Research Technical Completion Report

GEOHYDROLOGY AND DEVELOPMENT OF A STEADY STATE GROUND-WATER MODEL FOR THE TWIN FALLS, IDAHO AREA

by

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Abstract

Rapid growth in the city of Twin Falls, Idaho has stressed the current water supply system. In an effort to gain an understanding of the area geohydrology, the city contracted with the University of Idaho Water Resources Research Institute to develop a numerical ground-water flow model for the aquifer underlying the city of Twin Falls. The steady state ground-water flow model was developed based on recharge and discharge data from the last twenty years.

The primary source of recharge to the area is irrigation by the Twin Falls Canal Company. Evapotranspiration and unmeasured springs to the Snake River and other surface streams are important sources of discharge from the aquifer. A water budget for the basin was developed using precipitation, surface flow and crop distribution data. Evapotranspiration was calculated using average crop distributions and reference evapotranspiration values. Applied irrigation water was calculated from diversions, measured irrigation returns and land use data. Underflow from tributary basins was estimated or obtained from the literature.

The steady state numerical ground-water flow model was calibrated to water level measurements taken from December 1995 to December 1996. The network of 113 wells was measured five times in that thirteen month period. The model parameters which were calibrated were model hydraulic conductivity and spring conductance. Comparison of simulated water levels with measured water levels resulted in a mean absolute error of 17.5 ft and a root mean square of 24.4 ft, with eighty-one percent of simulated water levels being within 30 feet of measured water levels.

As stresses on the aquifer grow, water levels are dropping, causing concern over increased pump lifts and reduced spring flows. The calibrated steady state ground-water model provides the city with a management tool for evaluating changes in water and land use, as well as potential water development and recharge scenarios.

Chapter 1

Introduction

Background

The City of Twin Falls, Idaho, located in south central Idaho along the south side of the Snake River, is rapidly outgrowing its current municipal water supply. The city is experiencing the greatest growth of any city in Idaho, with an estimated annual growth rate of 2.5 percent. Water supply and water quality are of great concern to the city water department and city planners. To plan for future needs, the City of Twin Falls contracted with the Idaho Water Resources Research Institute of the University of Idaho to design and implement a numerical ground-water flow model. The model is intended to represent the current hydrological conditions of the city and to be used as a planning tool to assist in predicting the impact of projected growth and changes in local water use.

The study is being done in two phases. Phase 1 was the design, implementation, calibration and verification of a steady state numerical ground-water flow model for the Twin Falls area. This report covers the work done in Phase 1. Phase 2, which is ongoing, is conversion of the numerical model to a transient model to be used for growth projections and future planning.

Statement of Problem

The City of Twin Falls meets its municipal water demand using a ground-water right at Blue Lakes on the north side of the Snake River canyon and three municipal wells south of the city. The Blue Lakes ground-water right provides eighty-five to ninety percent of the current municipal supply. Approximately 26 mgd (40 cfs) is pumped from the Blue Lakes area to the city through a single 30 inch diameter pipe over the Snake River, with a lift of 500 feet on the south side of the Snake River canyon. The three city wells have a pumping capacity of approximately 10.5 mgd (16 cfs). The city stores water in two 5 million gallon storage tanks and a smaller 750,000 gallon storage tank. Peak water use of the City of Twin Falls is estimated at a rate of approximately 29 mgd (45 cfs). Peak water use occurs in the summer.

The current method of meeting the municipal water needs poses several concerns. During periods of peak water use, the city is near capacity for water delivery. The limited storage capacity indicates that demand must be met in real time. The current ground-water right at Blue Lakes allows for 32 mgd (50 cfs), however, the cost of developing the unused portion of the right is estimated at 1.7 million dollars. Full development of the ground-water right would stress the environmentally sensitive Blue Lakes area. The increase in dairy farming on the north side of the Snake River also introduces water quality concerns for Blue Lakes. The risk of a failure in the pipeline crossing the Snake River also puts the city's water supply at risk.

Partial to total replacement or augmentation of the Blue Lakes water supply with ground water from the south side of the Snake River Canyon poses a number of questions.

First, is the aquifer capable of meeting the additional water demand? Second, can the needed high yield wells be developed without injury to other water users? Third, will changing irrigation practices limit development potential because of decreased recharge? These issues form the basis for this research project.

Of primary concern to the city planners are the impacts to the ground-water resource of both further ground-water development and changing land use. Ground-water development in the tract is primarily for domestic and municipal purposes, with minimal ground water based irrigation. Irrigation on the Twin Falls tract is primarily by gravity delivery fed by diversions from the Snake River with only about ten to fifteen percent sprinkler irrigation in current practice. With increasing labor costs associated with surface irrigation (e.g. flood, furrow) and federal government incentives, conversion to sprinkler irrigation is expected to rise dramatically in the next several years. This will reduce incidental recharge associated with irrigation. Conversion of irrigated agricultural lands to municipal use due to increased population and reduction of irrigated acreage will also impact recharge volumes. Such diminished recharge will subsequently affect existing ground water users and bring into question new well development projects such as that proposed by the City of Twin Falls.

The onset of surface irrigation in 1905 with the building of the Twin Falls canal system raised ground-water levels dramatically, possibly as much 300 feet (Stearns, et al, 1938). Irrigation, coupled with the existence of low permeability loess sediments, caused localized water logging. To alleviate the situation, tunnels were excavated into the underlying basalt in the late 1920s to drain the fields. Water utilization, with the associated water rights, has been derived from the effluent of the these tunnels. Some tunnels flow only during the irrigation season. Other tunnels drain the upper portion of the aquifer throughout the year. Some tunnel drainage is captured and re-applied as irrigation water. Other tunnel rights are used by the aquaculture industry, which is highly dependent upon sustained flow levels, water quality, and stable water temperature. The reduction in recharge associated with conversion to sprinkler irrigation plus changes in land use will result in decreased flows from the tunnels. Increased ground-water pumpage also will impact water rights based on the tunnel discharges.

The City of Twin Falls plans to implement a managed recharge program along with development of new municipal wells south of the city to ensure a stable water supply. The recharge would be used to help sustain production at existing city wells and offset possible water level declines resulting from the new municipal wells. The recharge may also help offset the effects of the anticipated conversion from surface to sprinkler irrigation. The City of Twin Falls is sensitive to the need for balance between municipal water requirements, commercial water use and domestic water use. Lower aquifer levels would have an adverse impact on domestic wells, causing costly increases in pumping lifts and well deepening. Lower aquifer levels would also have an adverse effect on spring flows utilized by the aquaculture industry. In addition, local hydropower plants on Rock Creek and Pigeon Cove could be affected by reduced spring flows. This research project is designed to help provide the City of Twin Falls with the technical basis to judge alternative water development and management programs.

Purpose and Objectives

The purpose of this study is to provide the City of Twin Falls with a better understanding of the local geohydrology via a ground-water model which can be used as a predictive tool for municipal water planning. The objective of the ground-water model is to enable the city to run predictive simulations modeling various well development scenarios, population growth projections and potential recharge programs. The ground-water model will enable estimation of impacts of water level changes and reduced spring flows in specific regions within the study area, to address hydrological concerns of the water user community.

Another objective of the study is to provide the city with a comprehensive baseline of water levels throughout the greater Twin Falls area. This will enable city planners to track future aquifer changes to determine actual impacts of development. Water quality issues were not within the scope of the current study; however, the work done for this study included identification of potential water supply and quality concerns for future study.

A third objective of this research project was to develop spreadsheets which could be used by the City of Twin Falls water department personnel to calculate recharge for model scenarios. The spreadsheets facilitate the setting up and running of water use and management model scenarios by providing the user with a logical presentation of scenario variables which are then incorporated into the model recharge calculations.

Chapter 2

Study Area Description

Study Boundaries

The study area is bounded on the north by the Snake River, on the west and southwest by Salmon Falls Creek, on the south by the Cassia Mountains (locally called the South Hills) and on the east by the Murtaugh Lake area. The deeply incised canyons of the Snake River and Salmon Falls Creek provide natural hydrological boundaries, making them obvious choices for model boundaries. The Cassia Mountains, an uplifted sedimentary body, provide a boundary between developed and undeveloped land as well as a good hydrogeological boundary. The only significant underflow from that region is in the narrow alluvial valleys of streams draining the mountains (Rock Creek and Dry Creek). The Murtaugh area provides a good eastern boundary, with the Oakley Fan area east of Murtaugh being hydrologically distinct from the Twin Falls area. A geological fault to the southeast of the Murtaugh area (Young and Newton, 1989) provides a hydrological boundary with water levels east of the fault being several hundred feet lower than levels west of the fault. Figure 1 shows the physical boundaries of the study area and the study area context within Idaho.

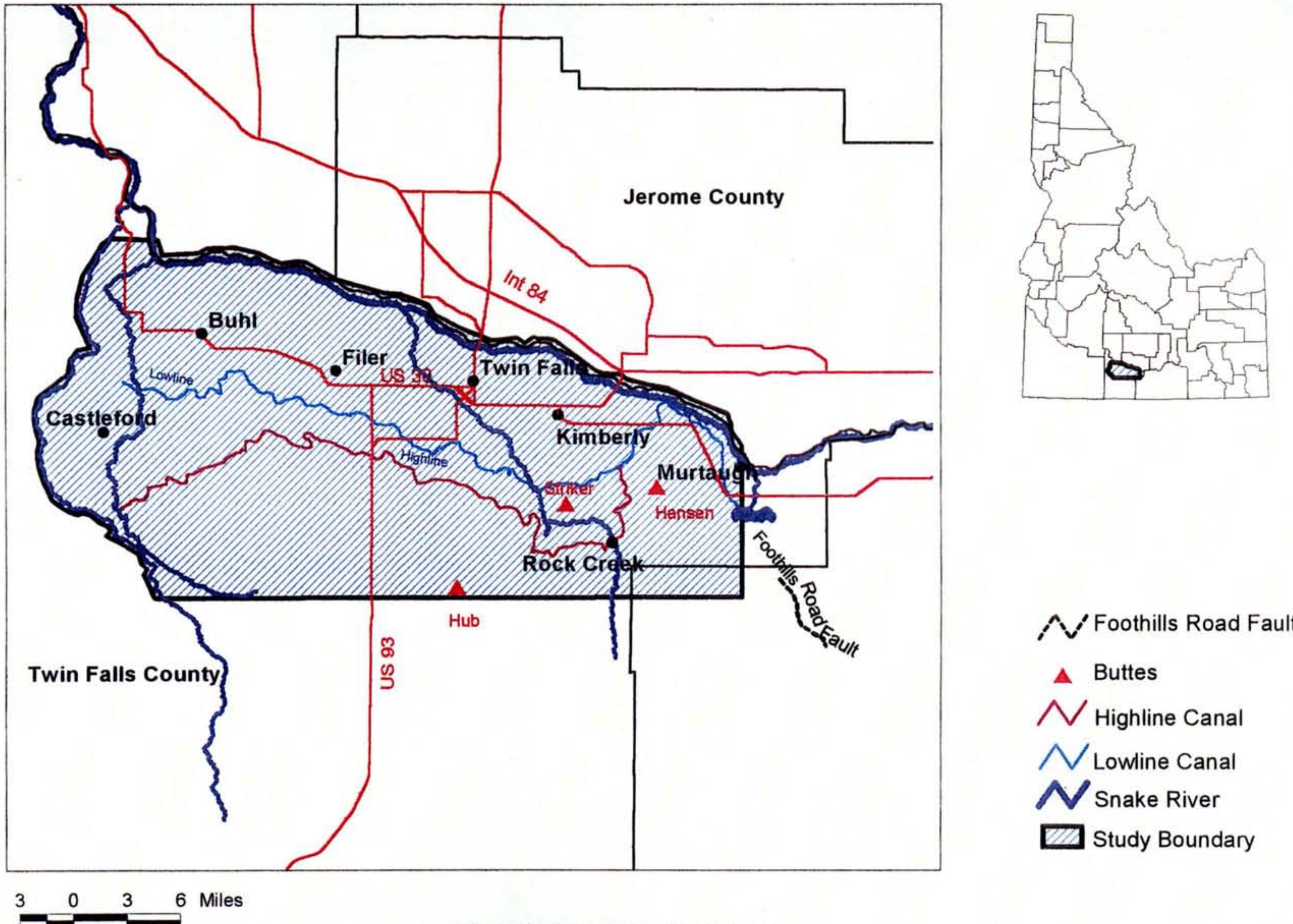


Figure 1. Twin Falls Study Area.

Climate

The study area is a high desert climate. Precipitation at the Twin Falls Weather Station Office (WSO) averaged 10.2 inches annually during the period of record (1945-1994), with the dominant precipitation occurring as snow in the winter months. The climate is typified by hot dry summers and cold winters, with summer temperatures exceeding 90°F and winter temperatures less than 20°F. Mean annual temperature in Twin Falls is 49°F (Street and DeTar, 1987). The frost-free season is typically early May through mid-September. During the growing season, crop evapotranspiration exceeds precipitation.

Geological Setting

The Twin Falls area is a gently undulating Quaternary basalt plain, dotted by shield volcanoes (Hub Butte, Stricker Butte and Hansen Butte) and overlain by Quaternary sediments. The plain slopes gently to the northwest with a grade of approximately one percent. The buttes rise from 100 to 400 feet above the plain. The basalts underlying the Twin Falls area were previously termed the Miocene Banbury Basalt of the Idaho Group and the Holocene and Pleistocene Glenns Ferry Formation of the Idaho Group (Street and DeTar, 1987 and Moffatt and Jones, 1984). The terminology used to refer to the basalts overlying the Banbury Basalts is undergoing a change, with the basalts being named with regard to the source of the flow such as Hub Butte Flow or Hansen Butte Flow (per personal communication with W. Bonnichsen). Collectively, these basalts are referred to as the Snake River Group. The basalt flows are typically lobe shaped with denser, thicker basalt near the point of origin, thinning with distance from the source, typically to the north. The flows are interfingered with clays, loess and other sediments in the interflow zones. The basalts vary in degree of fracturing. The variation in fractures and the existence of interflow zones causes a local variability in porosity and hydraulic conductivity.

The basalts overlie the Tertiary Idavada volcanics, which are comprised of rhyolites and welded tuffs. The Idavada volcanics collectively describe rhyolites from the Shoshone Falls, the Twin Falls and the Bruneau-Jarbridge eruptive centers. Rhyolites from the Shoshone Falls eruptive center underlie the eastern portion of the study area, as evidenced by an outcrop at the Snake River Canyon near the Perrine Bridge (Street and DeTar, 1987). There is also evidence of rhyolites and welded tuffs from the Bruneau-Jarbridge and Twin Falls eruptive centers in the study area. These rhyolites and tuffs are exposed near Salmon Falls Creek reservoir to the west and in the Cassia Mountains to the south and are thought to underlie the study area. The eruptive center for the Idavada volcanics in the Twin Falls area is thought to be north of the Snake River, with the rhyolites thicker to the north, thinning to the south. The Bruneau-Jarbridge eruptive center is thought to be west of Salmon Falls Creek, with occurrences of the Bruneau-Jarbridge rhyolites mostly in the western part of the study area (personal communication with W. Bonnichsen). The Idavada volcanics overlie Paleozoic and Mesozoic sedimentary and metamorphic units, dominantly quartzites and limestones (Street and DeTar, 1987). The Cassia Mountains on the south boundary of the study area consist of highly fractured and faulted metamorphic and sedimentary rocks uplifted during the Laramide orogeny. Between the Cassia Mountains and Salmon Falls Creek is the Rogerson graben, a basin and range extensional graben overlain by Quaternary sediments.

The possibility exists that some of the basalts within the study area have undergone a water alteration immediately after emplacement, with geochemical alteration causing significantly lower hydraulic conductivities. Their presence is most likely in an area extending from approximately the mid-range of the study area to the west, and thickening to the west (per personal communication with W. Bonnichsen). The water alteration would have occurred as the basalts flowed slowly into Lake Idaho, whose eastern extent was near Rock Creek in Twin Falls. The water-altered basalts are thought to be very dense and do not show the characteristic fractures of other basalt flows in the area. Evidence of these altered basalts can be seen in roadcuts near Banbury Hot Springs, in the western part of the study area. These altered basalts are thought to be overlain by younger, fractured basalts of higher hydraulic conductivity. The potential existence of these altered basalts could impact aquifer yields and flow characteristics.

Hydrological Setting

Surface Water

The Snake River occurs in a deep canyon (up to 500 feet deep in the Twin Falls area) cut in the Snake River Plain basalts. The Snake River is gaining in the reach between Milner Dam and Salmon Falls Creek, bordering the study area. Snake River reach gains from springs were analyzed by Kjelstrom (1995a, 1995b) and Thomas (1969). Although most previous work attributes the gains to springs from the north side, Kjelstrom (1995b) estimated that ten percent of Snake River spring gains are from the south side.

Salmon Falls Creek, which originates in Nevada, borders the study area on the southwest and the west. Salmon Falls Creek is dammed south of the study area; streamflow into the study area originates as seepage from the dam. Salmon Falls Creek is gaining along the entire border of the study area from springs emanating primarily from the east side (study area). Salmon Falls Creek flows northward in an increasingly deep canyon, reaching approximately 500 feet in depth as Salmon Falls Creek approaches its confluence with the Snake River. Crosthwaite (1969b) estimates that ninety percent of the gain in Salmon Falls Creek is from the east side (the Twin Falls tract), with only ten percent gain from the west side due to less irrigation in that area.

Rock Creek originates in the Cassia Mountains to the south of the study area and flows north/northeast through the study area. In the south part of the study area, Rock Creek is above the water table. In the more northern part of the study area, Rock Creek is incised in an increasingly deep canyon below the water table and gains water from springs and man-made tunnels.

Dry Creek is an intermittent stream which originates in the Cassia Mountains in the southeast corner of the study area and flows north into Murtaugh Lake and then from Murtaugh Lake into the Snake River. Deep Creek, Mud Creek and Cedar Draw are streams which originate within the study area and drain water from the study area. All three are incised in deeper canyons as they approach their respective confluence with the Snake River and all three are spring and drain fed.

Murtaugh Lake, a man-made lake developed as part of the Southside Irrigation Project, is located on the east border of the study area. Murtaugh Lake is completely filled only during the irrigation season and remains partially filled year-round. Murtaugh Lake seeps approximately 14,000 acre-feet into the aquifer annually (Young and Newton, 1989). Murtaugh Lake is hydraulically connected to the regional ground-water system, with seepage from Murtaugh Lake increasing as pumping west and south of Murtaugh Lake increases.

The study area is predominantly irrigated by the Twin Falls Canal Company (TFCC), the largest irrigation company in the state. The TFCC diverts an average of 1.1 million a-f/y from the Snake River. The irrigation water is delivered to the area by gravity feed via the High Line and Low Line canals. Approximately 202,000 acres are serviced by the TFCC. It is estimated that in current practice, eighty-five to ninety percent of irrigation in the Twin Falls tract is surface irrigated (primarily furrow irrigation) with sprinkler irrigation making up the balance (per personal communication with V. Alberdi). Surface irrigation provides an important source of recharge to the area aquifer; less recharge occurs from sprinkler-irrigated fields. Crop evapotranspiration is a significant source of water loss in the tract. Irrigation ditches and sub-surface drains conduct irrigation returns to surface streams leaving the tract.

The Salmon River Canal Company (SRCC) services a region south of the study area and extending north into the study area. Approximately sixty-five percent of the acreage served by the SRCC lies within the study area. However, SRCC diversions fluctuate greatly from year to year based upon water supply. There is also some limited surface irrigation within the study area from Rock Creek. In addition, in the southeastern part of the study area, there is limited irrigation by ground water.

Ground Water

The regional aquifer underlying the Twin Falls tract is predominantly in the Quaternary and Tertiary basalts. The dominant sources of recharge to the Twin Falls aquifer are underflow, precipitation in the winter, and irrigation in the summer. The aquifer is fed by relatively minor underflow from the Murtaugh area and from Rock Creek and Dry Creek in the southeast. The Twin Falls aquifer is also fed by underflow from the Salmon Falls area in the southwest. Dominant mechanisms of discharge from the aquifer are springs and man-made drains discharging to the surface streams. Figure 2 shows water table contours for the study area averaged throughout the year. Flow in the Twin Falls aquifer is generally south to north with an average gradient of 60 feet/mile.

Ground-water levels fluctuate in an annual cycle, responding to recharge from the surface irrigation. Figure 3 shows contours for the rise in water table between July and December of 1996, reflecting a water table high during irrigation and a water table low in the winter. Both sets of water level contours were generated using measurements taken during 1995-1996, in a well network discussed in a later section of this report.

The regional aquifer in the basalts overlies a geothermal aquifer in the Idavada rhyolite. Natural communication between the geothermal aquifer and the unconfined aquifer in the basalts is believed to be minimal (personal communication with C. Brockway). The geothermal aquifer is under artesian pressure and has higher hydraulic head than the basalt aquifer. Wells which are open to both aquifers show a mixed potentiometric head. The

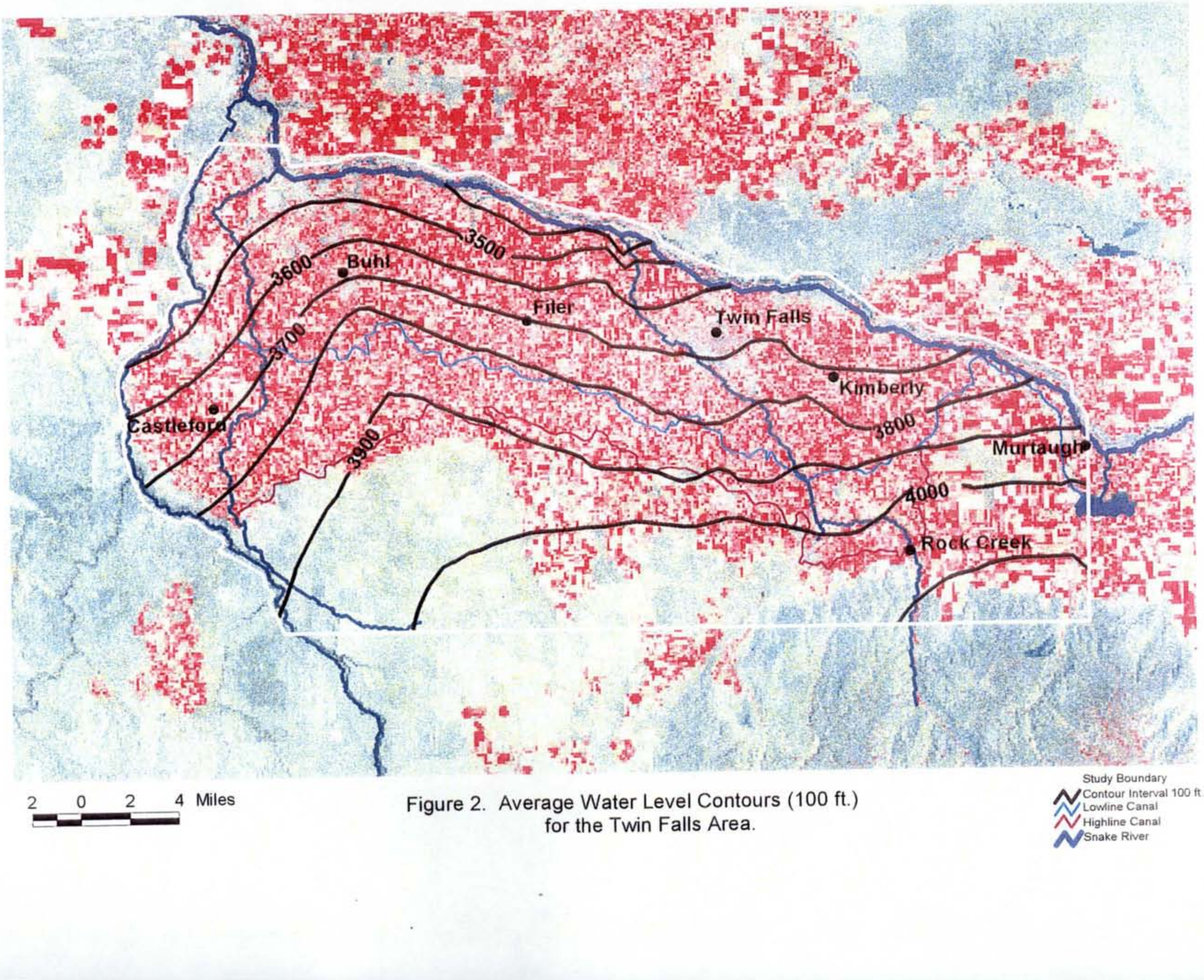


Figure 2. Average Water Level Contours (100 ft.) for the Twin Falls Area.

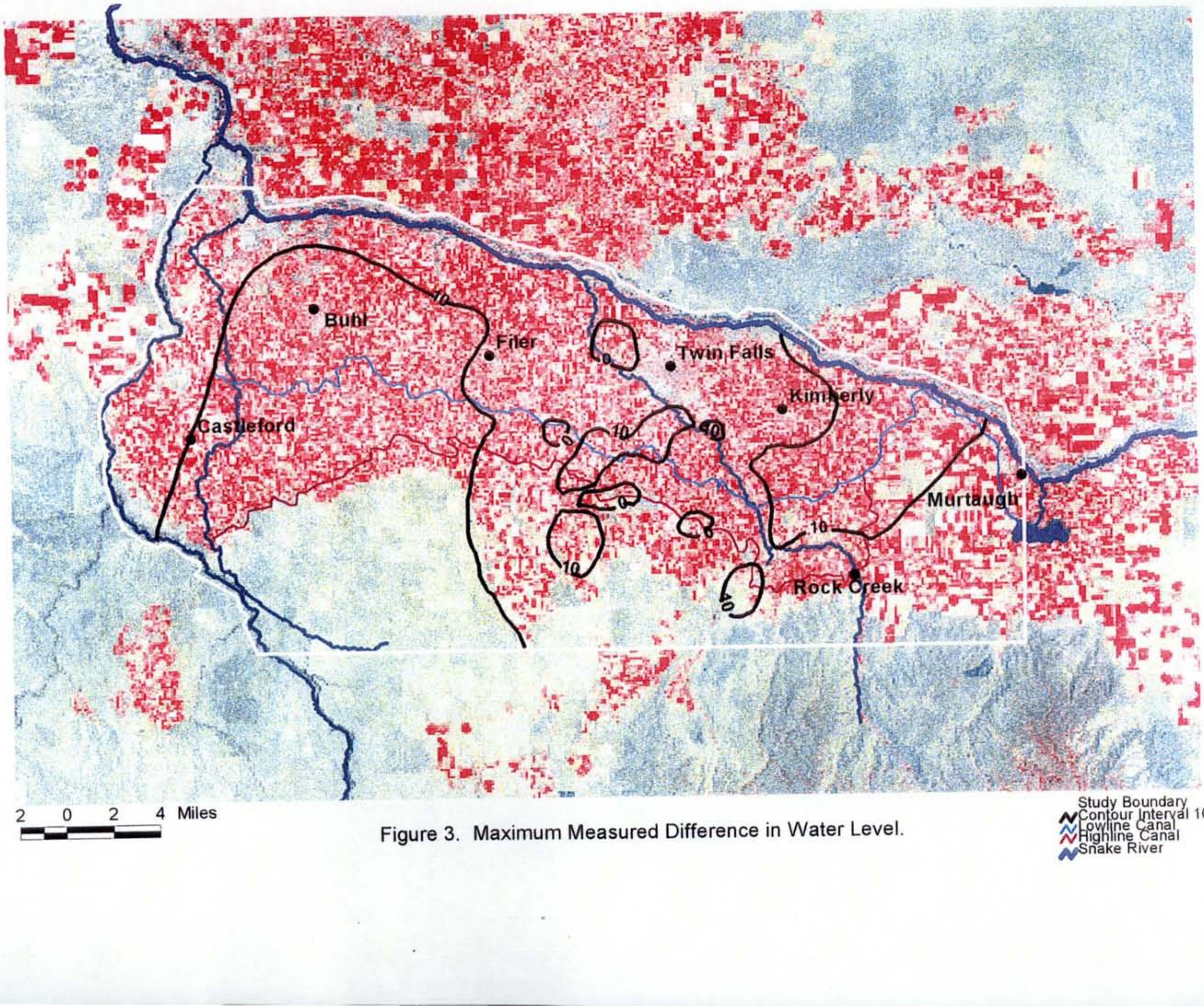


Figure 3. Maximum Measured Difference in Water Level.

geothermal aquifer is at great depth (around 1400 feet in the area near the city of Twin Falls). Geothermal wells in the heart of the study are cased to exclude the basalt aquifer and are used for geothermal heating. Wells which are open to both aquifers tend to be in the far southern reaches of the unconfined basalt system.

Moffatt and Jones (1984) document a perched zone in the study area extending from approximately Twin Falls to Buhl. They characterize the zone as being in basalt, perched on relatively impermeable layers of interbedded loess and clay. The perched zone is estimated by Moffatt and Jones (1984) to underlie 33,000 acres (Figure 4). The zone is drained by springs, man-made drains, and wells which penetrate both the perched system and the regional system. Moffatt and Jones (1984) estimate that the perched zone stores between 13,000 and 40,000 acre-feet, a small amount of water relative to the total volume of water in the regional system and small relative to the annual volume of recharge water.

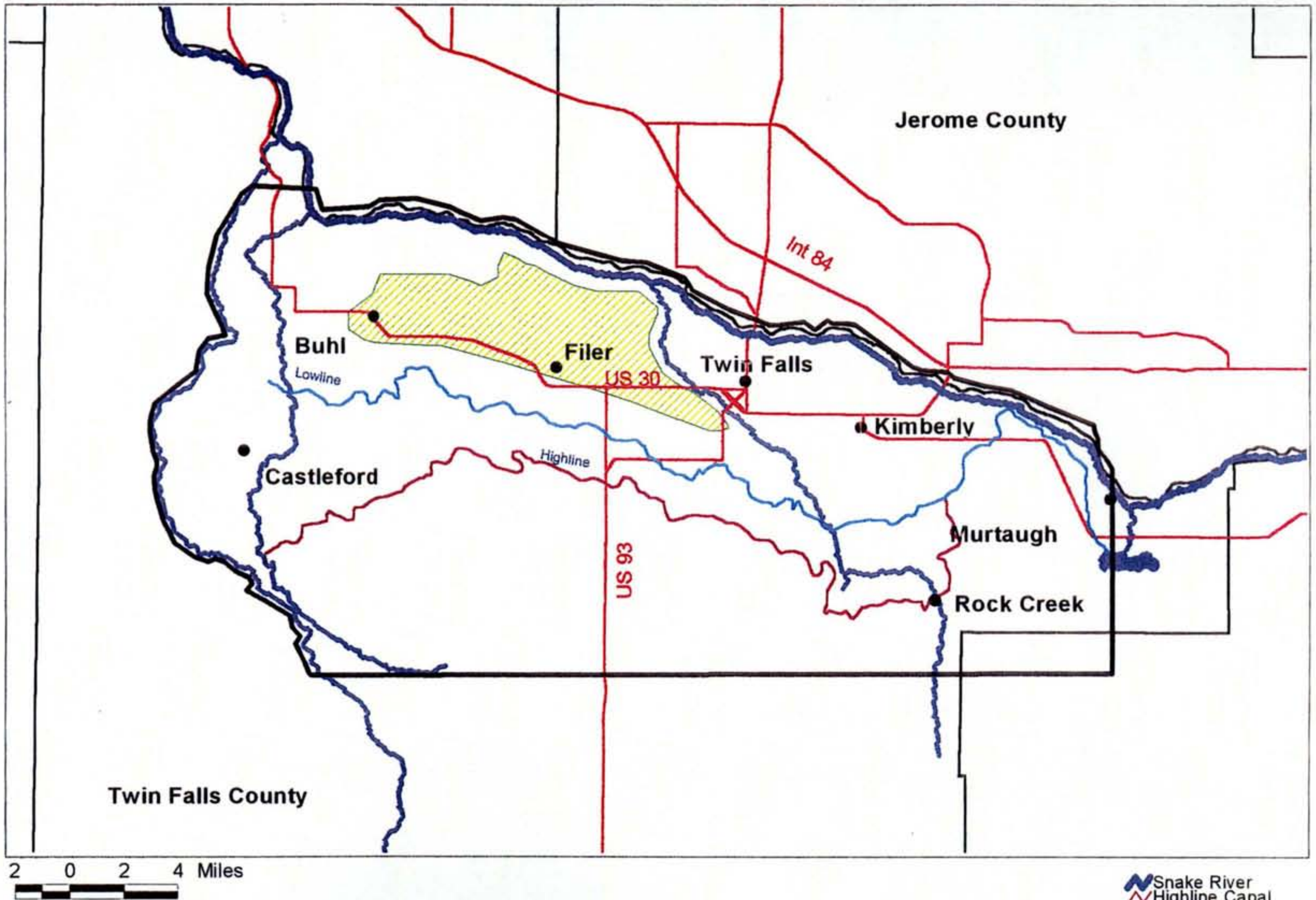


Figure 4. Perched Aquifier Zone, after Moffatt and Jones (1984).

Chapter 3

Water Budget

Water budgets were developed for surface and ground water within the study area and for ground water alone. A previous overall water budget was done by Ralston and Young (1971). The Ralston and Young report covered a subset of the current study area, with the southern boundary at the High Line Canal of the TFCC. The Ralston and Young report also extended east to Milner Dam, where the current study area ends on the eastern edge of Murtaugh Lake. The Ralston and Young water budget was used as a model for the water budgets for this study.

Overall Water Budget

Inflows to the study area and outflows from the study area were developed using a 20 year average based on the years 1973 to 1993, where possible. This period was chosen to reflect existing conditions due to the limited changes occurring during this 20 year period. Table 1 shows the overall water budget for the study area and the sources of the data. Figure 5 shows the conceptual model for the overall water budget.

Table 1. Water Budget for Study Area

		Rate Acre-ft/yr	Comment
Inflow			
	Municipal water imported from Blue Lakes	9,000.	Average of 1987-present. From city records.
	Precipitation	307,000.	10.3 in/yr spread across active model cells
	Creek Inflows		
	Dry Creek Inflow	2,800.	From 1994 records
	Rock Creek Inflow	25,000.	From 1944-1974 records
	Ephemeral Stream Inflow	10,200.	From Crosthwaite, 1969a
	Salmon Falls Creek Inflow	5,800	Estimated
	Underflow		
	Rock Cr./Dry Cr. Underflow	21,000.	From Crosthwaite, 1969a
	Salmon Falls Underflow	115,000.	From Crosthwaite, 1969b
	Murtaugh Area Underflow.	15,000.	Estimated
	Irrigation		
	Twin Falls Canal Divers.	1,090,000.	Average from 1973-1993
	Salmon Falls Irrigation	31,000.	Data from by Salmon River Canal Co.
Total In		1,626,000.	
Outflow			
	Creek Outflows		
	Salmon Falls Creek	103,500.	90% of 115K gain
	Deep Creek	46,000.	From USGS records.
	Mud Creek	62,000.	From USGS records.
	Cedar Draw	69,000.	From USGS records.
	Rock Creek	139,000.	From USGS records.
	Pumpage to West of Study Area		
	Salm. Falls Cr. Consumpt.	44,100.	90% of 49,000 acre-ft Consumption
	Irrigation Returns to Snake River		
	Measured Drains	70,000.	Brockway and Robison (1992). Pigeon Cove Corrected
	Estimated Drains	38,000.	
	Sewage Treat. Outflow	7,000.	Data provided by City of Twin Falls.
	ET	741,000.	Allen and Brockway method applied to model cells
Measured Outflow		1,320,000.	
Un-meas. surface and sub-surface outflow		306,000.	Difference of Total In and Measured Out

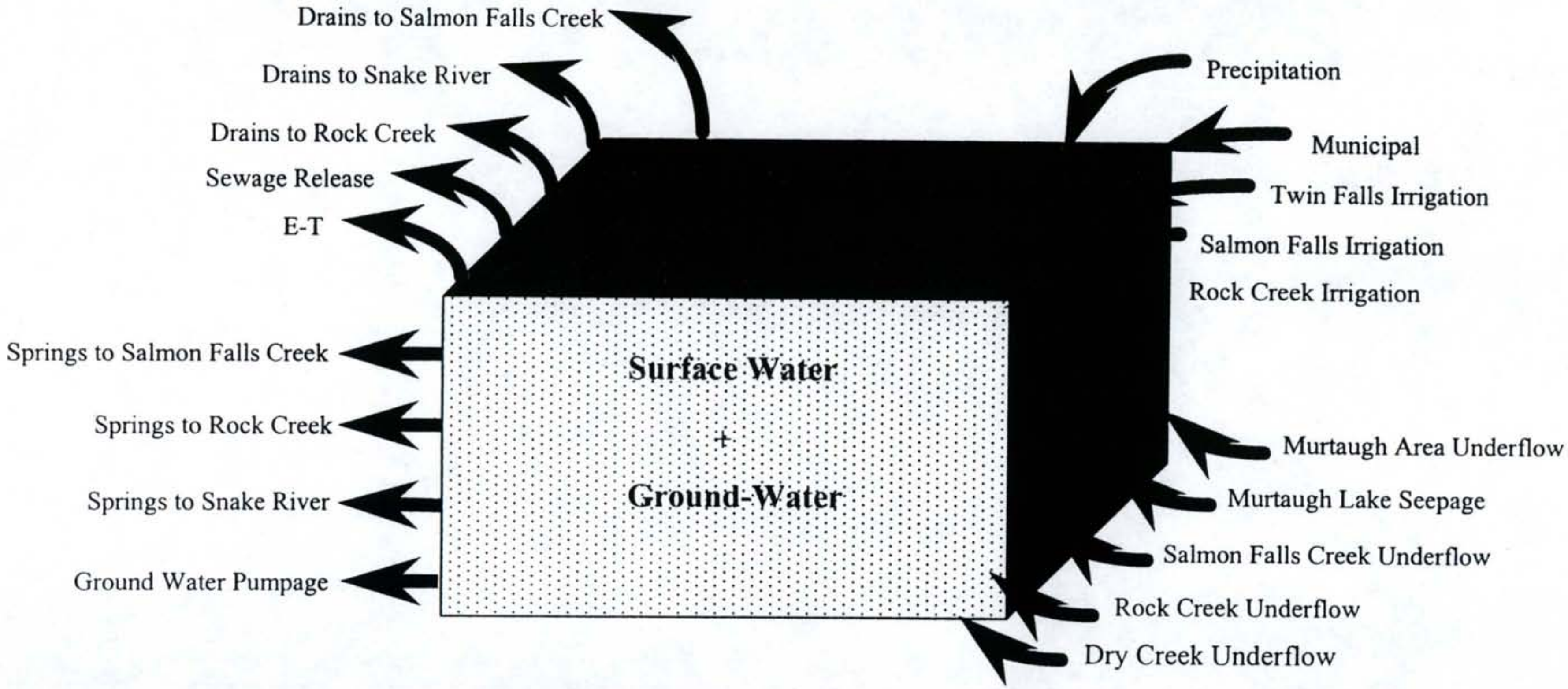


Figure 5. Water Budget Conceptual Model.

Inflows

Sources of inflow to the study area are precipitation, irrigation, underflow, surface-water inflow and municipal importation. Irrigation diversions from the TFCC constitute the single greatest source of inflow to the study area. Average diversions for the TFCC for the 1973 to 1993 period were used in the water budget. Irrigation diversions for the SRCC for the years 1992 to 1996 were provided by the canal company. The diversions were scaled based on the percentage of acres irrigated by the SRCC that falls in the study area. Precipitation was derived from 1945 to 1994 daily records from the Twin Falls, Idaho WSO. Precipitation was assumed to be uniform throughout the study area. Water imported to the study area from Blue Lakes by the City of Twin Falls was calculated using flow records from the city for 1987 to 1996.

Surface-water inflows were derived from the U. S. Geological Survey Water Resources Data, where available. The gage at Rock Creek Townsite was discontinued in 1974, so Rock Creek inflows were based on gage records from the Rock Creek Townsite for 1944 to 1974. Dry Creek inflows were gaged only in 1994. Mud Creek, Deep Creek and Cedar Draw inflows were estimated by Crosthwaite (1969a) and are listed as 'ephemeral streams'.

Underflow to the study area from Murtaugh was estimated based on calculated gradients and estimated hydraulic conductivities. Murtaugh Lake seepage estimates were taken from Young and Newton (1989). Underflow from the Rock Creek and Dry Creek drainages was estimated by Crosthwaite (1969a). Underflow from the Salmon Falls area was estimated by Crosthwaite (1969b).

Outflows

Evapotranspiration (ET), surface creek outflows, surface drains to the Snake River, subsurface drains and springs, water exportation and sewage treatment effluent comprise the outflows from the study area. Measurements or reasonable estimates are available on all of these elements except spring and drain outflows to the Snake River. This represents approximately twenty percent of the total water discharging from the study area.

Evapotranspiration is the single largest source of water leaving the study area. Crop distributions for Twin Falls County were provided by the Twin Falls Agricultural Stabilization and Conservation Service (ASCS) office for the years 1989 to 1995. These crop distributions were averaged to create the crop distribution in Table 2. The percentage of CRP/fallow land was adjusted from fourteen percent to four percent to be more representative of the crop profile within the study area (consensus between University of Idaho personnel and City of Twin Falls personnel). Table 2 shows the average crop distribution calculated from the ASCS data and the same crop distribution with the noted reduction in CRP/fallow percentage. Based on this average crop profile, an average annual evapotranspiration rate of 2.98 feet/year for irrigated land was calculated using reference ET rates shown in Table 3. For non-irrigated land, ET was presumed to equal precipitation. In the ground-water model, the average crop ET rate of 2.98 feet/year was applied to all irrigated acres, with the effect of assuming an average crop distribution on each acre planted. The calculation of ET for the ground-water model is more fully discussed in the Calculation of Recharge Section in Chapter 5.

Table 2. Crop Distribution for the Irrigated Acres within the Study Area

Crop	Twin Falls County Crop Distribution 1989-1995 ASCS Survey	Study Area Crop Dist.
Alfalfa	16.32	18.22
Barley	9.21	10.28
Beans	21.68	24.21
Corn	3.74	4.18
CRP	10.66	4.00
Dry Peas	2.84	3.17
Fallow	3.05	0.00
Grass	2.89	3.23
Oats	1.10	1.23
Potatoes	4.49	5.01
Sugar Beets	6.06	6.77
Sweet Corn	3.31	3.70
Wheat	14.64	16.34

Outflows for Rock Creek, Deep Creek, Mud Creek and Cedar Draw were obtained from the U. S. Geological Survey Water Resources Data for the available years. Outflow from the study area to Salmon Falls Creek was estimated as ninety percent of the total outflow of Salmon Falls Creek by Ralston and Young (1971). Total Salmon Falls Creek outflow includes water discharged to the Snake River and water pumped out of the creek for irrigation to the west. The volume of irrigation water pumped from Salmon Falls Creek was estimated based on IDWR water rights records. It was assumed that ninety percent of the pumped water also originates in the study area.

Drains to the Snake River were measured as part of the Mid-Snake Water Quality Study and are published in Brockway and Robison (1992). Approximately sixty percent of the drains to the Snake River were measured as part of that study, so an estimate was made for the unmeasured drains to the Snake River (personal communication with C. Brockway

Table 3. Average Monthly Evapotranspiration for Crops Grown in Study Area. (Derived from Allen and Brockway, 1983.)

Crop		% Coverage	ET ft/month Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ft/Year
Alfalfa	ALPH	0.18	0.04	0.06	0.15	0.26	0.59	0.64	0.67	0.53	0.35	0.12	0.09	0.04	3.54
Barley (Spr)	SGRAN	0.08	0.06	0.09	0.14	0.13	0.45	0.73	0.71	0.15	0.13	0.13	0.07	0.04	2.84
Barley (Fall)	WGRAN	0.02	0.06	0.09	0.09	0.38	0.63	0.74	0.66	0.13	0.13	0.13	0.07	0.04	3.14
Beans	BEANS	0.24	0.06	0.09	0.14	0.14	0.19	0.32	0.74	0.40	0.13	0.13	0.07	0.04	2.46
Corn	F.CRN	0.04	0.06	0.09	0.14	0.14	0.19	0.32	0.74	0.64	0.38	0.09	0.07	0.04	2.91
CRP	ET=Precip	0.04	0.04	0.06	0.15	0.26	0.49	0.57	0.63	0.53	0.39	0.26	0.09	0.04	3.52
Dry Peas	PEAS	0.03	0.06	0.09	0.14	0.12	0.36	0.60	0.29	0.13	0.13	0.13	0.07	0.04	2.17
Fallow	ET=Precip	0.00	0.04	0.06	0.15	0.26	0.49	0.57	0.63	0.53	0.39	0.26	0.09	0.04	3.52
Grass	PAST.	0.03	0.04	0.06	0.15	0.26	0.49	0.57	0.63	0.53	0.39	0.26	0.09	0.04	3.52
Oats	SGRAN	0.01	0.76	0.64	0.14	0.13	0.45	0.76	0.71	0.15	0.13	0.13	0.07	0.04	4.11
Potatoes	POTAT	0.05	0.06	0.09	0.14	0.12	0.20	0.51	0.69	0.54	0.30	0.13	0.07	0.04	2.90
Sugart Beets	SBEET	0.07	0.06	0.09	0.14	0.12	0.19	0.37	0.80	0.68	0.44	0.22	0.07	0.04	3.22
Sweet Corn	S.CRN	0.04	0.06	0.09	0.14	0.14	0.19	0.32	0.73	0.61	0.13	0.13	0.07	0.04	2.66
Wheat (Spr)	SGRAN	0.12	0.06	0.09	0.14	0.13	0.45	0.76	0.71	0.15	0.13	0.13	0.07	0.04	2.87
Wheat (Fall)	WGRAN	0.04	0.06	0.09	0.09	0.38	0.63	0.74	0.66	0.13	0.13	0.13	0.07	0.04	3.14
	total %	1.00													
Average ET			0.06	0.09	0.14	0.18	0.38	0.54	0.70	0.40	0.23	0.14	0.07	0.04	2.98

and C. Robison). Table 4 summarizes the drains measured as part of that study. The flows for Pigeon Cove were corrected based on data published in Sterling (1983); the numbers published in Brockway and Robison (1992) are believed to have been based on incorrect power production records. Records were obtained from the City of Twin Falls to estimate municipal outflow.

Ground-Water Budget

A ground-water budget was developed reflecting all water into and out of the regional aquifer. Figure 6 shows the conceptual model for the ground-water budget. Table 5 shows the overall ground-water budget.

Ground-Water Inflows

The primary sources of inflow to the regional aquifer are underflow from the areas surrounding the study area, canal seepage and deep percolation of precipitation and irrigation water applied in excess of crop demands. The underflow estimates for the ground-water budget are the same as for the overall water budget. Canal seepage was estimated as ten percent of the average TFCC diversion (based on personal communication with V. Alberdi). Canal seepage was measured in 1912 (Crosthwaite, 1969,a) and was calculated as thirty-five percent at that time. Seepage was estimated at seventeen percent in 1965 (Crosthwaite, 1969a). A decrease in canal seepage would be expected due to silts settling into the canal interstices, so a current estimate of ten percent loss due to canal seepage is reasonable. For the ground-water model, canal seepage was assumed to be only from the High Line and

Table 4. Summary of Measured Drains in the Twin Falls Study Area.

Measured Drain Flows
Average Daily Flow (cfs)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
East Perrine	27.4	30.4	46.9	51.5	43.6	22.4	19.9	13.8	11.1	8.5	13.7	36.5
Main Perrine	18.9	14.7	15.1	16.5	9.9	3.5	3.1	2.2	1.9	2.3	10.0	11.4
Pigeon Cove**	64.6	58.4	53.6	68.0	81.0	20.0	15.0	13.5	13.0	16.1	38.5	71.4
LS2/39A	7.6	8.2	9.5	8.3	7.0	2.5	1.9	1.6	1.2	1.2	2.6	6.8
Drain 39	8.3	5.3	3.6	9.3	7.4	1.5	0.9	0.6	0.4	0.5	3.6	7.9
Drain I	9.0	9.1	9.9	12.3	14.5	16.4	16.5	13.3	11.8	9.7	7.8	11.8
Drain N	4.1	4.1	4.1	3.9	5.4	4.9	4.7	4.4	4.5	3.5	4.1	4.5
West Perrine	3.6	3.0	2.4	1.5	1.7						2.4	2.6
TF Coulee	6.6	6.4	1.5	15.9	5.7						12.0	11.0
Drain A10	5.4	5.4	5.9	4.3	5.3						2.4	3.2
Drain 30	3.1	3.3	7.5	8.3	12.4						1.1	5.1
Drain 43	0.4	0.2	0.2	0.5	0.4						0.8	0.1

**Corrected for incorrect power production records.

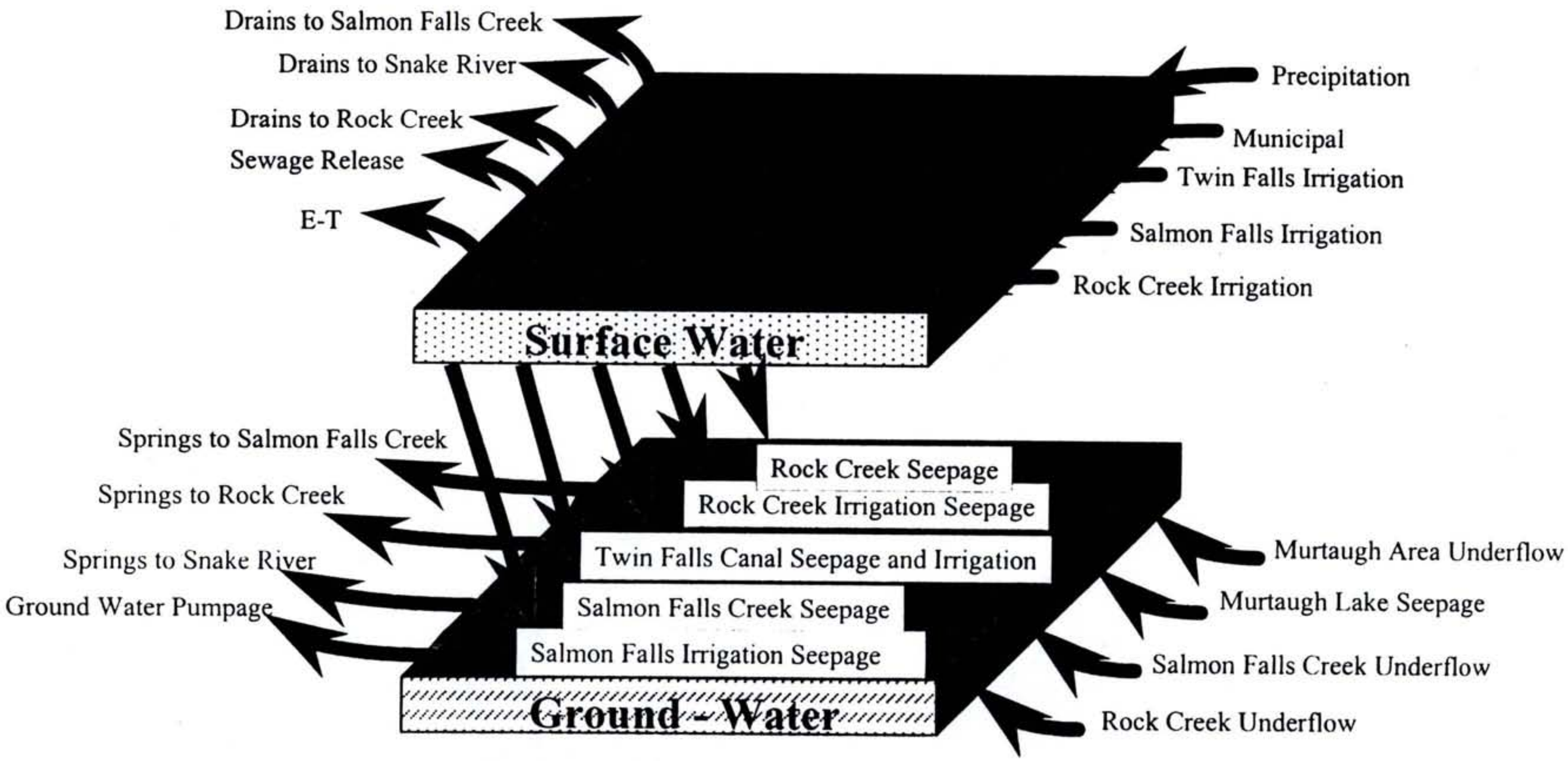


Figure 6. Ground-Water Budget Conceptual Model.

Table 5. Ground-Water Budget.

		Acre-Feet/Year
Inflow		
	Areally Distributed Recharge	
	Precipitation	307,000
	Irrigation Diversions-Canal Seepage	982,000
	ET**	-741,000
	Surface Returns	-168,000
	Total Areally Distributed Recharge	380,000
	Canal Seepage	109,000
	Underflow	
	Rock Creek/Dry Creek Underflow	21,000
	Salmon Falls Underflow	115,000
	Murtaugh Area Underflow	15,000
Total In		640,000
Outflow		
	Spring/Drain Flows to Surface Streams	
	SF Creek	102,000
	Rock Creek	96,000
	Cedar Draw	55,000
	Mud Creek	59,000
	Deep Creek	42,000
	Snake (measured)	26,000
	Total Measured Spring/Drain Flows	380,000
	Estimated Springs to Snake River	260,000

**Note: Ground-water pumping withdrawals are accounted for in the evapotranspiration term.

the Low Line canals of the TFCC and not from any of the laterals; however, seepage from laterals is included in irrigation recharge.

No direct measure of deep percolation from precipitation and applied irrigation water is available. Recharge from precipitation and applied irrigation water was estimated by taking the total volume of diverted water plus precipitation and subtracting water lost to consumptive use (ET) and irrigation return flows. Rock Creek probably is a losing stream in the southern part of the study; however, Rock Creek seepage was assumed to be negligible since most of the surface inflow for Rock Creek is diverted and applied for irrigation. All other surface streams bounding the study area are assumed to be gaining streams.

Ground-Water Outflows

Ground-water outflows from the study area consist of drains and springs to surface streams and the Snake River. Gains to Rock Creek, Mud Creek, Deep Creek, Cedar Draw and Salmon Falls Creek are from a combination of surface irrigation returns plus springs and drains. Monthly gains to each surface stream were used to determine stream gain due to springs and drains versus stream gain due to irrigation returns. In non-irrigation months, the assumption was made that all of the gain was due to spring and drain flow and that this flow would be relatively constant throughout the year. For irrigation months, the average spring and drain flow was subtracted from the total gain to determine the portion of the gain attributable to surface irrigation returns. Measured drains to the Snake River which have year-round flow were handled similarly. Unmeasured spring flows to the Snake River were calculated by taking the difference between all measured inflows to the ground water and subtracting the measured outflows. Approximately forty percent of the water leaving the aquifer in the study area is unmeasured springs to the Snake River. This assumes that there has been no net change in ground-water storage during the past few decades. The unmeasured spring flows to the Snake River is a large, ill-defined component of the ground-water budget. An estimate of unmeasured springs to the Snake River of 260,000 acre-ft is reasonable considering the total gain of the Snake River through this reach.

For ground-water irrigation, the assumption was made that any water pumped from the ground in excess of crop consumption seeps back into the aquifer. Therefore, no additional consumptive use beyond ET was considered as leaving the aquifer due to ground-water pumping.

Chapter 4

Well Measurement Network

A network of 118 wells was established for measuring ground-water levels in the Twin Falls area. The well network was designed to be most dense in the central part of the study area, with diminishing density as the distance from the center of the study area increased. Most of the wells in the network were domestic wells, due to the lack of ground-water irrigation in the tract. Figure 7 shows the location of the measured wells within the study area. An attempt was made to select wells sited along Rock Creek Canyon, the Snake River Canyon, Cedar Draw and Salmon Falls Creek Canyon to better establish water levels in those areas.

Very few wells exist in the extreme eastern and southern parts of the study area. Two wells measured by the U. S. Geological Survey in the extreme southeast part of the study area were used. Two additional wells measured by the U. S. Geological Survey in the southwest part of the study were initially used; however, those wells were dropped from the network because they penetrate both the regional basalt aquifer and the geothermal aquifer, so the measurements reflect mixed potentiometric heads (per personal communication with W. Young).

The water levels were measured five times in a thirteen month period during 1995 and 1996. Measurements were taken in November-December, 1995, and March, July, October and December, 1996. Water levels in the Twin Falls area fluctuate greatly due to surface

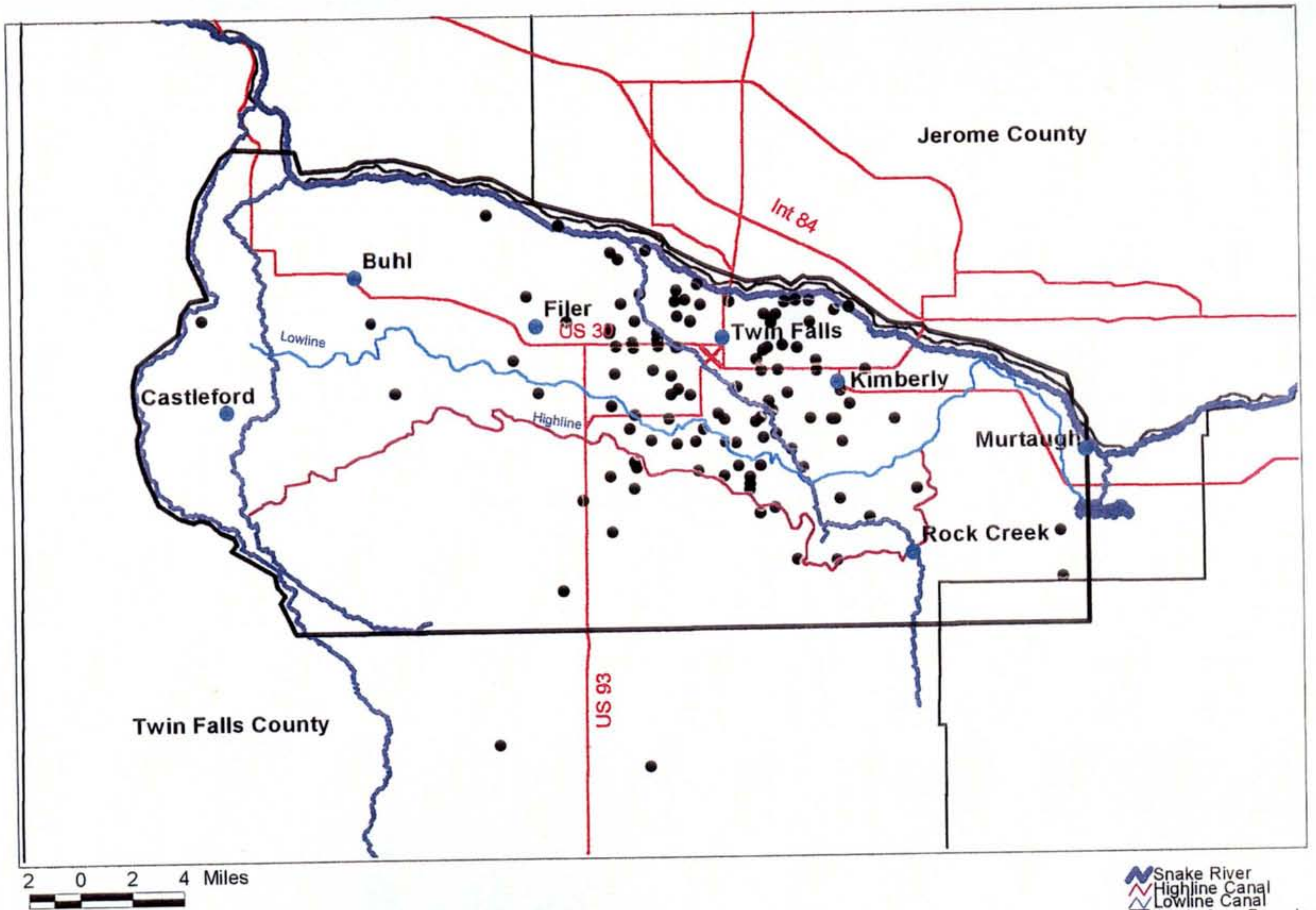


Figure 7. Well Network within Study Area.

irrigation. The March measurement was intended to establish the low annual aquifer level. The July measurement was to establish ground-water levels during irrigation. The October level established the high annual aquifer level and the November and December measurements established intermediate levels as the aquifer was falling to its low.

The first water level measurements were taken over a period of six weeks. During this time, field personnel were seeking appropriate wells for the network, which was very time-consuming. The water level measurements for the other four periods were taken within two or three days of each other to minimize measurement variability due to changing aquifer conditions. Measurements of depth to water were taken using electronic sounders.

For each measurement, the elevation of the water table at each well was calculated using the depth to water, elevation of the land surface, and height of the measuring point. Land surface elevation was estimated from 7.5" U. S. Geological Survey topographic maps. The well coordinates were based on the state plane coordinates taken from the topographic maps.

During each round of measurements, some wells could not be measured due to various causes, e.g. high well use for lawn watering in the summer or absence of owner. Missing measurements were estimated by taking the average change in water level since the last measurement for five to six neighboring wells and applying this average change to the last measurement for the unmeasured well.

Network sparsity in the east and the south means that the water level elevation contours in those regions are extrapolated from few data points. This extrapolation would potentially cause a great difference between the estimated potentiometric head and the actual potentiometric head. The well measurements taken in the more remote areas may also be subject to higher error due to more relief introducing more uncertainty in land surface elevations obtained from topographic maps. Resources were not available for Global Positioning System measurements with better accuracy.

High Frequency Wells

Nine wells from the well network were selected for bi-weekly measurements. The high frequency wells were selected to provide reasonable coverage around the City of Twin Falls. Locations and hydrographs for the nine high frequency wells are shown in Figure 8. The hydrographs show the aquifer response in the different locations to a typical annual cycle of irrigation and precipitation. It is clear from the hydrographs that the low in the annual aquifer cycle occurs in mid-April, approximately a month later than originally anticipated. The peak seems to occur anywhere between mid-August to early December, depending upon location. Most of the wells showed the peak occurring in late September or early October. The hydrographs also show the difference in the magnitude of the responses to the irrigation cycle at the different locations. The total response in the frequently measured wells ranged from a 25 foot response (between the absolute low and the peak) at the Ward well to a 3 foot response at the city well at Dierkes Lake, along the Snake River. Of note is the difference in response between the two wells at Amalgamated Sugar. The wells are only a half mile apart but are on opposite sides of Rock Creek. The Amalgamated well (#1) on the west side of Rock Creek showed a 15 foot response versus the Amalgamated well (#2) on the east side which showed only a 3.5 foot response. This reflects the higher amount of irrigation to the west of Rock Creek and implies that a partial hydrologic boundary is created by the canyon.

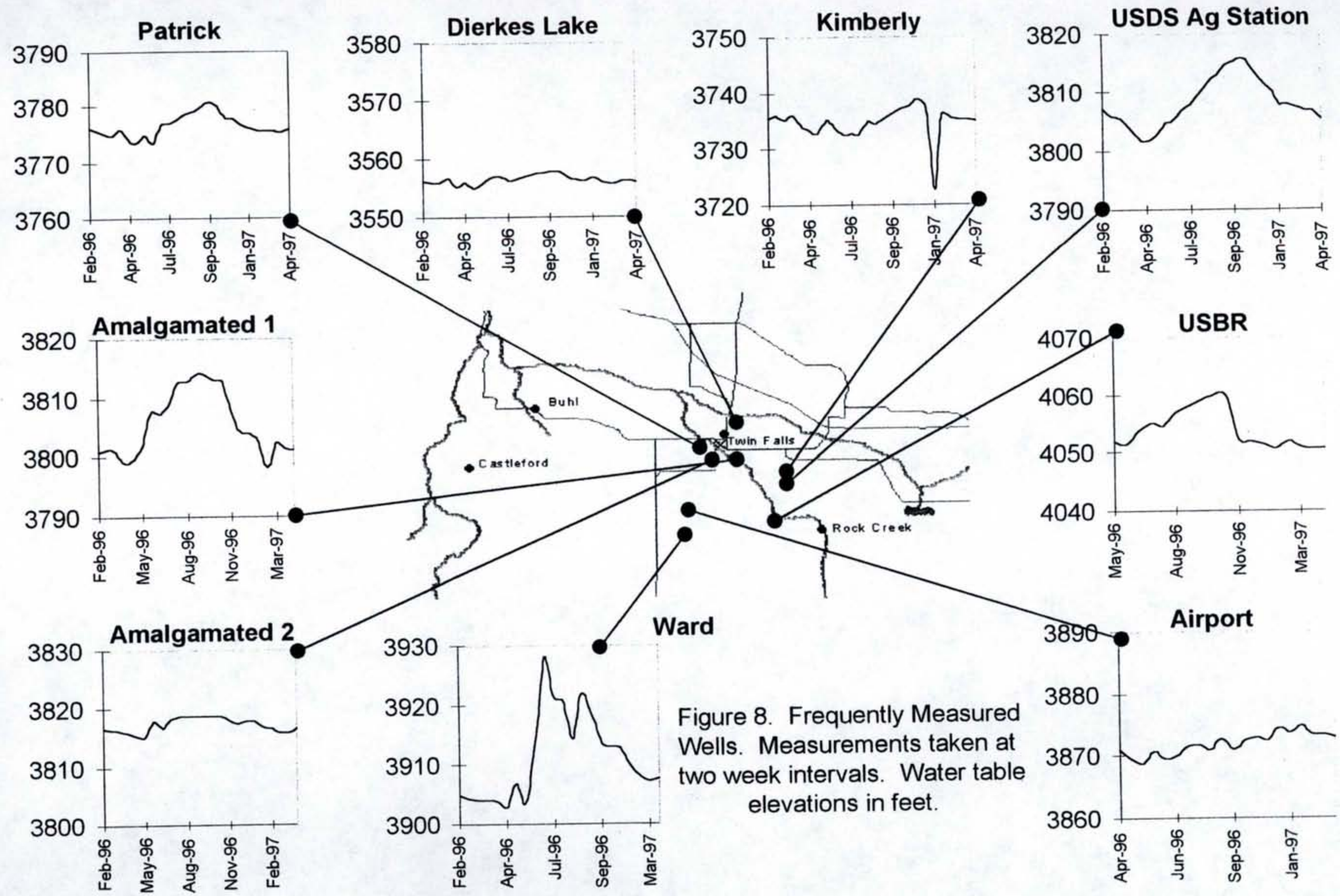


Figure 8. Frequently Measured Wells. Measurements taken at two week intervals. Water table elevations in feet.

Average Water *Level Contours*

The water level measurements taken during 1995-1996 were used to generate average water level contours. For any well in the network which was inaccessible during a measurement period, the missing measurement was estimated by determining the change in water level in the wells nearest the inaccessible well. The average change in water level was then applied to the missing well. Figure 2 shows the average water levels for the study area for the 1995-1996 period. The average water level contours are in good agreement with previously published water level contours for the Twin Falls area (Moffatt and Jones, 1984). The average water level contours were used to generate starting heads for the numerical ground-water model, as discussed in Chapter 5.

The changes in water levels between the March 1996 and the October 1996 measurements were also contoured to illustrate the maximum change in water levels during the year. These maximum change contours are shown in Figure 3.

The December 1996 measurements were virtually the same as the December 1995 measurements. This implies a dynamic equilibrium in the basin and supports the steady state assumption made in the recharge-discharge balance and in the model.

Chapter 5

Model Description

Introduction

This chapter describes the modeling process which was undertaken in development of the Twin Falls numerical ground-water model. The study area was modeled using a 2-dimensional steady state finite difference model. In a steady state model, recharge and discharge conditions are held constant and the model is run until equilibrium. In finite difference modeling, the flow equations are applied to each active model cell and the flows into and out of the model cell from surrounding cells are balanced with the modeled recharge/discharge terms. A hydraulic head is generated for each cell, representing the water level of that cell when the system is in equilibrium.

The modeling process comprised development of a conceptual model of the geohydrology of the Twin Falls area, generation of model starting heads, development of recharge and discharge for the model based on the area water budget, designing of the model grid, populating the model grid cells with data and, finally, calibrating the model parameters.

The finite difference modeling was done using the U. S. Geological Survey MODFLOW program (version 1.97 from Waterloo Hydrogeologic) finite difference modeling package. MODFLOW's strongly implicit solver (SIP) package was used for the numerical solution. The MODFLOW Drain package was used to model head-dependent spring discharge to surface streams and rivers. All other recharge/discharge terms were summed for each model cell and were applied using the MODFLOW Well package. EXCEL spreadsheets and macros were used in the generation of recharge and discharge (WEL term) for each model cell. These are discussed in Appendix A. Visual MODFLOW Version 2.11 was used initially in generation of the model grid and assignment of model parameters; however, Visual MODFLOW proved cumbersome for handling changes during calibration and was abandoned in favor of text modification of MODFLOW files.

Conceptual Model Description

The conceptual ground-water model for the Twin Falls area was defined as a single layer model of the regional aquifer in the basalts underlying Twin Falls. Perched water zones within the study area were assumed to be localized and to retain a small volume of water as compared with the regional aquifer (Moffatt and Jones, 1984), so the perched zones were not represented with a separate model layer. The minimal hydraulic interaction between the regional aquifer in the basalts and the geothermal aquifer in the rhyolites, interpreted from distinct water geochemistry signatures (personal communication with W. Young), indicated that the basalt aquifer could be modeled independently of the geothermal aquifer.

The model extends from the Snake River, south to the Cassia Mountains (South Hills), including the first and second courses of Township 12S (sections 1-12), east to the west edge of Murtaugh Lake (including all of Range 19) and west to Salmon Falls Creek. As Salmon Falls Creek angles to the southwest, it cuts the southwest boundary of the model. The model covers an area of 560 square miles and is about 15 miles in the north-south direction by 40 miles in the east-west direction.

Average annual water contours were generated using the five measurements of each well in the well network (see Chapter 4). The average water contours were gridded using the Surfer contouring package, the grid was read into Visual MODFLOW where the grid points were converted to starting heads for each model cell. The steady state model was calibrated to the gridded heads in model cells containing measured wells.

Recharge to the study area included precipitation, underflow, canal seepage and irrigation. Discharge from the study area was modeled as evapotranspiration and head-dependent drains.

Precipitation was areally distributed throughout the study area, using the average precipitation for the Twin Falls, Idaho WSO. Irrigation was distributed based on land use and the source of irrigation water. Sources of irrigation water included the TFCC surface and sprinkler irrigation, SRCC surface irrigation, Rock Creek surface irrigation and ground water. Land use within the model was characterized as urban, suburban, agricultural or range. For urban and suburban land uses, the only irrigation which was modeled was lawn watering. Agricultural land was modeled using an irrigation application rate appropriate for the source of irrigation. Canal seepage was restricted to the High Line and Low Line canals of the TFCC. A uniform application of irrigation water was assumed for all acres irrigated by the same irrigation source. Application of precipitation, irrigation water, and canal seepage was modeled as independent of aquifer head.

Evapotranspiration, calculated using an average crop profile, was applied uniformly to each irrigated acre. Each acre of cropped land was modeled as though it was planted with each of the crops listed in Table 2 and in the listed proportions; therefore, the same average

ET rate was applied to each irrigated acre. Range land was modeled as not irrigated or cropped, with ET equal to precipitation (all precipitation was presumed to evaporate, with no net gain to or loss from the aquifer).

Springs to surface streams and rivers were modeled as head-dependent drains. Major controlling factors on the model calculations are location and discharge rates of springs to the Snake River. A flow-net analysis (Lohman, 1972) was done to estimate the distribution of springs to the Snake River. Flow channels were established based on the average water contours generated using the well network. The study area was divided into five flow channels by drawing lines perpendicular to the water contours. Because flow is orthogonal to the water table contours (assuming an isotropic media), it could be assumed that there would be minimal flow between the flow channels. Within each flow channel, the total recharge should equal the total discharge, otherwise there would be significant flow between the channels. Figure 9 shows the flow channels superimposed upon the water contours. The flow channels were then used to determine the volume of discharge required to balance the volume of recharge within each channel. This facilitated identification of the location and discharge of springs within the model, consistent with known spring locations.

Starting Heads

Starting heads for the steady state finite difference model were generated using the average of the water levels measured in each well in the well network. Data points along Rock Creek were added to represent springs located an arbitrary 20 ft above the creek bed. These data points were added because the initial water contours showed flow across Rock Creek in locations where the canyon was deeply incised. Addition of the data points along

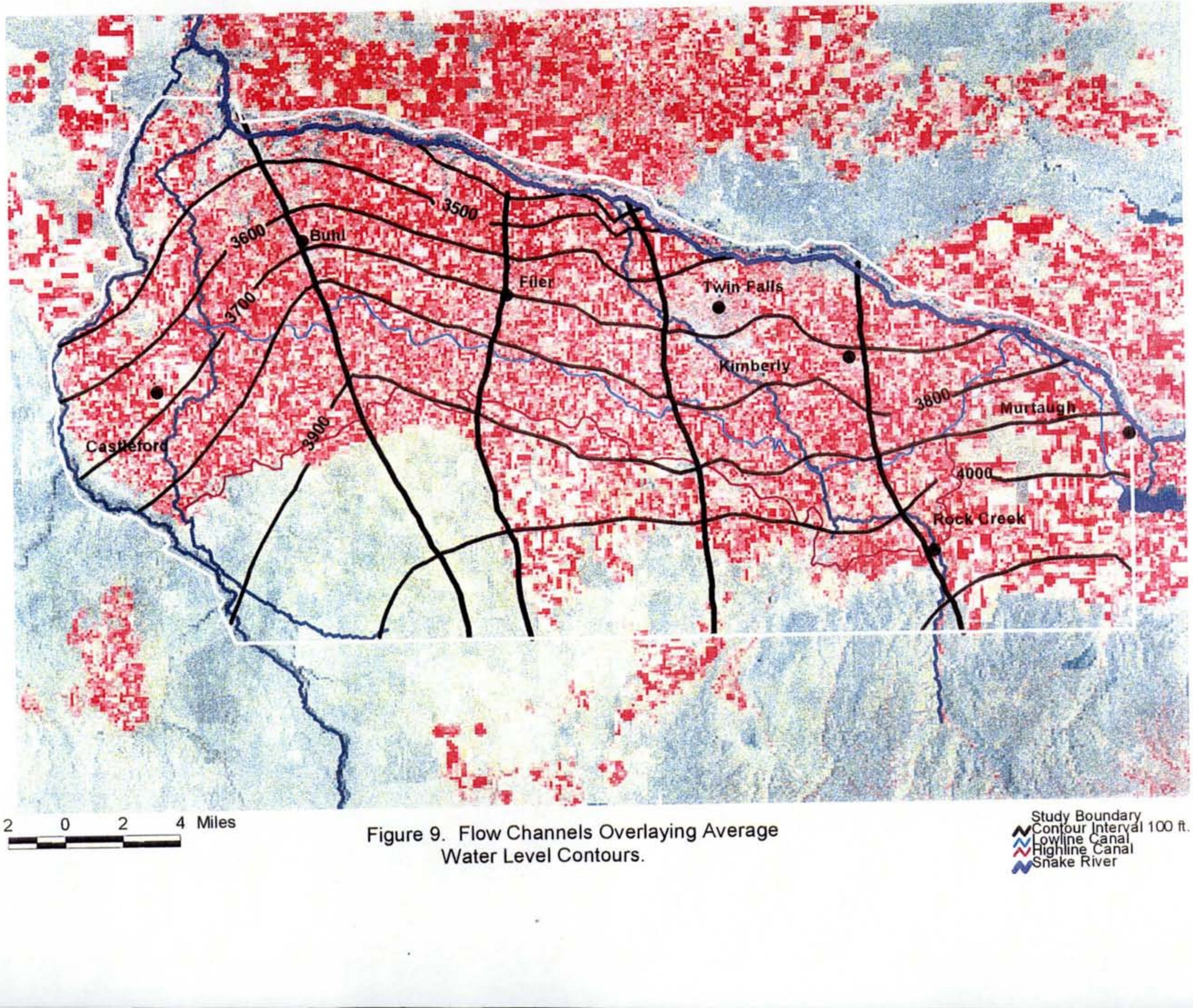


Figure 9. Flow Channels Overlaying Average Water Level Contours.

Rock Creek altered the generated contours to a more realistic flow pattern near Rock Creek.

A steady state model represents the average hydrological conditions run for an infinite period of time. For the Twin Falls steady state model, average water levels were used for the starting heads. Even though the average water levels did not reflect a true measurement, they were most representative of average conditions.

Spring elevations along the Snake River and Salmon Falls Creek were not used in generation of the starting heads. Introduction of estimated spring elevations into the water contours would make the modeled head-dependent drains unduly sensitive to changes in water levels at the canyon walls.

Calculation of Recharge

The components of recharge which were modeled were precipitation, applied irrigation water, evapotranspiration, underflow and canal seepage. All of the recharge components were summed into a single recharge term and were represented using the Well Package of MODFLOW. Model cells with a net loss of water were represented as wells with a negative Q term. Model cells with a net gain of water were represented as wells with a positive Q term.

Method of Estimation

A spreadsheet method was developed for calculating recharge for the finite difference model. The spreadsheets were designed with a row/column format to enable the user to modify variables in cells or groups of cells. This provided the user with a good visual representation of data in actual cell locations. The spreadsheets were created using

Microsoft EXCEL (version 5.0c). Macros were written using EXCEL's Visual Basic for Applications (VBA) language to process the data entered by the user and generate the MODFLOW well file. The spreadsheets are explained in more detail in the appendix. The following sections describe how the different components of recharge were calculated for the model.

Precipitation

Precipitation was uniformly distributed, based on the average annual precipitation at the Twin Falls WSO for the period of record. For each model cell, the precipitation component of recharge was calculated as cell area times the average annual precipitation of 10.3 inches.

Applied Irrigation Water

The applied irrigation water was calculated based on the number of irrigated acres in the cell and the source of the irrigation water. The Idaho Department of Water Resources provided the number of irrigated acres by section for Twin Falls County. These data were mapped to each cell of the model based on which section the cell was in and the size of the cell. The irrigated acreages were then corrected by applying a factor of 0.875 to represent the acreage which was actually planted versus roads, rights of way, houses and canals. The 0.875 scaling factor was derived by planimetering aerial photos of rural sections in the Twin Falls area.

IDWR also provided a map showing canal company service areas. From that map, each model cell was assigned a source of irrigation water. Four sources were modeled: the TFCC, the SRCC, Rock Creek and ground water.

For the TFCC, the total applied water was calculated as the total volume of water diverted minus the sum of measured and estimated return flows, canal seepage, and irrigation season tunnel flows. Tunnel flows during non-irrigation season were considered to be year-round spring flow. An underlying assumption was that drains and tunnels drain all cells uniformly. The total applied water was then divided by the total number of acres serviced by the TFCC. This yielded an application rate of 4.6 AF/acre of applied irrigation water per year. For each model cell with acres irrigated by the Twin Fall Canal Company, the total applied irrigation water was calculated as:

$$4.6 ft / acre \times Irrigated\_Acres\_In\_Cell .$$

The same application rate was applied to each cell in the model with acres serviced by the TFCC.

The SRCC provided data on their monthly diversions for 1992-1996 (Table 6). The land use data provided by the Idaho Department of Water Resources indicated that sixty-five percent of the land irrigated by the SRCC was within the study area. An irrigation application rate was calculated for SRCC-irrigated land within the study area. This application rate was well below the average crop consumption.

Table 6.
Salmon River Canal Company Diversions.
(From the Salmon River Canal Company)

Month	Year 1992	1993	1994	1995	1996		Average
May	5,000	5,000	3,000	2,000	9,000		4,800
June	4,000	8,000	5,000	6,000	16,000		7,800
July		16,000	4,000	4,000	19,000		8,600
August		15,000	2,000	8,000	13,000		7,600
September		3,000		4,000	2,000		1,800
						Total	30,600

Crosthwaite (1969b) indicated that the number of acres irrigated by the SRCC fluctuates annually, depending upon water availability. To compensate for this uncertainty in the model, the same application rate which was calculated for the TFCC, 4.6 AF/acre, was used for the SRCC, but the number of acres irrigated in each cell by the SRCC was reduced based upon the calculated production rate. The production rate for the SRCC was calculated as:

$$ProductionRate = \frac{\left(\dfrac{AverageSRCCWaterDivertedToStudyArea}{TFCCAppliedWaterRate}\right)}{TotalSRCCAcresInStudyArea} * 100$$

The calculated production rate was 0.35: that is, on the average, thirty-five percent of the acres assigned to the SRCC within the model area were actually irrigated. For each model cell with acres irrigated by the SRCC, the number of irrigated acres was multiplied by the production rate. The 4.6 AF/acre application rate was then applied uniformly to the resulting number of acres. This method of representing irrigation in the Salmon River area assumes the same net incidental recharge due to irrigation as in the Twin Falls tract. In reality, the SRCC may be more efficient, with a lower net recharge. This area warrants further investigation; however, the small magnitude of irrigation in the Salmon River area relative to the whole Twin Falls tract would indicate a relatively small impact on the model.

For land irrigated by Rock Creek, it was originally assumed that the total surface inflow of Rock Creek during growing season would be diverted for irrigation. Using the total surface inflow for Rock Creek and the number of acres irrigated by Rock Creek yielded an application rate of 13.3 AF/acre, which is almost a factor of three higher than the TFCC application rate of 4.6 AF/acre. It was clear that either the diversion was too high or the number of Rock Creek irrigated acres was too low. This is an area which warrants further study. For the current ground-water model, the Rock Creek irrigated acres indicated by the IDWR data were used with the TFCC application rate of 4.6 AF/acre. Uncertainty in the value of this number has little effect on simulation results due to the small magnitude relative to other water budget components.

For acres irrigated by ground water, it was assumed that any water applied in excess of crop consumption would infiltrate back to the aquifer and that the crops would be fully watered. The applied irrigation water for ground-water irrigated acres was set equal to the average crop evapotranspiration. Each model cell with ground-water irrigated acres was modeled using an application rate of 2.98 AF/acre, the average annual evapotranspiration rate.

Evapotranspiration

Every model cell has associated land use percentages representing the percentage of the cell which is urban, suburban, agricultural, and range land. These percentages are used to calculate evapotranspiration. The percentage of agricultural land in each model cell was based upon the irrigated acreage data received from IDWR. The percentage of urban and suburban land was estimated from maps and field surveys. The percentage of range land was derived as the balance of land not assigned to the other three land use categories.

Evapotranspiration within urban and suburban areas was based on the annual grass ET and on published averages for pervious ground within urban and suburban areas (van der Leeden, et al, 1990). For urban areas, a fixed percentage of thirty percent pervious ground was used; for suburban areas, the fixed percentage used was seventy-three percent. For example, for a model cell which was designated urban, the cell area was multiplied by .3 (reflecting the percent pervious area) and the average grass ET of 3.52 ft/year was applied to this area. Because the urban area is assumed to be on the city water supply which is derived largely from outside the basin, a better representation of urban ET might be to exclude it from the overall calculation, because the water is not derived from the aquifer. Urban ET is, however, a small component of total discharge.

For agricultural areas, ET was based on a weighted average ET reflecting the crop distribution for the study area. The average crop ET was calculated using growing season ET data from Allen and Brockway (1983) and non-growing season ET data from Wright (1993). The Brockway and Allen growing season ET data were derived for the Kimberly, Idaho area using the FAO-modified Blaney-Criddle method. The Wright non-growing season numbers were developed using lysimeters at the U. S. Department of Agriculture Research Station at Kimberly, Idaho. Average annual ET for each specific crop was proportionally applied to crop distributions obtained from the Twin Falls ASCS office. The ASCS numbers represented crop distributions for all of Twin Falls County for seven years. An average crop distribution for the county was calculated from this data. The study area lies wholly within Twin Falls County, but is not as large as Twin Falls County, and represents most of the agricultural development within the county. A consensus between University of Idaho researchers and the City of Twin Falls planners was that the percentage of fallow/CRP should be reduced for the study area, presuming that most of the fallow/CRP land in Twin Falls County lies outside the study area. The percentage of fallow/CRP land was reduced from fourteen percent to four percent and the other crop percentages were adjusted accordingly. This had the effect of increasing average ET per acre for the study area. Table 3 shows the average monthly ET for each crop grown in the area.

For range land, ET is assumed to be equal to precipitation, with all precipitation evaporating and no additional water drawn from aquifer. For any model cell with a mix of land uses, the appropriate ET was applied proportionately for each specific land use.

Canal Seepage

Canal seepage was modeled along the High Line and Low Line canals of the TFCC. Total canal seepage was estimated as ten percent of the average annual diversion for the TFCC. This volume of water was then distributed to the five flow channels discussed in Conceptual Model Description, based on the number of acres irrigated by the TFCC in each flow channel. The seepage was then apportioned within each flow channel along the High

Line and Low Line canals of the TFCC, based on the canal length in each cell. The canal seepage was distributed in this manner to model more seepage in areas of the model which have a higher percentage of irrigation laterals.

Underflow

Underflow was represented as fixed flux in the border cells where underflow enters the study area. The underflow coming into the model was apportioned to the affected model cells based on the length of the cell face (for example a cell with a 2 mile side facing the underflow received twice as much underflow as a cell with a 1 mile side). This positive flux term was added into the well term for each cell with underflow.

Model Grid

The model grid is 49 rows by 53 columns. The grid was established using cells of variable dimension, with .25 mile by .25 mile cells in the central region of the model covering 48 square miles in and around the City of Twin Falls, with increasing cell size away from the center, expanding to 1 mile by 2 mile cells at the boundaries. Figure 10 shows the model grid overlain on the study area. The model origin is in the southeast corner of Township 12 south, Range 13 east, section 9, with Universal Transverse Mercator coordinates of 4,694,750 meters north , 669,100 meters east and latitude and longitude of 114°56'45" west, 42°23'20"north. Figure 11 shows variable grid spacing coverage of the study area. The variable grid spacing was chosen to give the highest resolution and modeling detail in the central part of the model, which was of highest interest to the City of Twin Falls. Use of a smaller grid size minimizes error due to averaging of cell properties (all recharge,

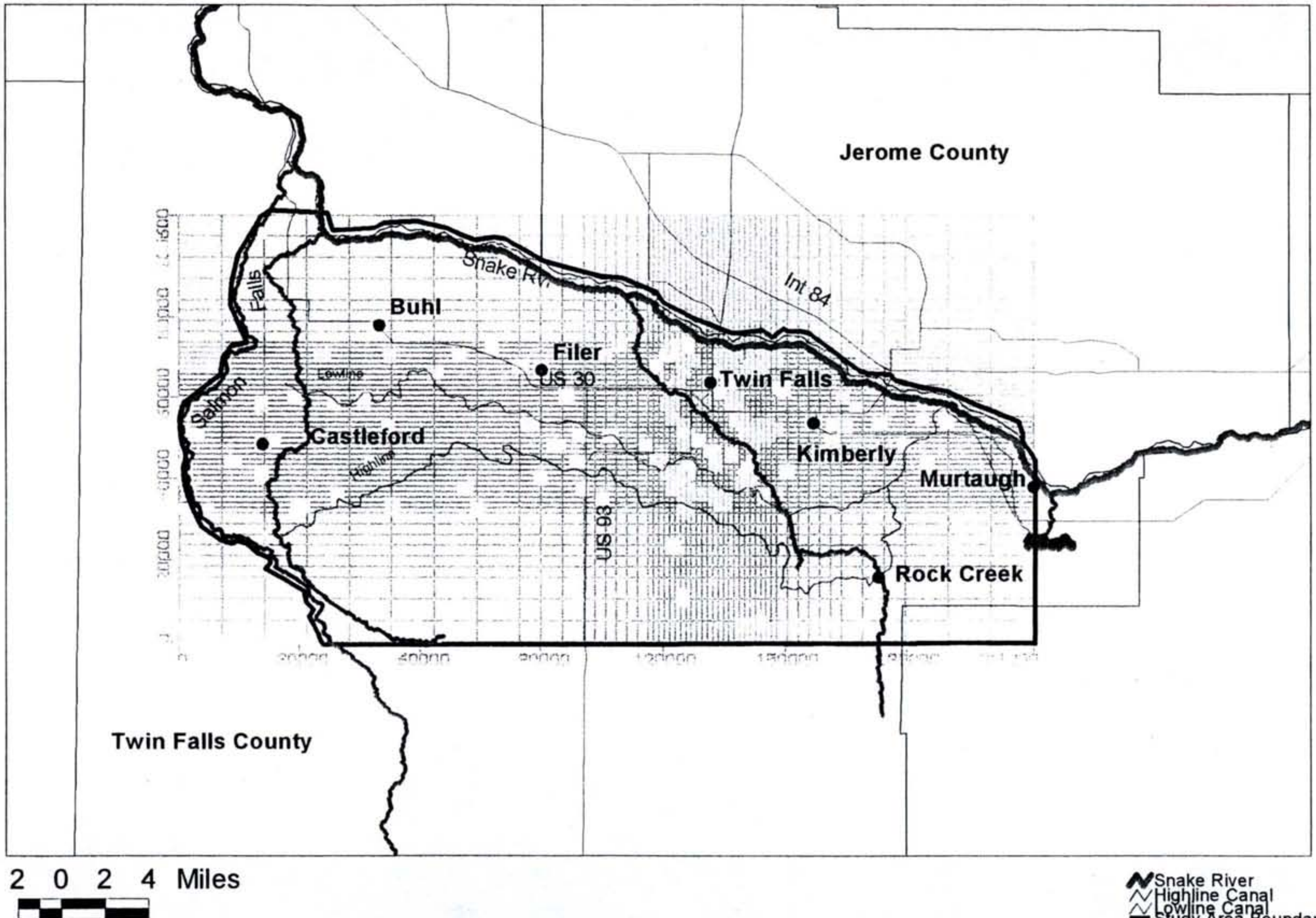


Figure 10. Model Grid Overlaying Study Area.

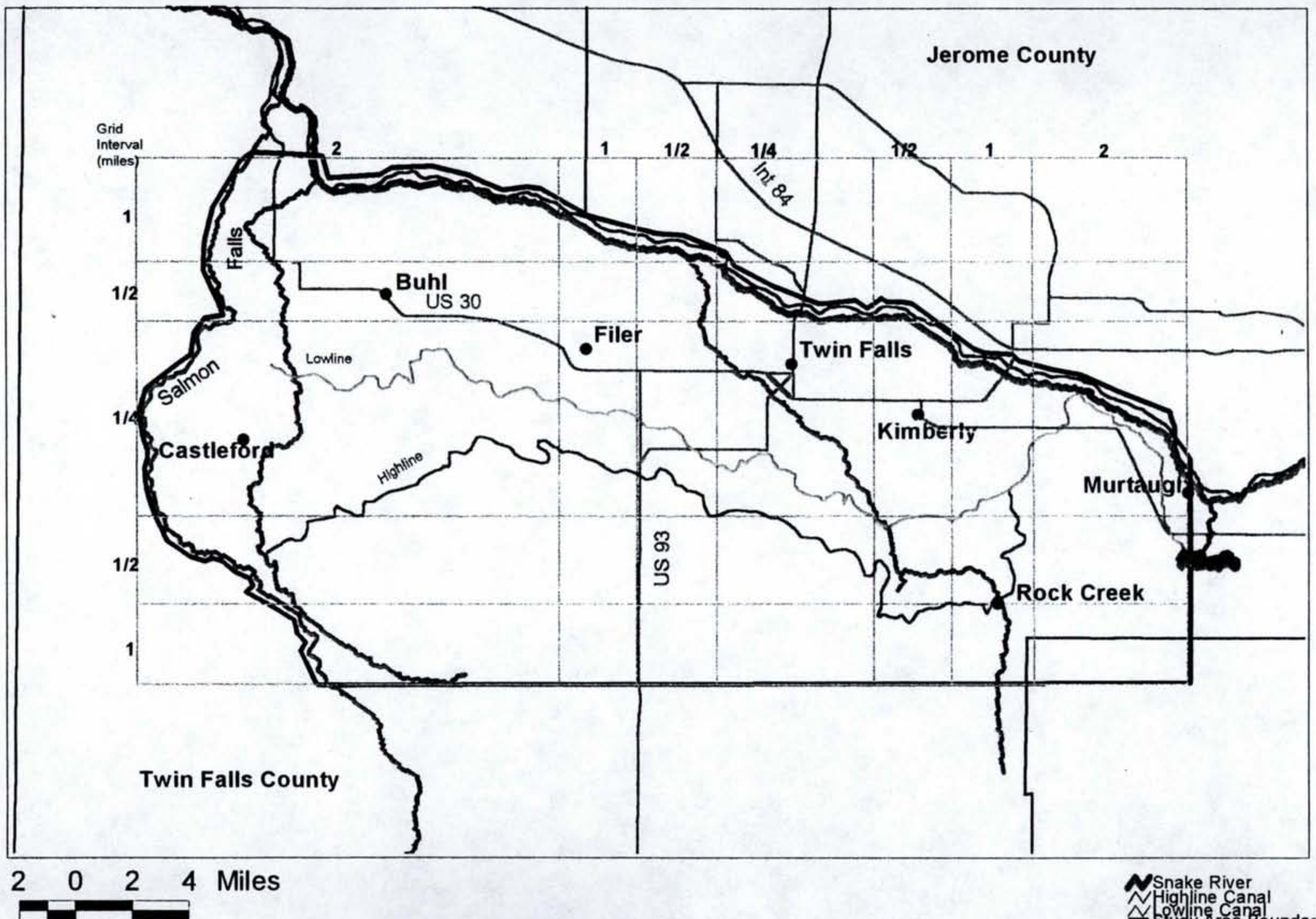


Figure 11. Simplified Grid Interval Zones.

discharge and hydraulic heads are represented at the center point of the model cell). However, use of a smaller grid size requires data collection for each model cell, implying that data are available for very localized areas of the model. In reality, the data which are available are usually generalized and not available to such fine detail. Thus, introduction of a fine grid size does minimize averaging errors within the model, but does not significantly increase the level of accuracy of the model.

Model Boundaries

Model cells along boundaries where underflow is entering the study area were assumed to be fixed flux cells. In Figure 10, these are the cells along the eastern boundary south of Murtaugh Lake and the cells along the southern boundary between Salmon Falls Creek and the Cassia Mountains. All other boundary cells have the default as representing no flow boundaries. The model boundaries were established based on physical boundaries and far enough from the area of high concern to minimize impacts of possible inaccuracies of representation in the area of primary interest near the city.

The Snake River to the north delineates the northernmost active model cells. These cells were modeled as no flow cells (representing the deep canyon) with a series of head-dependent drains at elevations and discharges designed to model natural springs in the canyon walls. Model cells north of the Snake River were modeled as inactive.

The South Hills are the southern boundary in the eastern part of the model. Cells along this boundary were modeled as no-flow cells with fixed flux cells representing the Rock Creek and Dry Creek drainages. In the western part of the model, the southern boundary is Salmon Falls Creek. Model cells along Salmon Falls Creek Canyon were modeled as no-flow cells with fixed flux cells representing underflow from the Salmon Falls area.

The eastern boundary of the model is located just to the west of Murtaugh Lake. This boundary is located far enough from the City of Twin Falls to minimize the impact of the boundary on water level changes related to pumping and recharge in the central study area. The Murtaugh Lake area is also a natural hydrological boundary. Geological faulting southeast of Murtaugh Lake has caused the hydrology east of the lake to be significantly different from the hydrology to the west of the lake with depth to water being far greater to the east (Young and Newton, 1989).

Salmon Falls Canyon provided a natural hydrological boundary to the west. The canyon was modeled using no-flow cells with head-dependent drains representing natural springs to Salmon Falls Creek. Flow lines in the Salmon Falls Creek area indicate that there is no ground-water flow under Salmon Falls Creek.

Rock Creek runs from the southeast up to the Snake River in roughly the center of the model. Rock Creek was viewed as gaining from approximately the Amalgamated Sugar Factory (cell row 26, column 36) on northward. Transmissivity of cells containing Rock Creek canyon were reduced relative to surrounding cells to represent a partial canyon penetration through the aquifer. From Amalgamated Sugar to the Hospital at the Highway 30 (cell row 20, column 28) crossing, the cells along Rock Creek are modeled with a hydraulic conductivity which is seventy-five percent of the surrounding cells. From the Highway 30 crossing on north, the cells are modeled with a hydraulic conductivity of fifty percent of the surrounding cells. Head-dependent drains are set in each cell through which Rock Creek flows; thus flow gradually increases from south to north. Rock Creek probably is a losing stream in the southern reaches of the study area, converting to gaining as it enters the incised canyon. However, because most of the water in Rock Creek is diverted and applied as irrigation, any additional seepage from Rock Creek is considered as minimal.

Springs and drains to surface streams and rivers were modeled as head-dependent drains using the Drain package in MODFLOW. All surface streams within the study area were modeled as gaining throughout the extent of the study area, with head-dependent drains representing springs discharging to the surface streams.

An attempt was made to map the bottom of the basalt aquifer from driller's logs. Uncertainty in the lithology in the driller's logs and a lack of wells in the west and south portions of the model yielded unreasonably low numbers for the depth to the bottom of the basalts. Street and DeTar (1987) show the Shoshone Falls rhyolites at a depth of approximately 200 feet in the central part of the study area. Geothermal wells drilled in the Snake River Canyon bottom indicate a depth to the bottom of the basalt of approximately 700 ft. below canyon floor. Wells drilled in the Salmon Falls Creek Canyon bottom indicate a similar depth to the bottom of the basalt (personal communication with C. Brockway). For the ground-water model, the bottom of the basalt was modeled as a uniform, sloping surface ranging from 700 ft. below land surface at the southern end of the model to 700 ft. below river bottom at the Snake River. This simplification of a complex variable in the study area was considered to be a reasonable assumption. The depth of the aquifer will affect calibration of hydraulic conductivity values. Errors in the depth of the aquifer are offset by changes to hydraulic conductivities made during the model calibration phase. Any attempt to model the basalt bottom with further sophistication and without additional data may introduce more error. This is an area which may warrant future study.

Validity of Boundary Assumptions

The choice of modeling the deeply incised Snake River Canyon as no-flow cells is valid due to the fact that the canyon bottom is well below the top of the aquifer. Both Garabedian (1992) and Young and Newton (1989) indicated no underflow beneath the Snake River in the Twin Falls area. Similarly, modeling the Salmon Falls Creek Canyon with no expected underflow either leaving or entering the study area is consistent with water contours generated for this study as well as those published in Moffatt and Jones (1984).

Representing the underflow from the Salmon Falls area as fixed flux cells is consistent with Crosthwaite (1969b). The choice of no-flow cells along the South Hills, with fixed flux cells representing the Rock Creek and Dry Creek drainages is consistent with the topography of the Cassia Mountains and with Crosthwaite (1969a). Representation of the eastern boundary as fixed flux underflow from the Murtaugh area is supported by Young and Newton (1989).

Chapter 6

Model Calibration

The steady state model was calibrated in steps, initially as a confined aquifer with fixed flux nodes to represent springs and drains to surface streams and rivers, then as a confined aquifer with head-dependent drains to represent springs and drains, and finally as an unconfined aquifer with head-dependent drains. This step-wise calibration enabled refinement of calibration parameters with each successive level of complexity. Initial calibration as a confined model, although not representative of the actual physical system, enabled refinement of model parameters such as hydraulic conductivity and drain conductance without having cells dry up.

Once model parameters were felt to be calibrated, the unconfined model was also run for pre-development conditions as a cross-check. A calibration attempt was also made using the U. S. Geological Survey parameter estimation program MODFLOWP.

General Calibration Methodology

For model calibration, zones of uniform transmissivity were established based on the gradients of the water contours generated from the average water level measurements. The transmissivity within each zone was varied by trial and error, MODFLOW was run and the simulated heads were compared with the measured heads. The zone boundaries or values within the zones were altered during calibration in an attempt to improve the calculated heads in areas where departures between measured head and calculated head were inordinately great. Improvement was measured based on the mean average error (MAE) and the root mean square (RMS) of the departures between simulated heads and measured heads.

Calibration Criteria

Several criteria were established to determine improvement in model calibration. The mean average error and the root mean square of the departures of the simulated heads from the measured heads were calculated and transmissivities were adjusted to improve those measures. Once head-dependent drains were introduced to the model, the calculated flow was compared with the expected flow from each drain. Drain elevations were set at an average level of halfway between the starting aquifer head and the river elevation. Drain conductances were set based on a balance of the recharge/discharge within the flow channels discussed in Chapter 5. It was not felt to be an improvement to the model to alter drain conductances or elevations to drive a desired outcome. Drain conductances and drain elevations were fixed and drain fluxes were manipulated only by varying cell hydraulic conductivities. The elevation of the aquifer bottom was also held constant during calibration.

Confined Aquifer Calibration

The model was initially calibrated as confined to avoid cells becoming dry due to water levels drawing down below the bottom of the aquifer. The drains were initially established as fixed flux nodes to provide control over the location and magnitude of flow from the model. Drain locations and fluxes were fixed based on balancing the recharge and discharge within the flow channels which were discussed in Chapter 5. By distributing discharge points along surface streams and rivers such that recharge and discharge within each flow channel was balanced, flow between the flow channels was minimized, forcing the modeled flow lines to match expected flow lines.

Head-dependent drains were added once the simulated heads matched the measured heads reasonably well. Drain elevations and conductances were set as noted above. Transmissivities were varied to improve both simulated heads and target drain fluxes. When no further significant improvements in MAE and RMS were made, the model was converted to unconfined.

MODFLOWP Calibration

An attempt was made to calibrate the confined steady state model using the U. S. Geological Survey model parameter estimation program MODFLOWP (Hill, 1992). The parameter estimation program converged with four transmissivity zones, with transmissivities in the 40,000 ft^2/d range (consistent with transmissivities calculated in the steady state model calibration), however, the parameter estimation program failed to converge with greater than four zones. This could have been due to some basic error in setting up the model within MODFLOWP.

Unconfined Model

The unconfined model hydraulic conductivities were calculated by dividing transmissivity in each cell by aquifer depth (calculated head minus aquifer bottom elevation). The hydraulic conductivities were then averaged in the same zones which were used in the confined model calibration. Several more model runs were made to tune the hydraulic conductivities. Figure 12 shows the zones of uniform hydraulic conductivity for the calibrated model. Table 7 lists the hydraulic conductivities for each zone. Final calibrated hydraulic conductivities ranged from 4 ft/d to 100 ft/d, which are consistent with published hydraulic conductivities for fractured basalts. Garabedian (1992) estimated hydraulic conductivity in the Twin Falls area to be 32 ft/d, highly consistent with the range of calibrated hydraulic conductivities for the steady state model.

Figure 13 shows contours for the heads generated by the calibrated steady state unconfined model. This simulated water table is consistent with the water table generated from the average well network measurements (Figure 2) and with the water contours published by Moffatt and Jones (1984).

Table 8 shows the locations, target flux, calculated flux and percent difference for the model drains. The departures between the calibrated model heads and the 113 measured heads have an MAE of 17.5 and an RMS of 24.4. eighty-one percent of the simulated heads were within 30 feet of the measured heads.

A comparison was made between simulated heads and measured heads at eighty-eight cells closer in to the City of Twin Falls. The measured heads between Filer and Kimberly and from the Snake River to 9 miles south of the Snake River were compared with simulated heads. This comparison yielded an MAE of 14.2 ft and an RMS of 18.9 ft. In this area, seventy-three percent of the simulated heads were within 20 feet of the measured heads and eighty-eight percent were within 30 feet.

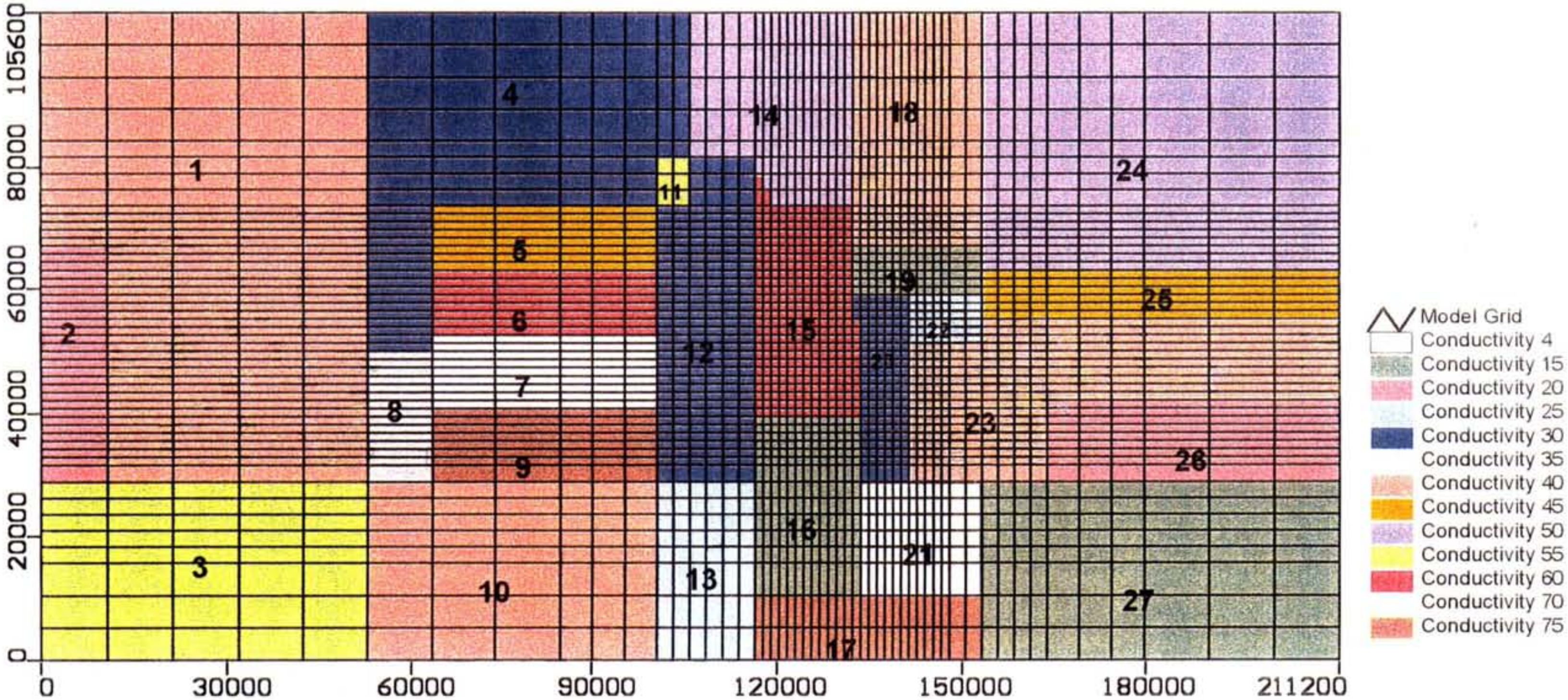


Figure 12. Zones of Uniform Hydraulic Conductivity in the Calibrated Steady State Model.

Table 7.
Hydraulic Conductivity (ft/d) for Zones of Uniform Conductivity.

Zone	Hydraulic Conductivity (ft/d)
1	40
2	20
3	55
4	30
5	45
6	60
7	70
8	35
9	75
10	40
11	55
12	30
13	25
14	50
15	60
16	15
17	75
18	40
19	15
20	30
21	4
22	25
23	40
24	50
25	45
26	20
27	15

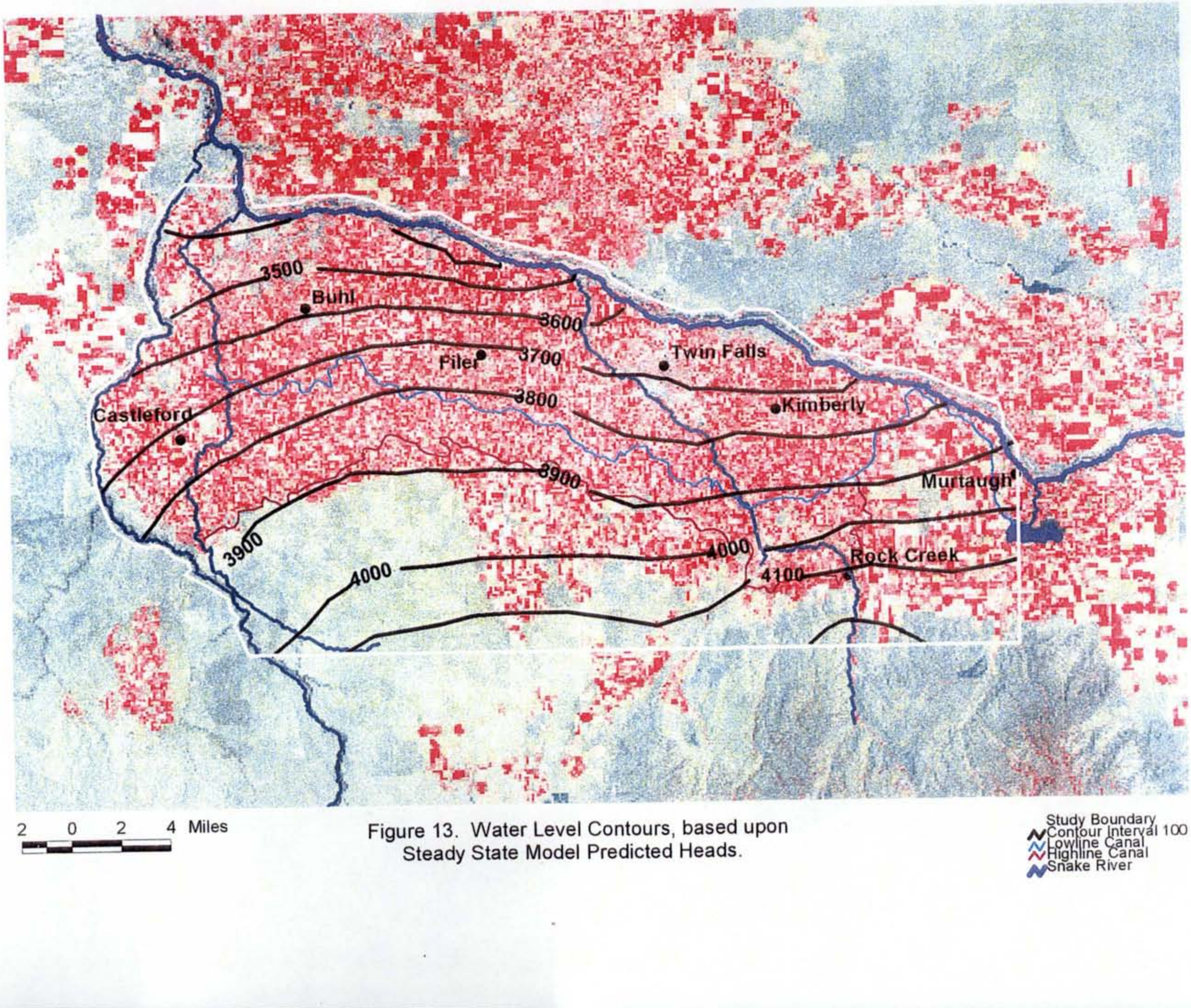


Figure 13. Water Level Contours, based upon Steady State Model Predicted Heads.

Table 8. Drains for Calibrated Steady State Model

Row	Col	Calculated Rate (Ac-ft)	Target Rate (Ac-ft)	Difference	%of target
26	1	-2050544	-2469721	-419177	-16.97
29	1	-637796.9	-823244.7	-185448	-22.53
30	1	-570165.2	-823244.7	-253079	-30.74
31	1	-619513.4	-823244.7	-203731	-24.75
2	2	-1456737	-1646438	-189701	-11.52
3	2	-2133462	-2469721	-336259	-13.62
8	2	-1766410	-1646438	119972	7.29
9	2	-953515.2	-823244.7	130271	15.82
10	2	-2123478	-1646438	477040	28.97
2	3	-3421993	-4318950	-896957	-20.77
2	4	-5086652	-7378974	-2292322	-31.07
2	5	-3692756	-5202928	-1510172	-29.03
2	6	-3260338	-4282372	-1022034	-23.87
2	7	-3751214	-4282372	-531158	-12.40
3	8	-6225928	-6852642	-626714	-9.15
3	9	-2783398	-2487547	295851	11.89
3	10	-2048714	-1590134	458580	28.84
3	11	-2347810	-2487547	-139737	-5.62
3	12	-1840635	-2487547	-646912	-26.01
4	13	-2390542	-2487547	-97005	-3.90
4	14	-626166.2	-570987.7	55179	9.66
4	15	-812342.9	-570987.7	241355	42.27
4	16	-857072.5	-583203.5	273869	46.96
5	16	-842210.7	-583203.5	259007	44.41
8	16	-332434	-291601.8	40832	14.00
9	16	-340117.9	-291601.8	48516	16.64
10	16	-300113.7	-291601.8	8512	2.92
11	16	-346641.2	-291601.8	55039	18.87
6	17	-745462.8	-583203.5	162259	27.82
7	17	-789961.2	-583203.5	206758	35.45
12	17	-363462.2	-291601.8	71860	24.64
13	17	-328319.9	-291601.8	36718	12.59
13	18	-324873.9	-291601.8	33272	11.41
14	19	-329534	-291601.8	37932	13.01
15	20	-371397.3	-291601.8	79796	27.36
16	21	-296216.5	-291601.8	4615	1.58
15	22	-291510.4	-291601.8	-91	-0.03
16	23	-254657	-291601.8	-36945	-12.67
17	23	-201827.8	-291601.8	-89774	-30.79
17	24	-194786	-291601.8	-96816	-33.20
18	25	-216289.9	-291601.8	-75312	-25.83
19	25	-241793.1	-291601.8	-49809	-17.08
20	26	-216275.1	-291601.8	-75327	-25.83
20	27	-200024.4	-291601.8	-91577	-31.40

Note:Negative indicates calculated flow is lower than target flow.

+ more calculated outflow
- less calculated outflow

Table 8 (continued). Drains for Calibrated Steady State Model

Row	Col	Rate (Ac-ft)	Rate (Ac-ft)	Difference	%of target
20	28	-188184.4	-291601.8	-103417	-35.47
21	29	-230461.2	-291601.8	-61141	-20.97
22	30	-265642.8	-291601.8	-25959	-8.90
23	30	-247624.1	-291601.8	-43978	-15.08
24	31	-201395.4	-291601.8	-90206	-30.93
25	31	-235084.8	-291601.8	-56517	-19.38
25	32	-182879.3	-291601.8	-108722	-37.28
25	33	-161574.2	-291601.8	-130028	-44.59
25	34	-179713	-291601.8	-111889	-38.37
26	35	-188637.1	-291601.8	-102965	-35.31
26	36	-212747.1	-291601.8	-78855	-27.04
7	37	-577748.9	-570987.7	6761	1.18
27	37	-201995.6	-291601.8	-89606	-30.73
7	38	-593963.1	-570987.7	22975	4.02
28	38	-593505.1	-1141966	-548461	-48.03
29	39	-291663.8	-291601.8	62	0.02
8	40	-513566.4	-570987.7	-57421	-10.06
8	41	-521652.3	-570987.7	-49335	-8.64
8	42	-447256.4	-570987.7	-123731	-21.67
8	43	-507115.7	-570987.7	-63872	-11.19
8	44	-1161162	-1468400	-307238	-20.92
9	45	-2378258	-2365813	12445	0.53
9	47	-2565963	-1468400	1097563	74.75
14	48	-1673087	-1468400	204687	13.94
14	49	-2542368	-2365813	176555	7.46
15	50	-2280224	-1468400	811824	55.29
16	51	-2690438	-1468400	1222038	83.22
18	52	-2606272	-1468400	1137872	77.49
25	53	-2082092	-1468400	613692	41.79

During calibration, simulated heads were also compared with gridded measured heads to determine the quality of fit near the model boundaries. The well network was highly concentrated in the central area of the model, causing greater uncertainty in the simulation results at the boundaries. When compared with gridded measured heads in all model cells, the MAE was 21.4 and the RMS was 31.7. Departures were much greater near model boundaries than closer to the center of the model.

The relatively poor match of simulated heads to extrapolated starting heads near the model boundaries was not thought to be a major problem for several reasons. Steady state models are sensitive to boundary effects; the condition of running the model to equilibrium causes maximum impact of model boundaries on simulated water levels. The model simulated heads in the area of highest interest (near the City of Twin Falls) matched the measured heads fairly well. The model was not intended to provide the same level of accuracy far away from the area surrounding the city.

Pre-Development Simulation

A simulation of pre-development conditions was run to compare the results with information available on the pre-developed Twin Falls tract. The only variable changed for the pre-development simulation was net recharge. The pre-development conditions simulated were prior to the initiation of surface irrigation in 1905. All irrigation was removed from the model and the entire tract was treated as urban, suburban or range land. The percentages of urban and suburban land use were not reduced for simplicity. This was not considered to be a major controlling factor in the pre-development simulation. Underflow from the Murtaugh Lake area and from the Salmon Falls irrigation area were also not changed. The underflow from the Murtaugh Lake area has probably not changed with the onset of development, because there is relatively little irrigation in that area. However, the underflow from the Salmon Falls irrigation area has probably increased with the onset of irrigation and should have been decreased for the pre-development scenario.

Figure 14 shows the simulated pre-development water table and Figure 15 shows the simulated changes from the present condition. Stearns et. al. (1938) noted rises in the water table approaching 300 feet, consistent with the simulated changes in the pre-development scenario.

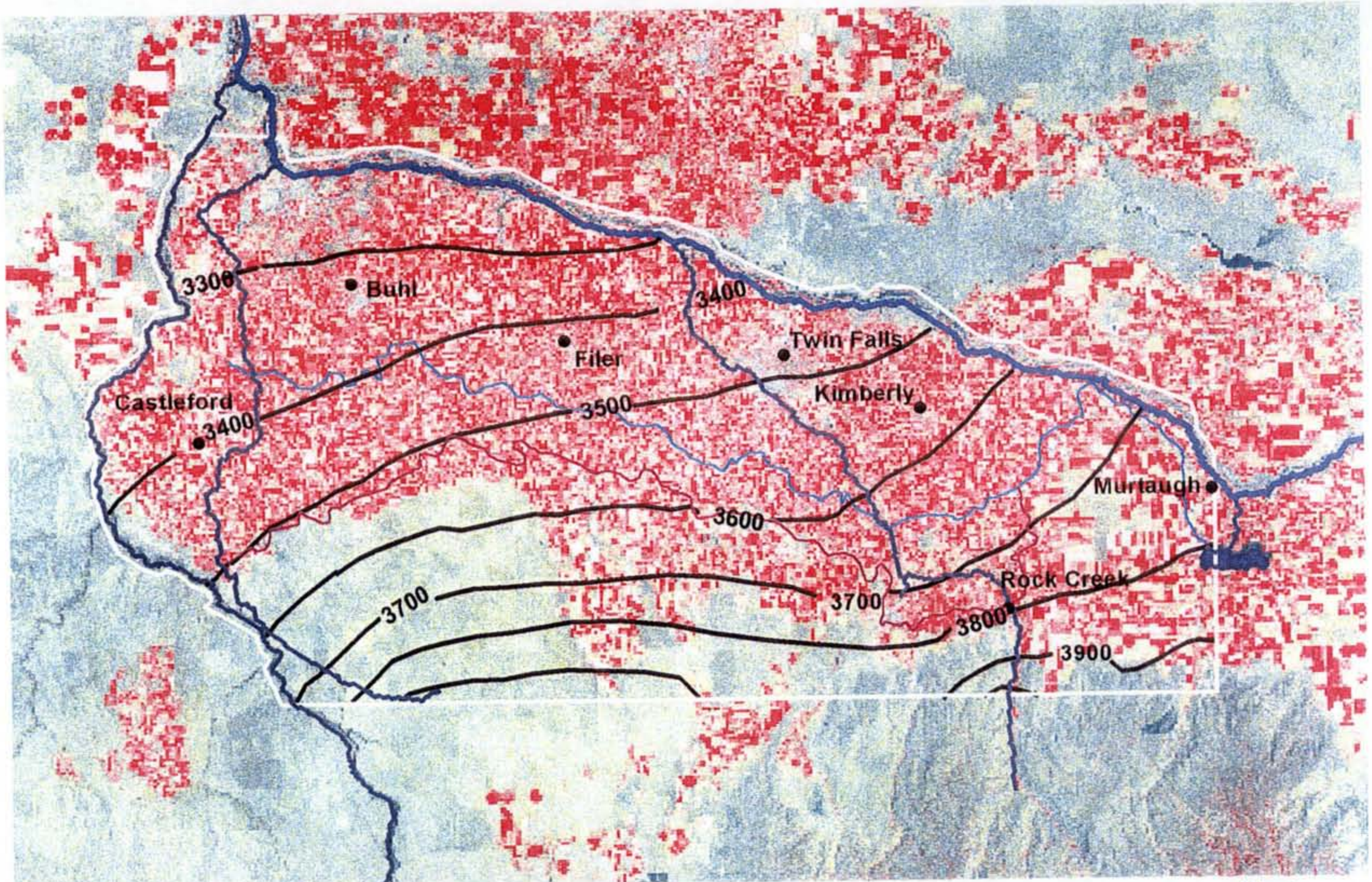


Figure 14. Water Table Contours for the Pre-Development Steady State Model.

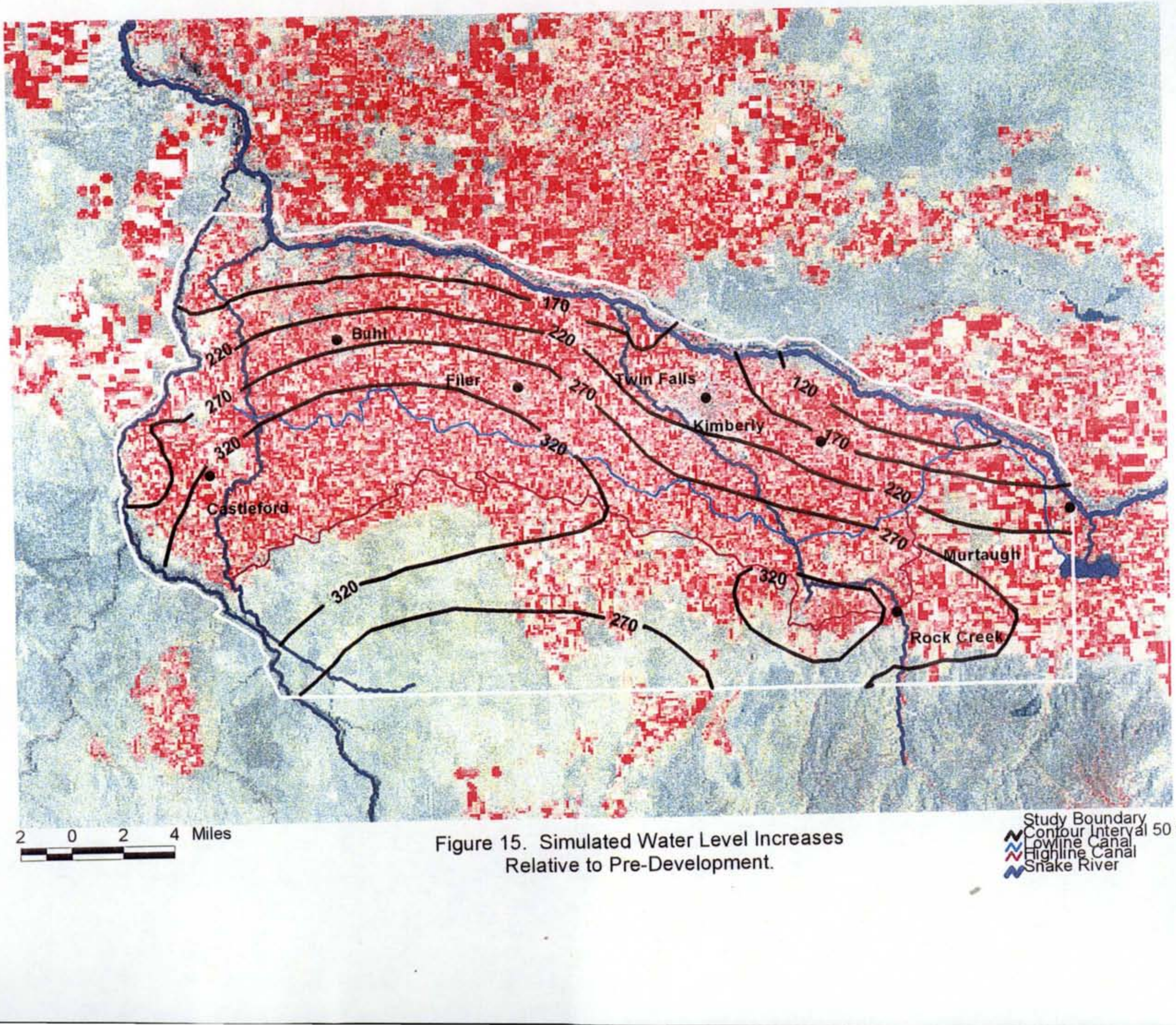


Figure 15. Simulated Water Level Increases Relative to Pre-Development.

Chapter 7

Results and Recommendations

This section summarizes the results of the first phase of the Twin Falls Ground-Water Study. The products resulting from this study provide the user with a set of tools by which to configure and run different steady state scenarios for the Twin Falls Steady State Ground-Water Model. The calibrated steady state model enables the user to explore scenarios reflecting changes in land use and irrigation practices and to model the impacts these changes have on the basin. Recommendations for future study and refinement of the current study are also presented.

Modeling Results

The calibrated steady state model provides a useful tool for studying long-term management scenarios. The steady state model does not allow changes to scenario conditions during the running of the model. The model is run until the basin reaches equilibrium, so the conditions are essentially applied for an infinite length of time. Model results represent an 'extreme case' since the stresses have been applied for an infinite length of time and the resulting changes represent an upper limit to expected responses.

The EXCEL spreadsheet provided with the model, which is documented in Appendix A, enables the user to easily reflect different model conditions and to set up the MODFLOW files for the new scenarios. This tool can be used to quickly set up different model scenarios to be run in the Twin Falls Steady State Ground-Water Model.

Model Limitations and Assumptions

The steady state ground-water model has several limitations which should be noted. Any steady state model is strongly influenced by boundary conditions. This was apparent during the calibration phase where the central part of the model showed a strong response to changes in hydraulic conductivity at the boundaries. The lack of data on location, elevation and flow of springs to the Snake River is a significant limitation on the model. By assigning spring locations and fluxes to balance flow within the flow channels, the springs are probably located as well as possible given the current amount of available information. However, the spring discharge to the Snake River is one of the primary controls on model response, so this area poses a high degree of uncertainty.

The problems encountered at the model boundaries during model calibration are also of concern. More investigation is warranted to determine whether the problems encountered were actually the result of lack of good measurement data near the boundaries or whether the problems actually indicated a flaw in the conceptual model.

Modeling of the tunnels in the Twin Falls area is also a potential limitation of this model. The discharge mechanism to the tunnels is not well understood. In the current steady state model, the tunnels are represented as head-dependent drains because the tunnels were constructed in the basalts which contain the regional aquifer. Representation of the tunnels as head-dependent drains was thought to be a reasonable assumption. In future work, it is recommended that more research be done on the construction of the tunnels, the interaction between the ground water in the loess sediments and in the basalts, and the mechanism of discharge to the tunnels.

Uncertainties are inherent with to numerical model. Therefore, the model should only be used to predict relative changes in water levels and not to predict water levels at a specific locality to minimize the impact of uncertainties.

Sample Scenarios

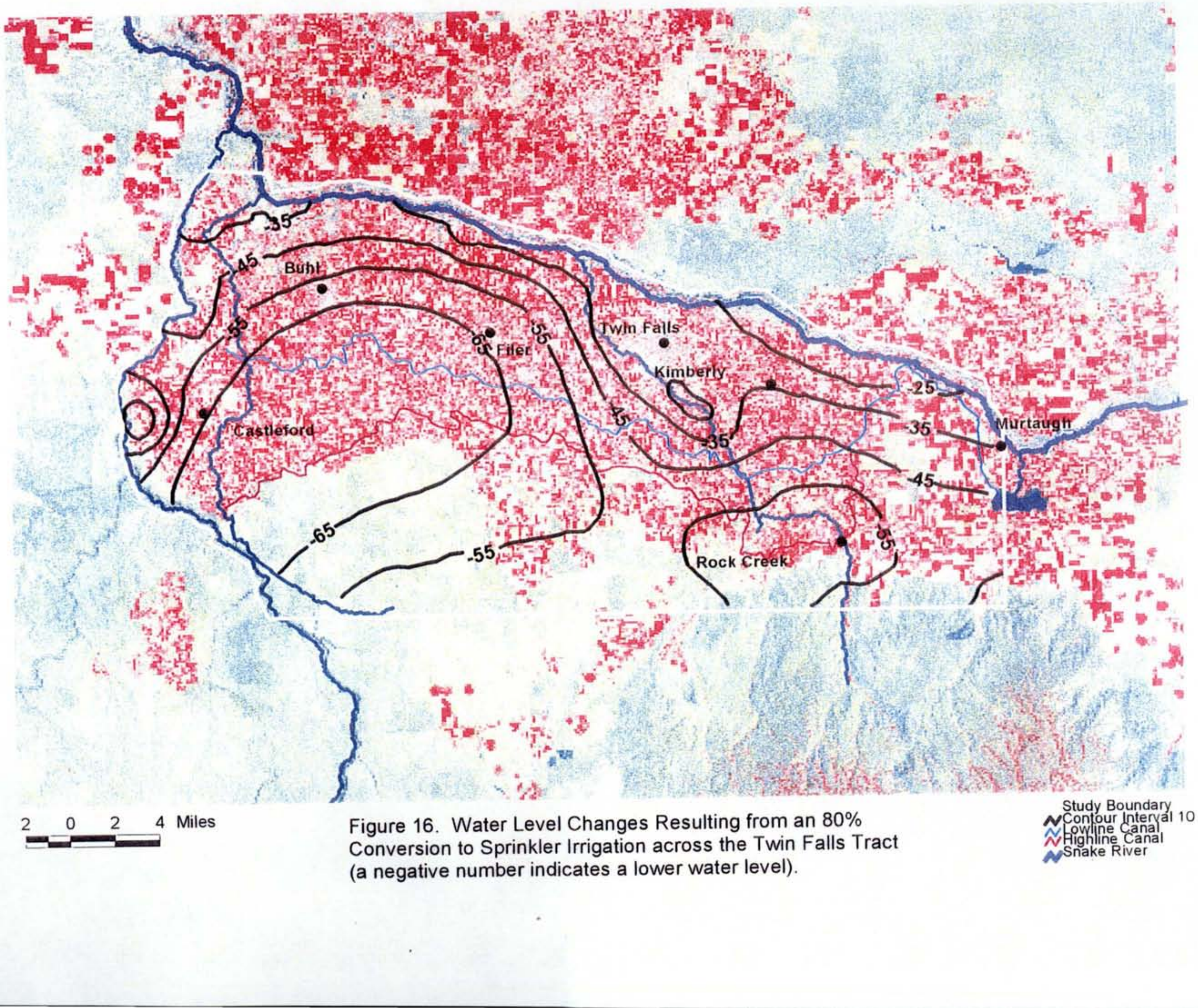
Two sample scenarios were run using the steady state model. The scenarios reflected a thirty percent conversion to sprinkler irrigation tract-wide and the addition of new municipal wells south of the Twin Falls airport. The scenarios were selected to demonstrate the types of impacts the city would be interested in studying with the ground-water model.

The scenario reflecting a thirty percent conversion to sprinkler irrigation was designed to show the impacts of changes in irrigation practice on the Twin Falls tract. With sprinkler irrigation, less water is applied and, therefore, less water infiltrates to the aquifer. Currently, irrigation on the Twin Falls tract is approximately ninety percent surface irrigation and ten percent sprinkler irrigation, with an incidental recharge of approximately 720,000 acre-ft/yr. With conversion to thirty percent sprinkler irrigation, the incidental recharge would decrease by approximately 110,000 acre-ft/yr causing water levels to drop over time.

The scenario which was run reflects a reduction in the overall application rate across the Twin Falls tract, not a conversion to sprinkler irrigation in specific locations (although, that could also be explored as a separate scenario). This is equivalent to a uniform distribution of sprinkler conversion occurring throughout the tract. The steady state model was run until the basin reached equilibrium, so the changes are applied for an infinite length of time. Figure 16 shows the drawdowns which would be expected from this conversion to sprinkler irrigation. The water contours represent 10 foot changes in water levels. The area most impacted by the conversion to sprinkler is the area between Filer and Castleford, south of Buhl. The maximum predicted impact is approximately 65 to 70 feet, a significant change in water level. As noted in the section on limitations, these changes are largely a function of spring and boundary conditions which include a high degree of uncertainty.

The second scenario which was run reflects the effects of locating new municipal wells continuously pumping a total of 27 cfs approximately 1 mile south of the Twin Falls airport. For the scenario, nine wells, each pumping 3 cfs, were placed in adjacent model cells in an east-west line south of the airport. The model was again run to equilibrium. This scenario reflects a higher stress on the aquifer than placement of actual wells would cause since the model is run as though the wells run at the full 3 cfs discharge for 24 hours a day for an infinitely long time. Effects over a shorter period of time are expected to be less. Figure 17 shows the drawdowns predicted by the model for this scenario. It should be noted that these drawdown contours are based on the average drawdowns for each model cell. At the actual well locations, the drawdowns are expected to be greater. The contours are spaced at 4 foot intervals, with the highest impact of 24 feet centered in the cells containing wells. The impact decreases to approximately 8 feet two miles from the wells, lessening with distance from the well locations. Impacts to spring flows to surface streams can also be predicted by the model.

These scenarios were established to demonstrate the types of scenarios which can be generated using the steady state model. The model was designed to flexibly reflect changes in land use and irrigation practices, as desired by the user. It should be noted that the two



2 0 2 4 Miles

Figure 16. Water Level Changes Resulting from an 80% Conversion to Sprinkler Irrigation across the Twin Falls Tract (a negative number indicates a lower water level).

Study Boundary
Contour Interval 10 ft.
Lowline Canal
Highline Canal
Snake River

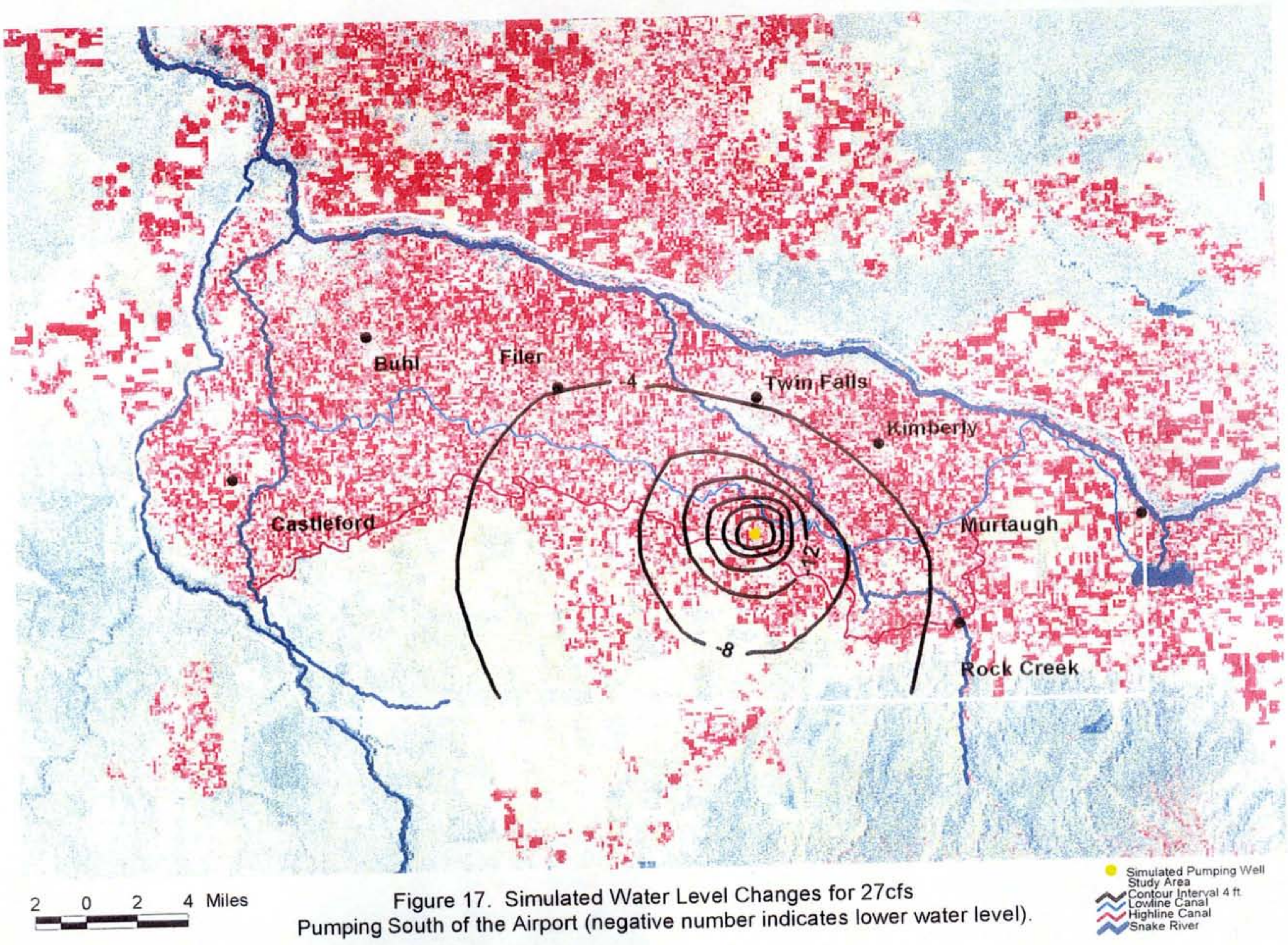


Figure 17. Simulated Water Level Changes for 27cfs
Pumping South of the Airport (negative number indicates lower water level).

steady state scenarios, as well as the pre-development scenario run during model calibration, produce results which appear reasonable, providing confidence in the model's validity.

Implementation of the Twin Falls Steady State Ground-Water Model required several assumptions which could be refined during future studies. The springs and drains to surface streams are a major controlling factor in the ground-water model. Approximately 20% of the water which enters the tract leaves via the springs and drains. Spring locations, elevations and conductances are an area which would benefit greatly from further work. The spring attributes were set in the current model at levels which were thought to minimize error in the model. Given the lack of data on the springs, further characterization of spring locations, elevations, and flows is strongly recommended. This is very likely the factor which exerts the most control on results of steady state simulations. When the transient model is complete, the effects of spring characteristics upon model results will depend on the length of time which is simulated. The spring characteristics will not exert as much control on simulations of short duration as on those of long duration.

Other recommended areas for further study are canal seepage rates, Rock Creek irrigation application rates and better elevation estimates for well heads to provide refinement of the measured water levels (perhaps obtainable with global positioning system equipment). Each of these areas is considered lacking in investigation or detail and warrants further study. With any of the recommended refinements, further effort at model calibration would be required.

Conclusions

This study has provided a good start towards understanding the hydrology of the Twin Falls area. The area is in transition with urban growth, increased water demands from both the municipality and from industry, changes in land use and changes in irrigation practices. The Twin Falls Steady State Ground-Water Model provides an excellent planning tool for the city. The model will enable estimation of impacts of expected changes and will assist the city in future planning. Completion of the transient model will allow the city and others to view how changes in water use affect aquifer water levels and discharge over time.

Recharge Spreadsheet Description

The spreadsheet WLTERMSS.XLS is provided for user generation of recharge for different scenarios for the Twin Falls Steady State Model. The spreadsheet is organized to give the user control over variables such as land use, irrigation source and irrigation application rates. The spreadsheet uses EXCEL macros to update ET and applied irrigation water based on the user's changes and to generate the new MODFLOW well file. The worksheets within the spreadsheet are listed in Table A1 and are discussed below.

Table A1. List of EXCEL Worksheets in Spreadsheet WLTERMSS.XLS.
*Denotes worksheets which are updated by the user.

Worksheet Name	Worksheet Description
Wellterm	Summarizes data for each model cell
MacroStartData*	User-input data for running ET/Irrigation Macro
IrrigationProfile*	Row by column listing of irrigation water source
UrbanUse*	Row by column listing of percentage of urban use for each cell
SubUrbanUse*	Row by column listing of percentage of suburban use for each cell
AgricUse*	Row by column listing of percentage of agricultural use for each cell
RangeUse*	Row by column listing of percentage of range use for each cell
Canal Seepage	Row by column listing of canal seepage
Underflow	Row by column listing of underflow
ACT-INACT	Row by column listing of active cells vs. inactive cells
NetFlux	Row by column listing of net flux in/out of each model cell
ETIrrigMacro	Module containing macro for calculating ET and irrigation
ModflowWellfileMacro	Module containing macro for generating MODFLOW well file
InitData	Initialization data required by macros
Constants	List of constants used within spreadsheet

Each worksheet is discussed separately below. Three distinct worksheet formats were used. The Wellterm Worksheet, the InitData Worksheet and the Constants worksheet have data in tabular format. The ETIrrigMacro Worksheet and the ModflowWellfileMacro Worksheet are in the EXCEL macro module format. The balance of the worksheets are in row/column format, with the data laid out spatially according to the model cells. In the row/column format, the rows and columns are laid out the same way the model cells are laid out. A cell in the southwestern portion of the model will appear in the lower left hand corner of the worksheet. This allows the user to visualize where the model cells are located spatially. The fields of each worksheet and allowable input for fields which will be modified by the user are described below.

Wellterm Worksheet

The Wellterm Worksheet is comprised of fields which describe each model cell location, size, land use and flux components. The Wellterm Worksheet is not updated by the user. Updates to other worksheets within the spreadsheet are used by EXCEL Macros to recalculate the fields in the Wellterm Worksheet. Figure A1 shows a sample of the Wellterm Worksheet.

The Wellterm Worksheet contains one row for every cell of the model grid. Table A2 lists the fields which are contained in the Wellterm Worksheet columns. Each field will have a value for each cell of the model. The Wellterm Worksheet serves as a tabular summary of all relevant information about each model cell. It enables the user to look at the individual components of flux for a particular model cell or group of cells, as well as other cell

Row	Column	miles Row Heigh	miles Col.Wid	miles Cell Area	Total #Acres	TWP	Range	Sect	ACT/ INACT	Irrigat Profile	Underflow	Urban Use	SubUrbanU	AgricUse	RangeUse	Scaled (Ag) Irrig Acres	Activity	ft^3/d Precip	ET ft^3/d	CanalSeep	Irrigation Water Ft^3/d	ft^3/d Wellterm
1	1	1	2	2	1280	9S	13E	4	I	0	0	0	0	0.724181	0.275819	926.9512	0	0	0	0	0	0
2	1	1	2	2	1280	9S	13E	9	I	0	0	0	0	0.321944	0.678056	412.0879	0	0	0	0	0	0
3	1	1	2	2	1280	9S	13E	16	I	0	0	0	0	0	1	0	0	0	0	0	0	0
4	1	1	2	2	1280	9S	13E	21	I	0	0	0	0	0	1	0	0	0	0	0	0	0
5	1	0.5	2	1	640	9S	13E	28	I	0	0	0	0	0.228969	0.771031	146.5401	0	0	0	0	0	0
6	1	0.5	2	1	640	9S	13E	28	I	0	0	0	0	0.228969	0.771031	146.5401	0	0	0	0	0	0
7	1	0.5	2	1	640	9S	13E	33	I	0	0	0	0	0.00143	0.99857	0.915003	0	0	0	0	0	0
8	1	0.5	2	1	640	9S	13E	33	I	0	0	0	0	0.00143	0.99857	0.915003	0	0	0	0	0	0
9	1	0.25	2	0.5	320	10S	13E	4	I	0	0	0	0	0.397738	0.602262	127.276	0	0	0	0	0	0
10	1	0.25	2	0.5	320	10S	13E	4	I	0	0	0	0	0.397738	0.602262	127.276	0	0	0	0	0	0
11	1	0.25	2	0.5	320	10S	13E	4	I	0	0	0	0	0.397738	0.602262	127.276	0	0	0	0	0	0
12	1	0.25	2	0.5	320	10S	13E	4	I	0	0	0	0	0.397738	0.602262	127.276	0	0	0	0	0	0
13	1	0.25	2	0.5	320	10S	13E	9	I	0	0	0	0	0.083391	0.916609	26.68515	0	0	0	0	0	0
14	1	0.25	2	0.5	320	10S	13E	9	A	SR	0	0	0	0.083391	0.916609	26.68515	1	32683.92	35577.63	0	5067.673	2173.968
15	1	0.25	2	0.5	320	10S	13E	9	A	SR	0	0	0	0.083391	0.916609	26.68515	1	32683.92	35577.63	0	5067.673	2173.968
16	1	0.25	2	0.5	320	10S	13E	9	A	SR	0	0	0	0.083391	0.916609	26.68515	1	32683.92	35577.63	0	5067.673	2173.968
17	1	0.25	2	0.5	320	10S	13E	16	A	SR	0	0	0	0.566117	0.433883	181.1574	1	32683.92	52328.41	0	34402.9	14758.41
18	1	0.25	2	0.5	320	10S	13E	16	A	TF	0	0	0	0.566117	0.433883	181.1574	1	32683.92	78607.92	0	80425.55	34501.55
19	1	0.25	2	0.5	320	10S	13E	16	A	TF	0	0	0	0.566117	0.433883	181.1574	1	32683.92	78607.92	0	80425.55	34501.55
20	1	0.25	2	0.5	320	10S	13E	16	A	TF	0	0	0	0.566117	0.433883	181.1574	1	32683.92	78607.92	0	80425.55	34501.55
21	1	0.25	2	0.5	320	10S	13E	21	A	TF	0	0	0	0.715987	0.284013	229.1159	1	32683.92	90765.55	0	101716.9	43636.27
22	1	0.25	2	0.5	320	10S	13E	21	A	TF	0	0	0	0.715987	0.284013	229.1159	1	32683.92	90765.55	0	101716.9	43635.27
23	1	0.25	2	0.5	320	10S	13E	21	A	TF	0	0	0	0.715987	0.284013	229.1159	1	32683.92	90765.55	0	101716.9	43636.27
24	1	0.25	2	0.5	320	10S	13E	21	A	TF	0	0	0	0.715987	0.284013	229.1159	1	32683.92	90765.55	0	101716.9	43636.27
25	1	0.25	2	0.5	320	10S	13E	28	A	TF	0	0	0	0.718903	0.281097	230.0491	1	32683.92	91002.12	0	102131.2	43813.01
26	1	0.25	2	0.5	320	10S	13E	28	A	TF	0	0	0	0.718903	0.281097	230.0491	1	32683.92	91002.12	0	102131.2	43813.01
27	1	0.25	2	0.5	320	10S	13E	28	A	TF	0	0	0	0.718903	0.281097	230.0491	1	32683.92	91002.12	0	102131.2	43813.01
28	1	0.25	2	0.5	320	10S	13E	28	A	TF	0	0	0	0.718903	0.281097	230.0491	1	32683.92	91002.12	0	102131.2	43813.01
29	1	0.25	2	0.5	320	10S	13E	33	A	TF	0	0	0	0.617791	0.382209	197.693	1	32683.92	82799.74	0	87766.58	37650.76
30	1	0.25	2	0.5	320	10S	13E	33	A	TF	0	0	0	0.617791	0.382209	197.693	1	32683.92	82799.74	0	87766.58	37650.76

Figure A1. Wellterm Worksheet Sample.

Table A2. Field Descriptions for Wellterm Worksheet

Field Name	**Units**	**Description**
Row	Counter	Row number of model cell, fixed value
Column	Counter	Column number of model cell, fixed value
Row Height	Miles	North-south dimension of model cell, fixed value
Column Width	Miles	East-west dimension of model cell, fixed value
Cell Area	Square Miles	Total area of model cell, calculated from row height and column width
Total Number of Acres	Acres	Number of acres in model cell, calculated from cell area and constant ft^2/acre
Township	Number	Township number, fixed value
Range	Number	Range number, fixed value
Section	Number	Section number within township/range, fixed value
ACT/INACT	A/I	Indicator for whether model cell is active or Inactive, read from ACT-INACT Worksheet
Irrigation Profile	Alpha Field	Indicates source of irrigation water--TF, SPRK, SR, RC, GW, or NI (described below), read from IrrigationProfile Worksheet
Underflow	ft^3/day	Boundary underflow into model from outside model area, read from Underflow Worksheet
Urban Use	decimal	Decimal indicator of proportion of cell which is urban, read from UrbanUse Worksheet
Suburban Use	decimal	Decimal indicator of proportion of cell which is suburban, read from SubUrbanUse Worksheet
Agricultural Use	decimal	Decimal indicator of proportion of cell which is agricultural, read from AgricUse Worksheet
Range Use	decimal	Decimal indicator of proportion of cell which is range, read from RangeUse Worksheet
Irrigated Acres	number	Number of irrigated acres in model cell, calculated by spreadsheet as Agricultural Use * Acres in Cell
Activity	1 or 0	Integer representation of whether model cell is active (1) or inactive (0), based on ACT-INACT indicator
Active Acres	number	Number of active acres in model cell(calculated as Activity * Acres in Cell)
Precipitation	ft^3/day	Average daily precipitation for model cell, calculated by spreadsheet
ET	ft^3/day	Average daily ET for model cell, calculated by CalcETandIrrig Macro
Canal Seepage	ft^3/day	Average daily canal seepage for model cell, read from CanalSeepage Worksheet
Applied Irrigation Water	ft^3/day	Average daily irrigation water applied in model cell, calculated by spreadsheet
NetFlux	ft^3/day	Calculated by spreadsheet as sum of canal seepage, underflow, precipitation and applied irrigation water minus ET.

characteristics such as cell size, location or land use. The Wellterm Worksheet enables the user to check the reasonableness of each flux term after data changes are made and prior to generating the MODFLOW well file.

MacroStartData Worksheet

The MacroStartData Worksheet contains the user-input parameters which will control the recharge calculation. Figure A2 shows the data fields of the MacroStartData Worksheet. The fields are described below:

Steady State or Transient Indicator. Indicator of whether the simulation is Steady State (SS) or Transient (TR). Steady state is currently the only option available.

Starting Stress Period Number. A single integer which indicates the starting stress period for which recharge will be calculated for a transient simulation. (Not currently used.)

Ending Stress Period Number. A single integer which indicates the ending stress period for which recharge will be calculated for a transient simulation. (Not currently used.)

Output File Name. A seven character alphanumeric field which conforms to the DOS file naming conventions, which is the name under which the MODFLOW well file will be saved. The MODFLOW well file is saved with the user input name with a 1 at the end of the name and with the .WEL extension. For example, if the user input name is TWSS, the MODFLOW well file will be saved as TWSS1.WEL. In the case of a transient simulation with many stress periods, several sequentially numbered MODFLOW well files will be generated which the user must then concatenate.

Input data for starting macro							
Steady Sta	SS						
(SS or TR)							
Starting St	1						
Ending Str	1						
Output File	newext		Note, output file name may be no longer than				
			7 characters.				
TFCC Floo	4.6	ft/year					
TFCC Spri	3.1	ft/year					
SRCC App	4.6	ft/year					
SRCC Effi	0.427761						
Rock Cree	4.6	ft/year					

Figure A2. Macro Start Data Worksheet.

TFCC Application Rate. This is the annual application rate of water used by customers of the TFCC for irrigation. It is expressed in feet of water per year.

TFCC Sprinkler Application Rate. This is the annual application rate of water used by customers of the TFCC for sprinkler irrigation. It is expressed in feet of water per year.

SRCC Application Rate. This is the annual application rate of water used by customers of the Salmon River Canal Company. It is expressed in feet of water per year.

SRCC Efficiency Rate. This is a decimal used to describe the percentage of Salmon River Canal Company-irrigated crops within the study area which are, on the average, irrigated. Historical data for the past six years indicates that if an irrigation application rate identical to that used for TFCC irrigation is assumed for the SRCC. In an average year, only forty-three percent of the land within the SRCC tract is irrigated, due to a shortage of water. The input decimal to reflect forty-three percent efficiency is .43.

Rock Creek Application Rate. This is the annual application rate of water used by irrigators with water rights from Rock Creek. It is expressed in feet of water per year.

Irrigation Profile Worksheet

The Irrigation Profile Worksheet is organized in the row/column format. Inactive cells are grayed out in the worksheet. The worksheet organization allows for a spatial visualization of the irrigator assignments (that is, irrigation assignments in the western part of the study area appear on the left of the worksheet). The worksheet contains a code for each model cell indicating the source of irrigation water for the cell. This worksheet is maintained by the user and can be used to reflect changes in irrigation practices, such as conversion to sprinkler irrigation or taking land out of irrigation. The codes which may be used by the user to reflect sources of irrigation are:

TF TFCC Irrigation

SPRK TFCC Sprinkler Irrigation

SR Salmon River Canal Company Irrigation

RC Rock Creek Irrigation

GW Ground-water Irrigation

NI Not irrigated.

The codes input by the user must be input exactly as shown and are case-sensitive. Any cell containing a code which does not exactly match the codes as shown is assumed to be not irrigated. Figure A3 contains a sample of the Irrigation Profile Worksheet.

Note, entries must match	TF	Twin Falls Canal Company Flood Irrigation	
these options exactly,	SPRK	Sprinkler Irrigation	
including case.	SR	Salmon River Canal Company	
	RC	Rock Creek Irrigation	
Irrigation Profile by Cell	GW	Groundwater Irrigation	
	NI	Not Irrigated	

Row/Col	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1			TF	TF	TF	TF												
2		TF	TF	TF	TF	TF	TF	TF										
3		TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF						
4		TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
5		TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
6		TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
7		TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
8		TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
9		TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
10		TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
11		TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
12		TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
13		TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
14	SR	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
15	SR	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
16	SR	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
17	SR	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
18	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
19	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
20	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
21	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
22	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
23	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
24	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
25	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
26	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
27	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
28	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
29	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
30	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
31	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
32	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF	TF
33	TF	TF	TF	TF	TF	TF	TF	TF	TF	SR	SR	SR	SR	TF	TF	TF	TF	TF
34	TF	TF	TF	TF	TF	TF	TF	SR	SR	SR	SR	SR	SR	SR	TF	TF	TF	TF
35	TF	TF	TF	TF	TF	TF	SR	SR	SR	SR	SR	SR	SR	SR	TF	TF	TF	TF
36	TF	TF	TF	TF	TF	TF	SR	SR	SR	SR	SR	SR	SR	SR	TF	TF	TF	TF
37	TF	TF	TF	TF	TF	TF	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	TF	TF
38	TF	TF	TF	TF	TF	TF	SR	SR	SR	SR	SR	TF	SR	SR	SR	SR	TF	SR
39	SR	TF	TF	TF	TF	SR	SR	SR	SR	SR	SR	TF	SR	SR	SR	SR	SR	SR
40	SR	TF	TF	TF	TF	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
41		TF	TF	TF	NI	NI	NI	NI	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
42		TF	TF	TF	NI	NI	NI	NI	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
43			TF	NI	NI	NI	NI	NI	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
44			TF	NI	NI	NI	NI	NI	SR	SR	SR	SR	SR	SR	SR	SR	SR	SR
45			NI	NI	NI	NI	NI	NI	SR	SR	SR	SR	SR	SR	SR	SR	SR	NI
46				NI	NI	NI	NI	NI	SR	SR	SR	SR	SR	SR	SR	SR	SR	NI
47				NI	NI	NI	NI	NI	SR	SR	SR	SR	SR	SR	SR	SR	SR	NI
48					NI	NI	NI	NI	NI	SR	SR	SR	SR	NI	NI	SR	SR	NI
49						NI	NI	NI	NI	SR	SR	SR	NI	NI	NI	SR	SR	SR

Figure A3. Irrigation Profile Worksheet Sample .

Urban Use Worksheet

SubUrban Use Worksheet

Agricultural Use Worksheet

Range Use Worksheet

These four worksheets are used together by the user to assign a land use profile to each model cell. The assignment of land use is used in the calculation of ET. By reassigning land use percentages, the user is able to set up model simulations reflecting changes such as agricultural land being turned into subdivisions or range land. Each worksheet is organized in the row/column format with inactive cells grayed out. Each model cell is assigned a decimal on each of the first three worksheets representing the percentage of the cell area assigned to urban, suburban and agricultural land use. The spreadsheet is then re-calculated and the Range Use is calculated as the balance of the use. For example, a specific cell may be .2 Urban Use, .3 SubUrban Use and .4 Agricultural Use. The user then re-calculates the spreadsheet and the Range Use is assigned a value of .1 by the spreadsheet (1-(.2+.3+.4)). This ensures that the total land use always sums to 1. After re-calculation, the user should check the calculated Range Use values to establish that none of the Range Use values are less than zero. A Range Use value less than zero would indicate that the Urban Use, Suburban Use and Agricultural Use values sum to greater than 1 and need to be altered. A sample of the Agricultural Use Worksheet is shown in Figure A4. The other three worksheets are identically formatted. (Note, the CalcETandIrrig Macro reduces the agricultural use

	Agricultural Use by Cell																	
Row/Col	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0.724181	0.544375	0.441781	0	0	0.002831	0	0	0	0	0	0	0	0	0	0	0	0
2	0.321944	0.241712	0.74588	0.05742	0.276736	0.631006	0.30412	0.083476	0	0	0	0	0	0	0	0	0	0
3	0	0	0.643122	0.301282	0.146054	0.73373	0.812254	0.616792	0.382914	0.089134	0.037506	0	0	0	0	0	0	0
4	0	0.575422	0.69235	0.337837	0.430782	0.878982	0.885271	0.73576	0.901696	0.886324	0.877356	0.650515	0.650515	0.37214	0.37214	0	0	0
5	0.228969	0.332995	0.838347	0.367717	0.589785	0.868451	0.875647	0.837769	0.897425	0.884242	0.892215	0.876423	0.876423	0.874066	0.874066	0.535117	0.535117	0.467372
6	0.228969	0.332995	0.838347	0.367717	0.589785	0.868451	0.875647	0.837769	0.897425	0.884242	0.892215	0.876423	0.876423	0.874066	0.874066	0.535117	0.535117	0.467372
7	0.00143	0.183285	0.837361	0.803582	0.436088	0.852369	0.878282	0.842179	0.879148	0.892005	0.900931	0.887122	0.887122	0.887726	0.887726	0.66699	0.66699	0.762726
8	0.00143	0.183285	0.837361	0.803582	0.436088	0.852369	0.878282	0.842179	0.879148	0.892005	0.900931	0.887122	0.887122	0.887726	0.887726	0.66699	0.66699	0.762726
9	0.397738	0.547234	0.841824	0.882823	0.868706	0.895226	0.905352	0.916329	0.876028	0.882841	0.917458	0.910375	0.910375	0.90776	0.90776	0.693473	0.693473	0.690557
10	0.397738	0.547234	0.841824	0.882823	0.868706	0.895226	0.905352	0.916329	0.876028	0.882841	0.917458	0.910375	0.910375	0.90776	0.90776	0.693473	0.693473	0.690557
11	0.397738	0.547234	0.841824	0.882823	0.868706	0.895226	0.905352	0.916329	0.876028	0.882841	0.917458	0.910375	0.910375	0.90776	0.90776	0.693473	0.693473	0.690557
12	0.397738	0.547234	0.841824	0.882823	0.868706	0.895226	0.905352	0.916329	0.876028	0.882841	0.917458	0.910375	0.910375	0.90776	0.90776	0.693473	0.693473	0.690557
13	0.083391	0.627363	0.788297	0.877869	0.870187	0.866391	0.873074	0.876326	0.659799	0.384241	0.869942	0.870462	0.870462	0.802393	0.802393	0.81984	0.81984	0.446221
14	0.083391	0.627363	0.788297	0.877869	0.870187	0.866391	0.873074	0.876326	0.659799	0.384241	0.869942	0.870462	0.870462	0.802393	0.802393	0.81984	0.81984	0.446221
15	0.083391	0.627363	0.788297	0.877869	0.870187	0.866391	0.873074	0.876326	0.659799	0.384241	0.869942	0.870462	0.870462	0.802393	0.802393	0.81984	0.81984	0.446221
16	0.083391	0.627363	0.788297	0.877869	0.870187	0.866391	0.873074	0.876326	0.659799	0.384241	0.869942	0.870462	0.870462	0.802393	0.802393	0.81984	0.81984	0.446221
17	0.566117	0.488046	0.832075	0.867603	0.87715	0.87299	0.886486	0.886194	0.811138	0.803392	0.87813	0.868173	0.868173	0.80626	0.80626	0.88291	0.88291	0.522454
18	0.566117	0.488048	0.832075	0.867603	0.87715	0.87299	0.886486	0.886194	0.811138	0.803392	0.87813	0.868173	0.868173	0.80626	0.80626	0.88291	0.88291	0.522454
19	0.566117	0.488048	0.832075	0.867603	0.87715	0.87299	0.886486	0.886194	0.811138	0.803392	0.87813	0.868173	0.868173	0.80626	0.80626	0.88291	0.88291	0.522454
20	0.566117	0.488048	0.832075	0.867603	0.87715	0.87299	0.886485	0.886194	0.811138	0.803392	0.87813	0.868173	0.868173	0.80626	0.80626	0.88291	0.88291	0.522454
21	0.715987	0.881734	0.779089	0.860634	0.867557	0.871826	0.878718	0.878284	0.849625	0.776928	0.800146	0.88269	0.88269	0.87515	0.87515	0.8735	0.8735	0.864237
22	0.715987	0.881734	0.779089	0.860634	0.867557	0.871826	0.878718	0.878284	0.849625	0.776928	0.800146	0.88269	0.88269	0.87515	0.87515	0.8735	0.8735	0.864237
23	0.715987	0.881734	0.779089	0.860634	0.867557	0.871826	0.878718	0.878284	0.849625	0.776928	0.800146	0.88269	0.88269	0.87515	0.87515	0.8735	0.8735	0.864237
24	0.715987	0.881734	0.779089	0.860634	0.867557	0.871826	0.878718	0.878284	0.849625	0.776928	0.800146	0.88269	0.88269	0.87515	0.87515	0.8735	0.8735	0.864237
25	0.718903	0.853263	0.683922	0.867356	0.870465	0.883399	0.878439	0.896651	0.877305	0.819074	0.873152	0.875255	0.875255	0.873145	0.873145	0.853051	0.853051	0.728815
26	0.718903	0.853263	0.683922	0.867356	0.870465	0.883399	0.878439	0.896651	0.877305	0.819074	0.873152	0.875255	0.875255	0.873145	0.873145	0.853051	0.853051	0.728815
27	0.718903	0.853263	0.683922	0.867356	0.870465	0.883399	0.878439	0.896651	0.877305	0.819074	0.873152	0.875255	0.875255	0.873145	0.873145	0.853051	0.853051	0.728815
28	0.718903	0.853263	0.683922	0.867356	0.870465	0.883399	0.878439	0.896651	0.877305	0.819074	0.873152	0.875255	0.875255	0.873145	0.873145	0.853051	0.853051	0.728815
29	0.617791	0.861865	0.871276	0.870622	0.865087	0.878319	0.862595	0.855226	0.844195	0.799033	0.801407	0.881504	0.881504	0.860357	0.860357	0.886984	0.886984	0.75663
30	0.617791	0.861865	0.871276	0.870622	0.865087	0.878319	0.862595	0.855225	0.844195	0.799033	0.801407	0.881504	0.881504	0.860357	0.860357	0.886984	0.886984	0.75663
31	0.617791	0.861865	0.871276	0.870622	0.865087	0.878319	0.862595	0.855226	0.844195	0.799033	0.801407	0.881504	0.881504	0.860357	0.860357	0.886984	0.886984	0.75663
32	0.617791	0.861865	0.871276	0.870622	0.865087	0.878319	0.862595	0.855225	0.844195	0.799033	0.801407	0.881504	0.881504	0.860357	0.860357	0.886984	0.886984	0.75663
33	0.462991	0.88417	0.87773	0.888403	0.8768	0.692663	0.150593	0.362818	0.812504	0.666234	0.84037	0.875958	0.875958	0.872723	0.872723	0.874409	0.874409	0.736835
34	0.462991	0.88417	0.87773	0.888403	0.8768	0.692663	0.150593	0.362818	0.812504	0.666234	0.84037	0.875958	0.875958	0.872723	0.872723	0.874409	0.874409	0.736835
35	0.462991	0.88417	0.87773	0.888403	0.8768	0.692663	0.150593	0.362818	0.812504	0.666234	0.84037	0.875958	0.875958	0.872723	0.872723	0.874409	0.874409	0.736835
36	0.462991	0.88417	0.87773	0.888403	0.8768	0.692663	0.150593	0.362818	0.812504	0.666234	0.84037	0.875958	0.875958	0.872723	0.872723	0.874409	0.874409	0.736835
37	0	0.837441	0.827433	0.636041	0.370056	0.028843	0	0	0.819691	0.709518	0.809773	0.873963	0.873963	0.797433	0.797433	0.800769	0.800769	0.163735
38	0	0.837441	0.827433	0.636041	0.370056	0.028843	0	0	0.819691	0.709518	0.809773	0.873963	0.873963	0.797433	0.797433	0.800769	0.800769	0.163735
39	0	0.837441	0.827433	0.636041	0.370056	0.028843	0	0	0.819691	0.709518	0.809773	0.873963	0.873963	0.797433	0.797433	0.800769	0.800769	0.163735
40	0	0.837441	0.827433	0.636041	0.370056	0.028843	0	0	0.819691	0.709518	0.809773	0.873963	0.873963	0.797433	0.797433	0.800769	0.800769	0.163735
41	0	0.250323	0.718139	0.162368	0	0	0	0	0.549624	0.532674	0.429301	0.774468	0.774468	0.749229	0.749229	0.785014	0.785014	0.447889
42	0	0.250323	0.718139	0.162368	0	0	0	0	0.549624	0.532674	0.429301	0.774468	0.774468	0.749229	0.749229	0.785014	0.785014	0.447889
43	0	0	0.367351	0	0	0	0	0	0.335846	0.844533	0.848162	0.560399	0.560399	0.721353	0.721353	0.690293	0.690293	0.708846
44	0	0	0.367351	0	0	0	0	0	0.335846	0.844533	0.848162	0.560399	0.560399	0.721353	0.721353	0.690293	0.690293	0.708846
45	0	0	0	0	0	0	0	0	0.077075	0.83526	0.872111	0.452046	0.452046	0.56947	0.56947	0.267523	0.267523	0.012922
46	0	0	0	0	0	0	0	0	0.077075	0.83526	0.872111	0.452046	0.452046	0.56947	0.56947	0.267523	0.267523	0.012922
47	0	3.13E-05	0	0	0	0	0	0	0.001317	0.738643	0.806489	0.429355	0.429355	0.196242	0.196242	0.004686	0.004686	0
48	0.074956	0.274231	0	0	0	0	0	0		0.329438	0.620326	0.258333	0.258333	0	0	0		0
49	0.395642	0.310885	0	0	0	0	0	0	0	0.010572	0.295638	0	0	0	0	0.495735	0.495735	0.002346

Figure A4. Agricultural Use Worksheet Sample.

percentage by thirteen percent to allow for non-irrigated surfaces such as right of ways, roads, houses, etc. The number input for Agricultural Use should be the total percentage of land dedicated to agricultural use, without any such correction).

Canal Seepage Worksheet

The Canal Seepage Worksheet is similarly laid out in the row/column format. Model cells which contain the High Line and Low Line Canals are highlighted and contain the average daily volume of water seeped from the canal into the ground water. The seepage is expressed in cubic feet/day. Inactive cells are grayed out. It is not anticipated that the user will modify the canal seepage data, however, if scenarios such as lined canals are to be simulated, the user could modify canal seepage on this worksheet. Figure A5 contains a sample of the Canal Seepage Worksheet. In the reproduction of this worksheet, the highlighted cells containing canals appear similar to the grayed out inactive cells.

Underflow Worksheet

The Underflow Worksheet is laid out in the row/column format with inactive cells grayed out. Boundary cells which have underflow entering them from the Salmon River area, the Murtaugh Lake area or from stream drainages from the South Hills have the average daily volume of underflow in the corresponding cell on this worksheet. All other cells are zero. The volume of underflow is expressed in cubic feet/day. It is not anticipated that the user will modify this worksheet. Figure A6 contains a sample of the Underflow Worksheet.

Canal Seepage																		
Row/Col	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	78264.14	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	251677.8	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	82271.73	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	52447.14	41063.27	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	86524.18	89589.94	64770.38	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	398695.1	82678.3	70365.13	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	398695.1	0	122957.5	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	107259.6	29908.92	0	94468.74	202586.5	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	59126.48	141020.7	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	16727.33	107391.8	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	101699.8	50969.37	46837.83	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	94616.5	103493.2	50130.79	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	18551.05	65777.49	74920.07	16853.44	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34668.17	0	0	0
27	0	0	0	0	0	0	111980.2	0	0	0	0	0	0	0	32541.04	0	0	0
28	0	0	0	0	0	0	160448.8	123218.8	0	0	0	0	0	0	8467.624	31763.82	0	0
29	0	0	0	0	0	0	98999.06	171542.2	125745.4	0	0	0	0	0	0	41213.2	0	0
30	0	0	0	0	0	77024.96	8276.542	223466.8	65031.75	0	0	0	0	0	0	26525.59	30434.36	0
31	0	0	0	0	0	147047.7	0	34412.99	11906.6	55121.37	0	0	22621.24	0	0	0	33256.9	29963.94
32	0	0	0	0	0	321127.3	0	0	0	87416.97	139490.8	58250.71	46653.75	10737.93	0	0	0	0
33	0	0	0	0	0	120287	0	0	0	0	0	23173.47	0	33911.4	0	0	0	0
34	0	0	0	0	0	106282.5	0	0	0	0	0	0	0	43156.25	49762.63	0	0	0
35	0	0	0	0	0	194326.5	0	0	0	0	0	0	0	0	22887.13	43810.75	0	0
36	0	0	0	0	286876.9	38485.34	0	0	0	0	0	0	0	0	0	29207.17	0	0
37	0	0	0	0	118604.3	0	0	0	0	0	0	0	0	0	0	12517.36	77742.61	31088.86
38	0	0	0	195303.6	159423.8	0	0	0	0	0	0	0	0	0	0	0	8099.467	0
39	0	0	0	119798.6	237806.7	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	114533.2	237805.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	257347	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure A5. Canal Seepage Worksheet Sample.

Underflow from East--14400 AF spread over 10.5 miles						ft^3/d	1718532			Total Underflow								
Underflow from SW--115000 AF spread over										Southeast								
Underflow from Rock Cr.and Dry Creek 21000 AF spread as 14000 and 7000										4224723								
							2506192			in 10,000								
	Underflow Sheet									422.4723								
Row/Col	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	1957216	1957216	1957216	1957216	978608.2	978608.2	978608.2	489304.1	489304.1	489304.1	489304.1	489304.1	0

Figure A6. Underflow Worksheet Sample.

ACT-INACT Worksheet

The ACT-INACT Worksheet indicates which cells are active model cells and which are inactive. It is laid out in a row/column format. "A" indicates an active model cell and "I" indicates an inactive model cell. It is not anticipated that the user will change this worksheet. Figure A7 contains a sample of the ACT-INACT Worksheet.

NetFlux Worksheet

The NetFlux Worksheet is organized in the row/column format and is generated by running the CalcETandIrrig Macro. The user does not directly modify the NetFlux Worksheet. After re-calculating ET and applied irrigation water, the CalcETandIrrig Macro reads the flux values from the Wellterm field on the Wellterm Worksheet and writes them into the appropriate cell on the NetFlux Worksheet. This worksheet is provided as a means of checking the calculated pumping rates for reasonableness. Figure A8 contains a sample of the NetFlux Worksheet.

ETIrrig Macro Module

The ETIrrig Module contains the CalcETandIrrig Macro, which is run after the user changes any of the simulation variables such as land use, irrigation source, or irrigation application rates. The macro updates the spreadsheet with the new input data, recalculates ET and Applied Irrigation Water, writes these values to the appropriate cells on the Wellterm Worksheet, re-calculates the net flux for each cell, writes these values to the Wellterm field

ACT-INACT Indicator		A-Active																
		I-Inactive																
Row/Col	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	I	I	A	A	A	A	I	I	I	I	I	I	I	I	I	I	I	I
2	I	A	A	A	A	A	A	A	I	I	I	I	I	I	I	I	I	I
3	I	A	A	A	A	A	A	A	A	A	A	A	I	I	I	I	I	I
4	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
5	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
6	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
7	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
8	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
9	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
10	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
11	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
12	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
13	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
14	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
15	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
16	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
17	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
18	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
19	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
20	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
21	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
22	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
23	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
24	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
25	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
26	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
27	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
28	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
29	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
30	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
31	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
32	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
33	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
34	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
35	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
36	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
37	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
38	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
39	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
40	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
41	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
42	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
43	I	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
44	I	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
45	I	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
46	I	I	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
47	I	I	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
48	I	I	I	I	A	A	A	A	A	A	A	A	A	A	A	A	A	A
49	I	I	I	I	I	A	A	A	A	A	A	A	A	A	A	A	A	A

Figure A7. ACT-INACT Worksheet Sample.

	Net Flux	Positive Value Indicates Recharge														
	ft^3/day	Negative Value Indicates Discharge														
Row/Col	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0	107696	-0.00216	-0.00216	690.0539	0	0	0	0	0	0	0	0	0	0
2	0	58923.9	181828.2	13997.57	67461.88	153824.6	74137.37	20349.57	0	0	0	0	0	0	0	0
3	0	-0.00216	156778.3	73440.74	35604.54	178866.5	198008.8	150359.6	46672.83	10864.43	4571.506	-0.00054	0	0	0	0
4	0	140274.5	168779	82356.77	-44092.5	214275.4	185765.3	179361.3	109906.3	108032.7	106939.6	39645.14	39645.14	-18437.4	-18437.4	-65487.7
5	0	40588.19	102184.9	44820.46	71887.97	105854.1	106731.3	102114.4	54692.88	53889.45	54375.37	26706.45	26706.45	22511.06	22511.05	1084.083
6	0	40588.19	102184.9	44820.46	71887.97	105854.1	106731.3	102114.4	54692.88	53889.45	54375.37	26706.45	26706.45	22511.05	22511.05	1084.083
7	0	22340.35	102064.6	97947.33	44514.28	103894	107052.5	102651.9	53578.96	54362.54	54906.55	27032.47	27032.47	23374.6	23374.6	9420.551
8	0	22340.35	102064.6	97947.33	44514.28	103894	107052.5	102651.9	53578.96	54362.54	54906.55	27032.47	27032.47	23374.6	23374.6	9420.551
9	0	33350.76	51304.28	53802.99	52942.58	54558.85	55175.99	55844.92	26694.41	26902.03	27956.87	13870.52	13870.52	12320.53	12320.53	5547.352
10	0	33350.76	51304.28	53802.99	52942.58	54558.85	55175.99	55844.92	26694.41	26902.03	27956.87	13870.52	13870.52	12320.53	12320.53	5547.352
11	0	33350.76	51304.28	53802.99	52942.58	54558.85	55175.99	55844.92	26694.41	26902.03	27956.87	13870.52	13870.52	12320.53	12320.53	5547.352
12	0	33350.76	51304.28	53802.99	52942.58	54558.85	55175.99	55844.92	26694.41	26902.03	27956.87	13870.52	13870.52	12320.53	12320.53	5547.352
13	0	38234.16	48042.14	53501.06	53032.87	131065.6	53208.81	53406.99	20105.46	11708.62	26508.97	13262.4	13262.4	8990.09	8990.09	9541.569
14	2173.968	38234.16	48042.14	53501.06	53032.87	304379.3	53208.81	53406.99	20105.46	9350.077	26508.97	13262.4	13262.4	8990.09	8990.09	9541.569
15	2173.968	38234.16	48042.14	53501.06	53032.87	135073.2	53208.81	53406.99	20105.46	9350.077	26508.97	13262.4	13262.4	8990.09	8990.09	9541.569
16	2173.968	38234.16	48042.14	53501.06	53032.87	105248.6	94272.07	53406.99	20105.46	9350.077	26508.97	13262.4	13262.4	8990.09	8990.09	9541.569
17	14758.41	29743.71	50710.18	52875.36	139981.4	142793.7	108796.6	54008.39	24717.08	24481.04	26758.48	13227.53	13227.53	9112.327	9112.327	11535.09
18	34501.55	29743.71	50710.18	52875.36	452152.3	135882	124391.3	54008.39	24717.08	24481.04	26758.48	13227.53	13227.53	9112.327	9112.327	11535.09
19	34501.55	29743.71	50710.18	52875.36	452152.3	53203.72	176983.7	54008.39	24717.08	24481.04	26758.48	13227.53	13227.53	9112.327	9112.327	11535.09
20	34501.55	29743.71	50710.18	160134.9	83366.14	53203.72	148495	256594.9	24717.08	24481.04	26758.48	13227.53	13227.53	9112.327	9112.327	11535.09
21	43635.27	53736.58	47480.99	52450.69	52872.56	53132.74	112679.2	194547	25889.88	23674.62	24382.14	13448.71	13448.71	11289.79	11289.79	11237.65
22	43635.27	53736.58	47480.99	52450.69	52872.56	53132.74	53552.79	70253.66	133281.6	23674.62	24382.14	13448.71	13448.71	11289.79	11289.79	11237.65
23	43635.27	53736.58	47480.99	52450.69	52872.56	53132.74	53552.79	53526.33	127569.7	74643.99	71219.97	13448.71	13448.71	11289.79	11289.79	11237.65
24	43635.27	53736.58	47480.99	52450.69	52872.56	53132.74	53552.79	53526.33	25889.88	118291.1	127875.3	63579.5	13448.71	11289.79	11289.79	11237.65
25	43813.01	52001.46	41681.09	52860.32	53049.81	53838.07	53535.79	54645.68	26733.34	24958.92	26606.78	31886.48	79112.92	86146.49	28079.86	10591.3
26	43813.01	52001.46	41681.09	52860.32	53049.81	53838.07	53535.79	54645.68	26733.34	24958.92	26606.78	13335.43	13335.43	11226.42	45894.6	10591.3
27	43813.01	52001.46	41681.09	52860.32	53049.81	53838.07	165516	54645.68	26733.34	24958.92	26606.78	13335.43	13335.43	11226.42	43767.46	10591.3
28	43813.01	52001.46	41681.09	52860.32	53049.81	53838.07	213984.5	177864.5	26733.34	24958.92	26606.78	13335.43	13335.43	11226.42	19694.06	42355.12
29	37650.76	52525.7	53099.25	53059.37	52722.03	53528.47	151569.3	223663.2	151469.8	24348.24	24420.57	13430.64	13430.64	10822.22	10822.22	52877.05
30	37650.76	52525.7	53099.25	53059.37	52722.03	130553.4	60846.74	275587.7	80756.16	24348.24	24420.57	13430.64	13430.64	10822.22	10822.22	37189.45
31	37650.76	52525.7	53099.25	53059.37	52722.03	200576.1	52570.2	86534.01	37631.02	79469.61	24420.57	13430.64	36051.88	10822.22	10822.22	11663.86
32	37650.76	52525.7	53099.25	53059.37	52722.03	374655.8	52570.2	52121.02	25724.41	111765.2	163911.4	71681.35	60084.39	21560.15	10822.22	11663.86
33	28216.6	53885.02	53492.58	54143	53435.89	162500.9	9177.802	22111.87	24758.72	8684.206	10954.04	28882.43	5708.955	45124.48	11213.08	11266.37
34	28216.6	53885.02	53492.58	54143	53435.89	148496.3	9177.802	9458.501	10690.81	8684.206	10954.04	5708.955	5708.955	46760.35	60975.71	11266.37
35	28216.6	53885.02	53492.58	54143	53435.89	236540.4	3925.902	9458.501	10590.81	8684.206	10954.04	5708.955	5708.955	3604.099	34100.21	55077.12
36	28216.6	53885.02	53492.58	54143	340311.8	80699.15	3925.902	9458.501	10690.81	8684.206	10954.04	5708.955	5708.955	3604.099	11213.08	40473.53
37	-0.00054	51037.17	50427.28	38763.02	141157.1	1757.83	-0.00054	-0.00054	10684.49	9248.403	10555.21	5695.957	5695.957	1880.769	1880.769	14474.49
38	-0.00054	51037.17	50427.28	234066.6	181976.6	1757.83	-0.00054	-0.00054	10684.49	9248.403	10555.21	13315.75	5695.957	1880.769	1880.769	1957.136
39	-0.00054	51037.17	50427.28	158561.5	260358.6	751.9337	-0.00054	-0.00054	10684.49	9248.403	10555.21	13315.75	5695.957	1880.769	1880.769	1957.136
40	-0.00054	51037.17	164980.5	276568.8	22552.8	751.9337	-0.00054	-0.00054	10684.49	9248.403	10555.21	5695.957	5695.957	1880.769	1880.769	1957.136
41	0	30511.48	87532.82	277137.8	-0.00108	-0.00108	-0.00108	-0.00108	14328.44	13886.58	11191.69	10095.02	10095.02	9766.034	9766.034	10232.48
42	0	30511.48	87532.82	19790.82	-0.00108	-0.00108	-0.00108	-0.00108	14328.44	13886.58	11191.69	10095.02	10095.02	9766.034	9766.034	10232.48
43	0	0	44775.85	-0.00108	-0.00108	-0.00108	-0.00108	-0.00108	8755.365	22016.59	22111.21	7304.682	7304.682	9402.671	9402.671	8997.809
44	0	0	44775.85	-0.00108	-0.00108	-0.00108	-0.00108	-0.00108	8755.365	22016.59	22111.21	7304.682	7304.682	9402.671	9402.671	8997.809
45	0	0	-0.00108	-0.00108	-0.00108	-0.00108	-0.00108	-0.00108	2009.302	21774.84	22735.54	5892.314	5892.314	7422.915	7422.915	3487.099
46	0	0	0	-0.00108	-0.00108	-0.00108	-0.00108	-0.00108	2009.302	21774.84	22735.54	5892.314	5892.314	7422.915	7422.915	3487.099
47	0	0	0	-0.00108	-0.00108	-0.00108	-0.00108	-0.00108	34.33669	19256.1	21024.82	5596.546	5596.546	2557.973	2557.973	61.08298
48	0	0	0	0	-0.00108	-0.00108	-0.00108	-0.00108	-0.00054	8588.306	16171.62	3367.318	3367.318	-0.00027	-0.00027	-0.00027
49	0	0	0	0	0	1957216	1957216	1957216	1957216	978883.8	986315.4	978608.2	489304.1	489304.1	489304.1	495765.9

Figure A8. NetFlux Worksheet Sample.

of the Wellterm Worksheet and writes the new fluxes to the NetFlux Worksheet in row/column format.

ModFlowWellfile Macro Module

The MODFLOW Wellfile Macro Module contains the MakeModWells Macro which is used to generate the MODFLOW well file. The MakeModWells Macro generates a text file in the precise format of the MODFLOW well file, containing the layer, row, column and flux for each active cell in the simulation. The file is saved in the name specified by the user on the MacroStartData Worksheet with a 1 appended at the end of the name and with a .WEL extension.

InitData Worksheet

The InitData Worksheet contains initialization data required by the macros. This worksheet will not be changed by the user unless the format of the Wellterm Worksheet is altered (the user is advised against changes to the Wellterm Worksheet or the InitData Worksheet). The data contained on the InitData Worksheet is predominantly row and column counters which are used by the macros. Figure A9 contains the InitData Worksheet.

Constants Worksheet

The constants worksheet contains constants used within the spreadsheet. Many of the constants are used for unit conversions. This worksheet also contains constants used in the calculation of the various flux components, such as average daily precipitation and average evapotranspiration. Figure A10 contains the Constants Worksheet. This worksheet is not normally altered by the user.

Starting Row Number	10	Note, these variables are derived
Ending Row Number	2606	the worksheet Wellterm and shou
Row Column Number	1	be altered unless the format of th
Column Column Number	2	worksheet is altered. Fields are
Act/Inact Column Number	10	write-protected to protect against
ActInt Column Number	18	inadvertent change.
Acres_In_Cell Column Nu	6	
Urban Column Number	13	
SubUrban Column Numbe	14	
Ag Column Number	15	
Range Column Number	16	
Irrig Source Col Number	11	
Irrig Acres Col Number	17	
ET Column Number	20	
Irrig Column Number	22	
Wellterm Column Number	23	

Figure A9. InitData Worksheet Sample.

General								
	Acres/Section	640						
	Days/Month	Jan	Feb	Mar	Apr	May	Jun	Jul
		31	28	31	30	31	30	31
	mm/inch	25.4						
	mm/ft	304.8						
	ft^2/acre	43560.00						
	in/ft	12						
	days/year	365.25						
	days/IrrigYear	180						
	ft Per Mile	5280						
Irrigation Percentages								
	UrbanIrrigAcrePercent		0.3					
	SuburbanIrrigAcrePercent		0.73					
ET								
	Ave. ET-ft/yr	2.98		AveETCuFTPerAcre		129808.8		
	GrassETftyr	3.52		GrassETCuFTPerAcr		153393.2		
	Ave ET-ft/d	0.008164						
	Grass ETft/d	0.009648						
	Ave ET by Per	1	2	3	4	5	6	7
	(Array)ft/per	0.032354	0.032354	0.046027	0.046027	0.070713	0.070713	0.090215
	Grass ET by Per	1	2	3	4	5	6	7
	(Array)ft/per	2.03E-02	2.03E-02	3.22E-02	3.22E-02	7.48E-02	7.48E-02	1.28E-01
Precip								
	Ann. Precip (in)	10.27	in.					
	Precip by Period (inches)							
	Period	1	2	3	4	5	6	7
		0.59	0.54	0.33	0.60	0.53	0.58	0.39
	PrecipFtPerYr		8.56E-01	ft/y				
	PrecipFtPerDay		2.34E-03	ft/d				
	Number of Active Cells							
	2251							

Figure A10. Constants Worksheet Sample.

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