WASHINGTON COUNTY
WATER CONSERVANCY DISTRICT
and
COOPERATING AGENCIES

DETERMINATION OF RECOMMENDED SEPTIC SYSTEM DENSITIES FOR GROUNDWATER QUALITY PROTECTION

Final Report

July 1997

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EXECUTIVE SUMMARY

This section contains a brief description and summary of the background, regulations and analytical methodology, as well as subsequent conclusions and recommendations for the Determination of Recommended Septic System Densities for Groundwater Quality Protection. The information is presented by report chapter. Also included are letters from the Utah Water Quality Board and the United States Environmental Protection Agency regarding their review of the final draft report.

SECTION I - INTRODUCTION

- Washington County, Utah, is one of the fastest growing areas in the United States. The current County population is approximately 50,000. Projections indicate that by the year 2040 the population will likely exceed 200,000. A significant portion of the area's culinary water supplies are obtained from groundwater. Reliance on groundwater as a culinary supply will likely continue well into the future. Therefore continuing to provide a high quality source of water to both current and future population is of great concern. Many rural parts of Washington County are now served by septic systems. The Washington County Water Conservancy District (the District), and several communities in the area have raised the question as to whether continued use of septic systems poses a threat to regional groundwater supplies.

- During 1995 HA&L was selected by the District to complete a preliminary analysis to determine whether there was potential risk related to septic systems. That effort, referred to as the Phase I Study, indicated that the potential did exist for contamination of regional groundwater supplies.

- During 1996 HA&L was retained to complete Phase II of the study. The purpose of the Phase II portion of the study was to recommend appropriate septic system densities that may be used to help ensure long term protection of regional groundwater quality, with specific emphasis on the Navajo aquifer.

SECTION II - HYDROGEOLOGY

- Several governmental and private entities have completed research to define area geology. In general, local geologic conditions are highly variable and extremely complex.

- The majority of ground water wells developed for public water supply in the study area have been developed either in the Navajo Sandstone or in adjacent formations which are recharged to some extent by the Navajo Sandstone. Other consolidated and unconsolidated formations have been developed but in most cases they have not been as productive for culinary purposes either from a quantity or quality standpoint.

o Most of the Navajo Sandstone in the study area is poorly cemented which, together with local fracturing and jointing, contributes to the relatively high overall porosity and permeability of the Navajo compared to other consolidated rock formations in the area.

o Recharge to ground water in the study area occurs through infiltration of streamflow, infiltration of precipitation, infiltration from irrigation, and subsurface flow from adjacent areas.

CHAPTER III - EXISTING GROUNDWATER QUALITY

o Much of the groundwater obtained from existing public water supply wells in the study area is of a high quality. The aquifers associated with these wells could likely be classified Class IA or "Pristine" according to the new State of Utah Groundwater Protection Regulations. A lesser number of existing public water supply wells obtain groundwater from aquifers which could likely be classified Class II or "Drinking Water Quality", which is a lower classification but still acceptable for public water supplies. A small number of wells in the study area obtain water from aquifers of poorer quality.

CHAPTER IV - FUTURE LAND USE AND SEPTIC SYSTEM USAGE

o Recent population and land use projection studies have been completed by Washington County and the Washington County Water Conservancy District.

o The current number of septic systems in the study area is estimated to be nearly 3,500. The projected number of septic systems at build out varies between approximately 7,200 and 21,100. The projections depend on a number of factors including the availability of water for future development.

CHAPTER V - SEPTIC SYSTEM RELATED POLLUTION

o Septic systems, if designed, installed, and maintained correctly, can be an effective means of preventing the spread of pathogens and other harmful substances. However, they do not remove 100% of the contaminants associated with residential wastewater. Their overall effectiveness from a groundwater quality standpoint depends on the ability of groundwater to assimilate the remaining pollutants. The assimilative capacity is dependent in part on the groundwater potential to dilute the remaining pollutants.

o Nitrate nitrogen was selected as the key pollutant indicator to be used in determining appropriate densities (number of acres required per septic system) for septic systems.

CHAPTER VI - REGULATORY CONSIDERATIONS

o Current Washington County, Southwest Utah Public Health Department, State of Utah and U.S. Environmental Protection Agency land use and water quality related regulations provide a general basis for addressing the protection of groundwater quality.

- For the purposes of this study, the State of Utah Drinking Water Standards, the State of Utah Groundwater Protection Regulations and the State of Utah Wastewater Disposal Regulations were selected as the most applicable regarding the determination of recommended septic system densities.

CHAPTER VII - SEPTIC SYSTEM DENSITY DETERMINATION

- Prior to completing the mass balance analysis, an analysis of the potential for contamination, or risk analysis, was completed for each subarea. This analysis provided a more subjective review of the conditions in each subarea according to a number of risk related factors associated with septic system use. Each risk factor was rated either low, medium or high with respect to its potential risk to local surface water, local groundwater, and regional groundwater. Based on the combined risk for each geographical area, an allowable degradation of groundwater was selected. The allowable degradation was expressed in terms of an increase in nitrate concentration in groundwater

- Following completion of the risk analysis, a mass balance analysis was conducted to determine the recommended septic system densities. The mass balance considered the flow and nitrate loading associated with septic system effluent, rainfall, irrigation, and existing groundwater. Analysis criteria were varied to account for the different physical conditions that exist throughout the study area. These included groundwater velocity, thickness of the groundwater mixing zone, and the amount of precipitation and irrigation received in specific areas. In addition, the quantity and strength of the septic system effluent was varied to account for current water conservation trends.

- Consideration was also given as to how the proposed density recommendations would be implemented. It was concluded that even though the study area varies greatly with respect to physical conditions, it would be most practical, economical, and fair to all concerned to combine subareas with similar risks and hydrogeological conditions.

- Consideration of the risk analysis, mass balance analysis and implementation factors resulted in the range of septic system densities included in the following table. A range of densities was provided to allow local decision makers the opportunity to make final determinations based on a chosen level of risk, the cumulative effect of combined subareas, and local economic and environmental priorities.

<table>
<tr><th colspan="9">RECOMMENDED SEPTIC SYSTEM DENSITIES
(number of acres required per septic system)</th></tr>
<tr><th></th><th></th><th colspan="7">COMBINED SUB AREAS</th></tr>
<tr><th></th><th></th><th>Pine Valley</th><th>Brookside
Veyo
Gunlock</th><th>Ivins
Santa Clara
St. George
Washington</th><th>Dameron Valley
Diamond Valley
Winchester Hills</th><th>New Harmony</th><th>Anderson Junction
Hurricane
La Verkin
Leeds
Pintura
Sky Ranch - Bench Lake Area
Toquerville</th><th>Apple Valley</th></tr>
<tr><td rowspan="3">ALLOWABLE DOWN GRADIENT NO_3^- CONCENTRATION (mg/L)</td><td>2 to 3*</td><td>4</td><td>11</td><td>12</td><td>15</td><td>10</td><td>12</td><td>11</td></tr>
<tr><td>2 to 4*</td><td>3</td><td>8</td><td>8</td><td>12</td><td>5</td><td>9</td><td>7</td></tr>
<tr><td>2 to 5*</td><td>2</td><td>6</td><td>6</td><td>10</td><td>4</td><td>7</td><td>5</td></tr>
</table>

* Range associated with risk analysis (see Chapter VII)

CHAPTER I

INTRODUCTION

BACKGROUND

Washington County, Utah, is one of the most rapidly growing areas in the United States. Its temperate climate and picturesque surroundings make it a most desirable place to live. Projections indicate that by the year 2040 the County population may increase from the current 50,000 people to more than 200,000. Currently, the more urbanized areas of the County are served by sewer systems. However, many parts in the County are served by septic systems, with no immediate plans to sewer those areas. The Washington County Water Conservancy District (the District) and several other public entities in the area, decided to determine whether the rapidly increasing number of septic systems might pose a potential threat to regional groundwater supplies.

AUTHORIZATION

During 1995 Hansen, Allen & Luce (HA&L) was retained by the District and Cooperating Agencies to complete a preliminary analysis to determine whether the potential existed for a problem related to septic systems. This effort, referred to as the Phase I Study, indicated that the potential did exist for contamination of regional groundwater supplies. During 1996, HA&L was selected to complete Phase II of the study.

PURPOSE

Generally stated, the purpose of the Phase II portion of the study was to recommend a range of septic system densities (number of acres required per septic system) that could be considered by local authorities. To help ensure long term protection of regional groundwater for use as a public drinking water supply, with primary emphasis on protection of the Navajo aquifer.

SCOPE OF WORK

Major tasks included in the scope of work are as follows:

Task 100 - Estimate Groundwater Flow Rates in Selected Areas

Task 200 - Assess Septic System Pollution Potential

Task 300 - Predict Septic System Effects on Water Quality

Task 400 - Prepare Septic System and Land Use Recommendations

Task 500 - Provide Aquifer Classification Information

CHAPTER II

HYDROGEOLOGY

INTRODUCTION

This chapter of the report includes a geohydrologic assessment of the Washington County area summarizing ground water flow patterns and occurrences within the area generally bounded on the north by New Harmony, on the south by St. George, on the east by Apple Valley, and on the west by Gunlock Reservoir. The specific task of this report chapter is to identify to the degree possible ground water occurrence, flow direction, and flow rates for subsequent use in estimating the potential for contamination of local and regional domestic ground water supplies. Specifically, the areas of focus for which a geohydrologic summary has been made include:

Anderson Junction	Ivins	Santa Clara
Apple Valley	La Verkin	St. George
Brookside	Leeds	Toquerville
Dameron Valley	New Harmony	Veyo
Diamond Valley	Pine Valley	Washington
Gunlock	Pintura	Winchester Hills
Hurricane	Bench Lake Area	

The conclusions found herein are based upon several data sources which include personal and HA&L knowledge of the area including: historic reports; documentation obtained directly from municipalities participating in the study; personal communications with project personnel; communications with local experts; communications with State regulators; local, state and federal publications; and printed literature. A more complete list of data and information sources is provided in the Reference section of this report.

Local development pressures in the rural areas of Washington County have for some time raised concern over the impacts said development may be having upon local and regional ground water systems. The majority of these developments continue to use septic systems for wastewater disposal and are therefore defined herein as "unsewered". As the concentration of these unsewered systems increases, the potential for contamination of existing and future ground water supplies increases. This is especially true in regions underlain by porous or fractured geologic strata wherein liquid waste transmits freely. Local geologic conditions are prone to rapid transmission of ground waters since much of the area consists of fractured sandstone and basalt units. A map depicting the overall generalized relative hydrogeology is included as Figure II-1.

GENERAL CONDITIONS

Geology

Local geologic conditions are extremely complex and highly fractured. A general stratigraphic overview, including the relative elevation of local towns and communities is shown in Figure II-2.

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 purposes of this report and are quoted directly herein. The following information came from Technical Publication No. 70.

> "Geologic units exposed in the upper Virgin River and Kanab Creek basins range in age from Permian to Holocene and consist of consolidated and unconsolidated rocks. Sandstone is the dominant exposed rock type with progressively lesser amounts of unconsolidated rocks, siltstone, mudstone, shale, limestone, igneous rocks, conglomerate, and coal. Many of those rocks have been noted in drillers' logs of wells... Most of the sandstone units are loosely to moderately cemented and contain impurities such as weathered feldspar, as well as quartz sand grains. The Navajo Sandstone of Triassic and Jurassic age is the most extensive sandstone formation in the area."

> "...The main body of the Navajo ... consists of a lower red member and an upper white member. In the study area, the maximum thickness of the red member is 800 ft (240 m) and that of the white member about 1,000 ft (300 m)."

> "Petrographic analyses of selected rock samples... show that the Navajo Sandstone includes subarkoses (sandstone with significant feldspar) and orthoquartzite (sandstone with small amounts of feldspar and other minerals). Almost all the Navajo samples were poorly cemented, indicating generally poor cementation in much of the formation. This, along with local fracturing and jointing, contribute to the relatively 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 ground water. This is indicated by springs that emerge from above those horizons."

> "Geologic formations in the study area generally dip to the north, northeast, or northwest at angles of less than 5E (commonly about 3E) and from 5E to 10E adjacent to faults. The dips probably have some local control on the movement of ground water."

> "Faults, which also have some control on the movement of ground water, are common throughout the study area. Most are normal faults and strike northeasterly and

FIGURE II-2.
GENERALIZED STRATIGRAPHIC OVERVIEW
SHOWING COMMUNITY LOCATIONS

GEOLOGIC AGE	FORMATION	TOWN / COMMUNITY
Quaternary	Muddy Creek	New Harmony, Pintura
	Volcanics	Pine Valley
Tertiary	Claron	
	Grapevine Wash	
Cretaceous	Iron Springs	Gunlock, Veyo
	Dakota	
	Carmel	Dameron Valley
	Temple Cap	Diamond Valley
Jurassic	Navajo Sandstone	Anderson Jtn, Hurricane, Toquerville, Winchester Hills
	Kayenta	St. George
	Moenave	Ivins, Leeds, Washington
	Chinle	Santa Clara
Triassic	Shinarump	Apple Valley
	Moenkopi	
	Kiabab	La Verkin
	Toroweap	
Permian	Queantoweap	
	Pakoon Dolomite	
Pennsylvanian	Callville LS	Virgin River Gorge
Mississippian	Redwall LS	
Devonian	Devonian	
Silurian	Nopah Dolomite	
Cambrian	Muav LS	
	Bright Angel	
Pre-Cambrian	Tapeats Quartzite	
	Vishnu Schist	

northwesterly. They include the Hurricane, ... which are of major scale in both length and vertical displacement."

"Joints are common in the study area, and open joints are especially common in the sandstone formations like the Navajo Sandstone and the Shinarump Member of the Chinle Formation. However, jointing is not consistently well developed throughout the study area. Jointing seems to be more highly developed in the upper Virgin River basin than in the upper Kanab Creek basin. This is especially true of the Navajo which is highly jointed in Zion National Park.".

Ground Water

Both unconsolidated and consolidated aquifers are found within the study area. A general description of both unconsolidated and consolidated aquifers taken from Technical Publication No. 40 follows.

Unconsolidated-rock aquifers

"Unconsolidated rocks crop out in about 20 percent of the project area and supply about 80 percent of the water discharged by wells. Most of these rocks were deposited by streams as alluvial fans and channel fill... Most wells and springs in the unconsolidated rocks yield less than 250 gpm (gallons per minute). Larger yields are reported from a few areas. The fairly large range in yield from wells results mainly from differences in the amounts of gravel penetrated. The largest yields are from zones containing large amounts of gravel."

"Two extensive and thick deposits of unconsolidated rocks ... are in Warner Valley and on the Santa Clara Bench. The only well drilled in Warner Valley did not reach the water table, although it did penetrate the full thickness of unconsolidated rocks. This suggests that the unconsolidated rocks in Warner Valley do not contain aquifers. The few wells drilled through the unconsolidated deposits on the Santa Clara Bench indicate that these deposits differ in thickness locally, and where thickest they do contain ground water. The local differences in thickness are shown by the logs of wells (C-42-16) 5bbb 1, (C-42-16) 6ada-1, and (C-42 16)22 baa-1. The first well penetrated 17 feet of unsaturated unconsolidated rock and bottomed in shale; the second well, about 1,800 feet away from the first, penetrated 40 feet of saturated unconsolidated rock and bottomed in shale; the third well bottomed in saturated unconsolidated rock at 100 feet. The differences in thickness, especially in short distances, suggest that erosional depressions, perhaps old stream channels, locally lie buried beneath the surface and may be potential sources of water to wells. The extent of such channels could be determined by test drilling or by geophysical study."

"Thin channel fill deposits, which are generally of small areal extent, are common in drainage ways throughout the project area. Some of these thin deposits discharge water to springs and wells that supply small amounts of water for irrigation, industry, and public supply..."

Consolidated-rock aquifers

"The principal consolidated rock aquifers in the area are in the Moenkopi, Chinle Moenave, and Kayenta Formations, the Navajo Sandstone, igneous rocks in the Pine Valley Mountains, and the basalts of Quaternary age. Most springs in the area discharge from the consolidated rocks, and generally yield less than 50 gpm. A few large springs, mostly in areas underlain by basalt, yield more than 1,000 gpm. Although about half the wells in the area derive their water from consolidated-rock aquifers, most of them yield only small amounts of water for stock and domestic use. A few public-supply and irrigation wells yield from 500 to 3,000 gpm, but only about 20 percent of the water withdrawn by wells in the project area comes from the consolidated rocks."

"The large range in yield results mainly from movement of water through fracture systems, which vary widely in their cross-sectional size and lateral extent. Hard, brittle rocks, such as basalt and sandstone, generally contain larger and more extensive fractures than softer, less brittle rocks such as shale and siltstone. In addition, some sandstone formations, such as the Navajo Sandstone, probably locally contain a significant amount of intergranular openings through which water moves."

Recharge

Recharge to the ground-water reservoir in the central Virgin River basin occurs through either infiltration of precipitation that falls on the area, infiltration of irrigation applied to an area, infiltration of streamflow from adjacent areas, and/or subsurface inflow from adjacent areas.

HYDROGEOLOGY

Local hydrogeology has been evaluated using available information provided from local, state and federal agencies, as well as from in-house files and reports. Where available, ground water potentiometric surface information has been taken or developed directly from existing USGS or State reports and/or databases. Spring and/or stream elevation data taken directly from USGS 7 ½ minute quadrangle maps were used to approximate ground water contours in areas where no data was available. These contours were then adjusted to match local stream flow elevations for major waterways to represent non artesian conditions. The use of these two varying data sources is believed consistent and valid for the purposes of this report as long as it is remembered that they represent two varying aquifer systems. The analysis made herein accounts for these two sources of information. A brief summary of data sources is provided in Table II-1 with aquifer characteristics being summarized in Table II-2.

TABLE II-1.
GROUNDWATER DATA SOURCE BY LOCATION

Location	Ground Water Table Data Source	Comment
SANTA CLARA RIVER DRAINAGE		
Pine Valley	Spring Data	Spring data used exclusively
Brookside	Spring Data	Spring data used
Veyo	Spring/Stream Elevations.	Stream data is combined with spring data
Dameron Valley	Extrapolation of USGS Data	USGS data for Navajo Aquifer was extrapolated northward
Gunlock	USGS Data	USGS data shows local conditions likely impacted by well drawdown. Spring data shows potential regional flow
Ivins	Spring/Stream Elevations.	Spring and Stream data integrated
Santa Clara	Spring/Stream Elevations.	Stream data is combined with spring data
Diamond Valley	Extrapolation of USGS Data	USGS data for Navajo Aquifer was extrapolated northward
Winchester Hills	Extrapolation of USGS Data	USGS data for Navajo Aquifer was extrapolated northward
VIRGIN RIVER DRAINAGE		
La Verkin	Spring/Stream Data	USGS data extrapolated into area using stream and spring data
Hurricane	S. Reber - Geologist	USGS, Spring and Stream data all combined to obtain generalized flow pattern
Apple Valley	Spring/Stream Elevations.	Stream data is combined with spring data
Sand Mountain (Bench Lake Area)	USGS Data	USGS records used as most recent data
Washington	USGS Data.	USGS data extrapolated using stream and spring data
St. George	USGS Well Data	USGS data used exclusively

TABLE II - 1.
GROUNDWATER DATA SOURCE BY LOCATION
(continued)

Location	Ground Water Table Data Source	Comment
ASH CREEK DRAINAGE		
New Harmony	USGS Data	Unpublished well data used
Pintura	Stream Data	Stream data only
Anderson Junction	USGS Data	USGS data is combined with local stream and spring data
Toquerville	Spring/Stream Elevs.	USGS data extrapolated using stream data
Leeds	USGS/Spring Elev.ations.	USGS data extrapolated using stream data

TABLE II-2.
GROUNDWATER CHARACTERISTICS

Location	Gradient i (%)	Principal Flow Direction	Hydraulic Conductivity k (ft/day)	Darcy Velocity v=ki (ft/day)	Comment
SANTA CLARA RIVER DRAINAGE					
Pine Valley	6.7	Westward	10 - 25*	0.67 - 1.68	Alluvial Flow - Lies above Navajo
Brookside	2.2	SW	10 - 25*	0.22 - 0.55	Alluvial over Basalts / Fracture Flow - Lies Above Navajo
Veyo	2.1	SW	10 - 25*	0.21 - 0.53	Alluvial over Basalt / Fracture Flow - Lies above Navajo
Dameron Valley	2.4	S to SW	5 - 10*	0.12 - 0.24	Alluvial Flow - Lies Above Navajo
	0.5	S to SE	5*	0.025	Flow within Deep Navajo
Gunlock	2.2	Southward	20	0.44	Alluvial / Fracture Flow - Lies in Iron Springs Formation above Navajo
Ivins	1.0	SE	200	2.0	Alluvial Flow - Lies below Navajo outcrop
Santa Clara	1.0	SE	200	2.00	Alluvial Flow - Lies below Navajo outcrop
Diamond Valley	2.0	S to SW	5 - 10*	0.10 - 0.20	Alluvial Flow - Lies Above Navajo
	0.5	S to SE	5*	0.025	Flow within Deep Navajo
Winchester Hills	0.5	S to SE	5*	0.025	Alluvial / Bedrock Flow - Lies within Navajo outcrop area
VIRGIN RIVER DRAINAGE					
La Verkin	3.0	S to W	5 - 10*	0.15 - 0.30	Alluvial over Basalts/ Fracture Flow - Lies above Navajo
Hurricane	2.2	NW to SW	15	0.33	Alluvial over Basalts / Fracture flow - Lies above Navajo
Apple Valley - Upper	0.9	NW	5*	.05	Alluvial flow - Lies below Navajo outcrop, east of Hurricane fault
Apple Valley - Lower	1.9	W		0.10	
Sand Mountain (Bench Lake Area)	0.1 - 1.1	NW to NE	1	0.001 - 0.011	Alluvial flow - Lies within Navajo outcrop area
Washington	2.8	SE to SW	100	2.80	Alluvial flow - Lies below Navajo locally, recharge from Navajo to North

TABLE II-2.
GROUNDWATER CHARACTERISTICS
(continued)

Location	Gradient i (%)	Principal Flow Direction	Hydraulic Conductivity k (ft/day)	Darcy Velocity v=ki (ft/day)	Comment
St. George - Navajo	0.5 - 6.0	SW to SE	12	0.13 - 1.5	City Lies below Navajo locally, recharge from Navajo to North
St. George - Alluvial	3.2		5 - 10	0.16 - 0.32	City built on Alluvial Deposits
ASH CREEK DRAINAGE					
New Harmony - No.	1.5 - 6.7	Southward	200	3.0 - 13.4	Alluvial Flow - Lies above Navajo - Believed to drain through fracture system near Ash Creek Reservoir
New Harmony - So.			35	0.53 - 2.35	
Pintura	2.2	SW	10-25*	0.22 - 0.55	Alluvial over Basalts / Fracture flow - Lies within Navajo
Anderson Junction	2.8	S to SE	1 - 32	0.028 - 0.90	Alluvial over Basalts / Fracture flow - Lies within Navajo outcrop area
			45	1.26	
Toquerville	3.3	S to SE	10 - 25*	0.33 - 0.83	Alluvial Flow - Lies within Navajo zone - Fracture flow along east boundary
Leeds	2.2	S to SE	45	0.99	Alluvial / Fracture flow - Lies within and below Navajo

* - Indicates that the data given has been estimated based on engineering judgement.

It is important to remember when reviewing the data in this report that the data has been summarized from multiple sources, and that the data should be considered to be generalized and not site specific. It is also important to note that data is presented in Table II-2 as found in existing reference documents listed at the end of this report. For discussion purposes the following material related to each area has been organized into drainage basins, moving in an upstream to downstream direction. Drainage basins, and the sub-basin areas assigned to those drainage basins are:

Santa Clara River Drainage	Virgin River Drainage	Ash Creek Drainage
Pine Valley	La Verkin	New Harmony
Brookside	Hurricane	Pintura
Veyo	Apple Valley	Anderson Junction
Dameron Valley	Bench Lake Area	Toquerville
Gunlock	Washington	Leeds
Ivins	St. George	
Santa Clara		
Diamond Valley		
Winchester Hills		

It should be noted that although some of the communities/areas identified above are not within a direct flow path of the identified drainage, they do tie into the drainage and have therefore been included within the categories as shown.

The following discussion provides additional insight and conclusions reached regarding each specific study area. Within the following discussion, reference is made at select locations to recent data which was sampled for chlorofluorocarbon content. This analysis is often used as a technique to aid in dating the sampled waters. Reference to this sampling program is considered herein to be ***very preliminary*** and subject to revision as the data is further reviewed and analyzed by the collecting agency. Several factors which could affect the results of the testing have not yet been taken into account including the mixing of young and old waters, the effect of large unsaturated zones, and possible inaccuracies in analysis assumptions, etc.. Reference is only made herein to this sampling program as an additional bit of information which may help clarify statements made. Results of the chlorofluorocarbon testing program will be made available in the future by the collecting agency as their study is completed.

Santa Clara River Drainage

Pine Valley. Pine Valley, a mostly summer home development, lies approximately 19 miles due north of St. George. The valley is generally located within a Tertiary sedimentary and igneous rock formation which in turn is underlain by the Claron, Grapevine Wash, Iron Springs, Dakota, Carmel and Temple Cap Formations before reaching the Navajo Sandstone.

Ground water flow patterns within the valley area are generally controlled by alluvial flow systems with ground water gradients of 6.7% to the west toward the Town of Central. With a developed zone 4,500 feet wide, an average saturated thickness on the order of 200 feet, and a permeability of between 10 and 25 feet/day, the total ground water flow moving westward would be between 5,050 and 12,630 acre-feet/year.

The hazard to down gradient communities as a result of local development could potentially impact two communities. The first would be through the conveyance of a contaminant westward within the alluvial flow system towards the town of Central. Using an average linear velocity (developed by dividing the average Darcy velocities shown in Table II-2 by a porosity of 0.3), it is estimated that it would take an approximate 18.5 years for a contaminant originating in Pine Valley to travel the 5 miles to Central.

The second community potentially impacted by Pine Valley contamination may be those utilizing the ground water well field located within the Millcreek drainage north of Washington. A review of geologic mapping shows strong north-south trending fracture systems which have been documented to traverse at least 2/3 the distance between Pine Valley and the city of Washington. It would appear that this fault system continues southward from Washington. A contamination source therefore within Pine Valley that entered an "open" fault system, may find its way to the Millcreek well field. Current development levels with Pine Valley, and the potential for confining geologic strata to be present along the supposed flow path, are believed to be contributing factors which limit the significance of this flow scenario, and the potential for contamination. Should such a flow path exist, it is estimated that it would take an estimated 75 to 80 years for the contaminant to show up in the Millcreek drainage (assuming k=25ft/day, 0=0.3, and i=4.3%). It is acknowledged that the actual flow scenario between these two systems is highly complex, and that the above assumptions have introduced some significant simplifying conditions making the contamination potential speculative. Even though the contamination potential is speculative, it should at least be considered as a potential during future evaluations and management decisions.

Brookside. Brookside, a small community northeast of Veyo, has hydrogeologic conditions similar in nature to Veyo. The community is founded upon a relatively thin layer of alluvial deposits underlain by 50 to 150 feet of volcanics. The Navajo Sandstone lies about 2,000 feet below the community and would likely receive little if any impact from development within the community, unless a heavy contaminant were discharged and travel vertically downward. The danger to contamination from Brookside would likely be upon the surface water system and Gunlock reservoir. Interflow between the shallow unconfined ground water table characteristic of alluvial systems and the Santa Clara river system would dilute and convey contaminants downstream.

The annual flow rate which would be attributed to the Brookside area is based upon a 4,000 foot width of development and an aquifer thickness of 150 feet. Using the Darcy velocity and area defined by the equation Q=kiA where, k=10 to 25 feet/day, and i=2.2%, gives an average flow rate of between 1,100 and 2,770 acre-feet/year (1.5 to 3.8 cfs). This flow moves to the southwest and follows the general gradient of the land surface contour.

Veyo. The city of Veyo is located approximately 18 miles northwest of St. George along Highway 18 at the point where the highway crosses the Santa Clara river. The city 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. The Santa Clara River passes just south of the main section of town and has created a deep incision through the basaltic layer. This deep cut is shown on 7 ½ minute mapping to have been named "The Gulch". The erosional channel created by the river is as much as 180 feet deep in the area just south of town to as deep as 360 feet just upstream from its confluence with Moody Wash just over a mile southwest of town. The presence of this gulch could potentially act as a ground water drain which collects percolating water from the Veyo area before continuing down gradient toward Gunlock Reservoir.

According to data shown on mapping provided by the Utah Geological Survey the top of the Navajo Formation is located 1900 feet below land surface datum. Local recharge moving vertically downward would have to move through a zone of bentonitic clay followed by the Dakota, Carmel and Temple Cap Formations before entering the Navajo Sandstone unit. The presence of the clay unit would limit local deep recharge from the Veyo area.

The local potentiometric surface is projected on Figure II-1 to be interconnected with the Santa Clara River and local spring systems. General local water table gradients just north of the town are on the order of 4.6% to the south while the gradient in the immediate vicinity of Veyo along the Santa Clara River is about 2.1% with the gradient following the river channel to the southwest. Darcy ground water velocities as shown on Table II-2 have been estimated to be between 0.21 and 0.53 feet/day. Average linear velocities, calculated by dividing the Darcy velocity by a porosity of 0.3, are estimated to be between 255 and 645 feet/year.

The potential for ground water contamination within the Veyo area appears to have three possible sources. The first and most important from a "local" perspective is that there is a potential danger for all development down gradient from any local septic system. The base material upon which Veyo is built (fractured volcanics) has the potential to be highly permeable, and as such will convey large quantities of subsurface water quickly. The average linear velocity used in the earlier paragraph assumes ground water is moving through alluvial material with a lower hydraulic conductivity. However, according to textural references, fractured igneous rock including fractured basalt can convey water at rates between less than 1 to over 22,000 feet per year. Care should be taken when placing a well in the Veyo area down gradient of any potential source of contamination including septic systems.

The second component of flow involves the surface conveyance of a contamination source into the Santa Clara River and eventually into Gunlock Reservoir. The impacts of this flow path would be diluted by the large volumes of water conveyed in the river system. The third potential flow path involves the conveyance of a contamination source through fracture systems. A review of geologic mapping shows the presence of a north-northeast to south-southwest fault just north of the town of Veyo. This fault appears to be in the same general orientation of, and lines up with the Gunlock fault system documented to start approximately 3 to 4 miles to the southwest. A contaminant from Veyo which entered this fault system could (assuming the fault system to have transmissive characteristics) have the potential of moving towards the Gunlock area aquifer system as a direct conveyance source.

The potential for dilution of any contaminant source is dependent upon the underlying flow rate. An estimate of flow rate was made through the equation $Q=kiA$. In the equation, hydraulic conductivity was estimated to be between 10 and 25 feet/day, the gradient to the south was determined to be 2.1%, and the flow area was taken as a developed width times a saturated thickness. The developed zone width producing the potential contaminant source was assumed to be 5,000 feet within the community of Veyo, and a saturated depth through the limestones unit was calculated to be 425 feet. Given these estimates, there would be an estimated 3,740 to 9,440 acre-feet/year (5.2 to 13.0 cfs) recharge water moving beneath the community of Veyo which would dilute a contamination source.

Dameron Valley. Dameron Valley is located approximately 11 to 12 miles north northwest of St. George along Highway 18. Information available for this area indicates that the valley lies within the upper portions of the Navajo Formation in the western and southern portions of the valley, and just above the Navajo within the northern and eastern portions. It is also estimated that there is upwards of about 200 feet of alluvium in some locations which would produce localized alluvial or perched flow to the southwest. This general ground water movement could potentially 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 within Dameron Valley, it is possible that it could be a direct source of connection with down gradient water supplies within the lower portions of Snow Canyon.

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

Local subsurface flow rates within the limited alluvial flow system were estimated by assuming a contribution width from development of approximately 6,000 feet, and a contributing depth of 100 feet. Using the equation $Q=kiA$ where k=varies between 5 and 10 feet/day in the alluvial system, and is estimated at 5 feet/day in the deeper Navajo aquifer; and where i=2.4%, gives average flow rates of between 600 to 1,200 acre-feet/year (0.83 to 1.7 cfs) for the alluvial system. Applying a porosity of 0.3 to the aquifer parameters yields average linear velocities of between 145 and 290 feet/year. If contaminated, water reaching the Navajo aquifer would travel at an estimated average linear velocity of approximately 30 feet/year. This estimate is based on a k=5 feet/day, i=0.5%, and an 0=0.3.

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. Gunlock Reservoir itself 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. According to the Utah Geological Survey, the Gunlock Fault is a vertical slip fault displaced along the west side just over 2 miles.

Water movement within the area is believed to be generally parallel to the Santa Clara River with some variation occurring in the vicinity of wells below Gunlock reservoir. The potentiometric surface within the Navajo Formation in the immediate area of the reservoir is believed to be generally directed to the southeast, while data from USGS shows localized contours within the well field to be to the southwest.

Ground and surface water contamination resulting from development in and around the Town of Gunlock would appear to be mostly confined to surface water impacts. It is believed that any infiltration into the subsurface strata would remain at or near the surface, or be returned to the surface as waters move southward. Projections of ground water contours within the Navajo both east and west of the Gunlock fault do not provide a good match, thereby indicating the influence of the fault system. Ground water contours west of the fault seem to be generally higher than those found to the east based on preliminary available data plotted and reviewed by Hansen, Allen & Luce, Inc.. This is likely due to the local interconnection between shallow alluvial systems and the Navajo Formation.

A projection of potential ground water flow is made by estimating the overall width and depth of local channel alluvium. It is estimated from topographic and geologic mapping that the alluvial fill is triangular in nature, is approximately 2,000 feet wide, and has a maximum depth of 150 feet. These values give an area of 3.4 acres (½*2,000*150/43,560) and a corresponding flow rate of 545 acre-feet/year (0.75 cfs). The flow rate was determined using the equation Q=kiA where, k=20 feet/day, i=2.2%, and A=3.4 acres. As indicated earlier, it is believed that the major issue of contamination at Gunlock is not ground water, but surface water impacts since flows will likely stay near the surface due to local confining conditions as the water makes its way toward Gunlock reservoir.

Ivins. The town of Ivins is located 4 to 5 miles northwest of the City of St. George and lies below the Navajo Formation. The community lies within the lower Kayenta Formation which consists of siltstones and sandstones. Since the town lies below the Navajo Formation there is no chance of direct contamination to major local water supplies tapping the Navajo aquifer.

As shown on Figure II-1, the potentiometric surface generally follows the land surface topography. Ground water typically moves towards the Santa Clara River after which it moves down through the Santa Clara valley. The overall ground water gradient shown is about 1% to the southeast, which when combined with the reported permeability of 200 ft/day translates to an overall ground water velocity of 2.0 feet/day. Assuming a porosity of 0.3 flows would then travel approximately 2,433 feet/year, and within 4.5 years could potentially reach the city of Santa Clara located approximately 11,000 feet downstream.

Uncontrolled contaminants deposited in Ivins have the potential of entering the shallow ground water system and moving within one of two flow mechanisms. The first is where the ground water moves southward towards the Santa Clara river where it is mixed and diluted with surface waters. The second flow scenario consists of water moving southward towards the river, then southeastward towards the town of Santa Clara. If ground water were used as part of the Santa Clara culinary supply, there might be a potential for the capture of contaminants originating in Ivins. The potential for contamination however is understood to be small since the town of Ivins currently utilizes a sewer collection system. The potential for contamination from Ivins would then be no more than the potential contamination from any other city with a sewer system.

The ground water flow rate for Ivins is calculated assuming a 4,000 foot wide band of development with an average saturated alluvial depth of 25 feet, as approximated from 1997 mapping produced by the Utah Geological Survey. Using an average k=200 feet/day and i=1% gives a Darcy velocity of 730 feet/year, an average linear velocity of 2,430 feet/year, and a flow rate of 1,680 acre-feet/year (2.3 cfs).

Santa Clara. The town of Santa Clara is located 2 to 3 miles west-northwest of the City of St. George and lies below the Navajo aquifer system within the Chinle Formation. Since the town lies below the Navajo Formation there is no chance of direct contamination to major local water supplies tapping the sandstone aquifer.

As shown on Figure II-1, the potentiometric surface generally follows the land surface topography. Flows typically move towards the Santa Clara River after which they move down central valley areas. The overall ground water gradient shown is about 1% to the southeast, which when combined with the reported permeability of 200 ft/day translates to an overall ground water Darcy velocity of 2.0, and linear velocity of 6.7 feet/day (assuming O=0.3). Within a one year period, ground water could potentially travel an approximate 2,500 feet. At this flow rate, it would take 10 years for ground water originating in Santa Clara to potentially reach the Bloomington area.

Uncontrolled contaminants deposited in Santa Clara have the potential of moving within one of two flow mechanisms. The first is where the water moves from outlying areas towards the Santa Clara river where it is mixed and diluted with surface and shallow alluvial waters. Downstream contamination would then be impacted where possible by the surface and shallow alluvial sources. The second flow scenario exists for the southeastern portions of the Santa Clara area. In this area, ground water contours are suggesting, given the proper conditions, that contaminants may potentially move in a southeasterly direction away from the river towards the Bloomington area. If ground water were pumped in the areas north of Bloomington, there might be an increased potential for the capture of contaminants originating in, or south of the Santa Clara. The potential for contamination however is understood to be small since the town of Santa Clara currently utilizes a sewer collection system. The potential for contamination from Santa Clara would then be no more than the potential contamination from any other city utilizing a sewer system.

The ground water flow rate for Santa Clara is calculated assuming a 3,000 foot wide band of development with an average saturated alluvial depth of 50 feet as given by 1997 mapping produced by the Utah Geological Survey. Using an average permeability of 200 feet/day, an average gradient of 1%, and a porosity of 0.3, the calculated Darcy and linear velocities are estimated to be 2.0 feet/day (730 feet/year) and 6.7 feet/day (2,430 feet/year) respectively. Using the equation Q=kiA gives a flow rate of 2,500 acre-feet/year (3.4 cfs).

Diamond Valley. Diamond Valley is located approximately nine miles almost due north of St. George along highway 18 and is similar in nature to the Winchester Hills area which lies to the south. General information available for this area indicates that the valley lies within the upper reaches of, and just above the Navajo Formation with upwards of about 200 feet of alluvium in 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 water movement are believed by some local experts to be present within the alluvium. The depth to water within the Navajo Formation is approximately 1,400 to 1,600 feet, and ground water flow paths within the Navajo 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.

Local subsurface flow rates within the limited alluvial flow system are estimated by assuming a contribution width from development of approximately 8,000 feet, a contributing depth of 200 feet, and a Darcy velocity of between 36 and 72 feet/year. Using the equation Q=kiA gives average flow rates between 1,320 and 2,645 acre-feet/year (1.8 and 3.6 cfs). The average linear velocity, calculated using a 0=0.3 ranges between 120 and 240 feet/year.

Winchester Hills. Winchester Hills is located approximately 6 miles north-northeast of St. George within the limits of the Navajo Formation with a cap of alluvium and basalts and is generally similar in nature to the Diamond Valley area which lies to the north. Although no significant regional faulting has been identified within 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%. Alluvial flow is believed by some local professionals to be only a minor portion of any total flow. The limited amount of alluvial flow that exists within the area is believed to move to the southwest, following the general trend of the land surface topography.

Local subsurface flow rates within the Navajo flow system were estimated by assuming a contribution width from development of approximately 4,000 feet, a hydraulic conductivity of 5 feet/day (1,825 feet/year), and various mixing depths as shown in the tables included within the appendices. A 50 foot aquifer and mixing depth was initially assumed for this area as a reasonable estimate of aquifer flow potential which gave a flow rate are estimate of 42 acre-feet/year (0.06 cfs) (using a velocity of 30.4 feet/year). The 50 foot depth was estimated based on engineering judgement taking into account consideration the known conditions regarding shallow alluvium and basalts that overlie the local Navajo formation.

After further review, a slight alteration was made to the general model developed for this area. Water collecting within shallow alluvium and basalts will move vertically downward until it joins the deeper Navajo formation. Once this shallow water joins the deep aquifer system, it has the potential for mixing over greater depths as the water moves downstream.

Virgin River Drainage

La Verkin. The town of La Verkin lies approximately 1 to 2 miles northeast of Hurricane and is bounded on the east by the Hurricane fault. La Verkin lies upon a relatively shallow bed of alluvial deposits which are believed to be locally about 30 feet thick. A 50 to 200 foot thick fractured basalt layer underlies the alluvium which in turn is underlain by the Upper Cetaceous Iron Springs Formation. The Utah Geological Survey has projected the Navajo Formation to lie at an approximate depth of 1,700 feet below land surface.

Overall hydrologic conditions of La Verkin are very similar to those at Hurricane except that the overall shallow ground water gradient is believed to be south and west towards the Virgin River. Flow is believed to be entering the ground water system from the Hurricane fault system as well as potentially out of the Virgin River east of the Hurricane fault.

There is a potential for direct flow path contamination of the La Verkin ground water system from ground water originating in New Harmony, Leeds, Anderson Junction, and Toquerville. It is believed at this time that significant concentrations of contaminants along these flow paths could directly impact the La Verkin ground water system.

Contamination of the ground water system at La Verkin would potentially move south and west where it could be recaptured by local well systems. Table II-2 shows an overall potential ground water gradient of approximately 3% and a ground water Darcy velocity ranging from 0.15 to 0.30 feet/day. Dividing by porosity (0=0.3), the calculated linear velocity becomes 185 to 370 feet/year). Assuming a potential development zone 4,000 feet wide and an average saturated aquifer depth (consisting of alluvium and basalts) of 175 feet, there would be between 880 and 1,760 acre-feet (1.2 to 2.4 cfs) of flow which could potentially dilute any contamination source entering the local ground water system.

Hurricane. Hurricane is located approximately 14 miles east-northeast of St. George and 1,250 feet above the top of the Navajo aquifer. The Hurricane area is underlain by several geologic layers including in descending order up to 100 feet of alluvial deposits, 50 to 200 feet of basalts, and 900 feet of mixed Cetaceous and Upper Jurassic Formations. The most dominant local and regional feature however is the Hurricane fault system. This fault is a major feature which has its down thrust side to the west. The Navajo Sandstone Formation which is at a depth of approximately 1250 feet west of the fault is upthrust 1,500 feet to the east. As is the case with most fault systems, there is also some parallel fracturing at distance from the fault which can affect local hydrogeology.

Ground water is believed to be confined within an aquifer lying below the shallow alluvial system in the Hurricane area. Projections of ground water contours shown on Figure II-1 indicate a westerly flow radiating away from the fault zone along the south border of Hurricane City. Local ground water flow paths therefore may be to the northwest, west and southwest. Local permeability is thought to be moderate with average reported permeabilities of 15 feet/day. With a local ground water gradient of 2.2%, this translates to a velocity of 0.33 feet/day.

Ground water recharge would appear to be derived from the Hurricane fault zone in the immediate area of Hurricane, and/or from unconsumed irrigation water diverted from the Virgin River. As indicated within the New Harmony discussion it is believed that waters leaving New Harmony enter the Ash Creek drainage west of the Hurricane Fault system and move southward towards Toquerville and Hurricane, potentially along or within the Hurricane Fault system. Ground water data within the Leeds and Anderson Junction area also show a ground water gradient towards the Ash Creek drainage. These waters would appear to be a major potential source of supply to the area north of Hurricane. Some waters may also be entering the ground water system from up gradient leakage out of the Virgin River at, or east of the fault zone.

There is a potential for direct flow path contamination of the Hurricane ground water system from New Harmony, Leeds, Anderson Junction, Toquerville and La Verkin. Significant concentrations of contaminants along these flow paths could directly affect the Hurricane ground water system should the local ground water table be lowered such that flow moves southward from the Virgin River towards Hurricane.

A local ground water contamination potential also includes the possible conveyance of contaminated water from the Hurricane area towards wells penetrating the Navajo aquifer west of town. This conveyance may occur as shallow alluvial waters move westward on localized perched (less permeable) geologic strata. Waters would then move horizontally and vertically when they reach the edge of the perched system thereby introducing the potential for contamination of deeper Navajo wells. The presence of fractured basalts underlying the alluvial system increases the potential for contaminant transport.

General flow calculations can be made assuming that the alluvial system is underlain by a less permeable aquitard, and that all flow moves horizontally until it reaches the border of the aquitard. If the zone of potential contamination consists of a band of land 15,000 feet wide paralleling the Hurricane fault, the aquifer depth is assumed to be 250 feet, and the Darcy velocity as shown in Table II-2 is 0.33 ft/day, then the average linear velocity and flow rate are 400 feet/year and 10,375 acre-feet/year (14.3 cfs) respectively. If these waters were not influenced by artificial stresses, such as well drawdown cones, the flow would move both north and west toward the Virgin River. An area of drawdown identified by USGS (located west of town and believed to have been created by well withdrawals), will have the effect of intercepting some westward moving waters. A preliminary flow path analysis using the contours shown on Figure II-2 indicates that approximately ½ of the total flow would move north to northwest toward the Virgin River while the other ½ would travel westward and likely be captured by the localized cone of depression.

Apple Valley. Little overall information is available in the Apple Valley area which lies east of the Hurricane fault and below the outcrop area of the Navajo Sandstone. It is believed however based on personal communications with local experts that the area is characteristic of relatively thin alluvial deposits of less than 100 feet in thickness. Ground water generally flows in a direction paralleling the valley bottom. Upper valley locations generally have a ground water flow to the northwest at a gradient of approximately 0.9%. Lower valley locations have a westward flow pattern with a gradient of about 2% (see Table II-2). Local geology generally dips to the east limiting the potential for significant regional recharge. Recharge to the Apple Valley unconsolidated aquifer appears to be from local drainages bordering the valley.

Overall ground water velocities within Apple Valley are believed to be on the order of 0.05 to 0.1 feet per day based on information provided in Table II-2. These velocities translate to Darcy velocities of between 18 and 36 feet per year, and average linear velocities of between 60 and 120 feet per year (using 0=0.3). Ground water flow rates within the valley can be estimated by applying the equation Q=kiA where it is assumed that the maximum alluvial thickness is 100 feet, the average flow width is 5,000 feet (both taken from topographic mapping), k=5 feet/day (1,825 ft/yr), and i=0.9 to 1.9%. Estimates using the Darcy velocity as shown indicate a flow of between 190 and 400 acre-feet/year (0.26 - 0.55 cfs).

Sand Mountain (Hurricane Bench, Bench Lake Area). Sand Mountain is generally located within the area between the Hurricane fault on the east and the Washington fault of 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% with a few exceptions as shown on Figure II-1. The exceptions appear to be related to the well field located west of Hurricane which result in the projected drawdowns shown on Figure II-1. Ground water gradients within the northern portions of Sand Mountain resulting from the well field are much lower and average 0.1%.

As shown in Table II-2, the average permeability of 1 foot/day (USGS, 1997). Darcy velocities for the range of gradients shown are estimated to be between 0.001 and 0.11 feet per day (0.37 and 40.1 feet/year). Average linear ground water velocities based on a porosity of 0.3 are estimated to be 1.2 to 130 feet/year. Based on information shown in Figure II-1, steeper gradient zones seem to dominate southern areas while flatter zones dominate northern zones. A ground water flow path analysis indicates that an approximate 25,000 foot wide zone could potentially be captured by the well field west of Hurricane as the water moves northward. Assuming that the saturated aquifer thickness is 1,350 feet as determined by 1997 USGS aquifer testing, the area has the potential of moving between 930 and 103,000 acre-feet (1.28 to 142.0 cfs) of water per year toward the well field.

It is understood that Sand Mountain may be the preferred site for a future surface water reservoir. It would be anticipated that such a reservoir would enhance northward flow and would essentially eliminate the potential for the development of a concentrated source of contaminants.

Increased flow to the north would also increase the dilution potential in down gradient wells thereby reducing contaminant hazards.

Washington. The city of Washington lies generally south of and below the Navajo Formation within the Kayenta and Moenave Formations. Since the city lies below the Navajo Formation, there is no potential for contamination by the City of water supplies tapping the sandstone unit.

The Washington fault, a north-south trending fault is located along the east edge of the City. It is possible that this fault system and other potential fractures within the area are contributing to subsurface flows within the Millcreek drainage, although it is the general opinion of the USGS that local faults have little flow potential. Several culinary wells now use and depend upon a continued and protected water source within this drainage.

Ground water contours within the Navajo Formation in the vicinity of Washington City would, without the influence of the Millcreek well field follow a southern flow path toward the Virgin River. The Millcreek well field is however creating a localized cone of depression which has influenced the local water table significantly (see Figure II-1). The influence is not believed to be detrimental to the developed water supply.

1997 geologic mapping provided by the Utah Geological Survey indicates that the average unconsolidated fill depth within the Washington City area (south of the Navajo Formation) to be generally less than approximately 25 feet (20 feet of which is assumed to be saturated). The overall local ground water gradient within this unconsolidated fill material is about 2.8% in the vicinity of the Millcreek drainage, which with the locally high permeability creates a relatively high flow condition. Local ground water has an estimated Darcy velocity of 2.8 feet/day (1,020 feet/year), and an average linear velocity (using 0=0.3) of 3,400 feet/year. The approximate ground water flow gradient between the central city area and the Virgin River is 2.5%. Using a developed width of 6,000 feet, a saturated thickness of 20 feet, and a hydraulic conductivity of 100 feet/day, there is an estimated 2,500 acre-feet (3.5 cfs) of water per year moving beneath the city which is potentially diluting local contamination sources.

Unless there is now, or will be a future culinary water supply well located within Washington or the area immediately south to the river, there is little likelihood for contamination to a drinking water supply. The quantity of contaminant which could theoretically discharge from the city to the river is far outweighed by the dilution potential of the Virgin River.

St. George. The city of St. George lies within the Kayenta Formation immediately below the Navajo Sandstone Formation. Since the city lies below and south of the Navajo Formation, there is no potential for contamination of water supplies tapping the sandstone unit. 1997 geologic mapping provided by the Utah Geological Survey indicates that the average unconsolidated fill depth within the St. George city area is approximately 30 feet. No faulting has been mapped in the immediate area of the city with the exception of a small north-south fault starting in the general area of the east I-15 interchange and heading north. It is not believed that this identified fault has a significant impact upon the local hydrogeology.

Ground water contours in the vicinity of the city generally follow a southern flow path toward the Virgin River. The overall ground water gradient varies from between 0.5 to 6.0% north of the city with the flat gradients being located in excess of one to two miles to the north. The steep gradients are typically found within the bottom margins of the Navajo Formation as shown on Figure II-1. Darcy ground water velocities in excess of one mile north of the city are estimated to be 0.06 feet/day (22 feet/year) with velocities near the base of the Navajo Formation in the area of St. George City estimated at 0.7 feet/day (260 feet/year). Dividing these velocities by the appropriate value for porosity gives linear velocities for the Navajo aquifer north of St. George, and in the alluvial system within and south of St. George of 130 feet/year (using 0=0.17 as documented in previous technical publications) and 870 feet/year (using an estimated 0=0.3) respectively.

The approximate ground water flow gradient between the north edge of the city and the Virgin River is 3.2%. Using a developed width of 10,000 feet and a saturated thickness of 30 feet, there is an estimated 900 to 6,000 acre-feet (1.2 to 8.3 cfs) of water per year moving beneath St. George which is diluting any local contamination source.

Unless there is now, or will be a future culinary water supply well located within St. George or the area immediately south to the river, there is little likelihood for contamination to a drinking water supply. The quantity of contaminant which could theoretically discharge from the St. George area to the river is far outweighed by the dilution potential of the Virgin River.

Ash Creek Drainage

New Harmony. New Harmony, located within the northeastern portion of the study area is located above the Navajo Sandstone Formation and is controlled mostly by alluvial flow mechanisms. Recharge from the local watershed contributes to the local water supply which generally follows the ground surface contour in a southerly flow pattern, beginning on the north at a ground water divide located just north of Kanarraville. Local ground water is expected to be of relatively young age considering its recharge source. Raw results of a recent chlorofluorocarbon sample taken on a well within the New Harmony area indicate that the waters may be as young as 5 to 10 years old which if true, would help verify the recharge assumption. However, the chlorofluorocarbon analyses completed at this time are very preliminary in nature. Young water mixing with older water could be tainting the results thereby giving an apparent reading characteristic of younger water. Water quality testing and analysis for this and other parameters will be documented by the USGS over the course of the next few years.

Surface flows travel southward until they enter Ash Creek Reservoir and are either used or lost to subsurface strata. 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 then conveys the water southward towards Toquerville. Communications with project personnel and State representatives have indicated that a dye test was completed several years ago with no evidence of a direct connection between Ash Creek Reservoir and Toquerville springs. No documentation was found regarding the dye test and therefore no conclusion could be made regarding its accuracy or validity. In spite of the dye test, it is believed possible that some interconnection exists between Ash Creek reservoir and the down gradient Ash Creek drainage, especially when reviewing reservoir and spring locations with fault and fracture mapping.

Unconsolidated deposits within the basin have been documented by the Utah Geological Survey to be as much as 500 feet thick near the town of New Harmony, to as deep as 2,000 feet near to, and paralleling the Hurricane fault. The threat of ground water contamination by septic systems within this basin is believed to be controlled by alluvial flow systems. Any residual contaminant which leaves the basin however could potentially travel great distances in short periods of time through the fracture systems associated with local faulting.

The preliminary chlorofluorocarbon dating analysis discussed earlier shows that water within Toquerville springs may be approximately 15 years old. If this is the case, and if New Harmony is the source of water for the spring, then the water is flowing at an average velocity of one (1) mile per year. It must be remembered that the dating analysis at this point in time is very preliminary and subject to several assumptions which could affect conclusions reached. One such conclusion may very well be that the water is assumed to be relatively young, when in reality, the water may be a mix of both young shallow, and old deep waters.

An estimate of ground water velocity and flow rate made from data shown in Table II-2 has been made. Assuming an average ground water gradient measured near Ash Creek Reservoir of 1.75% and an average permeability of 35 ft/day gives a Darcy velocity of 220 feet/year. Dividing by a porosity of 0.3 gives a ground water average linear velocity of 730 feet/year. An estimated flow rate of 22,700 acre-feet/year (31.3 cfs) was determined using the Darcy velocity and an average width and depth at the reservoir site of 3,000 and 1,500 feet respectively.

Pintura. The community of Pintura is located along I-15 approximately 23 miles northeast of St. George and lies within the upper portions of the Navajo Formation with an overlying zone of fractured basalts, debris and rubble. Since the community lies directly within the Navajo Formation it is a potential contamination source to down gradient water supplies. Geologic mapping shows several small fractures and fault systems which generally parallel I-15 and the Hurricane fault in the Pintura area. These fault and fracture systems may be contributing to both local recharge and discharge. It is believed that the area between Pintura and Toquerville is highly transmissive.

Recharge waters originating within the New Harmony area and points south have the potential of being conveyed to the Pintura area through these fault systems. General ground water flow direction appears however to be southward from the upland drainage basin. A southward ground water flow would potentially convey waters to either the Hurricane fault and/or Anderson Junction.

Projected local ground water gradients found within the shallow ground water system are on the order of 2.2% giving estimated Darcy velocities ranging between 0.022 and 0.70 feet/day (8.0 and 255 feet/year), and average linear ground water velocities ranging between 26 and 850 feet/year. Assuming a band of development 12,000 feet wide and a saturated depth of 300 feet, there would be an estimated flow rate of 660 to 21,150 acre-feet/year (0.9 to 29.2 cfs) available for the dilution of a potential contamination source. Most of any potential contamination source would be expected to move southward towards the Hurricane fault with some potential for flows to follow the smaller fault systems paralleling the Hurricane fault. This being the case, water moving southward has the potential of contributing a contamination source to the Toquerville, La Verkin and Hurricane areas while water moving to the southwest could potentially impact the Anderson Junction and Leeds areas.

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 within the limits of the Navajo aquifer. According to existing mapping, there are several local faults having a northeast-southwest orientation generally paralleling the local extent of the Hurricane fault.

Local ground water is likely recharged from two potential sources. The first is from local precipitation recharge being derived from the drainage basins to the northwest. The second is from a potential connection with north-south flows associated with the Hurricane fault.

According to available ground water contour data, local ground water contamination having the ability to move through alluvial deposits would have the potential of traveling towards the Toquerville spring area. The overall ground water gradient between Anderson Junction and Toquerville City appears to be relatively consistent at approximately 2.8 percent to the southeast. Since local geology consists of alluvial fill, basalts and fractured Navajo Sandstone, the potential for the conveyance of a contamination source would appear to be relatively high.

An estimate of average linear ground water velocity is calculated for any given area using the equation $\bar{v}=ki/0$. Given an alluvial fill with a local permeability (k) of 1 to 32 feet per day, an assumed porosity (0) of 0.3, and a gradient (I) of 2.8%, a contaminant source would have the potential of traveling between 34 and 1,090 feet per year. However, once a contamination source reaches fractured basalts, it could take as little as 6.5 years to travel the 10,000 feet to Toquerville (based on an average permeability of 45 ft/day and a 10,000 foot travel distance). The average dilution potential based on flow rate can be calculated by multiplying the average flow velocity by aquifer area.

Aquifer flow area for this location is assumed to have a flow width equal to the approximate width of development and a flow depth equal to the average local aquifer thickness. The best available information indicates the average width and thickness to be 4,000 and 250 feet respectively. Using these numbers one can estimate the potential volume of water moving through the ground water zone by multiplying the area by the Darcy velocity (v=ki). The equation for flow through the ground water aquifer then becomes Q=vA=kiA. For example, if k=1 ft/day (365 ft/yr), i=2.8%, A=4,000*250=1,000,000 ft^2 (23 acres), then Q=365*0.028*23=235 acre-feet/year. Applying this equation to the range of "k" values identified in Table II-2, there would be an approximate 235 to 7,500 acre-feet (0.32 to 10.3 cfs) of water per year potentially moving toward Toquerville if flow were in alluvium, and up to 10,560 acre-feet/yr (14.6 cfs) if the flow were moving through fractured basalts. The total volume of water moving southeastward is likely between the two estimates.

Toquerville. The town of Toquerville lies approximately 4 miles north of Hurricane and is bounded on the east by the Hurricane fault. Toquerville lies upon a relatively shallow bed of alluvial deposits which are believed to be about 20 to 30 feet thick. This alluvial deposit is underlain by a zone of fractured basalt which in turn is underlain by the Navajo Sandstone Formation. The Navajo Formation rises to the surface locally west of the Town.

Overall hydrologic conditions of Toquerville are very similar to those at La Verkin. Water is believed to be entering the ground water system from the Ash Creek drainage as well as from the Anderson Junction area.

As was the case with the La Verkin and Hurricane areas, there is a potential for direct flow path contamination of the Toquerville ground water system from New Harmony, Leeds, and Anderson Junction. Significant concentrations of contaminants along these flow paths could directly affect the Toquerville ground water system.

Contamination of the ground water system at Toquerville would potentially move south along the Ash Creek drainage where it could be recaptured by local water supplies near La Verkin. Table II-2 shows an overall potential ground water gradient of approximately 3.3% and a Darcy ground water velocity ranging from 0.33 to 0.83 feet/day. Dividing the Darcy flow rates by a porosity of 0.3 gives average linear velocities in the range of 400 to 1,010 feet/year. Assuming a potential development zone 3,000 feet wide and an average saturated aquifer depth of 50 feet, there would be between 408 and 1,030 acre-feet (0.56 to 1.42 cfs) of flow per year entering the area from Anderson Junction which could potentially dilute any contamination source entering the ground water system at Toquerville.

Leeds. The community of Leeds is located along I-15 approximately 15 miles northeast of St. George and lies within the Petrified Forest of the Chinle Formation. Since the community lies below the Navajo Formation it is not a potential contamination source to water supplies within the Navajo aquifer. Geologic mapping shows several small fault systems which generally parallel I-15 between Washington and Pintura. These fault systems may be contributing to both local recharge and discharge. Recharge waters originating within the New Harmony area and points south have the potential of being conveyed to the Pintura, Anderson Junction, Leeds, Harrisburg, and Washington areas through these fault systems. General ground water flow direction appears however to be southward from the upland drainage basin.

Local ground water gradients are moderately steep within the Leeds area and are on the order of 2.2% giving an estimated Darcy ground water velocity of 0.99 feet/day. Dividing by a porosity of 0.3 gives an average linear velocity of 1,200 feet/year. Assuming a band of development 10,000 feet wide and a saturated depth of 100 feet, there would be an estimated flow rate of 8,300 acre-feet/year (11.5 cfs) available for the dilution of a potential contamination source. Most of any potential contamination source however would be expected to move southward towards the Virgin River where the USGS has documented a gaining reach of stream. If the water moves southward as believed, any potential contamination source from Leeds would bypass Toquerville, La Verkin and Hurricane cities. The only potential hazard would appear to be the development of additional ground water supplies within the area between Leeds and the Virgin River wherein a contamination source could be picked up. Conveyance of a contamination source to the Virgin River and vicinity would be rapid once the contaminant left the alluvial fill and entered the underlying fractured basalt system.

SUMMARY

Hydrogeologic conditions within Washington County are highly complex and variable. This report has not intended to make hard conclusions, but rather take available verbal and documented information into account, and provide a general summary of findings and conclusions based on that data. A generalized summary of findings for the region is provided herein.

- Ground water level data is currently available in published form from federal, state and private sources for the St. George, Washington, Sand Mountain, and Leeds areas.

- Preliminary ground water level data is being updated for the St. George, Gunlock and New Harmony areas by the USGS.

- Ground water level projections in other areas were developed through the use of both spring and stream elevation data.

- Faults and fractures have the potential to increase the interconnectivity, and thereby increase ground water movement between the communities of New Harmony and Pintura, Anderson Junction, Toquerville, La Verkin and Hurricane; between Anderson Junction, Leeds, Harrisburg and Washington; between Pine Valley and the Millcreek well field; and between the Veyo and Gunlock areas.

CHAPTER III

EXISTING GROUNDWATER QUALITY

GENERAL

Significant groundwater development has taken place in the study area, particularly in the Navajo Sandstone as well as in formations that are adjacent to, or fed by, the Navajo Sandstone. As discussed in Chapter VI of this report, culinary water wells must meet the Primary Drinking Water Standards established by the U.S. Environmental Protection Agency (EPA) and adopted by the State of Utah. In addition, groundwater aquifers may now be classified for protective purposes in accordance with the Utah Groundwater Quality Protection Regulations. These requirements are also discussed in Chapter VI.

EXISTING CULINARY WATER WELLS

The approximate location of prominent culinary wells in the study area is shown as Figure III-1. High quality groundwater is obtained from many of the existing public water supply wells in the study area. The aquifers associated with these wells could likely be classified Class IA or "Pristine" according to the Utah Groundwater Quality Protection Regulations. Representative wells producing water meeting the requirements of the Pristine classification are included in Table III-1. A lesser number of existing public water supply wells obtain water from aquifers which could likely be classified Class II or "Drinking Water Quality", which is a lower classification, but still acceptable for public water supplies. Representative wells producing water meeting the requirements of the Drinking Water Quality classification "Class II" are included in Table III-2. A few isolated wells in the study area produce water from aquifers containing water of poorer quality than those included in the tables.

SEPTIC SYSTEM RELATED CONCERN

While this issue is analyzed and discussed at length in subsequent chapters, it is worth mentioning here because pollutants entering the groundwater from existing septic systems have likely not yet reached existing culinary wells. It may require 10's or even 100's of years for that to occur. In other words, studying the water quality of existing wells may provide a False Sense of Security regarding the potential effects of septic systems on regional groundwater quality.

TABLE III-1
SOURCES INDICATIVE OF CLASS IA GROUNDWATER (PRISTINE) [1]

System	Source	TDS (mg/l)	Cl (mg/l)	pH	SO_4 (mg/l)	NO_3 (mg/l)
Dammeron Valley	North Ridge Well	248	21	8.2	20	0.98
Ivins	Town Spring	232	20	8.1	69	0.80
Ivins	St. George Well	279	20	7.5	44	0.64
Kanarraville	Kanarraville Spring	434	13	7.9	160	0.37
La Verkin	Toquerville Spring	464	15	7.8	156	0.94
Pine Valley Mt. Farms	Well	288	21	8	17	1.53
Santa Clara	Beachem Spring	321	18	8.3	116	1.03
Santa Clara	Snow Canyon Well #1	166	13	7.6	20	0.91
St. George	Big Pine Canyon Spring	286	8	8.2	23	(2)
St. George	Carter Canyon	82	2	8.4	8	0.15
St. George	Gunlock Well #1	304	18	8.5	66	0.78
St. George	Gunlock Well #4	325	40	8.1	45	0.50
St. George	Millcreek No. 1	282	14	7.6	85	0.48
St. George	Quaking Aspen Spring	52	(2)	8.2	8	0.10
St. George	Snow Canyon Well #3	154	15	8	21	0.92
St. George	Snow Canyon Well #2	116	11	8.1	23	0.65
Veyo	Spring	330	28	8.2	26	1.65
Washington	Grape Vine Spring	236	7	(2)	28	0.32
Washington	Prisbrey Spring #1	362	12	8	132	0.47
Washington	Well No. 3	380	8	7.8	88	0.72
Washington	Well No. 4	312	8	7.9	114	0.36
Washington	Well No. 2	380	11	8.1	93	0.65
Washington	Westover Spring #2	364	16	7.9	250	0.47

Note: (1) The requirements associated with the Class IA (Pristine) classification are included in Chapter VI of this report.
(2) Data not available.

TABLE III-2

SOURCES INDICATIVE OF CLASS II GROUNDWATER (DRINKING WATER QUALITY)[1]

System	Source	TDS (mg/l)	Cl (mg/l)	pH	SO_4 (mg/l)	NO_3 (mg/l)
Hurricane	Ash Creek Spring	548	19	8.1	219	1.60
Hurricane	Hurricane West Well	532	22	8.1	245	0.39
Kanarraville	Well	510	26	7.7	156	3.60
Leeds	Well	720	23	7.9	288	0.55
New Harmony	Well	792	6	8.2	4	0.23
Santa Clara	Gray Spring #1	554	38	8.3	228	0.86
Santa Clara	Miller Spring #1	582	26	8.2	210	0.96
Santa Clara	Miller Spring #2	754	137	8.4	250	0.67
Santa Clara	Sheep Spring	520	28	8.2	200	0.90
St. George	City Creek #1 Well	1120	140	8.1	502	0.46
St. George	Gunlock Well #5	886	26	7.8	36	2.23
St. George	Millcreek Spring	702	160	8.2	187	0.35
Virgin	Spring 3 miles S. of Town	528	34	7.5	170	0.02
Virgin	Goosebury Mesa Well	888	30	8.4	380	0.04
Virgin	North Creek	760	62	8.4	356	1.05
Washington	Well No. 1	767	16	8	360	2.10

Note: (1) The requirements associated with the Class II (Drinking Water Quality) classification are included in Chapter VI of this report.

CHAPTER IV

PROJECTED GROWTH AREAS AND SEPTIC SYSTEM USAGE

LAND USE

The Washington County area is one of the fastest growing areas in Utah and in the United States. Its relatively mild temperatures and picturesque surroundings make it a very desirable location for permanent and seasonal residences. Planners estimate that by 2040 that the County population may increase from the current approximately 50,000 to more than 200,000 (Boyle/WWC/Alpha, 1995). This type of growth is unprecedented in the study area and in most of the intermountain area. It presents a tremendous burden on water resources planning.

Land use projections were obtained from the following sources:

- Meetings with John Willie, Washington County Planner and his administrative staff.

- “Population Management Study for Washington County, Utah”, completed for the Washington County Water Conservancy District by GEO/Graphics, Inc. in May of 1994.

- “Purpose and Need Study ” completed for the Washington County Water Conservancy District by Boyle Engineering, WWC, and Alpha Engineering in March of 1995.

Figure IV-1 depicts the subareas for which specific land use projections were developed for use in this study.

SEPTIC SYSTEM USE

Septic systems are used extensively in the study area, particularly in the less urban areas which tend to be more distant from St. George and the surrounding developed areas. While the rapidly growing areas closer to St. George are either now sewered or are considering installing sewer systems, the more distant and relatively undeveloped portions of the study area must use septic systems for wastewater disposal. As these distant areas experience increased development, they also require an increased number of septic systems, which in turn may place a greater stress on groundwater quality.

An estimate of the potential future number of septic systems was obtained by considering available land throughout the study area, current and likely future zoning patterns, and available water rights associated with land. In addition a projection was made assuming that the availability of water would not be a constraint (requires an external source of water). A summary of these projections is included in Table IV-1.

TABLE IV - 1
SEPTIC SYSTEM USE PROJECTIONS

Location	Private Land Area (acres)	Current Conditions Septic Systems	Buildout w/Constraints Septic Systems	Buildout w/out Constraints Septic Systems
Anderson Junction	653	7	20	660
Apple Valley	13312	486	500	3970
Brookside	5219	620	720	900
Dameron Valley	3497	200	300	3500
Diamond Valley	2064	404	440	620
Gunlock	3536	40	100	300
Hurricane	16130	56		
Ivins	5240			
La Verkin	3674	16		
Leeds	3871	200	300	780
New Harmony	15810	300	3000	3160
Pine Valley	2658	350	700	720
Pintura	1935	11	20	200
Bench Lake Area	3480	150	300	360
Santa Clara	8922			
St. George	30325			
Toquerville	4620	84		
Veyo	4155	100	100	830
Virgin	6193	80	100	2620
Washington	5961			
Winchester Hills	2510	350	600	2510
Total	143872	3454	7200	21130

Notes: Buildout with constraints means development is limited by available water
Buildout without constraints means development is not limited by available water
= Area is either currently sewered or is likely to be sewered in the near future

CHAPTER V

SEPTIC SYSTEM RELATED POLLUTION

BACKGROUND

The septic tank/soil absorption system was originally developed in France during the 1860's as a means for disposing of human wastes and for preventing the spread of pathogens (Canter and Knox, 1985 and DeFeo, Wait & Associates, 1991). Septic systems typically consist of a buried tank (septic tank) and a soil absorption system (leach field). A typical septic system is shown in Figure V-1. The septic tank is designed to remove scum, grease and settleable solids from wastewater by gravity separation. Bacteria then treat or reduce the organic portion of these materials anaerobically (without oxygen). The partially treated wastewater is then evenly distributed by piping to the leach field for aerobic treatment (with oxygen) of the remaining pollutants in the underlying soils.

EFFECTIVENESS OF SEPTIC SYSTEMS

Septic systems, if designed, installed, and maintained correctly, can be an effective means of preventing the spread of pathogens and other harmful substances. They function well when considering the parameters within which they are intended to operate. However, septic systems are not perfect wastewater disposal systems. They do not remove 100% of the pollutants associated with residential wastewater. There are some remaining pollutants which are discharged to the environment. How then do regulators, planners and designers deal with these remaining pollutants to help ensure that public health and the environment are protected to acceptable levels? In part the answer lies in the old adage: “Dilution is the Solution to Pollution”. This means that there must be sufficient groundwater available to decrease, or dilute, the concentration of the remaining pollutants to an acceptable level.

Therein lies the dilemma associated with septic systems. Septic systems are a good thing, but can there be too much of a good thing? The answer to that question depends on the assimilative capacity of the underlying groundwater. That is to say, how many septic systems can, or is the groundwater able to handle? The overall effectiveness of septic systems, including their impact on the environment is dependent on the determination of appropriate septic system densities (one septic system per “x” amount of acres). Appropriate densities help maintain adequate dilution potential in the underlying groundwater. The lower the development density, the higher the dilution potential.

SELECTION OF A KEY CONTAMINANT INDICATOR

Candidate Indicators

The determination of whether proper conditions exist for adequate dilution of septic system related pollutants is complex. To help simplify the determination, typical, well understood pollutants are usually selected as indicators of the effect septic systems may have on the environment. Four of these include: pathogens, organic compounds, phosphorus and nitrogen. The majority of reported health problems in the U.S. associated with septic systems are caused by pathogens which have passed through septic systems to groundwater. Organic compounds such as cleaning solvents have been identified as possible groundwater contaminants related to septic systems. Phosphorus released from septic systems can lead to eutrophication problems in surface water impoundments. Previous work by HA&L and others has indicated that pathogens, organic contaminants and phosphorus all have significant limitations as indicators and that nitrate nitrogen is an acceptable indicator of potential pollution from septic systems. A recent study completed for the State of Massachusetts concluded that **"using nitrogen loading as a means of determining acceptable density limits may be the most effective means of protecting the quality of water in wells or surface water bodies over the long term"** (DeFeo, Wait & Associates, 1991).

Nitrogen Related Health Risk

The United States Environmental Protection Agency (EPA) has determined that nitrate nitrogen poses an acute health concern at certain levels of exposure (Utah Drinking Water Board, 1993). Excessive levels of nitrate in drinking water may cause serious illness and sometimes death in infants under six months of age. EPA has set the maximum contaminant level (MCL) for nitrate in drinking water at 10 mg/L to prevent methemoglobinemia or "blue baby syndrome". Nitrate concentrations in public drinking water systems have been monitored on a regular basis for many years. Treatment for removal of nitrates from contaminated water sources, such a wells, is generally not cost effective for individual home owners, nor is it a typical form of treatment for public water suppliers that rely on large producing deep wells.

Sources of Nitrogen

The most common sources of nitrate in groundwater include fertilizer applied to the land, and sewage and wastes from humans and farm animals. Other typically minor sources of nitrogen to groundwater may include nitrogen associated with precipitation and naturally occurring nitrogen in the soil and underlying bedrock structure.

Septic Systems and Nitrogen

Septic systems have generally been found to be relatively ineffective in removing nitrogen from the wastewater stream. Figure V-2 shows schematically the effect of a typical septic system on the associated nitrogen compounds. Nitrogen entering the septic system is typically 70% organic nitrogen and 30% ammonia. The anaerobic environment in the septic tank transforms most of the organic nitrogen to ammonia nitrogen. The nitrogen leaving the septic tank is typically 25% organic nitrogen and 75% ammonia. A properly functioning absorption system has a biomat which forms at the soil interface directly below the absorption system. The biomat has a greatly reduced permeability and provides an unsaturated zone below the absorption system. This unsaturated zone is critical for the removal of pathogens. The unsaturated zone typically is an aerobic environment in which the ammonia is oxidized to nitrate (nitrification). An adequate depth of unsaturated flow, necessary for bacteriological treatment and for phosphorus removal, also establishes conditions which allow for rapid nitrification which converts ammonia and organic nitrogen to nitrate (Canter and Knox, 1985).

Transport and Fate of Nitrate

Figure V-3 represents the fate of nitrogen compounds associated with septic systems. When nitrate reaches the underlying groundwater, it becomes very mobile because of its solubility and anionic form. Nitrate moves with groundwater with minimal transformation. Nitrates can be removed from groundwater through two mechanisms: (1) direct uptake by plants, and (2) denitrification. Direct plant nitrate uptake adjacent to an absorption field is negligible if the drain field is installed properly so that an adequate unsaturated soil depth is maintained. Denitrification, or the bacteriological transformation of nitrate to nitrogen gas requires an oxygen free (anaerobic) environment. It would be unlikely for such an environment to occur in groundwater aquifers that typically produce high quality drinking water.

Advantages of Nitrate

Nitrate offers the following advantages as an indicator:

(1) Excessive concentrations of nitrate in drinking water present a well documented health hazard.
(2) Nitrate is an effective indicator of human activity because the major sources of nitrate in groundwater are wastewater disposal and application of fertilizer to land.
(3) Nitrate concentrations are relatively easy to measure.
(4) A reliable historical groundwater quality data base exists.
(5) Nitrate generally does not attenuate once it enters groundwater except by dilution.

CHAPTER VI

REGULATORY CONSIDERATIONS

The purpose of this chapter is to consider regulatory alternatives that may affect the determination of allowable or advisable septic system densities.

POLICY CONSIDERATIONS

Currently, the overall State of Utah water quality protection policy is “anti-degradation”. The following policy alternatives regarding further septic system usage were reviewed with Washington County:

- Non-degradation = no decrease in groundwater quality
- Anti-degradation = degradation allowed to an acceptable limit
- Selective degradation = degradation allowed in selected areas to an acceptable limit

After consultation with WCWCD and the cooperating agencies, anti-degradation was recommended as the County’s preferred general policy regarding protection of groundwater quality.

WASHINGTON COUNTY

Southwest Utah Public Health Department

In Utah, local health departments have the primary responsibility for assuring that proposed individual wastewater disposal systems, including septic tank leachfield systems, will not have an adverse impact upon groundwater quality. The Utah Department of Environmental Quality provides minimum standards for local health departments to use in assessing the adequacy of proposed individual wastewater disposal systems. The Utah Administrative Code gives local health departments the option to determine the minimum lot size based upon a number of factors including the “individual and accumulated gross effects on water quality”.

Washington County Planning Department

Current zoning requirements in Washington County dictate that all developable residential lots utilizing septic systems be one (1) acre minimum. Selected areas including the New Harmony Area require five (5) acres per lot for septic system use.

STATE OF UTAH

Drinking Water Standards

The Utah Drinking Water Board and Division of Drinking Water (a Division of the Utah Department of Environmental Quality) have primary responsibility for regulating all community water systems to ensure that public drinking water meets State primary and secondary standards. Source water drawn from either surface or groundwater supplies must either meet or be treatable such that compliance with primary and secondary standards is realized. Primary standards specify a maximum contaminant level (MCL) for organic, inorganic, and microbiological contaminants, as well as for turbidity and radioactivity. Secondary standards address taste, odor, color, and other conditions associated with drinking water aesthetics. A summarized listing of the State of Utah standards are presented in Tables VI-1 and VI-2.

TABLE VI-1
UTAH PRIMARY DRINKING WATER STANDARDS

PRIMARY INORGANIC STANDARDS	
Contaminant	Maximum Contaminant Level
Antimony	0.006 mg/l
Arsenic	0.05 mg/l
Asbestos	7 Million Fibers/liter(longer than 10
Barium	2 mg/l
Beryllium	0.004 mg/l
Cadmium	0.005 mg/l
Chromium	0.1 mg/l
Cyanide (as free Cyanide)	0.2 mg/l
Fluoride	4.0 mg/l
Mercury	0.002 mg/l
Nickel	0.1 mg/l
Nitrate	10 mg/l (as Nitrogen)
Nitrite	1 mg/l (as Nitrogen)
Total Nitrate and Nitrite	10 mg/l (as Nitrogen)
Selenium	0.05 mg/l
Sodium	NMCL[1]
Sulfate	1000 mg/l
Thallium	0.002 mg/l
Total Dissolved Solids	2000 mg/l

1. No maximum contaminant level has been established for sodium

TABLE VI-2
UTAH SECONDARY DRINKING WATER STANDARDS

SECONDARY INORGANIC STANDARDS	
Contaminant	Level
Aluminum	0.05 to 0.2 mg/l
Chloride	250 mg/l
Color	15 Color Units
Copper	1 mg/l
Corrosivity	Non-corrosive
Fluoride	2.0 mg/l
Foaming Agents	0.5 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor	3 Threshold Odor Number
pH	6.5-8.5
Silver	0.1 mg/l
Sulfate	250 mg/l
TDS	500 mg/l
Zinc	5 mg/l

The complete primary and secondary standards are presented in the Utah Administrative Code, Rules for Public Drinking Water Systems, Part I, R309-103.

Drinking Water Source Protection Rules

The Utah Drinking Water Board adopted the Drinking Water Source Protection Rule, R309-113, Utah Administrative Code, to govern the protection of groundwater sources of drinking water. The rule was established to require a uniform, statewide program for implementation by public water systems (PWS's).

The rule requires that each PWS submit a Drinking Water Source Protection (DWSP) Plan for each of its new groundwater sources and for each of its existing groundwater sources. DWSP Plans include the following:

- DWSP Delineation Report
- Prioritized Inventory of Potential Contamination Sources
- Management Program to Control Each Pre-existing Potential Contamination Source
- Management Program to Control or Prohibit Future Potential Contamination Sources for Existing Drinking Water Sources
- Implementation Schedule
- Resource Evaluation
- Record keeping

Management programs list each of the current controls that are in effect for each potential contamination source and assess whether current controls are stringent enough to prevent pollution from a potential contamination source from reaching a groundwater source of drinking water.

Wastewater Disposal Rules

General Policy. The Utah Water Quality Board and Division of Water Quality have responsibility to provide additional and cumulative remedies to prevent, abate, and control the pollution of the waters of the state under primacy of the federal Water Pollution Control Act as amended by the Water Quality Act of 1987. In R317-2-1(a) of the Utah Administrative Code it was declared public policy of the State of Utah to "...conserve the waters of the state and to protect, maintain and improve the quality thereof for public water supplies, for the propagation of wildlife, fish and aquatic life, and for domestic, agricultural, industrial, recreational and other legitimate beneficial uses; to provide that no waste be discharged into any waters of the state without first being given the degree of treatment necessary to protect the legitimate beneficial uses of such waters; to provide for the prevention, abatement and control of new or existing water pollution; to place first in priority those control measures directed toward elimination of pollution which creates hazards to the public health..."

Surface Water - Beneficial Use Classification System. The Utah Water Quality Board (UWQB) has grouped the surface waters of the state into classes so as to protect the beneficial uses of each designated class against controllable pollution. Surface waters of the state are classified as follows (Utah Department of Environmental Quality, 1994):

1. Class 1 - Protected for use as a raw water source for domestic water systems.
   A. Class 1A - Reserved.
   B. Class 1B - Reserved.
   C. Class 1C - Protected for domestic purposes with prior treatment by treatment processes as required by the Utah Department of Environmental Quality.
2. Class 2 - Protected for in-stream recreational use and aesthetics.
   A. Class 2A - Protected for primary contact recreation such as swimming.
   B. Class 2B - Protected for secondary contact recreation such as boating, wading, or similar uses.

3. Class 3 - Protected for in-stream use by aquatic wildlife.
   - A. Class 3A - Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
   - B. Class 3B - Protected for warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain.
   - C. Class 3C - Protected for non-game fish and other aquatic life, including the necessary aquatic organisms in their food chain.
   - D. Class 3D - Protected for waterfowl, shore birds and other water-oriented wildlife not included in Classes 3A, 3B, or 3C, including the necessary aquatic organisms in their food chain.
4. Class 4 - Protected for agricultural uses including irrigation of crops and stock watering.
5. Class 5 - The Great Salt Lake. Protected for primary and secondary contact recreation, aquatic wildlife, and mineral extraction.
6. Class 6 - Standards for this class are determined based on environmental and human health concerns.

Numeric criteria for the standards of water quality for the classes of water defined by the UWQB are listed in R317-2-14 of the Utah Administrative Code.

Individual Wastewater Disposal Systems. Individual wastewater disposal systems (IWDS) are those systems for underground disposal of domestic wastewater which are designed for a capacity of 5,000 gallons per day or less and are not designed to serve multiple dwelling units which are owned by separate owners except condominiums and twin homes. IWDS usually consist of a building sewer, a septic tank, and an absorption system.

Utah Administrative Code, R317-502-16 indicates that one of the following two methods shall be used for determining minimum lot size for a single-family dwelling when an individual wastewater disposal system is to be used:

METHOD 1: -The local health department having jurisdiction may determine minimum lot size. Individuals or developers requesting lot size determinations under this method will be required to submit to the local health department, at their own expense, a report which accurately takes into account, but is not limited to, the following factors:

A. Soil type and depth.
B. Area drainage, lot drainage, and potential for flooding.
C. Protection of surface and ground waters.
D. Setbacks from property lines, water supplies, etc.
E. Source of culinary water.
F. Topography, geology, hydrology and ground cover.
G. Availability of public sewers.
H. Activity or land use, present and anticipated.
I. Growth patterns.
J. Individual and accumulated gross effects on water quality.

K. Reserve areas for additional subsurface disposal.
L. Anticipated sewage volume.
M. Climatic conditions.
N. Installation plans for disposal system.
O. Area to be utilized by dwelling and other structures.

Under this method, local health departments may elect to involve other affected governmental entities and the Division in making joint lot size determinations. The Division will develop technical information, training programs, and provide engineering and geohydrologic assistance in making lot size determinations that will be available to local health departments upon their request.

METHOD 2: -Whenever local health departments do not establish minimum lot sizes for single-family dwellings that will be served by individual wastewater disposal systems, the required lot size ranges from 12,000 square feet to 1.75 acres depending on the type of water supply (public or private) and soil type (the specific requirements are discussed in the code).

Whenever an individual wastewater disposal system is found by the regulatory authority to create or contribute to any dangerous or unsanitary condition which may involve a public health hazard, the regulatory authority may order the owner to take the necessary action to cause the condition to be corrected, eliminated or otherwise come into compliance. A public health hazard consists of sufficient types and amounts of biological, chemical, or physical agents relating to water or sewage which are likely to cause human illness, disorders or disability. These include, pathogenic viruses and bacteria, parasites, toxic chemicals and radioactive isotopes.

Groundwater Quality Protection Rules

The State of Utah's Water Pollution Control Committee (now the Utah Water Quality Board) in 1989 passed the Groundwater Quality Protection Regulations for the protection of Utah's groundwater resources. The Utah Administrative Code, Rules for Groundwater Quality Protection, R317-6 (revised, March 20, 1995) provides for six groundwater classes based upon water quality. Representative characteristics of each class are described below:

1. Class IA - Pristine Groundwater
   Class IA groundwater has the following characteristics:
   A. Total dissolved solids of less than 500 mg/l.
   B. No contaminant concentrations that exceed the groundwater quality standards.
2. Class IB - Irreplaceable Groundwater
   Class IB groundwater is a source of water for a community public drinking water system for which no reliable supply of comparable quality and quantity is available because of economic or institutional constraints.
3. Class IC - Ecologically Important Groundwater
   Class IC groundwater is a source of groundwater discharge important to the continued existence of wildlife habitat.

4. Class II - Drinking Water Quality Groundwater
   Class II groundwater has the following characteristics:
   A. Total dissolved solids greater than 500 mg/l and less than 3000 mg/l.
   B. No contaminant concentrations that exceed groundwater quality standards.
5. Class III - Limited Use Groundwater
   Class III groundwater has one or both of the following characteristics:
   A. Total dissolved solids greater than 3000 mg/l and less than 10,000 mg/l, or;
   B. One or more contaminants that exceed the groundwater quality standards.
6. Class IV - Saline Groundwater
   Class IV groundwater has total dissolved solids greater than 10,000 mg/l.

OTHER STATES

Other states including California, Massachusetts, Montana and Washington have enacted and implemented regulations and constraints on the utilization of septic systems and the minimum lot size required to reduce the potential impacts on groundwater.

RECOMMENDED REGULATORY APPROACH

Our recommended regulatory approach to determining and controlling the density of septic systems in the study area includes the following:

1. Use of the individual wastewater disposal system requirements, specifically as they relate to determining lot sizes by requiring the consideration of "Protection of Surface and Groundwaters" and "Individual and Accumulated Gross Effects on Water Quality".

2. Use of the Primary Drinking Water Standards as the absolute limit for degradation of potential drinking water sources.

3. Use of the Utah Groundwater Quality Protection Rule to provide legal authority for protecting existing and probable future beneficial uses of groundwater including potential drinking water sources.

4. Use of the local planning and zoning ordinances to implement recommended septic system densities.

CHAPTER VII

SEPTIC SYSTEM DENSITY DETERMINATION

GENERAL

The U.S. Congress Office of Technology Assessment (OTA) stated that **"Major factors affecting the potential of septic systems to contaminate groundwater in general are the density of systems per unit area and hydro geological conditions**. **Areas with a density of more than 40 systems per square mile (1 unit per 16 acres) are considered regions with potential for contamination."** (OTA, 1984). The purpose of this chapter is to analyze a number of different factors in a effort to develop recommended septic system densities which will provide a tool to help protect ground water quality in this study area.

The methodology utilized to develop a range of septic system densities for consideration in this study incorporates a three step process as follows:

(1) Risk Analysis

(2) Mass Balance Analysis

(3) Implementation Considerations

RISK ANALYSIS

The risk analysis provides a qualifiable approach to considering the different risks that may be associated with septic system use in the individual subareas within the overall study area. Some subareas have conditions which make them a higher risk to groundwater quality than other subareas.

Risk Analysis Criteria

In general, the risk analysis criteria are not easily quantifiable and therefore do not lend themselves to incorporation into the mass balance equation. However, they are important and worthy of consideration. The criteria included in the risk analysis in this study area are as follows:

Predictability of Mixing Zone Formation Dispersive Potential. This criteria has to do with the type of formation underlying the study area. Reductions in key contaminant concentrations, specifically nitrate, are due to dilution and especially mixing or dispersion potential. It is relatively easy to predict the ability of an alluvial material to disperse pollutants. It is not as easy to make the same prediction in a bedrock formation.

Potential to Enter Down Gradient Faults. This criteria is sometimes referred to as "piping potential". It refers to the potential for rapid transmission of water and pollutants through faults that may exist in the study area.

Depth to Water Table. This criteria is considered because a greater depth to the water table may provide a greater opportunity for dispersion of the pollutants prior to their entering the ground water.

Potential for Pollutants to Travel Vertically to the Water Table. This criteria addresses the potential for intermediate confining layers that may impede the vertical travel of water and pollutants.

Proximity to Existing Down Gradient Culinary Water Supply. While this study focuses on the protection of the groundwater aquifer for all potential uses, it was felt that some extra emphasis on existing drinking water sources would be appropriate.

Potential to Affect Surface Water. Because groundwater and surface water are not really separate resources, it was felt that some recognition of their potential for interrelationship should be recognized. Some of the subareas in the study have the potential to discharge subsurface waters to adjacent surface waters.

Following selection of the risk criteria, a low, medium and high risk ranking was established for each criteria. Some of the rankings have a general numerical basis, others are simply ranked low, medium or high based on local conditions. Corresponding to the risk ranking, a risk score associated with the risk ranking was assigned to each criteria. The scores were weighted according to the relative importance of individual criteria in this study area. A display of the selected risk analysis criteria and their relative rankings and possible scores are included as Table VII-1.

The risk analysis criteria, their associated risk rankings and possible scores were then applied to each sub area. A total risk score was then determined for each sub area. Risk scores for each subarea are displayed in Table VII-2.

To incorporate the risk analysis into the mass balance analysis, and thus the septic system density determination, a correlation was developed between the risk scores and the recommended allowable degradation of groundwater quality. The ground water quality was allowed to degrade, or experience an increase in nitrate concentration, over a range of values above background (background assumed to be 1 mg/L based on historical water source data). The ranges were 1 to 2 mg/L above background, 1 to 3 mg/L above background and 1 to 4 mg/L above background. These three ranges resulted in total down gradient nitrate concentration ranges of 2 to 3 mg/L, 2 to 4 mg/L and 2 to 5 mg/L respectively.

TABLE VII-1
RISK ANALYSIS CRITERIA

	CRITERIA	RANKING			POSSIBLE SCORE		
		Low Risk	Medium Risk	High Risk	Low Risk	Medium Risk	High Risk
1	Predictability of Mixing Zone Formation Dispersive Potential (1)	High	Medium	Low	15	30	45
2	Potential to Enter Down Gradient Faults	Low	Medium	High	10	20	30
3	Depth to Water Table	> 600 ft	300 - 600 ft	< 300 ft	5	10	15
4	Potential for Pollutants to Travel Vertically to Water Table	Low	Medium	High	5	10	15
5	Proximity to Existing Down Gradient Culinary Water Supply	> 5 miles	1-5 miles	< 1 mile	10	20	30
6	Potential to Affect Surface Water	Low	Medium	High	1	3	5

(1) Dispersive Potential Predictability
High Predictability - Mixing zone composed primarily of alluvial fill
Medium Predictability - Mixing zone composed of a mixture of mostly fractured bedrock with some alluvial fill
Low Predictability - Mixing zone composed primarily of fractured bedrock

TABLE VII-2
RISK ANALYSIS

AREA	CURRENTLY SEWERED	CRITERIA / SCORE						TOTAL SCORE
		1	2	3	4	5	6	
Anderson Junction		15	30	5	30	20	1	101
Apple Valley		15	10	5	10	10	1	51
Bench Lake Area		30	20	5	15	20	1	91
Brookside		15	10	5	10	30	5	75
Dameron Valley		30	30	5	10	20	1	96
Diamond Valley		30	10	5	10	20	1	76
Gunlock		15	30	5	10	20	5	85
Hurricane	Yes	30	10	5	15	30	1	91
Ivins	Yes	15	10	5	10	30	3	73
La Verkin	Yes	30	30	5	15	30	5	115
Leeds		30	20	5	15	10	1	81
New Harmony		15	20	5	30	10	1	81
Pine Valley		15	10	5	15	10	3	58
Pintura		15	30	5	10	20	1	81
Santa Clara	Yes	15	10	5	10	20	5	65
St. George	Yes	15	10	5	30	10	1	71
Toquerville	Yes	30	30	5	15	20	1	101
Veyo		30	30	5	10	20	5	100
Washington	Yes	15	30	5	30	10	3	93
Winchester Hills		45	30	15	10	20	1	121

The highest and lowest possible risk scores were then plotted versus the down gradient nitrate concentration ranges. An equation describing the line between them was then determined. Subarea risk scores were then plotted on the line, and the corresponding allowable nitrate concentrations were determined. This relationship is displayed in Figures VII-1, VII-2 and VII-3.

Basically the relationship is as follows: the higher the septic system related risk associated with a particular sub area, the less the allowable degradation. The range of risk based allowable down gradient nitrate concentrations for each subarea was then entered into the mass balance equation.

MASS BALANCE ANALYSIS

Mass Balance Equation

The mass balance analysis provides a quantifiable approach to determining recommended septic system densities and to distinguishing the characteristics of the individual subareas within the overall study area. The mass balance analysis utilized in this study considers five flow and nitrate loading components as depicted in Figure VII-4. Those five components are:

1) The flow (Qs) and nitrate loading (Ns) associated with the effluent from the septic system(s).
2) The flow (Qi) and nitrate loading (Ni) associated with the watering and fertilizing of residential lawns and agricultural areas (both referred to generally as irrigation).
3) The flow (Qp) and nitrate loading (Np) associated with precipitation.
4) The flow (Qb)and nitrate concentration (Nb) associated with background or ambient groundwater flow.
5) The total flow (Qt) and nitrate concentration (Nt) resulting from combining the other four components.

The generalized equation used for analyzing the relationship of these factors is as follows:

$$QsNs + QiNi + QpNp + QbNb = QtNt$$

By fixing Nt (the desired or allowable nitrate concentration in down gradient groundwater as determined in the risk analysis), and by solving the equation for the flow and loading associated with the septic systems (based on the number of septic systems), the allowable contributors, or septic systems, can be calculated. Using available land in the sub area, density (one septic system per “x” amount of acres) of septic systems for a selected area can be determined. The expanded equation, including conversion factors, is included in Appendix A.

Criteria and Assumptions

A range of resultant densities are possible depending upon the specific assumptions included in the analysis. A discussion of selected criteria and assumptions follows.

Down-Gradient Nitrate Concentration. The down-gradient or allowable total nitrate concentration in the ground water associated with individual sub areas was determined using the risk analysis.

Mixing Depth. This factor refers to the vertical distance below the ground water table that is available for dilution. Some researchers and regulatory entities feel that there should be no allowance for the ability of the groundwater to accept pollutants, particularly where the hydro geology of the area is not well understood. This means that the nitrate concentration in the combined flows from sewer, precipitation and irrigation, immediately prior to entering the groundwater should be at or below the required or desired down gradient concentration. If this approach or restriction were applied in the Washington County area, the required density would likely exceed one septic system per 50 acres. Densities would be so high because of the relatively low groundwater flows and precipitation. Large acreages such as this can be seen on the tables found in the appendix. We feel that a restrictive approach such as this (i.e. mixing zone depth of "0" feet) is unreasonable for this study area, primarily because there is a reasonable understanding of local hydro geology. Our analysis therefore includes a range of analysis values for dilution to a maximum of 100 feet, or extent of saturated thickness, whichever is less.

Septic System Effluent Flow. Typical values for the amount of flow discharged by the average residence vary from approximately 200 to 400 gallons per system per day. The increasing awareness of water conservation will likely result in long term values that are nearer the lower end of this range or even lower.

Septic System Effluent Strength. Septic system effluent nitrate concentrations typically range from 30 to 80 mg/l NO_3-N. The increasing reality of water conservation practices will force this value toward the upper end of the range. A value of 40 mg/l was used in this study.

Precipitation. Precipitation values used in this analysis were obtained from historical data prepared by the U.S. Weather Bureau. Recharge was assumed to be 10% of the total amount of precipitation received in a year. Nitrate loading associated with precipitation and its entry into the soil structure was estimated to be 1 mg/l.

Irrigation. Irrigation was assumed to be 6 AF/ acre, as directed by the Steering Committee. The irrigated area was assumed to be 10% of the land area in each sub area. Nitrate loading associated with fertilizer applied to irrigated areas was assumed to be 1 mg/l.

Denitrification. Denitrification is the conversion of nitrate nitrogen to nitrogen gas. As discussed in Chapter V of this report, it would be unlikely for such a conversion to occur in groundwater aquifers that typically produce high quality drinking water. None of the water quality problems typically associated with the anaerobic environment required for denitrification are present in the study area. Denitrification was therefore assumed to be zero in these analyses.

Ambient Groundwater. Groundwater flows used in the analyses were determined using the data included in Chapter II of this report. Ambient or background nitrate concentration was assumed to be 1 mg/l throughout the study area based upon a review of the data included in Chapter III of this report.

Mass Balance Analysis Results

The results of a typical mass balance for the Pine Valley area are displayed as Figure VII-5. The assumptions and results of the analysis for all subareas are included in Appendix B.

IMPLEMENTATION CONSIDERATIONS

The recommendation of septic system densities for the study area depends not only upon the risk and mass balance analyses, but also upon how local regulatory authorities want to manage the development review process. It would be possible to establish procedures which could be used by developers to determine the site specific septic system density required for each development. This would involve the gathering of significant amounts of data, analyses similar to that included in this study, and review of the results by local officials. This approach, however, would require significant resources of both the developer and local officials. In addition, it would require longer time periods for the review of proposed developments. For these reasons, it was felt that the adoption of acceptable average septic system densities for areas having similar physical conditions and risks would be the most appropriate. The suggested grouping of subareas is shown in figure VII-6.

RECOMMENDED SEPTIC SYSTEM DENSITIES

Consideration of the risk analysis, mass balance analysis and implementation approach resulted in the ranges of possible septic system densities shown in Table VII-3.

When selecting a septic system density for individual subareas, local decision makers should consider the following:

1) The cumulative effects of combined subareas. As groundwater moves down gradient in the study area, the effect of each subarea is additive with respect to nitrate concentration.
2) The fact that nitrate is only an indicator. Excessive concentrations or other current and future contaminants may have a similar or more detrimental effect on groundwater quality.
3) Septic systems are not the only source of nitrates. Other sources including animal corrals, crop production and natural geological sources should be considered.
4) The hydrogeological information included in this report should be considered preliminary with respect to its level of accuracy and precision. More definitive information will become available when the United States Geological Survey completes its new groundwater model of the study area.

With all of the factors to consider, it would be advisable to be somewhat conservative and select densities that are midrange in Table VII-3.

TABLE VII-3

		RECOMMENDED SEPTIC SYSTEM DENSITIES (number of acres required per septic system)						
		COMBINED SUB AREAS						
		Pine Valley	Brookside Veyo Gunlock	Ivins Santa Clara St. George Washingto n	Dameron Valley Diamond Valley Winchester Hills	New Harmony	Anderson Junction Hurricane La Verkin Leeds Pintura Sky Ranch - Bench Lake Area Toquerville	Apple Valley
ALLOWABLE DOWN GRADIENT NO_3^- CONCENTRATION (mg/L)	2 to 3*	4	11	12	15	10	12	11
	2 to 4*	3	8	8	12	5	9	7
	2 to 5*	2	6	6	10	4	7	5

* Range associated with risk analysis

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