WASHINGTON COUNTY WATER CONSERVANCY DISTRICT

PETITION FOR CLASSIFICATION OF THE NAVAJO/KAYENTA AND UPPER ASH CREEK AQUIFERS

Final Report

July 2005

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Project Engineer

Prepared by:

HANSEN, ALLEN & LUCE, INC.
Consulting Engineers
6771 South 900 East
Midvale, Utah 84047
(801) 566-5599

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CHAPTER I

INTRODUCTION

Aquifer Classification provides a common water quality goal for an entire aquifer or parts of an aquifer. Aquifer Classification provides a foundation for local legislative decisions affecting the aquifer. It can also unify protection standards used for the aquifer. However, Aquifer Classification is not considered a regulation and, therefore, does not restrict land or water use. The following examples defining groundwater classification are provided in the "Aquifer Classification Guidance" document produced by the Division of Water Quality, April 7, 1998.

"Ground water Classification is:

1. *In the absence of other more site specific data, a predetermined basis of establishing protection levels and best available control technology in the issuance of ground water discharge permits by the Division of Water Quality (DWQ).*
2. *A common ground water quality management objective to be used as a land use management tool by respective local agencies.*
3. *A consolidation of knowledge about a given hydrologic setting from a number of scientific technical sources.*
4. *A formal administrative prioritization of the ground water resource.*

Ground water Classification is not:

1. *A mandatory requirement to take specific action by a local government including application of any land use zoning restrictions.*
2. *An obligation by local government to do technical assessments, monitoring or ongoing financial investments.*
3. *A restriction on existing land use or future land use not already allowed or prohibited by State law.*
4. *An assumption of the State responsibility to enforce or enact county or local ordinances on waste management practices."*

By classifying the Navajo/Kayenta and Upper Ash Creek aquifers, Washington County Water Conservancy District hopes to develop an additional tool to provide reasonable protection of the groundwater used by District and other water suppliers in the study area.

This petition to classify portions of the Navajo/Kayenta and Upper Ash Creek aquifers in Washington County, Utah was prepared on behalf of Washington County Water Conservancy District (WCWCD) for consideration by the Utah Water Quality Board in conformance with "Administrative Rules for Ground Water Protection, R317-6-5 (Ground Water Classification for Aquifers), March 20, 1995".

CHAPTER II

DESCRIPTION OF PETITION AREA

The aquifers proposed for classification are located in Washington County and a small portion of Iron County, Utah. Washington County is one of the most rapidly growing areas in the United States. Its temperate climate and picturesque surroundings make it a desirable place to live. Projections indicate that by the year 2040 the County population may increase from the current 100,000 people to more than 200,000. Currently many of the public water systems in this area rely on the Navajo/Kayenta and upper Ash Creek aquifers for culinary water supplies.

The boundaries of the petition areas are shown in Figure A1. The basis for the boundary delineation is described in the following sections. The petition area includes the Upper Ash Creek aquifer, exposed outcrops of the Navajo and Kayenta formations, and what has been defined in this report as the Extended Zone of the Navajo/Kayenta aquifer. The Extended Aquifer Zone is the developable area (slope $<30\%$) north of the exposed Navajo formation where the buried Navajo/Kayenta aquifer is estimated to remain unconfined. Based on US Geological Survey (USGS) Technical Publication No. 116 (Heilweil, et al., 2000), this buried, unconfined area was estimated to include the area within 4 miles of the northern boundary of the exposed Navajo Formation in the Dameron Valley area. While the Navajo and Kayenta formations generally dip to the north, these formations are shallow enough in the Extended Aquifer Zone that infiltration of surface water may reach the Navajo Aquifer. Similar conditions exist east of the exposed Navajo Formation and west of the Hurricane Fault from Hurricane to Pintura. This area is also included in the Extended Aquifer Zone.

The Upper Ash Creek aquifer is located in New Harmony Valley and is bounded by a topographic divide on the west, the hurricane fault on the east, and a groundwater divide located approximately 2 miles north of Kanarraville.

CHAPTER III

GEO-HYDROLOGIC DESCRIPTION

A current and comprehensive source of geo-hydrologic information for the Navajo/Kayenta and the Upper Ash creek aquifers is the USGS publication completed in 2000, titled "Geohydrology and Numerical Simulation of Ground-water Flow in the Central Virgin River Basin of Iron and Washington Counties, Utah", Technical Publication No. 116 (Heilweil, et al., 2000). Much of the geo-hydrologic information included in this petition was obtained from this technical publication. The other key source of geo-hydrologic information for this report is a July 1998 study by Hansen Allen & Luce, Inc. for Washington County Water Conservancy District and cooperating agencies entitled, "Determination of Recommended Septic System Densities for Groundwater Quality Protection".

UPPER ASH CREEK AQUIFER

The Upper Ash Creek aquifer consists of a basin fill aquifer overlying an alluvial fan aquifer and a monzonite bedrock aquifer (see Figure III-1). The approximate area of the basin recharging these aquifers is about 100 square miles. The following description of this aquifer was obtained from Heilweil, et al. (2000).

> *"The upper Ash Creek drainage basin includes numerous igneous and sedimentary rocks, and unconsolidated deposits that contain ground water. The aquifer system of the upper Ash Creek drainage basin consists of three aquifers, all on the west side of the Hurricane Fault. The uppermost Quaternary basin-fill aquifer has the smallest areal extent. It is confined between the Hurricane Fault and the beginning edge of the Harmony Mountains. From west to east it is about 2 to 3 mi wide near Kanarraville where the edge of the Harmony Mountains are closest to the Hurricane fault, and about 6 mi wide at the latitude of the town of New Harmony. The Tertiary alluvial-fan aquifer, which is thought to underlie the basin-fill aquifer in the vicinity of Kanarraville, extends about 5 mi west from the Hurricane Fault where it ends at the lower slopes of the Harmony Mountains. The alluvial-fan aquifer is about 6.5 mi wide at the latitude of the town of New Harmony. The Tertiary Pine valley monzonite aquifer and other consolidated rock aquifers of the Harmony Mountains extend throughout the rest of the drainage basin and underlie the alluvial-fan aquifer at the southwest end of the Ash Creek valley. The existence of this aquifer at depth under the alluval-fan deposits in the middle and northern parts of the valley has not been confirmed."*

> *"The basin-fill aquifer is thickest (1,500 ft)(Hurlow, 1998) near the Hurricane Fault, about 200 to 500 ft thick east of New Harmony, and less than 100 ft thick under most of the Ash Creek stream channel. The aquifer thins to less than 200 ft on the west as it merges with the alluvial-fan aquifer near the base of the Harmony Mountains. The alluvial-fan aquifer is thought to be about 1,200 to 1,400 ft thick throughout the upper Ash Creek drainage basin (Hurlow, 1998). The thickness*

of the Pine Valley monzonite aquifer is unknown, but it is thought to be in excess of 2,000 ft."

A generalized typical cross section, adapted from Heilweil, et al. (2000), through the Upper Ash Creek aquifer is shown in Figure III-1 and is further described below. The approximate location of this cross section is shown on Figure A-2.

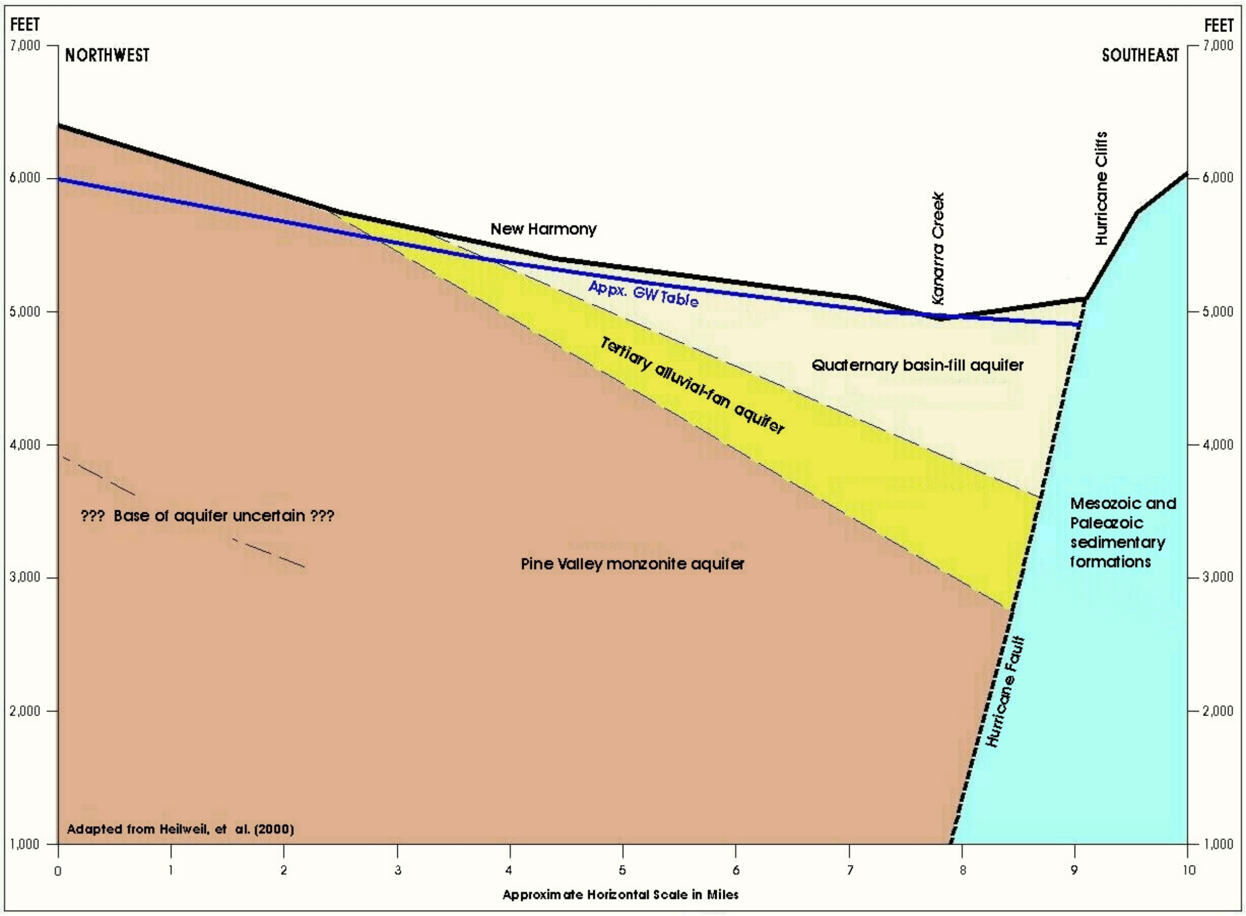


Figure III-1 Generalized Cross Section of the Upper Ash Creek Aquifer.

"The hydrological boundaries of the system are thought to correlate closely with structural and watershed boundaries. The eastern boundary is presumed to be the Hurricane fault, which because of large offset and associated fine-grained fault gouge (Hurlow, 1998), would likely be a barrier to ground-water flow from the east. The northern boundary is a ground-water divide north of Kanaraville, as defined in Thomas and Taylor (1946). Water-level measurements from 1995 indicate that the location of this divide has apparently moved about 2 mi farther south than the reported location in 1946, probably because of increased well discharge in Cedar Valley to the north. The northern, western, and southern lateral boundaries of the basin-fill and alluvial-fan aquifers are defined by their areal extent. The boundaries for the Pine Valley monzonite aquifer are defined

by the watershed boundaries (surface-water divide) of Ash Creek basin. The southern discharge boundary of all three aquifers is presumed to be the fractured basalt flows near Ash Creek Reservoir in the narrow part of the Ash Creek Valley."

Although Heilweil, et al. (2000) describes three separate aquifers, the recharge and discharge areas of all three aquifers appear to be identical. These aquifers likely have a strong interaction and are assumed to generally behave as a single aquifer. Heilweil, et al. (2000) also indicates that the Hurricane Fault is a groundwater flow barrier. Hurlow (1998) indicates that the Hurricane Fault may either be a groundwater flow barrier or may have significant transverse permeability depending on the composition of the formations adjacent to the fault. The classification boundary identified in this report terminates on the east at the Hurricane Fault. However, this position may be altered depending on future investigations.

Geologic Formations

Heilweil, et al. (2000) provided geologic descriptions of the formations in the Upper Ash Creek area and their relationship to the identified aquifers above. Table III-1 includes these descriptions as provided by Heilweil, et al. (2000) which was adapted from Hurlow (1998).

TABLE III-1
GEOLOGIC FORMATION DESCRIPTIONS IN UPPER ASH CREEK AREA
(from Heilweil, et al., 2000 adapted from Hurlow, 1998)

AGE	GEOLOGIC UNIT		THICKNESS (FEET)	LITHOLOGIC CHARACTER	AQUIFER
Quaternary	Quaternary sediments		0-1,500	Boulder gravel, sand, and silt	Basin fill
	Quaternary basalt		0-500	Fractured, broken basalt	
	Alluvial-fan deposits		0-150	Poorly sorted boulder conglomerate	
Tertiary	Alluvial-fan deposits	Upper	0-700	Unconsolidated boulder gravel	Alluvial fan
		Middle	0-450	Siltstone with conglomerate beds	
		Lower	350	Cemented breccia, sandstone, and siltstone	
	Racer Canyon Tuff		1,000		
	Pine Valley monzonite & latite			Fractured monzonite and latite	Pine Valley monzonite
	Stoddard Mountain Intrusion				
	Quichapa Group		1,000	Cemented to partially cemented volcanic ash	
	Claron Formation		700-1,000	Sandstone, limestone, shale, and conglomerate	
Cretaceous	Iron Springs Formation		3,800	Sandstone, shale, and conglomerate	

Structure

The Hurricane fault is the major structural feature of the Upper Ash Creek area as shown on Figure III-1 and as discussed above. Figure A-2 also shows the significance of the Hurricane Fault. There are also many faults within the formations of the Pine Valley monzonite aquifer in the Harmony Mountains and the Pine Valley Mountains. Based on Cordova (1978), most of these faults strike north to north-northwest with the exception of a fault striking southwest beginning just south of New Harmony and heading into the Pine Valley Mountains for a distance of about 9 miles. Heilweil, et al. (2000) reports that the formations in this area are fractured.

NAVAJO/KAYENTA AQUIFER

The Navajo/Kayenta aquifer boundaries are defined by the formations' erosional limits to the west and south, the Hurricane Fault to the east, and by an overlying confining formation to the north. The Navajo/Kayenta aquifer boundaries are shown on Figure A1 are based on the following description and figures presented by Heilweil, et al. (2000).

> *"The hydrologic boundaries of the Navajo and Kayenta aquifers are similar to the structural boundaries of the geologic formations. The aquifers are bounded to the east by the Hurricane Fault, which completely offsets these formations. Because the fine-grained fault-gouge material likely acts as a barrier to flow across the fault . . . the Hurricane fault is assumed to be a lateral no-flow boundary."*

> *"The southern boundaries of the Navajo Sandstone and Kayenta Formation are defined by their erosional extents. However, the formations are likely unsaturated along this southernmost edge, especially where they are locally uplifted... The Navajo Sandstone and Kayenta Formation become deeply buried toward the north. A structure contour map of the top of the Navajo Sandstone by Hurlow (1998, pl 5B) indicates that the top of the Navajo Sandstone is about 8,000 ft below land surface (2000 ft above sea level) in the Pine Valley Mountains."*

While Heilweil, et al. (2000) indicates the Hurricane Fault behaves as a no-flow groundwater boundary, Cordova (1978) concluded that the source of water to the Navajo Sandstone southwest of Hurricane originates east of the Hurricane Cliffs. This conclusion suggests that the Hurricane Fault may be a conduit for groundwater flow instead of a barrier. Hurlow (1998) indicates that the Hurricane Fault may either be a groundwater flow barrier or may have significant transverse permeability depending on the composition of the formations adjacent to the Navajo Sandstone across the fault. Heilweil, et al. (2000) indicated that further field investigation is necessary to determine conclusively whether the Hurricane Fault is a barrier, a conduit, or both. The classification boundary identified in this report terminates on the east at the Hurricane Fault. However, this position may be altered depending on future investigations.

The Navajo and Kayenta formations generally dip to the northeast and are overlain by the Carmel Formation. Because of the Carmel formation's low permeability and increasing thickness in the northern direction, seepage from this formation into the Navajo/Kayenta aquifer is limited. The USGS estimates that the Navajo/Kayenta aquifer probably becomes confined within 2 to 4 miles from its exposed boundary in the Dameron Valley area (Heilweil, et al., 2000).

> *"At some unknown distance north of the outcrop, the Navajo aquifer is assumed to become confined as it is buried by younger formations. . . . Assuming a flat potentiometric surface farther north (based on the assumption that little recharge reaches the aquifer where it is deeply buried) and a northeastward dip of the Navajo Sandstone of 3 to 10 degrees (Hurlow, 1998, pl. 5B), confined conditions may occur between 2 and 4 mi northeast of the outcrop in the Dameron Valley Area."*

For classification purposes, the northern boundary of Extended Aquifer Zone is assumed to be 4 miles north of the exposed Navajo Formation boundary in the Dameron Valley area. In the Pine Valley Mountains, the northern boundary of the Extended Aquifer Zone is assumed to be the extent of the developable area, or where the slope is less than 30%. The Extended Aquifer Zone is shown on Figure A1. The southern and western boundaries of this aquifer system are the erosional limits of the Kayenta formation. The eastern boundary of the aquifer for classification purposes is the Hurricane fault.

The Navajo/Kayenta aquifer consists mostly of poorly cemented sandstone formations. The Navajo formation lies above the Kayenta formation and the two formations are assumed to act as a single unconfined aquifer. At the base of the Kayenta formation exists low conductivity boundary which restricts flow from the underlying formation over most of the exposed Navajo/Kayenta formation. Heilweil, et al. (2000) reports the following.

> *"Because of the homogeneous nature of the Navajo Sandstone, the Navajo aquifer is assumed to be unconfined throughout the outcrop area. However, there may be local areas where the aquifer is confined."*

> *"The potentiomentric gradient between the two aquifers indicate that groundwater moves from the Navajo aquifer to the Kayenta aquifer (Cordova, 1978). . . . Cordova (1978) suggested that ground-water movement from the Navajo aquifer to the Kayenta aquifer occurs along the entire part of the outcrop within the study area. This theory is based on (1) the general direction of ground-water movement, inferred from potentiometric maps, toward the escarpment that form the erosional extent of the Navajo Sandstone outcrop; (2) the absence of natural discharge by springs, seeps, or phreatophytes along the escarpment above the base of the Navajo Sandstone; and (3) water levels at a few wells finished in both the Navajo Sandstone and the Kayenta Formation..."*

> *"The lowest part of the Kayenta Formation consists of siltstones and mudstones (Hurlow, 1998) that are relatively impervious and most likely act as a confining layer at the base of the Navajo and Kayenta aquifer system. Evidence for this hydrologic boundary includes (1) many springs that emanate from the lower part of the Kayenta Formation between Santa Clara and St. George; (2)*

seepage studies that show gain in the Santa Clara River as it crosses the Lower Kayenta formation; and (3) the Sullivan flowing well (C-41-13) 16bcd-1, which is an artesian well drilled along the Kayenta Formation outcrop near Sandstone Mountain but is finished in the underlying Springdale Sandstone member of the Moenave Formation (Wilkowske and others, 1998, table 1)."

Geologic Formations

Geologic descriptions have been provided in numerous levels of detail, and in several sources over the years. The geologic descriptions provided in the USGS Technical Publications seem to be relatively comprehensive for the purpose of this petition and are quoted directly herein. The following information about the Navajo Sandstone is quoted from USGS Technical Publication No. 70 by R.M. Cordova (1981).

"Almost all the Navajo samples were poorly cemented, indicating generally poor cementation in much of the formation. This, along with local fracturing and jointing, contributes to the relative high overall porosity and permeability of the Navajo compared to the other consolidated-rock units. However, well-cemented, poorly permeable horizons exist locally in the Navajo Sandstone aquifer... that impede vertical movement of groundwater. This is indicated by springs that emerge from above those horizons."

Heilweil, et al. (2000) provided geologic descriptions of the formations in the Virgin River basin area and their relationship to the identified aquifers. Table III-2 includes these descriptions as provided by Heilweil, et al. (2000) which was adapted from Hurlow (1998).

TABLE III-2
GEOLOGIC FORMATION DESCRIPTIONS IN VIRGIN RIVER BASIN AREA
(from Heilweil, et al., 2000 adapted from Hurlow, 1998)

AGE	GEOLOGIC UNIT	THICKNESS (FEET)	LITHOLOGIC CHARACTER	AQUIFER
Quaternary	Sediments and basalt	0-1,200	Boulders, gravel, sand, and silt	Quaternary basin-fill, alluvial-fan, and basalt aquifers
Quaternary - Tertiary	Basalt	0-550	Fractured, broken basalt	
	Alluvial-fan deposits	0-350	Poorly sorted boulder conglomerate	
Tertiary	Undifferentiated ingeous and sedimentary deposits	0-9,500	Fractured monzonite, volcanic ash-flow tuff, andesite, volcanic breccia, sandstone, conglomerate, and limestone	Pine Valley monzonite aquifer
Cretaceous	Undifferentiated	3,800-4,000	Sandstone, siltstone, mudstone, and conglomerate	

TABLE III-2 Continued

AGE	GEOLOGIC UNIT	THICKNESS (FEET)	LITHOLOGIC CHARACTER	AQUIFER
Jurassic	Carmel Formation	700	Limestone, shale, and gypsum	
	Navajo Sandstone	2,000-2,800	Fractured, cross-bedded sandstone	Navajo aquifer
	Kayenta Formation	800-900	Sandstone, siltstone, and silty mudstone	Kayenta aquifer
	Moenave Formation	450	Siltstone	
Triassic	Petrified Forest Member of Chinle Formation	400	Shale, claystone, and siltstone	
	Shinarump Member of Chinle Formation	80-150	Medium-to-course grained sandstone and chert pebble conglomerate	
	Moenkopi	1,550-2,500	siltstone, mudstone, and shale	
Permian	Undifferentiated	3,350-3,550	Limestone, shale, sandstone, dolomite	

Structure

Local geology is extremely complex and highly fractured. Heilweil, et al. (2000) describes the Navajo and Kayenta Formations as follows.

> *In general, the Navajo Sandstone is well sorted, consisting primarily of fine-to-medium sand-size quartz grains (Cordova, 1978, table 1). Petrographic analysis of borehole cuttings indicates that the cementation between sand grains includes varying amounts of calcite, silica, and hematite (J. Wallace, Utah Geological Survey, written commun., 1997).*

> *The Navajo Sandstone, where buried by overlying formations, is about 2,400 ft thick; individual measurements include 2,800 ft west of the Gunlock Fault, about 2,300 ft at Harrisburg Junction, and about 2,000 ft at Sandstone Mountain. The lowest 100 to 150 ft of the navajo Sandstone is defined by Hurlow (1998) as a transition zone containing siltstone and fine-grained sandstone typical of the Kayenta Formation interbedded with cross-bedded sandstone typical of the Navajo Sanstone. The Kayenta Formation consists of laminar beds of sandstone, siltstone, and silty mudstone. Where buried by overlying formations, thickness of the Kayenta Formation ranges from about 380 to 930 ft but is estimated to be about 850 ft through most of the study area (Hugh Hurlow, Utah Geological Survey, oral commun., 1998).*

> *The Navajo Sandstone, where buried by overlying formations, is about 2,400 ft thick; individual measurements include 2,800 ft west of the Gunlock Fault, about*

2,300 ft at Harrisburg Junction, and about 2,000 ft at Sandstone Mountain. The lowest 100 to 150 ft of the navajo Sandstone is defined by Hurlow (1998) as a transition zone containing siltstone and fine-grained sandstone typical of the Kayenta Formation interbedded with cross-bedded sandstone typical of the Navajo Sanstone. The Kayenta Formation consists of laminar beds of sandstone, siltstone, and silty mudstone. Where buried by overlying formations, thickness of the Kayenta Formation ranges from about 380 to 930 ft but is estimated to be about 850 ft through most of the study area (Hugh Hurlow, Utah Geological Survey, oral commun., 1998).

Tectonic forces have folded and faulted the Navajo Sandstone and Kayenta Formation. The major folds within the study area, from east to west, are (1) the Hurricane Bench syncline, (2) the Virgin anticline, (3) the St. George syncline, and (4) the Gunlock (or Shivwits) syncline (Cordova, 1978, p. 11; Hurlow, 1998). Because of a generally northward dip, the Navajo Sandstone and Kayenta Formation become deeply buried toward the northern boundary of the study area. . . . Tilting associated with the Hurricane Fault causes the Navajo Sandstone and Kayenta Formation in the northeast part of the study area to dip steeply; the top of the Navajo Sandstone is estimated to be buried as deep as 2,000 ft below sea level (Hurlow, 1998, pl. 5B). The Hurricane Fault completely offsets the Navajo Sandstone and Kayenta Formation along its entire trace. The Gunlock Fault offsets the Navajo Sandstone and the Kayenta Formation to some point north of Gunlock Reservoir (Hintze and Hammond, 1994). West of the Gunlock Fault, the Navajo Sandstone and Kayenta Formation dip northeast more steeply than the gently dipping synclines east of the fault (fig. 5; Hurlow, 1998, pl. 5B). Other faults that partly offset the Navajo Sandstone and Kayenta Formation within the study area include the Washington Hollow Fault north of Washington and an unnamed series of faults between Anderson Junction and Toquerville. These faults . . . likely act as barriers to ground-water flow perpendicular to the fault plane, yet may act as conduits parallel to the fault plane. Low transverse permeability is expected perpendicular to the fault because of poorly-sorted breccia and finer clay-rich materials generally found along the plane of the fault, such as cataclasite, gouge, and secondary calcite cementation (Hurlow, 1998, p. 20).

Extensive joints and joint zones are found in the Navajo Sandstone and Kayenta Formation outcrops. Unlike faults, there was no movement along the fracture plane of joints during their formation, so they do not contain low-permeability gouge or breccia zones and thus allow ground water to move perpendicular to the joint plane. Similar to fault zones, joints probaby act as conduits parallel to the joint plane. Joints within the study area are essentially vertical, dipping at angles generally greater than 70 degrees. Surface fracture mapping indicates that individual joints have surface traces of as much as 600 ft in length, and interconnected joint networks may extend thousands of feet laterally (Hurlow, 1998).

Two cross sections of the Navajo/Kayenta aquifers from Heilweil, et al. (2000) are shown on Figure A2. The locations of these cross sections are also shown in Figure A2 in Appendix A.

GEOLOGY OF SUBAREAS

The following subareas lie within the proposed Navajo/Kayenta and Extended Zone of the aquifer classification boundaries. This more localized geologic description comes from the July 1998 HAL study for Washington County Water Conservancy District, titled "Determination of Recommended Septic System Densities for Groundwater Quality Protection." Subarea locations are shown on Figure A1.

Anderson Junction

Anderson Junction is a growing area located along I-15 at the north end of Toquerville and one mile west of the Hurricane fault. It lies within an alluvial fill area, is believed to be underlain by fractured basalts, and is within the limits of the Navajo/Kayenta aquifer. According to existing mapping, there are several local faults having a northeast-southwest orientation generally paralleling the local extent of the Hurricane fault.

Dameron Valley

Dameron Valley lies within the upper portions of the Navajo Formation in the western and southern portions of the valley, and just above the Navajo Formation within the northern and eastern portions. It is also estimated that there is upwards of 200 feet of alluvium in some locations which would produced localized alluvial or perched flows to the southwest. This general ground water flow could be interrupted by local north-south trending faults which have been identified within Snow Canyon lying to the south (if they connect far enough north to intercept the flow). If this faulting is present with Dameron Valley, it is possible that there could be a direct source of connection with down gradient water supplies within the lower portions of Snow Canyon.

Groundwater flow paths within the Navajo are projected to be to the south-southeast at an overall gradient of about 0.5%.

Diamond Valley

Diamond Valley is located approximately nine miles almost due north of St. George along Highway 18 and lies in the south half of the extended zone. General information for this area indicates that the valley lies within the upper reaches of, and just above the Navajo Formation with upwards of 200 feet of alluvium at some locations. No regional faulting has been identified within the general Diamond Valley area which could be a direct source of connection with down gradient water supplies. Some aquitards capable of limiting downward movement are believed by a few local experts to be present within the alluvium. The depth of water within the Navajo formation is approximately 1,400 to 1,600 feet, and ground water flow paths within the Navajo/Kayenta aquifer are projected to be to the southeast at an overall gradient of about

0.5%. Alluvial flow is believed by some local professionals to be only a minor portion of any total flow.

Gunlock

The community of Gunlock and Gunlock Reservoir, located approximately 15 miles northeast of the town of St. George, lies within a highly geologically complex area. The southern half of Gunlock reservoir lies within the Navajo Sandstone formation while the Town of Gunlock lies above the Navajo within the Iron Springs Formation. The Navajo Formation west of the Gunlock Fault (a north-south trending fault which lies east of the Santa Clara River, reservoir and town) dips approximately 20 degrees to the north-northeast. Hurlow (1998) states that the "Gunlock fault zone . . . has components of down-to-the-west normal slip and left-lateral strike-slip." He also indicates that the "Navajo Sandstone is completely disconnected across the Gunlock fault zone except along a 1.6 mile stretch south of Gunlock Reservoir, where the vertical overlap is less than about 330 feet." Total strike-slip displacement appears to be just over 2 miles.

Sand Mountain

Sand Mountain includes Hurricane Bench and Bench Lake area and is generally located within the area between the Hurricane fault on the east and the Virgin anticline on the west. The area is mostly found within the Navajo Formation overlain by sand, and in some areas by fractured basalts.

The local ground water flow paths are believed to be generally oriented northward at a gradient of about 1.1%. West of Hurricane, the groundwater flow direction bends to the west where groundwater discharges into the Virgin River.

Veyo

Veyo is built upon a thin alluvial layer underlain by fractured volcanics and limestones and is generally within the Iron Springs Formation, and above the Navajo Formation. According to data shown on mapping provided by UGS, the top of the Navajo Formation is located 1900 feet below land surface datum. Local recharge moving vertically downward would have to move more than 700 feet through the Dakota, Carmel, and Temple Cap formations before entering the Navajo sandstone unit. Hurlow (1998) indicates that the Temple Cap formation contains significant shale and gypsum which would tend to limit local deep recharge from the Veyo area into the Navajo Sandstone.

Winchester Hills

Winchester Hills is located approximately 6 miles north-northwest of St. George within the limits of the Navajo Formation with a cap of alluvium and basalts. Although no significant regional faulting has been identified with the general area, there is prominent fracturing which could be a direct source of connection with down gradient water supplies.

The depth to water within the Navajo Formation is approximately 750 feet, and ground water flow paths within the Navajo are projected to be to the southeast at an overall gradient of about 0.5%. A local subsurface flow rate of 42 acre-feet/year (0.06 cfs) (using a velocity of 30.4 feet/year) within the Navajo was estimated by assuming a contribution width of approximately 4,000 feet, a hydraulic conductivity of 5 feet/day (1,825 feet/year), and a 50 foot flow depth.

CHAPTER IV

GROUND WATER FLOW

GENERAL CONSIDERATIONS

Groundwater contours developed by Heilweil, et al. (2000) for the Navajo/Kayenta and the Upper Ash Creek aquifers are shown in Figure A3. Flow directions derived from these contours are considered to be general and may not be directly applicable for determining local flow directions in smaller subareas within the aquifer.

Simulated water levels were compared to observed water levels in 30 wells in the Upper Ash Creek aquifer. The root mean square error from comparison of the computed and observed values was 24 feet in the basin fill aquifer (18 observations), 63 feet in the alluvial fan aquifer (4 observations), and 57 feet in the monzonite aquifer (8 observations). Referring to the simulated contours for the Upper Ash Creek Aquifer, Heilweil, et al. (2000) stated the following:

> *The model was developed to help understand the ground-water flow system in the upper Ash Creek drainage basin. . . . Because of the many uncertainties regarding boundaries, geometry, and aquifer properties, it is not considered a "calibrated" steady-state model. It should be thought of as a tool to use to explore the viability of alternative conceptualizations about the flow system.*

Simulated water levels were compared to observed water levels in 42 wells throughout the Navajo/Kayenta aquifer between the Gunlock and Hurricane Faults. The root mean square error from comparison of the computed and observed values was 58 feet in the Hurricane Bench area (17 observations), 196 feet in the Anderson Junction area (7 observations), and 91 feet in the Central area (18 observations). Heilweil, et al. (2000) indicated that the simulated Navajo/Kayenta aquifer contours provide a "general approximation to the actual hydrologic system" and that they "show a pattern of groundwater movement similar to that conceptualized from sparse water-level measurements."

Simulated water levels were compared to observed water levels in 9 wells in the Navajo/Kayenta aquifer west of the Gunlock fault. The root mean square error from comparison of the computed and observed values was 20 feet. Heilweil, et al. (2000) made the same comments about these simulated contours as for the Upper Ash Creek aquifer.

UPPER ASH CREEK

Recharge from the Upper Ash Creek watershed contributes to local water supplies. Groundwater generally follows the ground surface contours in a southerly flow pattern, beginning on the north at a groundwater divide located 2 miles north of Kanarraville (see Figure A3). The area of recharge is further bounded on the east by the Hurricane fault and on the west by the topographic divide.

Surface water travels southward until it enters Ash Creek Reservoir. Ground water flowing within the unconsolidated deposits moves from high to low topographic areas in a manner similar to surface water. Upon reaching the Ash Creek Reservoir area, it is believed that the ground water flows southward along the Ash Creek drainage which conveys the water southward towards Toquerville (Heilweil, et al., 2000).

Heilweil, et al. (2000) estimates the total recharge for the Upper Ash creek aquifer is between 6,100 to 18,800 acre-feet/year and discharge for the valley is between 3,000 and 28,000 acre-feet/year. The large range in estimated discharge is due mostly to variability in estimated evapotranspiration. Evapotranspiration estimates ranged significantly due to a large range of consumptive use values used for the types of phreatophytes identified and to uncertainty in the total area that phreatophytes exist within the study area. The estimated groundwater budget for the Upper Ash creek drainage basin is shown in Table IV-1.

TABLE IV-1
ESTIMATED UPPER ASH CREEK GROUNDWATER BUDGET
(adapted from Heilweil, et al., 2000)

Recharge Flow Component		Rate (acre-feet/year)	
		Conceptual	Baseline[3]
Infiltration of precipitation		2,100 to 9,200	10,410
Seepage from ephemeral streams		[1]3,500	2,650
Infiltration of unconsumed irrigation water		[2]0 to 5,000	880
Seepage from perennial streams		500 to 1,100	380
	Total	6,100 to 18,000	14,320
Discharge Flow Component		**Rate (acre-feet/year)**	
		Conceptual	Baseline[3]
Well discharge		1,200 to 1,500	1,440
Evapotranspiration		1,100 to 15,000	8,410
Spring discharge (excludes Sawyer Spring)		200 to 1,000	340
Seepage to Ash, Sawyer, and Kanarra Creeks (includes Sawyer Spring)		500 to 3,000	1,630
Subsurface outflow to lower Ash Creek Drainage		0 to 7,500	2,500
	Total	3,000 to 28,000	14,320

1 This is likely a minimum value.
2 Actual amount is thought to be nearer the lower end of this range.
3 Values used in the USGS baseline model of Upper Ash Creek aquifer (Heilweil, et al., 2000).

NAVAJO/KAYENTA

Because the Gunlock fault almost completely disconnects the Navajo/Kayenta aquifer (Hurlow, 1998), Heilweil, et al. (2000) simulated the aquifer west of the this fault as a separate aquifer from the aquifer east of the fault. Other faults that do not disconnect the aquifer, such as the Washington fault, were simulated as horizontal flow barriers due to fault gouge. Heilweil, et al. (2000) describes groundwater flow within the Navajo/Kayenta aquifer as follows.

"Groundwater in the Navajo/Kayenta aquifer generally moves from the base of Pine Valley Mountains southward towards the Santa Clara and Virgin Rivers. The exception to this is the part of the aquifers southwest of Hurricane, where ground water moves northwestward towards the Virgin River."

Within the unconfined outcrops, the potentiometric contours tend to follow ground surface elevation. Additionally there is a small downward vertical gradient between the Navajo and Kayenta formations.

Major sources of recharge for the Navajo/Kayenta aquifer, as reported by Heilweil, et al. (2000), include infiltration of precipitation over the exposed Navajo and Kayenta Formations, seepage from streams, and seepage from underlying formations. Other possible major sources of recharge not addressed by Heilweil, et al. (2000) include subsurface inflow from formations east of the Hurricane fault, subsurface inflow from the Upper Ash Creek aquifer, and subsurface inflow from overlying formations in the Pine Valley area. The principal sources of discharge for this aquifer include well discharge, spring discharge, and seepage to the Virgin River. The estimated groundwater budget for the Navajo/Kayenta aquifer is shown in Table IV-2.

TABLE IV-2
ESTIMATED NAVAJO/KAYENTA GROUNDWATER BUDGET
(adapted from Heilweil, et al., 2000)

Recharge Flow Component	Rate (acre-feet/year)	
	Conceptual	Model[1]
Infiltration of precipitation	7,900 to 23,900	15,900
Seepage from perennial streams	2,000 to 6,900	6,900
Seepage from ephemeral streams	200 to 4,500	3,600
Seepage from underlying formations	0 to 3,000	2,400
Infiltration of unconsumed irrigation water	0 to 4,400	1,100
Seepage from Gunlock Reservoir	0 to 2,200	1,000
Seepage from Sand Hollow Reservoir[3]	NA[3]	NA[3]
Subsurface inflow[4]	NA[4]	NA[4]
Total	10,100 to 40,400	30,900[2]
Discharge Flow Component	**Rate (acre-feet/year)**	
	Conceptual	Model[1]
Well discharge	10,600 to 16,400	14,400
Spring discharge	5,000 to 6,200	5,900
Seepage to Virgin River	4,700 to 5,700	5,200
Seepage to underlying formations	0 to 5,400	4,500
Seepage to Santa Clara River	400	1,100
Total	20,700 to 34,100	30,600

1 Actual values used in the USGS model of the Navajo/Kayenta aquifer (Heilweil, et al., 2000).
2 Discharge and recharge numbers do not match due to slight rounding errors.
3 Flow budget estimated prior to construction of the Sand Hollow Reservoir which was completed in 2003.
4 Potential recharge from subsurface inflow east of the Hurricane fault, from Ash Creek, & from Pine Valley not addressed by Heilweil, et al. (2000).

Recharge over the Navajo aquifer was investigated by the USGS in *Water-Resources Investigations Report 92-4160* (Freethey, 1993). This report found that recharge to the Navajo aquifer can vary significantly depending on many factors. Factors may include quantity of precipitation, topographical slope, presence and infiltration capacity of surficial deposits, location of intermittent and perennial stream channels, vegetation, soil development, and surface fractures.

A recharge study of the Navajo aquifer by Freethey (1993) summarized relative recharge potential over the aquifer due to precipitation. He also identified potential recharge locations for intermittent and perennial streams and subsurface inflow. For precipitation, emphasis was given to winter precipitation (October through April)

> *"because temperatures are cool enough so that evaporation rate is slow, and winter precipitation in the form of snow usually melts slowly, extending the period of runoff and increasing infiltration (Danielson and Hood 1984). Infiltration studies by Danielson and Hood (1984) generally indicate that areas with more than 8 inches of winter precipitation (water equivalent) contributed the most recharge to underlying aquifers."* (Freethey 1993)

Only the northern third of the exposed Navajo sandstone (essentially where the ground elevation exceeds about 3,700 feet) receives more than 8 inches of precipitation annually, and therefore, has the highest infiltration. Additionally, unconsolidated granular deposits near the towns of La Verkin and Hurricane increase the infiltration rates in these areas. Infiltration rates in the southern areas of the exposed outcrop are expected to be significantly lower (Freethey, 1993). Infiltration of precipitation into the Navajo aquifer from the overlying formations north of the exposed Navajo was considered by Freethey (1993) to be negligible where the Navajo was deeply buried and low where the depth to the top of the Navajo was the least. Precipitation recharge zones based on Freethey (1993) as discussed above are shown on Figure A4.

Freethey (1993) indicated that stream infiltration occurs at all times when water is present in the stream channel. Therefore, perennial streams would contribute to recharge of the Navajo aquifer year round, whereas intermittent streams would only contribute to recharge during spring runoff or during larger rainstorms. Locations of intermittent and perennial streams as indicated by Freethey (1993) are included on Figure A4.

Freethey (1993) indicated that subsurface inflow from older formations occurs across the Hurricane fault south of Hurricane. No other locations were indicated for subsurface inflow into the Navajo aquifer.

CHAPTER V

GROUND WATER QUALITY

USGS DATA

As part of their recent study (Heilweil, et al., 2000), the USGS collected samples from several of wells and springs within the Navajo/Kayenta and Upper Ash Creek aquifers. These samples were analyzed for various water quality parameters, including total dissolved solids (TDS). The locations of the sampled wells and springs are shown on Figures A5 and A6. The well identification numbers for wells with additional water quality data beyond just TDS are shown on Figure A5. The water quality results for these wells are included in Appendix B, Table B1. Figure A6 shows the TDS concentrations at each of the USGS well or spring locations.

UTAH DIVISION OF DRINKING WATER DATA

The Utah Division of Drinking Water (DDW) collects water quality test results from public drinking water supplies. Water quality results were obtained from DDW for public water supplies in the vicinity of the Navajo/Kayenta and Upper Ash Creek aquifers. Two were located within the Upper Ash Creek aquifer, 51 were located within the Navajo/Kayenta aquifer, and 14 were located outside both aquifers. Locations of the public drinking water supplies are shown on Figure A5. Public drinking water supplies are tested frequently resulting in an extensive database (over 1500 pages). Therefore, the summary of DDW water quality data given in Appendix B, Table B2, contains only the reported values that exceed primary and secondary drinking water standards. Public drinking water sources shown on Figure A5 are displayed according to whether there were any water quality exceedances reported on Table B2 for the drinking water source.

ANALYSIS OF DATA

The available water quality data indicates that the Upper Ash Creek aquifer and most of the Navajo/Kayenta aquifer are eligible for a Class IA - Pristine classification. Most TDS values within the study area ranged from 200 to 300 mg/l. Although there were occasional water quality parameters that exceeded Utah primary and secondary drinking water standards, these instances appeared isolated with preceding and following values being well within the state standards. It is possible that these isolated test values are due to sampling or laboratory error.

As part of its groundwater modeling effort for the Navajo/Kayenta aquifers, the USGS evaluated TDS concentrations at 73 different sampling sites.

> *"Dissolved-solids concentrations of ground-water samples from wells and springs in the Navajo and Kayenta aquifers ranged from 110 to 1,310 mg/L (Wilowske and others, 1998) at 73 sample sites. Ground water from most of the Navajo and Kayenta aquifers was low in dissolved minerals, with an average dissolved-solids concentration of about 300 mg/L in water from 54 well and spring samples. However, there were two distinct areas with dissolved-solids*

concentrations greater than 500 mg/L: a large area north of St. George and a smaller area a few miles west of Hurricane. Nineteen wells and springs from these areas had an average dissolved-solids concentration of about 1,020 mg/L.

The estimated boundaries of the two areas with TDS concentrations exceeding 500 mg/L are shown in Figure A6. Heilweil, et al. (2000) compared the chemical composition of groundwater samples within the high TDS areas with groundwater from the formations overlying the Navajo/Kayenta aquifer and groundwater from the formations underlying the Navajo/Kayenta aquifer. The resulting comparison demonstrated that samples from the areas of high TDS within the Navajo/Kayenta aquifer were similar to groundwater from underlying formations and dissimilar to groundwater from overlying formations. Heilweil's comparison (Figure 11 from Heilweil, et al., 2000) is included on Figure A6.

From this analysis, Heilweil, et al. (2000) determined that the elevated TDS values were due to infiltrating groundwater from the underlying formations. Higher groundwater temperatures observed in the high TDS areas led to the belief that the upward flow may be caused by hydrothermal flow mechanisms. Heilweil, et al. (2000) also indicated that an alternative explanation for the upward flow could be increased vertical permeability due to fractures associated with faulting in the area. Heilweil, et al. (2000) estimated the recharge from the underlying formations to be 2.7 cfs in the area north of St. George and 1.5 cfs in the area west of Hurricane.

Cordova (1978) summarized chemical quality information for 35 wells across the Navajo aquifer on Plate 3 of the USGS Technical Publication No. 61. This summary also indicated elevated TDS in the areas identified by Heilweil, et al. (2000) shown on Figure A6. Samples from wells with TDS greater than 500 mg/L in the area north of St. George were characterized by elevated sulfate (SO_4) and elevated sodium (Na) plus potassium (K) compared to samples with TDS lower than 500 mg/L. Samples from wells with TDS greater than 500 mg/L in the area west of Hurricane were characterized by elevated sulfate (SO_4) and calcium (Ca) compared to samples with TDS lower than 500 mg/L.

Because the TDS concentration is consistently above 500 mg/l in these two zones, groundwater from these areas cannot be classified as Class IA - Pristine. However, they are eligible for the Class II - Drinking Water classification.

CHAPTER VI

CURRENT BENEFICIAL USE

The Navajo/Kayenta and Upper Ash Creek aquifers are some of the most productive aquifers within Washington County. Heilweil, et al. (2000) describes the value of the Navajo/Kayenta aquifer as follows.

> *"Because of large outcrop exposures, uniform grain size, and large stratigraphic thickness, these formations are able to receive and store large amounts of water. In addition, structural forces have resulted in extensive fracture zones that enhance ground-water recharge and movement within these aquifers."*

Water withdrawn from the Navajo/Kayenta and Upper Ash Creek aquifers is currently being used for agricultural, industrial, and municipal purposes. The GIS land use database from State of Utah Division of Information and Technology Services – Automated Geographical Reference Center (AGRC) indicates that water is used for alfalfa, grass hay, and irrigated pastures in the Navajo/Kayenta aquifer zone just west of St. George and around the town of Hurricane. Alfalfa is grown in the lands surrounding the Town of Veyo. Alfalfa, grass hay, and grain are grown on land around New Harmony and Kanarraville in the Upper Ash Creek Aquifer (see Figure A7).

Based on the Utah Division of Water Rights point of diversion coverage, there are 1,276 active underground water rights with points of diversion within the Navajo/Kayenta and the Upper Ash creek aquifers. These water rights claim 590 cfs or 332,760 acre-feet/year from the petitioned aquifers. Accounting for the fact that some water rights declare more than one type of use, there were 160 commercial water rights, 249 stock watering rights, 296 domestic rights, and 969 Irrigation rights (DWR Database, 2000). The Utah Division of Drinking Water indicated there are 23 public water systems with 49 public drinking water wells with water quality data. A list of these public water systems is presented below.

- Dammeron Valley Water Works
- Gunlock Water Users Association
- City of St. George
- City of Santa Clara
- Winchester Hills Water Company
- Washington City
- Leeds Domestic Water Users Association
- Oak Grove Campground, Forest Service
- City of Hurricane
- City of New Harmony
- Silver Reef Special Service District
- Washington County Water Conservancy District
- Casa de Oro
- Diamond Valley Water Co.
- El Dorado Hills
- Angell Springs Special Service District

- Harmony Heights
- Kanarraville
- City of Leeds
- Pine Valley Mountain Farms
- Pine Valley Irrigation Company
- Pine Valley Ranchos
- Veyo Culinary Water Associations

The location of water sources for these water systems along with AGRC's landuse information is presented in Figure A7. The underground diversion locations of the 1,276 active water rights are also presented in Figure A7. Many of these water rights are so close together they are seen as a single point.

CHAPTER VII

POTENTIAL CONTAMINATION SOURCES

Identification of potential contamination sources (PCSs) within the Navajo/Kayenta and Upper Ash Creek aquifers is not intended to provide an all encompassing inventory nor is it intended to provide a prioritized list from which to manage PCSs. Rather, the intent is to identify the types and nature of PCSs typical to the area to provide justification for the classification petition. Information on PCSs for the Navajo/Kayenta and Upper Ash Creek Aquifers was collected from several sources. Key information sources for this petition include

- Utah's Automated Geographic Reference Center (AGRC)
- Drinking Water Source Protection (DWSP) Plans
- Utah Division of Oil, Gas, and Mining (DOGM)
- Utah Divison of Water Quality (DWQ)
- Septic system density report by Hansen, Allen, & Luce Inc

The various potential contamination sources (PCSs) identified by the above sources are discussed in the following sections.

MISCELLANEOUS PCSs IDENTIFIED IN DWSP PLANS

Several farms were considered potential contamination sources because of above ground fuel tanks and application of pesticides, herbicides, and fertilizers. Other potential contamination sources included gravel pits south of Leeds, an above ground fuel tank a mile northeast of Gunlock, and the St. George golf course. The locations of these sources are shown on Figure A9. Additional farms, gravel pits, fuel tanks, golf courses, and other potential contamination sources likely exist within the Navajo/Kayenta and Upper Ash Creek aquifers. However, only those identified within DWSP Plans are shown on Figure A9.

ABANDONED MINES

The Utah Division of Oil, Gas, and Mining (DOGM) provided GIS layers of abandoned mines for Washington and Iron counties. These data document 792 mines near the bottom edge of the Kayenta formation along both sides of I-15 between Leeds and Harrisburg. The majority of these mines are below the Kayenta formation and therefore should not impact the Navajo/Kayenta aquifer. Additionally, information from DOGM indicated that the mines have been backfilled which should reduce the risk from leachate generated by these mines. Locations of the mines are shown on Figure A8.

INJECTION WELLS

According to the Utah Division of Water Quality's Underground Control Database there are no registered well injection points within the study area.

CEMETERIES

Most communities have a cemetery nearby. The potential release of embalming fluids into the aquifer makes them a potential contamination source (PCS). However, concrete vaults provide secondary containment which reduces the risk of contamination from cemeteries. The locations of cemeteries shown on Figure A8 were obtained from AGRC.

UNDERGROUND STORAGE TANKS

Underground storage tanks (USTs) and leaking underground storage tanks (LUSTs) represent significant potential contamination sources (PCSs). The locations, along with identification numbers, owners, and addresses of these tanks were obtained from the AGRC's UST and LUST GIS layers. The locations of underground storage tanks are shown on Figure A9. The Utah Division of Environmental Response and Remediation (DERR) identification number, name, and address of underground storage tanks within the proposed aquifer classification boundaries are included in Table B3 in Appendix B. This table also indicates which tanks have had leaks recorded. The Utah DERR requires all UST owners to monitor for leaks and/or provide double walled tanks. When leaks are detected, the UST owner is required to monitor the extent of the leak and remediate, if necessary. On-going regulation of USTs and LUSTs by DERR reduces the risk of contamination from these PCSs.

CERCLA SITES

GIS layers from AGRC database were used to identify possible contamination of the aquifers from existing CERCLA sites. These layers identified ten CERCLA sites within or near the Navajo/Kayenta and Upper Ash Creek aquifers. The locations of these sites identified by the assigned identification numbers in Table VII-1 are shown on Figure A9. Only sites No. 3, 4, 5, and 10 are actually within the proposed aquifer classification boundaries.

TABLE VII-1
CERCLA SITES

ID Number	DERR- ID	Site Name	Location
1	UT0000935403	Barbee & Walker Mill	North end White Reef West of Leeds
2	UTD981550619	Leeds Silver Reclamation Site	2 miles West of Leeds to White Reef
3	UT0000934653	Leeds 5 Stamp Mill	Leeds Creek
4	UT0000935452	Stormont Company Mill	3.5 Miles south of I-80 Leeds Exit
5	UT0000032862	Cycle Town Yamaha	333 West St. George Blvd.
6	UTD988066239	Southwest Assay Site	1 mile north of Leeds
7	UT0001766252	Western Gold Floatation Mill	Northern end of White Reef, 1 mile west of Leeds
8	UT0001958420	Big Hill - Chloride Chief Mines	½ mile north of Leeds
9	UTN010161078	Pioneer 3-Stamp Mill Tailings	900 Red Cliffs Road, Leeds
10	PENDING11	Hurricane 5M Ore Processing Facility	674 North State Street, Hurricane

The EPA online database indicated that CERCLA sites No. 1-4 as listed in Table VII-1 consisted of mines and/or tailing piles with lead as the only known recorded contaminant. CERCLA sites No. 1 and No. 4 are considered low priority sites and no further remedial action is planned. CERCLA sites No. 2 and No. 3 were cleaned up by removal of the contaminated soils.

TOXIC RELEASE INVENTORY SITES

Based on the AGRC GIS database for Utah Division of Environmental Response and Remediation (DERR) Toxic Release Inventory (TRI) sites, there is only one TRI site within the proposed aquifer classification boundaries. This site is owned by St. George Steel Fabrication, Inc. and is located at 1302 East 700 North, St. George, Utah as shown on Figure A9.

URBAN AREAS

Potential contamination sources (PCSs) associated with commercial and residential areas include household hazardous waste, street and parking lot storm runoff, and application of fertilizers, pesticides, and herbicides. These potential hazards may be negligible when considering a single home or small business. However, the combined risk from a residential or commercial area may present a significant risk to groundwater quality. Urban areas are shown on Figure A10.

MAJOR TRANSPORTATION ROUTES

Large quantities of hazardous materials are transported regularly along major transportation routes such as Interstate 15 and other State and County roads. Accidents involving these shipments could result in spills that may reach the groundwater. Interstate 15 and other major roads are shown on Figure A10.

SEPTIC SYSTEMS

The most prevalent potential contamination source for the Navajo/Kayenta and Upper Ash Creek aquifers are septic systems spread across these aquifers. While the rapidly growing areas closer to St. George are either now sewered or are considering installing sewer systems, the more rural and relatively undeveloped portions of the study area continue to use septic systems for wastewater disposal. As these rural areas experience increased development, the number of septic systems also increases.

Table VII-2 identifies the current number of septic systems in each subarea with estimates for future septic system use. The future number of future septic systems was estimated considering available land throughout the study area, available water rights associated with the land, and current and likely future zoning patterns (Hansen, Allen, and Luce, 1998). In addition, a projection was made assuming that water availability would not be a constraint (requires an external source of water). The boundaries of the subareas listed in Table VII-2 are very general and are only loosely correlated to the areas of the Navajo/Kayenta and Upper Ash Creek aquifers. The general locations of the subareas can be seen in Figure A1.

TABLE VII-2
SEPTIC SYSTEM USE PROJECTIONS

Location	Private Land Area (acres)	Current Conditions Septic Systems	Buildout w/ Constraints Septic Systems	Buildout w/out Constraints Septic Systems	Aquifer Subarea Overlain
Anderson Junction	653	7	20	660	Navajo/Kayenta
Brookside	5219	620	720	900	Extended Zone
Dameron Valley	3497	200	300	3500	Extended Zone
Diamond Valley	2064	404	440	620	Navajo/Kayenta
Gunlock	3536	40	100	300	Extended Zone
Hurricane	16130	56*	0*	0*	Navajo/Kayenta
Ivins	5240	0*	0*	0*	Navajo/Kayenta
La Verkin	3674	16*	0*	0*	Navajo/Kayenta
Leeds	3871	200	300	780	Navajo/Kayenta
New Harmony	15810	300	3000	3160	Upper Ash Creek
Bench Lake Area	3480	150	300	360	Navajo/Kayenta
Toquerville	4620	0*	0*	0*	Navajo/Kayenta
Veyo	4155	100	100	830	Extended Zone
Washington	5961	0*	0*	0*	Navajo/Kayenta
Winchester Hills	2510	350	600	2510	Navajo/Kayenta
Total	80420	2443	5880	13620	

* Area is either currently sewered or is likely to be sewered in the near future.

Adapted from: *Determination of Recommended Septic System Densities for Ground Water Quality Protection. By* Hansen, Allen & Luce Inc.1998.

CHAPTER VIII

PROPOSED CLASSIFICATION

Based on the information contained in this report, and growing concerns over protection of the groundwater in the study area, WCWCD petitions the Utah Water Quality Board to classify portions of the Navajo/Kayenta aquifer as Class IA - Pristine Groundwater where the TDS is below 500 mg/l and Class II - Drinking Water where the TDS is above 500 mg/l. WCWCD also petitions to classify the Upper Ash Creek Aquifer as Class IA - Pristine Groundwater. The proposed Class IA and Class II classification areas are shown on Figure A11.

Boundaries of the Class IA - Pristine petition area in the Navajo/Kayenta Aquifer were delineated based upon the limits of the exposed Navajo and Kayenta formations, the estimated point where the Navajo Aquifer becomes confined by overlying formations, the Hurricane Fault, the developable area (slope $<30\%$) in the Pine Valley Mountains, and limits of the zones where TDS values exceed 500 mg/l. Boundaries of the Class II - Drinking Water petition area for the Navajo/Kayenta aquifer are defined by zones delineated by the USGS as having TDS values above 500 mg/l. The Class IA - Pristine petition area for the Upper Ash Creek Aquifer includes the entire aquifer as defined by faults, groundwater divides, and topographic divides.

REFERENCES

Averitt, P. 1967. *Geologic Map of the Kanarraville Quadrangle, Iron County, Utah.* U.S. Geological Survey Map GQ-694.

Cordova, R.M. 1978. *Ground-Water Conditions in the Navajo Sandstone in the Central Virgin River Basin, Utah.* State of Utah Department of Natural Resources Technical Publication No. 61. U.S. Geological Survey.

Cordova, R.M. 1981. *Ground-Water Conditions in the Upper Virgin River and Kanab Creek Basins Area, Utah.* State of Utah Department of Natural Resources Technical Publication 70. U.S. Geological Survey.

Damery, Bill. Utah Division of Water Quality. Personal Communication. 2000.

Freethey, Geoffrey W. 1993. *Maps showing recharge areas and quality of ground water for the Navajo aquifer, western Washington County, Utah.* U.S. Geological Survey Water-Resources Investigations Report 92-4160.

Hansen, Allen & Luce Inc. *Determination of Recommended Septic System Densities for Ground Water Quality Protection.* Washington County Water Conservancy District and Cooperating Agencies, Utah. 1998.

Heilweil, V.M., G.W. Freethey, C.D. Wilkowske, B.J. Stolp, and D.E. Wilberg. 2000. *Geohydrology and Numerical Simulation of Ground-Water Flow in the Central Virgin River Basin of Iron and Washington Counties, Utah.* State of Utah Department of Natural Resources Technical Publication No. 116. U.S. Geological Survey.

Hintze, L.F. and B.J. Hammond. 1994. *Geologic Map of the Shivwits Quadrangle, Washington County, Utah*. Utah Geological Survey Map 153.

Hurlow, H.A. 1998. *The Geology of the Central Virgin River Basin, Southwestern Utah, and Its Relation to Ground-Water Conditions*. Utah Geological Survey Water-Resources Bulletin 26.

Mize, Larry. 2000. Personal Communication. Utah Division of Water Quality.

U.S. Geological Survey. September 2000. GIS Layers obtained through Karen Hansen.

Utah Department of Oil, Gas, and Mining. September 2000. GIS Layers obtained from Jan Morse.

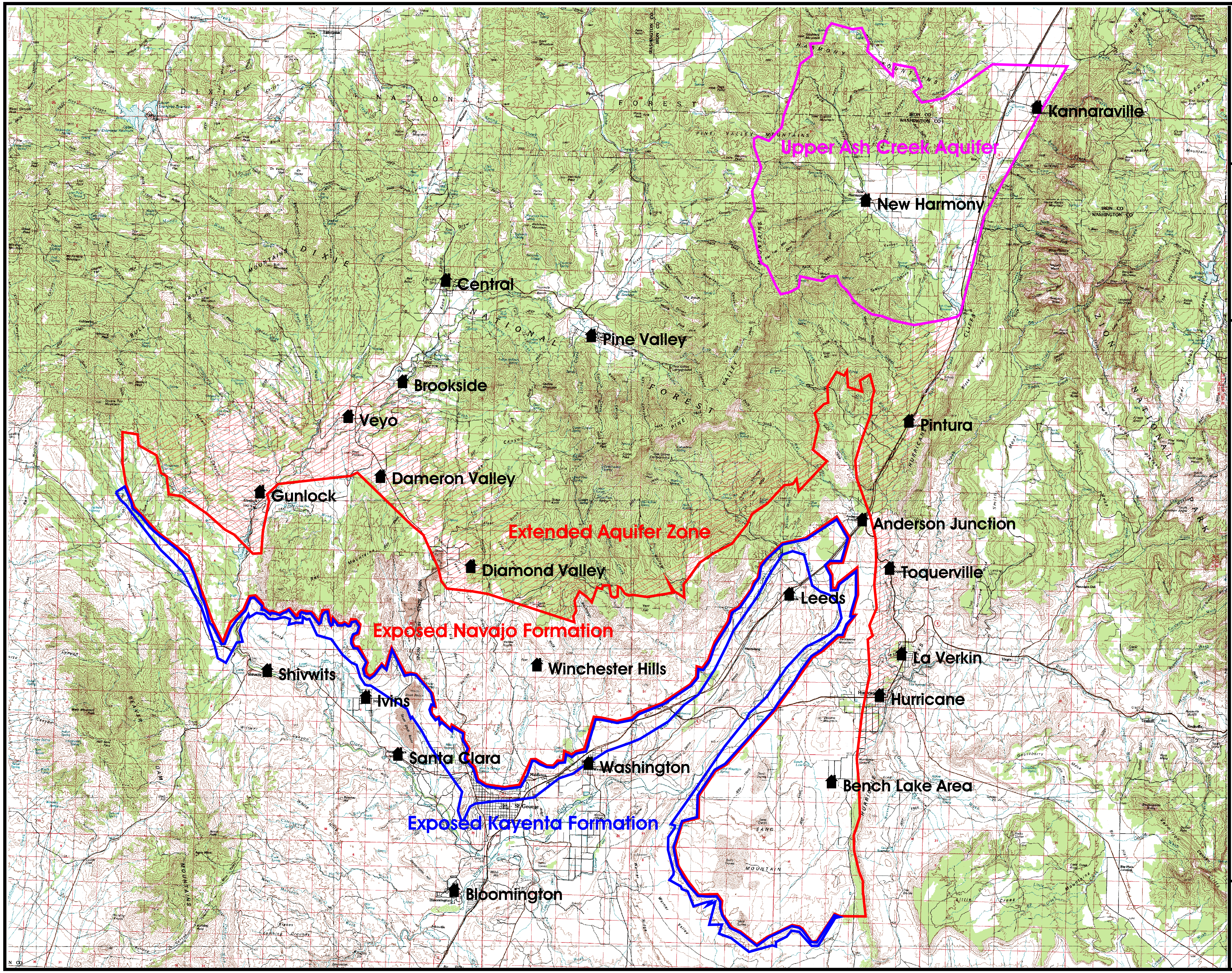
Utah Division of Drinking Water. August 8, 2000. Public Water Supply Information System.

Utah Division of Water Quality. 1998. *Aquifer Classification Guidance Document.*

Utah Division of Water Rights Website. 2004. GIS Layer for water rights points of diversion from http://www.waterrights.utah.gov/

Utah State Geographical Information Database. 2004. GIS Layers for Water Related Land Use, CERCLA sites, Toxic Release Inventory Sites, Underground Storage Tanks, and Roads from http://www.agrc.utah.gov/

Wilkowske, C.D., V.M. Heilweil, and D.E. Wilberg. 1998. *Selected Hydrologic Data for the Central Virgin River Basin Area, Washington and Iron Counties, Utah, 1915-97*. U.S. Geological Survey Open-File Report 98-389.



Navajo/Kayenta and Upper Ash Creek Aquifer Classification

for
Washington County
Water Conservancy District

Aquifer Boundaries and Subareas

- Subareas and Towns
- Extended Aquifer Zone
- Exposed Navajo Formation
- Exposed Kayenta Formation
- Upper Ash Creek Aquifer

Note:
There may be additional areas north of the Extended Aquifer Zone and east of the Hurricane Fault that contribute recharge to the Navajo/Kayenta aquifer.

N

2 0 2 4 6 Miles

HANSEN ALLEN & LUCE INC
ENGINEERS

FIGURE
A1

Navajo/Kayenta and Upper Ash Creek Aquifer Classification

for
Washington County
Water Conservancy District

Geologic Cross-Sections

(from Heilweil, et. al., 2000)

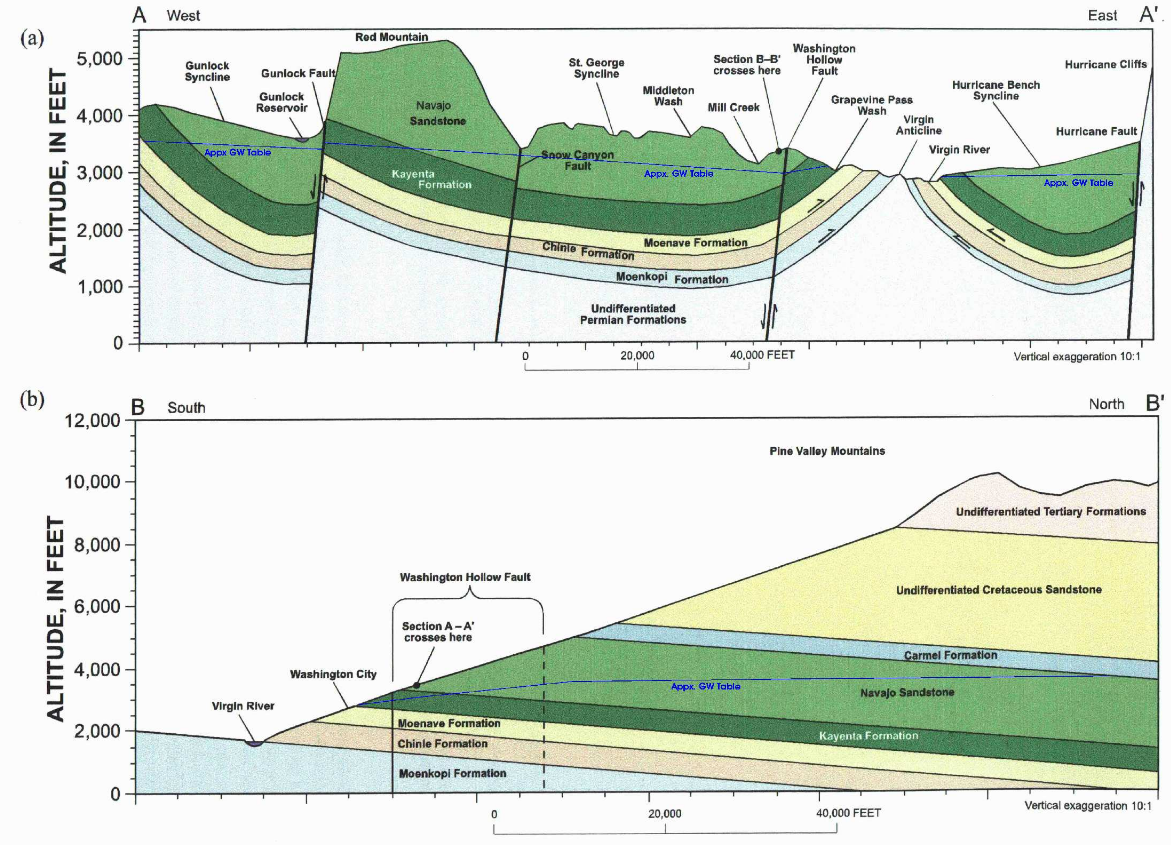
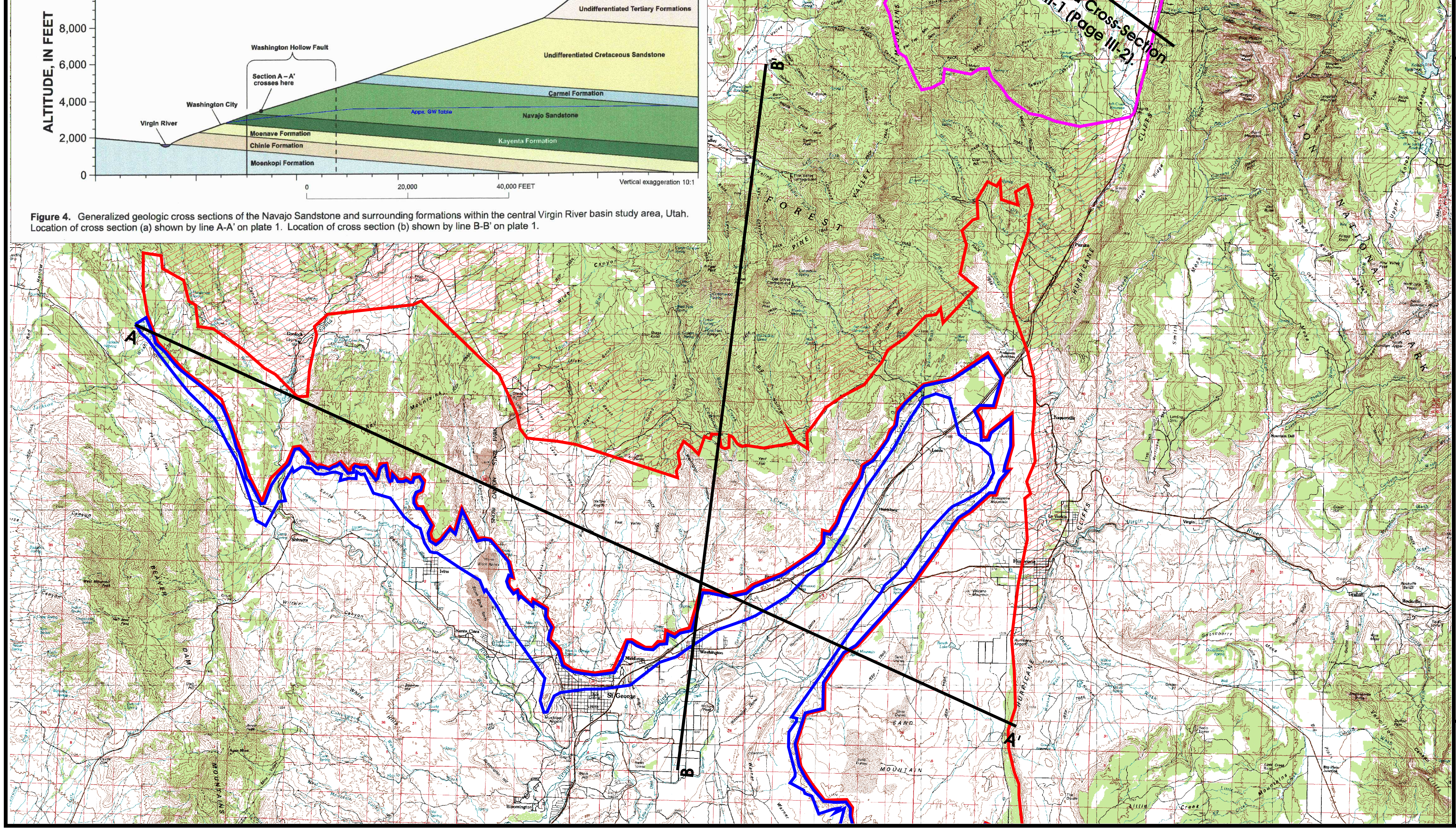


Figure 4. Generalized geologic cross sections of the Navajo Sandstone and surrounding formations within the central Virgin River basin study area, Utah. Location of cross section (a) shown by line A-A' on plate 1. Location of cross section (b) shown by line B-B' on plate 1.



- Cross-Section Location
- Extended Aquifer Zone
- Exposed Navajo Formation
- Exposed Kayenta Formation
- Upper Ash Creek Aquifer

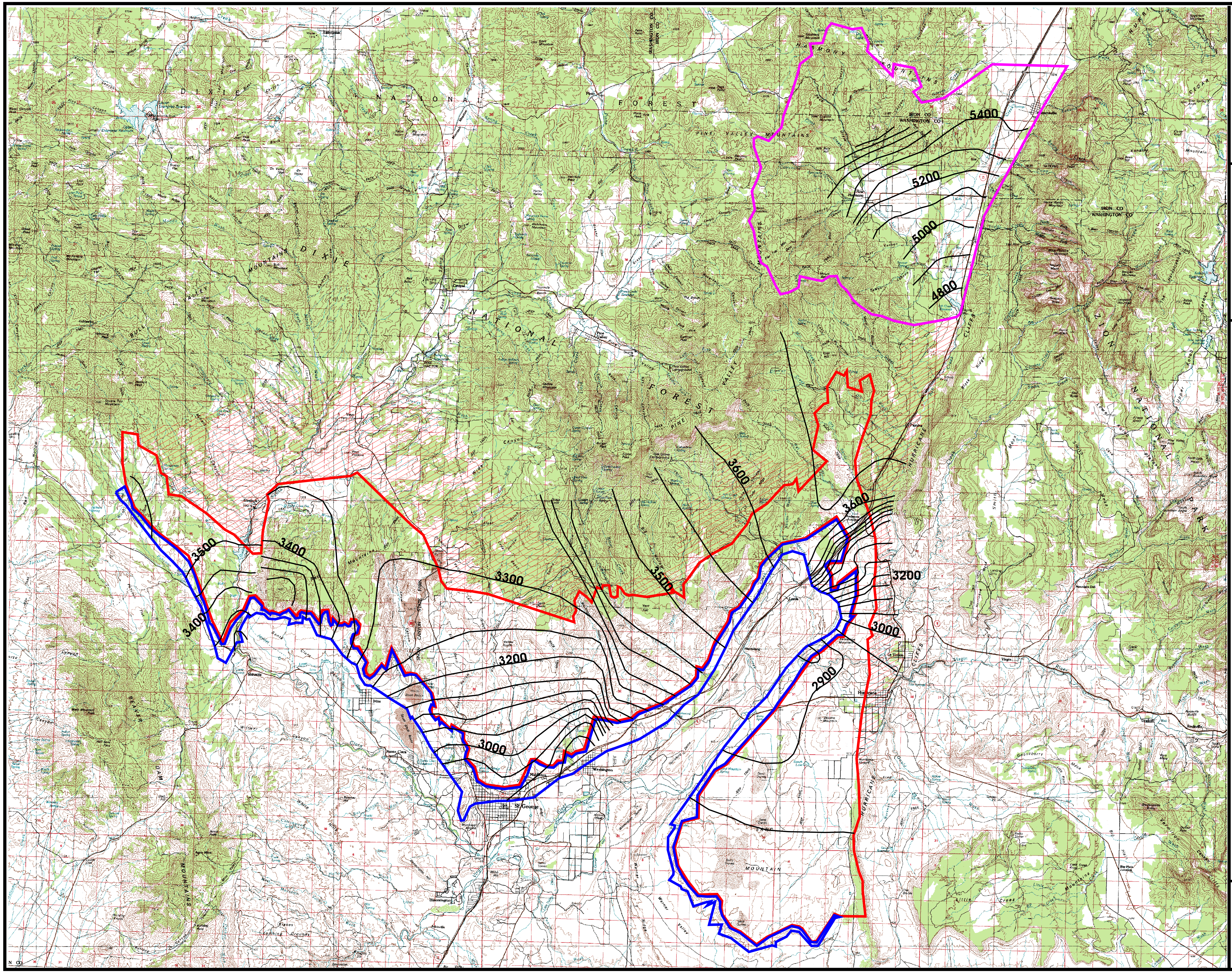
Note:
There may be additional areas north of the Extended Aquifer Zone and east of the Hurricane Fault that contribute recharge to the Navajo/Kayenta aquifer.

N

2 0 2 4 6 Miles

HANSEN ALLEN & LUCE INC
ENGINEERS

FIGURE
A2



Navajo/Kayenta and Upper Ash Creek Aquifer Classification

for
Washington County
Water Conservancy District

Groundwater Contours

(from Heilweil, et. al., 2000)

- Groundwater Contour
- Extended Aquifer Zone
- Exposed Navajo Formation
- Exposed Kayenta Formation
- Upper Ash Creek Aquifer

Note:
There may be additional areas north of the Extended Aquifer Zone and east of the Hurricane Fault that contribute recharge to the Navajo/Kayenta aquifer.

N

2 0 2 4 6 Miles

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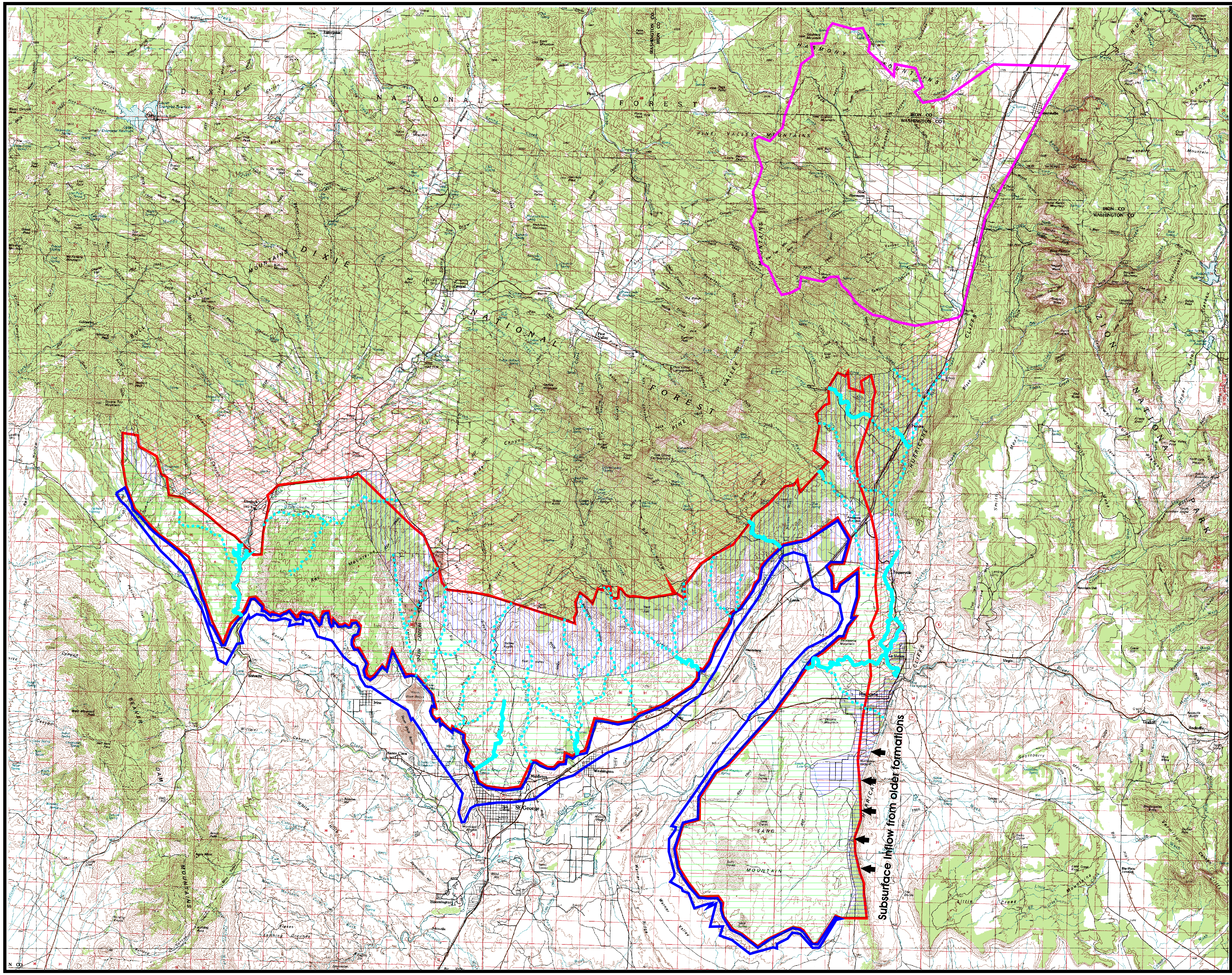
FIGURE
A3



Navajo/Kayenta and Upper Ash Creek Aquifer Classification

for
Washington County
Water Conservancy District

Recharge Areas for the Navajo Aquifer

(from Freethey, 1993)

Streams Recharging Navajo Aquifer
- Intermittent
- Perennial

Winter Precipitation (Surficial Formation)
- 8" - 25" (formations above Navajo)
- >8" (Navajo)
- <8" (granular deposits above Navajo)
- <8" (Navajo)

Aquifer Boundaries
- Extended Aquifer Zone
- Exposed Navajo Formation
- Exposed Kayenta Formation
- Upper Ash Creek Aquifer

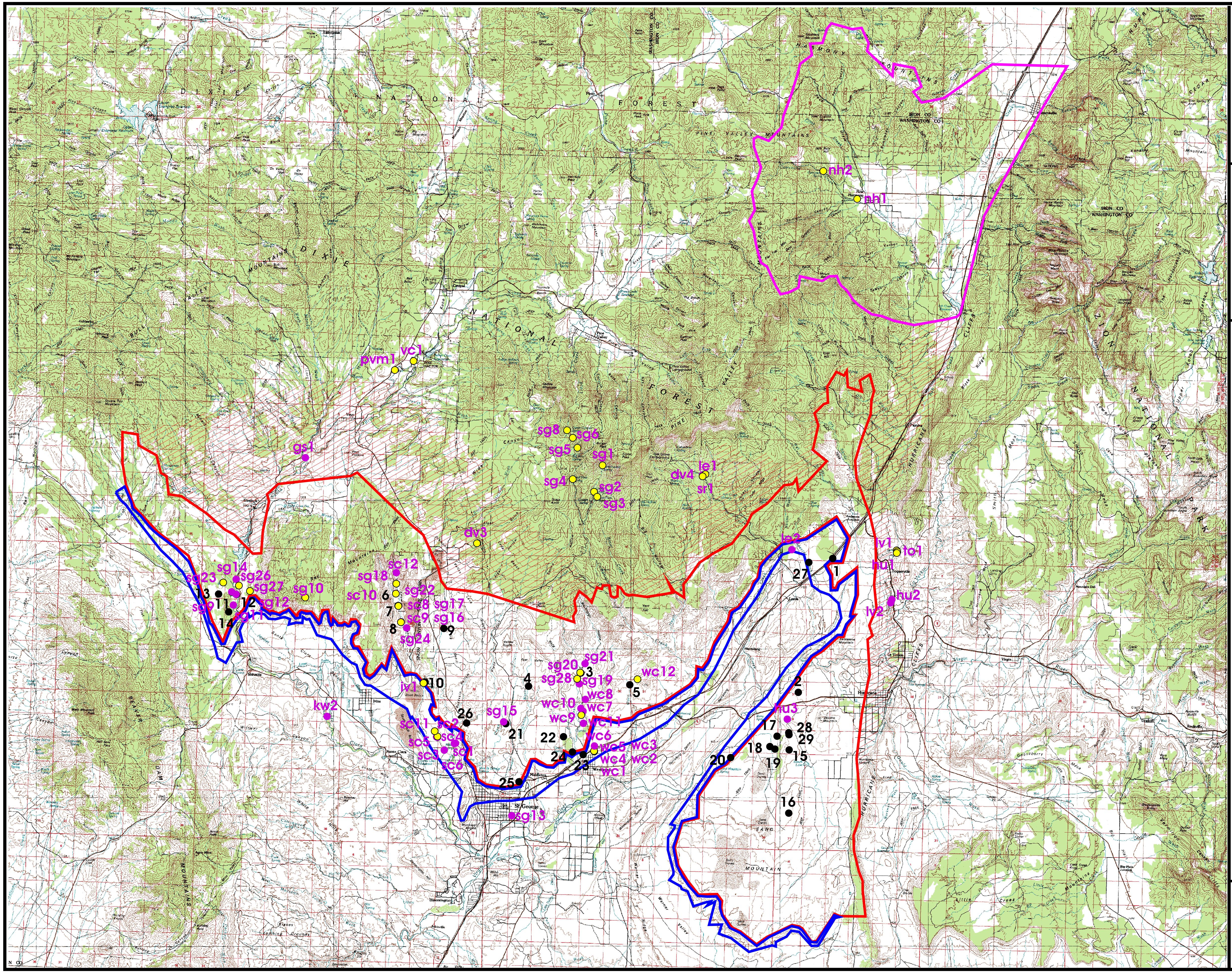
Note:
There may be additional areas north of the Extended Aquifer Zone and east of the Hurricane Fault that contribute recharge to the Navajo/Kayenta aquifer.

N

2 0 2 4 6 Miles

HANSEN ALLEN & LUCE INC
ENGINEERS

FIGURE
A4



Navajo/Kayenta and Upper Ash Creek Aquifer Classification

for
Washington County
Water Conservancy District

Wells and Springs with Water Quality Data

USGS Sampled Well or Spring
(USGS ID # in black)
See Table B1 for USGS Water Quality Data

- Well or Spring Location

Public Water Supply Well or Spring
(Public Water Supply ID # in purple)
See Table B2 for Water Quality Exceedances

- Water Quality Exceedance Reported
- No Exceedances Reported

Aquifer Boundaries

- Extended Aquifer Zone
- Exposed Navajo Formation
- Exposed Kayenta Formation
- Upper Ash Creek Aquifer

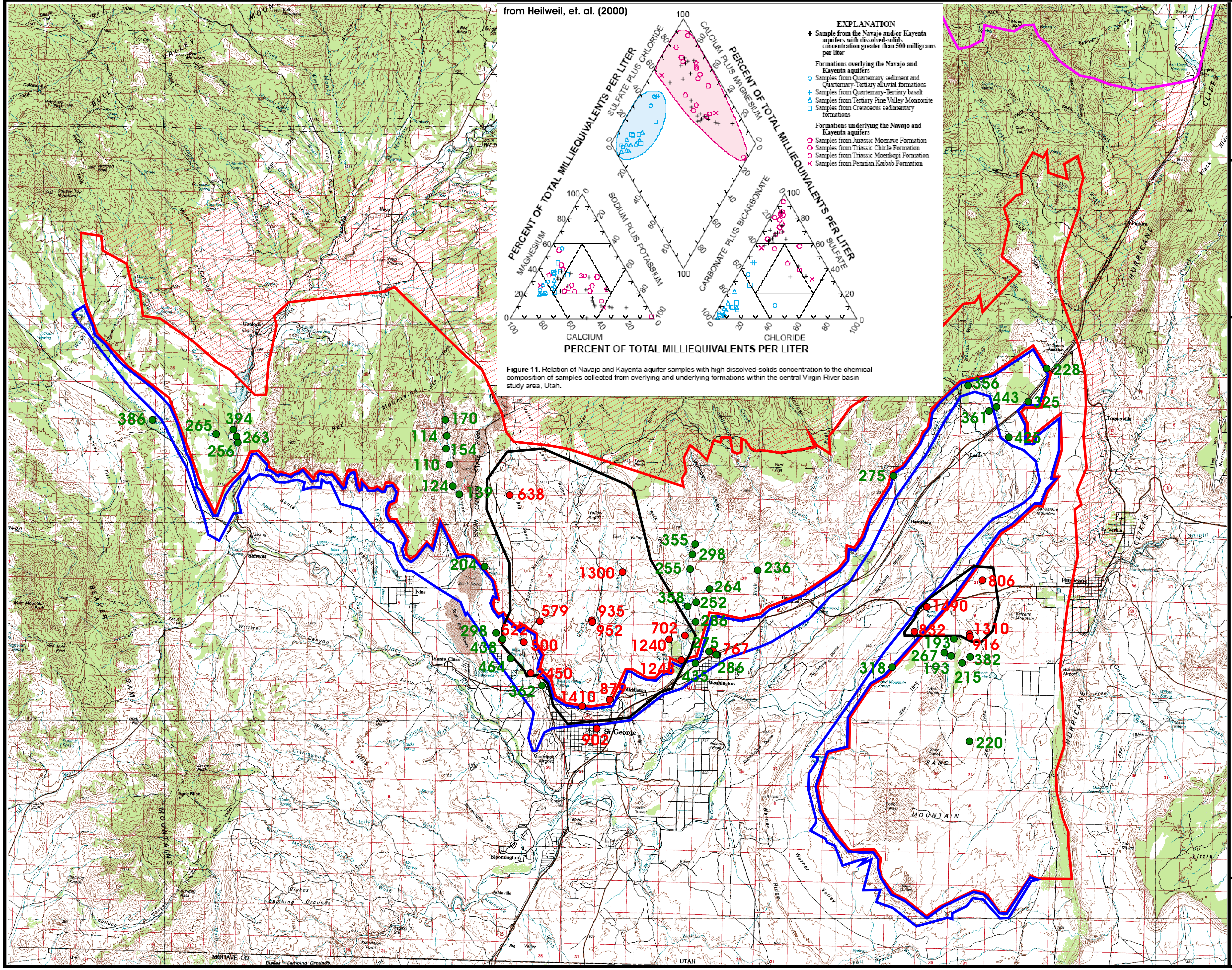
Note:
There may be additional areas north of the Extended Aquifer Zone and east of the Hurricane Fault that contribute recharge to the Navajo/Kayenta aquifer.

N

2 0 2 4 6 Miles

HANSEN ALLEN & LUCE INC
ENGINEERS

FIGURE
A5



Navajo/Kayenta and Upper Ash Creek Aquifer Classification

for
Washington County
Water Conservancy District

Water Quality Data - Total Dissolved Solids

TDS < 500 mg/l
TDS > 500 mg/l
Area with Elevated TDS
Extended Aquifer Zone
Exposed Navajo Formation
Exposed Kayenta Formation
Upper Ash Creek Aquifer

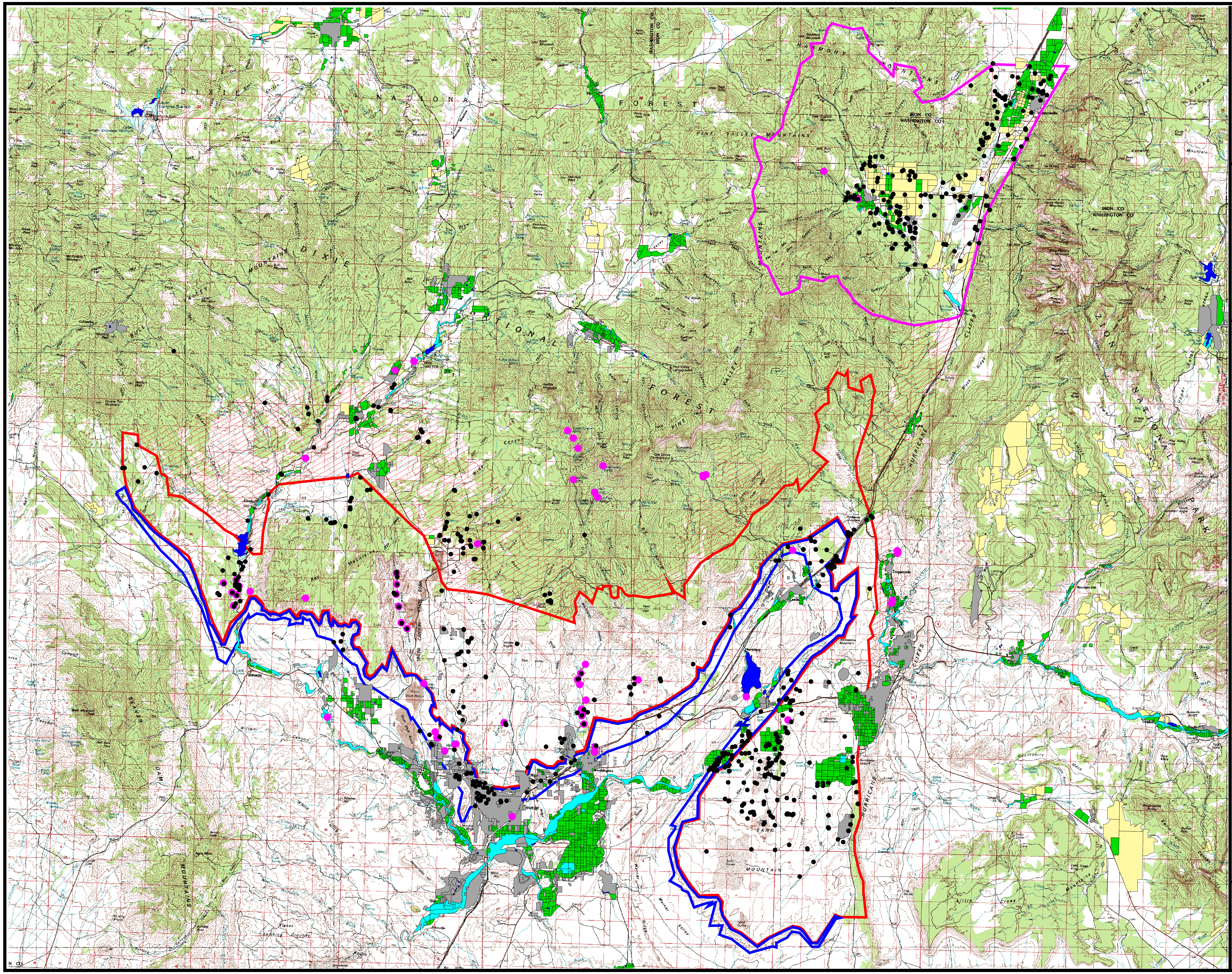
Note:
There may be additional areas north of the Extended Aquifer Zone and east of the Hurricane Fault that contribute recharge to the Navajo/Kayenta aquifer.

N

1 0 1 2 3 4 5 Miles

HANSEN ALLEN & LUCE INC
ENGINEERS

FIGURE
A6



Navajo/Kayenta and Upper Ash Creek Aquifer Classification

for
Washington County
Water Conservancy District

Beneficial Water Use

- Underground Water Right POD
- Public Water Supplies
- Extended Aquifer Zone
- Exposed Navajo Formation
- Exposed Kayenta Formation
- Upper Ash Creek Aquifer

LAND USE

- Agriculture - Irrigated
- Agriculture - Nonirrigated
- Riparian
- Urban Development
- Open Water Body

Note:
There may be additional areas north of the Extended Aquifer Zone and east of the Hurricane Fault that contribute recharge to the Navajo/Kayenta aquifer.

N

2 0 2 4 6 Miles

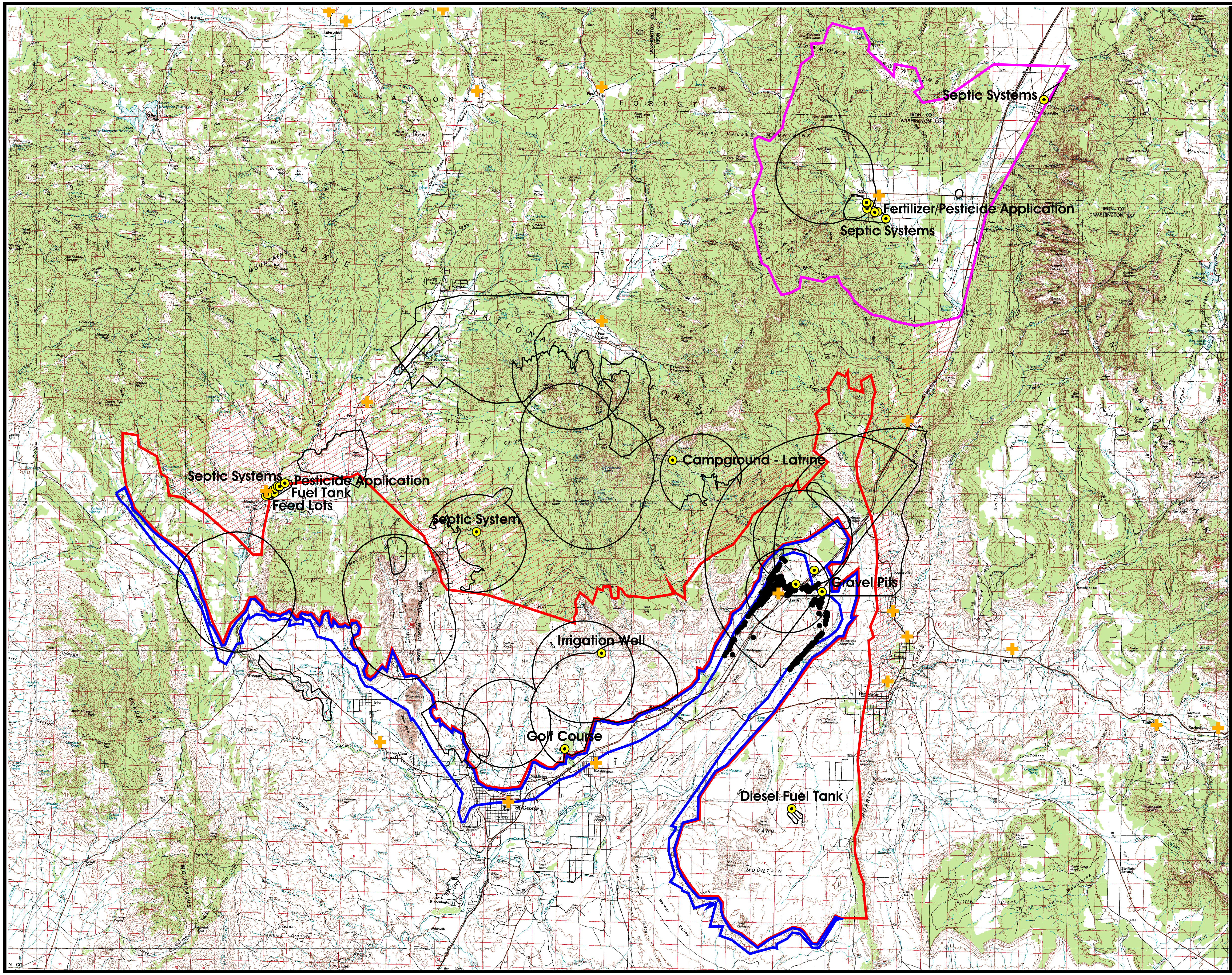
HANSEN ALLEN & LUCE INC
ENGINEERS

FIGURE
A7

Navajo/Kayenta and Upper Ash Creek Aquifer Classification

for
Washington County
Water Conservancy District

Potential Contamination Sources - Cemeteries, Mines, & Miscellaneous



- Abandoned Mine Shaft
- Cemetery
- DWSP Potential Contamination Source
- DWSP Zones
- Extended Aquifer Zone
- Exposed Navajo Formation
- Exposed Kayenta Formation
- Upper Ash Creek Aquifer

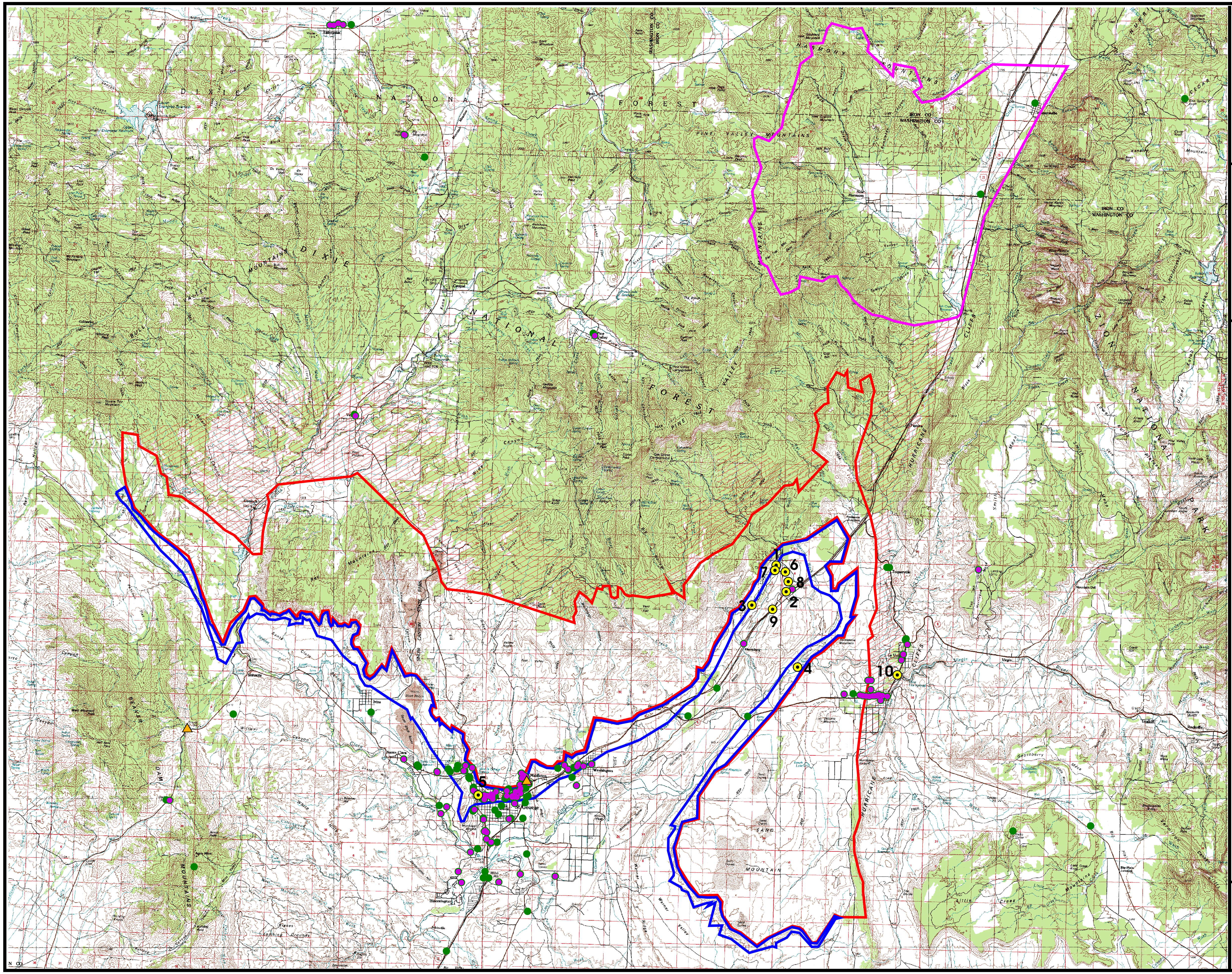
Note:
There may be additional areas north of the Extended Aquifer Zone and east of the Hurricane Fault that contribute recharge to the Navajo/Kayenta aquifer.

N

2 0 2 4 6 Miles

HANSEN ALLEN & LUCE INC ENGINEERS

FIGURE A8



Navajo/Kayenta and Upper Ash Creek Aquifer Classification

for
Washington County
Water Conservancy District

Potential Contamination Sources - CERCLA, TRI, UST, & LUST Sites

- Leaking Underground Storage Tank
- Underground Storage Tank
- Toxic Release Inventory Site
- CERCLA Site (with ID #)
- Extended Aquifer Zone
- Exposed Navajo Formation
- Exposed Kayenta Formation
- Upper Ash Creek Aquifer

Note:
There may be additional areas north of the Extended Aquifer Zone and east of the Hurricane Fault that contribute recharge to the Navajo/Kayenta aquifer.

HANSEN ALLEN & LUCE INC
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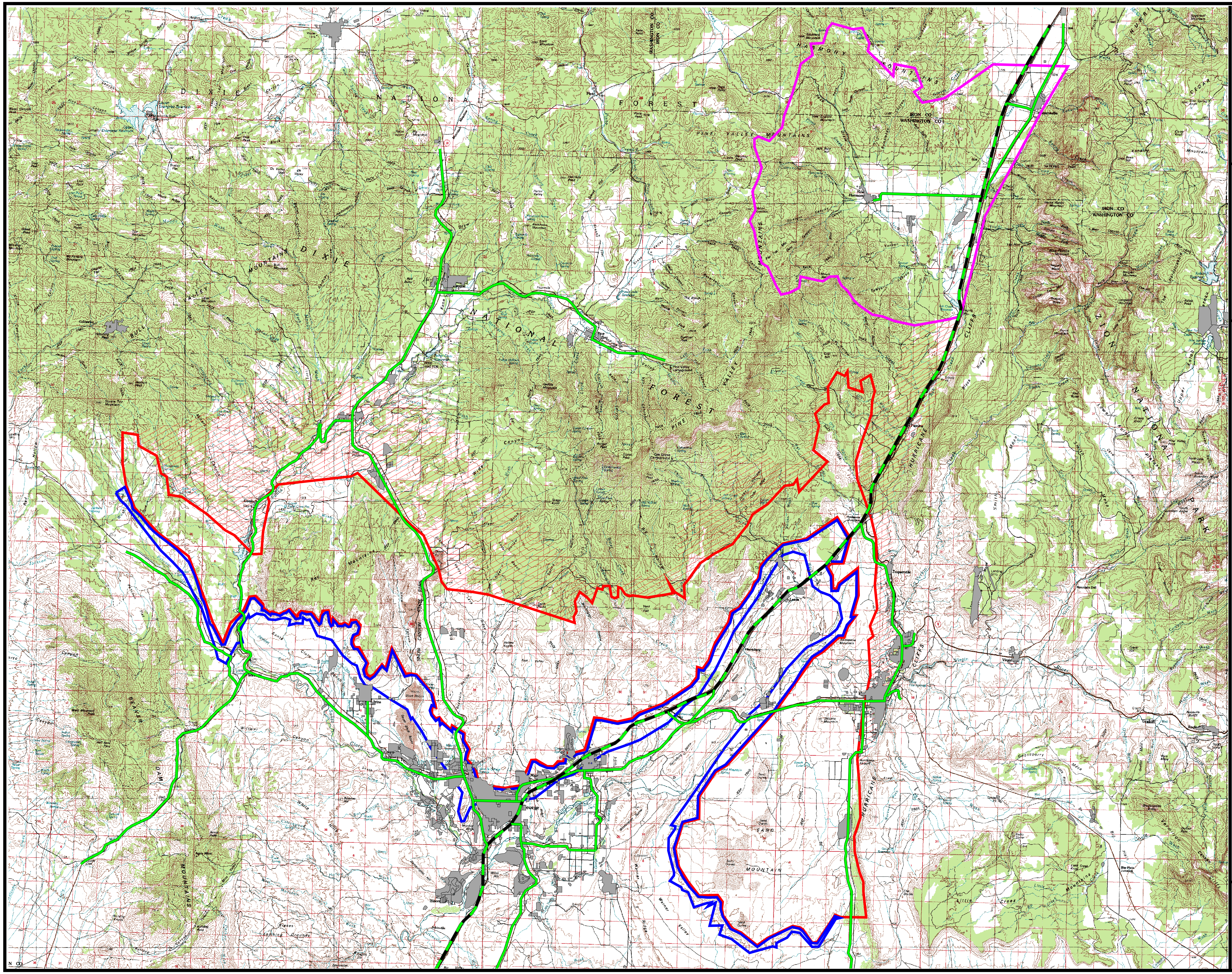
FIGURE
A9



Navajo/Kayenta and Upper Ash Creek Aquifer Classification

for
Washington County
Water Conservancy District

Potential Contamination Sources - Urban Areas and Major Roads

- Other Major Roads
- Interstate 15
- Urban Areas
- Extended Aquifer Zone
- Exposed Navajo Formation
- Exposed Kayenta Formation
- Upper Ash Creek Aquifer

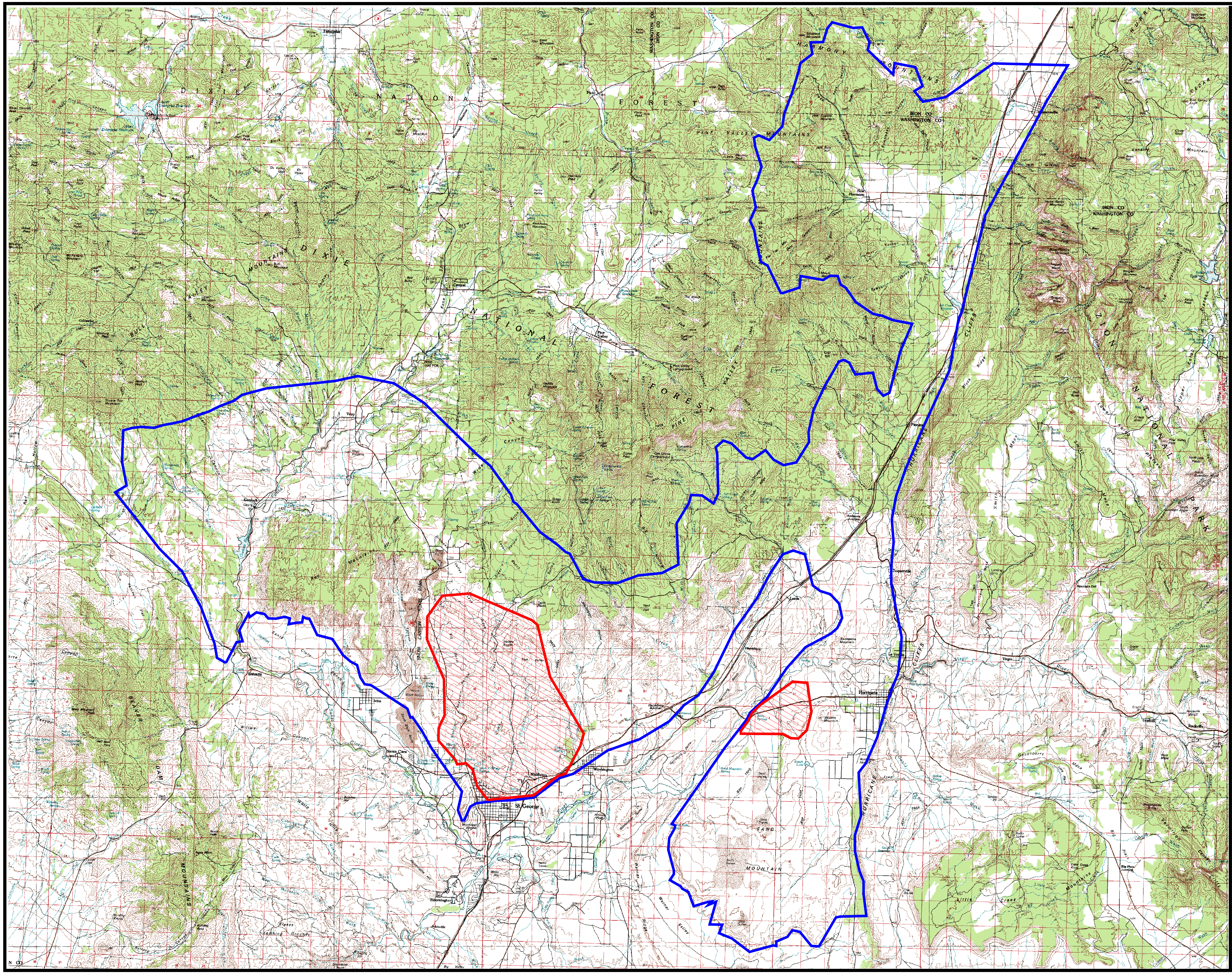
Note:
There may be additional areas north of the Extended Aquifer Zone and east of the Hurricane Fault that contribute recharge to the Navajo/Kayenta aquifer.

N

2 0 2 4 6 Miles

HANSEN ALLEN & LUCE inc
ENGINEERS

FIGURE
A10



Navajo/Kayenta and Upper Ash Creek Aquifer Classification

for
Washington County
Water Conservancy District

Proposed Classification Zones

- Class 1A - Pristine Aquifer
- Class II - Drinking Water Aquifer

Note:
There may be additional areas north of the Extended Aquifer Zone and east of the Hurricane Fault that contribute recharge to the Navajo/Kayenta aquifer.

N

2 0 2 4 6 Miles

HANSEN ALLEN & LUCE inc
ENGINEERS

FIGURE
A11

TABLE B1
GROUNDWATER QUALITY OF USGS WELLS

Well #	DATE	CA	MG	NA	K	CL	F	SO4	HCO3	ALK	PH	NO3	SIO2	TDS	SPCOND	TE
1	01/10/75	54.0	21.0	26.0	3.3	19.0	0.2	31.0	260	211	7.7	0.70	36.0	325	531	1
2	11/17/74	120.0	53.0	55.0	7.9	51.0	0.2	460.0	110	92	7.2	0.03	3.5	806	1220	2
3	07/06/88	94.0	1.0	8.0	2.0	13.0	0.2	84.0	184	151	8.2	0.40	14.0	298	451	1
4	03/14/74	63.0	23.0	350.0	29.0	430.0	1.2	310.0	100	85	8.3	0.12	39.0	1300	2230	4
5	10/29/96	43.6	16.8	10.5	1.9	7.0	0.3	28.0	212	174	6.8	0.32	10.9	236	375	2
6	07/06/88	26.0	4.0	7.0	1.0	15.0	0.2	11.0	83	68	7.7	0.92	12.0	154		2
7	08/23/89	22.0	8.0	5.0	1.0	11.0	0.1	13.0	94	77	7.1	0.56	12.0	110	204	1
8	04/02/85	20.0	7.0	7.0	2.0	15.0	0.1	13.0	71	58	7.0	1.01	13.0	124	185	1
9	11/15/89	70.0	13.0	110.0	13.0	26.0	1.5	290.0	158	129	7.9	0.47	22.0	638	902	2
10	05/17/78	39.0	11.0	12.0	1.0	20.0	0.6	62.0	112	92	7.3	0.80	14.0	204	310	2
14	08/23/89	74.0	18.0	14.0	2.0	17.0	0.2	60.0	245	201	7.3	0.49	18.0	302		1
15	03/25/86	46.0	27.0	37.0	2.0	44.0	0.3	106.0	154		7.7	0.00	15.0	382		2
16	02/28/86	31.0	17.0	27.0	2.0	33.0	0.2	35.0	149		8.1	0.00	14.0	220		1
17	10/23/74	32.0	16.0	10.0	1.7	6.3	0.5	49.0	112	92		1.70	15.0	193	318	1
18	03/25/86	37.0	23.0	17.0	2.0	41.0	0.2	43.0	141		7.9	0.00	14.0	267		1
19	05/21/74	33.0	16.0	8.6	1.7	18.0	0.2	20.0	140	113	7.9	2.80	15.0	193	321	1
20	02/25/86	52.0	23.0	29.0	0.0	68.0	0.3	62.0	154		8.2	0.00	15.0	318		2
21	03/26/86	90.0	18.0	176.0	19.0	41.0	2.7	462.0	197		7.0	0.00	20.0	952		2
22	05/18/74	100.0	22.0	290.0	26.0	340.0	1.1	330.0	220	184	7.3	0.10	22.0	1240	2030	2
23	10/16/68	63.0	35.0	16.0		29.0		100.0	220	180	8.0	2.12	19.0	435	673	2
24	02/06/86	104.0	23.0	274.0	24.0	270.0	1.3	404.0	234		7.0	0.00	22.0	1248		2
25	06/04/74	99.0	24.0	150.0	13.0	44.0	1.0	420.0	220	181	7.4	0.10	18.0	879	1310	2
26	11/14/74	65.0	14.0	100.0	10.0	27.0	0.6	260.0	170	141	7.2	0.71	15.0	579	935	1
27	10/10/74	76.0	29.0	30.0	2.6	39.0	0.1	120.0	250	203		0.30	23.0	443	717	1
28	10/30/96	180.0	69.0	75.0	9.5	96.0	0.2	650.0		164	7.3	0.00	14.0	1310	1720	2
29	11/17/74	140.0	48.0	90.0	5.2	96.0	0.3	440.0	150	121	7.5	1.30	18.0	916	1420	2

(1) Data from GIS layers provided by USGS September 2000.

TABLE B2
PUBLIC DRINKING WATER SUPPLIES - WATER QUALITY EXCEEDANCES

Id #	Owner	Source	Date	Contaminant	Conc. (mg/l)	Standard (mg/l)
dv3	Diamond Valley Acres	East Well #1	no exceedances reported			
dv4	Diamond Valley Acres	West Well #1	03/04/00	TDS	728	500
dv4	Diamond Valley Acres	West Well #1	All other TDS values were around 300 mg/l			
gs1	Gunlock SSD	Gunlock Spring	07/16/90	TDS	620	500
hu1	Hurricane	Toquerville Spring	no exceedances reported			
hu2	Hurricane	Ash Creek Spring	01/22/93	TDS	522	500
hu2	Hurricane	Ash Creek Spring	12/22/82	TDS	526	500
hu2	Hurricane	Ash Creek Spring	12/22/81	TDS	548	500
hu2	Hurricane	Ash Creek Spring	09/30/81	TDS	500	500
hu3	Hurricane	West Well	03/18/96	TDS	532	500
hu3	Hurricane	West Well	09/16/89	TDS	558	500
hu3	Hurricane	West Well	09/16/89	Sulfate	250	250
hu3	Hurricane	West Well	12/22/81	TDS	532	500
hu3	Hurricane	West Well	09/28/81	TDS	532	500
hu3	Hurricane	West Well	All Sulfates were near 250			
iv1	Ivans	Ivins Town Spring	no exceedances reported			
kw2	KWU	Kayenta Well #2	04/27/97	TDS	836	500
kw2	KWU	Kayenta Well #2	05/18/94	TDS	736	500
kw2	KWU	Kayenta Well #2	04/14/91	TDS	900	500
le1	Leeds	Oak Grove Spring	no exceedances reported			
le2	Leeds	Leeds Well	07/10/89	Sulfate	288	250
le2	Leeds	Leeds Well	07/10/89	TDS	720	500
le2	Leeds	Leeds Well	All other samples had TDS around 300mg/l and Sulfate around 70 mg/l.			
lv1	La Verkin	Toquerville Spring	no exceedances reported			
lv2	La Verkin	Ash Creek Spring	03/12/86	Iron	0.44	0.3
nh1	New Harmony	New Harmony Well	no exceedances reported			
nh2	New Harmony	Commanche Spring	no exceedances reported			
pvm1	Pine Valley Mountain	PV Mt. Farm's Well	no exceedances reported			
sc1	Santa Clara	Miller Spring #1	06/28/88	TDS	582	500
sc2	Santa Clara	Miller Spring #2	02/14/91	TDS	754	500
sc2	Santa Clara	Miller Spring #2	02/14/91	Sulfate	250	250
sc2	Santa Clara	Miller Spring #2	06/28/88	TDS	576	500
sc2	Santa Clara	Miller Spring #2	06/28/88	Sulfate	250	250
sc2	Santa Clara	Miller Spring #2	09/23/86	TDS	574	500
sc2	Santa Clara	Miller Spring #2	09/23/86	Sulfate	250	250
sc2	Santa Clara	Miller Spring #2	03/19/85	TDS	570	500
sc2	Santa Clara	Miller Spring #2	10/14/82	TDS	584	500
sc2	Santa Clara	Miller Spring #2	12/07/77	TDS	526	500
sc3	Santa Clara	Gray Spring #1	06/28/88	TDS	522	500
sc3	Santa Clara	Gray Spring #1	09/23/86	TDS	502	500
sc3	Santa Clara	Gray Spring #1	10/14/82	TDS	554	500

TABLE B2
PUBLIC DRINKING WATER SUPPLIES - WATER QUALITY EXCEEDANCES

Id #	Owner	Source	Date	Contaminant	Conc. (mg/l)	Standard (mg/l)
sg2	Saint George	Sullivan Spring	no exceedances reported			
sg3	Saint George	East Fork Spring	no exceedances reported			
sg4	Saint George	W. Fork Cottonwood Spr.	no exceedances reported			
sg5	Saint George	Quaking Aspen Spring	no exceedances reported			
sg6	Saint George	Big Pine Canyon Spring	no exceedances reported			
sg8	Saint George	Carter Canyon Spring	no exceedances reported			
sg9	Saint George	Gunlock Well #1	04/19/99	TDS	504	500
sg9	Saint George	Gunlock Well #1	All other TDS values were at or below 300 mg/l			
sg10	Saint George	Gunlock #2 Replacement	no exceedances reported			
sg11	Saint George	Gunlock Well #3	11/28/77	Iron	0.7	0.3
sg12	Saint George	Gunlock Well #4	04/25/90	Turbidity	9.2	3
sg12	Saint George	Gunlock Well #4	04/25/90	Iron	0.3	0.3
sg12	Saint George	Gunlock Well #4	04/25/90	Manganese	0.23	0.05
sg12	Saint George	Gunlock Well #4	04/01/86	Manganese	0.09	0.05
sg12	Saint George	Gunlock Well #4	11/23/82	Manganese	0.075	0.05
sg12	Saint George	Gunlock Well #4	04/25/78	Iron	1.34	0.3
sg13	Saint George	Millcreek Spring	07/06/88	TDS	702	500
sg13	Saint George	Millcreek Spring	04/02/85	TDS	665	500
sg13	Saint George	Millcreek Spring	07/15/81	TDS	648	500
sg13	Saint George	Millcreek Spring	04/25/78	TDS	665	500
sg13	Saint George	Millcreek Spring	04/25/78	Iron	0.36	0.3
sg14	Saint George	Gunlock Well #5	08/20/92	TDS	886	500
sg14	Saint George	Gunlock Well #5	11/23/82	Manganese	0.15	0.05
sg14	Saint George	Gunlock Well #5	04/25/78	Iron	1.73	0.3
sg15	Saint George	City Creek Well #1	07/07/99	Floride	2.4	2
sg15	Saint George	City Creek Well #1	07/07/99	TDS	928	500
sg15	Saint George	City Creek Well #1	07/07/99	Sulfate	437	250
sg15	Saint George	City Creek Well #1	03/12/96	Floride	2.2	2
sg15	Saint George	City Creek Well #1	03/12/96	TDS	884	500
sg15	Saint George	City Creek Well #1	03/12/96	Sulfate	452	250
sg15	Saint George	City Creek Well #1	08/20/92	Floride	2.42	2
sg15	Saint George	City Creek Well #1	08/20/92	TDS	886	500
sg15	Saint George	City Creek Well #1	08/20/92	Sulfate	442	250
sg15	Saint George	City Creek Well #1	08/07/91	Floride	2.33	2
sg15	Saint George	City Creek Well #1	08/07/91	TDS	942	500
sg15	Saint George	City Creek Well #1	08/23/89	226 & 228	10	5
sg15	Saint George	City Creek Well #1	07/06/88	Floride	2.27	2
sg15	Saint George	City Creek Well #1	07/06/88	TDS	1120	500
sg15	Saint George	City Creek Well #1	07/06/88	Sulfate	502	250
sg15	Saint George	City Creek Well #1	04/02/85	Alpha (PCi/L-g)	27	15
sg15	Saint George	City Creek Well #1	04/02/85	Floride	2.4	2
sg15	Saint George	City Creek Well #1	[illegible]	TDS	[illegible]	[illegible]

TABLE B2
PUBLIC DRINKING WATER SUPPLIES - WATER QUALITY EXCEEDANCES

Id #	Owner	Source	Date	Contaminant	Conc. (mg/l)	Standard (mg/l)
sg19	Saint George	Millcreek Well #1	06/03/85	Turbidity	4.5	4
sg20	Saint George	Millcreek Well #2	no exceedances reported			
sg21	Saint George	Millcreek Well #3 (Aban.)	08/23/89	226 & 228	11	5
sg21	Saint George	Millcreek Well #3 (Aban.)	10/24/83	Iron	5.61	0.3
sg22	Saint George	Snow Canyon Well #4	no exceedances reported			
sg23	Saint George	Gunlock Well #6	no exceedances reported			
sg24	Saint George	Snow Canyon Well #5	08/20/92	Iron	1.27	0.3
sg24	Saint George	Snow Canyon Well #5	06/08/88	Iron	3.5	0.3
sg24	Saint George	Snow Canyon Well #5	06/08/88	Manganese	0.18	0.05
sg26	Saint George	Gunlock Well #7	no exceedances reported			
sg27	Saint George	Gunlock Well #8	no exceedances reported			
sg28	Saint George	Millcreek Well #1	no exceedances reported			
sr1	Silver Reef SSD	Oak Grove Spring	no exceedances reported			
to1	Toquerville	Toquerville Spring	no exceedances reported			
vc1	Veyo Culinary Water	Spring 4 Mi NE of town	no exceedances reported			
wc1	Washington City	Sproul Springs	12/06/77	Iron	0.75	0.3
wc2	Washington City	Westover Spring #2	12/13/77	Iron	0.67	0.3
wc3	Washington City	Prisbrey Spring #1	no exceedances reported			
wc4	Washington City	Prisbrey Spring #6	no exceedances reported			
wc5	Washington City	Prisbrey Spring #7	no exceedances reported			
wc6	Washington City	Well #1	11/11/80	TDS	767	500
wc6	Washington City	Well #1		Sulfate	360	250
wc6	Washington City	Well #1	12/13/77	TDS	669	500
wc6	Washington City	Well #1		Sulfate	340	300
wc7	Washington City	Well #2	11/11/80	Turbidity	25	4
wc8	Washington City	Well #3	11/09/83	Iron	1.32	0.3
wc8	Washington City	Well #3	All other iron values were below 0.1 mg/l			
wc9	Washington City	Well #4	no exceedances reported			
wc10	Washington City	Well #5	11/09/83	Iron	0.73	0.3
wc11	Washington City	Well #6	05/19/89	Turbidity	7.1	4
wc11	Washington City	Well #6		Iron	0.36	0.3
wc12	Washington City	Grapevine Well	no exceedances reported			

Data provided by Utah Division of Drinking Water

TABLE B3
UNDERGROUND STORAGE TANK DATA

DERR ID #	LUST?	NAME	LOCATION ADDRESS	CITY	COUNTY	ZIP
6000187	Y	7-ELEVEN 1852-22379	440 W ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000430	N	A1 SERVICES INC.	47 N 600 E	SAINT GEORGE	WASHINGTON	84770
6000714	Y	ARCO AM PM # 6332	1036 W MIDDLETON DR	WASHINGTON	WASHINGTON	84780
6000745	N	BRENT GLOVER AUTO	689 N BLUFF	SAINT GEORGE	WASHINGTON	84770
6000206	Y	CHEVRON BOULEVARD TRI-MART #66	5 W ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000637	N	CHRISTIANSEN DRYWALL	1164 W 980 N	SAINT GEORGE	WASHINGTON	84770
6000645	N	CHUM'S LTD.	130 S MAIN	HURRICANE	WASHINGTON	84737
6000335	Y	CITY OF ST. GEORGE	895 E SKYLINE DR	SAINT GEORGE	WASHINGTON	84770
6000373	Y	CLIFTON WILSON HURRICANE POWER STATION	526 W 600 N	HURRICANE	WASHINGTON	84737
6000677	N	DAVE'S ST. GEORGE AUTOMOTIVE	1380 W SUNSET BLVD	SAINT GEORGE	WASHINGTON	84770
6000423	Y	DEPOT JUNCTION #2	921 W SUNSET BLVD	SAINT GEORGE	WASHINGTON	84770
6000733	N	DICK'S CAFÉ	114 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000374	Y	DIXIE DISCOUNT AUTO	309 W ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000049	Y	DIXIE LAND CHEVRON	2 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000414	Y	DON'S AUTO SERVICE	187 W STATE ST	HURRICANE	WASHINGTON	84737
6000327	Y	DUSTY ROSE CORP.	99 W ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000681	N	EXPRESS MART 2	84 N RIVER RD	SAINT GEORGE	WASHINGTON	84770
6000352	Y	EZ SHOP	471 W TELEGRAPH ST	WASHINGTON	WASHINGTON	84780
6000346	N	FRED A GOETTIG	705 N BLUFF RD	SAINT GEORGE	WASHINGTON	84770
6000138	Y	FUN STOP MARKET	875 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000734	Y	GATES AUTO SERVICE & SALES	190 W ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000047	Y	H & H SHELL OIL	880 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000079	N	HANDY MART #2	757 N BLUFF ST	SAINT GEORGE	WASHINGTON	84770
6000077	Y	HANDY MART I	101 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000076	N	HANDY STORAGE CENTER	530 N 1300 E	SAINT GEORGE	WASHINGTON	84770
6000655	N	HARTS GAS & FOOD	260 S GREEN SPRING DR	WASHINGTON	WASHINGTON	84780
6000139	Y	HOLT OIL CO.	845 N INDUSTRIAL RD	SAINT GEORGE	WASHINGTON	84770
6000483	Y	HURRICANE CHEVRON FOOD MART	687 W STATE	HURRICANE	WASHINGTON	84737
6000371	Y	HURRICANE FIRE HOUSE	202 E STATE ST	HURRICANE	WASHINGTON	84737
6000372	Y	HURRICANE MAINTENANCE SHED	650 W 600 N	HURRICANE	WASHINGTON	84737
6000136	Y	HURRICANE SHELL	309 W STATE ST	HURRICANE	WASHINGTON	84737
6000085	Y	INTERMOUNTAIN FARMERS ASSOC	310 N INDUSTRIAL RD	SAINT GEORGE	WASHINGTON	84770
6000089	Y	INTERSTATE ROCK PRODUCTS INC.	765 W STATE ST	HURRICANE	WASHINGTON	84737
6000094	Y	J & J CONCRETE PRODUCTS DIV.	1051 N BLUFF ST	SAINT GEORGE	WASHINGTON	84770
6000440	N	KV ELECTRIC, INC.	1125 W 1130 N	SAINT GEORGE	WASHINGTON	84770
6000660	N	KV ELECTRIC, INC.	992 N WESTRIDGE DR	SAINT GEORGE	WASHINGTON	84770
6000443	Y	L&L MECHANICAL CONTRACTORS	50 N 600 E P O BOX 278	SAINT GEORGE	WASHINGTON	84770
6000194	N	MAVERIK #242 ST. GEORGE BOULEVARD	702 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000192	Y	MAVERIK #243 HURRICANE	200 W STATE ST	HURRICANE	WASHINGTON	84737
6000412	N	MINUTE MARKET #8	1409 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000729	N	MIRA MONTE SINCLAIR	386 N Bluff St	SAINT GEORGE	WASHINGTON	84770
6000718	N	NEW HARMONY TEXACO	3802 E HWY 144	NEW HARMONY	WASHINGTON	84757
6000133	Y	NEWBY BUICK	391 W ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000051	N	NEWBY OIL DBA CHEVRON MARKET	995 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000008	Y	NORMAN HOWARD	214 N INDUSTRIAL RD	SAINT GEORGE	WASHINGTON	84770
6000394	Y	OLD CHEVRON	28 E STATE ST	HURRICANE	WASHINGTON	84737
6000144	Y	PACIFIC COAST BLDG. PRODUCTS	845 N RED ROCK	SAINT GEORGE	WASHINGTON	84770
6000145	Y	PARKE COX TRUCKING CO. INC.	396 N INDUSTRIAL RD	SAINT GEORGE	WASHINGTON	84770
6000173	N	PARKINSON SUBSTATION	SKYLINE DRIVE	SAINT GEORGE	WASHINGTON	84770
6000347	Y	PEARSON TIRE CO.	204 N BLUFF RD	SAINT GEORGE	WASHINGTON	84770
6000147	Y	PEPSI COLA BOTTLING GROUP	477 INDUSTRIAL RD	SAINT GEORGE	WASHINGTON	84770
6000151	N	PHILLIPS 66 COMPANY #010216	100 N 200 E	SAINT GEORGE	WASHINGTON	84770
6000726	N	PHILLIPS KICKS 66 MCDONALDS	1180 W STATE HWY U-17 (WEST OF LYNNS MARKET)	HURRICANE	WASHINGTON	84737
6000034	Y	PREMIUM OIL #6 (ST. GEORGE)	181 N BLUFF ST	SAINT GEORGE	WASHINGTON	84770
6000486	N	QUAIL CREEK DIVERSON DAM	HIGHWAY 9	HURRICANE	WASHINGTON	84737
6000263	N	R.W. JONES	675 N INDUSTRIAL RD	SAINT GEORGE	WASHINGTON	84770
6000157	Y	RANDALL DIST. CORP	765 REDROCK RD	SAINT GEORGE	WASHINGTON	84770
6000420	Y	RED HILLS MUNICIPAL GOLF COURSE	1000 N 700 W	SAINT GEORGE	WASHINGTON	84770
6000028	Y	RED ROCK AUTO SALES (OLD EXXON SERVICE S	916 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000170	N	RIVERBEND EXPRESS	1391 W REDLEDGE RD P O BOX 890	WASHINGTON	WASHINGTON	84780
6000166	Y	ROCKY MOUNTAIN COMPANY	825 INDUSTRIAL RD	SAINT GEORGE	WASHINGTON	84770
6000096	Y	RON'S BOULEVARD TEXACO	915 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000021	Y	RUSS'S TEXACO	297 W ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000176	Y	SCHOLZEN PRODUCTS CO., INC.	548 W 100 N PO BOX 628	HURRICANE	WASHINGTON	84737

TABLE B3
UNDERGROUND STORAGE TANK DATA

DERR ID #	LUST?	NAME	LOCATION ADDRESS	CITY	COUNTY	ZIP
6000229	N	SCOTT HIRSCHI	561 E TABERNACLE DR	SAINT GEORGE	WASHINGTON	84770
6000175	Y	SHORTSTOP DAIRY FREEZE	379 W STATE ST	HURRICANE	WASHINGTON	84737
6000180	Y	SINCLAIR #24955	994 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000738	N	SMITHS CONOCO #189	20 N BLUFF	SAINT GEORGE	WASHINGTON	84770
6000131	Y	SPANISH TRAIL SUPPLY	21 S MAIN ST	VEYO	WASHINGTON	84782
6000202	Y	ST. GEORGE #8 AMOCO	880 W RED CLIFFS DR	WASHINGTON	WASHINGTON	84780
6000329	Y	ST. GEORGE AMOCO	815 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000115	N	ST. GEORGE BISHOPS STOREHOUSE	516 N 1400 E	SAINT GEORGE	WASHINGTON	84770
6000020	N	ST. GEORGE FORD & RV	1295 N HIGHLAND DR	SAINT GEORGE	WASHINGTON	84770
6000535	Y	ST. GEORGE OPERATIONS	820 N 1080 E	SAINT GEORGE	WASHINGTON	84770
6000174	Y	ST. GEORGE STEEL FAB., INC.	1301 E 700 N	SAINT GEORGE	WASHINGTON	84770
6000132	Y	ST. GEORGE TOPPER	191 W ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000137	N	STEVE'S MINI MART	851 W SUNSET BLVD	SAINT GEORGE	WASHINGTON	84770
6000186	Y	TERRY'S STOP-N-SHOP TEXACO	810 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000415	N	TOQUERVILLE MERCANTILE	176 N TOQUER BLVD	TOQUERVILLE	WASHINGTON	84774
6000334	Y	U.S.WEST 671200	50 W 200 S	HURRICANE	WASHINGTON	84737
6000128	Y	U.S.WEST 671564	100 S 200 W	WASHINGTON	WASHINGTON	84780
6000127	Y	U.S.WEST 671571	104 E TABERNACLE	SAINT GEORGE	WASHINGTON	84770
6000125	Y	U.S.WEST 671572	596 N 1400 E	SAINT GEORGE	WASHINGTON	84770
6000235	Y	UDOT STA. 522	515 W STATE ST PO BOX 1165	HURRICANE	WASHINGTON	84737
6000378	N	VEYO MERC	13 N MAIN ST	VEYO	WASHINGTON	84782
6000749	N	WALMART #1439 MIRASTAR #62041	675 W TELEGRAPH ST	WASHINGTON	WASHINGTON	84780
6000184	Y	WALTER PACE, AFCE	98 E ST GEORGE BLVD	SAINT GEORGE	WASHINGTON	84770
6000744	N	WASHINGTON COUNTY ADMINISTRATION	197 E TABERNACLE	SAINT GEORGE	WASHINGTON	84770
6000748	Y	WASHINGTON COUNTY COURTS COMPLEX	FIFTH DISTRICT COURT BLDG 220 N 200 E	SAINT GEORGE	WASHINGTON	84770
6000473	Y	WASHINGTON COUNTY ROADS DEPT	500 E SKYLINE DR	SAINT GEORGE	WASHINGTON	84770
6000493	Y	WASHINGTON COUNTY SCHOOL DIST.	189 W TABERNACLE RD	SAINT GEORGE	WASHINGTON	84771
6000343	Y	WASHINGTON SERVICE	214 W TELEGRAPH ST	WASHINGTON	WASHINGTON	84780
6000262	Y	WEBB'S TEXACO	875 W STATE ST	HURRICANE	WASHINGTON	84737
6000228	N	WILKINSON ELECTRIC	245 W TABERNACLE DR	SAINT GEORGE	WASHINGTON	84770
6000272	Y	WINDER SERVICE INDUSTRIES	112 W STATE	HURRICANE	WASHINGTON	84737
6000530	Y	ZION TRAVEL CENTER	1550 W STATE ST	HURRICANE	WASHINGTON	84737
6000362	N	DALE & BECKY BRITTINGHAM	15 N MAIN ST	KANARRAVILLE	IRON	84742

DERR ID #: Identification number from Utah Division of Environmental Response & Remediation
LUST: Leaky Underground Storage Tank
Data obtained from the Utah Automated Geographical Reference Center - October 2004