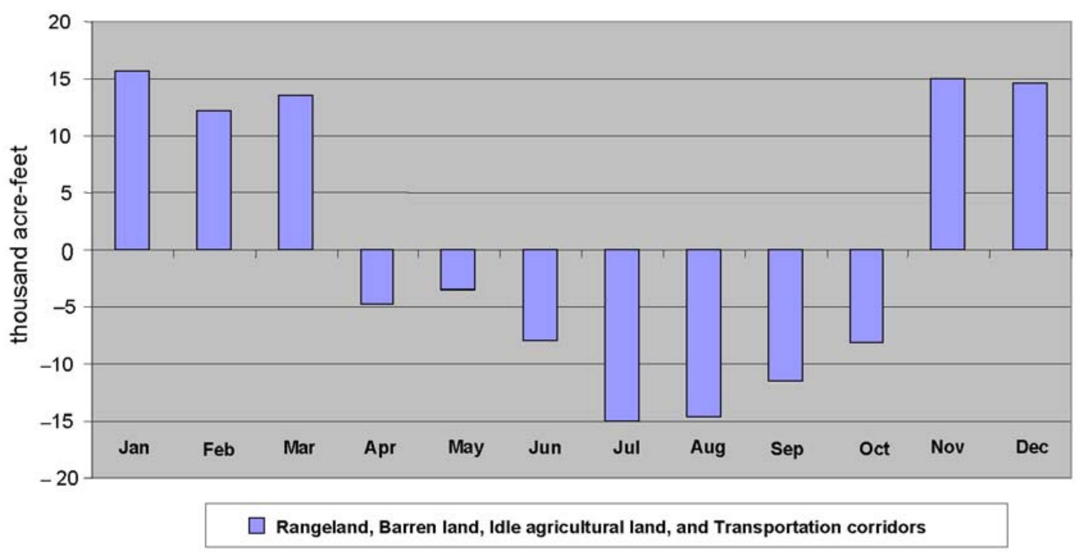

Figure 3–2. Average monthly net groundwater recharge-discharge on dry lands.

3.3. BASE FLOW TO BOISE AND SNAKE RIVERS

As noted, base flow refers to subsurface discharge of groundwater directly to channels and riparian wetlands of the Boise and Snake Rivers. (This is in contrast to the groundwater component of drain return which is discharged to rivers on the surface.) **Equation 3-2** is the general expression used to calculate base flow to Boise and Snake River reaches.

Equation 3-2. Boise River and Snake River reach base flow.

BaseFlo = NetRec/DisRv = TotalRchGn/Los + TotalRchDivr – TotalRchDrnRet – RivRchGn

where

BaseFlo = base flow discharge (of groundwater) to the main channels of a river reach

TotalRchGn/Los = total river reach gain or loss measured at upstream and downstream gages

TotalRchDivr = total diversion from a river reach, including re-diversions

TotalRchDrnRet = total drain returns to a river reach

TotalRivRchGn = total river reach gain from tributaries

River gaging station data is used to calculate total gain/loss (**TotalRchGn/Los**) in two reaches of the Boise River and one reach of the Snake River. The Boise River reaches extend from Glenwood Bridge to Middleton and from Middleton to Parma. The Snake River reach extends from Murphy to Nyssa. Gage data for these reaches is only available after 1977, so average base flow calculations in Equation 3-2 are based on diversion and return flow data from the period 1977-1997.

Average monthly and average annual base flow to rivers is distributed over river channel and wetland polygons in the *dry lands and water-bodies* GIS layer, as net groundwater recharge-discharge (**NetRec/DisRv**). Accordingly, the spatial distribution of base flow to rivers can be displayed concurrently with net groundwater recharge-discharge on dry lands, or net groundwater recharge-discharge on irrigated agricultural lands.

3.3.1. BASE FLOW TO BOISE RIVER REACHES

Base flow in the Glenwood-Middleton reach of the Boise River (**BaseFlo**) is calculated using Equation 3-2. This is done by adding total measured reach gains (**TotalRchGn/Los**) to the water diverted by Upper Boise River Diverters and by Pioneer I.D (**TotalRchDivr**). From this is subtracted **TotalRchDrnRet** - all of the drain returns from five drainage areas (Eagle, Fifteen Mile Creek, North Slough, Phyllis Wasteway, and Thurman) and half the drain returns from four others (North and South Middleton, Mason Creek, Hartley Gulch, and Boise River).

Calculation of base flow in the Middleton-Parma reach of the Boise River is done in similar fashion. In this case, the diversions that are added back to the total gains in the Middleton-Parma reach are those of the Lower Boise River Diverters. Drain returns that are subtracted off include Mason Creek, Dixie Slough, Conway Gulch drainage area, Indian Creek drainage area (excluding the portion that is re-diverted by the Black Canyon Irrigation District) and half of the drain returns of three drainage areas (North and South Middleton, Hartley Gulch, and Boise River).

During winter months, returns from the Garland, Golden Gulch, Riverside Canal, and Lake Lowell drainage areas are also subtracted from total reach gains, since none of these drain returns are re-diverted at this time of year. Base flow in the roughly eight-mile reach between Parma and the Snake River is accounted for by adding an additional ten percent to the Middleton to Parma base flow calculation. The ten percent addition (about 8.4 kaf annually) is comparable to recent estimates of the Parma to Snake River reach gain (USGS 2005).

Figure 3-3 shows the average monthly base flow for the Glenwood-Middleton and Middleton-Parma reaches of the Boise River. The monthly base flows in this chart have been smoothed using a three-month moving average.

On average, base flow in the Glenwood-Middleton reach is positive throughout the irrigation season indicating a net river gain; it is negative during winter months, indicating a net river loss at this time of year. River gains between April and September range from 2 to 12 kaf per month. Losses between October and March range from 2 to 7 kaf per month. Losses during winter months are somewhat of a surprise, but are attributed to lower groundwater levels at this time of year and to nearby canals which act as drains during winter months (Charles, Schmidt et al. 2006). It is likely that most of the losses during winter months return to the Boise River downstream from Middleton, either as drain discharge or as base flow.

On average, base flow in the Middleton-Parma reach is positive year-around, indicating a river gain throughout the year. Base flow gains to this reach range from 2 kaf in May to 13 kaf in October. Unlike the Glenwood-Middleton reach, Middleton-Parma base flow remains relatively low throughout the early part of the irrigation season. The delayed rise in August suggests that much of the groundwater flowing to the Middleton-Parma reach comes from a more distant source within the Boise Valley than does groundwater flowing to the Glenwood-Middleton reach.

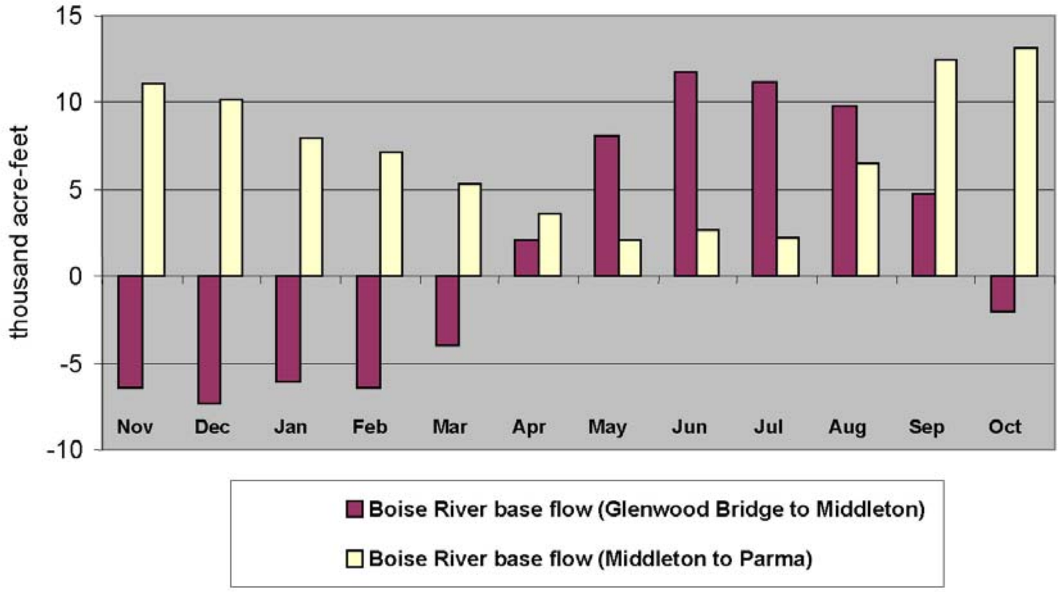

Figure 3–3. Average monthly base flow to the Boise River, Glenwood Bridge to Parma.

3.3.2. BASE FLOW TO THE SNAKE RIVER REACH

Base flow to the Snake River between Murphy and Nyssa (**BaseFlo**) is also calculated using Equation 3-2. To total reach gains (**TotalRchGn/Los**) are added the diversions made by Snake River pumpers (**TotalRchDivr**). From this are subtracted drain return from three drainage areas (the Snake River, Jensen Wasteway, and Sand Hollow) (**TotalRchDrnRet**). Also subtracted are river gains from the Boise River (measured at Parma) and the Owyhee River (measured at Lake Owyhee) (**TotalRivRchGn**). The result is then divided by two, since it is assumed that 50 percent of total base flow comes from the Boise Valley side of the river.

Figure 3-4 shows the average monthly base flow to the Snake River. The monthly base flows in this chart have been smoothed using a three-month moving average. Base flow to the Snake River is positive most of the year, indicating a net groundwater gain; however, small net losses from the river occur in November, December, and January. Snake River base flow increases steadily during spring and early summer and reaches a peak of about 32 kaf in June. As with the Boise River, the higher base flows during the irrigation season are attributed to generally higher groundwater levels at this time of year. The decline at the end of the season can be attributed, in part, to the influence of increased groundwater pumping at this time of year.

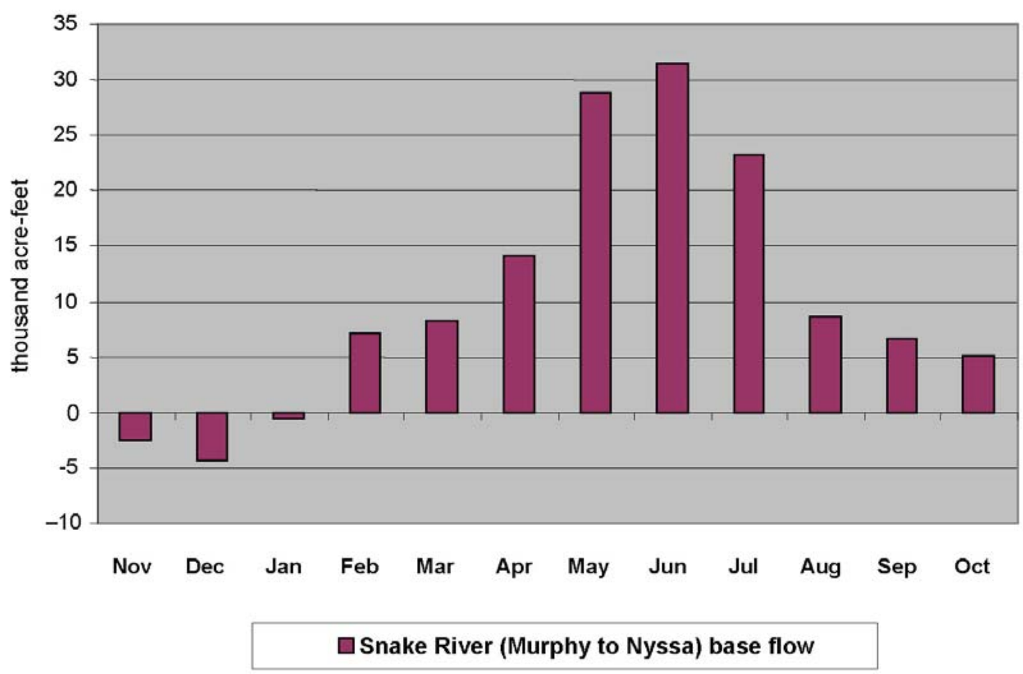

Figure 3–4. Average monthly base flow to the Snake River between Murphy and Nyssa.

3.4. LAKE LOWELL GAINS AND LOSSES

Average Lake Lowell gains and losses are based on the same BPBOC records (1967-1997) used to develop the *irrigated agricultural lands* budget. Monthly gains and losses from Lake Lowell are calculated using records of reservoir inflow and outflow, reservoir ET (which includes transpiration by lakeshore vegetation and lake evaporation) and change in reservoir storage (which is measured using the lake level/capacity table).

Lake Lowell receives a majority of its inflow from the New York Canal; it also receives all the drainage from the Lake Lowell drainage area. Total canal diversions and drainage area discharges into Lake Lowell are calculated by adding the diversions through the New York Canal, subtracting diversions to four canals which bypass Lake Lowell (South Nampa Feeder, the Heron Bay Feeder, the Robinson Lateral, and Deer Flat Highline), and adding the contributions of the Garland drain and the Ridenbaugh Canal wasteway. In the Lake Lowell drainage area, the two main surface drains that discharge directly into the reservoir are the Deer Flat Highline Wasteway #1 and Wasteway #3.

On average, about 15 kaf per month is diverted to Lake Lowell via the New York Canal prior to the start of the irrigation season and at the end of the irrigation season. Diversions to the reservoir at the end of the irrigation season are made in order to maintain lake level for wildlife habitat and recreational use and to ensure normal winter carryover of 100 kaf to130 kaf of storage.

After the start of the irrigation season, diversions from the reservoir are made to satisfy downstream demands in the Wilder, Big Bend, Nampa & Meridian, and Boise-Kuna irrigation districts. Drafts from Lake Lowell storage occur from May through August, and range from 8 to 32 kaf per month. Canal diversions from Lake Lowell are monitored at six locations (Deer Flat Low Line, Deer Flat North, Deer Flat Caldwell, Deer Flat Nampa, the Notus Feeder, and the Blickenstaff pump).

3.4.1. AVERAGE MONTHLY LAKE LOWELL GAIN AND LOSS

Lake Lowell gains and losses are calculated as the sum of diversions and drain returns into the lake, less diversions out of the lake, lake ET and change in lake storage. **Equation 3-3** is the expression used to calculate average monthly Lake Lowell gains and losses to groundwater.

Equation 3-3. Lake Lowell gains and losses.
LowGain = NetRec/DisLL = LowIn + LowDrnRet – LowOut – LowET – Δ LowStor where **LowGain** = net groundwater grain by Lake Lowell **LowIn** = diversions into Lake Lowell **LowDrnRet** = drain returns to Lake Lowell **LowOut** = diversion out of Lake Lowell **LowET** = Lake Lowell evapotranspiration **Δ LowStor** = change in Lake Lowell reservoir storage

Figure 3–5 shows the average monthly Lake Lowell gain/loss to groundwater (**LowGain**) for the thirty-year period 1967-1997. Also shown in this figure is the average monthly change in reservoir storage (**Δ LowStor**). In general, Figure 3-5 shows that lake losses occur mainly when reservoir storage is high; this is during late winter and at the start of the irrigation season (February to May). Lake gains occur

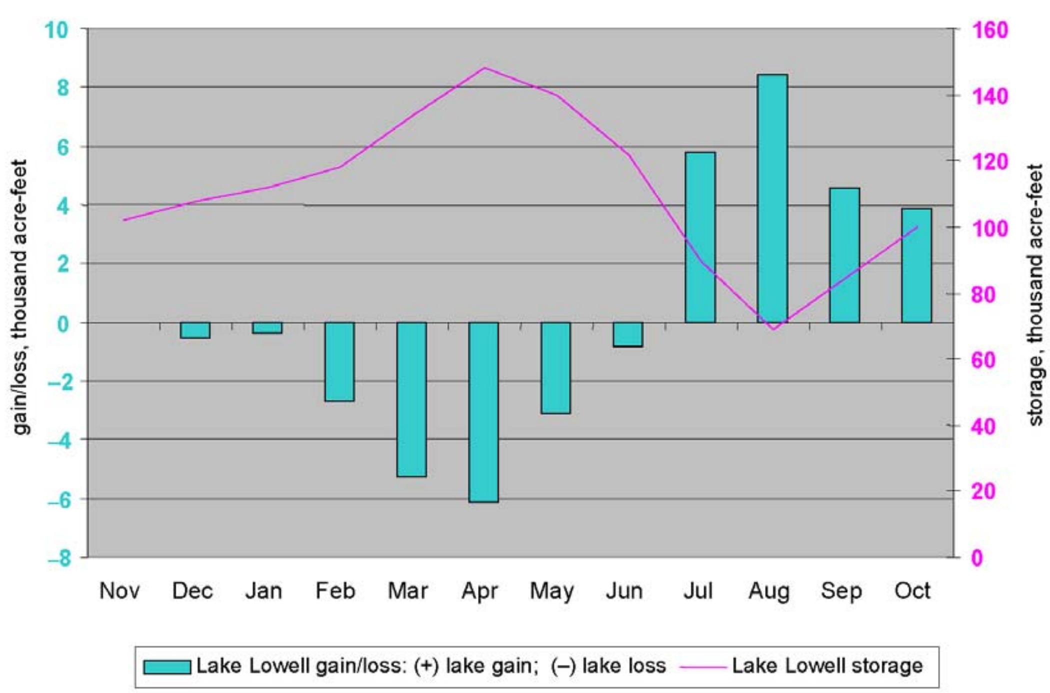

Figure 3–5. Average monthly reservoir level and gain-or-loss from Lake Lowell.

mainly toward the middle and end of the irrigation season (July to October) when reservoir storage is low. In an average year, Lake Lowell gains up to 8,100 acre-feet during August (when the lake level is lowest) and loses up to 6,100 acre-feet during April (when the lake level is highest).

The relationship between reservoir level and Lake Lowell gains and losses is apparent; never-the-less, there is ample evidence from drain return data that losses occur year around on the north and west sides of the lake. During the irrigation season however these losses are offset by gains due to seepage from two canals situated at higher elevations south of Lake Lowell (Mora and Deer Flat Highline canals). The lower lake level during the latter half of the irrigation season minimizes the groundwater gradient on the north side of the lake and therefore the losses in this area. At the same time, it maximizes the groundwater gradient on the south side of the lake where the gains occur. The result is that lake gains predominate over lake losses at this time of year. During winter months when the lake level is high and canals are dry, losses predominate over gains.

Budget calculations indicate that Lake Lowell gains from groundwater average about 4 kaf annually. However, in any given year Lake Lowell may either gain or lose water. Net annual gains occur mainly in dry years when average lake level is lower. Net annual losses are more likely in wet years when the average lake level is higher. Over the past three decades, annual Lake Lowell gains have been as much as 42 kaf and losses as much as 45 kaf.

Average monthly Lake Lowell gains or losses are uniformly distributed over Lake Lowell polygons in the *dry lands and water-bodies* GIS layer, as net groundwater recharge-discharge (**NetRec/DisLL**). Like base flow to rivers, the spatial distribution of Lake Lowell gain and loss can also be displayed along with other components of net groundwater recharge-discharge, including net groundwater recharge-discharge on dry lands and irrigated agricultural lands.

3.5. SPATIAL DISTRIBUTION OF DRY LANDS AND WATER-BODIES BUDGET COMPONENTS

Three budget components are developed for the *dry lands and water-bodies* GIS layer: ET, precipitation, and net groundwater recharge-discharge. **Table 3-1** (next page) summarizes the dependencies of each budget component on four geographic feature types: land class, river reach, reservoir, and precipitation zone. The number of feature objects in each feature type is indicated in the column headings. Net groundwater recharge-discharge is the only component dependent on all four feature types.

Attachment Table A-11 lists the attribute identifiers for each budget component in the *dry lands and water-bodies* GIS layer. Data tables containing average monthly and average annual values for each budget component are joined to polygons in the *dry lands and water-bodies* layer using the JOIN field.

All budget components in the *dry lands and water-bodies* GIS layer have units of feet. Multiplying attribute table entries by the associated acreage of each polygon yields a budget component having units of acre-feet.

Table 3-1. Spatial dependencies of dry lands and water-bodies budget components

Budget Components	**Feature types** *(feature objects)* Source			
	Land class (6); *Fig. 3-1*	**Boise R. and Snake R. reaches** (3)	**Lake Lowell** (1)	**Precip. zones** (8); *Fig. 2-4*
ET	x		x	
precipitation				x
Net groundwater recharge-discharge	x	x	x	x

Figure 3-6 shows the spatial distribution of average annual net groundwater recharge-discharge on lands in the *dry lands and water-bodies* GIS layer. Gradations of red represent lands where discharge exceeds recharge (negative values); gradations of green represent lands where recharge exceeds discharge (positive values).

Lake Lowell, Boise River channels, and riparian wetlands are areas where net groundwater discharge is occurring on an annual basis. Net groundwater discharge (in the form of reservoir gains and river base flow) ranges from one to three acre-feet per acre. Net groundwater recharge of up to one acre-foot per acre occurs on small isolated parcels of idle or abandoned agricultural land.

Net groundwater recharge and discharge on dry lands is generally small but varies slightly depending on the distribution of precipitation in the Boise Valley. On an average annual basis, lands on the north and east sides of the valley receive slightly more precipitation then do lands on the south and west sides, so groundwater recharge is slightly higher on dry lands in north and east. There is almost no net annual recharge or discharge on rangelands and barren lands located on the periphery of the Boise Valley.

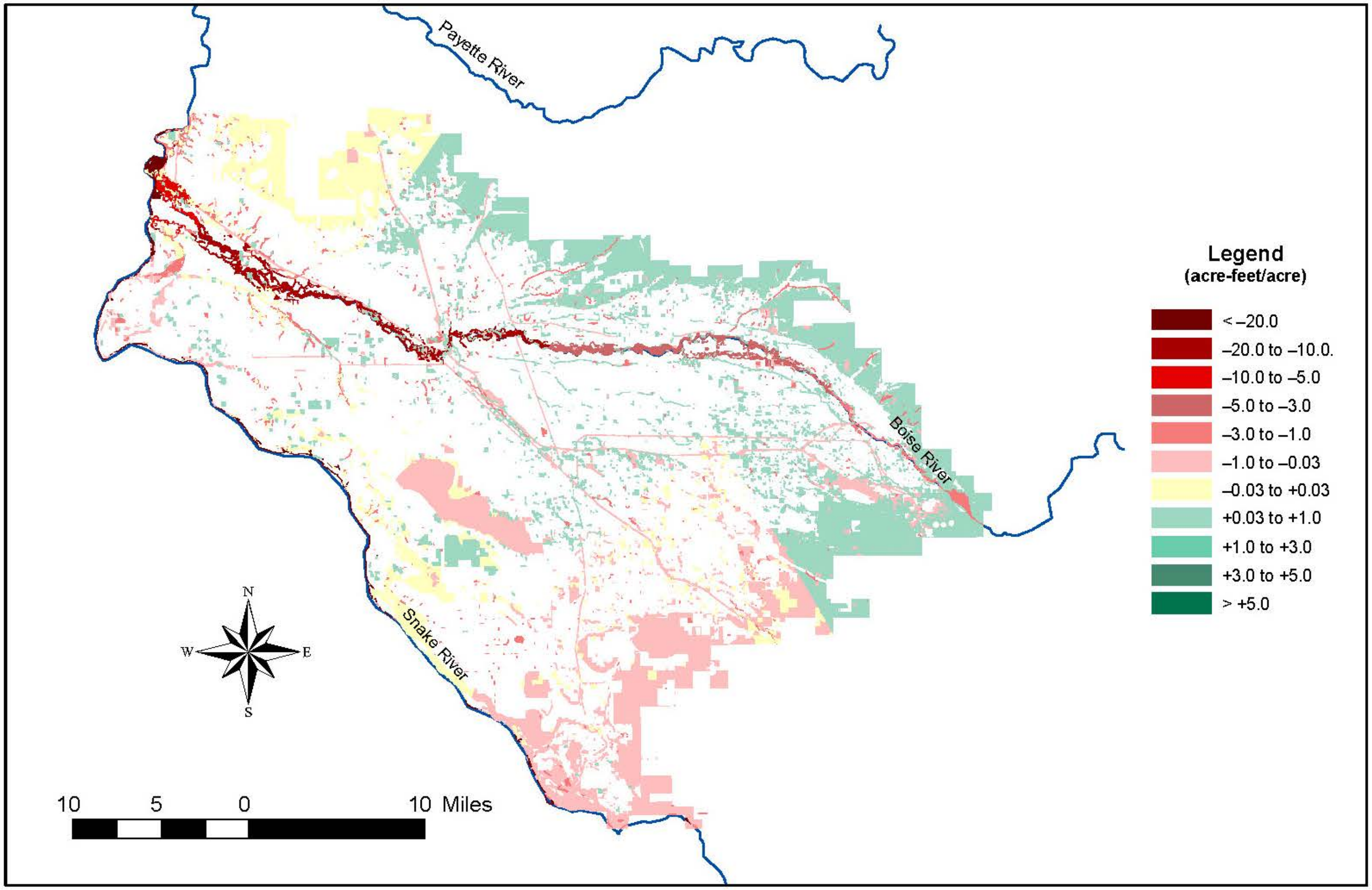

Figure 3–6. ***[map]*** **Spatial distribution of average annual net groundwater recharge-discharge on dry lands and water-bodies.**

4. RESIDENTIAL, COMMERCIAL, AND PUBLIC-RECREATION LANDS WATER BUDGET

The *residential, commercial, and public-recreation lands* GIS layer includes consumptive (relative to the aquifer) indoor and outdoor water-use on nine different land classes in Ada and Canyon Counties. These land classes are

- Old urban/high density residential lands
- Rural residential lands
- Residential farmsteads
- New subdivisions
- Agricultural lands in transition to urban
- Commercial-industrial lands (including feedlots, stockyards and dairies)
- Public lands and recreation areas
- Municipal supply wells. (These are unique to this water budget and are described in Subsection 4.3 “The municipal supply well land-class”.)

The land classes are grouped together into four major land-use classes: residential, commercial-industrial, public-recreation, and municipal supply well. **Figure 4–1** shows the distribution of these lands in Ada and Canyon Counties, based on the 1994 land-use classification (IDWR 1996).

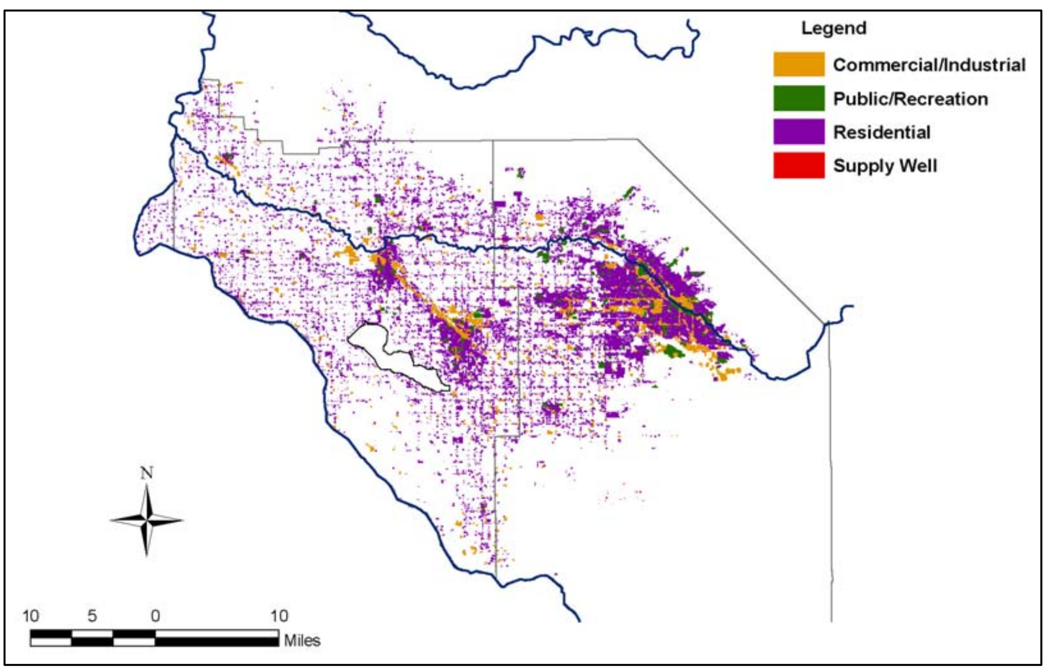

Figure 4–1. *[map]* Residential, Commercial, and Public-Recreation lands in Ada and Canyon Counties.

At the time this land classification was prepared, these land-classes comprised about 84,300 acres in the Boise Valley. Of this total, residential lands were about 72 percent (60,400 acres); commercial-industrial land about 19 percent (16,100 acres); and public-recreation lands about 9 percent (7,800 acres). Most of the nearly 16,000 land-use polygons in this GIS data layer are less then ten acres in size; the largest is 470 acres; the average is about five acres. Municipal supply wells are assigned to one-acre polygons.

4.1. DATA SOURCES

Water-use data for the *residential, commercial, and public-recreation lands* budget category comes from three main sources: records of municipal groundwater withdrawals; a recent domestic, commercial, municipal, and industrial (DCMI) water-use assessment and forecast for Ada and Canyon Counties; and ET estimates for different Boise Valley land-classes, including residential, commercial and public-recreation lands.

Records of municipal groundwater withdrawals made during from the 1996 through 2001 are available for seven Boise Valley cities (Boise, Caldwell, Eagle, Garden City, Kuna, Nampa, and Meridian) and for the United Water Idaho (UWI) service area (IDWR 2003b; UWI 2001b). UWI records are the most detailed and include a daily accounting of pumping from individual UWI wells. Monthly records of total pumping are available for city wells in three cities (Caldwell, Garden City, and Meridian). Only annual records are available for city wells in Boise, Caldwell, Eagle, Nampa, and Kuna. The UWI data is for the years 2000 and 2001 and was adjusted to account for population growth in Ada County between 1996 and 2001.

Estimates of current and future indoor water demand for all DCMI water-use sectors are available as part of a recent water-use assessment prepared for Ada and Canyon Counties by IDWR (Cook, Urban et al. 2003). The water-use sectors in this assessment included single and multi-family residential users, municipal users, and commercial and industrial users. Water-demand coefficients were developed for each water-use sector and combined with census-block population data and place-of-work statistics to describe the volume and spatial distribution of DCMI water-use within “traffic analysis zones” (TAZ).

Traffic analysis zones in Ada and Canyon Counties are comprised of one or more census blocks. TAZ vary in size but are more-or-less equivalent in terms of population. Figure 4–2 shows the 1995 distribution of 810 TAZ in Ada and Canyon Counties.

A TAZ-based DCMI water-use assessment for Ada and Canyon counties is used only for estimating indoor consumptive use on residential, commercial, and public-recreation lands. Outdoor consumptive use on these lands is estimated using Landsat thermal imaging data and a SEBAL analysis of water consumption (Kramber 2002;

Morse, Kramber et al. 2003). The Landsat data for the SEBAL analysis of evapotranspiration was obtained during the year 2000.

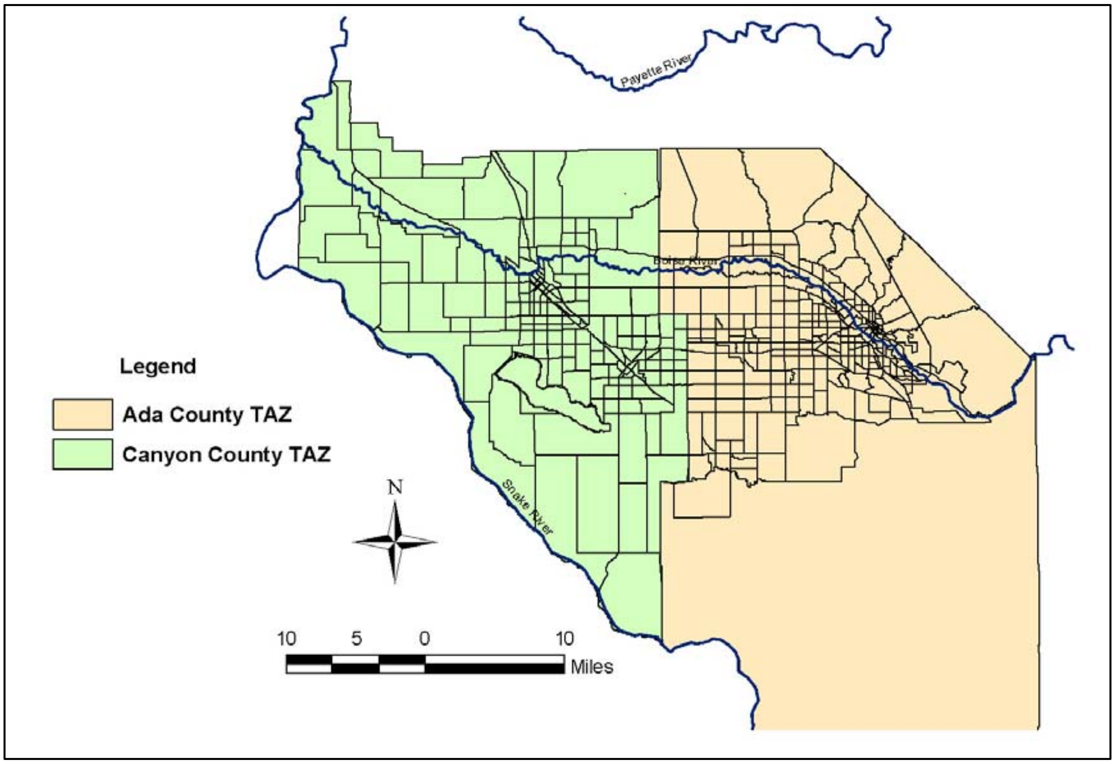

Figure 4–2. ***[map]*** **Ada and Canyon Counties 1995 traffic analysis zones (TAZ).**

Table 4-1 (next page) shows the SEBAL based estimates of annual outdoor consumptive use on eight different land-classes in the *residential, commercial, and public-recreation lands* budget category. In this budget, the ET values in this table are assumed to be uniformly distributed over these land-classes from April through October. During the remainder of the year, outdoor water consumption on these land-classes is assumed to be zero.

Table 4-1. Average seasonal ET on residential, commercial-industrial, and public-recreation land-classes.

Land-class	**April-October ET** (acre-feet/acre)
Residential – urban	2.247
Residential – rural	2.156
Residential – farmstead	1.995
Residential – new subdivision	1.988
Commercial-industrial [1]	1.246
Public-recreation lands	1.799
Recreation areas	2.709
Ag land in transition to urban	1.811

(1) All commercial-industrial lands including feedlots, dairies, junkyards, petroleum tanks, and sewage treatment plants.

Source: Kramber 2002.

4.2. Consumptive Water-Use in Urban and Rural TAZ

Urban centers are defined in this budget as residential, commercial, and public-recreation lands in the Boise Valley that have access to municipal water supply systems and that discharge treated wastewater to the Boise River. This includes Boise (the UWI service area), Garden City, Nampa, Caldwell, Meridian, Eagle and Kuna. TAZ that are located in urban centers are designated urban TAZ, and TAZ that are located outside of urban centers are designated rural TAZ.

In the *residential, commercial, and public-recreation lands* budget, indoor water-use on residential, commercial, and public-recreation lands located within urban TAZ is assumed to be consumptive with respect to the aquifer. Indoor water-use on residential, commercial, and public-recreation lands located in rural TAZ (outside of urban TAZ) is assumed to be non-consumptive. (Outdoor use is considered consumptive regardless of where it occurs.)

Of the 810 TAZ in the Boise Valley, 338 are designated urban TAZ, the rest are rural TAZ. **Figure 4–3** shows the distribution of urban TAZ in the Boise Valley. Not all lands in urban TAZ are residential, commercial, or public-recreation lands. Irrigated agricultural lands, dry lands and water-bodies are also present in urban TAZ.

When available, monthly records of groundwater withdrawals by municipal suppliers are used to determine indoor and outdoor water-use on residential, commercial, and public-recreation lands located within urban TAZ. Such records of groundwater withdrawal are available for the UWI service area, and for the cities of Caldwell, Garden City, and Meridian. When only annual pumping records are available (Boise, Eagle, Kuna, and Nampa), monthly pumping is assumed to be proportional to the monthly withdrawals of Caldwell, Garden City, and Meridian. Groundwater withdrawals made in other urban TAZ (Greenleaf, Marsing, Middleton, Parma, and Wilder) are estimated using the TAZ census block data and water-use coefficients (for indoor use) and SEBAL evapotranspiration data (for outdoor use).

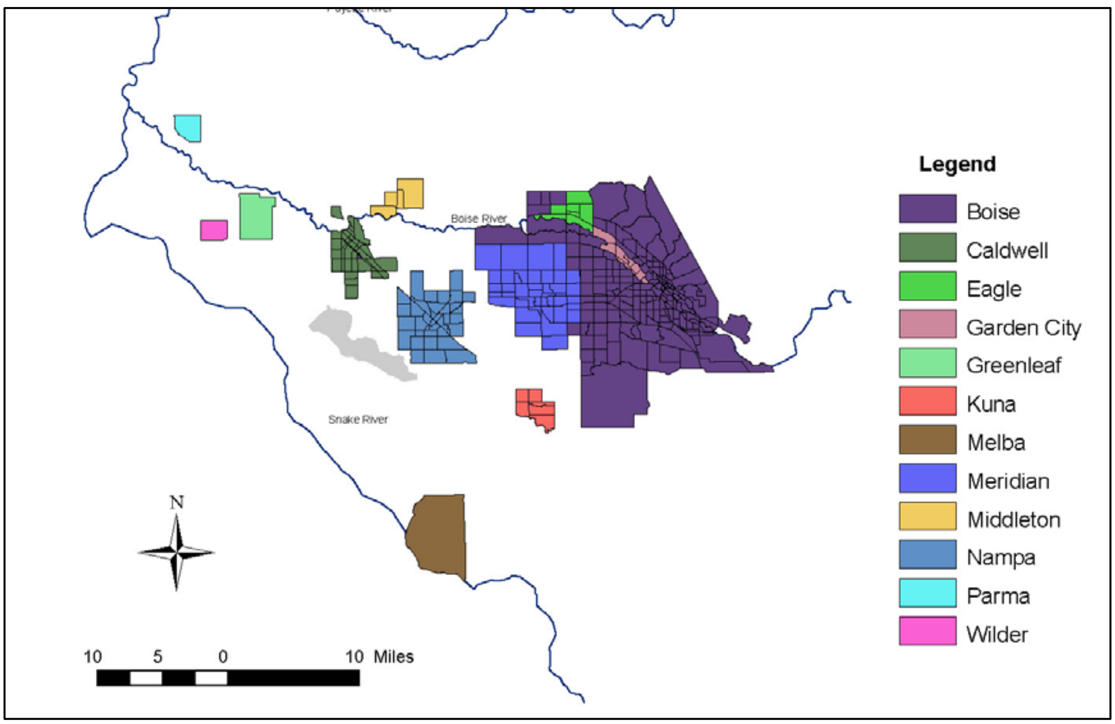

Figure 4–3. *[map]* Ada and Canyon Counties urban traffic analysis zones (TAZ), 1995.

4.3. MUNICIPAL SUPPLY WELL LAND-CLASS

As noted, a new land-class is included in the *residential, commercial, and public-recreation lands* GIS layer consisting of one-acre polygons at the locations of municipal-supply wells within urban TAZ. The inclusion of a supply well land-class in this data layer intended to make it easier for budget data to be used in modeling groundwater withdrawals.

There are 308 one-acre supply-well polygons in the *residential, commercial, and public-recreation lands* GIS layer. **Figure 4-4** shows the locations of some of the well polygons in an urban TAZ within Boise City. All groundwater withdrawals that are made to meet residential or public-recreation demand in urban TAZ are distributed spatially over one or more of these one-acre supply-well polygons.

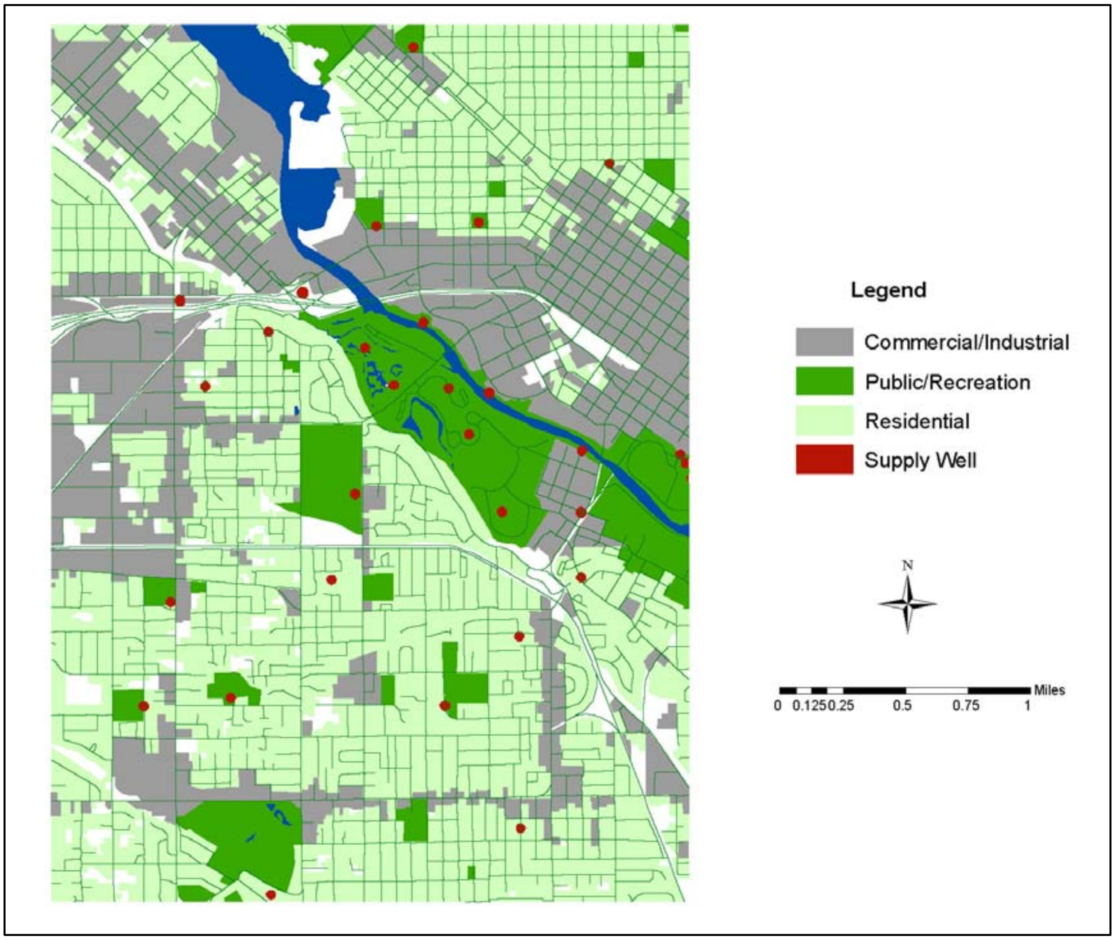

Figure 4–4. *[map]* Land uses in Boise TAZ, including one-acre supply well polygons.

For instance, to meet total indoor and outdoor demand within the 190 TAZ that made up its service area in 1996, UWI pumped approximately 30,204 acre-feet of groundwater from 77 wells. In the *residential, commercial, and public-recreation lands* GIS layer, these groundwater withdrawals are distributed over 77 supply-well polygons based on the pumping records of individual UWI wells.

Groundwater withdrawals from Boise City wells used to meet outdoor demand on public-recreation lands are also spatially distributed with respect to the locations of 61 Boise City and Boise School District wells.

The supply-well polygons are used only to identify the spatial location of groundwater withdrawals. The place of use for this water (the location of the water demand) is still the residential and public-recreation land-class polygons in urban TAZ.

In rural TAZ, groundwater withdrawals to meet indoor demand are considered non-consumptive, and so are not included in this budget. Groundwater withdrawals to meet outdoor demand are spatially distributed over the appropriate residential, commercial-industrial, and public-recreation land-class polygons in rural TAZ.

4.4. DUAL-USE SURFACE-WATER AND GROUNDWATER LANDS

Dual-use lands are lands in the *residential, commercial, and public-recreation lands* GIS layer that have a surface-water supply for outdoor use and a groundwater supply for indoor use. This includes most residential lands that have pressurized irrigation systems and residential lands that have access to gravity irrigation. A small percentage of residential pressurized irrigation systems pump groundwater and are not included in the dual-use category.

Dual-use lands in Ada and Canyon Counties are identified based on the preliminary results of an IDWR survey of residential and public-recreational lands served by pressurized irrigation systems (IDWR 2005). The survey identified broad areas of dual-use lands located within urban centers, including Boise, Eagle, Kuna, Meridian, and Nampa. In addition, there are residential lands outside of these urban centers that are likely to have pressurized irrigation systems. For example, residential lands in Canyon County with a land classification of New Subdivision and located within irrigation district boundaries are assumed to have pressurized irrigation with a surface-water source. Residential lands in Ada County that have access to gravity irrigation are also included in the dual-use category, as is a small portion of the UWI service area in east Boise that uses mainly Boise River water. Public-recreation lands and commercial-industrial lands located within these broadly defined dual-use areas are also assumed to have dual-use capability.

4.4 Dual-use surface-water and groundwater lands

The distribution of dual-use lands in this water budget is approximate and preliminary, and is determined by overlaying a 2005 dual-use map (IDWR 2005) onto the 1994 residential, commercial, and public-recreation land-use map.

Figure 4–5 shows the resulting distribution of lands in Canyon and Ada Counties that were assumed to have dual-use capability in this budget. Based on this map, about 26,200 acres of residential, commercial-industrial and public-recreation land in Ada County and 16,300 acres in Canyon County have a surface-water supply source for outdoor use (a dual-use system).

For lands in the *residential, commercial, and public-recreation lands* GIS layer that are located within a dual-use area (regardless of whether or not they are in an urban TAZ), outdoor ET demand (derived from Table 4-1) is assumed to be met by surface-water diversion and distributed spatially on these lands. For residential and public-recreation lands in an urban TAZ but not in a dual-use area, groundwater withdrawals made to meet outdoor ET demand are spatially distributed with respect to the location of the one-acre supply-well polygons. For residential, commercial-industrial, and public-recreation lands that are neither in dual-use areas nor in urban TAZ, outdoor ET demand is met by groundwater withdrawal which is spatially distributed on these lands.

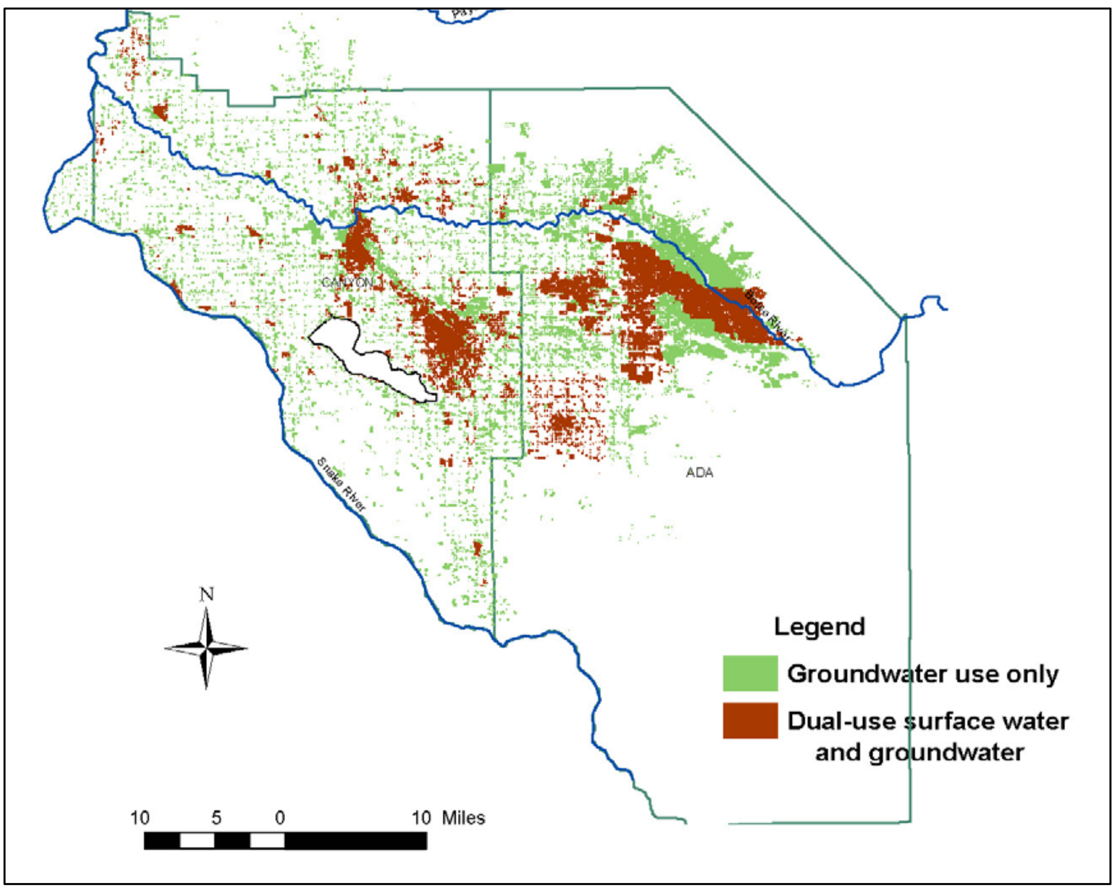

Figure 4–5. ***[map]*** **Dual-use lands in Canyon and Ada Counties, 1994.**

Outdoor consumptive use on dual use residential, commercial, and public-recreation lands located within surface-water irrigation district boundaries is considered part of the diversion and consumptive use (surface-water ET) of those irrigation districts. Therefore it is included, as part of the total ET of those districts, in the *irrigated agricultural lands* budget.

4.5. SUMMARY OF BUDGET

Total consumptive water use on residential, commercial, and public-recreation lands in the Boise Valley in 1996 is estimated at 208,500 acre-feet. This includes both indoor and outdoor consumptive use, from surface-water and groundwater sources. About 78 percent of this use occurs in urban TAZ and about 22 percent occurs in rural TAZ.

Figure 4–6 shows the distribution of indoor, outdoor, and total consumptive water-use in urban areas (actually urban TAZ) of the Boise Valley. Consumptive use in the Boise Valley is heavily skewed toward Boise City and the UWI service area. In 1995, total consumptive use in Boise was 57 percent (about 94,000 acre-feet) of the total use for all urban centers. The cities of Caldwell, Meridian, and Nampa account for 32 percent of the total consumptive use. The remaining 11 percent is split among eight other urban centers. Indoor use is consumptive only in urban TAZ; in Boise, it is estimated to be about 26,600 acre-feet per year. Outdoor consumptive use is about 67,500 acre-feet. Outdoor use is about 72 percent of the total water use in Boise. In other urban TAZ, outdoor use also makes up between 70 and 80 percent of the total consumptive use.

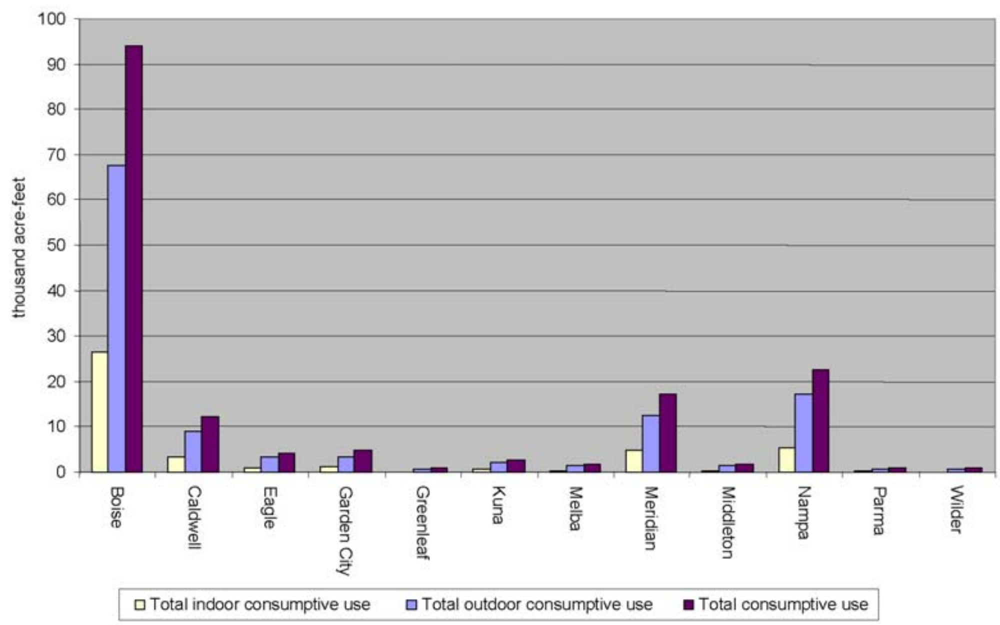

Figure 4–6. Indoor and outdoor consumptive use in urban centers in 1996.

Figure 4–7 shows the distribution of outdoor consumptive use with respect to eight different land-classes in the *residential, commercial, and public-recreation lands* GIS layer, including agricultural lands in transition to urban. The largest outdoor consumptive use (about 46,000 acre-feet) is associated with lands that are classified as Residential-Rural. The second largest use (40,700 acre-feet) is associated with lands classified as New Subdivisions. In all, the four residential land-use classes account for about 72 percent of total outdoor water-use in the *residential, commercial, and public-recreation lands* budget category. (The ET demand on lands denoted as Agricultural Lands in Transition to Urban is accounted for in the *irrigated agricultural lands* budget.)

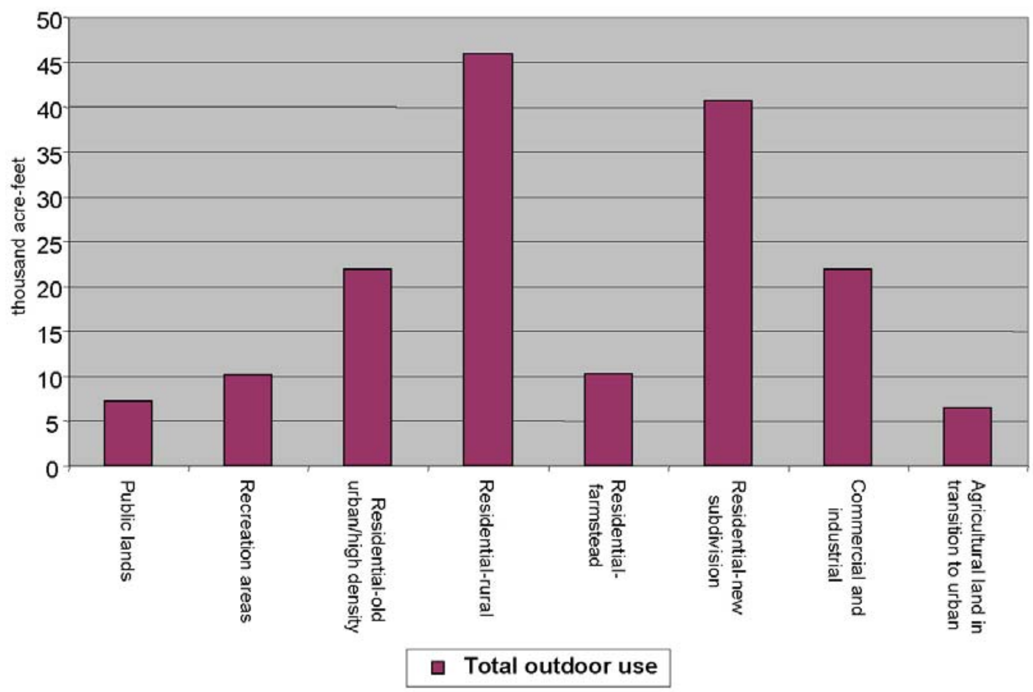

Figure 4–7. Outdoor consumptive use by eight land-use classes (1996).

The next two figures show how the distribution of dual-use lands in the Boise Valley affects outdoor use of surface-water and groundwater on residential, commercial, and public-recreation lands.

Figure 4–8 shows the distribution of outdoor surface-water and groundwater use by land-class. Residential areas that are classified as Old Urban–High Density and New Subdivisions tend to use mostly surface-water for outdoor uses. Areas that are classified as Residential-rural and Residential-farmstead tend to use mostly groundwater for outdoor uses. Public-recreation lands and commercial-industrial lands are more-or-less evenly split between surface-water and groundwater use. Across all land-classes, outdoor water use is almost evenly split between surface-water and groundwater.

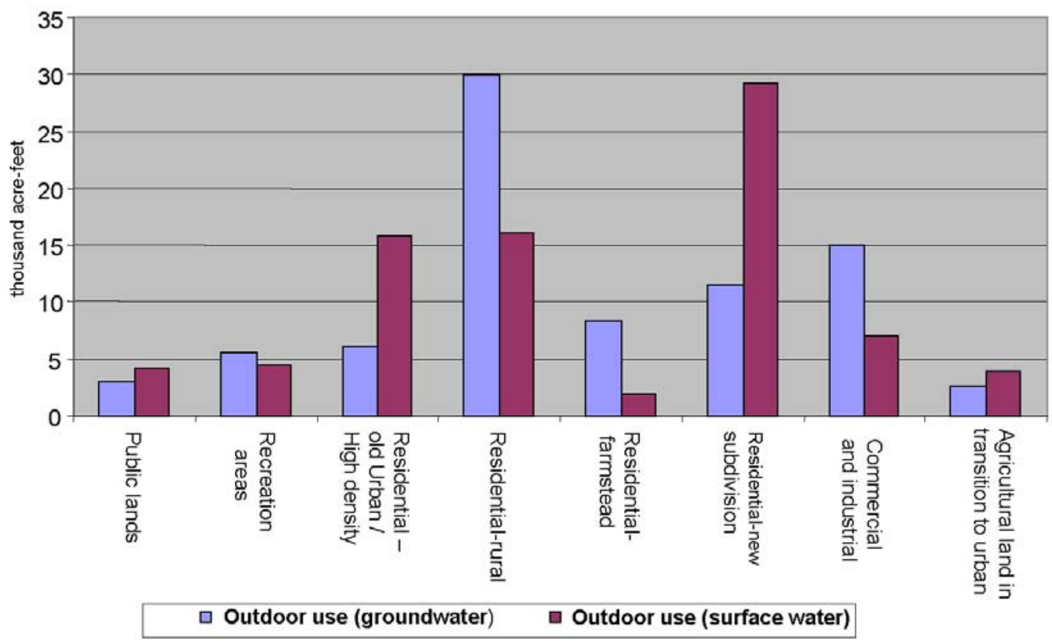

Figure 4–8. Outdoor surface-water and groundwater use by land-class.

Figure 4–9 shows the distribution of outdoor surface-water and outdoor groundwater use in urban centers (urban TAZ). In the TAZ that make up Boise City, surface-water accounts for about 55 percent of total outdoor use and groundwater for about 45 percent. The percentage of surface-water use is higher in urban areas that have pressurized irrigation systems. Surface-water constitutes about 73 percent of outdoor use in Caldwell, about 64 percent in Meridian, and about 81 percent in Nampa. Again, these percentages are representative of 1996 conditions.

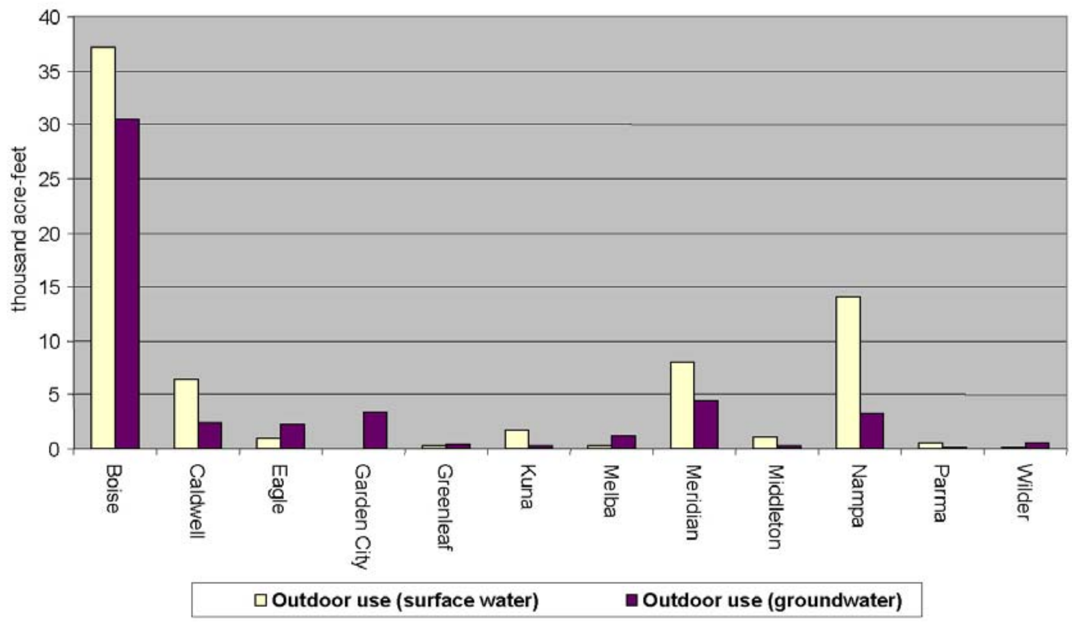

Figure 4–9. Outdoor surface-water and groundwater use in urban centers.

Figure 4–10 shows the monthly distribution of net groundwater recharge and discharge on residential, commercial and public-recreation land classes in the *residential, commercial, and public-recreation lands* GIS data layer. The predominantly negative values indicate net groundwater discharge occurs on these lands year-around due to well pumping, although most groundwater discharge occurs during summer months.

The largest component of net groundwater discharge is municipal supply well pumping, which averages just over 10 kaf during July and August. Other (consumptive) groundwater withdrawals on residential lands located outside of urban centers range between 4 and 6 kaf during summer months. Commercial-industrial withdrawals and public-recreation withdrawals are small by comparison, less than 1 kaf during summer months. Residential lands are the only lands where net groundwater recharge occurs during winter months.

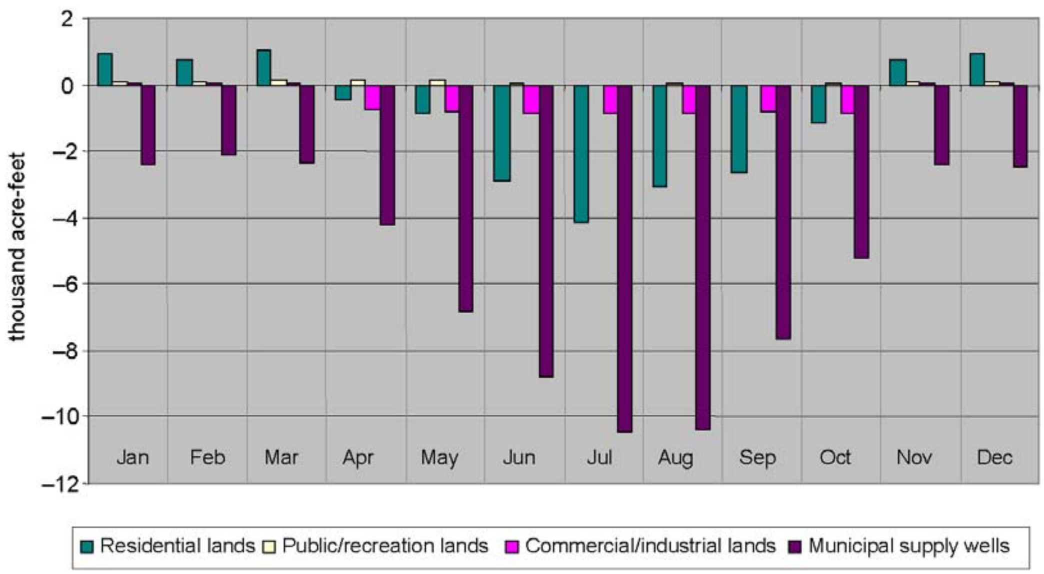

Figure 4–10. Monthly distribution of net groundwater recharge-discharge on all residential, commercial, and public-recreation lands.

4.5.1. NET GROUNDWATER RECHARGE-DISCHARGE

Net groundwater recharge-discharge on lands in the *residential, commercial, and public-recreation lands* GIS layer depends on land-class as well as other attributes, including dual-use and the urban/rural TAZ attributes. Net groundwater recharge-discharge on residential, commercial, and public-recreation lands is calculated using **Equation 4-1** as the difference between an average infiltration rate and the consumptive use of groundwater on these lands.

Equation 4-1. Net groundwater recharge-discharge on residential, commercial, and public-recreation lands.
NetRec/DisRcp = InfilRcp – GwPmpRcp where **NetRec/DisRcp =** Net groundwater recharge-discharge on residential, commercial, and public-recreation lands. **InfilRcp =** average infiltration rate of 0.25acre-feet per acre **GwPmpRcp =** consumptively used groundwater withdrawals

For simplicity and because residential, commercial, and public-recreation land classes comprise only about 15 percent of the Boise Valley, groundwater infiltration on these lands is assumed to be a uniform 0.25acre-feet per acre annually (Urban 2004). The monthly distribution of infiltration is proportional to average monthly on-farm infiltration. (See Attachment Table A-6.)

Since consumptive groundwater withdrawals in urban TAZ are concentrated at supply-well polygons, consumptive groundwater withdrawals on all other residential land-classes in urban TAZ will be zero. In addition, consumptive groundwater withdrawals are zero on dual-use lands, regardless of whether the lands are in an urban TAZ or a rural TAZ.

4.5.2. SPATIAL DISTRIBUTION OF BUDGET COMPONENTS

Four budget components are developed for the *residential, commercial, and public-recreation lands* GIS layer: Indoor consumptive use, Outdoor consumptive use, Groundwater withdrawals (**GwPmpRcp**), and Net groundwater recharge-discharge (**NetRec/DisRcp**).

Table 4-2 summarizes the dependencies of these four budget components on five geographic feature types: supply well location, land classification, TAZ, precipitation zone, and dual-use area. The number of feature objects in each feature type is indicated in the column headings of this table. Again, net groundwater recharge-discharge is the only component dependent on all five feature types.

Attachment Table A-10 lists the attribute identifiers for each budget component in the *residential, commercial, and public-recreation lands* GIS layer. Data tables containing average monthly and average annual values for each budget component are joined to polygons in the *residential, commercial, and public-recreation lands* GIS layer using one of four different attributes depending on the budget component. (The CONCATLU attribute is used to join net groundwater recharge-discharge.)

Table 4-2. Spatial dependencies of the *residential, commercial, and public-recreation lands* budget components.

	Feature types (feature objects); *source*				
Budget Components	**Supply well location** (308) *Fig. 4-4*	**SEBAL land-class** (8) *Table 4-1*	**Land-class within TAZ** (8x810) *Fig. 4-4*)	**Precip. zone** (8) *Fig 2-4*	**Dual-use areas** (2) *Fig. 4-5*
Indoor consumptive use	x		x		
Outdoor consumptive use (ET)	x	x			
Groundwater withdrawals	x	x	x		x
Net groundwater recharge-discharge	x	x	x	x	x

Figure 4–11 shows the spatial distribution of average annual net groundwater recharge-discharge on lands in the *residential, commercial and public-recreation lands* GIS layer. Because most groundwater withdrawals in urban TAZ are distributed over one-acre municipal supply well polygons, there is no widespread distribution of net groundwater discharge on these lands. To meet (consumptive) demand in rural TAZ, groundwater withdrawals of up to 3 acre-feet per acre are distributed over the land-use polygons as net groundwater discharge.

For the most part, net groundwater discharge occurs year-around on lands in the *residential, commercial and public-recreation lands* GIS layer. Not surprisingly, net groundwater discharge is greatest on municipal supply well land parcels. Annual groundwater discharge on the one-acre UWI parcels averages over 400 acre-feet.

As noted, in 1996 about 68 kaf was withdrawn from municipal and city wells in the Boise Valley. However, consumptive use of groundwater on residential and public-recreation lands within urban TAZ that do not have dual-use systems is about 80 kaf in 1996; this was indicated by TAZ water-use data and SEBAL evapotranspiration data. The discrepancy between the two estimates is attributed to at least three factors: not all residential users in urban TAZ have access to municipal water supplies; UWI diverts about 7 percent of its total supply from the Boise River (UWI 2001b); and some indoor demand in the UWI service area TAZ is met with surface-water.

Because these budget components also have units of feet, multiplying budget table entries by the associated acreage of each polygon yields a budget component having units of acre-feet.

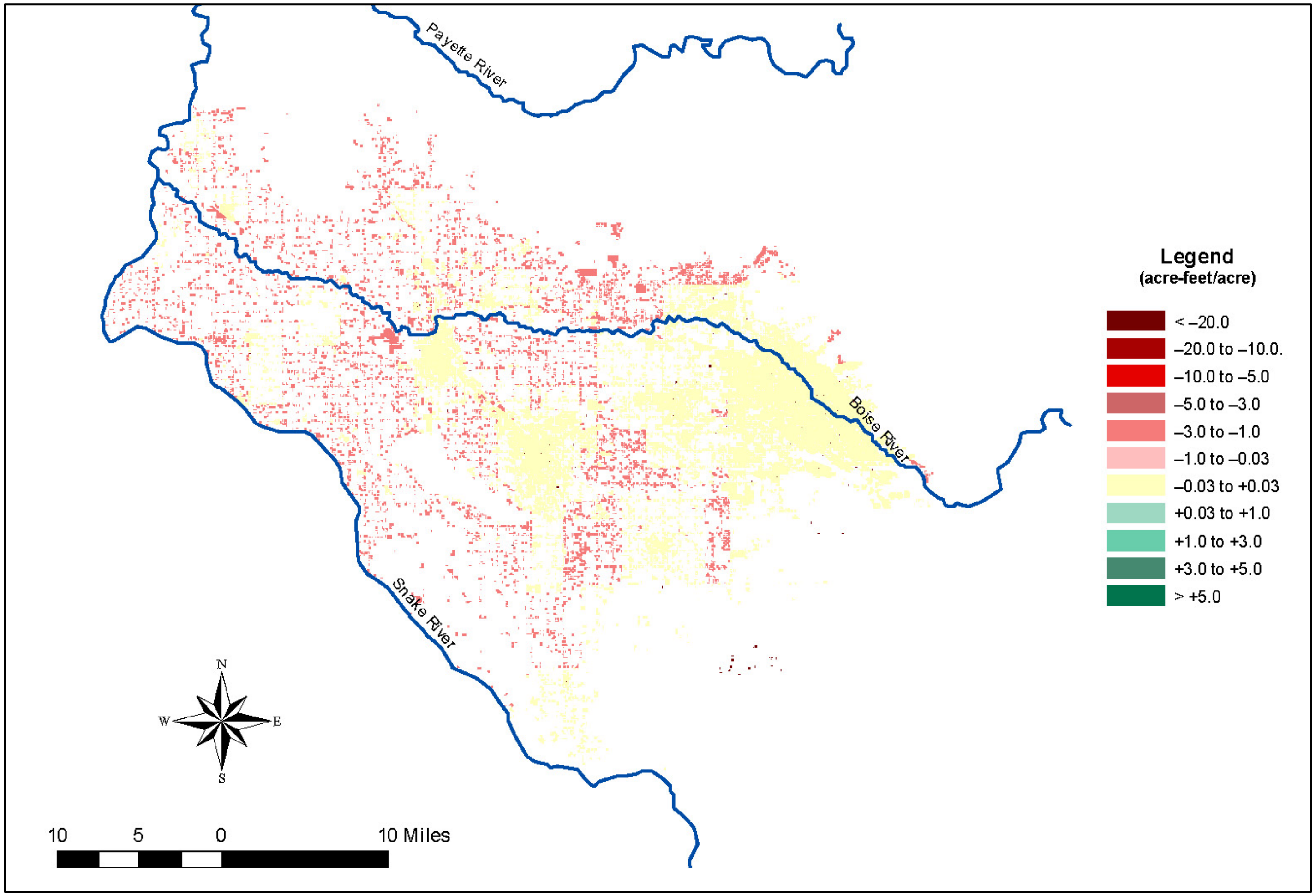

Figure 4–11. ***[map]*** **Spatial distribution of average annual net groundwater recharge-discharge on residential, commercial-industrial, and public-recreation lands.**

5. COMPOSITE DISTRIBUTIONS OF BUDGET COMPONENTS

As noted, there are three budget components are common to all three GIS layers; these are precipitation, ET, and net groundwater recharge-discharge. The spatial distribution of precipitation (based on Thiessen polygons) was described earlier. The composite spatial distributions of ET and net groundwater recharge-discharge in the Boise Valley are presented in this section.

5.1. BOISE VALLEY ET DISTRIBUTION

The composite distribution of Boise Valley ET combines the Blaney-Criddle based estimates of ET used in the *irrigated agricultural lands* budget, with the SEBAL-based estimates of ET used in the *dry lands and water-bodies* budget and the *residential, commercial and public-recreation lands* budget.

Figure 5–1 shows the average annual ET for five land use types in the Boise Valley. These are surface-water irrigated agricultural lands; groundwater irrigated agricultural lands; residential, commercial, and public-recreation lands; dry lands; and wetlands and water-bodies. (On residential, commercial, and public-recreation lands, "outdoor consumptive use" is the same as ET.) Not surprisingly, evapotranspiration on surface-water and groundwater irrigated agricultural lands (927 kaf per year) is the single largest component of Boise Valley ET. Evapotranspiration on residential, commercial, and public-recreation lands (165 kaf per year) is a distant second.

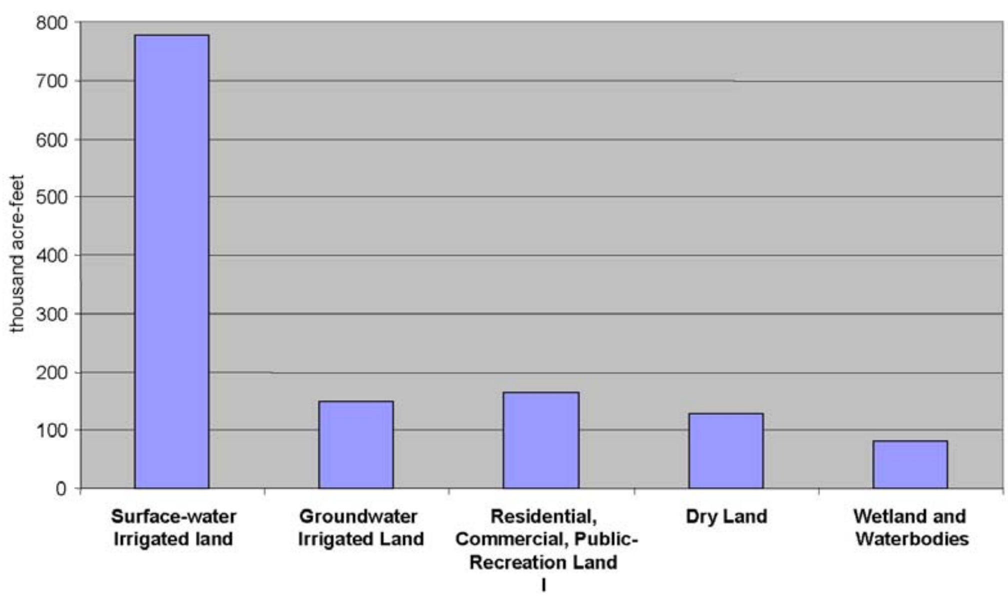

Figure 5–1. Composite distribution of ET and outdoor consumptive use.

Irrigated agricultural lands ET accounts for about 71 percent of the total annual consumptive use in the Boise Valley. Outdoor consumptive use on residential, commercial and public recreation lands accounts for about 13 percent of the total; dry land ET, about 10 percent; and water-bodies ET, about 6 percent.

Figure 5–2 shows the spatial distribution of average annual ET in the Boise Valley. The distribution ranges from under 0.5 to over 3.5 acre-feet per acre. Most irrigated agricultural lands are between 2.0 and 2.5 acre-feet per acre. However, ET on some agricultural land (notably the Snake River irrigated lands south of Lake Lowell) is as high as 3.5 acre-feet per acre. ET on Lake Lowell and adjacent wetlands is also between 3.0 and 3.5 acre-feet per acre. ET on dry lands and on residential, commercial and public-recreation lands ranges from less than 0.5 to 2.0 acre-feet per acre.

Seasonal variations in ET for representative months are shown in four “thumbnail” illustrations (second page following). The months are January (Figure 5–3), April (Figure 5–4), July (Figure 5–5), and October (Figure 5–6). Each figure is also shown as a full-page illustration in the PDF version of Attachment B.

During winter months (January), ET in the Boise Valley is uniformly low, less than 0.1 acre-feet per acre on nearly all lands.

At the start of the irrigation season (April), ET is still relatively uniform but somewhat higher at this time of year, between 0.1 and 0.2 acre-feet per acre on most land classes. ET on the Boise River, Lake Lowell, and some residential land classes is higher still, between 0.4 and 0.5 acre-feet per acre.

By the middle of the irrigation season (July), ET varies widely depending on the land class. On most irrigated agricultural lands, ET ranges between 0.5 and 0.6 acre-feet per acre. On dry lands, ET is generally between 0.1 and 0.2 acre-feet per acre. Water-bodies ET is between.0.4 and 0.5 acre-feet per acre. ET in urban centers (including Boise, Nampa, Caldwell, and Meridian) ranges between 0.1 and 0.5 acre-feet per acre.

By the end of the irrigation season (October), ET on most irrigated agricultural lands has dropped to less than 0.2 acre-feet per acre. ET on water-bodies remains between 0.4 and 0.5 acre-feet per acre. ET on most dry lands and in most urban centers is actually somewhat higher than on agricultural lands at this time of year, ranging between 0.1 and 0.2 acre-feet per acre.

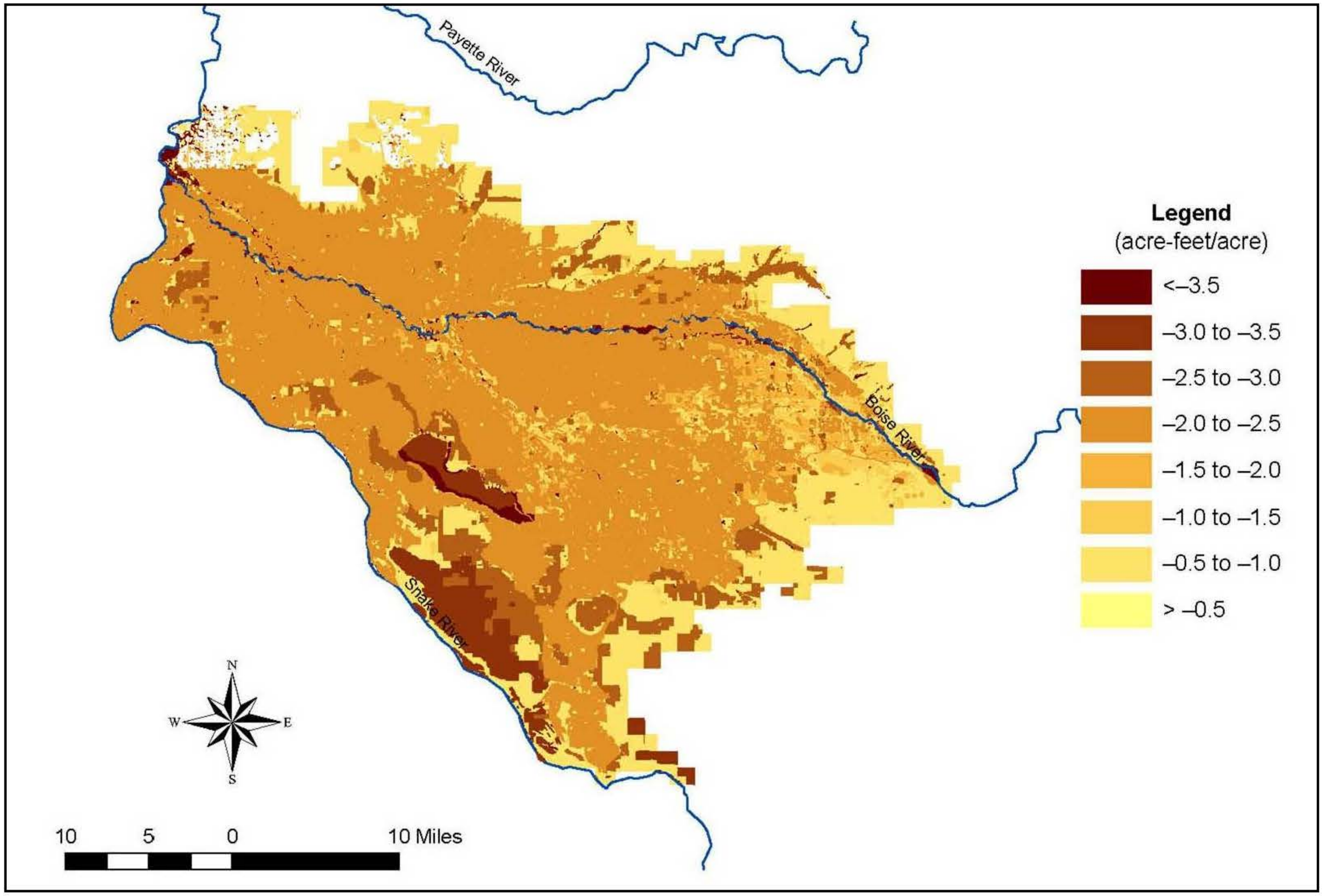

Figure 5–2. ***[map]*** **The spatial distribution of average annual ET in the Boise Valley.**

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5.1 Boise Valley ET distribution

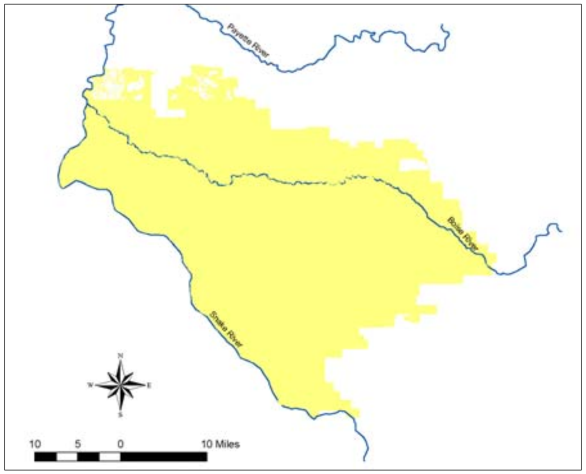


Figure 5–3. *[map]* **January, spatial distribution of ET.**

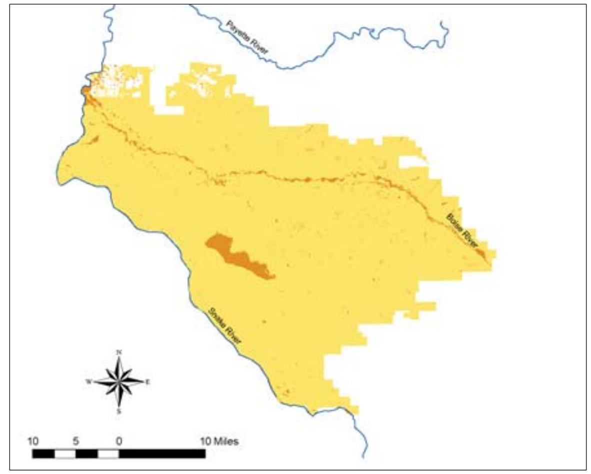
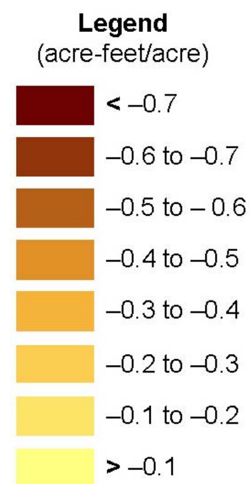


Figure 5–4. *[map]* **April, spatial distribution of ET.**



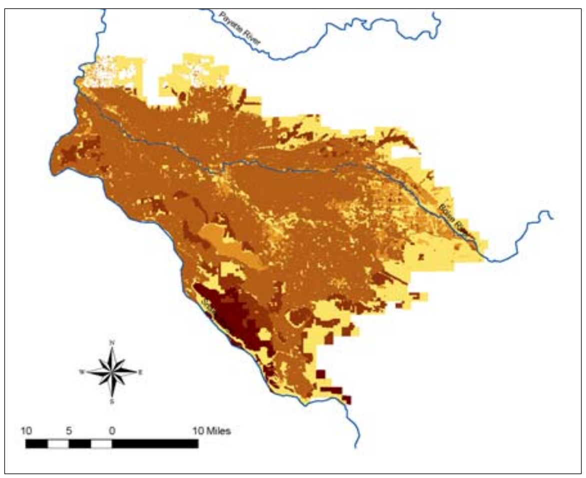


Figure 5–5. *[map]* **July, spatial distribution of ET.**

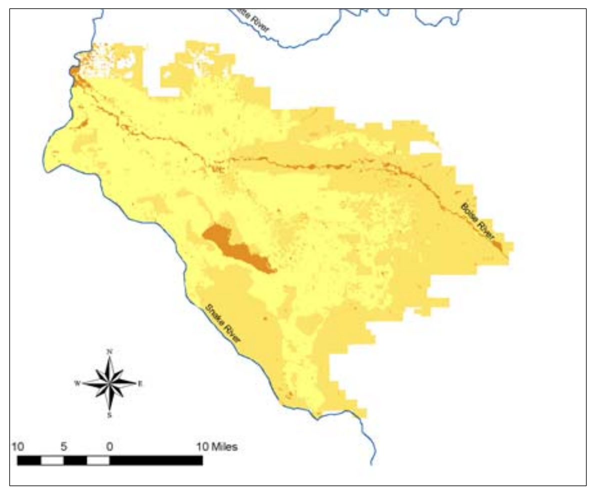


Figure 5–6. *[map]* **October, spatial distribution of ET.**

5.2. BOISE VALLEY NET GROUNDWATER RECHARGE-DISCHARGE DISTRIBUTION

The composite distribution of net groundwater recharge-discharge combines the net groundwater recharge-discharge distributions from all three GIS layers:

- **NetRec/DisAg** (from the *irrigated agricultural lands* GIS layer)
- **NetRec/DisDry, NetRec/DisLL**, and **NetRec/DisRv** (from the *dry lands and water-bodies* GIS layer)
- **NetRec/DisRcp** (from the *residential, commercial, and public-recreation lands* GIS layer).

Figure 5–7 shows the average monthly values of these net groundwater recharge-discharge budget components. During spring and summer months, irrigated agricultural lands account for virtually all of the net groundwater recharge occurring in the Boise Valley. During fall and winter months, they account for a considerable portion of the net groundwater discharge. Most groundwater recharge on agricultural lands is due to on-farm infiltration and canal seepage, and most groundwater discharge is due to groundwater return to drains.

Residential, commercial, and public-recreation lands are the locations of relatively small amounts of groundwater discharge throughout the year. Groundwater discharge is greatest on these lands during the summer months when outdoor water-use is greatest.

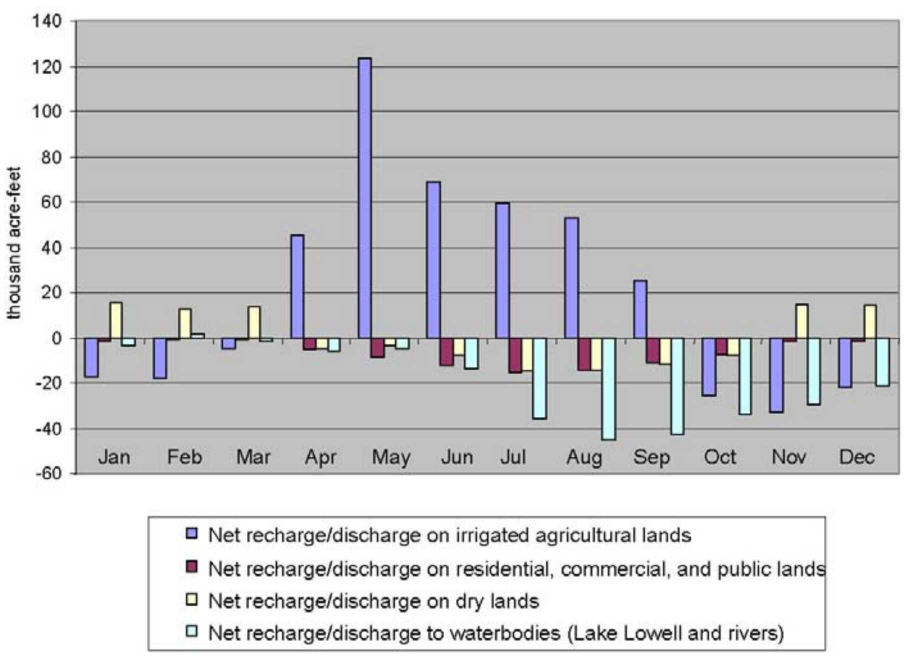


Figure 5–7. Average monthly net groundwater recharge-discharge on lands in all three budget categories.

Dry lands are the location of a small net recharge during winter months that is balanced by a small net discharge during summer months. Water-bodies (mainly the Boise River) are the location of groundwater discharge year-around. During late summer months, water-bodies are the principal locations for groundwater discharge, which occurs as base flow to rivers.

Figure 5–8 shows the composite monthly groundwater recharge and discharge that results from summing the individual components in Figure 5–7. From the composite viewpoint, net groundwater recharge in the Boise Valley is greatest in the spring (May is the principal month for recharge), and net groundwater discharge is greatest in the fall (October and November are the principal months for discharge). In contrast, July is one month during the irrigation season when, on average, groundwater recharge and discharge are nearly in balance.

Based on Figure 5–8, over the course of an average year and in the Boise Valley as a whole, there is an aquifer storage deficit of about 73 kaf. However, this relatively small deficit could be interpreted as a result of estimation error, indicating a near balance between groundwater recharge and discharge in the Boise Valley. This is possible given the magnitude of budget components such as irrigated lands ET (750 kaf), total drain return (1,140 kaf), and the uncertainty associated with estimating their values.

Indeed, a near balance between recharge and discharge could be expected as long as there is a substantial and widespread groundwater return to drains in the Boise Valley. Groundwater return to drains which average about 618 kaf per year (not including re-diverted drain return) can be thought of as excess groundwater recharge.

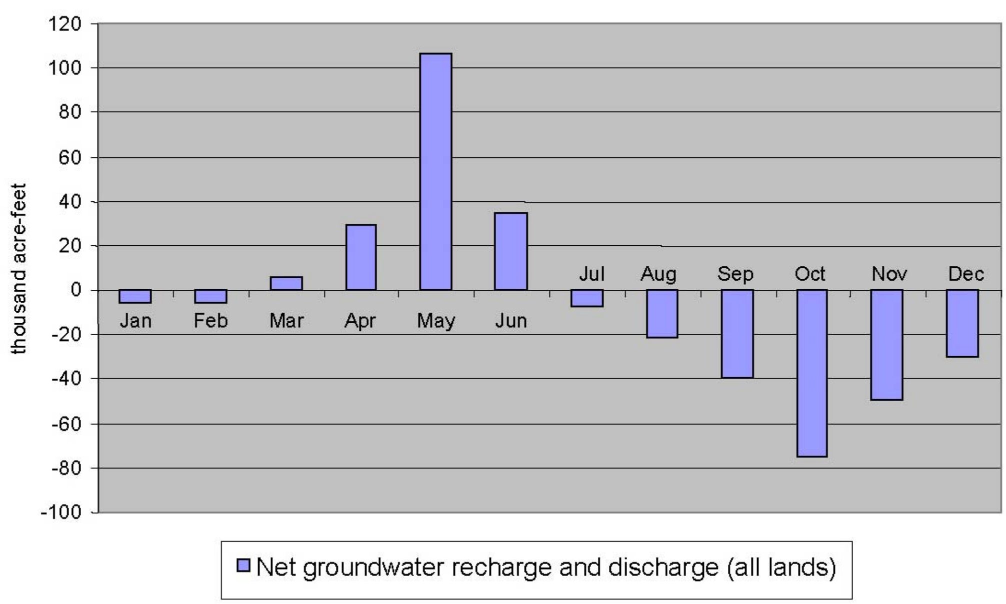


Figure 5–8. Average monthly net groundwater recharge-discharge, all lands.

5.3. SPATIAL DISTRIBUTION OF NEW GROUNDWATER RECHARGE-DISCHARGE

There may be a near balance between groundwater recharge and discharge conditions for the Boise Valley as a whole. Nevertheless, GIS budget data indicates that there is considerable spatial variability in the distribution of groundwater recharge and discharge conditions in the Boise Valley.

5.3.1. ANNUAL DISTRIBUTION

Figure 5–9 combines three spatial distributions: net groundwater recharge-discharge on irrigated agricultural lands (Figure 2–9); dry lands and water-bodies (Figure 3–6); and residential, commercial, and public-recreation lands (Figure 4–11). As before, gradations of red (negative values) denote areas where groundwater discharge exceeds recharge on an annual basis (net discharge areas); gradations of green (positive values) denote areas where groundwater recharge exceeds discharge on an annual basis (net recharge areas).

On an annual basis, Figure 5–9 presents a fairly complex picture of net groundwater recharge and discharge conditions in the Boise Valley. In general, however, the vast majority of aquifer recharge and discharge occurs on irrigated agricultural lands. Major recharge areas are associated with surface-water irrigated lands and most are located in the eastern half of the valley. Major discharge areas are associated with agricultural lands located near the Boise River, and groundwater irrigated lands.

Significant groundwater discharge also occurs along channels of the Boise River and beneath Lake Lowell. On an annual basis, all of the Boise River channels between Glenwood Bridge and the Snake River are net groundwater discharge areas.

By comparison, net groundwater recharge- discharge on most residential, commercial, and public-recreation lands is quite small. On an annual basis, only a few hundredths of a foot of net recharge or discharge occurs on these lands. The major exceptions are the land parcels associated with municipal supply wells where groundwater discharge in urban centers is concentrated. Net groundwater recharge and discharge on dry lands is also small. Due to differences in precipitation rates, some dry lands are net recharge areas and some are net discharge areas.

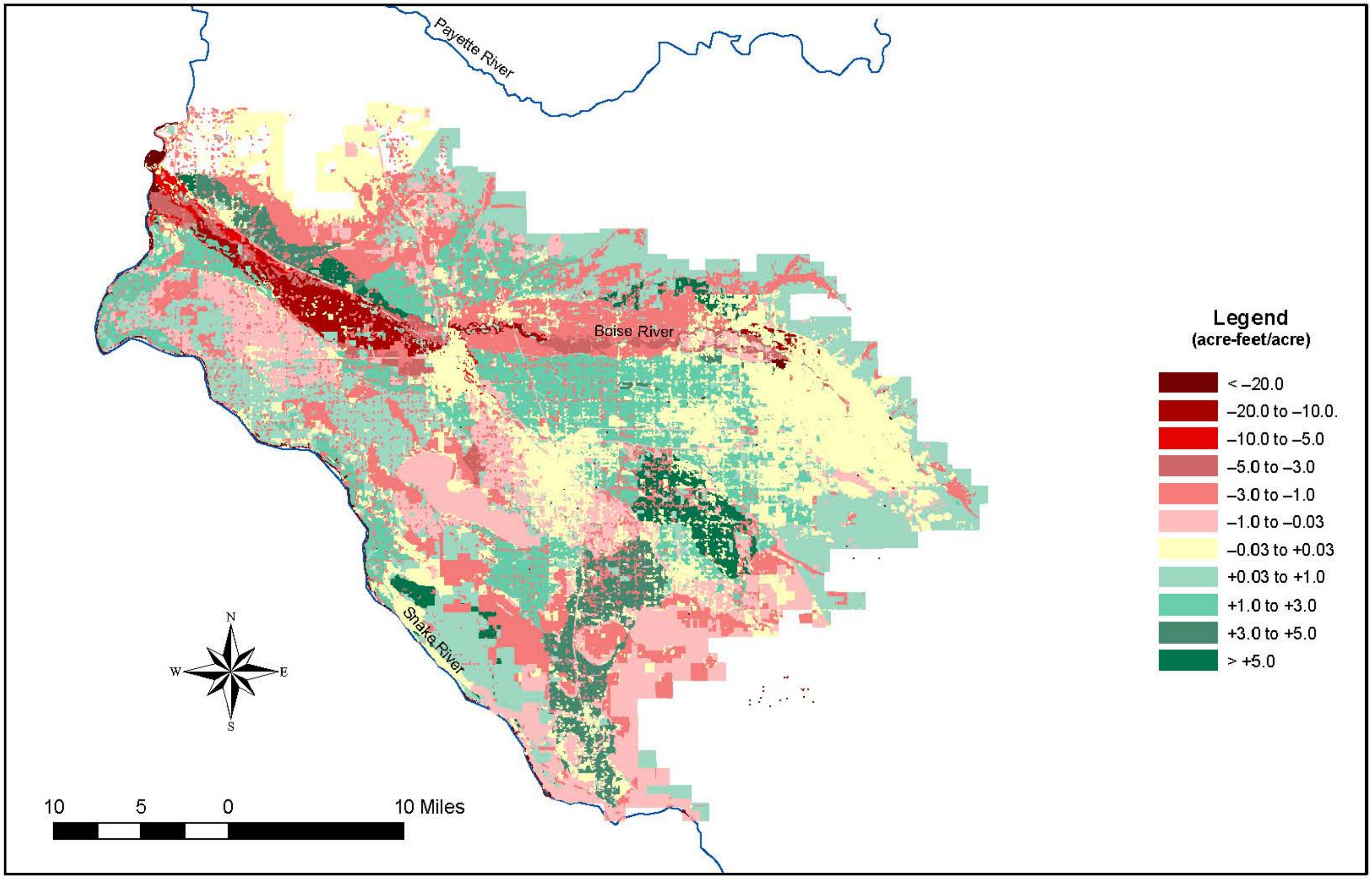


Figure 5–9. *[map]* **Average annual distribution of net groundwater recharge-discharge.**

5.3.2. Monthly distributions

Over the course of a year, most land classes in the Boise Valley alternate between being net groundwater recharge areas and net groundwater discharge areas. Surface-water irrigated agricultural lands are recharge areas during summer months and discharge areas during winter months; groundwater irrigated lands show the opposite pattern.

Dry lands and most water-bodies (including Lake Lowell and the Glenwood-Middleton reach of the Boise River), are groundwater recharge areas during winter months and groundwater discharge areas during summer months. Residential lands located outside of urban centers are also net discharge areas during summer months and net recharge areas during winter months. The exceptions are residential lands located within urban centers, which tend to be either recharge or discharge areas year-around.

Month-by-month, monthly distribution of net groundwater recharge-discharge in the Boise Valley is displayed in twelve "thumbnail" illustrations (**Figure 5–10** through **Figure 5–20**) on the next three pages. Each figure is also shown as a full-page illustration in the PDF version of Attachment B. The monthly sequence of figures begins with April, at the start of the irrigation season. This is because most of the month-to-month variability in groundwater recharge and discharge is the result of seasonal variations in *irrigated agricultural land* budget components.

Figure 5–10 (April) and Figure 5–11 (May) show the rapid expansion of groundwater recharge on irrigated agricultural lands that occurs at the beginning of the irrigation season. On average, May is the principle month for groundwater recharge on agricultural lands in the Boise Valley.

At the same time that farm deliveries are increasing, ET is increasing, with the result that on-farm infiltration is decreasing. Figure 5–12 (June) shows that the distribution of net groundwater recharge on irrigated agricultural lands grows smaller as a result of increased ET and groundwater pumping.

The increase in on-farm infiltration and canal seepage that occurs early in the irrigation season also elicits a corresponding increase in the groundwater component of drain return and base flow discharge to the Boise River, later in the season. This is evident in Figures 5-13, 5-14, and 5-15 (July, August, and September), which show an expanding area of net groundwater discharge on Boise River channels and irrigated agricultural lands.

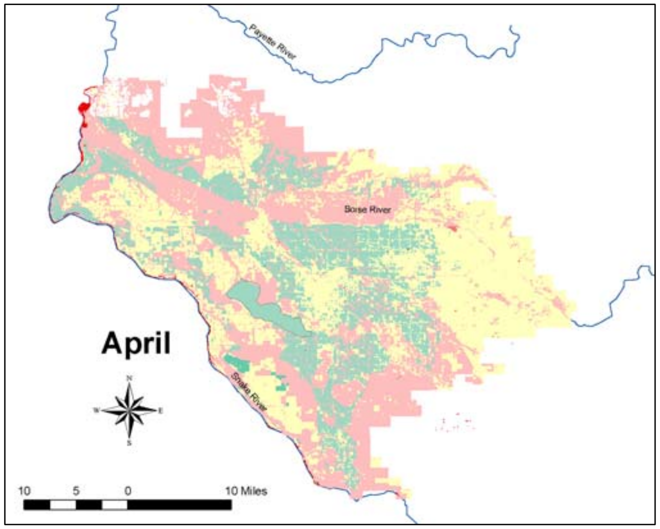


Figure 5–10. *[map]* **April, net groundwater recharge-discharge.**

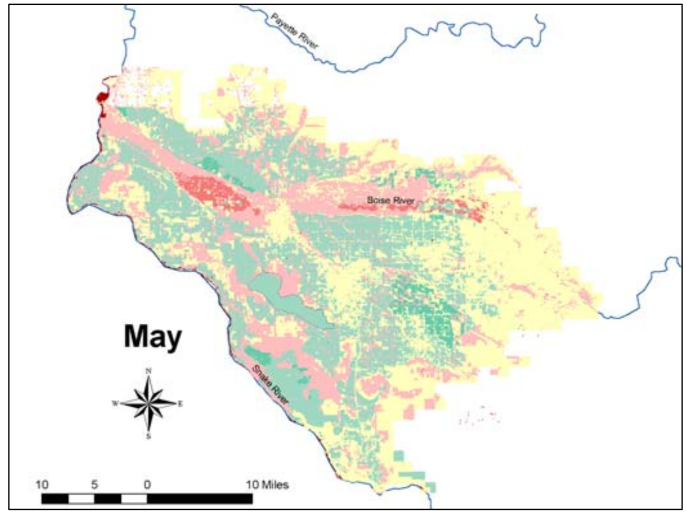
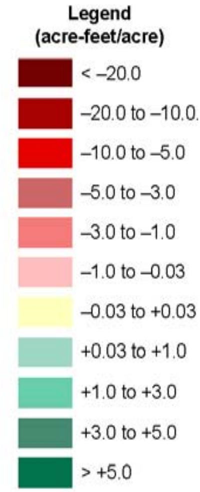


Figure 5–11. *[map]* **May, net groundwater recharge-discharge.**



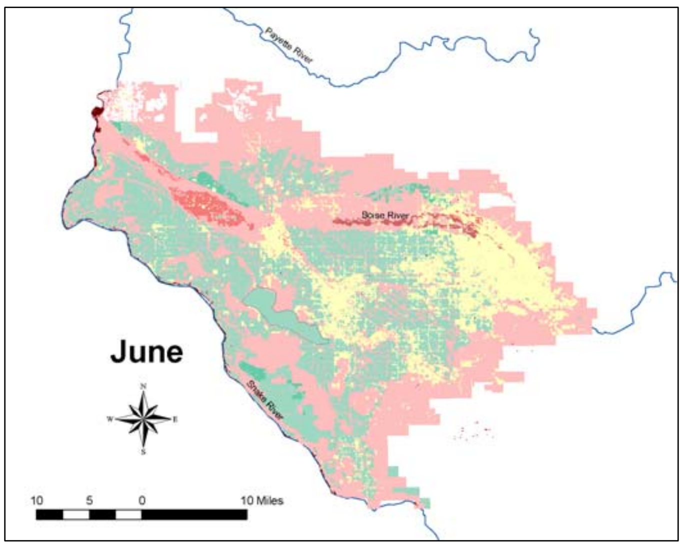


Figure 5–12. *[map]* **June, net groundwater recharge-discharge.**

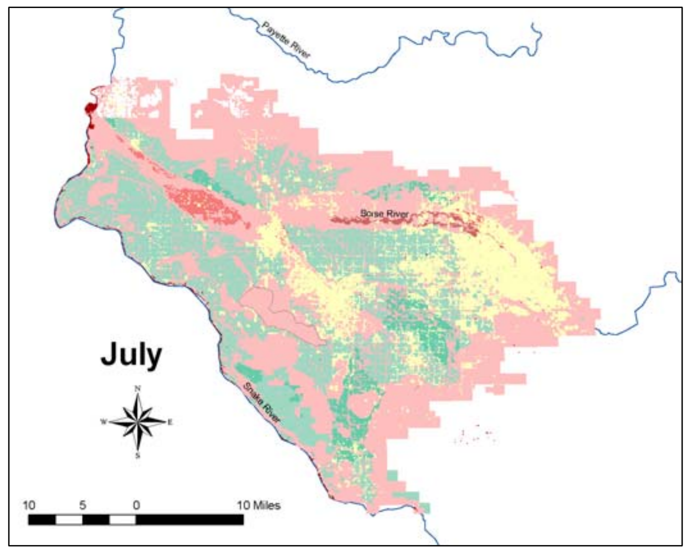


Figure 5–13. *[map]* **July, net groundwater recharge-discharge.**

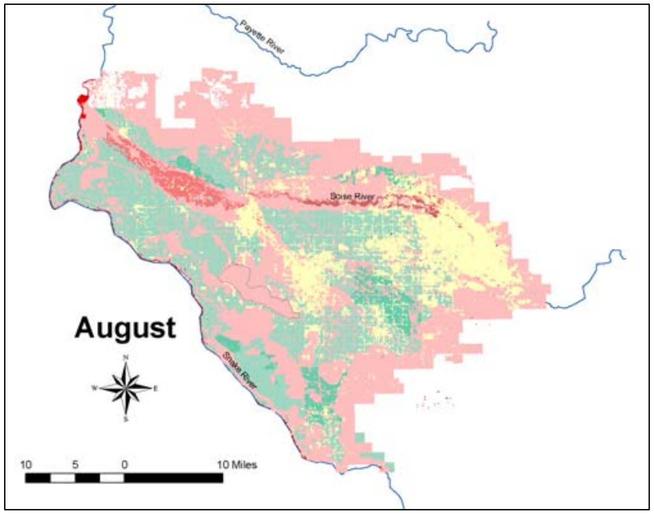


Figure 5–15. *[map]* **August, net groundwater recharge-discharge.**

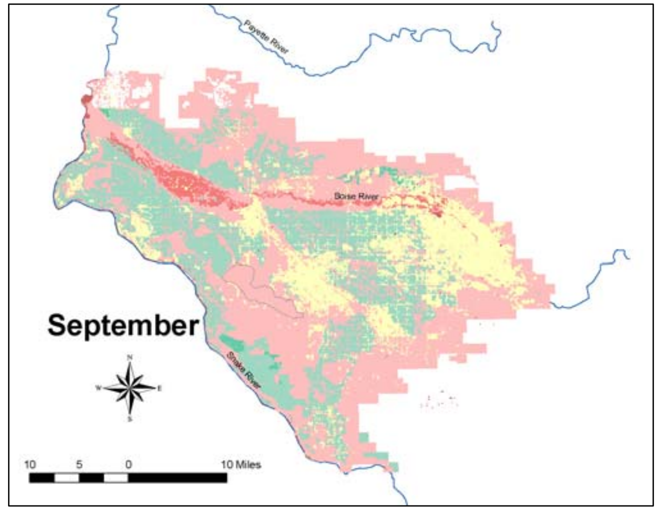
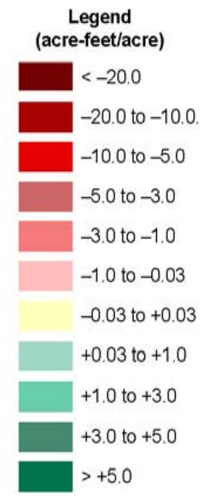


Figure 5–14. *[map]* **September, net groundwater recharge-discharge.**



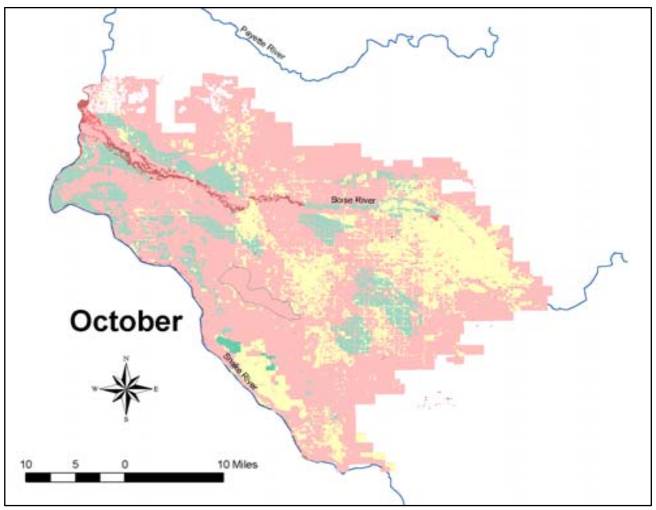


Figure 5–16. *[map]* **October, net groundwater recharge-discharge.**

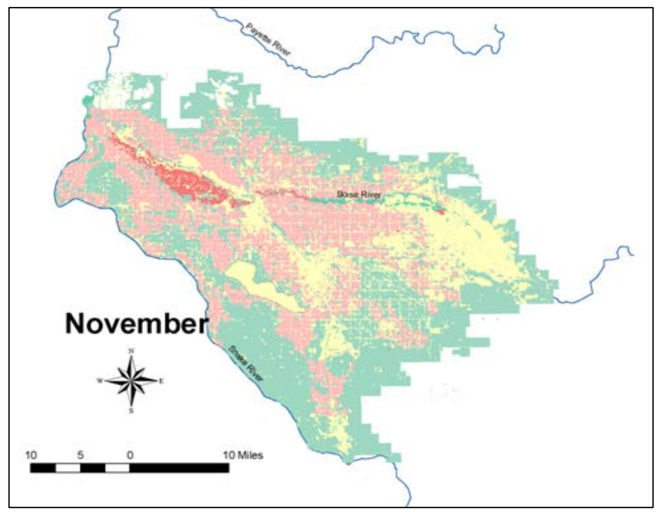


Figure 5–17. *[map]* **November, net groundwater recharge-discharge.**

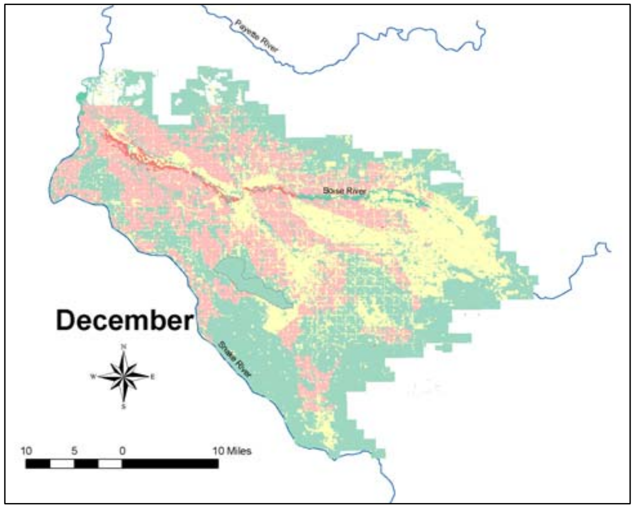


Figure 5–19. *[map]* **December, net groundwater recharge-discharge.**

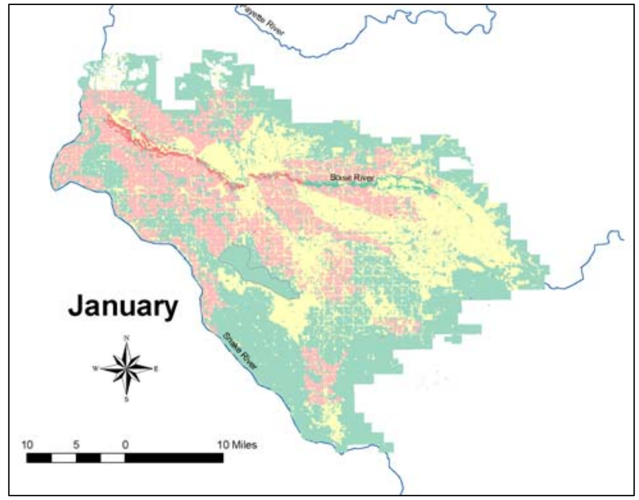
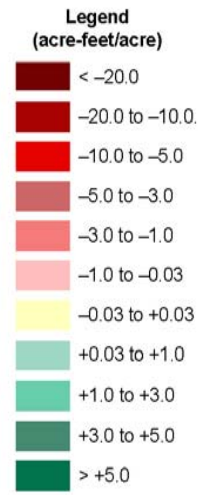


Figure 5–18. *[map]* **January, net groundwater recharge-discharge.**



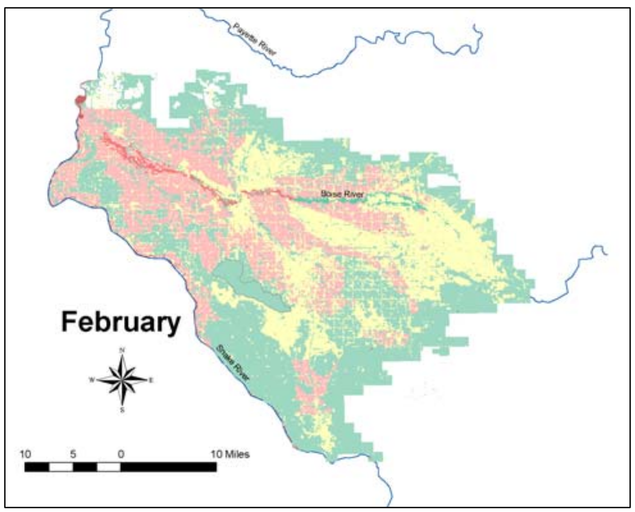


Figure 5–21. *[map]* **February, net groundwater recharge-discharge.**

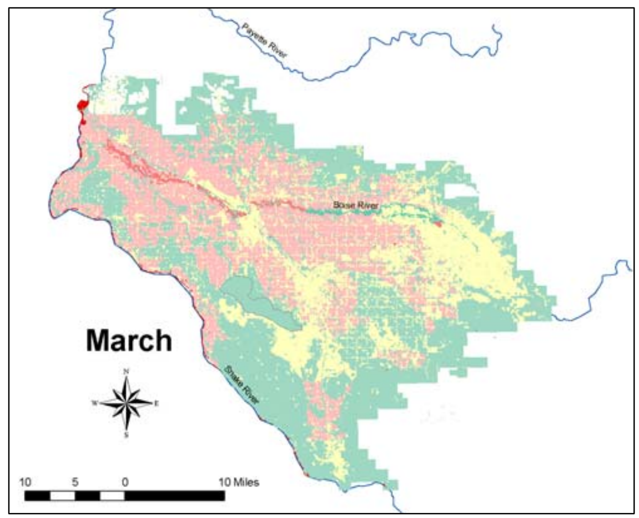


Figure 5–20. *[map]* **March, net groundwater recharge-discharge.**

The end of the irrigation season in October causes most irrigated agricultural lands to become net groundwater discharge areas almost immediately. This is apparent in Figure 5–16. The abrupt switch from recharge area to discharge area is a consequence of the groundwater discharge to drains that continues to occur on these lands after diversions have ended. The exceptions are surface-water irrigated lands that exhibit (on a year-around basis) either a comparatively small groundwater component of drain return or a somewhat higher drain return component of farm delivery. The abrupt decline in groundwater recharge in October also affects reach gains in the Boise River and drain discharge in the adjacent wetland areas. Gains in the Middleton-Parma reach decrease, as does drain discharge in the nearby Dixie Slough. The Glenwood-Middleton reach switches from a gaining to a losing reach.

The shutdown of groundwater pumping at the end of the irrigation season, combined with increased precipitation and reduced ET, results in an expansion of net groundwater recharge areas in the Boise Valley. Figure 5–17 (November) shows that during this month net groundwater recharge occurs mainly on dry lands and on agricultural lands that were groundwater irrigated. The absence of groundwater pumping and the extra recharge also induces a small increase in the net groundwater discharge from drains in the Dixie Slough area. Also during November, Lake Lowell begins a slow transition from net groundwater discharge area to net groundwater recharge area.

The pattern of net groundwater recharge and discharge remains fairly constant from December through March (Figure 5–19 through Figure 5–20). Net groundwater recharge occurs on most dry lands during winter months. As a consequence of continuing groundwater return to drains, most surface-water irrigated agricultural lands remain net groundwater discharge areas, although groundwater discharge to drains gradually decreases between December and March. Due to generally higher lake levels and lower groundwater elevations at this time of year, Lake Lowell becomes a net groundwater recharge area. The Glenwood-Middleton reach also remains a recharge area during the winter months.

The winter time pattern of net groundwater recharge and discharge ends in April (Figure 5–10) when farm deliveries begin again. The onset of on-farm infiltration and canal seepage in April has an almost immediate impact on base flow in the Glenwood-Middleton reach of the Boise River, which switches from being a groundwater recharge area (losing reach) to a groundwater discharge area (gaining reach). However, groundwater discharge (reach gain) in the Middleton-Parma reach continues to decline through July and does not begin to increase again until August (Figure 5–15). The three-to-four-month lag is due to the fact that most groundwater that is discharged to the river in the Middleton-Parma reach has a comparatively long subsurface flow path. In contrast, groundwater flow paths to the Glenwood-Middleton reach are generally shorter, so the lag between recharge and discharge is shorter.

The spatial distribution of groundwater recharge and discharge on residential, commercial and public-recreation lands appears to change little from month to month over the course of a year. This is true for the majority of lands located in urban centers since all of the groundwater discharge in these areas is concentrated at the location of a few municipal supply wells. The month-to-month discharge from supply wells is large, but because they are represented by only one-acre polygons it is not apparent in net groundwater recharge-discharge GIS data when displayed at this scale. Outside of urban centers, most residential lands are discharge areas between April and October, due to groundwater pumping for outdoor consumptive use. These rural lands are recharge areas during the remainder of the year.

6. FUTURE APPLICATIONS OF THE BOISE VALLEY WATER BUDGET

It is anticipated that one of the principal future uses of the *Lower Boise Valley Distributed Parameter Water Budget* will be to provide data that can used to develop more detailed hydrologic models of Boise Valley water use and water distribution.

However as previously noted, the GIS water budget data base contains water availability and water use data that is based largely on historical averages. The *irrigated agricultural lands* budget category is based on water-use data for the period 1967-1997; the *residential, commercial, and public-recreation lands* budget category is based largely on DCMI water-use data from the period 1995-2001. In addition, all three GIS data layers are based on a 1994 Boise Valley land-use classification. An updated map of Boise Valley land use would no doubt show a substantially different distribution of agricultural lands, dry lands, and urban and residential lands.

In order to be useful for future hydrologic model development, an efficient procedure for updating the GIS data base to reflect future land use distributions is essential. In this regard, recall that all of the budget components in GIS data layers are developed in units (acre-feet per acre) that are independent of acreage. One should also recall that budget components are assigned to land parcels based on there locations relative to geographic feature types.

For the *irrigated agricultural land* GIS layer, budget components and budget values are assigned to land parcels based on their location with respect to feature types that include irrigation district boundaries, BPBOC division boundaries, drainage areas, sprinkler/gravity irrigation classes, and precipitation zones (Table 2-1).

Similarly, budget components and budget values in the *residential, commercial, and public-recreation land* GIS layer are assigned to land parcels based on their locations relative to feature types that include residential, commercial-industrial, public land, TAZ, and dual-use classification (Table 3-1). The same is true for budget components and values in the *dry lands and water-bodies* GIS layer (Table 4-2).

Updating the Boise Valley water budget GIS data base to reflect changes in land-use involves reassigning land parcels to different GIS budget layers and then determining their locations relative to the geographic feature types of that layer.

This can be accomplished using GIS tools, by overlaying a new land-use classification on the current GIS budget layers, and assigning current layer feature types to the new land-use polygons based on location. New *irrigated agricultural lands* polygons would acquire the feature types of Table 2-1, including irrigation district, BPBOC division, drainage area, sprinkler/gravity irrigation class, and precipitation zone. New *residential, commercial, and public-recreation lands* polygons would acquire the feature types of Table 4-1.

Periodic updating of the *Lower Boise Valley Distributed Parameter Water Budget* data base following updates of Boise Valley land use classification will enable its continued use in the future, as a data resource for developing regional and sub-regional hydrologic models of the Boise Valley.

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ATTACHMENTS

Attachment A. Tables of budget-component descriptors

Attachment B. GIS-informed spatial figures (maps) from Chapter 5 in larger scale (8½ x 11” landscape). In PDF version on CD-ROM only.

Attachment C. CD-ROM containing Lower Boise Valley GIS water budget data base and shareware, and this report in PDF. [Inside back cover.]

ATTACHMENT A

Table A-1. Equations relating to water budget components.		
Eq.	**Description**	**Equation**
2-1	Relationship between major surface-water and groundwater components for irrigated agricultural lands.	**Δ AqStor = NetRivDivr + PrecipAg – TotalETAg – NetDrnRet – BaseFlo**
2-2	Relationship between seven principal surface-water budget components	**NetRivDivr + PrecipAg + LowGain – CanSeep – OnFrmInfl – SurfETAg – SurfDrnRet = 0**
2-3	Relationship between seven principal groundwater budget components	**Δ AqStor = OnFrmInfl + CanSeep – LowGain – GwPmpAg – GwDrnRet – BaseFlo**
2-4	Relationship between net river diversion, total diversion, and re-diverted drain return.	**NetRivDivr = TotalDivr – TotalReDrnRet**
2-5	Relationship between total farm delivery, net river diversion, re-diverted drain return, and canal loss.	**TotalFrmDel = NetRivDivr + TotalReDrnRet – CanLoss + LowGain**
2-6	Relationship between net farm delivery, total farm delivery and re-diverted drain return.	**NetFrmDel = TotalFrmDel – TotalReDrnRet**
2-7	Total re-diverted drain return, irrigation district, and drainage area components of re-diverted drain return.	**TotalReDrnRet = ReIrrRet + ReDrnRet**
2-8	Total irrigated agricultural lands ET as the sum of the ET components.	**TotalETAg = SurfIrrET + GwIrrET + CanET + LowET**
2-9	Groundwater withdrawal by private groundwater irrigation districts equaling the difference between ET and precipitation.	**GwPmpAg** = **GwIrrET – GwPrecip** *[during irrigation season]* **GwPmpAg** = **0** *[during winter months]*
2-10	Regression model calculating return flow for unmeasured individual drain areas.	**AreaDrnRet = 0.253 + 0.537 * AreaFrmDel – 0.639 * AreaIrrET**
2-11	Net drain return to rivers as the difference between total drain return and re-diverted drain returns.	**NetDrnRet = TotalDrnRet – ReDrnRet – ReIrrRet**

Table A-1. Equations relating to water budget components.		
Eq.	**Description**	**Equation**
2-12	Net drain return to rivers as the sum of surface-water and groundwater components.	**NetDrnRet = SurfDrnRet + GwDrnRe**t
2-13	On-farm infiltration on surface-water irrigated lands.	**OnFrmInfl = TotalFrmDel + PrecipAg – SurfIrrET – SurfDrnRet**
2-14	Net groundwater recharge-discharge on irrigated agricultural lands.	**NetRec/DisAg = OnFrmInfl + CanSeep – GwPmpAg – GwDrnRet**
2-15	The change in aquifer storage attributed to irrigation activity as the difference between net groundwater recharge-discharge and base flow to rivers.	**Δ AqStor = NetRec/DisAg – BaseFlo**
3-1	Net groundwater recharge-discharge on dry-lands classes..	**NetRec/DisDry = PrecipDry – ETDry**
3-2	Boise River and Snake River reach base flow.	**BaseFlo = NetRec/DisRv = TotalRchGn/Los + TotalRchDivr – TotalRchDrnRet – RivRchGn**
3-3	Lake Lowell gains and losses.	**LowGain = NetRec/DisLL = LowIn + LowDrnRet – LowOut – LowET – Δ LowStor**
4-1	Net groundwater recharge-discharge on residential, commercial, and public-recreation lands.	**NetRec/DisRcp = InfilRcp – GwPmpRcp**

Irrigated Agricultural Lands Budget

Table A-2. Attributes for *irrigated agricultural lands* GIS budget layer.	
Identifier	**Attribute description**
ACRES	acreage of each agricultural lands polygon
AREA	area of each irrigated agricultural land-use polygon (in square meters)
CONCAT	concatenated variable identifying unique groups of five previous agricultural land classifications
DISTRICT	irrigation district
DIVISION	Boise Project Board of Control, Arrowrock divisions
DRAINAREA	surface-water drain area
IRRGTYPE	sprinkler-irrigation or gravity-irrigated agricultural land
STATION	precipitation gaging station

Residential, Commercial, and Public Lands Budget

Table A-3. Attributes for *residential, commercial, and public lands* GIS budget layer.	
Identifier	**Attribute description**
ACRES	acreage of each residential, commercial, and public land-use polygon
AREA	area of each residential, commercial, and public land-use polygon (in square meters)
CITY	urban or non-urban land designation (blank indicates non-urban)
CONCAT	concatenated variable indicating TAZ (urban or rural) and land use
CONCATLU	concatenated variable indicating LANDUSE, dual use, and source of consumptive-use data
DUAL_USE	variable indicating whether surface water is available for outdoor use
LAND_CATAG	aggregated land-use categories (includes a well category)
LANDUSE	land-use designation (municipal supply wells are included as a land-use class)
TAZ_CI_ACR	total acres of commercial/industrial land in this TAZ
TAZ_PU_ACR	total acres of public/recreational land in this TAZ
TAZ_RE_ACR	total acres of residential land in this TAZ
TZONES	Traffic Analysis Zone number (1995)
URBAN_TAZ	variable indicating whether polygon is located in urban TAZ (yes) or rural TAZ (no)
WELL_DATA	variable indicating whether consumptive use is based on well records (yes) or DCMI water-use analysis (no).

Residential, Commercial, and Public Lands Budget (con't.)

Table A-4. Monthly distribution of outdoor consumptive water use from SEBAL (acre-feet per acre).

Type of use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	annual
Residential – old urban/high density	0.000	0.000	0.000	0.180	0.270	0.382	0.494	0.427	0.337	0.157	0.000	0.000	2.247
Residential – rural	0.000	0.000	0.000	0.172	0.259	0.367	0.474	0.410	0.323	0.151	0.000	0.000	2.156
Residential – farmstead	0.000	0.000	0.000	0.160	0.239	0.339	0.439	0.379	0.299	0.140	0.000	0.000	1.995
Residential – new subdivision	0.000	0.000	0.000	0.159	0.239	0.338	0.437	0.378	0.298	0.139	0.000	0.000	1.988
Commercial-Industrial	0.000	0.000	0.000	0.162	0.174	0.187	0.187	0.187	0.174	0.174	0.000	0.000	1.246
Public lands	0.000	0.000	0.000	0.144	0.216	0.306	0.396	0.342	0.270	0.126	0.000	0.000	1.799
Recreation areas	0.000	0.000	0.000	0.217	0.325	0.461	0.596	0.515	0.406	0.190	0.000	0.000	2.709

Table A-5. Proportional monthly distribution of indoor residential and commercial-industrial consumptive water use in urban TAZ.

Type of use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	annual
Residential within urban TAZ	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.08	0.08	0.08	1.00
Commercial-Industrial within urban TAZ	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.08	0.08	0.08	1.00

Table A-6. Proportional monthly distribution of of groundwater infiltration. 1/

type of use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	annual
Residential, commercial-industrial, and public-recreation lands	0.06	0.05	0.07	0.11	0.15	0.10	0.10	0.12	0.08	0.05	0.05	0.06	1.00

1/ at rate of 0.02 acre-feet per acre

Dry Lands and Water-Bodies Budget

Table A-7. Attributes for *dry lands and water-bodies* GIS budget layer.

Identifier	Attribute description
LANDUSE	Land-use designation
LAND_CATAG	Aggregated land use categories
WATR_BODY	Water-body designation for Boise River, Snake River, or Lake Lowell polygon
STATION	Precipitation station
AREA	Area of each Dry Lands and Water-Bodies polygon in square meters.
ACRES	Acreage of each Dry Lands and Water-Bodies polygon.

Table A-8. Proportional monthly distribution of dry-land infiltration.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	annual
Rangeland, barren land, idle or abandoned agricultural land	0.19	0.15	0.16	0.15	0	0	0	0	0	0	0.18	0.17	1.00

Four-letter identifiers used in GIS water budget

Table A-9. Attribute identifiers (ID) for *irrigated agricultural lands* budget. (1) (2)

Attribute ID	Attribute description
ARXD	Groundwater recharge/discharge due to on-farm infiltration and groundwater withdrawals for irrigation.
CLOS	Canal loss due to seepage and canal ET prior to farm delivery
DIVR	River diversions from the Boise River, Snake River, or Payette River.
ETSW	Evapotranspiration (ET) on surface-water irrigated agricultural lands only
EVTP	Total agricultural lands ET, including crop ET, canal ET, and Lake Lowell ET
FDEX	Farm delivery from diversions excluding re-diverted drain returns
FDIN	Farm delivery from diversions and re-diverted drain returns
FDOD	Component of farm delivery that is re-diverted drain returns between irrigation districts in different drain areas
FDOI	Component of farm delivery that is re-diverted drain returns between irrigation districts within the same drain area
FDRT	Total drain return component of farm delivery (**FDOI + FDOD**)
GWDR	Groundwater component of total drain return
GWPU	Groundwater withdrawals for primary and supplemental groundwater irrigation
NARD	Net groundwater recharge/discharge due to farm infiltration and canal seepage, groundwater withdrawals for irrigation, and groundwater return to drains
OFIN	On-farm groundwater infiltration, includes infiltration that returns to drains within the same year
PRCP	Precipitation on agricultural lands
SWDR	Surface-water component of total drain return
TODR	Total drain returns (**GWDR+SWDR**) from drain areas; returns between drain areas are included; this is not net drain return to rivers; net drain return to rivers is not spatially distributed.

(1) Within GIS Water Budget, numbers following attribute IDs denote monthly averages. The suffix ANN preceding attribute ID denotes annual averages. All units are acre-feet per acre (feet).

(2) Joins all *irrigated agricultural lands* budget category attributes to the *irrigated agricultural lands* GIS layer using the CONCAT field.

Table A-10. Attribute identifiers (ID) for *dry lands and water-bodies* budgets. (1) (2)	
Attribute ID	**Attribute description**
NARD	Net groundwater recharge and discharge due to dry-land infiltration, reservoir seepage, and river base flows
PRCP	Precipitation on rangeland, barren land, and idle agricultural land
RLET	Evapotranspiration (ET) on rangeland, barren land, and idle agricultural land

(1) Within GIS Water Budget, numbers following attribute IDs denote monthly averages; ANN preceding attribute ID denotes annual averages. All units are acre-feet per acre (feet)

(2) Joins all *Dry-lands and Water-Bodies* budget category attributes to the *Dry lands and Water-Bodies* GIS layer using the JOIN field.

Table A-11. Attribute identifiers (ID) for *residential, commercial, and public lands* budget. (1)	
Attribute ID	**Attribute description**
CGWW (2)	consumptive groundwater withdrawals (indoor and outdoor use in urban TAZ and outdoor use in rural TAZ) (associated with wells in urban TAZ)
GWIN (3)	uniform shallow groundwater infiltration on all DCMI lands
IDCU (4)	indoor consumptive water use on residential, commercial/industrial, and public lands
NARD (5)	net groundwater recharge/discharge due to groundwater withdrawals and groundwater infiltration on all residential, commercial and public lands
ODCU (6)	outdoor consumptive water use on all residential, commercial and public lands

(1) Within GIS Water Budget, numbers following attribute IDs denote monthly averages; suffix ANN preceding attribute ID denotes annual averages. All units are acre-feet per acre (feet).

(2) Joins the outdoor consumptive use budget attribute and the consumptive groundwater withdrawals attribute in the *residential, commercial and public lands* budget category to the *residential, commercial and public lands* GIS layer using the LANDUSE field.

(3) Joins the groundwater infiltration budget attribute in the *residential, commercial and public lands* budget category to the *residential, commercial and public lands* GIS layer using the ALL (annual) field.

(4) Joins the indoor consumptive use budget attribute in the *residential, commercial and public lands* budget category to the *residential, commercial and public lands* GIS layer using the CONCAT field.

(5) Joins the net groundwater recharge-discharge budget attribute in the *residential, commercial and public lands* budget category to the *residential, commercial and public lands* GIS layer using the CONCATLU field.

ATTACHMENT B

FROM CHAPTER 5 - GIS-INFORMED SPATIAL FIGURES (MAPS) IN LARGER SCALE AND IN LANDSCAPE FORMAT

[only in PDF version on CD-ROM]

Section 5.1. Boise Valley ET Distribution

Section 5.3.2. Monthly Distribution [of groundwater recharge-discharge]

ATTACHMENT C

PDF VERSION

***A DISTRIBUTED PARAMETER WATER BUDGET DATA BASE FOR THE LOWER BOISE VALLEY* (JANUARY 2007)**

ARCMAP 9.1 GIS FILES

ARCMAP 9.1 MXD FILE

ARCMAP 9.1 LAYER FILES

BOISE VALLEY BUDGET GIS DATA FILES

- **Irrigated lands budget**
- **Dry lands and water-bodies budget**
- **Residential, commercial, public lands budget**

EXCEL SPREADSHEET FILES

PRIMARY BOISE VALLEY BUDGET SPREADSHEETS

- **Composite budget**
- **Irrigated lands budget**
- **Dry lands and water-bodies budget**
- **Residential, commercial, public lands budget**

SECONDARY BUDGET SPREADSHEETS AND DATA

- **Irrigated lands data**
- **Crop distribution data**

MAPWINDOW GIS PROJECT FILES

ATTACHMENT B.

FROM CHAPTER 5 - GIS-INFORMED SPATIAL FIGURES (MAPS) IN LARGER SCALE AND IN LANDSCAPE FORMAT

[only in PDF version on CD-ROM]

Section 5.1. Boise Valley ET Distribution

Subsection 5.3.2. Monthly Distribution [of groundwater recharge-discharge]

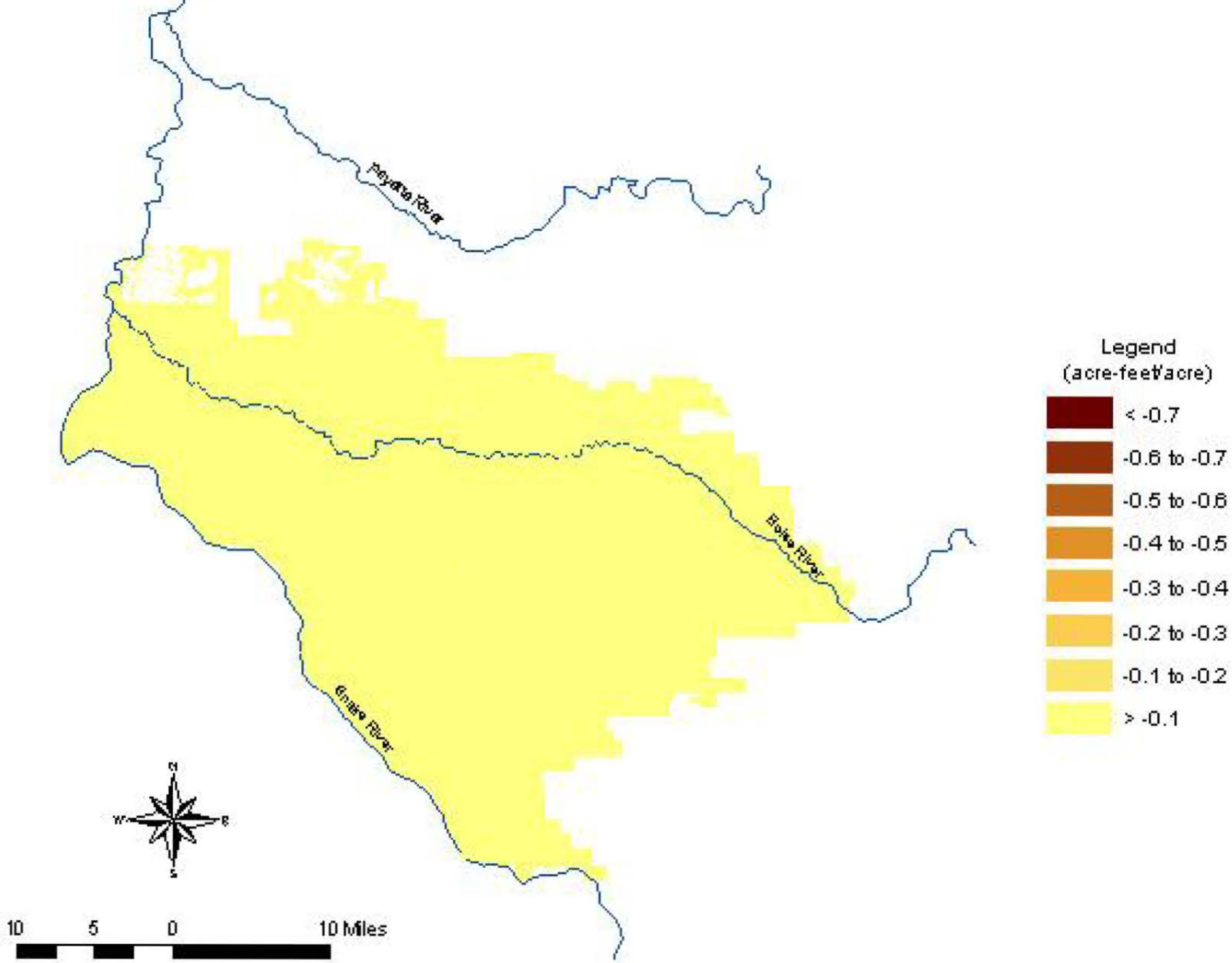

Figure 5-3. January, Boise Valley ET Distribution

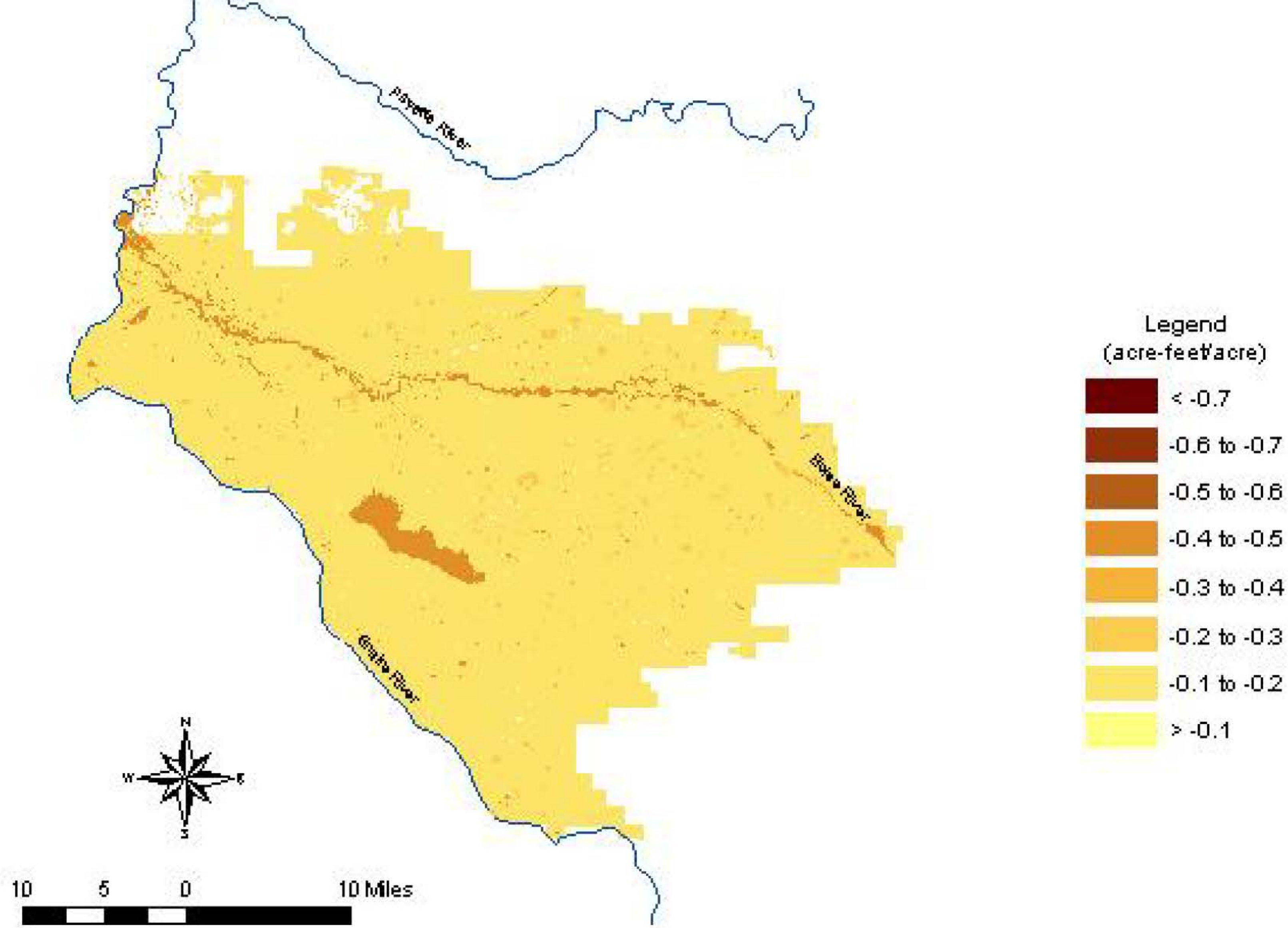

Figure 5-4. April, Boise Valley ET Distribution

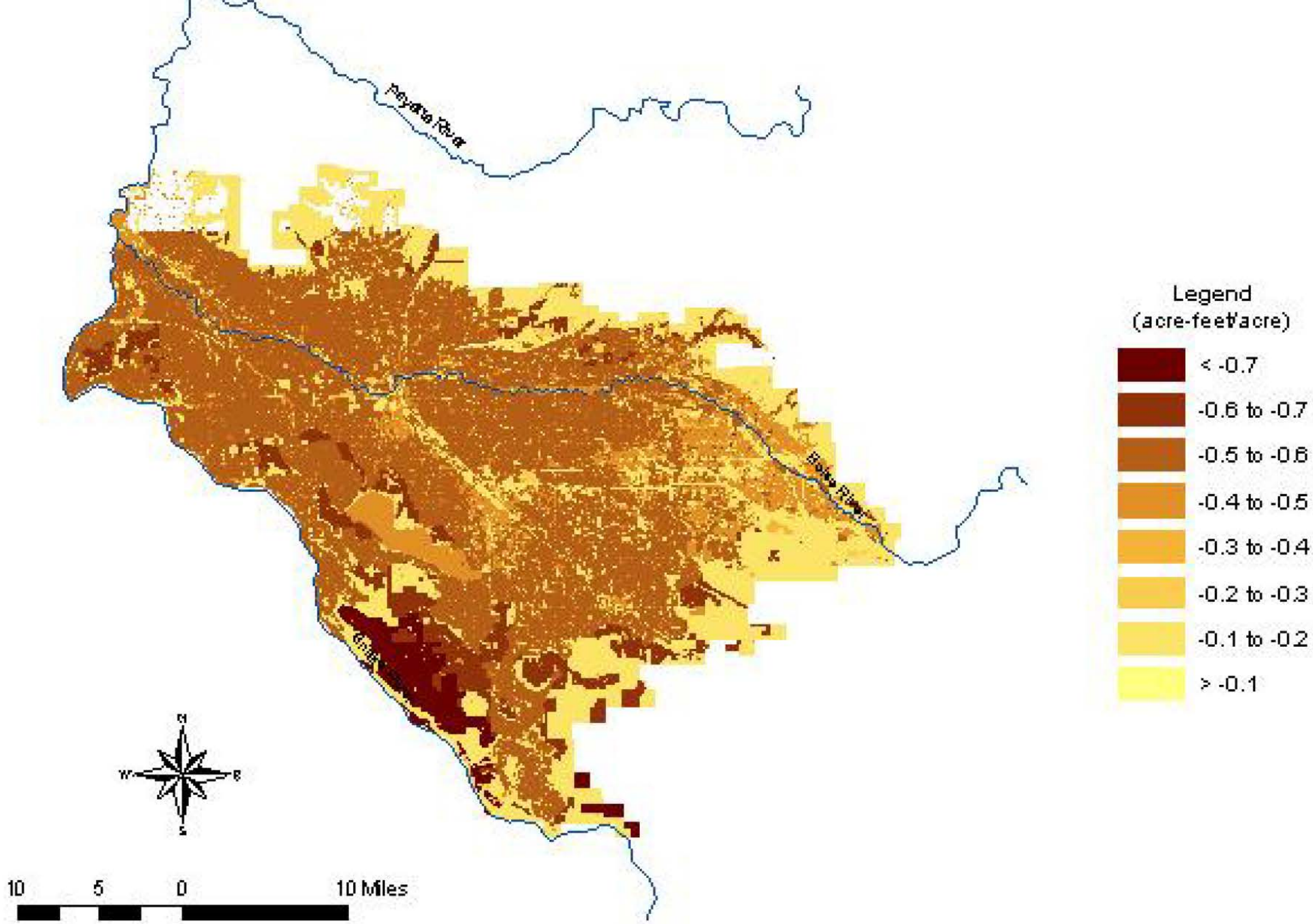

Figure 5-5. July, Boise Valley ET Distribution

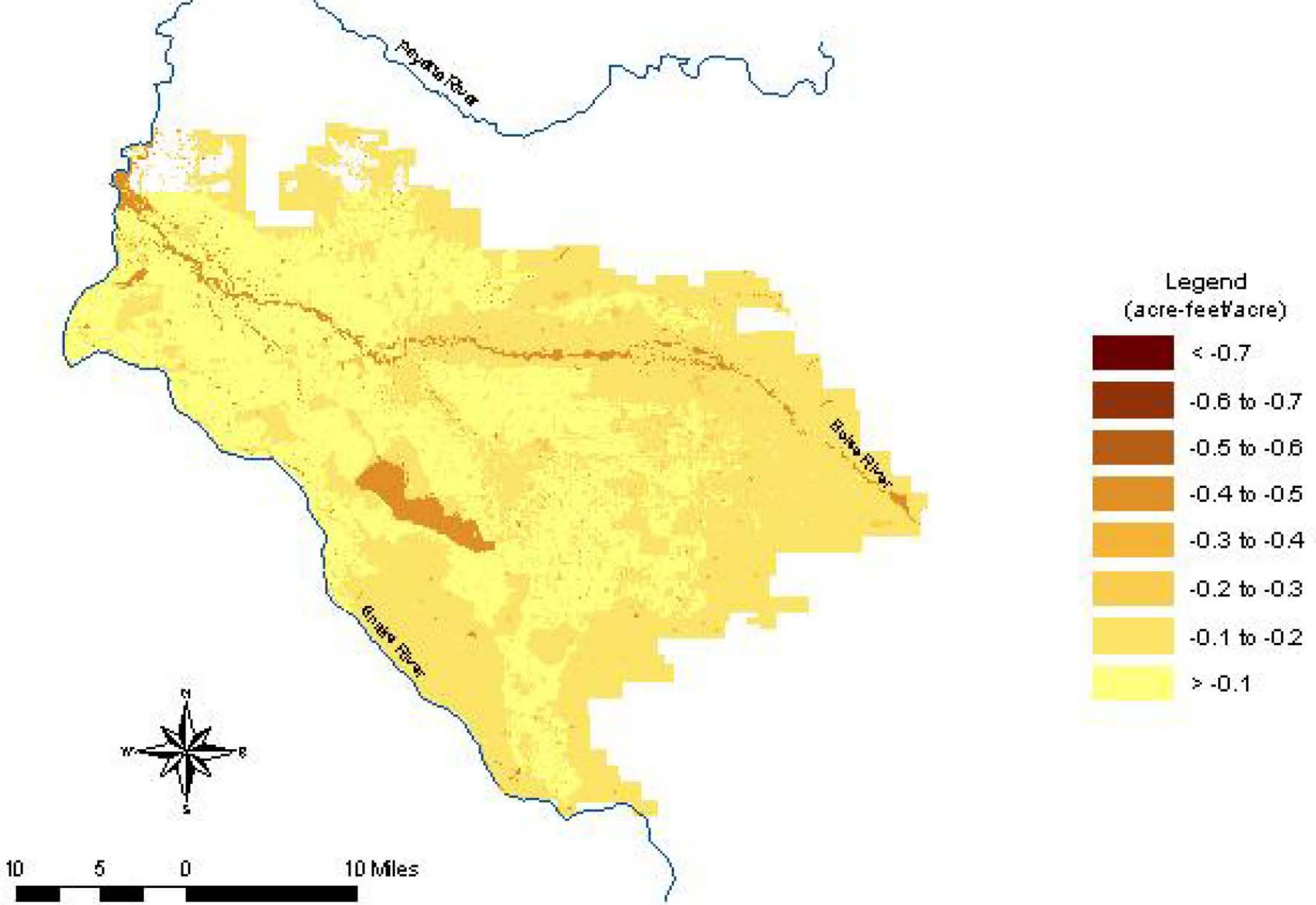

Figure 5-6. October, Boise Valley ET Distribution

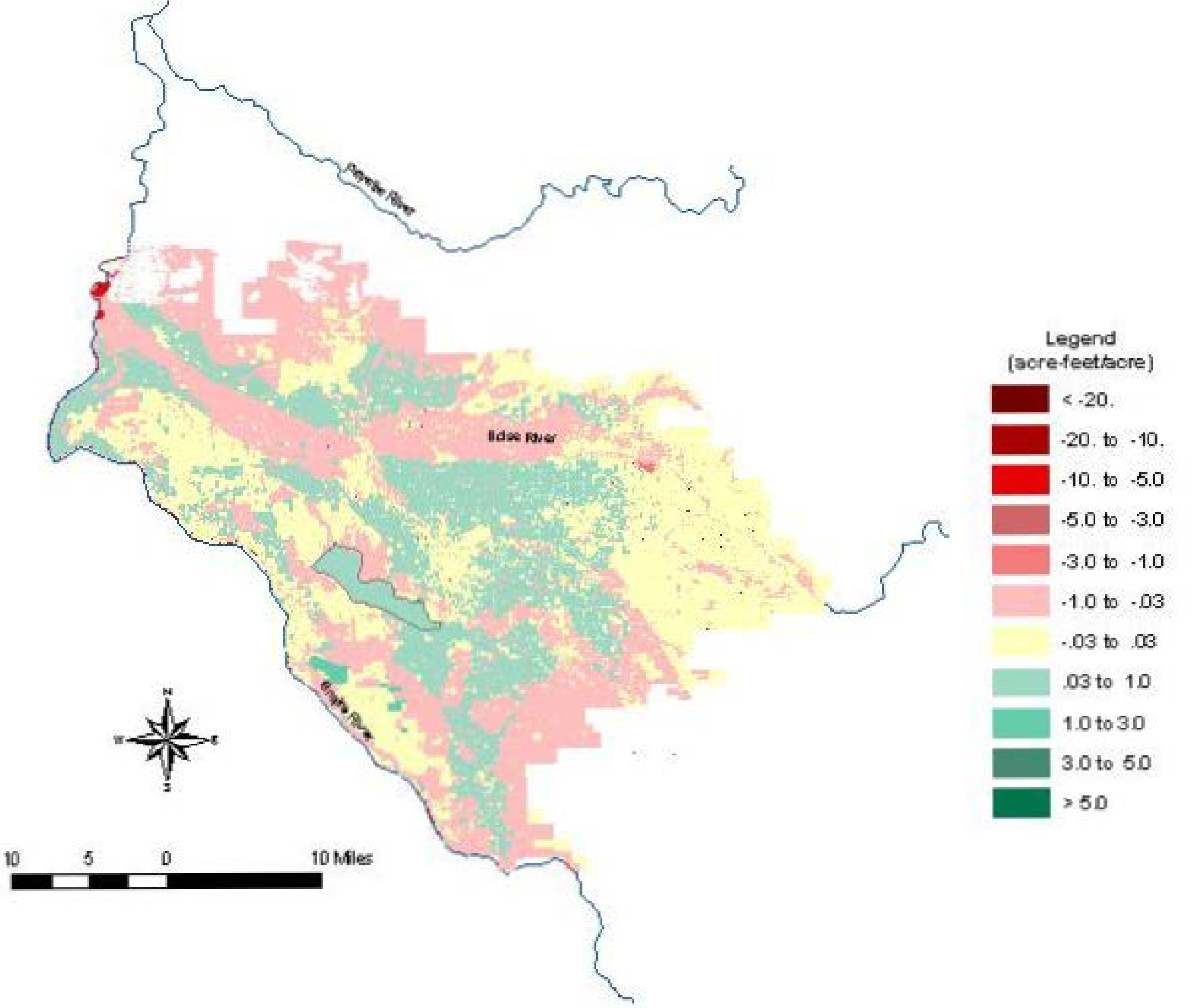

Figure 5-10. April, monthly distribution of groundwater recharge-discharge

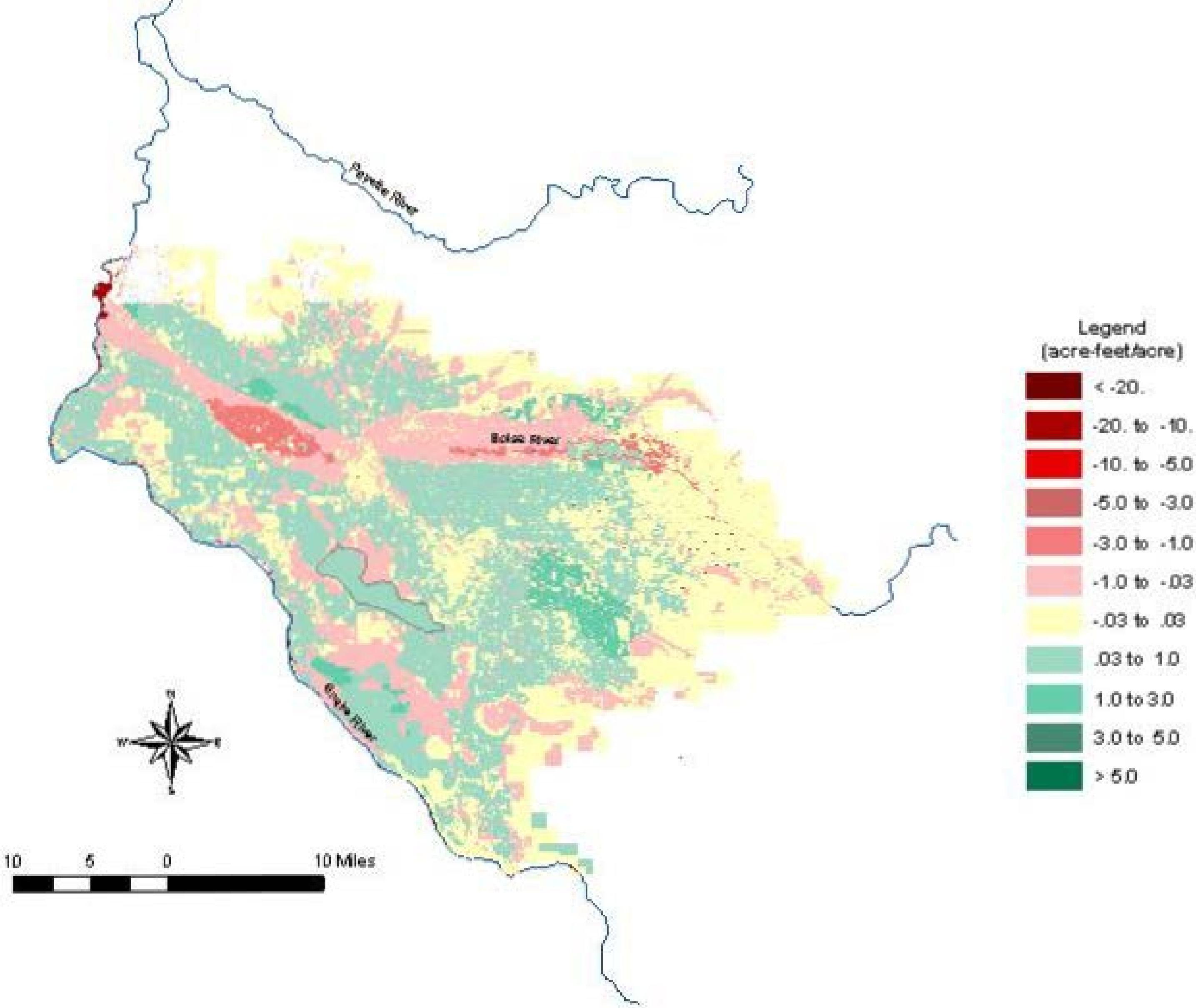

Figure 5-11. May, monthly distribution of groundwater recharge-discharge

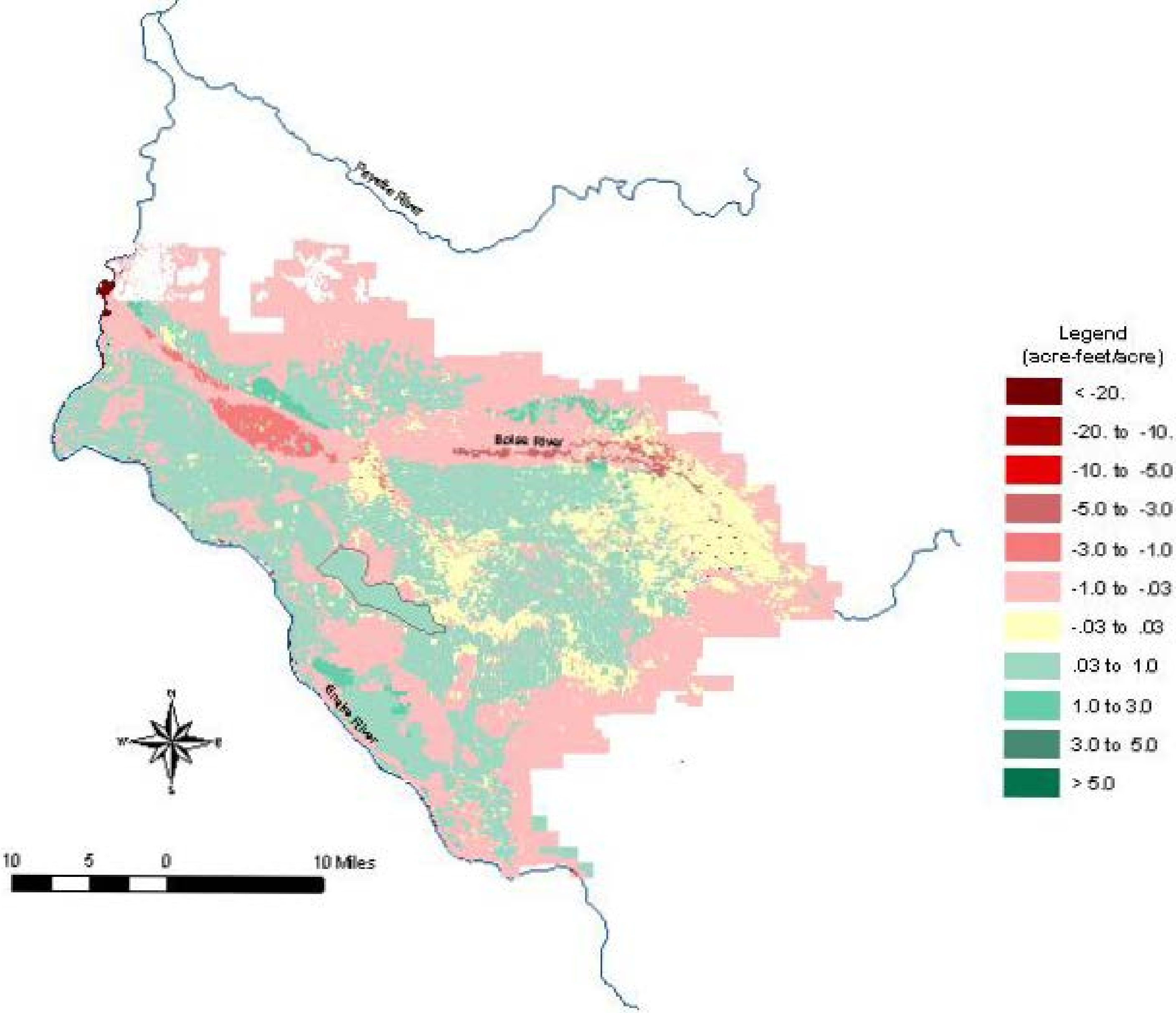

Figure 5-12. June, monthly distribution of groundwater recharge-discharge

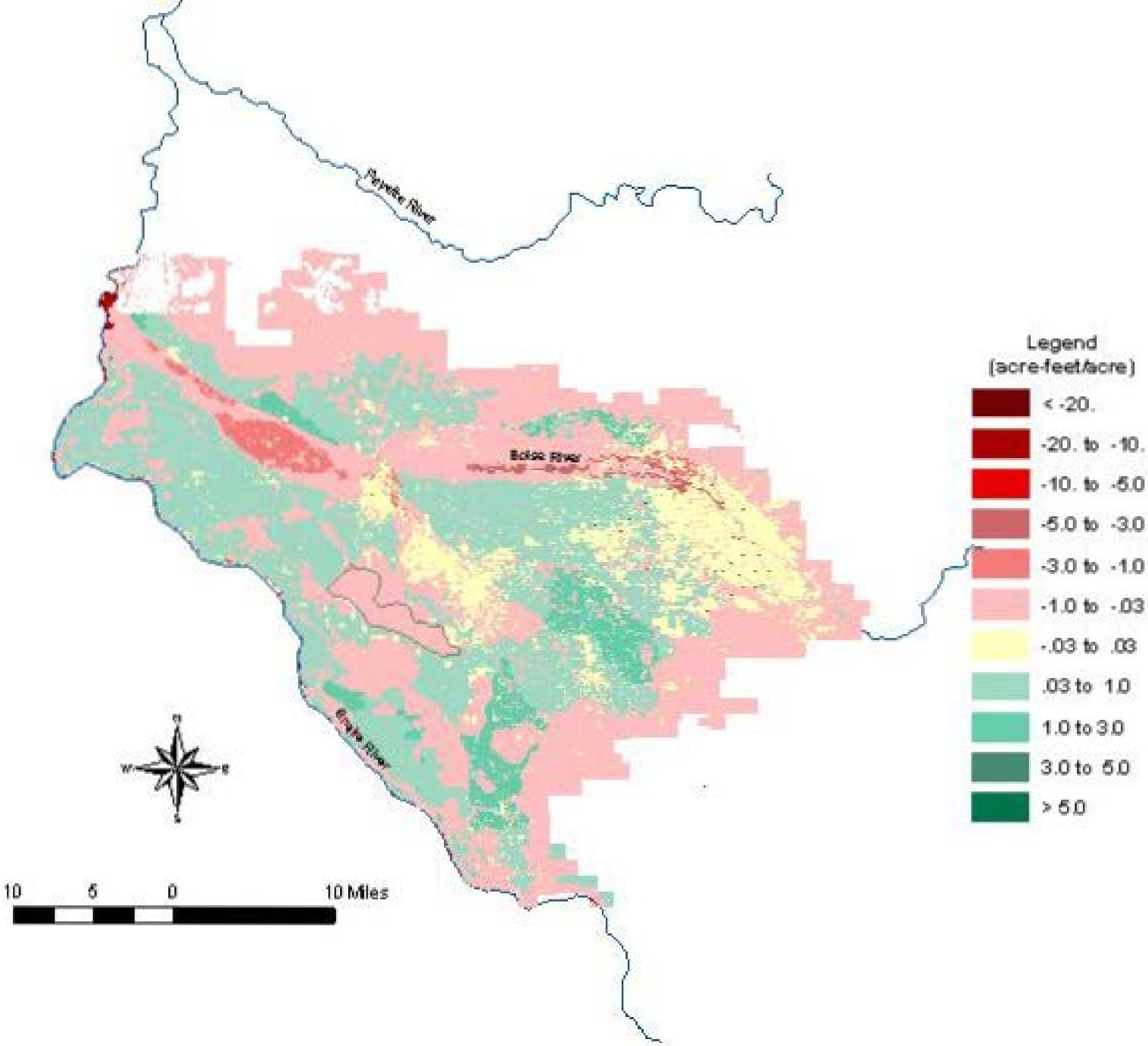

Figure 5-13. July, monthly distribution of groundwater recharge-discharge

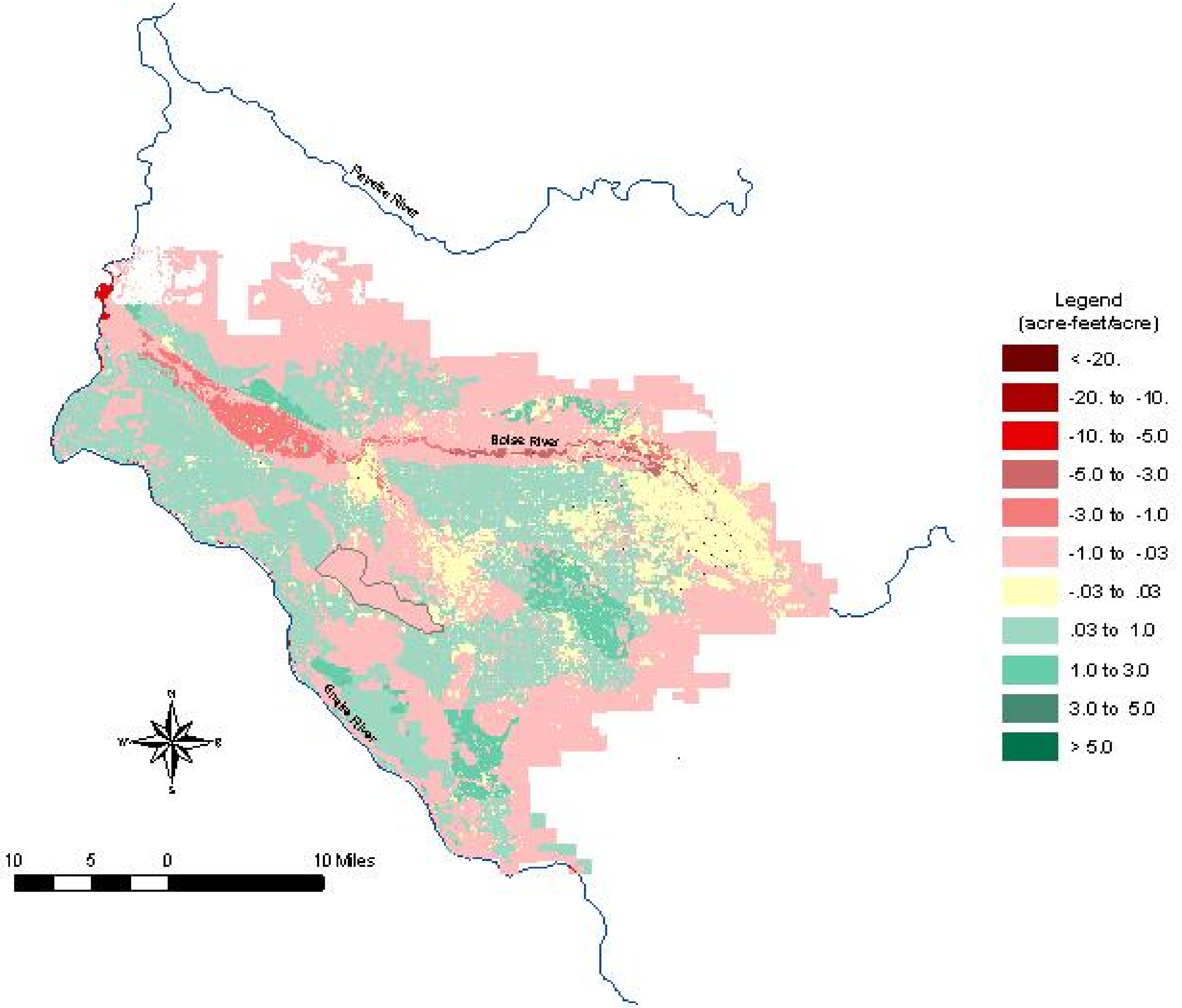

Figure 5-14. August, monthly distribution of groundwater recharge-discharge

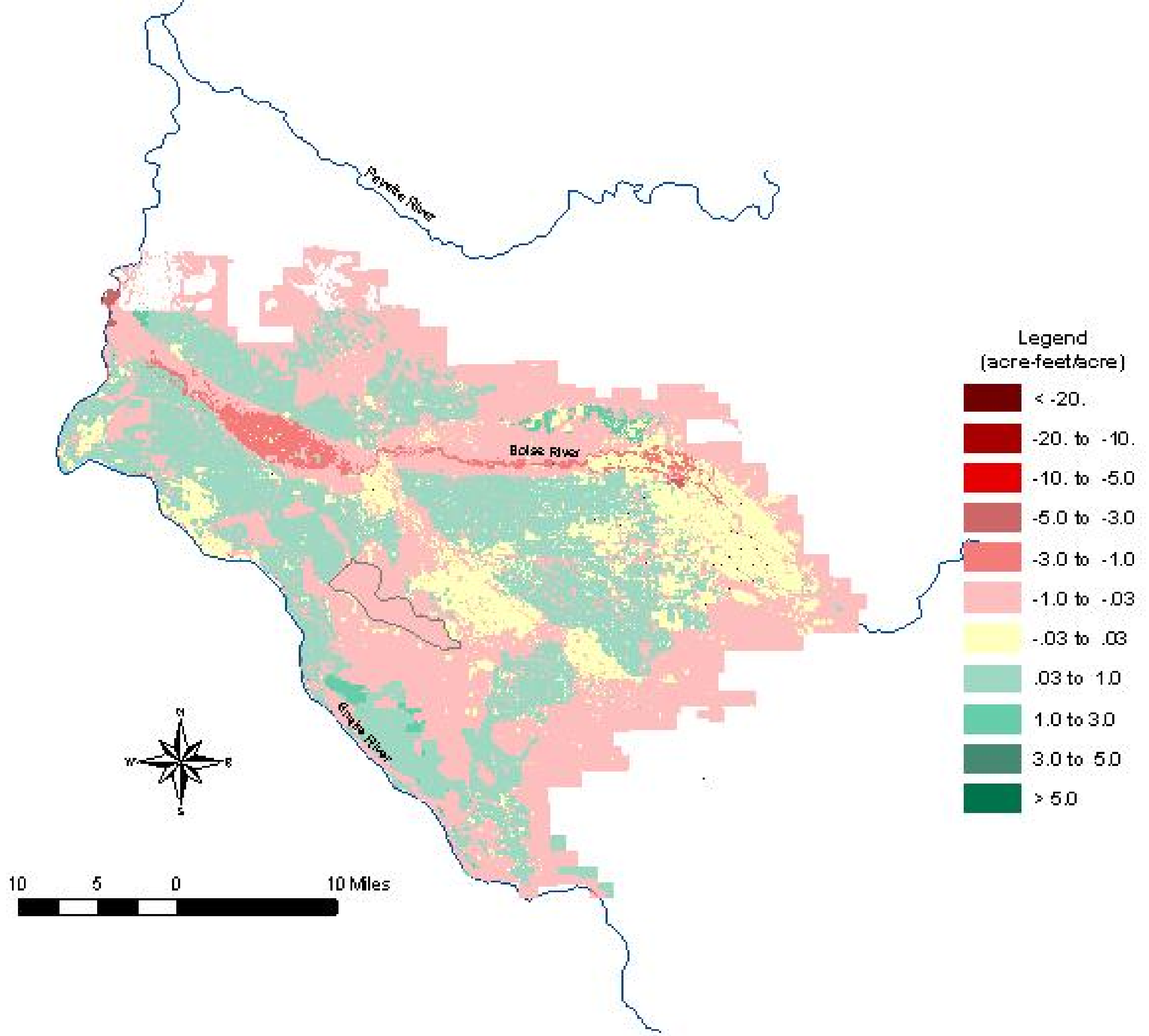

Figure 5-15. September, monthly distribution of groundwater recharge-discharge

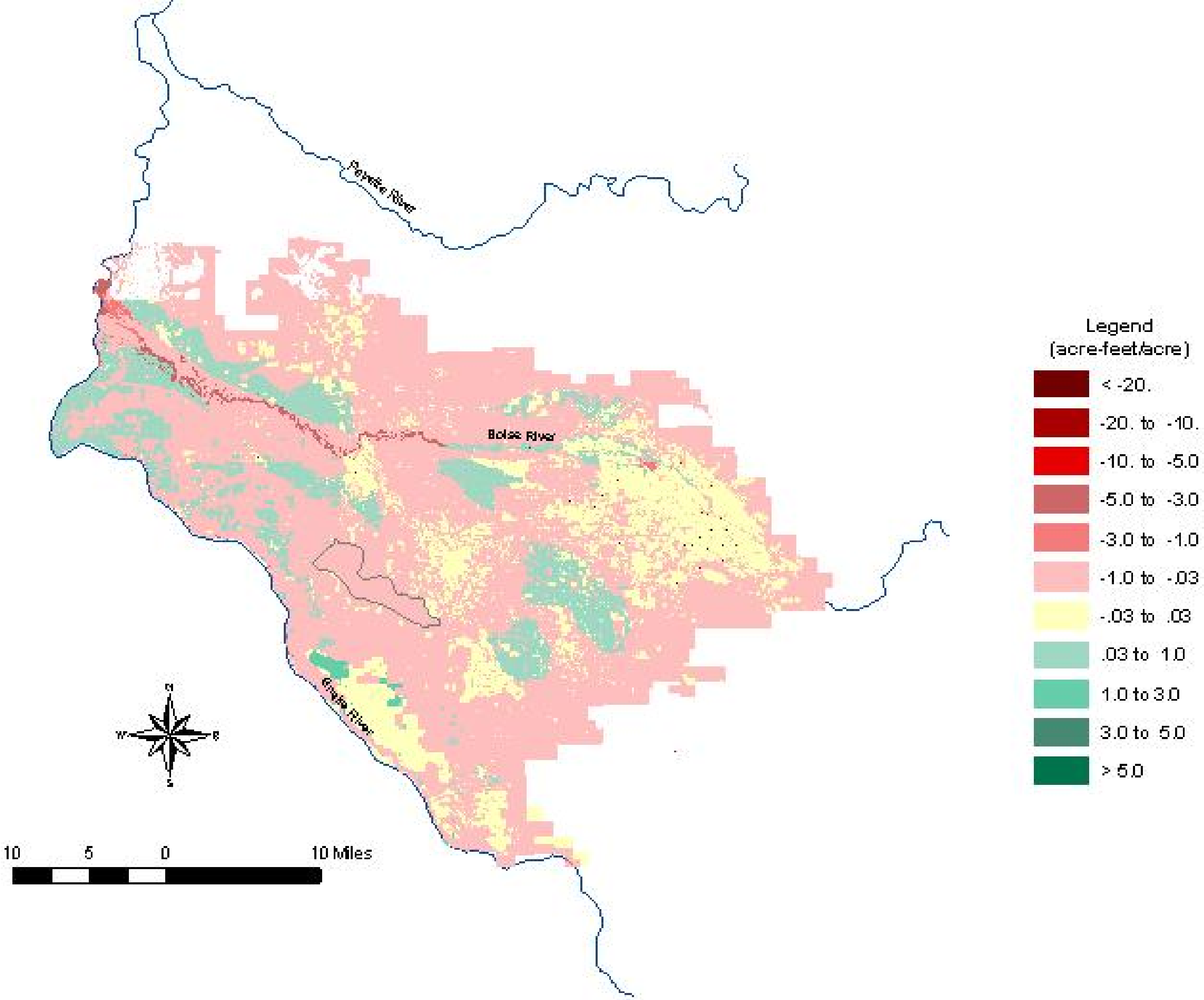

Figure 5-16. October, monthly distribution of groundwater recharge-discharge

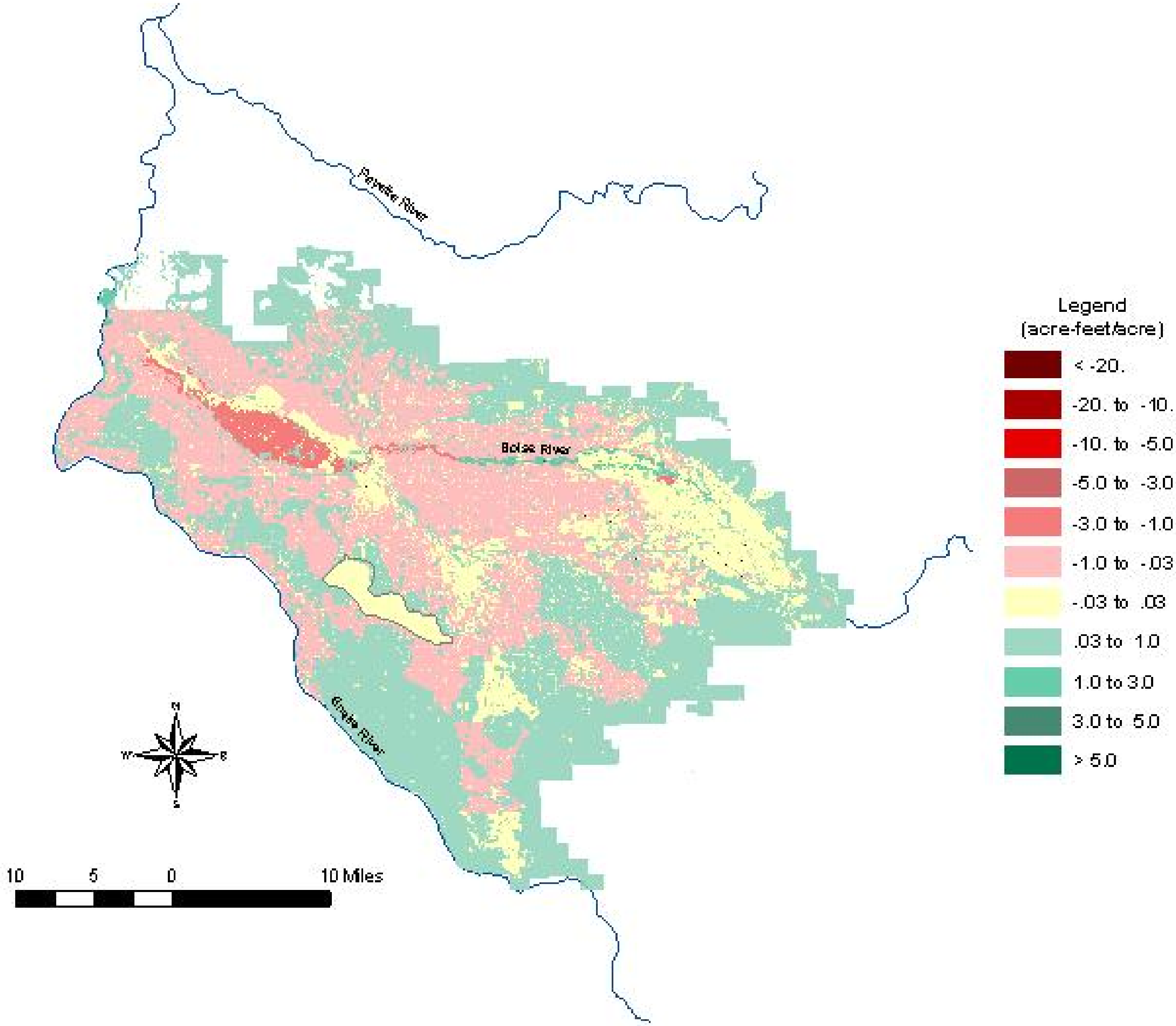

Figure 5-17. November, monthly distribution of groundwater recharge-discharge

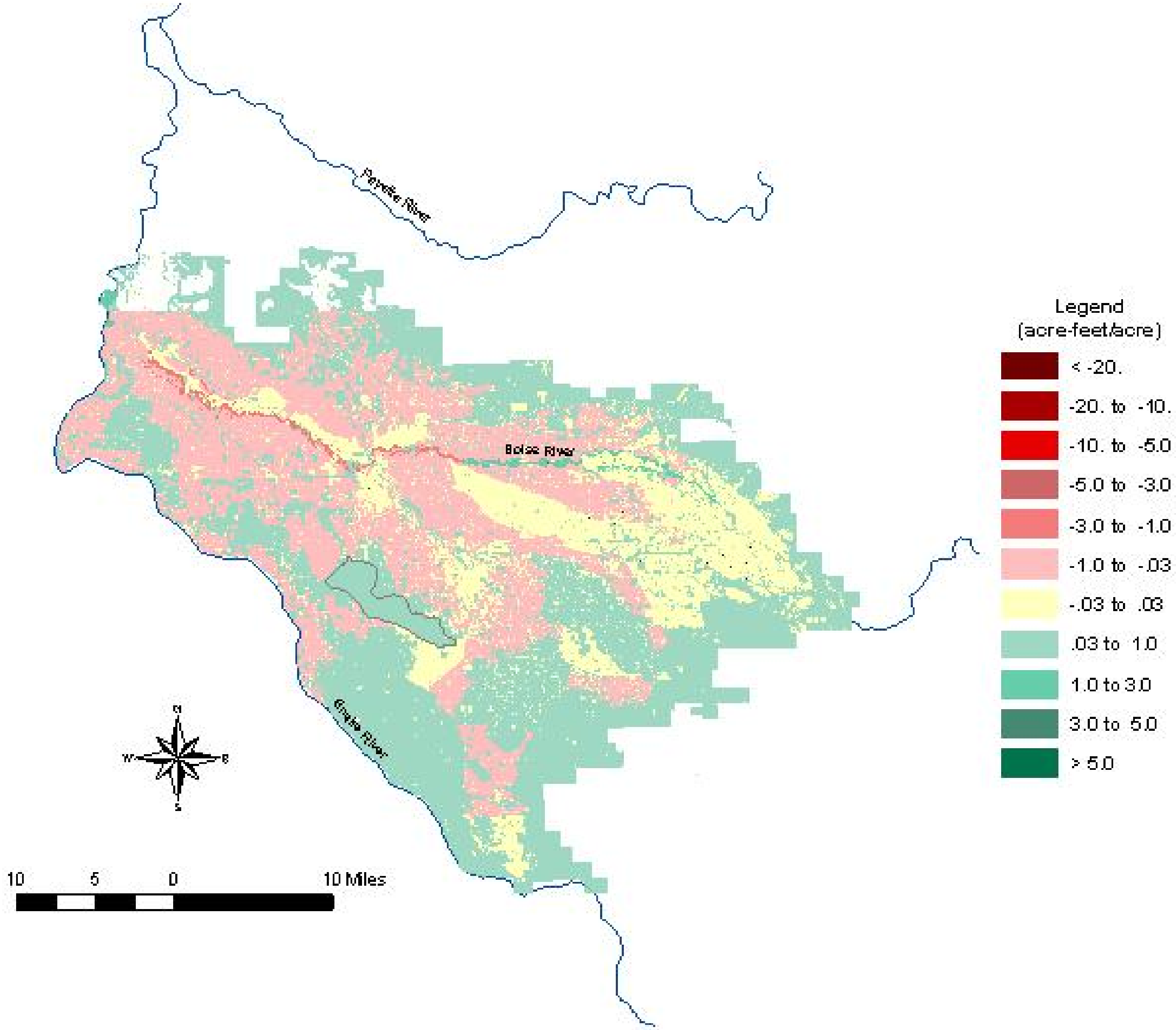

Figure 5-18. December, monthly distribution of groundwater recharge-discharge

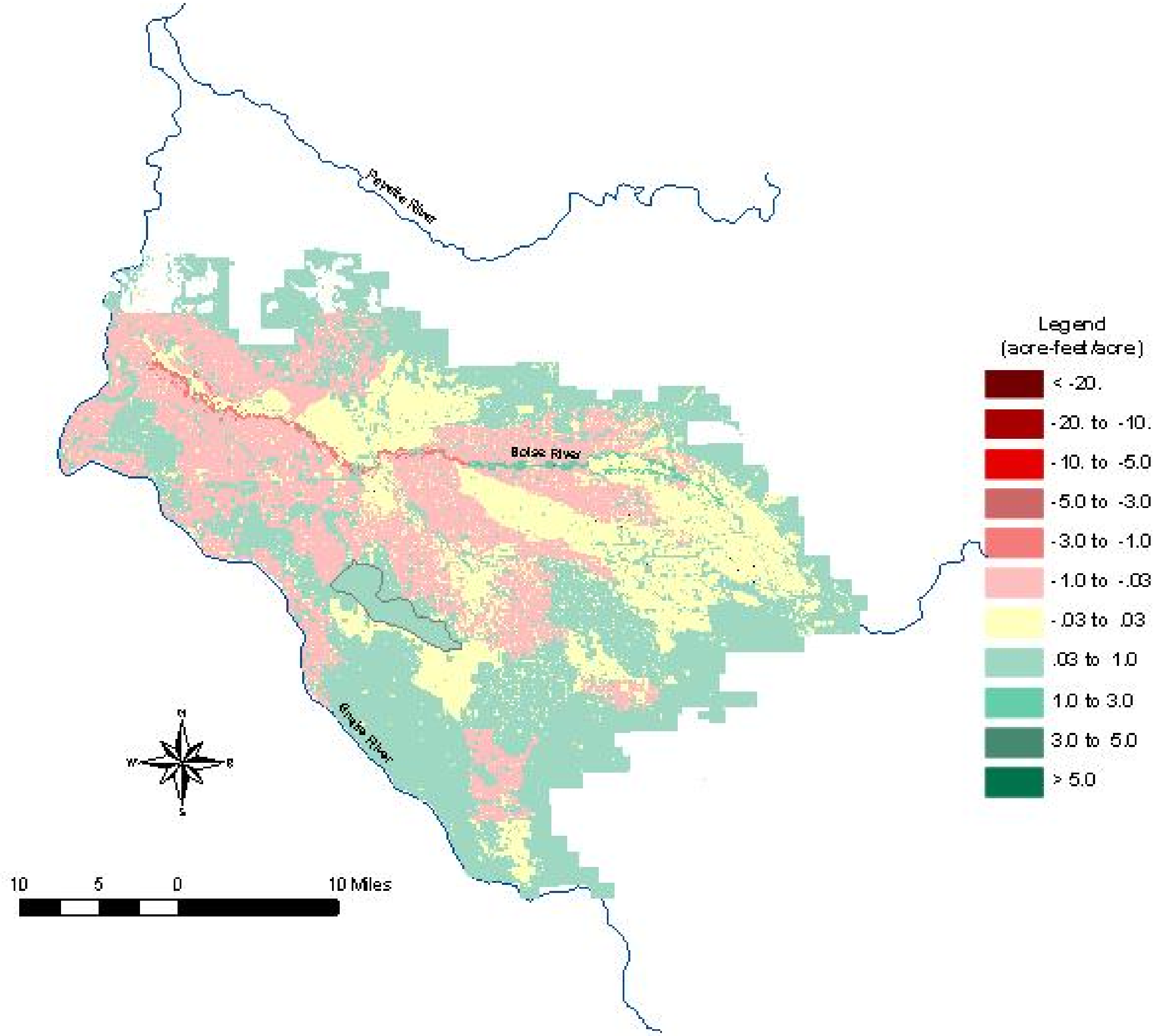

Figure 5-19. January, monthly distribution of groundwater recharge-discharge

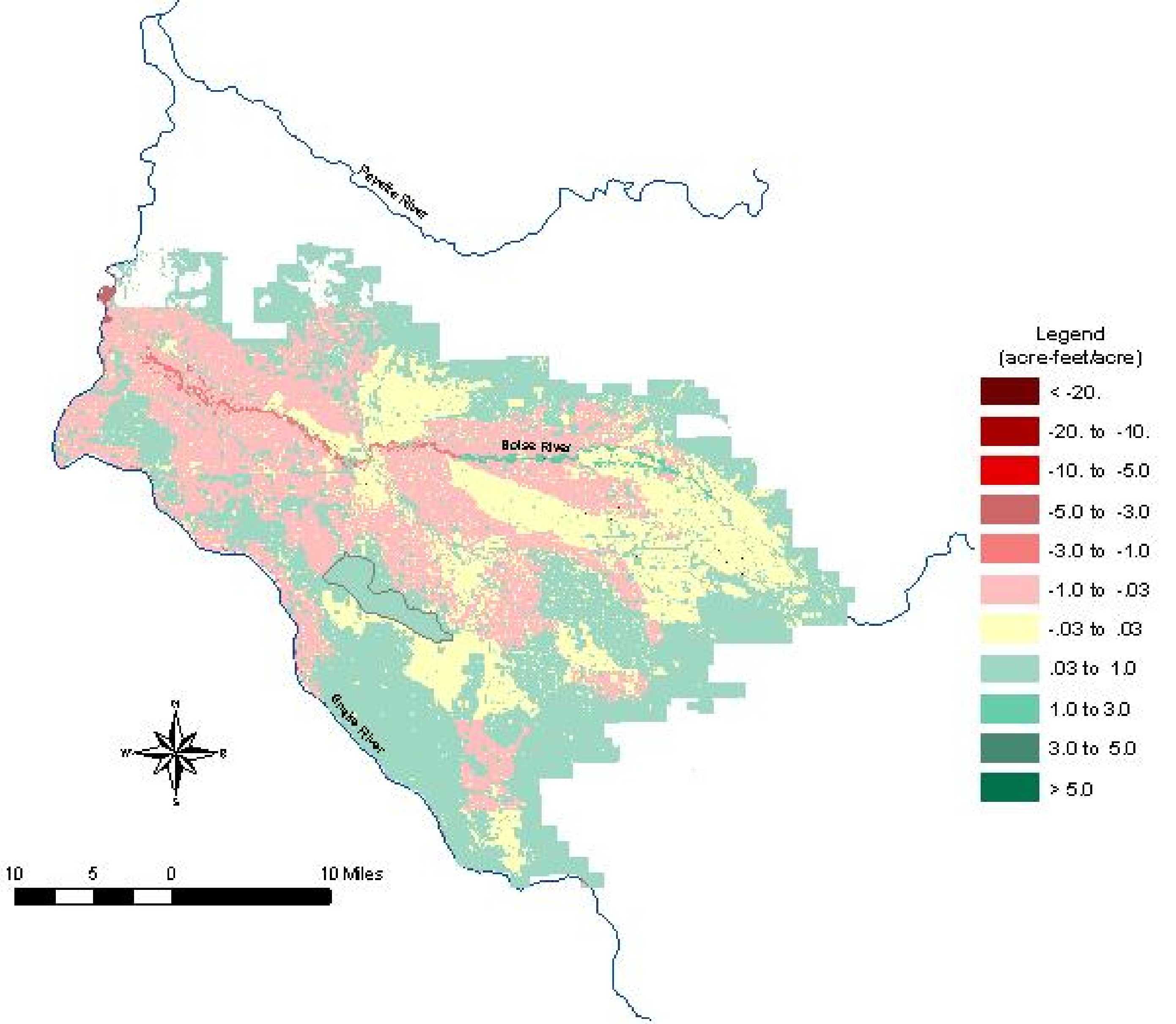

Figure 5-20. February, monthly distribution of groundwater recharge-discharge

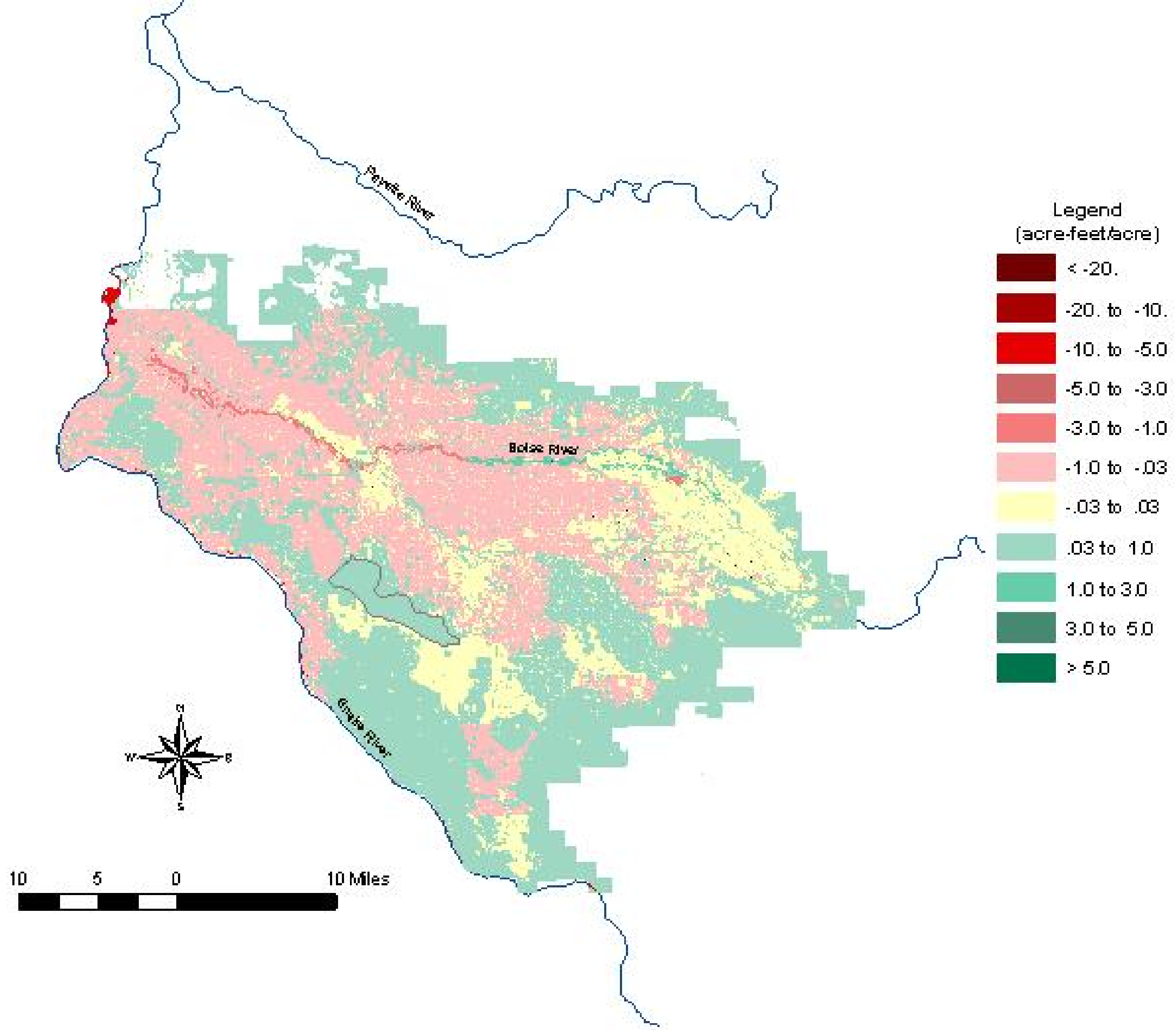

Figure 5-21. March, monthly distribution of groundwater recharge-discharge