GEOLOGY AND GROUND-WATER CHEMISTRY, CURLEW VALLEY, NORTHWESTERN UTAH AND SOUTH-CENTRAL IDAHO—IMPLICATIONS FOR HYDROGEOLOGY

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Hugh A. Hurlow and Neil Burk

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Cover photo: View south of North Hansel Mountains along the eastern margin of Curlew Valley in southern Idaho.

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EXECUTIVE SUMMARY

This study addresses the relationship between geology and ground water, and the possible causes for ground-water supply and quality issues in the Curlew Valley drainage basin in central Box Elder County, Utah, and southern Oneida and southeastern Cassia Counties, Idaho. The Curlew Valley ground-water system includes the Locomotive Springs complex at the north end of the western arm of Great Salt Lake. Discharge from the springs has decreased steadily since the early 1970s, resulting in substantial reduction in riparian habitat in the outflow area, which is a Waterfowl Management Area managed by the Utah Division of Wildlife Resources. Several agricultural areas in Curlew Valley experienced steadily decreasing ground-water levels and water-quality degradation during the same period. Understanding the hydrogeology of Curlew Valley is an essential component of addressing these problems and is the goal of this study.

The 1200-square-mile (3100 km^2) Curlew Valley surface-drainage basin is Y-shaped, having a broad lower part in Utah that bifurcates northward around the Sublett Range into two narrower valleys in Idaho, Juniper Valley on the west and Holbrook arm on the east. From south to north, Curlew valley is bounded on the east by the Hansel, North Hansel, and Pleasantview Mountains, and, on the west, by Peplin Mountain, the eastern Raft River Mountains, and the Black Pine Mountains. The main stream is Deep Creek, which has intermittent flow and is impounded by dams in Holbrook arm and west of Snowville, Utah. Agriculture is the main economic activity in Curlew Valley.

Curlew Valley is in the northeastern Basin and Range geologic province, characterized by generally north-trending mountain ranges separated by broad valleys. The ranges are composed of Tertiary and Quaternary volcanic deposits, and Paleozoic marine sedimentary rocks that were deformed by thrust faults and folds during the Mesozoic to early Tertiary Sevier orogeny. The range-valley boundaries are defined by large-magnitude Tertiary normal faults. The valleys are underlain by unconsolidated to semi-consolidated sedimentary deposits that accumulated on the subsiding hanging walls of the valley-bounding normal faults. Bedrock exposed in the ranges bounding Curlew Valley is mainly the late Paleozoic Oquirrh Group, composed of interbedded limestone and sandstone, but the Raft River Mountains contain Precambrian to early Paleozoic metamorphic and igneous rocks. Tertiary volcanic and sedimentary rocks are present in the Sublett Range, southern Deep Creek Mountains, Raft River Mountains, and the Wildcat Hills. Three Quaternary-age basalt shields occupy the southeastern part of the valley southwest of Snowville. The volcanic rocks in southern Curlew Valley are interbedded with coeval lacustrine and alluvial basin-fill deposits. Basin-fill deposits are composed of variably indurated Quaternary gravel, sand, and silt, deposited in both alluvial and lacustrine environments, above semi-consolidated conglomerate, sandstone, mudstone, and volcanic tuff of the Tertiary Salt Lake Formation. Young surficial deposits include lacustrine deposits of Pleistocene Lake Bonneville, eolian loess, and alluvium.

New gravity data collected and analyzed for this study delineate the subsurface structure and thickness variations of basin-fill deposits in the Curlew Valley Quaternary–Tertiary depositional basin. Major depositional centers exist below Juniper Valley, below Holbrook arm, and between the Raft River Mountains and the Wildcat Hills. Quaternary basalt in the southeastern part of the valley is up to 5000 feet thick (1520 m) in southeastern Curlew Valley. Several previously unrecognized, concealed intrabasin faults are interpreted to exist based on abrupt, linear gradients in basin-fill thickness derived from the gravity data. In particular, the west-northwest-trending Snowville transverse fault is interpreted to form the structural boundary between Quaternary basalt deposits on the southwest and thick basin-fill deposits on the northeast. These faults may strongly affect ground-water flow.

Basin-fill deposits form the principal aquifer in Curlew Valley. These deposits generally decrease in grain size from the range margins to the valley centers. Average hydraulic conductivity decreases toward the valley centers, and ground-water conditions likewise progressively change from unconfined to confined. Hydraulic conductivity and the extent of confined conditions are variable within the volcanic deposits.

Recharge to the basin-fill aquifer is about 74,000 acre-feet per year (90 hm^3/yr), mainly from infiltration of snowmelt and runoff from the mountain ranges, which receive about 12 to 30 inches (30-98 cm) of precipitation annually. Discharge from the basin-fill aquifer occurs by pumping from wells for irrigation and the resulting evapotranspiration in irrigated fields, and by discharge from the Locomotive Springs complex. The average annual discharge from wells in the Utah part of Curlew Valley is about 36,000 acre-feet (44 hm^3).

During the past 30 years, ground-water levels in the agricultural areas of Curlew Valley have gradually declined by up to 80 feet (24 m), and water quality has generally deteriorated, as illustrated by increasing total dissolved solids and salinity in some wells. Average annual discharge from the Locomotive Springs complex steadily decreased from about 40 cubic feet per second (1.1 m^3/s) in the late 1960s to less than 10 cubic feet per second (0.3 m^3/s) in the early 2000s. The primary cause of these problems is that the discharge rates from irrigation wells upgradient from Locomotive Springs is greater than the recharge rates to those areas by

local infiltration of precipitation and snowmelt and local- to regional-scale flow within the basin-fill aquifer. This situation has been exacerbated during the past 10 years by below-average annual precipitation. Previous studies suggested that the increasing TDS and sodium and chloride concentrations are due to evaporative concentration of dissolved solids in irrigation water.

Previous studies defined three major ground-water flow systems in Curlew Valley: the Holbrook-Snowville, Juniper–Black Pine, and Kelton flow systems. The Locomotive Springs complex is at the southern end of the Holbrook-Snowville and the southeastern margin of the Juniper–Black Pine flow systems. Flow-system boundaries are diffuse and only approximately defined. Ground-water flow is generally from north to south and from mountains toward valley centers in all three systems, which terminate southward in diffuse discharge areas along the northern margin of Great Salt Lake. Previous workers concluded that the Holbrook-Snowville flow system contributes the majority of discharge to the Locomotive Springs complex.

New general-chemistry and isotope data, combined with previously existing data, show the variation of water quality in Curlew Valley and provide insight into ground-water flow in the basin-fill aquifer. Total-dissolved-solids concentrations and ground-water temperatures are highest in the areas of intensive ground-water pumping, and water quality in some irrigation wells has gradually declined during the past 30 to 40 years. Most ground water is calcium-bicarbonate type, and deteriorating quality is principally due to increased sodium and chloride content.

Evidence for the contribution of irrigation water to declining ground-water quality in parts of Curlew Valley includes (1) time-series plots show that the pH of ground water increases one year after times of relatively high valley-floor precipitation, and the saturation indices of vadose-zone minerals follow the pH changes; the result is that carbonate minerals in the vadose zone reach saturation, whereas sulfides and halite remain undersaturated and are dissolved into these pulses of water moving through the vadose zone, thereby increasing the total-dissolved-solids concentration and sodium and chloride content of ground water below the agricultural areas, and (2) positive correlation of chloride and deuterium in ground-water samples from the Juniper–Black Pine flow system indicates an evaporative signature to ground-water chemistry, suggesting that evaporation of unused irrigation water concentrates sodium and chloride in the vadose zone.

From the water-level and water-quality data presented here we conclude that deterioration of ground-water quality in Curlew Valley is largely due to use of ground water as the primary source for irrigation and to evaporative concentration of dissolved solids in unused irrigation water. This problem is compounded in the central Juniper–Black Pine flow system by the presence of geothermal water that rises from depth and mixes with shallow ground water.

Ground water from the northern parts of the Juniper–Black Pine and Holbrook-Snowville flow systems have statistically distinct oxygen-18 and deuterium compositions, whereas the isotopic composition of ground-water samples from three wells in the central Juniper–Black Pine flow system is identical to that of the Holbrook-Snowville flow system. Ground-water levels in the central Juniper–Black Pine flow system have fallen by up to 80 feet (24 m) during the past 30 years in that area. We suggest that this cone of depression draws ground water westward from the Holbrook-Snowville flow system to the Juniper–Black Pine flow system, causing mixing of ground water from the two systems in the area between.

Ground-water ages determined by tritium and carbon-14 methods are between submodern and 12,000 years in the Juniper–Black Pine flow system, and generally modern in the Holbrook-Snowville flow system. Ground-water ages in the area of hypothesized mixing are intermediate between the average ages of the two systems.

The mean oxygen-18-deuterium composition and apparent age of Locomotive Springs water lies between the mean compositions of ground water in the Juniper–Black Pine and Holbrook-Snowville flow systems. We suggest that Locomotive Springs water is a mixture of ground water discharging from the Juniper–Black Pine and Holbrook-Snowville flow systems. Large-scale, long-term decrease of ground-water levels in the southern Juniper–Black Pine and Holbrook-Snowville flow systems, as illustrated by the increased area within the aquifer of water levels below 4215 feet (1285 m)—the elevation of the spring outlets—is the main reason for declining spring discharge.

INTRODUCTION

The Curlew Valley drainage basin bounds the northwestern arm of Great Salt Lake (figure 1). Ground water is the most important natural resource in Curlew Valley, because it supports agriculture (the main economic activity there), and flow from the Locomotive Springs complex (the principal discharge area for the valley's ground-water flow system). The Locomotive Springs outflow area on the north shore of Great Salt Lake provides riparian habitat for migratory birds and is a Utah State Waterfowl Management Area.

Steadily declining ground-water levels over the past 30 years have caused water-supply and environmental problems in Curlew Valley. Discharge from the Locomotive Springs complex has decreased substantially, and the reduced flow combined with environmental damage from flooding of Great Salt Lake in the mid-1980s has drastically reduced wetland acreage and avian habitat (Berger, 2000; Utah Division of Water Rights, 2005). Ground-water levels and quality have declined in areas of significant ground-water pumping for irrigation in the middle part of the valley, resulting in increased lift costs and the shutting down of at least one irrigation well (Atkin, 1998; this study).

Baker (1974), Atkin (1998), and Oaks (2004) described the hydrology and hydrogeology of Curlew Valley. The Curlew Valley surface-drainage basin covers about 1200 square miles (3100 km^2) in Box Elder County, northwestern Utah, and Cassia and Oneida Counties, south-central Idaho (figures 1 and 2). In Utah, Curlew Valley is a broad basin that is punctuated by low hills composed of volcanic rocks. Near the state line the valley bifurcates northward into Juniper Valley and Holbrook arm (informal name for northeastern Curlew Valley), which are narrower and steep-sided and are separated by the Sublett Range in Idaho (figures 2 and 3). The primary stream is Deep Creek, which originates in the Holbrook arm and flows south. Surface flow in Deep

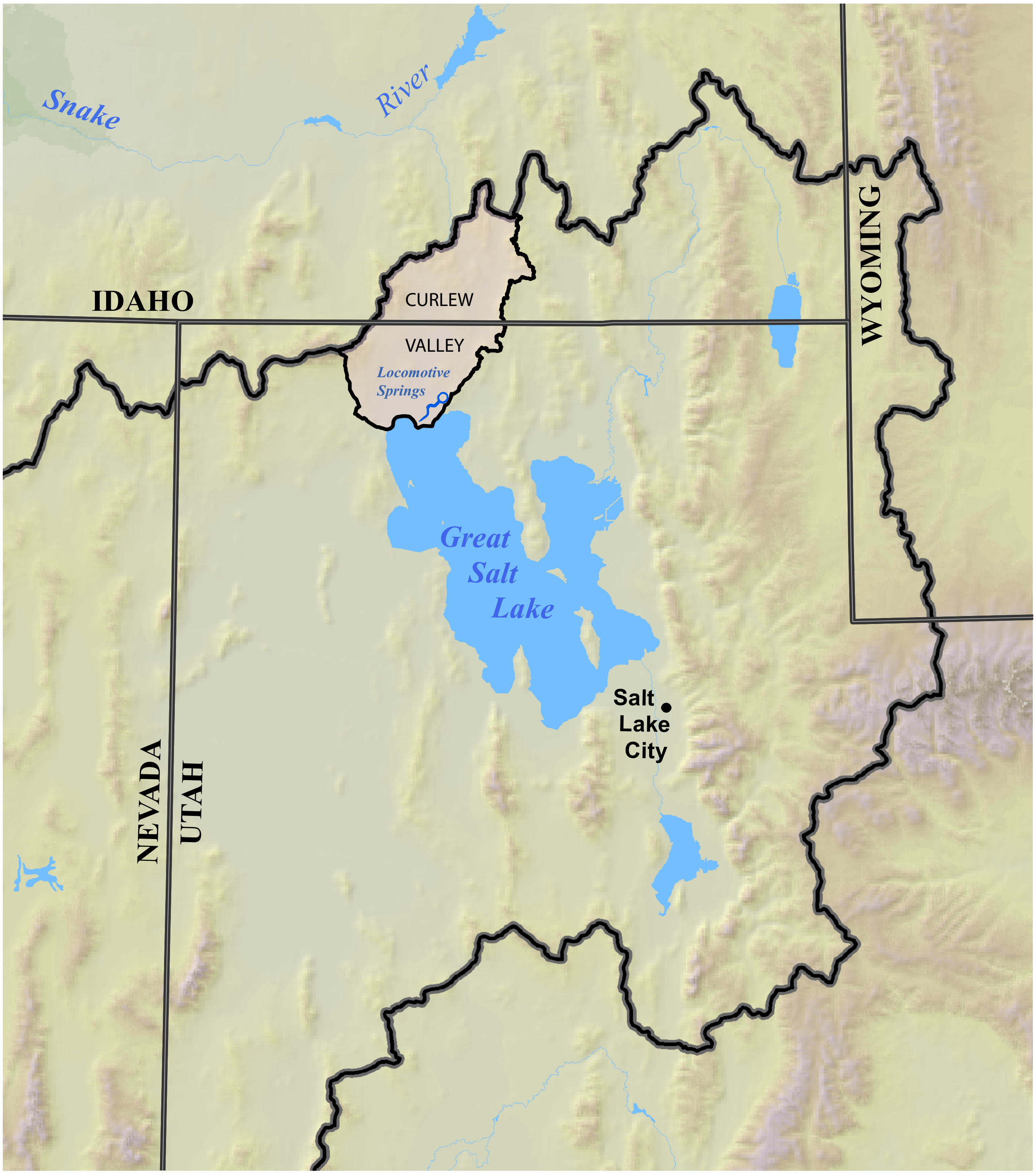

Figure 1. *Curlew Valley study area location, Utah and Idaho.*

Figure 2. Geographic setting of Curlew Valley study area.

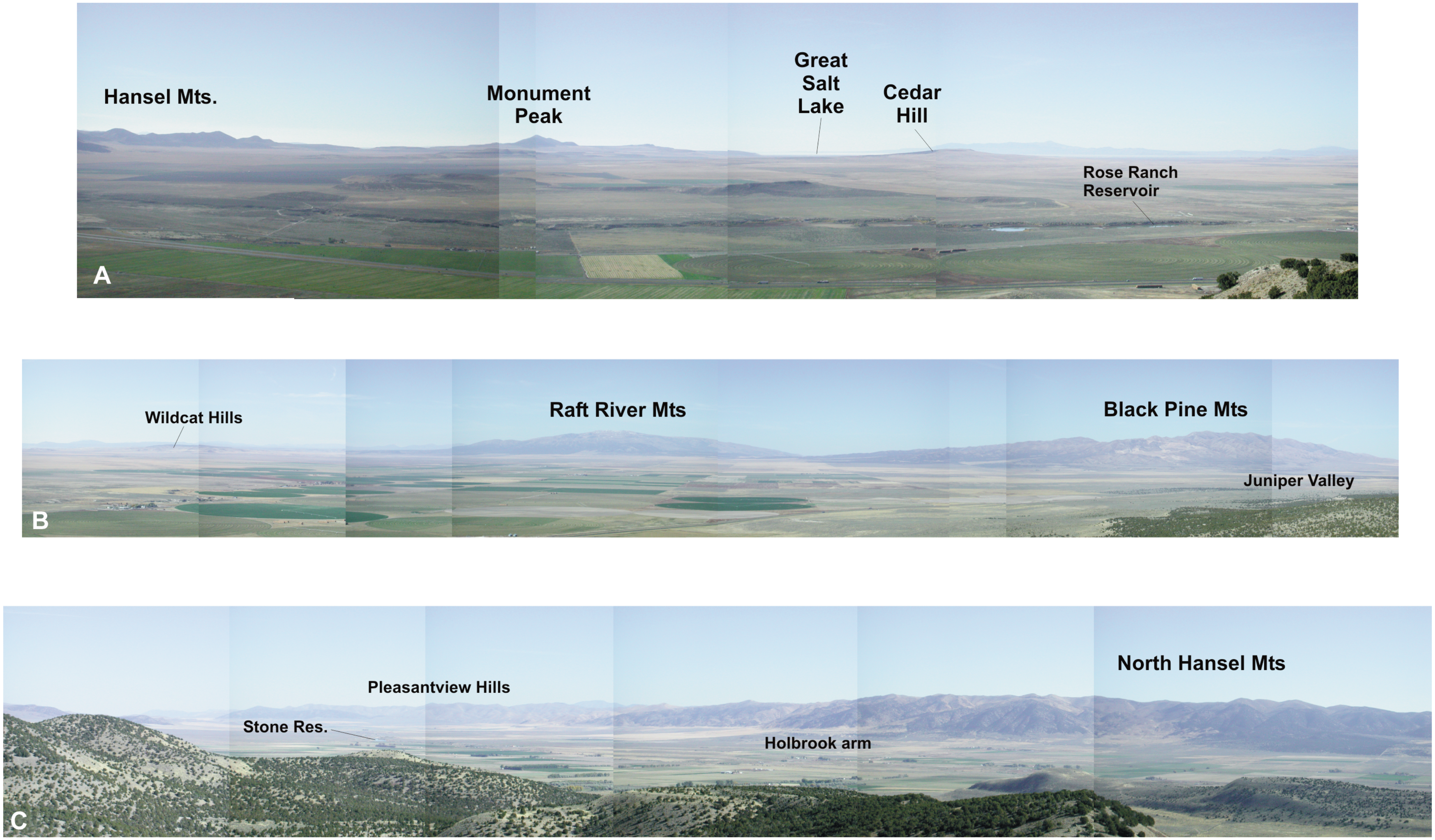

Figure 3. *Panoramic views of the Curlew Valley study area. A. View south of southeastern Curlew Valley in Utah, from southern Stone Hills. B. View southwest of southwestern Curlew Valley in Utah, from southern Stone Hills. C. View northeast of southern Holbrook arm in Idaho, from the southern Sublett Range.*

Creek is rare below the Rose Ranch Reservoir, west-southwest of Snowville, Utah. The principal aquifer in Curlew Valley is basin fill composed of unconsolidated Quaternary alluvial and lacustrine sediments and volcanic rocks, including thick and extensive Quaternary basalt in the southeastern part of the valley, above late Quaternary and Tertiary, semi-consolidated interbedded alluvial and volcanic rocks. These deposits, which are up to 5000 feet thick (1520 m), filled fault-bounded depositional basins during Quaternary-Tertiary time. Bedrock aquifers are chiefly interbedded limestone and sandstone of the Pennsylvanian-Permian Oquirrh Group. Few wells in the valley draw water from bedrock aquifers.

The decreased discharge at Locomotive Springs and declining ground-water levels in agricultural areas reflect an overall decrease in the amount of ground water stored in the basin-fill aquifer, and potentially threaten the quality of Curlew Valley's economy and environment. Government officials at the state and local levels need to understand the nature and magnitude of the problem to consider what remedies, if any, are necessary. This study assists them by characterizing the geology and ground-water chemistry of the Curlew Valley drainage basin and discussing the implications for ground-water flow paths in the aquifer. Our work builds upon the efforts of Baker (1974), Atkin (1998), and Oaks (2004) by characterizing the geology of the basin-fill and bedrock aquifers in greater detail, providing new ground-water chemistry data, and updating ground-water level and chemical data. Work performed for this study includes compilation and synthesis of existing geologic and hydrologic data, compilation of a geologic map of the Curlew Valley drainage basin that includes previously unpublished work by other authors and new mapping by the senior author (plate 1 and appendix A), construction of cross sections that show lithologic variations in the basin-fill aquifer (plate 2), collection and analysis of new gravity data to delineate the structure of the basin-fill aquifer, and collection and analysis of new ground-water chemistry data.

Use of technical terms and discipline-specific jargon is required to efficiently communicate geologic and hydrologic information. We have attempted to minimize, but could not avoid, use of terms that may be unfamiliar to non-specialists. To facilitate use of this report by the widest possible audience, we have included a glossary of geologic and hydrologic terms at the end of the report and a geologic time scale in appendix A.

GEOLOGIC SETTING

Curlew Valley is in the northeastern Basin and Range geologic province (figure 4). Topography in the Basin and Range is characterized by long, narrow ranges that trend roughly north, separated from broad valleys by gently sloping alluvial aprons that form the range-valley boundaries. Rocks exposed in the ranges typically display a complex geometry and history of deformation. The valleys are underlain by normal-fault-bounded depositional basins that formed during Tertiary and Quaternary time. The unconsolidated to semi-consolidated, sedimentary and volcanic deposits that fill these basins form the principal aquifers of the Great Basin, including Curlew Valley.

Other important geologic and geophysical characteristics of the Basin and Range include: (1) high average elevation (Eaton, 1982), (2) seismic activity that is concentrated in north-south trending, linear belts along the eastern and western province boundaries and in central Nevada, but is poorly correlated with known surface-breaking faults (Smith and Arabasz, 1991), (3) steeply dipping normal faults that form the boundaries between basins and ranges (Stewart, 1978), and (4) steep geothermal gradients (Eaton, 1982; Blackwell and others, 1991). All of these features result from active extension of the continental crust due to tectonic plate motions along the western margin of North America (Coney, 1987).

The geologic evolution of Curlew Valley and adjacent areas, including its stratigraphic and structural history (figures 5 and 6), is summarized as follows.

The oldest rocks exposed in the study area are Archean age igneous and metasedimentary rocks in the eastern Raft River Mountains, overlain by Early Proterozoic quartzite and schist (Compton, 1975). Similar rocks presumably comprise the crystalline basement below the younger sedimentary rocks and basin-fill deposits in northern Utah and south-central Idaho.

Beginning in Late Proterozoic time, a north-south trending, continental-scale rift formed in western North America (Stewart, 1972; Burchfiel and others, 1992). As the two halves of the continent moved away from each other, the crust between them gradually subsided and was flooded by an ocean, allowing accumulation of thick marine sediments through Permian time (Hintze, 1988; Burchfiel and others, 1992). Older rocks in this sequence are mainly clastic sandstone and shale, whereas the younger part is dominantly limestone and dolomite (Armstrong, 1968b). Only the uppermost part of the sequence (the Mississippian Great Blue Limestone and the Mississippian-Pennsylvanian Manning Canyon Shale) and the Pennsylvanian-Permian Oquirrh Group are exposed in the study area (figures 5 and 6).

The Oquirrh–Wood River basin formed during mid-Pennsylvanian through Early Permian time in northern Utah and south-central Idaho in a broad area of major crustal subsidence, which accumulated up to 25,000 feet (7600 m) of sandstone, siltstone, and limestone (Armstrong, 1968b; Jordan and Douglass, 1980; Yancey and others, 1980; Geslin, 1998). Rocks of the Oquirrh Group, which filled the Oquirrh depositional basin, form the vast majority of bedrock exposed in the ranges of the study area (figure 5; plate 1), and comprise the main bedrock aquifers. The stratigraphy of the Oquirrh Group is complex and problematic, and is discussed in more detail in the "Description of Map Units" in appendix A.

Beginning in Late Jurassic time, plate-tectonic interactions along the western North American continental margin caused compression within the crust, resulting in horizontal crustal shortening in the western United States accommodated by thrust faults and folds (Burchfiel and others, 1992). This episode of deformation, known as the Sevier orogeny, continued through early Tertiary time (Armstrong, 1968a; Allmendinger, 1992). In the present areas of the eastern Great Basin and western Rocky Mountains, closely spaced thrust faults and related folds translated Proterozoic to lower Mesozoic rocks of the miogeocline up to 100 miles (160 km) eastward, forming the Wyoming-Utah-Idaho thrust belt and

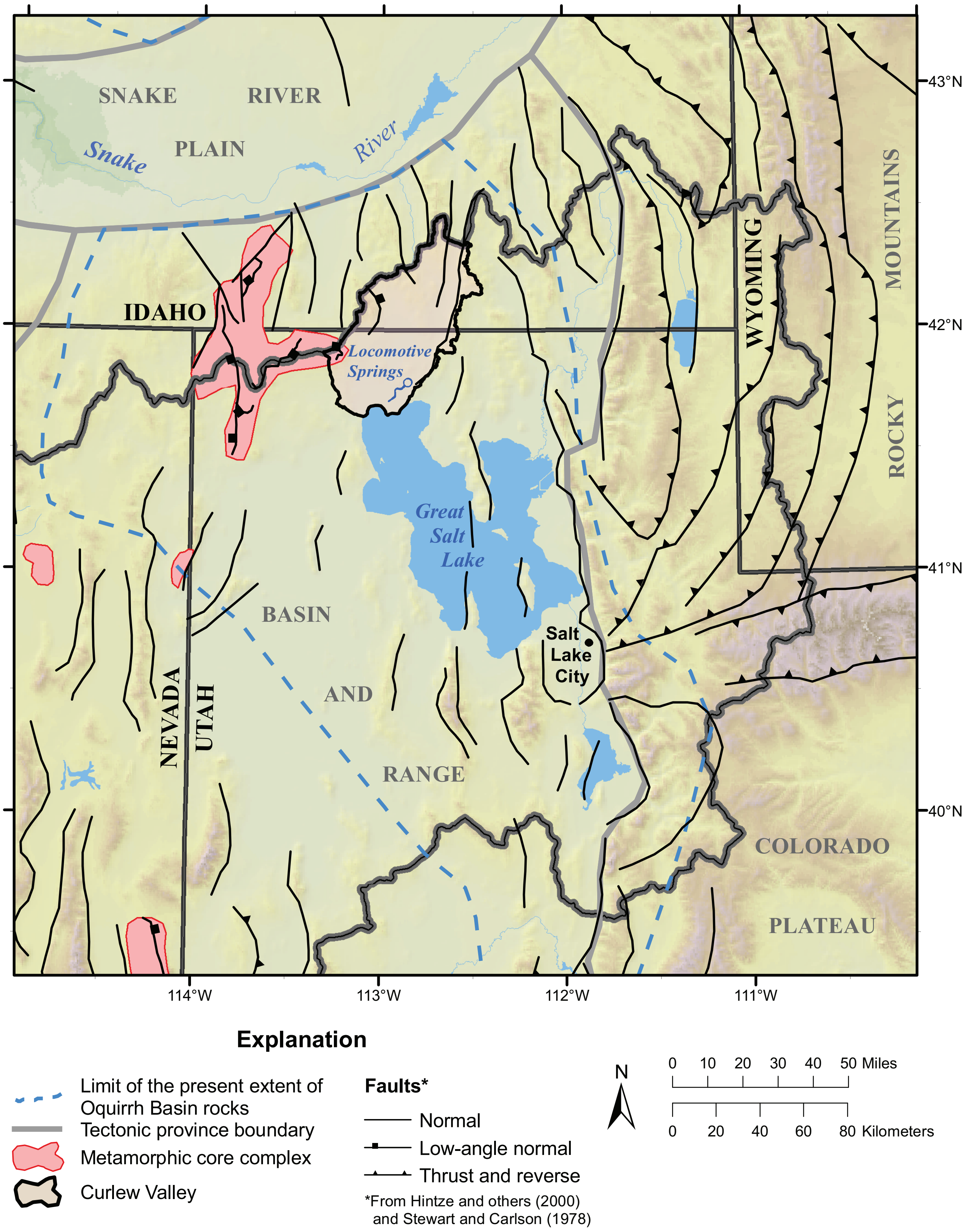

Figure 4. *Tectonic setting of Curlew Valley study area.*

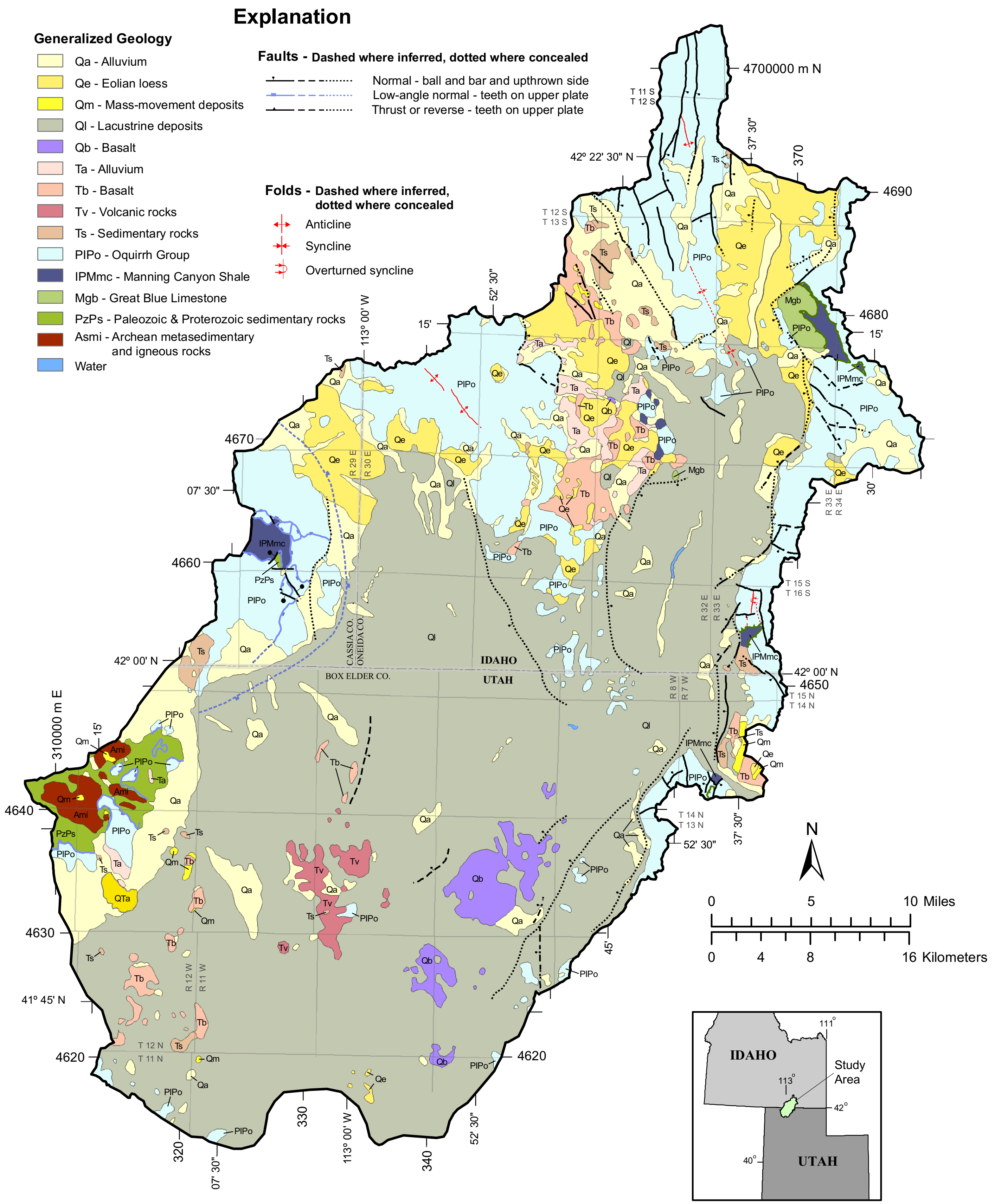

Figure 5. Simplified geologic map of Curlew Valley study area.

Era	Period/Epoch	Unit	Map Unit	Thickness (feet)	Lithology
Cenozoic	Quaternary – Holocene	Alluvial, mass-movement, and eolian deposits	Qa, Qm, Qe	≤300	
Cenozoic	Quaternary – Pleistocene	Lacustrine deposits of Lake Bonneville	Ql	≤400	
Cenozoic	Quaternary – Pleistocene	Basalt	Qb	0 - 600+	
Cenozoic	Quaternary – Pleistocene / Pliocene	Alluvial-fan deposits	QTaf	400	
Cenozoic	Pliocene	Rhyodacite	Trd	200+	
Cenozoic	Pliocene	Pediment gravel and alluvium	Ta2	0 - 250	
Cenozoic	Pliocene	Basalt	Tb, Tbc	300	
Cenozoic	Miocene	Alluvium	Ta1	0 - 215	
Cenozoic	Miocene	Tuff	Tt	0 - 50	
Cenozoic	Miocene	Salt Lake Formation	Ts	1700+	
Cenozoic	Miocene	Sedimentary breccia and conglomerate	Tc	0 - 500	
Paleozoic	Permian	Limestone, sandstone, and dolomite	Plsd	260 - 2300+	
Paleozoic	Permian	Oquirrh Group: Sandstone and quartzite	Pod	2200 - 3300	
Paleozoic	Permian and Pennsylvanian	Oquirrh Group: Sandstone	PIPos	8850	
Paleozoic	Permian and Pennsylvanian	Oquirrh Group: Limestone	PIPox	600	
Paleozoic	Permian and Pennsylvanian	Oquirrh Group: Sandy limestone, calcareous sandstone and siltstone, and bioclastic limestone	PIPoc	3800 - 6000+	
Paleozoic	Pennsylvanian	Oquirrh Group: Sandy limestone, calcareous sandstone and siltstone, and bioclastic limestone	IPob	1600 - 2750+	
Paleozoic	Pennsylvanian	Oquirrh Group: Cherty and sandy limestone	IPoa	1300-1445	
Paleozoic	Pennsylvanian	Oquirrh Group: Sandy limestone, dolomite	IPolsd	3500	
Paleozoic	Pennsylvanian / Mississippian	Manning Canyon Shale	IPMmc	2200 - 6000+	
Paleozoic	Mississippian	Great Blue Limestone	Mgb	3000+	

Era	Period/Epoch	Unit	Map Unit	Thickness (feet)	Lithology
Paleozoic	Devonian	Jefferson Formation	Dj	900+	
Paleozoic	Ordovician	Marble and quartzite	Omq	0 - 650	
Proterozoic		Quartzite and schist	Pqs	600 - 2000	
Archean		Metamorphosed igneous rocks	Ami	450 - 700	
Archean		Schist	As	400	

Explanation

Lithology

- fine sandstone
- coarse sandstone
- limestone
- limestone-bedded
- limestone-shaley
- conglomerate
- lava flows-basic
- lava flows-silicic
- breccia/tuff
- quartzite
- dolomite
- shale - carbonaceous
- claystone
- cherty limestone
- limestone - sandy
- marble
- schist
- schist and gneiss

Figure 6. *Generalized stratigraphic column for Curlew Valley study area.*

other thrust belts to the north and south (Allmendinger, 1992; Royse, 1993). Curlew Valley is in the western part of the Sevier fold and thrust belt (Armstrong, 1968a; Allmendinger and others, 1984; Allmendinger, 1992), where the geologic evolution during the Sevier orogeny is incompletely known, but included crustal thickening along thrust faults and folds, and metamorphism and igneous intrusion in the middle to lower parts of the crust (Snoke and Miller, 1988; Allmendinger, 1992). In the Curlew Valley study area, thrust faults and folds are exposed in the Sublett Range, Pleasantview Hills, and North Hansel Mountains (Platt, 1977; Smith, 1982; Allmendinger and Platt, 1983; Allmendinger and others, 1984; Coward, 1979). Metamorphic rocks in the Black Pine and Raft River Mountains are deformed by tight to recumbent folds that formed during the Sevier orogeny (Compton and others, 1977; Smith, 1982; Snoke and Miller, 1988). Crustal extension, localized above the areas of greatest crustal thickening, occurred along gently dipping faults and by penetrative stretching in the upper crust, including the Raft River and Black Pine Mountains in the study area (Wells, 1997).

After the Sevier orogeny, regional crustal extension began in the Basin and Range and Rocky Mountains in mid-Eocene to Oligocene time, depending on location (Snoke and Miller, 1988; Wernicke, 1992; Constenius, 1996). In the Basin and Range province, extension was synchronous with igneous intrusion and volcanism, and occurred along gently dipping normal faults, referred to as detachment faults. Displacement and associated uplift along these detachment faults brought footwall rocks from 6 to 9 miles (10-15 km) depth to near the surface, and thereby formed the features called metamorphic core complexes (figure 4) (Coney, 1987; Wernicke, 1992). In the Curlew Valley study area, Archean, Proterozoic, and lower Paleozoic rocks in the Raft River Mountains were exhumed from mid-crustal depths beneath the Raft River detachment fault, and the Black Pine Mountains were exhumed from shallower depths by tectonic unroofing along another, shallower detachment (Compton and others, 1977; Snoke and Miller, 1988; Wells and others, 2000). In the Rocky Mountains, west-dipping normal faults re-used steeply dipping thrust ramps that soled at depth into gently dipping faults (Constenius, 1996) and thereby reversed the original eastward direction of offset of the reactivated fault segments. Extension along gently dipping normal faults and deposition of the alluvial and lacustrine Salt Lake Formation occurred in southeastern Idaho during Miocene and Pliocene time (Goessel and others, 1999; Oaks and others, 1999; Janecke and others, 2003; Carney and Janecke, 2005; Steely and others, 2005).

Beginning around 10 to 5 Ma (million years ago), depending on location, the style of crustal extension changed to steeply dipping normal faults and associated rhyolitic and basaltic volcanism (Wernicke, 1992; Stewart, 1998). Major normal faults including the Wasatch and Bear Lake faults formed at that time. Active faulting continues today, as demonstrated by seismic activity along the Wasatch fault zone and by surface-rupturing earthquakes along other faults, including the 1934 Hansel Valley (M_S [surface-wave magnitude] = ~6.6) and 1983 Borah Peak (M_S = 7.3) earthquakes (Smith and Arabasz, 1991). Relative offsets on these normal faults produced the main elements of present-day Basin and Range topography. In the Curlew Valley study area, the Black Pine Mountains, Sublett Range, Pleasantview Hills, and Hansel Mountains are bounded by steeply dipping normal faults. Sedimentary basins formed in alluvial and lacustrine environments on the subsiding hanging walls of these normal faults. The sedimentary and volcanic rocks that were deposited in these basins form the principal aquifers of Curlew Valley and adjacent areas. Normal faults also underlie the central Curlew Valley floor in Utah, and may have localized the Quaternary basalt shields (Miller and others, 1995). Miocene and Quaternary volcanic rocks formed in the study area during Basin-and-Range faulting, including Miocene rhyodacite in the Wildcat Hills, Miocene basalt in the Sublett Range, and Quaternary basalt shields in southeastern Curlew Valley (Miller and others, 1995; D. Fiesinger, Utah State University, written communication, 2004).

During Quaternary time, lakes intermittently covered much of the northern Basin and Range, including Lake Bonneville in Utah and southern Idaho from about 30 to 10 ka (thousand years before present) (Scott and others, 1983; McCoy, 1987; Oviatt and others, 1992). The extent, shoreline elevation, and depth of these lakes varied with time in response to climatic changes (Scott and others, 1983; Oviatt and others, 1992). Prominent shorelines and associated nearshore deposits formed during periods of lake-level stability: from oldest to youngest, these are (1) the Stansbury oscillation (22 to 20 ka, shoreline at 4415 feet [1345 m]), (2) the Bonneville stage of Lake Bonneville (15.0 to 14.5 ka, highest shoreline at 5180 feet [1579 m], secondary shoreline at 5150 feet [1570 m]), (3) the Provo stage of Lake Bonneville (14.5 to 14.0 ka, highest shoreline at 4800 to 4750 feet [1460–1448 m]), and (4) the Gilbert stage of Great Salt Lake (10.9 to 10.3 ka, shoreline at 4250 feet [1295 m]) (Oviatt and others, 1992). Deposits from these lake stages cover most of the Curlew Valley floor below about 5180 feet (1580 m) elevation, and the resulting shorelines are conspicuous in places along the valley margins. The present-day elevations of these shorelines vary throughout the Lake Bonneville basin by up to 180 feet (60 m) due to isostatic rebound of the Earth's crust following the draining of Lake Bonneville (Gilbert, 1890; Scott and others, 1983).

GEOLOGY OF THE BASIN-FILL AQUIFER

Stratigraphy and Lithology

Sediments of the Curlew Valley basin-fill aquifer include a younger package of Quaternary-age, interbedded alluvial, lacustrine, and volcanic deposits, and an older package of alluvial, lacustrine, and volcanic rocks of the Miocene-Pliocene(?) Salt Lake Formation and other Tertiary-aged deposits (appendix A) (Baker, 1974; Miller and others, 1995; Miller, 1997a-c; Miller and Langrock, 1997a-c).

Quaternary deposits in Curlew Valley consist of interbedded, laterally grading gravel, sand, silt, and mud, deposited in stream, alluvial-fan, and lacustrine environments. Holocene sediments include gravel, sand, and silt deposited in stream and alluvial-fan environments, and eolian silt and sand redeposited from exposed fine-grained lakebed deposits. Pleistocene sediments on the valley floors and the range margins below about 5180 feet (1580 m) elevation were deposited in Lake Bonneville and its predecessors, which existed intermittently from about 600 to 10 ka (Scott and others, 1983; McCoy, 1987; Oviatt and others, 1992), and include shoreline and nearshore gravel and sand, barrier-beach sand, and lakebed silt (figures 7a–d). These deposits for the most part are less than 300 feet (90 m) thick, except near canyon mouths and adjacent to large-offset, range-bounding normal faults. The lacustrine deposits are interbedded with, and locally supplanted by, Quaternary basalt in the southeastern part of the valley. The Quaternary basalt forms three remnant shield volcanoes dated at, from north to south, 1.16 ± 0.8 Ma, 0.72 ± 0.15 Ma, and 0.44 ± 0.10 Ma (appendix A) (Miller and others, 1995). Based on well-drillers' logs (Utah Division of Water Rights, 2003-2005), the flows thin radially away from their thickest accumulations at the shield culminations, and some flows extend for several miles to the west and northwest.

Coarse-grained gravel deposits along range flanks and that are deeply incised by modern streams are interpreted here as Quaternary-Tertiary alluvium (plate 1; appendix A). The best examples of these deposits are along the eastern margin of the Deep Creek Mountains, the southeastern Raft River Mountains, and the northeastern Black Pine Mountains, where they are capped by surface-lag deposits of pebble- to boulder-size clasts on rounded hills sloping away from the range fronts. These deposits would be good aquifers based on their large grain size and locations adjacent to the mountain ranges, but their subsurface thickness and distribution are not known. Janecke and others (2003) interpreted generally similar deposits as fluvial gravel and placed them in the youngest member of the Salt Lake Formation, whereas the gravels in the Curlew Valley basin are more likely alluvial-fan deposits and may be younger.

The Salt Lake Formation in the study area is composed of interbedded conglomerate, tuffaceous sandstone, tuffaceous mudstone, rare micritic limestone, and water-lain tuff (appendix A) (Miller and others, 1995; Wells, 1996). Debris-flow deposits and conglomerate are most common along the margins of the Deep Creek and Hansel Mountains, whereas thinly interbedded tuffaceous sandstone, mudstone, water-lain tuff, and minor limestone characterize exposures in the Wildcat Hills, the eastern slopes of the Raft River Mountains, and the southwestern part of the map area (plate 1). The Salt Lake Formation likely underlies Quaternary deposits below most of Curlew Valley, but its original distribution and lithologic variations are not known. In the eastern Raft River and Hansel Mountains, the Salt Lake Formation exhibits highly variable dips, due to faulting and folding along these range margins. The Salt Lake Formation formed in Miocene and Pliocene time during active normal faulting, but the faults and related depositional basins may have been different from the present Basin-and-Range geometry, by analogy with work in southeastern Idaho and Cache Valley, Utah-Idaho, by Goessel and others (1999), Oaks and others (1999), Janecke and others (2003), Carney and Janecke (2005), and Steely and others (2005).

Cross sections through the Curlew Valley basin-fill aquifer constructed from well-drillers' logs (Utah Division of Water Rights, 2003-2005) characterize the distribution of sediment and rock types in various parts of the valley (plate 2; figure 8). The method is limited by the number, location, accuracy, and detail of the well logs, all of which vary considerably; the cross sections are most reliable where they intersect several wells having more or less consistent logs. The best examples are parts of sections A-A', A''-A''', and the central part of C-C' (plate 2), in which several lava flows are logged consistently in two or more wells.

Cross section A-A' (plate 2) trends north-northeast along the road between Locomotive Springs and Snowville in southeastern Curlew Valley. Basin-fill deposits there are mainly Quaternary basalt covered by thin alluvial and lacustrine deposits. The basalt was deposited on semi-consolidated gravel and sandstone, most likely the Salt Lake Formation. About 5 miles (8 km) southwest of Snowville, near well 26, the basalt thins markedly and interfingers with the younger basin-fill deposits (cross section A-A', plate 2). Interpretation of gravity data, presented in the following section, suggests that the thinning is due to a southwest–side-down normal fault that uplifts Oquirrh Group rocks in its footwall. About 3 miles (6 km) southwest of Snowville, near wells 89 and 85, two northeast-side-down normal faults displace the basement rocks, and sedimentary basin-fill deposits, composed of interbedded gravel, sand, and clay, thicken markedly to the northeast in their hanging walls (cross section A-A', plate 2).

Sections A''-A''' and B-B' (plate 2; figure 8) show that Quaternary basin-fill deposits in Holbrook arm consist of relatively thin, laterally discontinuous beds of gravel, sand, and clay. Overall grain size increases toward the margins of the North Hansel Mountains and Sublett Range, which reflects deposition of coarse-grained sediment on alluvial fans at the valley-mountain interfaces. Overall finer grained sediments in the basin center are interpreted as interbedded lacustrine and alluvial deposits.

Cross section B-B' shows two layers of lava, interpreted here as the distal parts of Quaternary and/or Tertiary basalt flows exposed to the southwest and/or east (plate 2; figure 8). The logs of several wells in both cross sections indicate a transition from unconsolidated to semiconsolidated deposits (change of typical description in logs from "sand" and "gravel" to "sandstone" and "conglomerate") that occurs at a relatively consistent depth range. The semi-consolidated deposits are here interpreted as the Salt Lake Formation below the younger basin-fill package.

The cross section through the central part of Curlew Valley just south of the state line (C-C', plate 2; figure 8) shows that basin-fill sediments are coarser overall near the valley margins. In southern Juniper Valley, basin-fill deposits are mainly clay and sand interbedded with up to six basalt flows. Four of these flows are intercepted at consistent depths by more than one well, indicating that their location in cross section C-C' is accurate. These flows are likely the distal parts of basalt flows exposed near the Wildcat Hills and/or the Quaternary shield volcanoes in the southeastern part of the valley.

Cross sections A-A', D-D', E-E', and F-F' (plate 2; figure 8) show the lithology of the upper 100 to 200 feet (30–60 m) of the basin fill in the Utah part of Curlew Valley. These sections show less detail and are shallower than those described in the preceding paragraphs. In general, they show that central and southeastern Curlew Valley in Utah consist of volcanic deposits locally overlain by and interbedded with thin surficial deposits, except along the range margins where alluvial-fan deposits predominate.

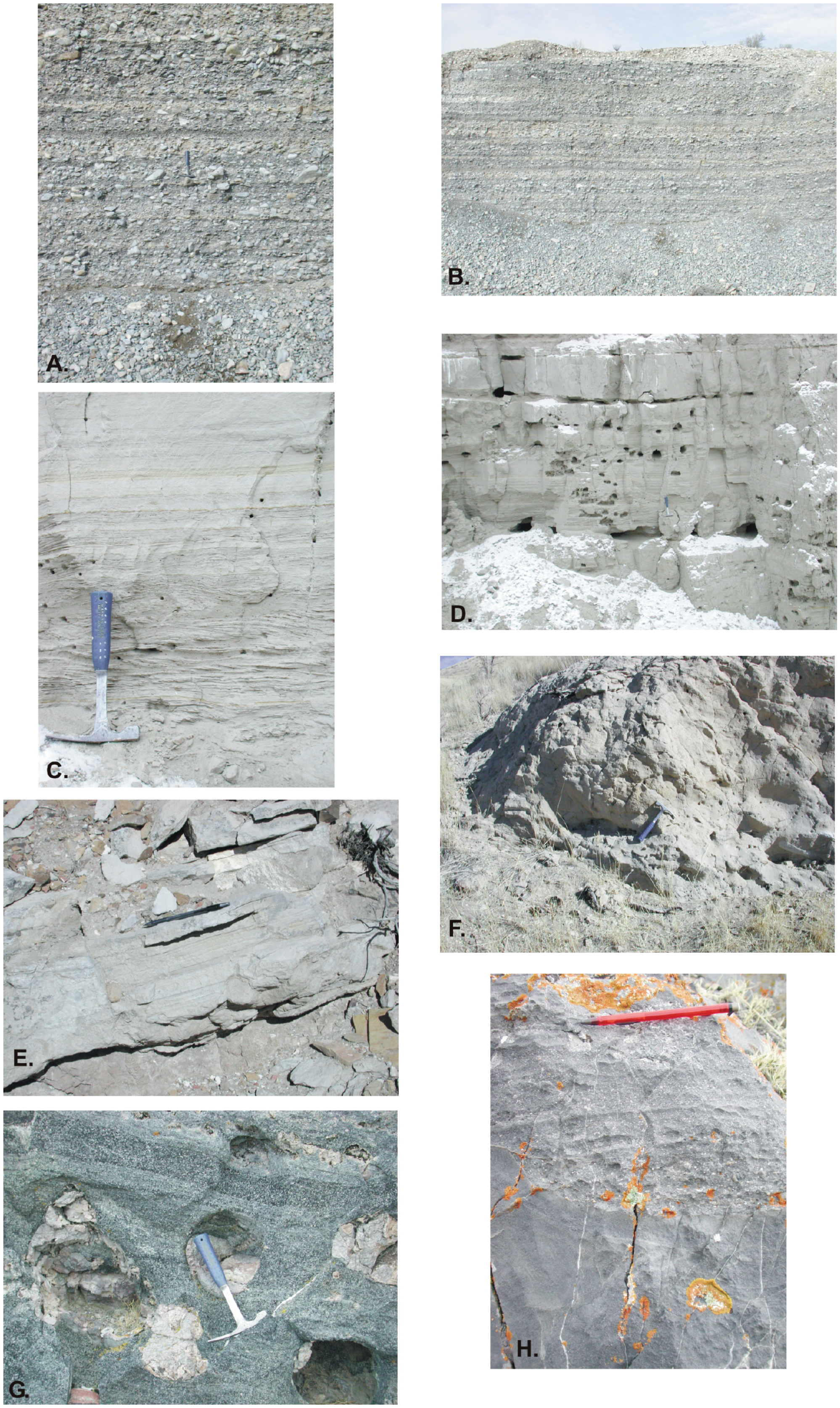

Figure 7. *Photographs of sedimentary deposits and rocks in the Curlew Valley study area. Rock hammer is 11 inches (23 cm) long. A. Stratified lacustrine gravel (map unit Qlgp) exposed on the western margin of the North Hansel Mountains. B. Larger view of lacustrine gravel shown in A. C. Laminated lacustrine clay and silt (Qlfp) exposed in Deep Creek gorge in Holbrook arm, south of Holbrook. D. Larger view of lacustrine clay and silt shown in C. E. Weakly stratified volcanic tuff in the Salt Lake Formation (Ts), exposed on the western margin of the North Hansel Mountains. Pen is 6 inches (15 cm) long. F. Structureless, unstratified volcaniclastic diamictite in the Salt Lake Formation, exposed on the western margin of the North Hansel Mountains. G. Rhyodacite welded tuff (Trd) in the Wildcat Mountains. H. Bioclastic calcarenite of unit PIPoc of the Oquirrh Group, exposed in the North Hansel Mountains.*

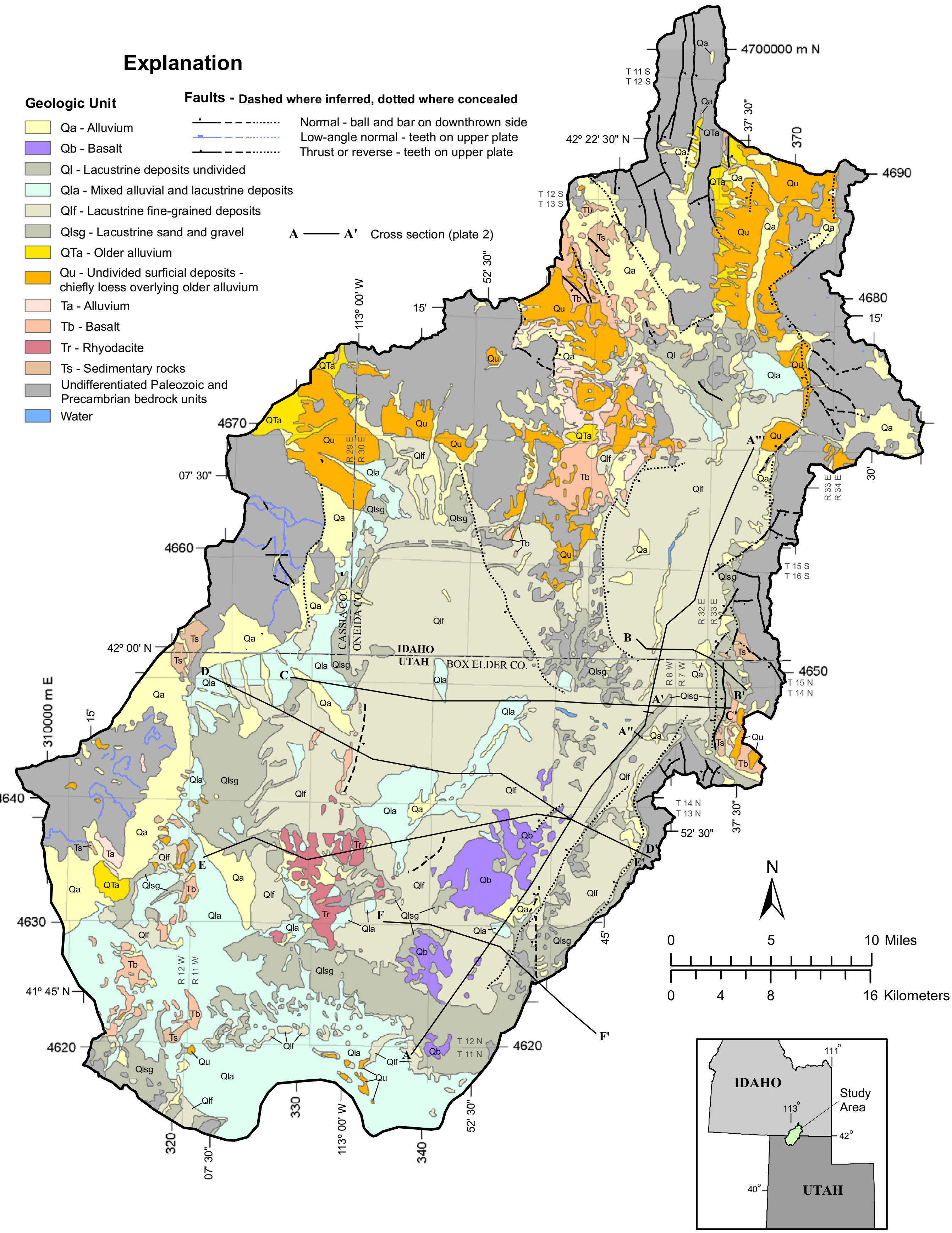

Figure 8. Geologic map of surficial units, Curlew Valley study area.

Gravity Survey and Implications for Basin Structure

Introduction

Cook and others (1964) and Peterson (1974) presented gravity data and two-dimensional models of basin geometry for Curlew Valley and adjacent areas, and Baker (1974) showed contours of basin-fill thickness below the valley based on their data. Cook and others (1964) and Peterson (1974) covered much greater areas than the Curlew Valley drainage basin, and the wide spacing of their gravity stations permits only a general evaluation of basin structure. Baker's (1974, plate 2) isopach map shows three areas of thick basin-fill accumulation below Curlew Valley: a small, oval-shaped depression up to 5000 feet (1500 m) thick in southern Holbrook arm, centered about 3 miles (5 km) north of Snowville; a broader oval-shaped depression up to about 4000 feet (1200 m) thick below Juniper Valley, with the thickest deposits centered about 4 miles (6 km) southeast of Juniper; and a north-northeast-trending, elongate trough over 3000 feet (900 m) thick between the eastern Raft River Mountains and the Wildcat Hills. Baker (1974, plate 2) showed Bouguer-anomaly contours but little detail on basin-fill thickness for southern Curlew Valley, and indicated that basin-fill deposits there are less than 1000 feet (300 m) thick.

Hatfield (1983) conducted a gravity study of southern Arbon Valley and northern Holbrook arm. His study area was smaller, and his station density was significantly greater than those of Cook and others (1964) and Peterson (1974). Hatfield's (1983) Bouguer-anomaly map shows gravity lows below the valley floor south and east of Holbrook and in southern Arbon Valley, and highs in the boundary area between the two valleys and in the adjacent mountains. Modeling of the gravity results along two-dimensional cross sections showed that both depositional basins are asymmetric; basin-fill deposits below Arbon Valley thicken to the north and west, whereas those below northern Curlew Valley thicken eastward toward the western margin of the North Hansel Mountains (Hatfield, 1983).

To provide greater coverage of gravity data in Curlew Valley, the senior author measured relative gravity and elevation at nearly 800 stations in the valley (figure 9; table B.1) during spring 2003. The objectives of collecting new data were to delineate the subsurface structure of the Curlew Valley depositional basin in sufficient detail to evaluate Baker's (1974) proposed ground-water flow systems, locate major concealed faults, detect the subsurface extent of basalt flows, and better define the geometry of the basin fill for a future ground-water flow model.

In this study, aeromagnetic and gravity data are used together to constrain the subsurface distribution of volcanic rocks and basin fill. A residual magnetic-anomaly (the magnetic signal that remains after the effects of Earth's present-day magnetic field have been removed) map of Curlew Valley, derived from aeromagnetic measurements, reflects the structure and distribution of rock units having contrasting magnetic properties (figure 10) (Bankey and others, 1998). Strong residual magnetic highs exist above the northern two Quaternary basalt shields in southeastern Curlew Valley, above outcrop areas of Tertiary basalt in southwestern Curlew Valley and in the Sublett Range, above the Tertiary volcanic rocks in the Wildcat Hills, and above the eastern Raft River Mountains where Precambrian igneous rocks are exposed. The utility of the aeromagnetic data for these purposes is limited by the relatively wide spacing of the flight lines used to acquire the data. The data lack sufficient resolution for analysis at scales smaller (more detailed) than about 1:250,000, except along flight lines where more detailed interpretations are appropriate.

Methods

The new gravity data include a one-mile (1.6 km) station grid over much of the valley, and linear traverses perpendicular and parallel to the predominant north-south structural grain having one-half mile (0.8 km) station spacing (figure 9). Most new stations are in locations not measured in the previous studies, but several measurements of previous stations were made to evaluate consistency with those studies, so that all existing stations could be used to evaluate the basin structure. The gravity data from Cook and others (1964) and Peterson (1974) were obtained from Bankey and others (1998).

Data collection and reduction followed standard methods (for example, Telford and others, 1976). These methods, along with the data from this and other studies used in subsequent calculations, are documented in appendix B. In short, the magnitude of a raw gravity measurement includes the effects of instrument drift, earth tides, latitude, elevation, and topography, in addition to subsurface variations in density that reflect geologic structure (e.g., Telford and others, 1976; Milsom, 1996; Parasnis, 1997). Corrections for the non-geologic components of gravity measurements are well established and accurate, and the corrected gravity value is referred to as the Bouguer gravity anomaly, expressed in units of milligals. The Bouguer anomaly reflects variations in gravity relative to a standard reference plane, typically sea level. In a geologic context, as one traverses over a progressively thickening sedimentary basin, the Bouguer anomaly decreases by one milligal for every 11 feet (3.5 m) of increased thickness of basin fill having an average density of 2.17 g/cm^3 that overlies basement having an average density of 2.67 g/cm^3.

Results

Bouguer-anomaly values for stations from this study are typically within 1 milligal of those from previous studies, within the approximate uncertainty of individual values. Where larger disagreements existed, the previous data were discarded to retain greater consistency of the entire data set.

Figure 11 is a Bouguer-anomaly map of the Curlew Valley drainage basin, derived by gridding and contouring our new data (table B.1) together with the data from previous studies (tables B.2 through B.4). The new data are generally similar to those from previous studies (Cook and others, 1964; Peterson, 1974), and show Bouguer anomaly highs and lows of approximately the same magnitudes and in the same locations, but figure 11 represents a much greater level of detail, and shows smaller-scale variations. Gravity highs are centered just southwest of the unnamed Quaternary basalt shield in southern Curlew Valley (labeled A on figure 11), on the Raft River Mountains (B, figure 11), on the southeastern

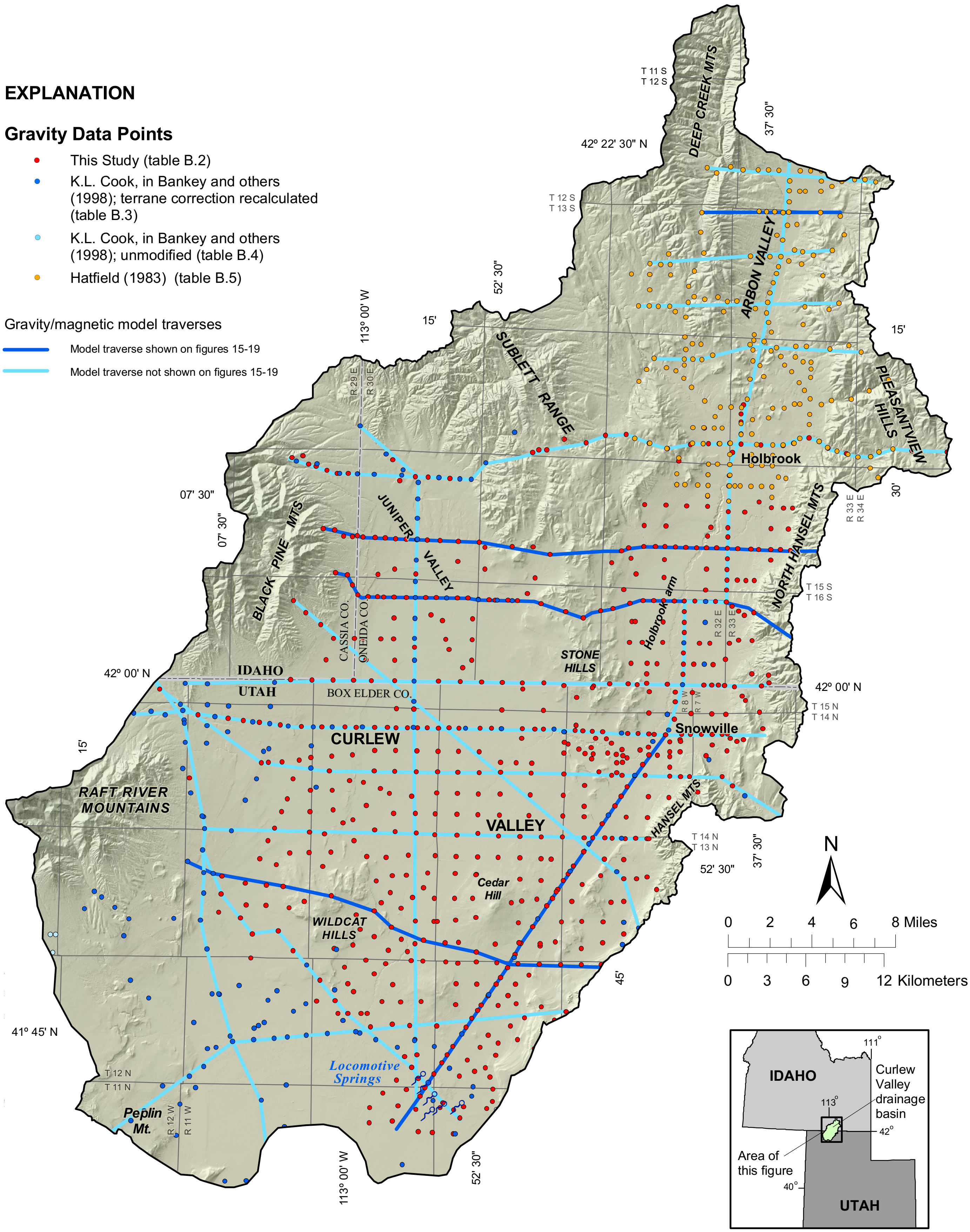

Figure 9. Locations and sources of gravity data used in this study.

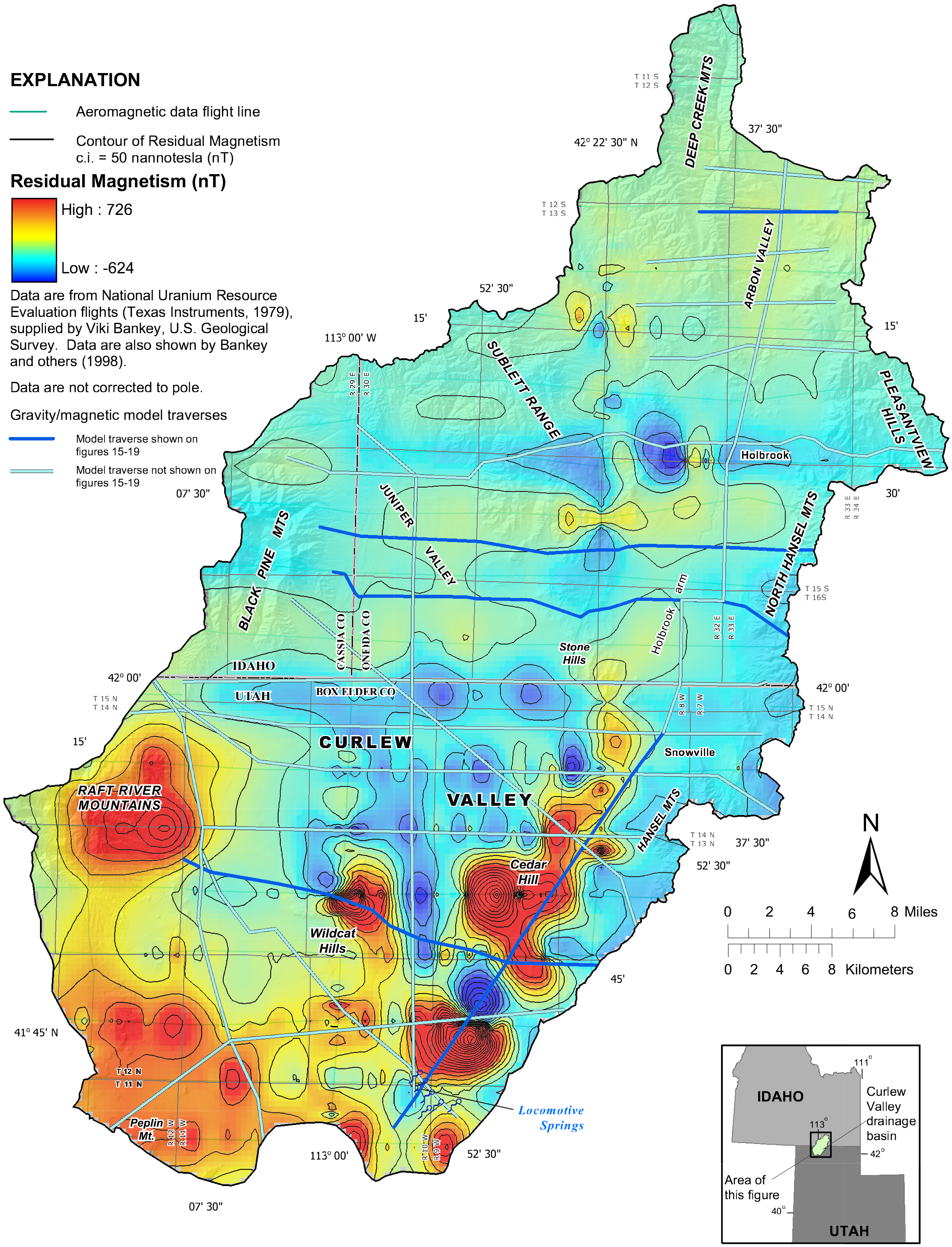

Figure 10. Contoured and gridded aeromagnetic data for Curlew Valley study area.

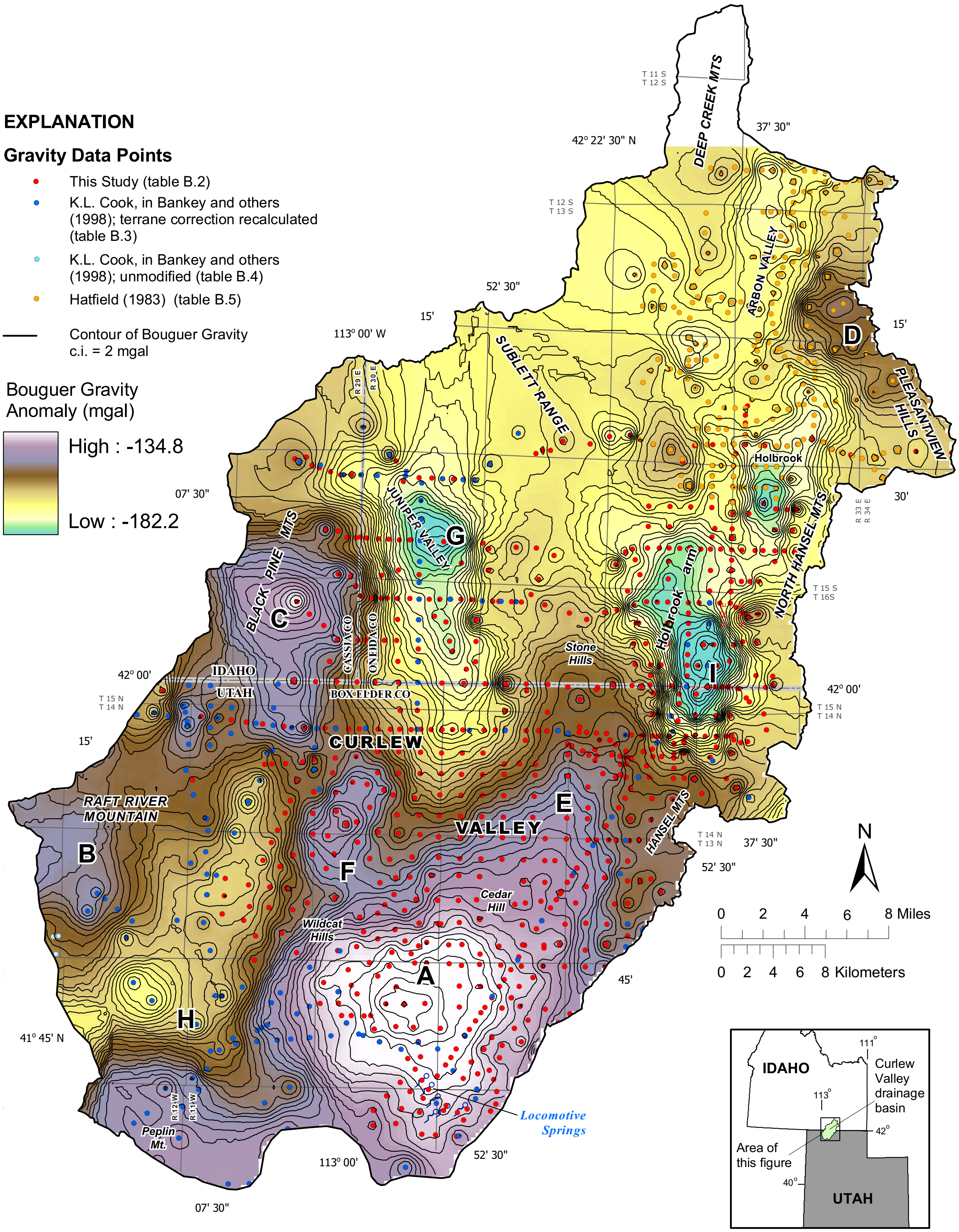

Figure 11. *Gridded and contoured complete Bouguer anomaly map for the Curlew Valley study area. Letters A through I denote prominent gravity highs and lows as discussed in text.*

margin of the Black Pine Mountains (C, figure 11), and on the central Pleasantview Hills (D, figure 11). A northeast-trending relative high extends from Cedar Hill to the Stone Hills (E, figure 11), and a northwest-trending high extends from the middle basalt shield to the southern Black Pine Mountains (F, figure 11). Significant gravity lows exist below northern Juniper Valley (G, figure 11), along the eastern margin of the Raft River Mountains (H, figure 11), and below Holbrook arm (I, figure 11). These gravity lows consist of a main, roughly oval-shaped zone of minimum Bouguer anomaly values and a subsidiary gravity low along the same axis. The subsidiary gravity low below Holbrook arm is offset significantly to the north-northeast from the main low.

Interpretation

Bouguer anomaly field: The gravity highs represent the presence of higher-density rocks near the surface. The gravity high in southern Curlew Valley is produced by the Quaternary basalt shields and associated flows (exposed and/or filling subsurface depressions), because the average density of basalt flows (2.9 g/cm^3) is significantly greater than that of the basin-fill deposits with which they are interbedded (2.0-2.3 g/cm^3) (Telford and others, 1976). The other highs are due to the uplift of dense basement rocks (2.4-2.67 g/cm^3; Telford and others, 1976) below the mountain ranges and to subsurface bedrock ridges.

Pronounced gravity lows below northern Juniper Valley, southern Holbrook arm, and southeast of the Raft River Mountains represent thick accumulations of Quaternary-Tertiary unconsolidated to semi-consolidated basin-fill deposits, and are produced by the density contrast between the basin fill and adjacent bedrock.

Regional and residual gravity fields: The Bouguer anomaly field is a composite signal resulting from density variations at different depths and length scales (wavelengths), due to lithologic variations and structures that juxtapose geologic materials of different densities (Telford and others, 1976; Parasnis, 1997). For this study, the primary goal is to understand variations in basin-fill thickness. Previous work (Cook and others, 1964; Peterson, 1974) showed that the depositional basins are up to 5000 feet (1600 m) thick, and their centers are spaced roughly 10 to 12 miles (16–19 km) apart. The basin-fill geometry can be more accurately quantified if the gravity signal from variations in basin-fill thickness can be isolated from gravity signals due to density variations at other length scales. This can be at least partially accomplished by calculating the gravity field due to deeper and larger-wavelength geologic variations, known as the regional gravity field, and subtracting it from the Bouguer anomaly field (Parasnis, 1997).

The regional gravity field is approximated by fitting a simple planar or low-order polynomial equation to the Bouguer anomaly field. To achieve this the Bouguer anomaly field for an area including and extending beyond the Curlew Valley drainage basin was gridded, and both planar and polynomial regressions were calculated for the grid (figure 12) using standard gridding software. These equations represent broadly varying surfaces fit to the complex Bouguer anomaly-field surface. The second-order polynomial was judged to be a better approximation to the regional gravity field because (1) it more closely resembles published crustal-thickness maps for the Basin and Range province (Pakiser, 1989), and (2) it may better account for gravity variations with intermediate wavelengths (between those due to large-scale variations in crustal thickness and those due to variations in basin-fill thickness). These intermediate wavelengths may be produced by variations in density in the middle to lower crust (about 5–15 km depth) related to intrusions that fed the Quaternary and Tertiary basalt shields and flows.

The residual gravity field is produced by subtracting the estimated regional field from the Bouguer anomaly field (Parasnis, 1997). In this study, this was accomplished by subtracting the regional gravity grid from the Bouguer anomaly grid; the two grids have identical node spacing and locations. The residual gravity field for the study area is similar in geometry to the Bouguer anomaly field: the highs and lows are in the same locations and have largely the same shapes, although the range of residual gravity values is substantially lower (figure 13). Variations in the residual field can be interpreted to represent variations in basin-fill thickness and in the density of consolidated-rock units above about 10,000 feet (3000 m) depth. The residual gravity field is appropriate input for quantitative modeling of the basin geometry.

Gravity and magnetic modeling: Modeling of gravity data involves constructing a geologic cross section, including the subsurface geometry and density of generalized rock units, calculating the gravity field predicted by this geometry, comparing the model-generated gravity field to the observed residual gravity field along the profile line, and modifying the cross-section geometry to better match the observed residual-gravity data (Northwest Geophysical Associates, 2001). Simultaneous solution for residual gravity anomaly and aeromagnetic data improves the accuracy of the modeling by providing an additional constraint on subsurface geometry based on contrasting magnetic properties. As noted above, however, the resolution of the available aeromagnetic data provides only a general constraint on subsurface geometry except where the model traverse coincides exactly with a flight line. This condition did not arise except in estimating the magnetic susceptibility of the volcanic deposits.

This modeling approach is a tool to quantitatively predict subsurface geologic structure, and is effective for determining the subsurface geometry of sedimentary basin fill due to the large density contrast between the unconsolidated to semi-consolidated deposits and basalt or bedrock. In this study, 21 profiles throughout the Curlew Valley basin were modeled, using software that incorporates both gravity and aeromagnetic data (Northwest Geophysical Associates, 2001) (figures 14 to 20).

Gravity-magnetic modeling requires independent determination of the density and magnetic susceptibility of the relevant geologic units. These values are known to within reasonable bounds for common rock types and their values can be assumed, instead of directly measured, without introducing major uncertainty into the models (Telford and others, 1967; Parasnis, 1997; Northwest Geophysical Associates, 2001). For this study, the density and the magnetic susceptibility of each major rock type used in the models (appendix B) were initially assumed to be in the middle of the commonly cited ranges (Telford and others, 1967), then were

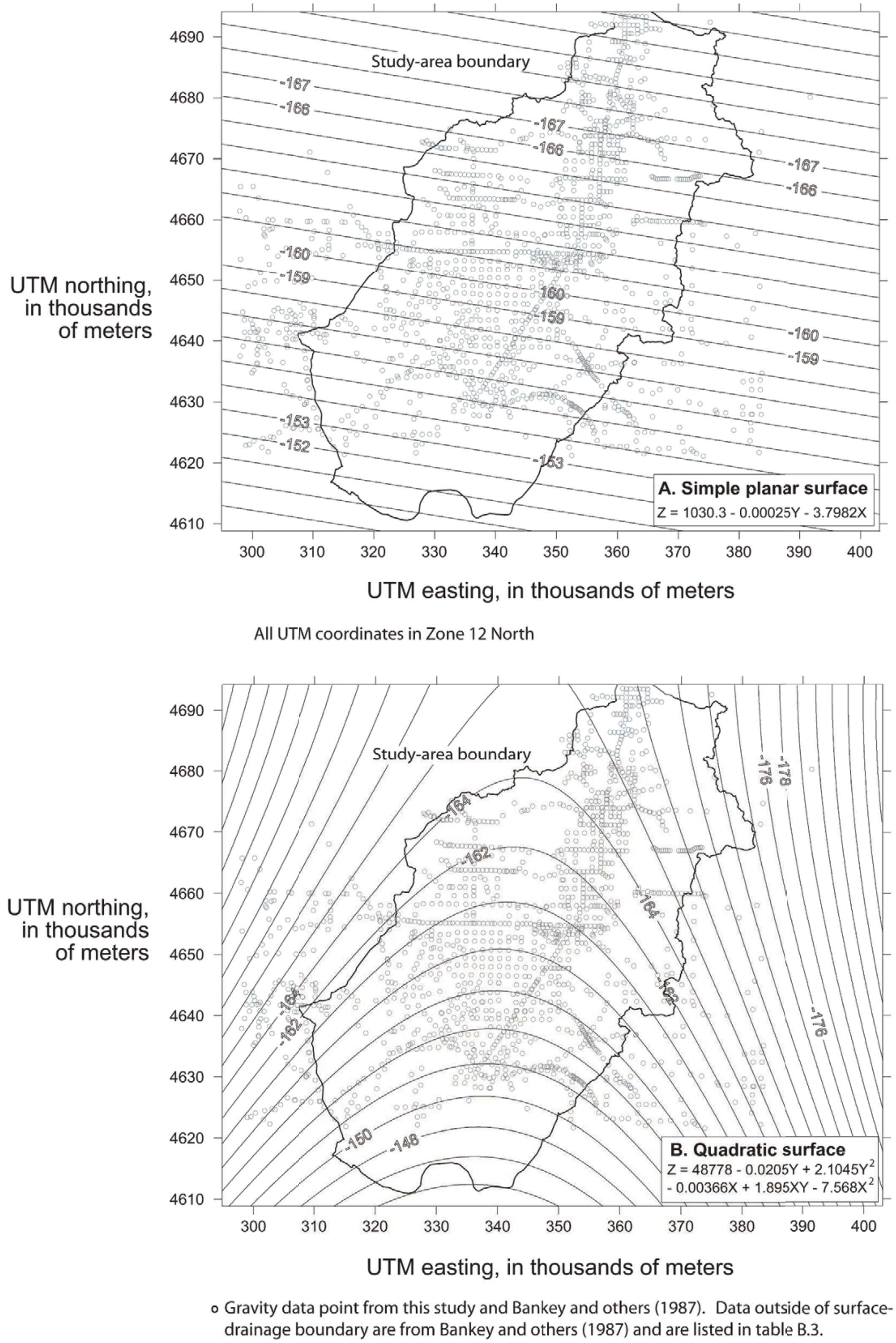

***Figure 12.** Contours of low-order surfaces fit to the Bouguer anomaly gravity field of the study area shown on figure 11. A. Simple-planar surface fit to observed Bouguer anomaly field. B. Quadratic-surface fit to observed Bouguer anomaly field. These surfaces are interpreted to represent different wavelengths of the regional gravity field below the study area The residual gravity fields were generated by subtracting the quadratic surface from the complete Bouguer field.*

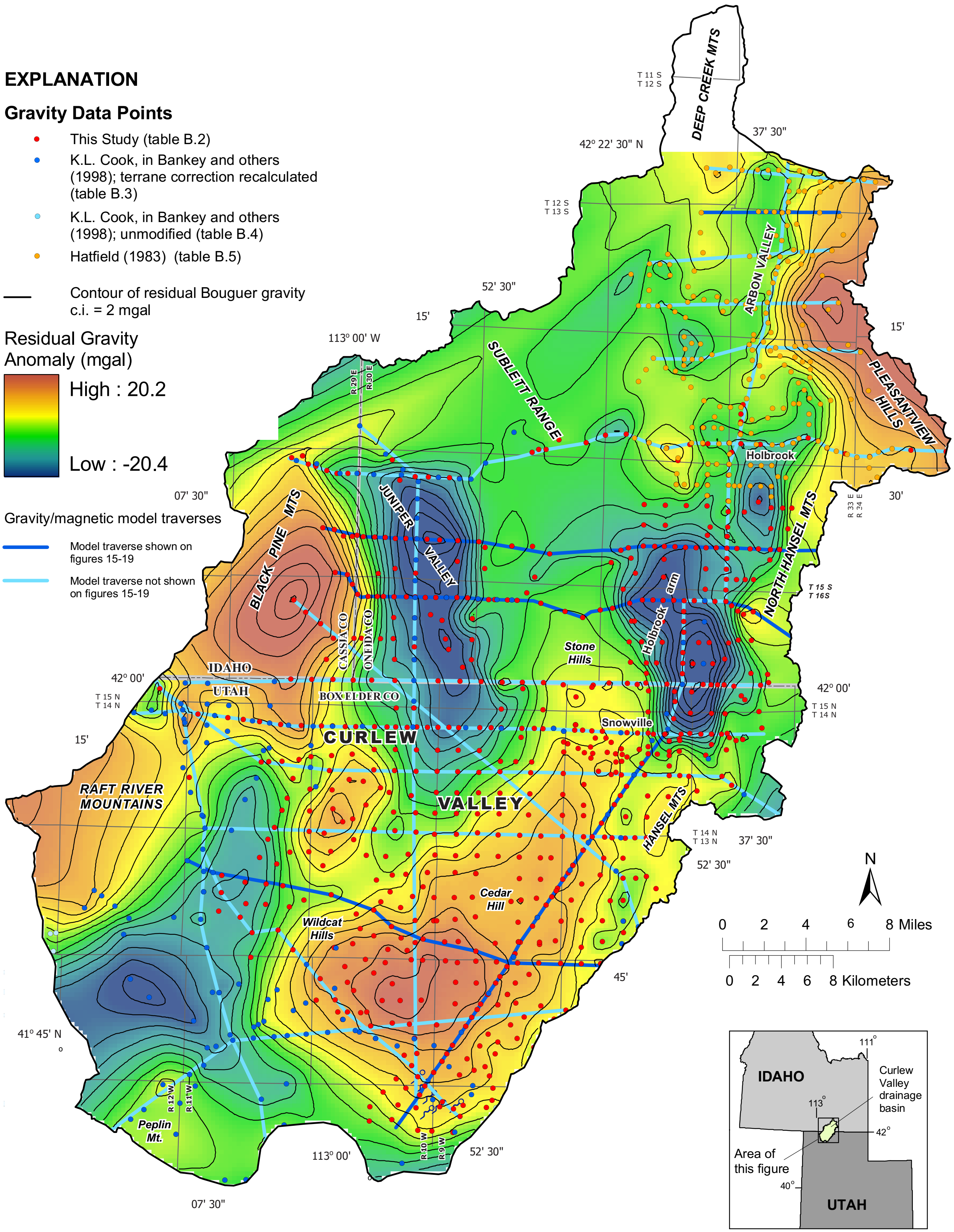

Figure 13. Gridded and contoured residual gravity map of Curlew Valley study area.

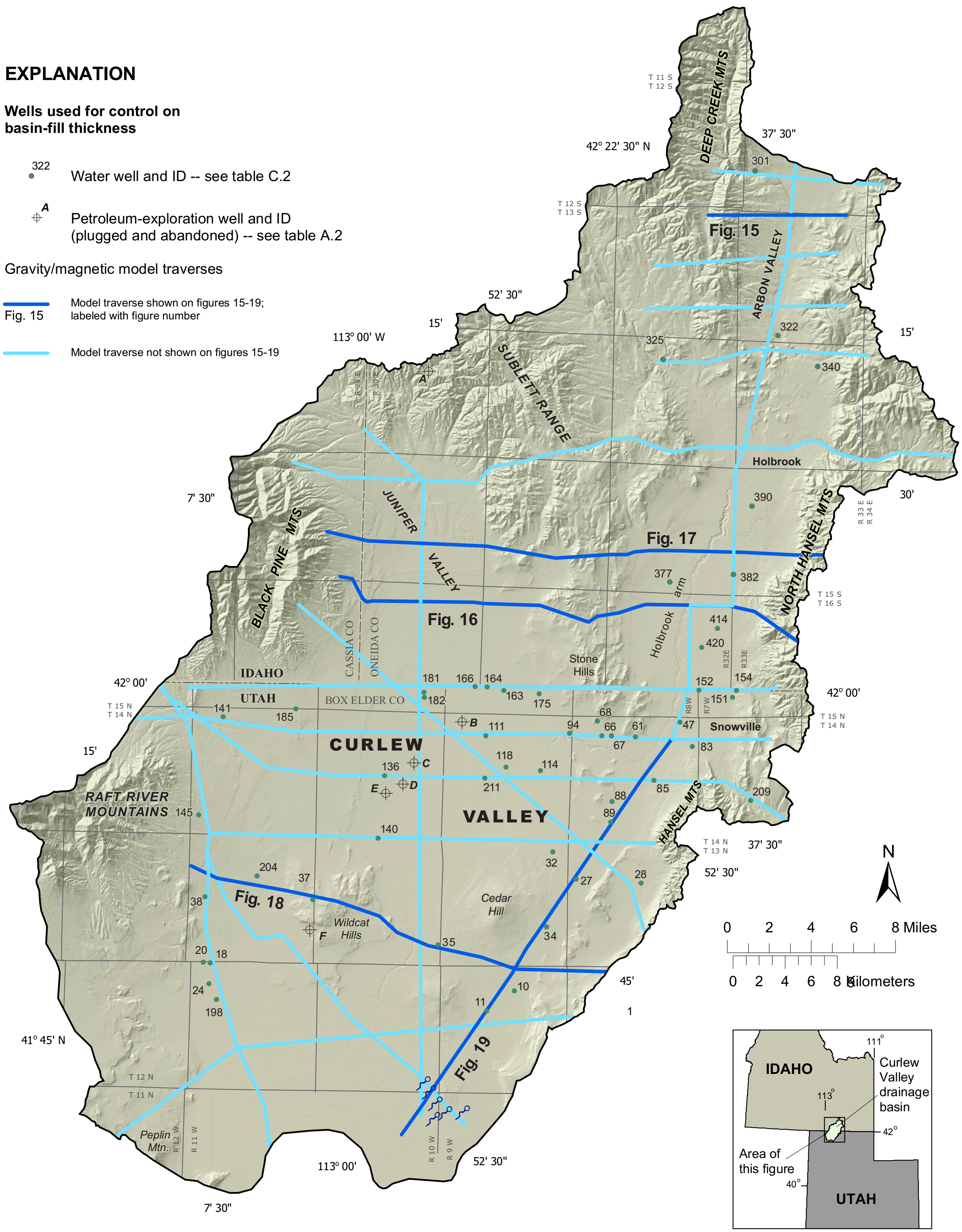

Figure 14. Locations of gravity and magnetic models in Curlew Valley calculated for this study. Figures 15 through 19 show the models.

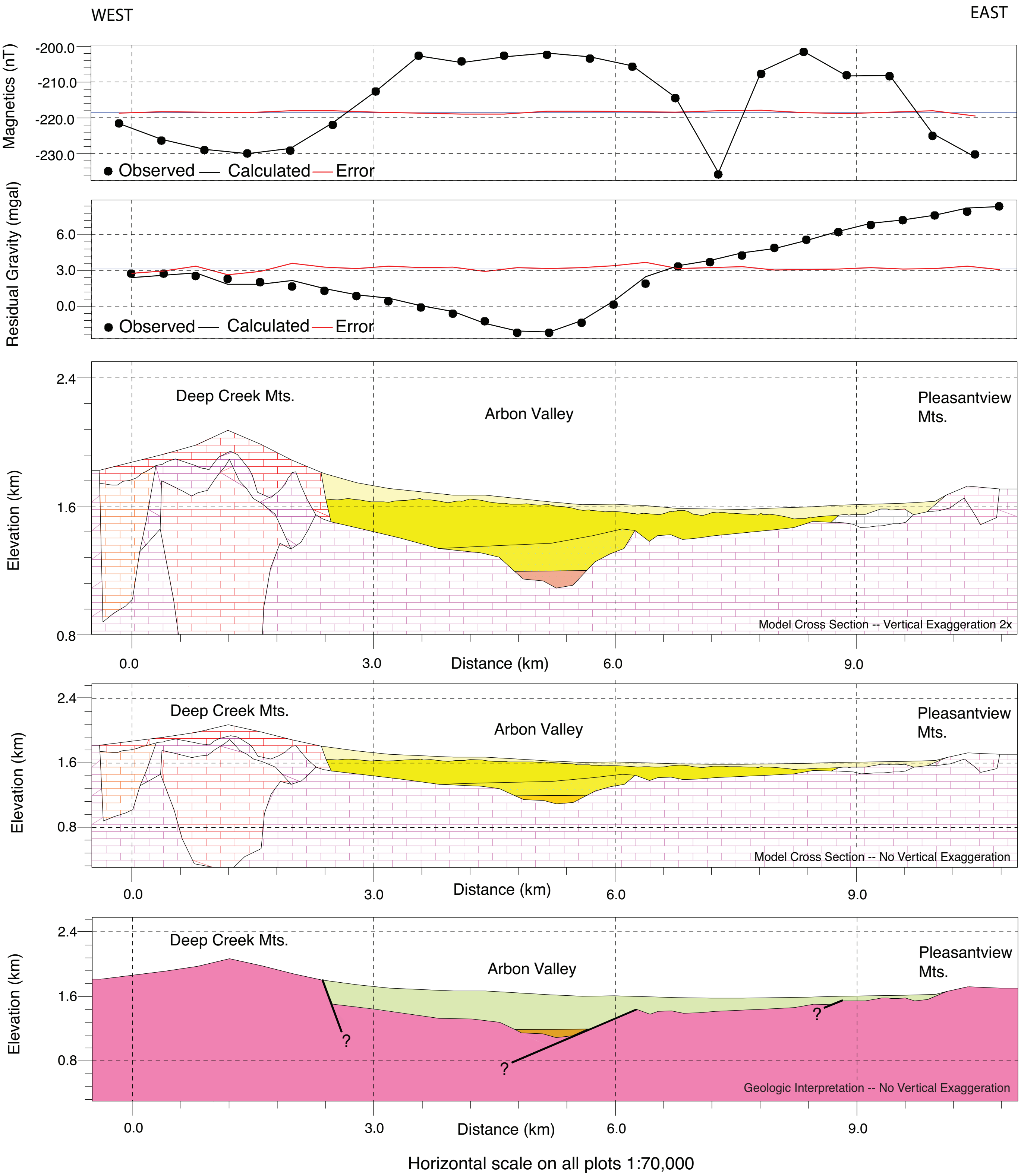

Figure 15. *Gravity and magnetic data, model cross sections, and geologic interpretations for traverse in southern Arbon Valley. See figure 14 for model location and figure 20 for explanation of symbols.*

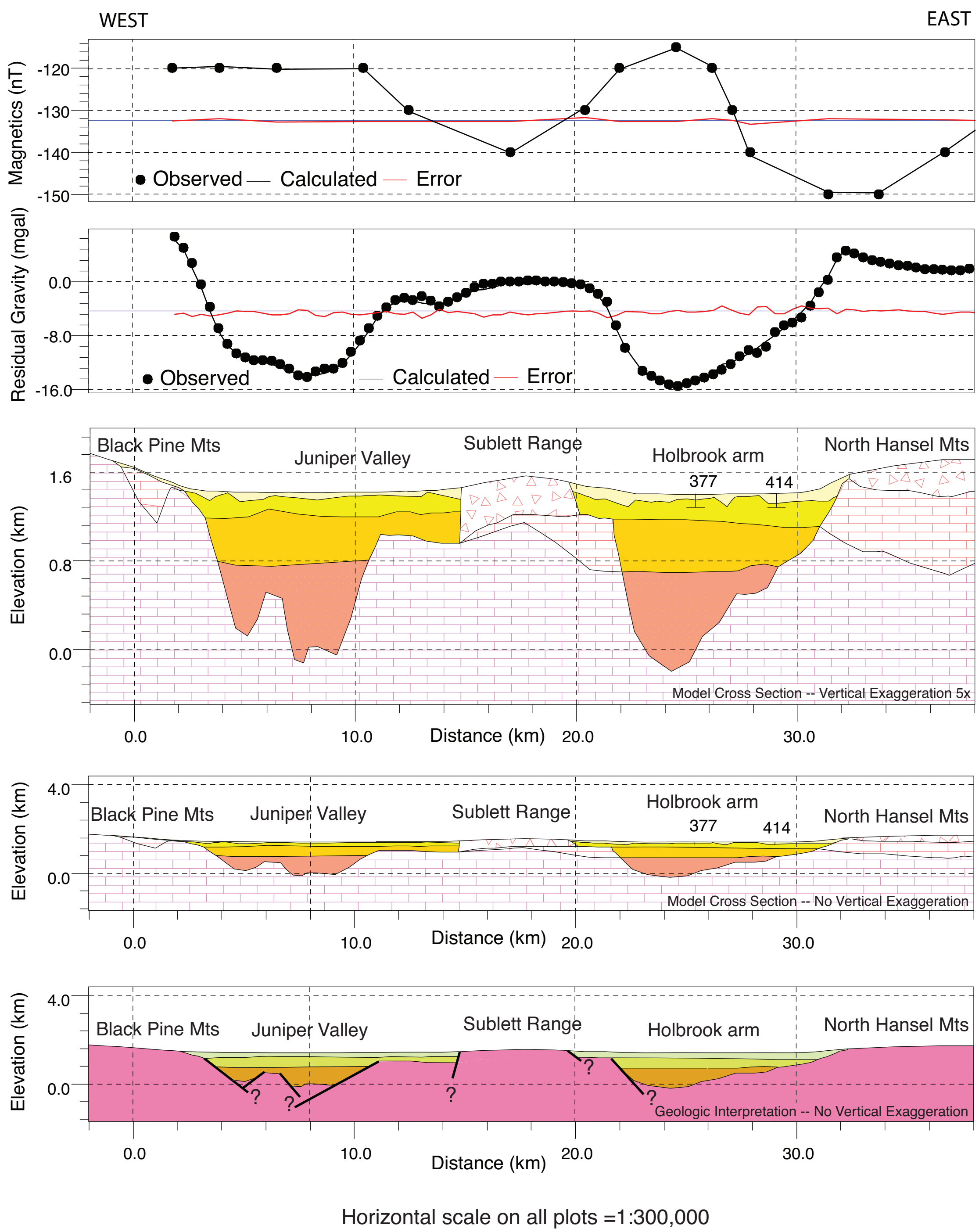

Figure 16. *Gravity and magnetic data, model cross sections, and geologic interpretations for traverse in central Juniper Valley and Holbrook arm at the latitude of Stone Reservoir. See figure 14 for model location and figure 20 for explanation of symbols.*

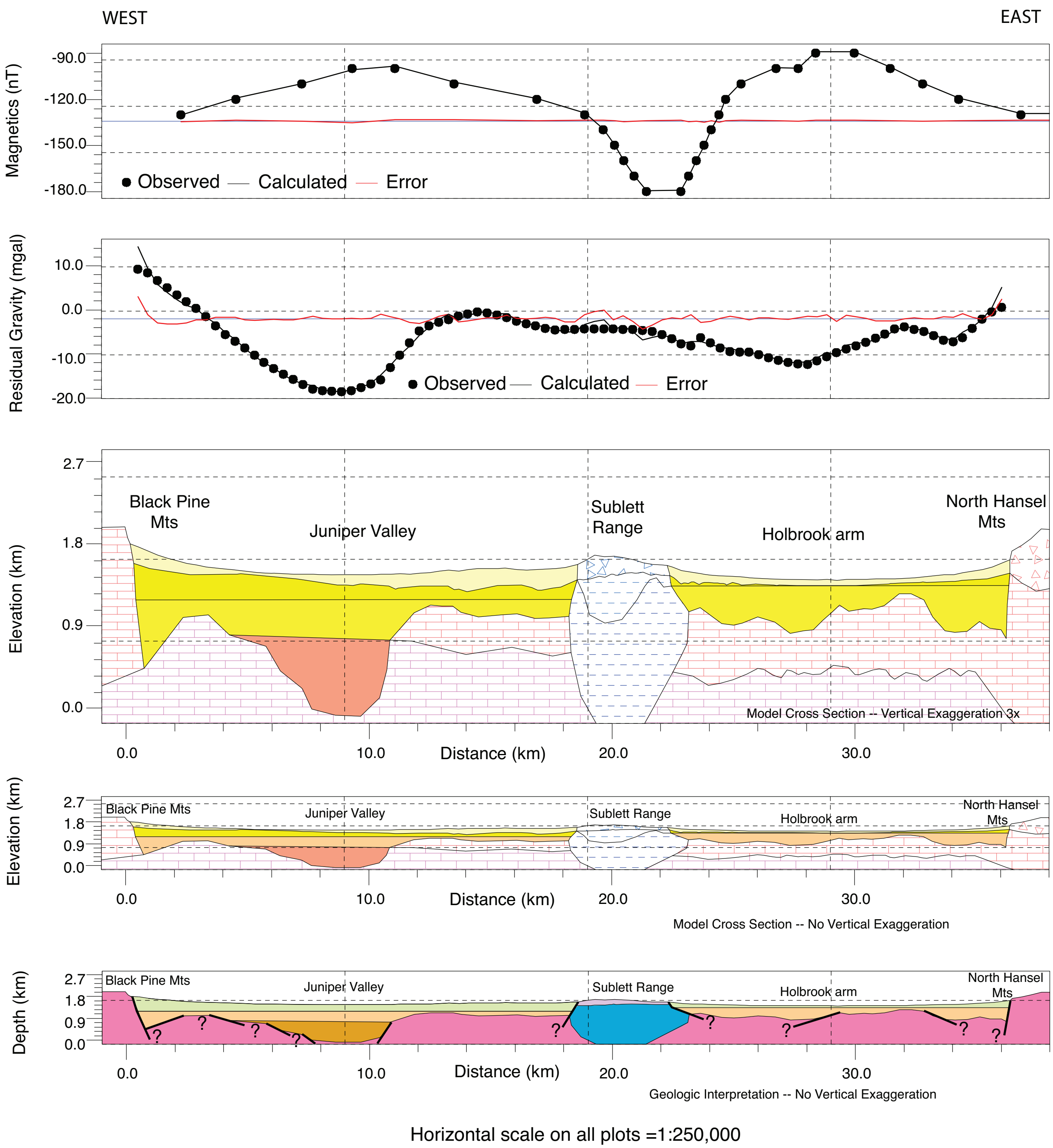

Figure 17. *Gravity and magnetic data, model cross sections, and geologic interpretations for traverse in central Juniper Valley and Holbrook arm north of Stone Reservoir. See figure 14 for model location and figure 20 for explanation of symbols.*

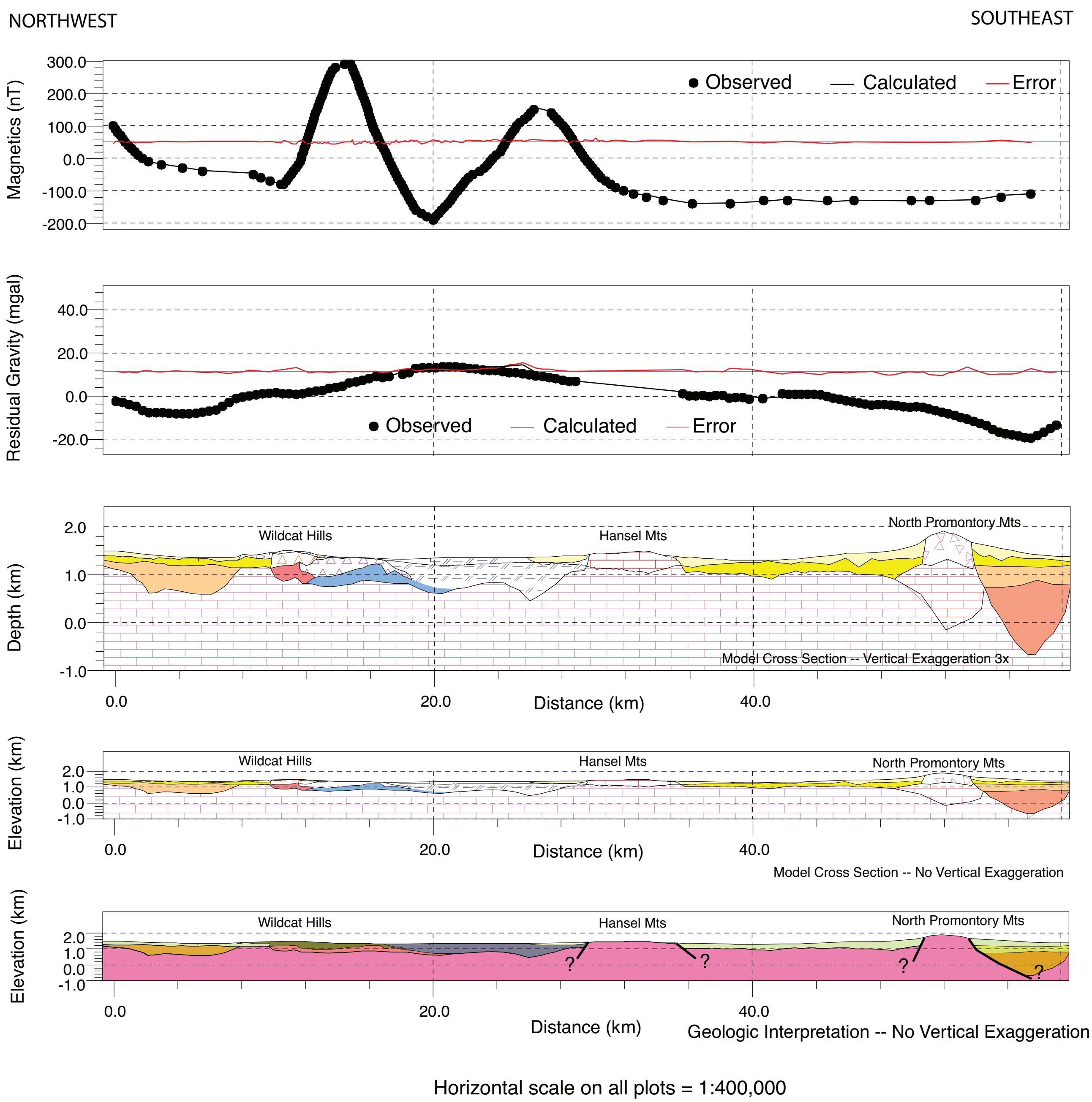

Figure 18. *Gravity and magnetic data, model cross sections, and geologic interpretations for traverse in southern Curlew Valley from the eastern Raft River Mountains to Monument Point. See figure 14 for model location and figure 20 for explanation of symbols.*

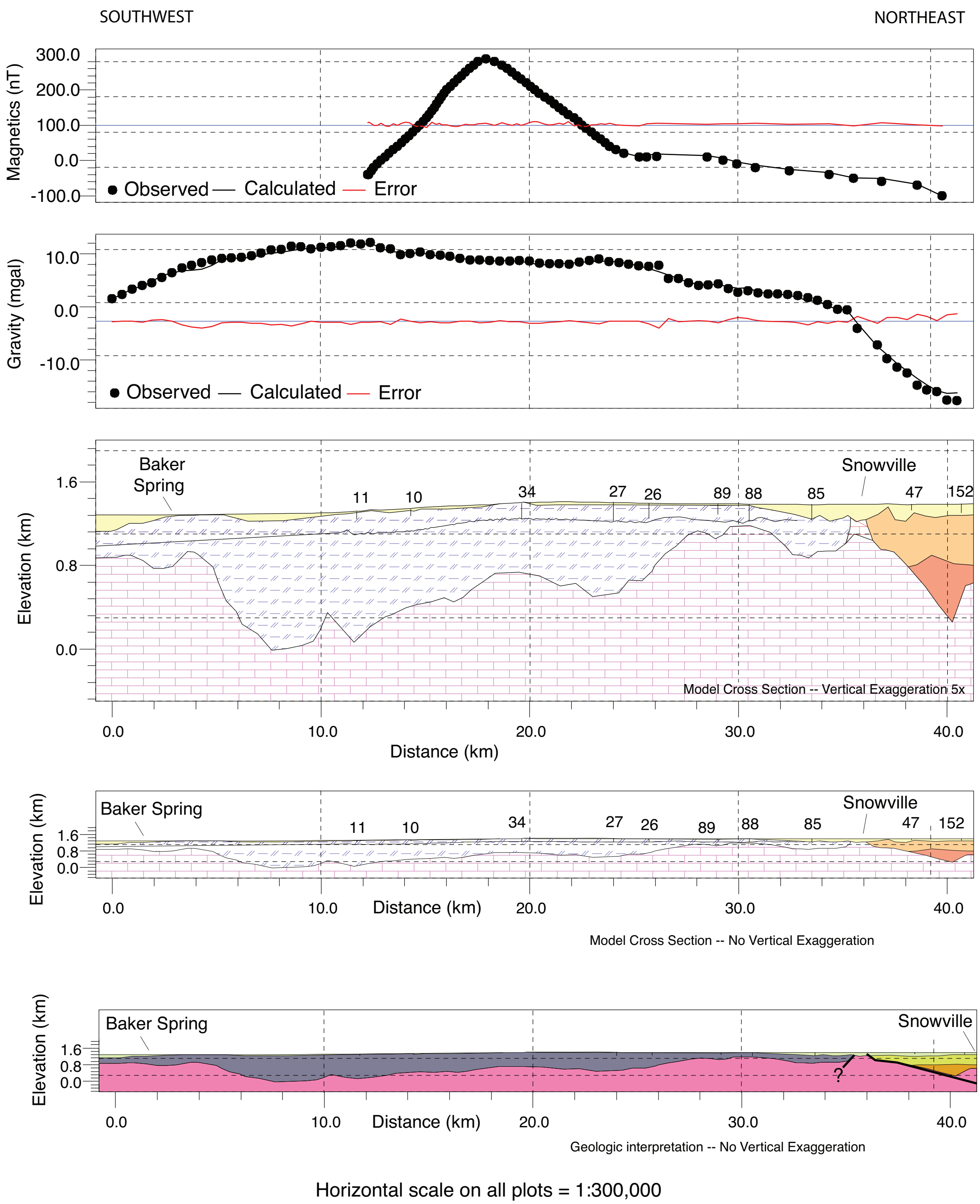

Figure 19. Gravity and magnetic data, model cross sections, and geologic interpretations for traverse in southeastern Curlew Valley from the Locomotive Springs complex northeast to north of Snowville. See figure 14 for model location and figure 20 for explanation of symbols.

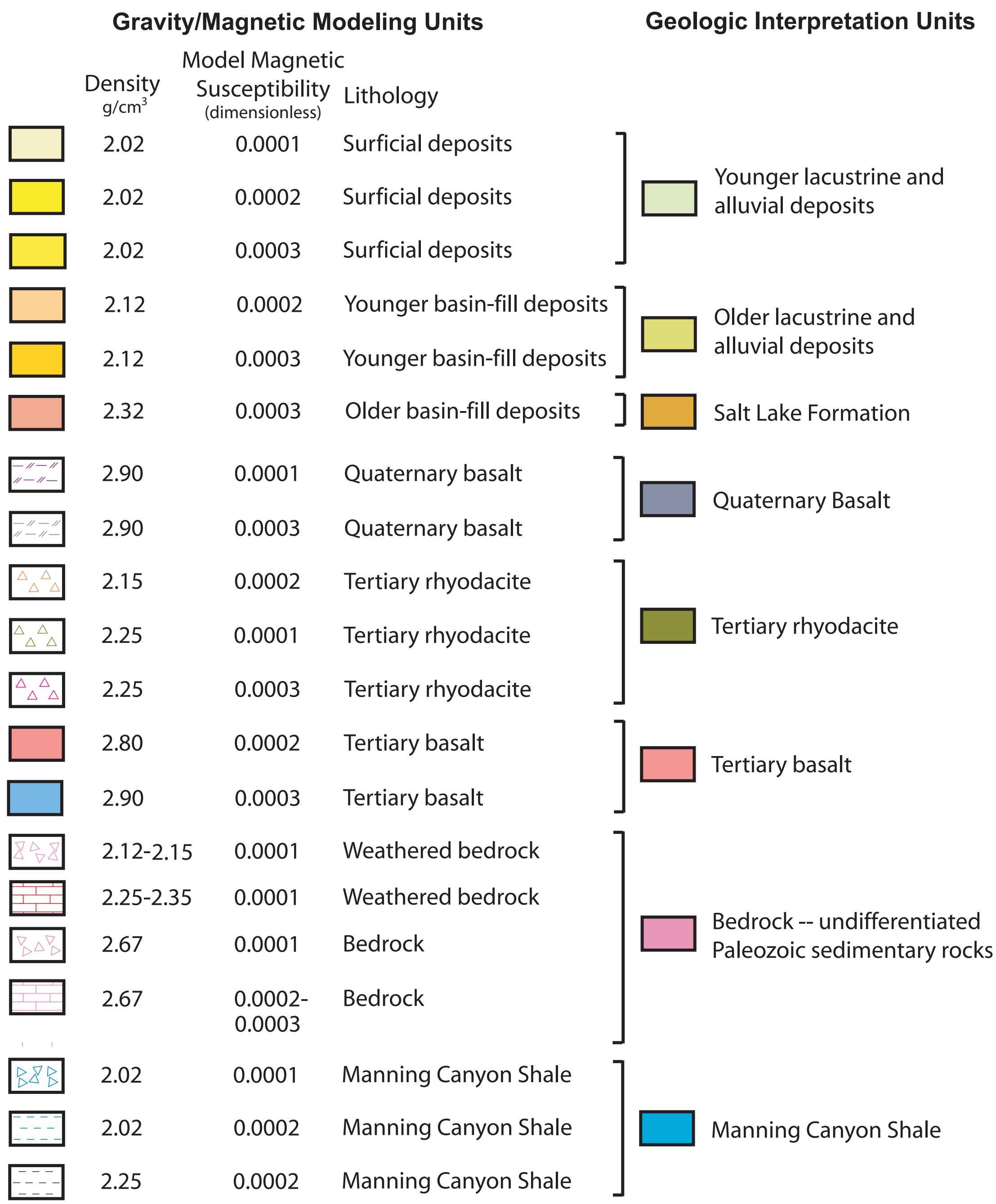

Figure 20. *Explanation of colors and patterns used in geophysical model and geologic interpretation cross sections, figures 15 through 19.*

adjusted in some cases as follows. The density of the basin-fill deposits was assumed to increase stepwise with depth, from 2.02 g/cm^3 within 660 feet (200 m) of the land surface to 2.42 g/cm^3 at greater than 3960 feet (1200 m) depth (table B.1), following the approach of Saltus and Jachens (1995) for Quaternary-Tertiary basin-fill deposits in the Basin and Range. The density and magnetic susceptibility of undifferentiated bedrock, which incorporates all pre-Tertiary rock units in the area except the Manning Canyon Shale, were adjusted as needed to better fit the gravity and magnetic data profiles above the mountain ranges. The required adjustments were toward lower density and magnetic susceptibility to account for the effects of surface weathering. These adjustments did not significantly affect the modeled subsurface geometry of the basin-fill deposits. The Manning Canyon Shale is assigned a lower model density than the undifferentiated bedrock unit based on its mica-rich composition. The magnetic susceptibility of the Quaternary and Tertiary basalt flows was determined by constructing model profiles of the raw aeromagnetic data along flight lines over exposures of these units.

Incorporating geologic data into geophysical models greatly increases their accuracy. Geologic contacts, known faults, and logs of petroleum-exploration and water wells (figures 14 to 20; tables A.2 and C.2) were incorporated into the models. Model traverses perpendicular to the long axes of the sedimentary basins cross the bedrock-basin fill contact at one or both ends to provide better control on the position of this contact below the valley. The models are cross-correlated, so that they are nearly identical at their intersection points and, therefore, form an internally consistent data set. No geophysical models are unique, and other workers could derive different model cross sections from the same data used here. More refined estimates of density and magnetic susceptibility of the model geologic units would improve the accuracy of the model cross sections.

The geophysical models (figures 14 to 20) illustrate several important aspects of the structural geometry and evolution of the Quaternary-Tertiary Curlew Valley depositional basin. Basin fill below southern Arbon Valley thickens to the west toward the eastern margin of the Deep Creek Mountains, and is bounded by a steeply dipping normal fault along the valley-range boundary (figure 15). A smaller, fault-bounded depositional basin underlies the valley center. This basin is not evident from surface exposures. The basin-fill geometry along this cross section and in the southern Arbon Valley-northern Holbrook arm area is based mostly on data from Hatfield (1983), and the geophysical models calculated in this study are similar to his models.

The model cross section in figure 16 crosses the central parts of Juniper Valley and Holbrook arm. The Juniper Valley depositional basin has a complex structure—it is bounded on the west by a moderately east-dipping normal fault along the eastern margin of the Black Pine Mountains, and contains a central horst block. The deepest part of the basin is filled by the Tertiary Salt Lake Formation. The eastern part of the basin adjacent to the Sublett Range is shallower, filled with Quaternary deposits, and bounded on the east by a relatively minor, steeply west-dipping normal fault. The depositional basin below Holbrook arm thickens westward toward the Sublett Range, and the lower part of the basin is bounded on the west by an east-dipping normal fault that does not cut overlying Quaternary deposits. The westernmost part of the basin overlies shallow bedrock, and is likely fault-bounded against the Sublett Range.

The cross section in figure 16 traverses a relatively shallow part of the Holbrook arm basin between two deeper depositional centers, and does not cross the Juniper Valley basin along its axis of maximum thickness. Figure 17 shows that the deepest part of the Juniper Valley depositional basin consists of a graben filled with Salt Lake Formation in its central part, and that the wider, shallower upper part of the basin is bounded on both sides by steeply dipping normal faults but is not cut by the faults that define the deeper basin. On figure 17 the Holbrook arm depositional basin contains a central horst block, and thickens toward normal faults along the North Hansel and Sublett Range margins.

Figure 18 shows that volcanic rocks, including Tertiary basalt and rhyodacite of the Wildcat Hills and the Quaternary basalt shields, form the majority of the basin-fill aquifer in southeastern Curlew Valley. The western margin of the Hansel Mountains is defined by a steeply west-dipping normal-fault system, that apparently created a hanging-wall basin filled chiefly with Quaternary basalt flows. The depositional basin along the eastern margin of the Raft River Mountains is filled with Tertiary Salt Lake Formation overlain by a thin veneer of Quaternary lacustrine and alluvial deposits, but does not appear to be fault-bounded.

The model cross section in figure 19 trends northeast from Locomotive Springs to Snowville. The Curlew Valley depositional basin along this profile is filled with Quaternary basalt erupted from the shield volcanoes that are just northwest of the section line. The Locomotive Springs complex is located above the southern margin of the volcanic deposits. The abrupt northern margin of the volcanic deposits may be a southwest-dipping fault, consistent with cross section A-A' (plate 2).

Northeast of these volcanic rocks and beginning about 3.5 miles (6 km) south of Snowville, sedimentary basin-fill deposits thicken toward the major depositional center in southern Holbrook arm. The southern margin of the depositional basin is bounded by two moderately north-dipping faults that controlled its development and defined its physical margin (faults near wells 89 and 85, cross section A-A', plate 2). This fault zone lies along a west-northwest trending zone of topographic and geologic discontinuities defined by the southern margin of the Sublett Range and the offset in the range front that forms the boundary between the Hansel and North Hansel Mountains (figures 10 and 14). This fault zone, herein informally named the Snowville transverse fault zone, may affect ground-water flow in the Curlew Valley basin-fill aquifer, as discussed in later sections. The Snowville transverse fault zone strikes approximately perpendicular to the dominant north-south regional structural grain, and may have accommodated strike-slip and/or oblique-slip displacement during the Mesozoic Sevier orogeny and normal and/or oblique slip during Tertiary extensional faulting.

Isopach maps: The 21 geophysical model cross-sections were combined to produce an isopach map showing basin-fill thickness, including both sedimentary and volcanic rocks, below Curlew Valley (figures 21 and 22). Figure 22 shows the thickness and approximate limits of volcanic rocks within the basin fill, based on the same model cross sections.

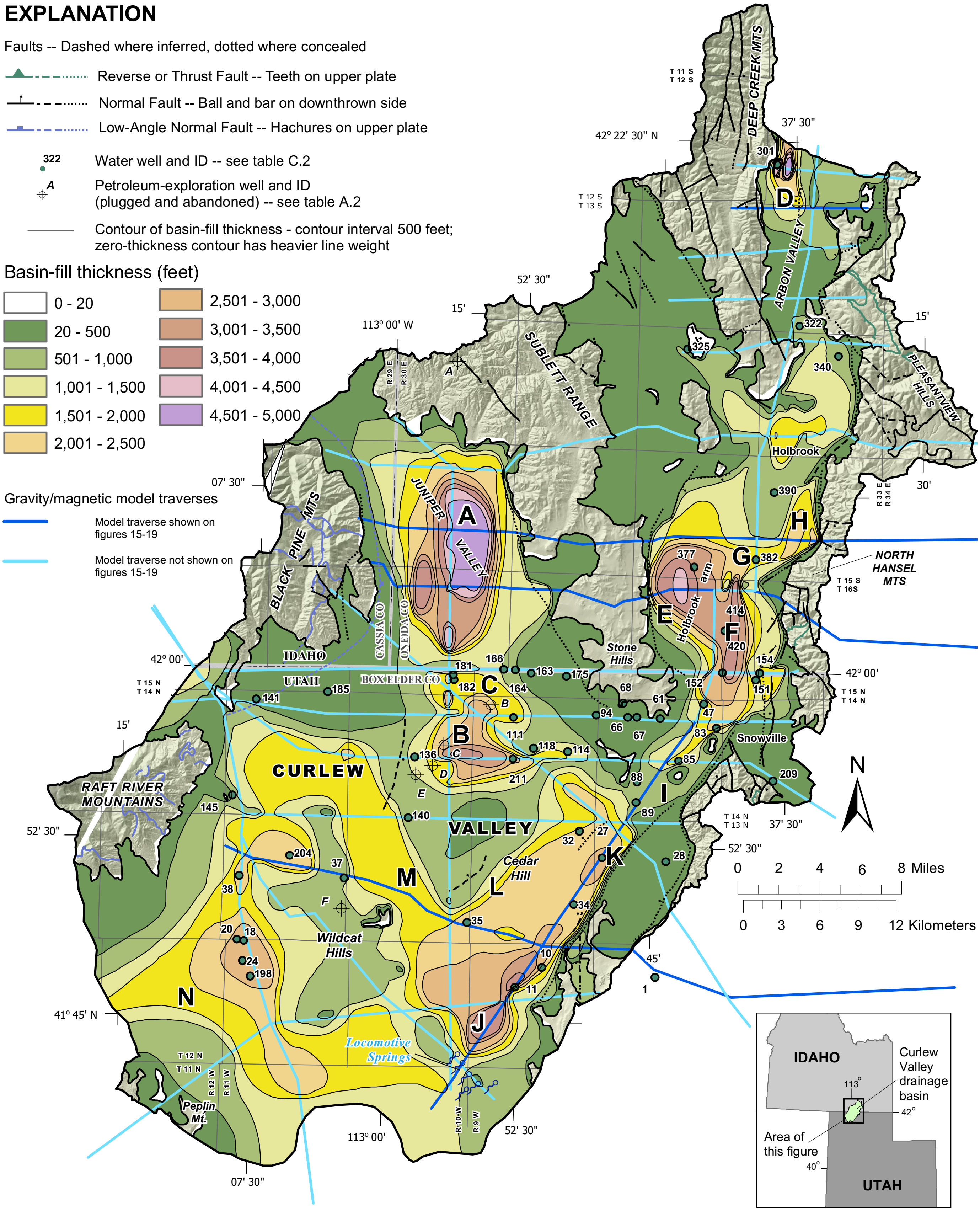

Figure 21. Schematic isopach map of basin-fill deposits in Curlew Valley, based on geophysical model cross sections (figures 15–19) and well data (tables A.2 and C.2). Letters A through N denote variations in basin-fill thickness discussed in text.

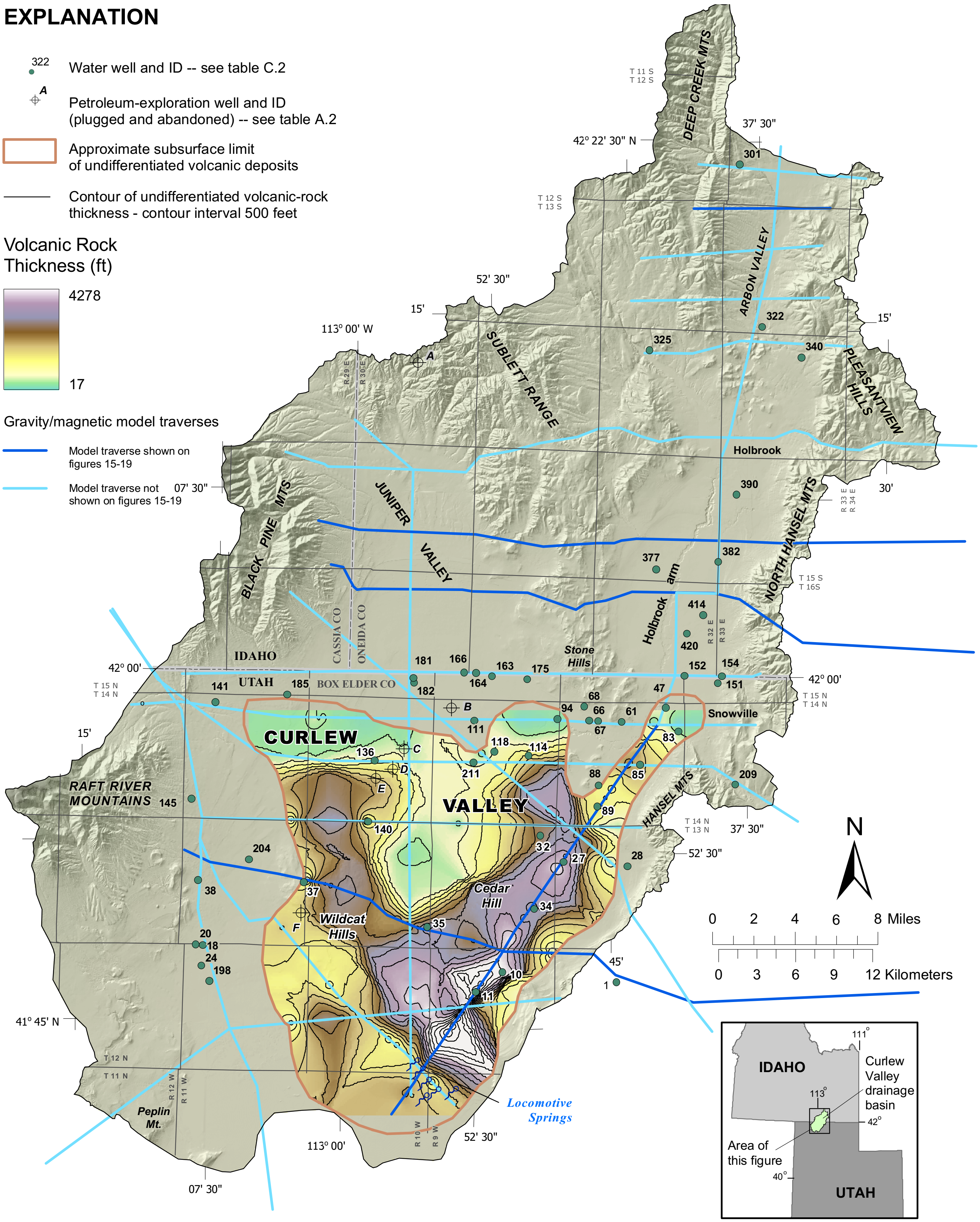

Figure 22. Schematic isopach map of undifferentiated volcanic rocks in basin fill, Curlew Valley, Utah and Idaho, based on geophysical model cross sections and well data (see figures 15–19).

Figure 23 shows intrabasin faults in the Curlew Valley depositional basin that are inferred from the geophysical cross sections (figures 15 through 19) and the basin-fill isopach map (figure 21). None of these inferred faults are apparent from the surface geology of the valley (figure 5; plate 1), but they may affect ground-water flow in the basin, as outlined in the Discussion section of this report. The locations of basin-bounding faults in the geophysical models coincide with the surface traces of mapped faults (plate 1).

The Juniper Valley depositional basin consists of two sub-basins separated by a roughly east-west trending intrabasin ridge at about the latitude of the state line (figure 21). The northern sub-basin (labeled A in figures 21 and 23) is oval shaped with a north-south long axis, is locally over 5000 feet (1500 m) thick, and includes three areas of thick deposits. The southern sub-basin (B in figures 21 and 23) is irregularly shaped and is locally over 3500 feet (1050 m) thick. The Juniper Valley basin is interpreted as a compound graben, bounded on either side by major basin-bounding faults and cut internally by subsidiary faults (figure 23). As interpreted from the geophysical model cross sections through the valley (figures 16 and 17), the central, deepest part of the basin formed first and filled with Tertiary Salt Lake Formation, then new, more widely spaced faults formed and the basin expanded to the west and east, to its present margins. The transverse intrabasin ridge (C in figures 21 and 23) formed where normal displacement on the two sets of basin-bounding faults decreased sharply as they approached each other. This ridge may have been localized by a preexisting structural discontinuity. Transverse intrabasin ridges are typically structurally complex and include closely spaced normal- and oblique-slip faults in a variety of orientations (Schlische and Anders, 1996; Faulds and Varga, 1998), consistent with the irregular pattern of basin-fill thickness between the two sub-basins (figure 21).

The depositional basin below southern Arbon Valley contains a small graben having up to 5000 feet (1500 m) of basin fill (figure 15; D in figures 21 and 23). The graben formed early in the history of basin development, then the depositional basin widened as the range-bounding faults stepped outward, a history similar to that inferred for Juniper Valley.

The Holbrook arm depositional basin is also structurally complex, containing three sub-basins and a northwest-trending intrabasin ridge. The deepest part of the Holbrook arm basin is below the west-central part of the valley, just east of the Sublett Range (figures 16 and 18; E in figures 21 and 23). This basin likely formed in response to normal displacement on the east-dipping fault that forms the western valley-range margin. To the southeast, a narrower and longer sub-basin formed in the hanging wall of the North Hansel range-bounding normal fault (F in figures 21 and 23). These two sub-basins are bounded on the north by a transverse intra-basin ridge (G in figures 21 and 23) that extends northwest from a prominent convex-west bend in the North Hansel Mountain front. North of the intra-basin ridge and adjacent to the western margin of the North Hansel Mountains is a smaller, north-trending, fault-bounded sub-basin, locally over 2000 feet (600 m) thick (figure 17; H in figures 21 and 23).

South of the main depositional centers, the Holbrook arm basin changes strike from north-south to southwest, and thins markedly. As discussed above, the southern boundary of this basin is interpreted as the Snowville transverse fault zone, a west-northwest striking fault zone that lies in a northwest-trending zone of topographic and geologic discontinuity (figure 18; I in figures 21 and 23; cross section A-A', plate 2).

Southeastern Curlew Valley is underlain by a northeast-trending depression filled chiefly with Quaternary basalt interbedded with less abundant basin-fill sediments, and is bounded on the southeast by the Hansel Mountains range-bounding normal-fault zone (figure 19; J in figures 21 and 23). The axis of greatest thickness is parallel to but between the Quaternary basalt shields and the Hansel Mountains range-margin fault zone. Subsidence in the hanging wall of the Hansel Mountains range-margin fault may have occurred in early Quaternary time, during eruption of the basalt but east of the intrusive centers. A zone of abrupt thickness change, which may represent a bedrock ridge uplifted by a northwest-trending fault, defines the northeastern margin of this depositional basin (K in figures 21 and 23; southwest-side-down fault shown near well 26 on cross section A-A', plate 2). This bedrock ridge trends northwest from a sharp jog in the Hansel Mountains range front to the margin of the southern Juniper Valley sub-basin, and is parallel to the Snowville transverse fault zone and may have a similar origin.

The northwest margin of thick volcanic deposits below southeastern Curlew Valley may be a northeast-striking fault, as inferred from a narrow, straight zone of abrupt thickness change (figure 18; L in figures 21 and 23). This fault apparently truncates a long, northwest-striking fault that forms the southwestern margin of the bedrock high that trends northwest from Cedar Hill toward the southern Black Pine Mountains (M in figures 21 and 23).

The depositional basin southeast of the Raft River Mountains is broad and shaped like an inverted Y. The upper stem is parallel to the southeast range margin, the southeastern stem trends southeast between Peplin Mountain and the Wildcat Hills, and the southwest stem lies between Peplin Mountain and the southeastern Raft River Mountains (N in figures 21 and 23). Geophysical model cross sections through this basin suggest it formed in a crustal downwarp between the Raft River, Peplin Mountain, and Wildcat Hills uplifts without significant influence from basin-bounding faults. Cook and others (1964) proposed a similar origin for this basin.

HYDROLOGIC SETTING

Physiography and Climate

The Curlew Valley surface-water drainage basin covers about 1200 square miles (3100 km^2), whereas the valley floor covers approximately 900 square miles (2300 km^2). The drainage basin is bounded by Great Salt Lake in the south and is surrounded by several mountain ranges. The climate of the region is semi-arid (Baker, 1974). Within the drainage basin, the Black Pine and Raft River Mountains receive about 35 and 30 inches (89 and 76 cm) of precipitation per year, respectively (figure 24) (Baker, 1974). Precipitation in the other mountainous areas is up to 20 inches (51 cm) per year. The valley floor locally receives as much as 12

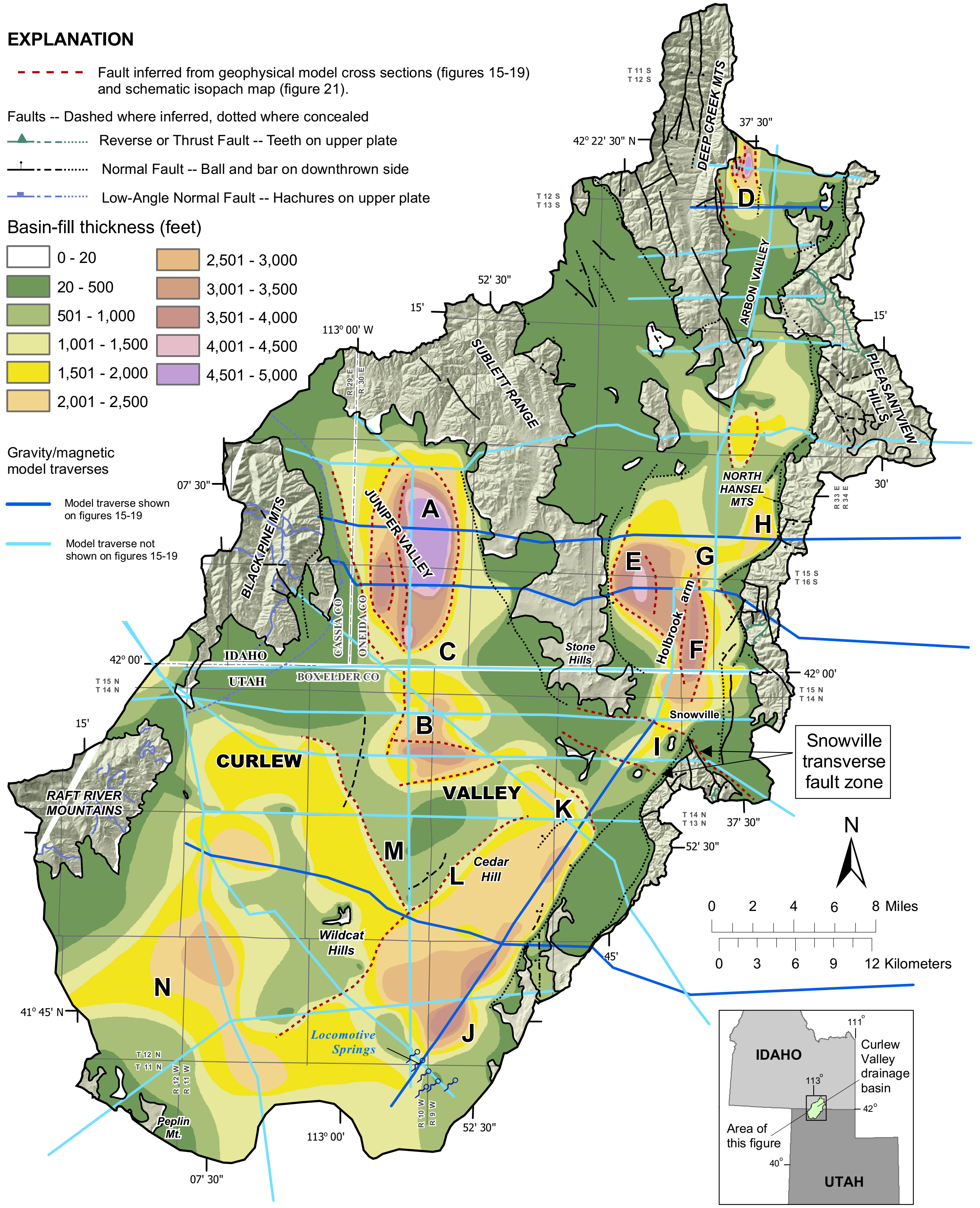

Figure 23. Intrabasin faults in Curlew Valley, based on geophysical model cross sections (figures 15–19) and schematic isopach map (figure 21). Letters A through N denote structural features discussed in text.

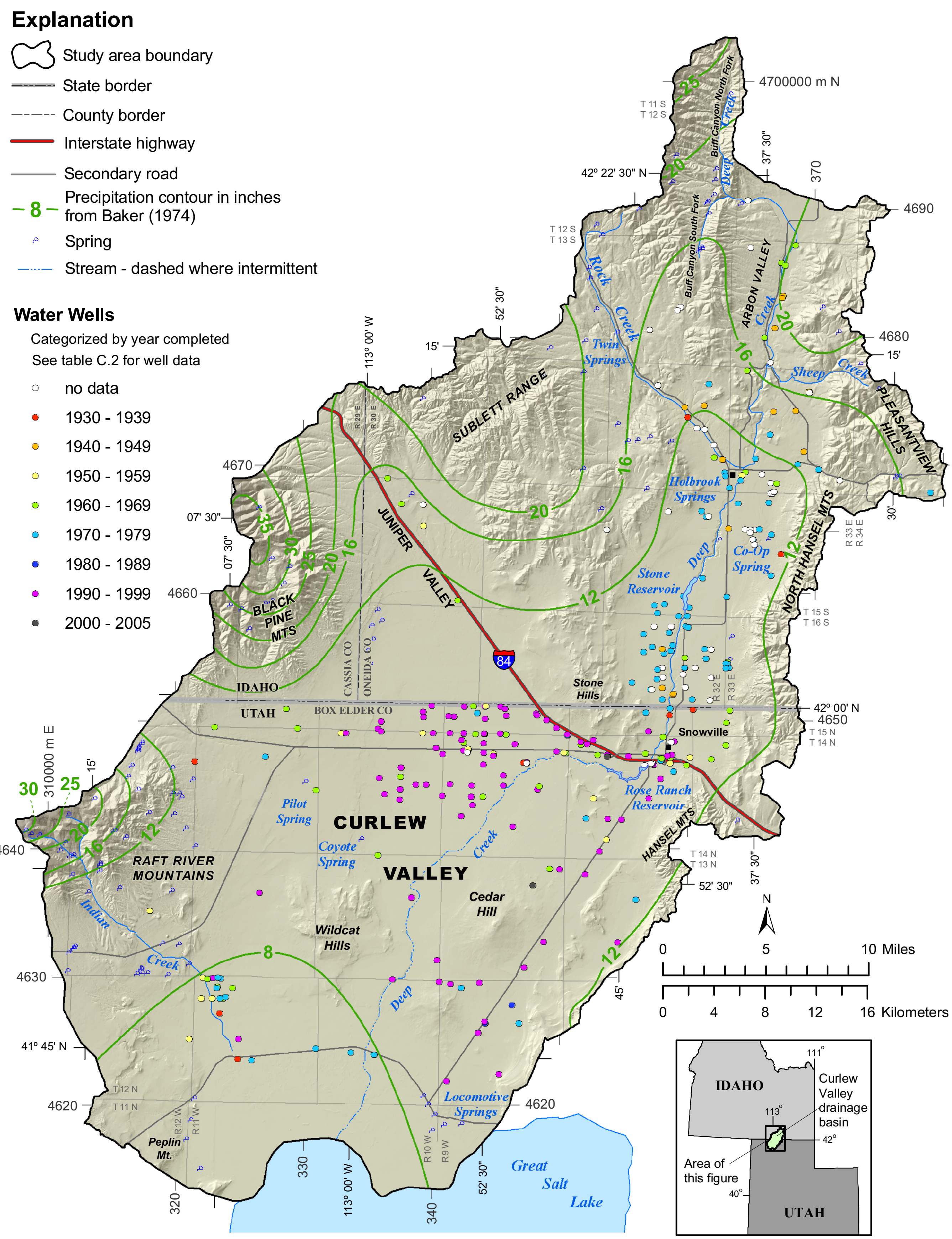

Figure 24. Hydrologic features of Curlew Valley study area.

inches (30 cm) per year (figure 24) (Baker, 1974).

Ashcroft and others (1992) indicated that average annual precipitation at Snowville is 12.80 inches (32.5 cm), based on data gathered from 1948 to 1991, and that evapotranspiration at Snowville is 46.17 inches (117.3 cm) per year. Figure 25 presents annual precipitation data over the past 40 years from Snowville and other climate stations near Curlew Valley, and figure 26 shows their locations. Annual precipitation on the valley floors in the region since 1960 ranged from about 4 to 22 inches (10.2–55.9 cm), except during the wet years of 1979 to 1986 when the area received 3 to 32 inches (25.4–83.8 cm) per year (figure 25).

Surface Water

The major streams in the Curlew Valley surface-drainage basin are Deep Creek, Indian Creek, and Rock Creek (figure 24). The surface-drainage basin is closed, and there is no stream flow into Great Salt Lake except during unusual floods. Deep Creek and its tributaries drain Holbrook arm and flow south toward Great Salt Lake. Deep Creek originates from springs in Bull Canyon, in the southeastern Deep Creek Mountains in Idaho. Rock Creek is fed by Twin Springs and meets Deep Creek near Holbrook.

The entire flow of Rock Creek is diverted for irrigation about 4 or 5 miles (6 or 8 km) northwest of Holbrook. The flow in Deep Creek is diverted for irrigation 10 to 12 miles (16-19 km) northeast of Holbrook, so in this area Deep Creek is dry during most months. About 3 miles (5 km) south of Holbrook a group of springs discharge into Deep Creek, and about 4 miles (6 km) downstream a dam creates Stone Reservoir, which when full extends almost to Holbrook Springs. Flow in Deep Creek between the springs and the reservoir averaged about 30 cfs (0.8 m^3/s) from September 1970 through August 1972 (Baker, 1974). Prior to about 1986, between Stone Reservoir and a small impoundment near Rose Ranch, Deep Creek was a perennial stream with average discharges of 8.5 and 6.4 cfs (0.24 and 0.18 m^3/s) at two gauging stations installed in 1970 (Baker, 1974). The old Rose Ranch Reservoir was abandoned due to leaky conditions around 1986 (Oaks, 2004) and was reconstructed farther west. Water released from the Rose Ranch Reservoir infiltrates into the ground a few miles below the dam, so that Deep Creek is typically dry downstream toward Great Salt Lake.

The springs south of Holbrook that feed Deep Creek have average total dissolved solids (TDS) concentrations of less than 500 mg/L (Baker, 1974). Below Stone Reservoir the TDS concentration in Deep Creek increases due to evaporation in the reservoir and irrigation return flow (Baker, 1974). The maximum measured TDS was 1660 mg/L (Baker, 1974).

Indian Creek drains the southeast end of the Raft River Mountains. Discharge ranged from 0.19 to 26 cfs (0.005-0.74 m^3/s) at the USGS gauging station near Park Valley for the 17-month period prior to and including September 1972 (Baker, 1974). During the growing season all of the water in Indian Creek is diverted for irrigation and during low flows water seeps into the ground before it reaches the valley floor (Baker, 1974).

Ground Water

Springs

The Locomotive Springs complex in southeastern Curlew Valley is the most significant natural discharge point in the Curlew Valley basin-fill aquifer system. The Locomotive Springs complex includes six separate springs—from northwest to southeast, West Locomotive, Baker, Bar M, Teal, Off, and Sparks—distributed along a 3-mile-long (5 km) arc just southwest of the exposed part of the Indian Hill Quaternary basalt shield (figure 27; table C.1). The springs issue from thin, fine-grained lakebed sediments overlying the basalt, except Bar M Spring, which issues directly from the basalt (Scott Clark, Utah Division of Water Rights, verbal communication, 2003). Discharge from the springs emanates from the heads of channels within the lakebed sediments that are up to 30 feet (10 m) wide, and these channels broaden but remain well-defined downstream (figure 28). The outflow area includes wetland, upland, and mud-flat complex environments and is an important habitat for migratory waterfowl and non-game avian species (Berger, 2000). Much of the outflow area is within the 18,000-acre (7300 hectare) Locomotive Springs Waterfowl Management Area, managed by the Utah Division of Wildlife Resources (Berger, 2000).

Flooding of the Locomotive Springs outflow area by Great Salt Lake during the mid-1980s damaged much of the wetlands, where "emergent marsh vegetation, pickleweed-covered mudflats, sheet-water-covered mudflats, and shallow open water depressions were replaced with dry mudflats and channelized outflow" (Berger, 2000, p.1), causing significant loss in wetland function. As a result, vegetative communities that cannot withstand seasonally variable water supply replaced the pre-existing community, significantly reducing waterfowl habitat, and waterfowl visitation dropped 84% between 1973–77 and 1996–2000. This change was not entirely climate-related because a similar large, spring-supported wetlands complex about 30 miles (48 km) to the southeast experienced a 38% reduction during the same time period (Berger, 2000). Reduced spring discharge compared to pre-1970 values has prevented recovery of the Locomotive Springs wetlands from the flooding, and the area of functional wetlands continues to decrease (Berger, 2000).

Records available from the Utah Division of Water Rights (2005) show that discharge from the Locomotive Springs complex has decreased steadily since the late 1960s (figures 29 and 30). The measured discharge of the six springs combined averaged about 40 cfs (1.1 m^3/s) in March 1939, about 38 cfs (1.1 m^3/s) in March 1967, and about 41 cfs (1.2 m^3/s) in April 1967 (Baker, 1974). Oaks (2004, figure 2) showed that the rate of decrease slowed or was flat during the late 1970s to early 1980s, when precipitation was relatively high and fewer new water wells were drilled. Daily records of spring flow collected by the U.S. Geological Survey from December 1, 1968, to September 30, 1980, (figure 29) show that discharge from Bar M Spring decreased from about 11 to about 4 cfs (0.3–0.1 m^3/s), variable discharge from Off and Sparks springs decreased from 1.2–1.6 to 0.1–1.4 cfs (0.03–0.05 to 0.003–0.04 m^3/s), and the maximum measured values of highly variable discharge from West Locomotive and Baker Springs decreased from about

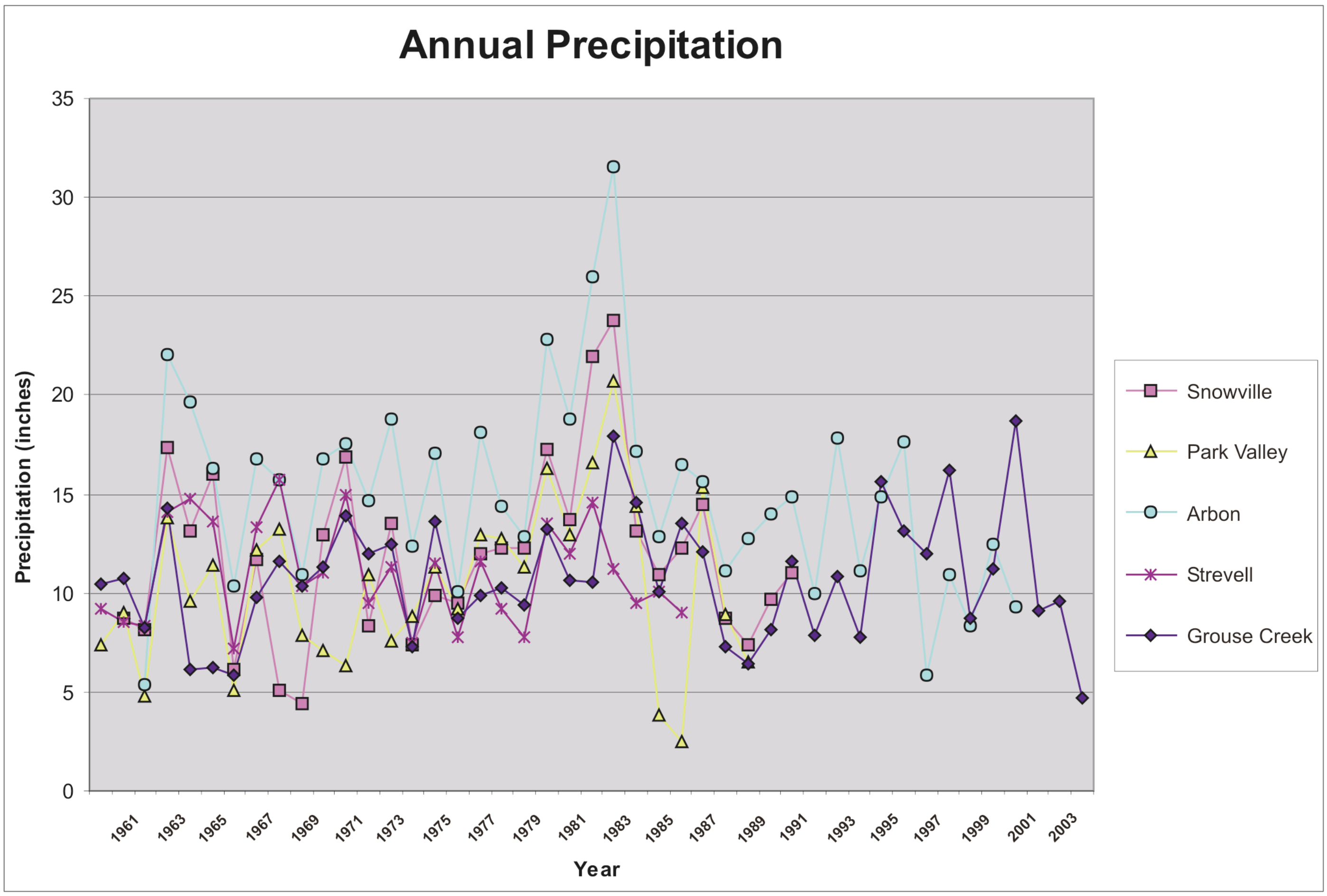

Figure 25. Records of precipitation from National Weather Service climate stations in and near Curlew Valley, 1960 to 2004. Data accessed from Western Regional Climate Center (2005). See figure 26 for climate-station locations.

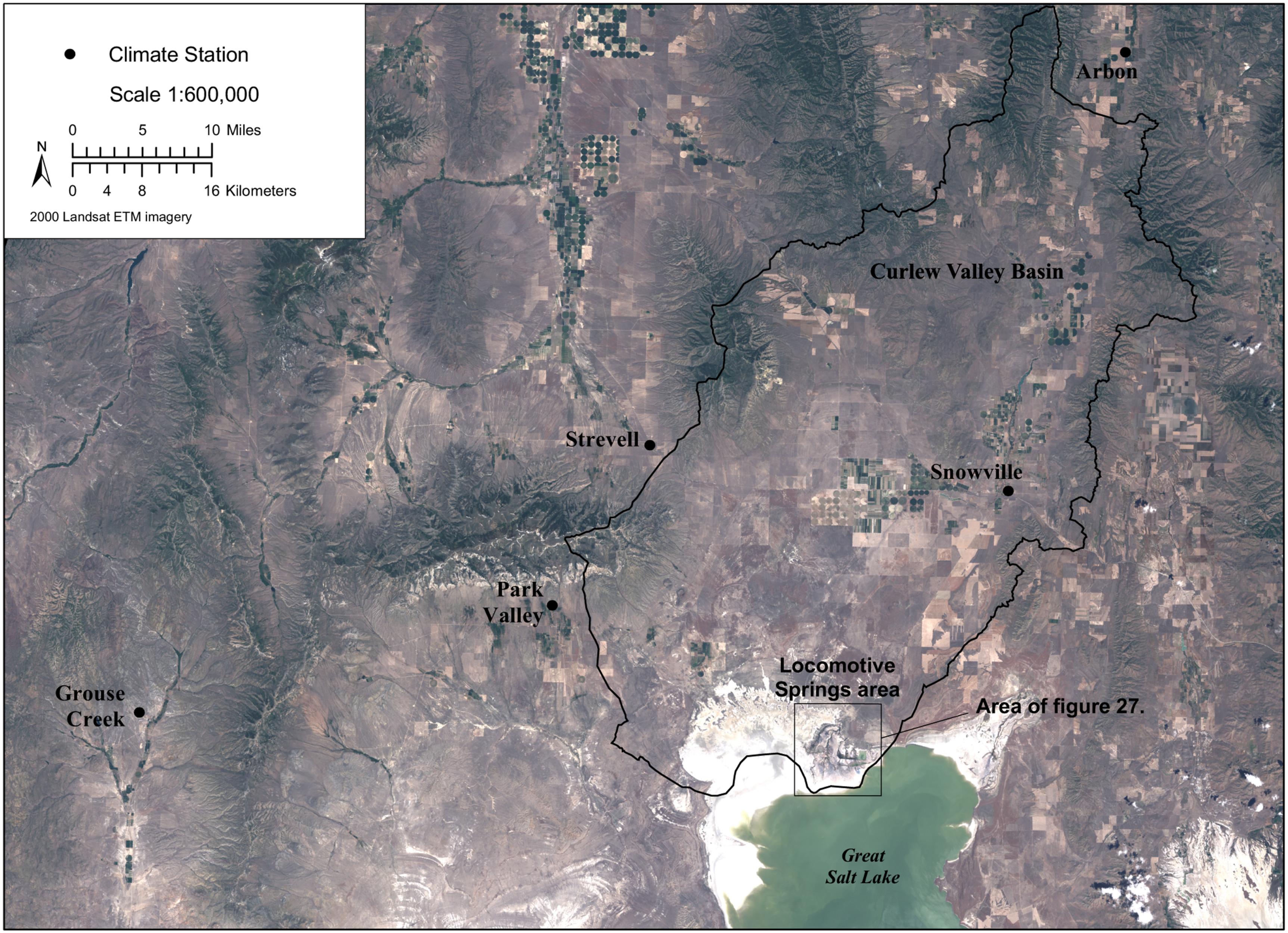

***Figure 26.** Locations of climate stations in the Curlew Valley region whose records are shown in figure 25.*

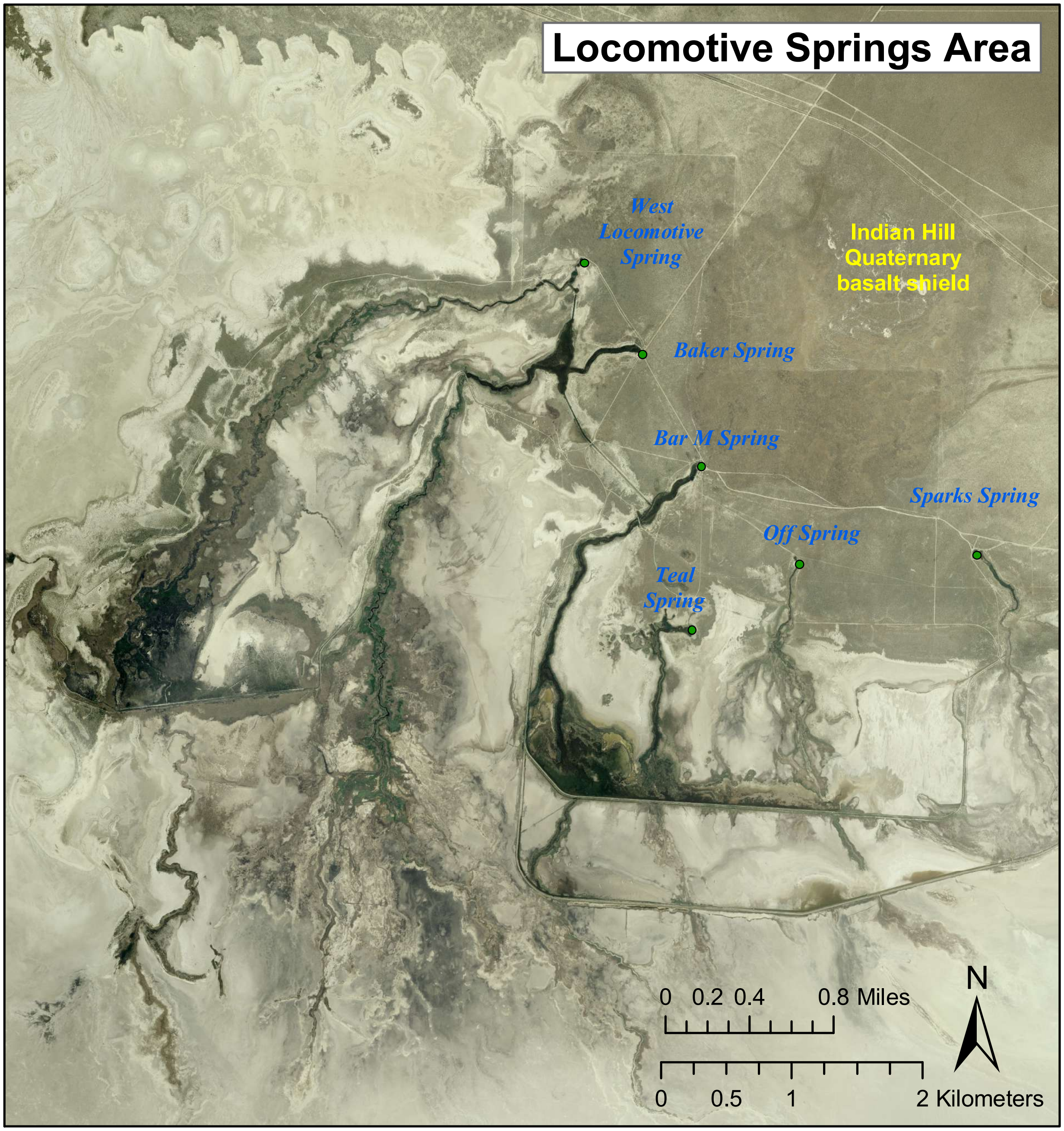

Figure 27. *Aerial photograph of Locomotive Springs complex and its outflow area. Image is from the Utah AGRC Web site (gis.utah.gov), October 4, 2007. Location is shown on figure 26.*

Figure 28. Photographs of Baker Spring outlet area. A. View northeast of the channel-head area where the ground water emerges. B. View southeast of the lower outlet-channel area.

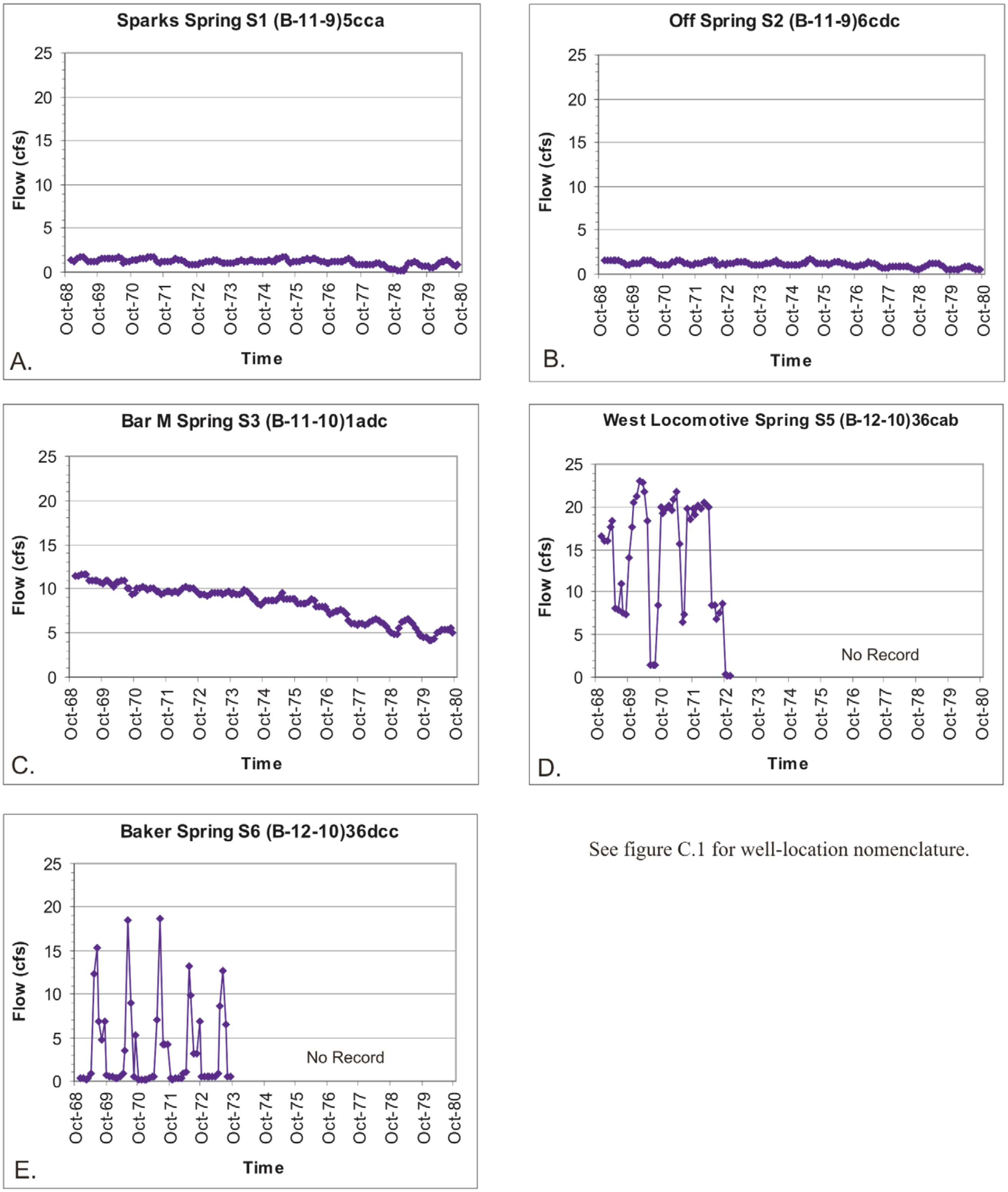

Figure 29. *Flow records for springs of the Locomotive Springs complex for 1968–80. Data are monthly averages of daily measurements by the U.S. Geological Survey, accessed from the Utah Division of Water Rights Web site (2005). A. Record for Sparks Spring. B. Record for Off Spring. C. Record for Bar M Spring. D. Record for West Locomotive Spring. E. Record for Baker Spring.*

19-23 to about 0-8 cfs (0.54-0.65 to 0-0.23 m^3/s); these numbers are based on monthly averages of daily discharge measurements (figure 29). This trend of decreasing discharge continued through the measuring periods of 1993 to 1997 and 1999 to 2003 (figure 30). The total annual discharge from each measured spring also decreased from 1968 to 2003 (figure 31). Considering years in which discharge from Bar M, Baker, and West Locomotive Springs was measured daily, the total annual (calendar year) discharge from these three springs combined decreased from about 20,800 acre-feet (25.6 hm^3) in 1969 to about 16,800 acre-feet (20.7 hm^3) in 1972, and was about 4800 acre-feet (5.9 hm^3) in 2000 and about 4030 acre-feet (5.0 hm^3) in 2001, a decrease of 80% from 1969 to 2001.

Precipitation measured from 1960 to 1980 at climate stations surrounding and within Curlew Valley varied from about 5 to 20 inches per year (13–51 cm) (with some exceptions) but generally increased slightly, while daily measurements of discharge from the Locomotive Springs steadily declined (compare figures 25 and 29). Measured precipitation increased significantly between 1979 and 1986, when flooding by Great Salt Lake prevented measurement of Locomotive Spring discharge. Although data after 1990 are limited, measured precipitation was equal to or slightly lower than in the 1970s until 2001 to 2004, which were exceptionally dry years.

Most springs in the Curlew Valley surface-drainage basin have relatively small, seasonably variable discharge and lie along the range margins, at the base of wave-cut benches or at canyon mouths (table C.1; figure 24; plate 1). These springs issue from thin nearshore lacustrine deposits or from isolated bedrock outcrops, and have low dissolved-solids concentrations (about 200 to 500 mg/L) and temperature (Baker, 1974). Discharge from the small springs along the range-valley margins is likely derived from snowmelt in the adjacent mountains, and is part of relatively shallow, short-time-scale ground-water flow systems. The Twin Springs are located in Rock Creek Canyon in the northwest part of the Holbrook arm (figure 24), and supply a major proportion of Rock Creek flow. Unnamed springs along the west margin of the North Hansel Mountains just north of the state line have sufficient discharge to support standing-water pools and minor phreatophyte growth.

Several springs having significantly greater discharge are present in the lower valley floor. The Holbrook Springs issue from fine-grained, laminated lakebed deposits in the gorge cut by Deep Creek, about 3 miles (5 km) south of Holbrook and 4 miles (6 km) north of Stone Reservoir dam. Holbrook Spring water has low electrical conductivity (789 µs/cm) and medium temperature (20°C [68°F]), and this water may discharge from the bedrock aquifer (Baker, 1974, p. 35 and 49). Co-op Spring, in the gently sloping part of Holbrook arm about one mile (1.6 km) west of the central North Hansel Mountains margin and about 8 miles (13 km) north of the state line (figure 24), was dry during Fall 2003 but has a significant pool and outflow area with phreatophytes along its fringes, evidence that its discharge has been significant in the past. Discharge from Co-op Spring is likely derived from snowmelt and infiltration of precipitation in the nearby North Hansel Mountains. Pilot Spring issues from fine-grained lakebed deposits, and its discharge is sufficient to support two standing-water pools and minor associated phreatophyte growth. Obvious topographic and/or geologic controls on the location of Pilot Spring are not apparent. Ground water discharging from Pilot Spring is relatively cool (14.5°C [58°F]) and low in TDS (332 mg/L) (Baker, 1974, p. 54-55), so is likely derived from snowmelt in the southern Black Pine and eastern Raft River Mountains.

The temperature of Coyote Spring water is about 43.5°C (110°F), 30°C warmer than all other springs measured in Curlew Valley, and its TDS concentration (about 3150 mg/L) is similar to that of Locomotive Spring water (about 1800 to 3700 mg/L) (Baker, 1974). Coyote Spring issues from fine-grained lakebed deposits and is about 0.5 mile (0.8 km) east of a topographic escarpment formed by Tertiary basalt in the footwall of an east-side-down normal fault (figure 5). This water may rise along the fault, and/or may be heated by an unexposed intrusive body (Baker, 1974; Davis, 1984; Davis and Kolenar, 1984).

Aquifers

Ground water in Curlew Valley exists in basin fill and in the consolidated rocks in the mountain ranges surrounding the valley. The primary permeability of the consolidated rocks is low, but secondary permeability in fractures and solution openings is locally moderate to high, especially in the carbonates (Baker, 1974). Very few wells exploit ground water directly from the consolidated rocks. The mountains surrounding Curlew Valley are important recharge areas, and large quantities of water may move through the consolidated rocks to recharge the basin fill (Baker, 1974).

Most of the wells in Curlew Valley produce from the basin-fill aquifer (figure 24; table C.2), which consists of Quaternary alluvium, colluvium, lakebed deposits, nearshore lake deposits, Tertiary and Quaternary volcanic rocks, and Tertiary Salt Lake Formation. Permeability of the Salt Lake Formation is generally low, due to compaction and cementation. The secondary permeability of the Quaternary basalt is highly variable and the flows may act as either aquifers or confining layers. Numerous wells are completed in and derive water from basalt in southeastern Curlew Valley (Baker, 1974). The oldest Quaternary alluvial and lacustrine deposits are composed of sediment that ranges in grain size from clay to cobbles. The beds can be poorly sorted and lenticular, and are locally intercalated with tuff and lava flows (Baker, 1974). These deposits, along with the lava flows, form part of the principal aquifer, where the permeability is highly variable, but on average is moderate to high (Baker, 1974).

Sand and gravel deposits along the range margins and in central Juniper Valley comprise the Quaternary nearshore lacustrine deposits (Baker, 1974). The permeability of these deposits is high, but they are generally located above the water table. The Quaternary lakebed deposits consist of clay and silt, are located in the valley centers below about 4800 feet (1463 m) elevation, and have low permeability (Baker, 1974). The younger alluvium and colluvium are exposed in active stream channels and on steep slopes above an elevation of 4300 feet (1310 m). Their permeability is variable but generally high; however, most of these deposits are above the water table (Baker, 1974).

Ground water in Curlew Valley is mainly recharged by precipitation in the mountains surrounding the valley (Baker,

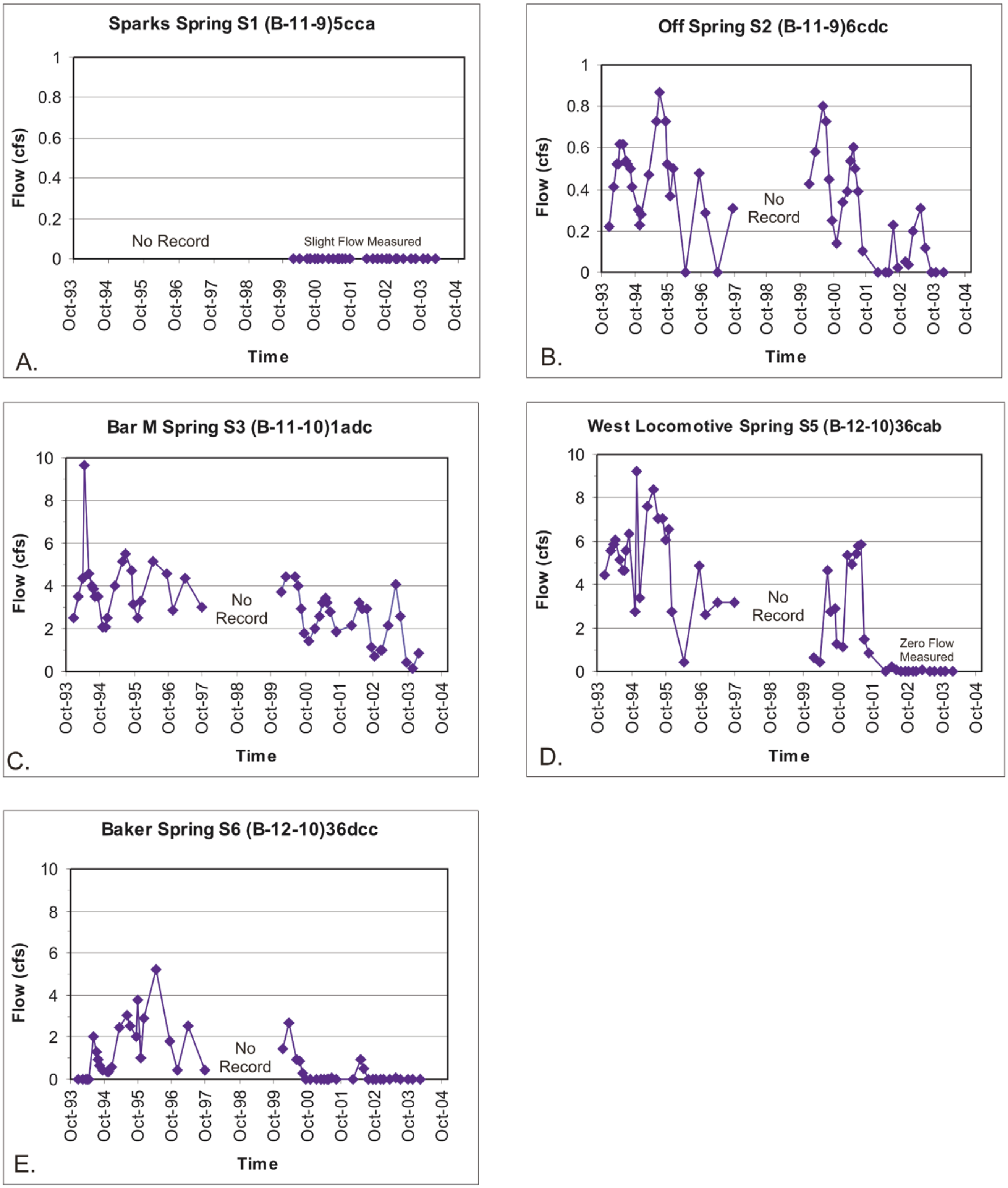

Figure 30. *Flow records for Locomotive Springs complex from the end of 1993 to early 2004. Data are daily measurements by the U.S. Geological Survey, accessed from the Utah Division of Water Rights Web site (2005). A. Record for Sparks Spring. B. Record for Off Spring. C. Record for Bar M Spring. D. Record for West Locomotive Spring. E. Record for Baker Spring.*

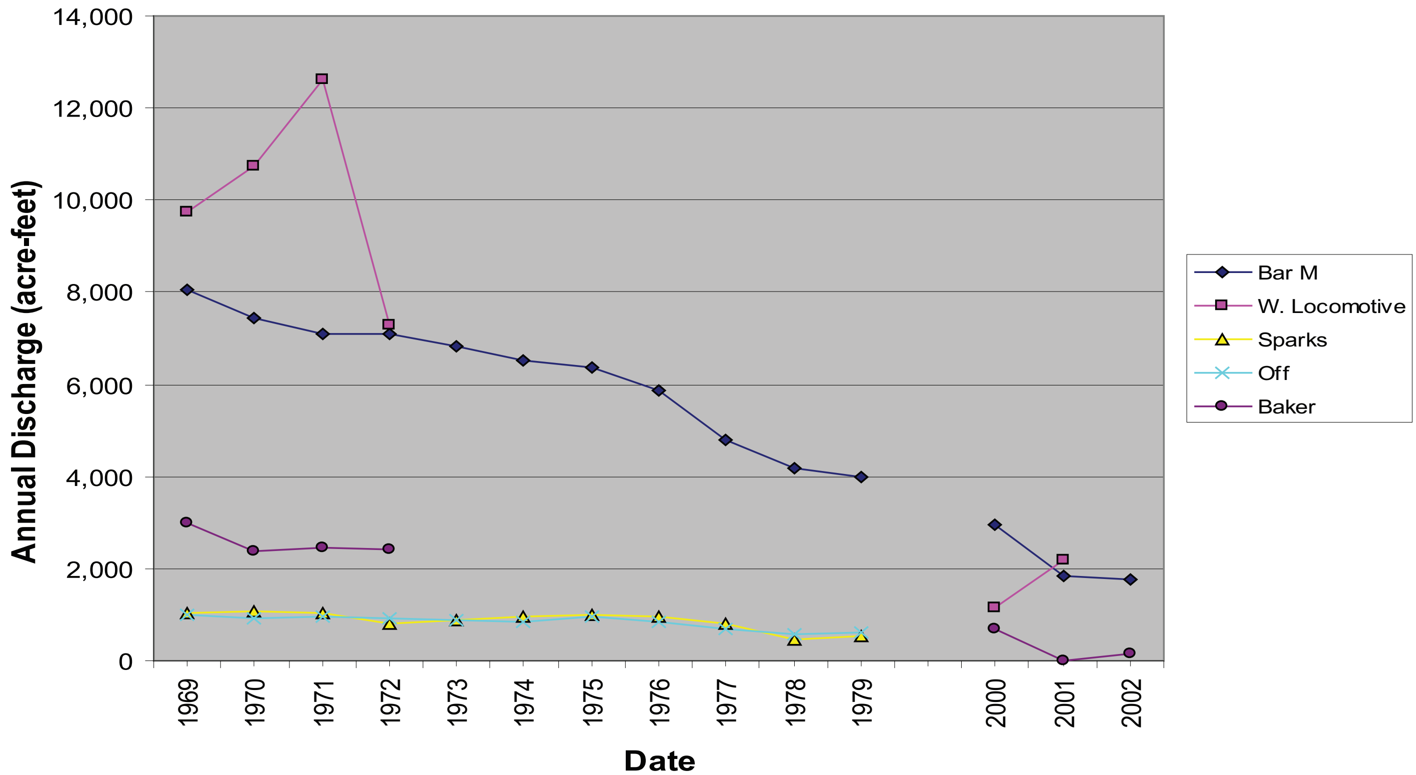

Figure 31. *Discharge records of springs of the Locomotive Springs complex in acre-feet per year for the time period 1968 to 2002. Data are derived from measurements by the U.S. Geological Survey, obtained from the Utah Division of Water Rights Web site (2005).*

1974). Ground water that enters the basin-fill aquifer flows generally eastward to the valley centers, then southward toward Great Salt Lake, where it is either lost by evapotranspiration, discharged at Locomotive Springs, discharged to the surface in the mud flats near Great Salt Lake, or flows into Great Salt Lake in the subsurface. Unconfined aquifers are typically present in the northern part of the valley and along the valley margins, where medium- to coarse-grained, unconsolidated deposits predominate. Leaky confined conditions occur locally, typically in the south-central part of the valley where most of the basalt flows are present.

Burden and others (2004, p. 12) reported that the average annual withdrawal of ground water by wells in the Utah part of Curlew Valley increased steadily from negligible amounts in 1963 to about 26,000 acre-feet (32 hm^3) in 1980. The estimated annual ground-water withdrawals stabilized from 1993 to 2002, ranging from about 29,000 to 41,000 acre-feet (35.7-50.4 hm^3) and averaging about 36,000 acre-feet (44.3 hm^3) (Burden and others, 2004). Records of ground-water withdrawal in the Idaho part of the valley are unavailable, but would presumably show similar trends. New well construction peaked during 1968 to 1979 in the Kelton and Holbrook areas, during 1990 to 1999 near Snowville, and in the early 2000s in Juniper Valley (figure 24) (Oaks, 2004, figure 2). Oaks (2004, figure 2) plotted the cumulative number of water wells in the Snowville area in Utah and discharge from the Locomotive Springs complex together on the same time line. His work showed that a period of sharp decline in discharge from Locomotive Springs occurred from about 1968 to 1981, during a rapid increase in new well construction. Both well construction and spring discharge leveled off from the early 1980s until the mid-1990s, when well construction again increased and spring discharge decreased.

Kirby and others (2005) mapped recharge and discharge areas for the principal basin-fill aquifer in the Utah part of Curlew Valley (figure 32), using the methods of Anderson and others (1994) and Snyder and Lowe (1998). Primary recharge areas are underlain by bedrock and/or unconsolidated deposits lacking significant fine-grained layers to inhibit downward infiltration from the land surface to the water table, and have a downward hydraulic gradient. In Curlew Valley, primary recharge areas include the lower slopes of mountain ranges where bedrock is exposed; the valley-margin benches, underlain by nearshore lacustrine and alluvial-fan deposits and, locally, shallowly buried bedrock; and volcanic-rock exposures in the south-central valley (figure 32) (Kirby and others, 2005). Secondary recharge areas have at least one fine-grained layer that is at least 20 feet (6 m) thick and less than about 100 feet (30 m) deep. The fine-grained layer(s) inhibits, but does not prevent, downward infiltration into the principal aquifer, and the ambient hydraulic gradient is downward. Kirby and others (2005) mapped central Curlew Valley in Utah as a secondary recharge area (figure 32). The area surrounding the Wildcat Hills and south of the agricultural area west of Snowville has very few wells, but is provisionally classified as a secondary recharge area due to the presence of clay-rich lakebed sediments at the surface that are at least 10 feet (3 m) thick, based on exposures in stream gullies. Discharge areas include zones of springs,

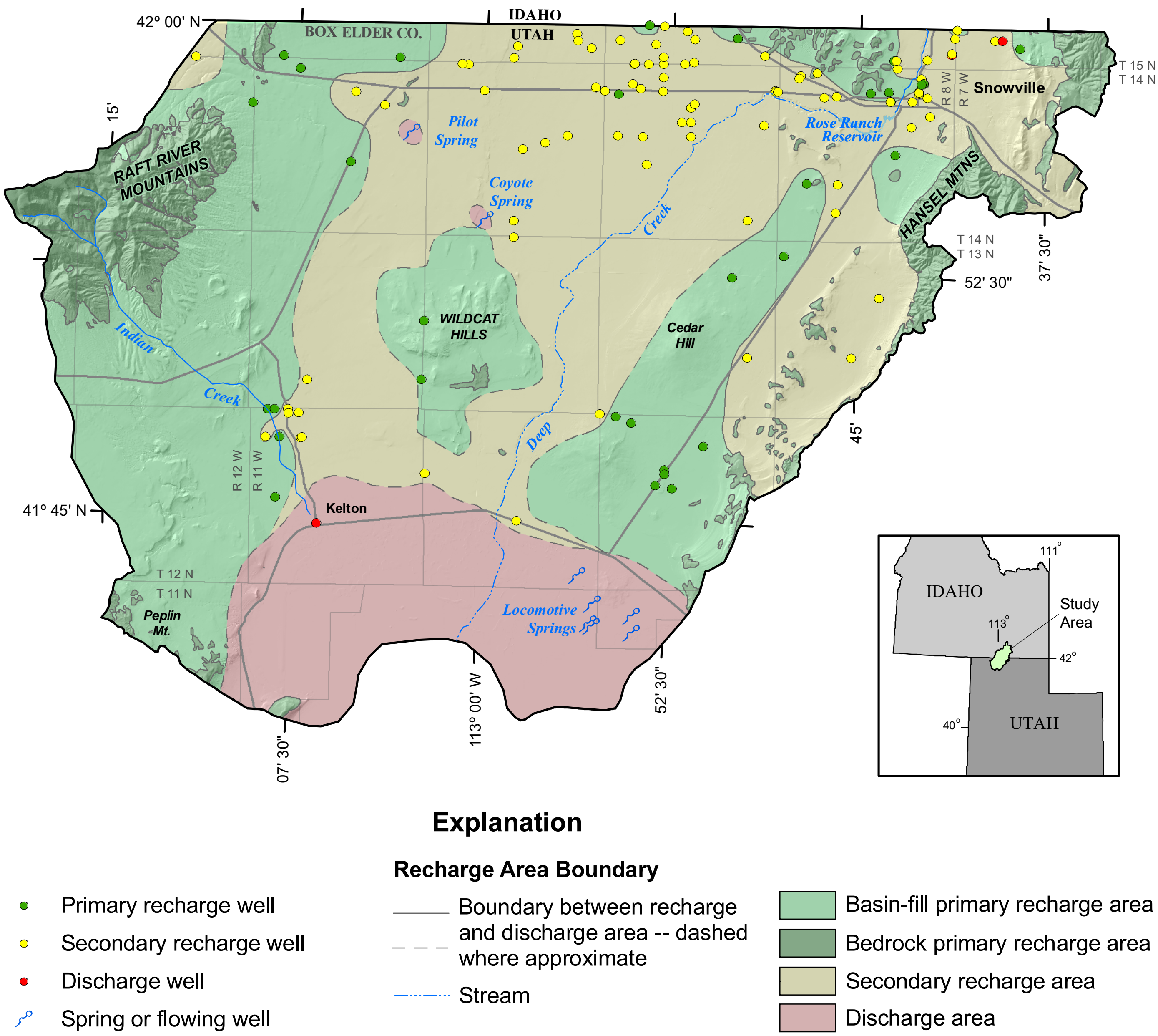

Figure 32. *Recharge and discharge areas for the principal basin-fill aquifer, Curlew Valley, Box Elder County, Utah (Kirby and others, 2005).*

seepage to streams, areas of flowing wells, or areas in which water in the lower, confined aquifer moves upward into a shallow, unconfined aquifer. The southern part of Curlew Valley, within about 5 miles (8 km) of Great Salt Lake, and the areas surrounding Coyote and Pilot Springs in the central part of the valley are discharge areas (figure 32) (Kirby and others, 2005).

Water Levels

Baker (1974, plate 3) documented ground-water levels throughout the Curlew Valley drainage basin using data collected from 1966 to 1972 from springs and wells; his water-level data are reproduced, with some modification, in figure 33. Ground-water elevations in the valley are generally higher adjacent to the mountains, and decrease toward the valley centers and toward Great Salt Lake. At the time of Baker's (1974) report, ground-water elevations throughout Curlew Valley were mostly higher than 4215 feet (1285 m), the elevation of the Locomotive Springs complex, except for small closed depressions in the agricultural areas west and south of Snowville and north of Kelton (figure 33). Oaks (2004, figure 5 and table 4) also compiled ground-water levels for the Utah part of Curlew Valley and showed slightly different ground-water-level contours.

Data from the mid-1990s (Atkin, 1998) show continued decline of ground-water levels in agricultural areas (figure 34). The closed depression in the agricultural area west of Snowville deepened and expanded in area, and ground-water elevations in the central part of Curlew Valley in Utah, encompassing the southern Juniper–Black Pine flow system and the southwestern Holbrook-Snowville flow system, were at or below 4215 feet (1285 m) elevation (compare figures 33 and 34). Water levels in many wells in the central and southeast part of the valley decreased by 20 to 30 feet (6–9 m) from the time of Baker's (1974) report to the time of Atkin's (1998) report (figures 35 and 36); the greatest decrease was 83 feet (25 m). During the same period, water levels in several wells near Snowville and in isolated wells south and west of Snowville increased by up to 30 feet (10 m) (figures 27 and 28). Annual precipitation in the area was greater than average during the early to mid-1980s, then returned to approximately average values through the mid-1990s (figure 25). Oaks (2004, figure 5) presented generally similar data, and included some water levels from the 1970s and 1980s not shown in figures 35 and 36.

The U.S. Geological Survey has regularly measured water levels in selected wells in Curlew Valley since as early as 1937 (U.S. Geological Survey, 2005a) (figures 35 and 36). Plots of water levels through time (figures 36A through 36L) illustrate trends in different parts of the valley and provide a continuous record of the changes documented in figure 35. In general, water levels have decreased in areas of concentrated agricultural activity near Snowville, west of Snowville, and north of Kelton, and have remained stable or have increased slightly in parts of the valley having little ground-water development.

Flow Systems

Baker (1974) delineated three major ground-water flow systems in Curlew Valley based on geologic and geographic features, chemical quality, and hydraulic head: the Kelton, Juniper–Black Pine, and Holbrook-Snowville flow systems (figure 37). A fourth system, the Coyote Spring thermal flow system, was also identified, but was not characterized in detail (Baker, 1974). Baker (1974) postulated that the boundaries between the flow systems generally corresponded to subsurface structures or bedrock highs, but that they are diffuse, difficult to locate precisely, and involve some mixing of ground water between adjacent flow systems.

The Kelton flow system occupies southwestern Curlew Valley west of a subsurface bedrock ridge that trends southeast from the southern end of the Black Pine Mountains to the Wildcat Hills (figures 37 and 38). This bedrock ridge creates a barrier to deep ground-water flow, causing water that recharges the basin-fill aquifer along the eastern Raft River Mountains and southern Black Pine Mountains to flow southeast. Gravity data from this study, Cook and others (1964), and Peterson (1973) suggest that the thickness of low-density basin-fill material in the bedrock trough east of the Raft River Mountains is locally greater than 2500 feet (760 m). The deepest part of the basin trends southeast from the Raft River Mountains, between the Wildcat Hills and Peplin Mountain (figure 38). Pilot Spring is on the eastern margin of the buried bedrock ridge (figure 38), suggesting that it may be part of the Juniper–Black Pine flow system, in contrast to Baker's (1974) assignment of this spring to the Kelton flow system. Baker (1974) estimated recharge to the Kelton flow system to be about 8000 acre-feet (9.9 hm^3) per year. Most recharge (5000 acre-feet per year [6.2 hm^3/yr]) comes from the Black Pine Mountains and the remaining 3000 acre-feet (3.7 hm^3) per year comes from the Raft River Mountains.

Chemical quality of ground water in the Kelton flow system varies depending on location. In the upgradient portion of the flow system, the dominant ions in the ground water are calcium and bicarbonate and the water contains less than 500 mg/L dissolved solids. In the agricultural area north of Kelton, calcium and bicarbonate are the predominant ions in the upgradient part of the irrigated area, whereas in the central part of the irrigated area the predominant anion is chloride and the concentrations of calcium and chloride are substantially greater. The increase in dissolved constituents in the irrigated area probably results from infiltration of unused irrigation water that has been concentrated by evapotranspiration. Downgradient of the irrigated area, near Great Salt Lake, the predominant ions are sodium and chloride, and ground water shallower than 100 feet (30 m) there contains nearly 63,000 mg/L TDS.

The Juniper–Black Pine flow system occupies the central part of Curlew Valley (figures 37 and 38). It is bounded on the west by the Black Pine Mountains, by the Sublett Range on the north and northeast, and by the Stone Hills on the east. The northern part of the flow system occupies a bedrock depression below Juniper Valley, filled with low-density basin fill up to 5000 feet (1524 m) thick (this study and Peterson, 1973). The flow system continues southward between the Wildcat Hills and Cedar Hill, to the Locomotive Springs complex (Baker, 1974). The concealed bedrock ridge between the Wildcat Hills and the southern Black Pine Mountains forms the southwestern boundary of the Juniper–Black Pine flow system, and Cedar Hill and the Quaternary basalt shield to its south form its southeastern boundary (figure 38). Recharge to the Juniper–Black Pine flow system is

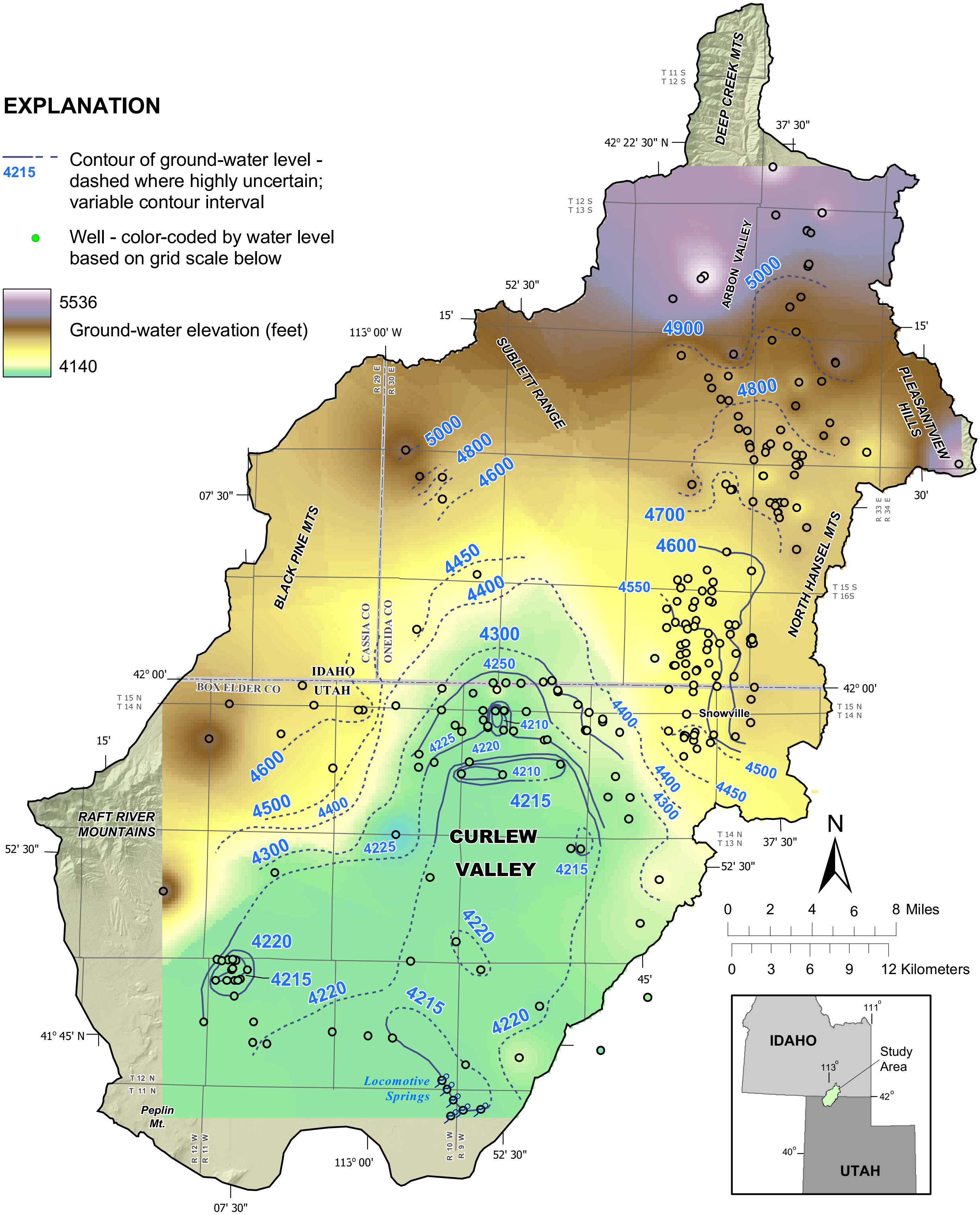

Figure 33. *Ground-water levels in Curlew Valley, 1966–72, from Baker (1974).*

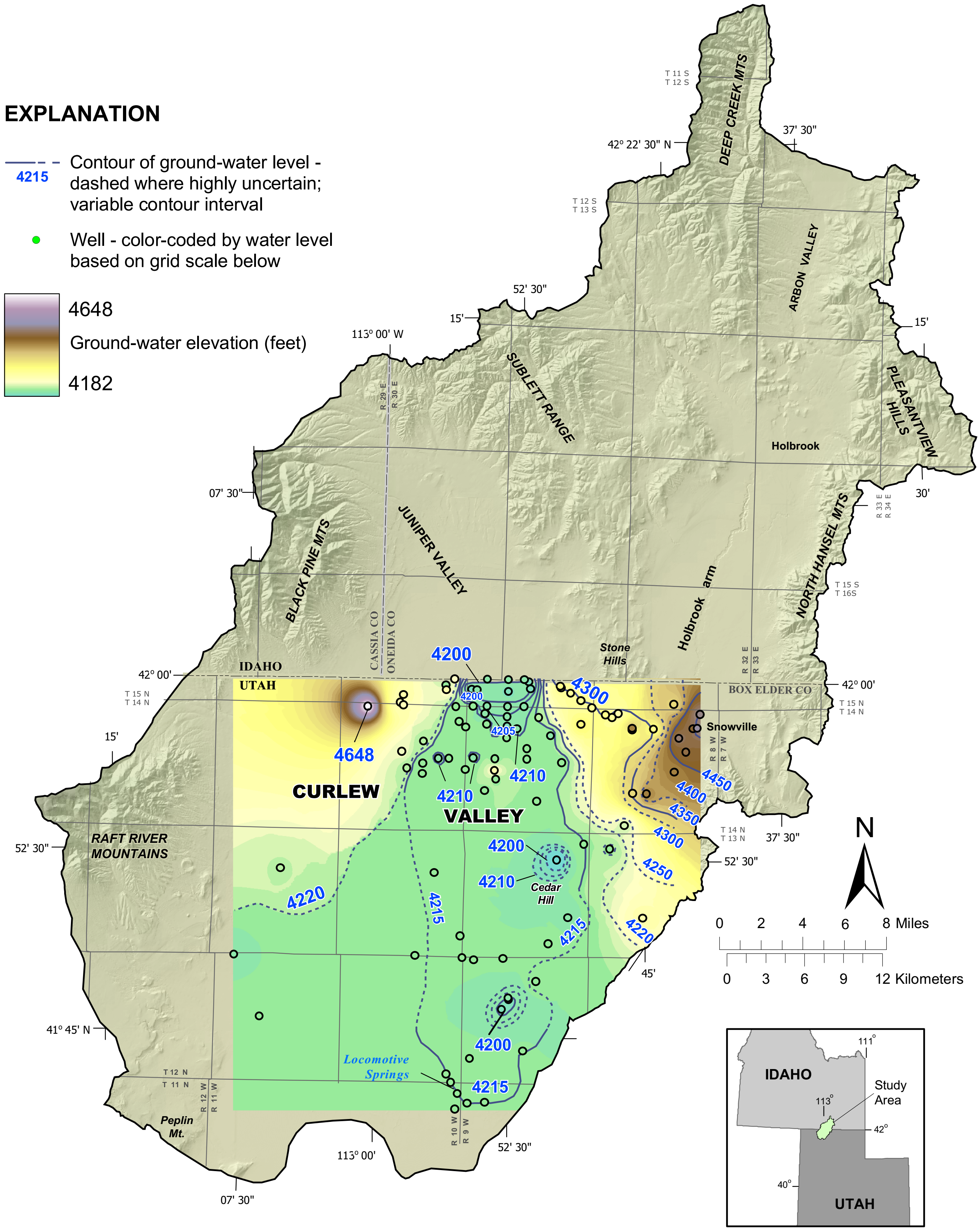

Figure 34. Ground-water levels in Curlew Valley, 1995–1996 from Atkin (1998).

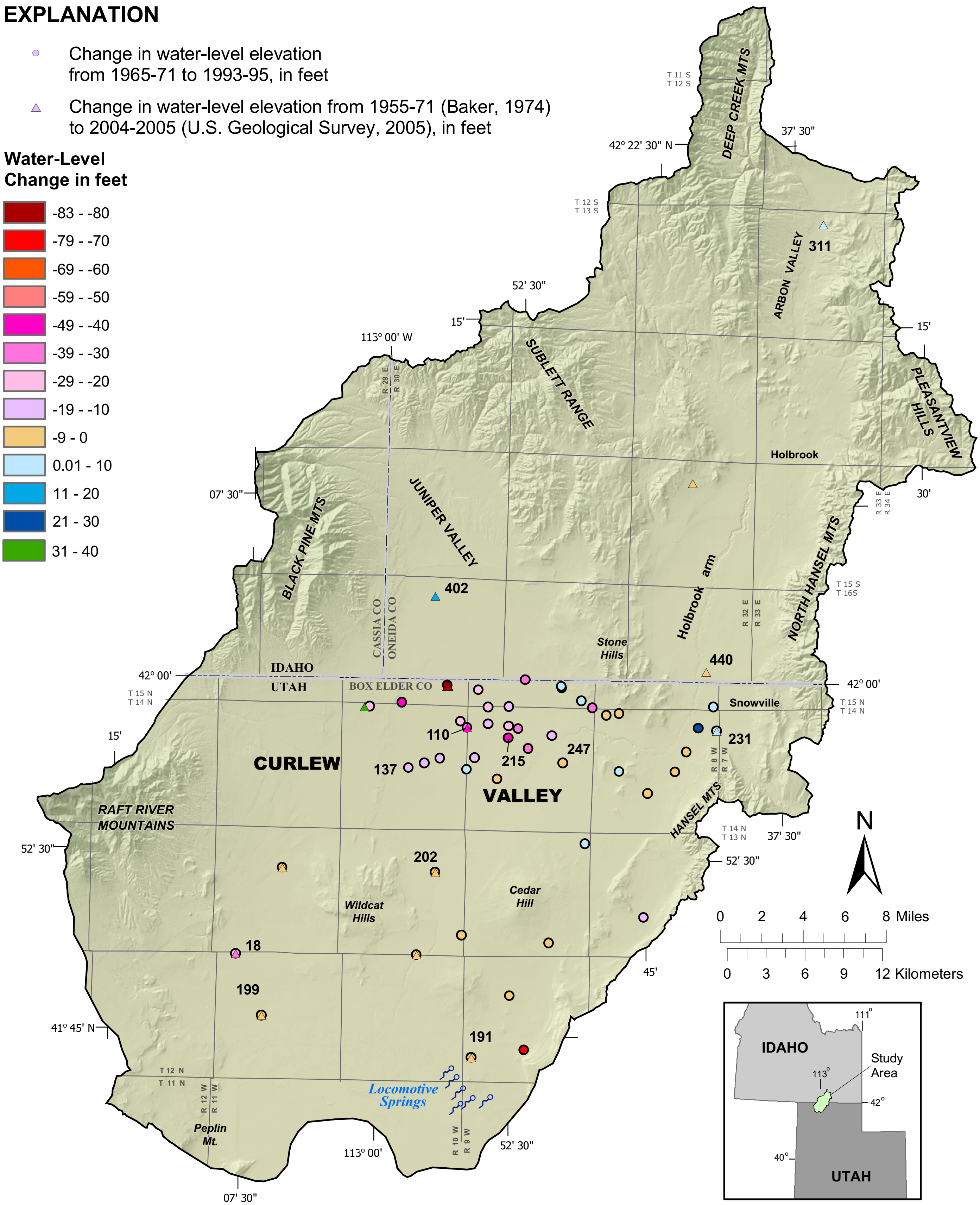

Figure 35. Changes in static water-level elevation in wells in Curlew Valley. Data sources are Baker (1974) for 1965–71, Atkin (1998) for 1993–95, and U.S. Geological Survey (2005a) for 2004–2005. ID numbers identify wells for which water-level plots are shown in figure 36.

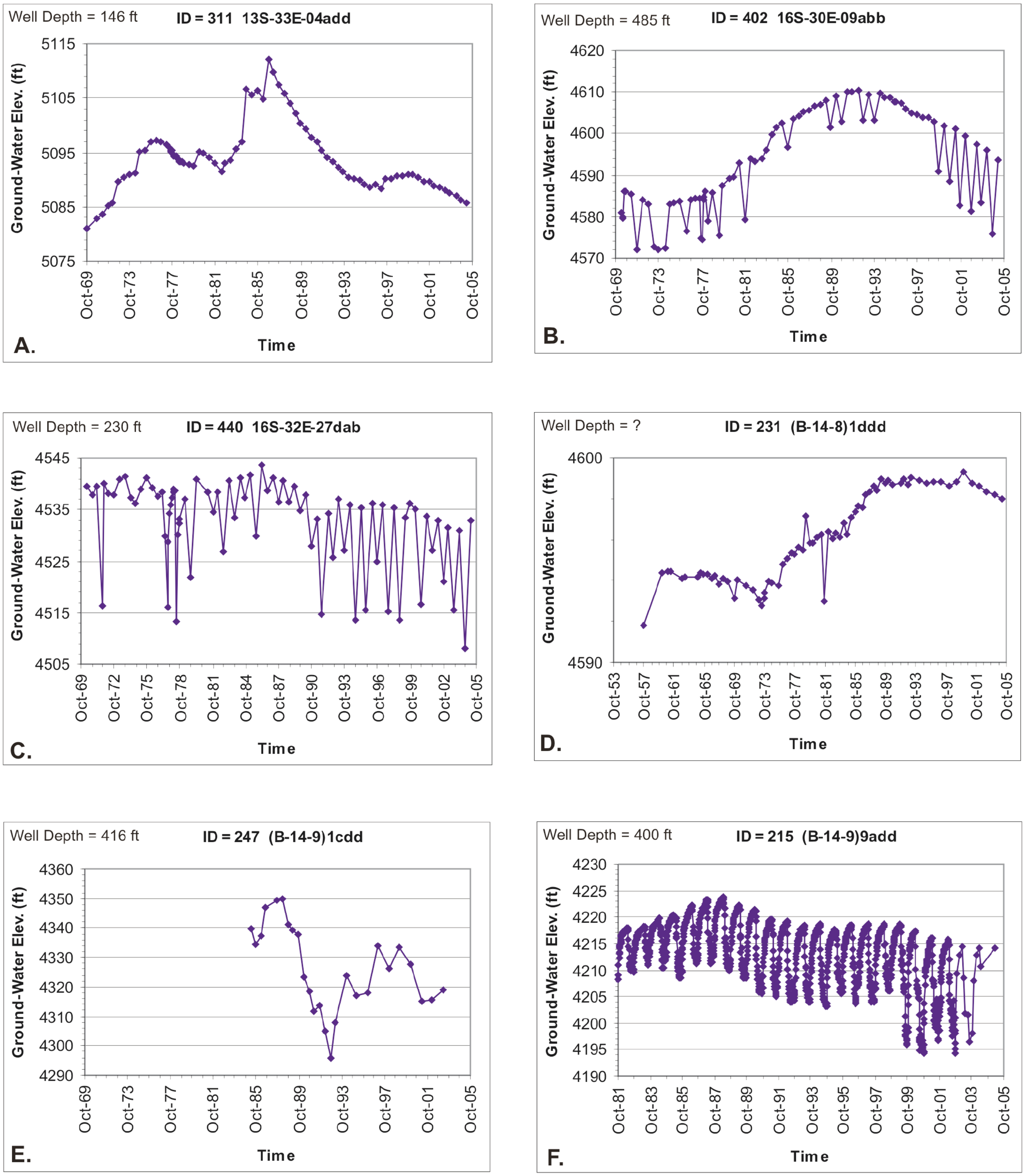

Figure 36. *Records of ground-water levels for select wells in Curlew Valley basin-fill aquifer. Figure 35 shows well locations. Well records are in table C.2. Data are from the U.S. Geological Survey (2005). A. Plot for well 311. B. Plot for well 402. C. Plot for well 440. D. Plot for well 231. E. Plot for well 247. F. Plot for well 215.*

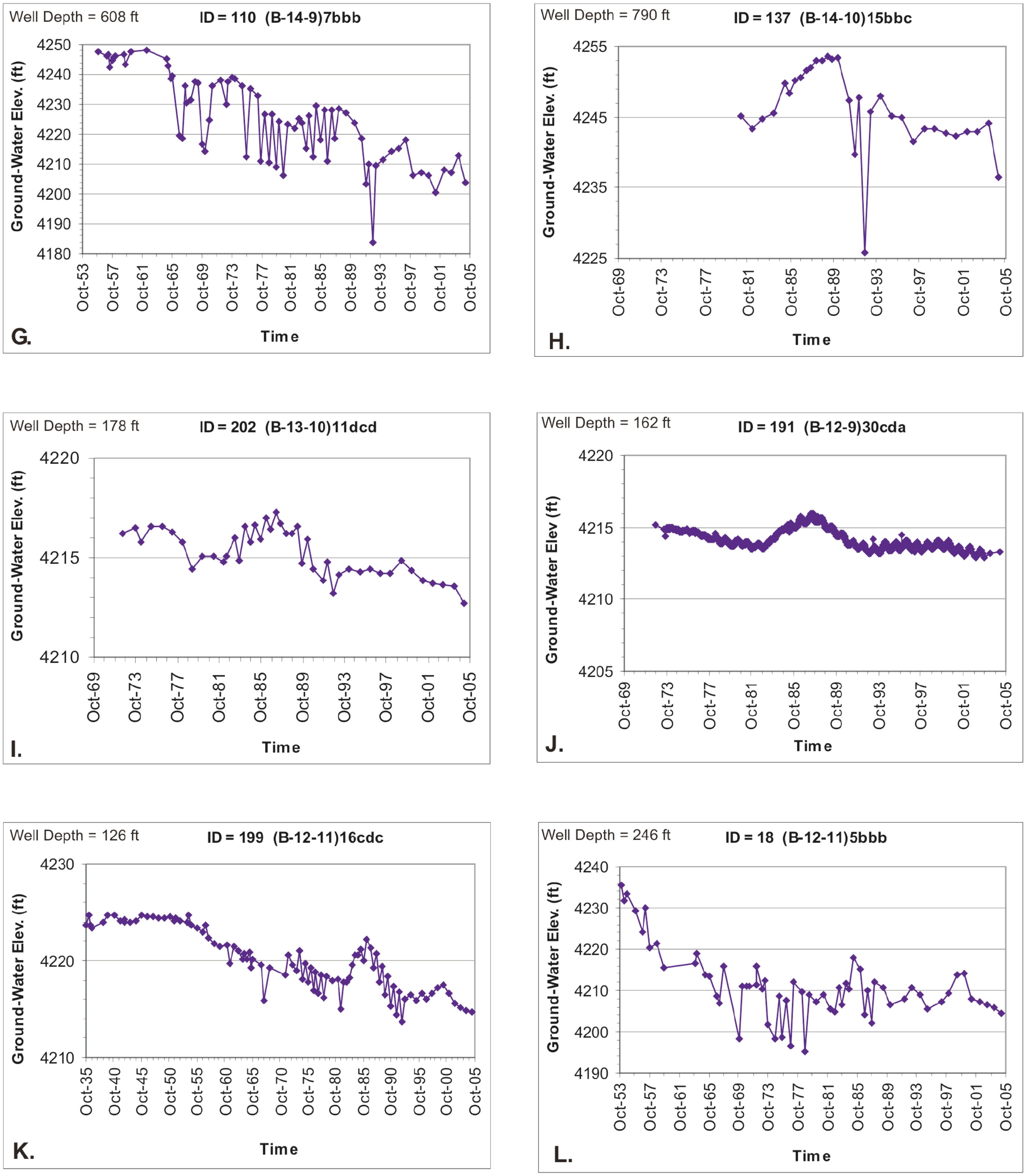

***Figure 36** (continued).* *G. Plot for well 110. H. Plot for well 137. I. Plot for well 202. J. Plot for well K. Plot for well 199. L. Plot for well 18.*

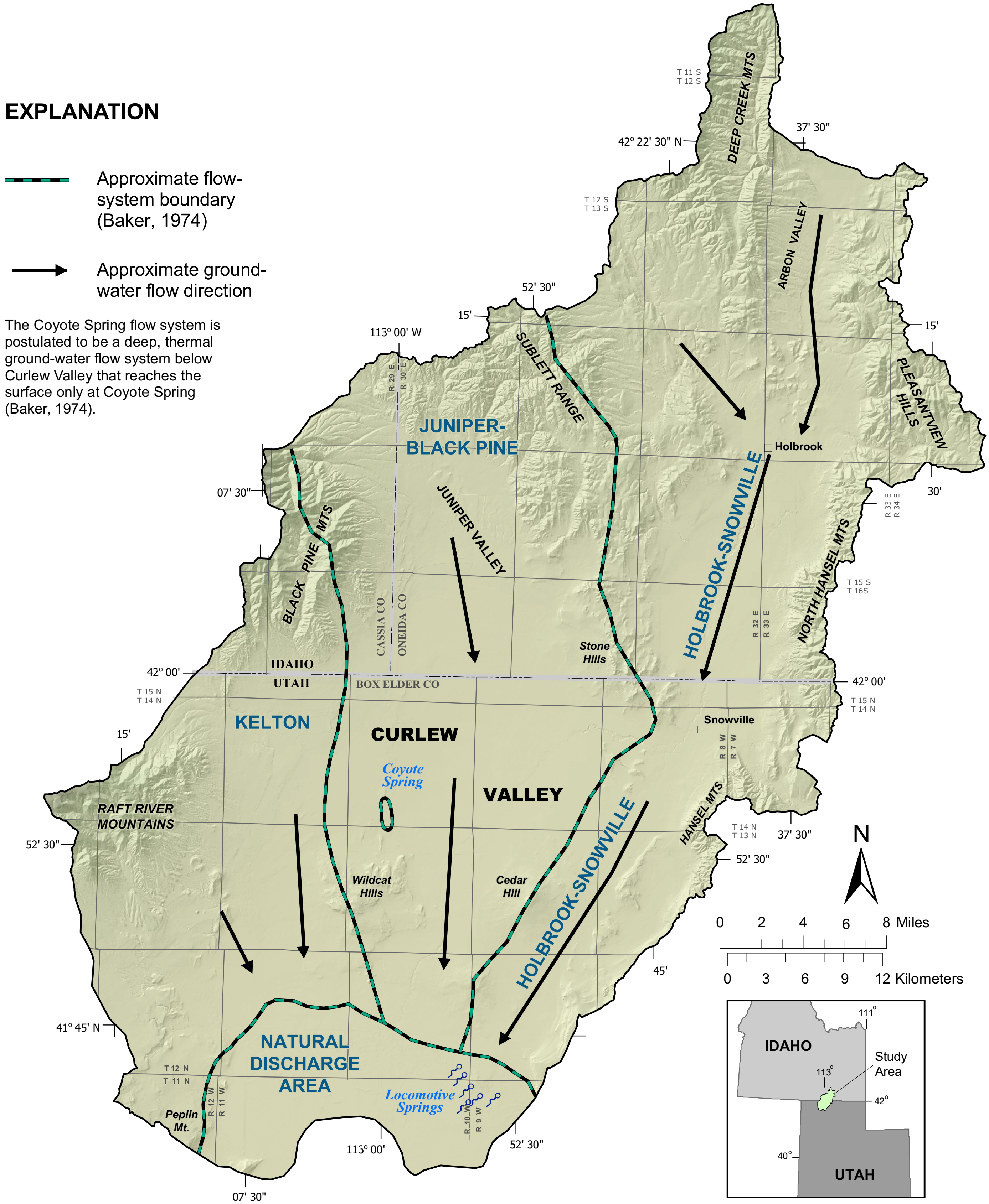

Figure 37. Ground-water flow systems in the Curlew Valley basin-fill aquifer, modified from Baker (1974). Inferred, approximate flow-system boundaries and flow directions are from this study.

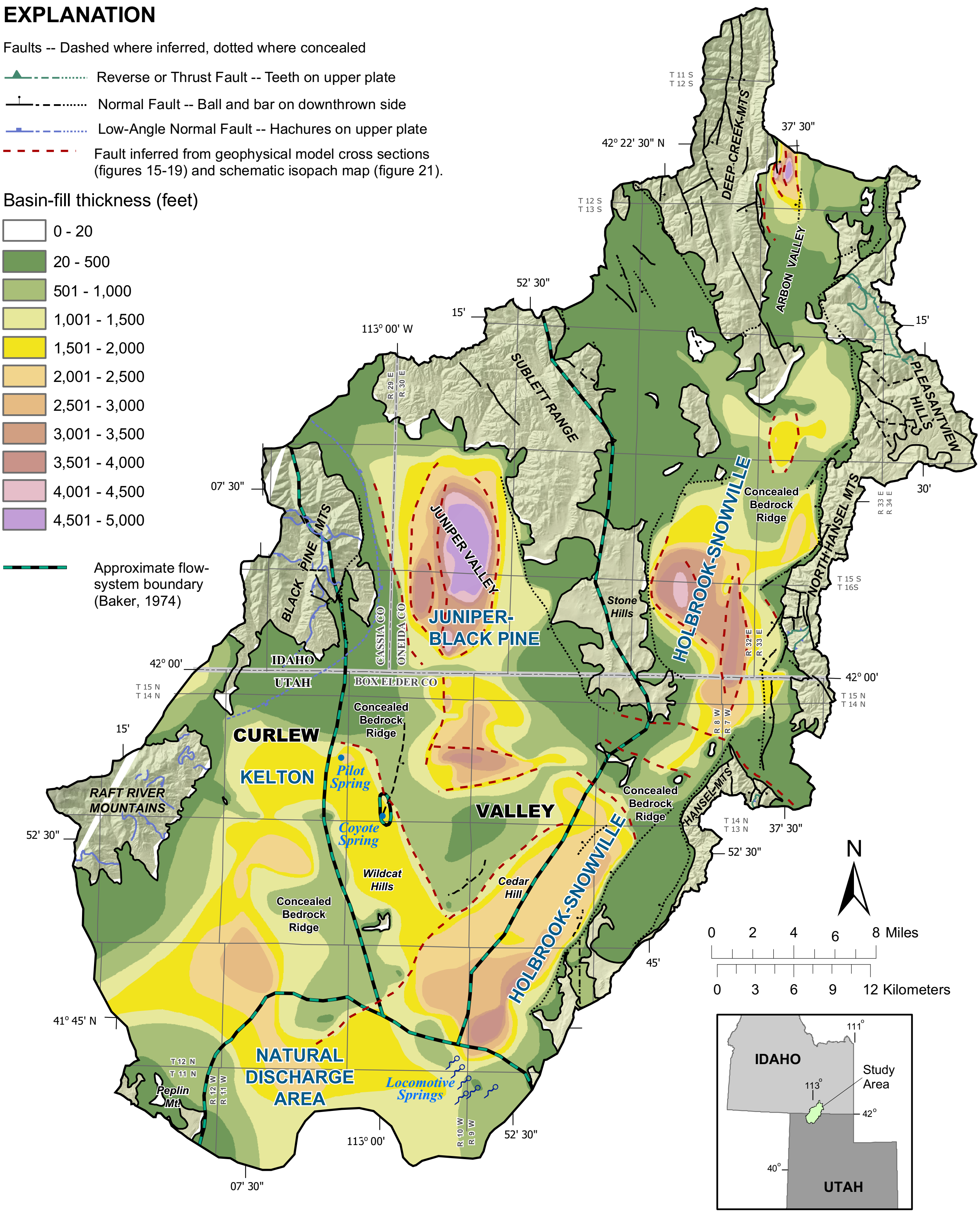

Figure 38. *Flow systems (Baker, 1974) superimposed on basin-fill isopach map (figure 21) and inferred intrabasin faults (figure 23) for Curlew Valley.*

from precipitation on the east side of the Black Pine Mountains and the west side of the Sublett Range. Baker (1974) estimated the average annual recharge to the flow system at 22,000 acre-feet (27 hm^3) per year.

Unconfined ground-water conditions generally predominate throughout the Juniper–Black Pine flow system, but the interbedded basalt and clay layers create leaky confined conditions locally in the southern portion of the flow system (Baker, 1974). Wells derive water from fractures in the basalt; from clean, well-sorted sand; and from poorly sorted clay, sand, and gravel. Baker (1974, p. 39-40) asserted that natural discharge from the Juniper–Black Pine flow system occurs by evapotranspiration in its central and southern parts, and that the flow system contributes little to discharge from the Locomotive Springs complex.

Water quality in the Juniper–Black Pine flow system generally decreases southward. In the northern portion of the flow system the TDS concentration is less than 500 mg/L and the major ions are typically calcium and bicarbonate. However, a well west of Stone Hills contains water with a TDS concentration greater than 26,000 mg/L and the predominant ions are sodium, calcium, and chloride. Baker (1974) suggested the source of this water could be from a concealed fault. Ground water in the southern Juniper–Black Pine flow system has higher TDS and salinity than in the northern portion.

The Holbrook-Snowville flow system occupies the eastern part of Curlew Valley, including Holbrook arm north of the town of Snowville, and the area from Snowville to the Locomotive Springs complex between the Hansel Mountains and Cedar Hill (figures 37 and 38). The Stone Hills, Sublett Range, and Deep Creek Mountains form the western boundary of Holbrook arm, and the Pleasantview Hills and North Hansel Mountains form the eastern boundary. South of Snowville the flow system is bounded by the Hansel Mountains on the east and by Cedar Hill and the unnamed Quaternary shield volcano southwest of Cedar Hill on the west. Holbrook arm occupies a bedrock trough that reaches its maximum thickness of 4500 feet (1370 m) just north of Snowville (this study and Peterson, 1973).

Recharge to the Holbrook-Snowville flow system, which Baker (1974) estimated to be about 44,000 acre-feet (54 hm^3) per year, is from precipitation on the east side of the Sublett Range, the southeast part of the Deep Creek Mountains, and the west side of the Pleasantview Hills and North Hansel Mountains. About 2000 acre-feet (2.5 hm^3) per year additional recharge comes from precipitation on the west side of the Hansel Mountains in Utah (Baker, 1974). Ground water in the flow system is unconfined in the Holbrook arm, leaky artesian conditions are common near the Utah-Idaho border, and basalt layers create locally confined conditions in the southern portion of the flow system (Baker, 1974).

Ground-water quality in the Holbrook-Snowville flow system generally declines southward (Baker, 1974). In Holbrook arm TDS values are generally below 600 mg/L TDS, but water from some wells near Snowville have TDS concentrations greater than 1000 mg/L, and south of Snowville near Cedar Hill ground water from two wells has TDS concentrations greater than 8000 mg/L (Baker, 1974; Riding and Quilter, 2004). This decline in water quality is due to dissolution of salts in the aquifers and addition of dissolved minerals in unused irrigation water (Baker, 1974).

Baker (1974) defined the Coyote Spring flow system in south-central Curlew Valley (figure 37) based on the great difference in temperature and chemistry between water discharging from Coyote Spring and all other ground water in Curlew Valley. In contrast to the other flow systems, the Coyote Spring flow system is defined based only on a single discharge point, so its existence is, therefore, more speculative. Baker (1974) interpreted the Coyote Spring flow system as a deep circulation system, heated by buried Tertiary and Quaternary intrusions associated with exposed volcanic rocks in the basin, that emerges at Coyote Spring where it is tapped by a normal fault. The extent of the Coyote Spring flow system is unknown, so it is represented in this study by a small, oval boundary surrounding the spring. The Coyote Spring flow system discharges thermal (43.5°C; 110°F), moderately saline (3240 mg/L TDS) water (Baker, 1974). There are no other thermal springs in Curlew Valley, but Baker (1974) reported that two wells in the Kelton area encountered warm saline water, and suggested that this water may be part of the Coyote Spring flow system below southwestern Curlew Valley.

Davis (1984) and Davis and Kolesar (1984) evaluated the geothermal potential of central Box Elder County, including the Utah part of Curlew Valley. They showed that Coyote Spring and the central Juniper–Black Pine flow system west of Stone Hills have low- to moderate-temperature geothermal potential, as defined by steeper than normal geothermal gradients (up to 267°C/km, compared to a typical value for the Basin and Range of 35°C/km, high TDS (up to 5168 mg/L), and high estimated reservoir temperatures (about 37 to 98°C, depending on estimation method). Davis and Kolesar (1984) attributed the high ground-water temperatures and TDS concentrations to heating of deeply circulating in an area having a step geothermal gradient, and return to near the land surface along faults. They did not speculate on the reasons for the localized steep geothermal gradients, but buried intrusions seem the most likely cause based on the presence of nearby Quaternary and Tertiary volcanic rocks (Baker, 1974).

Hydraulic Properties of Basin-Fill Sediments

Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Variations in transmissivity in the Curlew Valley basin-fill aquifer are expected based on variations in sediment composition and volcanic-rock content, and these variations affect the levels and movement of ground water within the aquifer. Baker (1974) reported transmissivity values calculated from the results of two multiple-well aquifer tests in Curlew Valley: 24,000 to 32,000 ft^2/day (2230–2980 m^2/d) in the Kelton agricultural area of the Kelton flow system, and 19,000 to 22,000 ft^2/day (1770–2050 m^2/d) in southern Holbrook arm.

To improve the distribution of transmissivity estimates in the Curlew Valley basin-fill aquifer, we calculated transmissivity values for selected wells, all screened in sedimentary deposits of the basin-fill aquifer, from specific-capacity data from drillers' logs, using the computer program TGUESS (Bradbury and Rothschild, 1985). The computer program takes the well diameter, static water level, drawdown, test duration, aquifer thickness, screened interval, storage coefficient, and well-loss coefficient as input parameters. We estimated aquifer thickness from the basin-fill isopach map (figure 15), used storage coefficients calculated from the multiple-well aquifer tests (Baker, 1974), and assumed well-loss coefficients of one based on lack of information on this parameter; the other input values were derived from the drillers' logs. We assumed unconfined conditions in wells having a static water level at or below the top of the screened interval and assigned these wells a storage coefficient of 0.03, the value calculated from the results of the unconfined aquifer test in the Kelton agricultural area (Baker, 1974, p. 17–19). We assumed confined conditions in wells having a static water level above the top of the screened interval and assigned these wells a storage coefficient of 0.007, the average of two values calculated from the results of the confined aquifer test in the Holbrook-Snowville flow system (Baker, 1974, p. 30-31).

For eight wells in the Kelton flow system, our transmissivity estimates ranged from 800 to 81,600 ft^2/day (74–7580 m^2/d) (table 1; figures 39 and 40). Transmissivity estimates from three tests on one well and one test on another well in the Holbrook-Snowville flow system range from 700 to 34,000 ft^2/day (65–3160 m^2/d), and data from 14 tests on 10 wells in the Juniper–Black Pine flow system yielded transmissivity estimates that ranged from 400 to 68,100 ft^2/day (37-6330 m^2/d) (table 1; figures 39 and 40). The transmissivity estimates are uncorrelated with well depth.

Transmissivity values calculated from aquifer tests are typically more accurate because water levels and pumping rates are generally measured more precisely, the storage coefficient is calculated, not assumed, and the well efficiency can also be determined. Our transmissivity estimates for wells including or near those used in the aquifer tests reported by Baker (1974) are consistent with his results (figure 40), suggesting that our calculations provide reasonable, albeit less precise, estimates of the hydraulic properties of the basin-fill aquifer for the parts of the aquifer open to the wells. Brooks and others (2003) suggested that transmissivity estimates from specific-capacity tests approximate the hydraulic properties of the basin-fill aquifer near the measured well to about an order of magnitude.

GROUND-WATER CHEMISTRY

Previous Work

Baker (1974) evaluated the ground-water chemistry of the Curlew Valley basin-fill aquifer, and showed that groundwater quality was generally good in the northern parts of the Kelton, Juniper–Black Pine, and Holbrook flow systems, and gradually declined to the south toward Great Salt Lake. Baker (1974) attributed this southward decline in groundwater quality, characterized by increasing TDS and sodium and chloride content, to and irrigation return flows, lack of recharge in the Utah part of the valley, and increased residence time in Lake Bonneville sediments. The descriptions of the three main flow systems and of Coyote Spring in the previous chapter summarize the general features of their ground-water chemistry. Oaks (2004) compiled groundwater-quality data for the Utah part of Curlew Valley, and showed expanded distribution of high-TDS areas and somewhat higher TDS values than Baker (1974).

The Utah Department of Agriculture and Food (UDAF) collected water-chemistry data from agricultural wells in the Holbrook-Snowville and Juniper–Black Pine flow systems, and from Baker, Bar M, and West Locomotive Springs of the Locomotive Springs complex during the years 1996-2004 (table D.1). Some of the UDAF samples lack chloride data and have large positive charge-balance errors (>30%), which create problems for some data analyses. We addressed this problem by estimating the appropriate chloride concentration based on the charge-balance error, because it is highly improbable that these samples lack chloride as a constituent and it is very likely that the negative ion deficiency observed in some samples is due almost entirely to the lack of chloride data.

The UDAF data include field measurements of electrical conductivity (EC). Electrical conductivity data are typically more common than TDS values, which require laboratory analyses. The EC of water is related to the amount and type of dissolved constituents and the temperature of the water, and typically correlates well with TDS. It is preferable, however, to discuss water chemistry in terms of TDS concentrations because they better represent water chemistry. For samples having both EC and TDS measurements, linear regression of these values produces an equation that can be used to convert EC values to TDS estimates (figure 41). All samples shown in figure 41 are from the Curlew Valley basin-fill aquifer, and the derived equation applies only to samples from this aquifer. This procedure results in better spatial coverage of TDS estimates for the Curlew Valley basin-fill aquifer and its flow systems (figure 42). The following discussion describes both measured and calculated TDS values.

Measured and calculated TDS concentrations of Curlew Valley ground water range from about 325 to over 10,000 mg/L (figure 42). Two wells in the southwestern part of the valley having very high TDS values are shallow observation wells only 64 feet (19.5 m) deep (Baker, 1974); their chemistry may in part reflect that of Great Salt Lake water.

Based on data from Baker (1974), Davis (1984), Atkin (1998), the UDAF, and the U.S. Geological Survey (2005b), the ground-water flow systems can be informally divided into different water-quality areas based on TDS (figure 42). The central part of the Juniper–Black Pine flow system contains ground water having high TDS concentrations, ranging from 832 to 5852 mg/L (average value 2515 mg/L). TDS concentrations are somewhat lower in the east-central (833-1119 mg/L; average 973 mg/L) and west-central (384–1012 mg/L; average 710 mg/L) parts of the Juniper–Black Pine flow system. The northern part of the Holbrook-Snowville flow system has high ground-water quality (347–1500 mg/L; average 753 mg/L), and TDS concentrations from wells in the Snowville area vary from 625 to 4310 mg/L (average 1540 mg/L). TDS concentrations in the Holbrook-Snowville flow system increase markedly south of Snowville, ranging from 807 to 1473 mg/L (average 1218 mg/L) in the south-central part and from 1784 to 3123 mg/L (average 2728 mg/L) in the southern part. The Kelton agricultural area has higher TDS concentrations (786–2155 mg/L; average 1288 mg/L) than the rest of the Kelton flow system (362–678 mg/L; average 483 mg/L). TDS concentrations of Locomotive Spring complex water range from 1820 to 4160 mg/L (average 2878 mg/L).

Table 1. *Input values and results of calculations of aquifer transmissivity from specific-capacity test data for wells in Curlew Valley. Data are from well drillers' logs available from the Utah Division of Water Rights (http://www.waterrights.utah.gov/).*

ID[1]	Location[2]	Well Diameter (in)	Static Water Level (ft)	Drawdown	Post-Test Water Level (ft)	Test Duration (hr)	Pumping Rate (gpm)	Aquifer Thickness (ft)	Open Interval (ft)	Well Depth (ft)	Screened Interval (ft)	Condition	Storativity	Transmissivity sq.ft/s	Transmissivity sq.ft/d	Flow System
3	N 1146 W 1181 NE 31, T12N R3W	8	355	411	766	4	100	600	33	500	450-483	confined	0.007	7.84E-03	700	H-S
3	N 1146 W 1181 NE 31, T12N R3W	8	355	418	773	4	150	600	33	500	450-483	confined	0.007	1.16E-02	1000	H-S
3	N 1146 W 1181 NE 31, T12N R3W	8	355	425	780	8	208	600	33	500	450-483	confined	0.007	1.59E-02	1400	H-S
16	N 2640 E 100 SW 4, T12N R11W	20	89	100	189	6	691	2100	100	235	80-180	unconfined	0.03	2.78E-01	24,000	Kelton
17	S 40 W 3800 NW 4, T12N R11W	16	92	180	272	2	270	1600	233	335	47-280	unconfined	0.03	2.04E-02	1800	Kelton
19	S 900 E 1520 NW 5, T12N R11W	16	143	60	203	3	950	2100	73	220	120-193	unconfined	0.03	9.44E-01	81,600	Kelton
20	S 100 W 925 NE 6, T12N R11W	16	173	125	298	4	1300	2100	170	400	200-370	confined	0.007	2.83E-01	24,500	Kelton
23	S 360 E 3398 NE 7, T12N R11W	16	72	84	156	3.5	710	2100	165	275	40-205	unconfined	0.03	2.24E-01	19,400	Kelton
25	S 60 W 1400 NE 8, T12N R11W	16	88	90	178	5	250	2100	136	220	88-224	unconfined	0.03	8.52E-02	7,400	Kelton
58	S 180 W 790 E4 2, T14N R8W	10	29	19	48	48	34	100	70	70	0-70	unconfined	0.03	5.08E-03	400	H-S
101	S 200 E 100 NW 4, T14N R9W	16	190	234	424	30	3000	1650	541	365	176-365	unconfined	0.03	1.12E-01	9700	J-BP
113	N 2640 SW 10, T14 R9W	18	132	170	302	28	300	900	363	400	35-398	unconfined	0.03	5.57E-03	500	J-BP
114	N 1902 W 1887 SE 14, T14N R9W	16	197	150	347	7	674	1300	84	450	351-435	unconfined	0.03	1.29E-01	11,100	J-BP
116	W 1650 NE 16, T14N R9W	18	153	253	406	24	1863	900	290	468	152-442	unconfined	0.03	5.09E-02	4400	J-BP
127	S 50 E 190 N4 1, T14N R10W	16	172	200	372	6	2540	1800	65	340	215-280	confined	0.007	7.88E-01	68,100	J-BP
149	S 150 W 250 E4 12, T14N R12W	6	162	18	180	3	40	500	21	215	193-214	unconfined	0.03	5.96E-02	5100	Kelton
153	N 3790 W 1510 SE 32, T15N R7W	18	20	150	170	6	900	1400	295	315	20-315	unconfined	0.03	5.96E-02	5100	H-S
155	S 5 E 1950 NW 32, T15N R7W	16	28	127	155	36	2250	1850	220	262	40-260	unconfined	0.03	3.93E-01	34,000	H-S
164	N 1460 E 50 SW 28, T15N R9W	16	203	80	283	5	460	600	197	434	207-404	confined	0.007	3.54E-02	3100	J-BP
164	N 1460 E 50 SW 28, T15N R9W	16	203	89	292	9	512	600	197	434	207-404	confined	0.007	3.62E-02	3100	J-BP
164	N 1460 E 50 SW 28, T15N R9W	16	203	96	299	24	552	600	197	434	207-404	confined	0.007	3.72E-02	3200	J-BP
168	S 1200 E 2640 NW 31, T15N R9W	18	215	242	457	5	2300	1600	102	407	220-322	unconfined	0.03	3.11E-01	26,900	J-BP
170	N 3600 E 1270 SE 32, T15N R9W	20	228	228	456	24	2500	800	163	400	233-396	unconfined	0.03	1.19E-01	10,300	J-BP
170	N 3600 E 1270 SE 32, T15N R9W	20	228	250	478	48	4000	800	163	400	233-396	unconfined	0.03	2.25E-01	19,400	J-BP
172	N 1300 E 10 SW 33, T15N R9W	18	240	300	540	12	2600	300	215	410	190-405	unconfined	0.03	2.63E-02	2300	J-BP
174	S 750 E 385 NW 34, T15N R9W	20	238	380	618	108	750	300	220	620	275-495	unconfined	0.03	5.38E-03	500	J-BP
183	S 2640 E 2640 NW 36, T15N R10W	18	220	257	477	12	2000	1750	210	425	220-430	unconfined	0.03	1.42E-01	12,300	J-BP
187	S 700 W 1000 NE 34, T15N R12W	13	133	267	400	10	800	1600	888	1447	259-1147	confined	0.007	1.26E-02	1100	Kelton
187	S 700 W 1000 NE 34, T15N R12W	13	138	250	388	10	900	1600	1384	1643	259-1343	confined	0.007	9.51E-03	800	Kelton

Notes

[1]See table C.2 for more complete data on water wells.

[2]Location given as point of diversion – see figure C.2.

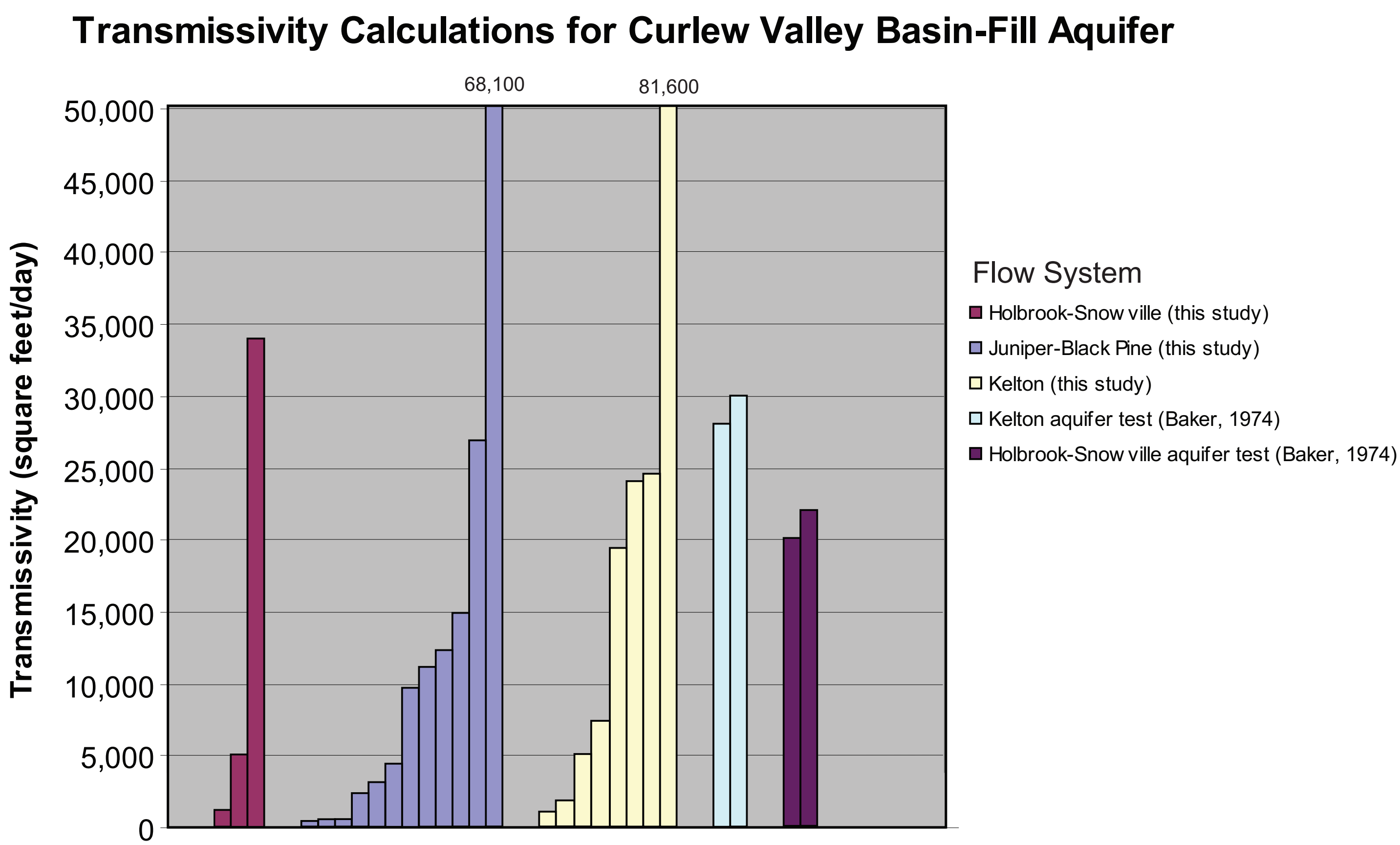

Figure 39. *Histogram of transmissivity estimates for the Curlew Valley basin-fill aquifer, from calculations performed as part of this study and from previous work.*

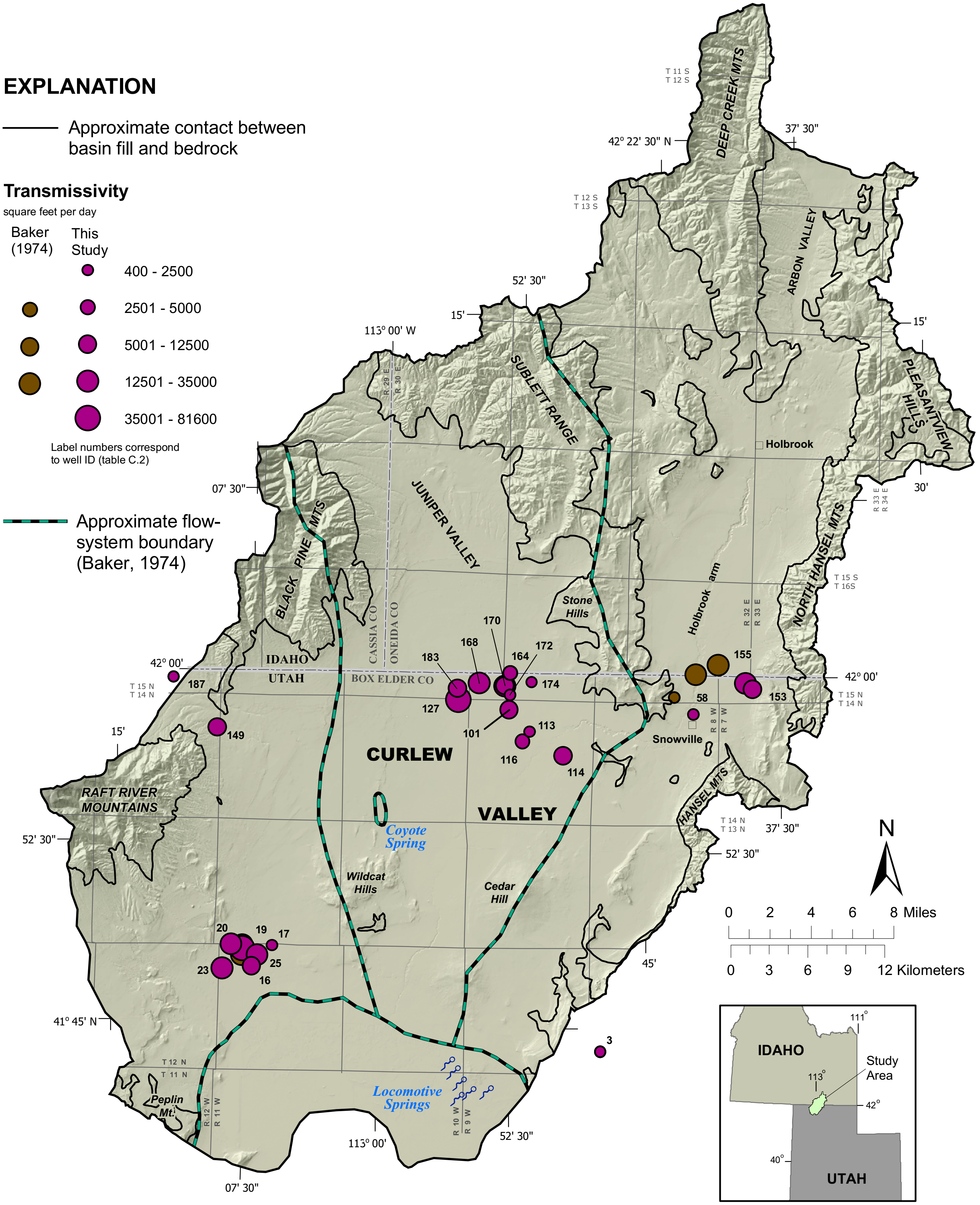

Figure 40. Graduated-symbol map of transmissivity estimates calculated from well drillers' specific-capacity test data for the Curlew Valley basin-fill aquifer.

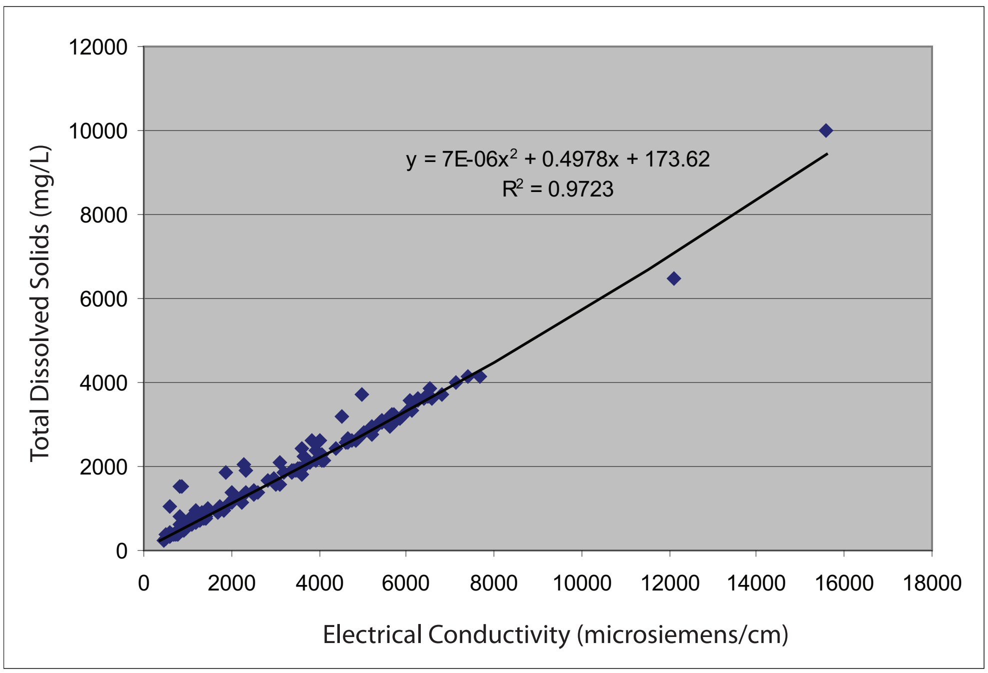

***Figure 41.** Plot of electrical conductivity versus total-dissolved-solids concentration measured in wells in the Curlew Valley basin-fill aquifer. Data are from Baker (1974) and the Utah Geological Survey (reported here). Regression line is statistically significant and provides a means for estimating TDS values from electrical conductivity.*

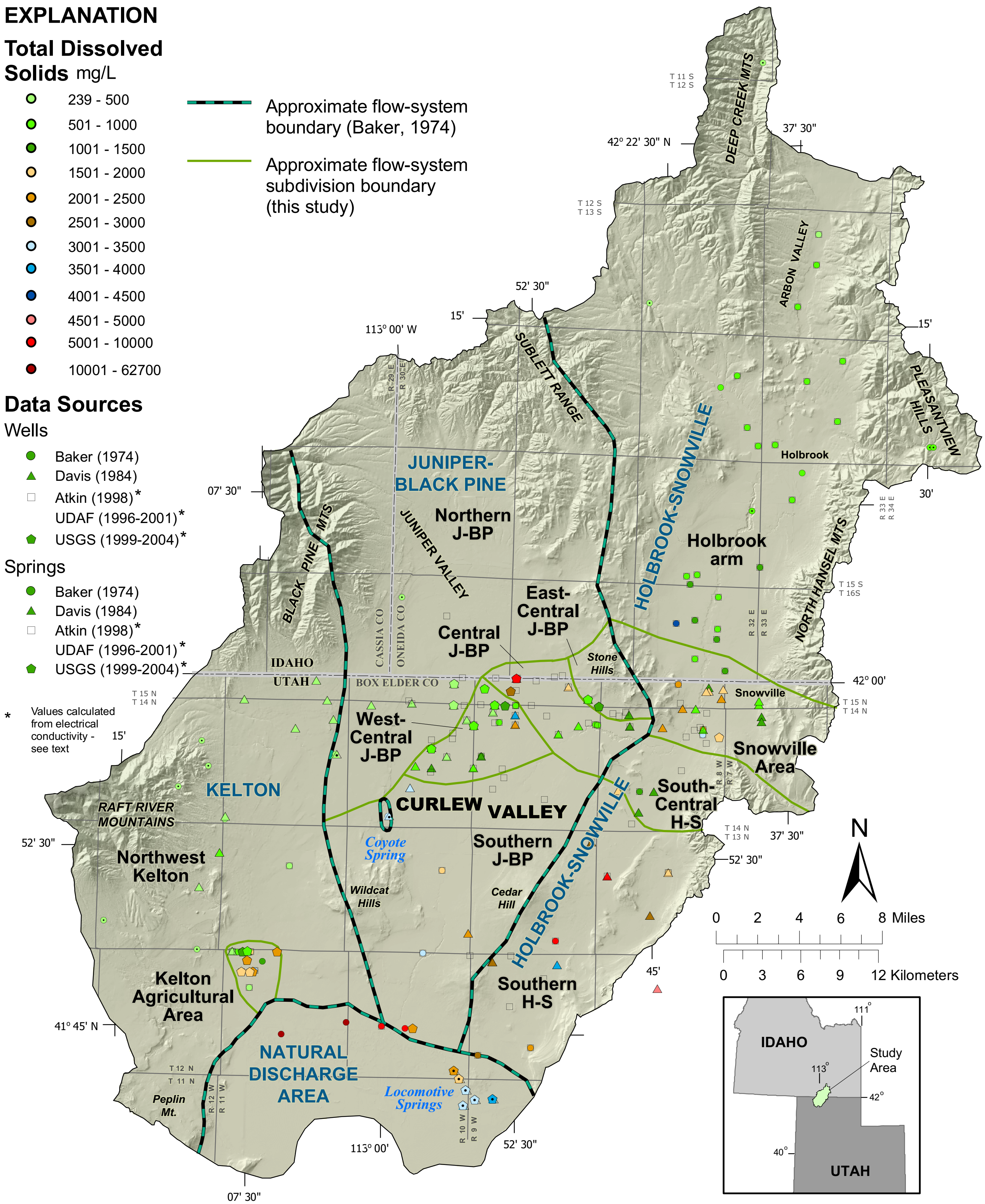

Figure 42. Total-dissolved-solids concentrations of ground-water samples from previous studies in Curlew Valley, and proposed subdivisions of flow systems based on water quality. For sites having multiple analyses, the most recent analysis is shown.

A piper plot of the UDAF data (figure 43) shows that the water type varies from calcium-bicarbonate to sodium-chloride compositions. The data fall along a narrow range in the cation field, and the anion data show that most samples cluster in the chloride area. Ground water from the Snowville and southern parts of the Holbrook-Snowville flow system; the northern, central, and west-central parts of the Juniper–Black Pine flow system; and from the Locomotive Springs complex form fairly distinct compositional fields in the quadrilateral plot (figure 43). Each area exhibits some compositional variability and substantial compositional overlap exists. Samples from the south-central Holbrook-Snowville flow system and the east-central Juniper–Black Pine flow system show greater compositional variability than those from the other areas. Stiff diagrams of the UDAF data (figure 44) show that sodium and chloride are the dominant ions in the ground water in areas having high TDS.

The U.S. Geological Survey (2005b) has collected electrical conductivity data annually from selected wells in Curlew Valley since as early as 1964 (figures 45 and 46). Because we use these data only to discuss temporal trends, we do not convert them to TDS estimates. The electrical conductivity of water from two wells in the Kelton agricultural area has gradually increased by up to 2000 µS/cm since the early 1970s (wells 18 and 197, figures 46A and 46B, respectively). In the agricultural area west of Snow-ville, two measured wells have shown no significant increase in electrical conductivity (wells 126 and 181, figures 46C and 46D, respectively), whereas two wells have increased by about 500 µS/cm (wells 107 and 259, figures 46E and 46F, respectively), and one well increased from just under 5000 to just over 9000 µS/cm (well 164, figure 46G). One well near Snowville has shown no significant increase in electrical conductivity (well 83, figure 46H). The electrical conductivity of water issuing from the Locomotive Springs complex showed no significant trends during a relatively limited sampling period in the 1970s (figures 46I through 46L).

Ground-water temperatures in Curlew Valley generally range from about 10 to 25°C (50–77°F) (figure 47). Water in wells in the central part of the Juniper–Black Pine flow system, in the agricultural area west of Snowville, is warmer on average than in the rest of the valley and ranges from about 21 to 38°C (70–100°F). Based on measurements from 1969, Baker (1974) reported temperatures of 9 to 14°C (48–57°F), averaging 10°C (50°F), for water issuing from Locomotive Springs complex, whereas temperatures measured by the U.S. Geological Survey in 1975 ranged from 14 to 17.5°C (57–64°F), averaging 16°C (61°F) (U.S. Geological Survey, 2005b). Discharge from the Locomotive Springs complex decreased between 1969 and 1975, while the temperature of water discharging from the springs increased (figure 29). As mentioned above, water issuing from Coyote Spring is about 43°C (110°F), anomalously high for the study area. Davis (1984) and Davis and Kolesar (1984) described ground-water temperatures in Curlew Valley in greater detail.

UGS Data

The Utah Geological Survey (UGS) collected ground-water samples from 28 wells and Bar M Spring during May 2004, and from four wells and Bar M and Baker Springs during August 2005 (figure 48). All samples were analyzed for general chemistry, and 10 well samples were analyzed for dissolved metals. In addition, we collected samples for environmental-tracer isotopes, including deuterium (^2H), tritium (^3H), carbon-14 (^{14}C), carbon-13 (^{13}C), and oxygen-18 (^{18}O), from 13 wells and Bar M and Baker Springs.

Methods

For the general-chemistry and dissolved-metals samples, we used pre-preserved plastic bottles provided by the Utah Division of Epidemiology and Laboratory Services and filled them with water to the top with limited headspace. For tritium, oxygen-18, and deuterium samples, we used clear plastic 2-liter bottles and filled them ¾ full, then squeezed out excess air in the field, to leave no headspace. For the carbon-14 samples, we used clear plastic gallon jugs and filled them ¾ full, then squeezed excess air out in the field to leave no headspace. For all environmental-tracer samples, we sealed the caps with black electric tape to prevent leakage. We performed field tests on most samples for pH, dissolved oxygen, temperature, and electrical conductivity with a hand-held Quanta Hydrolab. All sample bottles were packed in ice until delivery to the laboratories for analysis.

The samples collected for both general chemistry and isotopes were analyzed by the BYU Department of Geology environmental-geochemistry laboratory. The Utah Division of Epidemiology and Laboratory Services analyzed the samples collected only for general chemistry and dissolved metals. Details of analytical methods used at the Division of Epidemiology and Laboratory Services are available from that institution. Analytical methods used at BYU are briefly described here.

Stable isotope ratios ($\delta^{18}O_{VSMOW}$, δD_{VSMOW}, and $\delta^{13}C_{VPDB}$) were measured at BYU with a Finnigan Delta^{plus} isotope ratio mass spectrometer with methods similar to that described by McCrea (1950), Epstein and Mayeda (1953), and Gehre and others (1996). $\delta^{18}O_{VSMOW}$ and δD_{VSMOW} values were normalized to the VSMOW/SLAP scale following the procedure of Coplen (1988), Nelson (2000), and Nelson and Dettman (2001).

Samples for ^3H analysis were distilled and electrolytically enriched to increase ^3H concentration by a factor of at least 10 times. Analysis was done using a PerkinElmer Quantulus 1220 ultra low-level liquid scintillation counter. Samples were evaluated against blanks and a NIST traceable standard (SRM 4361C).

Samples analyzed for ^{14}C were processed to concentrate the carbon by precipitation as barium carbonate ($BaCO_3$). For each water sample, the pH was raised to above 11 using a purified sodium hydroxide (NaOH) solution followed by precipitation with barium chloride ($BaCl_2$). For samples analyzed by accelerator mass spectrometry the precipitate was shipped to the University of Georgia Center for Applied Isotope Studies (CAIS). CAIS analyzed the samples for ^{12}C, ^{13}C, and ^{14}C using a National Electrostatics Corporation Model 1.5SDH-1. For samples analyzed by conventional liquid scintillation counter at BYU the precipitate was acidified and the CO_2 gas released was synthesized into benzene for analysis in a PerkinElmer Quantulus 1220 ultra low-level liquid scintillation counter. Samples were evaluated against blanks and a NIST traceable oxalic acid standard (4990C). Percent modern carbon (PMC) values were calculated following the procedure of Stuiver and Pollach (1977).

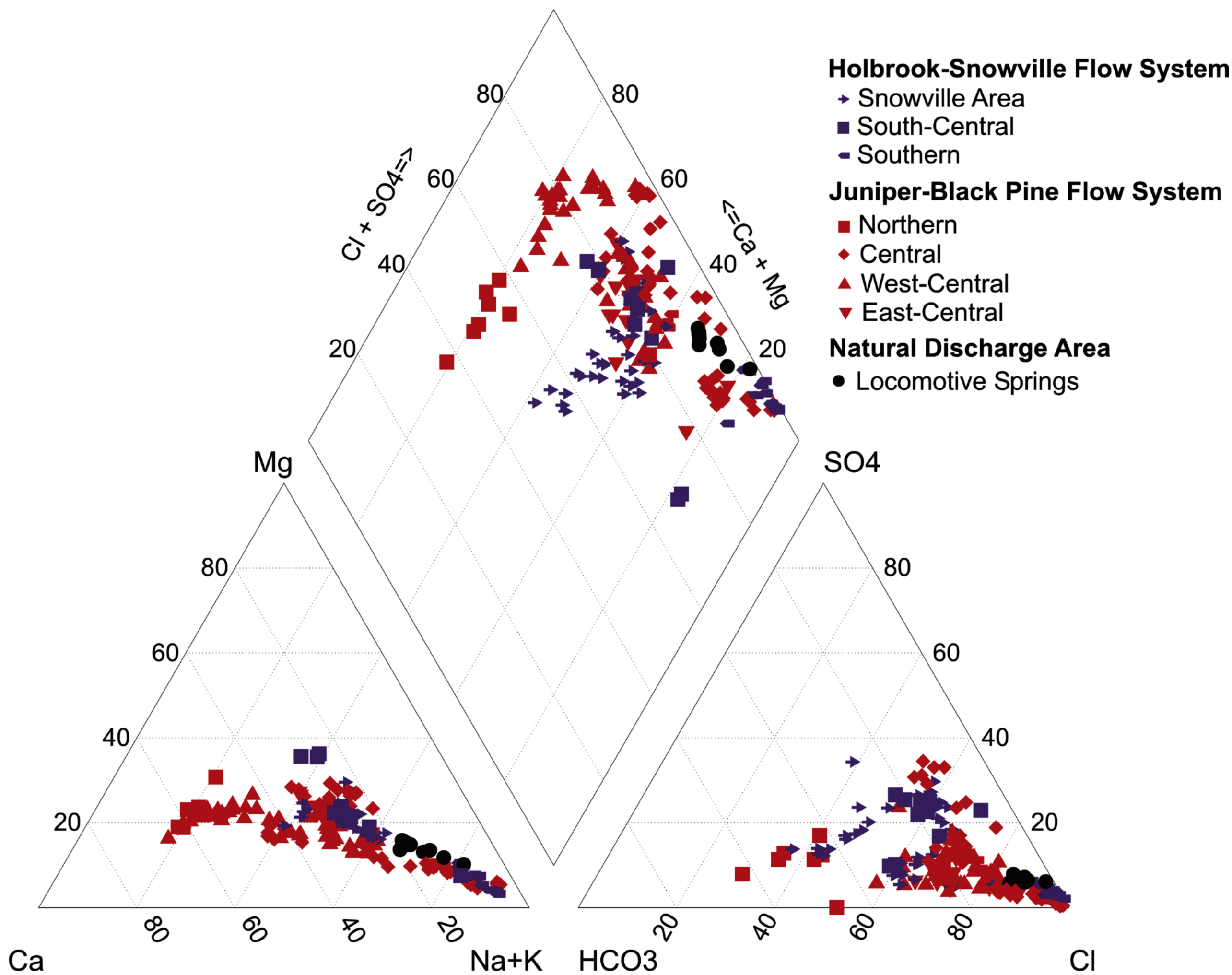

Figure 43. Piper plot of UDAF data. Data are in table D.1. Multiple analyses of some wells are included.

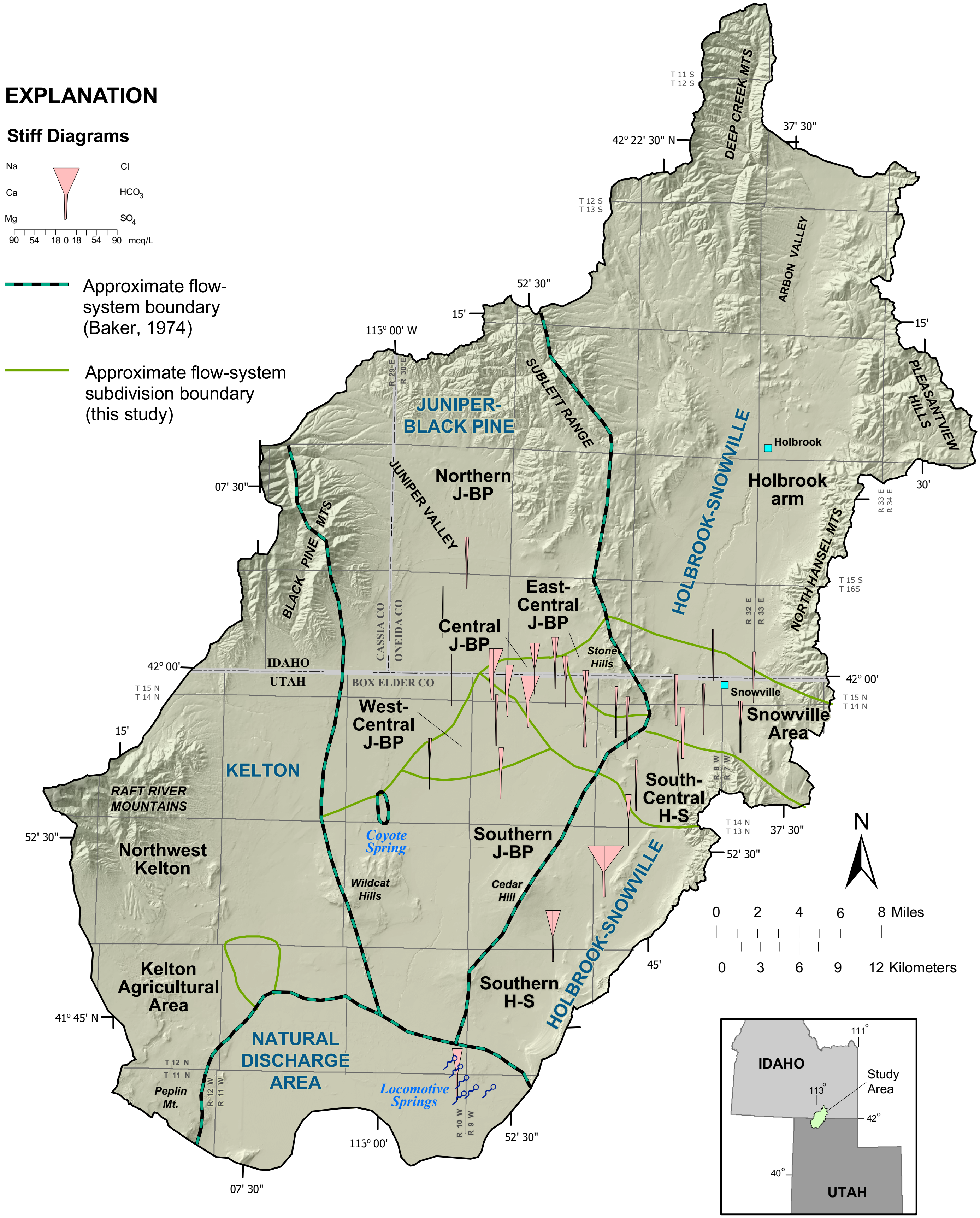

Figure 44. *Stiff diagrams of selected UDAF data from Curlew Valley.*

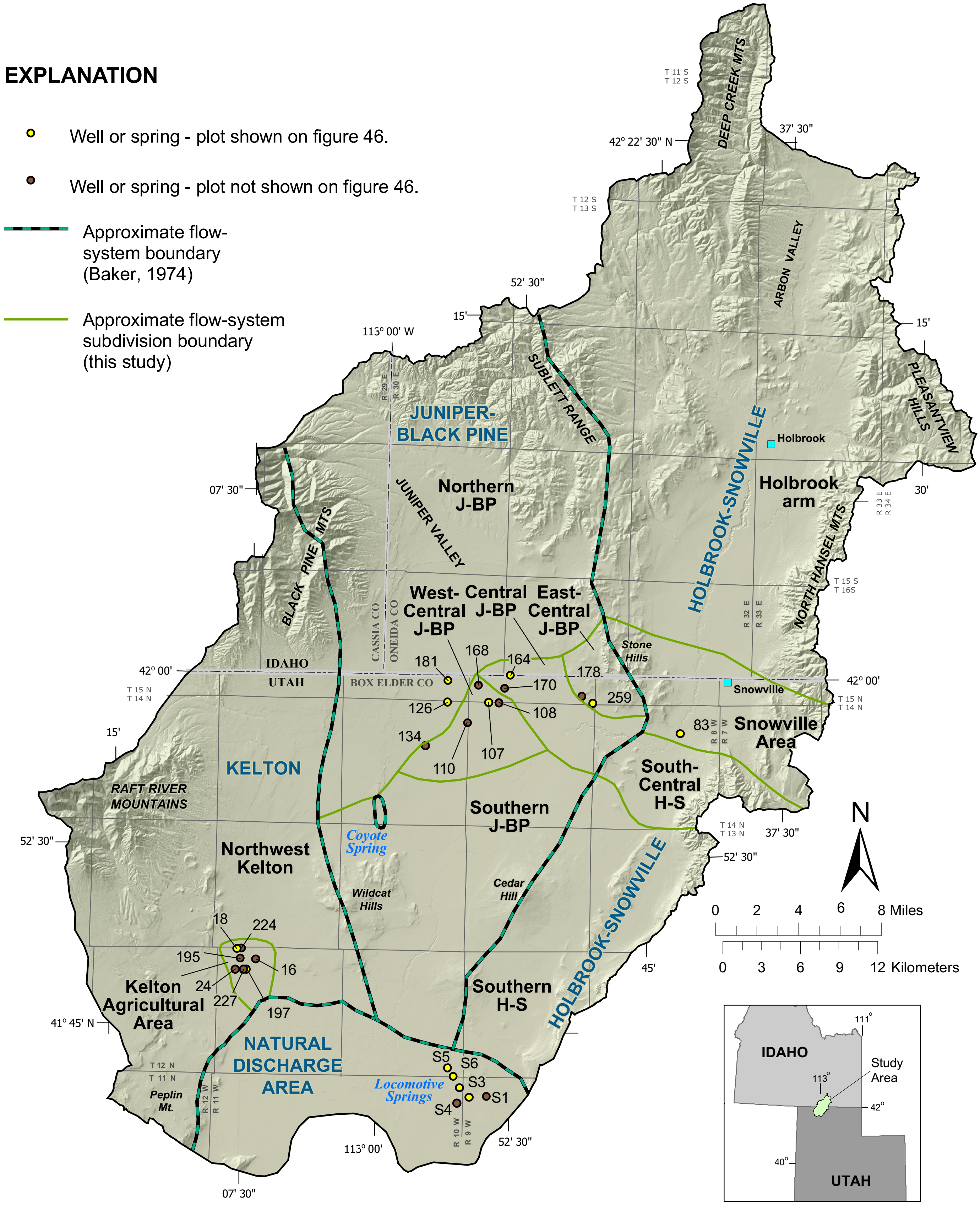

Figure 45. Locations of water wells and springs in Curlew Valley for which the U.S. Geological Survey (2005b) collected electrical conductivity data for multiple years. Figure 46 shows plots of electrical conductivity versus time for those wells and springs shown in yellow. Numbers are well and spring IDs (tabes C.1 and C.2).

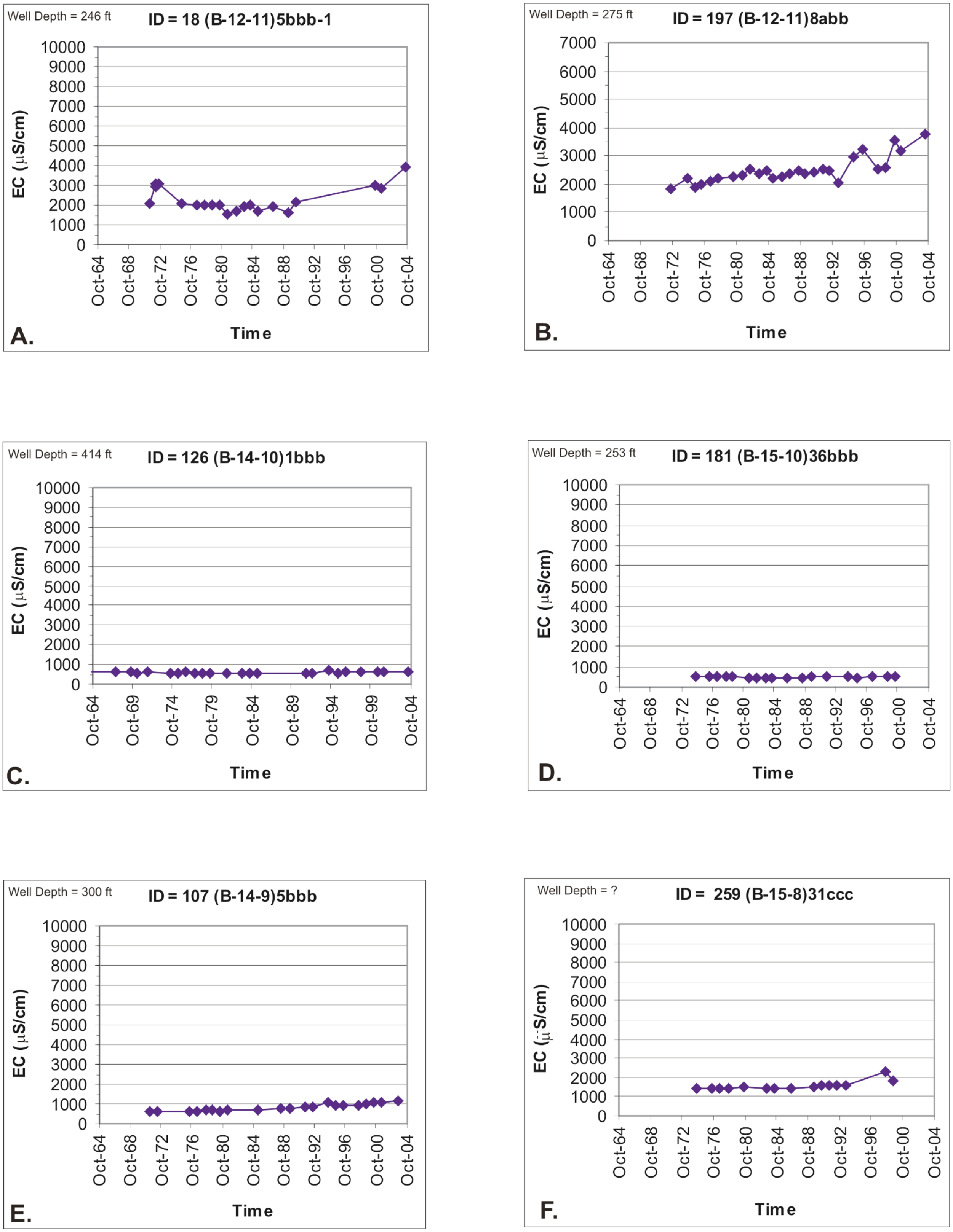

Figure 46. *Electrical conductivity (EC) versus time plots for selected wells and springs in Curlew Valley. Data are from the U.S. Geological Survey (2005b). See tables C.1 and C.2 for information on springs and wells, respectively.*

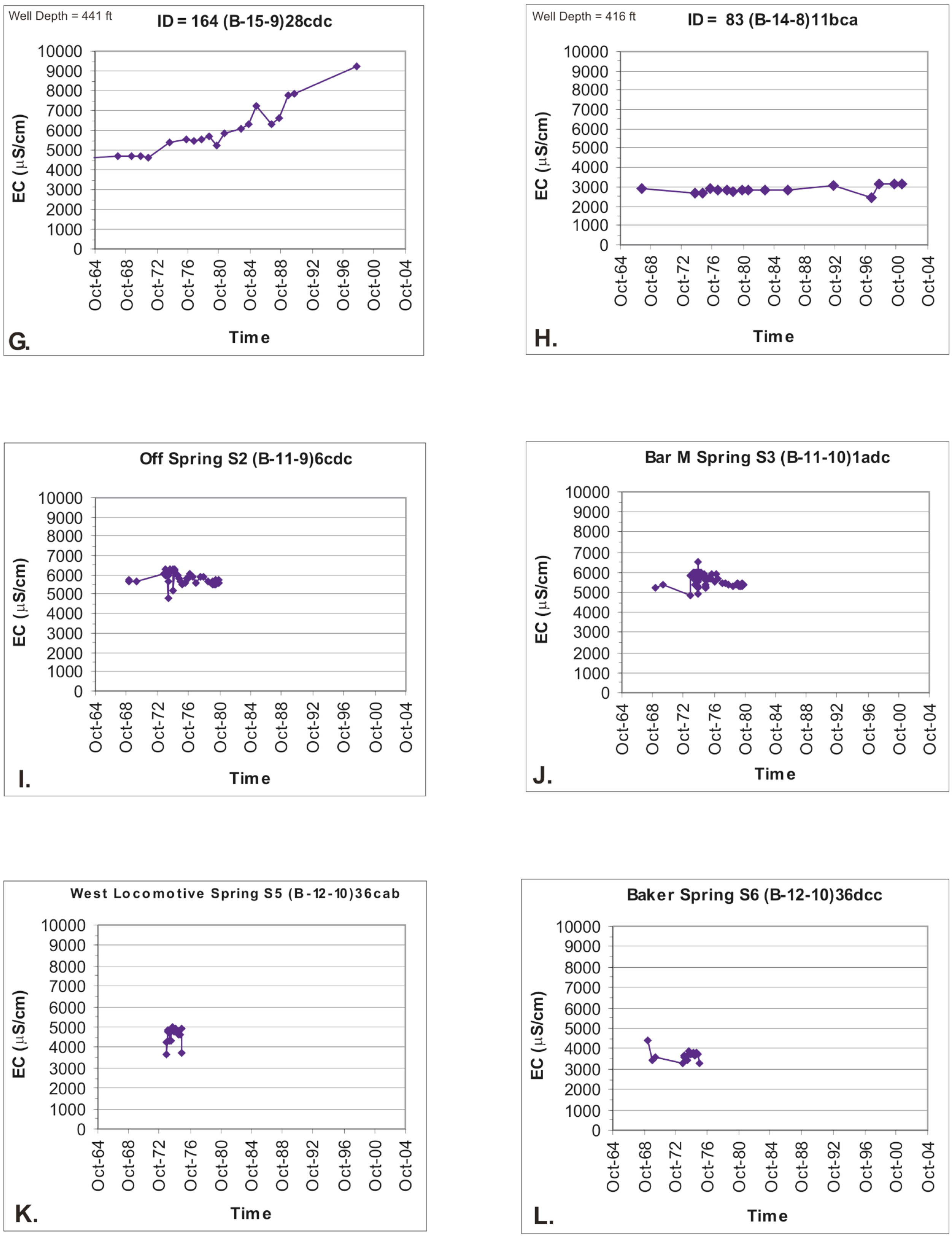

Figure 46. *(continued)*

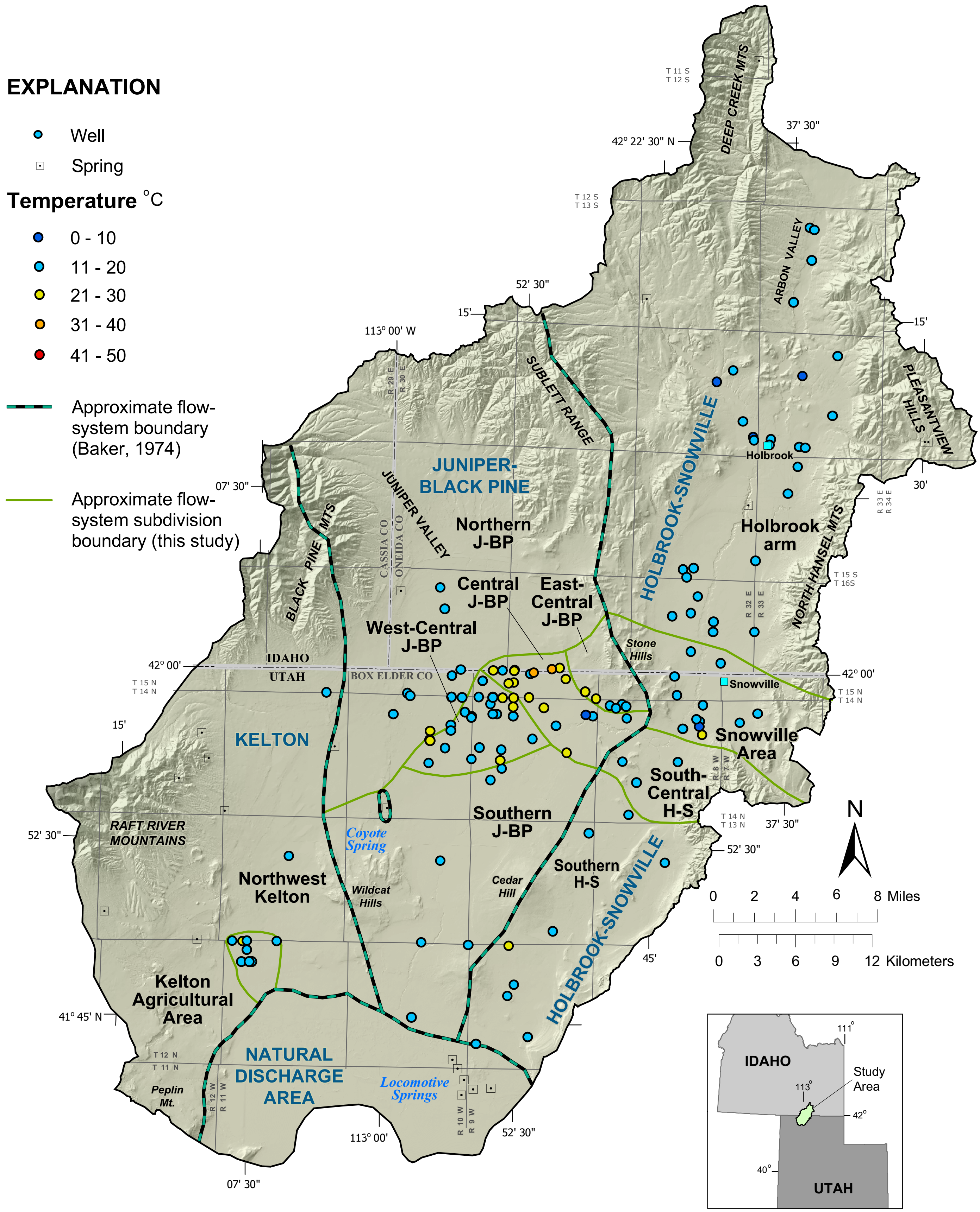

Figure 47. *Temperature of ground water in wells and springs of Curlew Valley. Data are from Baker (1974), Davis (1984), Atkin (1998), and the U.S. Geological Survey (2005b).*

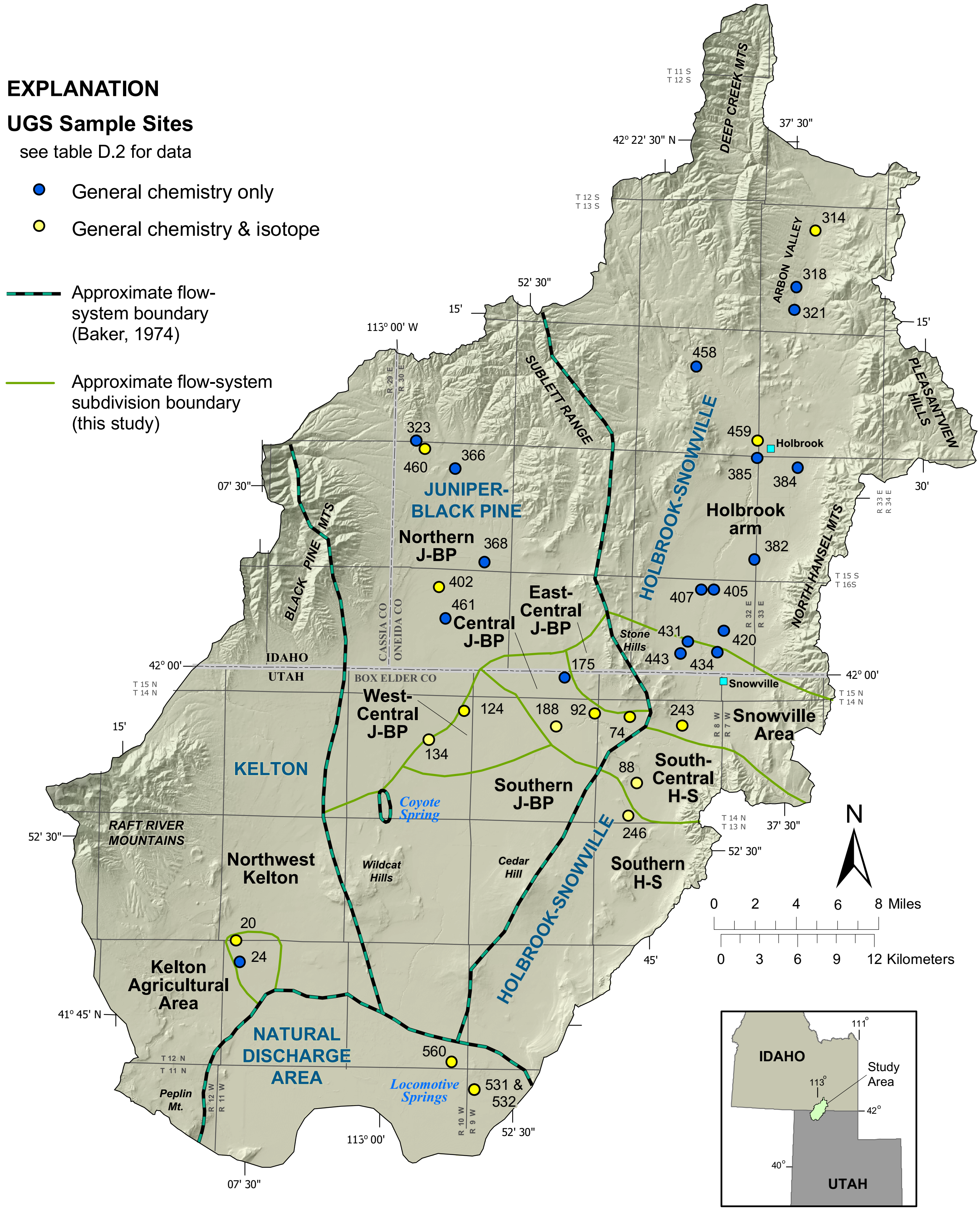

Figure 48. Utah Geological Survey water-chemistry sample sites in Curlew Valley.

Results

General Chemistry

Most of the UGS samples had low electrical conductivity, but some had values over 3000 µS/cm (table D.2). The highest measured electrical-conductivity value of 4980 m S/cm was from well 443 in Holbrook arm, and the lowest electrical conductivity value was 490 µS/cm from well 402 near Juniper. Figure 49 presents a piper plot of the UGS data. The data fall in the same range as the UDAF data, but are more calcium rich. The dominant anion in most samples is either bicarbonate or chloride. Ground-water samples that are dominant in sodium are from near Snowville, and southward to the Locomotive Springs complex. This is also evident in figure 50, a map showing stiff diagrams for the UGS samples.

Figure 51 shows total-dissolved-solids values for the UGS samples based on the Utah Water Quality Board's TDS classification system (table 2). Ground water in Curlew Valley is mainly Class I and II. Water from well 443 from the Holbrook arm had a TDS value of 3724 mg/L, and is classified as Class IV. The UGS data are broadly consistent with previous data (figure 42; table 3), except for lower values measured in the west-central Juniper–Black Pine flow system (figure 52). Figure 53 shows that TDS concentration is un-correlated with well-completion depth in the Curlew Valley basin-fill aquifer, even when each flow system and proposed subdivision are evaluated separately.

Geochemical modeling of the UGS data with the program PHREEQC (Parkhurst and Appelo, 2000) indicates that ground water in Curlew Valley is undersaturated with respect to gypsum and halite, near saturation or oversaturated with respect to calcite, and varies from oversaturated to undersaturated, depending on location, with respect to dolomite. Other phases that influence the concentration of dissolved constituents are barite, iron oxide, and other hydroxides. In general, if barium is detected in a water sample then it is oversaturated with respect to barite. Also, if iron is detected then the water sample is oversaturated with respect to numerous iron oxide and hydroxide phases, such as ferrihydrite ($5Fe_2O_3 \cdot 9H_2O$), goethite ($FeOOH$), or hematite (Fe_2O_3). Kinetics determines which phase precipitates. Due to the arid climate in Curlew Valley and the high evapotranspiration rates, many of these undersaturated mineral phases are probably found in the vadose zone, because evapotranspiration increases the concentration of the dissolved constituents, which likely leads to precipitation of mineral phases.

Isotope Chemistry

The oxygen-18 and deuterium isotope samples were collected to aid in delineation of the different flow systems in Curlew Valley, and to identify source waters and processes that occur in the aquifers. Tritium and carbon-14 samples were collected to determine the age of the ground water, and carbon-13 is useful in determining the source of alkalinity in ground water and processes involved in the carbonate cycle within the aquifer. Table 4 presents the results of the isotopic analyses.

Oxygen-18 and Deuterium: Oxygen-18 and deuterium are naturally occurring stable isotopes of oxygen and hydrogen. The oxygen-18 and deuterium compositions of a sample are expressed as ratios in delta notation (δ) as ‰ (parts per thousand, or per mil) relative to a reference standard according to the following equation:

$$\delta_x = \left(\frac{R_x}{R_{std}} - 1 \right) \text{ x } 1000 ‰ \qquad (1)$$

where:

R_x = isotopic ratio of the sample
R_{std} = isotopic ratio of the standard

The reference standard for oxygen-18 and deuterium is known as Vienna Standard Mean Ocean Water (VSMOW) (Gonfiantini, 1978). The isotopic ratio of the standard (R_{std}) is the ratio of the heavy isotope to the light isotope. For oxygen-18 this value is ($^{18}O/^{16}O$) = $2.0052 \text{x} 10^{-3}$, and for deuterium this value is ($^2H/^1H$) = $1.5575 \text{x} 10^{-4}$ (Clark and Fritz, 1997). The isotopic ratio of the sample is the ratio of the heavy isotope to the light isotope that is measured in the sample.

Figure 54 shows the oxygen and deuterium data and the global meteoric water line (GMWL) from Rozanski and others (1993). The Curlew Valley data plot below the GMWL, which indicates that the ground water is enriched in ^{18}O and depleted in ^2H (enriched samples plot below the GMWL because the slopes of evaporation-trend lines are lower than the slope of the GMWL). Samples from the northern and west-central Juniper–Black Pine flow system form a relatively close group and are the lightest isotopically, having the lowest $\delta^{18}O$ and δ^2H values on the plot. Samples from the Holbrook-Snowville flow system also form a distinct group but show greater dispersion. Samples from the central Juniper–Black Pine flow system form a linear trend having isotopic compositions similar to those of the Holbrook-Snowville flow system, and are distinct from samples from the rest of the Juniper–Black Pine flow system. The sample collected from the Kelton flow system is the heaviest isotopically, having the highest (least negative; more enriched) $\delta^{18}O$ and δ^2H values. Samples from the Locomotive Springs complex form a distinct cluster on the plot, between the clusters formed by the northern and west-central Juniper–Black Pine flow system and by the Holbrook- Snowville and central Juniper–Black Pine flow systems.

Tritium: Tritium (^3H) is a naturally occurring radioisotope of hydrogen that has a half-life of 12.43 years. Tritium is measured in tritium units (TU), where one tritium unit equals one tritium atom in 10^{18} hydrogen atoms. Tritium is produced naturally in the upper atmosphere by cosmic radiation, but greater quantities were created by atmospheric testing of nuclear weapons between 1951 and 1980, which resulted in higher tritium concentrations in precipitation and ground water that was recharged during that time (Clark and Fritz, 1997). Most of the "bomb" tritium has now been washed from the atmosphere, and tritium levels in precipitation are returning to natural levels.

Tritium is incorporated into the water molecule in the atmosphere and its concentration is not significantly affected by reactions other than radioactive decay, so it is an ideal tracer. Tritium analysis can provide model dates for ground water younger than about 40 years, but this method requires multiple samples from wells and was not employed in this

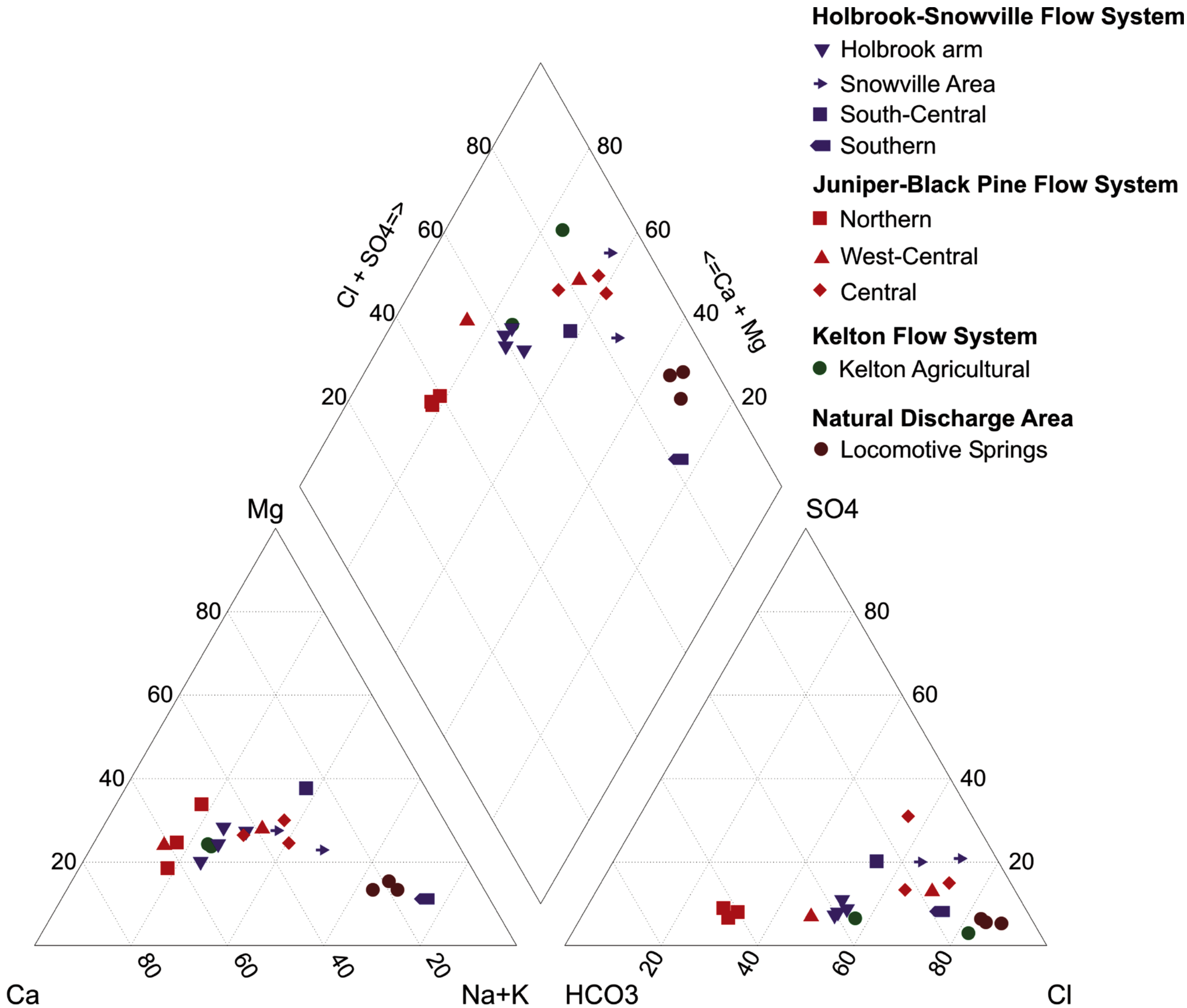

Figure 49. *Piper plot of UGS data.*

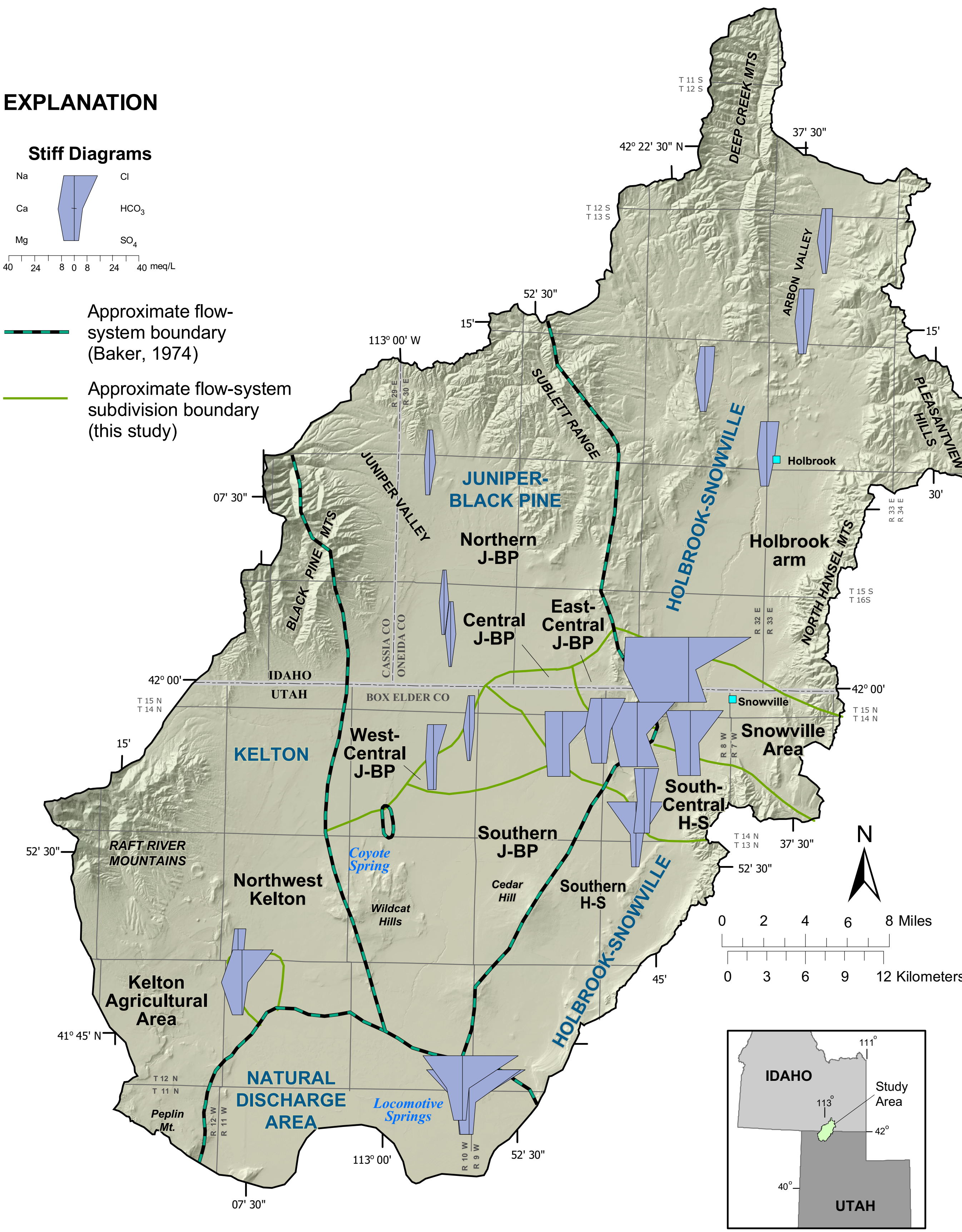

Figure 50. Stiff diagrams of UGS general-chemistry data from Curlew Valley.

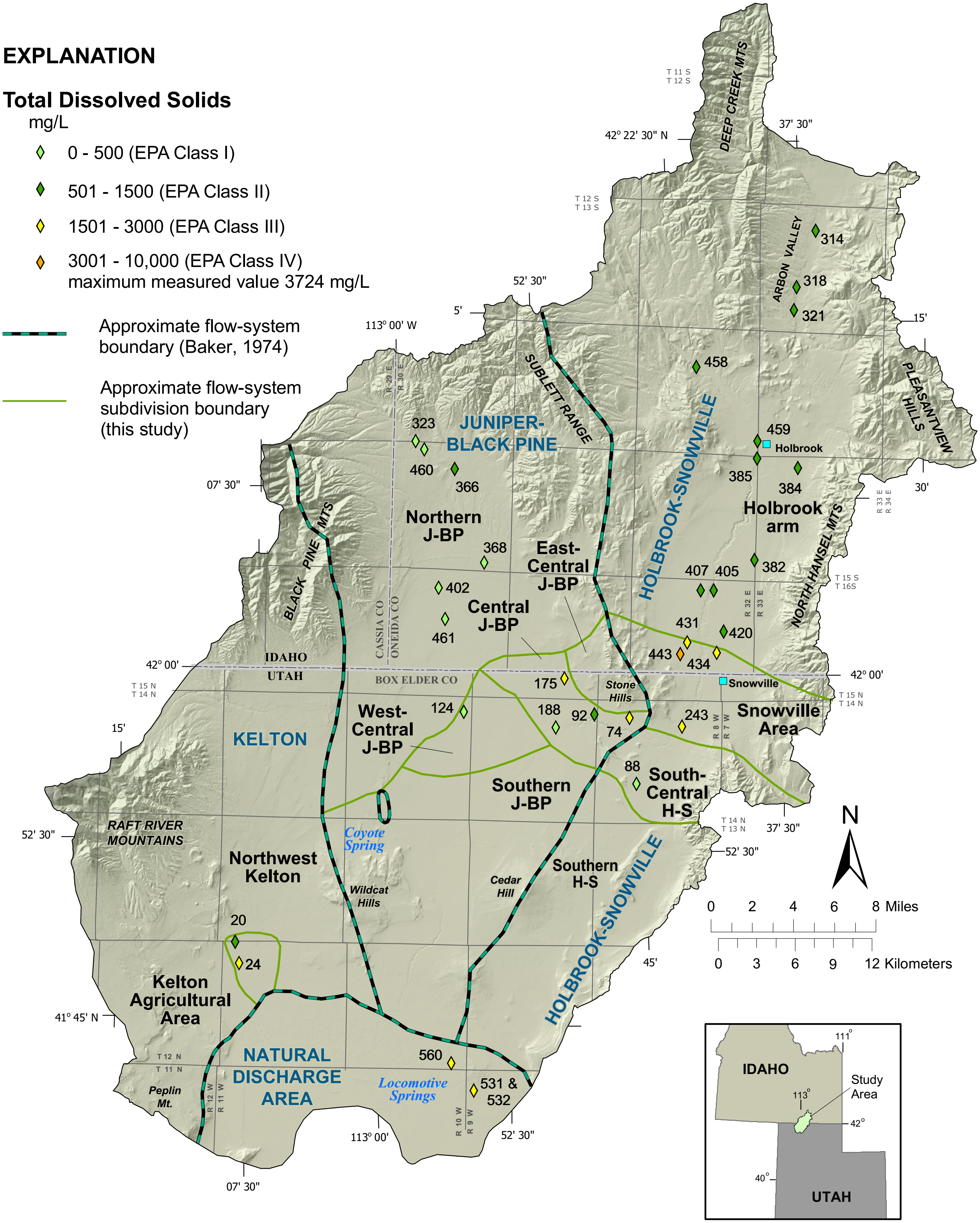

Figure 51. Total-dissolved-solids concentrations of UGS ground-water samples from Curlew Valley.

Table 2. *Ground-water quality classes under the Utah Water Quality Board's total-dissolved-solids (TDS) based classification system (modified from Utah Division of Water Quality, 1998).*

Ground-Water Quality Class	TDS Concentration	Beneficial Use
Class IA[1] /IB[1]/IC[2]	less than 500 mg/L[3]	Pristine/Irreplaceable/ Ecologically Important
Class II	500 to less than 3,000 mg/L	Drinking Water[4]
Class III	3,000 to less than 10,000 mg/L	Limited Use[5]
Class IV	10,000 mg/L and greater	Saline[6]

[1]Irreplaceable ground water (Class IB) is a source of water for a community public drinking-water system for which no other reliable supply of comparable quality and quantity is available due to economic or institutional constraints; it is a ground-water quality class that is not based on TDS. In addition to TDS, Class IA must not exceed any ground-water quality standards.

[2]Ecologically Important ground water (Class IC) is a source of ground-water discharge important to the continued existence of wildlife habitat; it is a ground-water quality class that is not based on TDS.

[3]For concentrations less than 7,000 mg/L, mg/L is about equal to parts per million (ppm).

[4]Water having TDS concentrations in the upper range of this class must generally undergo some treatment before being used as drinking water.

[5]Generally used for industrial purposes.

[6]May have economic value as brine.

Table 3. *Summary of total-dissolved-solids data for flow systems and subdivisions in the Curlew Valley basin-fill aquifer.*

Flow System Subdivision	**Number Of Analyses**	**Range**	**Average**
Holbrook-Snowville			
Northern	38	347-1500	753
Snowville	12	625-4310	1540
South-Central	4	807-1473	1218
Southern	6	1784-3123	2728
Juniper-Black Pine			
Northwestern	10	325-424	388
West-Central	15	384-1012	710
Central	9	832-5852	2515
East-Central	3	833-1119	973
Southern	5	1134-3077	2151
Kelton			
Northwestern	3	362-678	483
Agricultural Area	15	786-2155	1288
Natural Discharge Area			
Locomotive Springs	82	1820-4160	2878
Other Areas	6	2327-63,000	20,000

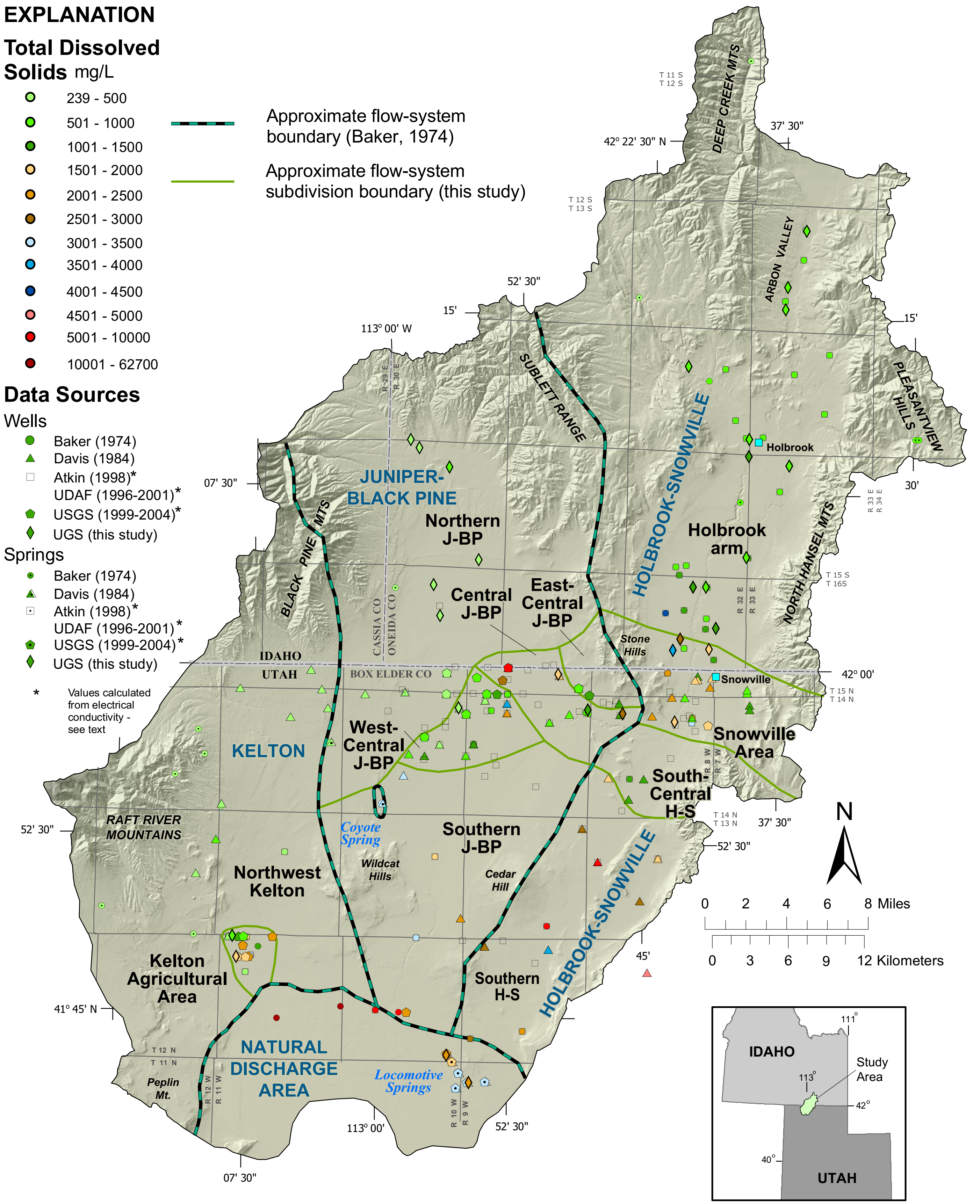

Figure 52. Total-dissolved-solids concentrations of ground-water samples from previous studies and UGS samples in Curlew Valley. For sites with multiple analyses, the most recent data are shown on top.

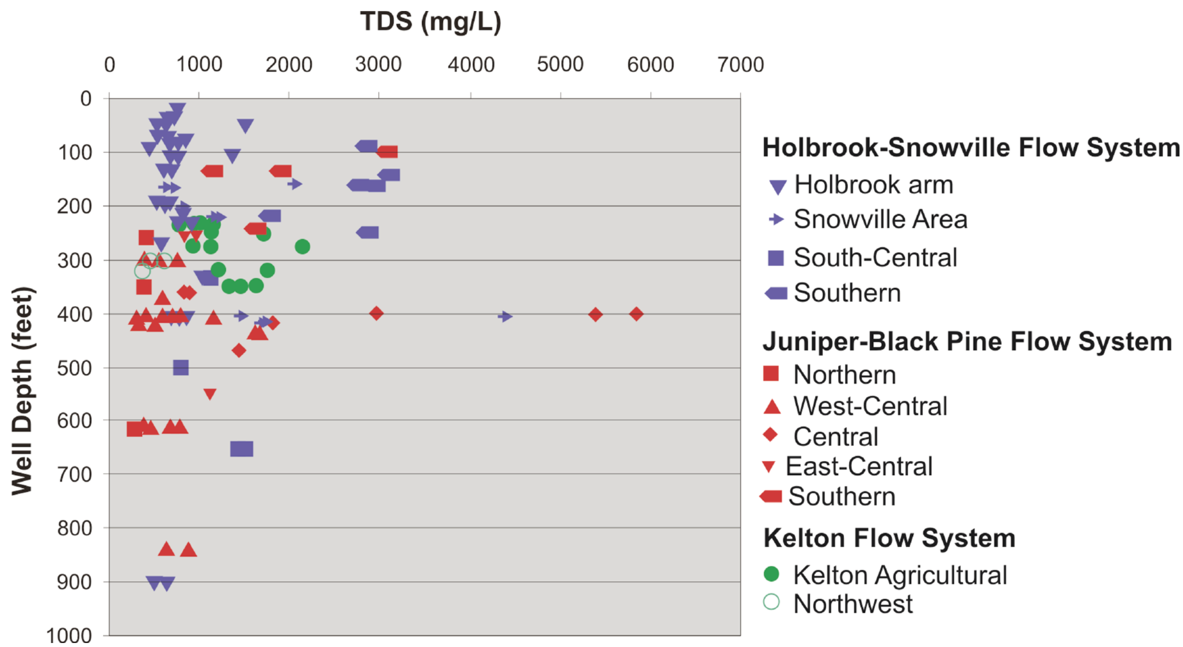

Figure 53*. Plot of well depth versus total-dissolved-solids for wells in the Curlew Valley basin-fill aquifer. No clear correlation exists.*

Table 4*. Results of isotopic analyses; age estimates based on tritium values are from Clark and Fritz (1997).*

Sample	δ^2**H** (‰)	δ^{18}**O** (‰)	δ^{13}**C** (‰)	^{3}**H** TU	^{14}**C** PMC	**Age** ^{14}C Years[1]	**Age** Tritium	**Well Depth** (ft)
Holbrook-Snowville flow system								
Holbrook arm subarea:								
314	-126.7	-16.28	-9.90	8.9	92.87	Modern	Modern (<10 years)	90
459	-127.9	-16.56	-10.43	6.4	86.40	Modern	Modern (<10 years)	--
Snowville subarea:								
243	-129.1	-16.38	-9.05	1.4	54.27	Modern	Mix (modern and submodern)	--
South-central subarea:								
88	-127.4	-16.38	-7.65	2.0	58.45	Modern	Mix (modern and submodern)	650
Southern subarea:								
246	-129.3	-16.67	-6.15	0.2	32.64	4000	Submodern (pre 1952)	--
Juniper–Black Pine flow system								
Northern subarea:								
402	-131.5	-17.33	-6.87	0.2	30.17	4500	Submodern (pre 1952)	485
460	-131.2	-17.16	-8.09	0.5	31.11	3500	Submodern (pre 1952)	--
Central subarea:								
74	-126.9	-16.27	-10.41	1.0	72.23	Modern	Mix (modern and submodern)	174
92	-130.7	-16.70	-10.72	0.8	60.11	Modern	Mix (modern and submodern)	255
188	-128.7	-16.43	-9.40	1.2	--	Likely Modern	Mix (modern and submodern)	245
West-central subarea:								
124	-133.0	-17.32	-8.06	0.9	22.87	7000	Mix (modern and submodern)	343
134	-132.2	-17.30	-7.10	0.2	11.58	12,000	Submodern (pre 1952)	840
Locomotive Springs								
531	-130.3	-16.99	-6.54	0.1	42.78	1400	Submodern (pre 1952)	--
532	-132.2	-17.03	-7.80	0.3	42.51	2000	Submodern (pre 1952)	--
560	-131.6	-17.01	-6.67	0.2	37.33	3000	Submodern (pre 1952)	--
Kelton flow system								
20	-125.0	-16.38	-6.74	10.1	--	Modern	Modern (<10 years)	--

-- No Data

1. Age uncertainties are 250 to 500 years (A. Mayo, Brigham Young University, written communication, 6/20/2006).

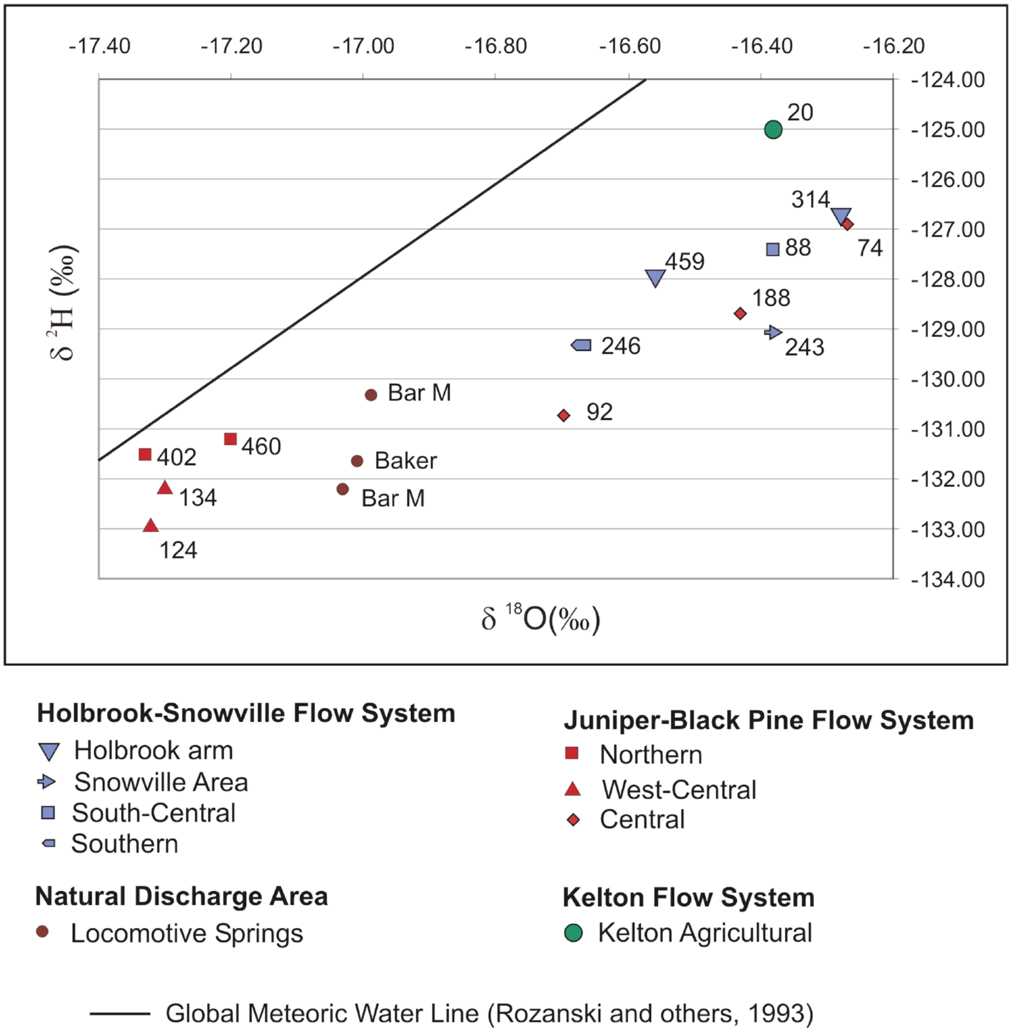

Figure 54. *Oxygen-18 versus deuterium plot of Curlew Valley samples. Number corresponds to well ID (table C.2).*

study. The concentration of tritium in single samples from wells and springs can, however, be used to qualitatively assess the time of recharge of the ground water. The presence in a ground-water sample of tritium in concentrations greater than that produced by cosmic radiation alone indicates that at least some of the water was recharged after 1952 (Clark and Fritz, 1997). Samples having less than 0.8 TU are classified as "submodern" (recharged before 1952), those having TU between 0.8 and 4 are interpreted to consist of a mixture of pre-1952 and post-1952 water, samples ranging between 5 and 15 TU are considered modern, having been recharged during the past 10 years, and samples with greater TU values were recharged during the bomb-testing period (Clark and Fritz, 1997, p. 185).

Tritium was detected in all analyzed samples, and measured TU values ranged from 0.1 to 10.1 (table 4). Ground water in the Holbrook arm of the Holbrook-Snowville flow system is modern, recharged after 1952. Ground water from the Snowville and south-central parts of the Holbrook-Snowville flow system is a mix of modern and submodern waters and is submodern in the southern part. Ground water from the northern Juniper–Black Pine flow system is submodern, and samples from the central and west-central parts of the Juniper–Black Pine flow system are a mix of modern and submodern waters. Three samples from the Locomotive Springs complex yielded submodern ages, and ground water in the Kelton flow system is modern. In general, the older tritium age estimates come from the deeper wells, samples from the agricultural areas north and west of Snowville yielded mixed ages, and samples from the upper part of the Holbrook-Snowville flow system, where the greatest amount of recharge to the Curlew Valley basin-fill aquifer occurs, yielded modern ages.

Carbon-14 and Carbon-13: Carbon-14 (^{14}C) is a naturally occurring radioactive isotope of carbon that has a half-life of about 5730 years. Carbon-14 data are expressed as percent modern carbon (PMC) based on the National Bureau of Standards oxalic acid standard. Atmospheric testing of nuclear weapons also produced carbon-14, so in some instances values greater than 100 PMC can occur in ground water that was recharged when the atmosphere had above-natural levels of carbon-14.

The carbon-14 method of dating ground water is complex, and we present only a very brief description here. The age calculations, which require estimates of some chemical parameters during recharge and model calculations of reactions during the transport history of the ground water, were performed for this study by Dr. Alan Mayo of Brigham Young University (written communication, 6/20/2006). For a more detailed description of carbon-14 dating and the various required corrections and calculations see Clark and Fritz (1997, p. 200–231).

To calculate an age estimate for ground water, the initial activity of carbon-14, established as the water infiltrates through the soil zone, must be estimated. Carbon-14 is not part of the water molecule, so its activity is affected by chemical reactions between the aquifer material and dissolved constituents in the water that occur during and after initial infiltration. Chemical reactions can either add or remove carbon; therefore, knowledge of which chemical reactions occurred during recharge and transport through the aquifer is necessary to estimate the initial carbon-14 activity. This is the most difficult aspect in using carbon-14 for dating ground water.

Chemical reactions between ground water and aquifer material that involve carbon can be evaluated by the carbon-13 composition of the water, a naturally occurring stable isotope of carbon. The carbon-13 composition of ground water is expressed using the delta notation, similar to oxygen-18 and deuterium. The reference standard for carbon-13 is the Vienna Pee Dee Belemnite (VPDB), which has an isotopic ratio ($^{13}C/^{12}C$) = 1.1237×10^{-2} (Clark and Fritz, 1997). The carbon-13 concentration in ground water depends upon numerous factors, including whether the system is open or closed, the type of vegetation in the recharge area, and whether carbonates are dissolved or precipitated during recharge.

The amount of carbon dioxide in ground water is in part a function of recharge conditions, including whether the ground water was recharged under open or closed conditions. Under open conditions, ground water is assumed to be in equilibrium with the soil CO_2, so the calculated log P_{CO2} (log of partial pressure of CO_2 in water) value of a water sample reflects that of the soil. The log P_{CO2} values of the UGS water samples, calculated using Henry's Law constants from Plummer and Busenberg (1982), range between -2.27 and -4.34, with an average of -2.86 (A. Mayo, Brigham Young University, written communication, 6/20/2006). Bacterial oxidation of vegetation in soils and respiration of CO_2 in the root zone maintains log P_{CO2} levels between -3 and -1 (Clark and Fritz, 1997); the levels found in Curlew Valley are in the lower part and below this range.

The calculated log P_{CO2} values of some Curlew Valley samples are consistent with open conditions, whereas others reflect closed conditions. Ground water that infiltrates through the vadose zone in the valley is under open conditions, but once ground water reaches the water table, conditions may become closed, especially where the aquifer is confined. In contrast, ground water recharged in the mountains can flow into joints and fractures in the bedrock under closed, or at least lower P_{CO2} conditions, so it does not spend significant time equilibrating with soil CO_2 under open conditions.

The $\delta^{13}C$ values of our samples lie between the $\delta^{13}C$ values characteristic of open and closed conditions, suggesting that both types of conditions occur along ground-water flow pathways in Curlew Valley (table 4). Under closed conditions at a soil log P_{CO2} level of -2.5, the $\delta^{13}C$ value of ground water calculated by Clark and Fritz (1997) is -12.1‰. Under open conditions at a soil log P_{CO2} level of -2.5, the $\delta^{13}C$ value of ground water calculated by Clark and Fritz (1997) is -5.3‰. The observed range in may $\delta^{13}C$ also be influenced in part by variations in vegetation type, which exhibit a range of characteristic $\delta^{13}C$ values.

The calculated carbon-14 age estimates of the UGS water samples indicate that ground water in Curlew Valley is between modern and approximately 12,000 years old (table 4). Ground water from the northern Holbrook-Snowville, Kelton agricultural, and central Juniper–Black Pine flow systems was determined to be modern. These are agricultural areas, so the ground water there is likely recharged in part by irrigation return flows. The ground-water samples from the northern and west-central Juniper–Black Pine flow system yielded ages from 3500 to 12,000 years; ground water from this flow system contains the oldest water in Curlew Valley. These age estimates increase from north to south, consistent with water-level contours that suggest generally southward flow of ground water in this flow system (Baker, 1974). Ground water from Bar M Spring is dated at about 1400 to 2000 years old, and the age of the Baker Spring sample is about 3000 years.

In the Holbrook-Snowville flow system, ground-water age and well depth are roughly correlated, based on limited information; the tritium age estimate from well 88 (650 feet [198 m] deep) is mixed modern and submodern, whereas the tritium age from well 314 (90 feet [27 m] deep) is modern (table 4). The carbon-14 age estimates of both samples are modern. Unfortunately, the depths of the other three sampled wells in the Holbrook-Snowville flow system are unknown. In the Juniper–Black Pine flow system, the youngest carbon-14 and tritium age estimates are from the three shallowest wells sampled (74, 92, and 188) (table 4). The oldest carbon-14 age estimate is from the deepest well (134), and water from two intermediate-depth wells (124 and 402) yielded intermediate ages, although the age from the deeper of these two wells is younger (table 4). Tritium ages are submodern or mixed modern and submodern for all samples having carbon-14 ages older than modern.

Interpretation and Discussion

Water-Quality Issues

Possible causes of the high TDS values in the central Juniper–Black Pine, southern Holbrook-Snowville, and Kelton agricultural areas include (1) infiltration of high-TDS irrigation water having dissolved solids concentrated by evaporation (i.e., irrigation return flow), (2) dissolution of evaporite minerals in lacustrine and/or playa deposits in the subsurface, and (3) mixing of meteoric-derived ground water with higher-TDS water heated by and/or derived from subsurface magmatic intrusions (Baker, 1974).

Several lines of evidence suggest that the composition and TDS concentration of ground water in the agricultural areas of Curlew Valley is related largely to processes that occur during infiltration and percolation of irrigation water and precipitation through the vadose zone, rather than to interaction with deeper geologic material. Ground water in the most intensively irrigated agricultural areas of Curlew Valley is characterized by (a) declining ground-water levels (figures 35 and 36), (b) higher TDS values (figures 42 and 48) than non-irrigated parts of the valley, (c) steadily increasing electrical conductivity due primarily to addition of sodium and chloride (figures 45 and 46), and (d) higher average ground-water temperature (excluding Coyote Spring) than non-irrigated parts of the valley (figure 47). Baker (1974) and Atkin (1998) documented all of the relations listed above, and our work shows that the trends they observed continue to the present.

Precipitation rates and pH influence the ground-water chemistry in Curlew Valley, based on the following data (figures 55 and 56). Figure 56 compares precipitation records and time-series plots of pH and calculated saturation indices of common vadose-zone minerals, from selected UDAF-sampled wells. Precipitation records were not collected at Snowville after 1991, so we used records from Grouse Creek, the nearest climate station with records for 1996 to 2001 (see figure 26 for locations), the same time period as the UDAF data. This approach is valid because comparison of annual precipitation records from climate stations in Grouse Creek and Snowville while both stations were active (figure 25) shows that precipitation in the Snowville area is typically higher, but varies in a similar manner.

The time-series plots of pH (figure 56) show a pattern similar to the precipitation data, with a one-year phase delay; the local maximum for precipitation occurred in 1998, whereas the maximum pH was measured in 1999. Increased rainfall, therefore, increases the pH of water infiltrating through the vadose zone, and this water takes about one year to reach the water table at around 100 to 200 feet (30–60 m). Figure 56 also presents time-series plots of saturation indices (see Glossary for definition) of common vadose-zone minerals, calculated from UDAF data (table D.1). The carbonate minerals aragonite, calcite, and dolomite are close to saturation (saturation index = 0), whereas the sulfate minerals (gypsum and anhydrite) and halite are always well below saturation. Pulses of infiltrated precipitation moving through the vadose zone raise the pH of vadose-zone water, decreasing the solubility product of the carbonate minerals until they reach saturation, whereas anhydrite, gypsum, and halite dissolve into vadose-zone water continuously when sufficient water is available. Dissolution of these minerals by infiltrating precipitation occurs periodically, when sufficient precipitation falls on the valley floor to recharge the aquifer. The soluble minerals accumulate in the vadose zone due to evaporative concentration of irrigation water, especially during times of low rainfall. In summary, figure 56 shows that the pH of ground water increases about one year after times of high precipitation and/or runoff of snowmelt. These pulses of higher-pH water preferentially dissolve sulfides and halite in the vadose zone and, thereby, increase the TDS and sulfate and sodium chloride content of Curlew Valley ground water.

The isotopic composition of ground water in Curlew Valley can provide more information about the cause of high sodium chloride content in ground water. If high chloride concentrations are due to evaporation, an evaporative isotopic signature would be imposed on the ground water because evaporation is a fractionation process, in which isotopically lighter water molecules require less energy to evaporate than isotopically heavier water molecules; the latter are thereby concentrated in the remaining ground water. In contrast, if the high chloride concentrations result from plant transpiration, the ground water should contain no isotopic evaporative signature because transpiration is not a fractionation process—both isotopically light and heavy water molecules are transpired at the same rate. To test these alternatives figure 57 presents a plot of chloride concentration versus δ^2H for the UGS data. If evaporation is the primary agent that concentrates salt in the soil and ground water then a positive correlation would exist between chloride and δ^2H, where the concentration of chloride increases as deuterium becomes more enriched. The data from the Juniper–Black Pine flow system show a positive correlation between deuterium and chloride concentration, whereas data from the Holbrook-Snowville flow system show a weak negative correlation. Evaporative concentration of dissolved solids in irrigation water apparently affects the composition of ground water in the Juniper–Black Pine Flow system, whereas other processes such as transpiration may be more important in the Holbrook-Snowville flow system. Samples from the Snowville (243) and southern (246) parts of the Holbrook-Snowville flow system, the two areas having highest average TDS, plot along the trend defined by samples from the Juniper–Black Pine flow system. This may be coincidence, or evaporation may strongly influence ground-water composition in these areas as well.

Several lines of evidence suggest that the high TDS concentrations in the central Juniper–Black Pine and Snowville and southern parts of the Holbrook-Snowville flow systems result from use of ground water for irrigation in a semi-arid climate. Evapotranspiration causes minerals to precipitate out of solution and/or concentrates solutes in the vadose-zone water. When irrigation water is pumped from wells and applied to fields, it percolates down through the soil and dissolves the more soluble minerals, such as halite, so cyclic wetting and drying of the soil leads to a buildup of sodium and chloride in the ground water. This problem is compounded by drought because farmers rely more on irrigation from ground water when precipitation is low. When precipitation or runoff from snowmelt occurs on the valley floor in sufficient amounts to recharge the aquifer, halite and sulfates dissolve into the percolating vadose-zone water, and eventually enter the ground water.

At the beginning of this section we suggested that dissolution of evaporite minerals in lakebed sediments and thermal water returning from deep circulation are also candidates for causing poor ground-water quality in Curlew Valley. The evidence presented above does not necessarily discount these ideas.

Bolke and Price (1969, p. 12) indicated that fine-grained Lake Bonneville lakebed deposits in the Curlew Valley basin-fill aquifer are "fair to poorly drained and have a medium to high salt content." These deposits are widespread in the basin-fill aquifer, so if they are responsible for poor ground-water quality only in the agricultural areas, they would need to be unusually thick or saline there but not elsewhere. Feth and others (1966, p. 62) and Clark and others

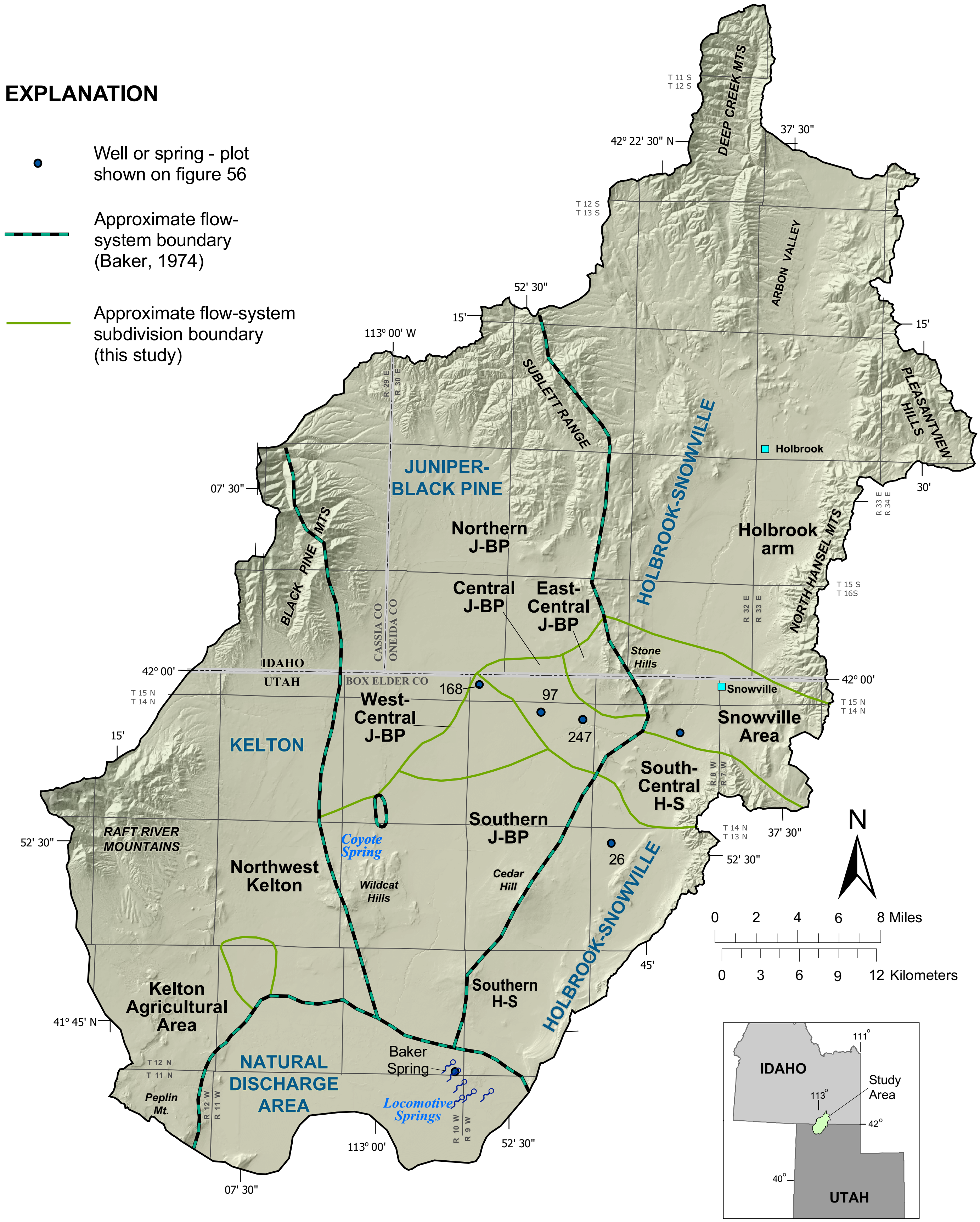

Figure 55. Location of water wells and Baker Spring in Curlew Valley for which time-series plots of pH and saturation indices are shown in figure 56.

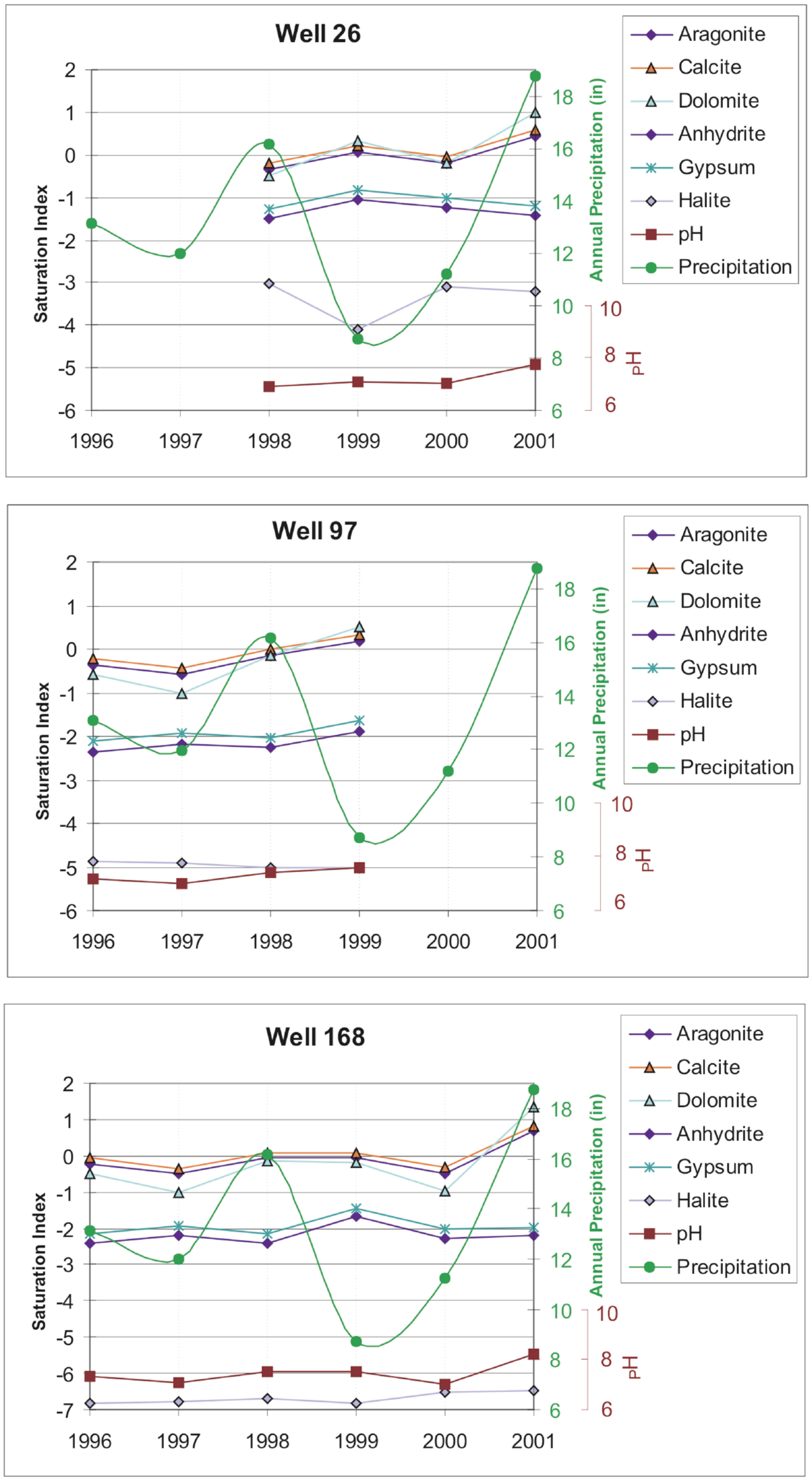

***Figure 56.** Time-series plots of saturation indices of common vadose-zone minerals from selected UDAF samples, calculated using PHREEQC (Parkhurst and Appelo, 2000), pH from UDAF data (table D.1), and annual precipitation at Grouse Creek climate station (Western Regional Climate Center, 2005). See figure 55 for sample locations.*

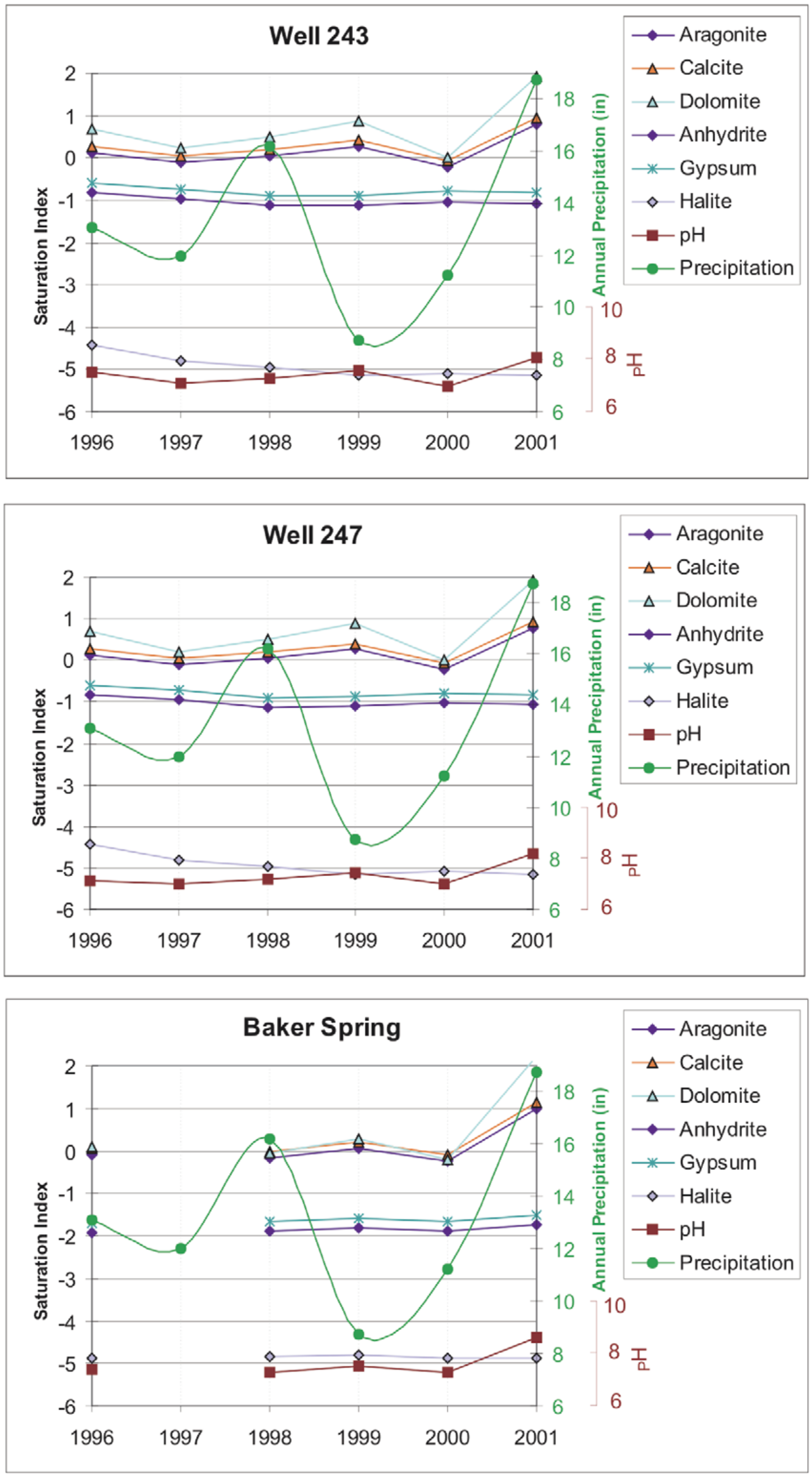

Figure 56. *(continued)*

(1990, p. 84) suggested that the anomalously high chloride content in ground water in the Ogden–Plain City area along the Wasatch Front in north-central Utah is due to dissolution of evaporite and other minerals in unusually thick deposits of fine-grained lacustrine sediment that accumulated in an embayment of Lake Bonneville in that area. Similar embayments and resulting poor ground-water quality may occur in parts of Curlew Valley. However, neither the central Juniper–Black Pine nor the southern Holbrook-Snowville flow system (both of which have diminished ground-water quality) is located in an appropriate topographic and geologic setting, and water-well logs do not display unusually thick clay deposits in these areas (cross sections A-A', A''-A''', and C-C', plate 2). Poor quality water occurs in the southern Holbrook-Snowville flow system where basalt, not lacustrine deposits, is the dominant lithology (cross section A-A', plate 2), and better-quality water is found in some areas dominated by fine-grained lacustrine deposits, namely the northern part of the Juniper–Black Pine flow system and the southern part of Holbrook arm in the Holbrook-Snowville flow system (cross section A''-A''', plate 2) (also compare figures 8 and 52). Although fine-grained lakebed or playa deposits influence the composition of ground water in the Curlew Valley basin-fill aquifer, these deposits are not likely responsible for the observed local degradation of ground-water quality in the agricultural areas.

Thermal water likely influences ground-water chemistry in the central Juniper–Black Pine flow system and at Coyote Spring and a nearby well (Davis, 1984; Davis and Kolesar, 1984). The thermal water is generated in localized areas having steep geothermal gradients, presumably caused by young igneous intrusions at depth. In these areas, deeply circulating water having high TDS due to dissolution of wall rocks and sediments rises along faults and mixes with shallow ground water (Davis, 1984; Davis and Kolesar, 1984). The presence of thermal water in the central Juniper–Black Pine flow system compounds the ground-water quality problems related to irrigation described above.

Isotopic Composition of Ground Water

Evaporation of surface water or soil water prior to recharge causes enrichment of heavier isotopes in ground water. If snowmelt is a significant recharge source, the enrichment could be from sublimation of the snow and evaporation of surface runoff. The isotopic composition of ground water that has undergone evaporation prior to recharge plots as a linear array below the GMWL on a deuterium-oxygen 18 plot (Clark and Fritz, 1997), as observed for the data from Curlew Valley (figure 54). A linear regression of the oxygen-18–deuterium isotopic data from Curlew Valley suggests an evaporative-trend line with a slope of about 5.3 (figure 58), consistent with the typical range for evaporation-trend lines of 2 to 6 (Clark and Fritz, 1997, p. 87-88; Kehew, 2001) for ground water in other arid regions known to have undergone extensive evaporation prior to recharge.

White and Chuma (1987) attributed enrichment of heavier isotopes in ground water in the western United States to paleoclimate effects. The samples from the northern and west-central Juniper–Black Pine flow system have the lightest (most negative) isotopic composition and the oldest ages (table 4; figure 58), suggesting that their distinct isotopic composition, as compared to the other samples from the basin, may largely result from having been recharged under different climatic conditions. The younger samples, all of which are from agricultural areas, have less negative isotopic compositions (more enriched in the heavier isotopes), perhaps in part due to having a significant component of recharge from irrigation return flow as discussed in the previous section. These younger samples, especially the three from the central Juniper–Black Pine flow system, form a diffuse linear array, suggestive of an evaporative trend, on the oxygen-18–deuterium plot. Some of the dispersion in isotopic composition among these samples may result from mixing with thermal ground water, especially in the central Juniper–Black Pine flow system. Positive shifts in $\delta^{18}O$ due to oxygen exchange between rocks and water at temperatures greater than 100° C (Craig, 1963; Giggenbach, 1978; Clark and Fritz, 1997) can produce dispersion of isotopic composition parallel to the oxygen-18 axis.

Ground-Water Flow Systems

On the oxygen-18–deuterium plot (figures 54 and 58), ground water from the northern and west-central Juniper–Black Pine and the Holbrook-Snowville flow systems cluster into statistically distinct groups based on the results of "t" and "U" statistical tests. Samples from the central Juniper–Black Pine flow system (samples 74, 92, and 188) plot within the cluster defined by the Holbrook-Snowville flow system (figures 54 and 58). The similar isotopic composition of samples from the central Juniper–Black Pine and Holbrook-Snowville flow systems suggests that ground water in that vicinity is a mixture of water derived from the two flow systems. The isotopic age data (table 4; figure 58) supports this idea; samples from the central Juniper–Black Pine flow system are distinctly younger than those from the northern and west-central parts, and ground water from the Holbrook-Snowville flow system is mostly modern to submodern. Although other possible explanations exist, the younger ages in the central Juniper–Black Pine flow system are interpreted here to result from mixing with Holbrook-Snowville flow-system water. The mixing may occur because the pronounced depression of water levels in the agricultural area west of Snowville (figure 34) creates a head gradient that draws water from the Snowville part of the Holbrook-Snowville flow system westward into the central Juniper–Black Pine flow system.

The possibility of mixing of ground water from the Snowville part of the Holbrook-Snowville flow system and the central Juniper–Black Pine flow system can be evaluated by defining hypothetical end-members of the mixing system as the mean isotopic compositions of the combined Holbrook arm and Snowville parts of the Holbrook-Snowville flow system, the combined northern and west-central parts of the Juniper–Black Pine flow system, and the product of the mixing, the central Juniper–Black Pine flow system. Linear regression of these three end members yields a statistically significant line with $R^2 = 0.98$ (figure 59), supporting the idea of simple linear mixing between the Holbrook-Snowville and Juniper–Black Pine flow systems. The mean composition of samples from the central Juniper–Black Pine flow system is not perfectly co-linear with the proposed end members, but plots slightly to the right of the proposed mix-

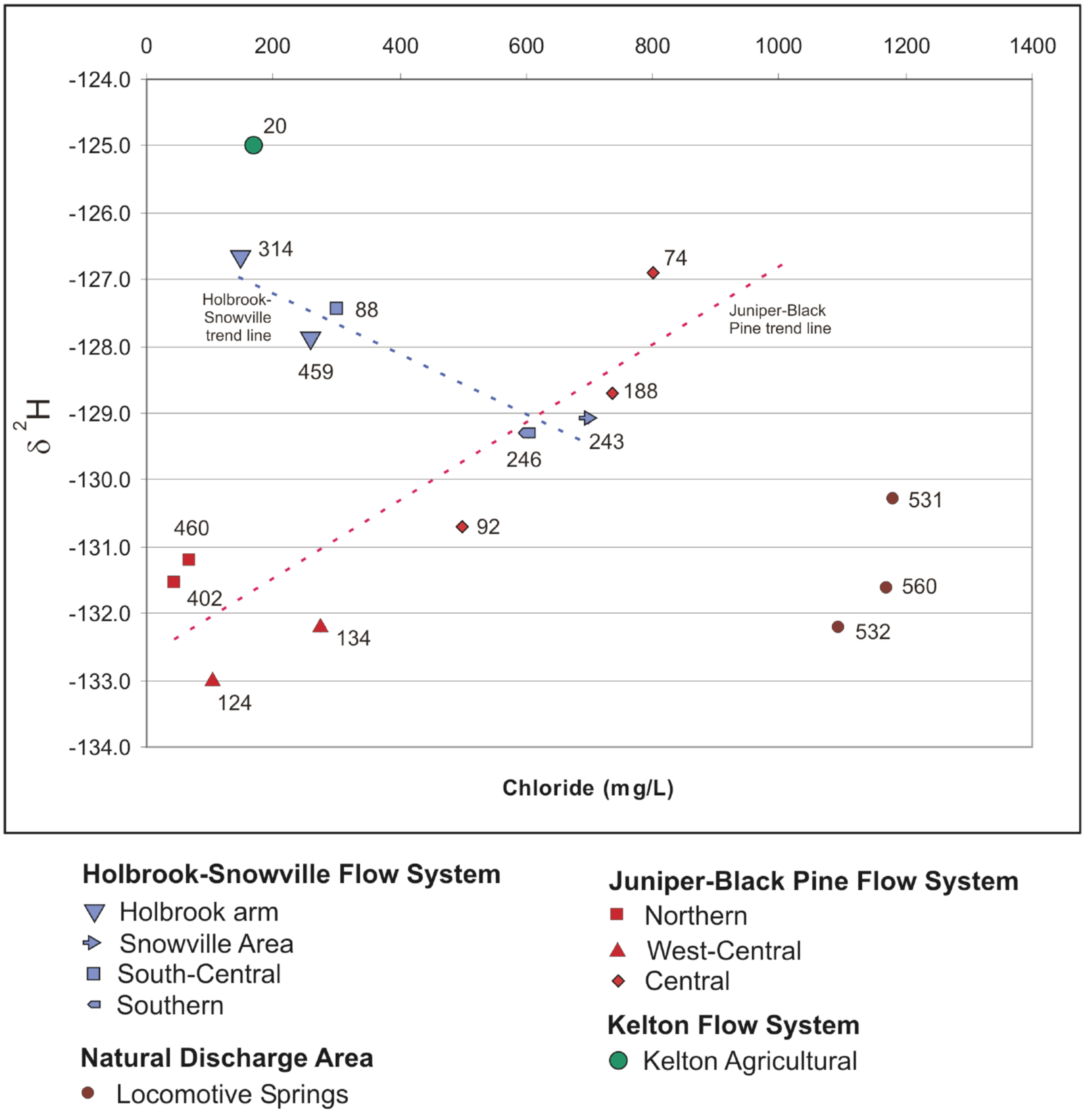

Figure 57. *Plot of chloride versus deuterium (^2H) in UGS isotope samples.*

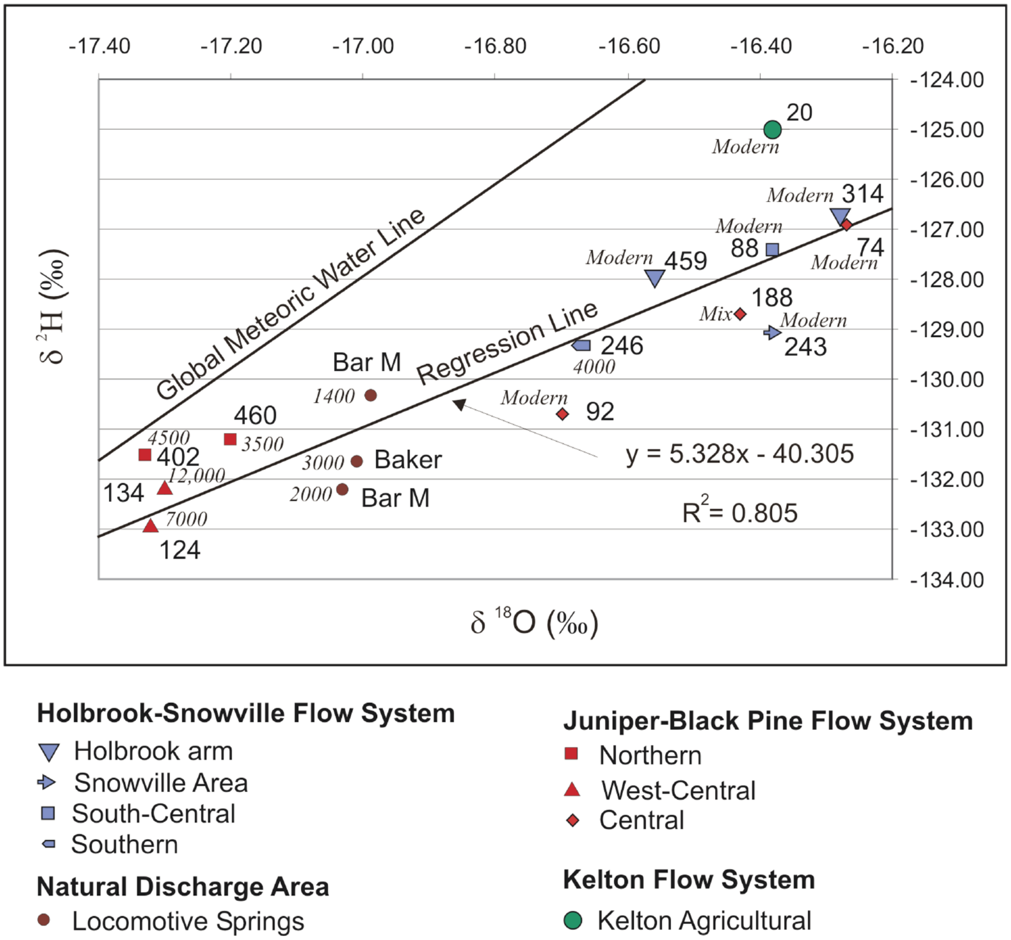

Figure 58. Linear regression results of oxygen-18 and deuterium data. Radiometric-age estimates (table 4) shown in italics.

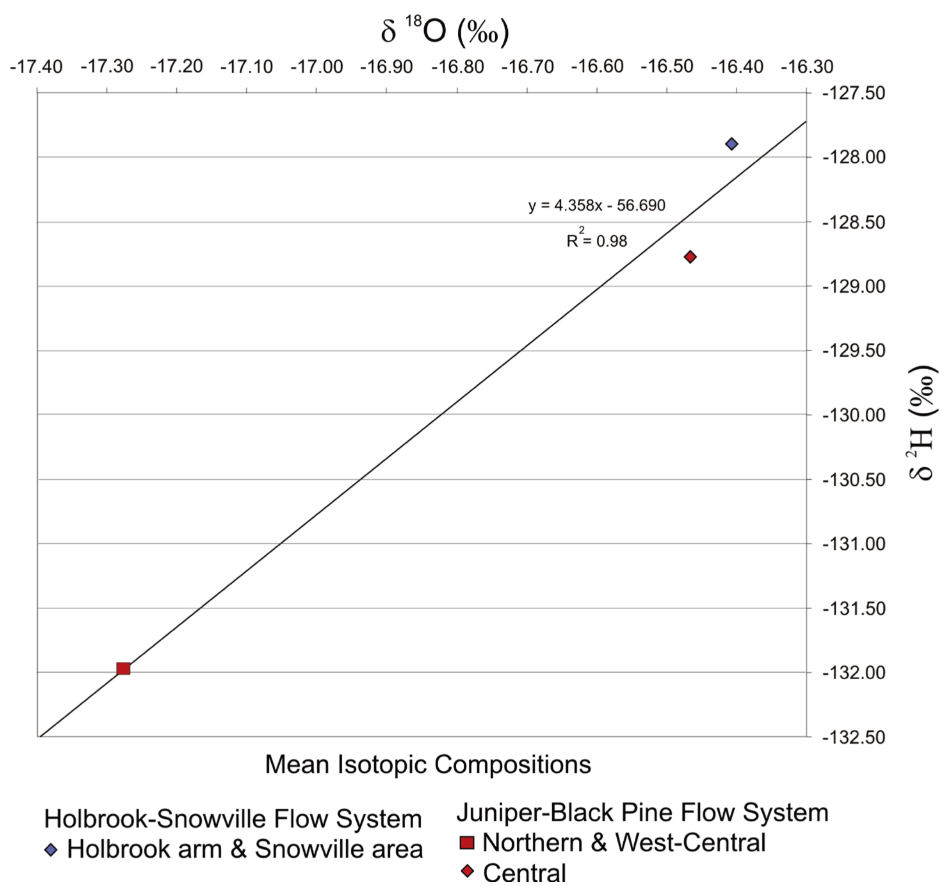

Figure 59. Regression line illustrating that mixing of the mean isotopic compositions of Juniper–Black Pine and Holbrook-Snowville flow-systems could produce the composition of samples from the central Juniper–Black Pine flow system.

ing line connecting them. This relation may reflect addition of ground water to the central Juniper- Black Pine flow system having isotopic composition affected by evaporation during irrigation, or the influence of thermal water (Davis, 1984; Davis and Kolesar, 1984).

The mean isotopic composition of samples from Bar M (samples 531 and 532) and Baker (sample 560) Springs is intermediate between the mean compositions of the northern and west-central Juniper–Black Pine and Holbrook-Snowville groups (figure 54). This relation is consistent with the interpretation that water issuing from the Locomotive Springs complex is a mixture of water from the two flow systems. Figure 60 shows evidence for this interpretation, where the means of the three data groups form a statistically significant line ($R^2 = 0.96$). If this line represents a simple binary mixing line between the Juniper–Black Pine and Holbrook-Snowville flow systems as end members, then water from the Locomotive Springs complex is composed of about 70% water derived from the Juniper–Black Pine flow system. This estimate could be refined by obtaining more isotopic data from the southern parts of the Juniper–Black Pine and Holbrook-Snowville flow systems, where the mixing likely occurs. Until such data are available, we interpret this mixing ratio as preliminary, and conclude that the Juniper–Black Pine flow system contributes a significant, but as yet unquantified proportion of discharge from the Locomotive Springs complex. The mean composition of the Locomotive Springs samples plot to the right of a line connecting the proposed end members, suggesting that additional sources having undergone evaporation, perhaps small amounts of recharge from the Hansel Mountains and adjacent agricultural areas in southeastern Curlew Valley, also contribute to Locomotive Springs discharge. The isotopic data do not suggest a significant contribution from the Kelton flow system to the discharge at Locomotive Springs.

The age estimate for ground water from the Locomotive Springs complex is about 1400 to 3000 years old, intermediate between the average age estimates of ground water in the Juniper–Black Pine and Holbrook-Snowville flow systems. This relationship is consistent with the hypothesis that ground water discharged from the Locomotive Springs complex is a mixture of water from the two flow systems.

The ground water sampled from wells and Locomotive Springs is a mixture of waters having various residence times in the Curlew Valley aquifer, possibly including unused irrigation water, water recharged before settlement of the valley, and water that was incorporated into the geologic formations during or shortly after deposition (Bethke and Johnson, 2002). An age estimate for a ground-water sample, therefore, does not represent the residence time of that sample in the aquifer, but is an average age that depends on the ages (residence time) and relative proportions of the different sources that comprise the mixture. Because the age estimates of the Locomotive Springs samples represent mixing of different-aged waters, they do not provide an estimate of the travel time of ground water from recharge areas to the springs, nor can the ages be used to directly estimate flow rates in the aquifer. Analysis of chlorofluorocarbons and

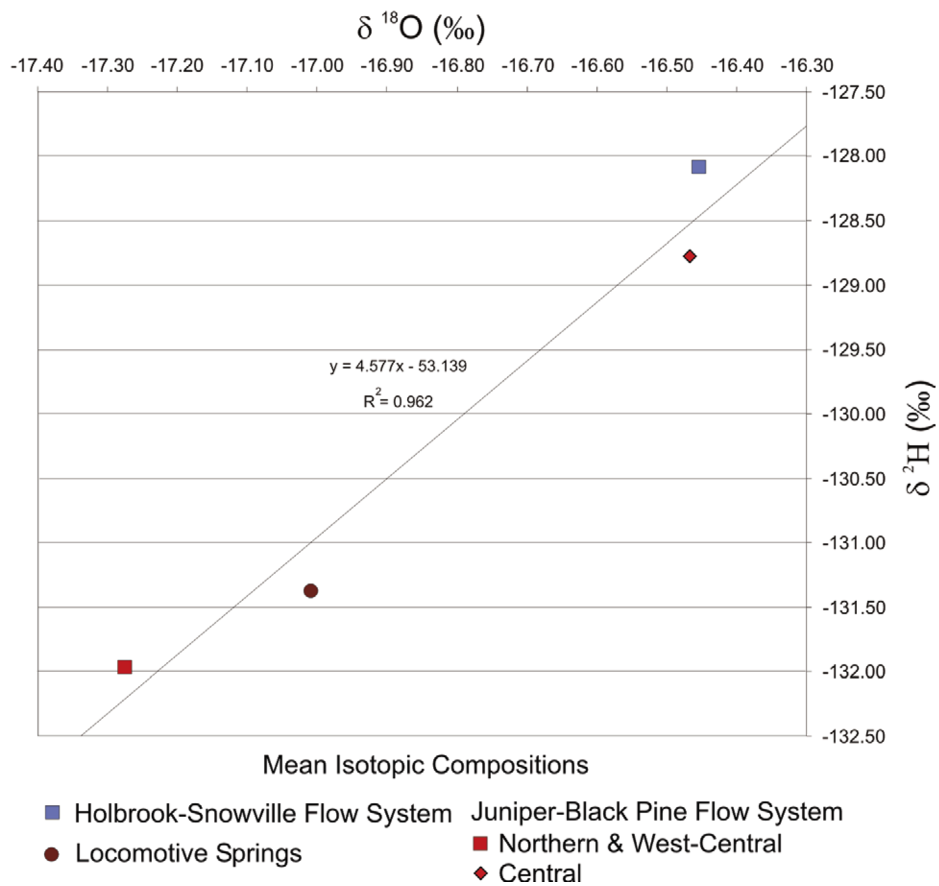

Figure 60. *Mixing line for Locomotive Springs mean between northern and west-central Juniper–Black Pine, central Juniper–Black Pine, and Holbrook-Snowville flow-system means as end-members.*

other dissolved gases could provide estimates of the ages and relative proportions of the different mixing components of Locomotive Springs water and ground water in the Curlew Valley basin-fill aquifer (International Atomic Energy Agency, 2006), and may also help resolve the relative contributions of the Juniper–Black Pine and Holbrook-Snowville flow systems to Locomotive Springs discharge. Such work was beyond the scope of this study.

In the Holbrook-Snowville flow system, ground water from well 246 has a ^{14}C age of 4000 years, but ground water from well 88 is modern. The tritium data suggest that ground water from well 88 is a mix of modern and older water. A similar situation exists with well 188, in which tritium data suggest a mix of "old" and modern ground water. Because agriculture is practiced in the vicinity of these wells, irrigation return flows probably provide the modern component of recharge. The older age of water sampled from well 246 supports Oaks' (2004) suggestion that flow in most of the southern Holbrook-Snowville flow system is very slow and contributes little to discharge from the Locomotive Springs complex.

In the Curlew Valley basin-fill aquifer, ground-water age and well depth are generally positively correlated (table 4), suggesting that the ground-water flow system may be crudely stratified, consisting of older, slower-flowing water below about 400 feet (120 m) depth and younger, faster-flowing water above. The plot of TDS versus well depth (figure 53) does not support this interpretation, but ground-water pumping and irrigation return flow in agricultural areas, which provide most of the data, may disrupt the stratification.

Summary and Conclusions

General-chemistry data indicate that ground water in the central Juniper–Black Pine, southern Holbrook-Snowville, and Kelton agricultural flow systems has greater TDS values and higher sodium and chloride content than other parts of the valley. Use of ground water for irrigation is the most likely cause of the deterioration of ground-water quality. Ground-water levels have declined by about 2 to 80 feet (1-24 m) in these areas during the past 30 years (figures 35 and 36), due to pumping of ground water for agricultural irrigation water. Evaporation of irrigation water concentrates dissolved solids in vadose-zone water, so unused irrigation water that reaches the ground-water table increases the dissolved-solids concentration of the ground water. Also, application of ground water to agricultural fields for irrigation, coupled with high evapotranspiration rates, leads to accumulation of salt in the soil, so that precipitation percolating through the vadose zone to the ground water is laden with soluble salts (mainly sodium and chloride). Ground-water quality problems in the central Juniper–Black Pine flow system may be compounded by the presence of geothermally heated water rising and mixing with the shallow ground-water system (Davis, 1984; Davis and Kolesar, 1984). Ground-water quality in the agricultural areas in Holbrook arm has not deteriorated substantially due to its location adjacent to the major areas of recharge to the Curlew Valley basin-fill aquifer.

Time-series plots of pH and vadose-zone mineral solubility, compared to precipitation records (figures 55 and 56), suggest that evapotranspiration of irrigation water concentrates salts in the vadose zone, and that when sufficient quantities of precipitation and/or runoff of snowmelt are available these minerals are dissolved and carried to the ground-water table. A plot of deuterium versus chloride concentration (figure 57) suggests that evaporation is the primary agent for this process in the Juniper–Black Pine flow system, but does not influence the composition of ground water in the Holbrook-Snowville flow system as strongly.

Oxygen-18 and deuterium data indicate an evaporative signature in the recharging water, especially for the modern-age samples. Some water from the Juniper–Black Pine flow system could have been recharged under cooler climatic conditions, because samples having the oldest isotopic ages are the least enriched in the heavier isotopes. Carbon-14 dating suggests that ground water from the Juniper–Black Pine flow system is significantly older than ground water from the Holbrook-Snowville flow system.

With three important exceptions, oxygen-18 and deuterium data for water samples from the Juniper–Black Pine and Holbrook-Snowville flow systems in Curlew Valley plot as distinct, clustered groups, evidence that they have geographically and isotopically separate source areas. The exceptions are samples from the central Juniper–Black Pine flow system, which have $\delta^{18}O$ and $\delta^{2}H$ values similar to ground water from the Holbrook-Snowville flow system. The cone of depression in the central Juniper–Black Pine flow system may be diverting water from the Holbrook-Snowville flow system westward, causing mixing of ground water from the two flow systems.

Baker (1974) and Oaks (2004) suggested that ground water discharging from the Locomotive Springs complex is derived almost entirely from the Holbrook-Snowville flow system. In contrast, our oxygen-18 and deuterium data from the Locomotive Springs complex are intermediate between the Holbrook-Snowville and Juniper–Black Pine data groups, which suggests that ground water discharged from the Locomotive Springs complex is a mixture of water from the two flow systems. The average isotopic compositions of the Locomotive Springs complex samples and of the Juniper–Black Pine and Holbrook-Snowville flow systems form a well defined line on a oxygen-18-deuterium plot (figure 60), suggestive of mixing of end-member source compositions to produce the composition of the spring water. This hypothesis is reinforced by the fact that the carbon-14 apparent ages of ground water from the Locomotive Springs complex are intermediate between the apparent ages derived for the Juniper–Black Pine and Holbrook-Snowville flow systems.

DISCUSSION—IMPLICATIONS OF BASIN STRUCTURE AND GROUND-WATER CHEMISTRY

Ground-Water Flow Systems and Source of Locomotive Springs

The isotopic composition and apparent age of ground water from wells 74, 92, and 188 in the central Juniper–Black Pine flow system, together with the ground-water levels and geology of central Curlew Valley, suggest that ground water in that area is a mixture of water from the Juniper–

Black Pine and Holbrook-Snowville flow systems (figure 61). The oxygen-18-deuterium composition and apparent ages of ground water from those wells are intermediate between the statistically distinct average compositions and apparent ages of the two flow systems (figure 59; table 4), which suggests that mixing of the two sources occurs in that area.

Ground-water levels in the central Juniper–Black Pine flow system are up to 300 feet (100 m) lower than those in the Snowville area of the Holbrook-Snowville flow system and are, in some wells, steadily declining, which creates a head gradient between the two areas. We do not know whether the head gradient and hypothesized westward flow existed prior to the pumping of ground water for agriculture, but ground-water pumping has at least increased the gradient between the two areas during the past 30 years. Gravity data from this study reveal a major fault zone, herein named the Snowville transverse fault zone, that is concealed beneath the valley and strikes east-southeast from the area immediately south of the Stone Hills (southern end of the Sublette Range) to the offset of the Hansel Mountains range front southeast of Snowville. This fault zone may, by virtue of enhanced secondary permeability in its damage zone (Caine and others, 1996), provide a pathway for flow of ground water from the Snowville area of the Holbrook-Snowville flow system west toward the central Juniper–Black Pine flow system (figure 61).

Oaks (2004) suggested that ground water in the Holbrook-Snowville flow system encounters a geologic barrier to south-southwest flow southwest of Snowville, based on an abrupt increase in slope of the piezometric surface. In his view this barrier diverts ground water to the east-southeast toward the range-bounding fault zone along the northwestern margin of the Hansel Mountains, which forms a pathway for ground-water flow southwest to the Locomotive Springs complex. Our work suggests that the Snowville transverse fault zone forms the barrier to south-southwest directed ground-water flow proposed by Oaks (2004), by juxtaposing a low-permeability footwall composed of bedrock and Salt Lake Formation on the south against a higher-permeability hanging wall composed of basin-fill deposits on the north. We speculate that the Snowville transverse fault zone also provides a pathway for ground-water flow from the Snowville area of the Holbrook-Snowville flow system to the east-southeast toward the Hansel Mountains range-bounding faults (figure 61).

Oaks (2004) noted that TDS concentrations of water from several wells in the southern Holbrook-Snowville and Juniper–Black Pine flow systems are greater than the TDS concentration of Locomotive Springs water, and that TDS concentrations of water from wells along the Hansel Mountains range-bounding fault zone are similar to those of Locomotive Spring water. He cited these relationships as evidence that the eastern part of the southern Holbrook-Snowville flow system is the primary source of Locomotive Spring water. Isotopic dates for ground water in the southern Holbrook-Snowville flow system are substantially older than those from the rest of the flow system (table 4; figure 61), suggesting that flow and recharge rates in the southern part are very low, and supporting Oaks' (2004) assertion that this area contributes little to Locomotive Springs discharge.

We agree that the Hansel Mountains range-bounding fault zone is the most likely pathway for ground-water flow from the southern Holbrook-Snowville flow system to the Locomotive Springs complex, but note that our isotopic data indicate that the Juniper–Black Pine flow system is also a significant source of Locomotive Springs water. Our estimate that the Juniper–Black Pine flow system contributes about 70% of the total discharge from Bar M and Baker Springs should, however, be regarded with caution because it is based on a simple, end-member mixing model for the isotopic data and uses average compositions of samples collected far to the north of Locomotive Springs, whereas the isotopic composition of the flow systems may change to the south and other sources may contribute to the springs. Our estimate contradicts Baker's (1974, p. 39–40) argument, based on water-budget estimates, that the Juniper–Black Pine flow system contributes little if any to the discharge from Locomotive Springs. More water-level data and water-chemistry sampling in the southern Juniper–Black Pine and Holbrook-Snowville flow systems may help resolve this problem and better define the location and nature of the boundary (and/or interaction) between the two flow systems and their relative contributions to Locomotive Springs discharge.

Declining Discharge from the Locomotive Springs Complex

Flow records for the Locomotive Springs complex show that discharge from the springs began to decline in the late 1960s (figures 29-31), soon after the beginning of a significant increase in ground-water withdrawal for agricultural irrigation in Curlew Valley near Snowville (Burden and others, 2004, p. 12; Oaks, 2004, figure 2). In the early 1970s, water levels in Curlew Valley upgradient of the Locomotive Springs complex were above 4215 feet (1285 m), the elevation of the springs, except for several isolated areas (figures 33 and 62) (Baker, 1974). By the mid-1990s, the area having water levels near or below 4215 feet (1285 m) elevation had expanded substantially to include an area about 8 miles wide (east-west) and 16 miles long (north-south) (13 by 26 km), from the Locomotive Springs complex in the south to the Utah-Idaho state line in the agricultural area west of Snowville (figures 34 and 62) (Atkin, 1998). This area includes the southeastern part of the southern Juniper–Black Pine flow system and the southwestern part of the southern Holbrook-Snowville flow system, which together form an important source area for the Locomotive Springs complex. Water levels in wells monitored by the U.S. Geological Survey west and south of Snowville have declined since the mid-1990s (figures 35 and 36), so the area having ground-water levels below 4215 feet (1285 m) likely has not decreased and may have expanded. Of course, any substantial decrease in ground-water levels of the source area may cause decreased discharge at the Locomotive Springs complex; we use the 4215 feet elevation as a convenient reference point.

We conclude that progressively declining ground-water levels, as illustrated by expansion of the area of the Curlew Valley basin-fill aquifer below 4215 feet elevation (1285 m) since the early 1970s (figure 62), has caused the decreasing discharge from the Locomotive Springs complex. Withdrawal of ground water from the agricultural areas near, west, and south of Snowville at rates greater than the local recharge

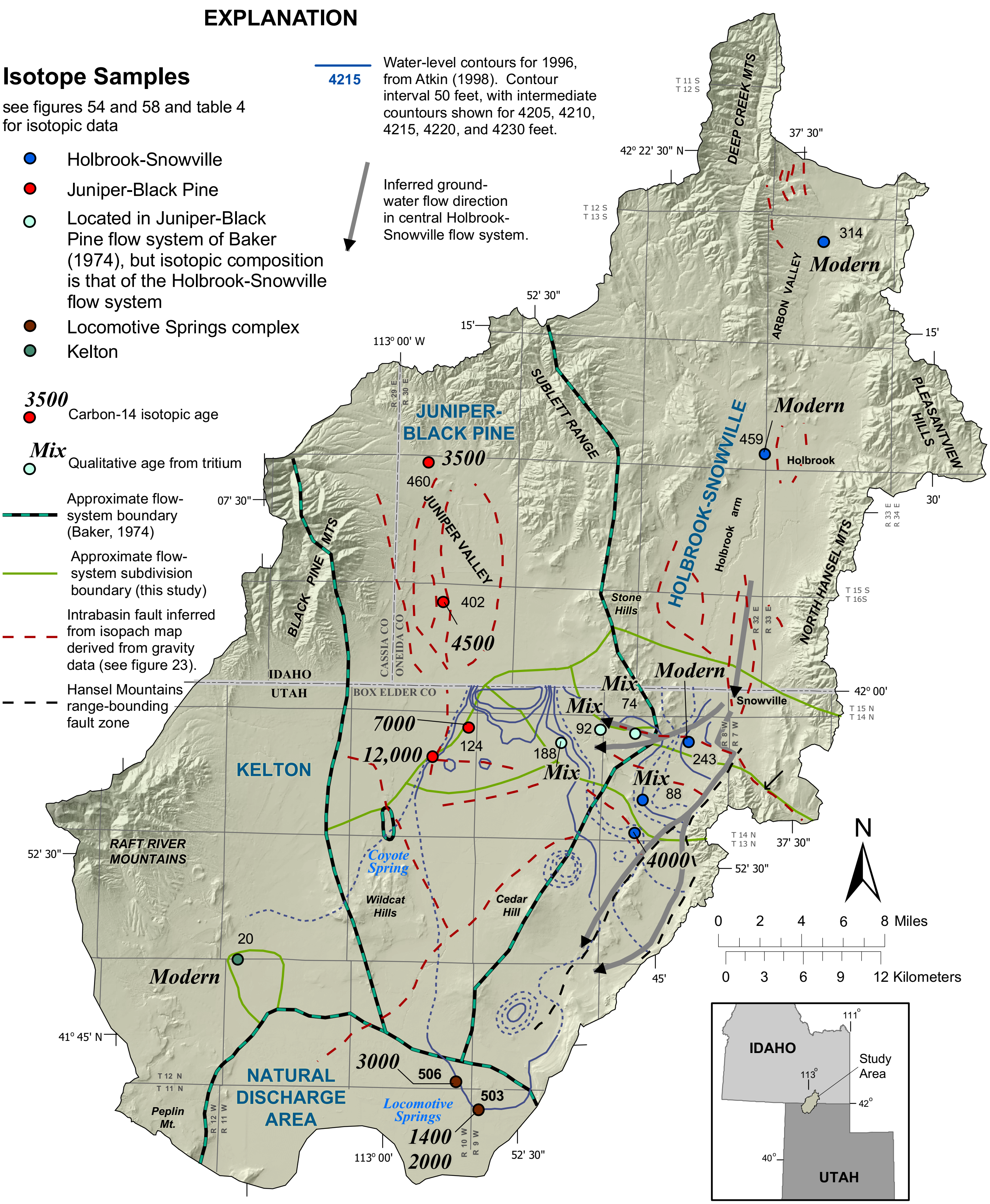

Figure 61. Hypothetical flow directions for ground water in the central part of the Holbrook-Snowville and Juniper–Black Pine flow systems, Curlew Valley. Also shown are locations of isotope samples, isotopic dates (table 4), water-level contours (data from Atkin, 1998), flow systems (as defined by Baker, 1974), and intrabasin faults inferred from gravity data.

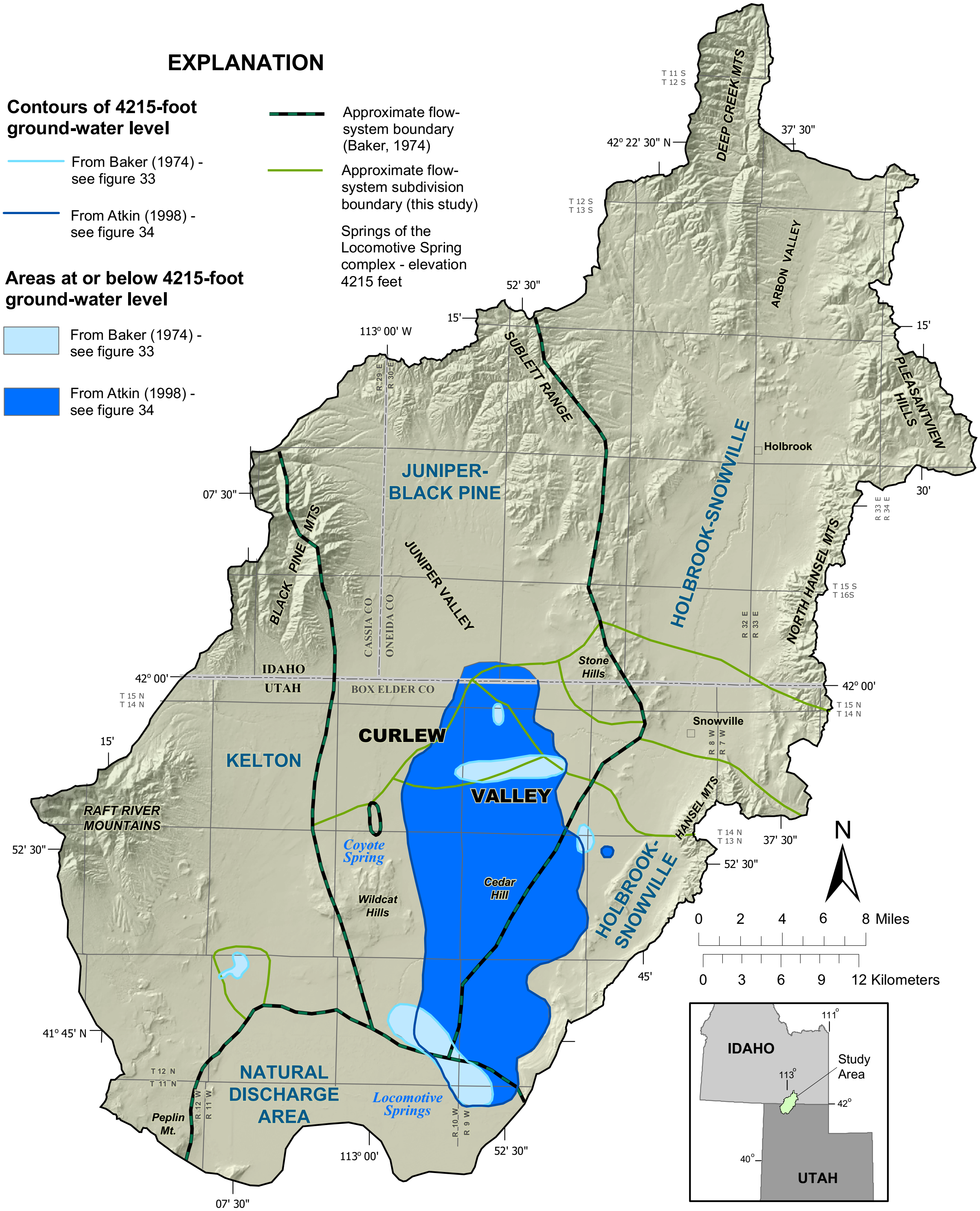

Figure 62. Comparison of area of ground water in Curlew Valley at or below the elevation of the Locomotive Springs complex (4215 feet [1285 m]) at the time of the Baker (1974) and Atkin (1998) reports. Water-level data are insufficient to construct such a diagram for more recent time, but the trend of increasing area below 4215 feet has likely continued since 1998 based on water-level records for individual wells (figure 36).

rates to the basin-fill aquifer, combined with relatively low precipitation in the recharge areas of the drainage basin since the mid-1980s (figure 25), has resulted in the ground-water level declines. Lowering of ground-water levels in the agricultural areas near Snowville decreases the difference in water-table elevation between the Locomotive Springs complex and its source area, thereby decreasing the hydraulic-head difference, which is the driving force for the discharge, and resulting in a lower flow rate.

Factors such as re-working of the outflow pools and channels and flooding of the Locomotive Springs outflow area by the Great Salt Lake during the mid-1980s may have slightly affected discharge at individual springs, but the declining discharge began before and continued after these changes. The discharge from the Locomotive Springs complex is driven primarily by large-scale head gradients, which would not have been affected by these local, small-scale changes. If decreased discharge were due to local, surficial changes, the discharge should have emerged elsewhere, but Berger (2000) did not report any evidence of a change from discharge primarily at springs to more diffuse seepage.

Records of the levels, quality, and use of ground water are much more complete for the Utah part of Curlew Valley than for the Idaho part, but agricultural water use in Idaho may also contribute to the decreased discharge from the Locomotive Springs complex. The number of agricultural wells in Holbrook arm north of Snowville increased substantially in the 1970s (figure 24), and the irrigated acreage there appears similar to that in the agricultural area west of Snowville, based on inspection of the bright green areas on the false-color satellite image on figure 26. In wells monitored regularly by the U.S. Geological Survey since the early 1970s, water levels have increased by less than 10 feet (3 m) in two wells in Holbrook arm and one well in Juniper Valley, and decreased by about 10 feet in one well in Holbrook arm about 3 miles (4.8 km) north of Snowville (figures 35 and 36A-D). More information is needed to characterize water-level trends in the Idaho part of Curlew Valley during the past 30 years, but increased ground-water withdrawal has probably reduced the head gradient between these areas and the Locomotive Springs complex.

Declining Water Levels and Water Quality West and South of Snowville

Declining water levels and water quality in the agricultural areas west and south of Snowville can be explained largely by factors typical for agricultural operations that rely on ground water for irrigation in a semi-arid climate. Declining ground-water levels in irrigation wells result from greater net discharge rates by ground-water pumping than recharge rates from the combination of infiltration of surface precipitation and irrigation return flow, and lateral flow of ground water within the aquifer. The difference between discharge and recharge rates has likely increased during 1995 to 2004 due to lower average annual precipitation (figure 25) and increased agricultural operations in Juniper Valley.

Several lines of evidence suggest that the geochemical composition and declining quality of ground water in the agricultural areas west and south of Snowville are due to evaporative concentration of salts in unused irrigation water that recharges the aquifer. Declining water levels, higher TDS and temperature, gradually increasing electrical conductivity, and increasing sodium and chloride content all occur in the agricultural areas of Curlew Valley and are absent or less pronounced elsewhere in the valley. Positive correlation of precipitation and pH, with a one-year phase delay (figures 55 and 56), confirms that infiltration of precipitation and/or runoff from snowmelt occurs in the agricultural areas. Time-series plots of the saturation indices of common vadose-zone minerals (figure 56) suggest that increased pH in Curlew Valley ground water, due to increased infiltration of precipitation and/or snowmelt, causes the carbonate minerals calcite, dolomite, and aragonite to become saturated, whereas halite and gypsum remain undersaturated. These relations indicate that halite and gypsum that are concentrated in the soil by evapotranspiration of irrigation water tend to dissolve into infiltrating water in the vadose zone, whereas carbonate minerals do not dissolve. These dissolved constituents are added to the ground water when the infiltrating water reaches the water table.

Declining ground-water quality in the agricultural areas of Curlew Valley is largely due to dissolution of vadose-zone minerals by infiltrating precipitation and/or snowmelt. The minerals accumulate in the vadose zone during relatively dry years by evaporative concentration of unused irrigation water. This argument neither disproves nor supports the idea that other factors, such as geologic units having unusual chemical composition, or magma-heated thermal waters rising from depth, also influence the ground-water chemistry in those areas. The topography west and south of Snowville does not suggest that these areas formed shallow embayments in Lake Bonneville in which thick accumulations of evaporite deposits would have formed. Thermal waters having elevated TDS may rise along faults and mix with shallow ground water in the central Juniper–Black Pine flow system and possibly in the irrigation wells south of Snowville that are completed in Quaternary basalt.

CONCLUSIONS

The primary conclusions of this study, based on compilation and analysis of previous work and on newly collected geophysical and water-chemistry data, are as follows.

The principal basin-fill aquifer in the Juniper Valley and Holbrook arm parts of Curlew Valley is composed primarily of gravel and sand along the basin margins adjacent to the mountain ranges, and is dominated by silt, clay, and sand in the basin centers. The basin-fill aquifer in southern Curlew Valley is predominantly volcanic rock interbedded with fine-grained sediments. The basin-fill aquifer was formed in a Tertiary-Quaternary age, fault-bounded depositional basin. Geophysical modeling of new gravity data collected for this study, combined with previously existing gravity and aeromagnetic data, delineates the structure of this depositional basin and the large-scale geometry of the basin-fill aquifer in substantially greater detail than was previously possible. Thick, structurally complex depositional centers exist below central Juniper Valley, Holbrook arm, southwestern Curlew Valley near the Raft River Mountains, and southeastern Curlew Valley north of Locomotive Springs. The basin-fill aquifer in the latter area is composed mainly of Quaternary basalt.

Analysis of the gravity data reveals several previously unrecognized concealed faults within the basin fill, most importantly the herein-named Snowville transverse fault zone. The Snowville transverse fault zone strikes west-northwest along the southern margin of the Holbrook arm of Curlew Valley, forms an abrupt boundary between thick basin-fill deposits to the north and bedrock to the south, and projects toward a major offset in the Hansel Mountains range margin to the east and a structurally complex depositional center below Juniper Valley to the west. The Snowville transverse fault zone likely inhibits north-south ground-water flow and accommodates east-west ground-water flow within the basin-fill aquifer.

The average annual discharge from the Locomotive Springs complex, the major discharge point of the Curlew Valley basin-fill aquifer, decreased from about 40 to less than 10 cubic feet per second (1.1 to <0.3 m^3/s) between 1969 and 2003. We attribute this decrease in flow to the combined effects of increased pumping of ground water for irrigation in southern Juniper Valley and Holbrook arm in Utah and Idaho, and below-average annual precipitation during 1993 to 2003. The main areas of ground-water pumping are about 15 to 20 miles (24–32 km) north-northwest and north-northeast—upgradient with respect to the potentiometric surface in the basin-fill aquifer—of Locomotive Springs. Ground water in the areas of concentrated agriculture and ground-water pumping has substantially greater total-dissolved-solids and sodium concentrations and higher temperatures than in non-agricultural areas. Ground-water quality and levels have steadily decreased in some, but not all, wells within the agricultural areas during the past 30 to 40 years.

Isotopic data collected and analyzed during this study confirm the presence of the distinct ground-water flow systems in the Curlew Valley basin-fill aquifer proposed by Baker (1974), and delineate flow paths within, and mixing zones between, these flow systems. Ground water in the northern and west-central Juniper–Black Pine flow system is isotopically "lighter" (contains lower proportions of the heavier isotopes of oxygen and hydrogen) and older than ground water in the northern Holbrook-Snowville flow system. In contrast, ground water in the central Juniper–Black Pine flow system is younger than in the northern part of the flow system, and its isotopic composition is indistinguishable from that of the Snowville area of the Holbrook-Snowville flow system. Based on this relation, and the steeply west-sloping hydraulic gradient between the two areas, we suggest that ground water flows west along the Snowville transverse fault zone from the Snowville area of the Holbrook-Snowville flow system to the central part of the Juniper–Black Pine flow system, and mixes with ground water there.

The isotopic composition and age estimates of water discharging from the Locomotive Springs complex are intermediate between the mean compositions and age estimates for ground water from the Holbrook-Snowville and the Juniper–Black Pine flow systems. Linear regression of the mean isotopic compositions of ground water from the Juniper–Black Pine flow system, Holbrook flow system, and Locomotive Springs yields a statistically significant line, supporting the idea that water discharging from Locomotive Springs is a mixture of water from the two flow systems. This conclusion is consistent with our conclusion that ground-water pumping and declining water levels in the agricultural areas upgradient of Locomotive Springs causes part of the steadily decreasing discharge from the springs.

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GLOSSARY

Definitions are from Neuendorf and others (2005) or Fetter (1994), with modification by the authors, and except where noted. Many of the terms appear only in the Description of Map Units in appendix B. Italicized words in definitions may not appear in the text but are defined in the glossary.

Adamellite – a felsic granitic rock, synonym of *quartz monzonite*.

Alkali feldspar – A group of *feldspars* composed of mixtures, or mixed crystals, of *potassium feldspar* and *sodium feldspar* in any ratio.

Alluvial – Deposited by a stream or other body of running water. Alluvium is a general term for unconsolidated *detrital* material deposited during comparatively recent geologic time by a stream or other body of running water, as sorted or semisorted sediment in the bed of a stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

Alluvial fan – A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or segment of a cone, deposited by a stream at the place where it issues from a narrow mountain valley upon a plain or broad valley, or where a tributary stream is near or at its junction with the main stream, or wherever a constriction in a valley abruptly ceases or the gradient of the stream suddenly decreases.

Aluminosilicate – A silicate in which aluminum substitutes for the silicon in the SiO_4 tetrahedra.

Amphibole – A group of dark rock-forming ferromagnesian silicate minerals, closely related in crystal form and composition and having the general formula: $A_{2\text{-}3}B_5(Si,Al)_8O_{22}(OH)_2$, where A = Mg, Fe^{2+}, Ca, or Na, and B = Mg, Fe^{2+}, Fe^{3+}, Li, Mn, or Al. They are an abundant and widely distributed constituent in igneous and metamorphic rocks.

Amphibolite – A *metamorphic rock* consisting mainly of *amphibole* and *plagioclase*.

Andesite – A dark-colored, fine-grained volcanic rock containing *phenocrysts* of Na-rich *plagioclase feldspar* and one or more of the following: *biotite*, *hornblende*, or *pyroxene*; in a *groundmass* composed generally of the same minerals as the *phenocrysts*.

Anhydrite – A mineral consisting of anhydrous calcium sulfate: $CaSO_4$.

Anticline – A *fold*, the core of which contains stratigraphically older rocks, and is convex upward.

Apatite – A group of variously colored minerals consisting of calcium phosphate together with fluorine, chlorine, hydroxyl, or carbonate in varying amounts and having the general formula: $Ca_5(F,OH,Cl)(PO_4,CO_3)_3$.

Aphanitic – An *igneous* texture characterized by fine grain size, in which components are not distinguishable with the unaided eye.

Aquifer – A body of rock or *sediment* that contains sufficient saturated permeable material to conduct ground water and to yield significant quantities of water to wells and springs.

Aquifer test – A test made by pumping a well for a period of time and observing the change in hydraulic head in the aquifer. Typically, water levels are measured in one or more observation wells and the pumping well. An aquifer test may be used to determine the capacity of the well and the hydraulic characteristics of the aquifer.

Aquitard – An impermeable layer that creates *confined ground-water* conditions, in which ground water is under pressure significantly greater than that of the atmosphere.

Aragonite – A white, yellowish, or gray orthorhombic mineral: $CaCO_3$.

Archean – The earliest eon of geologic time; the beginning of the Archean has not been established, and the end was 2,500 Ma. See geologic time scale, appendix A.

Ash – Fine *pyroclastic* material under 2 mm diameter.

Ash-fall tuff – Volcanic tuff deposited by showerlike fall of *pyroclastic* fragments.

Ash-flow tuff – A density-current deposit, generally a hot mixture of volcanic gases and tephra that travels across the ground surface; produced by the explosive disintegration of viscous lava in a *volcanic* crater, or from a fissure or group of fissures. The solid materials contained in a typical ash flow are generally unsorted and ordinarily include volcanic dust, *pumice*, *scoria*, and blocks in addition to ash.

Augite – A common mineral of the *clinopyroxene* group: $(Ca, Na)(Mg,Fe^{+2}, Al)(Si,Al)_2O_6$.

Basalt, basaltic – A dark-colored, *mafic* volcanic rock composed chiefly of calcic *plagioclase* and *clinopyroxene* and/or *olivine*.

Basalt shield – A shield volcano composed of *basalt* flows and *tuff*, in the shape of a flattened, broad, and low dome.

Bicarbonate – The anion HCO_3, a common component of water.

Biotite – A widely distributed rock-forming mineral of the *mica* group: $K(Mg,Fe^{2+})3(OH)_2[(Al,Fe^{3+})Si_3O_{10}]$.

Bomb – A *pyroclast* ejected while viscous and shaped while in flight. It is larger than 64 mm in diameter, and may be vesicular to hollow inside.

Brachiopod – Any solitary marine invertebrate belonging to the phylum Brachiopoda, characterized by two bilaterally symmetrical valves (shells).

Breccia – A coarse-grained *clastic* rock composed of angular broken rock fragments held together by mineral cement or in a fine-grained matrix.

Bryozoan – An invertebrate belonging to the phylum Bryozoa and characterized by colonial growth, a calcareous skeleton, and a U-shaped alimentary canal.

Calcarenite – A limestone consisting predominantly of sand-size carbonate grains; a consolidated calcareous sand.

Calcite – A common rock-forming mineral – $CaCO_3$.

Cambrian – The lowest system of the *Paleozoic Erathem* of the geologic time scale. Also the time during which these rocks were formed, the Cambrian Period, covering the time span between 543 and 490 Ma. See geologic time scale, appendix A.

Carbonate – Sediment formed by the organic or inorganic precipitation from aqueous solution of calcium-, magnesium-, or iron-carbonate minerals.

Cenozoic – The upper *erathem* of the geologic time scale. Also the time during which these rocks were formed, the Cenozoic Era, covering the time span between 65 Ma and the present. See geologic time scale, appendix A.

Chert/Cherty – A hard, dense, dull to semivitreous, *microcrystalline* or *cryptocrystalline* sedimentary rock, consisting dominantly of interlocking crystals of quartz less than about 30 µm in diameter, that may also contain impurities such as calcite, iron oxide, and the remains of siliceous and other organisms. It has a tough, splintery to conchoidal fracture, and may be variously colored. Chert occurs as nodular or concretionary segregations (chert nodules) in *limestones* and *dolomites*, or as areally extensive layered deposits (bedded chert); it may be an original organic or inorganic precipitate, or a replacement product.

Chronostratigraphic unit – A body of rocks established to serve as the material reference for all rocks formed during the same span of time. The body also serves as the basis for defining the specific interval of time. See geologic time scale, appendix A.

Clastic – Pertaining to a rock or sediment composed principally of broken fragments that are derived from preexisting rocks or minerals and that have been transported some distance from their places of origin.

Clinopyroxene – A group name for *pyroxenes* crystallizing in the monoclinic system and sometimes containing considerable calcium with or without aluminum and the alkalis.

Colluvium – A general term applied to any loose, heterogeneous, and incoherent mass of soil material and/or rock fragments deposited by rainwash, sheetwash, or slow continuous downslope creep, usually collecting at the base of gentle slopes or hillsides.

Confined aquifer – An *aquifer* bounded above and below by *confining* beds.

Confined ground water – Ground water under pressure significantly greater than that of the atmosphere. Its upper surface is the bottom of a *confining* bed.

Confining bed – A body of relatively impermeable or distinctly less permeable material stratigraphically adjacent to one or more *aquifers*.

Conglomerate – A coarse-grained *clastic* sedimentary rock, composed of rounded to subangular fragments larger than 2 mm in diameter, typically containing fine-grained particles in the interstices, and commonly cemented by calcium carbonate, iron oxide, silica, or hardened clay; the consolidated equivalent of gravel.

Conodont – One of a large number of small, disjunct fossil elements assigned to the order Conodontophorida, phosphatic in composition, and commonly toothlike in form.

Cretaceous – The upper system of the *Mesozoic Erathem*, above the *Jurassic* and below the *Tertiary* System of the *Cenozoic Erathem*. Also the time during which these rocks were formed, the Cretaceous Period, covering the time span between about 144 and 65 Ma. See geologic time scale, appendix A.

Crinoid – Any pelmatozoan echinoderm belonging to the class Crinoidea, characterized by quinqueradiate symmetry, by a disk-shaped or globular body enclosed by calcareous plates from which appendages, commonly branched, extend radially, and usually by the presence of a stem, or column.

Cryptocrystalline – Said of a texture of a rock consisting of crystals that are too small to be recognized and separately distinguished even under the ordinary microscope (although crystallinity may be shown by the use of the electron microscope).

Dacite – A fine-grained volcanic rock with the same general composition as *andesite* but having a less calcic *plagioclase* and more *quartz*.

Detritus/Detrital – A collective term for loose rock and mineral material that is worn off or removed by mechanical means, such as sand, silt, and clay, derived from older rocks and moved from its place of origin.

Devitrified – Texture of a *volcanic* or shallow *intrusive* rock in which glass has been converted into crystalline material.

Diamictite – A comprehensive, nongenetic term for a nonsorted or poorly sorted, noncalcareous, terrigenous *sedimentary* rock that contains a wide variety of particle sizes, such as a rock with sand and/or larger particles in a muddy matrix.

Dike – A tabular igneous intrusion that cuts across the bedding or *foliation* of the country rock.

Dip – The inclination of a planar surface (for example, bedding or a *fault*), as measured relative to horizontal and in a vertical plane that is perpendicular to the *strike* of the surface.

Dip slip – In a *fault*, the component of the movement or slip that is parallel to the *dip* of the *fault*.

Dolomite – A *carbonate* sedimentary rock of which more than 50% by weight or by areal percentage under the microscope consists of the mineral dolomite, or a variety of limestone or marble rich in magnesium carbonate. The mineral dolomite has the chemical formula $CaMg(CO_3)_2$.

Eolian – Pertaining to the wind, esp. said of such deposits as *loess* and dune sand, of sedimentary structures such as wind-formed ripple marks, or of erosion and deposition accomplished by the wind.

Erathem – The formal *chronostratigraphic unit* next lower than eonothem and higher than system.

Evaporite – A *sedimentary* rock composed primarily of minerals produced from a saline solution as a result of extensive or total evaporation of the solvent. Examples include *gypsum, anhydrite, sulfates, halite*, or primary *dolomite*.

Evapotranspiration – The sum of evaporation plus *transpiration*.

Facies – The aspect, appearance, and characteristics of a rock unit, usually reflecting the conditions of origin; a mappable, areally restricted part of a *lithostratigraphic* body, differing in *lithology* from other beds deposited at the same time and in lithologic continuity.

Fault – A discrete surface or zone of discrete surfaces separating two rock masses across which one rock mass has slid past the other.

Feldspar – A group of abundant rock-forming minerals, generally divided into two compositional groups, (1) the *plagioclase feldspar* series: $CaAl_2Si_2O_8$ to $NaAlSi_3O_8$, and (2) the *alkali feldspar* series: $(K,Na)AlSi_3O_8$.

Feldspathoid – A group of comparatively rare rock-forming minerals consisting of *aluminosilicates* of sodium, potassium, or calcium having too little silica to form *feldspar*. Feldspathoids are chemically related to the feldspars, but differ from them in crystal form and physical properties; they take the places of feldspars in igneous rocks that are undersaturated with respect to silica or that contain more alkalis and aluminum than can be accommodated in the feldspars.

Felsic – A mnemonic adjective derived from *feldspar* + lenad (*feldspathoid*) + *silica*, and applied to an igneous rock having light-colored minerals in its mode; also, applied to those minerals (*quartz, feldspars, feldspathoids, muscovite*) as a group.

Fold – A curve or bend of a planar structure such as rock strata or bedding planes.

Foliation – A general term for a planar arrangement of textural or structural features in any type of rock, especially the locally planar fabric in a rock defined by a fissility, a preferred orientation of crystal planes in mineral grains, a preferred orientation of inequant grain shapes, or from compositional banding.

Footwall – The lower block of a non-vertical *fault*.

Foraminifer – Any protozoan belonging to the subclass Sarcondia, order Foraminiferida, characterized by the presence of a test of one to many chambers composed of secreted calcite (rarely silica or aragonite) or of agglutinated particles.

Fusulinid – Any *foraminifer* belonging to the suborder Fusulinina, characterized by a multichambered elongate calcareous microgranular test, commonly resembling the shape of a grain of wheat.

Garnet – A group of minerals of formula: $A_3B_2(SiO_4)_3$, where A = Ca, Mg, Fe^{2+}, or Mn^{2+}, and B = Al, Fe^{3+}, Mn^{3+}, V^{3+}, or Cr^{3+}; it occurs as an accessory mineral in a wide range of igneous rocks, and is commonly found as distinctive euhedral or cubic crystal in metamorphic rocks.

Gneissic – Pertaining to the texture or structure typical of gneisses, with foliation formed by regional *metamorphism*, in which bands or lenticles of granular minerals alternate with bands or lenticles in which minerals having flaky or elongate prismatic habits predominate.

Gouge – A thin layer of soft, fault-comminuted rock material in the core of a *fault*.

Graben – An elongate trough or basin, bounded on both sides by high-angle *normal faults* that dip toward the interior of the trough.

Granite/Granitic – A *plutonic* rock in which quartz constitutes 10 to 50 percent of the *felsic* components and in which the *alkali feldspar*/total *feldspar* ratio is generally restricted to the range of 65 to 90 percent.

Groundmass – The finer grained and/or glassy material between the *phenocrysts* in a *porphyritic igneous* rock.

Gypsum – A widely distributed mineral consisting of aquated calcium sulfate: $CaSO_4 \cdot 2H_2O$.

Halite – A cubic mineral: NaCl. It is native salt, occurring in massive, granular, compact, or cubic-crystalline forms, and having a distinctive salty taste.

Hanging wall – The upper block of a non-vertical *fault*.

Hinge line – A line connecting the points of flexure or maximum curvature of the bedding planes in a *fold*.

Hornblende – The commonest mineral of the rock-forming *amphibole* group:
$(Ca,Na)_{2-3}(Mg,Fe^{2+}, Fe^{3+},Al)_5(OH)_2[(Si,Al)_8O_{22}]$.

Hydraulic conductivity - A coefficient of proportionality describing the rate at which a fluid can flow through a permeable medium. Hydraulic conductivity is a function of the physical properties of the porous or fractured medium and of the density and viscosity of the fluid. Typically reported in units of feet or meters per day.

Hydrostratigraphy – Division of a rock mass into hydrostratigraphic units; a hydrostratigraphic unit is a body of rock distinguished and characterized by its porosity and permeability. Hydrostratigraphy is the classification of rocks and sediment based on their capacity to transmit water, and rocks are typically designated as either *aquifers* or *aquitards* (Maxey, 1964; Hansen, 1991). Hydrostratigraphic units may (1) coincide with *lithostratigraphic units*, (2) have boundaries corresponding to *facies* changes within a single lithostratigraphic unit, or (3) encompass several lithostratigraphic units with similar water-transmitting properties (Maxey, 1964; Hansen, 1991).

Igneous – Said of a rock or mineral that solidified from magma (molten or partly molten rock material); also applied to processes leading to, related to, or resulting from the formation of such rocks.

Intrusion – The process of emplacement of magma in pre-existing rock; also the rock mass so formed within the surrounding rock.

Intrusive – Pertaining to *intrusion*.

Isotope – One of two or more species of the same chemical element, i.e., having the same number of protons in the nucleus, but differing from one another by having a different number of neutrons.

Jurassic – The middle system of the *Mesozoic Erathem*, above the *Triassic* and below the *Cretaceous*. Also the time during which these rocks were formed, the Jurassic Period, covering the time span between 210 and 144 Ma. See geologic time scale, appendix A.

Kyanite – A mainly blue triclinic mineral, Al_2SiO_5, usually in long, thin-bladed crystals and crystalline aggregates in *schists*, *gneisses*, and *granite*.

Lacustrine – Pertaining to, produced by, or formed in a lake.

Lapilli – *Pyroclastic* materials that may be essential, accessory, or accidental in origin, of a size range from 2 to 64 mm.

Lava flow – The solidified body of rock formed from a surficial outpouring of molten lava from a vent or fissure; also the outpouring itself.

Limestone – A *sedimentary rock* consisting chiefly of calcium carbonate, principally in the form of the mineral calcite; formed by either organic or inorganic processes, and may be *detrital*, chemical, oolitic, crystalline, or recrystallized; many are highly fossiliferous and represent ancient shell banks or coral reefs; rock types include micrite, calcarenite, coquina, chalk, and travertine.

Lithology – The description of rocks on the basis of such characteristics as color, mineralogic composition, and grain size.

Lithostratigraphic unit – A defined body of *sedimentary*, extrusive *igneous*, or *metamorphosed sedimentary* or *volcanic* strata that is distinguished and delimited on the basis of lithic characteristics and *stratigraphic* position. Boundaries of lithostratigraphic units are placed at positions of lithic change, either at distinct contacts or arbitrarily within zones of gradation. The fundamental unit is the formation.

Loess – A widespread, homogeneous, commonly nonstratified, porous, friable, slightly coherent, usually highly calcareous, fine-grained blanket deposit, consisting predominantly of silt with secondary grain sizes ranging from clay to fine sand.

Mafic – Said of an *igneous* rock composed chiefly of one or more ferromagnesian, dark-colored minerals; also, said of those minerals.

Magnetic susceptibility – A measure of the degree to which a rock can be magnetized; the ratio of induced magnetization to the strength of the magnetic field causing the magnetization.

Marble – A *metamorphic rock* consisting predominantly of fine- to coarse-grained recrystallized *calcite* and/or *dolomite*.

Marl – A loose, earthy deposit consisting chiefly of a mixture of clay and calcium carbonate, formed under marine or freshwater conditions.

Mesozoic – The middle erathem of the geologic time scale, above the *Paleozoic* and below the *Cenozoic*. Also the time during which these rocks were formed, the Mesozoic Era, covering the time span between 248 and 65 Ma. See geologic time scale, appendix A.

Metamorphic rock – Any rock derived from preexisting rocks by mineralogical, chemical, or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust.

Metamorphism – The mineralogical, chemical, and structural adjustment of solid rocks to physical and chemical conditions that have generally been imposed at depth, below the surface zones of weathering and cementation, and differ from the conditions under which the rocks in question originated.

Mica – A group of sheet-silicate minerals of general formula: $(K,Na,Ca)(Mg,Fe,Li,Al)_2(OH,F)_2[(Si,Al)_4O_{10}]$.

Micaceous – Consisting of, containing, or pertaining to *mica*.

Micrite – A *limestone* consisting dominantly of semiopaque crystalline matrix of *carbonate* mud with crystals less than 4 μm in diameter.

Microcrystalline – Said of a texture of a rock, consisting of crystals that are small enough to be visible only under the microscope.

Miocene – A series of the *Neogene* subsystem of the *Tertiary* System of the geologic time scale. Also the time during which these rocks were formed, the Miocene Epoch, covering the time span between 24 and 5 Ma. See geologic time scale, appendix A.

Mississippian – The lower subsystem of the *Carboniferous* System of the geologic time scale. Also the time during which these rocks were formed, the Mississippian Subperiod, covering the time span between 354 and 323 Ma.

Monzonite – A group of *plutonic* rocks containing approximately equal amounts of *alkali feldspar* and *plagioclase*, little or no *quartz*, and commonly *augite* as the main *mafic* mineral.

Mudstone – A fine-grained *sedimentary* rock in which the proportions of clay and silt are approximately equal.

Muscovite – A mineral of the mica group: $KAl_2(OH)_2[(AlSi_3)O_{10}]$.

Neogene – The upper subsystem of the *Tertiary* System of the geologic time scale. Also the time during which these rocks were formed, the *Neogene* Subperiod, covering the time span between 24 and 1.75 Ma. See geologic time scale, appendix A.

Normal fault – A fault along which the *hanging wall* has moved downward relative to the *footwall*.

Oblique-slip fault – A fault on which the net slip has *dip slip* and *strike slip* components.

Orthoclase – A mineral of the *potassium feldspar* group: $KAlSi_3O_8$.

Olivine – An olive-green mineral common in magnesium-rich *igneous* rocks: $(Mg, Fe)_2SiO_4$.

Orthoquartzite – A clastic *sedimentary* rock that is made up almost exclusively of *quartz* sand, and that is relatively free of or lacks a fine-grained matrix.

Ostracodes – Any aquatic crustacean belonging to the subclass Ostracoda, characterized by a bivalve, generally calcified carapace with a hinge along the dorsal margin.

Paleozoic – The lowest erathem of the *Phanerozoic* Eonothem of the geologic time scale. Also the time during which these rocks were formed, the Paleozoic Era, covering the time span between 543 and 248 Ma. See geologic time scale, appendix A.

Pelite/Pelitic – A fine-grained sedimentary rock composed of more or less hydrated aluminosilicates with which are mingled small particles of various other minerals.

Pennsylvanian – The upper subsystem of the *Carboniferous* System of the geologic time scale. Also the time during which these rocks were formed, the Pennsylvanian Subsystem, covering the time span between 323 and 290 Ma. See geologic time scale, appendix A.

Permeability – A coefficient describing the rate at which fluid can flow through a porous or fractured medium.

Permian – The uppermost system of the *Paleozoic Erathem* of the geologic time scale. Also the time during which these rocks were formed, the Permian Period, covering the time span between 290 and 248 Ma. See geologic time scale, appendix A.

Phanerozoic – The uppermost eonothem of the geologic time scale. It comprises the *Paleozoic*, *Mesozoic* and *Cenozoic erathems*. Also the time during which these rocks were formed, the Phanerozoic Eon, covering the time span between 543 Ma and the present. See geologic time scale, appendix A.

Phenocryst – A relatively large, conspicuous crystal in a *porphyritic igneous* rock.

Phreatophyte – A type of plant that typically has a high rate of *transpiration* by virtue of a taproot extending to the water table.

Plagioclase – A group of the *feldspar* minerals, including albite, $Na[AlSi_3O_8]$, and anorthite, $Ca[Al_2Si_2O_8]$, which form a complete solution series at high temperatures.

Pliocene – The uppermost series of the *Neogene* Subsystem of the *Tertiary* System of the geologic time scale. Also the time during which these rocks were formed, the Pliocene Epoch, covering the time span between 5 and 1.75 Ma. See geologic time scale, appendix A.

Plutonic – Pertaining to an *igneous* rock or intrusive body formed at great depth.

Porphyry/Porphyritic – An igneous rock of any composition that contains conspicuous *phenocrysts* in a fine-grained groundmass.

Potassium feldspar – An *alkali feldspar* of the composition $K[AlSi_3O_8]$, including *orthoclase*, microcline, and *sanidine*.

Precambrian – A commonly used term to designate all rocks older than the *Cambrian* Period of the geologic time scale. See geologic time scale, appendix A.

Proterozoic – The latest eon of the *Precambrian* of the geologic time scale. The beginning has been established at 2,500 Ma; the end was at 543 Ma. See geologic time scale, appendix A.

Pumice – A light-colored, *vesicular*, glassy *volcanic* rock commonly having the composition of *rhyolite*.

Pyroclast – An individual *pyroclastic* fragment.

Pyroclastic – Pertaining to clastic rock material formed by *volcanic* explosion or aerial expulsion from a volcanic vent.

Pyroxene – A group of dark-colored, rock-forming minerals with the general formula: $A_2B_2[Si_4O_{12}]$, where A = Ca, Na, Mg, or Fe^{2+}, and B = Mg, Fe^{2+}, Fe^{3+}, Cr, Mn, or Al.

Quaternary – The upper system of the *Cenozoic Erathem* of the geologic time scale. Also the time during which these rocks were formed, the Quaternary Period, covering the time span between 1.75 Ma and present. See geologic time scale, appendix A.

Quartz – Crystalline silica, an important rock-forming mineral: SiO_2.

Quartz monzonite – An intrusive rock in which *quartz* comprises 10-50% of the *felsic* constituents, and in which the *alkali feldspar*/total *feldspar* ratio is between 35% and 65%.

Quartzite – A metamorphic rock consisting mainly of *quartz* and formed by recrystallization of *sandstone* or *chert*.

Reverse fault – A fault that dips greater than 30 degrees, along which the *hanging wall* has moved upward relative to the *footwall*.

Rhyodacite – A volcanic rock intermediate between *rhyolite* and *dacite*.

Rhyolite – A group of light-colored volcanic rocks, typically *porphyritic* and exhibiting flow texture, containing *phenocrysts* of *quartz* and *alkali feldspar* in a glassy to *cryptocrystalline groundmass*.

Riparian – Pertaining to or situated on the bank of a body of water, esp. of a watercourse such as a river; e.g., “riparian land” situated along or abutting upon a stream bank.

Sandstone – A medium-grained clastic *sedimentary rock* composed of abundant rounded or angular fragments of sand size and more or less firmly united by a cementing material.

Sanidine – A high-temperature mineral of the *alkali feldspar* group: $(K,Na)(Al, Si_4)O_8$.

Saturation index – The saturation index SI of a mineral phase is SI = log(IAP/KT), where IAP = the ion activity product for the given mineral and KT = the reaction constant at a given temperature (Waterloo Hydrogeologic Inc., 2005, p. 307). For SI > 0, the solution is super-saturated with respect to the mineral phase, for SI = 0 the solution is in equilibrium with the mineral phase, and for SI < 0 the solution is undersaturated with respect to the mineral phase. When a solution is supersaturated with respect to a particular mineral phase, that phase tends to precipitate out of the solution, whereas when the solution is undersaturated with respect to a mineral phase, the solution will tend to dissolve that mineral when they are in contact.

For a generic dissolution/precipitation reaction xCD = cC + dD, the IAP (also commonly known as the solubility product) is $K_{sp} = (aC)^{c*}(aD)^d/(aCD)^x$ where aC, aD, and aX are the chemical activities of species C, D, and X, respectively, and x = c + d are the number of moles of species X, C, and D, respectively. The reaction constant (also commonly known as the equilibrium constant) is $Keq = [C]^{c*}[D]^d/[CD]^x$ where [C], [D], and [CD] are the molar or molal concentrations of species C, D, and X, respectively.

Scoria – A *bomb*-sized *pyroclast* that is irregular in form and generally very *vesicular*.

Schist – A strongly *foliated* crystalline rock, formed by dynamic *metamorphism*, that can be readily split into thin flakes or slabs because of the well-developed parallelism of more than 50% of the minerals present.

Sediment – Solid fragmental material that originates from weathering of rocks and is transported or deposited by air, water, or ice, or that accumulates by other natural agents, such as chemical precipitation from solution or secretion by organisms, and that forms in layers on the Earth's surface at ordinary temperatures in a loose, unconsolidated form.

Sedimentary rock – A rock resulting from the consolidation of loose sediment that has accumulated in layers; e.g. a clastic rock.

Sedimentary breccia – A terrigenous rock formed by lithification of angular gravel.

Seismicity – Pertaining to earthquake activity.

Sevier Orogeny – A name proposed by R.L. Armstrong for the well-known deformations that occurred along the eastern edge of the Great Basin in Utah during times intermediate between the Nevadan Orogeny further west and the Laramide Orogeny further east, culminating early in the Late *Cretaceous*. The orogeny involved folding and eastward thrusting of the rocks. It is roughly coeval with the formation of the Sierra Nevada batholith. Thus, it is thought to represent the back-arc thrust belt of an Andean convergent margin.

Shale – A laminated, indurated rock with >67% clay-sized minerals.

Silica – The chemically resistant dioxide of silicon: SiO_2. It occurs naturally in several crystalline polymorphs (for example, the minerals *quartz*, tridymite, cristobalite, coesite, and stishovite); in cryptocrystalline form (chalcedony); in amorphous and hydrated forms (opal); and combined in silicates as an essential constituent of many minerals.

Silicic – Said of a *silica*-rich *igneous* rock or magma.

Siliciclastic – Pertaining to *clastic* noncarbonate rocks which are almost exclusively silicon-bearing, either as forms of *quartz* or as silicates.

Sill – A tabular *igneous* intrusion that parallels the bedding or *foliation* of the *sedimentary* or *metamorphic* country rock, respectively.

Siltstone – An indurated silt having the texture and composition of *shale* but lacking its fine lamination or fissility.

Sodium feldspar – An *alkali feldspar* containing the albite molecule ($Na[AlSi_3O_8]$).

Specific capacity – An expression of the productivity of a well, obtained by dividing the rate of discharge of water from the well by the drawdown of the water level in the well.

Specific capacity test – An *aquifer* test in which water levels in only the pumping well are measured.

Staurolite – A dark reddish-brown, blackish-brown, yellowish-brown, or blue monoclinic mineral: $(Fe, Mg)_4Al_{17}(Si,Al)_8O_{45}(OH)_3$. It is a common constituent in rocks such as *mica schists* and *gneisses* that have undergone medium-grade *metamorphism*.

Stock – A relatively small, concordant and/or discordant *plutonic* body having an aerial extent less than 40 square miles (100 km^2) and no known floor.

Storage coefficient – Synonymous with *storativity*.

Storativity – The volume of water an *aquifer* releases from or takes into storage per unit surface area of the aquifer per change in head. In a confined water body, the water derived from storage with decline in head comes from expansion of the water and compression of the aquifer; in an unconfined water body, the amount of water derived from or added to the aquifer by these processes generally is negligible compared to that involved in gravity drainage or filling of pores.

Stratigraphy – The science of rock strata, concerned with the original succession and age relations of rock strata and with their form, distribution, lithologic composition, fossil content, and geophysical and geochemical properties.

Strike – The angle a planar feature makes relative to north, as measured in a horizontal plane.

Strike-slip fault – A *fault* on which the movement is parallel to the *strike* of the fault.

Subhedral – A grain partly bounded by crystal faces.

Sulfate – A mineral compound characterized by the sulfate radical SO_4.

Syncline – A *fold*, the core of which contains stratigraphically younger rocks, and is convex downward.

Tephra – A collective term used for all *pyroclastic* material ejected during an explosive volcanic eruption.

Terrace – Any long, narrow, relatively level or gently inclined surface, generally less broad than a plain, bounded along one edge by a steeper descending slope and along the other by a steeper ascending slope.

Tertiary – The lower system of the *Cenozoic Erathem* of the geologic time scale. Also the time during which these rocks were formed, the Tertiary Period, covering the time span between 65 and 1.75 Ma. See geologic time scale, appendix A.

Thrust fault – A *fault* that dips 30 degrees or less, along which the hanging wall has moved upward relative to the *footwall*.

Transmissivity – The rate at which a fluid is transmitted through a unit width of an *aquifer* under a hydraulic gradient.

Transpiration – The process by which plants give off water vapor through their leaves.

Triassic – The lower system of the *Mesozoic Erathem* of the geologic time scale. Also the time during which these rocks were formed, the Triassic Period, covering the time span between 248 and 210 Ma. See geologic time scale, appendix A.

Tuff – Consolidated or cemented *volcanic ash* and *lapilli*.

Unconfined aquifer – An *aquifer* having a water table, containing unconfined ground water.

Unconfined ground water – Ground water that is not confined under pressure beneath a *confining bed*.

Unconformity – A substantial break or gap in the geologic record where a rock unit is overlain by another that is not next in stratigraphic succession.

Unconsolidated – A *sediment* that is loosely arranged or unstratified, or whose particles are not cemented together, occurring either at the surface or at depth.

Vadose zone – A subsurface zone containing water under pressure less that that of the atmosphere, including water held by capillarity; and containing air or gases generally under atmospheric pressure. This zone is limited above by the land surface and below by the surface of the saturated zone, i.e., the water table.

Vesicular – Said of the texture of a lava rock characterized by abundant vesicles (cavities of variable shape, formed by the entrapment of a gas bubble during solidification of the lava).

Vitreous – Glassy.

Vitrophyre – Any *porphyritic igneous* rock having a glassy *groundmass*.

Vitric – Said of *pyroclastic* material that is characteristically glassy.

Volcanic – Pertaining to the activities, structure, or rock types of a *volcano*.

Volcano – A vent in the surface of the Earth through which magma and associated gases and ash erupt; also, the form or structure, usually conical, that is produced by the ejected material.

Welded tuff – A glass-rich *pyroclastic* rock that has been indurated by the welding together of its glass shards under the combined action of the heat retained by particles, the weight of overlying material, and hot gases. It is generally composed of silicic pyroclastics and appears banded or streaky.

Zircon – A mineral: $ZrSiO_4$, a common accessory mineral in *siliceous igneous* rocks, crystalline *limestones*, *schists*, and *gneisses*, in *sedimentary rocks* derived therefrom, and in beach and stream deposits.

APPENDICES

APPENDIX A

Explanatory material for geologic map (plate 1)

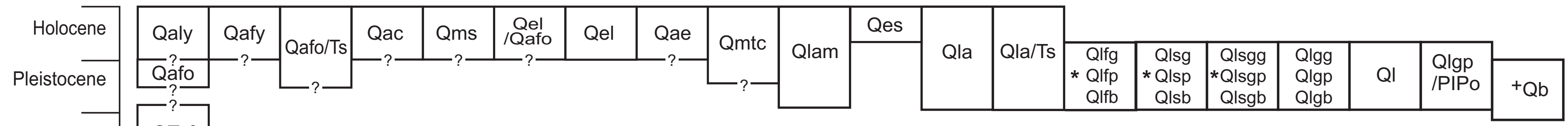
Eon	Era	Period		Epoch	Age	Age estimates in Ma[1]
Phanerozoic	Cenozoic	Quaternary		Holocene		0.01
				Pleistocene		1.8
		Tertiary	Neogene	Pliocene		5.3
				Miocene		23.8
			Paleogene	Oligocene		33.7
				Eocene		54.8
				Paleocene		65.0 (0.2)
	Mesozoic	Cretaceous		Late	Maastrichtian	71.3 (1)
					Campanian	83.5 (1)
					Santonian	87.5 (1)
					Coniacian	89.0 (2.5)
					Turonian	93.5 (4)
					Cenomanian	99.0 (1)
				Early	Albian	112 (2)
					Aptian	121 (3)
					Neocomian	144 (5)
		Jurassic		Late		159 (7)
				Middle		180 (8)
				Early		210 (8)
		Triassic		Late		227 (9)
				Middle		242 (9)
				Early		248 (10)

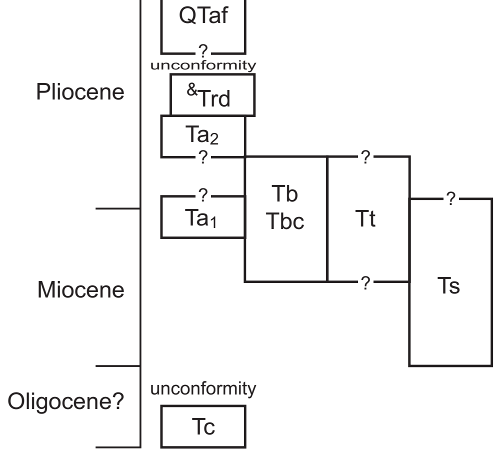
[1] *Uncertainties shown in parentheses except where none are reported.*

Eon	Era	Period	Epoch	Age	Age estimates in Ma[1]
					248 (10)
Phanerozoic	Paleozoic	Permian	Late		275
			Early		290
		Pennsylvanian	Late		310
			Middle		315
			Early		323
		Mississippian	Late		342
			Early		354
		Devonian	Late		370
			Middle		391
			Early		417
		Silurian	Late		423
			Early		443
		Ordovician	Late		458
			Middle		470
			Early		490
		Cambrian	Late		500
			Middle		520
			Early		543
Proter-ozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				3800?

Figure A.1. *Geologic time scale (after Palmer and Geissman, 1999).*

CORRELATION OF MAP UNITS





Notes:

? Age of contact uncertain or poorly constrained

* Lacustrine sediments are denoted by the last letter in the map symbol according to the lake stage during which they were deposited: g – Gilbert stage of the Great Salt Lake [10.9-10.3 ka, shoreline at 4,250 feet (1,294 meters)]; p – Provo stage of Lake Bonneville [14.5-14.0 ka, highest shoreline at 4,800-4,750 feet (1,263-1,448 meters)]; b – Bonneville stage of Lake Bonneville [15.0 - 14.5 ka, highest shoreline at 5,180 feet (1,579m); secondary shoreline at 5,150 feet (1,570 meters)]; Stage names, ages, and shoreline elevations from Oviatt and others (1992).

+ K-Ar whole-rock ages are 1.16 ± 0.08 Ma for the Cedar Hill (northern) shield, 0.72 ± 10.15 Ma for the middle shield, and 0.44 ± 0.10 Ma for the Locomotive Springs (southern) shield (table A.1; Miller and others, 1995).

& K-Ar ages range from 2.1 ± 0.06 Ma on sanidine from rhyolite, to 4.9 ± 0.4 Ma on whole-rock basalt (table A.1; Miller and others, 1995).

Qel/Qafo "Stacked Unit" - A thin, locally absent veneer of the unit above the backslash overlies the unit below the backslash

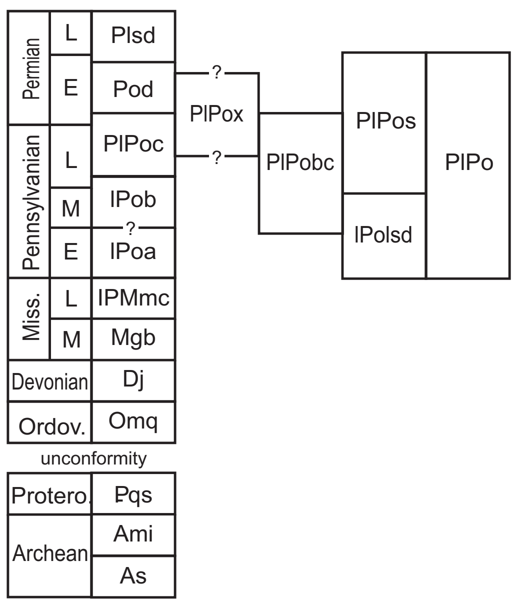


Figure A.2. *Correlation of map units shown on plate 1.*

CORRELATION OF PRE-TERTIARY SOURCE-MAP UNITS

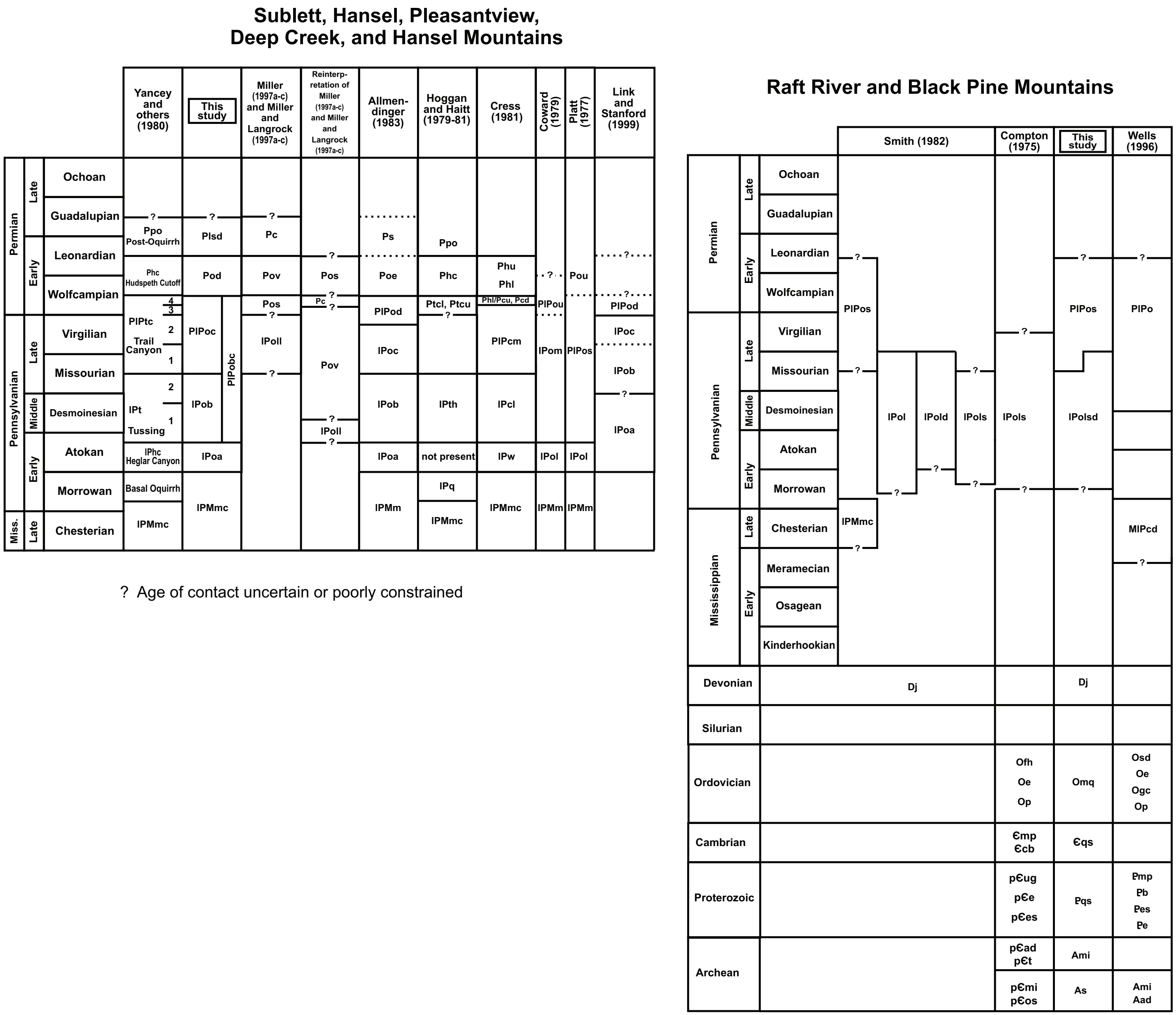


Figure A.3. *Correlation of pre-Tertiary map units—units used on plate 1 and its source maps.*

Table A.1. *Radiometric K-Ar ages from Curlew Valley study area.*

Map ID[1]	Source[2]	Sample[3]	Latitude	Longitude	Northing UTM 12N	Easting UTM 12N	Location	Rock Type	Material Dated	Age (Ma)
1	M	M93WI-40	41°50'43"	113°01'32"	4634368	331834	Wildcat Hills	Rhyolite	Sanidine	2.1 ± 0.06
2	M	M93WI-37	41°51'09"	113°00'48"	4635146	332868	Wildcat Hills	Rhyodacite	Plagioclase	4.4 ± 1.1
3	M	M93WI-43	41°49'03"	113°01'50"	4631294	331346	Wildcat Hills	Basalt	Whole Rock	3.6 ± 0.1
4	M	AD/WH/91-7	41°48'51"	113°02'01"	4630930	331083	Wildcat Hills	Basalt	Whole Rock	4.9 ± 0.4
5	M	M87LS-135	41°42'23"	112°54'29"	4618724	341247	Locomotive Springs	Basalt	Whole Rock	0.44 ± 0.1
6	M	M89CV-44	41°44'52"	112°54'24"	4623317	341465	middle shield	Basalt	Whole Rock	0.72 ± 0.15
7	M	M89CV-43	41°50'25"	112°51'33"	4633500	345637	Cedar Hill	Basalt	Whole Rock	1.16 ± 0.08
8	F	AD/TM/88-6	41°42'33"	113°08'37"	4619493	321655	Table Mountain	Basalt	Whole Rock	5.7 ± 0.6
9	F	AD/BB/88-7	41°51'56"	113°10'21"	4636918	319691	NW of Black Butte	Basalt	Whole Rock	8.6 ± 0.8
n/a[4]	F	AD/RP/91-1	41°53'48"	112°32'59"	4639251	371443	Rattlesnake Pass	Basalt	Whole Rock	14.7 ± 0.5
n/a[4]	F	AD/RP/91-2	41°53'43"	112°33'16"	4639104	371048	Rattlesnake Pass	Basalt	Whole Rock	14.9 ± 0.5
10	F	AD/TM/91-3	42°05'01"	112°51'15"	4660534	346667	Table Mountain ID	Basalt	Whole Rock	12.6 ± 0.5
11	F	AD/TM/91-4	42°05'02"	112°51'11"	4660473	346626	Table Mountain ID	Basalt	Whole Rock	13.1 ± 0.5
12	F	AD/PV/91-5	41°49'16"	113°09'20"	4631948	320973	South of Black Butte	Basalt	Whole Rock	6.1 ± 0.4
13	F	AD/KV/91-6	41°45'09"	113°11'26"	4624403	317872	Basalt dike	Basalt	Whole Rock	5.0 ± 0.4
14	F	AD/WH/91-7	41°48'51"	113°02'01"	4630930	331083	Wildcat Hills	Basalt	Whole Rock	4.9 ± 0.4

Notes
[1]Keyed to sample-site labels on plate 1.
[2]M = Miller and others (1995), F = D. Fiesinger, Utah State University, written communication (2004).
[3]Sample number listed in original source.
[4]Sample location is about 3 miles (4.8 km) east of the study area, along Interstate 84.

Table A.2. *Records of petroleum-exploration wells in Curlew Valley map area[1].*

Map ID[2]	Township, Range, Section	Spot[3]	Completion Date	Operator	Well Name	Wellhead Elev. (ft)	Total Depth (feet)
A	14 S 30 W 10	3250 FSL 152 FWL	2/12/51	UTAH SOUTHERN OIL COMPANY	1 JUNIPER	5840	12,841
B	14 N 9 W 6	1980 FNL 660 FEL	04/27/1956	UTAH SOUTHERN OIL COMPANY	2 FEDERAL	4420	7569
C	14 N 10 W 14	1998 FNL 1863 FEL	12/01/1954	UTAH SOUTHERN OIL COMPANY	GOVT-GABRIELSON	4408	4767
D	14 N 10 W 23	1980 FNL 660 FWL	12/01/1954	UTAH SOUTHERN OIL COMPANY	1 KEELER	4394	4760
E	14 N 10 W 22	891 FSL 1940 FWL	01/13/1956	UTAH SOUTHERN OIL COMPANY	1 FEDERAL	4412	6465
F	13 N 11 W 25	2210 FNL 330 FEL	10/08/1946	STANFORD PETROLEUM	1 FONNS BECK	5325	730

Notes
[1]Data from Utah Division of Oil, Gas and Mining
[2]Keyed to petroleum-well labels on plate 1.
[3]Well location within section is given in feet from south (FSL) or north (FNL), and from west (FWL) or east (FEL) section-boundary lines.

DESCRIPTION OF MAP UNITS

Sources include author's (Hurlow) field observations, Compton (1975), Yancey and others (1980), Hoggan and Haitt (1981), Allmendinger (1983), Wells (1996), Miller (1997a-c), and Miller and Langrock (1997a-c), and other sources cited in the text.

QUATERNARY

Alluvial Deposits

Qaly **Stream deposits** (Holocene) – Well- to moderately sorted gravel, sand, silt, and clay deposited in stream channels, terraces, and flood plains; many deposits are present in ephemeral drainages but are too small to show at this scale; up to about 30 feet (9 m) thick.

Qafy **Alluvial-fan deposits** (Holocene to ?Late Pleistocene) – Moderately to poorly sorted boulders, gravel, sand, and silt deposited by debris-flow and sheet-wash processes; form fan-shaped deposits at the mouths of canyons and smaller drainages, at the interface between bedrock-dominated mountains and adjacent basins, and at the mouths of smaller drainages within topographic basins; up to 100 feet (30 m) thick.

Qafo **Older alluvial-fan deposits** (Pleistocene and Holocene) – Moderately to poorly sorted pebble to boulder gravel, sand, and silt deposited by debris-flow and sheet-wash processes; form broad, coalesced fan-shaped deposits emanating from the mouths of major drainages where they intersect topographic basins; deeply incised by younger streams; at least 100 feet (30 m) thick, but may be substantially thicker locally.

Eolian Deposits

Qes **Eolian sand and silt** (Holocene) – Well-sorted, fine-grained sand to silt that forms small dunes in topographically low areas, stands of trees, or on the leeward sides of small hills; variably stabilized by vegetation; mapped chiefly along the east margin of the Raft River Mountains and the south margin of the Wildcat Hills; up to about 3 feet (1 m) thick.

Qel **Eolian loess** (Holocene to Late Pleistocene) – Light-brown silt with variable amounts of intermixed fine-grained sand; mantles older surficial deposits and bedrock in topographic lows along the margins of mountain ranges; most extensive deposits are in northern Juniper Valley and in the foothills of the Sublett Range northeast of Stone Valley; up to about 6 feet (2 m) thick.

Lacustrine Deposits

All lacustrine deposits shown on this map were deposited in Pleistocene Lake Bonneville and Holocene Great Salt Lake. The last letter in the map symbol refers to the lake stage during which the deposit formed: g – Gilbert stage of Great Salt Lake (10.9–10.3 ka, shoreline at 4250 feet [1294 m]); p – Provo stage of Lake Bonneville (14.5–14.0 ka, highest shoreline at 4800 to 4750 feet [1263–1448 m]); b – Bonneville stage of Lake Bonneville (15.0–14.5 ka, highest shoreline at 5180 feet [1579 m], secondary shoreline at 5150 feet [1570 m]). Stage names, ages, and shoreline elevations are from Oviatt and others (1992).

Qlfg, Qlfp, Qlfb **Lacustrine silt and marl** (Pleistocene) – Silt is tan to yellow tan, laminated to well-layered where exposed, and contains variable amounts of clay; locally contains beds of sand, pebbly sand, and gravel less than about 1 foot (0.3 m) thick. Marl is white to pale brown, and contains abundant ostracodes and sparse dropstones; lower part is typically white and laminated, upper part is white to pale brown; locally contains beds of sand, pebbly sand, and gravel less than about 1 foot (0.3 m) thick; includes "reworked marl" unit of Miller (1997a-c) and Miller and Langrock (1997a-c); thickness varies from about 0 to 40 feet (0–12 m), depending on local pre-lacustrine topography.

Qlsg, Qlsp, Qlsb **Lacustrine sand** (Pleistocene) – Tan to brown, well-sorted, fine-grained sand deposited on beaches, offshore bars, and a broad delta plain west of Rose Ranch Reservoir; thickness about 30 feet (10 m) or less.

Qlsgg, Qlsgp, Qlsgb **Lacustrine sand and gravel** (Pleistocene) – Tan to pale-gray, well-sorted, fine-grained sand and interbedded pebble gravel, deposited on beaches, offshore bars, and as thin mantles on slopes adjacent to shorelines cut on moderate to steep bedrock slopes; well-defined, planar, gently to moderately inclined bedding, only locally exposed; thickness about 30 feet (10 m) or less.

Qlgg, Qlgp, Qlgb **Lacustrine gravel** (Pleistocene) – Pale-gray, well-sorted pebble to cobble gravel with variable amounts of sand in discrete beds or as matrix, deposited on beaches, offshore bars, and as thin mantles on slopes adjacent to shorelines cut on moderate to steep bedrock slopes; where exposed in gravel pits, characterized by well-defined, planar, gently to moderately inclined bedding; thickness about 100 feet (30 m) or less.

Ql **Lacustrine deposits, undivided** (Pleistocene) – Gravel, sand, and silt, mapped where deposits are interbedded or intermixed at scales too fine to differentiate on map; thickness about 100 feet (30 m) or less.

Mass-movement deposits

Qms **Landslide and slump deposits** (Holocene to ?Pleistocene) – Poorly sorted debris ranging from large blocks to silt, deposited principally by rotational slides; thickness about 30 to 50 feet (10–15 m).

Qmtc **Talus and colluvium** (Holocene to ?Pleistocene) – Poorly sorted debris ranging from large blocks to silt, deposited by block fall, slope wash, and creep processes on steep to moderate slopes, chiefly below mesa-forming basalt outcrops; up to about 10 feet (3 m) thick.

Mixed-environment deposits

Qac **Alluvial and colluvial deposits** (Holocene to ?Pleistocene) – Poorly sorted, boulder- to silt-size, locally derived debris deposited on gentle to moderate slopes and in swales and small drainages by fluvial, slope wash, and creep processes; up to about 20 feet (6 m) thick.

Qae **Alluvial and eolian deposits** (Holocene to ?Pleistocene) – Fine-grained eolian sand reworked by and/or intermixed with stream or alluvial-fan deposits at a scale too fine to separate on the map; up to about 30 feet (10 m) thick.

Qla **Lacustrine and alluvial deposits** (Holocene to Pleistocene) – Moderately to well-sorted gravel, sand, silt, and clay deposited in lacustrine environments, reworked by ephemeral streams and/or slope wash, and intermixed with deposits formed from these processes; mapped adjacent to major stream channels and on the flanks of mountain slopes having lacustrine deposits; gradational with adjacent undisturbed lacustrine deposits; mapped where linear texture associated with shoreline processes is significantly disrupted or obscured by stream channels and/or slope wash, as seen on aerial photographs; forms a thin mantle on underlying lacustrine deposits; up to 3 feet (1 m) thick.

Qlam **Lacustrine and alluvial mud** (Holocene to Pleistocene) – Well-sorted clay and silt deposited by ephemeral streams on flats immediately north of Great Salt Lake; composed chiefly of reworked lacustrine clay and silt; may include some lacustrine mud from Holocene highstands of Great Salt Lake; maximum thickness about 3 feet (1 m).

Stacked-unit deposits

Qafo/Ts **Older alluvial-fan deposits over Salt Lake Formation** – Older alluvial-fan deposits overlying discontinuously exposed Salt Lake Formation; mapped on northwestern flank of North Hansel Mountains, and in the central Sublett Range in the northwest part of the map area.

Qel/Qafo **Eolian loess over older alluvial-fan deposits** – Older alluvial-fan deposits mantled by up to 3 feet (1 m) of pale-tan to brown eolian loess; alluvial-fan deposits are moderately sorted, moderately to well-bedded pebble to cobble gravel exposed where ephemeral streams have incised through the loess; mapped along range margins where fan morphology is clearly visible on aerial photographs but deposits present on the surface are predominantly loess.

Qla/Ts **Lacustrine and alluvial deposits over Salt Lake Formation** – Lacustrine deposits reworked by alluvial processes and intermixed and overlain by alluvial deposits that form a mantle up to 6 feet (2 m) thick on Salt Lake Formation; Salt Lake Formation is discontinuously exposed in stream bottoms, south-facing slopes of stream canyons, and along ridge crests.

Qlgp/PIPo **Lacustrine gravel over Oquirrh Group** – Lacustrine gravel deposited during the Provo stage of Lake Bonneville, that forms a thin mantle over discontinuously exposed Oquirrh Group rocks.

Igneous rocks

Qb **Basalt** – Brown- to black-brown-weathering, dark-gray to black on fresh surfaces, variably vesicular flow rock containing fine- to medium-grained, subhedral plagioclase, olivine, and pyroxene phenocrysts in various relative abundances, in an aphanitic groundmass; forms three shield volcanoes from Cedar Hill south to Locomotive Springs, with progressively decreasing radius and summit elevation. Miller and others (1995) reported K-Ar whole-rock ages of 1.16 ± 0.08 Ma, 0.72 ± 0.15 Ma, and 0.44 ± 0.10 Ma for the northern, central, and southern shields, respectively (table B.1). A water well 2.8 miles (4.5 km) northeast of the crest of Cedar Hill penetrated 523 feet (160 m) of basalt; flow thickness is probably much greater below central cone areas and tapers outward.

QUATERNARY AND TERTIARY

QTaf **Alluvial-fan deposits** – Moderately to poorly sorted pebble to cobble gravel; bedding not exposed; clasts consist of metamorphic rocks exposed on south flank of Raft River Mountains, and of Oquirrh Group rocks on east flank of Black Pine Mountains; eroded and deeply dissected by active drainages; up to about 400 feet (120 m) thick.

unconformity

TERTIARY

Trd **Rhyodacite and rhyolite** (Pliocene) – Pale- to medium-gray or pinkish-gray welded ash-flow tuff composed of flow-banded to structureless, cryptocrystalline to glassy groundmass containing sparse pyroxene and plagioclase phenocrysts and pebble-sized spherules composed of gray, white, and pinkish-gray devitrified glass, pumice, or black glass. Miller and others (1995) reported K-Ar ages of 4.4 ± 1.1 Ma on plagioclase from rhyodacite and 2.1 ± 0.06 Ma on sanidine from rhyolite from the Wildcat Hills (table B.1). At least 200 feet (60 m) thick.

Ta2 **Pediment gravel** (Pliocene) – Subangular to subrounded, locally derived cobble to pebble gravel, grading to diamictite; deposited by alluvial processes on broad, smooth erosional surfaces; locally includes a silty or tuffaceous matrix; up to 250 feet (75 m) thick.

unconformity

Tb, Tbc **Basalt** (Pliocene to Miocene) – Brown- to brown-black-weathering, dark-gray to black on fresh surfaces, variably vesicular, aphanitic groundmass with medium- to fine-grained subhedral phenocrysts of olivine and plagioclase; up to about 300 feet (100 m) thick; Tbc is a cinder cone in the south-central Sublett Range west of Stone Reservoir. D. Fiesinger, Utah State University (written communication, 2004) reported the following K-Ar whole-rock ages for Tertiary basalt from various parts of the map area (table A.1): 5.0 ± 0.4 to 8.6 ± 0.8 Ma for flows and a dike in the southwestern part of the map area; 4.9 ± 0.4 Ma for a flow in the Wildcat Hills (not differentiated on plate 1); 14.7 ± 0.5 and 14.9 ± 0.5 Ma for flows at Rattlesnake Pass, along Interstate 84 about 3 miles (4.8 km) east of the map area; and 12.6 ± 0.5 and 13.1 ± 0.5 Ma for flows of Table Mountain in the west-central Sublett Range. Miller and others (1995) reported K-Ar whole-rock ages for basalt flows from the Wildcat Hills of 3.6 ± 0.1 and 4.9 ± 0.4 (table A.1).

Ta1 **Alluvium** (Miocene to ?Pliocene) – Pebble to cobble gravel deposited in alluvial-fan and stream environments; mapped below Tertiary basalt flows; poorly exposed; up to 215 feet (65 m) thick.

Tt **Tuff** (Miocene to Pliocene) – This map unit includes several different tuff units mapped by Hoggan and Haitt (1981) and Cress (1981). In the Sublett Range, Hoggan and Haitt (1981) mapped vitric ash-fall tuff containing glass shards and lithic fragments; pinkish-gray vitric ash-flow tuff containing some lithic fragments; white to gray ash-fall and water-lain tuff, locally well-bedded, composed principally of glass shards; gray to pink, rhyolitic, densely welded tuff with basal vitrophyre and phenocrysts of sanidine and pyroxene; and gray, friable, rhyolitic, vitric, poorly welded ash-flow tuff containing columnar jointing. In the southwestern Deep Creek Mountains, Cress (1981) included the tuff of Arbon Valley and two ash-fall tuffs in the upper member of the Salt Lake Formation. The tuff of Arbon Valley is brown-weathering, buff-gray fresh, moderately welded to non-welded ash-flow tuff including a matrix of pumice and devitrified glass and phenocrysts of sanidine, smoky quartz, and biotite (see Trimble and Carr [1976] for a more complete description). The ash-fall tuff is poorly exposed, brown-weathering, light-gray fresh, poorly to well-bedded, reworked, and devitrified (Cress, 1981). About 0 to 50 feet (15 m) thick.

Ts **Salt Lake Formation** (Miocene to ?early Pliocene) – Sandstone, conglomerate, tuffaceous sandstone, tuffaceous siltstone and mudstone, rare lacustrine dolomite and limestone, and water-lain tuff; deposited in alluvial and lacustrine environments. The Salt Lake Formation is discontinuously exposed in four main parts of the study area: the western margin of the North Hansel Mountains, the southern Deep Creek Mountains, the eastern Raft River Mountains, and the southwestern part of the map area. Exposures are typically along south-facing walls of stream gullies and canyons; many small, discontinuous exposures are found near those depicted on plate 1 but are too small to include on the map. The Salt Lake Formation likely covered much of the study area during deposition and forms a substantial part of the basin fill below the fault-bounded valleys.

Janecke and others (2003) described the Salt Lake Formation in the Bannock Range in southeastern Idaho, and Goessel and others (1999) and Oaks and others (1999) described the formation in and adjacent to Cache Valley in Utah. The Salt Lake Formation was deposited in those regions between about 10 to 13 Ma and 4 to 5 Ma, chiefly in alluvial and lacustrine environments, during basin development related to low- and high-angle normal faulting (Goessel and others, 1999; Oaks and others, 1999; Janecke and others, 2003; Carney and Janecke, 2005; Steely and others, 2005). Individual beds are laterally discontinuous, and formation subdivisions vary substantially in thickness over relatively short distances. Janecke and others (2003) defined four members of the Salt Lake Formation, from oldest to youngest: (1) the Skyline Member, consisting of up to 1200 feet (370 m) of conglomerate, deposited between about 13 and 10 Ma; (2) the Cache Valley Member, a sequence of tuffaceous sandstone and mudstone interbedded with tuff and minor limestone and conglomerate, at least 1165 feet (355 m) thick, deposited around 10 Ma; interbedded pebble conglomerate, tuffaceous sandstone, mudstone, and limestone of the Third Creek Member, over 3260 feet (1000 m) thick, deposited from around 10 to 4 Ma; and (4) the New Canyon Member, consisting of poorly exposed cobble conglomerate, about 800 to 3200 feet (250–1000 m) thick, that was deposited around 4 Ma.

Rock types of the Salt Lake Formation similar to those described by Janecke and others (2003) are present in the study area. These rocks should not at present be assigned to the units described by Janecke and others (2003), due to limited exposure, lack of age dating, and the likelihood of diachronous deposition of similar rock types due to the fault-controlled nature and limited extent of depositional basins in the region.

The only age controls on the Salt Lake Formation in the study area are: (1) in the southern Deep Creek Mountains, diamictite of the Salt Lake Formation underlies the tuff of Arbon Valley, dated by the $^{40}Ar/^{39}Ar$ method at 10.27 ± 0.07 Ma (Janecke and others, 2003); (2) undated basalt flows overlie the middle part of the Salt Lake Formation in the southwestern Deep Creek Mountains (plate 1) – these flows are part of a large basalt field in the Sublett Range, and flows from the westernmost exposures of this field yielded K-Ar whole-rock ages of 12.6 ± 0.5 and 13.1 ± 0.5 Ma (D. Fiesinger, written communication, 2004); and (3) basalt in the eastern foothills of the Raft River Mountains dated at 8.6 ± 0.8 Ma by the K-Ar whole-rock method (D. Fiesinger, written communication, 2004) overlies the Salt Lake Formation there.

In the North Hansel Mountains, the Salt Lake Formation consists chiefly of tan to pale-gray, moderately sorted, medium- to fine-grained, poorly bedded tuffaceous sandstone; other rock types include well-sorted pebble conglomerate deposited in stream channels; pale-tan to brown, structureless diamictite deposited as mudflows; and moderately sorted, medium-grained, well-bedded tuffaceous sandstone consisting almost entirely of pale- to medium-gray glass shards. Exposures are along the lower western margin of the range in the hanging wall of the range-bounding fault zone. The Salt Lake Formation along the margin of the Hansel Mountains is at least 700 feet (210 m) thick, but this is difficult to determine due to poor exposure and lack of exposed bedding planes.

In the southern Deep Creek Mountains, the Salt Lake Formation includes diamictite that is tan to brown, poorly sorted, structureless, contains subangular to angular pebbles composed of Oquirrh Group and volcanic rocks, and is about 650 feet (200 m) thick (Cress, 1981). Exposures are chiefly along stream gullies and road cuts on the southern and southwestern flanks of the range. Cress (1981) mapped a gravel member, about 1,640 feet (500 m) thick, of the Salt Lake Formation along the margins of the southern Deep Creek Mountains; that unit along the eastern range margin is reinterpreted as Quaternary-Tertiary alluvial-fan deposits in this report, but may be equivalent to the New Canyon Member of Janecke and others (2003). Cress' gravel member on the southwestern margin of the Deep Creek Mountains is here included in the Salt Lake Formation. Cress (1981) included basalt flows and siliceous tuff in the Salt Lake Formation; those units are separated from the Salt Lake Formation and included in units Tb and Tt, respectively, in this report.

In the eastern Raft River Mountains and in the southwestern part of the map area, the Salt Lake Formation includes pale-gray to yellowish- or greenish-gray, well- to poorly sorted, well-bedded, fine to coarse tuffaceous sandstone; moderately to well-sorted, moderately to poorly bedded conglomerate containing rounded pebbles of Oquirrh Group and Paleozoic metasediments identical to those exposed in the Raft River Mountains; pale-green-gray, well-bedded tuffaceous siltstone to mudstone; pale-tan to yellow-tan, fine-grained, medium-bedded, unfossiliferous dolomite; and pale- to medium-gray, moderately to well-sorted, moderately to poorly bedded water-lain tuff consisting primarily of glass shards. The thickness of the Salt Lake Formation in this area is difficult to determine accurately due to discontinuous exposure, but is at least 1700 feet (520 m) (Wells, 1996).

unconformity

Tc **Conglomerate and sedimentary breccia** (?Oligocene) – Brown to reddish-brown, moderately to poorly sorted, structureless to weakly cross-bedded, clast-supported pebble to cobble conglomerate grading to sedimentary breccia; clasts are angular to subrounded and consist entirely of sandstone, limestone, and chert derived from the Oquirrh Group; likely deposited in alluvial-fan or colluvial-slope environments in the hanging wall of an east-side-down normal fault in the eastern foothills of the Raft River Mountains; age uncertain but inferred to be Oligocene, the time of extensive normal faulting in the eastern Raft River Mountains (Wells and others, 2000); at least 500 feet (150 m) thick.

unconformity

PERMIAN

Plsd **Limestone, sandstone, and dolomite** – Light-gray to tan, well-sorted, fine-grained, well-bedded calcareous sandstone; buff-tan, fine-grained, poorly bedded, sandy, variably fossiliferous dolomite; medium- to dark-gray bedded chert; and medium-gray, fine-grained, poorly bedded limestone; deposited in shallow-marine environments; contains Early Permian (Leonardian) conodonts (Yancey and others, 1980); about 2300 feet (700 m) thick, but top not exposed in study area.

Oquirrh Group

The Oquirrh Group consists of interbedded calcareous sandstone and siltstone, sandy to silty limestone, bioclastic limestone, and cherty limestone deposited in shallow to medium depth (up to 1300 feet [400 m]) marine environments in the Oquirrh-Wood River basin of Early Pennsylvanian to Early Permian age (figures 4, 5, and 6) (Armstrong, 1968b; Jordan and Douglass, 1980; Geslin, 1998). The Wood River basin refers to the depositional basin north of the Snake River plain in which mid-Pennsylvanian to mid-Permian rocks accumulated, and the Oquirrh basin is used for the depositional basin south of the Snake River Plain (figure 4); the two basins were contiguous during deposition. The Curlew Valley study area is situated in the northern part of the Oquirrh basin. The total thickness of the Oquirrh Group rocks in the study area is approximately 10,000 to 13,500 feet (3000–4100 m) (figure 6).

The map compilation for this report (plate 1; appendix B) includes nine sources of previous work that use seven different versions of Oquirrh Group stratigraphy. Reconciling these different versions was challenging. Plate 1 employs two stratigraphic nomenclatures for the Oquirrh Group, one for the majority of the study area, based on the section described by Yancey and others (1980) from the northeastern Sublett Range; and a second, simpler nomenclature, used for the Black Pine and Raft River Mountains and based on the work of Smith (1982) and Compton (1975). The twofold nomenclature is necessary because the complex structure and metamorphism, and perhaps original regional facies variations, in the Black Pine and Raft River Mountains prevent more detailed subdivision of the Oquirrh Group there.

The lithologic succession and marker beds described by Yancey and others (1980) are present in the Pleasantview Hills, North Hansel Mountains, Deep Creek Mountains, and Sublett Range. Because of potential variations in the ages of contacts, lithology, and the nature of marker beds among ranges, this report uses informal units for the Oquirrh Group rather than retain the formation names of Yancey and others (1980). Figure A.2 shows the relations between the formations of Yancey and others (1980), the map units used in this report, and those of previous workers in the study area.

The relation between the stratigraphy described by Miller (1997a-c) and Miller and Langrock (1997a-c) and the section of Yancey and others (1980) is problematic, due to sparse age control and structural complexity in the southwestern Hansel Mountains. Miller interprets his "cherty limestone" (his map unit Pc) and "variable lithology" (his map unit Pov) members to overlie a "sandstone" member (his unit Pos) in the southwestern Hansel Mountains. In contrast, thick sandstone (unit Pod, plate 1 and appendix B) forms the top of the Oquirrh Group throughout the rest of the study area (Hudspeth Cutoff Formation of Yancey and others, 1980; Smith, 1982). Miller's cherty limestone unit, which he does not include in the Oquirrh Group, closely resembles the top of Yancey and others' (1980) Trail Canyon Formation, which *underlies* the sandstone-rich unit (figure A.2), and Miller's "variable lithology" unit is similar to the rest of the Trail Canyon. In the southwest Hansel Mountains southeast of Snowville, Miller's sandstone unit (his Pos) dips east to northeast and is located west of and topographically below outcrops of the cherty limestone (Miller's Pc) and variable lithology (Miller's Pov) units. This geometric relationship implies that the sandstone unit underlies, and is older than, the cherty limestone and variable lithology units, but contradicts the stratigraphic relations observed in the structurally undisrupted section in Idaho as described above.

To help resolve the apparent disagreement between Yancey and others' (1980) and Miller's (1997a-c) versions of upper Oquirrh Group stratigraphy, one of us (Hurlow) collected samples from the southwestern Hansel Mountains for biostratigraphic analysis (sample locations shown on plate 1). Nine samples were analyzed for their fusulinid content by A.J. Wells (written communication, January, 2006), an independent contractor with extensive experience as a biostratigrapher in the petroleum industry. Seven samples were analyzed for their conodont content by Scott Ritter of Brigham Young University (written communication, January 2006).

Seven of the nine samples contained no fusulinids. Two samples from Miller's sandstone unit (his Pos) contained abraded and poorly preserved fusulinids, of early Virgilian age (*Tricities*) in one sample and of early Desmoinesian age (*Wedekindalina*) in the other (see figure A.3 for Permian time scale). The highly abraded state of the fusulinids suggests that they were eroded out of pre-existing rocks before deposition in the Oquirrh sandstone. The sandstone unit is, therefore, younger than the ages of the detrital fusulinids it contains, and is here interpreted as early Virgilian (Late Pennsylvanian) or younger. This partial age constraint is consistent with the mid-Wolfcampian to early Leonardian age of the Hudspeth Cutoff Formation reported by Yancey and others (1980), denoted in this study as unit Pod. One sample of bioclastic calcareous shale, collected east of and topographically and structurally above the sandstone samples, contained the calcareous algae *Komia* which is only found in lower Desmoinesian strata (A.J. Wells, written communication, January 2006). The sample is from overturned beds similar to the upper part of the Trail Canyon Formation of Yancey and others (1980) and overlies (but is older than, due to the overturned geometry of the section) bedded chert and cherty limestone that strongly resemble the top of the Trail Canyon Formation (Yancey and others, 1980).

Only one sample submitted for conodont analysis contained conodonts, but the identified element, *Hindeodus* sp., is a long-ranging form that does not permit age identification more specific than Pennsylvanian-Permian (S. Ritter, written communication, January 2006).

The biostratigraphy and lithology of the samples from the southwestern Hansel Mountains collected for this study are consistent with the following reinterpretation of Miller's (1997a-c) stratigraphy. Miller's Pc unit is here regarded as the uppermost part (mid-Wolfcampian) of Yancey and others' (1980) Trail Canyon Formation of the Oquirrh Group, and his Pov unit is regarded as the middle part (Lower Pennsylvanian to Lower Permian) of the Trail Canyon Formation—both are assigned to unit PlPoc on plate 1. Miller's Pos unit is interpreted to approximately correlate with the Hudspeth Cutoff Formation (Wolfcampian and Leonardian) of Yancey and others (1980) and is assigned to unit Pod of this report. These relationships are shown in figure A.3. We infer that a northwest-striking, steeply southwest-dipping normal fault separates units Pod and PlPoc in the southwest Hansel Mountains (plate 1). Unit Pod is in the hanging wall of this inferred fault, accounting for its structurally lower position than rocks of the older unit PlPoc.

Pod **Oquirrh Group unit d** – Brownish-tan to orange-brown on weathered surfaces, tan to grayish-tan on fresh surfaces, well-sorted, fine- to medium-grained, well-bedded (planar or, rarely, cross-bedded) to structureless, noncalcareous or, less commonly, calcareous sandstone grading to quartzite; forms a thick, monotonous section and is generally poorly exposed; thin beds of buff dolomite and silty, unfossiliferous to coarse-grained, bioclastic limestone are found near the top of the unit; pale-gray, medium-grained, cross-bedded sandstone is found near the middle; fusulinids suggest Early Permian (post-early Wolfcampian to early Leonardian) age (Yancey and others, 1980; R.C. Douglass *in* Allmendinger, 1983); about 2200 to 3300 feet (670–1000 m) thick.

PERMIAN AND PENNSYLVANIAN

PIPo **Oquirrh Group undivided** – Shown where exposures are poor or where previous work is of insufficient detail to assign a unit designation to outcrops.

PIPox **Bioclastic limestone unit of Oquirrh Group** – Medium- to dark-blue-gray, fine- to medium-grained, well-sorted, well- to poorly bedded, bioclastic calcarenite; visible fossil fragments include brachiopod shells, crinoid stems and heads, and coral; variable amounts of dark-gray chert, either bedded or as irregular nodules; mapped in the North Hansel Mountains by Allmendinger (1983) as fault-bounded masses above Oquirrh Group rocks of similar age; distinguished based on markedly different facies and appearance from other rocks in the North Hansel Mountains; age estimated as Late Pennsylvanian to Early Permian (Allmendinger, 1983); contains Virgilian fusulinids (R.L. Ballou *in* Allmendinger, 1983); upper contact not exposed, lower contact removed by low-angle faults; up to about 600 feet (300 m) thick.

PIPoc **Oquirrh Group unit c** – Interbedded sandy to silty limestone, calcareous sandstone to siltstone, and rare bioclastic limestone. Sandy to silty limestone includes medium-gray, tan-gray, or yellow-gray, well-bedded, unfossiliferous, silty micrite to calcarenite; and medium-gray, fine- to medium-grained, well-bedded to platy calcarenite with tan- to brown-weathering, fine- to medium- grained quartz sandstone that is diffusely distributed or in clearly defined layers. Calcareous sandstone is grayish-tan- to tan-weathering, tan or medium-gray on fresh surfaces, well-sorted, and fine-grained and has well- to poorly defined planar bedding. Calcareous siltstone is medium-gray varying to shades of pink, lavender, or brown, well-sorted, and well-bedded to platy. Bioclastic limestone is medium-blue-gray, well-sorted, medium-grained calcarenite having well-defined bedding and sparse visible fragments of crinoid, brachiopod, coral, and other remains; forms ledges about 3 to 12 feet (1–4 m) thick. The upper contact is marked by an abrupt transition from interbedded limestone and calcareous sandstone and shale, to sandstone of unit Pod; the lower contact is placed at a relatively thick (100 feet [30 m]) group of ledge-forming, variably sandy, well-bedded bioclastic limestone beds. Unit c ranges from about 3800 to over 6000 feet (1160–>1830 m) thick and contains Late Pennsylvanian to Early Permian (Virgilian to Wolfcampian) age fusulinids (Hoggan and Haitt, 1981; R.C. Douglass and R.L. Ballou *in* Yancey and others, 1980; and Allmendinger, 1983).

PIPos **Sandstone and siltstone unit of Oquirrh Group** – Tan- to brown-weathering, light-gray to yellowish-gray on fresh surfaces, poorly sorted, well- to moderately bedded, calcareous sandstone grading to siltstone; relatively minor gray-weathering, gray to dark-gray, fine-grained, unfossiliferous silty limestone is interbedded with the sandstone; contains Middle Pennsylvanian to Early Permian (Desmoinesian to early Wolfcampian) conodont, fusulinid, and bryozoan fossils (Smith, 1983); at least 8850 feet (2700 m) thick; mapped in the Black Pine Mountains (Smith, 1982).

PIPobc

Oquirrh Group units b and c undivided – Shown where source map did not differentiate Oquirrh Group sufficiently to differentiate units b and c.

PENNSYLVANIAN

IPob **Oquirrh Group unit b** – Interbedded sandy to silty limestone, calcareous sandstone to siltstone, and rare bioclastic limestone; lithology is essentially identical to unit c; contains Early to Late Pennsylvanian (late Atokan to Virgilian) fusulinids (R.C. Douglass and R.L. Ballou *in* Allmendinger, 1983); about 1600 to 2750 feet (490-840 m) thick.

IPoa **Oquirrh Group unit a** – Medium- to pale-gray to blue-gray, fine- to medium-grained, well-bedded to structureless, typically thick-bedded (3 feet [1 m]), variably fossiliferous, variably cherty or sandy limestone; contains Early to Middle Pennsylvanian (Atokan to early Desmoinesian) fusulinids (R.C. Douglass and R.L. Ballou *in* Allmendinger, 1983); well-bedded, fine-grained, calcareous sandstone increasingly common near top of section; upper contact placed above last prominent limestone ledge; lower contact placed below last prominent bed of cherty limestone; about 1300 to 1450 feet (400–440 m) thick.

IPolsd **Limestone, sandstone, and dolomite member of Oquirrh Group** – Limestone is dark- to light-gray weathering, gray on fresh surfaces, dense to fine-grained, sugary textured, well-bedded to structureless, in beds up to 18 feet (6 m) thick, locally silty to sandy; dolomite is light- to dark-gray, dense to fine-grained crystalline, structureless, forming ledges up to about 60 feet (20 m) high, and as blocks or irregular masses interbedded in limestone; sandstone is brown, calcareous, fine-grained, and grades to quartzite; contains Early to Middle Pennsylvanian (Desmoinesian to Missourian) coral, conodont, and fusulinid fossils (Smith, 1983); mapped in Black Pine and eastern Raft River Mountains; total unit thickness about 3500 (1070 m) thick.

PENNSYLVANIAN AND MISSISSIPPIAN

IPMmc **Manning Canyon Shale** – Dark-gray to black, fine-grained, well-bedded shale and mudstone; metamorphosed and deformed to scaly, olive-brown argillite in North Hansel Mountains; contains beds of gray, brown, and olivetan, planar or cross-bedded, subarkosic quartzite in beds 1 to 20 feet (0.3–6 m) thick; upper and lower contacts removed along low-angle faults; total thickness unknown due to poor exposure and structural disruption; approximately 2200 to 6000 feet (670–1800 m) thick.

MISSISSIPPIAN

Mgb **Great Blue Limestone** – Medium- to dark-blue-gray, medium- to fine-grained, well-bedded to structureless, variably cherty and fossiliferous calcarenite; upper contact cut out by low-angle faults, and lower contact not exposed; about 3000 feet (900 m) exposed.

DEVONIAN

Dj **Jefferson Formation** – Medium- to pale-gray weathering, light- to dark-gray on fresh surfaces, medium-grained, sugary-textured, thin-bedded to structureless dolomite comprising about 65 percent of the formation; gray to pale-gray, fine-grained, sugary-textured limestone (25 percent); fine-grained calcareous sandstone and quartzite (10 percent); 900 feet (275 m) exposed.

ORDOVICIAN

Omq **Marble and quartzite, undivided** – Calcitic marble, dolomitic marble, sandy dolomitic to calcitic marble, quartzite, micaceous schist, and vitreous white quartzite; comprises several map units shown by Wells (1996) but grouped together here for simplicity; mapped in the eastern Raft River Mountains, structurally below the main low-angle normal fault that separates unmetamorphosed, upper-plate rocks from metamorphosed and highly deformed middle- and lower-plate rocks; these units are the metamorphosed equivalents of well-known Ordovician stratigraphic units in eastern Nevada and western Utah; the total thickness of this combined unit is 0 to about 650 feet (0–200 m), but this value bears little relationship to the stratigraphic thickness of unmetamorphosed equivalents.

unconformity

PROTEROZOIC

Pqs **Quartzite and schist** – Basal pebble- to cobble-quartzite-clast metaconglomerate, white muscovite quartzite containing thin beds of muscovite schist, dark-brown to dark-gray quartz-muscovite-biotite-feldspar schist, platy muscovite quartzite with interlayered muscovite schist and marble, pelitic schist with characteristic metamorphic mineral assemblage of staurolite + biotite + garnet + muscovite + plagioclase + quartz, or muscovite + quartz + kyanite ± staurolite ± garnet ± zoisite; unit includes several formations mapped individually by Compton (1975) and Wells (1996) but mapped together here for simplicity; total thickness ranges from about 600 to 2000 feet (180–610 m), but this value bears little relation to stratigraphic thickness due to extensive deformation and metamorphism.

unconformity

ARCHEAN

Ami **Metamorphosed igneous rocks** – Includes metamorphosed mafic and granitic igneous rocks that intrude the Archean schist unit (Compton, 1975; Wells, 1996); mafic rocks are dark-green, dark-gray, or black, structureless, medium-grained, gneissic to schistose amphibolite composed of hornblende, andesine, quartz, and zoisite; granitic rocks are adamellite (monzonite) in composition, medium to coarse grained, equigranular to porphyritic, and composed of plagioclase, quartz, potassium feldspar, biotite, and muscovite, with minor amounts of garnet, zircon, and apatite; dated at about 2.5 Ga by the Rb-Sr isochron method (see references in Wells, 1996).

As **Schist** – Light-brown to medium-gray weathering, fine-grained, biotite-muscovite-feldspar schist with conspicuous quartz veins; 400 feet (120 m) thick.

APPENDIX B

Gravity Data

Gravity data-collection and reduction procedures

Instrument: Scintrex CG-3, borrowed from the University of Utah Department of Geology and Geophysics

Base Stations: For absolute gravity, University of Utah Department of Geology and Geophysics basement, 979,770.114 ± 0.002 mgal; field base station at Outsiders Inn, Snowville, Utah, gravity value established at 979908.031 ± 0.080 mgal during study, tied to University of Utah.

Measurement Time: 2 to 3 minutes; resulting in typical precision of 0.03 ± 0.02 mgal

Elevation: Derived from benchmarks (assumed accuracy ± 1 foot [0.3 m]), or average of four altimeter readings (accuracy ± 10 feet [3 m] based on repeat measurements and reference to stations with known elevation), or topographic maps (assumed accuracy ± 10 feet [3 m] or ± 20 feet [6 m] depending on contour interval)

Data Reduction Sequence (Geosoft Inc., 2001):

A. Instrument drift
B. Earth-tide correction
C. Latitude correction
D. Free Air Anomaly = absolute gravity (corrected for instrument drift and earth tide) – latitude correction + 0.308596*station elevation in meters.
E. Bouguer Anomaly – $g_{ba} = g_{fa} - 0.0419088*[\rho h_s + (\rho_w\text{-}\rho)h_w + (\rho_i\text{-}\rho_w)h_i] + g_{curv}$,

where

g_{ba}	=	Bouguer anomaly in milligals
g_{fa}	=	free air anomaly in milligals
ρ	=	Bouguer density of rock, assumed in this study to be 2.67 g/cm^3
ρ_w	=	density of water in g/cm^3
ρ_i	=	density of ice in g/cm^3
h_s	=	station elevation in meters
h_w	=	water depth in meters – does not apply to this study
h_i	=	ice depth in meters – does not apply to this study
g_{curv}	=	earth-curvature correction

F. Terrane correction, calculated using the algorithm of Geosoft Inc. (2001), with a 1-meter resolution digital elevation model for the local corrections and a 30-meter resolution digital elevation model for the regional corrections.
G. Complete Bouguer anomaly = g_{ba} + terrane correction

The uncertainty of individual Bouguer anomaly values from this study is likely about 0.08 to 1.5 mgal. The largest sources of uncertainty in Bouguer anomaly values are uncertainty in elevation, deviation of the Bouguer reduction density from the true density of the rocks, and inaccuracy of the terrain correction. The uncertainty due to errors in elevation ranges from about 1.2 to 0.06 mgal; stations in the mountains lacking surveyed elevation control likely have the largest elevation uncertainties. A single value was used for the Bouguer reduction density for all stations, and bedrock in the study area is predominantly the Oquirrh Group, so little error among stations should result from varying bedrock density. However, the density difference between basin fill and bedrock may result in some systematic uncertainty in Bouguer anomaly values between stations above bedrock and stations above thick basin-fill deposits. Errors of up to several tenths of a milligal in the terrain correction may arise in mountainous areas with significant topography that is not accounted for by the digital elevation model used to compute the reduction.

Table B.1. *New gravity data collected for this study. Missing station numbers are data points that were rejected during processing because they were judged to be imprecise or faulty measurements.*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
3	1387.4	979902.363	-14.436	0.584	-169.10	358339.20	4647115.50
4	1384.3	979902.375	-16.657	0.551	-171.00	358457.00	4648688.90
5	1389.2	979899.872	-17.366	0.557	-172.30	358994.70	4648330.40
6	1399.3	979892.098	-22.392	0.593	-178.40	360294.30	4648760.60
7	1415.1	979891.966	-17.650	0.770	-175.20	361901.60	4648730.70
8	1433.4	979901.292	-2.667	1.202	-161.90	362977.10	4648697.80
9	1390.1	979891.949	-26.692	0.630	-181.60	360389.90	4650376.80
10	1417.0	979889.417	-21.398	0.767	-179.20	361874.70	4650935.50
11	1403.8	979889.210	-25.679	0.706	-182.10	361277.20	4650947.40
12	1425.5	979891.809	-16.386	0.861	-175.00	362385.60	4650929.50
13	1434.0	979894.866	-10.704	1.043	-170.10	362881.50	4650917.60
14	1434.0	979894.869	-10.701	1.043	-170.10	362881.50	4650917.60
15	1495.9	979884.976	-1.414	1.188	-167.60	363643.30	4650807.00
16	1548.6	979873.954	4.399	1.226	-167.70	364230.90	4650089.00
17	1571.2	979868.876	6.554	1.607	-167.70	364479.80	4649764.40
18	1569.6	979873.309	11.206	1.251	-163.20	365586.10	4648864.70
19	1584.6	979870.001	13.550	1.167	-162.60	365804.50	4647596.70
20	1387.1	979895.463	-24.573	0.582	-179.20	359666.90	4650971.30
21	1387.4	979905.374	-14.572	0.531	-169.30	358474.90	4650998.20
22	1385.3	979898.528	-21.592	0.554	-176.00	359081.40	4650400.70
23	1384.9	979898.053	-21.581	0.549	-176.00	359090.30	4649647.90
24	1412.7	979901.519	-7.197	0.625	-164.60	359436.90	4646753.00
25	1406.6	979899.008	-11.911	0.601	-168.70	359574.30	4647147.30
26	1415.4	979895.312	-12.908	0.620	-170.70	360255.50	4647153.30
29	1432.8	979894.042	-8.822	0.759	-168.40	361925.50	4647138.40
30	1445.6	979897.187	-1.730	0.956	-162.50	362708.20	4647126.40
31	1468.2	979895.583	3.593	1.110	-159.60	363117.10	4647177.20
32	1424.0	979894.206	-11.365	0.671	-170.00	361095.00	4647144.30
33	1377.6	979912.054	-7.766	0.561	-161.40	357447.20	4647129.40
34	1376.1	979914.340	-5.147	0.574	-158.60	357023.00	4646155.50
35	1382.5	979913.264	-3.791	0.586	-157.90	357034.90	4645590.80
36	1394.4	979908.967	-4.404	0.644	-159.80	357735.70	4645561.30
37	1382.2	979913.728	-2.813	0.587	-156.90	356564.20	4644851.60
38	1399.0	979903.504	-9.289	0.615	-165.20	358669.10	4646582.70
39	1414.8	979903.434	-3.865	0.683	-161.50	358673.40	4645819.00
40	1578.8	979876.187	21.032	1.623	-154.00	360195.70	4643893.90
41	1648.9	979859.756	27.173	2.380	-155.00	360794.20	4642723.20
42	1516.3	979885.902	11.462	1.236	-157.00	359484.70	4643905.90
43	1463.0	979897.582	6.703	1.038	-156.00	358657.10	4643911.80
44	1449.0	979898.830	3.030	0.838	-158.30	358660.30	4644653.30
45	1427.3	979902.443	-0.709	0.728	-159.70	358666.50	4645461.60
47	1414.8	979901.951	-6.006	0.639	-163.70	359471.80	4646615.60
48	1439.8	979903.764	4.170	0.797	-156.10	359450.30	4645816.30
49	1479.7	979890.071	3.011	0.845	-161.70	361456.50	4645504.20
50	1512.3	979884.693	8.986	1.254	-159.00	362711.10	4643882.70
51	1531.9	979884.157	15.051	1.219	-155.10	363486.10	4643185.10
52	1393.5	979911.672	-0.678	0.689	-155.90	356773.50	4643977.90
53	1384.6	979913.534	-0.832	0.559	-155.20	355367.90	4643105.20
54	1385.6	979913.407	-0.063	0.536	-154.60	354907.80	4642388.20
55	1572.7	979871.997	22.027	2.392	-151.60	357648.20	4635217.00
57	1459.3	979892.917	7.206	1.770	-154.30	356906.10	4636153.70
58	1427.9	979898.775	3.496	0.902	-155.40	356092.50	4636018.70
59	1413.0	979903.532	3.671	0.685	-153.80	355116.20	4636018.70
60	1901.9	979797.186	49.620	9.023	-154.20	361184.40	4634141.50
61	1685.2	979849.492	34.410	1.409	-152.70	360414.50	4634951.10
65	1373.1	979919.004	-1.892	0.489	-155.00	353778.70	4646817.70
66	1375.8	979920.670	1.502	0.446	-152.00	353885.80	4645710.40
67	1376.1	979919.273	0.261	0.456	-153.30	354544.70	4645619.10
68	1376.1	979920.277	1.798	0.451	-151.70	354568.50	4644960.30
69	1382.2	979917.920	1.944	0.448	-152.30	354556.60	4644194.40
70	1374.0	979919.799	-0.553	0.477	-153.80	354175.60	4646480.40
71	1376.1	979918.102	-1.222	0.477	-154.70	354969.30	4645996.20

Table B.1. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
72	1371.2	979916.802	-3.653	0.473	-156.60	355048.70	4645523.90
73	1372.1	979916.452	-3.602	0.489	-156.60	355397.90	4645365.10
74	1369.4	979917.752	-3.621	0.552	-156.30	356354.40	4645944.60
75	1369.4	979917.747	-3.626	0.552	-156.30	356354.40	4645944.60
76	1374.0	979917.077	-2.102	0.472	-155.40	355013.00	4645015.90
78	1392.0	979916.144	0.722	0.584	-154.50	355405.90	4647226.50
79	1386.5	979917.123	0.004	0.562	-154.60	356215.50	4647210.60
80	1377.9	979913.838	-5.926	0.545	-159.60	357037.00	4647182.80
81	1384.0	979913.610	-1.657	0.573	-155.90	355953.60	4643976.10
82	1380.7	979915.892	-0.390	0.484	-154.40	354977.20	4643992.00
83	1382.2	979918.902	3.090	0.446	-151.10	354195.40	4643999.90
84	1409.0	979913.671	5.940	0.498	-151.20	353207.20	4644253.90
85	1371.5	979921.324	1.208	0.408	-151.90	352623.80	4645269.90
87	1370.0	979920.814	-0.073	0.411	-153.00	352762.70	4645646.90
88	1369.1	979921.695	0.518	0.407	-152.30	352139.60	4645674.70
89	1370.9	979919.843	-1.146	0.425	-154.10	352600.00	4646119.20
90	1367.0	979921.211	-0.892	0.407	-153.40	351663.30	4646027.90
91	1364.8	979922.357	-0.700	0.407	-153.00	350833.90	4646385.10
91	1364.8	979922.356	-0.701	0.407	-153.00	350833.90	4646385.10
92	1363.0	979923.078	-0.645	0.408	-152.80	350528.30	4646528.00
92	1363.0	979923.075	-0.648	0.408	-152.80	350528.30	4646528.00
93	1366.0	979920.434	-3.114	0.491	-155.50	351972.90	4647424.90
94	1370.9	979920.351	-1.666	0.511	-154.60	352711.10	4647385.20
95	1364.8	979920.323	-3.920	0.514	-156.10	351441.10	4647837.70
95	1364.8	979920.332	-3.912	0.514	-156.10	351441.10	4647837.70
95	1364.8	979920.391	-3.853	0.514	-156.10	351441.10	4647837.70
97	1363.0	979921.227	-3.145	0.444	-155.20	350544.10	4647329.70
99	1371.5	979919.203	-2.183	0.466	-155.20	352961.10	4646829.60
100	1364.2	979920.513	-3.591	0.471	-155.80	351385.50	4647436.80
105	1340.7	979922.945	-8.446	0.424	-158.00	347313.60	4647567.80
106	1344.7	979923.997	-6.170	0.430	-156.20	348262.10	4647559.90
107	1349.3	979923.985	-4.765	0.437	-155.30	348932.80	4647548.00
108	1357.8	979922.726	-3.424	0.443	-154.90	349758.30	4647559.90
109	1364.5	979923.754	1.143	0.425	-151.10	350516.40	4645726.30
110	1363.3	979924.084	2.424	0.379	-149.70	350504.50	4644095.10
111	1378.2	979918.879	2.491	0.373	-151.40	352088.00	4643230.00
113	1385.9	979918.278	6.221	0.365	-148.50	352048.30	4640816.90
114	1378.5	979921.278	6.925	0.321	-147.00	350444.90	4640864.60
115	1370.0	979922.954	4.687	0.343	-148.30	350460.80	4642460.00
116	1342.9	979923.474	-5.133	0.374	-155.00	348047.80	4644952.40
117	1346.5	979924.180	-2.673	0.366	-153.00	348000.20	4644158.60
118	1351.1	979924.302	0.200	0.341	-150.60	347924.80	4642515.60
119	1360.6	979923.180	3.319	0.320	-148.60	347837.50	4640900.30
120	1378.5	979920.870	7.838	0.299	-146.10	348778.00	4639269.10
121	1369.1	979920.098	4.168	0.310	-148.70	347135.00	4639300.90
122	1391.0	979917.241	9.409	0.302	-145.90	347115.10	4637645.90
123	1366.7	979921.012	5.669	0.341	-146.90	345472.10	4637697.50
124	1355.1	979923.363	3.118	0.334	-148.20	345499.90	4639328.70
125	1335.6	979926.427	-1.150	0.356	-150.20	345563.40	4640951.90
126	1325.5	979927.168	-3.519	0.362	-151.50	343907.00	4640979.00
127	1330.1	979925.783	-4.804	0.365	-153.30	345611.00	4642571.10
128	1329.8	979924.485	-7.529	0.378	-156.00	345630.80	4644218.20
129	1331.9	979922.510	-9.501	0.384	-158.20	345642.70	4645015.90
130	1334.0	979923.228	-8.130	0.384	-157.00	346833.40	4644984.10
131	1338.6	979922.414	-9.039	0.410	-158.40	347258.00	4646845.50
132	1338.9	979918.397	-13.541	0.417	-162.90	345714.20	4647591.60
137	1355.1	979922.849	-5.281	0.510	-156.40	348956.60	4648992.60
138	1360.3	979917.299	-10.524	0.520	-162.20	347373.10	4650627.70
139	1345.3	979915.655	-15.495	0.443	-165.60	345726.10	4649056.10
140	1387.4	979913.376	1.057	0.498	-153.70	354429.60	4641662.30
141	1387.7	979913.475	2.403	0.418	-152.50	353457.20	4640257.40
142	1390.1	979916.151	6.707	0.341	-148.50	352056.20	4639189.80

Table B.1. (continued)

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
143	1385.9	979918.875	8.121	0.306	-146.70	350421.10	4639241.40
144	1394.4	979917.071	10.311	0.291	-145.40	349540.00	4637566.50
145	1392.6	979917.390	10.069	0.289	-145.50	348738.40	4637590.30
146	1391.3	979913.797	4.712	0.372	-150.60	352727.00	4639189.80
147	1392.9	979911.919	3.328	0.446	-152.10	353667.60	4639169.90
148	1396.8	979911.315	3.932	0.521	-151.80	354243.00	4639154.00
149	1412.1	979907.123	4.472	0.762	-152.80	355263.00	4639118.30
151	1499.5	979888.311	12.595	2.101	-153.10	356910.00	4639130.20
152	1523.9	979884.886	16.698	2.442	-151.40	357045.00	4639130.20
153	1396.2	979914.807	8.087	0.334	-147.80	352032.40	4638149.90
154	1399.9	979914.414	9.776	0.306	-146.60	351234.70	4637006.90
159	1339.5	979916.694	-15.062	0.415	-164.50	344945.00	4647612.80
160	1339.2	979914.691	-17.139	0.414	-166.60	344065.30	4647608.30
161	1340.4	979913.262	-18.179	0.422	-167.70	342449.70	4647621.70
162	1342.0	979911.863	-19.061	0.438	-168.80	340845.20	4647627.80
163	1339.8	979911.782	-19.845	0.429	-169.30	341681.30	4647638.40
164	1342.6	979914.503	-16.230	0.452	-166.00	340019.70	4647639.70
165	1344.1	979916.181	-14.091	0.467	-164.00	339231.30	4647659.60
166	1350.8	979916.706	-11.479	0.478	-162.20	338478.50	4647653.00
167	1358.4	979917.021	-8.813	0.491	-160.30	337612.00	4647664.90
168	1365.4	979916.166	-7.499	0.504	-159.80	336912.20	4647670.20
169	1377.9	979914.379	-5.427	0.521	-159.10	335955.70	4647691.30
170	1405.1	979910.939	-0.448	0.530	-157.10	334505.80	4647692.70
171	1413.6	979911.370	2.612	0.542	-155.00	333685.60	4647704.60
172	1429.4	979908.889	5.002	0.559	-154.40	332706.60	4647733.70
173	1439.2	979906.572	5.726	0.575	-154.70	331865.20	4647733.70
174	1456.9	979912.260	16.880	0.626	-145.50	330320.10	4647765.40
175	1478.2	979905.042	16.167	0.652	-148.60	328706.10	4647887.10
176	1486.7	979901.147	14.763	0.728	-150.90	327085.50	4648090.90
177	1496.5	979897.854	14.404	0.799	-152.30	325840.70	4648232.40
178	1510.2	979893.068	13.737	0.841	-154.40	324673.90	4648395.10
179	1548.3	979890.502	22.756	0.964	-149.50	322368.00	4648665.00
180	1607.7	979868.368	17.420	0.917	-161.60	319413.90	4650633.50
185	1405.7	979913.732	11.364	0.293	-145.60	350855.80	4636421.40
186	1406.9	979912.945	11.370	0.281	-145.80	350481.40	4635906.80
187	1410.5	979911.560	11.652	0.269	-145.90	350042.20	4635229.40
188	1408.1	979910.693	9.721	0.569	-147.30	351922.00	4635589.30
189	1387.7	979915.159	10.591	0.298	-144.40	348116.00	4632334.90
190	1399.6	979913.219	11.806	0.280	-144.50	348507.60	4632964.60
191	1402.6	979912.611	11.312	0.273	-145.40	349179.60	4633954.10
192	1409.6	979910.994	10.956	0.268	-146.50	349941.60	4635049.50
193	1410.2	979911.134	11.688	0.266	-145.80	349618.80	4634552.10
194	1427.9	979901.552	5.056	2.346	-152.40	355116.90	4637541.90
195	1404.8	979910.959	7.342	0.580	-149.30	353629.90	4637563.10
196	1464.2	979899.144	14.909	0.665	-148.30	353355.30	4636270.30
198	1409.6	979900.313	0.788	0.618	-156.30	355116.90	4634308.70
199	1404.4	979904.914	3.847	0.475	-152.80	354137.90	4634250.50
200	1410.2	979901.372	3.338	0.798	-153.70	355122.20	4632694.70
201	1399.3	979907.619	6.227	0.416	-149.90	353529.40	4632721.20
202	1399.0	979902.471	2.271	0.429	-153.80	353497.60	4631133.70
203	1415.7	979901.162	5.544	0.850	-152.00	355122.20	4631807.80
204	1495.6	979887.866	18.862	0.722	-147.80	353375.90	4629424.50
205	1434.3	979897.908	10.012	0.544	-149.90	351873.10	4629424.50
206	1408.7	979905.134	8.310	0.373	-148.90	351873.10	4630694.50
207	1437.7	979901.713	14.880	0.451	-145.50	350285.60	4629440.30
208	1395.0	979910.408	10.401	0.371	-145.30	348608.10	4629472.10
209	1361.8	979919.869	9.628	0.336	-142.40	346973.00	4629493.30
214	1442.5	979901.994	4.464	0.645	-156.30	327795.70	4644993.60
215	1431.0	979906.342	5.213	0.602	-154.30	328830.20	4645029.30
216	1411.2	979909.894	3.704	0.553	-153.70	329684.80	4643714.30
217	1403.5	979907.189	-0.136	0.548	-156.60	329223.10	4642191.60
218	1398.0	979906.135	-2.102	0.558	-158.00	328811.70	4641231.20

Table B.1. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
219	1385.9	979907.111	-3.790	0.591	-158.30	328240.20	4639924.10
220	1377.6	979905.301	-7.394	0.623	-160.90	327742.80	4638987.50
221	1370.0	979903.556	-10.355	0.651	-163.00	327098.50	4637607.70
222	1571.2	979875.887	19.176	1.320	-155.30	321689.10	4643781.80
223	1455.7	979897.838	4.405	0.664	-157.80	327240.10	4644977.70
224	1410.5	979908.001	0.228	0.556	-157.00	331044.80	4645369.30
225	1400.5	979913.743	2.759	0.512	-153.40	332658.80	4645485.70
226	1385.2	979919.361	3.552	0.503	-150.90	334251.60	4645575.60
228	1394.4	979911.304	0.599	0.505	-154.90	330997.20	4642855.70
229	1384.0	979916.514	3.937	0.484	-150.40	330954.80	4641204.70
230	1374.9	979920.303	6.208	0.473	-147.20	330928.40	4639611.90
231	1373.7	979912.636	-0.511	0.539	-153.70	329420.30	4638019.10
232	1368.5	979908.283	-5.721	0.576	-158.30	328404.30	4637119.50
233	1378.2	979916.233	4.411	0.462	-149.30	330907.20	4638061.50
234	1367.0	979922.782	6.338	0.448	-146.20	332076.70	4639474.30
235	1363.9	979920.532	4.244	0.445	-147.90	332579.40	4638087.90
236	1343.8	979923.763	0.502	0.442	-149.40	334352.10	4638998.10
237	1360.3	979926.951	7.701	0.445	-144.10	333505.40	4640352.80
238	1374.3	979923.951	8.218	0.450	-145.10	332743.40	4641363.50
239	1379.2	979921.972	5.915	0.466	-147.90	334002.80	4643601.80
240	1380.7	979920.326	5.383	0.467	-148.60	332683.90	4642827.90
241	1391.3	979914.681	1.805	0.494	-153.40	332468.30	4644321.50
246	1324.3	979923.226	-7.817	0.363	-155.60	342273.70	4640998.30
247	1326.7	979921.437	-10.169	0.374	-158.20	342310.80	4642607.00
248	1329.2	979920.086	-12.057	0.386	-160.40	342358.40	4644221.00
249	1333.4	979917.153	-15.022	0.403	-163.80	342406.00	4645861.40
250	1334.7	979918.065	-13.716	0.390	-162.70	344020.00	4645834.90
251	1330.4	979922.319	-9.465	0.374	-158.00	343993.50	4644199.80
252	1326.7	979924.755	-6.863	0.368	-154.90	343951.20	4642585.80
253	1323.1	979925.363	-4.757	0.359	-152.40	342263.20	4639400.30
254	1334.3	979926.262	-0.519	0.351	-149.50	343886.40	4639508.70
255	1342.6	979925.404	2.623	0.364	-147.20	343855.90	4637733.40
256	1360.9	979922.196	6.165	0.426	-145.70	343750.10	4636373.40
257	1325.5	979926.935	-1.107	0.358	-149.10	342210.20	4637749.30
258	1326.1	979927.376	-0.507	0.348	-148.50	340601.60	4637818.00
259	1321.9	979923.855	-5.313	0.374	-152.90	338543.10	4637849.80
261	1323.4	979924.645	-5.463	0.377	-153.20	339151.60	4639569.60
262	1327.0	979921.436	-7.617	0.395	-155.70	337524.50	4639675.40
263	1334.7	979922.092	-4.638	0.415	-153.60	335937.00	4639778.60
264	1348.1	979927.011	3.797	0.440	-146.60	334283.30	4640580.30
265	1345.3	979925.369	0.385	0.441	-149.70	335304.60	4641675.70
266	1344.7	979927.154	0.898	0.437	-149.10	336400.00	4642993.30
267	1355.7	979926.641	3.426	0.468	-147.80	335092.90	4643459.00
268	1355.4	979924.632	0.595	0.462	-150.60	335907.90	4644342.70
269	1363.0	979920.419	-2.568	0.491	-154.60	335929.00	4645940.80
270	1349.9	979919.311	-7.744	0.463	-158.30	337558.90	4645935.50
271	1342.0	979922.541	-5.632	0.441	-155.40	337511.20	4644305.60
272	1334.0	979918.410	-12.232	0.416	-161.10	339162.20	4644268.60
273	1338.9	979917.213	-13.241	0.439	-162.60	339199.30	4645903.70
274	1335.6	979915.743	-15.724	0.415	-164.80	340813.20	4645861.40
275	1332.5	979917.599	-13.526	0.394	-162.20	340781.50	4644258.00
279	1324.6	979922.810	-8.148	0.371	-156.00	340622.60	4641043.10
280	1326.4	979923.672	-6.729	0.386	-154.80	339103.90	4641074.80
281	1329.8	979922.976	-6.361	0.409	-154.80	337415.80	4641096.00
282	1338.3	979924.502	-3.440	0.425	-152.80	337098.30	4642620.00
283	1330.7	979920.056	-10.078	0.401	-158.60	338775.80	4642392.40
284	1328.3	979919.334	-11.769	0.381	-160.00	340707.20	4642630.60
285	1402.6	979906.881	-8.207	0.631	-164.50	335722.50	4651282.50
286	1425.2	979908.441	0.333	0.688	-158.50	334309.60	4651308.90
287	1453.2	979906.112	6.651	0.746	-155.20	332761.80	4651336.70
288	1491.0	979903.158	15.385	0.855	-150.60	331134.60	4651346.00
289	1539.5	979898.689	25.898	0.903	-145.50	329488.90	4651367.10

Table B.1. (continued)

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
290	1373.4	979913.545	-10.575	0.595	-163.70	337516.40	4651266.60
291	1360.3	979910.223	-17.966	0.488	-169.70	340860.70	4651224.30
296	1373.4	979917.923	9.972	0.313	-143.40	347181.70	4631082.50
297	1372.4	979918.030	9.746	0.318	-143.50	347049.20	4631114.30
298	1369.1	979919.137	10.586	0.311	-142.30	346763.60	4630194.00
299	1354.8	979922.200	10.044	0.329	-141.20	346158.10	4629208.60
300	1340.4	979924.172	8.200	0.349	-141.40	345624.10	4628443.50
301	1331.9	979926.719	8.536	0.357	-140.10	345277.30	4627942.50
302	1321.9	979929.096	8.550	0.356	-139.00	344677.30	4627061.80
303	1313.6	979930.938	8.450	0.353	-138.20	344143.40	4626307.70
304	1307.8	979931.431	7.483	0.355	-138.50	343857.10	4625905.80
305	1304.2	979931.515	6.963	0.351	-138.60	343438.80	4625289.30
306	1299.0	979932.307	6.702	0.343	-138.30	342976.40	4624617.70
307	1295.9	979931.895	6.549	0.313	-138.10	341958.00	4623137.00
308	1294.1	979931.096	5.724	0.301	-138.80	341523.20	4622492.90
309	1292.0	979930.843	5.315	0.293	-139.00	341137.80	4621892.90
310	1291.4	979930.408	5.397	0.286	-138.80	340504.80	4621039.70
311	1287.1	979929.916	4.436	0.282	-139.30	339816.70	4619993.80
312	1285.6	979928.902	3.515	0.274	-140.10	339420.40	4619316.70
313	1285.9	979930.380	3.961	0.284	-139.60	339304.80	4620709.40
314	1291.4	979929.674	4.783	0.307	-139.40	342492.00	4620847.00
315	1288.0	979924.474	0.080	0.455	-143.60	345007.60	4618881.80
316	1470.6	979889.090	19.501	1.078	-144.00	346741.60	4620753.40
317	1360.9	979911.708	9.465	0.814	-142.00	346659.00	4619272.70
318	1285.6	979924.746	0.050	0.343	-143.50	344589.30	4618347.90
319	1285.6	979926.873	2.085	0.288	-141.50	342778.20	4618502.00
320	1285.6	979926.599	2.029	0.277	-141.50	342035.10	4618248.80
321	1287.4	979927.999	3.563	0.282	-140.20	341176.40	4618788.30
325	1377.0	979917.432	10.719	0.323	-143.00	348673.70	4630893.10
326	1394.4	979914.650	13.055	0.514	-142.50	349879.30	4631179.30
327	1400.2	979913.433	12.381	0.303	-144.00	350325.10	4632709.60
328	1402.3	979908.263	7.792	0.356	-148.80	351894.00	4632759.10
329	1408.7	979910.645	10.897	0.334	-146.40	351112.30	4634322.50
330	1378.2	979917.416	10.931	0.316	-143.00	348684.70	4631069.20
332	1406.6	979912.446	13.488	0.381	-143.50	347022.30	4632632.30
333	1434.9	979905.974	14.369	0.357	-145.80	347253.50	4634333.50
334	1475.2	979898.362	19.300	0.640	-145.10	346460.90	4634217.90
335	1424.9	979910.253	14.227	0.337	-144.90	347110.40	4635984.90
336	1415.7	979912.906	14.071	0.278	-144.10	348750.80	4635913.30
337	1421.8	979910.492	14.721	0.298	-144.10	348431.50	4634460.10
339	1354.8	979923.301	10.882	0.318	-140.40	345365.40	4629549.90
340	1385.2	979916.626	12.410	0.380	-142.20	345238.80	4631008.70
341	1347.8	979926.635	12.013	0.311	-138.50	343756.80	4629637.00
342	1359.6	979923.748	12.144	0.324	-139.70	343758.10	4630408.60
343	1346.8	979927.865	13.053	0.291	-137.40	342348.90	4629522.40
344	1364.2	979924.570	13.812	0.307	-138.50	342398.40	4631146.30
345	1326.4	979930.139	10.289	0.331	-137.80	343802.10	4627937.00
346	1339.5	979927.955	12.141	0.385	-137.40	342194.70	4627981.10
347	1333.4	979927.636	11.258	0.396	-137.50	342167.20	4626351.70
348	1377.6	979916.882	12.221	0.468	-141.50	347843.70	4628604.10
349	1349.6	979922.116	9.372	0.446	-141.20	346793.60	4627937.60
354	1347.2	979922.143	4.311	0.399	-146.00	335908.40	4633551.80
355	1321.2	979925.905	-1.135	0.390	-148.60	337163.10	4634985.70
356	1321.5	979925.646	-2.400	0.368	-149.90	338380.00	4636315.20
357	1326.4	979922.821	-4.794	0.402	-152.80	336816.70	4637685.80
358	1320.9	979924.028	-4.147	0.390	-151.60	337312.10	4636271.10
359	1342.6	979920.897	-1.757	0.467	-151.50	335319.40	4637768.40
360	1328.6	979922.722	-2.738	0.491	-150.90	336095.50	4635880.30
361	1328.3	979928.002	5.315	0.368	-142.90	337240.50	4632313.30
362	1315.1	979933.825	8.495	0.344	-138.30	336992.80	4630551.80
363	1310.9	979934.511	8.735	0.343	-137.60	336800.10	4629505.90
364	1312.1	979931.667	6.076	0.370	-140.40	335269.80	4629770.10

Table B.1. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
365	1308.7	979935.426	10.253	0.335	-135.90	337339.60	4627909.50
366	1328.3	979931.567	9.637	0.328	-138.70	339690.10	4631322.40
367	1358.4	979925.906	13.395	0.302	-138.30	341363.50	4631124.30
368	1329.2	979932.084	11.751	0.333	-136.60	339668.10	4629693.00
369	1347.8	979927.769	13.185	0.291	-137.30	341418.60	4629643.50
371	1341.7	979927.225	8.257	0.323	-141.60	340506.50	4632753.30
372	1376.4	979921.028	12.662	0.342	-141.00	342181.70	4632846.60
373	1427.9	979907.612	14.940	0.620	-144.20	343740.80	4633059.40
374	1334.3	979928.363	5.667	0.341	-143.30	340537.80	4634537.20
375	1357.8	979923.119	7.638	0.385	-143.90	342112.20	4634548.20
376	1412.7	979911.644	13.072	0.525	-144.50	343493.80	4634559.20
377	1360.9	979923.371	7.360	0.430	-144.50	343747.00	4636348.20
378	1327.9	979928.780	2.534	0.378	-145.70	342156.20	4636447.30
384	1344.1	979907.260	-11.741	0.670	-161.50	326049.50	4634047.20
385	1324.3	979911.853	-11.454	0.598	-159.00	326522.90	4631806.80
386	1313.3	979915.911	-9.274	0.565	-155.70	326423.80	4629935.20
387	1338.0	979908.035	-12.002	0.672	-161.00	325620.10	4633012.40
388	1363.9	979902.902	-9.479	0.795	-161.30	323952.20	4633469.20
389	1381.3	979898.824	-9.340	0.825	-163.10	324139.40	4634889.50
390	1397.4	979897.003	-7.286	0.858	-162.80	324188.90	4636238.10
392	1352.6	979907.740	-9.899	0.622	-160.60	327618.30	4635566.50
393	1367.3	979910.664	-2.378	0.678	-154.70	328895.40	4635461.90
394	1386.2	979906.901	1.014	0.710	-153.40	329385.30	4633816.00
395	1464.5	979892.644	10.489	0.686	-152.70	330513.50	4634322.10
396	1479.1	979890.471	12.447	0.690	-152.40	332616.60	4634735.30
397	1384.9	979914.284	5.380	0.479	-149.10	331962.40	4636986.70
398	1360.0	979917.578	3.957	0.458	-147.80	334537.70	4633260.10
399	1347.5	979923.113	6.538	0.420	-143.80	334840.50	4632137.10
400	1331.3	979927.879	6.726	0.386	-141.90	335919.40	4631592.10
401	1322.5	979930.636	7.301	0.573	-140.10	334284.50	4630970.10
402	1359.0	979922.641	10.833	0.456	-140.80	332842.30	4630678.40
403	1309.1	979933.011	6.969	0.419	-139.10	333651.70	4629220.40
404	1303.0	979933.401	6.470	0.379	-139.00	333882.70	4627986.60
405	1292.3	979933.580	4.444	0.373	-139.80	332908.30	4626654.50
406	1295.6	979935.462	6.743	0.362	-137.90	334328.50	4627364.60
407	1290.5	979931.773	2.140	0.398	-141.90	331477.10	4626615.90
408	1297.8	979934.298	5.589	0.508	-139.10	331757.90	4628250.80
409	1324.3	979922.484	0.157	0.507	-147.50	329677.10	4630518.70
410	1331.9	979916.938	-4.250	0.558	-152.70	328521.10	4632038.00
411	1343.5	979910.743	-8.424	0.603	-158.20	327568.80	4633986.70
416	1287.4	979932.797	5.395	0.295	-138.40	339211.20	4622498.40
417	1289.9	979934.860	7.275	0.310	-136.80	339046.10	4623681.90
418	1293.2	979936.527	9.090	0.330	-135.30	338662.50	4624765.80
419	1310.6	979932.020	9.952	0.353	-136.30	340734.10	4624720.50
420	1303.0	979936.523	10.671	0.358	-134.80	337934.10	4626560.90
421	1341.4	979928.039	13.981	0.401	-135.70	339547.00	4626593.90
422	1290.2	979936.444	8.043	0.321	-136.00	337312.10	4624843.40
423	1288.6	979935.522	6.810	0.322	-137.10	335655.20	4624656.30
424	1294.4	979938.228	9.730	0.337	-134.80	336535.90	4626582.90
425	1306.6	979934.606	8.165	0.342	-137.70	335908.40	4628707.70
426	1286.8	979931.984	4.521	0.295	-139.20	338231.40	4622366.30
427	1286.2	979931.461	4.462	0.287	-139.20	338803.80	4621551.60
433	1284.7	979922.893	-0.475	0.262	-144.00	341991.60	4616419.90
434	1284.7	979925.159	1.734	0.257	-141.80	340370.20	4616526.50
435	1285.0	979925.154	1.790	0.256	-141.70	339305.00	4616589.60
436	1283.8	979926.064	0.954	0.266	-142.40	339143.20	4618293.90
437	1284.7	979928.258	2.205	0.275	-141.30	338385.80	4619820.70
438	1285.6	979926.670	1.933	0.269	-141.70	337750.60	4618550.30
439	1284.7	979923.527	-0.557	0.263	-144.00	337300.90	4617410.20
440	1285.3	979920.883	-2.878	0.268	-146.40	335553.20	4617280.00
441	1286.2	979922.758	-1.642	0.273	-145.30	335584.70	4618412.20
442	1285.3	979925.996	0.383	0.276	-143.20	336598.60	4619544.50

Table B.1. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
443	1284.1	979928.352	1.536	0.281	-141.90	337636.20	4620550.50
444	1288.3	979931.943	2.794	0.346	-141.00	333513.50	4625130.80
445	1289.5	979932.390	3.174	0.354	-140.80	333130.60	4625679.50
446	1290.8	979932.559	3.724	0.346	-140.40	333872.50	4625687.10
447	1291.4	979934.109	5.450	0.335	-138.70	334882.50	4625675.30
448	1292.3	979934.834	6.437	0.338	-137.80	335375.60	4625683.20
449	1287.1	979932.054	3.678	0.311	-140.00	336042.30	4623659.30
450	1286.2	979927.640	3.136	0.274	-140.50	340973.80	4618420.10
455	1291.1	979925.390	1.169	0.703	-142.60	345068.90	4619848.30
456	1592.5	979865.964	29.824	1.750	-146.60	350690.70	4625821.20
457	1593.7	979864.772	29.554	1.516	-147.30	349783.30	4625158.50
458	1543.1	979878.903	27.261	1.335	-144.10	348773.40	4626180.20
459	1531.5	979874.177	21.560	1.609	-148.20	348240.80	4622972.80
460	1479.7	979887.075	19.987	1.069	-144.50	347230.80	4621122.60
461	1302.7	979925.216	1.705	0.573	-143.50	345459.40	4623387.10
462	1313.9	979921.745	2.444	0.633	-143.90	345266.10	4622460.00
463	1297.2	979927.089	3.430	0.557	-141.20	344485.00	4621493.40
464	1294.7	979929.538	4.647	0.334	-139.90	343096.30	4622093.10
472	1399.3	979915.404	-0.797	0.658	-156.70	348983.10	4651104.20
473	1459.3	979904.932	7.371	0.837	-155.10	350508.60	4650918.50
474	1580.3	979879.206	18.978	1.093	-156.80	352802.50	4650879.50
475	1571.5	979881.190	18.370	1.217	-156.30	352701.70	4650728.40
478	1365.7	979918.813	-7.743	0.534	-160.00	347333.90	4651121.90
479	1390.4	979916.119	-2.805	2.750	-155.60	345781.90	4651144.00
480	1357.8	979911.698	-17.276	0.466	-168.70	344172.50	4651166.10
481	1359.0	979908.667	-19.928	0.469	-171.50	342536.50	4651192.60
486	1292.9	979928.869	4.107	0.367	-140.20	343616.60	4621235.30
487	1329.2	979922.039	5.615	0.672	-142.40	346425.10	4624714.20
488	1364.8	979915.187	10.582	1.038	-141.10	346953.00	4623674.20
489	1362.4	979914.714	8.013	1.271	-143.20	347480.90	4625337.10
490	1329.2	979922.564	4.757	0.737	-143.20	346852.70	4626414.00

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
491	1299.3	979927.770	2.726	0.426	-142.20	344693.50	4624001.50
492	1301.7	979926.347	2.806	0.383	-142.50	344075.90	4623072.40
494	1316.1	979927.925	6.215	0.433	-140.60	345453.70	4626271.50
495	1330.4	979924.393	6.450	0.465	-142.00	346192.80	4627052.80
497	1397.4	979908.138	-0.385	0.707	-156.00	355309.60	4640767.60
498	1459.9	979897.729	8.484	1.954	-152.90	356925.00	4640746.50
499	1432.5	979903.339	4.337	1.016	-154.90	356998.90	4642351.30
500	1539.2	979883.417	17.360	2.054	-152.80	358587.90	4642298.50
504	1406.9	979911.903	-1.550	0.597	-158.40	357070.10	4650439.60
505	1405.1	979912.330	-2.176	0.688	-158.70	356861.40	4651058.10
506	1405.7	979911.733	-3.195	0.564	-159.90	356884.60	4651808.00
507	1444.4	979904.258	1.925	0.605	-159.10	355446.60	4651031.00
508	1502.6	979894.236	9.908	1.346	-156.90	356177.20	4650961.50
509	1533.1	979891.244	16.292	0.941	-154.30	354012.50	4651050.40
510	1406.0	979912.784	-2.708	0.667	-159.40	355678.70	4652641.60
511	1396.5	979909.878	-8.544	0.532	-164.30	356890.50	4652615.20
512	1392.3	979904.717	-15.010	0.516	-170.30	357694.80	4652609.90
514	1569.9	979870.860	6.472	1.906	-167.30	364976.20	4651810.80
515	1572.7	979870.711	7.926	2.281	-165.80	365717.00	4650884.80
516	1618.4	979866.370	17.502	2.744	-160.80	366304.40	4651101.70
517	1671.7	979854.048	21.124	2.807	-163.10	366246.20	4651726.20
522	1389.5	979895.283	-24.661	0.582	-179.60	359688.50	4651772.30
523	1391.0	979895.673	-24.462	0.584	-179.50	359707.70	4652578.20
524	1391.3	979896.407	-24.301	0.596	-179.40	359723.10	4653399.50
525	1393.2	979896.803	-23.956	0.597	-179.30	359742.20	4654186.20
526	1394.7	979897.710	-23.242	0.604	-178.70	359780.60	4654996.00
527	1397.1	979899.483	-21.376	0.606	-177.10	359780.60	4655794.20
528	1401.1	979900.836	-19.438	0.605	-175.60	359792.10	4656596.30
529	1416.6	979904.574	-12.296	1.159	-169.70	363042.70	4658235.00
530	1419.7	979903.844	-12.720	1.043	-170.50	363061.90	4659037.10
531	1424.0	979901.778	-14.112	0.928	-172.50	363077.20	4659843.00

Table B.1. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
532	1427.9	979902.273	-13.061	0.841	-172.00	363096.40	4660641.30
534	1433.7	979907.525	-7.416	0.717	-167.10	363138.80	4662365.00
534	1433.7	979907.525	-7.416	0.717	-167.10	363138.80	4662365.00
535	1445.0	979904.231	-7.792	0.656	-168.80	363154.00	4663066.70
536	1452.3	979908.006	-2.735	0.603	-164.60	363184.70	4664264.10
537	1453.8	979905.609	-5.329	0.587	-167.40	363196.20	4665077.70
538	1453.5	979906.367	-5.646	0.594	-167.70	363223.10	4666290.40
539	1451.4	979906.995	-6.298	0.606	-168.10	363242.30	4667069.50
540	1456.0	979907.367	-5.179	0.592	-167.50	363257.60	4667898.40
541	1456.6	979905.893	-7.242	0.597	-169.60	363461.00	4668850.20
542	1456.3	979905.816	-7.987	0.616	-170.30	363276.80	4669564.00
543	1454.4	979903.657	-10.697	0.636	-172.80	364167.20	4669502.60
544	1468.5	979904.609	-6.031	0.594	-169.80	364159.50	4670289.30
545	1484.3	979905.047	-1.435	0.572	-167.00	364167.30	4671174.80
546	1506.2	979902.172	1.361	0.659	-166.50	364339.90	4672511.40
547	1498.9	979902.590	0.106	0.561	-167.10	364167.20	4671801.40
549	1458.7	979899.597	-12.105	0.874	-174.50	366550.40	4667821.70
550	1456.0	979900.497	-12.054	0.659	-174.30	364938.50	4667871.60
552	1456.3	979895.983	-15.150	1.092	-177.00	366527.40	4666206.00
557	1403.5	979903.987	-16.203	0.661	-172.60	360605.70	4657390.70
558	1405.7	979904.510	-15.002	0.761	-171.50	361415.50	4657375.40
559	1410.2	979905.472	-12.654	0.916	-169.50	362185.70	4657363.70
560	1416.3	979904.458	-11.790	1.237	-169.00	363019.70	4657352.30
561	1429.7	979902.616	-9.226	1.520	-167.70	363457.20	4657010.80
562	1575.7	979880.028	13.603	4.169	-158.50	365130.40	4656531.10
563	1499.5	979897.783	8.017	2.536	-157.20	364385.90	4656331.50
564	1451.7	979902.865	-1.882	1.959	-162.40	363948.40	4656623.20
565	1424.9	979905.524	-12.164	0.700	-170.90	361595.90	4662433.50
566	1419.4	979904.137	-14.491	0.651	-172.70	361496.10	4661500.90
567	1421.8	979904.646	-13.245	0.693	-171.60	362271.30	4661489.40
568	1430.1	979906.242	-9.066	0.930	-168.20	363879.30	4661431.90
569	1453.5	979899.940	-8.137	1.145	-169.60	364894.60	4661401.30
570	1469.7	979894.200	-8.873	1.320	-172.00	365525.70	4661382.00
571	1484.3	979890.338	-8.227	1.837	-172.50	366439.10	4661362.80
572	1512.6	979888.617	-1.217	2.596	-167.90	367172.10	4661351.30
573	1574.2	979877.740	6.941	4.336	-164.90	367939.60	4661305.20
574	1537.6	979887.695	4.276	2.837	-164.90	367793.80	4662943.90
575	1458.1	979894.949	-13.012	1.539	-174.60	366473.60	4662978.50
576	1458.1	979895.001	-14.253	1.300	-176.10	366508.20	4664575.00
577	1571.2	979884.631	10.270	2.987	-162.60	368108.50	4664555.80
578	1508.7	979890.136	-3.501	1.711	-170.60	367394.00	4664555.10
579	1523.3	979884.339	-1.538	2.227	-169.80	366427.60	4660556.90
581	1401.1	979901.069	-19.861	0.562	-176.10	358997.70	4657421.40
582	1399.6	979900.755	-20.634	0.548	-176.70	358199.50	4657432.90
583	1398.4	979900.340	-21.416	0.558	-177.30	357405.10	4657444.40
584	1536.4	979889.174	11.176	0.514	-160.20	351982.30	4656108.90
585	1471.2	979901.613	3.021	0.570	-161.00	353360.10	4656665.40
586	1453.8	979902.813	-1.292	0.584	-163.40	354300.30	4656822.70
587	1403.5	979901.233	-18.745	0.642	-175.10	355601.30	4657229.50
588	1402.9	979900.742	-19.618	0.573	-176.00	356587.60	4657452.10
589	1447.7	979899.367	-7.821	0.636	-169.20	355110.10	4658288.70
590	1553.8	979886.847	10.755	0.701	-162.40	354196.70	4660338.10
591	1481.3	979892.907	-6.335	1.007	-171.10	354933.60	4661282.20
592	1481.9	979896.042	-3.193	0.678	-168.30	355501.50	4661489.40
593	1456.3	979900.828	-5.666	0.682	-167.90	355701.10	4660695.00
594	1408.1	979900.304	-19.909	0.557	-176.90	358218.70	4659217.50
599	1422.7	979902.041	-12.085	0.828	-170.50	337449.60	4657713.00
600	1428.5	979904.801	-7.525	0.960	-166.40	336655.90	4657718.30
601	1458.1	979909.598	6.417	1.205	-155.50	335449.40	4657734.20
602	1505.6	979903.280	14.647	1.272	-152.60	334660.90	4657887.70
603	1575.7	979892.182	23.948	1.796	-150.60	333859.20	4659428.90
604	1659.6	979878.892	36.434	2.444	-146.80	332913.30	4659594.20

Table B.1. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
605	1533.1	979899.221	18.452	1.476	-151.60	334248.20	4658665.50
606	1433.4	979907.997	-2.820	1.065	-162.10	336179.60	4657734.20
607	1477.6	979889.939	-10.893	0.752	-175.50	338375.70	4662195.10
608	1734.2	979859.537	37.429	2.443	-154.20	332861.70	4662893.60
609	1851.6	979839.064	53.111	3.974	-150.10	331971.40	4663004.70
610	1652.8	979874.889	28.037	1.889	-155.00	333576.10	4662412.10
611	1601.6	979881.088	18.449	1.570	-159.20	334248.20	4662380.30
612	1591.6	979882.937	17.150	1.382	-159.60	334613.30	4662449.10
613	1562.3	979886.196	11.443	1.268	-162.10	335079.00	4662343.30
614	1531.9	979887.857	3.731	1.069	-166.60	335973.20	4662311.50
615	1509.3	979889.386	-1.694	0.975	-169.60	336772.30	4662269.20
616	1489.8	979890.035	-7.035	0.837	-172.90	337576.60	4662216.30
617	1472.4	979886.713	-15.694	0.625	-179.80	340010.80	4662121.00
618	1473.3	979888.333	-13.812	0.679	-178.00	339201.20	4662158.10
619	1419.7	979901.382	-13.670	0.719	-171.80	338396.80	4657691.90
621	1471.2	979886.774	-15.992	0.599	-180.00	340989.80	4662084.00
622	1477.0	979888.450	-12.499	0.616	-177.20	342381.50	4662020.50
623	1486.7	979897.967	0.038	0.702	-165.60	344000.70	4661951.70
624	1485.8	979900.233	2.356	0.724	-163.20	344461.10	4661533.60
625	1537.9	979892.014	10.110	0.796	-161.20	346535.40	4661618.30
626	1549.8	979887.533	9.299	0.848	-163.30	348122.90	4661586.60
627	1533.1	979888.078	5.135	0.723	-165.70	349456.40	4661009.80
628	1473.3	979898.667	-1.249	0.622	-165.50	348293.60	4659206.60
629	1462.7	979902.659	0.464	0.603	-162.60	347699.60	4657993.50
630	1568.1	979883.427	14.847	0.599	-160.00	350636.50	4656587.20
631	1509.3	979895.028	7.826	0.709	-160.30	348757.90	4657215.60
632	1444.1	979905.194	-2.277	0.552	-163.30	346948.20	4657437.90
633	1438.0	979908.079	-1.286	0.541	-161.70	346196.80	4657469.60
634	1429.4	979909.577	-2.438	0.532	-161.90	345223.10	4657485.50
639	1557.5	979872.810	8.722	1.334	-164.20	364316.60	4646728.90
640	1536.1	979880.144	9.549	0.963	-161.40	363808.60	4646617.80
641	1484.3	979891.813	5.053	1.064	-160.00	363295.40	4646850.60
642	1485.8	979893.071	7.549	1.057	-157.60	363067.80	4645898.10
643	1453.8	979891.715	-4.016	0.730	-166.00	361914.20	4646332.00
646	1396.2	979910.074	-9.745	0.539	-165.40	356522.00	4654232.50
647	1405.7	979911.085	-5.790	0.593	-162.50	355564.20	4654237.80
648	1415.1	979905.033	-10.247	0.570	-168.00	355749.40	4655846.50
649	1405.7	979903.593	-14.588	0.554	-171.30	355977.00	4655841.20
650	1396.2	979901.259	-19.864	0.534	-175.60	358167.70	4655809.40
651	1398.7	979893.135	-25.932	0.714	-181.70	360945.90	4654169.00
652	1403.2	979892.684	-25.002	0.849	-181.20	361739.60	4654163.70
653	1426.1	979895.424	-15.202	1.292	-173.50	363231.90	4654142.60
654	1457.5	979896.489	-4.656	1.791	-166.00	363967.40	4654386.00
655	1533.1	979885.206	7.404	2.916	-161.20	365009.90	4654348.90
656	1419.7	979891.886	-19.733	1.111	-177.50	362930.20	4652936.10
657	1410.2	979889.811	-24.408	0.847	-181.40	362004.20	4652544.50
658	1393.5	979892.173	-27.189	0.657	-182.50	360496.10	4652560.30
659	1431.9	979902.375	-10.697	0.647	-170.30	356051.00	4659513.60
664	1420.6	979900.946	-13.847	0.617	-172.20	339877.60	4657680.30
665	1416.9	979899.590	-16.356	0.577	-174.30	340686.60	4657676.00
666	1417.3	979900.347	-15.476	0.557	-173.50	341491.20	4657658.60
667	1418.8	979900.858	-14.510	0.542	-172.70	342304.50	4657649.90
668	1420.3	979903.921	-10.991	0.538	-169.40	343117.90	4657641.20
669	1424.3	979909.807	-3.787	0.538	-162.60	344757.60	4657502.00
670	1422.7	979907.783	-6.311	0.531	-165.00	343935.60	4657528.10
671	1459.0	979893.711	-11.521	0.558	-174.20	342343.70	4660450.90
672	1459.9	979904.631	0.097	0.621	-162.60	344448.80	4659885.50
673	1430.1	979907.173	-3.430	2.811	-160.60	343496.30	4656046.60
674	1381.9	979908.464	-15.686	0.499	-169.80	343461.50	4654409.50
675	1369.1	979911.130	-15.711	0.485	-168.40	343434.60	4652855.00
676	1365.7	979908.647	-18.778	0.480	-171.10	342730.80	4652295.70
677	1374.9	979905.765	-19.915	0.510	-173.30	341665.20	4653670.10

Table B.1. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
678	1381.0	979904.464	-19.956	0.527	-174.00	341430.30	4654444.30
679	1396.5	979902.958	-17.861	0.545	-173.60	341156.30	4655910.10
680	1401.4	979902.363	-17.291	0.579	-173.50	340282.10	4656358.10
682	1446.2	979894.774	-13.592	0.669	-174.70	339112.10	4659515.80
683	1457.8	979895.536	-9.519	0.843	-171.80	337511.50	4659885.50
684	1466.6	979901.809	-0.179	1.136	-163.20	336228.40	4659481.00
685	1416.3	979915.152	1.696	0.995	-155.80	334962.70	4654505.20
686	1407.8	979910.651	-4.131	0.775	-160.90	335280.20	4652895.90
687	1382.2	979909.977	-12.732	0.638	-166.80	337485.40	4652878.50
688	1372.1	979910.562	-15.285	0.577	-168.20	339020.70	4652869.80
689	1376.7	979908.724	-16.490	0.603	-169.90	339033.80	4653839.70
690	1387.4	979910.202	-12.197	0.724	-166.70	337389.70	4654479.10
691	1401.1	979907.139	-12.347	0.789	-168.30	337424.50	4656101.50
698	1704.7	979861.258	24.941	0.736	-165.10	348091.30	4668849.30
699	1712.9	979858.525	24.550	0.555	-166.60	348588.80	4669071.60
700	1696.4	979865.970	26.280	0.972	-162.60	350149.80	4669807.10
701	1677.8	979873.059	28.008	1.067	-158.70	358457.70	4669166.80
702	1658.3	979874.223	22.852	0.846	-161.90	357087.20	4669569.00
703	1655.0	979866.763	13.845	0.548	-170.80	355330.30	4670256.90
704	1631.5	979872.010	11.943	0.489	-170.10	353737.60	4670161.70
705	1644.3	979874.234	18.610	0.857	-164.50	352250.60	4669584.90
708	1644.3	979868.929	15.551	0.890	-167.60	334671.60	4667203.60
709	1709.8	979857.238	24.087	1.113	-166.10	333063.00	4667224.80
710	1744.9	979851.432	28.934	1.308	-165.00	332295.70	4667462.90
711	1783.3	979846.814	35.947	1.506	-162.10	331438.40	4667754.00
712	1809.2	979844.566	41.558	1.672	-159.20	330856.30	4667933.90
713	1846.7	979837.771	45.816	1.765	-159.10	330422.40	4668584.70
714	1929.3	979821.145	54.821	3.030	-158.00	329561.00	4668430.60
715	1846.7	979837.802	45.846	1.765	-159.00	330422.40	4668584.70
716	1674.2	979862.050	17.905	0.971	-168.50	333904.30	4667214.20
717	1553.8	979885.287	4.141	0.721	-169.00	342503.30	4666827.90

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
718	1543.7	979885.866	1.582	0.680	-170.50	341736.00	4666870.20
719	1536.4	979888.391	1.840	0.648	-169.40	340889.40	4666907.30
720	1537.3	979886.200	-0.089	0.635	-171.50	340090.30	4666944.30
721	1518.4	979889.308	-2.834	0.773	-172.00	339095.50	4666992.00
722	1550.7	979881.330	-0.586	0.683	-173.40	337889.00	4666700.90
726	1458.4	979907.852	-5.251	0.618	-167.80	362476.10	4669515.90
727	1461.4	979906.987	-5.182	0.707	-168.00	361655.80	4669521.20
728	1473.0	979903.809	-5.752	0.742	-169.80	361296.00	4670727.70
729	1473.0	979904.965	-3.622	0.780	-167.70	361253.70	4669526.50
730	1527.0	979899.661	7.810	1.564	-161.50	360253.60	4669457.70
731	1575.7	979891.613	15.838	0.907	-159.60	359354.00	4668182.40
732	1520.6	979897.542	6.224	0.703	-163.20	359195.20	4666383.20
733	1453.2	979904.331	-7.116	0.591	-169.10	361592.30	4665510.10
734	1452.3	979903.955	-7.114	0.561	-169.10	361576.50	4664700.50
735	1455.3	979905.299	-4.845	0.595	-167.10	359967.80	4664732.20
736	1493.8	979898.007	-0.268	0.601	-166.80	358364.40	4664779.80
737	1534.6	979891.266	5.578	0.831	-165.30	356739.90	4664816.90
738	1470.6	979898.886	-5.273	0.692	-169.10	356697.50	4663240.00
739	1455.7	979903.772	-4.987	0.599	-167.30	358353.80	4663208.20
740	1418.2	979900.915	-17.296	0.563	-175.40	358263.90	4660594.10
741	1456.0	979897.657	-9.687	0.578	-172.00	356660.50	4661610.10
742	1438.0	979901.406	-11.498	0.585	-171.80	357549.50	4661599.50
743	1416.6	979903.232	-16.250	0.605	-174.20	360729.80	4661504.30
744	1415.7	979901.785	-17.988	0.587	-175.80	359904.30	4661536.00
745	1418.8	979902.328	-16.501	0.583	-174.70	359100.00	4661567.80
746	1425.8	979902.243	-14.430	0.576	-173.40	358295.60	4661589.00
748	1434.3	979907.034	-8.294	0.624	-168.20	361809.30	4663097.10
749	1459.3	979904.539	-5.683	0.634	-168.30	361613.50	4666319.70
750	1471.5	979903.900	-3.214	0.697	-167.20	361618.80	4667129.30
751	1487.4	979902.886	0.031	0.725	-165.70	361645.30	4667928.40
752	1454.1	979893.769	-17.073	0.867	-178.90	365550.50	4665028.50

Table B.1. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
753	1471.5	979900.537	-8.515	0.834	-172.30	367370.90	4669410.10
754	1771.4	979851.044	34.769	1.600	-161.80	380002.10	4668902.10
755	1646.4	979873.796	18.903	1.226	-164.10	377282.20	4669002.60
756	1567.8	979887.648	8.952	1.544	-164.90	374112.50	4668499.90
757	1546.8	979892.083	6.740	2.437	-163.90	372244.50	4668738.00
758	1532.8	979894.339	4.333	2.259	-164.90	370826.30	4669187.80
759	1512.6	979894.371	-2.279	1.666	-169.90	370143.70	4669706.40
760	1493.4	979895.675	-7.094	1.231	-173.00	369355.20	4669960.40
762	1480.6	979897.601	-8.766	0.933	-173.50	368196.40	4669547.60
765	1413.3	979903.914	-15.274	0.683	-172.70	361470.60	4659869.20
766	1452.9	979898.440	-12.107	0.715	-174.00	364439.30	4664229.50
767	1502.6	979890.301	-0.689	2.666	-166.20	365180.10	4659006.60
768	1463.6	979894.217	-8.802	1.811	-170.80	364513.40	4659011.90
769	1442.2	979897.267	-12.350	1.344	-172.40	363857.20	4659017.20
774	1323.4	979927.868	1.166	0.345	-146.60	339708.10	4635348.70
775	1344.7	979925.604	7.561	0.332	-142.60	340750.80	4632748.00
776	1326.1	979926.906	3.134	0.333	-144.90	339089.80	4632772.30
777	1318.5	979930.444	5.451	0.336	-141.70	338016.80	4631408.30
778	1318.8	979931.409	6.784	0.332	-140.50	339071.60	4631044.60
779	1317.6	979931.727	7.237	0.331	-139.90	338477.50	4630432.30
780	1318.2	979932.453	8.708	0.331	-138.50	338768.50	4629735.20
781	1319.1	979925.950	-0.756	0.367	-148.00	337974.40	4633754.30
784	1393.8	979911.988	-8.429	0.818	-163.60	336410.40	4654492.80
785	1501.1	979906.713	19.452	1.220	-147.30	332791.30	4654523.10
786	1596.2	979889.744	30.962	1.597	-146.00	331797.10	4655620.30
787	1703.1	979870.547	44.053	2.127	-144.40	330663.50	4656511.50
788	1832.4	979849.196	61.861	3.552	-139.60	329723.90	4657451.10
789	1472.7	979906.846	12.143	1.015	-151.60	332233.60	4652904.50
792	1364.5	979915.559	-9.581	0.524	-161.70	337644.90	4649132.20
1380	1323.4	979929.770	2.160	0.350	-145.60	340041.80	4636463.80
1494	1316.1	979927.901	6.191	0.433	-140.60	345453.70	4626271.50
1497	1330.4	979924.345	6.403	0.465	-142.00	346192.80	4627052.80
2002	1387.4	979905.008	-11.791	0.584	-166.50	358339.20	4647115.50
2005	1374.9	979919.625	-1.138	0.534	-154.50	353496.90	4647345.60
2011	1399.9	979914.267	9.628	0.306	-146.70	351234.70	4637006.90
2014	1416.0	979911.670	5.766	0.583	-152.10	330150.50	4645178.80
2017	1323.1	979925.384	-4.710	0.361	-152.40	340591.00	4639405.50
2020	1372.4	979918.857	10.574	0.318	-142.70	347049.20	4631114.30
2023	1328.6	979925.324	1.225	0.439	-147.00	336442.30	4634190.40
2026	1358.7	979904.498	-11.337	0.711	-162.70	325994.50	4635704.10
2029	1284.7	979925.164	0.784	0.275	-142.70	342524.20	4617658.70
2032	1299.0	979925.147	2.599	0.719	-142.00	344808.50	4620799.10
2035	1425.5	979912.281	5.033	1.027	-153.40	351472.50	4649981.10
2038	1354.2	979914.312	-14.020	0.495	-165.10	338968.30	4649118.90
2047	1392.6	979913.760	-2.791	0.593	-158.00	357046.90	4648816.10
2050	1425.2	979905.476	-11.350	0.789	-170.00	363109.20	4661454.90
2053	1403.2	979901.529	-18.741	0.605	-175.10	359799.80	4657390.70
2056	1417.9	979902.029	-13.584	0.662	-171.60	339100.60	4657681.30
2059	1432.8	979893.610	-9.255	0.759	-168.80	361925.50	4647138.40
2062	1393.2	979905.376	-15.373	0.522	-170.70	358130.70	4654206.10
2065	1397.7	979905.422	-15.126	0.644	-170.90	339059.90	4656079.70
2068	1726.3	979858.321	28.475	0.584	-164.10	349181.40	4669066.30
2071	1540.7	979892.091	5.831	0.830	-165.70	337338.60	4668267.20
2074	1467.5	979900.545	-9.741	0.674	-173.30	365666.90	4669441.80
2077	1406.9	979904.766	-15.093	0.742	-171.80	361428.30	4658260.50
2080	1321.2	979925.765	-0.996	0.350	-148.50	338871.60	4634603.00
2083	1434.0	979914.167	6.175	1.059	-153.20	334379.60	4654517.00
2086	1354.2	979914.456	-13.876	0.495	-164.90	338968.30	4649118.90

Notes

[1]Easting and northing in meters based on Universal Transverse Mercator Zone 12N projection, 1927 datum, used in GIS applications.

Table B.2. *Gravity data from Bankey and others (1998) used in this study. The terrane stations were recalculated from their original values.*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
3685	1385.6	979905.220	-12.270	0.570	-166.70	358558.90	4647496.80
JG008	1569.0	979872.350	23.650	1.570	-150.40	356276.70	4632252.60
M147	1506.6	979886.480	12.260	1.080	-155.20	322771.40	4640794.50
M148	1447.7	979907.490	9.340	0.590	-152.10	331239.90	4647734.80
M149	1429.4	979909.030	5.060	0.560	-154.30	332706.20	4647725.10
M151	1424.9	979911.280	7.440	0.570	-151.40	331060.60	4646262.10
M152	1406.6	979908.480	0.120	0.540	-156.70	331029.50	4644566.70
M153	1392.9	979911.530	0.270	0.500	-155.10	331432.50	4643072.70
M176	1356.0	979915.160	-13.180	0.510	-164.40	338968.50	4649668.30
M177	1363.0	979913.190	-13.970	0.540	-165.90	338998.20	4651248.80
M178	1373.1	979910.950	-14.290	0.580	-167.40	339015.90	4652860.60
M179	1382.8	979907.980	-15.570	0.620	-169.70	339036.60	4654530.20
M180	1398.4	979905.460	-14.670	0.640	-170.50	339059.80	4656084.50
M181	1417.6	979902.210	-13.350	0.660	-171.30	339093.70	4657678.60
M182	1434.9	979897.180	-14.120	0.670	-174.00	339096.20	4658943.50
M183	1458.4	979892.420	-12.980	0.660	-175.50	339150.00	4660553.50
M184	1472.7	979888.570	-13.740	0.680	-177.90	339218.90	4662169.80
M185	1500.5	979883.820	-11.180	0.660	-178.40	339222.80	4663755.30
M186	1503.8	979886.660	-8.610	0.700	-176.20	339247.30	4665247.00
M187	1517.5	979889.220	-3.160	0.740	-172.20	339307.40	4666557.10
M188	1533.1	979889.670	1.450	0.740	-169.40	338131.50	4667503.60
M2	1303.0	979911.410	-14.890	0.600	-160.10	323977.10	4627178.00
M210	1416.6	979901.570	-14.300	0.560	-172.30	341487.70	4657651.00
M211	1420.0	979907.930	-6.810	0.530	-165.20	343927.90	4657516.00
M212	1427.9	979908.590	-3.720	0.540	-163.00	345400.40	4657481.50
M213	1438.0	979905.210	-3.980	0.550	-164.30	346551.90	4657453.60
M216	1541.9	979885.240	0.390	0.850	-171.30	338047.10	4667098.50
M217	1591.6	979877.340	7.830	0.810	-169.50	335898.40	4667141.60
M218	1646.1	979867.870	15.180	0.890	-168.10	334621.20	4667204.30
M68	1548.9	979886.810	18.540	0.950	-153.80	323077.50	4649434.60
M219	1698.3	979857.300	20.450	1.070	-168.50	333283.50	4667229.20
M220	1736.4	979855.070	29.720	1.850	-162.70	331500.80	4667975.70
M221	1775.7	979851.490	38.130	3.450	-157.10	329926.50	4668180.10
M222	1535.5	979888.490	1.670	0.650	-169.50	340894.10	4666907.40
M223	1552.0	979885.410	3.680	0.720	-169.30	342500.10	4666821.10
M224	1580.0	979885.420	11.810	0.880	-164.10	343398.30	4666785.80
M225	1617.5	979879.180	16.090	1.210	-163.70	344503.70	4668023.00
M226	1671.1	979868.290	20.540	1.580	-164.90	346716.10	4670405.90
M227	1551.4	979895.390	12.010	0.880	-160.70	336827.60	4668706.50
M228	1595.2	979888.890	17.520	1.220	-159.80	334815.10	4670876.20
M236	1698.3	979820.420	13.000	13.590	-163.40	316623.80	4631680.00
M35	1285.3	979921.230	-8.310	0.460	-151.70	326662.10	4624540.90
M36	1287.1	979923.550	-5.730	0.450	-149.30	327006.20	4624748.50
M37	1287.7	979926.990	-2.620	0.440	-146.30	327441.70	4624996.20
M38	1289.5	979929.020	-0.250	0.410	-144.10	329720.40	4625830.80
M39	1293.2	979929.770	1.320	0.410	-143.00	330669.40	4626411.30
M40	1295.0	979933.200	4.260	0.450	-140.20	332874.60	4627510.30
M41	1287.4	979932.130	2.670	0.350	-141.00	333516.40	4625120.80
M42	1301.4	979913.340	-13.570	0.560	-158.60	325503.30	4627853.70
M44	1356.3	979921.770	9.110	0.460	-142.20	333003.90	4630629.80
M45	1327.6	979925.030	4.640	0.430	-143.50	330712.70	4629380.60
M46	1293.2	979927.500	-1.940	0.470	-146.20	328437.90	4627437.30
M47	1290.2	979925.760	-4.000	0.470	-147.90	327753.50	4626689.70
M62	1412.4	979893.010	-5.640	0.940	-162.70	322807.70	4634964.10
M63	1440.1	979891.080	-4.190	0.730	-164.60	325977.10	4642092.90
M64	1457.2	979897.680	3.910	0.670	-158.50	327410.00	4645856.00
M65	1483.7	979902.250	14.900	0.690	-150.40	327879.10	4647981.10
M66	1509.3	979900.210	19.730	0.740	-148.40	327911.10	4649295.70
M67	1531.5	979889.190	15.550	0.860	-155.00	324710.20	4649331.00
M67	1531.5	979889.190	15.550	0.860	-155.00	324710.20	4649331.00

Table B.2. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
M69	1529.7	979887.990	15.100	0.890	-155.20	323044.60	4647822.50
M70	1503.2	979894.860	13.980	0.810	-153.40	324639.50	4647346.90
M71	1516.6	979889.780	14.190	0.960	-154.60	323017.60	4646462.00
M72	1569.6	979886.030	25.180	0.990	-149.50	321287.90	4648270.70
M73	1609.9	979870.070	21.340	1.050	-157.80	319829.90	4648677.50
M221	1775.7	979851.490	38.130	3.450	-157.10	329926.50	4668180.10
M222	1535.5	979888.490	1.670	0.650	-169.50	340894.10	4666907.40
M223	1552.0	979885.410	3.680	0.720	-169.30	342500.10	4666821.10
M224	1580.0	979885.420	11.810	0.880	-164.10	343398.30	4666785.80
M225	1617.5	979879.180	16.090	1.210	-163.70	344503.70	4668023.00
M226	1671.1	979868.290	20.540	1.580	-164.90	346716.10	4670405.90
M227	1551.4	979895.390	12.010	0.880	-160.70	336827.60	4668706.50
M228	1595.2	979888.890	17.520	1.220	-159.80	334815.10	4670876.20
M236	1698.3	979820.420	13.000	13.590	-163.40	316623.80	4631680.00
M35	1285.3	979921.230	-8.310	0.460	-151.70	326662.10	4624540.90
M36	1287.1	979923.550	-5.730	0.450	-149.30	327006.20	4624748.50
M37	1287.7	979926.990	-2.620	0.440	-146.30	327441.70	4624996.20
M38	1289.5	979929.020	-0.250	0.410	-144.10	329720.40	4625830.80
M39	1293.2	979929.770	1.320	0.410	-143.00	330669.40	4626411.30
M40	1295.0	979933.200	4.260	0.450	-140.20	332874.60	4627510.30
M41	1287.4	979932.130	2.670	0.350	-141.00	333516.40	4625120.80
M42	1301.4	979913.340	-13.570	0.560	-158.60	325503.30	4627853.70
M44	1356.3	979921.770	9.110	0.460	-142.20	333003.90	4630629.80
M45	1327.6	979925.030	4.640	0.430	-143.50	330712.70	4629380.60
M46	1293.2	979927.500	-1.940	0.470	-146.20	328437.90	4627437.30
M47	1290.2	979925.760	-4.000	0.470	-147.90	327753.50	4626689.70
M62	1412.4	979893.010	-5.640	0.940	-162.70	322807.70	4634964.10
M63	1440.1	979891.080	-4.190	0.730	-164.60	325977.10	4642092.90
M64	1457.2	979897.680	3.910	0.670	-158.50	327410.00	4645856.00
M65	1483.7	979902.250	14.900	0.690	-150.40	327879.10	4647981.10
M66	1509.3	979900.210	19.730	0.740	-148.40	327911.10	4649295.70
MK462	1617.8	979863.180	28.210	0.420	-152.40	314953.90	4634659.00

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
M68	1548.9	979886.810	18.540	0.950	-153.80	323077.50	4649434.60
M69	1529.7	979887.990	15.100	0.890	-155.20	323044.60	4647822.50
M70	1503.2	979894.860	13.980	0.810	-153.40	324639.50	4647346.90
M71	1516.6	979889.780	14.190	0.960	-154.60	323017.60	4646462.00
M72	1569.6	979886.030	25.180	0.990	-149.50	321287.90	4648270.70
M73	1609.9	979870.070	21.340	1.050	-157.80	319829.90	4648677.50
M74	1645.8	979859.140	21.270	0.030	-162.90	318751.30	4648954.00
M75	1673.6	979857.310	28.180	0.030	-159.10	317415.80	4648807.10
M76	1616.9	979874.960	26.320	1.140	-153.50	321382.40	4651057.50
M77	1608.7	979879.170	28.050	1.100	-150.90	323087.00	4651037.20
M78	1542.2	979895.340	23.790	0.920	-147.90	328254.10	4651146.70
MB115	1291.7	979931.890	5.770	0.300	-138.50	340537.80	4623131.10
MB116	1285.9	979933.780	4.560	0.320	-139.00	334787.70	4624169.60
MB117	1287.7	979915.150	-12.610	0.500	-156.20	324823.40	4623934.70
MK 3	1303.0	979905.390	-20.910	0.600	-166.10	323967.50	4627191.40
MK332	1590.7	979873.670	22.310	1.550	-154.10	321188.90	4644522.40
MK333	1673.6	979857.210	28.140	0.030	-159.10	317414.40	4648791.10
MK448	1658.0	979853.960	32.400	4.210	-148.90	313619.40	4633724.30
MK449	1641.9	979862.030	34.510	0.180	-149.00	314368.20	4635071.70
MK450	1573.3	979886.770	26.370	1.050	-148.60	321022.30	4649463.30
MK451	1572.7	979886.890	27.340	0.980	-147.70	321324.60	4648007.90
MK452	1580.6	979880.170	24.390	1.170	-151.30	321384.80	4646524.60
MK453	1577.3	979874.300	20.170	1.290	-155.00	321770.70	4642626.20
MK454	1512.6	979885.850	13.440	1.100	-154.70	322674.80	4640877.50
MK455	1488.6	979887.930	9.350	1.040	-156.20	322886.70	4639898.40
MK456	1468.8	979887.420	4.050	1.050	-159.30	322713.10	4638253.20
MK457	1454.1	979888.670	1.800	0.990	-159.90	322799.80	4636518.20
MK458	1412.7	979892.660	-5.830	0.940	-163.00	322787.30	4634965.80
MK459	1497.1	979882.690	8.310	1.160	-158.10	321542.30	4637376.80
MK460	1520.9	979874.710	11.140	0.460	-158.60	317037.20	4632944.60
MK461	1569.6	979870.530	21.490	0.450	-153.70	315945.60	4633849.20
S182	1425.2	979879.860	-9.320	0.070	-168.70	317152.20	4628247.30

Table B.2. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
MK531	1479.4	979881.740	18.030	0.090	-147.40	317185.60	4617427.70
MK532	1408.7	979894.850	8.580	0.050	-149.00	318201.90	4618173.80
MK533	1363.0	979907.330	6.130	0.560	-145.80	319636.60	4620100.70
MK534	1306.3	979916.560	-3.190	0.700	-148.70	321698.70	4620874.50
MK535	1304.5	979909.850	-12.170	0.630	-157.50	323082.20	4622962.20
MK536	1286.8	979913.730	-14.380	0.480	-157.90	325018.30	4623538.60
MK537	1384.9	979899.890	-5.140	0.940	-159.20	322548.10	4632855.50
S1	1285.6	979919.550	-9.090	0.440	-152.50	326634.60	4623682.80
S10	1319.7	979913.670	1.850	0.480	-145.30	320654.40	4616288.30
S100	1297.2	979932.950	7.070	0.330	-137.80	342632.90	4624119.60
S101	1290.2	979931.920	5.220	0.310	-138.80	339025.10	4623616.20
S102	1286.8	979932.260	4.040	0.300	-139.70	337707.60	4623079.10
S103	1287.4	979932.680	4.220	0.310	-139.50	336046.70	4623676.30
S104	1287.1	979932.580	3.710	0.330	-140.00	334472.70	4624268.60
S105	1293.5	979930.060	5.540	0.290	-138.90	341703.30	4621479.30
S106	1290.2	979928.540	3.770	0.340	-140.30	343525.70	4620037.50
S107	1288.0	979925.290	0.560	0.320	-143.30	343431.40	4619310.70
S108	1288.3	979925.560	1.650	0.280	-142.20	340433.80	4618958.90
S143	1347.5	979916.660	-12.700	0.470	-163.00	338928.60	4647671.20
S144	1339.8	979915.160	-16.330	0.420	-165.80	342966.10	4647602.60
S145	1357.5	979923.300	-2.820	0.440	-154.30	349768.40	4647561.80
S146	1473.0	979906.810	16.380	0.630	-147.80	329316.50	4647792.40
S147	1441.9	979894.830	-1.760	0.680	-162.40	326855.80	4643730.30
S148	1429.1	979892.480	-4.910	0.820	-164.00	324925.50	4639711.80
S149	1422.4	979891.690	-4.600	0.910	-162.90	323514.20	4636451.40
S150	1450.2	979903.770	7.920	0.650	-153.70	327830.90	4646058.20
S151	1476.4	979880.070	3.170	0.950	-161.10	320506.10	4632996.10
S178	1336.2	979905.700	-12.520	0.780	-161.30	323045.10	4630663.50
S179	1305.7	979911.240	-14.000	0.630	-159.50	323457.40	4627211.90
S180	1300.8	979905.980	-19.000	0.640	-163.90	322011.90	4625001.70
S181	1365.7	979890.570	-15.550	0.010	-168.40	318583.10	4626842.30
S181	1365.7	979890.570	-15.550	0.010	-168.40	318583.10	4626842.30

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
S183	1404.4	979915.480	3.790	0.620	-152.70	354950.80	4647248.90
S184	1363.9	979920.930	-3.280	0.450	-155.50	350522.50	4647334.70
S185	1338.6	979920.850	-11.240	0.420	-160.60	345711.10	4647587.20
S186	1391.6	979913.970	-1.670	0.540	-156.80	335011.70	4647732.10
S189	1584.0	979882.220	25.510	1.070	-150.70	321163.60	4648996.00
S190	1524.8	979888.560	13.550	0.880	-156.20	323654.20	4648540.90
S191	1488.6	979901.540	15.690	0.760	-150.10	326571.50	4648141.60
S2	1285.0	979923.260	-5.710	0.410	-149.10	328212.00	4623791.20
S1	1285.6	979919.550	-9.090	0.440	-152.50	326634.60	4623682.80
S10	1319.7	979913.670	1.850	0.480	-145.30	320654.40	4616288.30
S100	1297.2	979932.950	7.070	0.330	-137.80	342632.90	4624119.60
S101	1290.2	979931.920	5.220	0.310	-138.80	339025.10	4623616.20
S102	1286.8	979932.260	4.040	0.300	-139.70	337707.60	4623079.10
S103	1287.4	979932.680	4.220	0.310	-139.50	336046.70	4623676.30
S104	1287.1	979932.580	3.710	0.330	-140.00	334472.70	4624268.60
S105	1293.5	979930.060	5.540	0.290	-138.90	341703.30	4621479.30
S106	1290.2	979928.540	3.770	0.340	-140.30	343525.70	4620037.50
S107	1288.0	979925.290	0.560	0.320	-143.30	343431.40	4619310.70
S108	1288.3	979925.560	1.650	0.280	-142.20	340433.80	4618958.90
S143	1347.5	979916.660	-12.700	0.470	-163.00	338928.60	4647671.20
S144	1339.8	979915.160	-16.330	0.420	-165.80	342966.10	4647602.60
S145	1357.5	979923.300	-2.820	0.440	-154.30	349768.40	4647561.80
S146	1473.0	979906.810	16.380	0.630	-147.80	329316.50	4647792.40
S147	1441.9	979894.830	-1.760	0.680	-162.40	326855.80	4643730.30
S148	1429.1	979892.480	-4.910	0.820	-164.00	324925.50	4639711.80
S149	1422.4	979891.690	-4.600	0.910	-162.90	323514.20	4636451.40
S150	1450.2	979903.770	7.920	0.650	-153.70	327830.90	4646058.20
S151	1476.4	979880.070	3.170	0.950	-161.10	320506.10	4632996.10
S178	1336.2	979905.700	-12.520	0.780	-161.30	323045.10	4630663.50
S179	1305.7	979911.240	-14.000	0.630	-159.50	323457.40	4627211.90
S180	1300.8	979905.980	-19.000	0.640	-163.90	322011.90	4625001.70
S97	1395.9	979913.560	11.700	0.280	-144.20	348505.90	4632969.60

Table B.2. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
S182	1425.2	979879.860	-9.320	0.070	-168.70	317152.20	4628247.30
S183	1404.4	979915.480	3.790	0.620	-152.70	354950.80	4647248.90
S184	1363.9	979920.930	-3.280	0.450	-155.50	350522.50	4647334.70
S185	1338.6	979920.850	-11.240	0.420	-160.60	345711.10	4647587.20
S186	1391.6	979913.970	-1.670	0.540	-156.80	335011.70	4647732.10
S189	1584.0	979882.220	25.510	1.070	-150.70	321163.60	4648996.00
S190	1524.8	979888.560	13.550	0.880	-156.20	323654.20	4648540.90
S191	1488.6	979901.540	15.690	0.760	-150.10	326571.50	4648141.60
S2	1285.0	979923.260	-5.710	0.410	-149.10	328212.00	4623791.20
S233	1408.7	979907.060	2.930	0.670	-154.00	354938.00	4639150.00
S234	1408.4	979903.450	1.900	1.770	-153.90	354559.40	4636570.80
S235	1406.6	979902.530	2.950	0.810	-153.60	355114.20	4632698.90
S236	1465.4	979891.860	12.100	0.880	-151.00	354995.00	4630979.70
S3	1285.3	979926.350	-2.780	0.390	-146.20	329233.60	4623892.70
S4	1285.3	979928.920	-0.480	0.370	-143.90	330695.00	4624013.70
S5	1286.2	979930.460	1.790	0.350	-141.80	332330.30	4624138.50
S6	1288.0	979911.770	-15.380	0.520	-159.00	323760.40	4623067.20
S7	1285.6	979913.170	-13.220	0.560	-156.50	322798.40	4621597.60
S8	1287.4	979918.410	-6.430	0.590	-149.90	322157.30	4619998.60
S86	1384.0	979902.240	-17.010	0.550	-171.30	358448.70	4648685.90
S87	1387.1	979898.320	-21.700	0.580	-176.30	359666.80	4650972.40
S88	1390.4	979895.670	-24.530	0.780	-179.30	361313.40	4652555.70
S89	1392.9	979896.970	-23.890	0.600	-179.20	359742.00	4654180.50
S9	1285.3	979919.650	-4.790	0.760	-147.90	320961.40	4618682.00
S90	1397.4	979896.610	-24.160	0.790	-179.70	361386.00	4655771.80
S91	1403.2	979902.340	-18.040	0.760	-174.30	361413.20	4657381.40
S92	1378.2	979914.400	-4.450	0.570	-158.10	357338.10	4646612.40
S93	1383.1	979913.390	-1.190	0.570	-155.40	355960.50	4643982.20
S94	1387.1	979913.600	2.650	0.450	-152.10	353915.10	4640937.50
S95	1392.9	979915.000	7.720	0.350	-147.80	352443.90	4638761.00
S96	1403.8	979913.240	11.120	0.300	-145.70	350995.40	4636618.90
S96	1403.8	979913.240	11.120	0.300	-145.70	350995.40	4636618.90
S98	1368.5	979918.970	10.300	0.310	-142.50	346672.80	4629956.50
S99	1322.5	979929.780	9.460	0.360	-138.20	344728.20	4627138.20
SI1	1485.5	979887.980	2.750	0.910	-162.60	361669.60	4645222.70
SI2	1516.0	979879.090	5.670	1.360	-162.60	364435.20	4642441.10
SL138	1280.1	979918.550	-2.770	0.020	-146.00	324429.80	4612752.40
SL139	1280.1	979917.620	-3.770	0.000	-147.00	326056.00	4612801.60
SL150	1280.1	979921.600	-3.560	0.320	-146.50	328998.90	4616983.30
SL151	1280.1	979916.530	-9.830	0.370	-152.70	327242.90	4618991.30
SL152	1280.1	979916.500	-11.140	0.350	-154.00	329146.90	4620173.70
SL154	1280.1	979916.990	-5.630	0.000	-148.90	338065.70	4614042.50
S233	1408.7	979907.060	2.930	0.670	-154.00	354938.00	4639150.00
S234	1408.4	979903.450	1.900	1.770	-153.90	354559.40	4636570.80
S235	1406.6	979902.530	2.950	0.810	-153.60	355114.20	4632698.90
S236	1465.4	979891.860	12.100	0.880	-151.00	354995.00	4630979.70
S3	1285.3	979926.350	-2.780	0.390	-146.20	329233.60	4623892.70
S4	1285.3	979928.920	-0.480	0.370	-143.90	330695.00	4624013.70
S5	1286.2	979930.460	1.790	0.350	-141.80	332330.30	4624138.50
S6	1288.0	979911.770	-15.380	0.520	-159.00	323760.40	4623067.20
S7	1285.6	979913.170	-13.220	0.560	-156.50	322798.40	4621597.60
S8	1287.4	979918.410	-6.430	0.590	-149.90	322157.30	4619998.60
S86	1384.0	979902.240	-17.010	0.550	-171.30	358448.70	4648685.90
S87	1387.1	979898.320	-21.700	0.580	-176.30	359666.80	4650972.40
S88	1390.4	979895.670	-24.530	0.780	-179.30	361313.40	4652555.70
S89	1392.9	979896.970	-23.890	0.600	-179.20	359742.00	4654180.50
S9	1285.3	979919.650	-4.790	0.760	-147.90	320961.40	4618682.00
S90	1397.4	979896.610	-24.160	0.790	-179.70	361386.00	4655771.80
S91	1403.2	979902.340	-18.040	0.760	-174.30	361413.20	4657381.40
S92	1378.2	979914.400	-4.450	0.570	-158.10	357338.10	4646612.40
S93	1383.1	979913.390	-1.190	0.570	-155.40	355960.50	4643982.20
S94	1387.1	979913.600	2.650	0.450	-152.10	353915.10	4640937.50
S95	1392.9	979915.000	7.720	0.350	-147.80	352443.90	4638761.00
S97	1395.9	979913.560	11.700	0.280	-144.20	348505.90	4632969.60

Table B.2. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
S98	1368.5	979918.970	10.300	0.310	-142.50	346672.80	4629956.50
S99	1322.5	979929.780	9.460	0.360	-138.20	344728.20	4627138.20
SI1	1485.5	979887.980	2.750	0.910	-162.60	361669.60	4645222.70
SI2	1516.0	979879.090	5.670	1.360	-162.60	364435.20	4642441.10
SL138	1280.1	979918.550	-2.770	0.020	-146.00	324429.80	4612752.40
SL139	1280.1	979917.620	-3.770	0.000	-147.00	326056.00	4612801.60
SL150	1280.1	979921.600	-3.560	0.320	-146.50	328998.90	4616983.30
SL151	1280.1	979916.530	-9.830	0.370	-152.70	327242.90	4618991.30
SL152	1280.1	979916.500	-11.140	0.350	-154.00	329146.90	4620173.70
SL154	1280.1	979916.990	-5.630	0.000	-148.90	338065.70	4614042.50
SL96	1280.1	979922.070	-2.490	0.260	-145.50	342132.70	4616439.80

Notes

[1]Easting and northing in meters based on Universal Transverse Mercator Zone 12N projection, 1927 datum, used in GIS applications.

Table B.3. *Gravity data from Bankey and others (1998) used in this study, unmodified.*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
JG007	1472.1	979889.630	11.840	0.490	-153.80	357128.60	4631022.50
78121	1600.1	979851.790	24.350	1.530	-154.62	367466.90	4617615.10
78122	1490.4	979872.300	10.510	1.120	-156.55	366696.50	4618262.50
78124	1398.7	979890.160	-0.850	0.580	-158.14	365677.90	4619425.50
78125	1342.0	979902.870	-6.750	0.390	-157.86	364539.60	4620835.30
78126	1309.7	979911.550	-8.990	0.300	-156.56	363522.50	4622043.10
78132	1601.0	979846.860	20.650	0.790	-159.16	368693.50	4616415.30
78133	1590.1	979847.390	18.220	0.820	-160.33	369582.80	4615877.00
78134	1590.1	979845.010	16.640	0.650	-162.08	369964.60	4614892.70
78226	1301.7	979918.530	-8.090	0.270	-154.80	360176.00	4626606.10
78227	1306.6	979918.990	-6.710	0.390	-153.85	359708.20	4627337.30
78228	1319.7	979917.540	-4.650	0.700	-152.95	359371.80	4627988.10
78229	1432.5	979895.200	7.400	1.130	-153.15	359032.70	4628494.60
78230	1438.9	979895.240	8.820	0.540	-153.03	358565.10	4629225.80
78231	1440.7	979895.500	9.030	0.590	-152.98	357982.20	4630003.80
78236	1300.8	979919.900	-7.150	0.330	-153.70	359074.40	4626816.60
78237	1316.7	979918.400	-3.830	0.270	-152.22	357563.20	4626913.20
78238	1340.7	979913.830	-1.370	0.270	-152.47	356725.60	4627429.80
78239	1382.8	979906.990	4.620	0.200	-151.27	355100.20	4627629.20
78329	1527.9	979883.210	4.430	1.000	-166.96	375137.00	4653373.40
78330	1539.2	979880.720	5.410	0.750	-167.49	374342.20	4653387.40
78331	1554.4	979878.270	7.670	0.610	-167.09	373911.70	4653395.10
78332	1586.7	979872.030	11.390	0.730	-166.88	373125.20	4653409.10
78333	1619.0	979867.860	17.130	0.960	-164.53	372695.60	4653472.40
78334	1703.7	979852.060	27.280	1.280	-163.57	371954.50	4653707.90
78335	1799.8	979831.810	36.860	2.490	-163.54	371138.20	4653445.00
78336	1853.4	979821.870	42.810	2.350	-163.74	370217.30	4654261.50
78337	1754.0	979841.640	32.510	1.740	-163.51	370146.30	4653552.00
78338	1779.9	979836.470	35.390	2.090	-163.19	369565.50	4653496.00
78339	1821.7	979827.140	39.380	1.670	-164.31	369596.90	4652951.20
78340	1528.2	979885.460	6.770	1.130	-164.52	376751.40	4653345.10

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
78341	1527.0	979885.020	5.960	1.360	-164.97	377537.90	4653331.50
78342	1522.4	979884.660	4.180	0.980	-166.61	378365.90	4653317.20
78343	1520.9	979882.870	1.940	0.690	-168.97	379152.00	4653281.60
78344	1521.8	979880.600	-0.060	0.720	-171.05	379955.40	4653290.10
78345	1522.1	979878.740	-1.810	0.890	-172.66	380783.00	4653253.90
78346	1524.8	979878.930	-0.790	1.590	-171.25	381569.90	4653262.90
78347	1534.9	979879.590	2.970	2.470	-167.73	382166.00	4653253.00
78348	1577.3	979873.810	10.620	1.490	-165.83	382912.00	4652796.40
78349	1557.5	979876.500	7.160	1.570	-166.98	382473.80	4652836.90
78433	1740.9	979849.120	29.180	3.480	-163.64	373012.20	4661874.70
79101	1292.9	979914.990	-12.360	0.130	-158.22	359271.50	4624158.10
79102	1301.1	979918.000	-8.360	0.230	-155.04	360514.20	4626044.10
79102	1301.1	979918.000	-8.360	0.230	-155.04	360514.20	4626044.10
79103	1302.0	979918.100	-8.440	0.270	-155.19	360159.80	4626628.60
79104	1301.7	979918.330	-8.130	0.260	-154.85	360280.10	4626404.10
79105	1302.7	979918.310	-8.310	0.340	-155.05	359950.30	4626966.00
79106	1306.3	979918.850	-6.920	0.380	-154.03	359732.40	4627303.50
79107	1310.0	979919.040	-5.850	0.460	-153.29	359530.80	4627618.40
79109	1299.0	979915.850	-9.070	0.220	-155.52	362459.20	4623418.50
79110	1300.8	979914.050	-10.070	0.240	-156.70	362702.90	4623113.90
79111	1296.9	979919.310	-6.740	0.210	-152.96	361847.00	4624019.00
79112	1297.8	979920.290	-5.810	0.220	-152.13	361522.40	4624436.20
79114	1312.1	979917.480	-5.260	0.220	-153.19	361588.90	4625723.40
79115	1329.5	979913.460	-3.920	0.280	-153.74	362735.90	4625701.20
79116	1370.6	979905.050	0.530	0.390	-153.80	363853.80	4625457.70
79117	1417.6	979892.670	1.980	0.480	-157.54	365340.50	4626251.50
79118	1452.3	979885.480	5.320	0.550	-158.03	366175.70	4626457.90
79119	1477.3	979879.010	6.630	0.870	-159.20	367719.70	4626329.20
79120	1591.0	979854.350	16.840	2.080	-160.55	369718.80	4626536.80
79121	1299.0	979916.590	-10.120	0.210	-156.58	360739.80	4625673.20
79121	1299.0	979916.590	-10.120	0.210	-156.58	360739.80	4625673.20

Table B.3. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
79122	1300.5	979917.000	-9.040	0.220	-155.66	360917.50	4625403.20
79123	1298.4	979917.880	-8.520	0.220	-154.90	361126.50	4625032.60
79125	1603.2	979852.350	26.130	1.230	-153.48	367776.80	4617265.10
79202	1303.9	979909.170	-9.810	0.120	-156.91	358775.80	4618003.30
79203	1291.1	979910.240	-12.820	0.110	-158.49	358429.60	4618176.70
79204	1287.4	979909.420	-14.910	0.070	-160.20	358158.40	4618348.70
79205	1286.2	979908.170	-16.670	0.070	-161.83	357878.80	4618520.90
79206	1285.6	979907.890	-17.250	0.040	-162.37	357590.70	4618682.10
79207	1284.7	979907.460	-18.090	0.050	-163.10	357385.50	4618830.60
79208	1349.6	979900.690	-3.330	0.170	-155.51	359969.80	4616913.60
79209	1384.9	979895.990	3.830	0.260	-152.24	361062.40	4615726.10
79210	1431.6	979885.940	9.270	0.320	-151.98	361809.70	4614323.30
79211	1346.2	979901.390	-3.840	0.190	-155.63	359849.30	4617138.10
79212	1342.6	979903.020	-3.530	0.160	-154.94	359554.30	4617377.10
79213	1336.2	979905.310	-3.390	0.150	-154.09	359334.00	4617603.60
79214	1328.6	979905.960	-5.240	0.170	-155.06	359071.40	4617797.60
79215	1285.3	979907.150	-18.490	0.050	-163.57	356677.10	4619200.20
79216	1286.2	979907.220	-18.530	0.010	-163.75	356087.70	4619689.60
79217	1284.4	979910.870	-15.640	-0.010	-160.68	355194.20	4619952.00
79218	1284.7	979915.460	-11.090	0.000	-156.15	354415.60	4620134.40
79219	1284.7	979919.110	-7.520	0.010	-152.57	353893.40	4620233.90
79220	1363.3	979897.600	-1.720	0.200	-155.42	360516.20	4616325.40
79221	1406.3	979890.800	5.770	0.280	-152.68	361432.00	4615030.30
79222	1474.6	979874.340	11.520	0.440	-154.44	362170.50	4613594.40
79223	1285.6	979920.630	-5.850	0.030	-150.98	353123.20	4620416.20
79224	1287.7	979921.180	-4.670	0.070	-150.00	352317.00	4620466.20
79225	1299.0	979919.330	-3.130	0.140	-149.66	351712.10	4620589.70
79226	1295.9	979923.330	0.290	0.190	-145.85	350255.50	4620175.70
79227	1292.3	979925.330	1.160	0.530	-144.23	348650.00	4620209.50
79302	1527.6	979886.750	1.350	0.530	-170.48	375775.20	4661414.60
79303	1529.4	979885.720	0.880	0.610	-171.07	375353.40	4661422.00
79304	1543.7	979883.400	2.980	0.650	-170.54	374939.90	4661429.40
79305	1563.5	979881.060	6.770	0.670	-168.96	374550.80	4661414.00
79306	1594.6	979876.630	11.970	0.800	-167.11	374095.00	4661366.60
79307	1624.5	979872.720	17.130	0.950	-165.16	373659.70	4661541.00
79308	1649.5	979867.840	19.780	1.150	-165.11	373258.50	4661770.30
79309	1302.3	979916.800	-5.710	0.120	-152.63	354900.00	4621857.30
79310	1298.7	979918.290	-4.870	0.090	-151.41	353390.90	4621299.40
79311	1299.0	979918.810	-3.630	0.140	-150.16	351695.20	4620579.00
79312	1298.4	979911.080	-13.330	0.080	-159.85	356397.00	4622660.20
79313	1295.6	979910.890	-15.240	0.080	-161.46	357358.60	4623740.60
79314	1292.9	979917.480	-10.390	0.140	-156.23	359832.60	4624780.10
79315	1296.6	979918.790	-8.520	0.190	-154.72	360212.00	4625472.50
79318	1316.1	979917.460	-5.160	0.310	-153.44	361075.40	4627110.60
79319	1361.2	979909.880	0.510	0.330	-152.82	361656.20	4627910.20
79320	1419.1	979892.760	-1.450	0.380	-161.24	363730.60	4631202.40
79321	1394.4	979902.150	1.680	0.380	-155.34	362868.10	4629552.90
8228A	1303.9	979916.310	-9.590	0.270	-156.54	360756.20	4626517.00
8228A	1303.9	979916.310	-9.590	0.270	-156.54	360756.20	4626517.00
GSL62	1277.4	979907.040	-15.520	-0.130	-159.89	349112.50	4612524.20
JG001	1605.9	979850.140	24.930	1.040	-155.18	368130.70	4617047.60
JG003	1438.6	979879.500	1.270	0.770	-160.32	366158.20	4618850.10
JG005	1296.9	979917.660	-8.130	0.220	-154.34	362114.90	4623680.60
JG006	1300.8	979920.190	-5.250	0.210	-151.91	361362.60	4624772.50
JG009	1525.8	979886.830	0.860	0.490	-170.80	376163.80	4661407.80
JG010	1530.6	979890.130	5.670	1.520	-165.51	380174.60	4661338.60
JG015	1528.8	979889.270	4.250	1.140	-167.10	379777.70	4661345.40
JG016	1527.3	979888.570	3.080	0.910	-168.34	379372.50	4661352.30
JG017	1526.4	979889.210	3.430	0.740	-168.05	378975.50	4661359.10
JG018	1525.8	979889.440	3.470	0.610	-168.07	378562.10	4661366.20
JG019	1526.1	979889.370	3.500	0.520	-168.17	378189.90	4661372.60
JG020	1645.5	979869.850	20.270	1.050	-164.28	381881.40	4661998.50
JG021	1625.4	979874.390	18.620	1.750	-162.97	382170.50	4661971.50
JG022	1605.3	979877.720	15.820	1.800	-163.47	381615.00	4661891.90

Table B.3. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
JG023	1581.8	979880.960	11.820	1.550	-165.08	381218.10	4661898.60
JG024	1555.9	979885.030	8.010	1.420	-166.11	380827.20	4661771.90
JG025	1537.9	979888.390	6.010	1.600	-165.91	380492.60	4661555.40
JG026	1528.8	979885.240	6.760	1.040	-164.70	375981.10	4653336.40
JG20A	1525.8	979888.960	3.000	0.490	-168.66	377776.40	4661379.70
M165	1626.0	979853.350	24.400	1.020	-157.99	311197.60	4630392.30
M166	1656.5	979847.200	27.170	1.200	-158.46	310236.60	4631236.00
M167	1719.9	979822.930	21.920	1.770	-170.25	297861.00	4632231.50
M168	1730.9	979821.360	23.430	1.900	-169.84	300006.00	4632537.70
M169	1681.5	979842.530	29.560	1.410	-158.67	309759.50	4632048.70
M170	1684.5	979841.360	29.340	1.510	-159.12	308787.10	4632052.50
M171	1691.6	979838.170	28.360	1.600	-160.80	305504.70	4632085.70
M172	1696.1	979832.000	23.610	1.650	-166.01	304374.70	4632105.40
M173	1703.1	979826.980	20.770	1.730	-169.56	302297.50	4632140.50
M174	1709.8	979819.600	15.520	1.760	-175.54	296896.20	4632214.40
M229	1602.3	979878.650	22.850	0.910	-156.98	316551.20	4654592.80
M230	1583.4	979881.680	18.810	0.900	-158.91	315895.50	4656143.20
M231	1747.9	979838.490	44.730	2.120	-150.23	306587.80	4633711.90
M232	1761.0	979833.650	43.900	2.300	-152.36	304545.90	4633800.90
M233	1833.6	979823.640	54.950	3.630	-148.10	305362.10	4635389.80
M234	1787.6	979830.850	48.340	2.480	-150.71	309069.70	4634845.00
M235	1851.6	979821.470	57.550	3.660	-147.49	309082.60	4636255.80
M243	1574.2	979838.930	-2.100	0.700	-179.00	298146.80	4626167.10
M244	1541.9	979844.040	-5.630	0.600	-178.99	297218.70	4624537.60
M245	1621.5	979836.280	7.530	1.030	-174.33	298226.20	4628976.30
M246	1742.8	979819.440	25.090	1.940	-169.48	298455.90	4632692.50
M247	1670.5	979823.670	8.450	1.400	-178.55	296446.00	4631004.90
M249	1595.6	979832.540	-3.100	0.880	-182.21	294987.90	4627712.80
M251	1601.6	979852.310	17.430	0.860	-162.39	307285.10	4628759.40
M252	1569.6	979852.790	9.270	0.670	-167.14	307443.90	4627243.90
M253	1544.3	979854.370	4.500	0.540	-169.20	307570.00	4625440.50
M254	1661.1	979842.240	24.020	1.270	-162.05	305471.40	4630864.30
M255	1673.3	979833.100	18.490	1.390	-168.83	303648.90	4631103.10
M256	1624.5	979842.330	14.080	1.020	-168.14	303909.00	4629373.60
M258	1557.8	979853.030	6.530	0.750	-168.46	303081.50	4626507.20
M259	1768.4	979813.350	26.050	2.410	-170.91	297314.20	4633758.30
M260	1693.4	979851.640	25.080	2.020	-163.87	303885.70	4653521.00
M261	1695.5	979847.430	21.490	1.800	-167.91	300292.90	4653665.80
M262	1766.5	979835.780	33.090	2.710	-163.36	301074.30	4651976.90
M263	1747.9	979834.970	26.570	2.600	-167.91	299499.20	4651976.80
M265	1502.9	979878.720	-14.150	0.630	-183.10	311612.20	4662645.20
M266	1443.2	979892.580	-21.710	0.510	-184.07	308305.60	4666445.60
M279	1823.8	979822.430	38.550	3.540	-163.50	299659.40	4650605.40
M280	2055.2	979779.060	68.260	7.430	-155.82	300145.20	4648424.70
M281	1695.8	979836.360	10.310	1.870	-179.06	296093.30	4654041.00
M282	1647.4	979846.640	4.620	1.340	-179.84	294887.50	4655331.60
M291	1515.7	979870.850	-15.510	2.120	-184.41	295063.10	4659960.80
M292	1501.1	979880.310	-10.640	1.630	-178.39	297440.30	4659981.20
M293	1570.3	979866.390	-1.500	1.050	-177.60	298438.90	4657830.10
MB101	1305.1	979902.070	-10.130	0.430	-157.05	380819.20	4609684.30
MB102	1306.0	979902.310	-9.600	0.360	-156.70	379153.20	4609712.20
MB110	1517.5	979858.170	11.530	0.390	-159.30	370197.50	4609812.90
MB111	1505.6	979869.920	19.030	0.900	-149.96	364097.00	4610647.70
MB112	1328.6	979906.640	-4.380	1.400	-152.98	357644.10	4617603.60
MB113	1296.6	979921.340	-1.750	0.410	-147.74	350552.90	4620469.40
MB114	1284.1	979926.170	0.750	0.000	-144.24	345326.90	4618300.40
MK 4	1689.4	979841.490	30.980	1.570	-157.97	306478.00	4632114.70
MK 4	1689.4	979841.000	30.480	1.570	-158.47	306478.00	4632114.70
MK 4	1602.3	979878.600	22.800	0.910	-157.03	316551.20	4654592.80
MK 5	1689.4	979841.060	30.550	1.570	-158.40	306478.00	4632114.70
MK300	1488.0	979859.490	-5.970	0.450	-173.42	307901.10	4623209.30
MK301	1484.0	979863.100	-2.300	0.310	-169.46	308208.10	4621623.20
MK302	1467.2	979866.110	-2.290	0.270	-167.60	307645.50	4618960.50
MK303	1439.5	979873.540	-2.600	0.280	-164.78	309007.90	4617901.80

Table B.3. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
MK304	1431.0	979876.640	-0.630	0.520	-161.61	309582.90	4616030.90
MK305	1418.8	979877.400	-1.940	0.290	-161.79	309943.80	4613932.50
MK306	1454.1	979877.730	9.450	0.370	-154.29	308206.70	4613789.80
MK307	1534.6	979860.340	16.830	0.800	-155.52	306609.30	4613888.30
MK308	1582.7	979847.300	18.480	0.620	-159.45	304949.00	4614122.10
MK309	1607.7	979843.040	21.600	0.760	-159.00	303644.50	4614568.80
MK310	1654.7	979832.260	26.370	0.750	-159.50	302358.80	4613270.70
MK311	1611.4	979838.530	19.970	0.440	-161.35	300736.70	4612482.20
MK312	1589.8	979843.280	18.350	0.380	-160.61	299335.20	4612143.40
MK313	1586.7	979840.740	15.290	0.350	-163.35	297588.20	4611681.30
MK314	1580.9	979839.210	12.680	0.410	-165.26	296038.80	4610847.30
MK319	2505.9	979686.960	115.140	12.760	-153.98	303724.50	4648291.50
MK320	2675.7	979652.150	133.910	13.160	-153.74	302131.40	4646780.00
MK321	2765.3	979633.070	143.760	12.330	-154.72	300486.30	4645214.70
MK322	2729.4	979640.090	141.050	10.340	-155.41	298847.30	4643594.00
MK323	3025.0	979569.850	163.170	22.310	-154.23	301955.40	4641951.00
MK324	2957.3	979583.790	156.310	19.460	-156.42	305271.80	4641803.80
MK325	2852.5	979609.480	149.680	17.870	-152.96	306806.40	4641762.00
MK326	2893.3	979599.720	151.830	23.450	-149.78	308711.70	4642543.90
MK327	2937.5	979591.460	157.860	17.870	-154.25	299590.10	4641972.80
MK328	2904.9	979593.530	150.270	18.990	-157.09	297784.80	4641546.10
MK329	2816.2	979608.430	138.340	15.950	-162.18	296489.20	4640949.60
MK341	1870.2	979825.340	58.430	3.110	-149.25	314551.90	4646889.20
MK342	1809.5	979833.720	47.190	2.880	-153.92	311871.30	4648082.00
MK343	1944.2	979804.800	61.110	4.810	-153.16	311430.70	4646482.50
MK353	1792.1	979827.430	33.520	3.380	-165.14	299510.80	4650920.80
MK354	2154.8	979750.700	72.560	5.930	-164.16	295062.40	4646180.40
MK357	1692.5	979847.560	20.690	1.850	-168.33	301162.40	4653641.30
MK358	1597.7	979874.190	18.130	1.750	-160.35	308340.80	4653387.90
MK359	1610.5	979875.350	23.240	1.190	-157.23	311545.60	4653302.00
MK360	1588.8	979882.170	23.390	0.960	-154.88	314949.20	4653212.30
MK361	1608.0	979875.880	23.020	0.930	-157.44	317342.50	4653150.20
MK362	1655.9	979867.280	30.450	1.430	-154.88	311926.10	4651714.00
MK363	1704.4	979857.630	37.050	1.900	-153.25	311916.60	4650103.10
MK364	1767.4	979844.840	44.710	2.420	-152.14	311842.10	4648860.60
MK365	1804.3	979834.460	46.420	4.010	-152.98	310600.30	4648004.70
MK366	1881.1	979814.860	51.190	5.120	-155.70	309400.90	4647192.30
MK367	1889.4	979811.920	50.610	6.920	-155.40	308138.70	4647448.50
MK368	1979.6	979791.480	58.440	9.030	-155.57	306606.20	4646912.30
MK369	2083.8	979767.460	66.820	11.360	-156.52	305155.40	4646640.80
MK370	1687.6	979861.600	34.790	2.270	-153.26	309101.80	4651489.50
MK371	1791.5	979838.760	45.110	3.350	-153.52	308650.20	4650112.70
MK372	1691.6	979837.920	28.100	1.610	-161.05	305505.30	4632107.90
MK373	1746.7	979836.340	42.240	2.180	-152.53	305548.60	4633695.70
MK374	1744.9	979836.770	42.100	2.130	-152.51	306628.10	4633666.30
MK376	1762.3	979832.990	43.630	2.290	-152.77	304553.60	4633778.40
MK377	1829.9	979820.100	50.510	3.360	-152.41	303818.60	4635154.30
MK378	1902.8	979803.740	55.830	5.270	-153.34	302890.50	4636146.70
MK379	1725.4	979828.600	28.640	1.940	-163.98	303771.90	4632855.40
MK380	1766.2	979818.730	30.560	2.700	-165.88	300543.80	4633933.90
MK381	1836.9	979811.180	43.900	3.650	-159.51	301098.30	4635040.80
MK382	1962.8	979786.120	56.600	6.470	-158.09	301383.60	4636333.00
MK383	2062.5	979767.050	67.880	6.900	-157.54	302143.70	4636778.50
MK384	1744.0	979815.810	21.580	2.070	-172.99	297443.20	4633032.30
MK385	1805.5	979810.970	34.430	3.060	-166.05	296990.40	4634645.40
MK386	1904.3	979795.050	47.850	5.170	-161.59	295468.50	4636055.80
MK388	1698.3	979819.900	12.240	1.790	-177.48	295841.30	4632244.60
MK390	1809.8	979809.930	34.800	2.970	-166.25	295783.20	4634568.80
MK395	1673.9	979832.780	18.360	1.390	-169.03	303665.50	4631102.60
MK396	1632.4	979840.330	14.230	1.080	-168.82	303810.70	4629731.90
MK397	1661.7	979839.070	21.030	1.290	-165.09	304990.10	4630899.60
MK398	1711.7	979822.840	20.200	1.530	-171.29	298494.20	4631102.30
MK399	1635.5	979835.210	10.330	1.120	-173.02	298566.60	4629544.50
MK400	1608.4	979837.190	5.180	0.960	-175.28	298232.20	4628009.30

Table B.3. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
MK401	1581.2	979838.870	-0.200	0.750	-177.83	298195.00	4626399.10
MK402	1551.4	979842.640	-4.490	0.640	-178.87	297564.50	4624994.50
MK403	1681.2	979828.810	16.850	1.450	-171.29	299230.40	4630970.40
MK404	1632.4	979834.360	8.650	1.100	-174.37	299642.50	4629358.70
MK405	1604.4	979836.980	3.620	0.910	-176.45	300239.80	4628119.60
MK406	1571.5	979841.590	-0.840	0.740	-177.38	300718.00	4626772.80
MK407	1459.9	979870.640	0.280	0.280	-164.20	307294.20	4618592.10
MK408	1470.3	979866.860	-1.240	0.300	-166.86	306351.70	4619773.20
MK409	1495.9	979864.030	3.530	0.570	-164.69	304930.60	4620178.40
MK410	1487.4	979860.360	-3.370	0.370	-170.84	303744.50	4620955.30
MK411	1520.9	979852.490	-1.950	0.820	-172.73	303322.40	4622255.90
MK446	1656.2	979851.030	30.260	1.300	-155.24	311400.20	4631778.90
MK463	1437.4	979876.710	3.930	0.510	-157.78	310732.90	4612889.40
MK464	1433.7	979878.280	5.160	0.300	-156.36	311957.20	4611901.70
MK465	1430.4	979878.490	5.400	0.470	-155.56	312788.70	4610546.70
MK466	1629.1	979836.350	24.910	0.700	-158.14	299096.70	4610472.20
MK467	1634.9	979832.260	23.260	0.610	-160.53	300306.90	4609616.10
MK527	1478.8	979874.510	13.520	0.340	-153.02	312821.90	4614056.80
MK528	1550.1	979864.770	24.510	0.640	-149.74	314319.90	4615595.60
MK529	1539.8	979868.330	24.160	0.510	-149.05	315549.30	4616430.50
MK530	1484.3	979879.750	19.600	0.390	-147.50	316471.10	4615018.00
MK538	1740.6	979835.400	39.380	1.900	-154.98	309029.30	4633646.00
MK539	1801.9	979827.850	49.420	2.760	-150.95	309072.40	4635256.10
MK540	1842.4	979821.360	54.830	3.380	-149.46	308477.70	4636005.40
MK541	1916.2	979806.990	62.570	4.830	-148.54	307120.70	4636819.80
MK542	2009.4	979783.420	66.960	6.680	-152.74	306342.40	4637829.90
MK543	1827.5	979824.090	53.440	3.400	-149.16	306569.00	4635468.00
MK544	1783.0	979830.260	46.660	2.770	-151.58	305446.70	4634531.80
MK545	1860.7	979815.170	54.580	3.910	-151.24	304806.70	4635738.30
MK546	1908.9	979804.060	57.830	5.620	-151.68	304375.20	4636361.30
ml0052	1585.8	979901.820	28.250	1.490	-149.16	383128.00	4668841.60
ml0067	1345.3	979928.750	-17.130	0.630	-168.38	393303.90	4666403.50

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
ml0085	1372.1	979915.250	-25.550	0.560	-179.89	393751.70	4670339.40
ml0137	1532.2	979900.880	25.050	3.980	-143.84	392608.40	4651065.80
ml0153	1621.5	979899.880	32.020	1.530	-149.34	384597.90	4675337.00
S109	1286.5	979926.560	1.590	0.820	-142.85	346319.60	4619037.30
S11	1352.6	979904.390	4.090	3.190	-145.42	318913.20	4614400.40
S110	1285.9	979924.990	-0.640	0.400	-145.44	347696.80	4619607.70
S111	1285.9	979924.030	-1.700	0.140	-146.75	349288.10	4619685.10
S112	1286.2	979921.580	-4.160	0.100	-149.29	350222.40	4619787.70
S113	1284.1	979918.680	-7.790	0.030	-152.75	351788.40	4619855.00
S114	1284.7	979922.060	-4.140	0.000	-149.20	352951.00	4619731.10
S115	1284.4	979908.460	-17.330	-0.020	-162.38	354136.30	4619084.80
S116	1284.7	979909.870	-14.770	-0.010	-159.84	355632.20	4617732.70
S117	1286.8	979916.210	-6.720	0.060	-151.96	356671.50	4616423.40
S118	1307.2	979912.100	-3.550	0.410	-150.74	357388.20	4615198.40
S119	1326.7	979907.730	-0.640	1.080	-149.35	357565.20	4613628.80
S12	1374.9	979898.400	6.230	0.590	-148.38	317141.40	4612878.80
S120	1346.8	979903.210	2.400	0.770	-148.88	357390.60	4611966.20
S121	1364.5	979900.350	6.190	0.810	-147.04	357361.00	4610478.40
S122	1386.5	979896.250	10.130	0.780	-145.60	357854.80	4608902.50
S13	1427.0	979887.500	10.810	0.390	-149.86	315877.70	4613644.40
S135	1368.2	979895.680	2.490	1.100	-150.85	376247.30	4610316.90
S136	1487.4	979870.390	14.110	0.620	-153.11	374369.90	4610160.70
S137	1481.9	979860.270	2.370	0.280	-164.58	372144.30	4610111.20
S138	1486.1	979859.140	3.230	0.350	-164.12	371504.70	4609289.60
S139	1308.1	979902.510	-9.080	0.430	-156.35	380476.10	4610100.90
S14	1425.8	979886.710	10.840	0.200	-149.88	315040.20	4612188.30
S140	1301.4	979904.220	-8.810	0.360	-155.39	381437.80	4609307.60
S141	1297.5	979899.280	-14.590	0.360	-160.73	382746.40	4608819.70
S15	1435.5	979881.800	9.910	0.270	-151.84	315142.60	4610985.70
S153	1665.7	979848.030	30.190	1.310	-156.36	310977.80	4631769.60
S154	1688.8	979840.710	30.070	1.520	-158.86	306891.50	4632036.90
S156	1720.2	979821.740	20.780	1.790	-171.40	298236.40	4632276.40

Table B.3. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
S157	1632.4	979827.730	1.920	1.120	-181.09	295533.00	4629608.50
S16	1421.2	979882.850	8.040	0.160	-152.21	314819.90	4609138.50
S167	1561.4	979865.160	7.990	0.390	-167.78	369309.30	4639561.40
S168	1487.0	979876.810	-0.660	0.260	-168.21	367490.30	4636351.80
S169	1466.9	979880.270	-3.290	0.640	-168.19	364242.60	4636268.60
S170	1444.4	979882.600	-4.880	0.420	-167.48	364237.70	4632525.60
S171	1306.9	979920.320	-3.010	0.320	-150.25	360825.20	4624505.30
S172	1318.2	979917.730	-2.950	0.430	-151.35	361127.40	4625510.20
S173	1474.9	979877.530	4.620	0.940	-160.88	367232.90	4626082.80
S174	1582.4	979853.390	13.300	2.040	-163.17	369667.50	4626460.00
S175	1564.8	979853.740	11.480	1.950	-163.10	368870.10	4622420.70
S176	1560.2	979841.750	5.470	0.420	-170.13	370260.10	4613276.90
S177	1580.6	979845.580	13.020	0.750	-164.54	368786.30	4616480.20
S187	1606.8	979875.990	23.430	0.930	-156.90	318074.70	4652298.00
S188	1614.4	979868.260	18.570	0.910	-162.63	318886.20	4651621.70
S192	1596.5	979881.140	24.660	1.020	-154.41	314371.00	4653282.90
S193	1608.7	979874.240	21.550	1.250	-158.65	310991.10	4653327.90
S194	1623.0	979866.710	18.490	1.880	-162.69	307817.50	4653346.50
S195	1693.7	979850.560	24.180	2.060	-164.76	304429.20	4653394.80
S196	1762.9	979830.730	27.030	2.730	-169.00	300589.50	4651834.90
S197	1427.6	979877.130	0.550	0.250	-160.33	309801.40	4613902.90
S198	1459.9	979870.450	0.040	0.280	-164.43	307362.20	4618645.90
S200	1513.0	979856.040	-1.610	0.480	-171.84	307756.10	4623079.80
S201	1608.0	979838.440	18.950	0.590	-161.85	301291.10	4612333.50
S202	1586.1	979837.740	12.670	0.430	-165.82	296735.00	4610994.20
S205	1580.9	979845.990	16.600	0.600	-161.15	305157.80	4614138.60
S226	1530.0	979870.130	1.830	7.170	-163.63	393434.10	4640947.20
S228	1776.9	979833.510	33.610	1.250	-165.47	387158.50	4650584.00
S229	1630.0	979863.160	19.430	4.650	-159.77	389200.60	4648730.40
SI10	1415.1	979890.100	-6.900	0.380	-166.24	380398.70	4632847.10
SI100	1311.5	979896.560	-19.500	1.210	-166.36	391823.50	4616728.50
SI101	1311.5	979893.030	-23.030	11.570	-159.53	390225.70	4616752.80
SI103	1313.0	979886.520	-29.220	20.720	-156.75	386975.00	4616992.10
SI104	1313.9	979880.340	-35.120	19.940	-163.53	385310.80	4617018.50
SI106	1304.2	979881.770	-34.070	21.800	-159.53	388489.00	4613725.60
SI107	1302.0	979891.280	-25.220	1.360	-170.88	391777.40	4613675.30
SI110	1299.9	979901.750	-12.040	0.230	-158.59	393313.90	4609487.90
SI115	1539.8	979850.170	8.880	0.400	-164.45	370048.00	4611681.50
SI116	1550.7	979840.230	0.970	0.380	-173.60	371643.50	4613318.70
SI117	1489.8	979850.320	-7.730	0.680	-175.16	373100.50	4613292.80
SI118	1599.5	979841.030	15.610	2.190	-162.63	368756.60	4614859.20
SI119	1582.7	979848.250	15.980	1.600	-160.98	368453.60	4616952.80
SI120	1624.8	979842.840	22.170	2.520	-158.58	368692.60	4618636.60
SI121	1604.1	979851.010	24.910	4.640	-151.40	366657.10	4617485.80
SI122	1484.0	979874.240	10.660	1.400	-155.40	365901.90	4618055.20
SI123	1432.2	979883.070	3.260	1.870	-156.52	364177.20	4618398.70
SI124	1487.7	979871.960	12.110	0.980	-154.78	364176.80	4614866.70
SI125	1560.5	979860.990	24.900	1.680	-149.48	364080.20	4613280.30
SI126	1600.7	979850.640	29.090	2.070	-149.41	365420.90	4610600.50
SI127	1577.6	979854.210	25.450	0.790	-151.73	368263.00	4610647.80
SI128	1483.1	979872.860	14.150	0.440	-152.77	362660.00	4611752.40
SI129	1498.9	979870.360	15.400	0.570	-153.17	361995.60	4613164.60
SI130	1408.7	979890.170	5.850	0.280	-152.88	360925.30	4615095.70
SI131	1356.6	979896.530	-3.550	3.000	-153.70	359943.80	4614726.00
SI132	1331.0	979905.930	-4.810	0.860	-154.22	358554.20	4618163.20
SI133	1292.3	979909.280	-13.840	0.100	-159.66	357874.60	4618732.00
SI134	1290.5	979906.990	-17.650	0.070	-163.29	356367.40	4619939.40
SI135	1287.7	979911.700	-14.160	0.030	-159.54	354754.70	4620438.50
SI136	1288.0	979915.490	-10.340	0.040	-155.73	353791.40	4620535.90
SI137	1288.0	979920.390	-5.400	0.050	-150.78	352842.00	4620499.80
SI138	1605.9	979845.660	25.660	0.750	-154.74	367012.80	4610626.40
SI15	1392.3	979888.720	-8.730	1.000	-164.88	393877.60	4624471.40
SI17	1600.4	979852.460	14.710	1.940	-163.88	387041.20	4630128.90
SI18	1490.7	979875.940	4.430	0.700	-163.08	383443.30	4630097.90

Table B.3. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
SI19	1505.6	979873.270	-1.130	0.240	-170.78	375614.40	4639481.70
SI20	1531.2	979865.580	-3.560	0.260	-176.07	375696.10	4642734.50
SI21	1533.4	979872.460	1.280	0.360	-171.37	377411.90	4646036.60
SI22	1559.0	979872.960	7.140	0.400	-168.34	374707.40	4649215.90
SI23	1434.9	979886.550	-5.830	0.390	-167.39	380470.90	4634678.40
SI24	1471.5	979882.440	-1.140	0.460	-166.74	380480.60	4637732.40
SI25	1532.8	979871.270	3.890	0.520	-168.52	380619.50	4641061.90
SI26	1563.5	979869.900	9.240	0.550	-166.61	380635.50	4644482.40
SI27	1556.2	979873.110	7.330	0.620	-167.63	380695.00	4648024.30
SI28	1507.8	979879.830	-3.130	1.000	-172.27	380741.30	4650777.90
SI28	1507.8	979879.830	-3.130	1.000	-172.27	380741.30	4650777.90
SI29	1527.0	979867.830	6.410	2.070	-163.80	391836.20	4631309.50
SI3	1552.0	979864.600	3.340	0.310	-171.45	368063.70	4640638.00
SI30	1558.1	979862.350	7.950	2.630	-165.20	390846.90	4634511.90
SI31	1627.6	979855.100	20.320	2.940	-160.32	392192.00	4636712.50
SI36	1317.0	979894.420	-21.220	0.450	-169.46	393369.70	4618282.20
SI37	1419.1	979878.220	-5.790	1.660	-164.29	390180.40	4618141.60
SI38	1502.6	979859.600	1.960	1.510	-166.08	385068.30	4617466.60
SI39	1427.0	979880.540	-1.370	0.710	-161.71	382142.10	4618691.40
SI4	1595.6	979861.560	14.850	0.460	-164.68	372670.50	4639589.30
SI40	1357.5	979893.480	-10.100	0.550	-162.80	380067.30	4619025.70
SI41	1328.9	979901.790	-6.740	2.650	-154.12	378255.40	4614258.50
SI42	1324.9	979902.440	-5.070	0.510	-154.14	378832.90	4611472.30
SI43	1302.0	979902.960	-11.940	0.360	-158.59	391606.00	4611701.10
SI44	1314.2	979900.200	-13.710	1.280	-160.82	391732.60	4615119.60
SI5	1478.8	979876.190	-5.430	0.260	-172.05	376520.90	4638166.50
SI6	1433.4	979881.690	-12.210	0.430	-173.56	378376.40	4636013.20
SI65	1471.8	979876.300	-5.680	0.360	-171.42	366033.40	4636134.70
SI67	1493.1	979877.140	0.470	0.600	-167.42	364478.20	4637741.40
SI68	1465.7	979878.560	-4.020	0.320	-169.11	367697.40	4634537.50
SI69	1471.8	979878.060	-2.640	0.730	-168.01	369258.00	4634508.70
SI7	1422.1	979889.240	-4.990	0.430	-165.07	380676.60	4632087.20
SI70	1471.5	979878.980	-0.470	0.450	-166.08	367666.50	4632872.10
SI71	1542.2	979864.010	6.360	1.650	-165.99	369850.20	4632831.90
SI72	1494.1	979873.740	-2.880	0.290	-171.18	375543.80	4637817.00
SI72	1494.1	979873.740	-2.880	0.290	-171.18	375543.80	4637817.00
SI73	1533.1	979871.200	6.610	0.580	-165.78	373817.90	4637847.40
SI74	1555.9	979865.340	9.230	0.750	-165.56	373786.80	4636093.10
SI75	1465.4	979870.900	-10.590	0.640	-175.32	376429.50	4632892.50
SI76	1540.4	979856.460	-1.900	0.830	-174.87	375042.90	4632916.70
SI77	1415.4	979889.080	-7.820	0.340	-167.24	378820.70	4632851.50
SI78	1372.4	979882.560	-22.270	0.430	-176.77	378601.20	4626291.50
SI79	1412.1	979869.620	-23.000	0.740	-181.64	377072.10	4626317.70
SI8	1468.5	979879.320	0.730	0.470	-164.52	382409.60	4630392.50
SI80	1490.7	979856.900	-11.460	1.840	-177.84	375343.50	4626347.60
SI80	1490.7	979856.900	-11.460	1.840	-177.84	375343.50	4626347.60
SI81	1392.0	979889.240	-3.650	1.150	-159.62	376463.80	4619009.20
SI82	1479.1	979856.880	-6.890	1.000	-172.80	373153.50	4616290.50
SI83	1362.7	979889.910	-13.890	0.460	-167.26	377892.60	4621305.90
SI84	1465.1	979873.710	1.500	2.940	-160.90	374524.50	4621364.10
SI85	1563.2	979852.610	11.260	2.500	-162.60	373164.00	4620644.00
SI86	1744.6	979822.890	37.090	3.440	-156.18	371093.10	4621147.40
SI87	1385.6	979888.560	-5.260	0.380	-161.28	364168.50	4617943.50
SI88	1335.3	979895.830	-16.650	0.610	-166.79	393556.60	4621333.40
SI89	1357.8	979894.060	-11.460	1.790	-162.95	391893.40	4621358.30
SI9	1385.6	979882.760	-19.500	0.430	-175.47	378632.00	4628101.30
SI90	1433.4	979875.850	-7.560	2.650	-166.68	390294.40	4622859.60
SI91	1375.8	979887.830	-13.570	1.100	-167.78	391853.40	4623113.50
SI92	1354.5	979892.350	-15.700	0.790	-167.81	393517.50	4623177.40
SI98	1310.9	979891.910	-24.340	0.390	-171.96	393695.80	4616700.50
SI99	1311.8	979896.420	-19.540	0.910	-166.74	392031.50	4616725.30
SL140	1280.1	979920.010	-1.540	-0.080	-146.17	327764.00	4612793.80
SL141	1280.1	979921.390	-0.280	-0.110	-144.93	329541.50	4612906.90
SL142	1280.1	979919.370	-2.370	-0.130	-147.04	330958.80	4612940.00

Table B.3. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
SL143	1280.1	979915.750	-5.950	-0.140	-150.64	332456.90	4612871.50
SL144	1280.1	979917.270	-2.970	-0.120	-147.64	329499.60	4611141.50
SL145	1280.1	979916.400	-3.650	-0.110	-148.31	328344.50	4610935.70
SL146	1280.1	979912.610	-6.250	-0.110	-150.90	328375.60	4609446.30
SL148	1280.1	979922.560	0.560	-0.080	-144.06	328052.10	4613342.30
SL149	1280.1	979923.790	-0.230	-0.090	-144.87	327970.50	4615843.90
SL153	1280.1	979918.550	-4.230	-0.150	-148.93	332446.40	4614204.90
SL94	1280.1	979923.130	-2.300	-0.110	-146.95	345979.90	4617178.40
SL95	1280.4	979917.430	-8.590	-0.070	-153.24	348769.30	4617974.30
SL97	1280.1	979920.400	-4.300	-0.150	-148.99	346235.00	4616262.10
H42	1658.0	979887.980	7.410	0.670	-161.25	357094.98	4669571.54
H43	1679.7	979886.620	7.670	0.860	-157.90	358436.41	4669155.69
BS-1	1515.1	979920.010	1.300	0.630	-161.86	366847.38	4676915.17
C1	1669.0	979899.810	-9.880	3.280	-161.94	363335.21	4690830.49
C2	1655.9	979901.720	-9.750	1.740	-164.02	364277.99	4690589.99
C3	1636.1	979899.410	-9.750	1.060	-170.90	365459.16	4690604.22
C4	1712.9	979892.440	-9.490	3.000	-160.56	362255.13	4690370.31
C5	1668.1	979880.930	-8.450	3.240	-163.42	361534.93	4690754.78
C6	1831.1	979863.840	-7.020	2.000	-164.43	361136.91	4687300.61
C7	1668.7	979887.400	-7.150	0.820	-169.49	365548.71	4687399.72
C8	1644.6	979891.040	-7.150	0.730	-171.15	366111.75	4687388.94
C9	1865.3	979857.250	-5.720	1.310	-163.69	361051.91	4685784.17
C10	1810.7	979867.590	-4.550	1.420	-162.81	361268.04	4684206.24
C11	1632.4	979895.040	-4.290	0.890	-166.77	364850.34	4683951.19
C12	1597.1	979901.000	-4.290	0.760	-168.59	365619.74	4683936.41
C13	1752.5	979875.550	-4.290	1.170	-166.29	358558.49	4684112.23
C14	1709.8	979883.030	-3.640	0.720	-167.00	357141.64	4683381.87

Notes

[1]Easting and northing in meters based on Universal Transverse Mercator Zone 12N projection, 1927 datum, used in GIS applications.

Table B.4. *Gravity data from Hatfield (1983) used in this study.*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
C15	1744.9	979872.840	-3.640	0.950	-170.07	357965.33	4683328.12
C16	1722.0	979879.870	-3.640	0.920	-167.57	358693.59	4683313.42
C17	1668.4	979887.460	-2.990	0.540	-170.26	355708.84	4682559.53
C19	1693.7	979885.640	-2.990	0.630	-167.01	357124.31	4682530.58
C20	1694.0	979883.730	-2.990	0.810	-168.68	358732.17	4682498.03
C21	1741.8	979877.990	-3.380	1.510	-164.70	360580.63	4682812.83
C22	1699.5	979885.910	-2.210	1.000	-164.45	360116.93	4681618.68
C23	1652.5	979893.860	-2.080	0.480	-166.13	357100.20	4681346.17
C24	1678.8	979888.370	-1.690	1.030	-165.52	360514.18	4680851.72
C25	1721.4	979877.580	-1.430	1.070	-167.61	361348.64	4680631.55
C26	1719.3	979878.250	-1.690	0.130	-167.56	362356.08	4680815.38
C27	1650.4	979893.940	-1.430	0.980	-165.32	363105.60	4680467.49
C28	1614.1	979900.220	-1.430	0.840	-166.31	363807.37	4680490.87
C29	1576.7	979905.360	-1.300	0.710	-168.55	364545.02	4680235.94
C30	1560.5	979907.310	-1.040	0.700	-169.53	365254.16	4679926.09
C31	1658.9	979891.190	-1.300	0.840	-166.40	360092.97	4680415.77
C32	1715.3	979879.350	-0.840	1.210	-166.31	362801.75	4679695.86
C33	1619.9	979897.940	-1.040	0.440	-167.46	356278.01	4680141.03
C34	1639.7	979897.330	-1.040	0.410	-164.21	357075.35	4680124.76
C35	1681.8	979883.860	-1.040	0.830	-168.98	357776.45	4680110.53
C36	1669.6	979888.540	-1.040	0.540	-166.99	358683.76	4680092.22
C37	1665.7	979888.570	-1.300	0.530	-168.01	359088.01	4679676.80
C38	1633.0	979894.030	-0.390	0.900	-167.68	359904.40	4679234.66
B1	1670.2	979901.020	-11.050	0.730	-164.81	367179.44	4692256.07
B2	1657.4	979909.130	-11.050	0.670	-158.68	367919.08	4692168.02
B3	1637.9	979911.850	-11.050	0.710	-159.76	368715.02	4692153.04
B4	1614.8	979909.970	-11.050	0.630	-162.68	369716.80	4692134.32
B5	1606.5	979908.980	-11.050	0.640	-165.44	370348.40	4692141.10
B6	1597.7	979908.240	-11.050	0.910	-167.83	371185.50	4692125.64
B7	1621.5	979904.570	-11.050	1.390	-169.59	371940.26	4692111.79
B8	1644.3	979902.290	-10.400	0.630	-163.31	367904.06	4691372.24
B9	1602.6	979906.300	-10.400	0.640	-168.33	384057.84	4691086.04
B10	1631.2	979902.380	-10.400	1.300	-169.30	371925.36	4691297.51
B11	1632.1	979899.260	-9.750	0.800	-172.09	366269.01	4690588.71
B12	1627.2	979899.540	-9.750	0.670	-169.07	367078.85	4690573.28
B14	1622.7	979901.900	-9.750	0.640	-167.73	368684.82	4690542.98
B15	1611.1	979903.980	-9.750	0.590	-168.20	369508.39	4690527.58
B16	1603.2	979904.630	-9.750	0.650	-169.21	370318.23	4690512.54
B17	1642.8	979900.500	-9.750	1.040	-168.52	371910.47	4690483.23
B18	1615.7	979901.070	-9.100	0.570	-169.50	367873.33	4689743.68
B19	1600.1	979906.310	-9.100	0.690	-167.50	370303.15	4689698.26
B20	1616.9	979906.450	-8.770	0.810	-163.28	371120.01	4689312.92
B21	1649.8	979904.240	-9.100	0.920	-162.87	371895.91	4689687.45
B22	1692.8	979893.980	-9.230	1.780	-163.95	372887.33	4689836.00
B23	1755.6	979885.850	-9.230	2.370	-159.13	373656.73	4689859.10
B24	1821.1	979871.900	-9.100	1.590	-160.84	374531.96	4689658.24
B25	1601.6	979903.910	-8.450	0.620	-168.99	367858.67	4688966.41
B26	1600.1	979905.350	-8.450	0.570	-167.93	368654.97	4688951.43
B27	1598.6	979908.240	-8.450	0.590	-165.35	369108.04	4688942.95
B28	1598.0	979910.100	-8.450	0.780	-163.43	370288.76	4688920.99
B29	1595.9	979906.750	-7.800	0.610	-166.76	367842.61	4688115.12
B30	1606.5	979900.240	-7.150	0.700	-170.22	366743.44	4687376.90
B31	1596.5	979904.970	-7.150	0.640	-167.73	367374.08	4687309.40
B32	1592.8	979907.820	-7.150	0.640	-165.67	367828.30	4687356.36
B33	1614.4	979908.850	-7.150	1.010	-163.17	370245.22	4687311.19
B34	1642.8	979903.790	-6.890	1.210	-162.20	371778.51	4687023.80
B35	1566.0	979908.970	-6.240	0.840	-169.22	367726.35	4686321.56
B36	1563.5	979913.480	-6.500	1.070	-165.27	368469.75	4686400.14
B37	1681.8	979894.810	-5.850	1.530	-162.14	372082.10	4685592.80
B38	1583.4	979903.080	-5.720	0.710	-170.96	366887.18	4685541.38
B39	1556.5	979908.790	-5.330	0.930	-170.44	367333.47	4685162.67
B40	1574.2	979908.620	-4.810	1.020	-168.97	368254.36	4684441.82

Table B.4. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
B41	1615.7	979902.430	-4.550	1.080	-166.64	368911.03	4684281.42
B42	1658.0	979899.780	-4.420	1.580	-160.37	369717.13	4684025.74
B43	1747.9	979883.700	-4.810	1.330	-159.40	371180.59	4684387.48
B44	1578.8	979904.530	-4.290	0.710	-169.07	366361.66	4683922.24
B45	1545.9	979912.290	-4.290	1.120	-168.02	367199.75	4683906.32
B46	1549.2	979913.110	-3.250	1.320	-165.24	367812.09	4683580.04
B47	1595.2	979908.130	-3.900	1.470	-163.96	368810.95	4683339.14
B48	1536.7	979915.150	-3.570	1.230	-166.31	367033.89	4683131.92
B49	1532.5	979916.660	-3.120	1.210	-165.29	366872.56	4682598.11
B50	1767.8	979881.110	-3.250	2.530	-155.33	370443.73	4682438.72
B51	1530.6	979915.800	-2.600	1.010	-166.23	366639.34	4681899.05
B52	1518.4	979915.600	-2.010	0.980	-168.51	366349.68	4681127.01
B53	1518.4	979917.130	-1.430	0.870	-166.62	366198.13	4680389.39
B54	1645.8	979904.640	-1.170	2.910	-153.33	369066.25	4680076.16
B55	1768.4	979881.880	-1.040	1.790	-152.97	370918.65	4679856.75
B56	1837.9	979867.880	-1.430	2.260	-153.22	371683.86	4680342.57
B57	1509.6	979918.470	-0.780	0.850	-166.45	366127.63	4679576.16
B58	1505.6	979918.580	-0.320	0.820	-166.77	366264.77	4678833.04
B59	1603.8	979908.630	-0.130	2.030	-157.45	368916.29	4678672.01
S1	1500.8	979919.950	0.390	0.800	-165.76	366484.44	4678088.35
S2	1502.0	979923.170	1.490	0.680	-162.67	366457.38	4676663.39
S3	1559.3	979911.370	1.170	0.840	-160.86	368362.63	4677016.23
S4	1595.9	979906.630	1.170	1.010	-157.38	369160.28	4677001.34
S5	1634.6	979902.760	1.300	2.540	-155.32	371000.09	4676800.73
S6	1718.1	979887.330	1.040	3.150	-153.97	372436.11	4677089.24
S7	1816.2	979864.050	1.560	3.530	-157.05	373403.53	4676571.93
S8	1524.8	979915.770	1.820	0.570	-163.57	367192.38	4676242.19
S9	1563.9	979907.090	1.820	0.760	-163.58	368333.63	4676202.22
S10	1578.5	979903.890	2.140	0.790	-163.26	368931.92	4675820.79
S11	1590.4	979902.580	2.140	0.960	-161.83	369523.39	4675809.80
S12	1548.3	979907.090	2.470	0.640	-166.41	367523.69	4675569.49
S13	1583.1	979901.360	2.730	0.940	-164.06	369526.50	4675235.86
S14	1550.4	979905.560	2.860	0.610	-167.12	368036.68	4675041.50
S15	1573.0	979900.260	3.120	0.900	-166.99	369501.08	4674606.91
S16	1541.0	979904.550	3.510	0.630	-169.51	368612.66	4674197.66
S17	1534.9	979903.330	3.900	0.760	-171.53	369042.59	4673634.27
S18	1535.5	979904.890	4.420	0.870	-169.20	369457.46	4672997.15
S19	1505.9	979911.150	4.740	0.630	-169.26	368252.34	4672593.81
S20	1516.6	979907.400	4.740	0.620	-170.71	368665.18	4672586.10
S21	1553.8	979900.090	4.740	1.260	-169.34	370316.54	4672555.49
S22	1579.4	979899.240	4.480	2.300	-166.76	371092.59	4672837.44
S23	1623.0	979895.690	4.420	3.250	-160.84	372636.14	4672938.93
S24	1676.3	979887.710	3.900	5.230	-156.87	374010.35	4673580.63
S25	1755.0	979874.430	3.250	4.030	-156.53	375484.20	4674424.45
S26	1488.6	979917.450	5.070	0.530	-165.49	366607.37	4672236.02
S27	1502.0	979915.050	5.070	0.510	-166.01	367460.97	4672238.42
S28	1496.5	979914.530	5.720	0.400	-167.18	366248.91	4671483.80
S29	1526.1	979902.950	5.460	0.760	-172.26	369434.82	4671775.76
S30	1514.5	979905.320	6.110	0.810	-171.70	369420.41	4670998.51
S31	1471.2	979912.770	7.470	0.450	-169.64	366581.64	4669422.61
S32	1471.5	979914.300	7.470	0.620	-170.85	367380.51	4669426.04
S33	1480.6	979911.370	7.340	0.790	-171.76	368223.10	4669558.34
S34	1484.9	979911.040	6.890	0.840	-171.56	368643.36	4669939.25
S35	1512.6	979908.440	7.210	1.660	-167.02	370153.58	4669689.12
S36	1533.7	979908.190	7.540	2.420	-163.62	370805.92	4669214.33
S37	1546.8	979906.140	7.800	2.900	-162.35	371544.66	4668941.66
S38	1548.9	979906.070	7.990	2.450	-162.26	372380.17	4668685.83
S39	1559.9	979904.930	8.190	1.770	-161.73	373133.79	4668468.60
S40	1567.8	979901.450	8.120	1.290	-164.20	374098.63	4668506.84
S41	1577.0	979901.880	7.800	1.460	-162.12	374766.44	4668883.69
S42	1596.5	979898.350	7.540	1.870	-161.66	375844.94	4669123.77
S43	1582.4	979900.290	8.840	0.940	-162.11	374083.09	4667637.07
S44	1627.2	979889.930	9.490	0.600	-163.34	374690.29	4666922.81
S45	1606.5	979896.610	10.010	0.630	-160.19	374759.45	4666162.61

Table B.4. *(continued)*

Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
S46	1569.6	979900.600	10.790	0.670	-162.64	375418.35	4665243.89
S47	1460.5	979913.470	8.190	0.530	-173.42	366580.35	4668626.59
S48	1457.5	979913.540	8.840	0.580	-173.31	366551.17	4667812.60
S49	1460.5	979913.050	9.490	0.960	-172.11	367017.44	4666970.74
S50	1502.6	979909.260	9.620	1.080	-167.93	367621.69	4666866.81
S51	1456.3	979909.830	10.140	0.810	-175.76	366534.83	4666220.84
S52	1456.3	979909.190	10.790	0.930	-175.63	366519.43	4665406.59
H1	1612.6	979893.410	0.780	0.580	-171.47	359805.76	4677737.03
H2	1634.6	979891.760	0.910	0.650	-168.60	403107.46	4676877.35
H3	1527.3	979913.010	0.520	0.550	-168.95	365160.47	4677909.98
H4	1535.5	979912.310	0.780	0.510	-167.81	365138.91	4677503.11
H5	1508.7	979920.910	0.910	0.590	-164.28	365920.65	4677377.08
H6	1602.6	979894.930	1.170	0.610	-171.51	360387.15	4677225.60
H7	1609.3	979895.060	1.170	0.650	-170.02	361074.42	4677193.47
H8	1527.6	979914.200	1.170	0.560	-167.04	364829.25	4677138.80
H9	1578.8	979902.030	1.040	0.590	-169.24	359883.21	4676791.30
H10	1545.3	979912.450	1.430	0.460	-165.15	365068.99	4676726.91
H11	1581.2	979902.170	1.820	0.420	-168.01	361938.24	4676343.37
H12	1538.3	979917.650	2.210	0.460	-170.55	359798.95	4676015.42
H13	1541.0	979906.630	2.210	0.460	-171.03	360418.29	4676021.61
H14	1554.4	979907.130	2.210	0.430	-167.93	361147.31	4676007.18
H15	1520.9	979914.040	2.080	0.530	-167.64	365053.36	4675912.65
H16	1525.8	979908.930	2.470	0.420	-171.51	359789.73	4675552.76
H17	1493.4	979923.710	1.880	0.600	-163.50	365596.14	4675513.49
H18	1504.7	979921.530	2.210	0.780	-162.95	357447.59	4676099.71
H19	1496.2	979919.940	2.730	0.740	-164.74	358395.91	4675358.52
H20	1493.4	979919.670	2.920	0.670	-166.43	359147.69	4675102.75
H21	1488.0	979923.040	3.250	0.740	-163.74	359742.30	4674553.99
H22	1494.1	979922.450	3.310	0.530	-163.28	364819.31	4674473.14
H23	1512.3	979916.110	3.120	0.420	-164.75	365869.13	4674675.20
H24	1515.4	979919.220	2.860	0.620	-162.67	356878.94	4675204.08
H25	1522.1	979916.630	3.640	0.720	-163.06	356296.39	4674308.78
H26	1487.0	979923.630	3.900	0.560	-162.86	360334.06	4673857.22
H27	1509.0	979915.910	4.480	0.350	-165.89	364625.03	4672958.82
H28	1472.7	979922.230	4.680	0.450	-165.61	361332.19	4672819.26
H29	1491.0	979918.880	5.070	0.380	-165.84	362548.27	4672351.11
H30	1504.1	979916.000	5.070	0.410	-166.11	363373.99	4672335.04
H31	1505.3	979914.610	5.070	0.350	-167.32	364172.19	4672319.59
H32	1469.4	979920.860	5.650	0.370	-166.82	362148.08	4671599.89
H33	1481.3	979919.350	6.110	0.350	-165.32	364161.33	4671042.42
H34	1468.5	979921.750	5.850	0.390	-165.91	365034.88	4671358.86
H35	1505.6	979915.520	6.430	0.650	-164.69	360437.93	4670763.45
H36	1473.0	979918.660	6.430	0.460	-168.16	361277.61	4670746.87
H37	1462.4	979920.210	6.430	0.380	-168.26	362103.53	4670730.65
H38	1459.3	979921.010	6.430	0.350	-168.09	362695.43	4670719.09
H39	1468.8	979918.340	6.760	0.340	-168.39	364145.63	4670228.16
H40	1460.5	979921.940	6.760	0.360	-166.35	364959.25	4670286.57
H41	1645.8	979889.430	7.020	0.440	-162.82	355973.21	4669946.13
H44	1509.3	979915.700	7.470	0.740	-162.73	360400.34	4669560.84
H45	1473.0	979919.700	7.470	0.490	-166.05	361240.16	4669544.25
H46	1459.0	979921.500	7.470	0.350	-166.02	362479.25	4669519.97
H47	1456.3	979919.730	7.280	0.340	-169.19	363306.38	4669559.42
H48	1457.2	979916.960	7.470	0.390	-171.52	365356.68	4669464.41
H49	1456.3	979920.880	8.190	0.370	-167.10	363289.51	4668689.64
H50	1454.7	979916.380	8.190	0.360	-171.94	364942.17	4668676.30
H51	1593.1	979902.550	8.450	0.600	-159.03	359330.37	4668397.26
H52	1487.0	979916.560	8.840	0.430	-165.12	361635.73	4667944.36
H53	1465.7	979920.900	8.840	0.380	-164.37	362324.26	4667930.88
H54	1456.0	979921.120	8.840	0.390	-166.25	363274.44	4667912.39
H55	1454.4	979914.360	8.840	0.360	-173.37	364926.22	4667843.54
H56	1456.0	979913.450	8.840	0.440	-173.87	365738.69	4667828.02
H57	1545.0	979907.230	9.490	0.450	-162.38	359223.37	4667177.52
H58	1471.5	979917.620	9.490	0.410	-165.72	361619.75	4667130.10
H59	1451.4	979920.900	9.490	0.410	-166.79	363258.66	4667098.14

Table B.4. *(continued)*

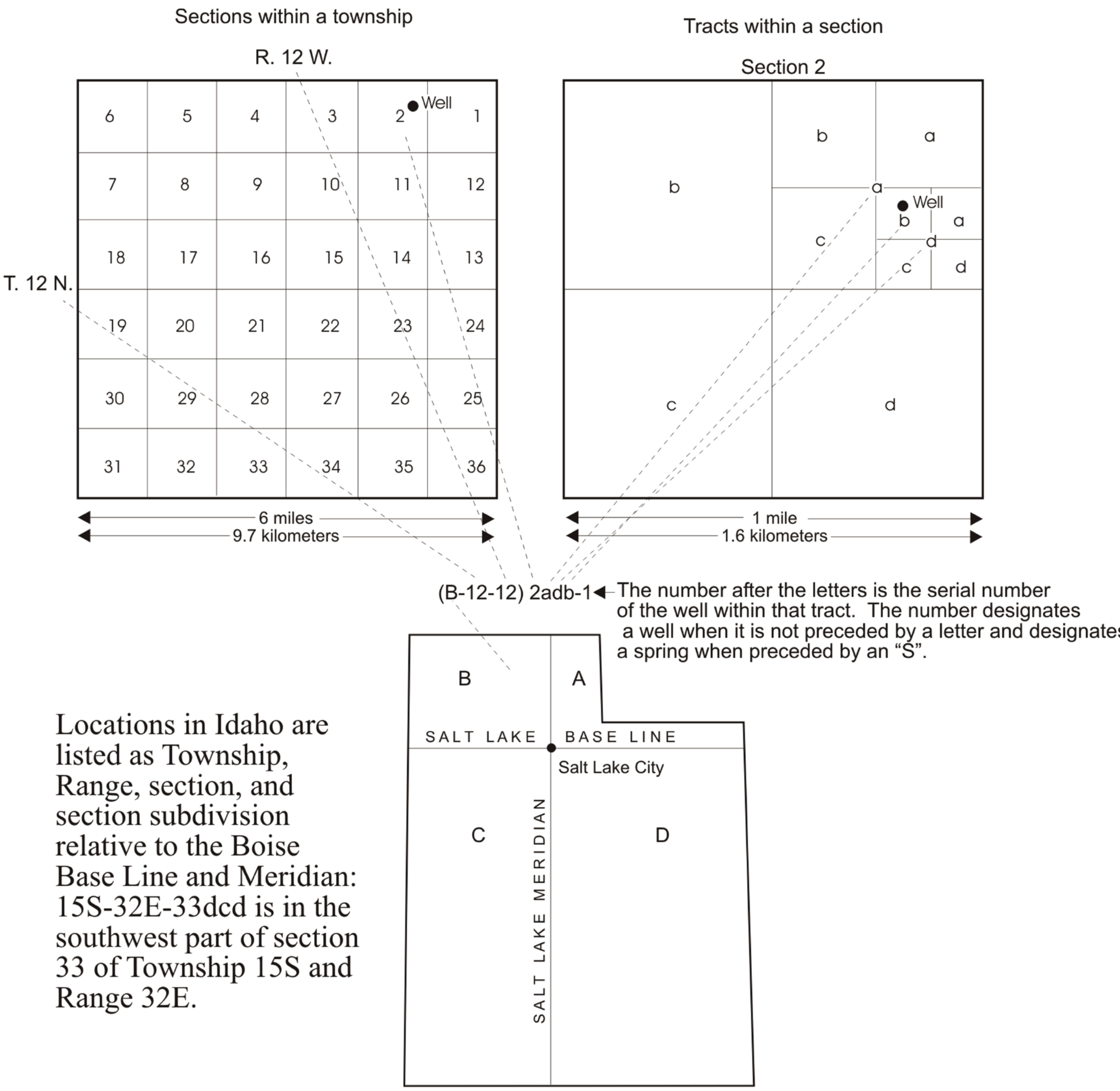
Station	Elevation (m)	Gravity (mgal)	Free Air Anomaly (mgal)	Terrain Correction (mgal)	Complete Bouguer Anomaly (mgal)	Easting[1]	Northing[1]
H60	1520.6	979911.020	10.140	0.470	-162.72	359207.49	4666381.77
H61	1514.2	979916.570	10.140	0.410	-158.49	359827.31	4666369.43
H62	1468.8	979918.570	10.140	0.480	-165.36	360791.12	4666331.83
H63	1459.3	979918.290	10.140	0.380	-167.07	361603.78	4666315.84
H64	1453.5	979920.260	10.140	0.460	-166.27	363242.87	4666283.88
H65	1454.1	979918.030	10.140	0.410	-168.42	363683.64	4666275.35
H66	1454.4	979914.740	10.140	0.380	-171.67	364083.08	4666267.65
H67	1454.7	979910.670	10.140	0.410	-175.65	364909.51	4666251.77
H68	1455.3	979909.390	10.140	0.530	-176.67	365708.40	4666236.52
H69	1453.2	979917.980	10.790	0.370	-168.05	361588.17	4665520.10
H70	1453.8	979919.430	11.050	0.490	-166.09	363219.56	4665081.01

Notes

[1]Easting and northing in meters based on Universal Transverse Mercator Zone 12N projection, 1927 datum, used in GIS applications.

APPENDIX C

Ground-Water Data



Locations in Idaho are listed as Township, Range, section, and section subdivision relative to the Boise Base Line and Meridian: 15S-32E-33dcd is in the southwest part of section 33 of Township 15S and Range 32E.

Figure C.1. *Numbering system for wells and springs in Utah—U.S. Geological Survey convention.*

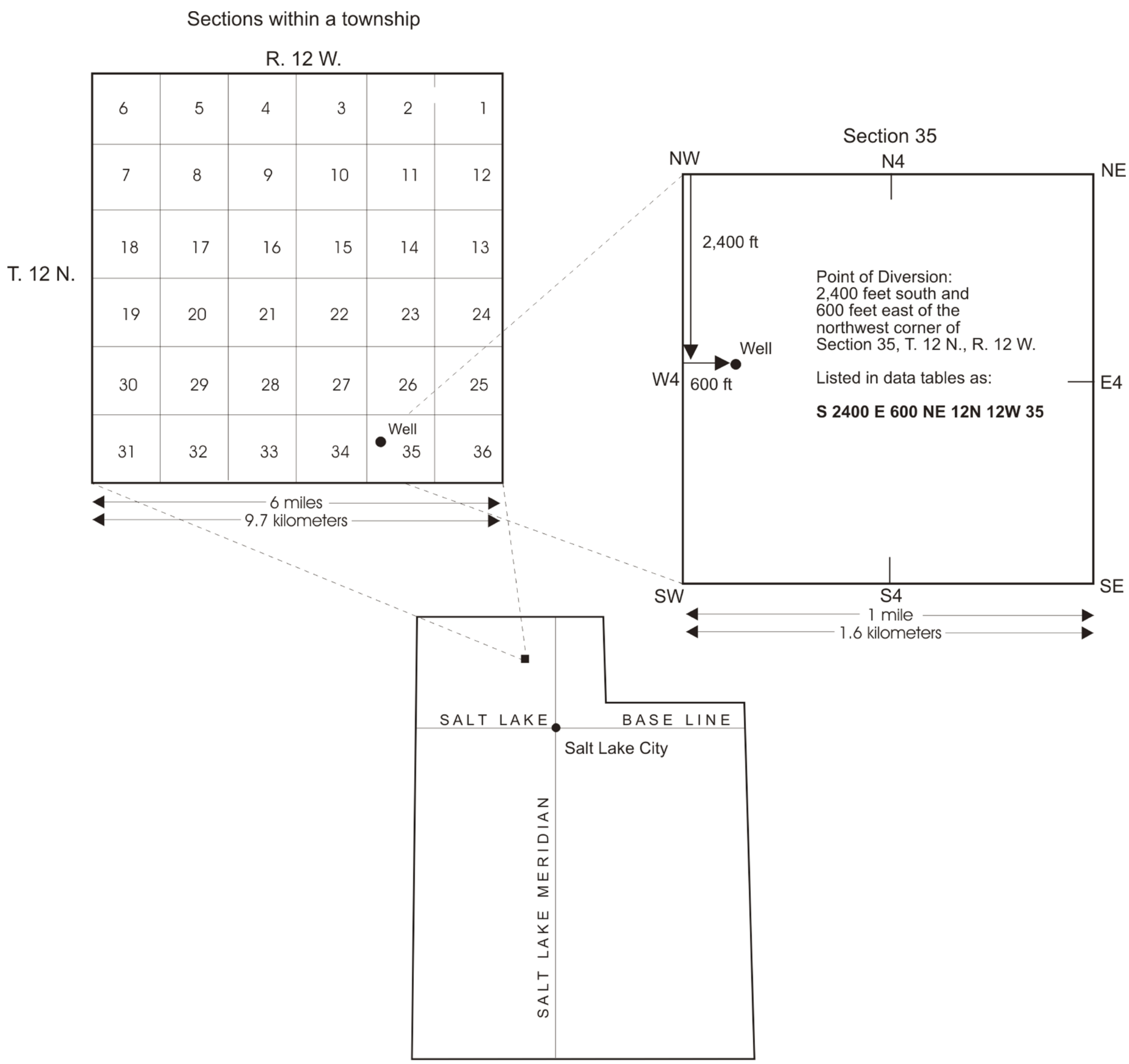


Figure C.2. *Numbering system for wells and springs in Utah—point of diversion convention.*

Table C.1. *Records of springs in Curlew Valley study area.*

ID[1]	Name[2]	Elevation (ft)[3]	Location[4]	Easting[5]	Northing[5]
1	Sparks Spring	4215	(B-11-9)5cca-S1	342325.02	4618479.66
2	Off Spring	4215	(B-11-9)6cdc-S1	340956.57	4618419.31
3	Bar M Spring	4215	(B-11-10)1adc-S1	340231.43	4619170.74
4	Teal Spring	4215	(B-11-10)12aac-S1	340027.03	4617972.01
5	West Locomotive	4215	(B-12-10)36cab-S1	339324.85	4620707.48
6	Baker	4215	(B-12-10)36dcc-S1	339728.52	4620045.56
7	Carter et al	6500	(B-13-12)5dba-S1	314092.98	4638854.05
8	Carter et al	6300	(B-13-12)5dbc-S1	314091.52	4638712.76
9	Carter et al	6160	(B-13-12)5dcc-S1	314047.96	4638294.89
10	Rose et al	6500	(B-13-12)6bac-S1	312004.14	4639510.07
11	Rose et al	6280	(B-13-12)6bbc-S1	311727.13	4639453.61
12	Carter et al	6520	(B-13-12)7bbd-S1	311904.83	4637977.76
13	Rose et al	5740	(B-13-12)8ccc-S1	313174.03	4636631.42
14	Morris et al	4810	(B-13-12)25bdd-S1	320229.50	4632523.96
15	Morris et al	4840	(B-13-12)26acd-S1	318939.39	4632594.70
16	Carter	5440	(B-13-12)30caa-S1	312111.72	4632373.15
17	Carter	5440	(B-13-12)30cac-S1	311961.01	4632266.95
18	Carter	5440	(B-13-12)30cac-S2	312038.88	4632235.40
19	Carter	5430	(B-13-12)30ccc-S1	311609.85	4631867.97
20	Callahan Spring	5300	(B-13-12)31ccb-S1	311528.87	4630470.79
21	Morris et al	4880	(B-13-12)34cdd-S1	316950.52	4630216.28
22	Morris et al	4880	(B-13-12)34dbd-S1	317256.64	4630657.94
23	Morris et al	4880	(B-13-12)34dbd-S2	317312.20	4630586.51
24	Morris et al	4820	(B-13-12)34dcd-S1	317342.86	4630300.82
25	Morris et al	4780	(B-13-12)34ddd-S1	317762.44	4630281.56
26	C. Pacific RR	4620	(B-13-12)35ddd-S1	319352.14	4630157.88
27	State of Utah	4520	(B-13-12)36add-S1	321013.24	4630987.86
28	Coyote Spring	4436	(B-14-10)33bcc-S1	334204.41	4640465.74
29	Pilot Spring	4645	(B-14-11)13bdd-S1	330127.58	4645269.13
30	Hardup Spring	5050	(B-14-11)31cbd-S1	321519.45	4640219.09
31	Dive Hollow #1	5540	(B-14-12)3cda-S1	317369.50	4648297.46
32	Dive Hollow #2	5540	(B-14-12)3cda-S2	317335.72	4648180.85
33	Dive Creek	5780	(B-14-12)9dda-S1	316563.34	4646522.06
34	Cassia Grazing	5590	(B-14-12)10bba-S1	317057.14	4647879.59
35	Cassia Grazing	5590	(B-14-12)10bba-S2	317101.05	4647948.06
36	Cassia Grazing	5630	(B-14-12)10bbd-S1	317025.67	4647701.03
37	Cassia Grazing	5630	(B-14-12)10bbd-S2	317056.74	4647610.34
38	Cedar Spring	5520	(B-14-12)11ddd-S1	319731.65	4646344.21
39	Carlson Spring	5240	(B-14-12)13daa-S1	321312.21	4645432.11
40	Dive Creek #1	5720	(B-14-12)15bbb-S1	317061.81	4644649.17
41	State of Utah	6000	(B-14-12)16bac-S1	316287.14	4645674.08
42	Crystal Spring	5850	(B-14-12)22dcc-S1	317911.25	4642788.48
43	Emigrant Spring	5550	(B-14-12)24bac-S1	320259.73	4644352.78
44	Bronson	5720	(B-14-12)24bbc-S1	319783.19	4644352.36
45	USFS	5600	(B-14-12)24bdc-S1	320427.74	4644039.67
46	Larsen	5460	(B-14-12)25bcb-S1	319867.38	4642686.86
47	Larsen	5250	(B-14-12)25ddb-S1	320786.23	4641553.02
48	Carter	9000	(B-14-13)34aaa-S1	308263.43	4641397.40
49	Birch Spring	8400	(B-14-13)35abc-S1	309319.12	4641095.78
50	Rocky Spring	8920	(B-14-13)35bbd-S1	308697.68	4641114.19
51	Rose et al	7120	(B-14-13)35daa-S1	311362.29	4640500.46
52	Rose et al	6900	(B-14-13)36dcc-S1	310954.25	4639881.34
53	Twin Springs	5200	13S-32E-30bda-S1	354522.42	4680334.68
54	Lower Ireland	5250	14S-34E-32aaa-S1	376292.34	4669100.60
55	Upper Ireland	5280	14S-34E-33bbb-S1	376576.26	4669100.60
56	Holbrook Springs	4760	15S-32E-13acb-S1	362476.47	4664166.37
57	Stone Spring	4800	16S-30E- 6ada-S1	335796.40	4658685.79
58	Black Pine Sprin	4718	16S-30E-5ccd-S1	336094.86	4657814.52
59	Bench Spring	4800	16S-30E-7abc-S1	335297.58	4657458.20
60	Anderson Spring	4700	16S-30E-7dda-S1	335428.54	4656370.76
61	Higley Spring	4700	16S-30E-18bddS1	334986.90	4655486.22
62	Rose Spring	4620	16S-30E-19abbS1	335218.20	4654445.92
-	South Bull Cyn 2	6100	12S-32E-2bda-S1	361152.63	4686884.13
-	South Bull Cyn 3	6070	12S-32E-2bdc-S1	360897.82	4686780.73
-	Pine Spring	7250	12S-32E-29bdc-S1	356228.01	4690018.43
-	Pettit Spring	5860	13S-33E-14cdc-S1	370550.44	4682299.45
-	Taylor Spring	6060	13S-33E-25bbb-S1	371830.78	4680394.65
-	Sheep Creek Spri	6220	13S-34E-31cca-S1	373501.48	4677869.09

Table C.1. *(continued)*

ID[1]	Name[2]	Elevation (ft)[3]	Location[4]	Easting[5]	Northing[5]
-	Wood Canyon Spri	6420	14S-34E-5ccb-S1	374942.77	4675960.04
-	Peterson Spring	5400	13S-31E-24bdb-S1	352893.23	4682182.12
-	Lonigan Springs	5350	13S-31E-11dda-S1	352384.07	4684623.01
-	Rock Springs	5490	13S-31E-26ddb-S1	351996.18	4679705.88
-	Hansen Spring	5770	13S-31E-34bbc-S1	349261.91	4679162.07
-	Quaking Asp Spri	5950	14S-31E-4dab-S1	348767.53	4676952.60
-	Salyer Spring	5440	14S-31E-2aca-S1	351878.29	4677256.83
-	Huffman Springs	5080	14S-32E-18cda-S1	354564.27	4673212.77
-	Meadow Brook Spr	5160	14S-32E-19dad-S1	355312.29	4671875.75
-	unnamed spring	5280	14S-32E-20caa-S1	356107.10	4671936.60
-	unnamed spring	5300	14S-32E-21bcc-S1	357038.80	4672172.37
-	Badger Hole Spri	5430	14S-31E-35aab-S1	351844.06	4669711.91
-	Littlw Rock Spri	5350	15S-31E-12aab-S1	353251.13	4666521.29
-	Glen Canyon Spri	5840	14S-30E-9ddc-S1	339298.36	4675210.88
-	unnamed spring	5040	15S-30E-4caa-S1	338412.29	4667742.02
-	Co-op Spring	4780	15S-33E-17ada-S1	366333.04	4664224.35
-	unnamed spring	4650	16S-33E-7bba-S1	363458.07	4656569.15
-	unnamed spring	4620	16S-33E-18bbd-S1	363295.02	4654770.95
-	Pollard Spring	6560	16S-29E-5bab-S1	326978.41	4659181.38
-	Corral Spring	6200	15S-29E-32dcd-S1	327513.16	4659385.10
-	Lost Tunnel Spri	6560	15S-29E-33bba-S1	328450.25	4660744.89
-	Silver Hills Spr	7040	15S-29E-28bda-S1	328862.77	4662033.39
-	Black Pine Sprin	6640	15S-29E-20dcc-S1	327487.70	4662705.65
-	Pole Canyon Spri	6540	15S-29E-7add-S1	326499.68	4666657.71
-	South Bull Cyn 1	6050	13S-32E-2bad-S1	361092.66	4687001.13
-	North Bull Cyn 1	6020	11S-32E-25dcb-S1	363339.15	4698994.88
-	Bear Hollow 1	6350	12S-32E-10ccc-1-S1	359110.09	4694223.39

ID[1]	Name[2]	Elevation (ft)[3]	Location[4]	Easting[5]	Northing[5]
-	Bear Hollow 2	5640	12S-32E-14add-S1	362229.91	4693149.59
-	Bear Hollow 3	5640	12S-32E-14ddd-S1	362157.35	4692300.71
-	unnamed	6640	12S-32E-21aaa-S1	358808.99	4692137.47
-	unnamed	5740	12S-32E-23dac-S1	362073.92	4691165.25
-	unnamed	5740	12S-32E-26abb-S1	361605.94	4690570.30
-	unnamed	5800	12S-32E-26abc-S1	361486.23	4690479.61
-	South Bull Cyn 4	5640	12S-32E-26dca-S1	361664.41	4689639.20
-	South Bull Cyn 5	5430	12S-33E-30bbd-S1	364197.82	4690402.65
-	Garden Spring	5930	12S-31E-36bbd-S1	352885.20	4688773.71
-	Sagehen Springs	5690	12S-31E-36cad-S1	353342.29	4687968.37
-	unnamed	5400	13S-31E-11ada-s1	352329.42	4685415.69
-	unnamed	5200	(B-14-7)27bac-S1	363897.17	4642171.36
-	Lookout Mt.	5380	14S-32E-22cbb-S1	358721.38	4671856.49
-	unnamed	5270	14S-32E-32ddd-S1	356815.05	4668139.88
-	Duffy Spring	6820	(B-14-12)20bdb-S1	313625.95	4643923.85
-	Tenmile 1	6680	(B-14-12)33bbb-S1	315210.32	4641393.18
-	Tenmile 2	6180	(B-14-12)33dbb-S1	316116.83	4640887.80
-	Hidden Spring	8200	(B-14-13)25aad-S1	311591.93	4642653.86
-	unnamed	5770	(B-13-12)9dcb-S1	315611.60	4636912.92
-	unnamed	5140	(B-13-12)12ccc-S1	319705.19	4636733.72
-	unnamed	4270	(B-12-11)31ccd-S1	321421.28	4620511.95
-	unnamed	4245	(B-11-11)6cdc-S1	321147.31	4618791.99
-	unnamed	4235	(B-11-11)7ccb-S1	320828.45	4617297.64
-	unnamed	4224	(B-11-11)19adb-S1	321893.56	4614967.86
-	Rice Canyon Spri	7240	16S-28E-1abc-S1	324246.70	4659051.31
-	Formation Spring	6780	16S-29E-6bcd-S1	325117.09	4658743.25
-	Middle Ridge Spr	6650	16S-29E-7acc-S1	325733.20	4657193.19

Notes

\- No data

[1]Identifier used on all figures and plates and in text.

[2]Spring names from Baker (1974) or U.S. Geological Survey 7-1/2 minute topographic maps.

[3]From U.S. Geological Survey topographic maps.

[4]Convention for specifying well location used by the U.S. Geological Survey; see figure C.1 for explanation.

[5]Easting and northing in meters based on Universal Transverse Mercator Zone 12N projection, 1927 datum, used in GIS applications.

Table C.2. *Records of water wells in Curlew Valley drainage basin, Utah and Idaho. Data are from the Utah Division of Water Rights and Idaho Division of Water Resources.*

	Location				Wellhead Elevation	Well	Depth to
ID[1]	USGS[2]	Point of Diversion[3]	Easting[4]	Northing[4]	(ft)[5]	Depth (ft)	Bedrock (ft)
Wells in Utah							
1	(B-12-8)10bcc	S 2350 E 224 NW 10 12N 8W	355136.94	4627070.76	4590	383	205
2	(B-12-8)19ddc	N 100 W 1000 SE 19 12N 8W	351526.93	4622996.54	4630	469	>469
3	(B-12-8)31dca	N 1146 W 1880SE 31 12N 8W	351207.16	4621646.37	4260	520	0
4	(B-12-8)33bdb	N 3900 E 1700 SW 33 12N 8W	353963.51	4620902.12	4230	248	146
5	(B-12-9)5bcb-1	S 1517 E 330 NW 05 12N 9W	342310.07	4629161.71	4415	90	>90
6	(B-12-9)5bcb-2	S 1570 E 330 NW 05 12N 9W	342312.99	4629134.34	4415	250	23
7	(B-12-9)6abb	S 500 E 200 N4 06 12N 9W	341466.96	4629486.81	4421	220	>220; basalt
8	(B-12-9)9ccc	N 300 E 1300 SW 09 12N 9W	344186.03	4626411.69	4315	-	-
9	(B-12-9)9cca	N 700 E 1250 SW 09 12N 9W	344163.34	4626535.86	4324	160	16
10	(B-12-9)10abb	S 200 E 62 N4 10 12N 9W	346282.48	4627834.61	4396	220	41
11	(B-12-9)16bba	S 120 E 1250 NW 16 12N 9W	344163.34	4626285.92	4311	183	>260; basalt
12	(B-12-9)17add	N 500 W 400 E4 17 12N 9W	343646.13	4625662.25	4285	140	>140; basalt
13	(B-12-10)1aaa	S 50 W 50 NE 01 12N 10W	340578.69	4629649.89	4402	240	>240; basalt
14	(B-12-10)18bca	NE4 SW4 NW4 18 12N 10W	331298.89	4626210.16	4230	283	>283
15	(B-12-10)22cbd	SE4 N4 SW4 22 12N 10W	336128.82	4623986.48	4225	162	>162; basalt
16	(B-12-11)4bcc	N 2640 E 100 SW 04 12N 11W	324442.29	4629179.42	4305	230	>235
17	(B-12-11)4aba	S 40 E 3820 NW 04 12N 11W	325592.93	4629952.44	4310	335	>335; ash, basalt
18	(B-12-11)5bbb	S 170 E 270 NW 05 12N 11W	322932.54	4629949.90	4370	246	196
19	(B-12-11)5bac	S 900 E 1520 NW 05 12N 11W	323282.68	4629713.68	4355	220	>220
20	(B-12-11)6bab	S 100 W 925 NE 06 12N 11W	322407.56	4630024.64	4390	400	>400
21	(B-12-11)6abb	S 200 E 400 N4 06 12N 11W	322104.94	4629979.25	4410	278	>278
22	(B-12-11)7abb	S 50 E 50 N4 07 12N 11W	321999.03	4628371.59	4350	250	>250
23	(B-12-11)8abd	S 860 E 3598 NE 07 12N 11W	321692.63	4628186.24	4350	275	>275
24	(B-12-11)8bbb	S 40 E 40 NW 08 12N 11W	322836.02	4628365.43	4320	350	>350
25	(B-12-11)8aab	S 60 W 1400 NE 08 12N 11W	323998.96	4628362.41	4300	224	>220
26	(B-13-8)6dad	N 1620 W 100 SE 06 13N 8W	351991.32	4638049.88	4582	485	basalt to 395
27	(B-13-8)7cdb	SE4 SW4 07 13N 8W	351010.96	4636415.96	4610	575	>575; basalt
28	(B-13-8)10dcc	N 590 E 235 S4 10 13N 8W	355987.03	4636083.77	4685	408	150
29	(B-13-8)21dcd	N 100 W 1900 SE 21 13N 8W	354540.32	4632716.86	4605	362	120
30	(B-13-8)33daa	S 3310 W 50 NE 33 13N 8W	355082.92	4630074.87	4719	274	5
31	(B-13-9)1adc	S 0 W 1320 E4 01 13N 9W	350011.78	4638439.40	4555	420	>420; basalt

Table C.2 *(continued).*

32	(B-13-9)1bdc	N 0 E 1320 W4 01 13N 9W	349215.97	4638488.36	4545	340	>340; basalt
33	(B-13-9)11abc	S 1320 W 0 N4 11 13N 9W	347911.72	4637211.21	4610	523	>523; basalt
34	(B-13-9)24ccc	N 200 E 200 SW 24 13N 9W	348761.14	4632757.62	4580	500	basalt to 440
35	(B-13-10)25ddd	N 200 W 200 SE 25 13N 10W	340427.35	4631354.71	4405	256	>250; basalt
36	(B-13-11)7bbc	S 1550 E 300 NW 07 13N 11W	321318.21	4637709.87	4970	280	>280
37	(B-13-11)13ccc-1	N 400 E 50 SE 13 13N 12W	330792.52	4634841.17	4800	179	76
38	(B-13-11)18ddc	N 500 W 750 SE 18 13N 11W	322550.51	4635033.22	4660	295	290
39	(B-13-11)33bbb	S 100 E 100 NW 33 13N 11W	324330.95	4631588.38	4410	160	>260
40	(B-13-12)30dda	SE4 SE4 30 13N 12W	312872.15	4632052.49	5340	350	>350
41	(B-13-12)33bac	S 850 W 890 N4 33 13N 12W	315012.67	4631488.35	5110	410	>410
42	(B-13-12)34dcc	N 260 E 336 S4 34 13N 12W	317089.18	4630196.04	4820	130	>120
43	(B-14-7)8bba	S 258 E 1303 NW 08 14N 7W	362320.56	4647065.30	4720	120	>120
44	(B-14-8)1ccc	N 6 E 50 SW 01 14N 8W	358685.67	4647171.38	4565	137	>137
45	(B-14-8)6acd-1	N 390 W 1600 E4 06 14N 8W	351678.72	4648220.56	4490	-	460
46	(B-14-8)1cbb	N 770 E 340 SW 01 14N 8W	358773.54	4647386.20	4562	140	>140
47	(B-14-8)1bbd	S 1100 E 1000 NW 01 14N 8W	358973.04	4648447.01	4557	198	185
49	(B-14-8)2ddb-1	N 810 W 1175 SE 02 14N 8W	358311.68	4647398.09	4550	59	>59
50	(B-14-8)2ddb-2	N 860 W 1235 SE 02 14N 8W	358293.23	4647417.87	4538	61	>61
51	(B-14-8)2ddb-3	N 920 W 1235 SE 02 14N 8W	358293.89	4647433.73	4550	61	>61
52	(B-14-8)2ddb-4	N 980 W 1235 SE 02 14N 8W	358292.19	4647447.73	4550	61	>61
53	(B-14-8)2ddb-5	N 1040 W 1240 SE 02 14N 8W	358292.93	4647469.67	4550	61	>61
54	(B-14-8)2ddb-6	N 1100 W 1240 SE 02 14N 8W	358291.08	4647487.23	4550	59	>59
55	(B-14-8)2cdd	S 0 W 330 S4 02 14N 8W	357932.21	4647171.38	4525	240	>240
56	(B-14-8)2aba	S 10 W 1840 NE 02 14N 8W	358111.01	4648779.58	4525	247	>247
57	(B-14-8)2bbb	S 70 E 180 NW 02 14N 8W	357097.95	4648798.91	4560	170	>170
58	(B-14-8)2dab	S 180 W 790 E4 02 14N 8W	358429.84	4647931.85	4535	70	basalt 22-26
59	(B-14-8)2ada	S 1665 W 510 NE 02 14N 8W	358516.39	4648275.14	4550	110	>110
60	(B-14-8)2adb	S 1850 W 750 NE 02 14N 8W	358454.38	4648219.22	4537	110	>110
61	(B-14-8)3ccc	N 660 E 660 SW 03 14N 8W	355549.72	4647319.51	4558	155	153
62	(B-14-8)3dcb	N 990 W 1000 SE 03 14N 8W	356721.83	4647491.38	4530	63	>63
63	(B-14-8)5dcd	N 100 E 900 S4 05 14N 8W	353271.24	4647364.12	4505	140	>140
64	(B-14-8)5ddd	N 250 W 500 SE 05 14N 8W	353625.20	4647336.09	4515	262	>262
65	(B-14-8)5ddc	N 400 W 1200 SE 05 14N 8W	353421.94	4647395.66	4509	400	>400
66	(B-14-8)5dcc	N 400 E 2640 SE 05 14N 8W	353001.40	4647402.67	4501	400	375
67	(B-14-8)5ddd	N 450 W 170 SE 05 14N 8W	353727.90	4647395.72	4515	262	basalt 30-70
68	(B-14-8)5bac	S 1200 E 1470 NW 05 14N 8W	352643.94	4648531.12	4545	550	505

***Table C.2** (continued).*

69	(B-14-8)6dcd	N 100 E 900 S4 06 14N 8W	351624.14	4647346.60	4478	140	>140
70	(B-14-8)6aca	S 1700 E 950 N4 06 14N 8W	351677.39	4648413.93	4500	295	>295
71	(B-14-9)5bcc	N 450 E 384 W4 05 14N 9W	342531.13	4648334.73	4410	405	>405
72	(B-14-8)6acd	S 2165 W 1775 NE 06 14N 8W	351648.66	4648264.19	4490	660	86
73	(B-14-8)8aaa	S 45 W 150 NE 08 14N 8W	353737.34	4647244.97	4510	203	>203
74	(B-14-8)8abb	S 240 E 240 N4 08 14N 8W	353060.98	4647199.41	4498	174	>174
75	(B-14-8)8baa	S 520 W 65 N4 08 14N 8W	352969.86	4647108.30	4995	460	72
76	(B-14-8)11dcc	N 50 W 2555 SE 11 14N 8W	357887.05	4645541.80	4590	200	>200
77	(B-14-8)11abc	S 690 E 260 N4 11 14N 8W	357927.52	4646960.25	4530	92	>92
78	(B-14-8)11bbd-1	S 800 E 960 NW 11 14N 8W	357304.90	4646950.59	4505	75	>75
79	(B-14-8)11bbd-2	S 800 E 1000 NW 11 14N 8W	357329.44	4646950.59	4505	75	>75
80	(B-14-8)11bbd-3	S 805 E 1020 NW 11 14N 8W	357336.45	4646929.57	4530	72	>72
81	(B-14-8)11bbd-4	S 820 E 1030 NW 11 14N 8W	357353.97	4646933.07	4505	75	>75
82	(B-14-8)11aad	S 1265 W 75 NE 11 14N 8W	358654.13	4646764.86	4575	100	>100
83	(B-14-8)11bca	S 1860 E 4150 NE 11 14N 8W	359940.28	4646572.11	4526	416	>416
84	(B-14-8)12cbd	S 720 E 810 W4 12 14N 8W	358914.75	4646119.57	4638	245	>245
85	(B-14-8)15ddd	N 50 W 50 SE 15 14N 8W	356990.54	4643995.12	4580	500	>500
86	(B-14-8)20ccc	S 0 E 0 SW 20 14N 8W	352086.73	4642422.80	4525	453	basalt 272-453
87	(B-14-8)20baa	S 100 W 350 N4 20 14N 8W	352654.46	4644010.33	4558	303	<200
88	(B-14-8)28bbb	S 60 W 5175 NE 28 14N 8W	353758.37	4642370.23	4540	650	basalt to 511
89	(B-14-8)32aaa-1	S 100 W 100 NE 32 14N 8W	353667.25	4640751.16	4558	330	50
90	(B-14-9)6add	N 6 E 3 NE 01 14N 9W	350611.54	4648917.94	4488	550	basalt 490-550
91	(B-14-9)1ddd-1	N 600 W 600 SE 01 14N 9W	350381.09	4647533.45	4470	312	>312
92	(B-14-9)1ddd-2	N 610 W 250 SE 01 14N 9W	350482.14	4647526.23	4470	255	>255
93	(B-14-9)1dda-1	N 782 W 767 01 14N 9W	350337.79	4647573.15	4470	360	>360
94	(B-14-9)1dda-2	N 930 W 270 SE 01 14N 9W	350529.83	4647569.89	4470	255	>255; lava 192-243
95	(B-14-9)1aaa	S 50 W 50 NE 01 14N 9W	350565.15	4648926.50	4485	275	>275; lava 196-200
96	(B-14-9)3aaa	S 300 E 300 NW 03 14N 9W	345812.19	4648973.41	4412	205	>205
97	(B-14-9)3acc	S 2640 E 2640 NW 03 14N 9W	346512.32	4648237.19	4405	467	>467
98	(B-14-9)4ccc	N 330 E 100 SW 04 14N 9W	344083.51	4647558.71	4394	360	>360
99	(B-14-9)4bbb-1	S 60 E 70 NW 04 14N 9W	344133.53	4649027.65	4410	350	>350
100	(B-14-9)4bbb-2	S 100 E 100 NW 04 14N 9W	344159.30	4649016.72	4410	372	>375
101	(B-14-9)4bcc	S 2421 E 10 NW 04 14N 9W	344097.94	4648309.37	4400	365	>365
102	(B-14-9)4bbb-3	S 200 E 100 NW 04 14N 9W	344142.67	4648984.98	4410	365	>365
103	(B-14-9)5aaa	N 10 E 10 NE 05 14N 9W	344123.21	4649063.64	4410	275	>275
104	(B-14-9)5ccd	N 390 E 100 SW 05 14N 9W	342497.18	4647724.73	4400	320	>320

***Table C.2** (continued).*

105	(B-14-9)5dcc	N 500 E 1320 SW 05 14N 9W	342852.86	4647753.59	4400	400	>400
106	(B-14-9)5cca-1	N 750 E 1320 SW 05 14N 9W	342856.47	4647858.25	4400	355	>355
107	(B-14-9)5bbb-1	S 50 E 50 NW 05 14N 9W	342493.15	4649062.76	4405	300	>300
108	(B-14-9)5abb	S 50 E 2650 NW 05 14N 9W	343300.07	4649033.89	4416	395	>395
109	(B-14-9)6ccc	N 270 E 105 SW 06 14N 9W	340868.81	4647565.86	4403	375	>375
110	(B-14-9)7bbb	S 60 E 70 NW 07 14N 9W	340858.15	4647465.27	4402	608	-
111	(B-14-9)9bbb	S 50 E 50 NW 09 14N 9W	344079.90	4647421.57	4392	672	basalt 185-255, 512-660
112	(B-14-9)9bab	S 75 E 2000 NW 09 14N 9W	344682.59	4647414.35	4392	640	-
113	(B-14-9)10cbb	N 2640 E 0 SW 10 14N 9W	345676.94	4646569.47	4386	400	>400; basalt
114	(B-14-9)14dbd	N 1902 W 1887 SE 14 14N 9W	348296.81	4644720.67	4415	450	439
115	(B-14-9)14dba	N 2640 W 1450 SE 14 14N 9W	348432.27	4644949.45	4415	450	>450
116	(B-14-9)16aba	S 0 W 1650 NE 16 14N 9W	345144.53	4645826.42	4375	468	>468
117	(B-14-9)16aaa	S 50 W 78 NE 16 14N 9W	345620.54	4645818.45	4375	400	>400
118	(B-14-9)16daa	S 2690 W 70 NE 16 14N 9W	345622.97	4645013.78	4370	400	>400
119	(B-14-9)17cab	S 2700 E 1900 NW 17 14N 9W	343188.49	4644974.72	4372	385	>385
120	(B-14-9)18bdd	S 2470 E 2230 NW 18 14N 9W	341452.60	4645126.29	4370	400	>400
121	(B-14-9)20acc	S 2397 W 2561 NE 20 14N 9W	343209.04	4643466.52	4360	305	>305
122	(B-14-9)27acc	N 2640 E 2640 SW 27 14N 9W	346364.39	4641758.80	4402	300	>300; basalt
123	(B-14-9)29cbb	N 2450 E 100 SW 29 14N 9W	342315.13	4641751.94	4349	434	>434; basalt
124	(B-14-10)1dcd	N 915 W1600 SE 01 14N 10W	340349.13	4647762.45	4405	343	>343
125	(B-14-10)1dca	N 943 W 1600 SE 01 14N 10W	340347.78	4647919.06	4405	208	>208
126	(B-14-10)1bbb	S 100 E 75 NW 01 14N 10W	339306.10	4649083.29	4435	414	>420
127	(B-14-10)1abb	S 50 E 190 N4 01 14N 10W	340116.79	4649073.13	4425	340	>340
128	(B-14-9)9baa	N 370 E 6 S4 04 14N 9W	344833.01	4647493.35	4395	672	>672; basalt > 512
129	(B-14-10)4ccd	N 100 E 1300 SW 04 14N 10W	334706.83	4647728.02	4600	261	>261
130	(B-14-10)5bba	S 300 E 660 NW 05 14N 10W	332926.24	4649086.90	4730	303	>303
131	(B-14-10)5bba	S 300 W 3300 NE 05 14N 10W	333322.73	4649097.71	4710	276	>276
132	(B-14-10)14acd	S 0 W 1320 E4 14 14N 10W	338769.04	4645082.36	4392	350	>350
133	(B-14-10)14bbb	S 594 E 32 NW 14 14N 10W	337573.50	4645752.20	4425	356	>350
134	(B-14-10)14bbc	S 910 E 50 NW 14 14N 10W	337581.87	4645687.58	4425	840	420
135	(B-14-10)14cbc	S 1320 E 20 W4 14 14N 10W	337541.65	4644717.10	4410	400	-
136	(B-14-10)15ccd	N 20 E 1320 SW 15 14N 10W	336318.02	4644336.25	4427	505	315
137	(B-14-10)15bbc	S 1100 E 15 NW 15 14N 10W	335935.95	4645608.61	4465	790	>790
138	(B-14-10)22ccd	N 560 E 730 SW 22 14N 10W	336076.52	4642901.68	4420	192	30
139	(B-14-10)34bcc	N 150 E 60 W4 34 14N 10W	335798.98	4640374.97	4385	350	>350
140	(B-14-10)34bbb	N 160 E 160 SW 34 14N 10W	335806.19	4639549.55	4385	365	230

***Table C.2** (continued).*

141	(B-14-11)5acb	S 1684 W 2552 NE 05 14N 11W	323919.93	4648869.60	5005	304	212
142	(B-14-11)10baa	S 380 W 50 N4 10 14N 11W	327039.07	4647582.93	4820	345	>345
143	(B-14-11)11caa	S 2640 W 2640 NE 11 14N 11W	328662.19	4646841.33	4795	280	>280
144	(B-14-11)22caa	N 2500 E 2000 SW 22 14N 11W	326780.67	4643644.19	4720	360	>320
145	(B-14-11)31baa	S 100 E 2500 NW 31 14N 11W	322051.65	4641344.56	5090	540	265
146	(B-14-12)3dcc	S 2500 W 2200 E4 03 14N 12W	314406.64	4647969.52	5010	104	15
147	(B-14-12)11bbd	S 580 E 1161 NW 11 14N 12W	318598.60	4647605.47	5500	259	>259
148	(B-14-12)11bdb	S 1250 E 1520 NW 11 14N 12W	318724.05	4647412.06	5520	259	>259
149	(B-14-12)12daa	S 150 W 250 E4 12 14N 12W	321325.80	4646941.31	5160	215	>215
150	(B-15-7)25ddd	N 180 W 50 NW 31 15N 7W	360315.99	4650453.08	4560	100	>100
151	(B-15-7)29dac	N 1700 W 700 SE 29 15N 7W	363332.26	4650864.39	4800	175	161
152	(B-15-7)30cbc	N 1760 E 335 NW 31 15N 7W	360439.39	4650910.09	4560	228	185
153	(B-15-7)32aca	N 3790 W 1510 SE 32 15N 7W	363053.48	4649886.39	4720	315	>315
154	(B-15-7)32aba	N 5280 W 1700 SE 32 15N 7W	363021.49	4650338.83	4740	400	275
155	(B-15-7)32baa	S 5 E 1950 NW 32 15N 7W	362514.21	4650334.26	4630	262	>262
156	(B-15-8)31dcd	N 220 W 1640 SE 31 15N 8W	351705.93	4648981.51	4540	650	>600
157	(B-15-8)34dad	N 1365 W 340 SE 34 15N 8W	356939.46	4649236.30	4600	365	240
158	(B-15-8)35cbc	N 1350 E 30 SW 35 15N 8W	357075.80	4649228.29	4540	204	>204
159	(B-15-8)36add	N 200 W 600 E4 36 15N 8W	360137.76	4649621.32	4560	68	>60
160	(B-15-8)36cbc-1	N 1600 E 300 SW 36 15N 8W	358771.30	4649278.57	4560	110	>110
161	(B-15-8)36daa	S 20 W 650 E4 36 15N 8W	360116.44	4649564.62	4560	260	169
162	(B-15-8)36cbc-2	S 675 E 590 W4 36 15N 8W	358864.91	4649395.95	4545	93	>93
163	(B-15-9)28ddc	N 620 W 1000 SE 28 15N 9W	345463.18	4650873.53	4450	450	335
164	(B-15-9)28cbc	N 1460 E 50 SW 28 15N 9W	344196.26	4651137.19	4455	441	424
165	(B-15-9)28dbd	N 0 W 1340 NE 28 15N 9W	345390.06	4651138.59	4458	243	-
166	(B-15-9)29cbc	N 1534 E 2490 SW 29 15N 9W	343283.24	4651175.16	4460	480	>480
167	(B-15-9)30bbb	S 75 E 75 NW 30 15N 9W	340943.35	4651193.44	4460	230	>230
168	(B-15-9)31abc	S 1200 E 2640 NW 31 15N 9W	341736.24	4650362.03	4444	404	278
169	(B-15-9)32ccc	N 40 E 104 SW 32 15N 9W	342509.61	4649090.19	4420	295	210
170	(B-15-9)32adb	N 3600 E 1270 SE 32 15N 9W	343753.96	4650151.45	4435	400	>400
171	(B-15-9)33dcd	N 10 W 1320 SE 33 15N 9W	345358.07	4649068.34	4415	465	>436
172	(B-15-9)33ccb	N 1300 E 10 SW 33 15N 9W	344137.85	4649443.09	4422	410	>410
173	(B-15-9)34dcc	N 382 E 64 S4 34 15N 9W	346549.53	4649161.49	4420	390	>320
174	(B-15-9)34bbc	S 750 E 385 NW 34 15N 9W	345860.78	4650430.23	4442	620	286
175	(B-15-9)35abb-1	S 30 W 2540 NE 35 15N 9W	348195.18	4650619.95	4485	404	98
176	(B-15-9)35abb-2	S 430 W 2440 NE 35 15N 9W	348232.66	4650489.64	4478	220	5

***Table C.2** (continued).*

177	(B-15-9)36bcb	N 1000 W 0 W4 36 15N 9W	348991.64	4650093.13	4490	490	114
178	(B-15-9)36cad	N 1750 W 25 S4 36 15N 9W	349756.63	4649508.03	4490	255	70
179	(B-15-10)33dda	N 760 W 570 SE 33 15N 10W	335819.32	4649413.90	4560	355	>355
180	(B-15-10)34bcc	N 150 E 60 W4 34 15N 10W	336046.71	4649989.94	4558	350	>350
181	(B-15-10)36bbb	S 100 E 100 NW 36 15N 10W	339337.64	4650735.33	4465	613	253
182	(B-15-10)36bcb	S 1370 E 270 NW 36 15N 10W	339389.46	4650348.23	4455	300	>300
183	(B-15-10)36acc	S 2640 E 2640 NW 36 15N 10W	340038.47	4649941.23	4440	423	>423
184	(B-15-11)31ddd	N 405 W 15 SE 31 15N 11W	323042.28	4649552.77	5095	410	>410
185	(B-15-11)36ccc	N 558 E 10 SW 36 15N 11W	329504.18	4649457.02	4870	320	150
186	(B-15-12)34ddd	N 78 W 43 SE 34 15N 12W	318170.83	4649515.90	5410	235	>235
187	(B-15-12)34aac	S 700 W 1000 NE 34 15N 12W	317923.77	4650882.67	5330	1449	480
188	(B-14-9)11bcb	S 1944 E 510 NW 11 14N 9W	347447.03	4646808.05	4395	245	>245
189	(B-14-9)13abb	S 200 W 2640 NE 13 14N 9W	349706.22	4645671.24	4445	75	60
190	(B-12-9)10ddc	N 499 W 677 SE 10 12N 9W	346837.71	4626403.28	4361	-	-
191	(B-12-9)30cda	N 1300 E 2000 SW 30 12N 9W	341181.35	4621892.62	4239	162	>162; basalt >23
192	(B-12-10)19bcb	N 783 E 404 W4 19 12N 10W	330946.19	4624436.76	4220	64	>64
193	(B-12-10)20adc	N 60 W 1220 E4 20 12N 10W	333689.92	4624138.17	4220	64	>64
194	(B-12-10)21daa	S 338 W 494 E4 21 12N 10W	335529.84	4623968.71	4220	64	>64
195	(B-12-11)5bdc-1	N 417 E 1534 W4 05 12N 11W	323271.80	4629270.57	4340	208	>208
196	(B-12-11)6aab	S 181 W 1125 NE 06 12N 11W	322480.96	4629900.02	4389	330	>330
197	(B-12-11)8abb	N 120 E 331 S4 05 12N 11W	323692.71	4628368.31	4303	275	>275
198	(B-12-11)8cda	N 1458 W 430 S4 08 12N 11W	323436.67	4627165.01	4280	510	>510
199	(B-12-11)16cdc	N 256 W 785 S4 16 12N 11W	324926.11	4625171.11	4233	126	>126
200	(B-12-11)21ddd	N 218 W 124 SE 21 12N 11W	325918.70	4623532.94	4220	64	>64
201	(B-12-11)35bbd	S 1175 E 568 NW 35 13N 9W	347220.47	4630751.76	4502	428	>428
202	(B-13-10)11dcd	N 189 E 965 S4 11 13N 10W	338410.76	4636250.96	4335	128	>128; basalt >10
203	(B-13-10)34ddc	N 286 W 982 SE 34 13N 10W	336925.92	4629843.53	4305	95	>95; basalt >51
204	(B-13-11)10cdc	N 615 W 966 S4 10 13N 11W	326540.07	4636622.17	4480	283	>283
205	(B-14-7)2bab	S 340 W 834 N4 02 14N 7W	365686.71	4648783.37	5110	398	169
206	(B-14-7)5aca	N 468 W 1636 E4 05 14N 7W	362999.47	4648153.92	4730	250	>250
207	(B-14-7)7aaa	S 261 W 203 NE 07 14N 7W	361861.62	4647064.50	4705	100	>100
208	(B-14-7)8bbd	S 1320 E 1304 NW 08 14N 7W	362346.82	4646741.08	4745	120	>120
209	(B-14-7)22dcc	N 10 E 530 S4 22 14N 7W	364390.56	4642429.06	5020	485	72
210	(B-14-9)19bbb	N 5198 E 260 SW 19 14N 9W	340840.44	4644199.28	4371	350	>350
211	(B-14-9)21bbb	S 24 E 239 NW 21 14N 9W	344020.96	4644156.63	4365	586	>586
212	(B-15-8)25ddd	N 213 W 255 SE 26 15N 8W	358620.48	4650485.80	4560	100	>100

Table C.2 *(continued).*

213	(B-13-8)18abb	S 550 E 3000 NW 18 13 N 8W	351240.96	4635794.30	4616	-	-
214	(B-14-8)6add	S 2310 W 150 NE 06 14N 8W	352164.80	4648224.80	4500	-	-
215	(B-14-9)9add	N 2640 SW 09 14N 9W	344044.46	4646637.46	4384	400	-
216	(B-15-9)33bcb	S 1640 E 50 NW 33 15N 9W	344171.37	4650213.83	4430	-	-
217	(B-15-10)25cad	N1530 E2250 SW 25 15N 10W	340007.50	4651219.61	4464	-	-
218	(B-12-9)28add	S2000 W500 NE 28 12N 9W	345258.55	4622442.09	4311	162	-
219	(B-13-9)33ccc	N75 E75 SW 33 13N 9W	343755.76	4629594.45	4424	-	-
220	(B-14-8)20baa	S270 W270 N4 20 14N 8W	343086.73	4644128.11	4560	-	-
221	(B-15-9)28dda	N1120 W165 SE 28 15N 9W	345727.27	4650980.83	4455	-	-
222	(B-15-9)29cbc	N1534 E50 SW 29 15N 9W	342557.94	4651167.63	4459	-	-
223	(B-12-11)5abb	S 62 W 290 N4 05 12N 11W	323539.92	4629928.42	4333	700	-
224	(B-12-11)5bba	N 122 W 615 S4 32 13N 11W	323286.19	4629986.71	4355	-	-
225	(B-12-11)5bdc-2	N 146 E 1401 W4 05 12N 11W	323231.33	4629187.81	4340	100	-
226	(B-12-11)5dcd	N 458 E 954 S4 05 12N 11W	323882.79	4628471.20	4300	150	-
227	(B-12-11)8baa	N 64 W 441 S4 05 12N 11W	323457.63	4628351.20	4303	320	-
228	(B-12-11)21cdc	N 407 W 1001 S4 21 12N 11W	324842.84	4623612.66	4223	60	-
229	(B-12-12)13ddd	N 63 W 156 SE 13 12N 12W	321067.79	4625186.46	4300	83	-
230	(B-13-12)14ccc	N 793 E 150 SW 14 13N 12W	317978.48	4635191.56	5160	179	-
231	(B-14-8)1ddd	N 140 W 310 SE 01 14N 8W	360200.33	4647183.06	4650	-	-
232	(B-14-8)1abb	S 177 E 546 N4 11 14N 8W	358012.78	4647127.07	4525	100	-
233	(B-14-9)10ada	N 817 W 211 E4 10 14N 9W	347207.04	4646799.14	4402	171	-
234	(B-14-11)7cbb	S 222 E 220 W4 07 14N 11W	321488.42	4646875.12	5140	-	-
235	(B-14-11)10bad	S 1384 W 174 N4 10 14N 11W	327027.26	4647263.04	4840	350	-
236	(B-14-11)13dda	N 1026 W 147 SE 13 14N 11W	330962.44	4644659.58	4600	-	-
237	(B-15-9)28cbb	S 83 E 248 NW 28 15N 9W	344247.66	4651186.22	4456	400	-
238	(B-15-9)32aba	S 307 E 727 N4 32 15N 9W	343563.81	4650634.34	4445	400	-
239	(B-15-11)26cdd	N 181 W 307 S4 26 15N 11W	328646.92	4650986.26	5050	485	-
240	(B-14-8)2ddc	N 640 W 720 SE 2 14N 8W	358442.33	4647332.69	4537	252	-
241	(B-14-8)4ddd	N 240 W 65 SE 4 14N 8W	355392.74	4647298.35	4571	-	-
242	(B-14-8)11aba	S 270 W 1690 NE 11 14N 8W	358160.72	4647071.69	4535	-	-
243	(B-14-8)11bca-1	N 850 E 1265 W4 11 14N 8W	357363.98	4646601.20	4526	-	-
244	(B-14-8)11bca-2	S 1860 W 4150 NE 11 14N 8W	357415.50	4646601.20	4526	-	-
245	(B-14-8)28aba	S 155 W 1675 NE 28 14N 8W	354863.87	4642322.16	4558	-	-
246	(B-14-8)32dba	S 3180 W 1900 NE 32 14N 8W	353133.02	4639849.51	4562	4400	-
247	(B-14-9)1cdd	N 400 E 2600 SW 1 14N 9W	349777.78	4647672.68	4452	416	-
248	(B-14-9)6add	N 400 W 400 E4 6 14N 9W	342346.11	4648544.97	4409	-	-

Table C.2 *(continued).*

249	(B-14-9)9baa	S 350 E 2500 NW 9 14N 9W	344822.19	4647332.69	4392	-	-
250	(B-14-9)17caa	S 2661 E 2552 NW 17 14N 9W	343149.72	4645035.19	4372	-	-
251	(B-14-9)29bbb	S 20 E 160 NW 29 14N 9W	342328.94	4642583.16	4352	-	-
252	(B-14-10)11cbc	S 940 E 70 W4 11 14N 10W	337603.45	4646405.45	4434	-	-
253	(B-14-10)12bcb	S 1900 E 20 NW 12 14N 10W	339231.27	4646906.85	4402	-	-
254	(B-14-10)12cbc	N 1840 E 10 SW 12 14N 10W	339224.40	4646460.40	4396	-	-
255	(B-14-10)13cab	S 10 E 1330 W4 13 14N 10W	339591.86	4645079.84	4382	-	-
256	(B-14-10)23bbc	S 1320 E 10 NW 23 14N 10W	337507.29	4643901.90	4402	-	-
257	(B-15-7)32bab	S 40 W 1025 N4 32 15N 7W	362360.78	4650341.07	4664	-	-
258	(B-15-7)32dbd	N 1325 W 1495 SE 32 15N 7W	363037.33	4649121.92	4720	-	-
259	(B-15-8)31ccc	N 40 E 60 SW 31 15N 8W	350605.43	4648970.82	4488	-	-
260	(B-15-9)31bab	S 1200 E 1320 NW 31 15N 9W	341326.15	4650392.59	4445	-	-
261	(B-15-9)31cdc	N 25 W 780 S4 31 15N 9W	341425.74	4649101.32	4424	-	-
262	(B-15-9)32aca	S 1320 E 3960 NW 32 15N 9W	343726.67	4650313.60	4435	-	-
263	(B-15-9)36dbc	N 1730 W 2620 SW 36 15N 9W	349770.91	4649509.99	4492	-	-
264	(B-15-10)34ccc	N 180 E 165 SW 34 15N 10W	336054.61	4649211.21	4549	-	-
265	(B-14-8)11bcb-1	S 1575 E 250 NW 11 14N 8W	357103.00	4646707.00	4518	-	-
266	(B-14-8)1bbc-1	S 1350 E 20 NW 1 14N 8W	358679.00	4648372.00	4542	-	-
267	(B-14-8)11bca	S 1370 E 750 NW 11 14N 8W	357252.00	4646746.00	4516	-	-
268	(B-14-8)1bbc-2	S 1320 E 330 1 14N 8W	358746.00	4648382.00	4550	-	-
269	(B-14-9)5ccd	N 420 E 1260 SW 5 14N 9W	342810.00	4647597.00	4397	-	-
270	(B-14-8)11bcb-2	S 1570 E 420 NW 11 14N 8W	357171.00	4646716.00	4515	-	-
271	(B-14-8)10aca	S 1450 W 1285 NE 10 14N 8W	356640.00	4646592.50	4518	-	-
273	(B-14-8)11bcc	S 2110 E 510 11 14N 8W	347439.00	4646758.00	4396	-	-
Wells in Idaho							
301	12S-33E-19DCC1	-	364725.16	4690727.00	5520	355	>355
302	12S-33E-26BCC1	-	370391.09	4689714.50	5262	150	-
303	12S-33E-27CDC1	-	369182.06	4688935.00	5245	-	-
304	12S-33E-28BCC1	-	367097.66	4689838.50	5295	200	-
305	13S-32E-02BDA1	-	361157.84	4686973.50	6080	240	>240
306	13S-32E-22BAA1	-	359449.91	4682369.50	5680	232	171
307	13S-32E-22BAD1	-	359229.25	4682043.50	5620	460	0
308	13S-32E-22BAD2	-	359214.91	4682149.50	5620	565	190
309	13S-32E-29AAD1	-	357038.63	4680629.50	5340	160	110
310	13S-33E-04AAA1	-	368482.75	4687231.00	5500	105	>275
311	13S-33E-04ADD1	-	368474.69	4686418.50	5153	146	-

Table C.2 *(continued).*

312	13S-33E-04CDB1	-	367341.34	4685823.00	5200	72	-
313	13S-33E-04CDB2	-	367341.94	4685853.50	5200	80	-
314	13S-33E-04DCC1	-	367658.91	4685662.50	5150	90	-
315	13S-33E-06AAA1	-	364951.22	4687055.00	5500	275	-
316	13S-33E-16BDA1	-	367476.69	4683290.00	5100	70	-
317	13S-33E-16BDC1	-	367405.13	4683137.00	5100	65	-
318	13S-33E-20CDA1	-	365883.56	4681026.50	5040	200	>200
319	13S-33E-28BBB1	-	366855.69	4680741.00	5000	40	-
320	13S-33E-29ACC2	-	366039.66	4680016.00	5000	34	-
321	13S-33E-29DCB1	-	365983.94	4679492.50	5000	90	-
322	13S-33E-32DAC1	-	366487.16	4678077.00	4924	130	120
323	14S-30E-32CDD1	-	336568.25	4669021.29	5117	-	-
324	14S-32E-02DDA1	-	361708.25	4676396.50	5200	-	-
325	14S-32E-04CDD1	-	357709.75	4676275.50	4960	185	>381
326	14S-32E-10DDC1	-	359788.16	4674553.00	4880	75	-
327	14S-32E-14CDD1	-	360748.06	4672927.50	4840	381	-
328	14S-32E-14DCD1	-	361356.88	4672824.50	4832	80	-
329	14S-32E-15ADD1	-	360046.53	4673776.00	4853	20	-
330	14S-32E-23ABA1	-	361327.50	4674677.00	4800	80	-
331	14S-32E-24BAD1	-	362470.06	4672326.50	4890	120	>120
332	14S-32E-24CBD1	-	362076.38	4671593.00	4800	255	>255
333	14S-32E-25ACD2	-	362759.69	4670484.00	4790	100	-
334	14S-32E-25BDA1	-	362091.03	4670658.00	4795	107	>107
335	14S-32E-25BDA2	-	362453.53	4670599.00	4790	507	>507
336	14S-32E-36AAB1	-	362902.69	4669462.50	4785	86	-
337	14S-32E-36AAC1	-	362963.84	4669214.50	4784	222	-
338	14S-33E-06AAB1	-	364683.31	4677419.50	5020	245	-
339	14S-33E-10AAB1	-	369514.53	4675786.00	5190	130	-
340	14S-33E-10AAB2	-	369538.00	4675702.00	5220	505	475
341	14S-33E-10CCD1	-	368479.66	4674293.00	5050	-	-
342	14S-33E-16BBB1	-	366753.09	4674232.00	4950	200	-
343	14S-33E-19BAD1	-	365328.03	4670557.00	4955	200	-
344	14S-33E-20AAD1	-	366470.03	4672417.00	4950	130	-
345	14S-33E-22DCC1	-	369105.66	4671103.50	4980	193	-
346	14S-33E-26CDB1	-	370269.91	4669723.50	4986	233	-
347	14S-33E-27CAB1	-	368649.25	4670124.50	4985	200	-

Table C.2 *(continued).*

348	14S-33E-30DCD1	-	364530.91	4669493.00	4767	60	-
349	14S-33E-31ABC1	-	364270.78	4669281.00	4764	70	-
350	14S-33E-31ACC1	-	364151.19	4668852.00	4763	95	>95
351	14S-33E-31BCD1	-	363578.19	4668894.00	4772	-	-
352	14S-33E-31BDA1	-	364131.59	4668914.00	4764	100	-
353	14S-33E-31CBC1	-	363271.25	4668304.48	4778	300	-
354	14S-33E-32ABB1	-	365842.03	4669341.00	4810	430	340
355	14S-33E-32ADD1	-	366490.44	4668653.50	4798	110	-
356	14S-33E-32DDD1	-	366499.63	4667851.00	4790	195	>195
357	14S-33E-33ACB1	-	366632.31	4667846.50	4860	400	>400
358	14S-33E-33CBA1	-	366968.94	4668613.00	4805	325	-
359	14S-33E-33CCC1	-	366622.94	4667845.50	4790	280	>280
360	14S-33E-33CCD1	-	366775.25	4667969.00	4790	280	-
361	14S-33E-36BDB1	-	371906.84	4668858.50	4880	308	148
362	14S-34E-31DBD1	-	374262.41	4668170.50	5160	399	-
363	14S-34E-34DCA1	-	379010.41	4667933.50	5455	32	-
364	15S-30E-04BDD1	-	338347.84	4667946.50	5045	175	-
365	15S-30E-08AAA1	-	337633.30	4667004.01	5150	-	-
366	15S-30E-10BBB1	-	339356.81	4666936.00	5000	306	-
367	15S-30E-15BBB1	-	339388.47	4665268.50	4900	540	-
368	15S-30E-35DAC1	-	342054.38	4659483.12	4750	-	-
369	15S-32E-02DCD1	-	361119.41	4666442.50	4784	232	-
370	15S-32E-07CCC1	-	353702.63	4664976.50	5400	200	106
371	15S-32E-09AAA1	-	358523.56	4666401.50	5032	248	-
372	15S-32E-09AAA2	-	358339.28	4666374.50	5040	270	-
373	15S-32E-11AAD1	-	361500.59	4665972.50	4772	140	-
374	15S-32E-12BBC1	-	361662.47	4666031.00	4773	128	-
375	15S-32E-26AAC1	-	361200.59	4661226.50	4648	68	-
376	15S-32E-26AAC2	-	361177.06	4661196.00	4648	44	-
377	15S-32E-33ADD1	-	358217.97	4659187.50	4620	400	370
378	15S-32E-33CAA1	-	357411.25	4659080.50	4620	400	-
379	15S-32E-33DCD1	-	357674.63	4658458.00	4592	267	-
380	15S-32E-34AAA1	-	359679.25	4659837.00	4623	600	-
381	15S-32E-35CCA1	-	360143.47	4658902.50	4607	94	-
382	15S-32E-36AAA1	-	363079.88	4659770.50	4672	331	96
383	15S-33E-04BBB1	-	365132.59	4664233.00	4787	300	-

***Table C.2** (continued).*

384	15S-33E-05ADD1	-	366369.41	4667113.00	4778	75	-
385	15S-33E-06BBA1	-	363254.69	4667604.00	4775	100	-
386	15S-33E-06CAA1	-	363979.16	4667035.50	4590	332	-
387	15S-33E-06CAA2	-	363954.72	4667036.00	4590	185	-
388	15S-33E-07CCB1	-	363230.13	4665075.00	4769	54	-
389	15S-33E-07CCB2	-	363230.13	4665075.00	4768	227	-
390	15S-33E-07DCA1	-	364495.06	4665015.00	4775	670	493
391	15S-33E-08CCA1	-	365263.28	4664987.00	4770	572	570
392	15S-33E-08CCB1	-	364923.50	4664974.50	4770	600	>600
393	15S-33E-08CCC1	-	364919.22	4664753.00	4770	633	222
394	15S-33E-09DCC1	-	367728.69	4663754.50	5000	-	-
395	15S-33E-16BBB1	-	366571.13	4664609.50	4550	43	-
396	15S-33E-16DCC1	-	367302.66	4663083.50	4889	135	-
397	15S-33E-17BBD1	-	365124.66	4664227.50	4775	210	105
398	15S-33E-17BCD1	-	365240.72	4663806.50	4753	398	-
399	15S-33E-20AAD1	-	366378.34	4662730.50	4785	142	-
400	15S-33E-21CCC1	-	366534.91	4661401.50	4888	137	-
401	15S-34E-06ABB1	-	373953.16	4667559.00	5160	85	-
402	16S-30E-09ABB2	-	338401.77	4657656.29	4658	485	-
403	16S-32E-02BCD1	-	360015.16	4658226.00	4604	190	-
404	16S-32E-02CCC1	-	359861.94	4657458.00	4600	50	-
405	16S-32E-02CCC2	-	359861.94	4657458.00	4600	80	-
406	16S-32E-03ACD1	-	359325.66	4658240.00	4604	226	-
407	16S-32E-03CCD1	-	358753.03	4657412.00	4592	161	>161
408	16S-32E-04CDD1	-	357403.69	4657424.50	4588	300	>300
409	16S-32E-09BCB1	-	356584.25	4656844.50	4603	220	-
410	16S-32E-10BBD1	-	358564.25	4656959.00	4592	240	-
411	16S-32E-10CDA1	-	358843.41	4655966.00	4590	86	-
412	16S-32E-11BBA1	-	360066.94	4657361.00	4602	66	-
413	16S-32E-11BBB1	-	359843.34	4657317.00	4600	70	>70
414	16S-32E-13BAB1	-	361872.13	4655635.50	4610	400	158
415	16S-32E-13BCD1	-	361468.03	4654927.00	4620	322	-
416	16S-32E-14AAA1	-	361344.53	4655670.00	4609	300	-
417	16S-32E-14CBB1	-	359790.06	4654991.00	4576	210	-
418	16S-32E-14CCC1	-	359751.25	4654189.50	4562	49	-
419	16S-32E-14CCC2	-	359797.25	4654188.50	4580	44	-

***Table C.2** (continued).*

420	16S-32E-14DCC1	-	360626.22	4654194.00	4585	350	>350
421	16S-32E-15BAD1	-	358719.22	4655506.00	4570	110	-
422	16S-32E-15BBC1	-	358189.81	4655485.50	4579	130	-
423	16S-32E-15BCB1	-	358163.72	4655332.00	4573	90	-
424	16S-32E-16AAA1	-	358032.56	4655674.00	4575	100	-
425	16S-32E-16BAA1	-	357253.38	4655813.00	4576	100	-
426	16S-32E-16BCB1	-	356578.47	4655425.50	4585	400	-
427	16S-32E-16DDD1	-	358025.75	4654185.50	4570	355	>355; basalt 349-355
428	16S-32E-20DCB1	-	355678.69	4653037.00	4607	310	-
429	16S-32E-21AAB1	-	357655.50	4654077.00	4568	114	-
430	16S-32E-21ADD1	-	358068.56	4653451.50	4565	336	>336
431	16S-32E-21DAB1	-	357639.97	4653306.00	4570	105	-
432	16S-32E-22ADA1	-	359672.38	4653693.50	4570	142	>142
433	16S-32E-23CCC1	-	358318.25	4652706.00	4567	40	-
434	16S-32E-23CCC2	-	359843.00	4652689.00	4560	330	>330
435	16S-32E-24BDC1	-	361878.81	4653432.50	4605	790	>790
436	16S-32E-25CAB1	-	361769.50	4651662.00	4655	220	>220
437	16S-32E-26CAA1	-	360370.09	4651739.50	4562	220	-
438	16S-32E-27ACB1	-	358858.59	4652109.00	4564	79	-
439	16S-32E-27ACB2	-	358928.88	4652169.50	4565	54	-
440	16S-32E-27DAB1	-	359407.98	4651762.40	4559	230	>230
441	16S-32E-27DDB1	-	356745.51	4650687.19	4559	-	-
442	16S-32E-28BAA1	-	357117.84	4652514.00	4607	104	-
443	16S-32E-28BAA2	-	357221.84	4652501.00	4580	101	>101
444	16S-32E-28DAA1	-	358033.84	4651722.50	4555	358	>358; basalt 160-183
445	16S-33E-06CDB1	-	363689.75	4656827.50	4689	240	-
446	16S-33E-18BBC2	-	363162.92	4654628.94	4685	-	-
447	16S-33E-18BCA1	-	363161.78	4654493.00	4670	60	-
448	16S-33E-18BCD1	-	363248.31	4654213.50	4685	400	-
449	15S-33E-08CDA1	-	365610.11	4665013.12	4780	900	-
450	16S-32E-21DD1	-	358029.52	4652654.69	4570	165	-
451	16S-32E-27CCD1	-	358637.25	4651019.43	4560	80	-
452	16S-32E-18BBC1	-	363003.28	4654541.84	4670	430	-
453	16S-32E-18BCC1	-	363011.28	4654174.00	4670	125	-
454	16S-30E-16AAB	-	338761.70	4656018.31	4588	-	-
455	16S-30E-16CBB	-	337410.59	4655285.05	4571	-	-

***Table C.2** (continued).*

456	16S-31E-28ACC	-	347761.17	4651367.52	4500	-	-
457	16S-31E-29BCD	-	347139.93	4651262.28	4465	-	-
458	14S-32E-9DDB	-	358411.35	4674895.37	4895	-	-
459	14S-32E-36AAD	-	363190.05	4669127.20	4782	-	-
460	15S-30E-5ABD	-	337175.64	4668478.00	5055	-	-
461	16S-30E-16DAB	-	338813.61	4655229.77	4560	-	-
462	16S-31E-28BAB	-	347390.00	4652065.00	4511	-	-
463	16S-32E-25DAD	-	362878.00	4651429.00	4729	-	-
464	16S-32E-23CDD	-	360471.08	4652599.81	4572	-	-

Notes

\- No data

[1]Identifier used on all figures and plates and in text.

[2]Convention for specifying well location used by the U.S. Geological Survey; see figure D.1 for explanation.

[3]Point of Diversion convention for specifying well location used by Utah Division of Water Rights; see figure D.2 for explanation.

[4]Easting and northing in meters based on Universal Transverse Mercator Zone 12N projection, 1927 datum, used in GIS applications.

[5]From U.S. Geological Survey topographic maps.

APPENDIX D

Water-Chemistry Data

Table D.1. *Ground-water quality data for Curlew Valley from the Utah Division of Agriculture and Food (UDAF)*[1].

UDAF Sample No.	ID[2]	Sample Date	Easting[3]	Northing[3]	pH	Conductivity uS/cm	Total Dissolved Solids (mg/L)[4]	Al mg/L	As mg/L	B mg/L	Ba mg/L	Be mg/L	Ca mg/L	Cd mg/L	Cl mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L
2262	26	6/30/02	351927.86	4638043.10	7.30	22900	15244	-	0.06	1.59	0.08	0.0781	457.08	-	-	-	-	-	-	308.98
3096	26	6/30/03	351991.32	4638049.88	7.07	32300	23556	-	-	1.25	0.05	-	356.24	-	-	-	-	0.04	0.53	273.21
4340	26	6/30/04	351927.86	4638043.10	7.45	17240	10836	-	0.05	1.29	0.06	-	345.30	-	-	-	-	-	-	330.63
99225	26	08/25/1999	351997.00	4638052.00	7.10	37000	28175	-	-	1.21	0.06	---	465.00	-	12990.00	-	-	-	-	304.00
98090	26	08/26/1998	351995.38	4638051.00	6.90	34000	25191	-	---	1.19	---	---	277.00	---	10947.00	---	---	---	0.13	186.00
1406	26	08/29/2001	352069.11	4638048.24	7.77	23100	15408	-	0.04	1.39	0.07	-	290.12	-	-	-	-	-	0.08	218.63
156	26	08/30/2000	351927.86	4638043.10	7.00	2420	1419	0.840	0.37	1.72	0.36	-	391.24	-	-	0.03	-	2.76	0.40	379.79
2264	34	6/30/02	348783.29	4632792.49	7.30	7980	4592	-	-	0.62	0.10	0.1020	238.26	-	-	-	-	-	-	98.53
3097	34	6/30/03	348783.29	4632792.49	8.88	13230	7985	-	-	0.38	0.33	-	181.57	-	-	-	-	-	10.96	114.82
4341	34	6/30/04	348783.29	4632792.49	7.94	8061	4641	-	-	0.41	0.14	-	162.70	-	-	-	-	-	0.63	117.03
1408	34	08/29/2001	348783.29	4632792.49	8.19	8420	4861	-	-	0.60	0.09	-	165.23	-	-	-	-	-	-	96.84
2267	47	6/30/02	358976.63	4648447.50	7.70	1550	962	-	-	0.17	0.16	0.1591	113.62	-	375.10	-	-	-	0.04	12.71
3092	47	6/30/03	358976.63	4648447.50	7.55	1745	1064	-	-	0.14	0.11	-	84.51	-	379.93	-	-	-	-	10.73
96061	47	06/26/1996	358976.63	4648447.50	7.40	1700	1040	-	---	-	---	---	76.31	---	350.00	---	---	---	-	9.00
97129	47	08/05/1997	358976.63	4648447.50	7.20	2700	1569	-	---	-	---	---	77.10	---	349.00	---	---	---	-	9.00
161	58	08/30/2000	358347.70	4647917.37	7.00	1229	796	0.067	-	0.24	0.11	-	94.60	-	182.22	-	-	0.08	0.06	15.18
3105	66	6/30/03	352960.79	4647398.95	7.44	2290	1350	-	-	0.16	0.18	-	160.79	-	636.15	-	-	-	0.02	22.82
4348	66	6/30/04	352960.79	4647398.95	7.72	1989	1191	-	-	0.13	0.17	-	116.95	-	508.49	-	-	-	-	9.79
96089	66	06/26/1996	353029.91	4647407.94	7.30	2340	1377	-	---	-	---	---	135.24	---	569.00	---	---	---	-	15.00
1413	66	08/29/2001	353077.75	4647418.51	7.95	2280	1345	-	-	0.12	0.17	-	158.25	-	620.47	-	-	-	-	18.02
1433	66	08/29/2001	353101.14	4647415.47	8.38	3020	1741	-	-	0.12	0.23	-	90.99	-	-	-	-	-	0.03	26.21
164	66	08/30/2000	352960.79	4647398.95	7.00	2270	1340	-	-	0.11	0.16	-	163.54	-	548.96	-	-	-	-	23.46
3106	72	6/30/03	351655.75	4648256.50	8.02	4300	2444	-	-	0.16	0.14	-	121.98	-	512.49	-	-	-	0.07	10.85
4350	72	6/30/04	351655.75	4648256.50	7.96	1747	1065	-	-	0.11	0.22	-	108.80	-	446.14	-	-	-	-	7.18
98096	72	08/26/1998	351655.75	4648256.50	7.50	1720	1051	-	---	-	---	---	98.90	---	367.00	---	---	---	-	5.00
1415	72	08/29/2001	351720.75	4648247.64	8.37	1899	1144	-	-	0.12	0.15	-	106.71	-	531.55	-	-	-	0.02	11.03
3102	85	6/30/03	356990.54	4643995.12	8.06	1555	965	-	-	0.27	0.07	-	33.32	-	314.67	-	-	-	-	12.66
4338	85	6/30/04	356990.54	4643995.12	8.08	1455	913	-	0.02	0.23	0.04	-	28.57	-	308.75	-	-	-	-	10.24
2261	87	6/30/02	352627.52	4643944.41	7.90	2030	1213	-	-	0.18	0.09	0.0904	155.65	-	474.65	-	-	-	-	18.63
3103	87	6/30/03	352627.52	4643944.41	7.51	2140	1271	-	-	0.19	0.08	-	149.67	-	536.18	-	-	0.03	-	20.12
4339	87	6/30/04	352627.52	4643944.41	7.90	1900	1145	-	-	0.16	0.07	-	129.89	-	518.48	-	-	-	-	17.48
1409	87	08/29/2001	352712.53	4644043.78	8.80	1919	1155	-	-	0.17	0.08	-	116.33	-	496.04	-	-	-	0.07	18.77
157	87	08/30/2000	352627.52	4643944.41	7.00	2310	1361	0.104	0.04	0.18	0.09	-	116.94	-	548.44	-	-	0.07	0.46	30.46

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Sample Date	Easting[3]	Northing[3]	pH	Conductivity uS/cm	Total Dissolved Solids (mg/L)[4]	Al mg/L	As mg/L	B mg/L	Ba mg/L	Be mg/L	Ca mg/L	Cd mg/L	Cl mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L
158	87	08/30/2000	352535.51	4644157.41	7.00	2110	1255	-	-	0.17	0.11	-	119.73	-	445.09	-	-	0.05	0.22	23.27
3101	88	6/30/03	353707.00	4642517.00	7.80	1781	1082	-	-	0.15	0.06	-	93.64	-	345.00	-	-	-	-	15.02
4347	88	6/30/04	353707.00	4642517.00	8.00	1923	1157	-	-	0.16	0.06	-	87.62	-	373.88	-	-	-	0.02	14.98
99227	88	08/25/1999	353707.00	4642517.00	7.70	1800	1092	0.340	-	0.11	0.05	---	104.00	-	348.00	-	-	-	0.07	12.70
2268	94	6/30/02	350529.83	4647569.89	7.50	2920	1687	-	-	0.46	0.06	0.0607	218.96	-	-	-	-	2.59	0.06	25.34
3110	94	6/30/03	350529.83	4647569.89	7.73	2580	1505	-	-	0.30	0.04	-	141.86	-	616.92	-	-	0.06	-	21.01
4351	94	6/30/04	350529.83	4647569.89	7.91	2190	1297	-	-	0.25	0.04	-	154.03	-	561.62	-	-	0.09	-	17.34
4359	97	6/30/04	346518.94	4648202.38	7.99	2680	1558	-	-	0.13	0.24	-	92.18	-	-	-	-	-	-	28.05
96067	97	06/26/1996	346518.94	4648202.38	7.20	3350	1920	-	---	-	---	---	88.24	---	1152.00	---	---	---	-	23.00
97133	97	08/05/1997	346518.94	4648202.38	7.00	3380	1936	-	---	-	---	---	88.10	---	1109.00	---	---	---	-	23.00
99229	97	08/25/1999	346533.00	4648241.00	7.60	3250	1865	-	-	0.10	0.22	---	101.00	-	835.00	-	-	-	-	24.20
98098	97	08/26/1998	346530.88	4648241.00	7.40	3350	1920	0.160	---	-	---	---	88.70	---	848.00	---	---	---	0.10	23.00
99230	98	08/25/1999	344080.00	4647444.00	7.50	2700	1569	-	-	-	0.05	---	160.00	-	647.00	-	-	-	-	20.80
96068	101	06/26/1996	344127.44	4648223.00	7.10	7000	4001	-	---	-	---	---	520.38	---	2180.00	---	---	---	-	37.00
99231	101	08/25/1999	344091.00	4648245.00	7.50	3200	1838	-	-	0.11	0.05	---	178.00	-	774.00	-	-	-	-	25.00
98099	101	08/26/1998	344089.69	4648244.00	6.90	7900	4543	-	---	-	---	---	559.00	---	2256.00	---	---	---	-	41.00
174	101	08/30/2000	344058.04	4648214.01	7.50	3690	2106	-	-	0.11	0.08	-	289.84	-	-	-	-	-	0.16	41.11
177	101	08/30/2000	344021.60	4648236.01	7.00	2120	1260	-	-	0.09	0.10	-	154.53	-	557.44	-	-	-	-	17.67
3107	104	6/30/03	342497.18	4647724.73	7.80	2370	1393	-	-	0.13	0.08	-	158.12	-	671.46	-	-	0.03	-	26.37
4354	104	6/30/04	342497.18	4647724.73	7.88	2230	1319	-	-	0.12	0.07	-	154.35	-	689.80	-	-	-	-	24.64
2276	105	6/30/02	342852.86	4647753.59	7.60	1982	1188	-	-	0.12	0.12	0.1155	215.92	-	572.50	-	-	-	0.02	23.72
4360	105	6/30/04	342852.86	4647753.59	7.92	1739	1060	-	-	0.11	0.09	-	171.18	-	592.60	-	-	-	-	18.88
2271	107	6/30/02	342493.15	4649062.76	7.80	1024	691	-	-	0.07	0.29	0.2917	150.64	-	249.66	-	-	-	-	15.20
3111	107	6/30/03	342493.15	4649062.76	8.02	1109	734	-	-	0.07	0.26	-	124.38	-	255.22	-	-	-	0.03	12.59
4356	107	6/30/04	342493.15	4649062.76	8.07	1159	760	-	-	-	0.25	-	119.97	-	280.68	-	-	-	-	12.01
2270	108	6/30/02	343242.00	4649121.00	7.60	1901	1145	-	-	0.09	0.35	0.3546	241.07	-	573.18	-	-	-	0.02	23.31
3108	108	6/30/03	343242.00	4649121.00	7.61	1910	1150	-	-	0.09	0.32	-	228.98	-	599.26	-	-	0.02	-	20.19
4355	108	6/30/04	343242.00	4649121.00	7.82	1950	1171	-	-	0.08	0.32	-	183.65	-	681.55	-	-	-	-	20.05
99236	108	08/25/1999	343242.00	4649121.00	7.50	1600	988	-	-	-	0.17	---	171.00	-	368.00	-	-	-	-	14.20
1419	108	08/29/2001	343373.85	4649104.14	8.12	1667	1023	-	-	0.08	0.25	-	160.16	-	536.06	-	-	-	-	17.07
2275	110	6/30/02	340858.15	4647465.27	7.70	1106	733	-	-	0.09	0.31	0.3107	154.66	-	290.20	-	-	-	-	17.71
99245	116	08/25/1999	345020.00	4645844.00	7.70	2100	1250	-	-	-	0.12	---	108.00	-	462.00	-	-	-	0.51	13.90
98097	116	08/26/1998	344576.75	4645851.00	7.30	2250	1329	-	---	-	---	---	101.00	---	486.00	---	---	---	-	14.00
170	116	08/30/2000	344950.63	4645835.04	7.00	2040	1218	-	-	0.09	0.14	-	114.96	-	499.24	-	-	-	0.03	20.58

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Sample Date	Easting[3]	Northing[3]	pH	Conductivity uS/cm	Total Dissolved Solids (mg/L)[4]	Al mg/L	As mg/L	B mg/L	Ba mg/L	Be mg/L	Ca mg/L	Cd mg/L	Cl mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L
4358	117	6/30/04	345620.54	4645818.45	7.74	2180	1292	-	-	0.13	0.07	-	148.54	-	672.71	-	-	0.03	-	19.77
99244	117	08/25/1999	345647.00	4645795.00	7.30	2650	1542	-	-	0.11	0.05	---	165.00	-	651.00	-	-	-	-	16.70
98093	117	08/26/1998	345645.38	4645794.00	7.20	2780	1612	-	---	-	---	---	153.00	---	595.00	---	---	---	-	17.00
1431	117	08/29/2001	345700.13	4645839.85	8.01	2420	1419	-	-	0.13	0.07	-	147.30	-	643.61	-	-	-	0.07	17.13
99241	119	08/25/1999	342912.00	4645006.00	7.30	3100	1784	0.370	-	0.11	0.15	---	190.00	-	659.00	-	-	-	0.18	22.70
1425	119	08/29/2001	343007.53	4645002.64	8.00	2800	1622	-	-	0.13	0.16	-	183.27	-	-	-	-	-	-	23.65
99242	120	08/25/1999	341439.00	4645184.00	7.40	2750	1596	-	-	-	0.17	---	235.00	-	810.00	-	-	-	-	19.80
1427	120	08/29/2001	341491.09	4645131.75	7.98	2550	1489	-	-	0.12	0.19	-	209.05	-	-	-	-	-	-	20.62
96072	121	06/26/1996	343160.19	4643457.38	7.50	3300	1893	-	---	-	---	---	154.35	---	857.00	---	---	---	-	21.00
99240	121	08/25/1999	343217.00	4643533.00	7.40	3100	1784	-	-	0.10	0.09	---	164.00	-	836.00	-	-	-	-	19.00
1426	121	08/29/2001	343284.17	4643490.06	8.03	2870	1660	-	-	0.14	0.12	-	152.42	-	-	-	-	-	-	23.01
173	121	08/30/2000	343090.76	4643448.44	7.00	2990	1725	-	-	0.12	0.12	-	178.44	-	-	-	-	-	-	31.62
96075	126	06/26/1996	339304.19	4649082.38	7.50	610	480	-	---	-	---	---	62.27	---	-	---	---	---	71.40	-
97138	126	08/05/1997	339304.19	4649082.38	7.10	610	480	-	---	-	---	---	63.10	---	84.70	---	---	---	-	8.00
96074	134	06/26/1996	337579.00	4645655.88	7.60	1300	833	-	---	-	---	---	80.30	---	331.00	---	---	---	-	23.00
97137	134	08/05/1997	337579.00	4645655.88	7.50	1010	684	-	---	-	---	---	84.20	---	195.00	---	---	---	-	11.00
1429	135	08/29/2001	337590.96	4644218.73	8.37	2120	1260	0.042	-	0.25	0.28	-	95.19	-	605.73	-	-	-	0.02	19.26
1411	157	08/29/2001	357033.51	4649277.78	7.88	2640	1537	-	-	0.20	0.05	-	210.21	-	670.72	-	-	-	-	19.88
162	157	08/30/2000	356833.65	4649187.36	7.00	2840	1644	-	-	0.14	0.04	-	224.75	-	634.84	-	-	-	0.04	19.92
2266	158	6/30/02	357075.80	4649228.29	7.30	2550	1489	-	-	0.19	0.06	0.0554	290.82	-	681.34	-	-	-	0.02	19.38
99233	164	08/25/1999	344309.00	4651127.00	7.10	7200	4121	-	-	0.11	0.26	---	522.00	-	2368.00	-	-	-	0.06	43.00
2272	168	6/30/02	341720.22	4650395.19	7.60	1144	752	-	-	0.08	0.39	0.3909	164.09	-	297.46	-	-	-	-	19.28
3114	168	6/30/03	341720.22	4650395.19	7.94	1177	769	-	-	0.07	0.29	-	119.82	-	306.05	-	-	0.04	-	13.88
4357	168	6/30/04	341720.22	4650395.19	7.96	1344	855	-	-	0.07	0.36	-	142.90	-	355.41	-	-	-	-	16.01
96071	168	06/26/1996	341720.22	4650395.19	7.30	880	617	-	---	-	---	---	89.72	---	163.00	---	---	---	-	11.00
97136	168	08/05/1997	341720.22	4650395.19	7.10	910	632	-	---	0.02	---	---	93.80	---	172.00	---	---	---	-	13.00
99239	168	08/25/1999	341751.00	4650387.00	7.50	800	576	-	-	-	0.17	---	98.50	-	206.00	-	-	-	1.47	10.90
98104	168	08/26/1998	341749.31	4650386.50	7.50	950	653	-	---	-	---	---	94.10	---	187.00	---	---	---	-	13.00
1423	168	08/29/2001	341823.67	4650397.20	8.22	1094	727	-	-	-	0.29	-	118.88	-	295.56	-	-	-	-	14.73
172	168	08/30/2000	341650.74	4650386.18	7.00	1054	706	-	-	-	0.26	-	121.24	-	232.72	-	-	-	-	17.38
1421	169	08/29/2001	342579.79	4649112.17	8.54	1012	685	-	-	-	0.22	-	111.97	-	275.05	-	-	-	-	11.33
99232	170	08/25/1999	344157.00	4650264.00	7.20	5900	3354	-	-	0.13	0.23	---	269.00	-	1702.00	-	-	-	-	33.70
99237	170	08/25/1999	343699.00	4649959.00	7.40	5100	2894	-	-	-	0.59	---	421.00	-	1579.00	-	-	-	-	28.10
98101	170	08/26/1998	343721.34	4649897.50	7.10	5250	2980	-	---	-	---	---	388.00	---	1459.00	---	---	---	-	28.00

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Sample Date	Easting[3]	Northing[3]	pH	Conductivity uS/cm	Total Dissolved Solids (mg/L)[4]	Al mg/L	As mg/L	B mg/L	Ba mg/L	Be mg/L	Ca mg/L	Cd mg/L	Cl mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L
1420	170	08/29/2001	343794.06	4649933.93	7.95	5090	2889	-	-	0.11	0.74	-	457.88	-	-	-	-	-	0.04	34.31
176	170	08/30/2000	344087.60	4650254.99	7.60	5760	3273	-	-	0.14	0.30	-	297.68	-	-	-	-	-	0.13	37.32
98100	171	08/26/1998	345329.00	4649042.50	6.90	10400	6108	-	---	-	---	---	361.00	---	3132.00	---	---	---	-	73.00
175	171	08/30/2000	345272.28	4649103.37	7.40	9520	5547	0.041	-	0.17	0.29	-	483.35	-	-	-	-	-	0.03	91.32
96069	175	06/26/1996	348207.13	4650599.50	7.40	3400	1947	-	---	-	---	---	71.74	---	1010.00	---	---	---	-	8.00
97134	175	08/05/1997	348207.13	4650599.50	7.10	3380	1936	-	---	-	---	---	73.30	---	947.00	---	---	---	-	9.00
99246	175	08/25/1999	348170.00	4650721.00	7.70	3150	1811	-	-	-	0.08	---	72.60	-	846.00	-	-	-	-	8.18
1416	175	08/29/2001	348249.24	4650618.97	8.46	2890	1671	-	-	0.11	0.09	-	71.19	-	-	-	-	-	-	10.14
166	175	08/30/2000	348100.73	4650711.99	7.00	3070	1768	-	-	0.10	0.10	-	79.09	-	-	-	-	-	0.03	13.53
2269	178	6/30/02	349776.88	4649481.44	7.80	2860	1655	-	-	0.14	0.14	0.1369	99.52	-	-	-	-	-	0.60	11.38
4353	178	6/30/04	349776.88	4649481.44	8.05	2680	1558	-	-	0.13	0.11	-	79.34	-	-	-	-	-	-	11.81
96078	178	06/26/1996	349776.88	4649481.44	7.50	1600	988	-	---	-	---	---	76.98	---	261.00	---	---	---	-	4.00
96079	178	06/26/1996	349756.63	4649508.00	7.70	1800	1092	-	---	-	---	---	48.18	---	422.00	---	---	---	-	5.00
97140	178	08/05/1997	349776.88	4649481.44	7.20	1600	988	-	---	-	---	---	78.60	---	335.00	---	---	---	-	5.00
2274	181	6/30/02	339337.64	4650735.33	7.80	450	399	-	-	-	0.18	0.1835	73.22	-	59.60	-	-	-	-	10.96
2273	183	6/30/02	340038.47	4649941.23	7.90	523	436	-	-	-	0.20	0.2009	74.76	-	82.37	-	-	-	0.02	15.49
4342	201	6/30/04	347220.47	4630751.76	7.78	6160	3506	-	-	0.50	0.09	-	110.73	-	-	-	-	-	-	68.02
96082	206	06/26/1996	362936.63	4648107.38	7.10	1600	988	-	---	-	---	---	74.24	---	366.00	---	---	---	-	7.00
96083	206	06/26/1996	363010.59	4647854.00	7.30	1900	1145	-	---	-	---	---	82.89	---	457.00	---	---	---	-	7.00
96084	207	06/26/1996	361854.84	4647090.63	7.10	1700	1040	-	---	-	---	---	120.98	---	625.00	---	---	---	-	12.00
96073	210	06/26/1996	340797.66	4644234.06	7.20	1700	1040	-	---	-	---	---	164.65	---	420.00	---	---	---	-	13.00
1428	210	08/29/2001	340848.95	4644230.74	8.45	1678	1029	-	-	0.11	0.26	-	160.66	-	518.83	-	-	-	-	14.80
2263	213	6/30/02	351240.96	4635794.30	7.80	7980	4592	-	-	0.61	0.10	0.1003	219.17	-	-	-	-	-	-	87.58
4346	213	6/30/04	351240.96	4635794.30	7.78	13700	8307	-	-	0.69	0.11	-	273.86	-	-	-	-	-	0.28	220.83
2277	214	6/30/02	352164.80	4648224.80	7.50	1870	1129	-	-	0.14	0.19	0.1946	146.78	-	500.17	-	-	-	-	10.61
3109	214	6/30/03	352164.80	4648224.80	7.80	1996	1195	-	-	0.12	0.16	-	123.98	-	501.56	-	-	0.03	0.02	9.49
4349	214	6/30/04	352164.80	4648224.80	7.93	1946	1169	-	-	0.13	0.17	-	119.44	-	507.16	-	-	-	-	9.85
3112	216	6/30/03	344171.37	4650213.83	7.46	5180	2940	-	-	0.12	0.83	-	547.46	-	-	-	-	-	0.02	38.71
1424	217	08/29/2001	340069.02	4651237.55	8.38	533	441	-	-	-	0.12	-	65.67	-	82.71	-	-	-	-	6.82
171	217	08/30/2000	339935.11	4651206.36	7.00	584	467	-	-	-	0.12	-	72.00	-	61.56	-	-	-	-	8.89
96080	221	06/26/1996	345794.81	4651636.00	7.40	6300	3588	-	---	-	---	---	37.69	---	1908.00	---	---	---	-	16.00
99234	221	08/25/1999	345655.00	4651051.00	7.50	5550	3152	-	-	0.14	0.14	---	87.10	-	1644.00	-	-	-	1.71	26.00
98102	221	08/26/1998	345777.69	4651615.50	7.40	6600	3764	-	---	-	---	---	48.30	---	1960.00	---	---	---	0.22	17.00
1417	221	08/29/2001	345835.52	4651653.08	9.30	5880	3343	-	-	0.17	0.05	-	42.07	-	-	-	-	-	0.04	20.78

Table D.1. (continued)

UDAF Sample No.	ID[2]	Sample Date	Easting[3]	Northing[3]	pH	Conductivity uS/cm	Total Dissolved Solids (mg/L)[4]	Al mg/L	As mg/L	B mg/L	Ba mg/L	Be mg/L	Ca mg/L	Cd mg/L	Cl mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L
1418	221	08/29/2001	345803.11	4651043.58	8.36	5080	2883	-	-	0.18	0.17	-	91.70	-	-	-	-	-	0.15	30.20
168	221	08/30/2000	345709.65	4651606.98	7.00	5630	3198	0.058	-	0.16	0.05	-	43.73	-	-	-	-	-	0.38	53.04
169	221	08/30/2000	345585.65	4651041.99	7.00	5310	3014	-	-	0.17	0.33	-	96.69	-	-	-	-	-	0.33	39.67
99238	222	08/25/1999	342571.00	4651192.00	7.00	9400	5471	-	-	0.10	0.67	---	741.00	-	2927.00	-	-	-	-	47.60
98103	222	08/26/1998	342569.56	4651192.00	7.00	9200	5346	-	---	-	---	---	661.00	---	2879.00	---	---	---	-	51.00
96081	231	06/26/1996	360218.53	4647214.00	7.60	1300	833	-	---	-	---	---	57.65	---	271.00	---	---	---	-	26.00
163	231	08/30/2000	360149.64	4647205.01	7.00	1295	830	-	-	0.15	0.18	-	63.20	-	256.64	-	-	-	0.06	33.20
1432	233	08/29/2001	347546.39	4646791.62	8.17	2420	1419	-	-	0.11	0.15	-	179.61	-	665.58	-	-	-	-	14.61
1412	240	08/29/2001	358531.21	4647374.31	8.24	1724	1053	-	-	0.14	0.12	-	94.85	-	443.26	-	-	-	0.02	12.31
2259	243	6/30/02	357363.98	4646601.20	7.90	2750	1596	-	-	0.18	0.07	0.0655	159.20	-	666.16	-	-	-	-	19.42
3094	243	6/30/03	357363.98	4646601.20	8.39	1004	680	0.220	-	0.12	0.08	-	56.62	-	159.54	-	-	-	0.15	9.32
4336	243	6/30/04	357363.98	4646601.20	8.05	2048	1222	-	-	0.19	0.06	-	174.69	-	-	-	-	-	0.37	20.94
96064	243	06/26/1996	357363.44	4646599.81	7.50	3250	1865	-	---	-	---	---	170.63	---	790.00	---	---	---	-	18.00
97131	243	08/05/1997	357363.44	4646599.81	7.10	3340	1914	-	---	0.17	---	---	185.00	---	751.00	---	---	---	-	19.00
99224	243	08/25/1999	357358.00	4646613.00	7.60	3050	1757	-	-	0.15	0.07	---	180.00	-	718.00	-	-	-	-	18.40
98089	243	08/26/1998	357356.00	4646613.00	7.30	3350	1920	-	---	-	---	---	159.00	---	704.00	---	---	---	-	17.00
159	243	08/30/2000	357294.46	4646590.83	7.00	2910	1681	0.092	0.06	0.22	0.09	-	193.55	-	661.79	-	-	0.07	0.10	28.11
2260	244	6/30/02	357415.50	4646601.20	8.20	940	648	0.436	-	0.13	0.11	0.1080	68.35	-	164.83	-	-	-	0.43	9.83
3095	244	6/30/03	357415.50	4646601.20	7.73	2830	1638	-	-	0.19	0.06	-	183.97	-	701.50	-	-	-	-	23.16
4337	244	6/30/04	357415.50	4646601.20	8.63	956	656	0.558	-	0.12	0.09	-	52.20	-	149.06	-	-	-	-	7.70
1404	244	08/29/2001	357432.29	4646633.65	8.05	2740	1590	-	-	0.18	0.06	-	153.63	-	631.44	-	-	-	-	20.39
96088	246	06/26/1996	353111.31	4639803.13	7.30	3200	1838	-	---	0.18	---	---	55.25	---	875.00	---	---	---	-	33.00
96070	247	06/26/1996	349714.88	4647489.56	7.10	8400	4849	-	---	0.01	---	---	425.85	---	2293.00	---	---	---	0.06	26.00
97135	247	08/05/1997	349714.88	4647489.56	7.00	5500	3123	-	---	-	---	---	281.00	---	1262.00	---	---	---	-	23.00
99228	247	08/25/1999	349592.00	4647455.00	7.40	3700	2111	-	-	0.21	0.05	---	193.00	-	726.00	-	-	-	0.06	18.30
98094	247	08/26/1998	349590.34	4647454.50	7.20	4500	2555	-	---	-	---	---	211.00	---	998.00	---	---	---	-	19.00
1414	247	08/29/2001	349690.45	4647413.26	8.17	3420	1958	-	-	0.28	0.05	-	170.95	-	-	-	-	0.03	-	19.58
165	247	08/30/2000	349645.65	4647480.58	7.00	3370	1931	-	0.08	0.23	0.04	-	198.58	-	-	-	-	0.09	0.71	26.26
4352	259	6/30/04	350605.43	4648970.82	8.05	1530	952	-	-	0.08	0.14	-	83.12	-	397.87	-	-	-	-	5.77
96077	259	06/26/1996	350593.75	4648966.31	7.70	1600	988	-	---	-	---	---	103.99	---	391.00	---	---	---	-	4.00
98095	259	08/26/1998	350599.50	4648970.50	7.40	1750	1066	-	---	-	---	---	112.00	---	612.00	---	---	---	-	5.00
1422	261	08/29/2001	341431.93	4649137.75	8.27	995	676	-	-	-	0.20	-	183.27	-	253.61	-	-	-	0.03	15.42
154	265	08/30/2000	357103.02	4646707.02	7.40	1282	823	1.151	-	0.18	0.10	-	66.10	-	204.74	-	-	0.07	0.82	14.41
160	266	08/30/2000	358679.07	4648372.00	7.00	1699	1040	0.065	0.04	0.15	0.15	-	92.18	-	365.93	-	-	0.07	0.10	15.92

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Sample Date	Easting[3]	Northing[3]	pH	Conductivity uS/cm	Total Dissolved Solids (mg/L)[4]	Al mg/L	As mg/L	B mg/L	Ba mg/L	Be mg/L	Ca mg/L	Cd mg/L	Cl mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L
167	267	08/30/2000	347394.34	4652065.34	7.00	3340	1914	-	-	0.10	0.10	-	82.32	-	-	-	-	-	-	13.34
3104	268	6/30/03	352938.08	4648332.29	7.78	2120	1260	-	-	0.15	0.21	-	154.51	-	607.00	-	-	0.02	-	17.41
1405	268	08/29/2001	357251.57	4646745.70	8.88	1149	755	0.183	-	0.16	0.10	-	67.35	-	217.38	-	-	-	0.14	10.69
99222	269	08/25/1999	358748.00	4648381.00	7.70	1600	988	-	-	0.12	0.11	---	76.60	-	337.00	-	-	-	-	8.94
98087	269	08/26/1998	358746.06	4648381.50	7.20	1720	1051	-	---	-	---	---	76.80	---	320.00	---	---	---	-	9.00
1410	269	08/29/2001	358771.74	4648380.10	8.30	1495	933	-	-	0.17	0.13	-	99.22	-	374.78	-	-	-	0.04	12.89
99243	270	08/25/1999	342810.00	4647597.00	7.40	2250	1329	-	-	-	0.07	---	178.00	-	568.00	-	-	-	-	17.20
1430	270	08/29/2001	342924.35	4647569.40	8.08	1867	1127	0.041	-	0.10	0.08	-	160.50	-	557.41	-	-	-	0.03	17.88
99223	271	08/25/1999	357172.00	4646716.00	8.10	1375	871	0.180	-	0.13	0.08	---	72.00	-	217.00	-	-	-	0.11	9.58
98088	271	08/26/1998	357170.84	4646716.00	7.70	1380	874	0.540	---	-	---	---	70.50	---	224.00	---	---	---	0.30	9.00
96063	272	06/26/1996	356640.25	4646592.50	7.40	1450	910	0.810	---	-	---	---	75.15	---	240.00	---	---	---	0.39	10.00
97130	272	08/05/1997	356640.25	4646592.50	7.50	1500	936	-	---	-	---	---	82.40	---	246.00	---	---	---	-	11.00
96066	273	06/26/1996	347439.44	4646757.63	7.50	2050	1224	-	---	-	---	---	129.13	---	451.00	---	---	---	-	12.00
97132	273	08/05/1997	347439.44	4646757.63	7.00	2250	1329	-	---	-	---	---	142.00	---	487.00	---	---	---	-	12.00
98092	273	08/26/1998	347446.31	4646754.00	7.20	2450	1435	-	---	-	---	---	158.00	---	577.00	---	---	---	-	13.00
96085	274	06/26/1996	362884.44	4650957.19	6.90	1900	1145	-	---	-	---	---	135.22	---	469.00	---	---	---	-	17.00
96062	368	06/26/1996	340502.59	4659883.50	7.30	1750	1066	-	---	-	---	---	119.41	---	643.00	---	---	---	-	12.00
96086	434	06/26/1996	359728.13	4652709.50	7.20	1370	869	0.190	---	0.15	---	---	95.16	---	167.00	---	---	---	-	23.00
96087	440	06/26/1996	359405.81	4651776.00	7.80	2300	1356	-	---	0.32	---	---	96.21	---	271.00	---	---	---	-	11.00
96076	454	06/26/1996	338650.34	4656044.00	7.40	500	424	-	---	-	---	---	62.18	---	48.10	---	---	---	-	5.00
97139	454	08/05/1997	338650.34	4656044.00	7.30	490	419	-	---	-	---	---	84.20	---	49.70	---	---	---	-	5.00
2265	Baker	6/30/02	339728.52	4620045.56	8.10	3520	2013	-	-	0.29	0.12	0.1192	147.41	-	-	-	-	-	0.05	46.29
3098	Baker	6/30/03	339728.52	4620045.56	8.89	3550	2029	-	-	0.28	0.09	-	105.89	-	-	-	-	-	-	44.51
3099	W. Loco.	6/30/03	339324.85	4620707.48	8.89	5880	3343	-	-	0.50	0.17	-	122.88	-	-	0.54	-	-	-	88.93
3100	Bar M	6/30/03	340231.43	4619170.74	8.05	4070	2316	-	-	0.24	0.07	-	120.69	-	-	-	-	-	-	37.89
96065	Baker	06/26/1996	339748.69	4620001.69	7.40	4000	2277	-	---	-	---	---	124.10	---	1121.00	---	---	---	-	28.00
99226	Baker	08/25/1999	339811.00	4620005.00	7.50	3900	2222	1.380	-	0.16	0.08	---	150.00	-	1207.00	-	-	-	-	27.30
98091	Baker	08/26/1998	339808.59	4620004.00	7.30	4120	2343	-	---	0.20	---	---	129.00	---	1171.00	---	---	---	-	29.00
1407	Baker	08/29/2001	339842.09	4620025.39	8.62	3710	2117	-	-	0.28	0.11	-	135.51	-	-	-	-	-	-	43.50
155	Baker	08/30/2000	339679.17	4619992.98	7.30	3620	2067	0.106	0.07	0.28	0.14	-	123.50	-	-	-	-	0.09	0.30	48.10

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Li mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Na mg/L	Ni mg/L	NO_3 as N mg/L	P mg/L	Pb mg/L	S mg/L	SO_4[4] mg/L	Se mg/L	Si mg/L	Sr mg/L	V mg/L	Zn mg/L	SAR[5]	HCO_3 meq/L	HCO_3[4] mg/L	Temp °C	Meas. Hardness grns/gal
2262	26	3.63	163.23	0.10	---	8947.56	---	-	-	-	197.99	594.56	-	---	---	---	0.06	91.40	4.44	270.88	17.00	36.30
3096	26	28.59	137.31	0.09	---	7413.59	---	-	-	-	158.36	475.56	-	---	---	---	0.04	84.50	4.63	282.48	20.00	28.90
4340	26	2.91	127.45	0.10	---	6816.70	---	-	-	-	163.40	490.69	-	---	---	---	-	79.60	4.93	300.78	21.50	27.60
99225	26	---	175.00	0.06	-	7.00	355.00	-	-	-	-	-	182.00	-	7.11	8.13	---	-	73.80	4502.54	4.82	37
98090	26	---	115.00	0.09	-	5267.00	---	-	-	---	132.00	396.40	---	---	7.08	---	-	67.12	5.00	305.05	---	22.92
1406	26	2.05	109.44	0.13	0.01	4563.85	-	0.20	-	-	134.16	402.88	-	---	---	-	0.06	57.92	4.27	260.39	16.80	23.37
156	26	-	164.40	0.13	2.38	5067.30	-	1.00	-	0.11	167.65	503.45	-	---	---	-	0.27	54.20	4.58	279.30	17.10	32.50
2264	34	0.82	134.12	-	---	2152.22	---	1.30	-	-	88.03	264.35	-	---	---	---	0.12	27.60	2.95	179.98	22.90	21.80
3097	34	7.52	111.05	1.28	---	2437.40	---	0.30	-	-	39.72	119.28	-	---	---	---	1.91	35.10	0.64	39.05	16.50	17.10
4341	34	0.71	105.61	0.35	---	2253.48	---	-	-	-	52.29	157.03	-	---	---	---	0.40	33.80	4.56	278.21	19.70	15.70
1408	34	0.63	109.42	-	-	1544.60	-	0.80	-	-	73.96	222.11	-	---	---	-	0.12	22.87	2.99	182.27	23.30	16.06
2267	47	0.13	48.51	-	---	262.79	---	0.50	-	-	31.54	94.71	-	---	---	---	0.14	5.20	4.21	256.85	13.20	9.50
3092	47	0.69	35.49	-	---	226.82	---	0.30	-	-	22.75	68.32	-	---	---	---	-	5.20	5.33	325.18	12.80	7.00
96061	47	---	32.10	-	---	209.00	---	0.30	-	---	15.97	47.95	---	17.06	1.24	---	-	5.06	4.30	262.34	---	6.34
97129	47	---	32.40	-	---	219.00	---	0.10	-	---	24.80	74.47	-	---	1.23	---	0.84	5.28	4.11	250.75	---	6.40
161	58	-	40.44	-	0.10	131.99	-	0.80	-	-	24.20	72.68	-	---	---	-	0.18	2.90	5.43	331.41	19.30	7.90
3105	66	1.22	76.65	-	---	254.31	---	1.70	-	-	70.10	210.51	-	---	---	---	-	4.10	3.68	224.52	18.30	13.90
4348	66	0.06	51.28	-	---	206.19	---	1.00	-	-	40.39	121.29	-	---	---	---	0.04	4.00	3.72	226.96	20.30	9.80
96089	66	---	51.75	-	---	233.00	---	2.00	-	---	37.08	111.35	---	19.70	1.90	---	-	4.32	3.70	225.74	---	10.94
1413	66	0.10	62.49	-	-	239.27	-	2.70	-	-	55.86	167.74	-	---	---	-	0.06	4.07	3.49	213.05	18.10	12.91
1433	66	0.11	34.11	-	-	487.56	-	0.70	-	-	18.95	56.90	-	---	---	-	-	11.06	3.24	197.66	24.20	7.32
164	66	0.16	70.09	-	-	260.10	-	2.30	-	-	56.66	170.15	-	---	---	-	-	4.30	3.69	224.88	17.60	13.70
3106	72	0.69	54.59	-	---	250.22	---	1.10	2.83	-	38.71	116.25	-	---	---	---	-	4.70	3.47	211.70	27.30	10.30
4350	72	0.05	49.52	-	---	170.58	---	1.00	-	-	22.73	68.26	-	---	---	---	-	3.40	3.40	207.43	20.50	9.30
98096	72	---	46.70	-	-	172.00	---	0.80	-	---	13.80	41.44	---	---	1.74	---	-	3.57	3.57	217.81	---	8.51
1415	72	0.07	53.93	-	-	193.75	-	1.60	-	-	36.51	109.64	-	---	---	-	-	3.81	5.28	321.94	22.40	9.39
3102	85	1.12	14.51	-	---	297.18	---	0.40	-	-	24.05	72.22	-	---	---	---	-	10.80	4.55	277.60	18.80	2.80
4338	85	0.10	12.29	-	---	253.50	---	-	-	-	23.05	69.22	-	---	---	---	0.06	10.00	4.75	289.80	18.60	2.40
2261	87	0.12	73.14	-	---	294.38	---	1.00	-	-	94.06	282.46	-	---	---	---	-	4.90	4.19	255.63	13.90	13.40
3103	87	1.14	69.41	-	---	311.43	---	0.40	-	-	90.65	272.22	-	---	---	---	0.06	5.30	4.48	273.32	21.80	12.80
4339	87	0.10	59.02	-	---	282.27	---	-	-	-	75.71	227.36	-	---	---	---	-	5.20	1.38	84.19	14.10	11.00
1409	87	0.09	62.55	0.06	-	237.69	-	0.80	-	-	94.91	285.01	-	---	---	-	0.18	4.42	3.80	231.98	14.30	10.46
157	87	-	57.37	-	0.13	315.44	-	0.90	-	-	63.43	190.48	-	---	---	-	0.04	6.00	4.33	263.93	15.60	10.20
158	87	-	59.81	0.03	0.11	267.09	-	0.40	-	-	75.21	225.85	-	---	---	-	0.24	5.00	4.33	263.93	18.00	10.50

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Li mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Na mg/L	Ni mg/L	NO_3 as N mg/L	P mg/L	Pb mg/L	S mg/L	SO_4[4] mg/L	Se mg/L	Si mg/L	Sr mg/L	V mg/L	Zn mg/L	SAR[5]	HCO_3 meq/L	HCO_3[4] mg/L	Temp °C	Meas. Hardness grns/gal
3101	88	1.08	82.64	-	---	160.13	---	0.70	-	-	72.91	218.95	-	---	---	---	0.31	2.90	3.82	233.06	23.20	10.30
4347	88	0.10	73.16	-	---	143.95	---	-	-	-	79.00	237.24	-	---	---	---	0.19	2.70	4.10	250.14	19.00	9.40
99227	88	---	77.40	-	1.05	140.00	-	0.74	-	-	80.50	241.74	-	19.70	1.24	---	0.93	2.50	4.28	261.12	---	10.61
2268	94	0.20	150.13	-	---	670.34	---	7.30	-	-	278.28	835.67	-	---	---	---	0.07	8.50	4.93	300.78	21.10	21.60
3110	94	1.26	104.47	-	---	361.98	---	2.70	-	-	158.67	476.49	-	---	---	---	0.04	5.60	4.77	291.02	20.40	14.40
4351	94	0.10	85.37	-	---	277.74	---	4.80	-	-	146.66	440.42	-	---	---	---	0.05	4.50	4.97	303.22	22.90	14.00
4359	97	0.12	35.62	-	---	463.45	---	-	-	-	21.54	64.68	-	---	---	---	-	10.40	3.61	220.25	22.50	7.50
96067	97	---	32.91	-	---	484.00	---	0.30	-	---	14.25	42.79	---	27.53	1.51	---	-	11.16	3.60	219.64	---	7.08
97133	97	---	33.20	-	---	493.00	---	0.30	-	---	22.10	66.37	-	---	1.54	---	-	11.36	3.39	206.82	---	7.09
99229	97	---	33.30	0.07	1.57	512.00	-	0.37	-	-	37.80	113.51	-	25.90	1.47	---	-	11.30	3.93	239.77	24.00	7.85
98098	97	---	33.80	0.03	-	499.00	---	0.40	-	---	16.70	50.15	---	---	1.50	---	-	11.43	3.57	217.81	---	7.16
99230	98	---	44.00	-	0.43	346.00	-	2.41	-	-	70.20	210.81	-	27.00	1.37	---	-	6.20	4.32	263.56	24.00	11.93
96068	101	---	155.44	-	---	488.00	---	4.00	-	---	25.44	76.40	---	30.11	3.83	---	-	4.82	2.30	140.32	---	39.52
99231	101	---	50.50	-	-	385.00	-	3.41	-	-	89.20	267.87	-	28.90	1.47	---	-	6.60	4.82	294.07	23.00	13.36
98099	101	---	179.00	-	-	579.00	---	4.00	-	---	31.80	95.50	---	---	4.20	---	-	5.45	2.50	152.53	---	43.16
174	101	0.22	93.41	-	-	531.92	-	3.50	-	-	82.17	246.76	-	---	---	-	-	7.00	4.15	253.31	22.00	22.40
177	101	0.09	42.72	-	-	194.04	-	3.70	-	-	29.22	87.74	-	---	---	-	-	3.60	3.12	190.53	22.10	11.50
3107	104	0.93	48.71	-	---	330.34	---	1.70	-	-	70.14	210.63	-	---	---	---	0.07	5.90	4.09	249.53	21.10	12.10
4354	104	0.09	46.67	-	---	270.15	---	3.10	-	-	63.92	191.95	-	---	---	---	-	4.90	4.47	272.71	21.00	11.80
2276	105	0.08	61.45	-	---	275.72	---	3.70	-	-	41.05	123.27	-	---	---	---	-	4.30	2.91	177.54	18.50	16.20
4360	105	0.06	47.89	-	---	187.95	---	3.70	-	-	33.25	99.85	-	---	---	---	-	3.30	3.11	189.74	18.10	12.80
2271	107	-	37.03	-	---	54.34	---	2.20	-	-	14.82	44.50	-	---	---	---	-	1.00	2.31	140.93	19.20	11.00
3111	107	0.22	29.51	-	---	47.92	---	1.50	-	-	13.09	39.31	-	---	---	---	0.04	1.00	2.46	150.08	17.80	9.00
4356	107	-	29.75	-	---	45.26	---	1.50	-	-	12.04	36.16	-	---	---	---	-	1.00	2.58	157.41	18.00	8.80
2270	108	0.06	67.14	-	---	137.09	---	4.90	-	-	21.86	65.65	-	---	---	---	-	2.00	2.23	136.05	20.20	18.00
3108	108	0.41	55.84	-	---	121.86	---	3.00	-	-	18.90	56.76	-	---	---	---	-	1.90	2.26	137.88	20.20	16.70
4355	108	-	58.02	-	---	126.13	---	6.20	-	-	19.72	59.22	-	---	---	---	-	2.10	2.34	142.76	19.60	14.10
99236	108	---	36.60	-	1.22	59.60	-	3.84	-	-	29.80	89.49	-	26.60	0.89	---	-	1.10	2.50	152.53	23.00	12.14
1419	108	-	46.94	-	-	93.79	-	4.70	-	-	17.46	52.44	-	---	---	-	-	1.68	2.25	137.30	20.90	12.11
2275	110	-	42.28	-	---	73.96	---	0.60	-	-	14.69	44.11	-	---	---	---	-	1.40	2.43	148.25	19.80	11.50
99245	116	---	38.10	-	-	259.00	-	0.53	-	-	27.60	82.88	-	23.10	1.25	---	-	5.50	4.46	272.10	21.00	8.54
98097	116	---	38.40	-	-	283.00	---	0.50	-	---	22.30	66.97	---	---	1.28	---	-	6.08	4.28	261.12	---	8.15
170	116	0.14	47.60	-	-	289.94	-	0.60	-	-	33.36	100.17	-	---	---	-	-	5.70	4.33	263.93	17.90	9.50
4358	117	0.10	55.92	-	---	249.35	---	1.70	-	-	54.96	165.04	-	---	---	---	-	4.40	4.51	275.16	18.00	12.00

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Li mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Na mg/L	Ni mg/L	NO_3 as N mg/L	P mg/L	Pb mg/L	S mg/L	SO_4[4] mg/L	Se mg/L	Si mg/L	Sr mg/L	V mg/L	Zn mg/L	SAR[5]	HCO_3 meq/L	HCO_3[4] mg/L	Temp °C	Meas. Hardness grns/gal
99244	117	---	60.00	-	-	284.00	-	0.28	-	-	57.00	171.17	-	19.60	2.14	---	-	4.80	5.00	305.05	17.00	13.16
98093	117	---	62.50	-	-	302.00	---	1.80	-	---	48.70	146.25	---	---	2.24	---	-	5.20	4.82	294.07	---	12.60
1431	117	0.09	58.92	0.02	-	277.51	-	1.20	-	-	50.93	152.95	-	---	---	-	-	4.89	4.29	261.57	15.20	12.06
99241	119	---	53.90	0.07	1.55	326.00	-	1.26	-	-	54.80	164.56	-	26.60	1.49	---	-	5.40	3.75	228.79	21.00	14.26
1425	119	0.08	57.45	-	-	304.85	-	1.20	-	-	38.65	116.08	-	---	---	-	-	5.03	3.26	198.84	20.20	14.08
99242	120	---	64.30	-	-	165.00	-	0.84	-	-	24.20	72.67	-	25.60	1.58	---	-	2.50	2.86	174.49	19.00	17.50
1427	120	0.06	68.26	-	-	165.17	-	0.90	-	-	30.16	90.57	-	---	---	-	-	2.54	2.58	157.42	17.80	16.22
96072	121	---	49.13	-	---	386.00	---	1.10	-	---	40.62	121.98	---	25.98	1.44	---	-	6.93	4.30	262.34	---	11.90
99240	121	---	43.90	-	-	393.00	-	0.95	-	-	44.30	133.03	-	22.00	1.21	---	-	7.00	4.23	258.07	20.00	12.16
1426	121	0.09	51.09	-	-	373.71	-	1.20	-	-	50.95	153.01	-	---	---	-	-	6.69	3.88	236.72	18.20	11.90
173	121	0.19	63.53	-	-	446.07	-	2.30	-	-	48.12	144.50	-	---	---	-	-	7.30	3.98	242.64	18.20	14.20
96075	126	---	16.48	7.00	---	30.43	---	-	0.60	---	-	-	---	7.87	30.48	---	0.46	0.89	3.20	195.23	---	4.61
97138	126	---	11.70	-	---	19.00	---	0.40	-	---	15.80	47.45	-	---	0.47	---	-	0.58	2.50	152.53	---	4.37
96074	134	---	30.59	-	---	105.00	---	0.40	-	---	8.43	25.32	---	37.27	1.27	---	-	2.53	2.90	176.93	---	6.48
97137	134	---	32.00	-	---	60.80	---	1.00	-	---	18.10	54.35	-	---	0.89	---	-	1.43	2.50	152.53	---	6.80
1429	135	0.18	40.25	0.03	-	277.20	-	0.40	-	-	16.88	50.71	-	---	---	-	-	6.00	3.45	210.68	21.70	7.92
1411	157	0.10	96.08	-	-	336.44	-	0.90	-	-	121.54	364.98	-	---	---	-	0.11	4.82	4.37	266.31	16.50	17.91
162	157	0.15	87.48	-	-	303.07	-	0.50	0.15	-	134.15	402.86	-	---	---	-	0.04	4.30	4.60	280.52	18.80	18.30
2266	158	0.17	103.85	-	---	383.18	---	0.70	-	-	158.63	476.37	-	---	---	---	0.06	4.90	4.37	266.61	19.40	23.10
99233	164	---	124.00	0.06	0.73	678.00	-	3.71	-	-	37.70	113.21	-	30.80	4.20	---	-	6.90	2.14	130.56	27.00	37.78
2272	168	-	40.91	-	---	59.16	---	1.00	-	-	13.79	41.41	-	---	---	---	-	1.10	2.29	139.71	18.60	12.00
3114	168	0.23	29.22	-	---	46.49	---	1.00	-	-	11.71	35.17	-	---	---	---	0.05	1.00	2.36	143.98	19.10	8.70
4357	168	-	35.60	-	---	53.61	---	1.00	-	-	12.77	38.35	-	---	---	---	-	1.00	2.59	158.02	18.40	10.40
96071	168	---	21.03	-	---	34.97	---	1.50	-	---	7.93	23.81	---	31.27	0.55	---	-	0.86	2.90	176.93	---	6.48
97136	168	---	22.40	-	---	35.90	---	1.20	-	---	12.60	37.84	-	---	0.58	---	-	0.86	2.32	141.54	---	6.80
99239	168	---	20.10	0.10	2.48	29.40	-	0.98	-	-	42.10	126.43	-	25.70	0.49	---	-	0.70	2.50	152.53	22.00	6.94
98104	168	---	23.10	-	-	39.70	---	1.20	-	---	7.70	23.12	---	---	0.58	---	-	0.95	2.57	156.80	---	6.85
1423	168	-	30.56	-	-	43.65	-	1.10	-	-	10.81	32.46	-	---	---	-	-	0.92	2.29	139.66	20.10	8.74
172	168	-	31.97	-	-	47.73	-	1.30	-	-	8.99	27.00	-	---	---	-	-	1.00	2.56	156.25	18.70	9.00
1421	169	-	27.12	-	-	39.69	-	2.30	-	-	11.95	35.89	-	---	---	-	-	0.87	2.33	142.03	18.20	8.13
99232	170	---	64.00	-	0.55	820.00	-	31.20	-	-	47.60	142.94	-	29.80	2.34	---	-	11.70	2.86	174.49	26.00	19.47
99237	170	---	93.90	-	-	389.00	-	3.32	-	-	14.70	44.14	-	27.30	2.70	---	-	4.50	2.32	141.54	24.00	30.11
98101	170	---	106.00	-	-	371.00	---	3.20	-	---	13.20	39.64	---	---	2.91	---	-	4.31	2.21	134.83	---	28.89
1420	170	0.09	122.05	-	-	431.46	-	3.30	-	-	24.57	73.78	-	---	---	-	-	4.63	1.90	115.99	21.90	33.91

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Li mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Na mg/L	Ni mg/L	NO_3 as N mg/L	P mg/L	Pb mg/L	S mg/L	SO_4[4] mg/L	Se mg/L	Si mg/L	Sr mg/L	V mg/L	Zn mg/L	SAR[5]	HCO_3 meq/L	HCO_3[4] mg/L	Temp °C	Meas. Hardness grns/gal
176	170	0.28	81.69	0.03	-	790.83	-	22.50	-	-	39.09	117.40	-	---	---	-	-	10.50	2.43	147.95	21.70	22.20
98100	171	---	106.00	-	-	1437.00	---	0.80	-	---	33.50	100.60	---	---	5.03	---	-	17.09	3.03	184.86	---	27.31
175	171	0.76	136.03	0.02	-	1383.82	-	1.30	-	-	34.29	102.98	-	---	---	-	-	14.30	2.66	162.16	25.60	36.20
96069	175	---	29.61	-	---	529.00	---	0.40	-	---	15.09	45.32	---	9.57	2.29	---	-	13.26	3.60	219.64	---	5.93
97134	175	---	30.50	-	---	543.00	---	0.30	-	---	19.90	59.76	-	---	2.32	---	-	13.45	3.57	217.81	---	6.07
99246	175	---	28.00	-	-	502.00	-	1.85	-	-	16.40	49.25	-	8.05	1.98	---	-	12.70	3.75	228.79	25.00	5.88
1416	175	0.13	30.22	-	-	483.95	-	0.60	-	-	17.45	52.39	-	---	---	-	-	12.11	3.41	208.31	24.80	5.93
166	175	0.27	35.27	-	-	528.54	-	0.70	-	-	16.17	48.56	-	---	---	-	-	12.40	3.84	234.34	22.80	6.70
2269	178	0.21	42.05	-	---	720.16	---	0.60	-	-	23.96	71.95	-	---	---	---	-	15.30	3.36	204.99	24.20	8.30
4353	178	0.15	34.43	-	---	534.48	---	-	-	-	20.07	60.27	-	---	---	---	-	12.60	3.79	231.23	23.60	6.70
96078	178	---	36.74	-	---	179.00	---	0.70	-	---	10.99	33.00	---	9.69	1.00	---	-	4.20	3.20	195.23	---	6.65
96079	178	---	21.60	-	---	300.00	---	0.30	-	---	11.08	33.27	---	9.03	1.34	---	-	9.02	3.60	219.64	---	4.08
97140	178	---	38.00	-	---	183.00	---	0.80	-	---	16.10	48.35	-	---	1.59	---	-	4.24	3.21	195.84	---	6.82
2274	181	-	17.16	-	---	24.61	---	0.60	-	-	9.57	28.74	-	---	---	---	-	0.70	2.46	150.08	17.20	5.30
2273	183	-	18.91	-	---	33.94	---	1.00	-	-	10.44	31.35	-	---	---	---	-	0.90	2.37	144.59	21.40	5.50
4342	201	0.45	65.31	0.40	---	1333.46	---	-	-	-	69.06	207.39	-	---	---	---	0.04	24.80	3.51	214.15	19.80	10.30
96082	206	---	32.81	-	---	208.00	---	0.10	-	---	12.79	38.41	---	7.68	1.84	---	-	5.05	3.20	195.23	---	6.26
96083	206	---	35.44	-	---	251.00	---	-	-	---	13.99	42.01	---	7.27	2.14	---	-	5.81	3.60	219.64	---	6.92
96084	207	---	56.16	-	---	350.00	---	0.70	-	---	69.29	208.08	---	22.41	2.15	---	-	6.59	3.60	219.64	---	10.36
96073	210	---	43.89	-	---	87.36	---	0.80	-	---	15.19	45.62	---	26.87	1.01	---	-	1.56	2.90	176.93	---	12.20
1428	210	-	49.94	-	-	94.62	-	0.80	-	-	21.86	65.65	-	---	---	-	0.08	1.67	2.46	150.32	16.80	12.32
2263	213	0.82	136.45	-	---	2176.57	---	1.40	-	-	84.59	254.02	-	---	---	---	-	28.40	2.99	182.42	19.90	20.80
4346	213	1.24	129.92	0.10	---	3173.91	---	-	-	-	95.42	286.55	-	---	---	---	0.10	39.50	2.76	168.39	20.40	23.60
2277	214	0.13	67.97	-	---	258.20	---	1.50	-	-	39.93	119.91	-	---	---	---	-	4.40	3.32	202.55	21.20	12.60
3109	214	0.69	55.30	-	---	252.10	---	0.70	-	-	36.44	109.43	-	---	---	---	0.06	4.70	3.47	211.70	20.70	10.50
4349	214	0.07	53.05	-	---	216.70	---	1.20	-	-	41.97	126.04	-	---	---	---	-	4.10	3.66	223.30	20.90	10.10
3112	216	1.00	129.76	-	---	505.26	---	2.10	-	-	27.22	81.74	-	---	---	---	-	5.00	2.01	122.63	21.80	39.60
1424	217	-	15.71	-	-	20.25	-	0.90	-	-	9.83	29.52	-	---	---	-	-	0.58	2.56	156.23	17.30	4.76
171	217	-	18.39	-	-	25.66	-	1.40	-	-	8.83	26.53	-	---	---	-	-	0.70	2.66	162.16	16.90	5.30
96080	221	---	33.77	0.13	---	1094.00	---	0.30	-	---	2.30	6.89	---	2.07	1.42	---	-	31.17	1.10	67.11	---	4.18
99234	221	---	27.00	-	-	988.00	-	0.20	-	-	16.60	49.85	-	20.70	2.65	---	-	23.70	3.03	184.86	28.00	6.67
98102	221	---	37.60	0.07	-	1175.00	---	-	-	---	7.60	22.82	---	---	2.23	---	-	30.80	1.50	91.52	---	5.02
1417	221	0.29	37.18	0.08	-	1078.34	-	0.30	-	-	2.60	7.82	-	---	---	-	-	29.20	0.74	44.98	38.30	4.63
1418	221	0.26	30.70	-	-	921.71	-	0.30	-	-	25.27	75.89	-	---	---	-	0.16	21.27	2.87	175.17	25.10	7.16

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Li mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Na mg/L	Ni mg/L	NO_3 as N mg/L	P mg/L	Pb mg/L	S mg/L	SO_4[4] mg/L	Se mg/L	Si mg/L	Sr mg/L	V mg/L	Zn mg/L	SAR[5]	HCO_3 meq/L	HCO_3[4] mg/L	Temp °C	Meas. Hardness grns/gal
168	221	0.66	37.51	0.09	-	1169.76	-	2.70	-	-	4.96	14.88	-	---	---	-	-	31.30	0.91	55.64	37.00	4.80
169	221	0.61	34.63	-	-	911.49	-	0.50	-	-	24.28	72.90	-	---	---	-	0.27	20.20	3.01	183.46	27.80	7.70
99238	222	---	162.00	-	1.20	735.00	-	0.63	-	-	35.80	107.51	-	29.60	5.65	---	-	6.40	1.96	119.58	26.00	52.81
98103	222	---	181.00	-	-	718.00	---	0.80	-	---	17.10	51.35	---	---	6.99	---	-	6.38	1.78	108.60	---	49.24
96081	231	---	42.02	0.03	---	130.00	---	-	-	---	10.21	30.66	---	37.91	1.27	---	-	3.18	3.90	237.94	---	5.83
163	231	0.18	49.13	0.04	-	130.88	-	0.60	-	-	14.45	43.38	-	---	---	-	-	3.00	3.88	236.72	22.20	-
1432	233	0.10	88.53	-	-	211.91	-	6.50	-	-	61.84	185.71	-	---	---	-	-	3.23	3.82	233.17	18.10	6.60
1412	240	0.07	41.94	-	-	210.69	-	0.60	-	-	37.62	112.97	-	---	---	-	0.04	4.53	4.15	253.29	21.20	15.68
2259	243	0.11	89.14	-	---	404.79	---	-	-	-	120.06	360.54	-	---	---	---	-	6.40	4.81	293.46	13.30	8.00
3094	243	0.45	30.22	-	---	104.91	---	0.30	-	-	19.81	59.49	-	---	---	---	-	2.80	4.57	278.82	23.00	14.54
4336	243	0.11	85.18	-	---	320.49	---	1.20	-	-	127.05	381.53	-	---	---	---	-	5.00	5.39	328.84	13.20	5.10
96064	243	---	85.66	-	---	343.00	---	1.50	-	---	97.78	293.63	---	23.12	2.57	---	-	5.35	5.00	305.05	---	15.20
97131	243	---	93.30	-	---	373.00	---	1.30	-	---	126.00	378.38	-	---	2.81	---	-	5.58	4.50	274.55	---	14.99
99224	243	---	79.50	-	-	343.00	-	1.32	-	-	108.00	324.32	-	20.20	2.47	---	-	5.40	5.36	327.01	---	16.27
98089	243	---	81.80	-	-	323.00	---	1.50	-	---	98.70	296.40	---	---	2.37	---	-	5.19	5.00	305.05	---	15.18
159	243	-	103.47	-	0.13	385.62	-	1.10	-	-	135.83	407.89	-	---	---	-	0.07	5.60	9.27	565.75	13.30	14.08
2260	244	0.06	36.72	0.03	---	123.74	---	0.30	-	-	25.54	76.70	-	---	---	---	-	3.00	3.78	230.62	16.70	17.40
3095	244	1.08	92.28	-	---	384.13	---	1.00	-	-	130.51	391.92	-	---	---	---	-	5.80	4.92	300.17	13.20	6.10
4337	244	-	27.40	-	---	93.72	---	-	-	-	20.81	62.49	-	---	---	---	-	2.60	4.05	247.09	12.70	16.20
1404	244	0.10	83.62	-	-	324.37	-	1.70	-	-	108.60	326.13	-	---	---	-	-	5.23	4.75	289.98	12.50	4.70
96088	246	---	24.82	-	---	524.00	---	0.30	-	---	21.54	64.68	---	23.09	1.16	---	0.10	14.71	3.90	237.94	---	13.87
96070	247	---	286.08	-	---	810.00	---	41.45	-	---	257.61	773.60	---	12.85	4.90	---	0.04	7.44	5.00	305.05	---	4.68
97135	247	---	183.00	-	---	578.00	---	18.50	-	---	212.00	636.64	-	---	3.35	---	-	6.59	4.82	294.07	---	41.63
99228	247	---	112.00	-	0.85	446.00	-	12.90	-	-	169.00	507.51	-	12.40	1.93	---	0.07	6.30	5.36	327.01	21.00	27.13
98094	247	---	141.00	-	-	499.00	---	15.80	-	---	162.00	486.49	---	---	2.52	---	-	6.52	5.00	305.05	---	17.84
1414	247	0.12	122.28	-	-	432.47	-	8.60	-	-	207.65	623.58	-	---	---	-	-	6.17	4.87	297.08	13.60	20.58
165	247	0.23	139.11	-	-	454.20	-	5.20	0.15	-	219.50	659.17	-	---	---	-	0.46	6.00	4.75	289.98	20.10	17.15
4352	259	-	39.91	-	---	171.43	---	-	-	-	18.58	55.80	-	---	---	---	-	3.90	3.37	205.60	21.20	19.70
96077	259	---	49.57	-	---	140.00	---	0.80	-	---	12.74	38.26	---	10.02	1.92	---	-	2.83	3.20	195.23	---	7.20
98095	259	---	55.10	-	-	149.00	---	1.50	-	---	15.40	46.25	---	---	2.04	---	-	2.88	3.00	183.03	---	8.98
1422	261	-	28.25	-	-	48.82	-	1.20	-	-	11.19	33.59	-	---	---	-	-	0.89	2.33	142.03	20.50	9.77
154	265	-	36.86	0.03	0.08	130.41	-	3.50	0.14	-	30.48	91.53	-	---	---	-	-	3.20	6.17	376.37	18.70	12.37
160	266	-	42.39	-	0.09	241.59	-	0.60	-	-	26.07	78.29	-	---	---	-	0.16	5.20	4.27	260.39	15.50	-
167	267	0.29	36.71	-	-	574.70	-	0.60	-	-	19.95	59.92	-	---	---	-	-	13.20	3.53	215.43	21.90	-

Table D.1. *(continued)*

UDAF Sample No.	ID[2]	Li mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Na mg/L	Ni mg/L	NO_3 as N mg/L	P mg/L	Pb mg/L	S mg/L	SO_4[4] mg/L	Se mg/L	Si mg/L	Sr mg/L	V mg/L	Zn mg/L	SAR[5]	HCO_3 meq/L	HCO_3[4] mg/L	Temp °C	Meas. Hardness grns/gal
3104	268	1.06	61.60	-	---	258.51	---	1.40	-	-	47.36	142.22	-	---	---	---	-	4.40	3.45	210.48	20.90	7.00
1405	268	0.06	36.08	-	-	151.79	-	0.20	-	-	36.68	110.15	-	---	---	-	-	3.71	4.23	258.02	17.10	12.60
99222	269	---	32.30	-	0.58	191.00	-	0.15	-	-	26.30	78.98	-	15.10	1.23	---	-	4.60	4.64	283.09	---	6.05
98087	269	---	32.70	-	-	208.00	---	0.20	-	---	17.80	53.45	---	---	1.23	---	-	5.01	4.46	272.10	---	6.37
1410	269	0.08	41.18	-	-	192.57	-	0.40	-	-	29.77	89.41	-	---	---	-	0.22	4.10	4.11	250.92	14.70	6.40
99243	270	---	42.90	0.05	2.78	186.00	-	4.25	-	-	69.40	208.41	-	26.30	1.00	---	-	3.20	3.57	217.81	22.00	8.21
1430	270	0.05	44.17	0.03	-	186.13	-	3.30	-	-	33.79	101.47	-	---	---	-	0.05	3.35	2.93	178.72	18.60	12.92
99223	271	---	35.60	-	-	131.00	-	0.11	-	-	36.10	108.41	-	7.63	0.98	---	-	3.20	5.00	305.05	---	6.29
98088	271	---	35.40	-	-	143.00	---	0.10	-	---	36.70	110.21	---	---	0.94	---	-	3.47	4.64	283.09	---	6.19
96063	272	---	39.64	-	---	161.00	---	0.20	-	---	44.18	132.67	---	9.36	1.05	---	-	3.74	4.30	262.34	---	6.71
97130	272	---	41.20	-	---	174.00	---	0.20	-	---	57.80	173.57	-	---	1.09	---	-	3.91	4.82	294.07	---	7.23
96066	273	---	61.77	-	---	176.00	---	3.40	-	---	33.89	101.77	---	22.05	2.67	---	-	3.19	4.60	280.65	---	11.16
97132	273	---	69.00	-	---	188.00	---	4.30	-	---	46.60	139.94	-	---	2.94	---	-	3.24	4.28	261.12	---	12.34
98092	273	---	79.20	-	-	203.00	---	5.40	-	---	46.10	138.44	---	---	3.22	---	-	3.29	4.28	261.12	---	13.87
96085	274	---	38.65	-	---	144.00	---	3.20	-	---	13.53	40.63	---	8.87	1.14	---	0.19	2.81	2.10	128.12	---	10.17
96062	368	---	52.31	-	---	338.00	---	0.70	-	---	42.48	127.57	---	19.55	2.06	---	-	6.49	5.40	329.45	---	10.04
96086	434	---	41.51	-	---	120.00	---	1.70	0.10	---	28.06	84.26	---	18.82	0.84	---	0.18	2.58	6.40	390.46	---	7.99
96087	440	---	48.59	-	---	319.00	---	0.40	-	---	108.00	324.32	---	19.20	1.48	---	-	6.61	5.40	329.45	---	8.47
96076	454	---	11.35	-	---	18.81	---	0.70	-	---	5.77	17.33	---	23.28	0.27	---	-	0.58	2.90	176.93	---	4.30
97139	454	---	32.00	-	---	60.80	---	0.60	-	---	11.30	33.93	-	---	0.27	---	-	1.43	2.50	152.53	---	6.80
2265	Baker	0.36	75.16	-	---	759.31	---	0.30	-	-	47.55	142.79	-	---	---	---	-	12.70	2.70	164.73	18.80	13.00
3098	Baker	2.79	61.56	-	---	608.63	---	-	-	-	42.74	128.35	-	---	---	---	-	11.60	2.28	139.10	21.20	9.80
3099	W. Loco.	6.42	86.17	-	---	1270.12	---	-	-	-	69.37	208.32	-	---	---	---	-	21.50	1.47	89.68	23.60	12.20
3100	Bar M	2.38	71.33	0.02	---	864.43	---	0.30	-	-	48.18	144.68	-	---	---	---	-	15.40	3.23	197.06	19.20	11.20
96065	Baker	---	61.85	-	---	519.00	---	0.50	-	---	30.97	93.00	---	17.86	2.52	---	-	9.50	3.20	195.23	---	10.87
99226	Baker	---	62.10	-	-	560.00	-	0.39	-	-	34.80	104.50	-	15.90	2.43	---	-	9.70	3.21	195.84	---	12.40
98091	Baker	---	66.30	-	-	534.00	---	0.50	-	---	33.20	99.70	---	---	2.59	---	-	9.52	3.21	195.84	---	11.42
1407	Baker	0.26	69.72	-	-	530.44	-	0.60	-	-	44.91	134.86	-	---	---	-	-	9.23	2.89	176.36	16.30	12.00
155	Baker	-	64.38	-	0.23	534.55	-	1.40	0.24	-	33.17	99.62	-	---	---	-	0.47	9.70	3.43	209.51	15.80	11.00

Table D.1. *(continued)*

UDAF Sample No.	ID[2]	Hardness[4] mg/L	Coliform	Ecoli
2262	26	620.73	0	0
3096	26	494.2	0	0
4340	26	472.0	0	0
99225	26	640.0	1	0
98090	26	392.0	---	---
1406	26	399.6	0	0
156	26	555.8	0	0
2264	34	372.8	1	0
3097	34	292.4	0	0
4341	34	268.5	0	0
1408	34	274.7	0	0
2267	47	162.5	0	0
3092	47	119.7	0	0
96061	47	108.4	---	---
97129	47	109.5	---	---
161	58	135.1	1	0
3105	66	237.7	0	0
4348	66	167.6	0	0
96089	66	187.0	---	---
1413	66	220.7	0	0
1433	66	125.1	1	0
164	66	234.3	0	0
3106	72	176.1	1	0
4350	72	159.0	1	0
98096	72	145.6	---	---
1415	72	160.6	1	0
3102	85	47.9	1	1
4338	85	41.0	1	0
2261	87	229.1	0	0
3103	87	218.9	1	0
4339	87	188.1	1	0
1409	87	178.9	1	1
157	87	174.4	1	0
158	87	179.6	1	0

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Hardness[4] mg/L	Coliform	Ecoli
3101	88	176.1	1	1
4347	88	160.7	0	0
99227	88	181.4	1	0
2268	94	369.4	1	0
3110	94	246.2	1	0
4351	94	239.4	0	0
4359	97	128.3	0	0
96067	97	121.2	---	---
97133	97	121.3	---	---
99229	97	134.3	0	0
98098	97	122.5	---	---
99230	98	204.0	0	0
96068	101	675.8	---	---
99231	101	228.5	1	1
98099	101	738.0	---	---
174	101	383.0	1	0
177	101	196.7	0	0
3107	104	206.9	1	0
4354	104	201.8	1	0
2276	105	277.0	0	0
4360	105	218.9	0	0
2271	107	188.1	0	0
3111	107	153.9	0	0
4356	107	150.5	0	0
2270	108	307.8	0	0
3108	108	285.6	0	0
4355	108	241.1	0	0
99236	108	207.6	1	1
1419	108	207.1	0	0
2275	110	196.7	0	0
99245	116	146.1	1	1
98097	116	139.4	---	---
170	116	162.5	1	0
4358	117	205.2	0	0

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Hardness[4] mg/L	Coliform	Ecoli
99244	117	225.0	1	1
98093	117	215.5	---	---
1431	117	206.2	0	0
99241	119	243.9	0	0
1425	119	240.7	0	0
99242	120	299.3	1	0
1427	120	277.3	0	0
96072	121	203.5	---	---
99240	121	207.9	0	0
1426	121	203.5	0	0
173	121	242.8	0	0
96075	126	78.8	---	---
97138	126	74.8	---	---
96074	134	110.9	---	---
97137	134	116.2	---	---
1429	135	135.4	1	0
1411	157	306.3	0	0
162	157	312.9	1	0
2266	158	395.0	0	0
99233	164	646.0	1	0
2272	168	205.2	1	0
3114	168	148.8	0	0
4357	168	177.8	1	0
96071	168	110.7	---	---
97136	168	116.2	---	---
99239	168	118.6	1	0
98104	168	117.2	---	---
1423	168	149.4	1	0
172	168	153.9	1	0
1421	169	139.1	0	0
99232	170	333.0	1	1
99237	170	514.9	0	0
98101	170	494.0	---	---
1420	170	579.9	1	0

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Hardness[4] mg/L	Coliform	Ecoli
176	170	379.6	1	0
98100	171	467.0	---	---
175	171	619.0	0	0
96069	175	101.4	---	---
97134	175	103.8	---	---
99246	175	100.6	0	0
1416	175	101.4	0	0
166	175	114.6	0	0
2269	178	141.9	1	0
4353	178	114.6	1	0
96078	178	113.7	---	---
96079	178	69.8	---	---
97140	178	116.6	---	---
2274	181	90.6	0	0
2273	183	94.1	1	0
4342	201	176.1	1	1
96082	206	107.0	---	---
96083	206	118.3	---	---
96084	207	177.1	---	---
96073	210	208.5	---	---
1428	210	210.6	0	0
2263	213	355.7	0	0
4346	213	403.6	0	0
2277	214	215.5	0	0
3109	214	179.6	0	0
4349	214	172.7	1	1
3112	216	677.2	1	0
1424	217	81.4	0	0
171	217	90.6	1	0
96080	221	71.5	---	---
99234	221	114.1	1	0
98102	221	85.9	---	---
1417	221	79.3	1	1
1418	221	122.4	0	0

Table D.1. (continued)

UDAF Sample No.	ID[2]	Hardness[4] mg/L	Coliform	Ecoli
168	221	82.1	1	1
169	221	131.7	0	0
99238	222	903.0	0	0
98103	222	842.0	---	---
96081	231	99.7	---	---
163	231	112.9	1	0
1432	233	268.1	0	0
1412	240	136.8	0	0
2259	243	248.6	0	0
3094	243	87.2	1	1
4336	243	259.9	0	0
96064	243	256.3	---	---
97131	243	278.3	---	---
99224	243	259.5	1	0
98089	243	240.8	---	---
159	243	297.5	1	0
2260	244	104.3	1	1
3095	244	277.0	0	0
4337	244	80.4	1	1
1404	244	237.3	1	0
96088	246	80.1	---	---
96070	247	711.9	---	---
97135	247	464.0	---	---
99228	247	305.0	0	0
98094	247	352.0	---	---
1414	247	293.2	1	0
165	247	336.9	1	0
4352	259	123.1	0	0
96077	259	153.6	---	---
98095	259	167.1	---	---
1422	261	211.5	0	0
154	265	-	1	1
160	266	-	0	0
167	267	119.7	1	0

***Table D.1**. (continued)*

UDAF Sample No.	ID[2]	Hardness[4] mg/L	Coliform	Ecoli
3104	268	215.5	1	1
1405	268	103.4	1	1
99222	269	108.9	0	0
98087	269	109.5	---	---
1410	269	140.4	0	0
99243	270	220.9	1	0
1430	270	#REF!	0	0
99223	271	107.6	1	1
98088	271	105.9	---	---
96063	272	114.8	---	---
97130	272	123.6	---	---
96066	273	190.9	---	---
97132	273	211.0	---	---
98092	273	237.2	---	---
96085	274	173.9	---	---
96062	368	171.7	---	---
96086	434	136.7	---	---
96087	440	144.8	---	---
96076	454	73.5	---	---
97139	454	116.2	---	---
2265	Baker	222.3	1	0
3098	Baker	167.6	1	1
3099	W. Loco.	208.6	1	0
3100	Bar M	191.5	1	1
96065	Baker	186.0	---	---
99226	Baker	212.1	1	1
98091	Baker	195.3	---	---
1407	Baker	205.2	1	0
155	Baker	188.1	1	1

Notes

- Below minimum detection limit

--- Analysis not made

[1]UDAF ground-water data are available at <http://ag.utah.gov/conservation/gw_report.pdf>

[2]Identifier used on all figures and plates and in text. The final 9 samples listed are from the Locomotive Springs complex.

[3]Easting and northing in meters based on Universal Transverse Mercator Zone 12N projection, NAD 1927 datum, used in GIS applications. Reported values are from hand-held GPS measurements made at time of sample collection, so values for a single well may vary.

[4]Recalculated from reported value.

[5]SAR = Sodium absorption ratio.

Table D.2. *General chemistry data for samples of Curlew Valley ground water collected by the UGS[1].*

ID[2]	Sample Date	Easting[3]	Northing[3]	pH	Conductivity uS/cm	As µg/L	Ba µg/L	Ca mg/L	Cl mg/L	CO_2 mg/L	CO_3 solids mg/L	Cr µg/L	Dissolved Oxygen mg/L	Fe µg/L	HCO_3 mg/L	K mg/L	Mg mg/L	Mn µg/L	Na mg/L
20	5/19/04	322410.24	4630017.79	7.7	910	1.3	<100.0	87.7	167.0	3	92	<5.0	6.8	<20.0	187	3.15	24.2	<5.0	45.8
24	5/20/04	322718.61	4628362.33	7.2	2330	1.3	260.0	245	659.0	5	103	55.5	5.7	<20.0	210	8.29	68.6	<5.0	122.0
74	8/30/05	353195.00	4647492.00	7.18	4020	-	-	289.10	798.74	4	.1	-	4.47	-	339	16.38	121.20	-	368.60
88	5/19/04	353752.29	4642369.95	7.7	1727	-	-	85.40	300.35	-	.1	-	6.1	0.09	240.9	14.24	77.56	0.60	138.50
92	8/30/05	350464.00	4647781.00	6.97	2290	-	-	201.40	499.75	5	.1	-	4.35	-	313	13.57	73.22	-	149.80
124	8/29/05	340277.00	4647971.00	7.32	669	-	-	72.36	104.63	1	.1	-	4.95	-	173	4.71	17.50	-	17.02
134	5/19/04	337495.62	4645739.22	-	-	-	-	97.11	275.42	-	.1	-	-	0.11	118.2	12.69	43.01	0.00	87.28
175	5/19/04	348123.38	4650604.22	7.9	3090	-	-	-	775	2	108	-	4.7	-	220	-	-	-	-
188	5/17/04	347451.12	4646765.87	7.26	3197	-	-	201.00	737.82	-	.1	-	5.06	0.13	232.2	17.99	108.50	0.70	240.80
243	8/30/05	357297.00	4646830.00	7.01	3220	-	-	183.90	697.09	3	.1	-	3.74	-	312	29.69	87.43	-	331.40
246	5/19/04	353099.71	4639781.83	-	-	-	-	67.79	604.34	-	.1	-	-	0.10	266.0	33.20	31.58	0.65	393.40
314	5/17/04	367728.00	4685534.73	7.4	923	1.6	172	97.3	148.0	4	94	<5.0	6.1	22.7	192	5.73	21.1	7.6	45.5
318	5/17/04	366250.61	4681123.35	7.5	1080	-	-	-	196	5	116	-	6.5	-	236	-	-	-	-
321	05/17/2004	366052.89	4679335.07	-	1252	5.2	227.0	108	214.0	4	0	<5.0	-	40.1	264	6.22	39.2	8.5	62.6
323	5/18/04	336498.01	4669117.53	7.5	686	-	-	-	81.9	4	118	-	4.5	-	240	-	-	-	-
366	5/18/04	339566.14	4666938.10	7.6	802	-	-	-	127	3	104	-	6.1	-	212	-	-	-	-
368	5/18/04	341865.51	4659643.02	7.6	611	-	-	-	90.7	2	79	-	5.5	-	161	-	-	-	-
382	5/18/04	362946.73	4659825.00	7.6	1081	-	-	-	196	3	115	-	3.7	-	234	-	-	-	-
384	5/18/04	366333.62	4667018.83	7.6	1344	-	-	-	236	4	105	-	8.9	-	214	-	-	-	-
385	5/18/04	363170.97	4667762.60	7.7	1721	-	-	-	302	10	192	-	6.1	-	390	-	-	-	-
402	5/18/04	338309.78	4657679.32	7.6	490	1.1	124.0	58.2	44.9	2	84	<5.0	5.4	<20.0	171	1.49	14.8	<5.0	18.8
405	5/18/04	359763.58	4657460.39	7.7	1180	-	-	-	176	3	140	-	4.6	-	284	-	-	-	-
407	5/18/04	358770.13	4657456.08	7.3	2030	-	-	-	233	6	163	-	3.1	-	332	-	-	-	-
420	5/19/04	360553.99	4654230.96	7.5	1935	-	-	-	429	4	150	-	7.6	-	304	-	-	-	-
431	5/19/04	357723.95	4653385.66	7.4	3830	-	-	-	625	4	175	-	6.2	-	356	-	-	-	-
434	5/19/04	360024.20	4652573.41	7.9	2840	-	-	-	667	7	171	-	6.2	-	348	-	-	-	-
443	5/19/2004	357166.00	4652484.20	7.5	4980	3.5	<100.0	769	1310	4	0	5.0	5.1	29.8	248	44.9	353	<5.0	861.0
458	05/17/2004	358411.35	4674895.37	7.6	1225	4.5	198.0	113	212.0	3	0	<5.0	6.9	<20.0	284	9.81	33	<5.0	61.5
459	5/17/04	363193.27	4669124.71	7.5	1456	3.8	244	112	259.0	4	152	<5.0	3.2	1670.0	308	10.6	43.2	937.0	84.8
460	5/18/04	337177.48	4668472.26	7.6	621	1.3	<100.0	62.5	65.4	3	114	<5.0	4.3	<20.0	232	2.68	26.2	<5.0	24.6
461	5/18/04	338814.37	4655234.88	7.5	517	1.8	130.0	64.5	56.4	11	0	<5.0	4.1	<20.0	184	5.45	11.4	<5.0	18.2
531 Bar M Spring	5/26/2004	340222.51	4619142.24	8.09	3920	-	-	-	1180	2	3920	-	-	0.08	166	31.44	68.34	0.62	538.20

Table D.2. (continued)

ID[2]	Sample Date	Easting[3]	Northing[3]	pH	Conductivity uS/cm	As µg/L	Ba µg/L	Ca mg/L	Cl mg/L	CO_2 mg/L	CO_3 solids mg/L	Cr µg/L	Dissolved Oxygen mg/L	Fe µg/L	HCO_3 mg/L	K mg/L	Mg mg/L	Mn µg/L	Na mg/L
532 Bar M Spring	8/29/05	340143.00	4619353.00	7.28	4080	-	-	141.75	1094.56	2	.1	-	4.51	-	247	40.98	61.86	-	580.00
560 Baker Spring	8/29/05	339715.00	4620222.00	7.68	3930	-	-	183.80	1170.27	1	.1	-	6.94	-	246	57.66	62.48	-	533.70

ID[2]	NO_3 as N mg/L	Se µg/L	SO_4 mg/L	Zn µg/L	TDS (180°C) mg/L	Temp °C	Meas. Alkalinity mg/L	Meas. Hardness mg/L	TSS[4] mg/L	Turbidity NTU
20	0.63	1.7	25.1	-	628	14.4	-	-	-	-
24	2.67	4.0	31.4	-	1922	13.6	-	-	-	-
74	5.87	-	601.32	-	2602	14.26	280	1431.2	<4.0	0.285
88	0.69	-	149.44	-	1054	12	-	-	-	-
92	6.06	-	139.51	-	1356	11.94	266	730.9	<4.0	0.623
124	0.28	-	21.98	-	396	16.35	139	261.7	<4.0	2.45
134	1.65	-	71.89	-	-	-	-	-	-	-
175	0.42	-	38.1	-	1568	21.10	180	-	<4.0	0.67
188	7.34	-	206.65	-	1837	15.4	-	-	-	-
243	0.79	-	294.44	-	1854	11.59	259	760	<4.0	0.236
246	0.81	-	87.29	-	-	-	-	-	-	-
314	6.14	2.2	29.3	40.6	616	10.2	157	329.6	8.0	29.2
318	1.09	-	31.1	-	786	10.8	194	-	<4.0	0.1
321	5.16	6.8	59.5	67.5	858	-	216	430.7	<4.0	1.09
323	1.04	-	23.7	-	396	12.90	197	-	<4.0	0.19
366	1.72	-	25.4	-	606	10.9	174	-	28	34.1
368	8.05	-	<20.0	-	430	13.80	132	-	<4.0	0.127
382	0.52	-	28.9	-	680	17.8	192	-	<4.0	0.397
384	2.37	-	108	-	886	11.4	175	-	<4.0	0.199
385	<0.1	-	<20.0	-	1052	11.60	320	-	7.2	16.8
402	0.54	1.6	<20.0	37.6	290	13.3	140	206.1	4.7	0.6
405	0.22	-	106	-	698	11.60	233	-	<4.0	0.7
407	0.92	-	473	-	1382	11.8	272	-	<4.0	0.282
420	0.41	-	82.3	-	1092	13.5	249	-	<4.0	0.504
431	3.51	-	1030	-	2610	10.70	292	-	<4.0	0.167
434	0.6	-	159	-	1662	11.3	285	-	<4.0	0.27
443	1.91	33.6	512.0	39.0	3724	12.3	203	3371.1	<4.0	0.463
458	1.29	2.7	38.4	<30.0	802	10.6	233	417.7	<4.0	0.1

Table D.2. *(continued)*

ID[2]	NO_3 as N	Se	SO_4	Zn	TDS (180°C)	Temp	Meas. Alkalinity	Meas. Hardness	TSS[4]	Turbidity
	mg/L	µg/L	mg/L	µg/L	mg/L	°C	mg/L	mg/L	mg/L	NTU
459	0.11	1.2	54.9	36.7	990	10.4	253	457.2	<4.0	12.7
460	0.74	1.2	<20.0	<30.0	376	13.4	190	263.7	<4.0	0.1
461	0.51	1.2	<20.0	51.5	380	14.2	151	207.8	<4.0	2.4
531 Bar M Spring	0.36	-	94.4	-	2370	-	136	-	<4.0	0.3
532 Bar M Spring	0.41	-	111.64	-	2166	15.96	161	443.4	<4.0	0.621
560 Baker Spring	0.25	-	100.67	-	2128	16.78	153	120.6	<4.0	1.36

Notes

- No data

[1]Analyses performed by the Utah Division of Epidemiology and Laboratory Services and the Brigham Young University environmental geochemistry laboratory.

[2]Identifier used on all figures and plates and in text.

[3]Easting and northing in meters based on Universal Transverse Mercator Zone 12N projection, 1927 datum, used in GIS applications. Values are from hand-held GPS measurements made at time of sample collection, and may not exactly match values in other tables.

[4]Total suspended solids.

Plate 1
Utah Geological Survey Special Study 126
Geology and Ground-Water Chemistry, Curlew Valley, Northwestern Utah and South-Central Idaho—Implications for Hydrogeology

Utah Geological Survey
a division of
Utah Department of Natural Resources

EXPLANATION

Contacts

Depositional or intrusive contact

Faults

Normal - dashed where inferred or approximately located, dotted where concealed; ball and bar on down-thrown side

Low-angle normal - dashed where inferred or approximately located, dotted where concealed; teeth on upper plate

Thrust - dashed where inferred or approximately located, dotted where concealed; teeth on upper plate

Displacement sense uncertain; dashed where inferred or approximately located, dotted where concealed

Folds

Anticline, showing plunge direction

Overturned anticline, showing plunge direction

Syncline, showing plunge direction

Overturned syncline, showing plunge direction

Other Features

Shoreline of Lake Bonneville - b = Bonneville, p = Provo, g = Gilbert, s- Stansbury; no letter = intermediate

Radiometric age sample location - see table B.1; number keyed to "Map ID" column

Petroleum-exploration well - plugged and abandoned - see table B.2; letter keyed to "Map ID" column

Strike and dip of bedding

Strike and dip of overturned bedding

Strike and dip of foliation

Biostratigraphy samples

Fusulinid and conodont

Fusulinid and conodont (barren)

Fusulinid only

Fusulinid (barren)

Map Units

Quaternary

Qaly — Younger stream alluvium

Qlam — Alluvial and lacustrine mud

Qafy — Younger alluvial-fan deposits

Qac — Alluvium and colluvium

Qae — Alluvium and eolian deposits

Qes — Eolian sand

Qms — Landslide and slump deposits

Qmtc — Talus and colluvium

Qla — Alluvial and lacustrine deposits

Qla/Ts — Alluvial and lacustrine deposits over Salt Lake Formation

Qlfg, Qlfp, Qlfb — Lacustrine silt and marl

Qlsg, Qlsp, Qlsb — Lacustrine sand

Qlsgg, Qlsgp, Qlsgb — Lacustrine sand and gravel

Qlgg, Qlgp, Qlgb — Lacustrine gravel

The last letter of map symbols for lacustrine deposits represent the stage of Lake Bonneville during which the deposit formed: b - Bonneville, p - Provo, g - Gilbert

Qlgp/PIPo — Lacustrine gravel over Oquirrh Group

Ql — Lacustrine deposits, undivided

Qel — Eolian loess

Qel/Qafo — Eolian loess over older alluvial-fan deposits

Qafo — Older alluvial-fan deposits

Qafo/Ts — Older alluvial-fan deposits over Salt Lake Formation

Qb — Basalt

Quaternary and Tertiary

QTaf — Alluvial-fan deposits

Tertiary

Trd — Rhyodacite

Ta2 — Pediment alluvium

Tb, Tbc — Basalt - Tb, flows; Tbc, cinder cone

Ta1 — Alluvium

Tt — Tuff

Ts — Salt Lake Formation

Tc — Conglomerate and sedimentary breccia

Permian

Plsd — Limestone, calcareous sandstone, and dolomite

Oquirrh Group

Pod — Sandstone and siltstone

Permian and Pennsylvanian

Oquirrh Group

PIPox — Unit x- bioclastic limestone

PIPoc — Unit c- sandy to silty limestone and calcareous sandstone to siltstone

PIPobc — Units b and c, undivided

PIPos — Sandstone and quartzite

PIPo — Oquirrh Group, undivided

Pennsylvanian

Oquirrh Group

IPob — Unit b- sand to silty limestone and calcareous sandstone to siltstone

IPoa — Unit a- cherty limestone

IPolsd — Limestone and dolomite

Pennsylvanian and Mississippian

IPMmc — Manning Canyon Formation

Mississippian

Mgb — Great Blue Limestone

Devonian

Dj — Jefferson Formation

Ordovician

Omq — Marble and quartzite, undivided

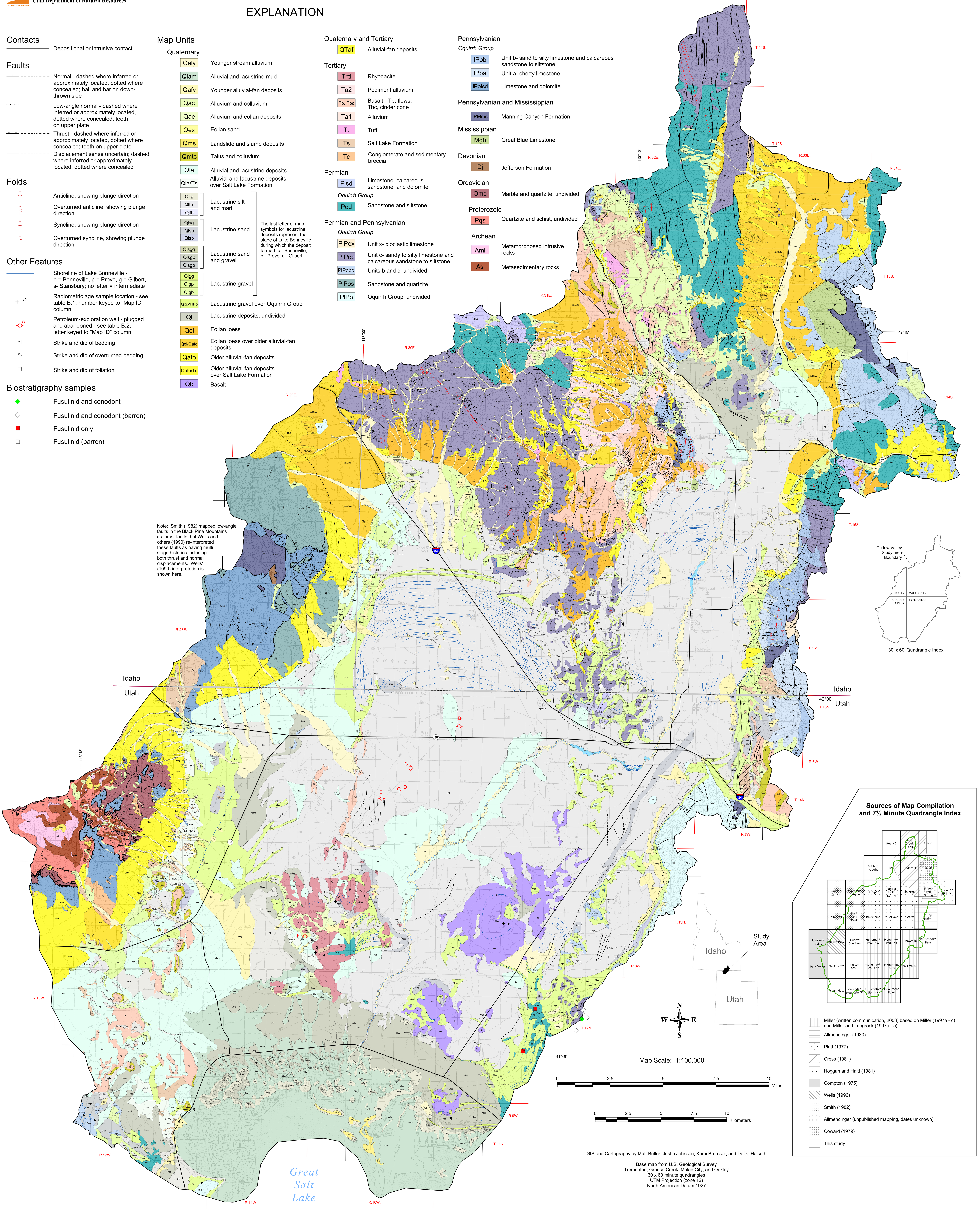
Proterozoic

Pqs — Quartzite and schist, undivided

Archean

Ami — Metamorphosed intrusive rocks

As — Metasedimentary rocks



Note: Smith (1982) mapped low-angle faults in the Black Pine Mountains as thrust faults, but Wells and others (1990) re-interpreted these faults as having multi-stage histories including both thrust and normal displacements. Wells' (1990) interpretation is shown here.

Miller (written communication, 2003) based on Miller (1997a - c) and Miller and Langrock (1997a - c)
Allmendinger (1983)
Platt (1977)
Cress (1981)
Hoggan and Haitt (1981)
Compton (1975)
Wells (1996)
Smith (1982)
Allmendinger (unpublished mapping, dates unknown)
Coward (1979)
This study

Map Scale: 1:100,000

0 2.5 5 7.5 10 Miles

0 2.5 5 7.5 10 Kilometers

GIS and Cartography by Matt Butler, Justin Johnson, Kami Bremser, and DeDe Halseth

Base map from U.S. Geological Survey
Tremonton, Grouse Creek, Malad City, and Oakley
30 x 60 minute quadrangles
UTM Projection (zone 12)
North American Datum 1927

Compiled Geologic Map of the Curlew Valley Drainage Basin, Box Elder County, Utah, and Oneida and Cassia Counties, Idaho

UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

SCHEMATIC CROSS SECTIONS THROUGH THE BASIN-FILL AQUIFER, CURLEW VALLEY, UTAH AND IDAHO

Plate 2
Special Study 126
Geology and Ground-Water Chemistry, Curlew Valley, Northwestern Utah and South-Central Idaho—Implications for Hydrogeology