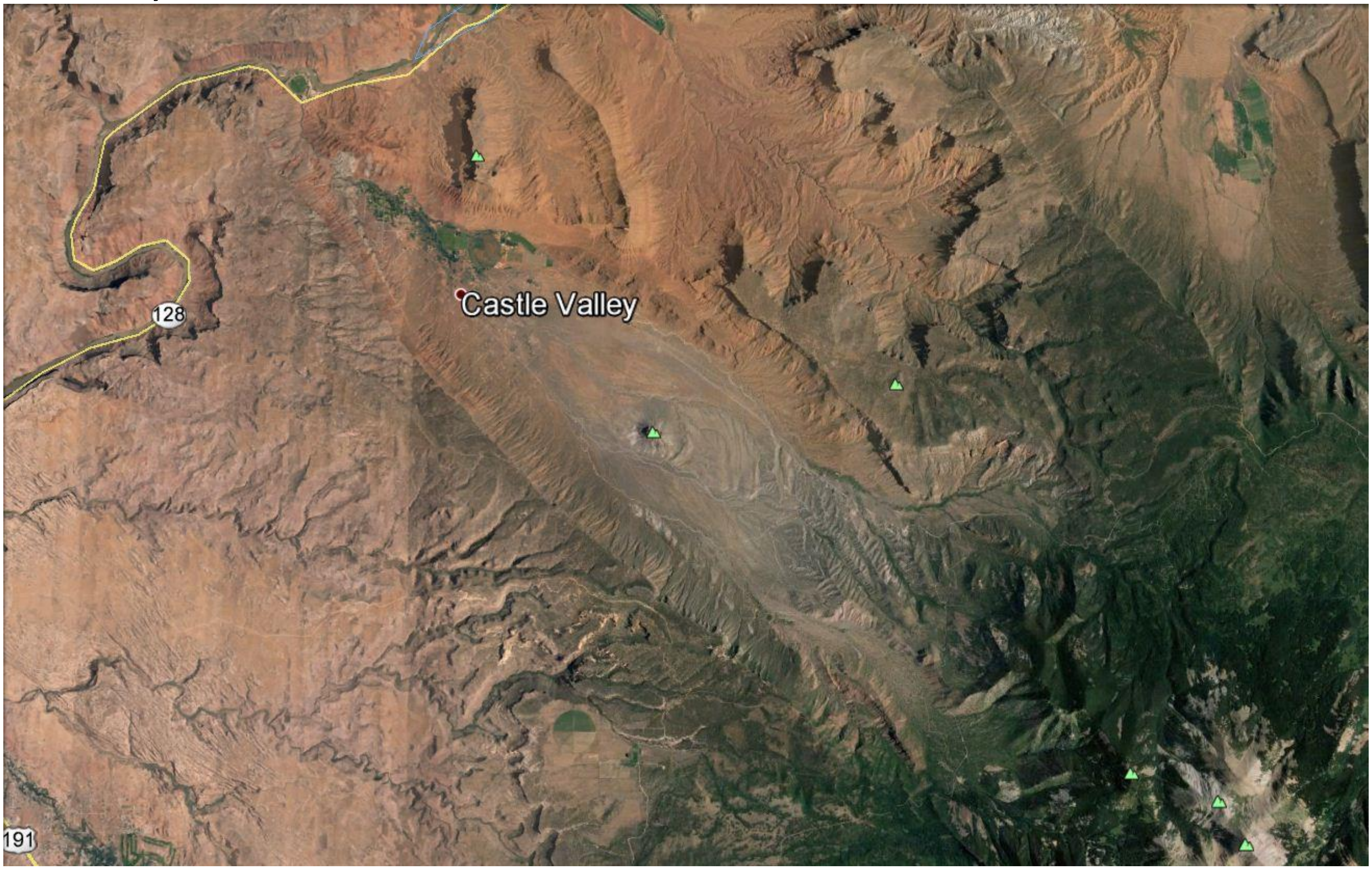
2020

Town of Castle Valley, Utah

Hazard Mitigation Plan

TABLE OF CONTENTS

Castle Valley Overview



Town of Castle Valley Overview

DEFINITIONS

Catastrophic Disaster: An event that results in large numbers of deaths and injuries; causes extensive damage or destruction of facilities that provide and sustain human needs; produces an overwhelming demand on State and local response resources and mechanisms; causes a severe long-term effect on general economic activity; and severely affects State, local, and private-sector capabilities to begin and sustain response activities. Note: the Stafford Act provides no definition for this term. (**FEMA,** *FRP Appendix B*, 1992)

Hazard: "A potential event or situation that presents a threat to life and property." (**FEMA**, *Hazards Analysis for Emergency Management (Interim Guidance)*, September **1983**, p. 5)

BACKGROUND

INTRODUCTION:

The Castle Valley Hazard Mitigation Plan is a localized plan that details the several natural and manmade hazards that are specific to Castle Valley and the Town of Castle Valley municipality, located in Grand County in the State of Utah. (See Appendix A1 –A2) This plan fulfills the requirements set forth by the Disaster Mitigation Act of 2000 (DMA 2000). The DMA 2000 requires a hazard mitigation plan in order to be eligible for mitigation grants made available by the Federal Emergency Management Agency (FEMA).

PURPOSE:

The Castle Valley Hazard Mitigation Plan is designed to evaluate and identify local hazards that would negatively affect Castle Valley. The plan outlines mitigation strategies for each hazard with an assessment to the potential benefit, the financial viability and community acceptance /political viability. The plan will be an important step in outlining and recommending government roles, public participation, regulations and emergency systems to create a safer environment for citizens and efficient emergency response.

SCOPE:

The Castle Valley Hazard Mitigation Plan includes all incorporated and unincorporated areas in Castle Valley. The plan addresses all natural hazards identified by the Federal Emergency Management Agency. All hazards that may affect Castle Valley and its residents are analyzed. Hazard mitigations are discussed in both long and short term goals in mind. The implementation of each mitigation strategy is discussed and possible resources and funding options are identified.

FUNDING:

Funding for the mitigation planning process has been largely by volunteer hours. Minimal costs for office supplies, such as paper, ink, and hours worked by the Town clerk will also be included.
Funding for mitigation strategies include budgeting by the Town of Castle Valley and the Grand County Service Area for Castle Valley Fire Protection District (Castle Valley Fire Protection District and possible grant and loan sources. Possible Grant and loan sources include: C.I.B., USDA, Rural Development Grants, credit unions, and other Grant Websites.
Recruiting volunteers for some of the mitigation efforts was also considered.
Volunteer hours will be counted at the current FEMA rate.
Town Clerk hours are counted at the current FEMA rate.

PROFILE

General:
Castle Valley was initially a large ranch which was subdivided into five-acre minimum lots (now Town of Castle Valley municipal boundaries) platted, and recorded on May 11, 1973. The Town of Castle Valley was officially incorporated on July 26, 1985.

The 2010 US Census stated that the population of the Town of Castle Valley was 319 as compared to the 2000 US Census which stated a population of 349 for the Town. The 2010 US Census also showed the following demographics for Town residents:

Male	166	White	310
Female	153	African American	0
Under 18	26	American Indian or Alaska Native	1
20-34 years old	23	Asian	2
35-49 years old	42	Native Hawaiian and Pacific Islander	0
50-64 years old	159	Other	2
65 years old and over	62	Identified by two or more	4

* The above data will be updated with results from the 2020 Census when available.
Castle Valley is surrounded by large tracts of open space and minimally developed public land that provides a natural setting, integral to the character of the Town. The sensitive nature of the land and water of Castle Valley and the effects of climate change call for creative and new ways of managing Town and surrounding lands and our local and global environments.

Government:
The Town of Castle Valley has an elected 5 member Town Council including a Mayor. The Town also has a Planning and Land Use Commission, a Road Committee and the Hazard Mitigation Committee that meet monthly in open and public meetings in accordance with Utah Code 52-4. The Town Council adopts Ordinances and Resolutions with recommendations and public hearings presented from each committee and works together to ensure the health and safety of Valley residents. Ordinance 85-3 is the Town's governing Land Use Ordinance and governs and protects the resources and natural setting of Castle Valley. Ordinance 95-6 outlines processes and forms that make residents aware of natural hazards when going through the building process. Ordinance 2007-6 Prohibits Fire Hazards in periods of high fire danger. Ordinance 1996-1

protects the Town's Watershed. The Town also adopted Ordinance 2013-1 which created the Hazard Mitigation Committee. Many regional Hazard Mitigation plans have been adopted in the past by Resolutions by the Town Council as well as a "Firewise Standard" Resolution.

Land Use:

Castle Valley is a rural residential and agricultural community, made up of five-acre minimum lots with single-family homes and accessory buildings in association with low-impact livestock and agricultural uses. The Town currently allows home and premises businesses, but no other commercial or industrial activity is permitted.

The Town has a modest level of public facilities and services. A community building was built on the Town lot in 2004 and serves as a gathering place for community and Town government events. The Town building is the only non-affiliated public facility in the Town and houses the Town office, meeting rooms, and a branch of the Grand County Public Library. The Town lot is home to a fire station owned and managed by the Castle Valley Fire Protection District, a shed for Roads Department equipment, a basketball court, playground and an outdoor picnic area. The Town has a small, part-time staff. The Town has a cemetery that is maintained by the Grand County Cemetery District. There is private commercial garbage removal service for residents. There is no municipal water delivery system or wastewater treatment facility.

Water:

Water is provided through individual wells and waste is managed by individual septic wastewater disposal systems. Castle Valley's aquifer is the sole source of drinking water for its residents and an irreplaceable resource.

The Castle Valley Aquifer has been declared as a Sole Source Aquifer by the Federal Environmental Protection Agency in 2001[1] (See Appendix WC-1) and classified by the Utah Division of Water Quality as "pristine" in certain areas, however water quality varies in different parts of the Town. About 40% of the Town's lots have very hard water that must be purified in order to drink. The aquifer is extremely vulnerable to contamination. It is an unconsolidated valley-fill type and exposed at the surface with no overlying confining geologic formation. This allows contaminates to move more quickly downward to the water supply. The Town has six monitoring wells for measuring water quality changes over time. There are approximately 6,700 acre feet of water in the watershed during a wet period and around 5,700 during a dry period. There are just over 6,900 acre feet of water rights in the valley so it is effectively at full appropriation.

Two streams originating from the La Sal mountains pass through the town boundaries: Castle Creek which is perennial and Placer Creek which is intermittent. There are several users with water rights for Castle Creek that use the partially spring fed creek for irrigation purposes.

Transportation and Roads:

Castle Valley is served by County Road 96. State Highway 128, which is about 1.7 miles outside of the Town's municipal boundary, is the principal transportation access to the Town. Castle Valley Drive serves as the main road leading in and out of the Town. Shafer Lane has been dedicated as an emergency ingress and egress road for emergency responders and for the public should Castle Valley Drive become impassable. Castle Valley Drive is the only paved (chipped sealed) Town road and is paved for the first 3.64 miles. The remaining portion of Castle Valley Drive is gravel and dirt. All other Town roads are either crowned dirt and/or gravel and are approximately 17 miles in combined length. Roads on the west side of Castle Valley Drive proceed to the base of Porcupine Rim. This results in progressively steeper grades, some exceeding 20%, making winter maintenance difficult and in some cases impossible.

[1] Environmental Protection Agency, August 6, 2001, Sole source aquifer Notice of final determination for the Castle Valley Aquifer System, Castle Valley, UT: Environmental Protection Agency, (FRL-7024-2).

The Town Roads Department is responsible for maintenance and improvements of all Town roads and for all drainages within the Town's easements. This includes flood control, dirt work, paving/chip sealing of Castle Valley Drive, signage for all Town roads, snow removal for dirt roads that receive winter maintenance, and Town vehicle and equipment maintenance and repair. Castle Valley contracts with Grand County Road Department to provide winter snow removal from Castle Valley Drive.

Fire Protection and Emergency Preparedness:
Castle Valley is a Wildland Urban Interface - a place where residential areas border and interact with undeveloped wildland vegetation. The Town and outlying areas are served by the Grand County Service Area for Castle Valley Fire Protection District (Castle Valley Fire Protection District), which funds and manages the Castle Valley Volunteer Fire Department. Castle Valley has received Firewise Communities/USA recognition status. On behalf of the Castle Valley community, the Castle Valley Fire District maintains this status with annual membership in Firewise Communities, a project of the National Fire Protection Association.

Until recently residents with medical emergencies experienced an approximate 30 to 45 minute response time from Grand County EMS who travel from Moab. The Grand County Emergency Special Service District and the Castle Valley Fire District established an Emergency Medical Response (EMR) team for more rapid, first response to medical emergencies. These trained EMR's cannot do transports, but do have a non-transport ambulance with medical supplies to treat patients until Grand County EMS arrives. The EMR team also received training involving the emergency helicopter contractor that recently established itself in the Moab area. As of 2020 the EMR team is active with very limited staff.

PLANNING PROCESS

Section Contents

1. **Town of Castle Valley participation and Plan adoption**
2. **Hazard Mitigation Planning Process**
3. **Public and Other Stakeholder Involvement**
4. **Integration with Existing Plans**

1. Town of Castle Valley planning participation and Plan adoption.
On December 18, 2013 in open session the Town of Castle Valley passed Ordinance 2013-1 creating a local Hazard Mitigation Committee. The Town of Castle Valley Town Council formally adopted Resolution 2016 – The Castle Valley 2016 Hazard Mitigation Plan after the Plan was approved by the State of Utah and FEMA in March 2016..

2. Hazard Mitigation Planning Process
The Castle Valley Hazard Mitigation Plan was developed through interaction between the Hazard Mitigation Planning Committee for the Town of Castle Valley, the Town of Castle Valley Municipality and Planning and Land Use Commission, Grand County Service Area for Castle Valley Fire Protection District, CERT, the Grand County Emergency Manager and the local community.

The tasks of the Hazard Mitigation Planning Committee:

- Attend Meetings
- Represent interests of Castle Valley and its residents
- Collect information on jurisdiction's resources
- Identify and prioritize the threat of local hazards
- Facilitate development of jurisdiction's mitigation strategy.
- Create local hazard mitigation plan according to FEMA's guidelines set forth in "State and Local Mitigation Planning How-To-Guide" dated September 2002 FEMA 386-1

The Hazard Mitigation Planning Committee met on the 2nd Wednesday of each month in open and public meetings beginning on November 13th, 2013. The Hazard Mitigation Committee will continue to meet until a draft is ready for approval. They will review and update the plan every 4 years or as new information becomes available and will hold public hearings to seek community input.

3. Public and Other Stakeholder Involvement

All Hazard Mitigation Committee meetings were open to the public and were posted in accordance with the Open and Public Meetings Act (Utah Code 52-4-202). The Hazard Mitigation Meeting Agendas and Minutes are posted to the Town's website as well as Utah's Public Notice Website. All Agendas, Minutes and meeting documents are kept in a book which will remain a permanent record in the Town office.

The Hazard Mitigation Committee Meetings on September 10th and October 8th, 2014 had regional Rocky Mountain Power representatives participate to discuss power outages and protocol between the Town and private power company. Members of the Castle Valley Fire Protection District, local CERT members and Planning and Land Use members were also a part of the Hazard Mitigation Committee.

The Hazard Mitigation Committee Members reached out to local groups such as the Day Star Academy, Sorrel River Ranch, Red Cliffs Lodge, Castle Valley Irrigation Company, Frontier Communications and Rocky Mountain Power to receive input and seek support in creating the Hazard Mitigation Plan for Castle Valley Utah.

Public Hearings will be held to review preliminary drafts as well as the final draft of the Castle Valley Hazard Mitigation Plan. Notice of Public Hearings for input on the drafts will be posted with a minimum of 2 weeks before the hearings will be held.

4. Integration with Existing Plans

The Town of Castle Valley participated in the development of and adopted the Southeastern Utah Regional Natural Hazard: Pre-Disaster Mitigation Plan in 2013 and implemented many projects outlined in that plan. This was a broad regional plan and even though Castle Valley was included, it was to a very small degree. The Town then formed the Hazard Mitigation committee to develop a plan that was more in depth and would better serve the community.

Data was reviewed from the Town of Castle Valley records including: The Drainage Master Plan, Water Studies, UGS geologic studies, the Town's General Plan, Grand County's Regional Plan, and the Southeastern Utah Hazard Mitigation Plan, The Utah Division of Forestry, Fire and State Lands local Community Fire Plan, private records, newspaper articles and the Castle Valley Fire Protection Districts records were all used in the development of the Castle Valley Hazard Mitigation Plan.

Representatives from the Castle Valley Road Department, Castle Valley Fire Protection District, Castle Valley Town Council, Castle Valley Planning and Land Use Commission, and the Grand County Emergency Manager, brought different aspects to the planning process. The goals and priorities which were incorporated into the plan were brought back to each department to integrate into their capital projects and policies. The Road Department has already implemented a maintenance plan that includes many of the discussed goals and priorities to prevent major flooding in Castle Valley.

4 Step Planning Process:

1. Organized resources: Original 2015 Plan

Assess community support- Introduced the idea and through public meetings determined if there was enough support to begin the planning process.

Build the planning team- Public invitations went out through gatherings, word of mouth and public meetings for those interested in participating in the planning process. After a group was established an ordinance was adopted forming the Hazard Mitigation Committee.

Members include:

Jazmine Duncan- Chair, Town Council member, Fire Dept. member, CERT member
Greg Halliday- Co- chair, Fire Dept. member, former Town of Castle Valley Road Supervisor, current Road Committee member
Ron Drake- Fire Chief, Castle Valley Service District for Fire Protection, CERT member, Castle Valley Comments- Times Independent
Dave Erley- Mayor Town of Castle Valley, Road committee member
Pat Drake- Community member, CERT member
Leta Vaughn- Fire District Commissioner and Fire Dept. member, EMR member
Bob Russel- Fire District Commissioner and Fire Dept. member, EMR member, CERT member
Bob Lippman- Fire District Commission Chair and Fire Dept. member
Bill Rau- Planning and Land Use Commission- Chair
David Smith- Community member, CERT member
Rick Bailey- Grand county emergency manager
Steve White- Grand county sheriff
Ali Fuller- Town of Castle Valley Clerk, CERT member

Engage the public- Public hearings were held May 13, 2015 and Oct. 14, 2015. All meetings were open public meetings with members of the community attending and contributing on the May 13th, 2015 and Oct. 14, 2015 Public hearings held by the Hazard Mitigation Committee.
Input was also taken via letters and email throughout the entire planning process.

Identify and profile hazards- As a group we listed all hazards which affect the community, we prioritized the list in order of most probable to occur and which have the greatest impact on the community or have the greatest probability of affecting the community.

Inventory assets and estimate losses- We created a list of resources and assets. Taxable values of private property were obtained from the County Clerk which provides a base for possible losses within each hazard area. The average assessed taxable home value in Castle Valley in November 2015 is $73,659 it would however cost substantially more to replace a household in a disaster. Since property owners maintain their own wells for water, septic tanks, and propane tanks, the main infrastructure that the town maintains are roads. The maintenance, construction and rebuilding of roads and drainages is a part of the town's annual budget.

Benefit cost review- A list of priority projects was created based on actions which were seen as having the greatest impact using resources the community currently has available, or we felt could be budgeted for. Cost analysis was done on each project using known costs for certain items and amounts given by the FEMA schedule for some unknown costs.

2. Develop mitigation plan:

Develop goals and objectives- As a group we decided what we wanted to achieve with our planning process. The committee used FEMA's guidelines set forth in "State and Local Mitigation Planning How-To-Guide "dated September 2002 FEMA 386-1.

Identify and prioritize mitigation actions- As a group we went through each hazard and came up with a list of possible mitigation strategies for each one, we then rated each strategy based on Potential Benefit, Financial Viability and Political Viability. Potential Benefit was given a high, medium or low rating. Financial and Political Viability were rated 1-5 with 1 being easy and 5 being very difficult.

Prepare implementation strategy- We are going to mitigate potential impacts from hazards thru executing the Action Plan Projects and thru community awareness and policy development.

Document the planning process- Each member of the committee was assigned a hazard to profile and research histories on. Each member or team working on a hazard then prepared a summary and history to add to the final plan. Agendas, Minutes and meeting documents were kept of every meeting.

3. Implement the plan and monitor progress:

Adopt the Hazard Mitigation Plan-

The Plan was initially adopted by the Town of Castle Valley on March 16th 2016.

Implement Plan recommendations-

The group will work with the Town and stakeholders to continue to implement parts of the plan and implement priority project within the next 5 years.

Evaluate planning results-

Continual evaluation of planning progress will be ongoing and reviewed with plan every 4 years.

Review and Revise the Hazard Mitigation Plan-

The Hazard Mitigation Committee will review and revise the Hazard Mitigation Plan every 4 years.

4. 2020 Review and Update of Existing Plan

Assess community support- Introduced the ideas and the process to update the existing 2015 Plan through public meetings.

Build the planning team- Public invitations went out through gatherings, word of mouth and public meetings for those interested in participating in the planning process. After that a group was established in compliance with Ordinance 2013-1 adopted to form the 2020 Hazard Mitigation Committee.

Members include:
Jazmine Duncan- Chair, Mayor- Town of Castle Valley, Road Committee member, Fire Dept. member, CERT member
Mingo Gritts- Co- chair, Town of Castle Valley Road Supervisor.
Ron Drake- Fire Chief, Castle Valley Service District for Fire Protection, CERT member, Castle Valley Comments- Times Independent
Dave Erley- Town of Castle Valley Road Committee member, previous Mayor Town of Castle Valley
Leta Vaughn- Fire District Commissioner and Fire Dept. member, EMR member
Bob Russell- Fire District Commissioner and Fire Dept. member, EMR member, CERT member
Bill Rau- Planning and Land Use Commission- Chair
David Smith- Community member, CERT member
Jocelyn Buck- Town of Castle Valley Clerk.

Engage the public- All meetings were open public meetings with members of the community welcome and contributing on February 12, March 11, May 13, and June 10. Due to concerns regarding the potential spread of COVID-19 the May- July Meetings were held via Conference Call with the Town Building #2 Castle Drive as the anchor site. Input was also taken via letters and email throughout the entire review and planning process. The hazard Mitigation Committee held a Public Hearing on the Plan July 8, 2020.

Identify and profile hazards- As a group we listed all hazards which affect the community, we re-prioritized the list in order of most probable to occur and which have the greatest impact on the community or have the greatest probability of affecting the community. And Biological Hazards was added as a potential hazard.

Inventory assets and estimate losses- We created a list of resources and assets. Taxable values of private property were obtained from the County Clerk which provides a base for possible losses within each hazard area. The average assessed taxable residential building value in Castle Valley November 2015 was $73,659 this value increased to $146,000 in 2019. (These averages do not include secondary residences or land values). However the costs would be substantially more to replace a household in a disaster. Since property owners maintain their own wells for water, septic tanks, and propane tanks, the main infrastructure that the town maintains are roads. The maintenance, construction and rebuilding of roads and drainages is a part of the Town’s annual budget.

Benefit cost review- A list of priority projects was created based on actions which were seen as having the greatest impact using resources the community currently has available, or we felt could be budgeted for. Cost analysis was done on each project using known costs for certain items and amounts given by the FEMA schedule for some unknown costs.

RESOURCES

Town of Castle Valley:

- Town Hall and Library (with Wifi internet access)
- Radio base station , 2 hand held radios
- Road shed
- Maintenance shed
- Fuel storage
- Staff
- Town Council
- Planning and Land Use Commission
- Hazard Mitigation Committee
- Road Committee
- Road Department

Roads Equipment

- 1981 JD 670A Motor Grader 14ft. $130/hr.
- 2018 JD 310SL Backhoe- Leased $70/hr.
- 1983 Ford Dump Truck (8cubic yds.) $60/hr.
- 1998 GMC Dump Truck (8cubic yds.) $60/hr.
- 1000 Gallon Water tank $75/hr.
- 1984 Ford Tractor w/ Boom Mower $60/hr.
- Rock Sieve/Grizzly $15/hr.
- Gas Compressor $20/hr.
- Gas Generator $20/hr.
- Gas Pressure Washer $27/hr.
- Insurance

Castle Valley Fire District:

- Station 1
- Station 2
- Generator
- CIB grant purchase of Lot 13 w/ its large volume well.
- 20 Volunteer personnel
- Commissioners
- Equipment
- #39 5 Ton Wildland Engine
- #33 Hummer
- #38 Water Tender
- #8-structure
- #37-structure
- #1 chief's truck
- #31 brush truck
- SCBA Trailer (compressed air unit)
- Radios
- Satellite phone
- Cots

Church Groups:

- Day Star Academy and Farms
- LDS
- Buildings
- Tables and Chairs

Grand County Utah:

- Roads Department
- Snow plow
- Brush Chipper
- Non transport ambulance
- CERT-Kris Hurlburt
- Emergency Manager - Rick Bailey
- Sheriffs' Department – mobile command post and repeater
- County Council

Emergency Medical Special Service District

- C.V. EMRs

Interagency Fire:

- Forestry Fire and State Lands - local representatives.

State of UT:

- Planning support- Brad Bartholomew/ FEMA
- CIB – Bruce Adams
- USU- Mike Jones/Roads
- Regional engineer- Mark Stilson
- State Roads and Highway patrol
- Health Department- Orion Rodgers
- Agriculture extension- Mike Johnson

Federal Government:

- Rural development USDA
- FEMA
- EPA
- NRCS-Don Andrews
- Soil Conservation Agency

Private Sector:

- C.V. business owners
- Private property owners who volunteer
- Privately owned equipment: chainsaws, tractors, back hoes etc.
- Local doctors and nurses
- Water hand pumps on wells
- Frontier Communications
- Rocky Mountain Power
- Red Cliffs Lodge
- Sorrel River Ranch
- School bus
- Outbuildings and spare bedrooms

Moab Scouts BSA & CFI

- Cooking/ feeding Equipment
- Tents/Shades/Tipis/Yurts.
- Misc. Outdoor Gear
- Volunteers and Tools

Moab Area Watershed Partnership

Memorandums of Understandings:

- Grand County Road Department – Snowplowing CV Drive.
- CV Fire Protection District- access to well water on Lot 13.
- Grand County School District- School bus parking.
- Manti LaSal National Forest – Cooperating Agency Status.
- Grand County Building Department
- CV Fire Protection District with Grand County for equipment use.

POTENTIAL HAZARDS WITH RISK ASSESSMENTS & MITIGATION STRATEGIES

FIRE

BACKGROUND

Castle Valley is a Wildland Urban Interface - a place where residential areas border and interact with undeveloped wildland vegetation. This presents a number of fire-fighting challenges due to Town and residential proximity to large areas of fire-prone vegetation. Trees, shrubs, grasses, and weeds all provide significant fuel for fires; winds, topography, and difficulty of access add to fire hazards. Periods of drought, invasive vegetation, and modern fire suppression practices have helped to increase heavily overgrown areas of dry combustible vegetation. During summer “monsoon” season, frequent thunderstorms and cloudbursts occur, posing a threat to life and property from lightning triggered wildfires and debris flow (flood) events. These variables make Castle Valley very vulnerable to Fire, however several mitigation efforts are in place and due to more development there are more firebreaks throughout the municipality.

Over the past 35 years, the Castle Valley Fire Department responded to approximately 100 fires, an average of just under three fires per year. Some years the area experiences a lot of fire activity like 1984, 2009, and 2011, which had eight and nine fires and some years like 1982, 1983 and 2010, for instance, only two fires were reported. Lightning is the leading cause of fires at nearly one third followed by human caused fires at 26 percent and controlled fires that got out of control at 22 percent. Forty-four percent of the fires occur within the Castle Valley Town area and fifteen percent each are in the Castleton area and along State Route 128 and 16 percent of the fires are on State or BLM lands. There have been fires reported in every month but nearly a quarter of the responses occur in July followed by June with 19 percent and August with 13 percent. Grass, brush and trees are the most common source of fire at 75 percent followed by structure fires at 23 percent and vehicle fires at six percent and other sources, like power poles, at four percent. Some fires will burn two or more of these categories. The Fire District has a current Community Wildfire Protection plan that is updated every two years (Appendix F-1)

HISTORY

There were not many inhabitants in Castle Valley when the Castle Valley Fire Department was formed in 1976 but the young community had already experienced some disastrous fires and fatalities. Included in those events was a fire involving an A-frame structure near Castle Creek and Castle Valley Drive where a child perished in the building. Former Castle Valley resident and County Fire Warden

Robin Donoghue said that he remembered helping Grand County Sheriff Heck Bowman sift through the rubble to find the remains of the young boy's body.
Donoghue and Dave Durrant, another early settler to the valley recognized the need for local fire protection and approached District Ranger Dick Buehler for help in organizing the fire department and acquire equipment. During the summer of 1977 the fire department acquired an excess military 2.5-ton fire truck and obtained a state lease on the property, which now houses Fire Station One on the Castleton Road. Fire department volunteers eventually built a fire house with money collected by hosting barbeques and other fund raising activities and, when there were enough residents in Castle Valley to form a tax base, formed the Castle Valley Fire Protection District.

Donoghue served as the first fire chief followed by Durrant, Frank Mendonca, John McGann, Dave Seibert, Floyd Stoughton, and Ron Drake. The fire department bought their first engine, a used, refurbished American LaFrance pumper engine in 1994 and took possession of a new International 2,000 gallon pumper/water tender in 2007, which was purchased with a CIB grant. Currently the fire department maintains nine structure and wildland fire vehicles, five of which are owned by the fire district and four are excess military vehicles on loan from the State of Utah. In 2003, the district built a second fire station, which is located behind the Castle Valley Town Hall and in December, 2010 purchased the property where Fire Station I is located, both with funds furnished by CIB grants.
In 2019 the Fire District received a Community Impact Board (CIB) grant to purchase Lot 13 where an established large volume well was located.

EVENTS:* (Last nineteen years)

Mar 3, 2005	Grass	Human	Buchanan Lane
Jun 30, 2005	Structure	Lightning	Castleton
May 22, 2006	Brush Fire	Lightning	Buchanan Lane
Jun 15, 2006	Brush	Lightning	Round Mtn Fire, 213 ac.
Jun 22, 2006	Brush	Lightning	Upper Castle Valley
Aug 31, 2006	Brush	Lightning	34 Rim Shadow Lane
May 21, 2007	Tree Fire	Lightning	Taylor Lane
Aug 5, 2007	Structure	Lightning	Lazaris Lane
Sep 30, 2007	Brush	Human	Lazaris Lane, 15 ac.
Oct 9, 2007	Brush	Human	Homestead Lane
July 19, 2008	Grass	Human	Loop Road
Aug 11, 2008	Structure	Electrical	DayStar Academy
Aug 27, 2008	Brush	Lightning	Porcupine Ranch, 4K acres
Apr 12, 2009	Power Pole	Weather	Lower Pope Lane
May 18, 2009	Power Pole	Failed Equip.	SR 128
May 19, 2009	Trees	Lightning	Castleton
July 16, 2009	Tree	Lightning	Loop Road
July 19, 2009	Power Pole	Lightning	Lazaris Lane
Aug 6, 2009	Trash	Human	Red Cliff Lodge
Aug 13, 2009	Tree	Lightning	Keogh Lane
Aug 13, 2009	Trees	Lightning	Upper 80s section

Sep 30, 2009	Tree Fire	Lightning	Keogh Lane
Mar 18, 2010	Structure (pole)	Lightning	Castle Valley Drive/Keogh Lane
Aug 5, 2010	Brush Fire	Lightning	Between Pope and Miller Ln.
Jan. 7 2011	Structure Fire	Electrical cause	Sorrel River Ranch
May 18, 2011	Tent fire	Human cause	Mile 21, SR 128
Jun 8, 2011	Trash Fire	Human cause	Sorrel River Ranch
Jun 18, 2011	Arson Fire	Human cause	SR 128
Jul 17, 2011	Brush Fire	Lightning	159 Buchanan Lane
Jul 19, 2011	Brush Fire	Lightning	Porcupine Ranch
Jul 30, 2011	Brush fire	Lightning	Shafer Lane
Dec 8, 2011	Structure/Grass	Human, hot ashes	447 Castle Valley Drive
Feb 10, 2012	Straw fire	Human	SR 128
Apr 19	Dryer fire	Mechanical	Sorrel River Ranch
May 26, 2012	Structure/Brush	Unknown/weather	413 Cliffview Lane
July 13, 2012	Brush Fire	Lightning	Castleton Road #1
Jul 13, 2012	Brush Fire	Lightning	Castleton Road #2
Jul 20, 2012	4 Trees	Lightning	Porcupine Ranch Rd.
Jul 21, 2012	Free Fire	Lightning	Upper 80s section
Aug 23, 2012	Grass Fire	Human	Creekside Lane
Sep 24, 2012	Brush Fire	Lightning	Adobe Mesa (Assist USFS)
Sep 1, 2013	Cedar Trees	Lightning	Upper 80s/BLM
May 30, 2014	Brush	Lightning	South Round Mountain
Jun 15, 2014	Brush	Arson Fire	Mile 13, SR 128
Jul 11, 2014	Tree Fire	Lightning	Castleton Road
Jul 15, 2014	Single Trees	Lightning	272 Pope Lane/350 Taylor Lane
Aug 25, 2014	Tree Fire	Lightning	Gravel Pit, Castleton
Sep 14, 2014	Structure/Dryer	Human	Sorrel River Ranch
Jan 30, 2015	Power pole	Unknown	399 Cliffview
July 22, 2015	Grass Fire	Human	Daystar Academy
July 23 2015	Grass Fire rekindled	Human	Daystar Academy
Aug.1, 2015	Brush	Lightening	Round mountain
Sept. 1, 2015	Single Tree	Lightening	Dewey Bridge
Mar.22, 2016	Tree	Unknown	Hittle Bottom Campground
Apr 16, 2016	Burn pit Fire	Human Caused	Daystar Academy
May 4, 2016	Car Fire	Mechanical	Gateway Road
May 29, 2016	Grass Fire	Unknown	MP 10 SR128
Jun 7, 2016	Power Pole	Unknown	Miller Lane
Jun 12, 2016	Incinerator Fire	Human	Daystar Academy
Jun 25, 2016	Grass Fire	Unknown	CV Drive at Chamisa Ln
Oct 13, 2016	Out of Control burn	Human	Amber Lane
Jun 27, 2017	Grass Fire	Unknown	Castleton Road
July 12, 2017	Power pole	Wind/Lightening	MP 16 SR128
Aug 4, 2017	Grass Fire	Lightning	240 Miller Lane
Sept14, 2017	Tree	Lightning	Shafer Lane
Dec 5, 2017	Structure Fire	Electrical	Willow Basin
July 2, 2018	Grass Fire	Human	395 Castle Valley Dr.
July 7, 2018	3 Fires	Lightning	Keogh, end of CV Drive, Rim

July 8 2018	Brush	Lightning	Base of Adobe Mesa
Apr 27, 2019	Brush	Lightning	384 Castle Valley Dr.

*During those years when there were few fire events the Castle Valley Fire Department was still busily involved in responding to false alarms, controlled burn stand-by, medical assists, requested to assist with vehicle accidents and many other important requests.

Fire Probability Analysis

Potential Magnitude		**Negligible**	**Less than 10%**
	X	**Limited**	**10-15%**
		Critical	**25-50%**
		Catastrophic	**More than 50%**
Probability	**X**	**Highly likely**	
		Likely	
		Possible	
		Unlikely	
Location	**Anywhere there is fuel**		
Seasonal Pattern or Conditions	**March- November. – Wildfires, Year Round – Structure fires**		
Duration	**Hours to days.**		
Analysis Used	**Documented events C.V.F.D., identifying resources available currently.**		

Risk Assessments and Mitigation Strategies:

While the community can do little to temper the extreme weather that causes fires, much can be done to mitigate the effects of those weather related events. Human caused fires can also be mitigated with public awareness programs and continued participation with the Firewise Program.

(1 =Easy – 5= Difficult)

1. Mowing Roads to expand the firebreak.
   Potential benefit= High
   Financial viability= 1 [24 hrs for all roads, 2-3x a year]
   Political viability=1

2. Policy changes to require property owners to keep fuel down.
   Potential benefit= High
   Financial viability=4
   Political viability=5

3. Increase FireWise campaign to increase public awareness
   Potential benefit=High
   Financial viability=2
   Political viability=1

4. Reduce fuel around power poles and ground transformers; get in touch with Rocky Mountain Power.
   Potential benefit= High
   Financial viability= 2
   Political viability= 3

5. Identify water sources with and without power sources. Determine usability and viability for fighting fires and refilling trucks-See Fire Plan
   Potential benefit= High
   Financial viability=3
   Political viability=1

6. Create a program for the emergency siren located on C.V. Drive
   Potential benefit=High
   Financial viability= 2
   Political viability= 3

7. Create pre-planned fire breaks in the town and along its boundaries.
   Potential benefit= High
   Financial viability=4
   Political viability= 5

8. Review Town policies for the storage and disposal of fuels and hazardous materials. See Ordinance 85-3 Fuel storage.
   Potential benefit= High
   Financial viability= 1
   Political viability= 3

9. Use goat or sheep herds for fuel reduction.

Potential benefit= High
Financial viability = unknown
Political viability= 3

10. Have certified Fire Inspector perform structure inspections on request.
    Potential benefit= High
    Financial viability= 2
    Political viability=3

11. Identify lots with overgrowth, use Forestry Fire State Lands assessments and teach property owners defensible space.
    Potential benefit= High
    Financial viability= 2
    Political viability= 3

12. Invest in specialized Town equipment to reduce fuels.
    Potential benefit= Medium
    Financial viability= 5
    Political viability= 4

13. Reducing fuels on private lots with proper education first. And encourage alternatives to burning such as pickups or mulching/chipping.
    Potential benefit= High
    Financial viability= 1
    Political viability= 2

14. Public notices to educate the Public on firewise guidelines
    Potential benefit= High
    Financial viability= 1
    Political viability=1

15. Encourage residents to maintain 72 hour Kits. And stock the Town Building with 72 hour kit provisions.

    Potential benefit= High
    Financial viability= 2
    Political viability= 1

16. Add Fire Danger interpretive signage at the entrance of the Town.

    Potential benefit= High
    Financial viability= 1
    Political viability= 2

FLOOD

BACKGROUND

The Town of Castle Valley occupies the lower (northwestern) portion of Castle Valley, extending from the gorge of Castle Creek to the southern side of Round Mountain, Porcupine Rim on the west, the Castle Valley loop road on the east, comprising 448 five acre properties. According to the Town's Drainage Master Plan done in 1988 there are 52 square miles of drainage basins. The Valley ranges in elevation from approximately 4,500 to 5,500 feet above sea level with the adjacent mountains to the southeast rising to approximately 12,000 feet. Vegetative cover on a watershed has a major effect on the amount of precipitation that runs off, an affects the storm water in several ways. Both the foliage and the litter of the plants can retain water for longer thereby lengthening the time of concentration and reduces the peak discharge rate. Castle Valley is vulnerable to flooding in severe concentrated rain events, when the water comes over a longer period of time the multitude of drainages can handle the water quite well, however more and more isolated cloudburst are effecting Castle Valley in very destructive short lived storms. The Castle Valley Road Department works to mitigate and mend the effects of storm water runoff from Placer and Castle Creeks and drainages along Porcupine Rim, Parriott Mesa, Castle Rock, Adobe Mesa, (elevations surrounding Castle Valley).

HISTORY

Within the last 10 years there has been significant rain events that have exceeded the flow of the Colorado River during one period of time on just the Placer Creek drainage. Placer Creek drains into Castle Creek, which flows under Castle Valley Drive through a 10-foot culvert at lot 447. According to the Drainage Master Plan dated September 1988, by Armstrong Consultants, Inc., this area should have had two (2) 10-foot culverts instead of one. This culvert also was never designed to function as a check dam, however due to only one 10 foot culvert, storm water has come within a few feet of exceeding the carrying capacity of this culvert, should storm water overtop the road above this culvert, significant damage may occur to Castle Valley Drive including loss of road surface and underlying earthen fill as well as damage to downstream structures and creating a significant safety hazard.
(See Appendix F-1)
In 2018, the Town secured an emergency egress via the Shafer Lane extension leading out to the Castleton Road This extension also provided faster access to and from Fire Station #1 .
The Town of Castle Valley commissioned a Drainage Master Plan dated September 1988 by Armstrong Consultants, Inc. The recommendations in that Master Plan have yet to be implemented. The facilities designed for the Master Plan are based on a 10 year storm which is a reasonable level of risk for the planned facilities (culverts and channels).
Currently the Town of Castle Valley is not participating in the National Flood Insurance Program since the area is not mapped by FEMA.
(See Appendix FL-2 and FL-3)

<u>Events:</u> 6 Oct. 2011 to 14 Sept. 2017

Storm Runoff	19 Aug 2010	Castle Valley	Castle Valley	erosion
Storm Runoff	20 July 2011	Castle Valley	Castle Valley	erosion
Storm Runoff	4 Aug 2011	Castle Valley	Castle Valley	erosion
Flash Flood	6 Oct 2011	Placer Creek crossings Placer Ditch	Upper eighty east Pope	erosion/mud
Flash Flood	26 Oct 2011	Porcupine Rim Drainage	Buchanan	erosion
Flash Flood	14 Jul 2012	Rim Drainage	Keogh/CVD	mud/erosion
Flash Flood	25 Sep 2012	Rim Drainage	Keogh/Pope Holyoak/Miller	mud/erosion
Flash Flood	12 Oct 2012	Placer Drainage	Rimshadow/Pace Miller/Pope/Holyoak Keogh/Taylor/Connector	mud/erosion
Storm Runoff	13 Oct 2012	Castle Valley	Castle Valley	erosion
Flash Flood	23 Oct 2012	Placer Drainage	Miller/CVD/Keogh Holyoak/Buchanan/Pace	mud/erosion
Storm Runoff	8 May 2013	Castle Valley	Castle Valley	erosion
Runoff	17 Jul 2013	Rim Drainage	Keogh/Taylor	mud/erosion
Flash Flood	19 Jul 2013	Placer Drainage	Keogh/Connector	erosion
Flash Flood	29 Jul 2013	Placer Drainage	Placer crossings Holyoak/Miller/Keogh	mud/erosion
Runoff	30 Jul 2013	Placer Drainage	Upper 80/Holyoak	erosion
Runoff	1 Aug 2013	Placer Drainage	Rimshadow/Shafer Miller/Holyoak	mud/erosion
Storm Runoff	23 Aug 2013	Castle Valley	Castle Valley	erosion
Storm Runoff	24 Aug 2013	Castle Valley	Castle Valley	erosion
Storm Runoff	25 Aug 2013	Castle Valley	Castle Valley	erosion
Storm Runoff	1 Sep 2013	Placer Drainage	Connector	road washout
Flash Flood	12 Sep 2013	Placer Drainage	Crossings/Keogh Miller	mud/washout
Flash flood	14 Sep 2013	Placer/Cain Hollow	Upper 80/Chamisa Rimshadow/Shafer Miller/Pope/Keogh	mud/washout
Storm Runoff	18 Sep 2013	Placer Drainage	Crossings/Keogh Miller/Meadow	mud/washout
Storm Runoff	10 Oct 2013	Placer/Cain Hollow	Crossings/Miller	mud/rock, erosion
Storm Runoff	30 Oct 2013	Placer Drainage	Crossings/Miller	mud/rock, erosion
Storm Runoff	10 Feb 2014	Placer Drainage	Lower crossing	erosion
Storm Runoff	13 Aug 2014	Castle Valley	Castle Valley	erosion
Storm Runoff	14 Aug 2014	Castle Valley	Castle Valley	erosion
Storm Runoff	6 Jun 2015	Castle Valley	Castle Valley	erosion
Storm Runoff	30 Aug 2015	Castle Valley	Castle Valley	erosion
Storm Runoff	19 Oct2015	Castle Valley	Castle Valley	erosion

Flash Flood	3 Aug 2016	Porcupine Rim Drainage	Homestead	mud/rock/washout
Flash Flood	3 Aug 2016	Placer/Cain Hollow	Lower/Upper Crossing washout	

Flood Probability Analysis

Potential Magnitude		**Negligible**	**Less than 10%**
		Limited	**10-15%**
	X	**Critical**	**25-50%**
		Catastrophic	**More than 50%**
Probability		**Highly likely**	
		Likely	
	X	**Possible**	
		Unlikely	
Location	**All drainages and creeks.**		
Seasonal Pattern or Conditions	**June- Oct.**		
Duration	**Initial flow not more than a few hours, event including clean up could take days or up to months.**		
Analysis Used	**Historic documentation of events, Town of C.V. road department and the Grand County regional plan and the NCDC. NOAA.gov website. Available resources. Town of Castle Valley Drainage Master Plan 1988**		

FLOOD:

Risk Assessments and Mitigation Strategies:

(1 =Easy – 5= Difficult)

1. Re-enforce or replace the Castle Creek culvert that flows under Castle Valley Drive, the Town's main ingress and egress.
   Potential benefit= High
   Financial viability= 4-5
   Political viability= 2

2. Build and maintain large catchment ponds in strategic places on both of the main drainages. One above the Upper 80 on the Placer Creek drainage and another on the Castle Creek drainage.
   Potential benefit= High
   Financial viability= 5
   Political viability= 3

3. For road crossings in the Upper 80 continually washed out, document and map all affected areas and tie in with Natural Resource Conservation Service study.
   Potential benefit= High
   Financial viability= 1
   Political viability= 1

4. Evaluate and consider engineering structural options for armoring major drainage crossings including concrete slips, aprons, culverts and spans.
   Potential benefit= High
   Financial viability= 5
   Political viability= 5

5. Design and build pre-fabricated Structures for crossings on upper and lower Placer Creek.
   Potential benefit= High
   Financial viability= 5
   Political viability= 5

6. Obtain needed easements in all areas where there currently isn't one granted. Enabling the Town of Castle Valley road department to legally work on flood effected areas.
   Potential benefit= High
   Financial viability= 3
   Political viability= 5

7. Put in 10 foot culverts at upper and lower Placer Creek crossings and Cain Hollow.
   Potential benefit= High
   Financial viability= 5
   Political viability= 5

8. Remove dead trees, garbage and other debris from Castle Creek above the Castle Valley Drive culvert.
   Potential benefit= High
   Financial viability= 4
   Political viability= 5

9. Maintain all road crossings and diversions by monitoring and clearing culverts of weeds and sediment and keeping clear, excavating channels, reinforcing and extending berms and maintaining road surfaces.
   Potential benefit= High
   Financial viability= 3
   Political viability= 1

10. Continue to inform residents and buyers on safe building practices for flood prone areas and ensure land use codes allow for proper flood safety building.
    Potential benefit= High
    Financial viability=3
    Political viability=3

11. Encourage residents to maintain 72 hour Kits. And stock the Town Building with 72 hour kit provisions.

    Potential benefit= High
    Financial viability= 2
    Political viability= 1

SEVERE WEATHER

BACKGROUND

High winds, thunderstorms and severe winter weather are all forms of severe weather which affect our area. High winds typically accompany thunderstorms and frontal systems. They have been responsible for various damages to property. Tornadoes are not a regular occurrence but dust devils which are much lesser tornadoes are sometimes formed. Hail and lightning also accompany thunderstorms. Hail has caused damage to crops on multiple occasions. Lightning is probably the number one severe weather hazard in our area. Lightning has been responsible for numerous fires, both wild and structural. Severe winter weather can include heavy snow fall and prolonged periods of below freezing temperatures. Some homes would need to have heavy snow removed from roofs to prevent roof failure. Castle Valley does not have a municipal water system, people use individual wells for water. Many residents have been without water during prolonged periods of cold because of frozen pipes and pressure systems.

IMPACT ON COMMUNITY

The impacts of severe weather on the community would depend on the event and duration of the event. Heavy hail can destroy crops. Daystar Farms provides produce for many of Castle Valleys' residents. Severe hail, winds or flooding affecting their farm would also hurt them financially. Many residents also rely on their own crops for food & food storage.
Any severe weather event causing residents to be displaced would impact the community, currently there are not adequate plans in place for temporary housing and backup power for municipal buildings.
High winds and thunderstorms can also cause power and communication outages which slow emergency response times and also have potential to destroy food storage for many residents. Most personal wells are also run on electricity, so outages can leave residents without water, this could impact large portions of the community in event of a fire accompanying thunderstorms.
Heavy snow fall can leave many residents unable to get out for hours while limited staff work to open roads. This also slows emergency response times. Castle Valley has an aging population and many would need help to clear their own roofs and driveways, and there are limited resources for them to find this help. Residents who experience prolonged water outages because of frozen pipes and systems would not have anywhere in Castle Valley to fill water storage containers until their systems are thawed, they would have to rely on neighbors who may allow them to fill or take containers to Moab. All parts of the community are vulnerable to severe weather hazards.

GOALS TO REDUCE AND AVOID LONG TERM VULNERABILITIES

Goals for reducing long term vulnerabilities to severe weather include developing an emergency operations plan that will include the Town of Castle Valley, Castle Valley Fire District, Grand County EMS, Grand County Roads, Grand County Emergency Management, Daystar Academy and Farms, Red Cliffs Lodge, Sorrel River Ranch, members of the community and surrounding communities. 2020 Plan Update :Installing back up power for all municipal buildings and equip at least one municipal building with enough supplies to temporarily house up to 20 people is another goal.

HISTORY

From the time this plan was first adopted in 2016 the following events occurred

Location, Date and Time	Type of Event
Castle Valley, UT 08/03/2016 17:00	Flash Flood
Castle Valley. UT 09/14/2017 13:00	Flash Flood
Castle Valley, UT 07/14/2018 13:30	Debris Flow
Castle Valley, UT 10/04/2018 9:40	Flash Flood

Note:
https://www.ncdc.noaa.gov/stormevents/listevents.jsp?eventType=ALL&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2016&endDate_mm=12&endDate_dd=31&endDate_yyyy=2019&county=GRAND%3A19&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=49%2CUTAH

Storm events are taken from these recorded events at ncdc.noaa.gov. Snow storms occurred during this time as well but none were considered severe enough to be recorded as such.
Below is the previous history of events which was taken from the regional mitigation plan available at the time.

Recorded Severe Winter Weather events	Recorded severe thunder storm events
12/7/1997 Winter Storm	06/2003 lightning
12/19/1997 Winter Storm	07/2003 lightning
12/21/1997 Extreme Cold	09/16/2002 winds over 50mph
12/24/2000 Heavy Snow	06/25/2005 thunderstorm
01/28/2001 Winter Storm	09/23/2005 thunderstorm
11/28/2006 Heavy Snow	04/05/2006 thunderstorm
12/19/2006 Winter Weather	06/09/2006 wind over 50mph
01/12/2007 Winter Weather Heavy Snow	06/2006 lightning
12/10/2007 Winter Weather	07/10/2006 quarter size hail/arches
02/03/2008 Winter Weather Heavy Snow	08/26/2006 wind over 50mph
12/13-24/2008 Winter Weather Storm	08/2007 lightning
02/24/2009 Dense Fog	08/2008 lightning
10/27/2009 Winter Weather	10/06/2010 wind over 50mph
12/07/2009 Winter Storm and Blizzard	08/23/2013 thunderstorm/G.C.
12/13,18/2009 Dense Fog	Note: info from weather.gov
12/22/2009 Winter	Grand County

Weather
01/26/2010 Winter
Weather
01/28,29/2010
Dense Fog
02/02-04/2010
Dense Fog

02/06/2010 Winter
Weather
02/08,16/2010
Dense Fog
02/19/2010 Winter
Storm
03/15/2010 Dense
Fog
12/29/2010 Winter
Storm
Note: taken from regional mitigation plan
Grand
County

Note: lightning events were recorded

fire events from CV CWPP 2/14/13

Severe Weather Probability Analysis

Potential		**Negligible**	**Less than 10%**
Magnitude	**X**	**Limited**	**10-15%**
		Critical	**25-50%**
		Catastrophic	**More than 50%**
Probability	**X**	**Highly likely**	
		Likely	
		Possible	
		Unlikely	
Location	**Anywhere**		

Seasonal Pattern or Conditions	**Anytime, depending on season, winds in spring and fall, heavy snow fall in winter. Lightning with monsoons**
Duration	**Hours to days**
Analysis Used	**State of Utah hazard plan** **Grand County regional plan** **Weather.gov** **Weather.com/encyclopedia** **Resources available, response times observed**

SEVERE WEATHER:

Risk Assessments and Mitigation Strategies:
(1 =Easy – 5= Difficult)

1. Backup power sources at municipal buildings, including propane alternatives for generators.
   Potential benefit= high
   Financial viability=5
   Political viability=3

2. Create an Emergency Operations Plan and train staff on power outage protocol.
   Potential benefit=high
   Financial viability=3
   Political viability=3

3. Fire and Emergency Medical Responders provide presence at Town building when communications are out.
   Potential benefit= high
   Financial viability= 2
   Political viability=1

4. Public education on dealing with various severe weather issues.
   Potential benefit= high
   Financial viability= 3
   Political viability= 1

5. Develop and make use of warning systems i.e. Town Siren, social media, “Alert Sense”, weather stations etc.
   Potential benefit= high

Financial viability= 4
Political viability= 2

6. Clear trees and snow from power poles and propane tanks.
   Potential benefit= high
   Financial viability= 3
   Political viability= 2

7. Assure availability of backup water supply and other resources such as fuel, food, firewood, cots, etc.
   Potential benefit= high
   Financial viability= 5
   Political viability= 3

8. Power infrastructure map and grid available for Fire, Town and Mitigation.
   Potential benefit= medium
   Financial viability= 2
   Political viability= 5

9. Have Town Road Department clear roads of trees.
   Potential benefit= high
   Financial viability= 2
   Political viability= 2

COMMUNICATION/POWER OUTAGES

BACKGROUND

<u>ELECTRICTY</u>

Electricity to Castle Valley is provided by Rocky Mountain Power, a subsidiary of Pacific Corp. Electricity for Castle Valley "originates from the Rattlesnake substation southwest of [the town of] La Sal and travels over the top of the [La Sal] mountain[s], over Porcupine Rim [above Castle Valley] to [the settlement] of Castleton then to Castle Valley. It continues on to Cisco then follows the river to Colorado – a total of 125 miles, and is the longest cul-de-sac power line of all of Rocky Mountain

Power's electrical lines."[2] The length of the power transmission lines and the difficult terrain it follows adds to the potential for disruptions. Castle Valley is very vulnerable to losing power and modes of communication for at least short periods of time with longer outages occurring less frequently in comparison.

Disruptions in electricity service are periodic. Disruptions often are associated with adverse weather events, such as high winds and heavy or wet snow falls, or technical failures on the power lines or poles.

Prior to 2018 it was not uncommon It is not uncommon for electricity to go out in part or all of Castle Valley at least once a month. Outages can be momentary (although disruptive of electrical equipment), a couple hours in length, or multiple hours and into more than a full day. For example, during the weekend of November 23, 2013, electricity was out for 30 hours "as a result of the wet and heavy snow from the storm that dropped 8 to 10 inches beginning last Friday afternoon."[3] In May 2012, high winds were responsible for the electricity outage which also coincided with a structure and brush fire in Castle Valley. The lack of electricity caused "additional problems for firefighters since nearby water sources required electrical power to pump water from the ground."[4]

In 2017 and 2018 Rocky Mountain Power upgraded its infrastructure to reduce the risks of power disruption to both Castle Valley and other areas served by that electrical line. As a result, power disruptions have significantly been reduced in the Town, both short and long term disruptions still occur.

In most instances, short disruptions in power are an inconvenience to most residents of Castle Valley. However, longer disruptions impact different residents in different ways. Some residents rely on digital phones (rather than landlines). When the electricity goes out their ability to charge their phone's batteries is compromised. This can be a serious situation if a medical or fire emergency should occur. All residents who have an internet connection through Frontier Communications receive service via DSL and an in-home modem. The modem needs electricity to operate. Without the modem, wireless internet connects are lost. For residents who work from home, that is likely to mean disruption in their work. Also, the loss of the internet reduces the communications options for learning about or reporting an emergency situation.

The cost of electricity outages is difficult to determine. For people who rely upon electricity for their home occupations, any outage over one hour begins to assume some cost impact. The BandB in Town has lost customers during overnight power outages. For people dependent on electricity for home medical purposes, lengthy outages can become life-threatening. Also, loss of telephone service (through the DSL service) raised adverse issues of safety and health to residents. The loss of power hindered the ability of the Castle Valley Fire Department to respond to a fire in the valley in 2012.

2 "Castle Valley Comments," *Moab Times-Independent*, November 29, 2007.

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Telephone

Telephone service is provided in one of two ways in Castle Valley: to customers by Frontier Communications through landline or wireless telephone service; to customers with cell phones who are able to access service.

For the most part, telephone service to Castle Valley as provided by Frontier is fairly reliable. A wireless transmission tower from Bald Mesa in the La Sal Mountains south of Castle Valley relays transmissions into and out of the valley, using a reflector above the valley on Porcupine Rim. The reflector directs a signal to a distribution station located near the center of Castle Valley.

Outages have occurred in the service. The most significant recent outage occurred on November 30, 2013. On that date 911 service was down for 10-15 hours. During much of that time, the company, local residents, nor Grand County emergency services were aware of the outage. Frontier has since responded that similar outages were unlikely to occur in the future. However in 2018/19 there was a three month period of frequent disruptions in service, including no phone access, dropped calls and multiple outages of varying length through the day. Each outage was followed by Frontier assuring the Town that the problem was resolved. It was only after three months did Frontier finally installed the appropriate equipment which allowed normal service to resume.

It is not possible to accurately estimate the cost of disruptions in telephone coverage to Castle Valley residents. Major losses were experienced by Castle Valley residents who depend on telephone service to run home-based businesses. The B&B in Town reported lost reservations due to phone outages. On several occasions during the 2018/19 outage the Castle Valley Fire Department set up a command post at the Town building with a satellite phone for emergency communication. The command post was run by volunteers at a personal inconvenience and expense.

For residents with wireless telephones with Frontier service, electricity outages also mean loss of telephone coverage.

Some residents are able to access telephone service with their cell phones. Text messages seem to go through more efficiently than telephone connections. Private cell phone companies have said they are unwilling to invest in building a cell tower in or near Castle Valley.

Internet

In 2017 River Canyon Wireless introduced internet service to Castle Valley, thereby expanding options for residents. Until then Internet service was provided by as single company, Frontier Communications. River Canyon Wireless service is all wireless networks, with several repeaters spaced throughout the Valley. Occasional outages from several minutes to hours does occur, these outages are corrected fairly quickly Frontier Communications is DSL, coming through telephone lines. Thus, the quality of internet service is similar to that for telephones. However, a number of residents who continue to use Frontier and live further away from the distribution station in the center of the valley have noted a fall-off in both reliability and speed of internet connections. Also, it is not uncommon for customers to have to reboot their modems once, twice, or several times per day, thus disrupting service.

Like wireless telephones, internet service is dependent on electricity. When electrical outages occur, there is no internet coverage.

River Canyon Wireless and Frontier's internet system is connected in Moab to a transmission system operated by Emery Telcom. , Emery reports that there is sufficient bandwidth to handle all of the areas internet traffic. At the same time, Frontier reports that bandwidth is sufficient to handle all of Castle Valley's traffic. At some point in these statements, it appears too many residents of Castle Valley that a gap remains in reliable and efficient internet coverage.

An estimate of the cost of disruptions to the internet will parallel those of electricity outage costs, although the actual cost is likely to be somewhat lower.

As of early 2020 Emery Telecom is installing fiber optic cable within Castle Valley. It plans to offer internet and phone service by early 2021. Fiber optic internet offers the benefits of fewer disruptions, less dependency on existing internet providers and faster internet connections

Electronic Communication Summary

For a small, relatively remote rural community, Castle Valley has reasonable communications systems. However, as a small, rural community, Castle Valley is very vulnerable to electricity and telephone outages, especially if those outages coincide with other emergency situations. The major gaps are in always-on electricity and telephone/internet services. Providers of both electricity and telephone/internet services report improvements in their ability to reliably meet the needs of Castle Valley residents, but the vulnerability of the lengthy electrical power line to storms and technical problems continues to place the town at risk of break downs in effective communications. The Town and the Fire District have taken steps to mitigate potential utility outages.

Mitigation Initiatives

The town of Castle Valley, the Castle Valley Fire District, and Grand County emergency services have made several improvements to help mitigation communications issues in the valley.

Both the town and the Fire District have met with electricity and telephone providers to voice concerns and seek solutions to existing problems. On several occasions in recent years, the Town has sought to open communication with cell phone providers, but is regularly told that cell phone infrastructure investments are not in those companies' interests.

The Fire District is in constant contact with the Grand County Sherriff's Office through handheld radios. In addition, the Fire District has acquired one satellite phone for use in emergencies when the handheld radios do not function. The Sherriff's Office has been very responsive to the potential emergency needs of the town. In the past it has brought in portable communication equipment. Finally, the Fire District and town have collaborated to set up an emergency communication system available to all residents during prolonged electrical or telephone outages. Notices have been posted to inform residents how they can access that assistance.

Mitigation Goal

The goal is to assure that all Castle Valley residents are aware of communication options during emergency conditions.

Objectives to reach that goal include:

- Developing and distributing awareness-raising materials on emergency response options available to Town residents.
- Maintaining the Fire District assistance at the Town Center during power and/or telephone outages.
- Maintaining good working relationships with the Grand County Sheriff's Office for emergency services and with utility companies.
- Assuring that Town ordinances and regulations remain up-to-date so to provide clear guidance for emergency prevention and, when needed, mitigation.

Communications Power Outage Probability Analysis

Potential Magnitude		**Negligible**	**Less than 10%**
		Limited	**10-15%**
	X	**Critical**	**25-50%**
		Catastrophic	**More than 50%**
Probability	**X**	**likely**	
		Likely	
		Possible	
		Unlikely	
Location	**Entire Length of Rattlesnake line**		
Seasonal Pattern or Conditions	**Generally occurs along with severe weather events**		
Duration	**Seconds to days**		
Analysis Used	**History of occurrence, utility company, Times independence column, Ron Drake local reporter and Fire Chief.**		

COMMUNICATION/POWER OUTAGES:

Risk Assessments and Mitigation Strategies:

(1 =Easy – 5= Difficult)

1. Develop protocol for reporting problems with communication.

Potential benefit= High
Financial viability= 1
Political viability= 1

2. Assure a culinary water backup source is available for town residents for at least 72 hours.

Potential benefit= High
Financial viability= 5
Political viability= 3

3. Set up a command post at the Town Hall during prolonged electricity and/or telephone outages.

Potential benefit= High
Financial viability= 2 [Volunteer hours]
Political viability=1

4. Increase public awareness of the need to have available 72 hour emergency kits,

Potential benefit= high
Financial viability= 3
Political viability= 1

5. Install back-up power for all municipal buildings and church. Have supplies for 20 people, including food, water, bedding etc.

Potential benefit= High
Financial viability= 4 - However there are potential donations from other agencies.
Political viability= 1

6. Develop MOUs with surrounding communities and agencies for appropriate support during emergencies. The Town has passed "Resolution 2020-1 Delegating the Authority in the Absence or Vacancy of the Mayor" for continuity of government to give power to the council if the Mayor is not available during an emergency.

Potential benefit = High
Financial viability= 3 Political viability= 2

ROCKFALL

BACKGROUND

The study, GEOLOGIC HAZARDS OF CASTLE VALLEY, GRAND COUNTY, UTAH by William E. Mulvey of the Utah Geological Survey, states the following regarding rockfalls:

> “Rockfalls occur along cliffs in Castle Valley. As development advances higher on alluvial fans and slopes below cliffs, the risk from falling rocks will increase.
>
> Rockfalls originate when erosion and gravity dislodge rocks from cliffs or slopes. The most susceptible unit in Castle Valley is the Wingate Sandstone where outcrops are disrupted by bedding surfaces, joints, or other discontinuities that break rock into loose fragments, clasts, or slabs. Rocks in talus and cliffs may dislodge, fall onto steep slopes, and travel great distances by rolling, bouncing, and sliding.
>
> Primary causes of rock falls are weathering, freeze-thaw of water in outcrop discontinuities, and ground shaking during earthquakes. Keefer (1984) indicates that rockfalls may occur in earthquakes as small as magnitude 4.0.
>
> Rock falls present a hazard to structures and personal safety. Homes built on slopes below Porcupine Rim are particularly vulnerable.”

A rockfall hazard map is available to the public at the Town Building and their website.

IMPACT ON COMMUNITY

The impacts of Rockfall on the Community would depend on the location and severity of the event. Rockfalls can cause damage to structures, roads, and can alter drainages which could negatively impact other properties and roads. Rockfalls will mostly happen higher up on the rim side of the valley.
(See Appendix R-1)

HISTORY

Although rockfalls occur often few are documented or cause damage below is a list of witnessed rock falls:

<ins>July 8, 1985 -</ins> 48,000 cubic yards of rock fell from Porcupine Rim barely missing a home at the top of Rim Shadow Lane. No damage was reported but an inch of dust covered the surfaces inside the house due to open windows.
<ins>July, 2003</ins> A medium sized rock fall was sited between Rim Shadow and Lazaris lanes. No damage to properties was reported.
<ins>February, 2004</ins> A small rock fall was sited southeast of Lazaris lane. No damage to properties was reported.

<ins>August, 2010</ins> A medium sized rock fall was seen above Holyoak lane. No damage to properties was reported.
<ins>December 31, 2014</ins> A rock fall on rim side of Bailey Lane. No damage to properties was reported.
<ins>November 2015</ins> A large rock fall was seen above Holyoak lane. No damage to properties was reported.
<ins>March 2 2019</ins> A large rock fall came down on Highway 128 about mile marker 1. No damage was done although the road was closed for most of the day for blasting and removal of debris.
<ins>March 17, 2020</ins> A rock fall was sited at end of Cliffview Lane. No damage to properties was reported.
<ins>April 30, 2020</ins> A rock fall was sited between Miller and Pope Lanes on rim side. No damage to properties was reported.

GOALS TO REDUCE VULNERABILITIES
Typical mitigation measures to reduce the impacts from Rockfalls would be cost prohibitive for property owners and the Town. Strategies to decrease vulnerability include continuing to inform property owners of this hazard through the building permit process, and having the road department continue to clear roads after rockfalls. These strategies should be included in a future emergency operations plan.

Rock Fall Probability Analysis

Potential Magnitude	X	**Negligible (in Town)**	**Less than 10%**
		Limited	**10-15%**
		Critical (on SR 128)	**25-50%**
		Catastrophic	**More than 50%**
Probability	X	**Highly likely**	
		Likely	
		Possible	
		Unlikely	
Location	**Rim sides of Castle Valley, Pace Hill, and Hwy. 128.**		
Seasonal Pattern or Conditions	**Early spring and during rain events, could occur at any time.**		
Duration	**Minutes, with cleanup lasting hours to days**		
Analysis Used	**Observations of residents, recorded events, Grand County regional plan, geologic hazard reports, C.V hazard maps.**		

ROCKFALL:

Risk Assessments and Mitigation Strategies:

(1 =Easy – 5= Difficult)

1. Develop plans for road closure if rock fall closes roads.
   Potential Benefit=High
   Financial viability= 2   Political viability= 1

2. Continue to provide property owners and renters with hazard information.
   Potential benefit= High
   Financial viability= 2
   Political viability= 1

3. Obtain equipment for stabilization and cribbing.
   Potential benefit= Medium
   Financial viability= 4-5
   Political viability= 1

4. Build deflection berms, slope benches and rock catch fences.
   Potential benefit= Medium
   Financial viability= 5
   Political viability= 5

5. Continue to identify lots affected by rock fall hazard.
   Potential benefit= High
   Financial viability= 1
   Political viability= 1

DROUGHT

HISTORY

The Freemont and Ute people were in the area of Castle Valley long before white settlers arrived in the region. The Martin brothers were the first white settlers and had the first non-native child in the area in 1886. Farming and ranching was the primary focus of the area with many irrigation ditches coming off of springs along Castle Creek irrigating the lower valley and large irrigation wells in the upper valley. Much more water was used for farming than the current residential use that exists present day. According to local irrigation ditch users the flows from the springs and in the ditch have decreased in the last 30 years mostly due to less annual snowpack.

BACKGROUND

The Town of Castle Valley states the following to be our Goal with regard to water: *To maintain or enhance water quality and quantity in the Castle Valley watershed by improving our knowledge, developing policies, and taking action as needed.*

The source of well water for Town residents, depending on location, is either the valley-fill aquifer or, for those who live closer to Porcupine Rim, the Cutler formation aquifer. The latter tends to have significantly more solids and salts in it, and it impacts the quality of valley-fill aquifer in the lower part of the Valley.

The quality of the water varies in different parts of the Town. The Utah Division of Water Quality has officially classified the water quality based on a classification system focused primarily on total dissolved solids (see **Water Classification Map Appendix A-5**).

IMPACT ON COMMUNITY

The Valley-fill aquifer is fed from a large watershed in the La Sal Mountains whose boundaries were defined by the Federal Environmental Protection Agency in 2001 (see **Watershed Map Appendix A-6**) when it declared the watershed to be a sole source aquifer. Appendix WC-1 .This means that the aquifer system is the sole and principle source of drinking water for the residents of the Town and that contamination or depletion of this aquifer system would be detrimental to the health and safety of the town residents.

In 1996, the Town passed a **Watershed Protection Ordinance**. The Town is committed to working with private landowners, agencies and authorities that own property in the Town's watershed to protect water quality and quantity. The Town also tries to use the EPA sole source aquifer designation as much as possible in these interactions.

The Town has six monitoring wells for measuring water quality and quantity changes over time. These wells are generally very consistent from year to year in both quality and quantity. A number of publications regarding what we know and don't know about our watershed and its process are gathered in the Town Building and are available to the public. Included in the collection is a recent water study, Hydrologic and Environmental Analysis (HESA) and Preliminary Water Budget, (2016), which covered from 1980 to 2000, a wet period which yielded 6,819 ac-ft/yr. At the request of the Division of Water Rights, this analysis was updated a dry period, 2000 to 2016, which resulted in a 19% reduction to 5, 527 ac-ft/yr. The Castle Valley watershed has over 6,900 ac-ft/yr of adjudicated water rights so it is at full appropriation with the Town's surplus water rights taken into consideration. According to a recent scientific study, climate change has contributed 30% to our current drought, and pushed it to mega-drought status, which coincides with the dry period numbers of the study. While our wet period numbers coincide with the wettest 19-year period in at least 1200 years*! So, the Town has a pretty good idea of the high and low yield of the watershed.

'*Large contribution from anthropogenic warming to an emerging North American megadrought. A. Park Williams[1]*, Edward R. Cook[1], Jason E. Smerdon[1], Benjamin I. Cook[1,2], John T. Abatzoglou[3,4], Kasey Bolles[1], Seung H. Baek[1,5], Andrew M. Badger[6,7,8], Ben Livneh[6,9] 2020

GOALS TO REDUCE VULNERABILITIES

In 2006, Alice Drogin formed a Watershed Protection Group, since then there have a series of groups and committees which have looked into how to best protect the quality and availability of Castle Valley's water. Work continues today for watershed protection as the Town Committee is currently taking the information from the recent HESA water studies and creating a Master Water Plan to further protect the Castle Valley aquifer and the Town's water rights.

The following are the highlights from two papers, one from the Utah Climate Center, the other from the Colorado College. Using information from instrumental records dating back 60 years, Great Salt Lake shoreline data dating back a century, and tree ring data dating back 900 years, the UCC concludes that:

1) in the context of the past thousand years, 20th-century Utah - and the latter half in particular - has been exceptionally wet. The commonly assumed "30-year average" cycle is misleading, because the year-to-year deviation from the average is high. While dry periods in the late 20th century usually lasted less than a decade, drought lasted during most of the 13th and 17th centuries.

2) they found a clear 12-year pattern for northern Utah (which fades in the south) but also two more strong patterns - a 40-year cycle and a 150-200 year cycle. These appear to be linked to a climate pattern in the Pacific Ocean called the Pacific Quasi-Decadal Oscillation which affects the path of the jet stream and hence the moisture we receive.

The Colorado College study also showed a "Little Ice Age" running from about 1300 A.D. to the early 1800's, preceded by a "Medieval Warm Period" from about 800 A.D. to the mid-1200's.

Looking forward, the study projects
(1) a reduction of 6% and 20% in annual runoff between 2041-2060 for the Colorado River Basin, principally because of markedly lower snowpack.
(2) a slight increase in average annual temperatures.
(3) increased desertification resulting in an increased number and severity of wildfires: fire risk rising by 30%-60% under current greenhouse emission rates.
(4) the 21st century may "be nasty".

If the floods don't get us, the fires probably will.....

DROUGHT:

Risk Assessments and Mitigation Strategies:

(1 =Easy – 5= Difficult)

1. Monitor water depths in Castle Valley wells.
    Potential benefit= High
    Financial viability= 1
    Political viability= 1

2. Determine the point at which the Town would implement a groundwater drought management plan.

Potential benefit= High
Financial viability= 5
Political viability= 3

3. Build large retention ponds above the community.

Potential benefit= High
Financial viability= 5
Political viability= 5

4. Install rain water catchment systems.

Potential benefit= Medium high
Financial viability= 5
Political viability= 1

5 Educating the Community on water wise behavior/systems

Potential benefit= high
Financial viability= 2
Political viability= 3

Drought Probability Analysis

Potential Magnitude		**Negligible**	**Less than 10%**
		Limited	**10-15%**
		Critical	**25-50%**
	X	**Catastrophic**	**More than 50%**
Probability		**Highly likely**	
	X	**Likely**	
		Possible	
		Unlikely	
Location	**Everywhere**		

Seasonal Pattern or Conditions	**Long term condition with seasonal breaks**
Duration	**Years to decades**
Analysis Used	**Utah Climate Center, Colorado College, National Weather service**

WATER CONTAMINATION

BACKGROUND

Castle Valley's primary water resources are the aquifer that underlies the valley, Castle Creek and a small number of springs that mostly occur adjacent to Castle Creek. The aquifer is the sole source of drinking water for Castle Valley residents and Castle Creek provides surface water for irrigation, recreation and maintenance of important riparian areas. There is significant interaction between the aquifer and surface sources such as Castle Creek, springs and intermittent sources such as Placer Creek. Because of that interaction and because the Castle Valley community has very limited sources of water, contamination of any of the sources could be disastrous. The watershed is at or near full appropriation, depending on drought or wet periods with the Town's surplus water rights taken into account. To date there have been no contamination problems, but it is vital that any potential sources of contamination be identified and action taken to prevent or mitigate contamination. Through the years the Town has done water and septic density studies to identify such things as septic density, the location of a culinary well site, the amount of water moving through the aquifer, water budget, in a wet period (1980 - 2000) and a dry period (2001 – 2016) the storage capacity of the aquifer.

See Appendixes:

WC-1 Sole Source Aquifer Designation
WC-2 Ground water Quality Classification Map
WC-3 Aquifer System Map
WC-4 Septic Density Study by UGS (Lowe, Gibson, & Wallace) during Bruce Keeper time as Mayor
WC-5 HESA Part 1 Water Budget 1980 – 2000
WC-6 HESA Part 2 Culinary Well Siting
WC-7 Updated to HESA / Water Budget 2001 – 2016)

<u>CONTAMINATION HAZARDS</u>

<u>Contamination of the Aquifer</u>

Widespread contamination of Castle Valley's aquifer would be a major threat to the Castle Valley community and could be extremely difficult to mitigate or cure, therefore the emphasis should be on prevention. An ongoing water quality monitoring program will help identify potential contamination problems before they become widespread, but at the same time it is important to regulate activities or materials that are known to have caused water contamination issues elsewhere. Possible sources of aquifer contamination are:

1) Airborne Pollutants – There are a variety of airborne pollutants that can bond with or dissolve in surface water and then through seepage make their way into an aquifer. Aquifer contamination from airborne VOCs produced by oil drilling activity has occurred in other parts of Utah.

2) Agricultural Chemical / By-Product Seepage – Most agricultural chemicals and by-products are water soluble and if used in large amounts or high concentrations can migrate into aquifers. This is a common problem in areas with a lot of conventional agricultural activity or feedlots.

3) Septic System Seepage – By design, septic system effluent is leached into the adjacent soil and will be cleaned by microbiological action in the soil. However, if the density of septic systems in an area is too high for the cleaning capacity of the soils and / or the water table is relatively close to the surface then an aquifer can become contaminated by the effluent.

4) Industrial / Chemical Spills – There are many products available for industrial, yard or household use that contain high concentrations of chemicals and compounds that could pose a considerable threat to aquifer water. It is not expected that yard, garage or household use of such products would occur on a level that could contaminate an entire aquifer, but there are commercial or industrial activities that might use hazardous chemicals or compounds in volumes and / or concentrations that could pose such a threat.

<u>Contamination of Individual Wells</u>

There are any number of ways that an individual well can become contaminated and in such cases there are generally better opportunities for mitigation and repair. However, due to the movement of water within the aquifer the contamination of any individual well should be considered a serious matter because a high concentration of contaminants introduced in a specific location could become a widespread problem. Possible sources of individual well contamination are:

1) Surface Water Intrusion – Wells that are inadequately sealed (grouted) at the top can be contaminated by surface water intrusion (i.e. contaminated from the top down). Sources of such intrusion are flooding, irrigation runoff or precipitation pooling near the wellhead. More specific threats from such intrusion are covered in the following paragraphs.

2) Agricultural Chemical / By-Product Seepage – Most agricultural chemicals and by-products are water soluble and if present in large amounts or high concentrations near a well could potentially contaminate an individual well by seeping into the water that the well draws. Spills or runoff containing dissolved agricultural chemicals or feedlot by-products could also be a cause of individual well contamination, particularly if the wellhead is not adequately sealed.

3) Chemical Spills – There are many products available for yard, garage or household use that contain high concentrations of chemicals and compounds that could contaminate an individual well if spilled near the well, particularly if the wellhead is not adequately sealed.

4) Septic System Seepage – Septic system effluent could contaminate an individual well if the septic system and well are not adequately separated, particularly if the water table is close to the surface.

Contamination of Castle Creek
Being a surface water body, Castle Creek is more susceptible to contamination. Castle Creek is not a source of drinking water so its contamination may be viewed as less of a threat to the community than contamination of the aquifer, but because there is significant interaction between surface water and aquifer water and because Castle Creek water is distributed and used for flood irrigation contamination of its water could become a serious problem. Possible sources of Castle Creek contamination are:

1) Airborne Pollutants – There are a variety of airborne pollutants that can bond with or dissolve in surface water. Castle Creek could be contaminated by such pollutants if they are present in large amounts or local high concentrations. Such contamination has occurred in other areas where commercial or industrial activity occurs near surface water.

2) Agricultural Chemical / By-Product Runoff – Most agricultural chemicals and by-products are water soluble could contaminate Castle Creek if present in large amounts or high concentrations in areas where there is a large volume of irrigation or storm water runoff into the creek.

3) Industrial / Chemical Spills – There are many products available for industrial, yard or household use that contain high concentrations of chemicals and compounds that could contaminate Castle Creek if spilled or used in areas where there is a large volume of irrigation or storm water runoff into the creek.

4) Septic System Seepage – It is conceivable that septic system effluent could seep into Castle Creek, particularly in areas where there are springs and a high water table.

5) (Geo) Thermal Wells – Depending on the design and material used (glycol for example) in (geo) thermal wells they potentially cause a major threat to contamination of underground water.

6) Mining – There are several gold deposits and a long history of mining in the La Sal mountains. Placer Creek in Castle Valley was named after the Placer Gold; such an industry also poses a threat of water contamination.

Water Contamination Probability Analysis

Potential Magnitude		**Negligible**	**Less than 10%**
		Limited	**10-15%**
		Critical	**25-50%**
	X	**Catastrophic**	**More than 50%**
Probability		**Highly likely**	

		Likely
	X	**Possible**
		Unlikely
<u>Location</u>	**Would depend on the source of contamination.**	
<u>Seasonal Pattern or Conditions</u>	**Anytime**	
<u>Duration</u>	**Would depend on where and what type and quantity of contaminate.**	
<u>Analysis Used</u>	**Utah Geologic Survey (UGS)**	

WATER CONTAMINATION:

Risk Assessments and Mitigation Strategies:

(1 =Easy – 5= Difficult)

1. Regular water quality monitoring and sampling of selected wells and Castle Creek, to provide an early warning of future issues.
   Potential benefit= High
   Financial viability= 2
   Political viability= 1

2. Delineate and Protect the Castle Valley Watershed. The Town should take whatever legal action is available to create broad protection for the entire Castle Valley watershed.
   Potential benefit= High
   Financial viability= 3
   Political viability= 2

3. Educate Castle Valley residents, agricultural and livestock operators to help them understand how water source contamination can occur and how to prevent it.
   Potential benefit= High
   Financial viability= 2
   Political viability= 3

4. Continue to monitor septic system placement, construction and use done by the State, any indication of water contamination caused by septic systems should trigger action by the Town.
   Potential benefit= High
   Financial viability= 1 to 4 (if the Town is involved)
   Political viability= 1 to 4 (if the Town is involved)

5. Continue to monitor wellhead sealing (grouting) done by the State, any indication that a well has been contaminated by surface water intrusion should trigger action by the Town.

Potential benefit= High
Financial viability= 1
Political viability= 1

6.Use appropriate mechanisms to regulate Town business activities limit pollutants used in commercial and industrial activity so sources of VOCs and other concentrated chemical contaminants are prohibited or severely limited .

Potential benefit= High
Financial viability= 2
Political viability= 3

7. Use Appropriate Zoning to Limit Septic System Density (i.e. population density)

Potential benefit= High
Financial viability= 2
Political viability= 2

8. Construct a Community Water System

Potential benefit= High
Financial viability= 5
Political viability= 5

9. Construct a Community Sewer System.

Potential benefit= High
Financial viability= 5
Political viability= 5

10. Property owners should consult with the Southeastern Utah Health Department to select the most appropriate human waste disposal system for their property as this varies based on the different geologic conditions found within incorporated Castle Valley.

Potential benefit= High
Financial viability= 4
Political viability= 2

12. Purchase and maintain above ground water storage for a back-up culinary water source.

Potential benefit= High
Financial viability= 5
Political viability= 2

SUBSIDENCE

BACKGROUND

Subsidence is the motion of a surface (usually, the Earth's surface) as it shifts downward relative to sea-level. Subsidence is what can create sinkholes, which typically occur naturally as a result of percolating water and the gradual removal of soluble bedrock. This process creates a void that ultimately results in a collapse of the overlying cave roof. Though most often occurring in regions with heavy limestone deposits, sinkholes also appear in areas of chalk, gypsum, basalt, and where there are underlying salt beds, several of which are abundant in Grand County.

Human activities such as mining, groundwater over-extraction, extraction of natural gas, earthquake, overly dry expansive soils, drainage diversion and failing infrastructure – such as water main leaks, or the collapse of sewer systems and other buried pipes – can also create sinkholes.

HISTORY

Castle Valley is part of a large, regional, collapsed salt anticline that includes Paradox Valley to the Southeast. It is surrounded by Permian to Tertiary sedimentary and igneous rocks. Beneath the Valley is the Pennsylvanian Paradox Formation that contains thick salt layers deposited in a shallow sea. As these salt layers were buried they became mobile and formed diapir in what is now Castle Valley. The uplift of the Colorado Plateau in the late Tertiary increased erosion rates and allowed ground water to dissolve the salt layers from the core of the anticline. As a result the overlying rock collapsed and eroded, leaving Castle Valley in the core of the anticline. In 1992 Mulvey mapped a suspected Quaternary fault parallel to Porcupine Rim northwest of Round Mountain. Several sinkholes along this fault are attributed to localized dissolution or piping.

IMPACT ON COMMUNITY

Present day subsidence and sinkholes have yet to make a big impact on the Castle Valley community however the larger concern could be directed at the reason why they appear or increase in size. Many of the activities that are responsible for creating sinkholes could be very detrimental to the holistic health of Castle Valley. Over-mining water in the valley could lead to drought and seriously impact the community. Other activities such as mining in the region could affect Castle Valley's Sole Source Aquifer if sinkholes begin to appear from mining practices.

GOALS TO REDUCE VULNERABILITIES

The Town of Castle Valley has had many geologic and hydrologic studies done in the past which have helped the valley understand more about the local aquifer and the effects the geology plays on the valley as a whole. Continuing to monitor local subsidence and draw conclusions as to why they have formed will protect the community by forecasting possible future problems. The knowledge gained from continual water monitoring and a general understanding of Castle Valley's watershed will help the community create a water budget that will not over mine the valley's water and create sinkholes.

SUBSIDENCE:

Risk Assessments & Mitigation Strategies:

(1 =Easy – 5= Difficult)

1. Monitor water depths in Castle Valley wells.
   Potential benefit= High
   Financial viability= 1
   Political viability= 1

2. Determine the point at which the Town would implement a groundwater drought management plan.
   Potential benefit= High
   Financial viability= 3
   Political viability= 2

3. Create log of current sinkholes and monitor their changes.
   Potential benefit= High
   Financial viability= 3
   Political viability= 2

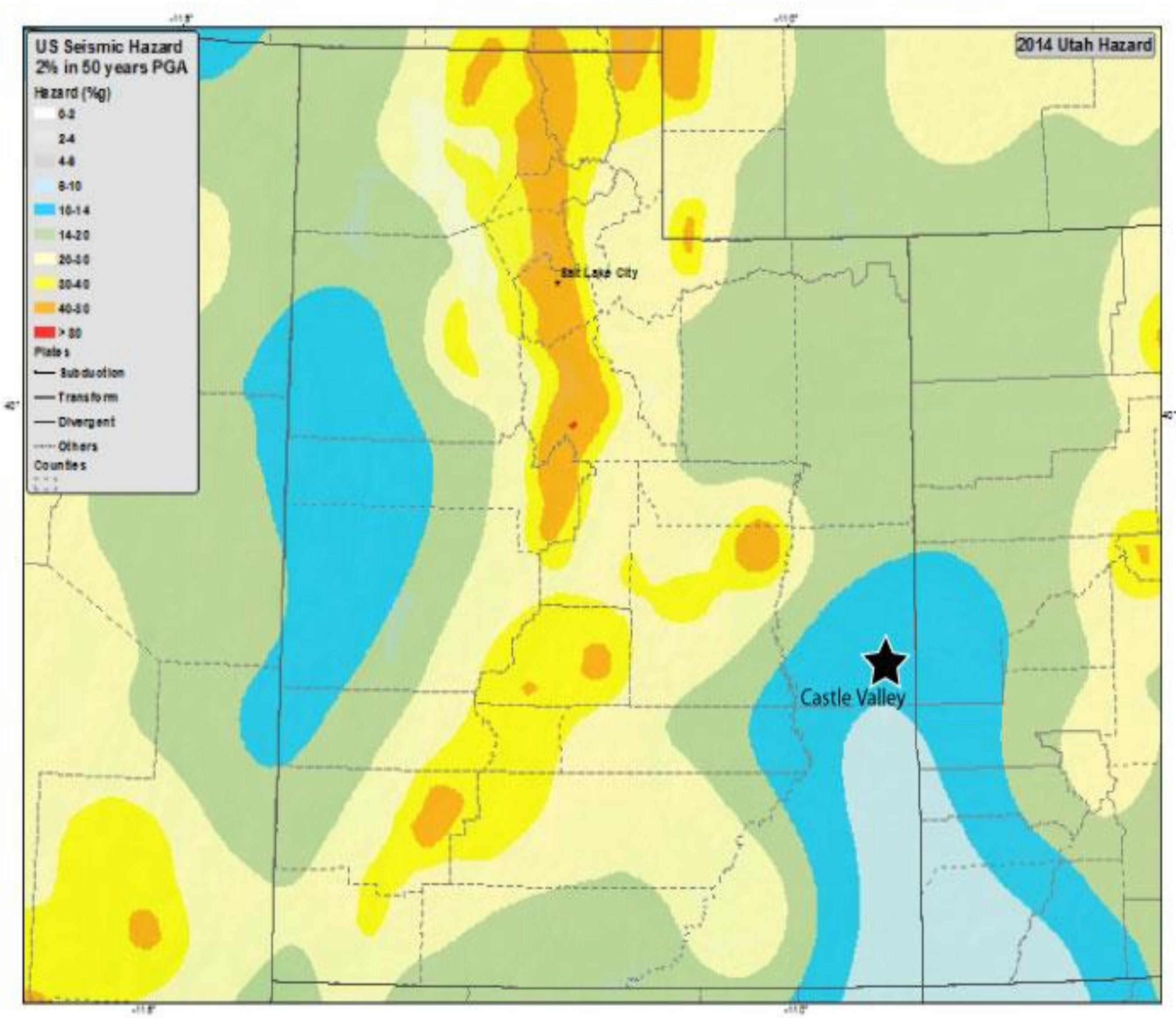
4. Prevent any kind of mining in the local region that may create subsidence.
   Potential benefit= High
   Financial viability= 5
   Political viability= 3

5. Bring awareness and education to subsidence to the community.
   Potential benefit= High
   Financial viability= 1
   Political viability= 1

EARTHQUAKE

BACKGROUND

Earthquakes are not a major threat or hazard to Castle Valley. The underlying geology is stable. However, north of Castle Valley, along the Wasatch Front (see map), a number of faults exist and have produced earthquakes within recorded history. This is the most recent 2% in 50 year probability map from 2014
data.



Source: http://earthquake.usgs.gov/earthquakes/states/utah/hazards.php

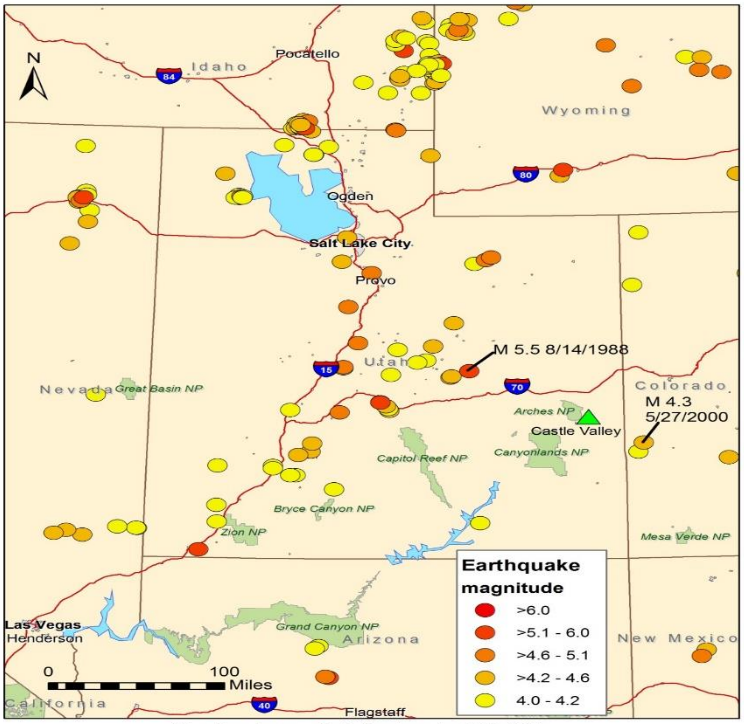
Available at http://earthquake.usgs.gov/earthquakes/states/utah/hazards.php

IMPACT ON COMMUNITY

The map illustrates that Castle Valley has a 2% probability that it will shake harder than 0.10 to 0.14g's every 50 years. It also means that there is a 98% probability that it will not shake harder than 10 -14%g every 50 years.
The probability of exceeding those acceleration values in the next ~2500 years is ~100%.

The table below will help translate the expected acceleration for Castle Valley into relative terms should an event of that size occur.

Instrumental Intensity	Acceleration (g)	Velocity (cm/s)	Perceived Shaking	Potential Damage
I	**< 0.0017**	< 0.1	Not felt	None
II-III	**0.0017 - 0.014**	0.1 - 1.1	Weak	None
IV	**0.014 - 0.039**	1.1 - 3.4	Light	None
V	**0.039 - 0.092**	3.4 - 8.1	Moderate	Very light
VI	**0.092 - 0.18**	**8.1 - 16**	Strong	Light
VII	0.18 - 0.34	**16 - 31**	Very strong	Moderate
VIII	0.34 - 0.65	**31 - 60**	Severe	Moderate to heavy
IX	0.65 - 1.24	**60 - 116**	Violent	Heavy
X+	> 1.24	**> 116**	Extreme	Very heavy



All earthquakes magnitude 4 and greater, 1900 -2014.
Source: http://earthquake.usgs.gov/earthquakes/search/

Earthquakes and Rock Falls

The August 14, 1988 magnitude 5.3 San Rafael Swell earthquake caused numerous rockfalls on the edge of Lockhart Basin.

Source: http://www.seis.utah.edu/lqthreat/nehrp_htm/1988sanr/1988sanr.shtml

Given the rock fall hazard from Porcupine Rim, it is reasonable to say that the rock fall hazard is increased by the seismic potential beyond what would be expected in an aseismic environment. Further, rockfalls can occur by seismic occurrences outside of Castle Valley, including occurrences over 50 miles away.

It is known that landslides have been initiated by earthquakes as low as magnitude 4.
Source: Keefer, D. K, 1984, Landslides caused by earthquakes: Geological Society of America Bulletin, v. 95, p. 402-421.

Induced Earthquakes

The M4.3 Paradox, Colorado, earthquake in 2000 was caused by deep well brine injection and has been the source of over 4,500 small earthquakes since the well was put into operation in 1991. Only 22 earthquakes, about 0.5% of the induced events, have magnitudes greater than or equal to M2.5. It is possible that larger earthquakes could be generated from this known source but well operators have reduced the injection rate since the M4.3 event in 2004 however, a M3.9 earthquake occurred in 2004.

Only 4 induced earthquakes with magnitude greater than or equal to M 3.0 have occurred. All but one of these occurred prior to the mid-2000 decrease in injection rate, including the largest induced event – the M4.3 event which occurred on May 27th, 2000 (after ~4 years of continuous injection). On March 4, 2019 a M4.5 earthquake occurred 7 miles southeast of Paradox, largest ever in the area, leading to a temporary shut-down of operations and likely leading to the drilling of a new injection well.

Source: http://www.usbr.gov/uc/wcao/progact/paradox/annualRep/PVSN-2008Annual-Rep.pdf

Another source for information on this project see:
http://www.coloradoriversalinity.org/docs/PVU%20Briefing%20Document%202015-04-30.pdf\

GOALS TO REDUCE VULNERABILITIES

Discourage deep well brine injections that have been known to cause small earthquakes.
Create awareness for the community to a have 72- hour kit with ample food and water storage if roads and passes are shut down due to the effects of an earthquake.

Earthquake Probability Analysis

Potential Magnitude		**Negligible**	**Less than 10%**
	X	**Limited**	**10-15%**
		Critical	**25-50%**
		Catastrophic	**More than 50%**
Probability		**Highly likely**	
		Likely	
		Possible	
	X	**Unlikely**	
Location	**River corridor and along steep slopes and cliffs.**		
Seasonal Pattern or Conditions	**Potential from fracking or injection wells.**		
Duration	**Seconds to minutes with clean-up lasting hours to days.**		
Analysis Used	**USGS and government records**		

<u>EARTHQUAKE:</u>

Risk Assessments and Mitigation Strategies:

1. Culinary water backup- cistern research
   Potential benefit = High
   Financial viability= 5
   Political viability= 3

2. Include information about earthquakes in public awareness publications.
   Potential benefit= medium
   Financial viability=2
   Political viability=2

3. Work with Grand County to keep Loop Road open year around as Hwy 128 is likely to experience excessive rockfall.
   Potential benefit=medium
   Financial viability=2
   Political viability=1

4. Develop community accountability system to ensure no one is left behind.
   Potential benefit=High
   Financial viability= 1
   Political viability=1

5. Encourage residents to maintain 72 hour Kits. And stock the Town Building with 72 hour kit provisions.
   Potential benefit= High
   Financial viability= 2
   Political viability= 1

BIOLOGICAL HAZARDS

BACKGROUND

Biological hazards include virus, infectious diseases of all kinds, toxic substances, and can include animal and plant diseases. Some biological hazards that have occurred, affected or are present in Castle Valley include chronic wasting disease, COVID-19, West Nile virus, and E.coli. There is potential for many other types of biological hazards to occur.

Chronic wasting disease (CWD) is common among the mule deer population in this region and specifically inside of the Town of Castle Valley where mule deer congregate and spend the entire year. CWD has not yet been identified in humans but research is incomplete and we don’t know enough at

this time to rule out potential issues from the deer living in close proximity to humans and water sources.
COVID-19 is a novel virus at the time of this plan update and has become a global pandemic. No cases of the virus have been identified in Castle Valley at this time but the impacts of global shut downs to combat the virus have impacted people's lives and our economy.
West Nile Virus has occurred in the region and happens seasonally with the mosquito population in 2019 the county had a very wet spring and a large mosquito problem. No cases in Castle Valley were identified but there were cases in the adjacent areas.
E-coli has been found in surface water in Castle Creek in the past and the potential for it to occur is present with livestock operations and grazing in the area, this would be included in the Water Contamination Hazard section of this plan.

IMPACTS ON THE COMMUNITY

Biological hazards can occur without warning and in varying degrees of severity. With a global pandemic and local shut downs our Town operating budget will be less than normal, potentially reducing the level of service we are able to provide the community. Town offices are staffed but remain closed to walk in traffic and our library branch is closed. The Town Hall is unavailable for community activities and the playground is closed. Some residents who are at high risk for the virus are in need of help with getting groceries and other needs as they have been recommended to stay home to stay safe.
Grocery stores have seen a reduction of available products and prices of some commodities are increasing. Prolonged food shortages without adequate food storage on hand would have a great impact on all residents. Obtaining health care during a pandemic for elective procedures or dental care has been reduced and can impact the health of residents as well. Long term effects on mental health from social isolation and distancing can also occur. Our community is isolated and people live a good distance from neighbors already, and we only have a limited number of community events so the impacts from this should be minimal.
Other biological hazards could potentially threaten our air quality, and water supply. We currently have no back up source for our sole source aquifer and no storage for community use should the need arise. Residents who do not have adequate storage of water would need to find a way to have it delivered.

GOALS TO REDUCE IMPACTS AND VULNERABLITIES

Improving community resilience is a goal for reducing the long-term impacts of biological hazards. Educating residents on the importance of food and water storage for at least 2 weeks' worth of household needs, and encouraging home gardens and back up means to run well pumps would also help reduce some vulnerability to biological hazards. Water management plans with long term goals of protecting our water quality and availability given the drought hazard is also a community goal. Educating residents on efficient crop watering methods to ensure long term sustainability of home food production as well as encouraging sustainable methods of animal husbandry would improve resilience as well. Neighbor helping neighbor has been a very important for the community getting through the current pandemic, and will remain one of the ways we build resilience.

Biological Hazards Probability Analysis

Potential Magnitude	**X**	**Negligible**	**Less than 10%**
	X	**Limited**	**10-15%**
		Critical	**25-50%**
		Catastrophic	**More than 50%**
Probability		**Highly likely**	
	X	**Likely**	
		Possible	
		Unlikely	
Location	**Town wide**		
Seasonal Pattern or Conditions	**Some Biological Hazards could be seasonal, others less often.**		
Duration	**Variable event to ongoing**		
Analysis Used	**Division of Water Quality , DWR , CDC , Southeast Health Department**		

BIOLOGICAL HAZARDS:

Risk Assessments & Mitigation Strategies:

(1 =Easy – 5= Difficult)

1 Bring awareness and education of the Biological hazard to the community through communications with the Southeastern Utah Health Department, Grand County and the State of Utah.

Potential benefit= High
Financial viability= 1
Political viability= 1

2 Develop protocol for closing Public Buildings and conducting electronic Public Meetings.

Potential benefit= High
Financial viability= 3 Political viability= 2

3 Have a supply of Personal Protection Equipment (PPE) for employees, Town officials and residents.

Potential benefit= High
Financial viability= 3
Political viability= 2

4. Encourage and support Community based initiatives to provide groceries, pharmaceuticals and other essential / critical supplies to higher risk residents.

Potential benefit= High
Financial viability= 2
Political viability= 1

5. Develop a Community Fund to help citizen initiatives provide groceries, pharmaceuticals and other essential/critical supplies to higher risk residents.

Potential benefit= High
Financial viability= 2
Political viability= 1

6. Create a protocol for the Town lot facilities such as the Pavilion and Playground

Potential benefit= High
Financial viability= 1
Political viability= 1

7. Bring awareness and education of Chronic Wasting Disease to avoid residents feeding and/or encouraging deer.

Potential benefit= High
Financial viability= 1
Political viability=3

8. Depending on the nature of the biological hazard, consider protocols for partial or total evacuation of the Town.

Potential benefit= High
Financial viability= 1
Political viability=3

9. Encourage home orchards and gardens to supply fruits and vegetables for seasonal consumption and storage.

Potential benefit= High
Financial viability= 1
Political viability-2

10. Encourage residents to maintain 72-hour Kits. And stock the Town Building with 72-hour kit provisions.

Potential benefit= High
Financial viability= 2
Political viability= 1

2013 Disaster Mitigation Plan for Southeastern Region of Utah Priority Projects Update

The following mitigation strategies were formulated in efforts with the Southeastern Utah Association of Local Governments in the updated *Natural Hazards: Pre-Disaster Mitigation Plan for the Southeastern Region of Utah*. The following summary highlights efforts to implement those goals where applicable and practical as part of the Association's overall mitigation planning efforts.

CASTLE VALLEY

Category	Goal / Objective	Action	Status	Comments
Flooding	1 - Reduce risk of damage from flooding 1 - Minimize flood damage by re-vegetating Pin-Hook burn area directly above Castle Valley.	1 – Seeded grasses and forbes in burn area and managed livestock grazing for success.	Complete	Re-seeded in 2014, monitored in 2015.
Drought/ Water Quality	2 - Reduce risk of damage due to drought & poor water quality 2 - Monitor wells to track changes in water quality and quantity.	1 – Create Water Monitoring program/schedule and budget for the ongoing cost.	Complete/ ongoing	Data has been collected for decades & is ongoing. The Town Council has included this ongoing cost in the budget.
Drought/ Water Quality	3 - Reduce risk of damage due to drought & poor water quality 3 - Create water budget to adhere to in the watershed.	1 – Have a Water Study for the Town to create a water budget.	In process	Study began in 2015 with data used from years past and present. This study should be completed in 2016.
Flooding	4 - Reduce risk of damage due to flooding 4 – Work with beavers and their natural habits to reduce extensive flooding & obstructed culverts.	1 – Beaver introduction, education and beaver deceiver program for private landowners.	In process	The Utah Beaver Management plan was created for 2010-2020; currently the habitat is not ready for beavers.

The 2015 updated Priority Projects have been created based on the specific needs of Castle Valley and do not include previous projects as they are currently already implemented or no long are relevant to the needs of Castle Valley at this time.

2020 - UPDATED RECOMMENDED PRIORITY PROJECTS

Goal	**Priority - 1**
Objective	Have an Emergency Operations Plan in place to be prepared for major disasters.
Action Project:	Develop an Emergency Operations Plan. To include budgeting, emergency evacuation planning and post event “neighborhood rapid assessment planning (NRAP)” (FEMA FA-197 Appendix B)
Time Frame:	6 months
Funding:	Volunteers based, with support from the Town Clerk under the salary position.
Estimated Cost:	Depends on number of people and time involved, unknown. An estimate from Rick Bailey, the Grand County Emergency Manager, it would take a trained individual 15 hours to complete the plan.
Jurisdictions Involved:	Town of C.V staff, C.V.F.D, volunteers, County emergency manager, Sheriffs’ Department staff. Representatives from Daystar Academy and the Castle Valley branch of the Church Jesus Christ of Latter-day Saints.

Goal	**Priority - 2**
Objective	Maintain the ingress and egress roads open for the community in case of an emergency.
Action Project:	A -Finish Upper 80 easements to Green Gate to access BLM land. B- Finish four-season surface on Shafer Lane extension to Fire Station. C- Continue to maintain ingress and egress for community. D- Repair/ Armor Castle Creek Culvert at Castle Valley Dr.

Time Frame:	Present and Ongoing
Funding:	Town of C.V. annual Roads budget.
Estimated Cost:	Variable and Pending
Jurisdictions Involved:	Town of Castle Valley Road Department and MOU with Grand County Road Department.

Goal	**Priority -3**
Objective	Bring awareness to the community about how to be prepared for and mitigate possible hazards.
Action Project:	Annual - quarterly public awareness publications. To include the Mayor's Annual Letter ,Castle Valley Fire District Newsletters and outreach a Community Events
Time Frame:	On going
Funding:	Town of Castle Valley Tax Base
Estimated Cost:	Current rate of postage and printing supplies plus Town Clerks regular salary.
Jurisdictions Involved:	Town of Castle Valley Town Clerk will be responsible for the mailing with info from the CV Fire District. and CV Hazard Mitigation Committee.

Goal	**Priority - 4**
Objective	Identify in detail issues in the major drainages in Castle Valley Town boundaries to prevent or mitigate major events that may occur.
Action Project:	Annual and interim inspections and reports of Placer and Castle Creek drainages.

Time Frame:	Annual Inspections and after every major flooding event events, beginning immediately.
Funding:	Town of Castle Valley Tax Base
Estimated Cost:	8 hours each inspection at current per hour for staff labor.
Jurisdictions Involved:	Town of C.V. Road Department staff and the Bureau of Land Management.

Goal	**Priority - 5**
Objective	Have back-up generators and/or battery backups tied into public buildings for prolonged power outages.
Action Project:	Install back-up power for municipal buildings. Propane generator, battery backups and investigate solar options.
Time Frame:	Two years for all buildings, Town and Fire Department.
Funding:	Possible Grants or from the Town's Tax Base for capital improvements.
Estimated Cost:	Thousands of dollars
Jurisdictions Involved:	Town of C.V and C.V.F.D

Goal	**Priority - 6**
Objective	Mitigate Fire Hazard Fuels in Town Greenbelt by reducing biomass.

Action Project:	Finish riparian plan, build stakeholder support with Utah Forestry, Fire and State Land, Daystar Academy and County and Town property owners along Castle Creek.
Time Frame:	1 year.
Funding:	Town of Castle Valley Tax Base and possible grant funding
Estimated Cost:	At Current FEMA rate
Jurisdictions Involved:	Town of C.V. Road Department staff, Grand County, State and Private property owners.

Goal	**Priority - 7**
Objective	Create Interlocal agreements to efficiently handle mitigation and disaster recovery efforts.
Action Project:	Advise and seek agreements with other organizations in the community, Interagency and government. Create an updated resources list of Interlocal agreements and Memorandums of Understanding.
Time Frame:	Immediately and ongoing.
Funding:	Town of Castle Valley Tax Base.
Estimated Cost:	Will depend on time of people involved at the current FEMA rate.
Jurisdictions Involved:	Town of C.V. staff and C.V.F.D. along with utility companies, Grand County road department, Daystar Academy and Farms, C.V B and B, Redcliff's Lodge and Sorrel River Ranch, UDOT ,BLM and the Castle Valley branch of the Church Jesus Christ of Latter-day Saints.

PLAN MAINTENANCE PROCESS

The Hazard Mitigation Committee will update the plan every four years or as determined by events. The plan will be updated by November of 2025.
Public hearings will be held prior to updating the plan.

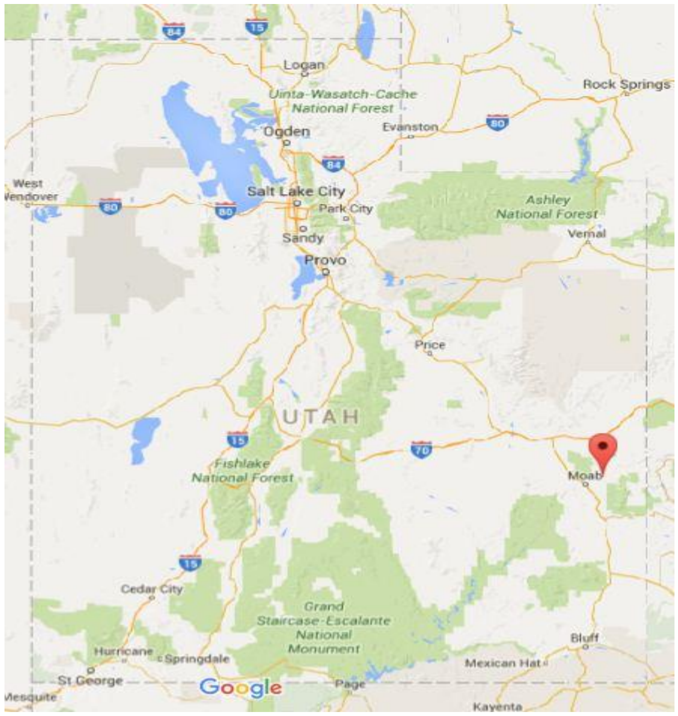
Appendices will be added as information becomes available and as events occur.

Because the majority of committee members involved in the process are members of the Fire District or of the Town of Castle Valley Public Body, updating the plan every four years will also help maintain continuity in local government.

TABLE OF APPENDICES

Appendix A:

A1 – State of Utah



A2 - Grand County, Utah

State of Utah

Photo Courtesy of Bill Rau

Community Wildfire Preparedness Plan

For the Wildland – Urban Interface

Grand County Service Area for Castle Valley Fire Protection (Castle Valley Fire District)

Department of Natural Resources
Division of Forestry, Fire and State Lands
1594 W North Temple, PO Box 145703, Salt Lake City, UT 84114-5703

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Declaration and Concurrence Page

This list needs to be customized to the individual plan. Provide the names and affiliations of all cooperators. This page will then be signed after all cooperators have reviewed the plan and concur with its contents.

Name	Affiliation
Bob Lippman	Firefighter, Community Member/Homeowner
Signature	**Date**
[signature]	7/2/19

Name	Affiliation
Ron Mengel	Firefighter, Community Member/Homeowner
Signature	**Date**
Ron Mengel	7/9/19

Name	Affiliation
Leta Vaughn	Fire Commission, Firefighter, Community Member/ Homeowner
Signature	**Date**
[signature]	7/2/19

Name	Affiliation
Ron Drake	Castle Valley Fire Chief, homeowner, media representative (Times Independent)
Signature	**Date**
Ron Drake	JULY 2, 2019

Name	Affiliation
Jazmine Duncan	Mayor of The Town of Castle Valley, Firefighter, Homeowner
Signature	**Date**
Jazmine Duncan	07/02/2019

Declaration and Concurrence Page, continued

Name	Affiliation
Rick Bailey	Grand County Emergency Manager
Name	**Affiliation**
Rick M Bailey	7 July 2019
Signature	**Date**
Greg Halliday	Grand County Council Member, Firefighter, Homeowner
Name	**Affiliation**
	3 July 2019
Signature	**Date**
Bruce Jenkins	State Fire Warden
Name	**Affiliation**
Bruce Jenkins	7/10/19
Signature	**Date**
Jason Johnson	FFSL
Name	**Affiliation**
	7/10/2019
Signature	**Date**
Steve White	Grand County Sheriff
Name	**Affiliation**
	7/9/19
Signature	**Date**

Castle Valley Fire District Wildfire Preparedness Plan 2019

Randy Ward	Daystar Academy Director
NAME	**AFFILIATION**
[signature]	7.4.2019
SIGNATURE	**DATE**

INTRODUCTION

Over 600 of Utah's communities have been classified as "at risk" of wildfire. The safety of the citizens of any community and the protection of private property and community infrastructure is a shared responsibility between the citizens; the owner, developer or association; and the local, county, state and federal governments. **The primary responsibility, however, remains with the local government and the citizen/owner.**

The purpose of wildfire preparedness planning is to…

- Motivate and empower local government, communities, and property owners to organize, plan, and take action on issues impacting the safety and resilience of values at risk
- Enhance levels of fire resilience and protection to the communities and infrastructure
- Identify the threat of wildland fires in the area
- Identify strategies to reduce the risks to structures, infrastructure and commerce in the community during a wildfire
- Identify wildfire hazards, education, and mitigation actions needed to reduce risk
- Transfer practical knowledge through collaboration between stakeholders toward common goals and objectives

Outcomes of wildfire preparedness planning…

- Facilitate organization of sustainable efforts to guide planning and implementation of actions:
  1. Fire adapted communities 2. Resilient landscapes 3. Safe and effective fire response
- Improve community safety through:

  ✓ Coordination and collaboration
  ✓ Public awareness and education
  ✓ Firefighter training
  ✓ Fuel modification
  ✓ Improved fire response capabilities
  ✓ Fire prevention
  ✓ Development of long-term strategies

RESOURCES

For resources to complete a wildfire preparedness plan for your community, consider organizations such as the following:

✓ Local / Primary fire protection provider
✓ Local Resource, Conservation and Development Districts
✓ Utah Division of Forestry, Fire and State Lands
✓ Utah State Fire Marshal (Dept. of Public Safety)
✓ Utah Division of Emergency Management
✓ Utah Living With Fire
✓ Local fire agencies
✓ Local emergency management services
✓ USDA Forest Service
✓ U.S. Department of Interior Agencies
✓ Utah Resource Conservation Districts
✓ Utah Soil Conservation Districts

Castle Valley Fire District Wildfire Preparedness Plan 2019

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✓ U.S. Department of Interior Agencies
✓ Utah Resource Conservation Districts
✓ Utah Soil Conservation Districts

STATEMENT OF LIABILITY

The activities suggested by this template, associated checklist and guidance document, the assessments and recommendations of fire officials, and the plans and projects outlined by the community wildfire council, are made in good faith according to information available at this time. The Utah Division of Forestry, Fire and State Lands assumes no liability and makes no guarantees regarding the level of success users of this plan will experience. Wildfire still occurs, despite efforts to prevent it or contain it; the intention of all decisions and actions made under this plan is to reduce the potential for, and the consequences of, wildfire.

This document provides the outline for and specifies the information recommended for inclusion in a wildfire preparedness plan. **Completed Community Wildfire Preparedness Plans should be submitted to the local Area Manager or Fire Management Officer with the Utah Division of Forestry, Fire and State Lands for final concurrence.**

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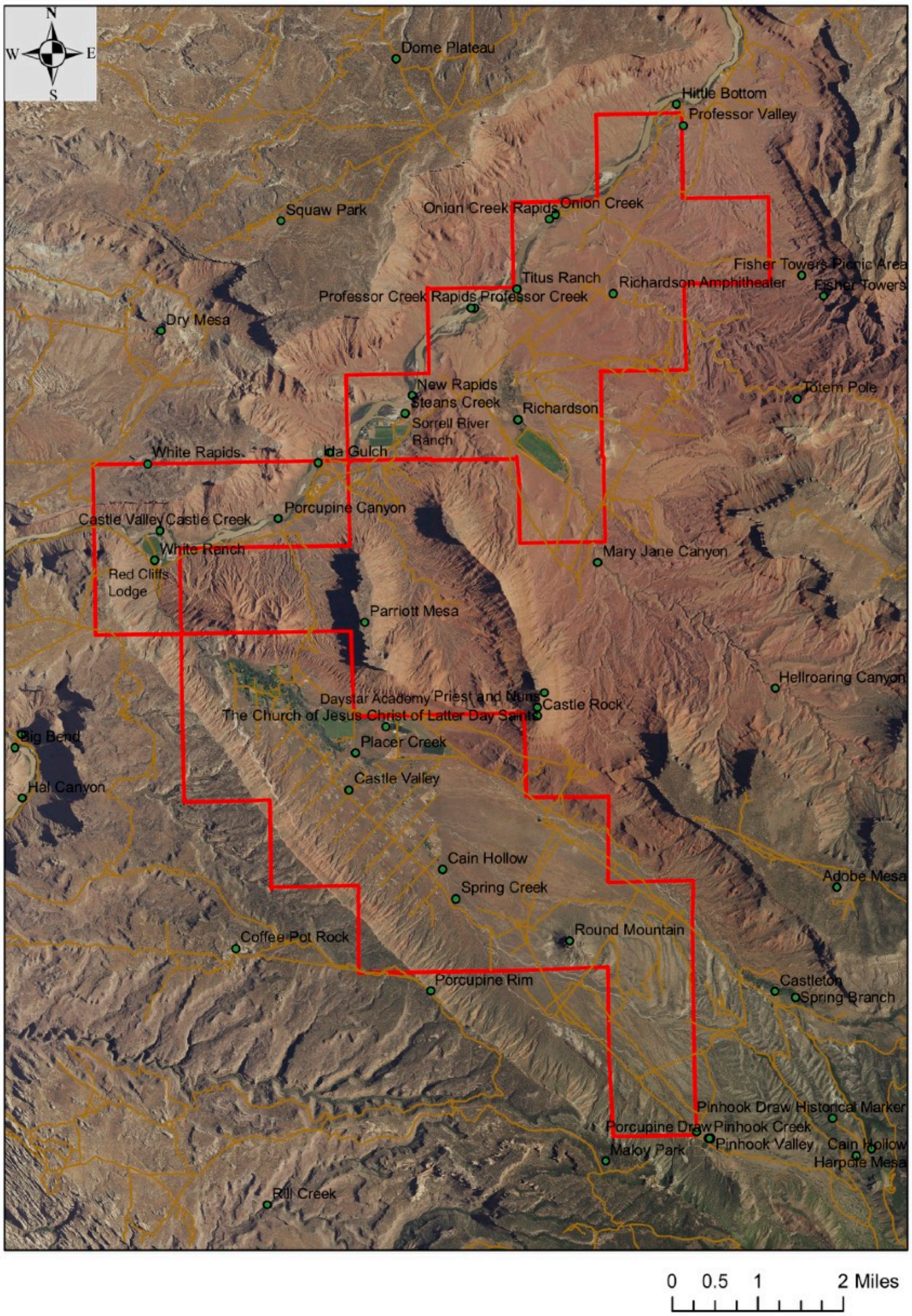
Castle Valley Fire District Wildfire Preparedness Plan 2019

PLANNING OVERVIEW

Castle Valley Fire District



Briefly describe the overall planning process that took place to complete this plan. Be sure to include a timeline of the events/meetings, the organizations and partners that participated, a description of why this planning process was initiated, and the overall intended outcome of the process, and how outcomes were accomplished. This is much like the information described above (purpose and outcome) but tailored to your community. If desired, please acknowledge any individuals or organizations that were essential to accomplishing the final plan.

The Community Fire Plan for Castle Valley was developed by the district Fire Commission over a 17 year period beginning in 2002, with significant and valuable assistance from Firewise USA, the Utah Dept. of Natural Resources (Div. of Forestry, Fire and State Lands, WUI Coordinator), and the Grand County Fire Warden. Many individuals, stakeholders and agencies were involved, and Fire Commissioners charged with development and oversight over the tenure of the CWPP included Ron Mengel, Bob Lippman, and Leta Vaughn. Other agencies consulted and represented included the U.S. Forest Service, U.S. Bureau of Land Management, Utah School Institutional Trust Lands Administration, Grand County Sheriff's Office and Emergency Manager, Grand County Weed Supervisor, Town of Castle Valley, and Castle Valley Volunteer Fire Department.

The focus, goals and objectives of the planning process have included community wildfire education and resources, identification and marshaling of community resources, assistance to property owners in creating defensible space, interagency cooperation to create a community protection zone and shaded fuel break, cooperative efforts to implement fuels reduction projects that are also sensitive to ecological considerations and watershed protection, restoration of burned and impacted areas, community emergency planning, and support for development of the Castle Valley Volunteer Fire Department.

PLAN OVERVIEW MAP
Area of Interest
PARTNERSHIPS AND COLLABORATION

Briefly describe surrounding lands and the partners involved in coordinating the fuels treatments identified in the CWPP. This section can be added to as new projects and partners are developed. Community buy-in and desires to support and move these projects forward is critical to overall success.

The Grand County Service Area for Castle Valley Fire Protection is located at the foot of the La Sal Mountains, 17 miles east of the City of Moab. The area includes most of the physiographic landform of Castle Valley, the incorporated town of Castle Valley, and area within the Colorado River corridor. The fire district includes lands administered by the BLM, US Forest Service, State of Utah School Trust (SITLA), private landowners and a non-profit land trust (Utah Open Lands). Castle Valley, at 4400 ft to 6000 ft. elevation, is high desert with typical desert vegetation consisting of sagebrush, rabbit brush, black brush, pinion pine and juniper trees, cottonwoods, and various cultivated trees and shrubs. Invasive fuels such as cheatgrass, tamarisk, Russian olive, and Russian thistle are present in most areas of the district. The valley is narrow and deep, being approximately twelve miles long and one and one half miles wide, and is drained by Castle Creek (and its intermittent tributaries) and Placer Creek (intermittent). The west edge of the valley is extremely steep-sloped, abutting the 2000 foot escarpment of Porcupine Rim. The head or south end of the Valley is defined by heavy fuel loading, increasing slope and no natural or man-made fire breaks. The east edge of the valley is bounded by cliffs, and also traversed by the Castleton/LaSal Mt. Loop Road which handles significant tourist and recreational traffic. The foot or north end of the valley is bounded by cliffs, and defined as the green belt due to the dense vegetation growth adjacent to Castle Creek and around several natural water sources.

Homes in the valley are very diverse in setting, value, and architecture. The Castle Valley River Ranchos subdivided area of the fire district was originally platted with approximately 443 five-acre lots, zoned for single family residences. These lots are not built out as of this writing. Lots on which homes have been built, frequently have multiple structures and generally lack defensible space. Access to homes is often difficult due to narrow gravel and dirt roads, cross-road drainages prone to intermittent flooding, steep grades and limited or tight cul-de-sacs the ends of most roads. These conditions can create challenges for fire fighting equipment to access properties safely. The singular and steep public road ingress/egress to and from Castle Valley also presents a potential challenge to access, emergency services, public safety, and evacuation. The community is also challenged by the historic, non-topographic layout of lots, the unpaved roads that access the lots, steep western slopes, and significant drainage and flooding issues. The town does not provide municipal water or a water supply for fire protection; however, the fire district owns and maintains a well, and has access to other water sources.

Red Cliffs Lodge, Sorrel River Ranch are two commercial entities that reside within the Fire District. Both provide overnight lodging and food for visiting tourists. Red Cliffs Lodge has it's own water hydrant system which the Castle Valley Fire Department will use for fighting fires within the ranch boundaries. Sorrel River Ranch has two large water tanks that hold 25,000 gallons of water. These are connected to hydrant system at the resort across the highway. They have hydrants located all over the farm, especially near the housing that could be used for fire suppression. The CVFD carry cam lock *adapters that transitions to our couplings in some of the engines. I think they irrigate their fields from pumps located in the river.*

Castleton and Willow Basin residential communities are located up Castle Creek drainage, in the south end of the valley. Castleton sits at 5,800ft elevation and Willow Basin sits at 8,500ft respectively. There are approximately 35 homes, the majority being vacation cabins. The Castleton and Willow Basin residential areas are bordered by BLM and USFS lands. Willow Basin completed a Community Wildfire Protection Plan in February 2010, which outlines the challenges and needs of the community. The vegetation type surrounding these communities include: ponderosa pines, dense oak underbrush, dense pinyon and juniper stands, and mixed mountain shrub communities. Pinyon/juniper, gambel oak and mountain shrub woodlands have proven susceptible to fast moving and intense fire due to live fuel layers (gambel oak and other shrub species) that have increased with lack of natural fire activity. The access routes are narrow and over grown by very flammable vegetation, which poses a significant risk to the public, residents and firefighters. There are few homes that have defensible space, and the fuel break that was created by the State of Utah is in need of maintenance. The communities of Castleton and Willow Basin have opted not to be annexed by the Castle Valley fire district, but the fire department currently exercises discretionary responses to these areas.

Castle and Placer Creeks have been identified as major recharge sources for the unconsolidated aquifer that provides domestic water, via private wells, to the residents of Castle Valley; the water supply has been officially designated as a Sole Source Aquifer by the US EPA. In 2008, The Porcupine Ranch Fire severely burned 17% of the Placer Creek Watershed (see Castle Valley Watershed map in appendix C). The post-fire effects on the watershed have yet to be realized, however, such an event is known to be detrimental to water quality and quantity. A resulting debris flow did occur the following year, which had significant surface impacts on the community. Currently, the Castle Creek Watershed is also at risk because it shares similar vegetation conditions and types, topography and weather patterns that promoted the Porcupine Ranch Fire into a fast moving, high-intensity fire. The fire district has included the Placer Creek and Castle Creek Watersheds within its CWPP boundary. This has been done primarily for two reasons: (1) firefighter safety (as the Castle Valley VFD is the first to respond to fires in these watershed areas and in the Castleton and Willow Basin residential areas), and (2) watershed health (as Castle Valley has a high, vested interest in these two watersheds by including them in the CWPP, thus allowing funding to become more available for creating defensible space around homes, and to reduce hazardous fuels on the public lands.

Services in the community are extremely limited. The district fire department is a volunteer unit under County authority, and must address both structural and wildland fires, in a wildland-urban interface (WUI). The fire department presently has eight engines (3 structural, 4 wildland, and 1 tender) capable of carrying approximately 8,500 gallons of water to many areas of the valley. These vehicles range from one new (2007) structural engine, to former military vehicles converted to fire service. The fire department has access to several reliable water sources including a well at the centrally located, Fire Station 1, and a hydrant valve on a high-pressure pipeline owned and maintained by the adjacent Daystar Academy. Also a well in close vicinity to Station 2 within the Town. There are no local police or County emergency medical services within the valley and residents must rely on services provided by Grand County, BLM, US Forest Service to obtain assistance. In 2014, an emergency first responder network was developed and activated for Castle Valley, under the authority of Grand County EMS; one *ambulance is deployed in Castle Valley and available for first responder use, but patient transport currently is not authorized.*

Several projects have been identified by the CWPP planning committee as priorities for the community and the various adjacent land management agencies and entities. These include a maintained, shaded fuel break that follows the existing fence line roads along the south and east boundaries of the Castle Valley River Ranchos development within the Town of Castle Valley, to be coordinated with private landowners along the boundary, for various thinning options. When grant funding allows, hand crews, mechanical treatments and fuels chipping will also be made available to private landowners within the valley for creating and maintaining defensible space. Fuels reduction and thinning options will also be pursued for the Greenbelt area within and adjacent to Castle Creek, in the lower valley. Several lots encompassing the Greenbelt are owned by the Town of Castle Valley.

PART I
COMMUNITY DESCRIPTION

Community Legal Structure

List the government entities associated with the community – city, town, unincorporated community, special service district, homeowner association(s), other.

Organization	Contact Person	Phone Number	E-mail
CVFD	Chief Ron Drake	435-259-8588	rimshadow35@gmail.com cvfpa@frontiernet.net
Bureau of Land Management	Jason Kirks	435-259-2194	jkirks@blm.gov
State of Utah, Div. Forestry Fire and State Lands	Ben Huntsman	801-538-5413	benhuntsman@utah.gov
Grand County Fire Warden	Bruce Jenkins	435-220-0179	bjenkins@utah.gov
US Forest Service, Manti-LaSal N.F., Moab Ranger District	Michael Diem	435-259-7155	mdiem@fs.fed.us
US Forest Service, South Zone AFMO/Fuels	Mark Atwood	435-669-4666	matwood02@fs.fed.us
SITLA	Brian Torgerson	435-259-7417	bryantorgerson@utah.gov
Grand County Emergency Manager	Rick Bailey	435-259-8115	rbailey@grandcountysheriff.org
Grand County Council	Greg Halliday	435-259-4606	lasalflintlock@yahoo.com council@grandcountyutah.net
Executive Director, Utah Open Lands	Wendy Fisher	801-463-6156	wendy@utahopenlands.org
CV firefighter/Fire Commissioner/home owner/ CERT representative	Bob Russell	435-259-4561	bobrussell@castlevalleyfire.org
Moab Fire Chief, MFD	TJ Brewer	435- 259-5557	moabfire1@gmail.com
Grand County Weed Supervisor	Tim Higgs	435-259-1369	twhiggs@grandcountyutah.net
Town of Castle Valley Mayor	Jazmine Duncan	435-259-1064	jazmined@castlevalleyutah.com
Plateau Restoration	Tamsin McCormick	435-259-7733	tamsin@frontiernet.net
Grand County Sheriff	Steve White	435-259-8115	swhite@grandcountysheriff.org
State of Utah, Div. Forestry, Fire and State Lands	Jason Johnson	435-259-3762	jasonajohnson@utah.gov

Population	
Approximate number of homes within TCV	291
Approximate number of lots within TCV	443
Approximate number of full-time residents within TCV	319
Approximated number of part-time residents within TCV	100-500
All other residents within the fire district	35
Approximate number of commercial entities within entire fire district	4
Approximate accommodations at Sorrel River Ranch and Red Cliffs Lodge	632
Notes/comments: visitor population is based on people visiting properties/people in the Castle Valley area. Casual tourists passing through the area are not included in the visitor estimate.	

Restricting Covenants, Ordinances, etc. (Attach as appendix) For example, home association bylaws may have requirements regarding building construction materials or vegetation removal, or regarding access in a gated community.	
Source	**Details**
See appendix B	

Access
Directions to community
From Moab, Utah, travel north on route 191 to route 128. Turn east (right) on 128 and drive approximately 17 miles to LaSal Mt. Loop Road/Castleton Rd. Turn South (right), onto Castleton (Loop) Road and drive approximately 1.25 miles to Castle Valley Dr. 1. To enter Castle Valley, turn right on Castle Valley Dr., at the mailbox hub, and enter the town of Castle Valley 2. To enter the area referred to as Castleton; continue on the Castleton (Loop) Rd. for approximately 5 miles. Castleton has no formal entrance but is the collection of homes along the Castleton Rd. A turnoff to the Porcupine Ranch area is to the right, at mp 8.1. The Castleton Road continues up the mountain, to Gateway, Colorado. The LaSal Mountain Loop Road turnoff is to the right, at mp 10.4 , and continues appr. 41 miles to route 191.
All-weather access
Rte. 128, Castleton (Loop) Rd. and Castle Valley Drive as well as all roads at Sorrel River Ranch are all paved. All other roads in the TCV, Redcliffs Lodge etc… are dirt or gravel. Access may also be compromised by a steep hill (Pace Hill) between Hwy. 128 and Castle Valley, which is subject to flooding and ice.
Seasonal access
No restrictions (Note that access may be compromised by seasonal flooding, streambed crossings, mud, snow, ice, rockfalls, and steep slopes, and that certain (rim side) roads within the town of Castle Valley are not maintained/plowed during winter months)

Roads

Reset Option Buttons	None	Some	All	Adequate	Inadequate	% Pavement	% gravel	% dirt
Roads within TCV				X		24	10	66
Roads within Fire Distict (including TCV)				X		55	35	10
Road signs present	☐	☐	☐	X	☐			
Will support normal flow of traffic	☐	☐	☐	X	☐			
Are loop roads	☐	X	☐	☐	☐			

Are dead-end roads		X						
Turnaround space available at end of road for emergency equipment (based on turning radius listed in the guidance document)		X						

Notes/comments:

1. Most will support 40,000# of traffic.
2. Most (95%) roads branch off of Castle Valley Dr. and dead end. There is generally insufficient turn-around space for heavy equipment at the ends of these roads (based on turning radius listed above). The roads that branch west (towards Porcupine Rim) are often steep and difficult to access with emergency equipment, especially in winter as roads within a designated rim zone are unmaintained/unplowed during winter (see Appendix C).
3. The Town of Castle Valley is currently installing 45' radius cul-de-sacs at ends of side roads at a rate of 2 per year.

Driveways

Reset Option Buttons	Adequate	Inadequate	No	Few	Most	All
Most driveways width and height clearance, road grades and vegetation appearance are…	X					
Individual homeowners have posted their name and address	X					

Notes/comments:

1. The width, height clearance, road grade and vegetation appearance for most driveways are generally adequate for emergency equipment, although some lots on steep grades (west rim area) or within drainage areas present compromised access for large equipment.

2. Homeowners have been encouraged to post their name and lot numbers on their driveways, but compliance is incomplete.

Structures						
Reset Option Buttons	None	Few	Some	Many	Most	All
Wood frame construction					X	
Have wood decks or porches					X	
Have wood, shake or shingle roofs		X				
Are visible from the main subdivision road					X	
Notes/comments:						

Bridges, Gates, Culverts, other			
Reset Option Buttons	No	Some	All
Bridges support emergency equipment			X
Gate provides easy access to emergency equipment		X	
Culverts are easily crossed by emergency equipment		X	
Notes/comments: 1. All gates provide easy access to emergency equipment (one gate, at Fire Station 1, eastern end of Shafer Lane extension, is normally locked, as the Shafer Lane extension is not a public road, but designated for emergency and administrative uses only). 2. It is believed that all public culverts adequately support emergency/heavy equipment; although some private culverts may be inadequate.			

Utilities						
Reset Option Buttons	**Below ground**	**Above ground**	**Provided by**	**Phone number**	**% marked with a flag or other highly visible means**	**% utilized**
Telephone service	X	X	Frontier & River Canyon Wireless*	435-259-5157 & 435-259-		
Electrical service	X	X	Rocky Mountain Power	435-259-5920		
Are there homes utilizing propane?	X	X			80%	
Are there homes utilizing natural gas?						
Notes/comments: River Canyon Wireless provides phone service on via wifi See **APPENDIX C** for GIS generated list and map of propane tanks, wells and septic fields (Note that this list is incomplete, as some residents denied access for GIS mapping).						

List locations of propane tanks above ground:		
Owner	**Address, lat/long, etc.**	**Size**
*Notes/comments: See **APPENDIX C** for GIS generated list and map of propane tanks, wells and septic fields (Note that this list is incomplete, as some residents denied access for GIS mapping).*		

Primary Water Sources			
Approximate % homes using central water system		0%	
Approximate %homes using individual wells		95%	
Approximate % homes having additional private water source		5%	
Water provided by		**Phone**	
Notes/comments: The Town of Castle Valley is considering a municipal well and fill station for the future.			

List locations of water sources:		
Owner	**Address, lat/long, etc.**	**Accessible**
Daystar Academy	UTM: 639381 E 4279140 N	Permanent
Daystar Academy	UTM: 639389 E 4278947 N	Intermittent
Daystar Academy	UTM: 639479 E 4278895 N	Intermittent
Pond 1 Green Belt Lot 375 (Zuckerman)	Homestead and Castle Creek Lane UTM: 636323 E 4279990 N	Intermittent
Pond 2 Green Belt (Lot 373) (Jorgen)	Homestead and Castle Creek Lane UTM: 636431 E 4280014 N	Intermittent
Pond 3 Green Belt (Lot 373) (Jorgen)	Homestead and Castle Creek Lane UTM: 636493 E 4280040	Intermittent
Pond 4 (Erley)	Castle Valley Dr. and Holyoak Lane UTM:	Permanent
Pond 5 (R Schwartz)	Just off Loop Rd in Castleton UTM: 645868 E 4274152 N	Permanent
Pond 6 (CFI)	Castle Rock Ranch UTM: 638431 E 4279104 N	Permanent
Pond 7 (BLM)	Daystar Academy Irrigation Storage Pond “Quakey Shake” Castleton Rd. UTM: 642103 E 4277185 N	Permanent
Colorado River	BLM Boat Ramp (“Take-out Beach”)	Permanent
Colorado River	Red Cliffs Ranch Resort Boat Ramp	Permanent

Colorado River	Rocky Rapid Boat Ramp	Permanent
Fire Station 1	Pressurized Irrigation at Driveway	Intermittent
Well (high volume) Castle Valley Fire District	Lot 13 Chamisa Lane	Permanent
Swimming Pool (lot 113) End of Pace Lane	UTM: 638885 E 4277915 N	Permanent
Fire Trailer (lot 365/Upper 80) with pump/foam/hose reel Bob Lippman	Lot 365 Castle Valley Drive (upper 80)	Intermittent
Cistern David Smith Residence	Lot 381 and 382 Homestead Lane	Permanent
Professor Valley Pond	Professor Valley Ranch 1 acre foot pond	Permanent
6000 County Water Tender	Parked at Fire Station 1	Intermittent
*Notes/comments: * Ponds: measure 1000's of gallons; Creeks; measure in cfs during fire season*		

PART II:

RISK ASSESSMENT

Estimated Values at Risk Provide an approximation of the estimated current values of residential and commercial property in the area. The County Assessor should be able to assist with this information.	
Estimated values at risk of commercial and residential property	$103,393,917
Year	2019

Natural Resources at Risk

Describe the natural resources at risk in the area, such as watershed, forest products, wildlife, recreation tourism, etc.

Water Quality: Castle and Placer Creeks have been identified as major recharge sources for the unconsolidated aquifer that provides domestic water, via private wells, to the residents of Castle Valley; the water supply has been officially designated as a Sole Source Aquifer by the US EPA.

Wildlife: The Utah Division of Wildlife Resources has identified areas within the municipal boundaries of the Town of Castle Valley as critical winter habitat for the La Sal Mountain Mule Deer herd. Land within the Town boundaries has been identified by the Utah Division of Wildlife Resources as critical calving grounds for the La Sal Mountain Mule Deer herd. Safeguarding these areas as open lands is essential for protection of wildlife and for the preservation of our rural atmosphere.
Natural resources at risk from wildfire in the Castle Valley planning area vary based on area. Resources at risk and potential fire impacts vary based on the location: Castle Valley Town, the talus slopes, Castle Creek bottom, and the Colorado River bottom.

On the flats in Castle Valley, where most of the homes are located, the primary risk is to life and property. In this highly modified environment there are also natural resources that can be impacted by fire: The patches of trees and shrubs scattered between the homes provide important hiding cover for small animals and nesting and perching sites for birds. Some species, like tamarisk or Russian olive would re-sprout after fire, but other species that reproduce by seed could take a long time to reestablish. Cheatgrass can be found in a number of areas around the valley and can be expected to increase with repeated fire. As cheatgrass increases it displaces native forbs and bunchgrasses and reduces the value of the grasslands to wildlife and other grazers. Increasing cheatgrass also encourages more fire, perpetuating the cycle. Another possible consequence of fire in this area is water contamination. If fire burns through settled areas with storage sheds, trash and debris piles, parked or abandoned vehicles, and other equipment, subsequent rains can carry contamination and contaminate wells and surface waters.

Talus slopes: The talus slopes on either side of the valley are covered with pinyon-juniper forest, sagebrush, and mountain shrubs. The forest provides important hiding cover for deer and other wildlife, as well as nesting and foraging space habitat for birds. Fire in this area could have detrimental effects for soil and slope stability by exposing the soil to the effects of heavy summer rainstorms. In some areas the effect could be positive if small shrubs, grasses, and forbs are released by the removal of the pinyon-juniper overstory. Generally, these plants are better at conserving and protecting the soil than pinyon and juniper because these trees are aggressive competitors for soil moisture and as they increase tend to crowd out understory species. As in the main part of the valley, cheatgrass is present on the talus slopes and could increase with fire.

Creek Bottom: The Castle Creek bottom represents the richest wildlife habitat in the Castle Valley planning area. There is a great diversity of plant life – forbs, reeds, grasses, shrubs and trees of many species. A wide variety of wildlife also uses the creek bottom: Deer, turkey, squirrels, ducks, and a wide variety of perching birds are frequently seen. It is not uncommon to see signs of beavers and a variety of predators including bobcats, coyotes, and even mountain lion. In many areas there are dense fuels that could easily allow fire spread. A primary result of fire in the creek bottom could be a loss of wildlife habitat. Other risks include a possible loss of bank stability leading to increased meandering and soil erosion. Such loss could also lead to increased headcutting upstream. Post-fire many of the species in the creek bottom would re-sprout fairly quickly, including many native shrubs, grasses, sedges, and reeds. The tree component could be negatively affected because non-native invasives like Russian olive and Tamarisk would be expected to re-sprout quickly while native trees like cottonwood and box elder would need to regrow from seed or be planted and protected from browsing deer.

River bottom: The river bottoms along the Colorado River have many of the species and risks found in the Castle Creek river bottom. Similarly, we would expect fire in this area to lead to a loss of wildlife habitat and an increase in soil erosion. Heavy recreational use may inhibit a rapid recovery in some areas along the river. In addition, the river corridor has additional invasive species, including knapweed, whitetop, and various thistles that are not common in Castle Creek. All of these could increase their ranges after fire.

Air quality is also affected by fire. Large, long duration fires can negatively impact the health and quality of life for visitors and residents. Because of the closed valley setting Castle Valley is vulnerable to fire in the La Sal mountains.

The following information is based on the Communities At Risk (CARs) list that was developed cooperatively at the local and state level to assist land management agencies and other stakeholders in determining the scope of the WUI challenge and to monitor progress in mitigating the hazards in these areas. This information is updated annually through the interagency fuel groups. Input the fields that are reflected on the state list found on our website at forestry.utah.gov.

Fire Occurrence: Number of fires in the area for the last 10 years 2009 to present			
	0	**No Risk**	
	1	**Moderate**	**0 to 1 fire/township**
X	**2**	**High**	**2 to 14 fires/township**
	3	**Extreme**	**Greater than 14 fires/township**
Rating			Reset Option Buttons

Area Fire History

Month/Year of fire	Ignition point	Ignition source	Acres burned
5/2000	Lat. 38-40-03 Long. 109-17-09	Lightning	660
6/2003	Lat. 38-35-32 Long. 109-17-27	Lightning	4
6/2003	Lat. 38-35-40 Long. 109-18-31	Lightning	2
5/2003	Lat. 38-49-6 Long. 109-17-03	Human	44
7/2003	Lat. 38-36-5 Long. 109-19-46	Lightning	0.1
6/2006	Lat. 38-37-55 Long. 109-22-01	Lightning	220
8/2007	Lot 43 Lazaris Lane	Lightning	Structure
8/2008	Lat. 38-34-45 Long. 109-19-57	Lightning	3277

2/10/2012	Highway 128 mile 9	Trailer wheels overheated	0
4/19/2012	Sorell River Ranch	Mechanical	0 dryer
5/26/2012	413 Cliffview & beyond	unknown/weather	20 acres Structure/WUI
7/13/2012	Castleton Road #1	Lightning	not known
7/13/2012	Castleton Road #2	Lightning	not known
7/20/2012	Porcupine Ranch Rd.	Lightning	4 trees
7/21/2012	Upper 80	Lightning	1 tree
8/23/2012	Creekside Lane	Human	not known
9/24/2012	Adobe Mesa (Assist USFS)	Lightning	not known
9/1/2013	Upper 80s/BLM	Lightning	Juniper trees
5/30/2014	South Round Mountain	Lightning	1/4 acre
6/15/2014	Mile 13, SR 128	Arson	not known
7/11/2014	Castleton Road	Lightning	Tree
7/15/2014	272 Pope Lane/350 Taylor Lane	Lightning	Single Trees
8/25/2014	Gravel Pit Castleton	Lightning	Tree
9/14/2014	Sorrel River Ranch	Human	Structure/Dryer
1/20/15	399 Cliffview Lane	Mechanical	Power Pole Fire
7/22/15	Daystar Academy	Human	1/4 acre grass
7/23/15	Daystar Academy	Human	grass
8/1/2015	Round Mountain Area	Lightning	1/4 acre
9/1/2015	Dewey Bridge Area	Lightning	Single Tree
2/18/2016	Castleton Road	Mechanical	Power Line Fire
3/22/2016	Hittle Bottom off SR128	Not Known	Tree Fire
4/16/2016	Daystar Academy	Human	not known
5/4/2016	Gateway Road, Willow Basin	Mechanical	Car fire
5/29/2016	SR 128 mile 10	Not Known	.64 acre grass
6/7/2016	Miller Lane	Mechanical	Power Pole Fire
6/12/2016	Daystar Academy	Human	.5 Acre

6/25/2016	Chamisa Lane & CV Drive	Not Known	.01 Acre
10/13/2016	Amber Lane	Human	3 Acres
6/27/2017	Castleton Road	Power Line	3.4 Acres
7/12/2017	SR 128 mile 16	Mechanical	Power Pole Fire
8/4/2017	240 Miller Lane	Lightning	3 Acres
9/14/2017	Shafer Lane	Lightning	Single Tree
12/5/2017	Willow Basin	Chimney Fire	Structure
7/2/2018	395 Castle Valley Drive	Human	1/8 Acre
7/7/2018	331 Keogh Lane	Lightning	not known
7/7/2018	End of CV Drive	Lightning	not known
7/7/2018	Porcupine Rim	Lightning	not known
7/8/2018	Base of Adobe Mesa	Lightning	not known
4/27/2019	Castle Creek Lane	Lightning	Single tree base

Fuel Hazard: Assess the fuel conditions of the landscape and surrounding the community			
	0	**No Risk**	
	1	**Moderate**	Moderate to low to control, fire intensities would generally cause moderate damage to resources based on slope, wind speed and fuel. Vegetation Types: Ponderosa pine/mountain shrub, grassland, alpine, dry meadow, desert grassland, Ponderosa pine, Aspen and mountain riparian.
X	**2**	**High**	High resistance to control, high to moderate intensity resulting in high to moderate damage to resources depending on slope, rate of spread, wind speed and fuel loading. Vegetation Type: Maple, mountain shrubs, sagebrush, sagebrush/perennial grass, salt desert scrub, Black Brush, Creosote and Greasewood.
	3	**Extreme**	High resistance to control, extreme intensity level resulting in almost complete combustion of vegetation and possible damage to soils and seed sources depending on slopes, wind speed, rate of spread and fuel loading.
Rating			Reset Option Buttons

Values Protected: Evaluate the human and economic values associated with the community or landscape, such as homes, businesses and community infrastructure.			
	0	**No Risk**	
	1	**Moderate**	Secondary Development: This would be seasonal or secondary housing and recreational facilities.
X	**2**	**High**	Primary Development: This would include primary residential housing, commercial and business areas.
	3	**Extreme**	Community infrastructure and community support: This would be water systems, utilities, transportation systems, critical care facilities, schools manufacturing and industrial sites. It may also include valuable commercial timber stands, municipal watersheds and areas of high historical, cultural and/or spiritual significance which support and/or are critical to the well-being of the community.
Rating			Reset Option Buttons

Insurance Rating Provide the current insurance rating for the community	
ISO Fire Insurance Rating:	

Protection Capabilities: Insurance Services Organization (ISO) rating for the community will serve as an overall indicator of the protection capabilities.			
	1	**Moderate**	**ISO Rating of 6 or lower**
X	**2**	**High**	**ISO Rating 7 to 9 (rated at 8b)**
	3	**Extreme**	**ISO Rating 10**
Rating			Reset Option Buttons

Fire Occurrence	**Fuel Hazard**	**Values Protected**	**Fire Protection Capabilities**	**Overall Rating**
				8b
Total: 4-7 Moderate, 8-11 High, 12 Extreme				

The following information is based on the Utah Wildfire Risk Assessment Portal (UWRAP) and Area of Interest (AOI) Summary Reporting Tool. Reports are generated using a set of predefined map products developed by the West Wide Wildfire Risk Assessment (2012) project. The UWRAP provides a consistent, comparable set of scientific results to be used as a foundation for wildfire mitigation and prevention planning in Utah.

Wildland Development Area (WUI) Impacts: Data set is derived using a Response Function modeling approach. To calculate the Wildland Development Area Impact Response Function Score, the Wildland Development Area housing density data was combined with flame length data and Response Functions assignments to represent potential impacts.

Wildfire Threat: A number that is closely related to the likelihood of an acre burning.

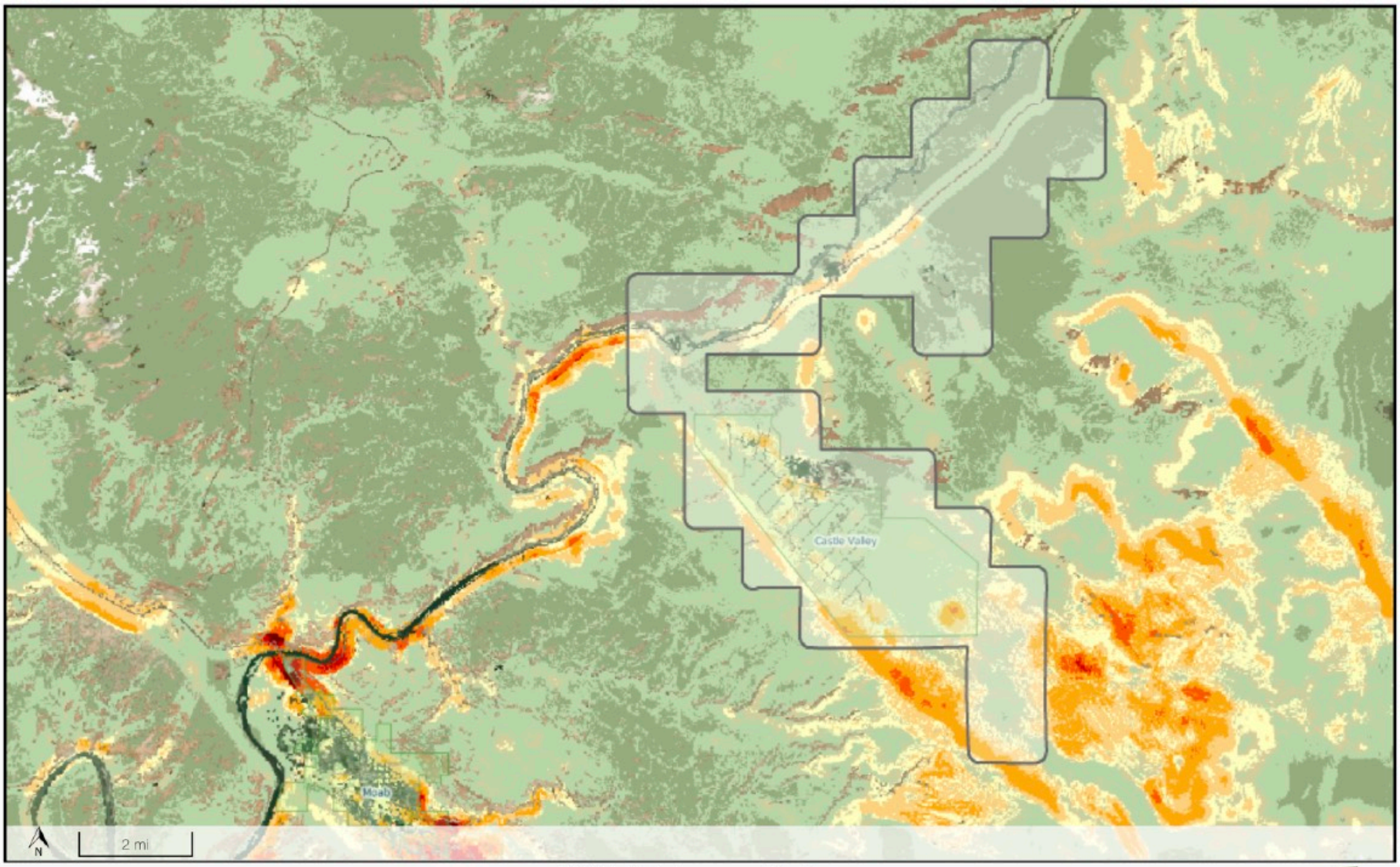
Wildfire Risk: Combines the likelihood of a fire occurring (Threat), with those of areas of most concern that are adversely impacted by fire (Fire Effects). Wildfire Threat Index is derived from historical fire occurrence, landscape characteristics including surface fuels and canopy fuels, percentile weather derived from historical weather observations and terrain conditions. Fire Effects are comprised of Value Impacts and Suppression Difficulty.

	Total Acres AOI for each Category with the percentages added		
	Wildfire Risk	**WUI Impacts**	**Wildfire Threat**
Low (1-4)	*21,5297/81.7%*	*1532/86.4%*	*22303/84.7%*
Moderate (5-7)	*4784/18.2%*	*231/13%*	*4025/15.3%*
High (8-10)	*14/.1/5*	*12/.7*	*0/0%*

Including maps from the UWRAP report may also be beneficial in this section. Consider using the following as an example. ***See Appendix for other maps***

- Location Specific Ignitions
- Ignition and Fire occurrence density
- Water Impacts
- Rate of Spread
- Suppression Difficulty
- Fire Effects

CV District Widlfire Risk 2019



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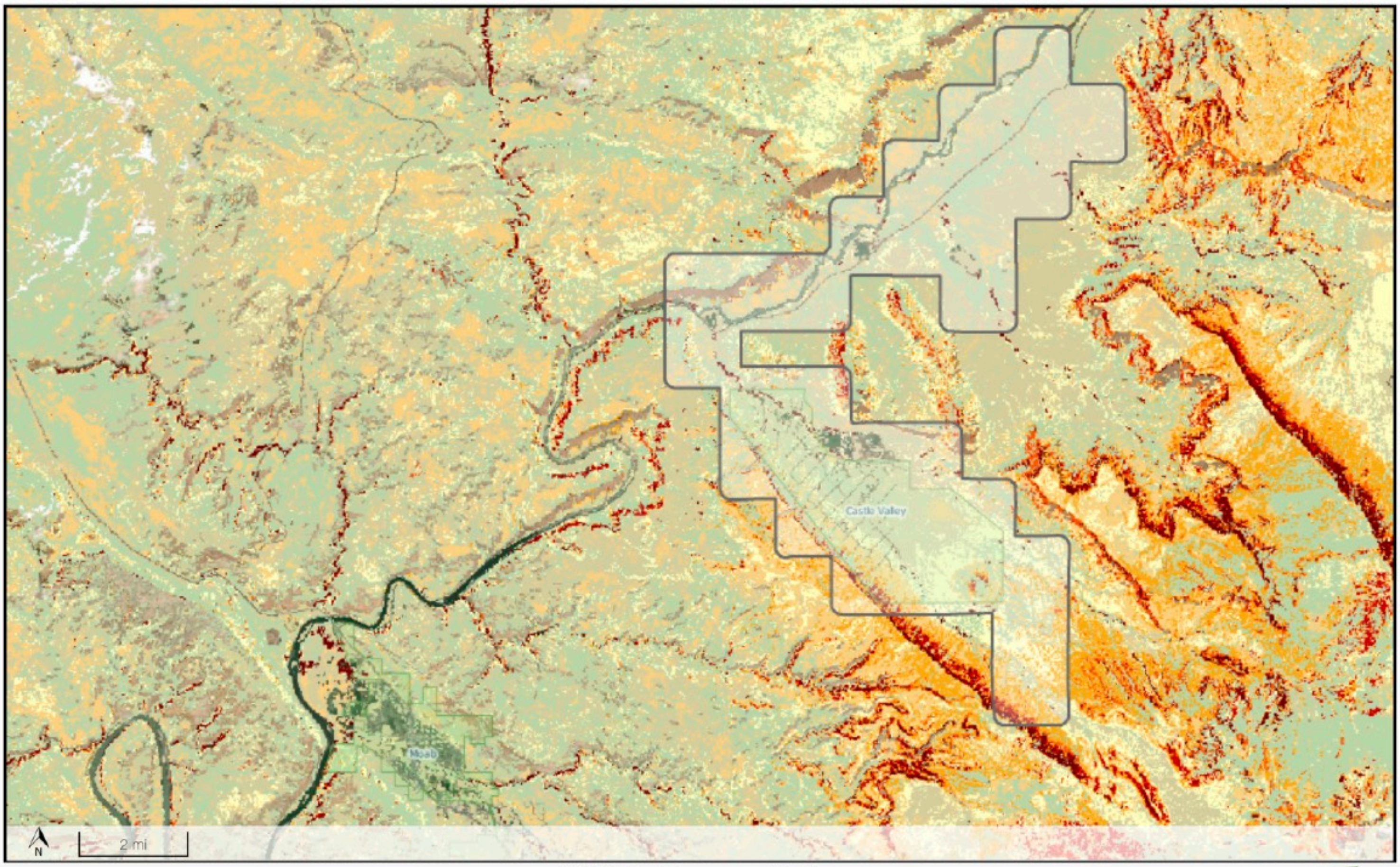
Wildfire Risk Assessment Portal
http://utahwildfirerisk.utah.gov

Wildfire Risk

Rate of Spread - Expected

- Urban, Agriculture, Barren or Water
- Very Low < 5.5 ft. / min.
- Low 5.5 to 10.9 ft. / min.
- Low - Moderate 11.0 to 16.4 ft. / min.
- Moderate, 16.5 to 21.9 ft. / min.
- Moderate - High 22.0 to 32.9 ft. / min.
- High 33.0 to 43.9 ft. / min.
- Very High 44.0 to 54.9 ft. / min.
- Extreme >= 55.0 ft. / min.

CV District Rate of Spread Expected 2019



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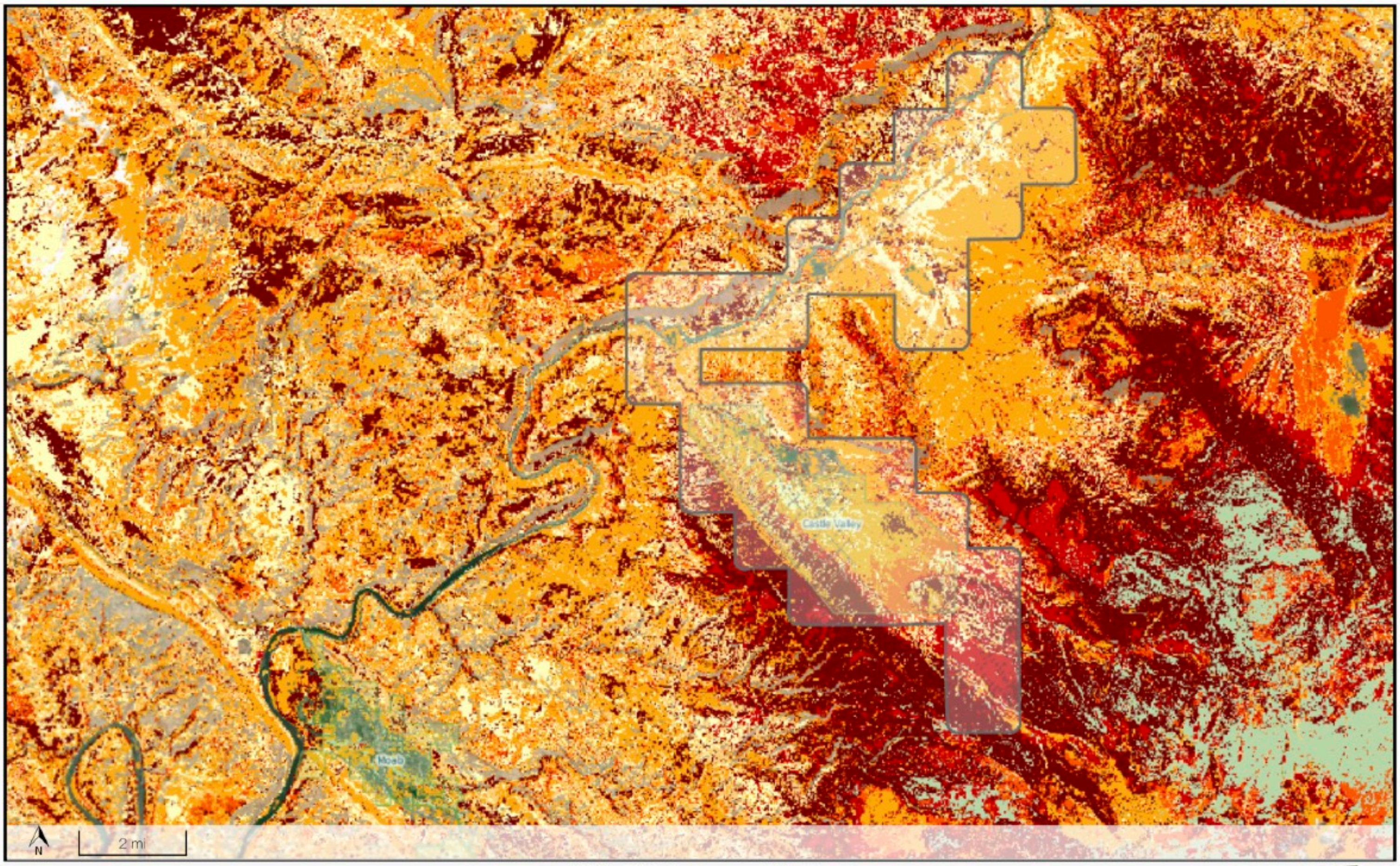
Wildfire Risk Assessment Portal
http://utahwildfirerisk.utah.gov

UTAH DNR FORESTRY

Rate of Spread - High

- Urban, Agriculture, Barren or Water
- Very Low < 5.5 ft. / min.
- Low 5.5 to 10.9 ft. / min.
- Low - Moderate 11.0 to 16.4 ft. / min.
- Moderate 16.5 to 21.9 ft. / min.
- Moderate - High 22.0 to 32.9 ft. / min.
- High 33.0 to 43.9 ft. / min.
- Very High 44.0 to 54.9 ft. / min.
- Extreme >= 55.0 ft. / min.

CV District Rate of Spread High 2019



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Wildfire Risk Assessment Portal
http://utahwildfirerisk.utah.gov

Past Accomplishments	
Prevention	• *Recognized nationally as a Firewise Community (2004).* • *Formed an active CWPP committee that meets once a month, composed of residents, Mayor and Fire Dept. (2014).*
Preparedness	• *Completed a community wildfire protection plan (CWPP) in 2011.* • *FEPP acquisition for fire department including a five ton truck was converted to a wildland fire engine in 2016* • *Training in wildland firefighting including S-190, S-130* • *Annual Refresher course for firefighters by Fire Warden (RT-130)*
Mitigation	• *Secured a $300,000 Western States Fire Assistance (SFA) grant in 2013 for mitigation and education purposes. Funds were directed towards vegetation projects; nearly 40 acres have been treated so far. Grant targets a total of 236 acres.* • *Since 2014, community has contributed approximately $60,000 of in-kind service, including organizing the LDS youth conference in 2014 to help with fuels mitigation.* • *Davis property and east exit access improved (2014).* • *Bi-annual community Chipper Day participation with roughly 75 properties participating.* • *City has evaluated over 70% of the lots for compliance of vegetation code.* • *Town of Castle Valley Hazard Mitigation Plan completed in 2015*
Maintenance	• *Provide Chipper day bi-anually for residents to maintain their defensible spaces.*
Prevention	• *Completed 15 lot assessments for residents in 2017 (everyone had an opportunity for assessments).*
Mitigation	• *Removal and treatment of Russian olive and tamarisk along Castle Creek as part of larger effort to reduce these invasive along the Colorado River and its tributaries.*
Prevention	• *Hosted FFSL defensible space disscussion-WUI coordinator presented to the community in May 2018*
Prevention	• *Publish a quarterly newsletter that is distributed to residents 8/2016 to present. Contains tips and info about preventing wildfire.* • *Created a Castle Valley Fire Department website in 2015* • *Started an annual 4th of July event to help provide education on preventing fires in 2018.* • *Started providing community conversations about defensible spaces around homes 2019*

PART III:
RISK REDUCTION GOALS/ ACTIONS

Goals of Plan: Provide a brief statement under the Prevention, Preparedness, Mitigation and Maintenance goals. These should align with the pillars of the National Cohesive Strategy and the Utah Catastrophic Wildfire Reduction Strategy (1. Resilient Landscapes 2. Fire Adapted Communities 3. Wildfire Response).

Identification of Actions: Provide detailed project information. These projects/actions can be mapped/tracked in the Utah WRA portal and should be consistent with a Cooperative Agreement in compliance with the Wildfire Policy if applicable.

GOAL A: PREVENTION – Activities directed at reducing the occurrence of fires, including public education, law enforcement, personal contact.

Goal A.1 –			
Action(s):	**Timeline:**	**Community Lead:**	**Priority:**
Private property – Implement 'The Defensible Space Checklist' from Utah Living with Fire Homeowner Guide; ***(See Appendix M)*** *Creation of a property assessment team with firefighters and community members being trained to perform property firewise assessments.*	Ongoing and in planning stages	Private Landowners, FFSL, Castle Valley Fire Dept. (CVFD), Town CV (TCV)	High
Encourage through education firewise landscaping, vegetation and grasses into green spaces and private property where possible (with ecological emphasis on native vegetation).	Ongoing	CVFD, TCV	High
Smokey Sign showing degrees of fire danger within Town limits	Ongoing	CVFD	High
Seek funding resources and in-kind matching for implementation of the above actions	Ongoing	FFSL, CV Fire Commission (CVFC)	High

<u>GOAL B: PREPAREDNESS</u> – Activities that lead to a state of response readiness to contain the effects of wildfire to minimize loss of life, injury, and damage to property. Including access to home/community, combustibility of homes/structures and creating survivable space.

Goal B.1 – Evaluate, upgrade and maintain community wildfire preparation			
Action(s):	**Timeline:**	**Community Lead:**	**Priority:**
Create cul-de-sac turnarounds for all side roads	Ongoing	TCV	High
Annual RT130 refresher course for firefighters	Annually	Fire Warden	High
Notes, updates ,and monitoring			

Goal B.2 – Educate community members to prepare for and respond to wildfire.			
Action(s):	**Timeline:**	**Community Lead:**	**Priority:**
Provide community events eg. Gourd Festival, July 4th to learn about Firewise, emergency evacuation procedures ect…	Ongoing	CVFD, Fire Commission	High
Discussions on Emergency Evacuation Procedures for Town and District	2019	CVFD, Fire Commission, TCV	High
See Appendix O for evacuation procedures in TCV. Still working on evacuation procedures for rest of fire district.			

Goal B.3 – Address identified regulative issues impacting community wildfire prevention and response needs.			
Action(s):	**Timeline:**	**Community Lead:**	**Priority:**
Assess current regulations for updates or additions	2019	Fire Com-mission, TCV	High
Fire Commission to pass resolution or SOG to Maintain CWPP every 1-2 years	2019	CV Fire Commission	High
Notes, updates ,and monitoring			

Goal B.4 – Evaluate response facilities and equipment.			
Action(s):	**Timeline:**	**Community Lead:**	**Priority:**
Assess and Update Firefighting equip. as necessary	Ongoing	Fire Commission	High
Lot 13 Development	Ongoing	Fire Commission	Low
Notes, updates ,and monitoring: Replaced water tender in April 2019. Started (2019) building an air compressor system to provide all engines with continuous air directly for faster brake fill and faster response time.			

<u>GOAL C: MITIGATION</u> – Actions that are implemented to reduce or eliminate risks to persons, property or natural resources including fuel treatments and reduction.

Goal C.1 – Decrease fuels within the community to reduce wildfire impact in and around the community.			
Action(s):	**Timeline:**	**Community Lead:**	**Priority:**
Bi-annual Chipper day for residents to reduce fuels on their property	ongoing	CVFD, FFSL	High
Provide standby help for private land owners to burn weeds etc… in spring and fall	ongoing	CVFD	High
Provide complete mowing of lot 13 owned by Fire District	ongoing	CVFD	High
Cooperate with private landowners to maintain and expand shaded fuel breaks and "brush outs" along existing roadways, fence lines, and natural and existing fuel breaks	Ongoing	TCV, CVFD, private landowners	High
Plan for volunteer maintenance of green belt treatment areas on private and town-owned land; (See Appendices D, J)	Ongoing	Private landowners, TCV, CVFD	High
Provide semi-annual chipper events for private landowners within Castle Valley	Semi-Annual	FFSL, private landowners, CVFD	High
Implement a weed mitigation/control program	Ongoing	TCV, CVFD, BLM, Grand County	High
Provide roadside mowing of weeds	Ongoing	TCV	High
Notes, updates ,and monitoring			

Goal C.2 – Work with local, state and federal fire officials to decrease fuels on private and adjacent public lands to reduce wildfire intensity and impact in and around the community.			
Action(s):	**Timeline:**	**Community Lead:**	**Priority:**
BLM Fuel reduction project in Round Mountain Area	Fall 2019	BLM	High
BLM Mowing of Town/BLM Boundaries	Spring 2019	BLM/TCV	High
Notes, updates ,and monitoring			

<u>GOAL D: MAINTENANCE</u> – the process of preserving actions that have occurred including fuel treatments and reduction.

Goal D.1 - Regularly evaluate, update and maintain project commitments.			
Action(s):	**Timeline:**	**Community Lead:**	**Priority:**
Review all mitigation projects and reassess	Annually	Fire Commission	High
Maintain work in greenbelt	Annually	Volunteers	High
Notes and updates			

PART IV:
CONTACTS

The contacts in this part identify community resources that can be used to complete the goals of the plan.

Planning Committee Member List			
Name	**Affiliation**	**Phone Number**	**E-mail**
Bob Lippman	CVFD, Former Commissioner, CV Resident	435-259-1182	bob.Lippman@nau.edu
Ron Mengel	CVFD, Former Commissioner, CV Resident	435-259-6726	rmengel@frontiernet.net
Ron Drake	Castle Valley Fire Chief and homeowner, media representative (Times Independent)	435-259-8588	rimshadow35@gmail.com
Bob Russell	Castle Valley Fire Commissioner, firefighter, CERT Team and CV Resident	435-259-4561	bobrussell@castlevalleyfire.org
Leta Vaughn	Castle Valley Fire Commissioner, firefighter, and CV Resident	435-259-2364	letavaughn@castlevalleyfire.org
Mitch Stock	Castle Valley Fire Commissioner, firefighter, and CV Resident	435-259-8508	mitchstock@castlevalleyfire.org
Jason Kirks	BLM	435-259-2184	jkirks@blm.gov
Jason Johnson	FFSL	435-259-3762	jasonajohnson@utah.gov
Bruce Jenkins	Grand County Fire Warden	435-220-0179	bjenkins@utah.gov
Ben Huntsman	FFSL	801-538-5413	benhuntsman@utah.gov
Rick Bailey	Grand County Emergency Manager	435-259-8115	rbailey@grandcountysheriff.org
Steve White	Grand County Sheriff	435-259-8115	swhite@grandcountysheriff.org
Jazmine Duncan	Mayor of Castle Valley	435-259-9828	jazmined@castlevalleyutah.com
Greg Halliday	Grand County Council	435-259-4606	council@grandcountyutah.net

Tim Higgs	Grand County Weed Supervisor	435-259-1369	twhiggs@grandcountyutah.net
Wendy Fisher	Executive Director, Utah Open Lands	801-463-6156	wendy@utahopenlands.org
Tamsin McCormick	Plateau Restoration	435-259-7733	tamsin@frontiernet.net

Commercial Entities				
Organization	**Contact Person**	**Phone Number**	**E-mail**	**Address**
Red Cliffs Lodge	Colin Fryer	435-259-2002 435-259-7077	info@redcliffslodge.com	Mile 14, Hwy. 128
Sorrel River Ranch	Dave Ciani	435-259-4642	stay@sorrelriver.com	HC64 Box 4002 Mile 17, Hwy. 128
Castle Valley Inn	Jason & Janette Graham	435-259-6012	info@castlevalleyinn.com	HC64 Box 2602 425 Amber Ln.
Mayberry Preserve	Kara Dowerend	435-259-6670	info@reveg.org	Mile 15, Hwy. 128

Formal Associations			
Organization	**Contact Person**	**Phone Number**	**E-mail**
Castle Valley Volunteer Fire Department	Ron Drake (Chief)	435-259-8588	rimshadow35@gmail.com
Day Star Academy/Seventh Day Adventist Community Farm	RandyWard	435-259-7719	daystar_academy@frontiernet.net
Castle Valley Water Company (Greenbelt)	Ken Drogin	435-259-4838	
LDS Church	Ron Drake	435-259-8588	rimshadow35@gmail.com
Grand County Library/CV Branch	Jenny Haraden	435-259-9998	jenny@moablibrary.org

Media Support			
Organization	**Contact Person**	**Phone Number**	**E-mail**
Moab TI	Zane Taylor	435-259-7525	zane@moabtimes.com
Moab Sun News	Heila Ershadi	435-259-6261	publisher@moabsumnews.com
KZMU Radio	Sarah Mead	435-259-8824	program-director@kzmu.org
KCYN Radio	General Office	435-259-1035	kcyn@kcynfm.com

Schools				
School	**Contact Person**	**Phone Number**	**E-mail**	**Address**
Daystar Academy	Randy Ward	435-259-7719	daystar_academy@frontiernet.net	Castleton Rd. (La Sal Mt. Loop Rd)

Transportation			
Organization	**Contact Person**	**Phone Number**	**E-mail**
Town of CV Road Dept.	Mingo Gritts	435-260-0871	mingog@castlevalleyutah.com
Grand County Road Dept.	Bill Jackson	435-259-5308	bjackson@grandcountyutah.net
UDOT	Chet Johnson	801-965-4000	cejohnson@utah.gov

Private Equipment Capabilities				
Type of Equipment	**Contact Person**	**Phone Number**	**E-mail**	**Address**
See Appendix A				

Other			
Organization	**Name**	**Phone Number**	**E-mail**

APPENDIX

Appendix A:

Contents:

Private Equipment List For Emergency Use	

Appendix B:

Contents:

Municipal and County Ordinances	

Appendix C:

Contents:

Maps	

Appendix D:

Contents:		
	Firewise Project Data	

Appendix E:

Contents:		
	Emergency Water Access Plan	

Appendix F:

Contents:		
	Sole Source Aquifer Protection & Protocol	

Appendix G:

Contents:		
	Fire History	

Appendix H:

Contents:		
	UWRAP Report on Fire District Risk Eval.	

Appendix I:		
Contents:	Wildfire Hazard Lot Assessments that have been completed	

Appendix J:		
Contents:	Fuel Modification Projects	

Appendix K:		
Contents:	Pre-Attack Plan	Not Finished

Appendix L:		
Contents:	Grand County Wildland Mobilization Plan	Needs updating

Appendix M:		
Contents:	Firewise “10 steps” List	

Appendix N:		
Contents:	Emergency Personnel Roster	

Appendix O:		
Contents:	Fire District Evacuation Plans	Areas Beyond Castle Valley need to be added

Appendix P:		
Contents:	Monthly In-kind Tracking Forms	

Appendix Q:		
Contents:	Miscellaneous Firewise and Other Forms	

Appendix R:		
Contents:	Firewise USA Membership	

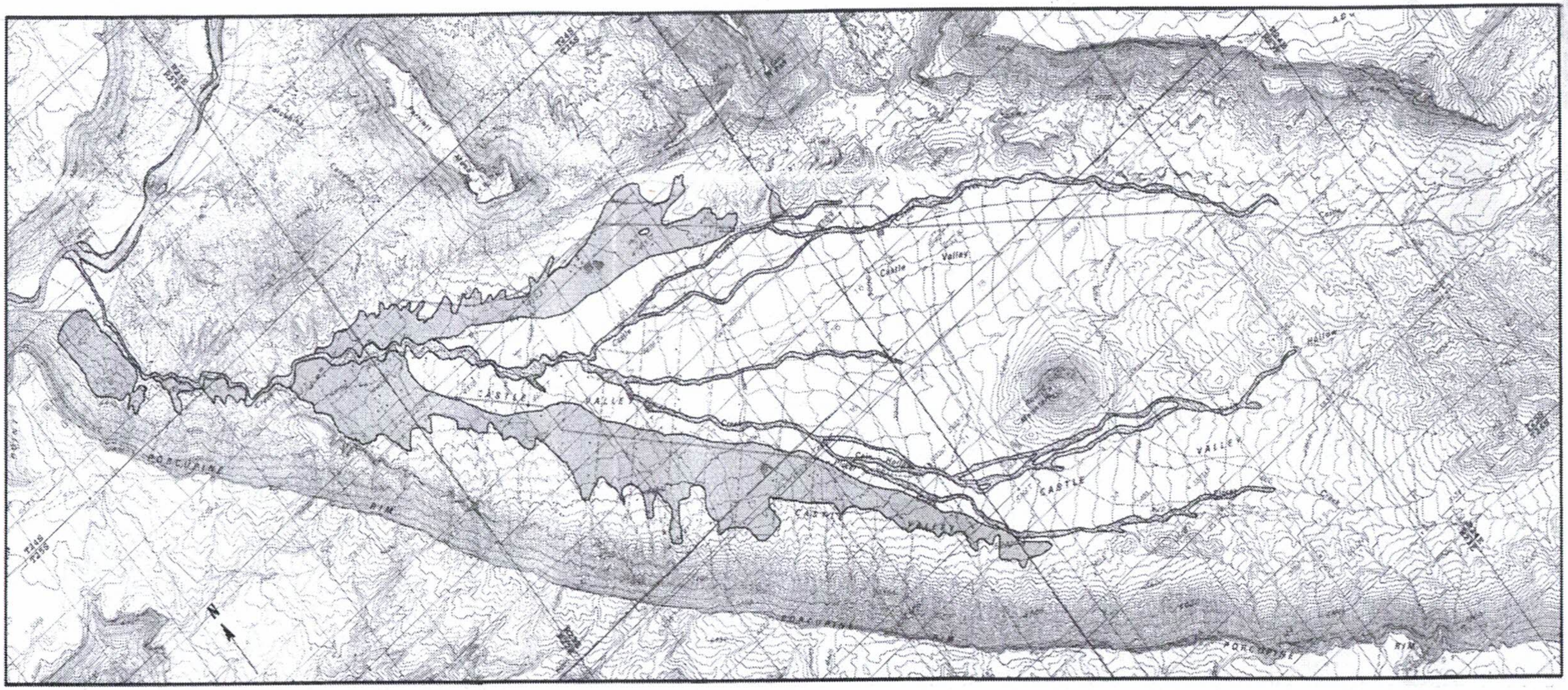
Appendix S:		
Contents:	Miscellaneous Watershed Studies & Reports	

Appendix T:		
Contents:	Utah Wildland-Urban Interface Code	

Appendix U:		
Contents:	Emergency Downed Powerline Procedures & PCB Spill Clean Up Procedures	

Appendix V:		
Contents:	Cooperative Agreement Between The Utah Division of Forestry, Fire and State Lands and Grand County Service Area for Castle Valley Fire Protection	

Appendix FL-1



ALLUVIAL-FAN FLOODING, STREAM FLOODING, DEBRIS-FLOW HAZARDS, AND COLLAPSIBLE SOIL IN CASTLE VALLEY, GRAND COUNTY, UTAH

Utah Geological Survey
Open-File Report 238
Plate 2

By

William E. Mulvey

SCALE 1:24000

CONTOUR INTERVAL 40 FEET

Explanation

Alluvial-fan/debris-flow-flood-hazard areas and collapsible soil.

Stream-flooding-hazard areas.

Hazard map based on unpublished geologic mapping by M.L. Ross and H.H. Doelling.

Base map from USGS 1:24,000 scale topographic maps of Big Bend, Warner Lake, Fisher Towers, and Rill Creek.

DISCUSSION

Flooding in Castle Valley results from cloudburst storms and spring snowmelt. Localized, high-intensity, convective-type thunderstorms centered over tributary areas are most effective in generating alluvial-fan flooding, stream flooding, and debris flows in areas like Castle Valley. Such storms, which last from a few minutes to several hours, generally occur between mid-April and September. Cloudburst thunderstorms are generally characterized by high peaks, high velocity, short duration, and small volume of runoff. The flooding potential of cloudburst rainstorms is dependent upon many factors including: 1) the intensity or amount of rainfall per unit time, 2) the duration or length of time of rainfall, 3) the distribution of rainfall and direction of storm movement over a drainage basin, 4) soil characteristics, 5) antecedent soil-moisture conditions, 6) vegetation conditions, 7) topography, and 8) drainage pattern. Because many of these conditions are generally not known until rain is actually falling on critical areas, the magnitude of flooding from a given cloudburst storm is difficult to predict. Snowmelt floods are characterized by large volume runoff, moderately high peak flows, and marked diurnal fluctuation in flow. They are somewhat predictable because flood levels depend primarily on the volumes of snow in the mountains and temperature. Whether generated by cloudburst storms or snowmelt, three types of flooding may result: (1) alluvial-fan flooding, (2) stream flooding, and (3) debris flows.

Alluvial-fan flooding occurs with little advance warning and can be quite severe and damaging with unpredictable flow paths. Cloudburst storms cause most alluvial-fan flooding, generating high velocity flows that may occupy several different channels on the fan surface at once. These floods can erode some channels and deposit large volumes of sediment in others. Flood waters on alluvial fans can contain large amounts of sediment as suspended and bed loads, including boulders and cobbles.

As with alluvial-fan flooding, stream flooding in Castle and Placer Creeks is caused by cloudbursts as well as seasonal snow- melt. However, the primary cause is rapidly melting snow, usually from late April to early July. Snowmelt floods are characterized by large volume runoff, moderately high peak flows, and marked diurnal fluctuation in flow. They are somewhat predictable because flood levels depend primarily on the volumes of snow in the mountains and temperature. Flood waters are generally contained within the channels of Placer and Castle Creeks, which are incised to depths of 10 to 30 feet (3 to 10 meters).

Debris flows are mixtures of water, rock, soil, and organic material (70-90 percent solids by weight; Costa, 1984) that form a muddy slurry much like wet concrete, and flow downslope due to gravity, commonly in surges or pulses. They generally remain confined to perennial or ephemeral stream channels in mountainous areas, but may reach and deposit debris over large areas on alluvial fans at and beyond canyon or drainage mouths.

Debris flows can form in at least two different ways: (1) heavy precipitation during cloudburst storms, and (2) directly from debris slides. In the La Sal Mountains and Castle Valley, cloudburst rainstorms are common. Runoff from these storms can scour materials from the ground surface and stream channels, increasing the proportion of soil materials to water until the mixture becomes a debris flow. The size and frequency of debris-flow events generated by rainfall depend on several factors including the amount of loose material available for transport, the magnitude and frequency of the storms, the density and type of vegetative cover, and the moisture content of the soil.

Debris flows also mobilize from debris slides. A debris slide is a type of landslide involving predominantly coarse-grained debris, chiefly colluvium. A debris flow may be generated when the debris slide reaches a stream, or when the water content is increased by some other means until sufficient to flow. Rapid melting of snow during the spring can also increase water content in soils enough to cause debris slides and flows.

Collapsible soils are subject to volume reductions that can damage overlying structures. They are chiefly debris-flow, loess, and alluvial-fan deposits. When wetted for the first time following deposition, collapsible soils lose the internal bonds holding them together, causing the ground surface to subside or collapse. Alluvial fans on the southwestern side of Castle Valley, that are subject to and mapped as debris-flow and alluvial-fan-flood-hazard areas can also be an environment favorable for collapsible soils. Collapsible soils are common in Utah, particularly in alluvial fans with shale in their source areas. The Moenkopi and Chinle Formations contain shale, and contribute sediments to alluvial fans in southwestern Castle Valley.

This hazard map shows areas where alluvial-fan-flooding, stream-flooding, and debris-flow hazards and collapsible soils may occur. The map is designed to show potential hazard areas for planning purposes only. In mapped hazard areas, site-specific studies are needed to evaluate hazards and, if necessary, recommend hazard-reduction measures. The studies must be prepared by qualified professionals (engineering geologists, geotechnical engineers, hydrologists). Because of the relatively small scale of the maps (1:24,000), the possibility exists that some small hazard areas are not shown; studies are therefore recommended for critical facilities even outside the hazard areas.

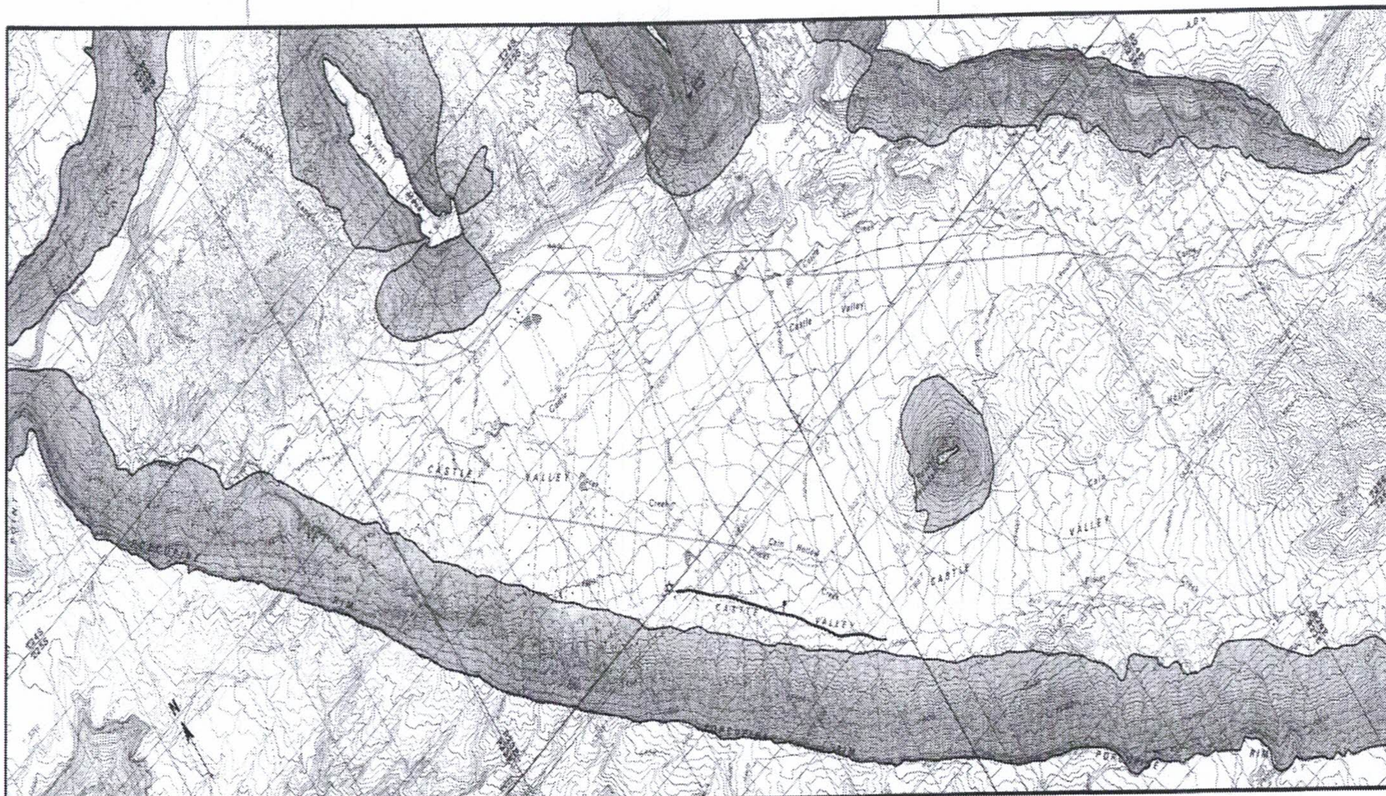
Appendix FL-2

Castle Valley Drive consists of 3.64 miles of pavement (chip seal x 2) and there are 14 miles of additional dirt and gravel roads. There is a single 10-foot culvert at Castle Creek and Castle Valley Drive, a 10-foot and two 6-foot culverts at Castle Creek and Willoughby Way. There are 5-foot culverts on Placer Creek and Buchanan Lane, Placer Creek and Shafer Lane and Placer Ditch and Miller Lane. There are 3-foot culverts under or parallel to Castle Valley Drive at Amber Lane, Chamisa Lane, Rimshadow, Lazaris, Bailey, Pace, Buchanan, Shafer, Miller, Pope and Holyoak Lanes. As well as 3-foot culverts under other sections of all of the above-mentioned roads to also include Rimrock, Castle Creek, Homestead, Cliffview, Keogh and Taylor Lanes. Additionally, there are numerous culverts that have silted up or are undersized and currently nonfunctional. Originally the ranch that preceded the town had four retention ponds to catch runoff, one located at the eastern end of Pope Lane, one west and north of Castle Valley Drive and Holyoak Lane, one between Buchanan and Shafer Lanes east of Castle Valley Drive on historic Placer Creek drainage and between Bailey and Lazaris Lanes west of Castle Valley drive. All check dams have either been silted in or breeched with the exception of the one between Holyoak and Pope Lanes west of Castle Valley Drive, which is still functional. Two 3 foot culverts one on Placer Creek in the upper eighty at lots 359 and 358 and one on the connector portion of Castle Valley Drive at Placer Creek were washed out or are nonfunctional due to damage by severe storm water events. These two areas are now subject to periods of road closure, until repairs can be made.

Appendix FL-3

The area from east Holyoak to east Buchanan Lanes is relatively flat and is the historic flood plain for Castle and Placer Creeks. There are numerous former channels that these creeks have made in the past. Placer Creek was diverted into a manmade ditch from lot 328 alongside the Bureau of Land Management fence northeast to lot 277 then north to lot 242/233 into a 5 foot culvert under Miller Lane thence across lots 232 and 203 to a 5 foot culvert under Shafer Lane to another 5 foot culvert under Buchanan Lane to lot 369 (Town of Castle Valley, greenbelt lot) to Castle Creek. Should runoff flow exceed the capacity of this ditch, floodwaters have and may breech the berm at lot 328/308 and proceed into the historic Placer Creek channel. This channel can no longer handle the water from Placer Creek, as there is not a culvert across Holyoak and the culverts under Pope, Miller, Shafer and Buchanan Lanes are not sufficient to handle Placer Creek storm water runoff anymore.

Appendix R-1



ROCK-FALL AND SURFACE-FAULT-RUPTURE HAZARDS IN CASTLE VALLEY, GRAND COUNTY, UTAH

Utah Geological Survey
Open-File Report 238
Plate 3

By

William E. Mulvey

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET

Hazard map based on unpublished geologic mapping by H.L. Ross and H.H. Doelling.

Base map from USGS 1:24,000-scale topographic maps of Big Bend, Warner Lake, Fisher Towers, and Rill Creek.

Explanation

Rock-fall-hazard areas.

Area of possible surface fault rupture (bar and ball on downthrown side of fault) and sinkhole formation.

Sinkhole.

DISCUSSION

Rock falls originate when erosion and gravity dislodge rocks from cliffs or slopes. In Castle Valley, cliffs of Triassic-age Wingate Sandstone are the most common rock-fall source. The most susceptible cliffs are those with outcrops broken by bedding surfaces, joints, or other discontinuities that break rock into loose fragments, clasts, or slabs. Rocks in talus and cliffs may dislodge, fall onto steep slopes, and travel great distances by rolling, bouncing, and sliding.

Weathering and freeze-thaw in outcrop discontinuities is responsible for triggering most rock falls. In addition, rock falls can be initiated by earthquakes of magnitude 4.0 or larger.

The region is one of low historical earthquake activity. In general, earthquakes in the Colorado Plateau are small to moderate magnitude, and occur infrequently. The strongest recorded earthquake in the area occurred on February 1, 1967 (magnitude 3.8) near Upheaval Dome in northern Canyonlands National Park.

The surface-fault-rupture hazard is low because no active faults with evidence for Holocene or late Pleistocene activity are present in Castle Valley. However, in the southeastern part of Castle Valley there is a fault of suspected Quaternary age. This fault could have a tectonic origin, but is most likely related to salt dissolution beneath Castle Valley. Although improbable during 50-100 year time frames, surface rupture is possible on this fault. In addition, the sinkhole at the northwest end of the fault indicates dissolution or piping along the fault zone. Such sinkholes may develop elsewhere along the fault in the future, particularly if water is introduced into the zone.

This hazard map shows areas where site-specific studies concerning rock-fall hazards are recommended prior to development. The map is designed to show potential hazard areas for planning purposes only. Site-specific studies should evaluate hazards and, if necessary, recommend hazard-reduction measures. The studies must be prepared by qualified professionals (engineering geologists, geotechnical engineers). Because of the relatively small scale of the maps (1:24,000), the possibility exists that some small hazard areas are not shown; studies are therefore recommended for critical facilities even outside the hazard areas.

Appendix WC-1

From: Janae Wallace [janaewallace@utah.gov]
Sent: Wednesday, September 29, 2010 10:16 AM
To: townofcastlevalley@frontiernet.net
Subject: Sole Source Aquifer for the Castle Valley Aquifer System, Castle Valley, UT for Ron M.

Sole Source Aquifer Determination for the Castle Valley Aquifer System, Castle Valley, UT

Note: EPA no longer updates this information, but it may be useful as a reference or resource.

[Federal Register: August 6, 2001 (Volume 66, Number 151)]
[Notices]
[Page 41027-41029]
From the Federal Register Online via GPO Access [wais.access.gpo.gov]
[DOCID:fr06au01-80]

ENVIRONMENTAL PROTECTION AGENCY
[FRL-7024-2]

Sole Source Aquifer Determination for the Castle Valley Aquifer System, Castle Valley, UT

AGENCY: Environmental Protection Agency (EPA).
ACTION: Notice of final determination.

SUMMARY: Pursuant to section 1424(e) of the Safe Drinking Water Act, the Regional Administrator of the U.S. Environmental Protection Agency (EPA) in Region VIII has determined that the Castle Valley Aquifer System, at Castle Valley, Utah and the immediately adjacent recharge area is the sole or principal source of drinking water for the region. The Castle Valley Aquifer System consists of undifferentiated Quaternary valley-fill deposits and the underlying Cutler Formation. The aquifer is located in southeastern Utah extending from the Town of Castle Valley, Utah southeast to the La Sal Mountains and northwest to the Colorado River encompassing approximately 24,000 acres in parts of Township 24 South, Ranges 22, 23, and 24 East and parts of Township 25 South, Ranges 22, 23, and 24 East SLB&M. The area is irregularly shaped with maximum dimensions of about 16 miles from southeast to northwest and approximately 3 miles from northeast to southwest. The entire area is within Grand County, Utah. No reasonable alternative sources of drinking water with sufficient supply exist to meet the needs of this area because of the complexity and limitations of water rights in

southeastern Utah. A significant hazard to public health would occur if this aquifer becomes contaminated.

The boundaries of the designated area have been reviewed and approved by EPA. As a result of this action, federal financially assisted projects constructed in the approximately 50 square mile area mentioned above will be subject to EPA review to ensure that these projects are designed and constructed in a manner which does not create a significant hazard to public health. For the purposes of this designation the Aquifer Service Area and the Project Review Area are the same as the Designated Area.

DATES: This determination shall be promulgated for purposes of judicial review at 1:00 p.m. Mountain Standard Time on August 6, 2001.

ADDRESSES: The data upon which these findings are based, and a map of the designated area are available to the public and may be inspected during normal business hours at the U.S. Environmental Protection Agency, Region VIII, 999 18th Street, Suite 300, Denver, CO 80202-2466.

FOR FURTHER INFORMATION CONTACT: William J. Monheiser, Regional Sole Source Aquifer Coordinator, Ground Water Program, 8P-W-GW, USEPA Region VIII, 999 18th Street, Suite 300, Denver, Colorado 80202-2466, Phone:

[[Page 41028]]

303.312.6271, Fax: 303.312.7084, e-mail: monheiser.william@epa.gov.

SUPPLEMENTARY INFORMATION: Notice is hereby given that, pursuant to section 1424(e) of the Safe Drinking Water Act, 42 U.S.C. 300f, 300h-3(e), Public Law 93-523 as amended, the Regional Administrator of the U.S. Environmental Protection Agency (EPA) Region VIII has determined that the Castle Valley Aquifer System is the sole or principal source of drinking water for the Castle Valley area of southeast Utah described above. Pursuant to section 1424(e), federal financially assisted projects constructed anywhere in the designated area described above will be subject to EPA review.

I. Background

Section 1424(e) of the Safe Drinking Water Act states:

If the Administrator determines, on his own initiative or upon petition, that an area has an aquifer which is the sole or principal drinking water source for the area and which, if contaminated, would create a significant hazard to public health, he shall publish notice of that determination in the Federal Register. After the publication of any such notice, no commitment for federal financial assistance (through a grant, contract, loan guarantee, or otherwise) may be entered into for any project which the Administrator determines may contaminate such aquifer through a recharge zone so as to create a significant hazard to public health, but a commitment for federal financial assistance may, if authorized under another provision of the law, be entered into to plan or design the project to assure that it will not so contaminate the aquifer.

Effective March 9, 1987, authority to make a Sole Source Aquifer Designation Determination was delegated to the U.S. EPA Regional Administrators.

On August 7, 2000, EPA received a petition from the Town of Castle Valley, HC 64 Box 2812, Castle Valley, Utah 84532-9608, requesting that EPA designate the ground water resources of the Castle Valley Aquifer System near the Town of Castle Valley as a Sole Source Aquifer. In response to this petition, EPA published a Public Notice of Intent to Designate and invited any citizen to request a public meeting or to comment in writing or by telephone. This notice was published in the Moab Times-Independent, a newspaper of general circulation in the Castle Valley area on November 30, 2000. EPA also sent copies of the notice with descriptive information to all postal patrons in the Castle Valley area. This notice announced receipt of the petition and requested public comment for a 30 day comment period. Comments received in writing, by telephone, fax and e-mail were accepted. The public comment period extended from November 7, 2000 to December 15, 2000.

Subsequently, EPA determined that the petition was both administratively and technically complete and adequate for the purposes of Sole Source Aquifer determination.

II. Basis for Determination

Among the factors considered by the Regional Administrator for designation of a Sole Source Aquifer under section 1424(e) are: (1) Whether the aquifer is the area's sole or principal source of drinking water, (2) if the designated area has been adequately delineated and, (3) whether contamination of the aquifer would create a significant hazard to public health.

On the basis of information available to EPA, the Regional Administrator has made the following findings of fact, which are the basis for this determination:

1. The Castle Valley Aquifer System serves as the ``sole source'' of drinking water for approximately 300 permanent residents within the review area. There is no existing alternative drinking water source or combination of sources which could provide fifty percent or more of the drinking water to the designated area, nor is there any projected alternative source capable of supplying the area's drinking water needs at an economical cost.

2. The boundaries of the aquifer were determined by hydrogeologic mapping. The boundaries were delineated by a geological consultant with special expertise in drinking water source protection and confirmed by EPA professional staff.

3. The Castle Valley Aquifer System supplies water of varying quality depending on the impacts of the underlying Cutler Formation and is used as a drinking water source with softening. This constitutes a resource isolated in this immediate area that if contaminated would create a significant hazard to public health. Potential sources of contamination include: (a) Petroleum, mineral exploration, and geophysical drilling, (b) accidental spills along roadways, (c) abandoned but unplugged petroleum, mineral and geophysical wells, and tunnels (d) non-sustainable agricultural and forestry practices and (e) upward migration of lower quality water from bedrock aquifers through man-made conduits.

III. Description of the Petitioned Aquifer

The designated area of the Castle Valley Aquifer System encompasses about 24,000 acres in an irregularly shaped area approximately 16 miles long by approximately 3 miles wide. Drinking water production is from individual domestic wells, most tapping Quaternary alluvium while some of the wells derive at least part of their drinking water from the underlying Cutler Formation. Most wells are between 40 and 300 feet deep. The boundaries of the aquifer were determined by hydrogeologic mapping of the surface area, which is interpreted to contribute water to the alluvium. The boundaries were delineated by a geological consultant with special expertise in drinking water source protection and confirmed by EPA professional staff.

IV. Information Utilized in Determination

The information utilized in this determination includes the petition from the Town of Castle Valley, review of available literature, and a published ground water investigation conducted by the Utah Geological Survey. These data are available to the public and may be inspected during normal business hours at EPA Region VIII, 999 18th Street, Suite 300, Denver, Colorado 80202-2466.

V. Project Review

EPA, Region VIII, will work with any federal agencies that may, in the future, provide financial assistance to projects in the designated area. Interagency procedures will be negotiated by which EPA will be notified of proposed commitments by federal agencies for projects which could contaminate the aquifer. EPA will evaluate such projects and, where necessary, conduct an in-depth review, soliciting public comments where appropriate. Should EPA determine that a project may contaminate the aquifer, so as to create a significant hazard to public health, no commitment for federal assistance may be entered into. However, a commitment for federal assistance may, if authorized under another provision of law, be entered into to plan or design the project to assure that it will not contaminate the aquifer.

Although the project review process of section 1424 (e) cannot be delegated to state or local agencies, the EPA will rely upon any existing or future state and local control mechanisms to the maximum extent possible in protecting the ground water quality of the aquifer. Included in the review of any federal financially assisted project will be coordination with local agencies. Their comments will be given full consideration, and the federal review process will attempt to complement and

[[Page 41029]]

support state and local ground water quality protection mechanisms.

VI. Summary and Discussion of Public Comments

In response to the Public Notice, EPA received 6 comments endorsing Sole Source Aquifer designation. No additional questions were raised during the comment period. No comments objecting to designation were received during any portion of public participation process.

During the public comment period no data were presented to EPA regarding aquifer characteristics, boundary delineation or potential errors of fact presented in the petition.

VII. Economic and Regulatory Impact

Pursuant to the provisions of the Regulatory Flexibility Act (RFA), 5 U.S.C. 605(b), I hereby certify that this designation will not have a significant impact on a substantial number of small entities. For purposes of this Certification, ``small entity'' shall have the same meaning as given in section 601 of the RFA. This action is only applicable to projects with the potential to impact the Castle Valley Aquifer System Sole Source Aquifer as designated.

The only affected entities will be those businesses, organizations or governmental jurisdictions that request federal financial assistance for projects which have the potential for contaminating the Sole Source Aquifer so as to create a significant hazard to public health. EPA does not expect to be reviewing small isolated commitments of financial assistance on an individual basis, unless a cumulative adverse impact on the aquifer is anticipated or brought to the Agencies attention; accordingly, the number of affected small entities will be minimal.

For those small entities that are subject to review, the impact of today's action will not be significant. Many projects subject to this review will be preceded by a ground water impact assessment required pursuant to other federal laws, such as the National Environmental Policy Act (NEPA) as amended 42 U.S.C. 4321, et seq. Integration of those related review procedures with sole source aquifer review will allow EPA and other federal agencies to avoid delay or duplication of effort in approving financial assistance, thus minimizing any adverse effects on those small entities which are affected. Finally, today's action does not prevent grants of federal financial assistance which may be available to any affected small entity in order to pay for the redesign of the project to assure protection of the aquifer.

Under Executive Order 12866, EPA must judge whether a regulation is ``major'' and therefore subject to the requirement of a Regulatory Impact Analysis. This regulation is not major because it will not have an annual effect of $100 million or more on the economy, will not cause any major increase in costs or prices and will not have significant adverse effects on competition, employment, investment, productivity, innovation, or the ability of United States enterprises to compete in domestic or export markets. Today's action only affects the Castle Valley Aquifer System in Grand County, Utah. It provides an additional review of ground water protection measures, incorporating state and local measures whenever possible, for only those projects which request federal financial assistance.

Dated: July 26, 2001.
Jack W. McGraw,
Acting Regional Administrator, Region VIII.
[FR Doc. 01-19566 Filed 8-3-01; 8:45 am]
BILLING CODE 6560-50-P

- Notices For
- 2009
- 2008
- 2007
- 2006
- 2005
- 2004
- 2003
- 2002
- 2001
- 2000
- 1999
- 1998
- 1997
- 1996
- 1995

- 1994

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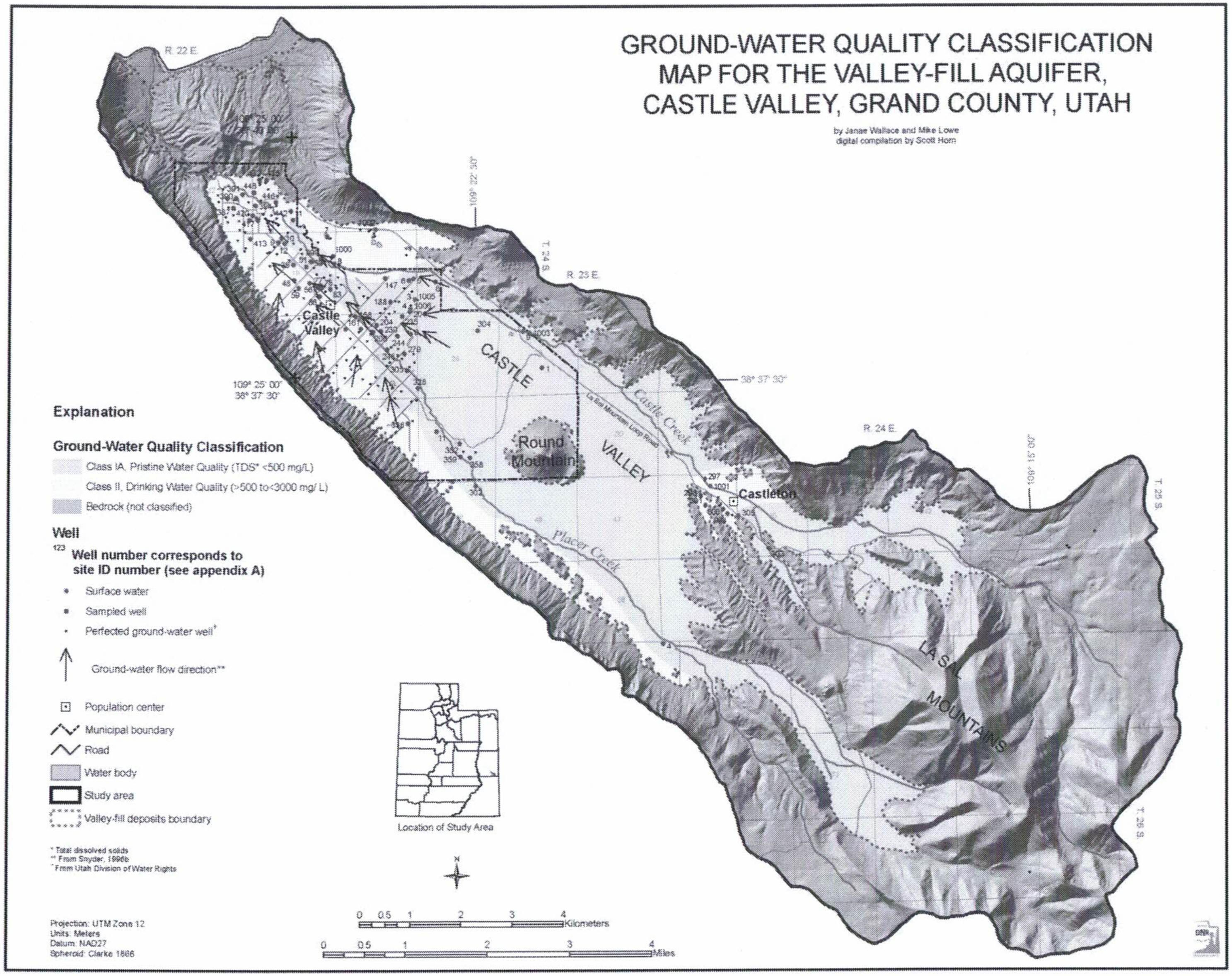
Local Navigation

- FR Home
- About the Site
- FR Listserv
- FR Search
- Selected Electronic Dockets
- Regulatory Agenda
- Executive Orders
- Current Laws and Regulations

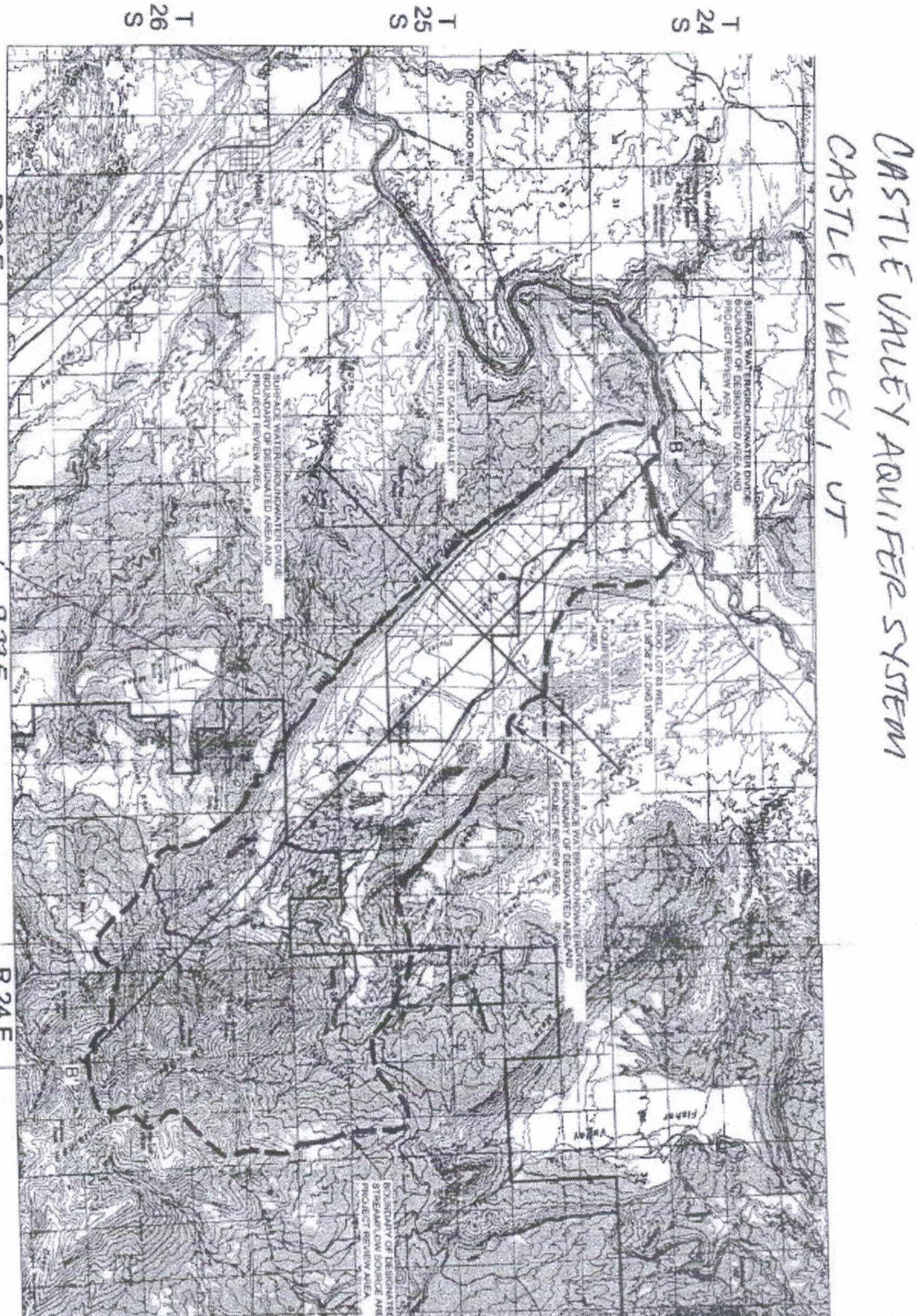
- EPA Home
- Privacy and Security Notice
- Contact Us

Jump to main content.

Appendix WC-2



Appendix WC-3



Appendix WC-4

GROUND-WATER QUALITY CLASSIFICATION AND RECOMMENDED SEPTIC TANK SOIL-ABSORPTION- SYSTEM DENSITY MAPS, CASTLE VALLEY, GRAND COUNTY, UTAH

by

Mike Lowe, Janae Wallace, Charles E. Bishop, and Hugh A. Hurlow

View to the northeast of Castle Valley, Grand County, Utah. The foreground shows part of the River Ranchos Community, where most of the population in the valley resides. The lone spire of Castle Rock is on the end horizon of Parriott Mesa.

ISBN 1-55791-714-0

SPECIAL STUDY 113
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

2004

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email: geostore@utah.gov

THE UTAH GEOLOGICAL SURVEY
contact
1594 W. North Temple, Suite 3110
Salt Lake City, UT 84116
telephone: 801-537-3300
website: http://geology.utah.gov

1/04

CONTENTS

TABLES

FIGURES

PLATES

GROUND-WATER QUALITY CLASSIFICATION AND RECOMMENDED SEPTIC TANK SOIL-ABSORPTION-SYSTEM DENSITY MAPS, CASTLE VALLEY, GRAND COUNTY, UTAH

by

Mike Lowe, Janae Wallace, Charles E. Bishop, and Hugh A. Hurlow

ABSTRACT

Castle Valley in southeastern Utah is experiencing an increase in residential development, all of which uses septic tank soil-absorption systems for wastewater disposal. Most of this development is on unconsolidated deposits of the unconfined valley-fill aquifer, the primary source of drinking water. The purposes of our study are to (1) classify the ground-water quality of the principal aquifer to formally identify and document the beneficial use of the valley's ground-water resource, and (2) apply a ground-water flow model using a mass-balance approach to determine the potential impact of projected increased numbers of septic-tank systems on water quality in the Castle Valley valley-fill aquifer and thereby recommend appropriate septic-system density requirements to limit water-quality degradation.

Utah's ground-water quality classes are based mostly on total-dissolved-solids (TDS) concentrations as follows: Class IA (Pristine), less than 500 mg/L; Class II (Drinking Water Quality), 500 to less than 3,000 mg/L; Class III (Limited Use), 3,000 to less than 10,000 mg/L; and Class IV (Saline), 10,000 mg/L and greater. Aquifer classification is based on data from water wells representing the valley-fill material.

In the mass-balance approach, the nitrogen mass from projected additional septic tanks is added to the current nitrogen mass and then diluted with ground-water flow available for mixing plus the water added by the septic-tank systems themselves. Ground water available for mixing was calculated based on estimated parameters representing existing conditions using a Brigham Young University simulation of the ground-water flow system in Castle Valley.

The quality of water in the Castle Valley valley-fill aquifer is generally good. In the northwestern part (40 percent) of the valley, we classify ground water in 48 percent of the aquifer as Class IA and 52 percent as Class II, based on data from 54 wells sampled during either October 2001 or February 2003, and on TDS values converted from specific-conductance data for 14 wells and 4 surface-water sites reported by the Utah Department of Agriculture and Food, the Utah Division of Water Rights, the Utah Geological Survey, and the Utah Department of Water Quality. Total-dissolved-solids concentrations in the valley-fill aquifer range from 204 to 2,442 mg/L, and average 785 mg/L. Data are insufficient to classify the southeastern part (60 percent) of the valley-fill aquifer. Nitrate-as-nitrogen concentrations in the valley-fill aquifer range from less than 0.1 to 4.27 mg/L, the average (background) nitrate concentration being 0.52 mg/L.

The results of our ground-water flow simulation using the mass-balance approach indicate that two categories of recommended maximum septic-system densities are appropriate for development in Castle Valley: 5 and 15 acres per system (2 hm^2/system and 6 hm^2/system). These recommended maximum septic-system densities are based on hydrogeologic parameters incorporated in the ground-water flow simulation and geographically divided into four ground-water flow domains (background nitrate concentrations ranging from 0.18 to 0.48 mg/L) on the basis of flow-volume similarities.

INTRODUCTION

Castle Valley, Grand County, is a rural area in southeastern Utah (figure 1) experiencing an increase in residential development, all of which uses septic tank soil-absorption systems for wastewater disposal. Most of this development is situated on unconsolidated deposits of the valley-fill aquifer. Ground water, mostly from the valley-fill aquifer, provides all of the drinking-water supply in Castle Valley. Preservation of ground-water quality and the potential for ground-water quality degradation are critical issues that should be considered in determining the extent and nature of future development in Castle Valley. Local government officials in Castle Valley have expressed concern about the potential impact that development may have on ground-water quality, particularly development that uses septic tank soil-absorption systems for wastewater disposal.

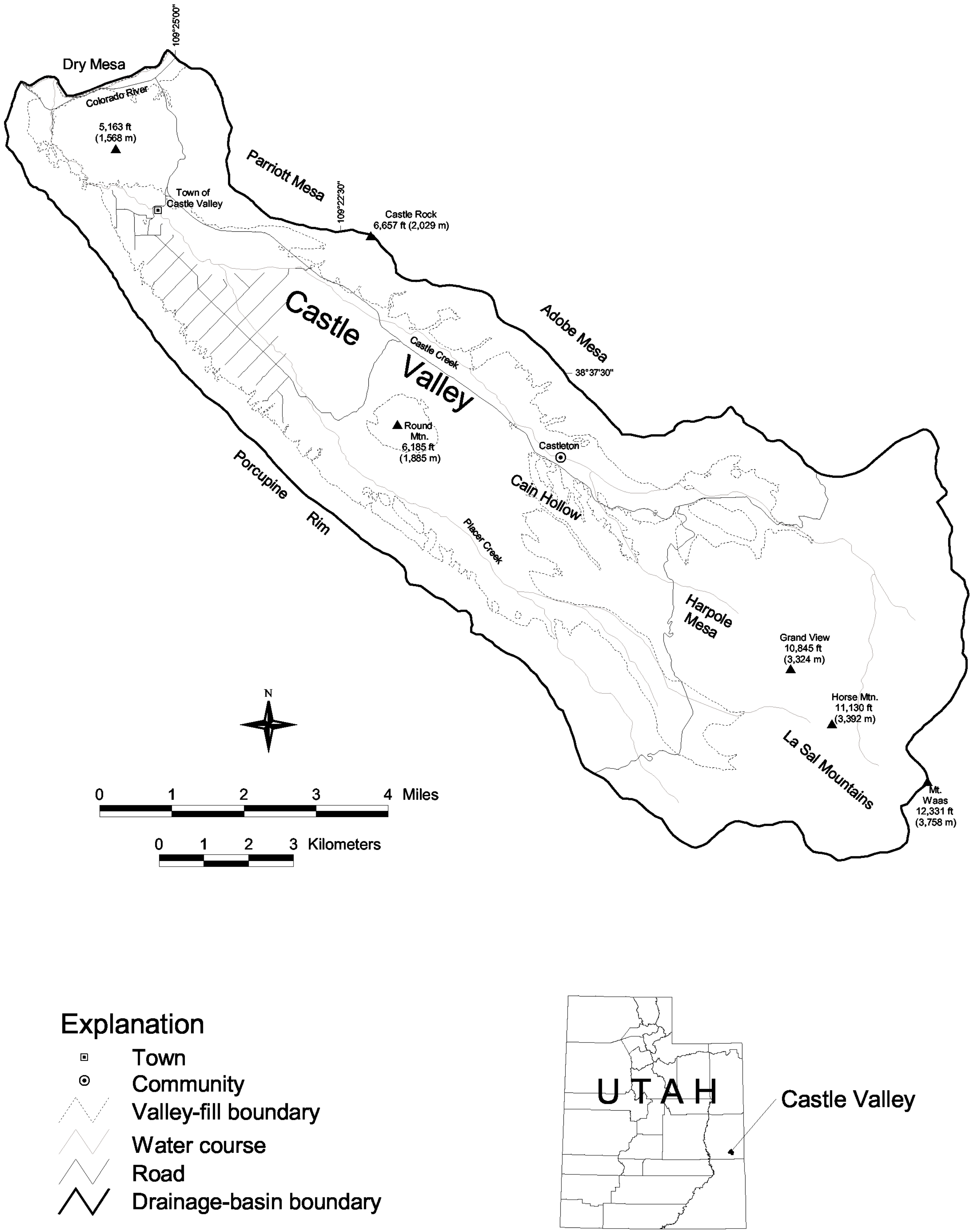

***Figure 1**. Drainage-basin study area, Castle Valley, Grand County, Utah.*

Purpose and Scope

The purposes of our study are to (1) classify the ground-water quality of the valley-fill aquifer to formally identify and document the beneficial use of Castle Valley's ground-water resource, and (2) apply a ground-water flow simulation and use a mass-balance approach to determine the potential impact of projected increased numbers of septic-tank systems on water quality in the valley-fill aquifer and thereby recommend appropriate septic-system-density requirements. These two study components will, in concert, provide land-use planners with a tool to use in approving new development in a manner that will be protective of ground-water quality.

Ground-Water Quality Classification

Ground-water quality classes under the Utah Water Quality Board classification scheme are based largely on total-dissolved-solids (TDS) concentrations (table 1) (for the ranges of chemical-constituent concentrations used in this report, including those for TDS, mg/L equals parts per million). If any contaminant exceeds Utah's ground-water quality (health) standards (appendix B) (and, if human caused, cannot be cleaned up within a reasonable time period), the ground water is classified as Class III, Limited Use ground water.

To classify the quality of ground water in the Castle Valley valley-fill aquifer, we sampled ground water from 40 wells in October 2001, and had the samples analyzed for general chemistry and nutrients by the Utah Department of Epidemiology and Laboratory Services; of these 40 wells, ground water from 10 wells was analyzed for organics and pesticides and ground water from 5 wells was analyzed for radionuclides (appendix A). These data were augmented by (1) another 43 wells sampled in September 2000 that were analyzed for bacteria, specific conductance, pesticides, and nutrients (appendix A) by the Utah Department of Agriculture and Food (Quilter, 2001), (2) specific-conductance and TDS-concentration data from ground water from 6 wells measured by the Utah Division of Water Rights between 1991 and 1996 (appendix A) (Ford and Grandy, 1997), and (3) specific-conductance data we collected in February 2003 from another 5 wells (appendix A). Specific-conductance data that we collected from four surface-water sites in February 2003 were also used as part of this classification (appendix A); because of an apparent hydraulic connection between ground and surface water in the valley-fill aquifer, surface-water quality is likely representative of ground-water quality. Appendix B summarizes the constituents analyzed for and, where appropriate, ground-water quality (health) standards for the constituents; our water-quality data are presented in appendix A.

In July 2003, some local citizens of Castle Valley sampled water from 17 wells and surface-water sites, and had the samples analyzed for TDS concentration by the Utah Department of Epidemiology and Laboratory Services (appendix A); of these samples, eight were from wells, eight from springs, and one from Castle Creek. Total-dissolved-solids-concentration values range from 188 to 1,944 mg/L. However, these data were not used to supplement the TDS concentration data from Lowe and Wallace (2003) because they did not meet sampling protocol requirements associated with our Quality Assurance Project Plan approved by the U.S. Environmental Protection Agency.

Table 1. *Ground-water quality classes under the Utah Water Quality Board's total-dissolved-solids (TDS) based classification system (modified from Utah Division of Water Quality, 1998).*

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

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

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

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

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

[5] *Generally used for industrial purposes.*

[6] *May have economic value as brine.*

Another component of the classification process is to document existing and potential pollution sources that may threaten the public's drinking-water supply. We mapped potential pollution sources based on Utah's Drinking Water Source Protection Rules (appendix C).

Septic-Tank Density/Water-Quality Degradation Analysis

To provide recommended septic-tank densities for Castle Valley using the mass-balance approach to evaluate potential water-quality degradation, we used the digital ground-water flow simulation of Downs and Lasswell (undated), after modifying the simulation using data from an aquifer test we conducted in 2000 and slug tests, to estimate ground-water flow available for mixing (dilution). We then (1) grouped areas into four ground-water flow domains (geographic areas having similar characteristics of flow volume per unit area); (2) determined area acreage, ground-water flow volumes, number of existing septic-tank systems, and ambient (background) nitrate concentrations for each domain; and (3) calculated projected nitrogen loadings in each domain, based on increasing numbers of septic tank soil-absorption systems and using the appropriate amount of wastewater and accompanying nitrogen load introduced per septic-tank system. By limiting allowable degradation of ground-water nitrate concentration to 3 mg/L, the amount of water-quality degradation determined to be acceptable by local government officials, we were then able to derive septic-tank density recommendations for each domain.

Well-Numbering System

The numbering system for wells in this study is based on the federal government cadastral land-survey system that divides Utah into four quadrants (A-D) separated by the Salt Lake Base Line and Meridian (figure 2). The study area is in the southeastern quadrant (D). The wells are numbered with this quadrant letter (D), followed by township and range, all enclosed in parentheses. The next set of characters indicates the section, quarter section, quarter-quarter section, and quarter-quarter-quarter section designated by letters a through d, indicating the northeastern, northwestern, southwestern, and southeastern quadrants, respectively. A number after the hyphen corresponds to an individual well within a quarter-quarter-quarter section. For example, the well (D-25-23) 17adb-1 would be the first well in the northwestern quarter of the southeastern quarter of the northeastern quarter of section 17, Township 25 South, Range 23 East (NW1/4SE1/4 NE1/4 section 17, T. 25 S., R. 23 E.).

Location and Geography

Castle Valley is a northwest-trending valley in the Colorado Plateau physiographic province (Stokes, 1977), and is about 10 miles (19 km) long and 2 miles (3 km) wide with an area of about 21.5 square miles (56 km^2) (figure 1). Castle Valley is bordered by Parriott and Adobe Mesas to the northeast, the La Sal Mountains to the southeast, Porcupine Rim to the west, and the Colorado River to the northwest (figure 1). Castle Valley ranges in elevation from about 4,120 feet (1,250 m) at the Colorado River to the northwest to about 6,800 feet (2,100 m) in the upper reaches of Castle Creek within valley-fill material in the foothills of the La Sal Mountains to the southeast; the drainage basin reaches 12,331 feet (3,758 m) in elevation at Mount Waas (figure 1).

The headwaters of Castle Creek and Placer Creek, the principal drainages in Castle Valley, are in the La Sal Mountains (figure 1). Castle Creek is a perennial stream whereas Placer Creek is ephemeral (Ford and Grandy, 1997). These streams flow into the valley on either side of Cain Hollow and Round Mountain, join near the town of Castle Valley, and then flow through a short, narrow canyon and enter the Colorado River.

Population and Land Use

Most people in Castle Valley live within the limits of the recently incorporated (November 27, 1985) Town of Castle Valley, but some live outside the town limits. The 2000 U.S. Census population of the Town of Castle Valley is 349, a 65.4 percent increase from the 1990 Census population of 211 (Demographic and Economic Analysis Section, 2001). The Utah School and Institutional Trust Lands Administration (SITLA) is anticipating the sale of its land for the development of new lots, which may lead to continued growth in Castle Valley.

Much of the land use in Castle Valley is residential, but some of the valley is irrigated cropland. Cattle grazing also takes place in the valley, primarily in the winter (Snyder, 1996a, b).

Climate

Average annual precipitation in the Castle Valley drainage basin increases with altitude and ranges from about 9 inches (23 cm) at the Colorado River to more than 30 inches (76 cm) in the La Sal Mountains (Blanchard, 1990). Average annual precipitation from 1978 to 1992 was 11.5 inches (29.2 cm) at the Castle Valley Institute in the Town of Castle Valley (elevation 4,720 feet [1,439 m]). Average annual precipitation from 1963 to 1978 in the community of Castleton, farther southeast in Castle Valley at an elevation of 5,840 feet (1,780 m), was 13.63 inches (34.6 cm) (Ashcroft and others, 1992). Summer precipitation is usually in the form of brief, localized, intense thunderstorms, whereas winter precipitation is of longer duration, less localized, less intense and, at higher elevations, primarily in the form of snow (Blanchard, 1990). Temperatures range from a record high of 107°F (41.2°C) at the Castle Valley Institute for the 1978 to 1992 time period to a record low of -15°F (-26.1°C) at Castleton for the 1963 to 1978 time period. Average mean temperatures were 53.9 and 50.2°F (12.2 and 10.1°C) at the Castle Valley Institute and Castleton, respectively, for the periods of record (Ashcroft and others, 1992). Average annual evapotranspiration was 4.4 and 3.4 times precipitation at the Castle Valley Institute and Castleton, respectively, for the same time periods (Ashcroft and others, 1992). Because of the brevity of precipitation events and higher evapotranspiration rates in the summer, most recharge to ground-water aquifers takes place during spring snowmelt (Blanchard, 1990).

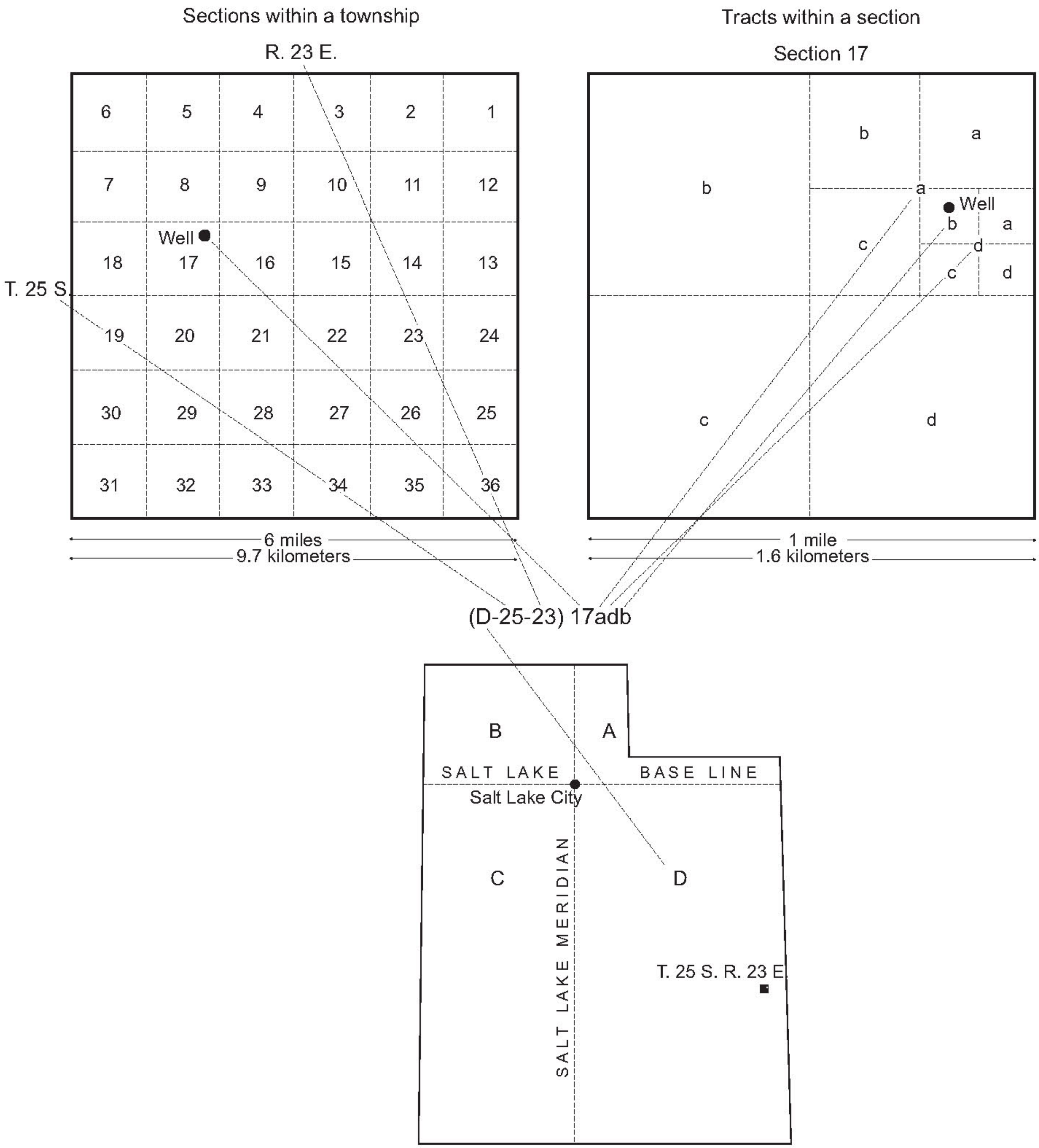

Figure 2. Numbering system for wells in Utah (see text for additional explanation).

PREVIOUS INVESTIGATIONS

Geologic mapping in Castle Valley includes that of Shoemaker (1952), Harper (1960), Doelling and Ross (1998), and Doelling (2001, 2002). We used unpublished geologic mapping of the Mount Waas and Warner Lake quadrangles by M.L. Ross, formerly with the Utah Geological Survey, as part of this study. Mulvey (1992) mapped geologic hazards in Castle Valley and provided information on the potential for ground-water contamination. Hydrogeologic studies relevant to Castle Valley were conducted by Sumsion (1971), Weir and others (1983), Blanchard (1990), Freethey and Cordy (1991), Snyder (1996a, b), Ford and Grandy (1997), Eisinger and Lowe (1999), and Town of Castle Valley (2000).

GEOLOGIC SETTING

Structurally, Castle Valley is part of a regionally extensive, collapsed salt anticline that includes Paradox Valley to the southeast (figure 3) (Doelling and Ross, 1998). The Pennsylvanian Paradox Formation, which underlies the Paradox basin region, contains thick salt layers deposited under marine conditions (Hintze, 1988). As these salt layers were buried by younger sediments, they became mobile and formed a diapir under present-day Castle Valley. Due to differences in the specific gravity of salt and bedrock, the diapir rose, folding overlying rocks into an anticline. The subsequent uplift of the Colorado Plateau in the late Tertiary resulted in high rates of erosion and allowed ground and surface water to contact and dissolve the salt layers from the core of the anticline (Mulvey, 1992; Doelling and Ross, 1998). Subsequently, the overlying rock strata collapsed and eroded, forming Castle Valley in the core of the anticline. Mulvey (1992) mapped a suspected Quaternary fault parallel to Porcupine Rim on the southwest side of the valley and attributed a sinkhole along this fault to localized dissolution or piping. High-angle normal fault systems that developed as a result of the collapse of the salt diapir are present along both margins of Castle Valley (plate 1, appendix D) (Doelling and Ross, 1998). Geologic cross sections display the relationship between the "cap rock" of the Paradox Formation and the overlying valley-fill material (plate 2) (see also, Town of Castle Valley, 2000, plate 1).

Geologic units surrounding Castle Valley include Pennsylvanian to Tertiary sedimentary and igneous rocks (plate 1; table 2; appendix D) (Doelling, 2001). Gypsum, mudstone, and shale of the Pennsylvanian Paradox Formation cap rock are exposed along the southwest margin of Castle Valley and around Round Mountain; interbedded evaporite, clastic, and carbonate rocks of the Paradox Formation underlie Quaternary valley-fill deposits (Doelling, 2001). Sandstone, conglomerate, and mudstone of the Permian Cutler Formation overlie the Paradox in cliffs at the northwest end and central northeast margin of the valley (Doelling and Ross, 1998; Doelling, 2001). Sandstone, siltstone, and mudstone of the Triassic Moenkopi and Chinle Formations, sandstone of the Jurassic Wingate Formation, and sandstone, siltstone, and mudstone of the Jurassic Kayenta Formation overlie the Cutler and form the cliffs along much of the northeast and southwest sides of the valley (Doelling, 2001). Round Mountain and the La Sal Mountains are composed largely of Oligocene intrusive rocks, mainly porphyritic trachyte (Doelling, 2001).

The valley fill of Castle Valley consists mainly of alluvial-fan, mass-movement, and stream deposits (Doelling, 2001). Holocene stream deposits along Castle and Placer Creeks are generally poorly sorted sand, silt, and clay, with some gravel lenses; the amount of gravel in these deposits generally increases updrainage (Doelling and Ross, 1998). Coarse-grained older alluvium (including the Geyser Creek Fanglomerate; appendix D), composed of mainly poorly sorted, sandy, cobble gravel with some small, localized accumulations of boulders, is exposed in the higher parts of Castle Valley and underlies the younger stream alluvium in lower Castle Valley (Snyder, 1996a, b; Doelling and Ross, 1998). Alluvial-fan deposits form apron-like gentle slopes at the base of Porcupine Rim and Adobe Mesa (Doelling and Ross, 1998; Doelling, 2001). The fans consist mainly of poorly sorted boulders, cobbles, and gravels in a crudely bedded fine-grained matrix (Doelling and Ross, 1998). Talus and colluvium, consisting of rock-fall blocks, boulders, angular gravel, sand, and silt, are present along the southern part of Porcupine Rim, and mass-movement deposits are mapped along the upper reach of Placer Creek (Doelling, 2001).

GROUND-WATER CONDITIONS

Introduction

Ground water in Castle Valley occurs in two types of aquifers: (1) fractured bedrock, and (2) unconsolidated valley-fill deposits (figure 4). The geologic and hydrologic characteristics of the rock units in the Castle Valley drainage basin are summarized in table 2. Ground water in fractured-rock aquifers is recharged primarily from infiltration of precipitation and stream flow, and flows primarily through fractures. Blanchard (1990) reported that approximately 30 wells receive water from the Cutler Formation aquifer along the base of Porcupine Rim on the west side of the valley. The Cutler Formation is the main fractured-rock aquifer currently used in Castle Valley, but the number of wells completed in bedrock has increased only slightly over the past 12 years. Bedrock well depths are typically 150 to 300 feet (45-90 m) below the land surface (Snyder, 1996a, b). Recharge to the Cutler Formation aquifer is from the La Sal Mountains (Doelling and Ross, 1998).

Valley-Fill Aquifer

Occurrence

The valley-fill aquifer is the most important source of drinking water in Castle Valley. The valley fill consists predominantly of gravelly stream alluvium and alluvial-fan deposits that are generally coarser grained near source areas at the base of Porcupine Rim and the La Sal Mountains, and finer grained along the lower reaches of Castle Creek (Snyder, 1996a, b; Doelling and Ross, 1998). Although drillers' logs of water wells indicate that a few wells in Castle Valley intersect clay lenses, none of these clay layers is extensive enough to act as a confining layer, so the valley-fill aquifer is

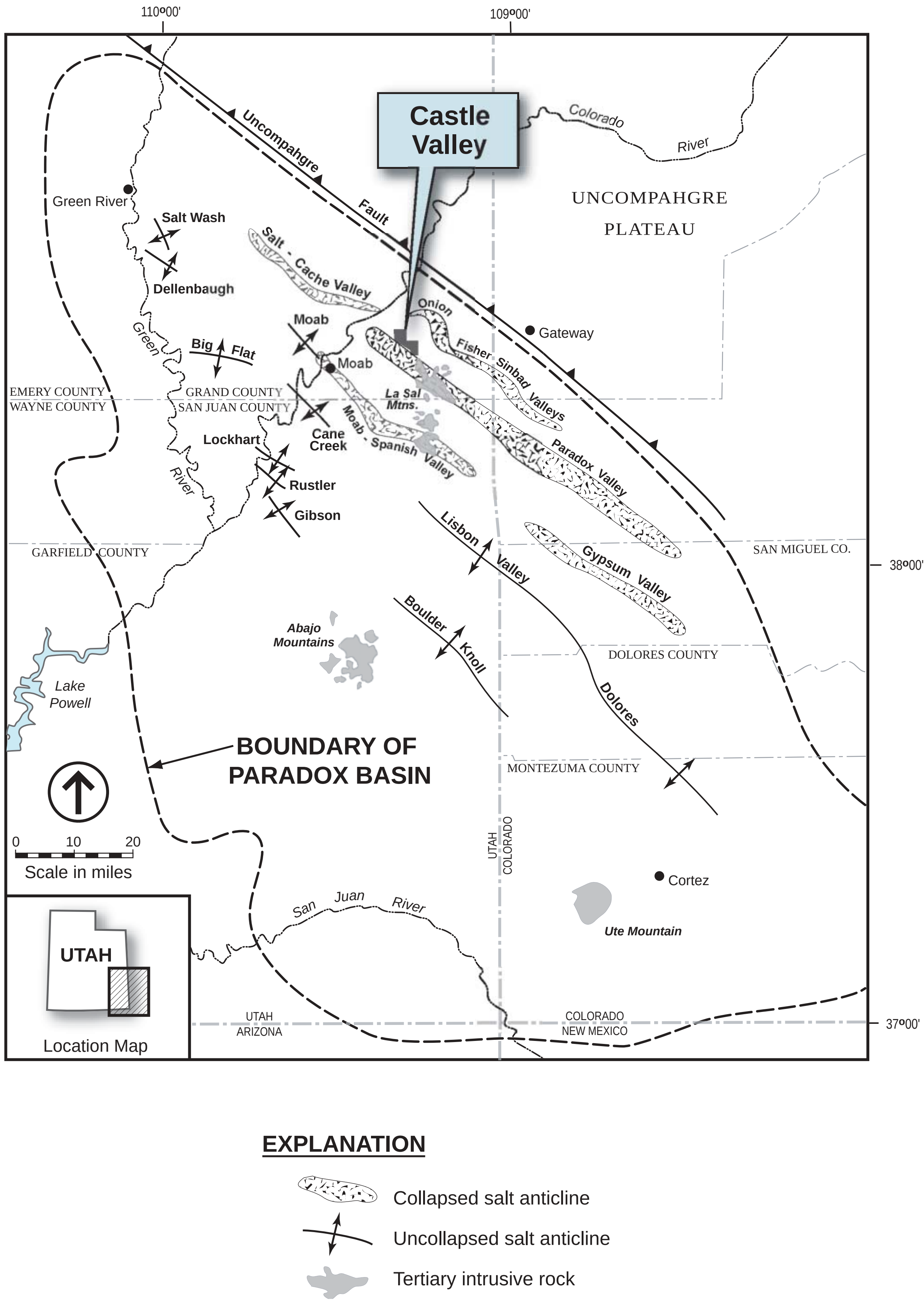

Figure 3. *Regional tectonic setting of the study area showing major tectonic features including salt anticlines, Paradox basin, Uncompahgre uplift and fault, and Tertiary intrusions (modified from Doelling, 1988).*

Table 2. *Geologic and hydrologic characteristics of aquifers in southern Grand County, including Castle Valley. Compiled from Blanchard (1990) and Doelling and Morgan (2000).*

Geologic Unit (aquifer)	**Thickness[1] in feet (m)**	**Lithology**	**General Hydrologic Characteristics**	**Yield (gallons per minute)**	**Water Quality[2]**	
					Total Dissolved Solids (mg/L)	**Chemistry Type**
Cedar Mountain Formation	120-200 (37-61)	Interbedded sandstone, conglomerate, and mudstone	Sandstone and conglomerate yield small amounts of water to wells and springs	Springs: < 1 Wells: <1	Spring: 1,020 Well: 1,470	Calcium magnesium sodium sulfate bicarbonate
Brushy Basin Member of Morrison Formation	295-450 (90-135)	Mudstone to fine-grained sandstone	Yields small amounts of water to wells and springs	Springs: < 1 Wells: < 1	Spring: 1,020	Calcium magnesium sodium sulfate bicarbonate
Salt Wash Member of Morrison Formation	130-300 (40-90)	Interbedded sandstone, conglomerate, and mudstone	Sandstone and conglomerate yield small amounts of water to wells and springs	Springs: < 1 Wells: < 1	Spring: 1,160	Calcium magnesium sodium sulfate bicarbonate
Moab Member of Curtis Formation[3]	70-110 (21-34)	Cross-bedded, well-sorted, fine- to medium-grained sandstone, moderately indurated with calcite cement	Yields abundant water to springs and wells	Springs: 0.1-11.1	Springs: 143-157	Calcium carbonate; hard to very hard
Slick Rock Member of Entrada Sandstone	180-400 (55-122)	Cross-bedded, well-sorted, fine- to medium-grained sandstone, weakly to moderately indurated with calcite cement	Yields moderately abundant water to springs and wells	—	Well: 300	Calcium carbonate; hard to very hard
Navajo Sandstone	165-800 (50-244)	Cross-bedded, well-sorted, fine-grained sandstone, weakly to moderately indurated with calcite cement	Yields abundant water to springs and wells	Springs: <1-5	Springs: 102-350 Well: 210-360	Calcium bicarbonate to calcium magnesium bicarbonate
Wingate Sandstone	250-400 (76-122)	Cross-bedded, well-sorted, fine-grained sandstone, indurated with calcite cement	Yields moderately abundant water to springs and wells	Springs: 10-240	Springs: 161-174 Well[4]: 280-45,000	Calcium magnesium bicarbonate; moderately hard to hard
Arkosic member of Cutler Formation	0-4,000 (0-1,220)	Cross-bedded, medium- to coarse-grained sandstone and minor conglomerate	Yields small amounts of water to wells	Wells: 1-40	Wells: 1,420-3,450	Calcium magnesium sulfate; very hard

Notes:

1. *Unit thicknesses are from Doelling and Morgan (2000) and represent ranges from a wider area than shown on the cross sections on plate 2.*
2. *Data from oil-test wells not included. Total-dissolved-solids concentrations of water from oil wells range from about 2,000 to over 100,000 mg/L (Blanchard, 1990, p. 28).*
3. *Blanchard (1990) does not differentiate the Moab Member of the Curtis Formation (considered a member of the Entrada Sandstone at the time of his report) from the underlying Slick Rock Member of the Entrada Sandstone. Assignment of Blanchard's (1990) data to the Moab or Slick Rock Member is based on work done as part of this study.*
4. *Blanchard (1990) reports a measured value of 45,000 mg/L for one shallow well in the Wingate aquifer. He suggests that this anomalous value is caused by an upward gradient moving ground water from the salt-rich Paradox Formation and/or underlying formations into the Wingate aquifer here.*

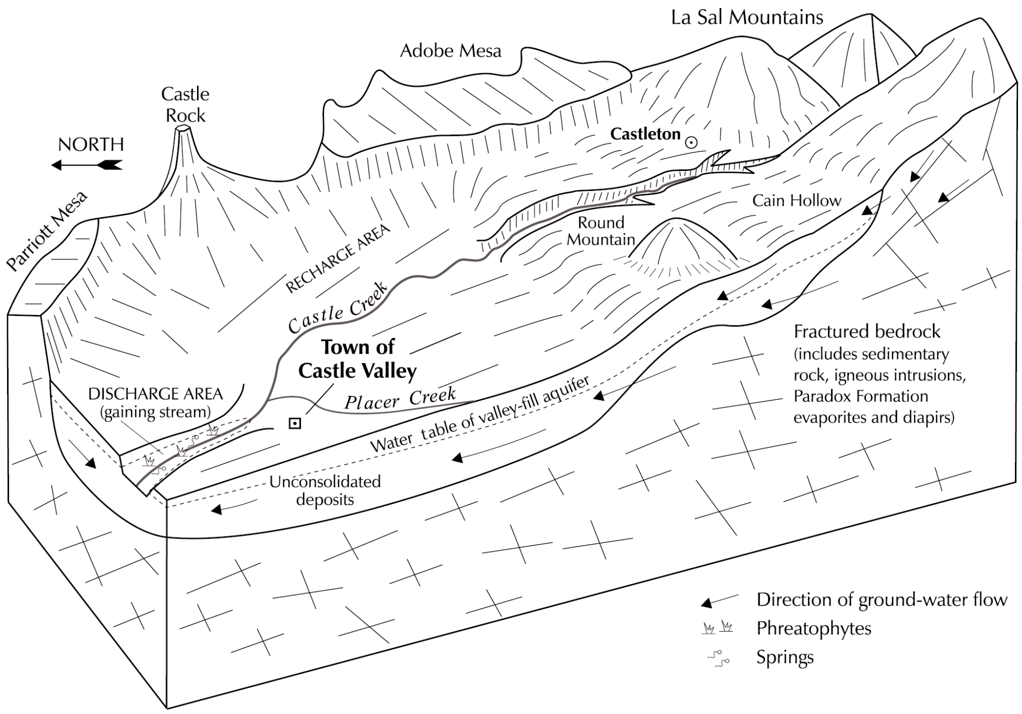

Figure 4. *Schematic block diagram showing ground-water flow in Castle Valley (from Snyder, 1996a).*

unconfined (Snyder, 1996a, b). Wells depths in valley fill range from 58 to 248 feet (18-79 m) and are typically less than 150 feet (45 m) below the land surface (appendix A).

Thickness

Plate 3 illustrates the thickness of unconsolidated valley-fill deposits in Castle Valley. The 25-, 50-, and 100-foot contours (8-, 15-, and 31-m contours, respectively) define a "Y" shape, with the lower arm pointing northwest along Castle Creek and the upper arms diverging from northwest of Round Mountain and following Pinhook Creek and upper Castle Creek. The thickest deposits form a narrow trough over 350 feet (107 m) thick below Castle Creek in sections 8, 9, and 15, T. 25 S., R. 23 E., Salt Lake Base Line and Meridian (SLBM), and deposits southeast of this trough below the central part of the valley are up to 250 feet (76 m) thick. Elsewhere in the valley, unconsolidated deposits are generally less than 150 feet (46 m) thick with numerous buried bedrock ridges and small, deep troughs. The most prominent buried ridge is in sections 7 and 17, T. 25 S., R. 23 E., SLBM, where it strikes northwest and is bounded to the northeast and southwest by narrow troughs 150 to 250 feet (46-76-m) thick. The shapes of these second-order features are not well constrained, and some may be artifacts of the driller's interpretation of relatively soft sedimentary rocks as unconsolidated deposits or large slide blocks as bedrock. The thickness of alluvial-fan deposits along the valley margins is highly variable, and in many places between the 0- and 25-foot (0 and 8 m) contours, it may locally exceed 25 feet (8 m) or thin to zero.

The isopach map was constructed from water-well driller's logs and detailed logs of water-well cuttings by Wallace (2002). The majority of wells are in the northwestern third of the valley, so the contours are best constrained there. The comparatively simple structure southeast of this area is likely a result of sparse well coverage. For this reason, the maximum valley-fill thickness between Round Mountain and the area of greatest residential development is poorly constrained.

The Geyser Creek Fanglomerate consists of poorly to moderately consolidated conglomerate and sandstone, and is not included with the valley-fill deposits on plate 3 because its hydraulic conductivity is likely significantly lower than that of the unconsolidated Quaternary deposits. The Geyser Creek Fanglomerate may, however, underlie unconsolidated deposits below northwestern Castle Valley, and could have been interpreted as gravel, conglomerate, or bedrock in the drillers' logs, depending on its degree of cementation. The isopach contours may, therefore, locally include some Geyser Creek Fanglomerate. Some well logs show "conglomerate" below unconsolidated deposits; this "conglomerate" may represent the Geyser Creek Fanglomerate or younger, partially cemented stream deposits, or both. These wells are aligned in a narrow belt below the valley center northwest of Round Mountain (plate 3), suggesting the course of a former stream draining the valley.

Ground-Water Depth, Volume, and Flow Direction

The water table ranges from 30 feet (9 m) to over 100 feet (30 m) below the land surface (Ford and Grandy, 1997). Based on Snyder's (1996a, b) potentiometric surface map (figure 5), the thickness of valley fill shown on plate 3, and an assumed specific yield of 0.25, we estimate the average volume of ground water stored in the valley-fill aquifer is about 150,000 acre-feet (187 hm^3). Ground water flows from valley margins toward Castle and Placer Creeks and

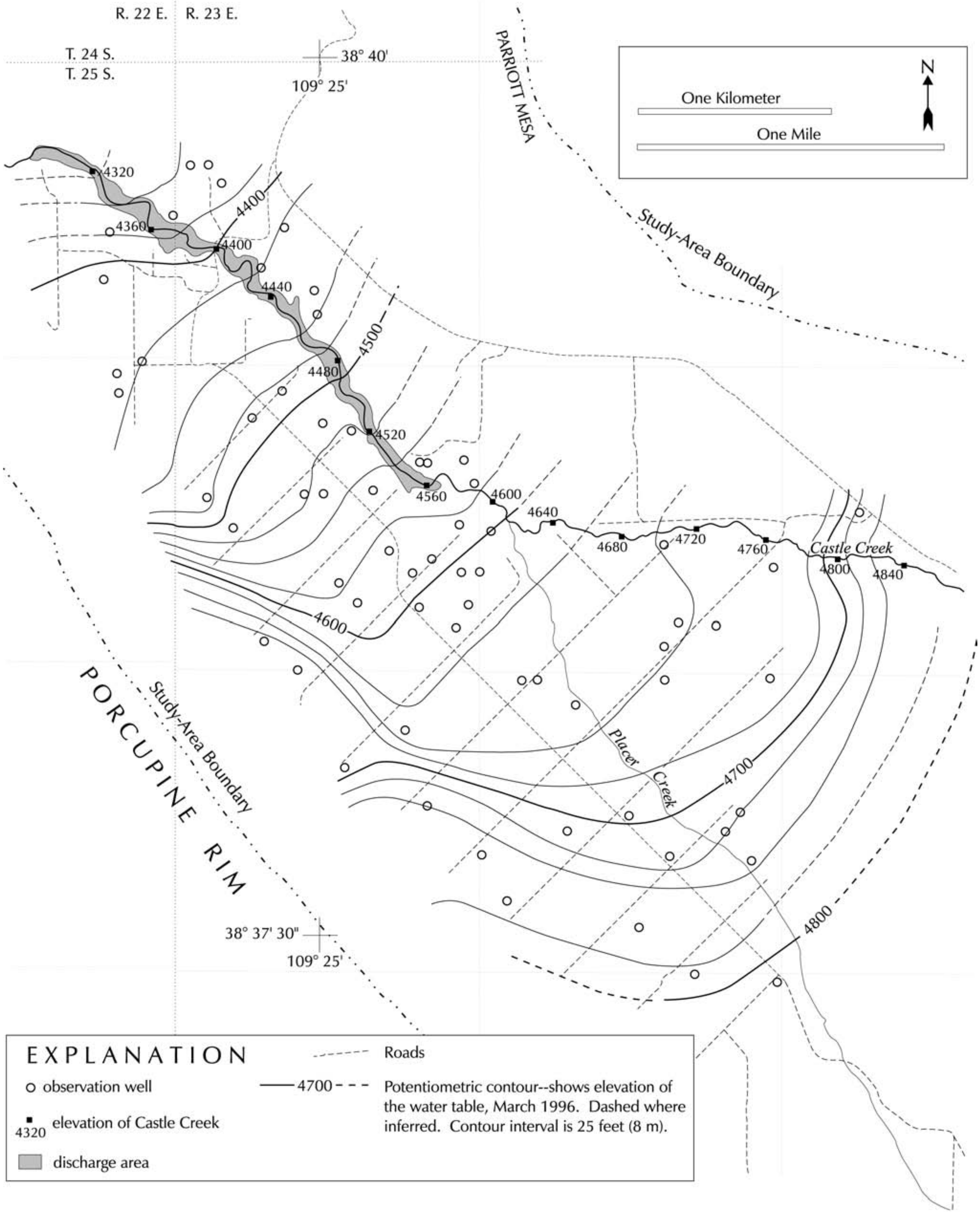

***Figure 5**. Potentiometric-surface map of northern Castle Valley showing discharge area and elevations of Castle Creek (from Snyder, 1996a).*

then generally to the northwest parallel to Castle and Placer Creeks toward the Colorado River (figure 5). The hydraulic gradient is estimated to be 0.027 (Town of Castle Valley, 2000) to the northwest parallel to the flows of Castle Creek and Placer Creek (figure 5).

Recharge and Discharge

Castle and Placer Creeks, which originate high in the La Sal Mountains, are sources of recharge to the valley-fill aquifer (Snyder, 1996a, b). As Castle Creek flows across the coarse-grained valley fill along most of its course, much of the flow percolates into the aquifer (Ford and Grandy, 1997); it acts as the primary source of recharge in the valley. Castle Creek is a losing stream and most of the valley is a primary recharge area, except near the town of Castle Valley where the stream channel is incised up to 40 feet (12 m) into the valley fill and has intersected the water table, forming a small discharge area (Snyder, 1996a, b) (figures 4 and 5). Other sources of recharge include (1) direct infiltration of precipitation, especially in the higher parts of the valley, (2) seepage of irrigation water, and (3) subsurface inflow from adjacent fractured bedrock aquifers (Snyder, 1996a, b). Discharge is from (1) wells, (2) evapotranspiration, especially along lower Castle Creek, and (3) underflow to the Colorado River (Snyder, 1996a, b). An annual water budget has not been developed for the Castle Valley valley-fill aquifer system.

Relationship of Geology to Ground-Water Quality

Ground-water quality in Castle Valley is generally good and is suitable for most uses. Most wells in Castle Valley are completed in either the Cutler aquifer or the unconsolidated valley-fill aquifer. Ground-water quality in both aquifers is influenced by proximity to various bedrock units, with the Paradox Formation having the strongest influence.

The Cutler aquifer in Castle Valley typically contains calcium-magnesium-sulfate- or calcium-magnesium-sodium-sulfate-type water (Blanchard, 1990). Ground water from wells completed in the Cutler Formation is generally higher in TDS concentration than ground water from wells completed in adjacent valley fill (Snyder, 1996a, b). The lowest TDS values come from the shallower wells in eastern Castle Valley that may be receiving some recharge from the valley-fill aquifer; the highest values come from wells at the base of Porcupine Rim where gypsum along drainages may indicate proximity to Paradox Formation evaporites (Snyder, 1996a, b). Blanchard (1990) reported that ground-water samples from three wells in the Cutler Formation near the town of Castle Valley had TDS concentrations ranging from 1,420 mg/L to 3,450 mg/L, and that two of these wells exceeded the ground-water quality (health) standard of 10 micrograms per liter for selenium (the wells yielded 21 and 30μg/L selenium; the standard is presently 50 micrograms per liter). Ford and Grandy (1997) reported that ground-water samples from wells completed in the Cutler aquifer in Castle Valley had specific-conductance values ranging from 835 to 4,650 micromhos per centimeter at 25°C. However, Ford and Grandy (1995) did not find high selenium concentrations in any of the wells they sampled. Snyder (1996a, b) noted that most of the ground water yielded to wells from the Cutler aquifer fell within Class II, but that some wells yielded Class III ground water in the northern part of the valley. Snyder (1996a, b) attributed the poor-quality ground water in the Cutler aquifer to be the result of some combination of three possible factors: (1) long residence time and flow path, (2) dissolved fine-grained constituents, such as evaporites, of the Cutler Formation, and (3) hydraulic connection to the Paradox Formation evaporites beneath the Cutler Formation.

Ford and Grandy (1995) reported that specific-conductance values for samples from eight valley-fill aquifer wells in Castle Valley ranged from 357 to 1,960 micromhos per centimeter at 25°C. Ground water from wells and springs in the valley-fill aquifer exhibits a general down-valley increase in dissolved solids (Weir and others, 1983; Ford, 1994; Snyder, 1996a, b). Higher quality ground water (less than 1,000 micromhos/cm) along Castle and Placer Creeks confirms that Castle Creek is a principal source, and Placer Creek a subordinate source of recharge to the valley-fill aquifer (Snyder, 1996a, b; Doelling and Ross, 1998). Lower-quality ground water (greater than 2,000 micromhos/cm) from valley-fill wells and springs, and from Castle Creek in the far northwestern part of Castle Valley, is probably due to a local hydraulic connection to water in the Paradox Formation (Snyder, 1996a, b; Doelling and Ross, 1998). Snyder (1996a, b) attributed the down-valley increase in TDS concentrations in the valley-fill aquifer to recharge from the Cutler and Paradox Formations which contain poorer-quality water.

Ford and Grandy (1995) reported nitrate concentrations of less than 1 mg/L for ground-water samples from wells completed in the Castle Valley valley-fill aquifer. Additionally, Ford and Grandy (1995) found no fecal coliform in the eight valley-fill wells sampled in Castle Valley.

GROUND-WATER QUALITY CLASSIFICATION

Introduction

Ground-water quality classification, based primarily on TDS (table 1), is a tool for local governments in Utah to use for managing potential ground-water contamination sources and for protecting the quality of their ground-water resources. Information regarding ground-water quality classification, including what is required to classify ground-water quality and why ground-water quality classification should be considered as a tool to protect ground-water quality, is presented in the Utah Division of Water Quality's (1998) *Aquifer Classification Guidance Document* and Lowe and Wallace (1999a, b).

Results

2000-2003 Data for Valley-Fill Aquifer

Data sources: As part of this ground-water quality classification, we sampled ground water from 40 wells in October 2001, and had the samples analyzed for general chemistry and nutrients by the Utah Department of Epidemiology and Laboratory Services; of these 40 wells, ground water from 10 wells was analyzed for organics and pesticides and ground water from 5 wells was analyzed for radionuclides (appendix

A). We also measured specific conductance of water from another five wells and four surface-water sites in February 2003; because of an apparent hydraulic connection between ground and surface water in the Castle Valley valley-fill aquifer, surface-water quality is likely representative of ground-water quality. These data were augmented by another 43 wells sampled in September 2000 and analyzed for specific conductance, pesticides, and nutrients (appendix A) by the Utah Department of Agriculture and Food (Quilter, 2001), and specific-conductance and TDS concentration data from ground water from 6 wells measured by the Utah Division of Water Rights between 1991 and 1996 (appendix A) (Ford and Grandy, 1997). Data reported by the Utah Division of Water Rights were also analyzed by the Utah Department of Epidemiology and Laboratory Services.

Total-dissolved-solids concentrations: The Utah Water Quality Board's drinking-water quality (health) standard for TDS is 2,000 mg/L for public-supply wells (appendix B). The secondary ground-water quality standard is 500 mg/L (U.S. Environmental Protection Agency, 2002) (appendix B), and is primarily due to imparting a potential unpleasant taste to the water (Bjorklund and McGreevy, 1971). Plate 4 shows the distribution of TDS in Castle Valley's valley-fill aquifer. Based on data from ground-water samples from 54 wells and the 4 surface-water sites, TDS concentrations in the valley-fill aquifer range from 204 to 2,442 mg/L. Only 17 wells exceed 1,000 mg/L TDS and the overall average TDS concentration of the 54 wells is 785 mg/L (appendix A, plate 4).

The higher TDS concentrations exist along the northwest margins of Castle Valley (plate 4) where the Cutler Formation is encountered at relatively shallow depths and where negligible mixing of ground and surface water occurs. Relatively high TDS concentrations are also present around Castleton and at the northwest end of the valley (figure 1, plate 4) where the Paradox Formation is exposed (plate 1).

Nitrate concentrations: The ground-water quality (health) standard for nitrate is 10 mg/L (appendix B) (U.S. Environmental Protection Agency, 2002). More than 10 mg/L of nitrate in drinking water can result in a condition known as methoglobinemia, or "blue baby syndrome" (Comley, 1945) in infants under six months and can be life threatening without immediate medical attention (U.S. Environmental Protection Agency, 2002). This condition is characterized by a reduced ability for blood to carry oxygen. Based on data from ground-water samples from 52 wells, nitrate-as-nitrogen concentrations range from less than 0.1 to 4.27 mg/L. Six wells yield ground water above 1 mg/L and the overall average nitrate concentration for the 52 wells is 0.52 mg/L (appendix A). No apparent trend in the distribution of nitrate concentrations exists (plate 5); the highest concentrations (1.54 and 4.27 mg/L) are likely attributed to proximity to stables/corrals.

Other constituents: Based on the data presented in appendix A, no wells exceeded primary water-quality standards for any chemical constituent, and no pesticides were detected (Quilter, 2001). However, one well exceeded the secondary ground-water quality standards for iron and chloride, and 25 wells exceeded the secondary ground-water quality standard for sulfate (figure 6, appendix A).

The secondary ground-water quality standard for iron is 300μg/L (appendix B) (U.S. Environmental Protection Agency, 2002), primarily to avoid objectionable staining to plumbing fixtures, other household surfaces, and laundry (Fetter, 1980; Hem, 1989). Water high in dissolved iron can also lead to the growth of iron bacteria which may lead to the clogging of water mains, recirculating systems, and sometimes wells (Driscoll, 1986). At concentrations over 1.8 mg/L, iron imparts a metallic taste to drinking water (Fetter, 1980). Concentrations of dissolved iron in Castle Valley's principal aquifer from ground-water samples from 52 wells range from less than 20 to 330 μg/L, with an average (background) dissolved-iron concentration of 53.6 μg/L. A total of 30 wells yielded ground water that was below the detection limit for dissolved iron of 20 μg/L (appendix A) for the analysis method listed in table 2. The location of the one well that yielded water exceeding the secondary ground-water quality standard for iron is shown on figure 6.

The secondary ground-water quality standard for sulfate is 250 mg/L (appendix B) (U.S. Environmental Protection Agency, 2002), primarily because of odor/taste problems and because high-sulfate water can have a laxative effect (Fetter, 1980). Concentrations of dissolved sulfate in Castle Valley's principal aquifer range from 39.6 to 1,350 mg/L, with an average (background) sulfate concentration of 340 mg/L. No wells yielded ground water below the detection limit for sulfate of 10 mg/L (appendix A) for the analysis method listed in appendix B. Twenty-five wells yielded water samples that exceed the secondary ground-water quality standard for sulfate (figure 6). Geologic provenance (source rock for valley-fill sediment) likely is an important factor determining the distribution of sulfate in the valley-fill aquifer; metallic sulfides in both igneous and sedimentary rocks are common sources of sulfur in its reduced form (Hem, 1989), as is gypsum which is found in the Paradox Formation.

The secondary ground-water quality standard for chloride is 250 mg/L (appendix B) (U.S. Environmental Protection Agency, 2002), primarily because of the potential for imparting a salty taste to drinking water (Hem, 1989). Chloride at concentrations over 500 mg/L can cause corrosion to wells and plumbing (Driscoll, 1986). Concentrations of dissolved chloride in Castle Valley's principal aquifer (figure 6) range from 13.7 to 282 mg/L, with an average (background) chloride concentration of 68.2 mg/L. No wells yielded ground water below the detection limit for chloride of 3 mg/L (appendix A) for the analysis method listed in appendix B. One well yielded a water sample that exceeds the secondary ground-water quality standard for chloride (figure 6). Geologic provenance likely is an important factor determining the distribution of chloride in the valley-fill aquifer; although chloride is present at low concentrations in many rock types, it is more common in sedimentary rocks, especially evaporites (Hem, 1989). The Paradox Formation is a known source of chloride (Sumsion, 1971).

Resulting Ground-Water Quality Classification

Shown on plate 6 is our ground-water quality classification for the northwestern part (40 percent) of the valley-fill aquifer in Castle Valley, approved by the Utah Water Quality Board on December 5, 2003. The classification is based on data from 54 wells presented in appendix A and discussed above, and on TDS values converted from specific-conductance data for 14 wells and 4 surface-water sites reported by

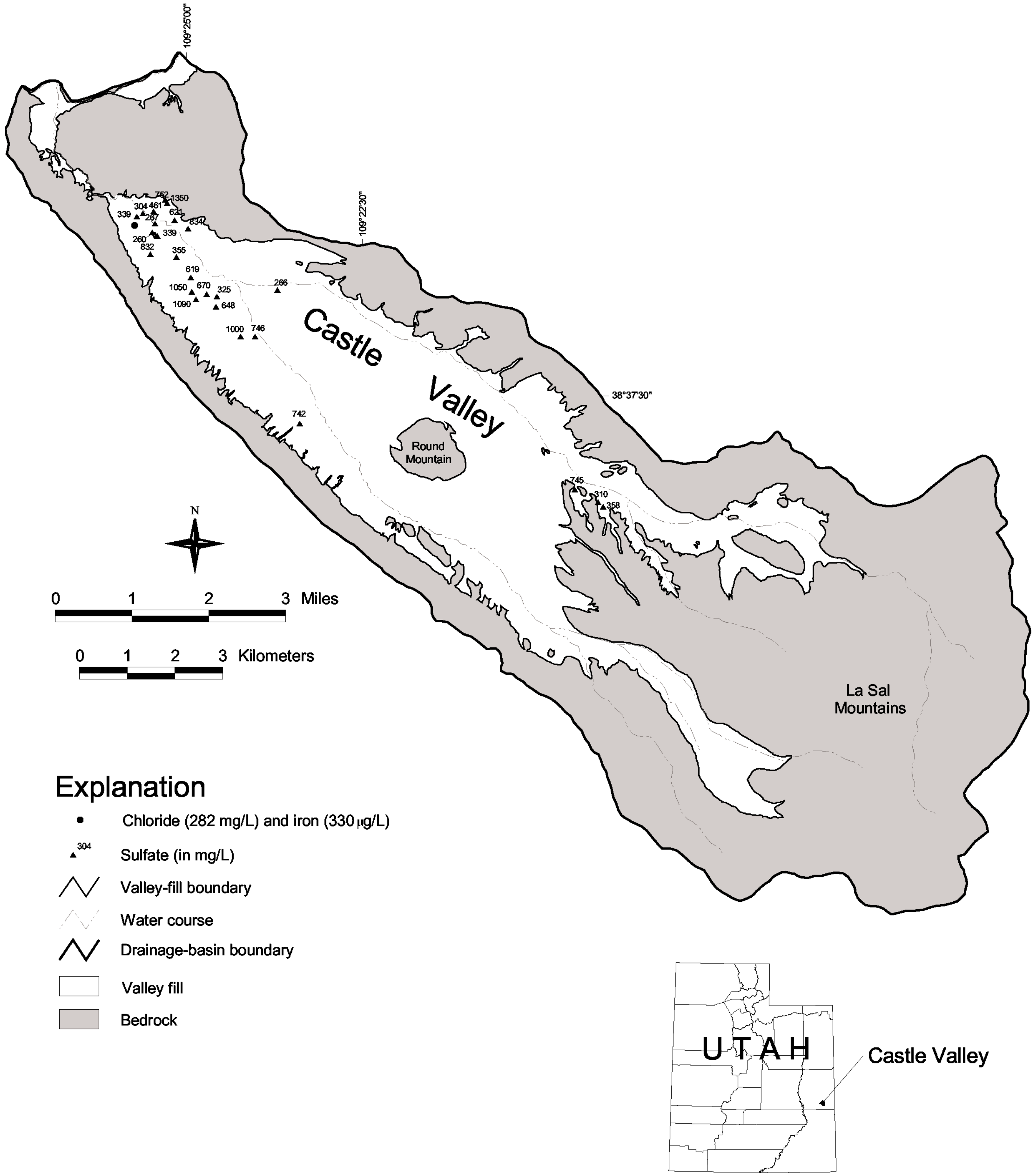

Figure 6. *Water wells having chemical constituents that exceed secondary drinking-water standards in Castle Valley, Grand County, Utah. One well has elevated chloride and iron concentrations and 25 wells have elevated sulfate concentrations.*

the Utah Geological Survey (UGS), Utah Department of Agriculture and Food, Utah Division of Water Rights (UDWRi), and Utah Division of Water Quality (UDWQ). Total-dissolved-solids concentrations for the 14 wells and 4 surface-water sites were calculated based on the relationship between specific conductance and TDS derived from data from 44 wells in Castle Valley for which both values are known (figure 7, appendix A). Some TDS data collected in the southern part of the valley by the UGS, UDWQ, and UDWRi were resampled by citizens of Castle Valley during different seasons; the resulting data show variations in water quality (seasonally fluctuating between Class IA and Class II), and were not useful in classifying ground water in the southeastern part (60 percent) of Castle Valley because of insufficient water-quality data. Where limited and variable water-quality data exist (temporally and spatially), extrapolation of ground-water quality conditions is required. We based the extrapolation on local geologic characteristics (see geologic cross sections, plate 1, Town of Castle Valley, 2000). The classes (plate 6) are described below.

Class IA- Pristine ground water: For this class, TDS concentrations in Castle Valley range from 204 to 480 mg/L (appendix A). Class IA areas are mapped primarily in the central part of northwestern Castle Valley near the confluence of Castle and Placer Creeks where recharge from surface water is sufficient to keep ground water diluted below 500 mg/L total dissolved solids (plate 6), or are pristine due to the presence of less-soluble minerals in the alluvium there. Areas having Pristine water quality cover about 48 percent of the classified part of the valley-fill material in northwestern Castle Valley.

Class II- Drinking Water Quality ground water: For this class, TDS concentrations in the Castle Valley valley-fill aquifer range from 602 to 2,442 mg/L (appendix A). Class II areas defined by TDS data, and some specific-conductance data converted to TDS, collected as part of this and previous studies represent about 52 percent of the classified part of the valley-fill material in northwestern Castle Valley, and are found along the western margin and northern end of the valley (plate 6).

Unclassified part of valley-fill aquifer in Castle Valley: Areas having limited data within the drainage basin cover about 60 percent of the total valley-fill material. We believe this area will yield both Class IA and Class II quality ground water based on extrapolated geologic conditions (see plate 1 cross sections, Town of Castle Valley, 2000; plate 2) and water-quality information collected from all four agencies described earlier. The water-quality data indicate both temporal and spatial fluctuations in water quality. Based on the nature of the Cutler Formation beneath valley-fill material in some areas, and along faults, we believe proposed water wells adjacent to or tapping into this unit may potentially yield water having TDS between 500 and 3,000 mg/L (Drinking Water Quality ground water) or greater, similar to water quality reported from bedrock wells (Ford and Grandy, 1997). We also recognize areas near the less-soluble igneous

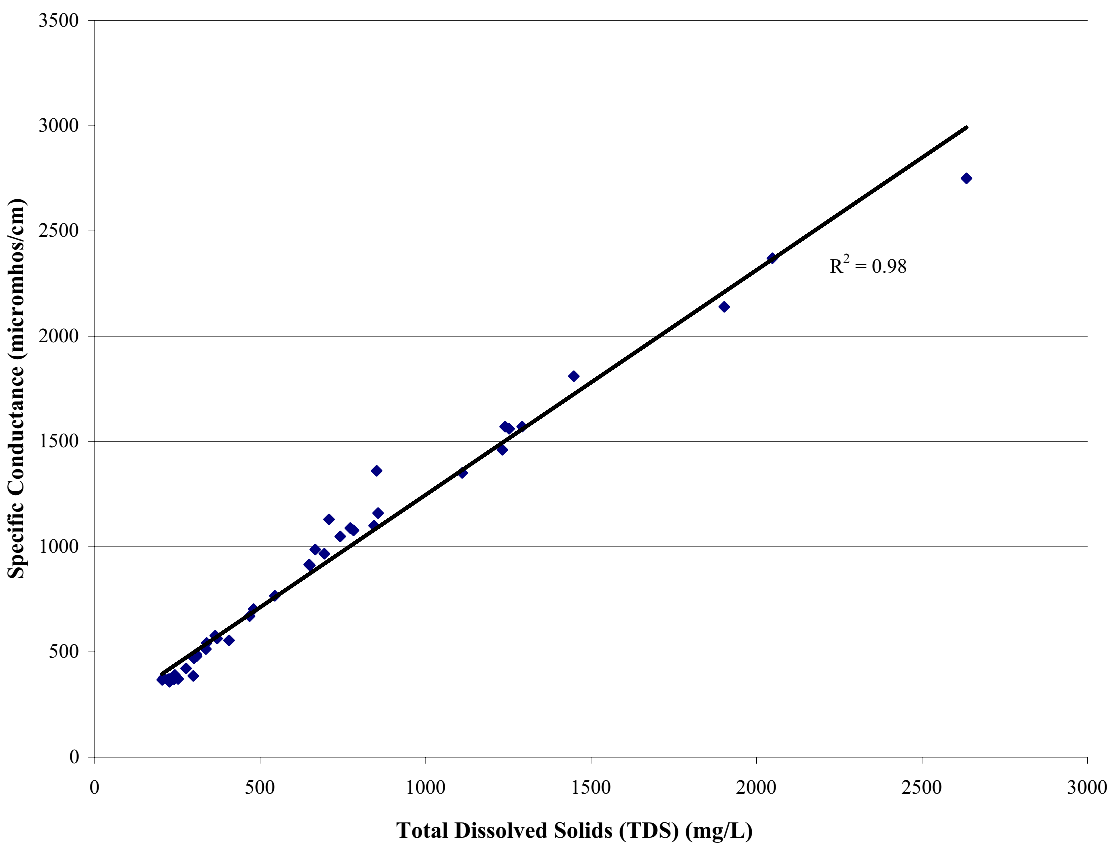

Figure 7. *Specific conductance versus total-dissolved-solids concentration data for 44 wells in Castle Valley, Grand County, Utah. R-squared is 0.98. Based on Hem's (1985) equation for estimating TDS from specific conductance: KA=S, where K is specific conductance, S is TDS, and A is a coefficient slope that ranges from 0.55 to 0.96. We used an average A=0.69 to compute TDS in Castle Valley.*

rocks of the La Sal Mountains, especially in the extreme southeast part of the valley, as well as areas near Castle Creek, may yield water having TDS less than 500 mg/L (Pristine ground water) (plate 5). However, insufficient data are available to bring a proposed ground-water quality classification before the Utah Water Quality Board.

Land-Use Planning Considerations

Current beneficial uses of ground water: Ground water, most of which is from the valley-fill aquifer, is the most important source of water in Castle Valley. All of the domestic (culinary) water and, on average, 50 percent of the irrigation water used in Castle Valley is from ground-water sources (Casey Ford, Utah Division of Water Rights, verbal communication, July 29, 2002). Castle Valley has 270 approved water wells, one of which is a public-supply well that serves a private school community (Mark Jensen, Division of Drinking Water, verbal communication, August 2002) accommodating up to 25 attendees during the school year. The locations of all water-supply wells are shown on plate 6. The results of the ground-water quality classification for Castle Valley indicate the valley-fill aquifer contains mostly high-quality ground-water resources that warrant protection.

Potential for ground-water quality degradation: We mapped potential ground-water contaminant sources including facilities related to mining, agricultural practices, and junkyard/salvage areas (appendix C, plate 7). A primary objective was to identify potential contaminant sources to establish a relationship between water quality and land-use practices. We mapped 85 potential contaminant sources in the following categories:

(1) mining, which includes abandoned and active gravel mining operations,

(2) agricultural sites, which consist of irrigated and non-irrigated farms, active and abandoned animal feed lots, corrals, stables/barnyards, and animal wastes, including wastes dominantly produced from feeding facilities, waste transported by runoff, and excrement on grazing or pasture land,

(3) junkyard/salvage areas that potentially contribute metals, solvents, and petroleum products,

(4) government facility/equipment storage associated with a variety of sources such as salt storage facilities, transportation/equipment storage, and mosquito abatement equipment that may contribute metals, solvents, and petroleum,

(5) cemeteries, nurseries, greenhouses, and a golf course that may contribute chemical preservatives, fertilizer, and pesticides,

(6) storage tanks that may contribute pollutants such as fuel and oil, and

(7) oil and gas wells that may also contribute pollutants such as petroleum and oil.

In addition to the above-described potential contaminants, plate 7 shows the distribution of septic tank soil-absorption systems in Castle Valley. Castle Valley currently has approximately 235 septic-tank systems (Jim Adamson, Southeastern Utah District Health Department, written communication, June 2002). Septic-tank systems may contribute contaminants such as nitrate and solvents. All approved water wells, shown on plate 6, are also considered potential contaminant sources because of the potential for substances to be placed in or poured down them.

Possible land-use planning applications of this ground-water quality classification: Ground-water quality classification is a tool that can be used in Utah to manage potential ground-water contamination sources and protect the quality of ground-water resources. As such, the wide range of land-use planning applications of this tool have not been fully explored. Ground-water quality classification has been used in Heber Valley in Wasatch County and Ogden Valley in Weber County, in concert with septic-tank density/water-quality degradation studies (Hansen, Allen, and Luce, Inc., 1994; Wallace and Lowe, 1998a, 1999; Lowe and Wallace, 2001), to determine appropriate sizes of lots using septic-tank systems for wastewater disposal.

One possible application of the ground-water quality classification presented above is using the classification in conjunction with the septic-tank density/water-quality degradation analysis presented below to set areal maximum densities for development using septic-tank systems for wastewater disposal in Castle Valley. Additional potential uses include using ground-water quality classification as a basis for prohibiting the dumping of poor-quality water and other liquid or solid wastes into creek beds or canals and ditches. Ground-water quality classification can also be used in conjunction with the existing Sole Source Aquifer designation to enhance restrictions to the siting of new potential pollution sources in the valley-fill portion of the Castle Valley drainage basin.

SEPTIC-TANK DENSITY/WATER-QUALITY DEGRADATION ANALYSIS

Introduction

Land-use planners have long used septic-tank suitability maps to determine where these systems will likely percolate within an acceptable range. However, they are now becoming aware that percolation alone does not remediate many constituents found in wastewater, including nitrate. Ammonium from septic-tank effluent under aerobic conditions can convert to nitrate, contaminating ground water and posing potential health risks to humans (primarily very young infants). The U.S. Environmental Protection Agency's maximum contaminant level for drinking water (Utah ground-water quality standard) for nitrate is 10 mg/L. With continued population growth and installation of septic tank soil-absorption systems in new developments, the potential for nitrate contamination will increase. One way to evaluate the potential impact of septic-tank systems on ground-water quality is to perform a mass-balance calculation (Hansen, Allen, and Luce, Inc., 1994; Zhan and McKay, 1998; Lowe and Wallace, 1999c, d; Wallace and Lowe, 1999; Lowe and others, 2000). This type of analysis may be used as a gross model for evaluating the possible impact of proposed developments using septic-tank systems for wastewater disposal on ground-water quality, allowing planners to more effectively determine appropriate average septic-system densities.

Ground-Water Contamination from Septic-Tank Systems

Pathogens

As the effluent from a septic tank soil-absorption system leaves the drain field and percolates into the underlying soil, it can have high concentrations of pathogens, such as viruses and bacteria. Organisms such as bacteria can be mechanically filtered by fine-grained soils and are typically removed after traveling a relatively short distance in the unsaturated zone. However, in coarse-grained soils, or soils containing preferential flow paths like cracks, worm burrows, or root holes, these pathogens can reach the water table. Living pathogens can travel up to 40 feet (12 m) in the unsaturated zone in some soils (Franks, 1972). Some viruses can survive up to 250 days (U.S. Environmental Protection Agency, 1987), which is the minimum ground-water time of travel for public water-supply wells or springs to be separated from potential biological contamination sources.

Household and Industrial Chemicals

Many household and industrial chemicals (table 3) are commonly disposed of through septic systems and, unless they volatilize easily, are not remediated by percolation through soils in the unsaturated zone. Contamination from these chemicals can be minimized by reducing their disposal via septic-tank systems, maximizing the potential for dilution of those chemicals that do reach ground water (Lowe and Wallace, 1999e).

Phosphate

Phosphate, typically derived from organic material or some detergents, is discharged from septic-tank systems (Fetter, 1980). While phosphate (and phosphorus) is a major factor in causing eutrophication of surface waters (Fetter, 1980), it is generally not associated with water-quality degradation from septic-tank systems (Lowe and Wallace, 1999e). Phosphates are removed from septic-tank system effluent by adsorption onto fine-grained soil particles and by precipitation with calcium and iron (Fetter, 1980). In most soils, complete removal of phosphate is common (Franks, 1972).

Nitrate

Ammonia and organic nitrogen are commonly present in effluent from septic-tank systems (table 3), mostly from the human urinary system. Typically, almost all ammonia is converted into nitrate before leaving the septic tank soil-absorption system drain field. Once nitrate passes below the zone of aerobic bacteria and the roots of plants, there is negligible attenuation as it travels farther through the soil (Franks, 1972). Once in ground water, nitrate becomes mobile and can persist in the environment for long periods of time. Areas having high densities of septic-tank systems risk elevated nitrate concentrations reaching unacceptable levels. In the early phases of ground-water quality degradation associated with septic-tank systems, nitrate is likely to be the only pollutant detected (Deese, 1986). Regional nitrate contamination from septic-tank discharge has been documented on Long Island, New York, where many densely populated areas without sewer systems existed (Fetter, 1980).

A typical single-family septic-tank system in Castle Valley discharges about 171 gallons (747 L) of effluent per day containing nitrate concentrations of around 54.4 mg/L; see discussion below. The U.S. Environmental Protection Agency maximum contaminant level for drinking water (ground-water quality [health] standard) for nitrate is 10 mg/L. Therefore, distances between septic-tank system drain fields and sources of culinary water must be sufficient to allow dilution of nitrate in the effluent to levels below the ground-water quality standard.

We consider nitrate to be the key indicator for use in determining the number or density of septic-tank systems that should be allowed in Castle Valley. Projected nitrate

Table 3. *Typical characteristics of wastewater from septic-tank systems (from Hansen, Allen, and Luce, Inc., 1994).*

Parameter	Units	Quantity
Total Solids	mg/L	680 - 1000
Volatile Solids	mg/L	380 - 500
Suspended Solids	mg/L	200 - 290
Volatile Suspended Solids	mg/L	150 - 240
BOD	mg/L	200 - 290
Chemical Oxygen Demand	mg/L	680 - 730
Total Nitrogen	mg/L	35 - 170
Ammonia	mg/L	6 - 160
Nitrites and Nitrates	mg/L	<1
Total Phosphorus	mg/L	18 - 29
Phosphate	mg/L	6 - 24
Total Coliforms	**MPN/100 mL	10^{10} - 10^{12}
Fecal Coliforms	**MPN/100 mL	10^{8} - 10^{10}
pH	-	7.2 - 8.5
Chlorides	mg/L	86 - 128
Sulfates	mg/L	23 - 48
Iron	mg/L	0.26 - 3.0
Sodium	mg/L	96 - 110
Alkalinity	mg/L	580 - 775
P-Dichlorobenzene*	mg/L	0.0039
Toluene*	mg/L	0.0200
1,1,1-Trichloroethane*	mg/L	0.0019
Xylene*	mg/L	0.0028
Ethylbenzene*	mg/L	0.004
Benzene*	mg/L	0.005

* *Volatile Organics are the maximum concentrations*
** *Most probable number*

concentrations in all or parts of aquifers can be estimated for increasing septic-tank system densities using a mass-balance approach.

The Mass-Balance Approach

General Methods

We use a mass-balance approach for water-quality degradation assessments because it has been used elsewhere in the western United States for land-use planning purposes (Hansen, Allen, and Luce, Inc., 1994; Wallace and Lowe, 1998a, b, c, 1999; Zhan and McKay, 1998; Lowe and Wallace, 1999c, d; Lowe and others, 2000), is easily applied, and requires few data. In the mass-balance approach to compute projected nitrate concentrations, the average nitrogen mass expected from projected new septic tanks is added to the existing, ambient (background) mass of nitrogen in ground water and then diluted with the known (or estimated) ground-water flow available for mixing, plus water that is added to the system by septic tanks. We used a discharge of 171 gallons (747 L) of effluent per day for a domestic home based on a per capita indoor usage of 70 gallons (265 L) per day (Utah Division of Water Resources, 2001a; 2001b, p. 28) by Grand County's average 2.44 person household (U.S. Census Bureau, 2002). We used an estimated nitrogen loading of 54.4 mg/L of effluent per domestic septic tank for nitrogen loadings based on (1) an average number of people per household of 2.44, (2) an average nitrogen loading of 17 g N per capita per day (Kaplan, 1988, p. 149), and (3) an assumed retainment of 15 percent of the nitrogen in the septic tank (to be removed later during pumping) (Andreoli and others, 1979, *in* Kaplan, 1988, p. 148); this number is close to Bauman and Schafer's (1985, *in* Kaplan, 1988, p. 147) nitrogen concentration in septic-tank effluent of 62 ± 21 mg/L based on the averaged means from 20 previous studies. Ground-water flow available for mixing, the major control on nitrate concentration in aquifers when using the mass-balance approach (Lowe and Wallace, 1997), was determined using the ground-water flow model of Downs and Lasswell (undated).

Limitations

All mass-balance approaches have limitations (see, for example, Zhan and McKay [1998]). We identify the following limitations to our application of the mass-balance approach:

1. Calculations are typically based on a short-term hydrologic budget, a limited number of aquifer tests, and limited water-gradient data.
2. Background nitrate concentration is attributed to natural sources, agricultural practices, and use of septic-tank systems, but projected nitrate concentrations used in this approach are based on septic-tank systems only and do not include nitrate from other potential sources (such as lawn and garden fertilizer).
3. Calculations do not account for localized, high-concentration nitrate plumes associated with individual or clustered septic-tank systems, and also assume that the septic-tank effluent from existing homes is in a steady-state condition with the aquifer.
4. The approach assumes negligible denitrification.
5. The approach assumes uniform, instantaneous ground-water mixing for the entire aquifer or entire mixing zone below the site.
6. Calculations do not account for changes in ground-water conditions due to ground-water withdrawal from wells (see Recharge and Discharge section above).
7. Calculations are based on aquifer parameters that must be extrapolated to larger areas where they may not be entirely representative.
8. Calculations may be based on existing data that do not represent the entire valley.

Although many caveats to applying this mass-balance approach exist, we think it is useful in land-use planning because it provides a general basis for making recommendations for septic-tank-system densities. In addition, the approach is cost-effective and easily applied with limited information.

Ground-Water Flow Calculations

Introduction

We used the GMS ground-water modeling system, applied to a modified three-dimensional, steady-state MODFLOW model of Downs and Lasswell (undated), to determine the available ground-water flow in the saturated, unconsolidated valley-fill deposits in Castle Valley. We modified the model by incorporating hydraulic conductivities determined from an aquifer test in the valley. The model simulated unconfined conditions, withdrawal from wells, evapotranspiration, seepage to and from streams, areal recharge, seepage to drains, and seepage from consolidated rock.

Computer Modeling

We used Downs and Lasswell's (undated) numerical model of ground-water flow in Castle Valley to simulate ground-water flow in the unconsolidated valley-fill aquifer, because it provides the best representation currently available of the Castle Valley valley-fill aquifer. The ground-water flow model extends from the surface-water divide in the La Sal Mountains to the Colorado River, and covers an area of about 110 square miles (280 km^2). Because of its rectangular construction, the model area is larger than the 56-square-mile (145 km^2) Castle Valley drainage basin, but this does not affect the results of the mass-balance analysis. The model simulates ground-water flow by approximating the differential equation for steady-state flow of water in an aquifer, in this case, both fractured rock and unconsolidated valley fill in the drainage basin. Application of the model to the valley-fill aquifer requires estimates of recharge, discharge, and the hydraulic characteristics of the aquifer throughout the area. Hydraulic characteristics include saturated thickness, hydraulic conductivities, storage coefficients, and water levels. We made initial estimates for each of these characteristics from field data, and then adjusted the model to improve the estimates of hydraulic characteristics based on aquifer- and slug-test data (appendix E). The steady-state ground-water flow model provided the cells that we used to determine the amount of ground water available in the valley-fill aquifer.

Description of Model of Downs and Lasswell (Undated)

Downs and Lasswell (undated) used the USGS modular three-dimensional, finite-difference, ground-water flow simulator (MODFLOW) by McDonal and Harbaugh (1988) to test and refine their conceptual understanding of the ground-water flow system in Castle Valley. The model assumes three-dimensional flow in the aquifer and one-dimensional vertical flow between layers using a vertical leakance term, and ignores storage.

Downs and Lasswell (undated) developed a generalized conceptual model using limited geologic and hydrologic information. Their conceptual model includes (1) ground-water boundaries, (2) rates of recharge and discharge, (3) estimated values of hydraulic properties, and (4) water levels in the valley-fill aquifer.

The conceptual model does not account for subsurface inflow from adjoining areas outside the surface-drainage basin. The location of the ground-water divides, and general directions of ground-water flow were determined from Snyder's (1996a, b) potentiometric-surface map. Where no water-level data were available, the water table was estimated by extrapolating of the potentiometric-surface gradient from areas having data.

Downs and Lasswell (undated) identified infiltration of precipitation and an areal distribution of representative recharge from the streams as main sources of recharge to the valley-fill aquifer. The estimates of recharge from precipitation are based on the distribution of annual precipitation and evapotranspiration rates. Net recharge rates are relatively high in the mountains and upper valley due to the higher precipitation and stream recharge there. In the lower parts of the valley, evapotranspiration exceeds precipitation and recharge from precipitation is negligible (Downs and Lasswell, undated).

In the Downs and Lasswell (undated) model, the valley-fill aquifer is mostly recharged from the underlying bedrock. However, throughout most of Castle Valley, Castle and Placer Creeks are losing streams and are the primary sources of recharge to the valley-fill aquifer (Snyder, 1996a, b). As modeled by Downs and Lasswell (undated), ground-water discharge from the valley-fill aquifer is primarily from (1) evapotranspiration, (2) seepage to Castle Creek and Placer Creek where streams contact the valley-fill aquifer, (3) withdrawals from water wells, and (4) seepage to the Colorado River.

Downs and Lasswell (undated) simplified this conceptual model of the Castle Valley ground-water system to facilitate creation of their numerical model of ground-water flow. Their simplified assumptions for the aquifer are, from the surface downward:

- An upper unconsolidated valley-fill aquifer of variable thickness. The alluvial sediments consist of as much as 350 feet (107 m) of poorly sorted, coarse gravel, sand, and silt, 0 to 300 feet (0-90 m) of which can be saturated with ground water. The thickness of the valley-fill aquifer decreases toward the mountains. There is no lateral subsurface inflow from adjoining areas.
- A semiconfining boundary condition between the valley-fill aquifer and the underlying fractured-rock aquifers that allows some vertical ground-water movement.
- An extensive, lower fractured-rock aquifer that consists of sandstone having an unknown thickness that Downs and Lasswell (undated) arbitrarily designate as 500 feet (150 m). This aquifer acts as a single water-bearing unit. There is no lateral subsurface inflow to it from adjoining areas.
- An impermeable base of bedrock (no-flow boundary condition) at depths greater than 500 feet (150 m).

The steady-state model incorporates averaged hydraulic characteristics and pumping in Castle Valley over several time periods.

Boundary conditions imposed on the Castle Valley model involved considerable simplification of the hydrologic system. Downs and Lasswell (undated) specified most of the lateral boundaries surrounding the valley as "no-flow" boundaries (figure 8) on the assumption that they coincide with low-permeability bedrock. In layer one, the no-flow boundaries of the active model area were selected to coincide with the natural valley-fill/bedrock boundaries on the northeastern and southwestern sides of the aquifer. In the southeastern part of the drainage, the model boundary coincides with ground-water divides underlying the highest points of land. The northwestern boundary corresponds to the Colorado River, where the aquifer is narrow and flow lines are perpendicular to the river. Exceptions to the no-flow boundaries are the 30 constant-head cells at the north end of the model that simulate the elevation of the Colorado River. The upper boundary of the model is a specified-flux boundary formed by using the recharge, well, evapotranspiration, and drain packages of MODFLOW to simulate the infiltration of precipitation and discharge of ground water for layer one. The lower boundary of the model is a no-flow boundary below layer two. We did not modify the boundary conditions of the model.

Because aquifer characteristics are not uniform, the aquifer was divided into rectangular cells in which the characteristics were assumed to be uniform at a node in the center of each cell, but can vary from node to node. The ground-water flow simulator solves for the flow at each node using a three-dimensional, finite-difference approximation to the partial differential equation of ground-water flow. Downs and Lasswell (undated) discretized the valley-fill aquifer into a three-dimensional grid of 93 rows by 53 columns, and divided the model into a valley-fill layer and a bedrock layer. The rectilinear grid consists of 4,836 cells per layer and covers an area of 110.25 square miles (284 km^2). The model has non-uniform grid-cell dimensions ranging from 50 feet by 50 feet (15 by 15 m) to 300 feet by 300 feet (90 by 90 m) (cell

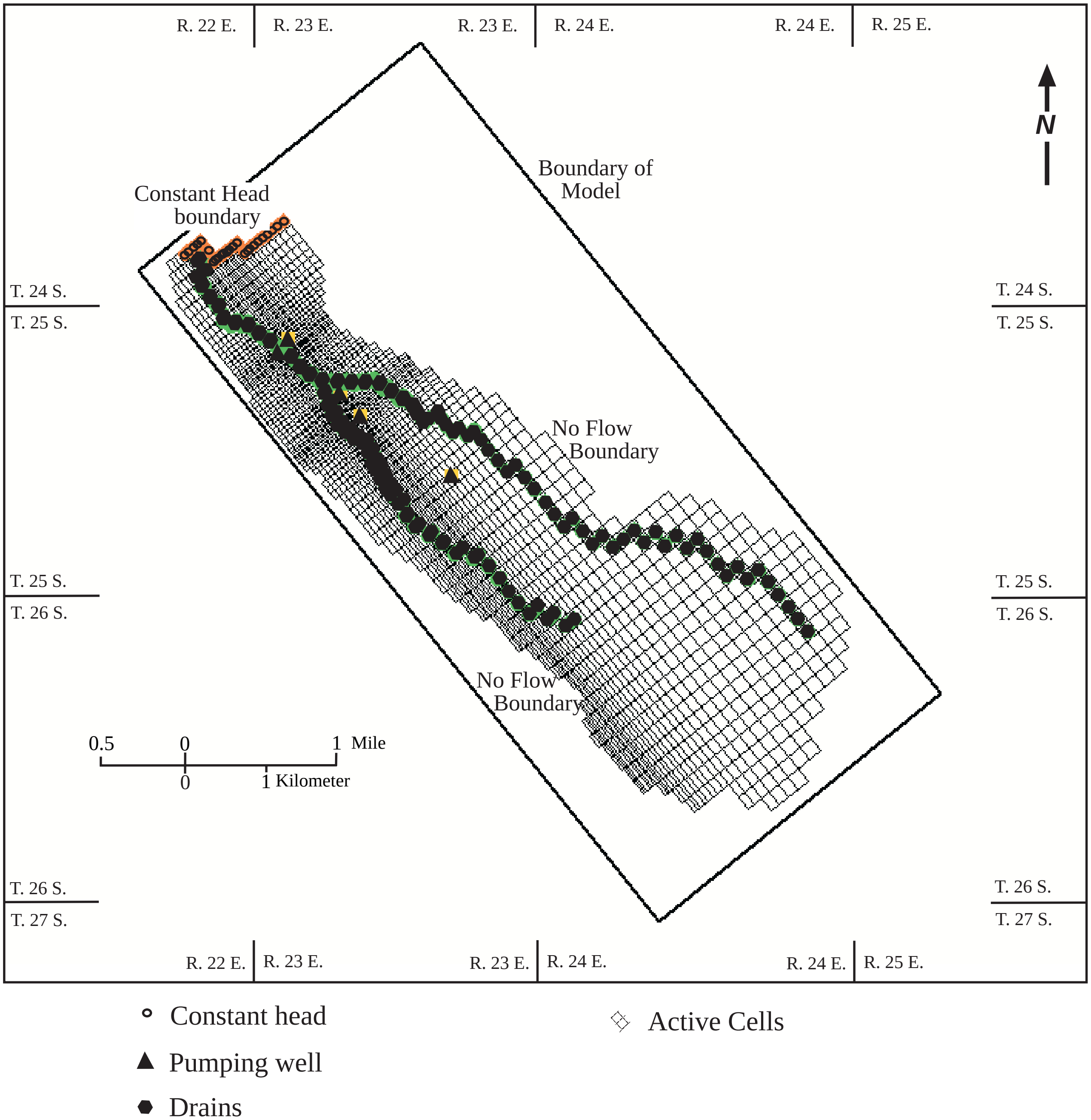

Figure 8. *Finite-difference grid and some boundary conditions used in the mathematical model for the valley-fill aquifer in Castle Valley, Grand County, Utah.*

areas ranging from 2,500 square feet to 90,000 square feet [230-8,300 m^2]). The variable grid dimensions emphasize areas of special interest and/or where more data exist, particularly in the vicinity of the town of Castle Valley. Layer one, the valley-fill aquifer layer, has a variable thickness, and layer two, the bedrock aquifer layer, has a constant thickness of 500 feet (150 m). Each layer has 2,893 active grid cells that cover an area of about 46 square miles (120 km^2). The active cells in layer one cover the major parts of Castle Valley where the Quaternary-age valley-fill material is more than 10 feet (3 m) thick. Layer two represents saturated bedrock from the bottom of the valley-fill deposits to a thickness of 500 feet (150 m). The y-axis of the model is oriented northwest-southeast in alignment with the primary surface-water drainages and predominant direction of ground-water flow. We did not modify the model grid.

The hydraulic characteristics of the valley-fill aquifer affect the amount of water moving through the aquifer, the amount of water in storage, and water levels in the valley. Downs and Lasswell (undated) initially estimated hydraulic parameters and aquifer thickness based on geologic descriptions of valley-fill deposits. The hydraulic parameters for the bedrock aquifer were based on an aquifer test in Spanish Valley.

We modified the hydraulic conductivity in layer one in the model to incorporate new data that we collected as part of this study. To derive an improved estimate of the hydraulic conductivity of the valley-fill aquifer, we (1) conducted a single-well aquifer test of a water well completed in the valley-fill aquifer and analyzed the data, (2) analyzed data from 30 slug tests conducted by the Utah Division of Water Rights on water wells completed in the valley-fill aquifer (appendix F), and (3) calculated hydraulic conductivity from well-test data reported on drillers' logs. All additional data were obtained from wells within the town of Castle Valley. We did not change the value of transmissivity used for layer two and the vertical leakance used to represent the connection of layers one and two from the values used by Downs and Lasswell (undated), because no new information on these parameters was gained from any of the tests we analyzed.

Downs and Lasswell (undated) originally matched averaged water levels in two wells in the valley-fill aquifer to calibrate their model; during the calibration procedure, they modified their original hydraulic-conductivity estimates to obtain acceptable agreement between measured and model-calculated water levels. During our steady-state calibration of the model, we assigned hydraulic conductivities based on the values derived from our aquifer and slug tests (appendix F), and then systematically varied these values until we matched the water levels in the two wells that Downs and Lasswell (undated) used. Horizontal hydraulic-conductivity values of the first layer ranged from 1 to 225 feet per day (0.3-69 m/d) (table 4). The low values of hydraulic conductivity at the edge of the valley reflect the low transmissivity of finer-grained material and no-flow boundary effects.

The model supports Snyder's (1986a, b) determination that ground-water flow in the valley-fill aquifer is from southeast to northwest. The volume of water in the valley-fill aquifer increases with increasing valley-fill thickness and higher transmissivity, resulting in higher storativity. Table 5 summarizes the water budget for the valley-fill aquifer used in the ground-water flow model.

Results

The ground-water flow model used for this study is the best available tool to estimate the amount of water available for mixing with septic-tank effluent. Use of the simulation improved our understanding of the aquifer system and provided the volumetric flow budget needed for the budget for the aquifer in relation to aquifer characteristics, volume of water in storage, and volumes and rates of inflow and outflow. We assume mixing/dilution of septic-tank effluent will occur within ground-water model layer one.

Based on the spatial distribution of the cell-by-cell flow terms calculated by MODFLOW, we identified four domains in Castle Valley with similar flows in layer one. We then used the MODFLOW budget to determine the available ground-water flow in saturated, unconsolidated valley-fill deposits of the unconfined aquifer for each domain. Domains vary in area from 176 to 1,632 acres (71-660 hm^2) and have volumetric flows from 0.28 to 1.1 cubic feet per second (7.9-31.1 L/s) and flow in cubic feet per second per acre of 0.0002 to 0.002 (0.006-0.06 L/s/acre) (table 6; figure 9). We use the volumetric flows in the mass-balance calculations.

Model Limitations

Constructing a numerical model of a natural hydrogeologic system requires simplifying assumptions. Some assumptions limit the scope of the application of the model and the hydrologic questions that can reasonably be addressed,

Table 4. *Final hydraulic parameter values used in the Castle Valley ground-water flow model, Castle Valley, Grand County, Utah.*

Locations	Hydraulic conductivity (feet per day)	Transmissivity (square feet per day)	Vertical leakance (feet per day per feet)
Model Layer one			
Active cells around the lower perimeter of valley	1	—	—
Lower interior active cells in the main valley	5-210	—	—
Higher interior active cells in the main valley	210-225	—	—
Between Layers one and two			
All active cells	—	—	0.0002-0.0018
Model Layer two			
All active cells	—	5,000	—

Table 5. *Simulated steady-state ground-water budget for the valley-fill aquifer in Castle Valley, Grand County, Utah, determined from ground-water flow simulation.*

Component	Steady-state calibration (acre-feet per year)
Recharge	
Infiltration of precipitation for layer one	1,100
Areal distribution at recharge representing recharge from streams	22,500
Total recharge	23,600
Discharge	
Evapotranspiration	2,000
Seepage to streams (Castle Creek)	1,000
Withdrawals from wells	1,600
Seepage to Colorado River	19,000
Total discharge	23,600

Table 6. *Parameters used to perform a mass-balance analysis for ground-water flow domains in Castle Valley, Grand County, Utah.*

Domain	Area (acres)	Flow* (cfs)	Flow per acre (cfs per acre)	Average nitrate concentration (background) (mg/L)	Number of wells sampled	Current number of septic tanks+
1	564	1.1	0.002	0.40	7	15
2	176	0.40	0.0023	0.18	2	14
3	1590	0.70	0.0004	0.48	21	62
4	1632	0.28	0.0002	0.25	17	61

** Data derived using ground-water flow computer model (see text for explanation).*

+ Number of septic tanks estimated by the Southeast Utah Health Department (Jim Adamson, written communication, August 2002).

and may influence the model results. We used a steady-state simulation with time-averaged and measured conditions; thus, the model cannot predict the transient response of the system, because it is not calibrated to transient conditions. This means we cannot use the model to predict flows in the system if new stresses, such as adding a large well, are applied. The simplified boundary conditions and insufficient data to accurately calibrate the model also limit its accuracy. The simulation reasonably reproduces our conceptual model of the ground-water flow system in the valley. No measured ground-water budget exists to compare to the budget we determined through ground-water flow simulation using the model. We believe our revision of Downs and Lasswell's (undated) model is the best tool currently available to simulate steady-state conditions and estimate ground-water flow volumes (figure 9) for use in modeling septic-tank system density/water-quality degradation.

Septic-Tank System/Water-Quality Degradation Analyses

Introduction

We calculated projected domain-specific nitrate concentrations in four ground-water flow domains (table 6) by

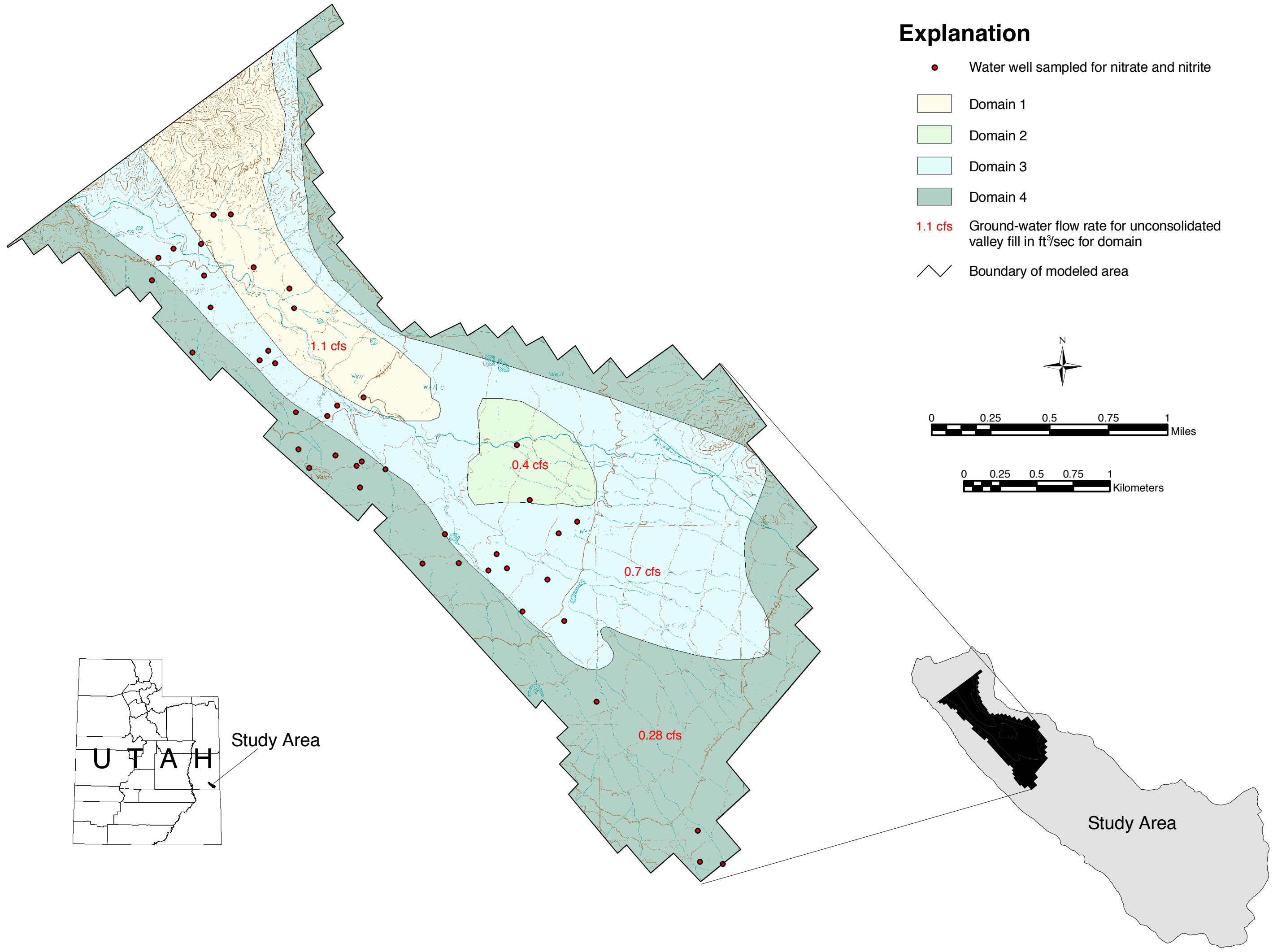

***Figure 9**. Ground-water flow domains in Castle Valley, Grand County, Utah.*

***Table 7**. Results of the mass-balance analysis using the best-estimate nitrogen loading of 54.4 mg N/L** for different ground-water flow domains in Castle Valley, Grand County, Utah.*

Domain	Current density (acres/system)	Current number of septic tanks	Projected number of septic tanks (additional)	Total # projected septic systems (for 1* mg/L)	Calculated lot-size recommendation (acres)		Lot-size recommendation (acres)
					1* mg/L	3* mg/L	
1	38	15	79	94	6	2.5	5
2	12.6	14	28	42	4.2	1.8	5
3	27	62	51	113	15	8.7	15
4	27	61	21	82	20	13.5	15

***Best-estimate calculation is based on a nitrogen load of 17 g N per capita per day (from Kaplan, 1988) for a 2.44-person household and 171 gallons per day as the amount of water generated per household based on the 2001 Utah State Water Plan (Utah Division of Water Resources, 2001a).*

**1 mg/L increase above background nitrate concentration as acceptable level of degradation and a total of 3 mg/L as acceptable level of degradation.*

applying a mass-balance approach using domain-specific parameters, such as the existing nitrogen load (background nitrate concentration) and amount of ground water available for mixing (table 7), and our estimated 171 gallons per day (747 L/d) contributed by each septic-tank system with an estimated nitrogen loading of 54.4 mg/L of septic-tank effluent. The mass-balance approach predicts the impact of nitrate from use of septic-tank systems over a defined area.

We used the mass-balance approach to calculate septic-tank density/water-quality degradation for each area based on a range of parameters that affect nitrogen loading and the amount of ground water available for dilution. We obtained the number of septic-tank systems in each area from the Southeast Utah Health Department (Jim Adamson, written communication, 2002). Tables 6 and 7 list the number of septic-tank systems estimated for each domain. The total number of septic-tank systems in the valley currently is estimated at 152 for all the domains, and ranges from a low of 14 (domain 2) to a high of 62 (domain 3) (tables 6 and 7). Background nitrate concentrations for each domain range from 0.18 mg/L (domain 2) to 0.48 mg/L (domain 3). We consider two scenarios: (1) allowing a 1 mg/L degradation above current background levels of nitrate (a value adopted by Wasatch and Weber Counties as an acceptable level of degradation), and (2) allowing nitrate levels in each domain to increase to 3 mg/L.

Results

We describe our septic-tank-system density calculations only for domain 1 (figure 10a). We calculated septic-tank-system densities for domains 2, 3, and 4 in the same manner as for domain 1, using the information in tables 6 and 7 and figures 10b, 10c, and 10d.

Figure 10a shows a plot of projected nitrate concentration versus septic-tank density and number of septic-tank systems in domain 1 in the central part of northwestern Castle Valley (plate 8). Background nitrate concentration for domain 1 is 0.4 mg/L. Fifteen septic systems are in domain 1 (Jim Adamson, Southeast Utah Health Department, written communication, 2002). Domain 1 has an area of approximately 564 acres (228 hm^2), so the existing average septic-system density is 38 acres per system (15 hm^2/system). Based on our analyses (table 6), estimated ground-water flow available for mixing in domain 1 (figure 10a) is 1.1 cubic feet per second (0.03 m^3/s) (table 6). For the domain 1 area to maintain an overall nitrate concentration of 1.4 mg/L (which allows 1 mg/L of degradation), the total number of homes using septic tank soil-absorption systems should not exceed 94 based on the estimated nitrogen load of 54.4 mg/L per septic-tank system (figure 10a, table 7). This corresponds to an increase of 79 septic systems and an average septic-system density of about 6 acres per system (2.4 hm^2/system) in domain 1 (table 7). If the overall nitrate concentration in domain 1 is allowed to reach 3 mg/L, the total number of homes using septic-tank soil absorption systems should not exceed 227 based on the estimated nitrogen load of 54.4 mg/L per septic-tank system (figure 10a). This corresponds to an increase of 212 septic systems and an average septic-system density of about 2.5 acres per system (1.0 hm^2/system) in domain 1 (table 7).

Recommendations for Land-Use Planning

These approximations of nitrate concentrations/water-quality degradation provide a conservative (worst case) first approximation of long-term ground-water pollution from septic-tank systems. For land-use planning purposes, we be-

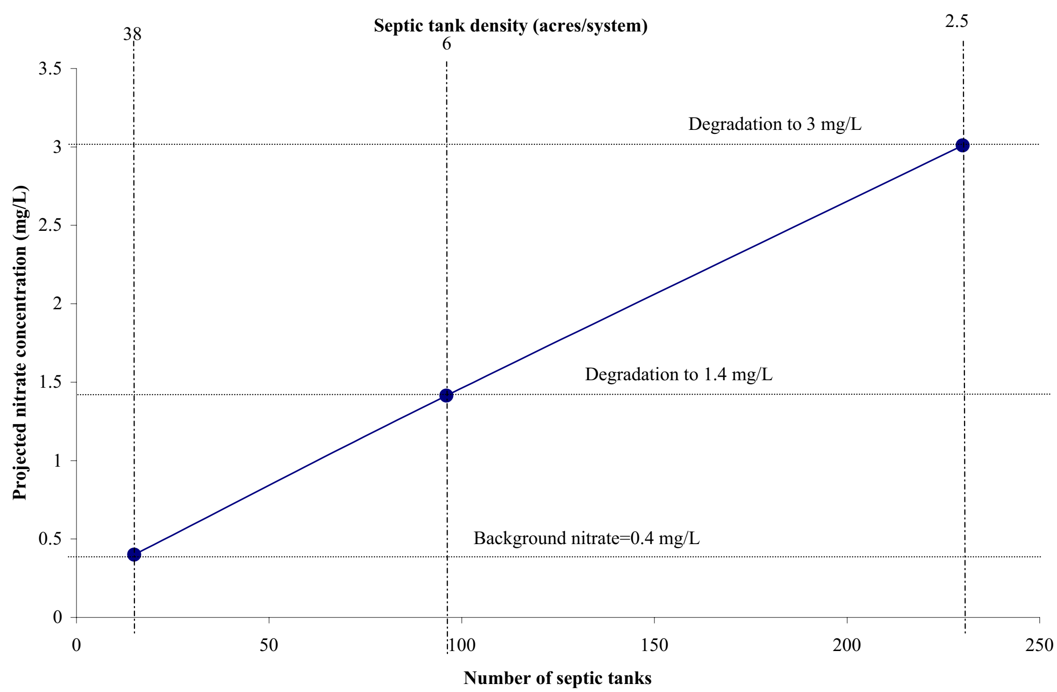

Figure 10a. *Projected septic-tank density versus nitrate concentration for Domain 1 in Castle Valley, Grand County, Utah, based on 15 existing septic tanks (see table 6).*

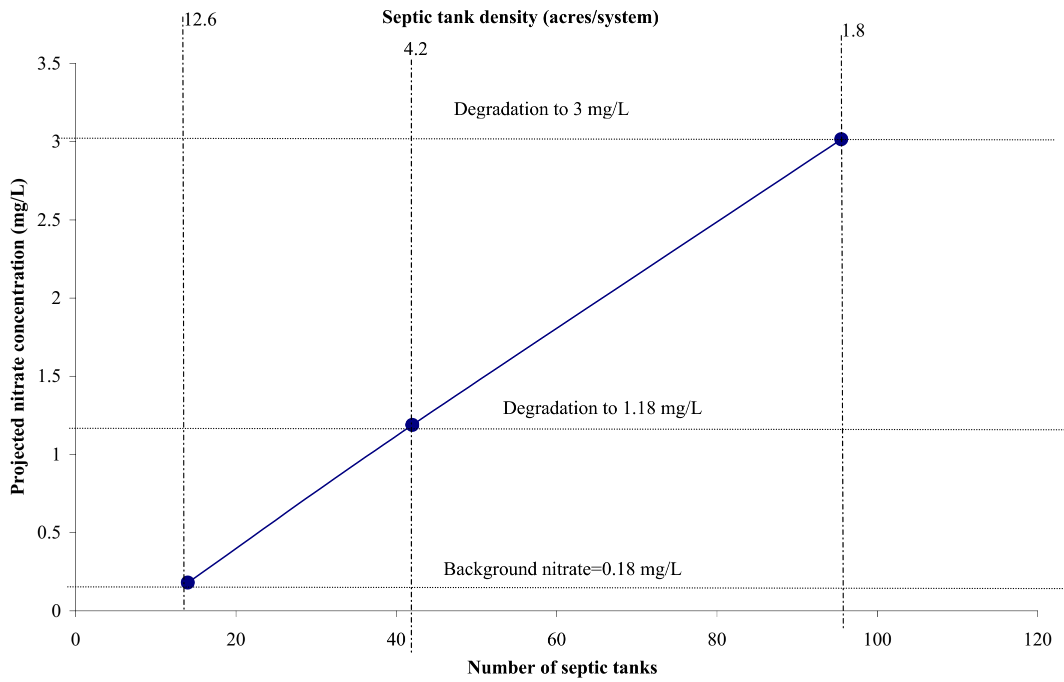

Figure 10b. *Projected septic-tank density versus nitrate concentration for Domain 2 in Castle Valley, Grand County, Utah, based on 14 existing septic tanks (see table 6).*

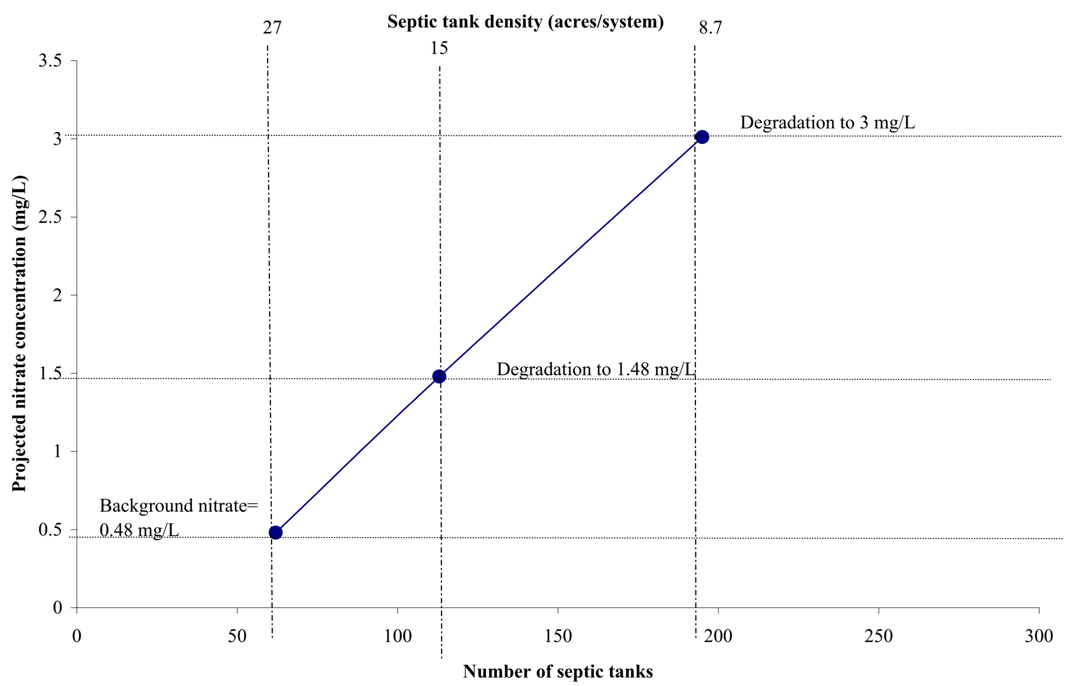

Figure 10c. *Projected septic-tank density versus nitrate concentration for Domain 3 in Castle Valley, Grand County, Utah, based on 62 existing septic tanks (see table 6).*

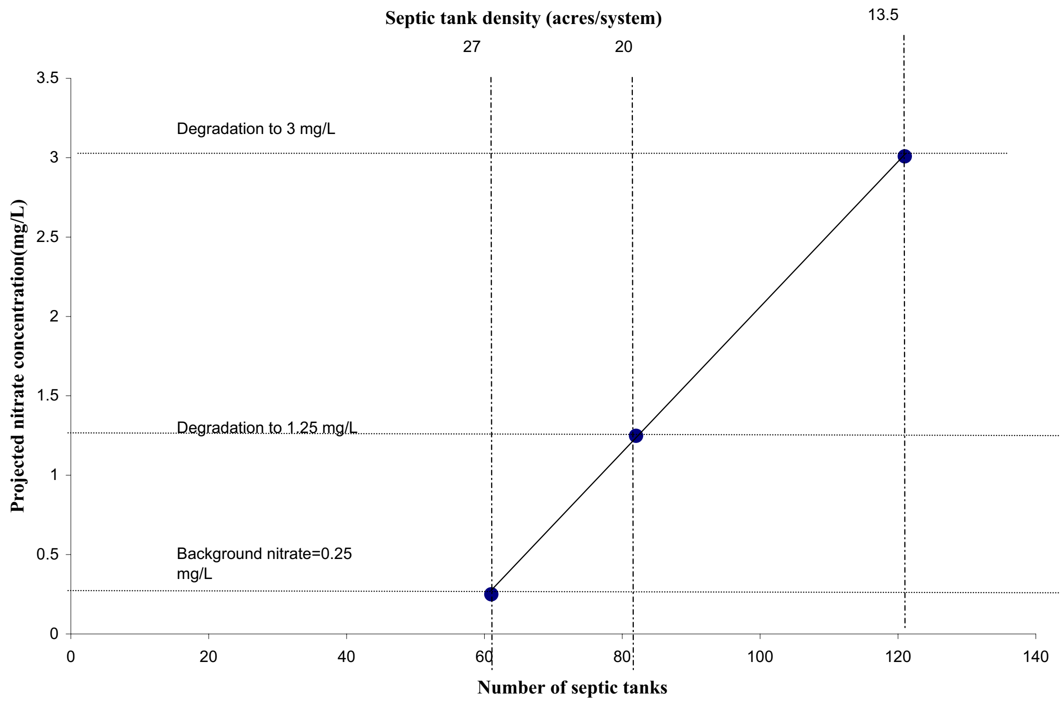

Figure 10d. *Projected septic-tank density versus nitrate concentration for Domain 4 in Castle Valley, Grand County, Utah, based on 61 existing septic tanks (see table 6).*

lieve two categories of recommended maximum septic-tank system densities are appropriate for development in Castle Valley: 5 and 15 acres per system (2 and 6 hm^2/system) (table 7; figure 11; plate 8). Because ground-water flow per acre is similar for domains 1 and 2 (0.002 cfs/acre; table 6) and domains 3 and 4 (~0.0003 cfs/acre; table 6), we grouped the similar flow domains together to create our recommended lot-size map (figure 11). Based only on our septic-tank density/water-quality degradation analysis, a greater number of septic systems can exist in the central areas of Castle Valley along Castle Creek compared to the outer margins of the valley where the amount of ground-water available for mixing is an order of magnitude smaller (table 6); this is due to Castle Creek being a primary source of recharge to the valley-fill aquifer, and the greater average thickness of the valley-fill deposits in northwestern Castle Valley. Our lot-size recommendations apply to development using septic systems for wastewater disposal, and are not relevant to development using well-engineered, well-constructed sewer lagoon systems. However, poorly engineered, poorly constructed sewer lagoon systems could have even greater negative impacts on ground-water quality than septic-tank systems.

SUMMARY AND CONCLUSIONS

Ground water is the principal source of drinking water in Castle Valley. Ground-water quality classification is a tool that can be used in Utah to manage potential ground-water contamination sources and protect the quality of ground-water resources. Our proposed ground-water quality classification for the northwestern part (40 percent) of Castle Valley indicates that the valley-fill aquifer contains mostly high-quality ground-water resources that warrant protection. Forty-eight percent of the land-surface area in the classified part of the valley-fill aquifer is classified as Class IA, and 52 percent is classified as Class II, based on chemical analyses of water from 54 wells and five surface-water sites sampled between 1991 and 2003 (TDS range of 204 to 2,442 mg/L). Insufficient data are available to classify the southeastern part (60 percent) of the valley-fill aquifer in Castle Valley.

The valley-fill material is thickest (about 350 feet [107 m]) along a narrow trough in the northern part of the valley. This area is a reasonable place to site a potential water-supply well (potential well site A; plate 1) for the town of Castle Valley due to its proximity to existing wells and the greatest population density. If the town of Castle Valley opts to drill a public-supply well, the entire valley-fill aquifer can be reclassified by the town of Castle Valley as Class IB, Irreplaceable ground water; this action could strengthen the town's ability to enact policies and regulations to help preserve the quality of Castle Valley's ground-water resource.

All developed areas of Castle Valley use septic tank soil-absorption systems to dispose of domestic wastewater. Many constituents in septic-tank effluent are known to undergo little remediation in the soil environment as they travel through the unsaturated zone to ground water; once they enter ground water, dilution is the principal mechanism for lowering concentrations of these constituents. We used nitrate in septic-tank effluent as an indicator species for evaluating the dilution of constituents in wastewater that reach aquifers; this evaluation uses a mass-balance approach that is based principally on ground-water flow available for mixing with effluent constituents in the aquifer of concern. The mass-balance approach for the valley-fill aquifer in Castle Valley indicates that two categories of recommended maximum septic-tank system densities are appropriate for development: 5 and 15 acres per system (2 and 6 hm^2/system). These recommended minimum lot sizes are based on hydrogeologic parameters incorporated in the ground-water flow model and geographically divided into four ground-water flow domains on the basis of flow-volume similarities.

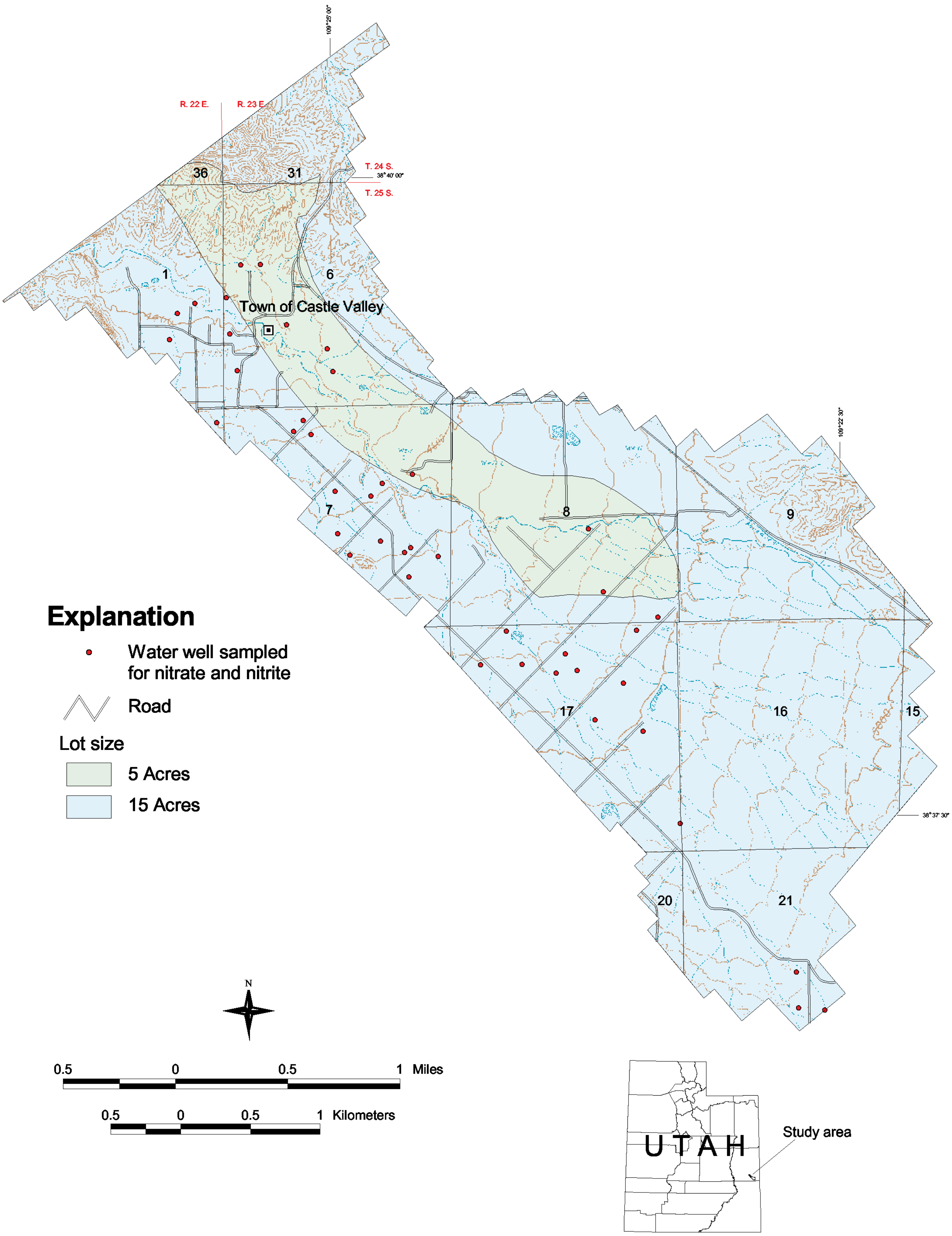

Figure 11. Recommended lot size based on septic-tank system density for northwestern Castle Valley, Grand County, Utah.

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APPENDICES

APPENDIX A

WATER QUALITY DATA

(Site ID numbers shown on plate 6)

Site ID	Data source[1]	Well Depth (feet)	Sample Date	Nitrogen NO2 + NO3 dissolved (mg/L)	Nitrate as N (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Field Temperature, (°C)	Field, Specific Conductance (µmhos)	Lab, Specific Conductance (µmhos)	pH, Field	pH, Lab	Field, Dissolved Oxygen	Alpha, gross (pCi/L)	Aluminum, dissolved (µg/L)	Ammonia (mg/L)	Arsenic, dissolved (µg/L)	Barium, dissolved (µg/L)	Bicarbonate (mg/L)	Cadmium dissolved (µg/L)
9	UGS	102	10/22/2001	0.38	-	772	14.8	899	1059	7.5	8.03	5.8	<2	-	-	<5.0	12.2	152	<1.0
9	UDAF	"	Sept.2000	-	0	-	16.6	929	-	7.74	-	-	-	-0.1	-	-0.1	-0.1	2.4638	-0.1
10	UGS	180	10/24/2001	0.37	-	468	14.7	580	670	7.8	8.19	6.2	-	<30.0	-	<5.0	15.8	157	<1.0
10	UDAF	"	Sept.2000	-	2.3	-	16.3	696	-	7.68	-	-	-	-0.1	-	-0.1	21	2.6578	-0.1
11	UGS	71	10/24/2001	0.33	-	308	13.7	410	479	7.8	8.24	6.5	-	<30.0	-	<5.0	26.7	157	<1.0
11	UDAF	"	Sept.2000	-	0.9	-	16	508	-	7.73	-	-	-	-0.1	-	-0.1	31	2.8906	-0.1
12	UGS	120	10/24/2001	0.36	-	480	14.2	587	703	7.8	8.03	6	-	<30.0	-	<5.0	14.6	156	<1.0
12	UDAF	"	Sept.2000	-	0.7	-	19.3	737	-	7.67	-	-	-	-0.1	-	-0.1	-0.1	2.3668	-0.1
35	UGS	140	10/23/2001	0.39	-	1232	14.6	1290	1460	7.4	7.85	5	-	<30.0	-	<5.0	8.7	150	<1.0
35	UDAF	"	Sept.2000	-	0.6	-	18.7	1549	-	7.72	-	-	-	-0.1	-	-0.1	-0.1	2.4444	-0.1
48	UGS	195	10/23/2001	<0.1	-	2020	15.9	1920	2250	7.3	7.89	4.1	-	<30.0	-	<5.0	7.1	153	<1.0
48	UDAF	"	Sept.2000	-	1.1	-	16.4	2300	-	7.44	-	-	-	-0.1	-	-0.1	-0.1	2.4638	-0.1
51	UGS	339?	10/24/2001	0.73	-	336	16.1	432	514	7.8	8.11	5.2	-	<30.0	-	<5.0	23.3	156	<1.0
51	UDAF	"	Sept.2000	-	1.3	-	19.6	539	-	8	-	-	-	-0.1	-	-0.1	29	2.5414	-0.1
53	UGS	168	10/24/2001	0.31	-	276	13.3	364	422	7.7	8.31	8	-	<30.0	-	<5.0	33.0	150	<1.0
53	UDAF	"	Sept.2000	-	1.3	-	16.4	450	-	8.08	-	-	-	-0.1	-	-0.1	37	2.425	-0.1
56	UGS	136	10/23/2001	<0.1	-	1290	15.2	1320	1570	7.5	7.96	6.2	-	<30.0	-	<5.0	8.9	168	<1.0
56	UDAF	"	Sept.2000	-	0.9	-	15.8	1637	-	7.75	-	-	-	-0.1	-	-0.1	-0.1	2.3668	-0.1
59	UGS	168	10/24/2001	0.31	-	2138	16.8	2040	2320	7.3	7.83	5.4	-	<30.0	-	<5.0	7.6	153	<1.0
59	UDAF	"	Sept.2000	-	0.9	-	7.5	2370	-	7.5	-	-	-	-0.1	-	-0.1	-0.1	2.425	-0.1
77	UGS	122	10/24/2001	<0.1	-	370	13.5	482	564	7.6	8.2	4.9	-	<30.0	-	<5.0	20.6	155	<1.0
77	UDAF	"	Sept.2000	-	1.2	-	16.2	652	-	7.56	-	-	-	-0.1	-	-0.1	26	2.5414	-0.1
78	UGS	139	10/24/2001	0.29	-	650	13.5	802	911	7.6	8.03	5.8	-	<30.0	-	<5.0	12.4	155	<1.0
78	UDAF	"	Sept.2000	-	0.9	-	18.3	942	-	7.45	-	-	-	-0.1	-	-0.1	-0.1	2.2892	-0.1
83	UGS	105	10/22/2001	0.32	-	272	15	213	389	7.8	8.14	4.7	<2	-	-	<5.0	32.0	153	<1.0
83	UDAF	"	Sept.2000	-	1	-	14.2	455	-	8.04	-	-	-	-0.1	-	-0.1	40	2.425	-0.1
86	UGS	158	10/23/2001	0.31	-	1252	16.4	1326	1560	7.4	7.88	5.8	-	<30.0	-	<5.0	10.5	152	<1.0
86	UDAF	"	Sept.2000	-	0.9	-	16.2	1654	-	7.86	-	-	-	-0.1	-	-0.1	-0.1	2.425	-0.1
141	UDWRi	130	12/20/1995	-	0.31	280*	-	-	400	-	-	-	-	<0.15	-	<1.0	-	176.90	<0.05
147	UGS	169	10/24/2001	0.27	-	666	18.2	855	987	7.6	8.0	5.2	-	<30.0	-	<5.0	14.0	166	<1.0
147	UDAF	"	Sept.2000	-	1.4	-	20.7	1038	-	7.7	-	-	-	-0.1	-	-0.1	25	3.007	-0.1
158	UGS	121	10/24/2001	<0.1	-	406	14.4	468	555	7.7	8.17	5.9	-	<30.0	-	<5.0	22.4	156	<1.0
158	UDAF	"	Sept.2000	-	0.9	-	17.1	559	-	8.02	-	-	-	-0.1	-	-0.1	28	2.5414	-0.1
161	UGS	115	10/22/2001	0.14	-	2058	17.2	2000	2210	7.3	7.83	4.8	<2	-	-	<5.0	7.7	153	<1.0
161	UDAF	"	Sept.2000	-	1.1	-	22.1	2300	-	7.42	-	-	-	-0.1	-	-0.1	-0.1	2.5996	-0.1
180	UGS	132	10/24/2001	0.27	-	1902	17.4	1830	2140	7.1	7.76	2.4	-	<30.0	-	<5.0	8.1	153	<1.0
180	UDAF	"	Sept.2000	-	0.8	-	21.6	1997	-	7.45	-	-	-	-0.1	-	-0.1	-0.1	2.5414	-0.1
188	UGS	125	10/24/2001	<0.1	-	338	15.4	434	543	7.8	8.12	6.1	-	<30.0	-	<5.0	28.1	165	<1.0
188	UDAF	125	Sept.2000	-	0.9	-	19.7	541	-	8.04	-	-	-	-0.1	-	-0.1	32	2.3668	-0.1
193	UGS	367	2/28/2003	-	-	466*	-	675	-	-	-	-	-	-	-	-	-	-	-
201	UGS	155	10/24/2001	0.11	-	242	14.6	321	379	7.9	8.18	5.5	-	<30.0	-	<5.0	37.7	137	<1.0
201	UDAF	"	9/27/2000	-	0.8	-	20.5	540	-	8	-	-	-	-0.1	-	-0.1	34	2.3862	-0.1
204	UGS	125	10/24/2001	0.34	-	228	15.9	336	372	7.8	8.2	6.6	-	<30.0	-	<5.0	42.0	149	<1.0
204	UDAF	"	9/27/2000	-	1.1	-	14.7	394	-	8.02	-	-	-	-0.1	-	-0.1	47	2.3668	-0.1
206	UDAF	300	9/27/2000	-	.3	434*	16.1	620	-	7.92	-	-	-	-0.1	-	-0.1	32	2.4832	-0.1
230	UGS	125	10/24/2001	0.77	-	230	14.7	316	374	8	8.24	3.2	-	<30.0	-	<5.0	42.7	150	<1.0
230	UDAF	"	Sept.2000	-	1.1	-	17.8	389	-	7.97	-	-	-	-0.1	-	-0.1	47	2.4444	-0.1
235	UGS	132	10/22/2001	0.26	-	238	16.4	342	386	7.9	8.24	5.4	<2	-	-	<5.0	34.3	141	<1.0
235	UDAF	"	Sept.2000	-	0.9	-	15	400	-	8.17	-	-	-	-0.1	-	-0.1	41	2.2504	-0.1
237	UGS	202	2/28/2003	-	-	345*	-	500	-	-	-	-	-	-	-	-	-	-	-
238	UGS	185	2/28/2003	-	-	500*	-	725	-	-	-	-	-	-	-	-	-	-	-
244	UGS	142	10/23/2001	0.68	-	208	13.8	315	377	7.9	8.16	6.1	-	<30.0	-	<5.0	41.0	142	<1.0
244	UDAF	"	Sept.2000	-	1	-	15.8	385	-	8.06	-	-	-	-0.1	-	-0.1	98	2.1728	-0.1
244	UGS	"	2/29/03	-	-	-	15	300	-	-									
248	UDAF	140	9/27/2000	-	.3	279*	17.4	399	-	7.95	-	-	-	-0.1	-	-0.1	51	2.5026	-0.1
275	UGS	135	2/28/2003	-	-	207*	-	300	-	-	-	-	-	-	-	-	-	-	-
279	UGS	126	10/22/2001	0.52	-	226	15.2	315	358	7.7	8.35	5.8	<2	-	-	<5.0	44.2	143	<1.0
279	UDAF	"	Sept.2000	-	0.9	-	18.5	387	-	8.16	-	-	-	-0.1	-	-0.1	49	2.2892	-0.1
297	UDAF	unknown	9/28/2000	-	0.9	676*	15.1	-	965	-	7.76	-	-	-0.1	-	-0.1	0.037	3.647	-0.1
298	UDAF	unknown	9/28/2000	-	0.8	1234*	14.9	-	1762	-	7.41	-	-	-0.1	-	-0.1	-0.1	4.035	-0.1
300	UDAF	1507	9/28/2000	-	3.5	721*	18.9	-	1031	-	7.82	-	-	-0.1	-	-0.1	0.051	3.24	-0.1
305	UDWRi	135	12/10/1991	0.437	-	232	11.6	-	376	-	8.0	-	-	-	<0.05	<0.005	0.045	152.00	<0.001
328	UGS	248	10/23/2001	0.26	-	240	14.3	331	371	7.8	8.02	7	-	<30.0	-	<5.0	41.2	154	<1.0
328	UDAF	"	Sept.2000	-	1	-	21.2	418	-	8.01	-	-	-	-0.1	-	-0.1	42	2.5414	-0.1
338	UDWRi	230	12/20/1995	-	0.16	1400*	-	-	2000	-	-	-	-	<0.15	-	<1.0	-	176.90	<0.05
352	UGS	135	10/23/2001	0.25	-	204	13.6	307	367	7.7	8.28	6.7	-	<30.0	-	<5.0	45.9	151	<1.0
352	UDAF	"	Sept.2000	-	0.7	-	14.6	377	-	8.09	-	-	-	-0.1	-	-0.1	174	2.425	-0.1
358	UGS	110	10/23/2001	0.26	-	222	12.5	315	371	7.7	8.19	6.5	-	<30.0	-	<5.0	48.3	156	<1.0
358	UDAF	"	Sept.2000	-	1	-	14	388	-	8.02	-	-	-	-0.1	-	-0.1	51	2.7548	-0.1
359	UGS	105	10/23/2001	<0.1	-	252	12.8	345	372	7.7	8.14	6.6	-	<30.0	-	<5.0	39.7	166	<1.0
359	UDAF	"	Sept.2000	-	1.3	-	14.8	447	-	7.95	-	-	-	-0.1	-	-0.1	47	2.91	-0.1
387	UGS	129	10/22/2001	0.32	-	852	14.9	1218	1360	7	7.76	4.5	-	<30.0	-	<5.0	<5.0	170	<1.0
387	UDAF	"	Sept.2000	-	1.1	-	17.1	1105	-	7.39	-	-	-	-0.1	-	-0.1	-0.1	4.9664	-0.1
390	UGS	100	10/24/2001	0.4	-	844	13.6	992	1100	7.2	7.88	4.4	-	<30.0	-	<5.0	16.1	270	<1.0
390	UDAF	"	Sept.2000	-	1	-	16.4	1176	-	7.47	-	-	-	-0.1	-	-0.1	20	4.5978	-0.1
391	UGS	68	10/24/2001	0.58	-	742	14.2	884	1049	7.6	7.95	4.3	-	<30.0	-	<5.0	12.9	194	<1.0
391	UDAF	68	9/27/2000	-	0.7	-	15.9	1011	-	7.92	-	-	-	-0.1	-	-0.1	20	3.1234	-0.1
394	UGS	103	10/24/2001	<0.1	-	694	15.2	836	967	7.7	7.9	6	-	<30.0	-	<5.0	16.8	202	<1.0
394	UDAF	"	Sept.2000	-	0.9	-	16.5	993	-	7.62	-	-	-	-0.1	-	-0.1	23	3.2592	-0.1
413	UGS	85	10/24/2001	0.59	-	2440	16.4	2340	2980	7.3	7.88	5.4	-	<30.0	-	<5.0	7.2	136	<1.0
413	UDAF	"	9/27/2000	-	0.8	-	21	2800	-	7.83	-	-	-	-0.1	-	-0.1	-0.1	2.1728	-0.1
417	UGS	100	10/25/2001	1.54	-	708	11.2	969	1130	7.4	8.01	6.1	-	<30.0	-	<5.0	<5.0	174	<1.0
420	UDWRi	40	12/10/1991	0.661	-	648	13.8	-	915	-	8.1	-	-	-	<0.05	<0.005	0.020	193.00	<0.001
432	UDAF	121	9/27/2000	0.1	-	629*	20.4	898	-	9.33	-	-	-	-0.1	-	-0.1	-0.1	2.5608	-0.1
435	UGS	95	10/24/2001	0.41	-	2048	15.2	2070	2370	7.3	7.81	6.3	-	<30.0	-	<5.0	7.5	183	<1.0
435	UDAF	"	Sept.2000	-	0.9	-	17.9	2400	-	7.43	-	-	-	-0.1	-	-0.1	-0.1	3.0846	-0.1
436	UDWRi	130	12/20/1995	-	0.21	1841*	-	-	2630	-	-	-	-	<0.15	-	<1.0	0.015	262.30	<0.05
442	UGS	145	10/24/2001	0.34	-	2442	14.5	2380	2680	7.1	7.58	4	-	<30.0	-	<5.0	8.0	272	<1.0
442	UDAF	"	Sept.2000	-	0.8	-	16.3	2740	-	7.78	-	-	-	-0.1	-	-0.1	-0.1	4.4426	-0.1
446	UGS	305	10/23/2001	0.51	-	1448	16	1630	1810	7.2	8.01	2.5	-	<30.0	-	<5.0	8.3	232	<1.0
446	UDAF	"	Sept.2000	-	0.6	-	17.5	1956	-	7.72	-	-	-	-0.1	-	-0.1	-0.1	3.7636	-0.1
448	UGS	58	10/24/2001	0.6	-	1850	14.2	1840	2120	7.1	7.65	5.4	-	<30.0	-	<5.0	16.0	278	<1.0
448	UDAF	"	Sept.2000	-	0.6	-	16.6	1906	-	7.39	-	-	-	-0.1	-	-0.1	20	4.4232	-0.1
998	UGS	120	10/25/2001	4.27	-	856	13.4	1001	1160	7.3	8.09	7	-	<30.0	-	<5.0	45.7	232	<1.0
999	UGS	70	10/25/2001	0.93	-	364	15.2	485	577	7.6	8.14	5.7	-	<30.0	-	<5.0	35.1	160	<1.0
999	UDAF	"	Sept.2000	-	0.6	-	27.9	531	-	7.81	-	-	-	-0.1	-	-0.1	39	2.5608	-0.1
1000	UDWRi	83	12/20/1995	-	-	671*	-	-	-	-	-	-	-	-	-	-	-	-	-
1001	DWQ	CREEK	3/13/1978	-	0.7	602	-	-	-	-	-	-	-	-	-	-	-	-	-
1002	UGS	SPRING	2/28/2003	-	-	690*	-	1000	-	-	-	-	-	-	-	-	-	-	-
1003	UGS	CREEK	2/28/2003	-	-	483*	-	700	-	-	-	-	-	-	-	-	-	-	-
1004	UGS	93	2/28/2003	-	-	1415*	-	2050	-	-	-	-	-	-	-	-	-	-	-
1005	UGS	CREEK	2/28/2003	-	-	466*	-	675	-	-	-	-	-	-	-	-	-	-	-
1006	UGS	CREEK	2/28/2003	-	-	449*	-	650	-	-	-	-	-	-	-	-	-	-	-
2001	CCV	116	Jul-03	-	-	484	-	-	-	-	-	-	-	-	-	-	-	-	-
2002	CCV	unknown	Jul-03	-	-	674	-	-	-	-	-	-	-	-	-	-	-	-	-
2003	CCV	SPRING	Jul-03	-	-	826	-	-	-	-	-	-	-	-	-	-	-	-	-
2004	CCV	SPRING	Jul-03	-	-	188	-	-	-	-	-	-	-	-	-	-	-	-	-
2005	CCV	300	Jul-03	-	-	286	-	-	-	-	-	-	-	-	-	-	-	-	-
2006	CCV	unknown	Jul-03	-	-	1944	-	-	-	-	-	-	-	-	-	-	-	-	-
2007	CCV	SPRING	Jul-03	-	-	1364	-	-	-	-	-	-	-	-	-	-	-	-	-
2008	CCV	SPRING	Jul-03	-	-	188	-	-	-	-	-	-	-	-	-	-	-	-	-
2009	CCV	150	Jul-03	-	-	660	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	CCV	150	Jul-03	-	-	438	-	-	-	-	-	-	-	-	-	-	-	-	-
2011	CCV	CREEK	Jul-03	-	-	576	-	-	-	-	-	-	-	-	-	-	-	-	-
2012	CCV	SPRING	Jul-03	-	-	284	-	-	-	-	-	-	-	-	-	-	-	-	-
2013	CCV	SPRING	Jul-03	-	-	382	-	-	-	-	-	-	-	-	-	-	-	-	-
2014	CCV	125	Jul-03	-	-	386	-	-	-	-	-	-	-	-	-	-	-	-	-
2015	CCV	236	Jul-03	-	-	392	-	-	-	-	-	-	-	-	-	-	-	-	-
2016	CCV	SPRING	Jul-03	-	-	308	-	-	-	-	-	-	-	-	-	-	-	-	-
2017	CCV	SPRING	Jul-03	-	-	284	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX B

EPA PRIMARY GROUND-WATER QUALITY STANDARDS AND ANALYTICAL METHOD FOR SOME CHEMICAL CONSTITUENTS SAMPLED IN CASTLE VALLEY, GRAND COUNTY, UTAH.

CHEMICAL CONSTITUENT	EPA ANALYTICAL METHOD	GROUND-WATER QUALITY STANDARD (mg/L)
Nutrients:		
total nitrate/nitrite	353.2	10.0
ammonia as nitrogen	350.3	-
total phosphorous and dissolved total phosphate	365.1	-
Dissolved metals:		
arsenic	200.9	0.05
barium	200.7	2.0
cadmium	200.9	0.005
chromium	200.9	0.1
copper	200.7	1.3
lead	200.9	0.015
mercury	245.1	0.002
selenium	200.9	0.05
silver	200.9	0.1
zinc	200.7	5.0
General Chemistry:		
total dissolved solids	160.1	2000+** or (500*++)
pH	150.1	between 6.5 and 8.5
aluminum*	200.7	0.05 to 0.2
calcium*	200.7	-
sodium*	200.7	-
bicarbonate	406C	-
carbon dioxide	406C	-
carbonate	406C	-
chloride*	407A	250
total alkalinity	310.1	-
total hardness	314A	-
specific conductance	120.1	-
iron*	200.7	0.3
potassium*	200.7	-
hydroxide	406C	-
sulfate *++	375.2	250
magnesium*	200.7	-
manganese*	200.7	0.5
Organics and pesticides:		
aldicarb	531.1	0.003
aldicarb sulfoxide	531.1	0.004
atrazine	525.2	0.003
carbofuran	531.1	0.04
2, 4-D	515.1	0.07
methoxychlor	525.2	0.4

CHEMICAL CONSTITUENT METHOD	**EPA ANALYTICAL**	**GROUND-WATER QUALITY STANDARD (mg/L)**
methiocarb	531.1	-
dinoseb	515.1	0.007
dalapon	515.1	0.2
baygon	515.1	-
picloram	515.1	0.5
dicamba	515.1	-
oxamyl	531.1	0.2
methomyl	531.1	-
carbaryl	531.1	-
3-Hydroxycarbofuran	531.1	-
pentachlorophenol	515.1	0.001
2, 4, 5-TP	515.1	0.05
Radionuclides:		
Alpha, gross	600/4-80-032	15 pCi/L(picocuries per liter)
Beta, gross	600/4-80-032	4 millirems per year
U^{238}MS Fil (Uranium)	600/4-80-032	0.030 mg/L
^{226}Radium	600/4-80-032	5 pCi/L
^{228}Radium	600/4-80-032	5 pCi/L

- no ground-water quality standard exists for the chemical constituent
* for secondary standards only (exceeding these concentrations does not pose a health threat)
+ maximum contaminant level is reported from the Utah Administrative Code R309-103 (Utah Division of Water Quality)
** For public water-supply wells, if TDS is greater than 1000 mg/L, the supplier shall satisfactorily demonstrate to the Utah Water Quality Board that no better water is available. The Board shall not allow the use of an inferior source of water if a better source of water (i.e., lower in TDS) is available
++TDS and sulfate levels are given in the Primary Drinking Water Standards, R309-103- 2.1. They are listed as secondary standards because levels in excess of these recommended levels will likely cause consumer complaint

APPENDIX C

POTENTIAL CONTAMINANT SOURCES

(Site numbers are shown on plate 7)

SITE #	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
1	ABANDONED CORRAL	Abandoned corral, hay, (fenced in, temporary horses housing?)	fertilizer, manure
2	JUNK/SALVAGE	Abandoned cars & trucks, lots of car parts	metals, solvents, petroleum
3	STORAGE TANK	Gravity-driven gas tank	petroleum
4	STORAGE TANK	Abandoned petroleum storage tank?, rusty red color, has door to it and an outlet on outside, all corroded; petroleum tank?	metals, solvents, petroleum
5	JUNK/SALVAGE	Personal junk yard, abandoned cars, trailers, metal garbage-like cans with petroleum?	metals, solvents, petroleum
6	CORRAL	Corral with horse, adjacent to property with cars, trailer, tires stacked, skimobiles-abandoned cars, farm equipment, personal junk yard & a corral	fertilizer, manure
7	CORRAL	Corral and a small barn/shed & horse trailers	fertilizer, manure
8	JUNK/SALVAGE	Personal junk yard, canisters-metal cylinder shaped (like trash cans) contained some type petroleum product?, pallets, abandoned cars, trucks, van, trailers, tires.	metals, solvents, petroleum
9	ABANDONED CORRAL	Abandoned corral, big fenced in and gated area where they ran horses, next to a water well	fertilizer, manure
10	ABANDONED CORRAL	Abandoned corral	fertilizer, manure
11	JUNK/SALVAGE	Wood pallets, canisters w/ probable petroleum product, personal junk yard, rusted out old car windows, old car & bus frames	metals, solvents, petroleum
12	CORRAL	Active corral, lots of hay, several horses, barn	fertilizer, manure
13	CORRAL	Corral, inactive?	fertilizer, manure
14	STORAGE TANK	Gravity-driven gas tank	petroleum
15	STORAGE TANK	Gravity-driven gas tank	petroleum
16	ABANDONED CORRAL	Abandoned corral	fertilizer, manure
17	JUNK/SALVAGE	Abandoned cars, trucks, trailers, vans on personal property	metals, solvents, petroleum
18	CEMETERY	Cemetery, NOT large lawn, some green, interred	preservative chemicals
19	STORAGE TANK	Gravity-driven gas tank (small)	petroleum
20	STORAGE TANK	Gravity-driven gas tank	petroleum
21	CORRAL	Active corral, lots of manure, active	fertilizer, manure
22	ABANDONED CORRAL	Abandoned corral and barnyard/shed, sheep? little stables	fertilizer, manure
23	JUNK/SALVAGE	Personal junkyard, several abandoned cars, trucks, trailers, equipment, cement mixers, a drilling rig-water well drill (not abandoned), lumber, ammunition looking items, scraps, metal	metals, solvents, petroleum

SITE #	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
24	CORRAL	Horses in little corral and horse trailers	fertilizer, manure
25	CORRAL	Active corral, lots of horses, hay & manure	fertilizer, manure
26	CORRAL	Active corral - horses	fertilizer, manure
27	ABANDONED CORRAL	Abandoned corral, small, little barn/shed next to it (small animals)	fertilizer, manure
28	STORAGE TANK	Gravity driven gas tank	petroleum
29	JUNK/SALVAGE	Personal junk yard, vans, car, tires, metal scraps, few metal canisters, lumber, truck, old stove equipment	metals, solvents, petroleum
30	CORRAL	Active corral, couple of horses	fertilizer, manure
31	ABANDONED CORRAL	Abandoned corral, with hay and dilapidated fence	fertilizer, manure
32	FORMER ANIMAL FEEDING OPERATION	Abandoned shed for animals, chickens?, seed next to shed & cooped in area"	fertilizer, manure
33	CORRAL	Corral, llama, bales of hay, barn/stable, feed trough for animals, animal feeding operation?	fertilizer, manure
34	CORRAL	Active corral, horses, horse trailer, barn	fertilizer, manure
35	ABANDONED CORRAL	Abandoned corral with a little shed	fertilizer, manure
36	JUNK/SALVAGE	Personal junkyard, abandoned jeep, milk delivery truck, lots of lumber and metal scraps, old bathtubs and jewel tanks, old chicken coop, trash	metals, solvents, petroleum
37	JUNK/SALVAGE	Personal junk yard, school bus, metal scraps, storage garage, trailer, boat, (owner may run his personal business out of warehouse/garage)	metals, solvents, petroleum
38	CORRAL	Pasture, fenced area with horse	fertilizer, manure
39	CORRAL	Corral, horses, manure, active	fertilizer, manure
40	ABANDONED CORRAL	Abandoned corral and chicken coops	fertilizer, manure
41	JUNK/SALVAGE	Personal junk yard, vans, campers, trailers, wood and metal scraps, tires, fiberglass cylinders	metals, solvents, petroleum
42	CORRAL	Corral with mules	fertilizer, manure
43	ABANDONED CORRAL	Abandoned corral	fertilizer, manure
44	ABANDONED CORRAL	Abandoned corral with a fence all the way around it, stock water well (irrigated water) piles of dirt or possibly manure, old barn/shed	fertilizer, manure
45	STORAGE TANK	Gravity driven gas tank	petroleum
46	CORRAL	Active corral with horses	petroleum
47	GOLF COURSE	Small personal golf course in large back yard with large lawn	pesticides, fertilizer
48	NURSERY/GREENHOUSE	Nursery business, Greenhouse-indoor/outdoor	pesticides, fertilizer
49	CORRAL	Corral, active?, horse trailers	fertilizer, manure

SITE #	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
50	JUNK/SALVAGE	Personal junkyard, truck, vans, lumber, vans, metal scraps, wooden shed storage	metals, solvents, petroleum
51	CORRAL	Ranch, corrals, horses, stables, Big operation	fertilizer, manure
52	STORAGE TANK	Gravity-driven gas tank	petroleum
53	NURSERY/GREENHOUSE	Farm, 3 greenhouses, nursery operation?, lots of farm equipment, tractors, trailers, cement mixers	pesticides, fertilizer, metals, solvents
54	STORAGE TANK	Cylinder/canister of potassium chloride (sylvite) salt	metals, solvents
55	STORAGE TANK	Gravity-driven gas tank	petroleum
56	STORAGE TANK	Gravity-driven gas tank	petroleum
57	CORRAL	Corral - active	fertilizer, manure
58	JUNK/SALVAGE	Personal junkyard, big one, metal piping, wood & metal scraps, tractor, trailer, vans, bus, cars, lumber	metals, solvents
59	STORAGE TANK	Gravity-driven gas tank	petroleum
60	GOVERNMENT	Government- fire department, fire dept. truck, Natural Resource fire dept., green Gov't trucks - (look like army trucks), facility; cement & brick (fenced in), equipment, mosquito control truck.	metals, solvents, petroleum
61	ABANDONED CORRAL	Abandoned? corral	fertilizer, manure
62	CEMETERY	Graveyard	preservative chemicals
63	MINING	Gravel pit	metals, solvents, petroleum
64	CORRAL	Big corral (presently no horses or cows, but occupied by cows October 2001 grazing in area)	fertilizer, manure
65	MINING	Mining adit (inactive?)	metals, solvents, petroleum
66	CEMETERY	Cemetery, not a greenery, desert, no lawn fertilizer	preservative chemicals
67	ABANDONED CORRAL	Abandoned corral?	fertilizer, manure
68	MINING	Abandoned mine structure, old metal dilapidated structure, inactive	metals, solvents, petroleum
69	ELECTRICAL POWER SUPPLY	Mini transformer station, high voltage, local power supplier?	PCBs, metals, solvents
70	ANIMAL FEEDING OPERATION	Small peacock coop?, (maybe turkeys) BIRD Coop	fertilizer, manure
71	ABANDONED CORRAL	Corral, abandoned?, horse trailers	fertilizer, manure
72	JUNK/SALVAGE	Personal scrap yard, lots of lumber, cars, trucks, metal scraps, large semi-type trailer	metals, solvents, petroleum
73	JUNK/SALVAGE	Dump site, lumber, metal, sink, toilet, oil paint cans, waste disposal site, community junk yard?, old washing machine	metals, solvents, petroleum

SITE #	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
74	ABANDONED CORRAL	Abandoned corral	fertilizer, manure
75	MINING	Gravel pit, mining, mining river sediment, active, bull dozers	metals, solvents, petroleum
76	ABANDONED CORRAL	Corral, abandoned?	fertilizer, manure
77	ABANDONED CORRAL	Abandoned corral	fertilizer, manure
78	MINING	Gravel pit, mining	metals, solvents, petroleum
79	BUSINESS	Plastics, small business manufacturers?	metals, solvents
80	CORRAL	Pasture, with horses	fertilizer, manure
81	OIL/GAS WELL	Oil and gas well	petroleum
82	OIL/GAS WELL	Oil and gas well	petroleum
83	OIL/GAS WELL	Oil and gas well	petroleum
84	OIL/GAS WELL	Oil and gas well	petroleum
85	OIL/GAS WELL	Oil and gas well	petroleum
86-240	Septic tanks	Septic tank soil absorption systems from S.E. Utah Health Department (not numbered on the map)	metals, solvents, nitrate

APPENDIX D

EXPLANATION FOR PLATE 1

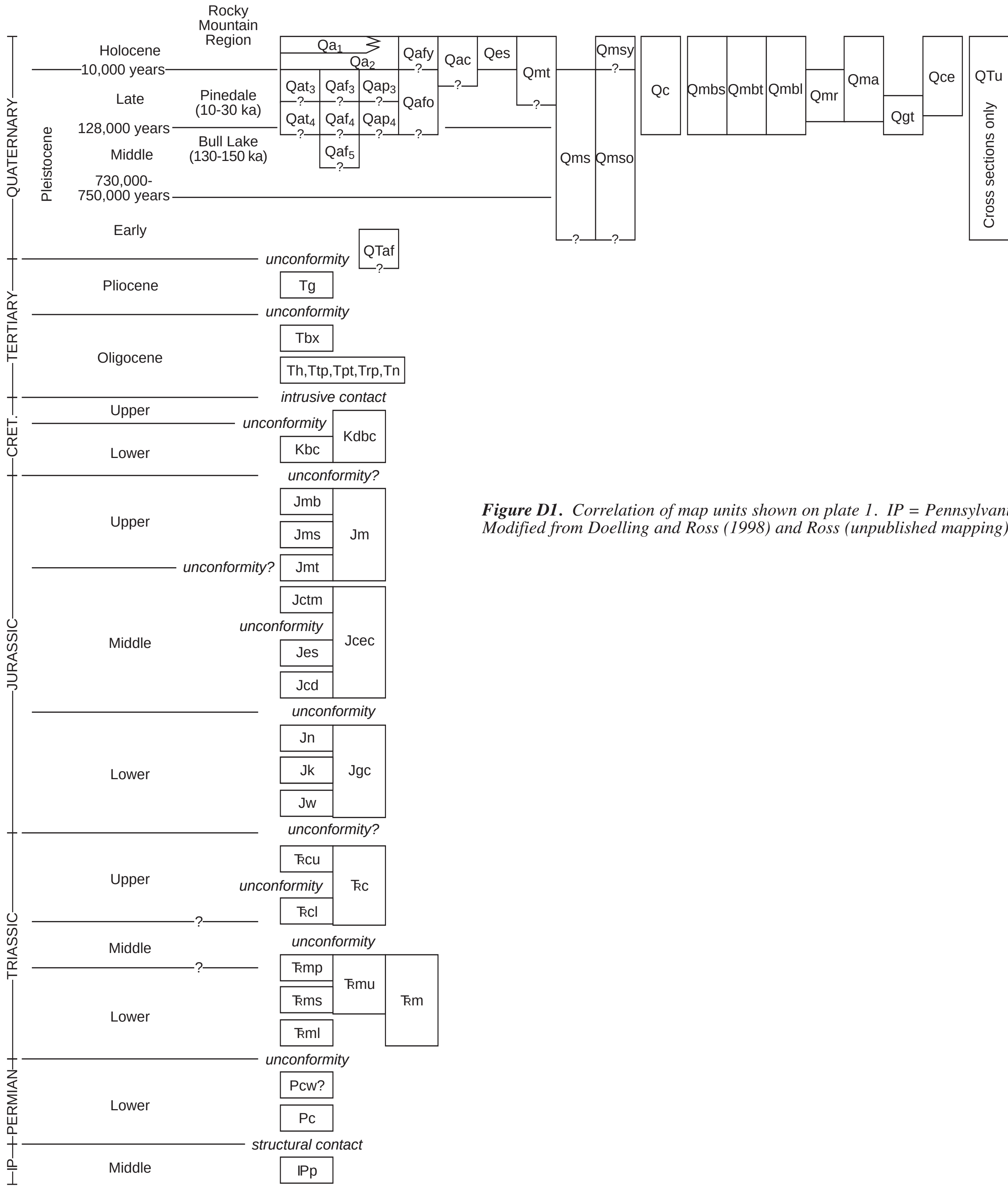


Figure D1. *Correlation of map units shown on plate 1. IP = Pennsylvanian. Modified from Doelling and Ross (1998) and Ross (unpublished mapping).*

DESCRIPTION OF GEOLOGIC UNITS

Modified from Doelling (2001) and Doelling and Ross (1988)

Quaternary

Qa_1 Qa_2	Alluvium-- Unconsolidated deposits of poorly to moderately sorted silt, sand, and gravel; Qa_1 is located in active larger channels and floodplains; Qa_2 deposits form the first surface 6-40 feet (2-12m) above the active channels. Thickness up to 25 feet (8 m).
Qaf_3 Qaf_4 Qaf_5 Qafy Qafo	Alluvial-fan deposits-- Unconsolidated deposits of poorly sorted, generally unstratified, muddy to sandy cobble gravel; boulders present in proximal areas; Qaf_3 and Qaf_4 form dissected surfaces and in Castle Valley; younger (Qafy) and older (Qafo) deposits form coalesced fans along the margins of Castle Valley. Up to 350 feet (107 m) thick as basin-fill deposits.
Qap_3 Qap_4	Alluvial-pediment-mantle deposits-- Poorly sorted, sandy, matrix-supported gravel; gravel ranges from pebbles to boulders; deposited as a relatively thin veneer on uneven pediment surfaces; coarsens upslope. Deposits are subdivided based on height above current drainage and grading to alluvial terraces along the river. Maximum thickness 25 feet (8 m).
Qgt	Glacial till-- Very poorly sorted, angular to subangular clasts of all sizes; larger clasts are commonly striated; as much as 300 feet (90 m) thick; early Holocene to late Pleistocene.
	Mass movement deposits
Qmt	Talus deposits and colluvium-- Generally angular rock-fall blocks, boulders, and small fragments deposited as veneers on slopes below ledges and cliffs; colluvium contains additional slopewash debris in a sandy to muddy matrix. Thickness 0 to 30 feet (0-9 m).
Qms Qmsy Qmso	Landslide deposits-- Large coherent blocks to fragmented masses of bedrock and surficial debris transported downslope by mass movement. Thicknesses vary.
Qmbl Qmbs Qmbt Qmbl/ Qmso	Block-slope deposits-- Poorly sorted, angular, locally derived debris ranging from block to sand size, deposited as thin accumulations. Qmbl- lateral-spread deposits; Qmbs- slide deposits; Qmbt- talus; Qmbl/Qmso- veneer of lateral-spread deposits overlying older slide deposits. Variable thickness.
Qma	Rock-avalanche deposits-- Poorly sorted, angular, locally derived debris ranging from block to sand size, characterized by flow morphology and lobate form. Deposited by rapid downslope flowage which formed thin, narrow, laterally extensive deposits. Variable thickness.
Qmr	Rock-glacier deposits-- Poorly sorted, angular, boulder- to sand-size debris forming lobate to tongue-shaped deposits in high valleys and cirques of the La Sal Mountains. Contains interstitial ice at least 3 feet (1 m) below the surface. Deposited by downslope flowage of ice from cirque walls or other steep slopes, carrying and incorporating rock-fall debris. Variable thickness.
Qc Qce Qc/ Qmso	Colluvial deposits-- Poorly to moderately sorted, locally derived gravel, sand, and soil; locally includes talus and alluvial deposits. Deposited by slope wash, soil creep, and minor debris flows. Qce is mixed colluvial and eolian deposits. Qc/Qmso is thin veneer of colluvium over older landslide deposits. Less than about 25 feet (8 m) thick.
Qes	Eolian sand deposits-- Generally fine- to medium-grained quartzose sand forming thin, discontinuous accumulations of sheets and small dunes. Thickness up to 10 feet (3 m).
Qac	Mixed alluvial and colluvial deposits-- Poorly sorted, unconsolidated mixtures of clay- through cobble-size detritus with random boulders; clasts vary from subrounded to angular. Thickness up to 15 feet (5 m).

Quaternary-Tertiary

QTaf	Older alluvial-fan deposits-- Sand, silt, pebbles, cobbles, and sparse boulders deposited at the foot of the La Sal Mountains; thickness 200 to 300 feet (60-90 m); early Pleistocene to Pliocene(?).

Tertiary

Tg	Geyser Creek Fanglomerate-- Yellow-brown to light-gray conglomerate, sandstone, and siltstone derived from the La Sal Mountains; generally poorly sorted and weakly cemented with calcium carbonate; thickness as much as 1,000 feet (305 m), but exposures are generally less than 300 feet (92 m) thick; Pliocene(?).
Tbx	Breccia-- Highly fractured, silicified, and thermally altered rock derived from the Glen Canyon Group and Chinle Formation. Crops out as resistant narrow ridges and cliffs.
Th Ttp Tpt Trp Tn	La Sal Mountains intrusive rocks-- Alkaline silicic rocks intruded at shallow depths as laccoliths, plugs, sills, and dikes 25 to 28 million years ago (Oligocene).

Cretaceous

Kdbc	Dakota Sandstone and Burro Canyon Formation, undivided-- Mapped in areas where they are too thin to separate accurately. Dakota Sandstone is yellow-gray to brown sandstone, conglomeratic sandstone, and conglomerate interbedded with gray mudstone, carbonaceous shale, coal, and claystone; 0 to 120 feet (0-37 m) thick.
Kbc	Burro Canyon Formation-- Brown to gray sandstone, conglomerate, and limestone and olive-green to gray mudstone; 0 to 200 feet (0-60 m) thick.

Jurassic

Jm	Morrison Formation, undivided
Jmb	Brushy Basin Member-- Bright-green, slope-forming mudstone with thin ledges of conglomeratic sandstone, conglomerate, nodular-weathering limestone, and gritstone. Thickness 300-400 feet (91-104 m).
Jms	Salt Wash Member-- Light-yellow-gray, cross-bedded sandstone interbedded with red and gray, slope-forming mudstone and siltstone. Thickness about 250 feet (76 m).
Jmt	Tidwell Member-- Red silty shale, with interbeds of fine-grained yellow sandstone and gray limestone; Thickness 40-60 feet (12-18 m).
Jcec	Moab Member of Curtis Formation, Slick Rock Member of Entrada Sandstone, and Dewey Bridge Member of Carmel Formation, undivided.
Jctm	Moab Member of Curtis Formation-- Pale-orange or gray-orange, fine- to medium-grained, cliff-forming sandstone. Thickness 90-110 feet (27-34 m). Formerly mapped as a member of the Entrada Sandstone.
Jes	Slick Rock Member of Entrada Sandstone-- Red-brown to brown, fine-grained eolian sandstone; weathers to form smooth cliffs and bare rock slopes. Thickness 250-350 feet (76-107 m).
Jcd	Dewey Bridge Member of Carmel Formation-- Dark-red, fine-grained, silty sandstone; mostly iron-oxide cemented. Thickness 40-60 feet (12-18 m). Formerly mapped as a member of the Entrada Sandstone.
Jgc	Glen Canyon Group-- Includes Navajo Sandstone, Kayenta Formation, and Wingate Sandstone.
Jn	Navajo Sandstone-- Orange to light-gray, eolian sandstone, mostly fine grained, cemented with silica or calcite; well displayed, high-angle cross-beds. Thickness 250-400 feet (76-122 m).

Jk	Kayenta Formation-- Orange-pink, red-brown, and lavender sandstone interbedded with dark-red-brown to gray-red silty mudstone, lavender-gray conglomerate, and limestone; light-orange to light-gray eolian sandstone beds more prominent in upper third; mostly cemented with calcite. Thickness 240-300 feet (73-91 m).
Jw	Wingate Sandstone-- Light-orange-brown, orange-pink, or red-orange, fine-grained, well-sorted, cross-bedded sandstone; calcareous or siliceous cement. Thickness 250-350 feet (76-107 m).
	Triassic
	Chinle Formation
TRc	Chinle Formation, undivided.
TRcu	Upper Member-- Red-brown or gray-red, fine- to coarse-grained sandstone and siltstone with subordinate gritstone and gray limestone; slope forming with prominent ledges. Thickness 200-460 feet (61-140 m).
TRcl	Lower member-- Mottled gray, purple, and red-brown interbedded sandstone, conglomerate, and siltstone. Thickness 0-380+ feet (0-116+ m).
	Moenkopi Formation
TRm	Moenkopi Formation, undivided.
TRmu	Pariott and Sewemup Members, undivided-- Undivided where poorly exposed.
TRmp	Pariott Member-- Red-brown sandstone interbedded with "chocolate"-brown, orange-brown, or red siltstone, mudstone, and shale; sandstone is fine to medium grained and commonly pebbly, micaceous, poorly to well sorted, and forms a series of ledges; siltstones and mudstones form steep slopes. Thickness 0-450 feet (0-137 m).
TRms	Sewemup Member-- Pale-red-orange to gray-red, slope-forming siltstone with subordinate red-brown, fine-grained sandstone; gypsum is common as irregular veinlets and thin beds. Thickness 0-470 feet (0-143 m).
TRml	Lower Member-- Red-brown and lavender, silty sandstone and conglomeratic sandstone interbedded with red-brown to red-orange sandstone, siltstone and silty mudstone. Thickness 0-450 feet (0-137 m).
	Permian
	Cutler Formation
Pcw?	White Rim Sandstone Member(?)-- Gray-white, cross-bedded sandstone interbedded with minor siltstone and arkose. Thickness 0-250 feet (0-76 m), exposures limited to southwest flank of Castle Valley.
Pc	Arkosic sandstone member-- Red-brown and red-purple sandstone, conglomeratic sandstone, and conglomerate interbedded with silty and sandy mudstone and shale. Thickness 0-6,235+ feet (0-1,900+ m).
	Pennsylvanian
IPp	Paradox Formation-- Paradox Formation cap rock consists of light-gray to yellow-gray gypsum, gypsiferous claystone, silty shale, fine-grained sandstone, and thin-bedded carbonates; disrupted and contorted bedding in two small exposures. Estimated thickness may be as much as 1,000 feet (309 m). Subsurface consists of interbedded coarse crystalline halite and other salts, massive anhydrite, sparse gray dolomite, gray to black shale, and gray siltstone. Estimated thickness 300-9,500+ feet (90-2,900+ m).

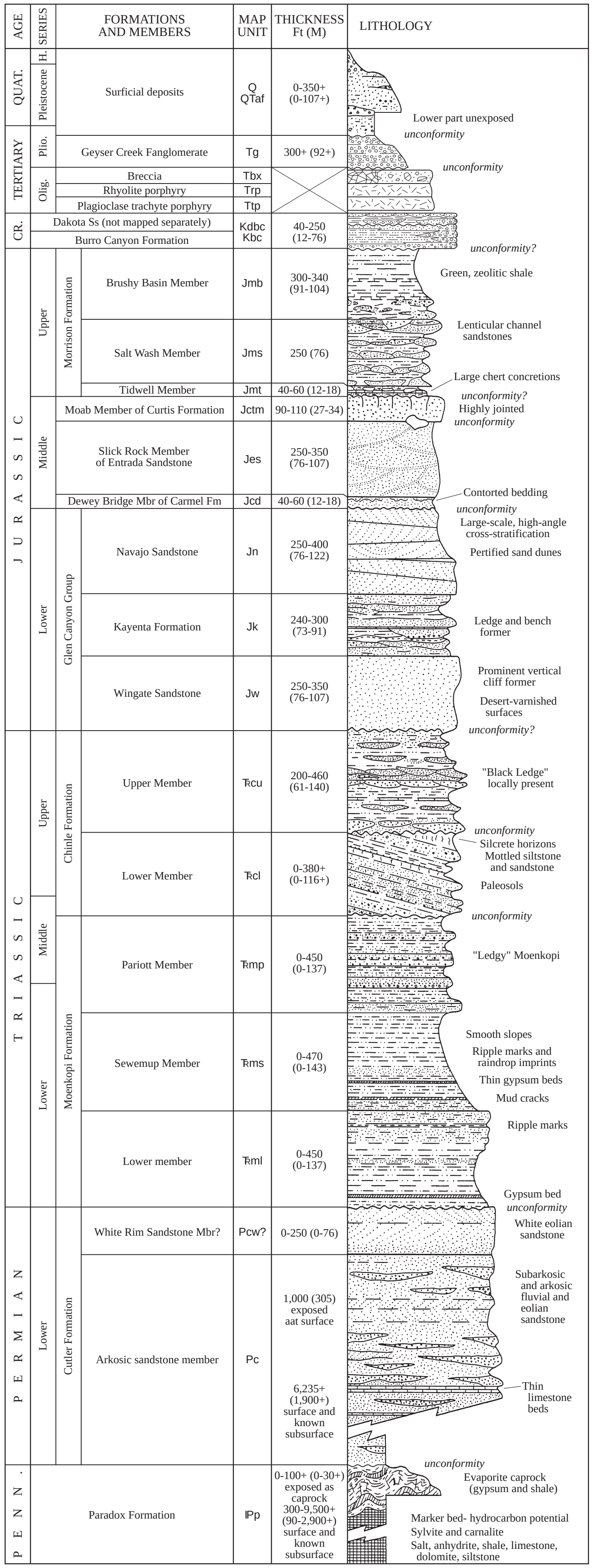


Figure D.2. *Stratigraphic column for units shown on plate 1. From Doelling (2001).*

APPENDIX E

WATER-WELL DATA FOR VALLEY-FILL ISOPACH MAP (PLATE 3)

Table E.1. *Wells used to constrain isopach contours for valley-fill sediment in Castle Valley.*

ID[1]	Location[2]	Depth to Bedrock[3] (feet)
1	N 190 W 1660 SE 25 S22 E1	21
2	N 460 W 1990 E 425 S22 E1	160
3	N 550 W 1660 SE 25 S22 E1	40
4	N 720 W 2045 SE 25 S22 E1	10
5	N 900 W 1660 SE 25 S22 E1	29
6	N 980 W 40 SE 25 S22 E1	5
7	N 1070 W 1000 SE 25 S22 E1	4
8	N 1130 W 110 SE 25 S22 E1	5
9	N 1570 W 1570 SE 25 S22 E1	10
10	N 1720 W 200 SE 25 S22 E1	31?
11	N 1750 W 2090 SE 25 S22 E1	<60
12	N 2160 W 1125 SE 25 S22 E1	>70
13	N 2180 W 630 SE 25 S22 E1	>68
14	N 3470 W 2270 SE 25 S22 E1	>102
15	S 85 W 30 E 425 S22 E1	>58
16	S 1400 W 1700 E 425 S22 E1	15
17	S 50 W 530 NE 25 S22 E12	<125
18	S 280 W 980 NE 25 S22 E12	98
19	S 610 W 980 NE 25 S22 E12	33
20	S 620 W 310 NE 25 S22 E12	>85
21	S 625 W 325 NE 25 S22 E12	30
22	S 1120 W 960 NE 25 S22 E12	56
23	S 1305 W 310 NE 25 S22 E12	40
24	S 1670 W 1040 NE 25 S22 E12	17
25	S 2390 W 430 NE 25 S22 E12	8?
26	N 300 E 1250 SW 25 S23 E5	45?
27	N 50 W 240 SE 25 S23 E6	25?
28	N 700 E 930 SW 25 S23 E6	>100
29	N 780 E 280 SW 25 S23 E6	0
30	N 965 E 780 SW 25 S23 E6	0
31	N 1100 W 1300 SE 25 S23 E6	0
32	N 1700 E 140 SW 25 S23 E6	>103
33	N 1740 E 1725 SW 25 S23 E6	>120?
34	N 1850 W 550 S 425 S23 E6	0
35	N 2340 E 2330 SW 25 S23 E6	2
36	N 2440 E 1930 SW 25 S23 E6	0
37	N 2480 E 55 SW 25 S23 E6	>58
38	N 3160 E 970 SW 25 S23 E6	110
39	N 3510 E 1070 SW 25 S23 E6	8
40	N 3530 E 220 SW 25 S23 E6	102
41	N 3770 E 850 SW 25 S23 E6	4
42	N 40 W 1190 SE 25 S23 E7	290?
43	N 160 E 515 SE 25 S23 E7	0
44	N 180 W 75 SE 25 S23 E7	15
45	N 400 E 550 W 425 S23 E7	8
46	N 580 W 85 E 425 S23 E7	>197
47	N 595 E 120 S 425 S 23 E7	2
48	N 770 W 1230 SE 25 S23 E7	>200
49	N 950 W 300 SE 25 S 23 E7	>83

ID[1]	Location[2]	Depth to Bedrock[3] (feet)
50	N 1070 W 995 SE 25 S23 E7	100
51	N 1100 W 100 SE 25 S23 E7	>110
52	N 1300 W 190 SE 25 S23 E7	>109
53	N 1300 W 200 SE 25 S23 E7	67
54	N 1470 E 200 SE 25 S23 E7	140
55	N 1660 W 1130 SE 25 S23 E7	6
56	S 109 W 332 E 425 S23 E7	>102
57	S 150 E 1000 W 425 S23 E7	45
58	S 220 W 525 NE 25 S23 E7	>106
59	S 267 W 741 E 425 S23 E7	130
60	S 300 E 700 W 425 S23 E7	30
61	S 650 E 2640 W 425 S23 E7	95
62	S 390 W 790 NE 25 S23 E7	>102
63	S 450 E 150 NW 25 S23 E7	20
64	S 475 E 1700 NW 25 S23 E7	>180
65	S 500 E 450 NW 25 S23 E7	30
66	S 605 W 1575 E 425 S23 E7	4
67	S 650 W 1170 NE 25 S23 E7	0
68	S 660 E 2080 NW 25 S23 E7	>105
69	S 970 W 100 N 425 S23 E7	>85
70	S 1070 E 410 N 425 S23 E7	>55
71	S 1210 E 930 NW 25 S23 E7	90
72	S 1310 E 1160 NW 25 S23 E7	10
73	S 1370 W 1945 NE 25 S23 E7	120
74	S 2146 E 2567 NW 25 S23 E7	125
75	N 40 W 1940 SE 25 S23 E8	>155
76	N 92 W 500 SE 25 S23 E8	196
77	N 100 E 250 S 425 S23 E8	>119
78	N 325 W 2120 SE 25 S23 E8	>113
79	N 450 E 1000 SW 25 S23 E8	100
80	N 490 E 700 S 425 S23 E8	>129
81	N 650 E 1280 SW 25 S23 E8	>130
82	N 730 E 270 SW 25 S23 E8	107
83	N 735 W 1150 SE 25 S23 E8	157?
84	N 779 W 1454 SE 25 S23 E8	>202
85	N 800 E 640 SW 25 S23 E8	>136
86	N 810 E 830 S 425 S23 E8	>125
87	N 900 W 1000 SE 25 S23 E8	>150
88	N 1055 W 55 S 425 S23 E8	90
89	N 1115 E 1900 SW 25 S23 E8	>140
90	N 1150 E 850 SW 25 S23 E8	>190
91	N 1510 W 880 SE 25 S23 E8	>137
92	N 1645 E 70 SW 25 S23 E8	>102
93	N 1650 E 1600 SW 25 S23 E8	120
94	N 1720 W 240 SE 25 S23 E8	110
95	N 3710 W 665 SE 25 S23 E8	116
96	S 275 E 210 W 425 S23 E8	>105
97	S 280 W 2030 E 425 S23 E8	110
98	S 600 W 618 E 425 S23 E8	>367
99	S 735 E 405 W 425 S23 E8	>100
100	S 1000 W 2225 NE 25 S23 E15	97
101	N 15 W 1560 SE 25 S23 E17	25
102	N 140 W 820 E 425 S23 E17	85
103	N 200 W 620 S4 25 S23 E17	24
104	N 210 W 280 E 425 S23 E17	>142

ID[1]	Location[2]	Depth to Bedrock[3] (feet)
105	N 250 W 1500 SE 25 S23 E17	>102
106	N 280 W 440 S 425 S23 E17	10
107	N 310 W 640 S 425 S23 E17	0
108	N 460 E 1460 SW 25 S23 E17	0
109	N 580 E 1150 W 425 S23 E17	>146
110	N 640 E 920 S 425 S23 E17	45
111	N 750 W 1610 E 425 S23 E17	>119
112	N 900 W 455 S 425 S23 E17	35
113	N 970 E 1980 W 425 S23 E17	20
114	N 1080 W 600 SE 25 S23 E17	>130
115	N 1213 E 2015 SW 25 S23 E17	85
116	N 1660 E 2020 SW 25 S23 E17	90
117	N 2830 W 372 SE 25 S23 E17	>165
118	N 2100 W 400 SE 25 S23 E17	>248
119	S 200 E 640 N 425 S23 E17	>195
120	S 200 E 1100 NW 25 S23 E17	>121
121	S 240 W 910 NE 25 S23 E17	120
122	S 360 E 1280 W 425 S23 E17	80
123	S 400 W 220 E 425 S23 E17	>130
124	S 430 W 295 E 425 S23 E17	>95
125	S 500 E 1050 NW 25 S23 E17	>132
126	S 565 W 500 N 425 S23 E17	77
127	S 600 E 700 NW 25 S23 E17	40
128	S 660 E 1000 W 425 S23 E17	20
129	S 700 W 550 E 425 S23 E17	>135
130	S 750 W 700 NE 25 S23 E17	>194
131	S 800 E 100 W 425 S23 E17	60
132	S 800 W 1400 E 425 S23 E17	>133
133	S 900 W 2620 E 425 S 23 E17	20
134	S 910 E 600 NW 25 S23 E17	110
135	S 1050 W 275 N 425 S23 E17	>112
136	S 1095 E 215 N 425 S23 E17	>125
137	S 1142 E 2455 NW 25 S23 E17	201
138	S 1405 E 1700 W 425 S23 E17	<93
139	S 1450 W 4250 NE 25 S23 E17	10
140	S 1500 W 2300 NE 25 S23 E17	>145?
141	S 1800 E 850 NW 25 S23 E17	>170
142	S 1810 W 545 NE 25 S23 E17	>135
143	S 2450 E 1050 NW 25 S23 E17	18
144	S 2487 E 2157 W 425 S23 E17	35
145	S 2600 E 50 N 425 S23 E17	>148
146	S 4455 E 2806 NW 25 S23 E17	85
147	N 500 W 600 E 425 S23 E18	35
148	N 600 W 1300 E 425 S23 E18	30
149	N 840 W 2360 E 425 S23 E18	6
150	N 1900 W 880 SE 25 S23 E18	0
151	S 50 W 200 N 425 S23 E18	60
152	S 140 W 3156 NE 25 S23 E18	35
153	S 450 W 280 N 425 S23 E18	20
154	S 450 W 800 NE 25 S23 E18	60
155	S 515 W 1170 NE 25 S23 E18	0
156	S 635 W 420 E 425 S23 E18	30
157	S 800 E 1250 NW 25 S23 E18	0
158	S 1050 W 2200 NE 25 S23 E18	40
159	S 1520 W760 NE 25 S23 E18	25
160	S 1695 W 200 NE 25 S23 E18	30

ID[1]	Location[2]	Depth to Bedrock[3] (feet)
161	S 2000 W 370 NE 25 S23 E18	0
162	S 2420 W 830 NE 25 S23 E18	20
163	N 500 W 950 E 425 S23 E20	40
164	S 100 W 1635 NE 25 S23 E20	25
165	S 100 E 1650 NW 25 S23 E20	0
166	S 600 W 450 N 425 S23 E20	50
167	N 1630 E 330 S 425 S23 E21	>110
168	S 3700 E 2650 NW 25 S23 E21	90
169	S 1920 W 50 NE 25 S23 E25	40
170	N 264 E 1056 SW 25 S23 E26	2
171	N 1183 E 214 S 425 S23 E26	55
172	N 2100 E 0 S 425 S23 E	69
173	S 1050 E 2220 NW 25 S23 E34	0
174	S 100 E 754 W 425 S23 E35	0
175	S 3370 E 1326 NW 25 S23 E35	0

[1] *Corresponds to number on plate 3.*

[2] *Location is given in "Point of Diversion" (POD) notation.*
Example: well 1 is located 190 feet north and 1660 feet west of the southeast corner of section 1 in Township 25 South, Range 22 East, relative to the Salt Lake 1855 Base Line and Meridian.

[3] *Values given are authors' interpretations of drillers' logs from Utah Division of Water Rights files.*
Examples: 35 - well encountered bedrock at 35 feet depth; >110 - well is 110 feet deep, all in unconsolidated deposits, so bedrock is deeper than 100 feet; 157? - best interpretation is that bedrock was encountered at 157 feet, but log is somewhat ambiguous; <60 - log of well repair, beginning at 60 feet depth in bedrock; 0 indicates all bedrock well. Drillers' logs and water rights data are available on the Utah Division of Water Rights Web site: <http://nrwrt1.nr.state.ut.us> and from paper files.

Table E.2. *Records of petroleum-test wells in Castle Valley study area 1.*

ID[2]	Operator	Well Name	API Number	Township	Range	Section	Spot[3]	Completion Date	Elevation (ft)	Total Depth (ft)
OW1	GOLD BAR RESOURCES INC	1 CASTLE VALLEY UNIT	4301910397	25 S	23 E	16	660 FNL 660 FEL	05/18/1965	5019	6502
OW2	INTER-MOUNTAIN OIL & GAS	1 GOVT	4301910599	25 S	23 E	35	660 FNL 660 FEL	07/10/1961	6250	50
OW3	GRAND RIVER OIL & GAS	1 STATE	4301911560	24 S	23 E	36	990 FNL 2310 FEL	01/05/1950	4042	3711
OW4	GRAND RIVER OIL & GAS	1 PACE	4301911564	25 S	23 E	16	1980 FSL 660 FEL	11/11/1950	6250	1725
OW5	CONOCO INC	1 CONOCO FEDERAL 31	4301931180	24 S	23 E	31	1972 FSL 1973 FEL	07/10/1985	4395	11300

Notes

[1] *Data from Utah Division of Oil, Gas and Mining records.*
[2] *Corresponds to letters on figures 3 and 6 and plates 1a and 1b. corresponds to letters on plates 1 and 3.*
[3] *Distances in feet from north (FNL), south (FSL), east (FEL), and west (FWL) section lines.*

APPENDIX F

AQUIFER TESTS

Introduction

The hydraulic properties of an aquifer can be determined by conducting one or more aquifer tests; aquifer tests involve either pumping water from a well at a constant rate or instantaneously changing the water level of a well, and observing the changes in water levels with respect to time. To obtain information about the valley-fill aquifer in Castle Valley, we analyzed specific-capacity data from, and conducted a single-well constant-flow-rate aquifer test using the existing pump on, one well, and evaluated data from 30 slug tests conducted by the Utah Division of Water Rights, all within the Town of Castle Valley.

Evaluation of Specific Capacity

We estimated the hydraulic conductivity of the valley-fill aquifer from a well test performed after the 1979 completion of a private well on lot 425 (figure F.1). The well test involved pumping the well at 30 gallons per minute (100 L/min) for 2 hours and measuring 5 feet (1.5 m) of drawdown. The specific capacity of the well can be determined from these values. Specific capacity is expressed as gallons per minute per foot of drawdown (gpm/ft) derived from the following equation:

$$\text{Specific Capacity } (C_s) = \frac{\text{Yield (Q)}}{\text{Drawdown (s)}}$$

The specific capacity of the well based on the 1979 well test is 6 gpm/ft (7 L/min/m).

We used the calculated specific capacity, Theis' (1963) aquifer-test solutions, and an assumption of a 100 percent efficient well to estimate the hydraulic conductivity of the aquifer penetrated by the well to be 0.67 feet per minute (0.20 m/min). Hydraulic conductivities calculated from specific-capacity data are generally lower than hydraulic conductivities calculated from aquifer tests, due to well (water) losses related to well construction.

Evaluation of Single-Well Constant-Flow-Rate Aquifer-Discharge Test

We also used the well on lot 425 to conduct an aquifer test (figure F.1). This well is used to water the surrounding field, and had not been pumped for some time prior to the test. The driller's report for the well indicates that the aquifer at the well site consists of clay and silt from the surface to a depth of 30 feet (9 m), gravel from 30 feet (9 m) to 98 feet (30 m), and sand and silt from 98 feet (30 m) to the bottom of the well at 102 feet (31 m). The 6-inch (15-cm) diameter well draws water from the bottom of the casing in the gravel, at 96 feet (29 m). With the pump in the well running at its maximum capacity, we measured the drawdown of water levels in the well from February 22 to February 23, 2000; after turning the pump off, we measured recovery of water levels in the well from February 23 to February 24, 2000. Water was discharged into Castle Creek, about 500 feet (152 m) east of the well house, through a 3-inch (8-cm) diameter pipe extending from the well to the creek.

To obtain a current static (initial) water-/piezometric-surface level, we measured the water level in the well several times using an electric tape before performing the aquifer test. The static water level in the well at the time of the aquifer test was 43.22 feet (13.17 m). We assumed this piezometric-surface level to be horizontal for analysis of the aquifer-test data. We measured discharge rates during the aquifer test using a Controlotron clamp-on portable flow meter. Discharge varied between 36 to 38.1 gallons per minute (136-144 L/min) (figure F.2). This low pumping rate probably did not stress the aquifer significantly, and limited the aquifer's area for us to characterize.

After 25 hours of pumping, we turned the pump off and ended the drawdown phase of the test. We monitored recovery and recorded water levels for 6 hours, until water levels returned to the pre-test static water level. Figure F.3 illustrates the water-level response during the aquifer test, showing that the observed water-level change in the well was 9.25 feet (2.82 m), and that the well recovered to the pre-test static water level. The well responded to pumping with an initial rapid drawdown, as indicated by the steep early-time segment portion of the water-level response curve (figure F.3); 95 percent of the drawdown occurred within the first minute of the drawdown phase of the test. After the initial steep drawdown, there was a gradual decline in water levels for the next 24 hours and 59 minutes of the test (figure F.3). After the pump was shut off, 95 percent of the recovery occurred within the first minute of the recovery phase of the test, with a gradual recovery for the rest of the test (figure F.3). In a single-well aquifer test, the drawdown and recovery data can be affected by well losses and well-bore storage effects. We assume that the early drawdown and recovery data are the result of well-bore storage effects; therefore, we do not use this early data in our aquifer test analysis. After the first minute, the flatter water-level response curve reflects dewatering that accompanies the falling water table. The short water-level recovery time of the well in response to the pump stopping suggests high horizontal ground-water flow velocities at the well site.

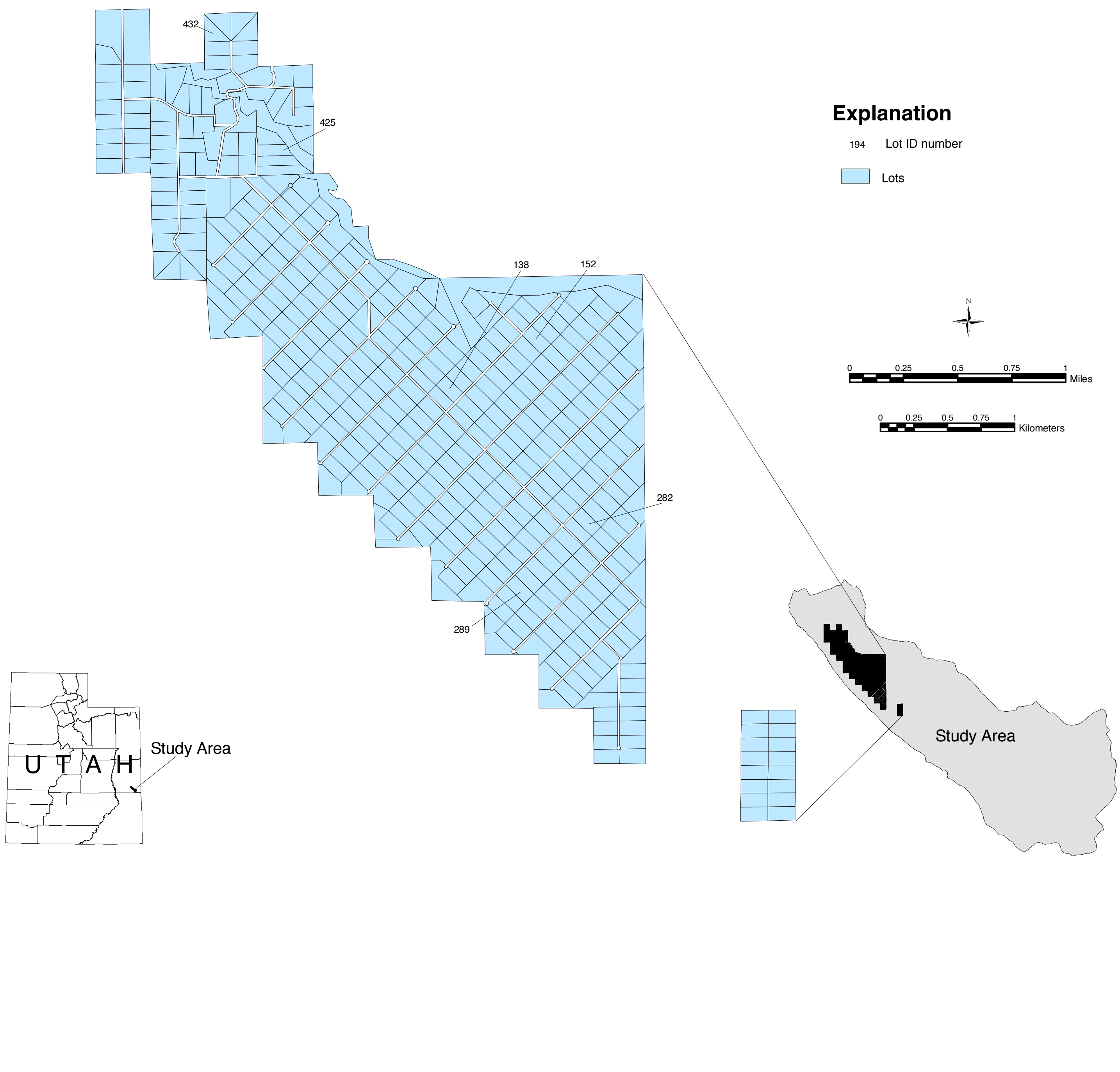


Figure F.1. *Locations of wells used for aquifer and slug tests in Castle Valley, Grand County, Utah.*

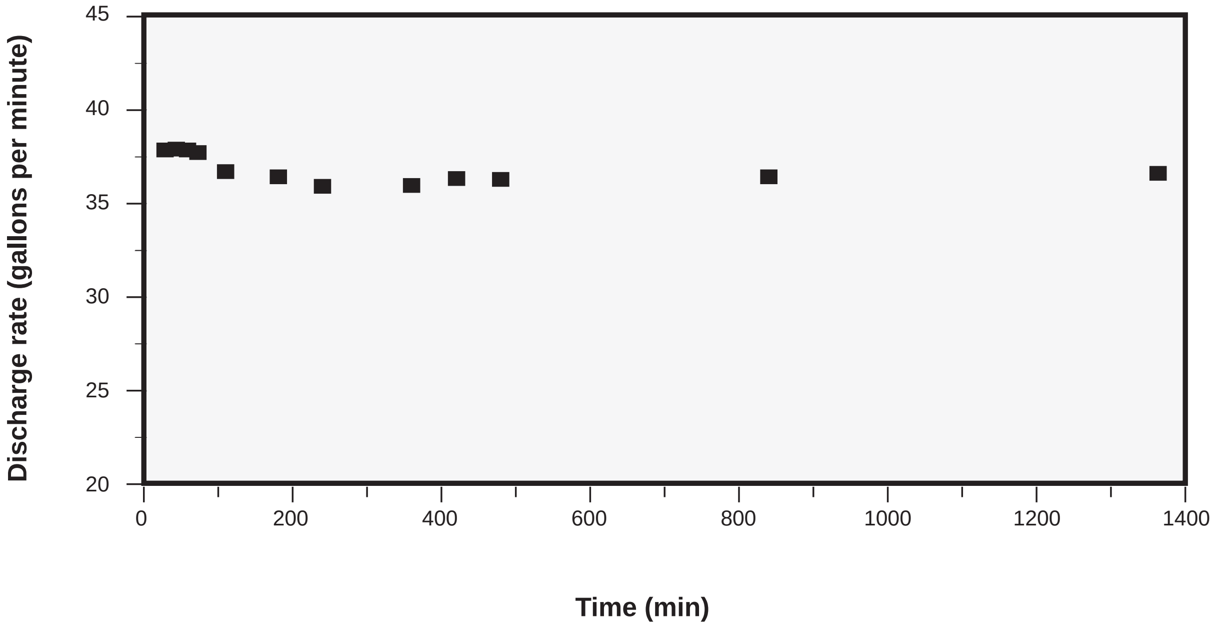


Figure F.2. Discharge rates for the aquifer test conducted using Lot 425 well from February 22 to February 23, 2000. Time is relative to the aquifer test.

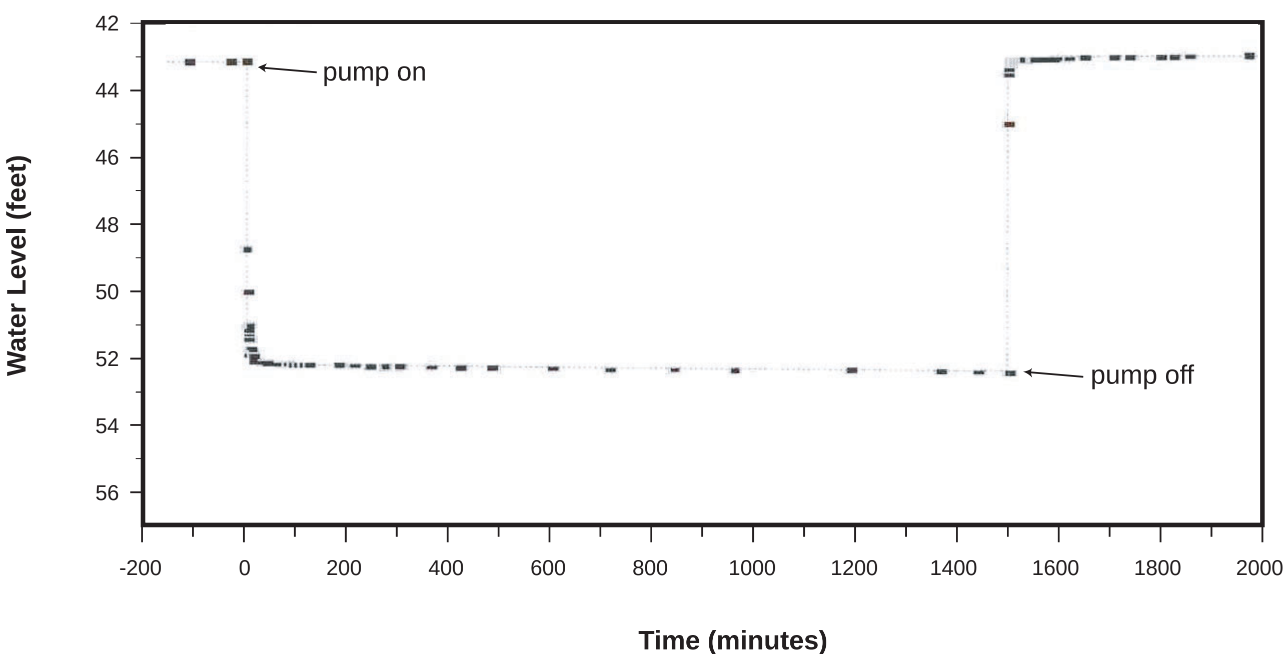


Figure F.3. Water-level response for the aquifer test conducted using well on Lot 425 from February 22 to February 23, 2000, in Castle Valley, Grand County, Utah. Time is relative to the aquifer test.

We analyzed the drawdown phase of the aquifer-test data using the Theis (1935) method for an unconfined aquifer with a partially penetrating well as implemented in the computer program AQTESOLVE for Windows (Hydrosolve, 1996), and determined the "best fit" match (figure F.4). The analysis involved traditional type-curve matching procedures using Theis' (1963) model and the hand-measured data to obtain the aquifer parameters. We matched the post-1 minute data to the Theis curve, because of the well-bore storage affects in the first minute of drawdown. This method may slightly overestimate the hydraulic parameters from the drawdown data. A recovery test is invaluable in a single-well test, because well losses have less effect on the calculated hydraulic parameters. We used the Theis (1935) recovery method to evaluate the recovery data; this method consists of calculating hydraulic parameters from the slope of a semi-log straight line (figure F.5). Because recovery occurred in about one-quarter of the time required for drawdown, the recovery data represents aquifer properties even more proximal to the well than the aquifer properties represented by the drawdown data.

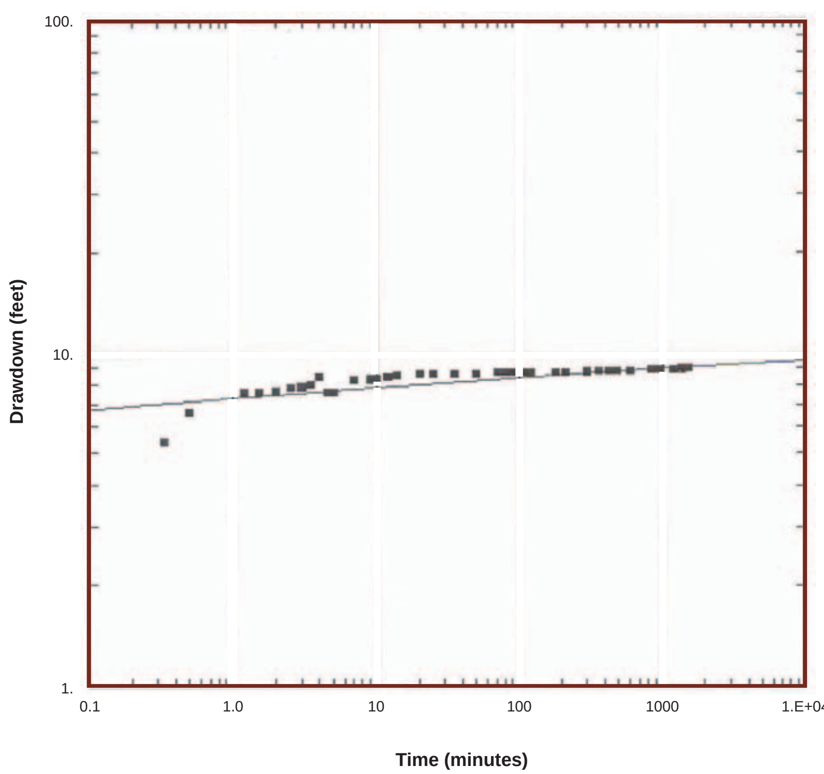
Using the drawdown data, we determined a hydraulic conductivity of 0.004 feet per minute (0.001 m/min) using a Theis type curve for an unconfined aquifer. Using the recovery data, we determined a hydraulic conductivity of 6.38 feet per minute (1.9 m/min) using a Theis recovery method. The drawdown and recovery analysis results from the Theis type curve matching and recovery methods yield hydraulic conductivities characteristic of gravel, sand, and sand and gravel (Freeze and Cherry, 1979); in this case we feel the hydraulic conductivity determined using the drawdown data is more accurate because it reflects a larger area of the aquifer.

Evaluation of Slug Tests

Slug tests are used to evaluate aquifer hydraulic properties near individual wells. We interpreted data from 30 slug tests conducted by the Utah Division of Water Rights. These tests consisted of three sets of falling and rising slug tests (six data sets) per site, and were completed in wells on five sites (lots 282, 138, 432, 289, and 152) (figure F.1). The slug tests were conducted by measuring the fall and rise of the water level in wells caused by the introduction of a solid slug, which displaces the water. The slug apparatus was a 3-foot-long (0.9 m), 3-inch-diameter (8 cm) PVC pipe filled with cement and capped on both ends. The slug was quickly submerged in the well to displace a finite volume of water. The subsequent water-level response was measured with a pressure transducer. The duration of all the slug tests was relatively short, and the estimated hydraulic properties determined from the tests are considered to be only representative of aquifer material near the well.

We analyzed data from the slug tests using the method developed by Bouwer and Rice (1976) for an unconfined, incompressible aquifer with a partial penetrating well. Hydraulic conductivities estimated from the slug tests are summarized in tables F.1 through F.5. Figure F.6 shows a typical graph of water-level changes during one slug test for the well on lot 138. Hydraulic conductivities at two of the wells ranged between 0.2372 and 3.022 feet per minute (0.08-0.92 m/min) (lots 432 and 152); the hydraulic conductivities for the other wells ranged from 0.00033 to 0.04779 feet per minute (0.0001-0.007 m/min) (lots 282, 138, and 289).

Figure F.4. *Drawdown versus time for the 25-hour aquifer test using well on Lot 425 in Castle Valley, Grand County, Utah. Logarithmic presentation used in matching test data to Theis type curve.*



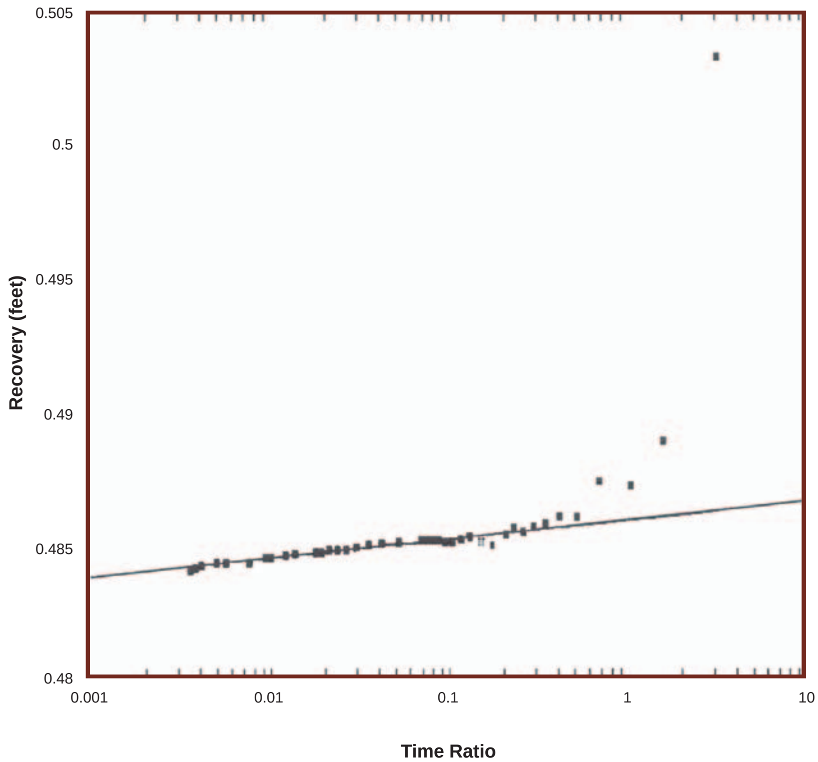


Figure F.5. *Recovery data versus time for the 6-hour recovery test using well on Lot 425 in Castle Valley, Grand County, Utah. Semilogarthmic presentation used in fitting a straight line to test data.*

Table F.1. *Values of hydraulic conductivity determined from slug tests on the well on lot 282, Town of Castle Valley, Grand County, Utah.*

Test	Hydraulic Conductivity ft/min
282-1 falling head	0.03
282-1 rising head	0.02
282-2 falling head	0.02
282-2 rising head	0.02
282-3 falling head	0.02
282-3 rising head	0.02

Table F.2. *Values of hydraulic conductivity determined from slug tests on the well on lot 138, Town of Castle Valley, Grand County, Utah.*

Test	Hydraulic Conductivity ft/min
138-1 falling head	0.002
138-1 rising head	0.001
138-2 falling head	0.001
138-2 rising head	0.002
138-3 falling head	0.002
138-3 rising head	0.003

Table F.3. *Values of hydraulic conductivity determined from slug tests on the well on lot 432, Town of Castle Valley, Grand County, Utah.*

Test	Hydraulic Conductivity ft/min
432-1 falling head	0.30
432-1 rising head	1.62
432-2 falling head	1.99
432-2 rising head	2.41
432-3 falling head	2.0
432-3 rising head	3.02

Table F.4. *Values of hydraulic conductivity determined from slug tests on the well on lot 289, Town of Castle Valley, Grand County, Utah.*

Test	Hydraulic Conductivity ft/min
289-1 falling head	0.03
289-1 rising head	0.04
289-2 falling head	0.14
289-2 rising head	>0.01
289-3 falling head	0.01
289-3 rising head	Could not interpret data

Table F.5. *Values of hydraulic conductivity determined from slug tests on the well on lot 152, Town of Castle Valley, Grand County, Utah.*

Test	Hydraulic Conductivity ft/min
152-1 falling head	0.33
152-1 rising head	0.37
152-2 falling head	0.36
152-2 rising head	0.26
1523 falling head	0.24
152-3 rising head	0.34

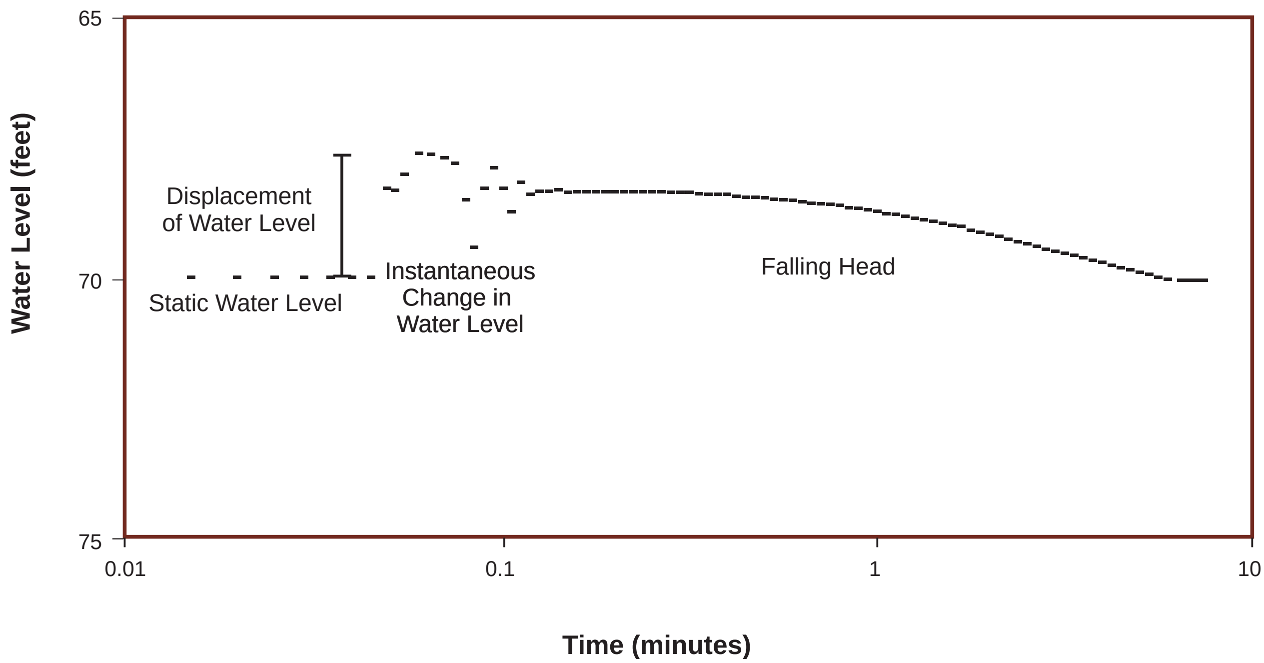


Figure F.6. *Water-level change as a function of time for slug test using well on Lot 138 in Castle Valley, Grand County, Utah. The graph represents a typical falling head slug test used in the Castle Valley study.*

APPENDIX G

POTENTIAL SITES FOR PUBLIC-SUPPLY WELLS

Future population growth in Castle Valley will require additional water-supply sources. Should these additional water-supply sources include a public-supply well, the entire Castle Valley drainage basin may qualify for a Class IB, Irreplaceable ground water, classification based on the U.S. Environmental Protection Agency Sole Source Aquifer designation (Town of Castle Valley, 2000). Here we describe several potential sites for future water wells, as requested by the Town of Castle Valley. We selected the sites primarily for their geologic and hydrologic setting, with some consideration of logistical and water-rights concerns. The latter factors were not thoroughly researched, however, and may eliminate some sites from consideration. Any potential water-well site should receive a site-specific evaluation by a professional hydrogeologist or engineer before development begins. The following paragraphs describe potential well sites in Castle Valley, including their likely advantages and disadvantages. The potential well sites are shown on plates 1, 2, and 3.

Potential site A is northeast of the eastern Castle Valley town boundary, in the northeast quarter of section 16, T. 25 S., R. 23 E., SLBM (plate 1), on land presently owned by the Utah State Institutional and Trust Lands Administration (SITLA). Site A is in a narrow belt of unconsolidated deposits greater than 300 feet (90 m) thick, the thickest unconsolidated deposits known in the valley (plate 3). This belt of thick sediment is defined by only two wells (wells 98 and OW-3, appendix D). We consider the logs of these wells to be reliable, so are confident that unconsolidated deposits in this area are greater than 300 feet (90 m) thick, but the shape and extent of this belt of thick unconsolidated deposits are poorly constrained. A new well should be constructed to draw water exclusively from the alluvial aquifer and not penetrate the underlying Cutler Formation, based on ground-water quality considerations (Town of Castle Valley, 2000).

Advantages of site A include (1) use of a proven aquifer, (2) proximity of the well to Castle Creek, the main recharge source for the unconsolidated aquifer (Snyder, 1996a, b; Town of Castle Valley, 2000), and (3) proximity to present water-distribution systems. Disadvantages of site A include (1) potential decreased flow of Castle Creek and the resulting environmental and water-rights consequences, and (2) vulnerability of the unconfined, unconsolidated aquifer to contamination (Snyder, 1996a, b; Town of Castle Valley, 2000).

Sites B1 and B2 are in the upper part of the north arm of Castle Valley, in sections 29 and 28, respectively, of T. 25 S., R. 24 E., SLBM (plate 1). Site B1 is on U.S. Bureau of Land Management property and site B2 is on U.S. Forest Service property; both sites have similar geologic and hydrologic settings, and are presented as alternatives because the logistics of negotiating drilling permits and water rights may be different for the two agencies.

Sites B1 and B2 penetrate the hinge zone of a syncline below the northern valley margin (cross sections C-C' and D-D', plate 2), and would draw water from the Navajo Sandstone, Kayenta Formation, and Wingate Sandstone aquifers. Recharge to these units likely comes from both Adobe Mesa and Grand View Mountain, and perhaps from Castle Creek. Any site between B1 and B2 would encounter similar geologic and hydrologic conditions and would be equally suitable.

Advantages of sites B1 and B2 include (1) use of aquifers that are proven producers throughout the Colorado Plateau (Freethey and Cordy, 1991) but that are not currently used in Castle Valley, (2) the likelihood that the target aquifers receive recharge from several source areas, and (3) at the potential well sites, the relatively low-permeability Dewey Bridge and Slick Rock Members of the Entrada Sandstone overlie the target aquifers, providing hydrologic isolation from Castle Creek and the unconsolidated aquifer and some protection from contamination. Disadvantages of sites B1 and B2 include (1) possible effects on wells and springs downgradient in Castleton, (2) vulnerability to contamination from activity in the recharge areas, especially the flanks of Grand View Mountain, (3) costliness of deep drilling (~1,000 feet [300 m] for B2), and (4) their distance from present water-distribution systems.

Potential sites C1 and C2 are on the northwestern flank of Grand View Mountain, in section 5, T. 25 S., R. 24 E., SLBM (plate 1), on SITLA property. Fractured trachyte porphyry of the La Sal Mountains intrusion is the target aquifer for both sites. Recharge to the aquifer at the potential well sites comes from precipitation on Grand View Mountain. Site C1 is in a topographic depression, enhancing its recharge potential, but is near the northwestern margin of the intrusion. Because the subsurface geometry of the La Sal Mountains intrusion is poorly known, closer proximity to the intrusion margin results in greater uncertainty about the thickness of the target aquifer there and increases the possibility of encountering salt- and gypsum-rich cap rock of the Paradox Formation (see cross sections C-C′ and D-D′, plate 2). Site C2 is near Spring Branch, a perennial stream, and is closer to the center of the La Sal Mountains intrusion.

Advantages of sites C1 and C2 include (1) their proximity to a large potential recharge area, and (2) the target aquifer presently has little water development. Disadvantages of these sites include (1) the uncertainty in the thickness of trachyte porphyry below the sites, (2) the potential for interference with existing wells in the nearby Castleview subdivision (especially for site C1, which is downgradient from the subdivision), (3) the potential for decreased flow of Spring Branch (especially for site C2), and (4) the great distance from present water-distribution systems.

Appendix WC-5

HYDROLOGIC ASSESSMENT OF THE SURFACE WATER AND GROUNDWATER RESOURCES OF CASTLE VALLEY, UTAH: PART 1: HYDROLOGIC AND ENVIRONMENTAL ANALYSIS (HESA) AND PRELIMINARY WATER BUDGET

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Prepared For:
Town of Castle Valley, Utah

March 2016

Front Page: Town of Castle Valley, Utah (November 2013)

Table of Contents

List of Tables

List of Figures

1 INTRODUCTION

Under an agreement with Town of Castle Valley, Utah, Hydrologic Systems Analysis LLC (HSA) of Golden, Colorado, in conjunction with Heath Hydrology, Inc. (HHI) of Boulder, Colorado, was tasked: 1) to perform a Hydrologic and Environmental System Analysis (HESA) of the surface water and groundwater resources of the valleys and uplands of the Castle Creek Watershed and Castle Valley Groundwater Basin in the vicinity of the Town of Castle Valley in Grand County, Utah**;** 2) develop hydrological, hydrogeological and other data bases necessary for constructing a water budget for the Valley; and based on the HESA results and GIS databases developed: 3) develop an as-accurate-as-possible water budget for the Valley in support of watershed management issues including water supply and allocation, water quality and protection, and watershed protection; and 4) determine the siting and protecting of a municipal well and a shallow well(s) near the Castle Valley Ditch Co. diversion to augment surface flows in Castle Creek and irrigation ditches. Each of these tasks constitutes a phase of the project. This report contains the results of phase 1, Hydrologic and Environmental System Analysis (HESA) and includes a preliminary water budget analysis.

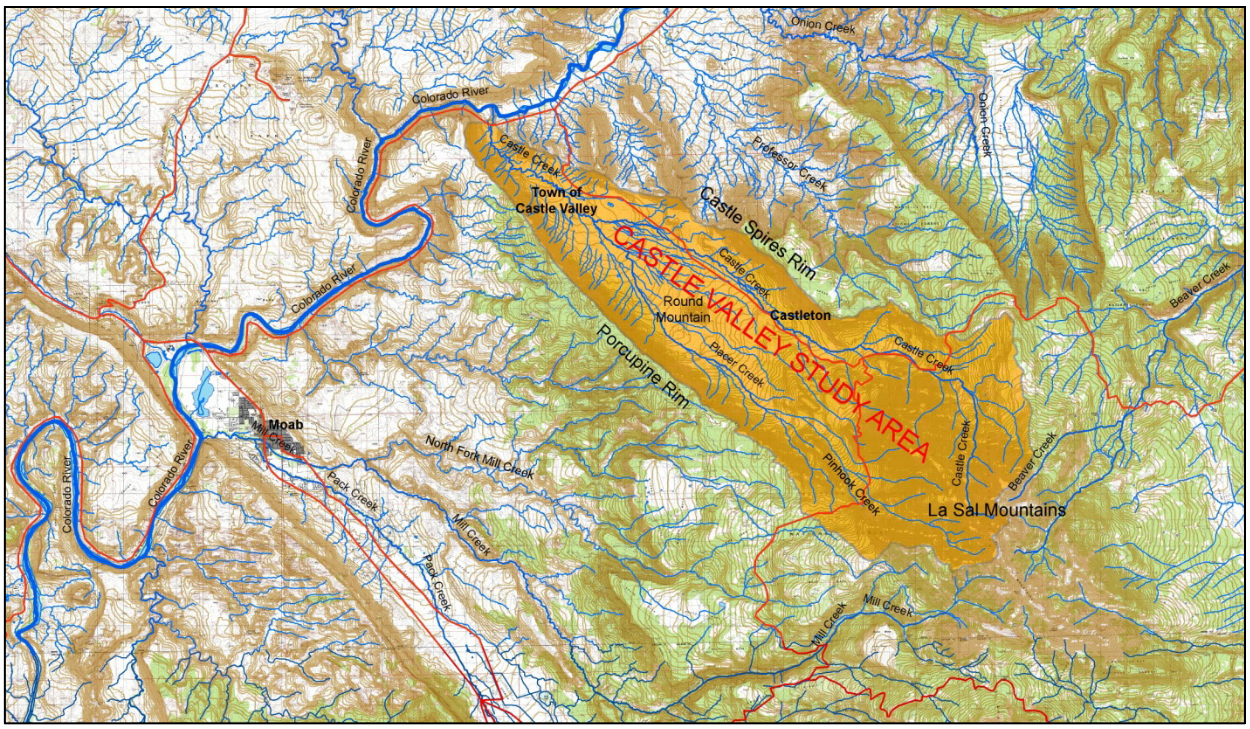

Figure 1. Topographic Map Showing the Location of the Castle Valley Study Area, Grand County, Utah. (Utah GIS, 2015).

The study area is located between the La Sal Mountains to the south, the Colorado River to the north, the Porcupine Rim to the west, and the Castle Spires Rim to the east (Figures 1 and 2). The delineation of the study area is based on the nature and extent of the major hydrogeological systems present, the surface hydrology of the area, and water resources related land use considerations. The area covers the Castle Creek and Placer Creek watersheds as delineated in the GIS files downloaded from the data portal of the Natural Resources Conservation Service (NRCS, 2015). The study distinguishes between 3 hydrologic entities: 1) the entire Castle Creek Watershed (including Placer Creek drainage); 2) the lower Castle Valley hydrologic system (northwest of roughly a line from the Castleton area to the Porcupine Ranch); and 3) the Castle Valley Groundwater Basin (quaternary and tertiary sand and gravels, and underlying fractured bedrock). The lower Castle Valley hydrologic system will be the setting for the water budget to be developed in a later phase of this study.

The HESA of the surface water and groundwater systems in the Castle Valley (TCV) study area makes extensive use of existing GIS databases and maps of geologic, hydrogeologic and hydrologic characteristics, collected specifically for this study. Additional data layers and evaluations were needed to illustrate the HESA – particularly with respect to the hydrogeological characteristics of the rock types present and the significance of hydrostructures. The results of the HESA of the TCV area are documented in this report, which also contains an introduction to the development of the water budget elements to be evaluated in a later report. The results of the HESA provides support for planning, zoning and other decision-making tasks, including those related to protection of groundwater resources for use as public or communal water supplies, and prepares for the next phase of the study involving water budget quantification and location of the Town of Castle Valley municipal well. The HESA included a few scoping site visits to the study area; no additional fieldwork has been conducted.

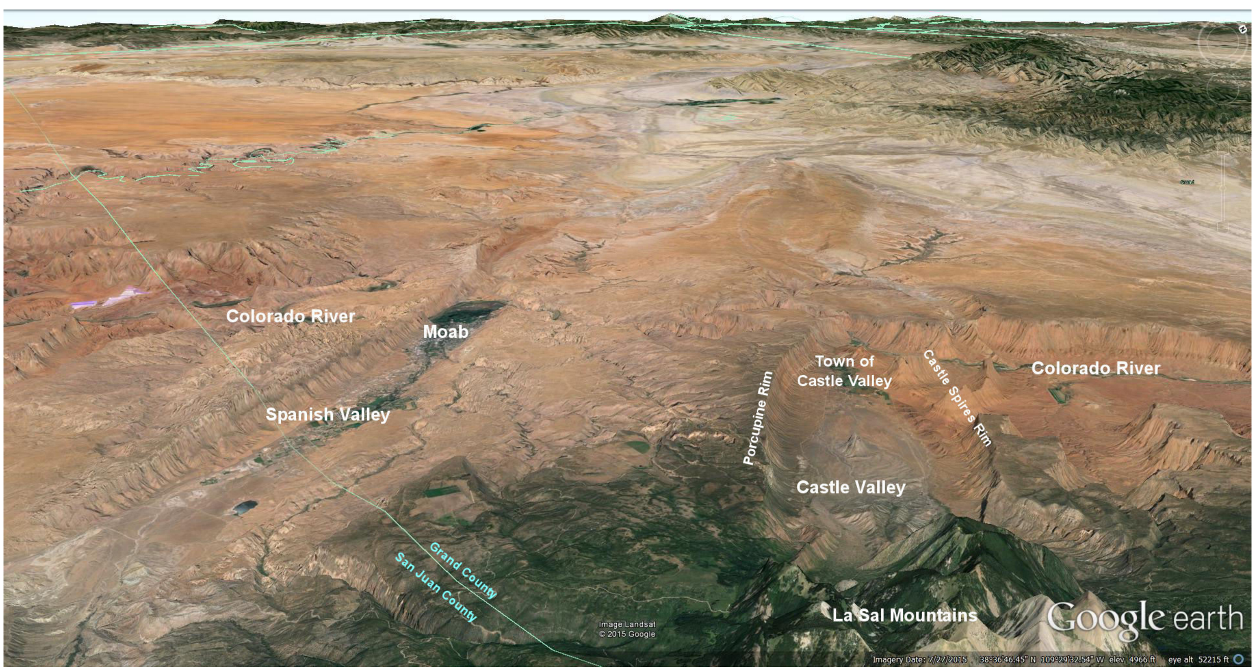

Figure 2. View of the Regional Setting of the Castle Valley Study Area (Google Earth, 2015)

It should be noted that that this report will not obviate the need for additional hydrogeologic analysis on a site-specific/parcel-specific basis by developers and/or the Town, or in any water right, geotechnical, or environmental study requiring due diligence. The information in this report is intended to be used as indicator only, as part of a multi-step land use decision-making process, and to provide a starting point for further study of the Town's surface water and groundwater resources. Additional data bases will be developed as the result of the water budget analysis, and the location of a new municipal well for the Town of Castle Valley.

2 DEVELOPMENT OF A CONCEPTUAL SITE MODEL OF THE HYDROLOGIC SYSTEMS OF THE CASTLE VALLEY (TCV) STUDY AREA

HESA is an approach used to conceptualize and characterize relevant features of hydrologic and environmental systems, integrating relevant considerations of climate, topography, geomorphology, groundwater and surface water hydrology, geology, ecosystem structure and function, and the human activities associated with these systems into a holistic, three-dimensional dynamic conceptual site model (CSM). This watershed-based, hierarchical approach is described by Kolm and others (*1996*) and codified in ASTM D5979 Standard Guide for Conceptualization and Characterization of Ground Water Systems *(ASTM 1996(2008))*. The CSM of the TCV study area covers elements of climate, topography, soils and geomorphology, surface water characteristics, hydrogeologic framework, hydrology, and anthropogenic activity as related to the surface water and groundwater systems in the study area.

Based on field surveys and a preliminary HESA, a number of hydrogeologic subsystems were identified within the TCV study area. Each of these subsystems has a unique hydrogeologic setting and groundwater flow system and is described in detail in forthcoming sections of the report. Furthermore, current anthropogenic modifications of the natural hydrologic features in these subsystems are minimal, and are primarily related to domestic water use (wells, lawn watering and septic systems), and irrigation (surface water diversions and irrigation return flow). A brief discussion of potential modification of natural flow patterns and impacts on water budgets and water quality, particularly salts, from agricultural and urbanization activities is included.

2.1 Climate

The climate in the study area has both local and regional components and includes effects of elevation and slope aspect (*i.e.*, steepness and orientation with respect to the prevailing winds and sun exposure). The presence of the Porcupine Rim, Castle Spires Rim, and the La Sal Mountains (uplift) further influences the climate at the lower elevations by orographic precipitation effects, causing enhanced precipitation on the windward side and local and regional rain shadows on the leeward sides. Most of the TCV area is in the rain shadows of these three prominent features, and the precipitation is reduced significantly in comparison to surrounding areas. Relevant weather stations of the National Weather Service (NWS) Cooperative Network (COOP) in the study area, as available from the Western Regional Climate Center (WRCC) at the Desert Research Institute (DRI) for the valley are Castle Valley (COOP 421241), located in the town of Castle Valley and Castleton (COOP 421230). For the watershed in its entirety, La Sal (COOP424946) is also of interest. These stations provide an overlapping period of observations useful for comparative analysis. Active and historic (inactive) stations have also been identified by the Utah Climate Center (UTC) at Utah State University. Those data will be used in the water budget analysis and potential effects of climate change in a later phase of this study. Figure 3 shows the approximate locations of each of these stations.

Tables 1a-c show monthly and annual long-term averages for maximum and minimum temperature, precipitation, snowfall and snow depth.

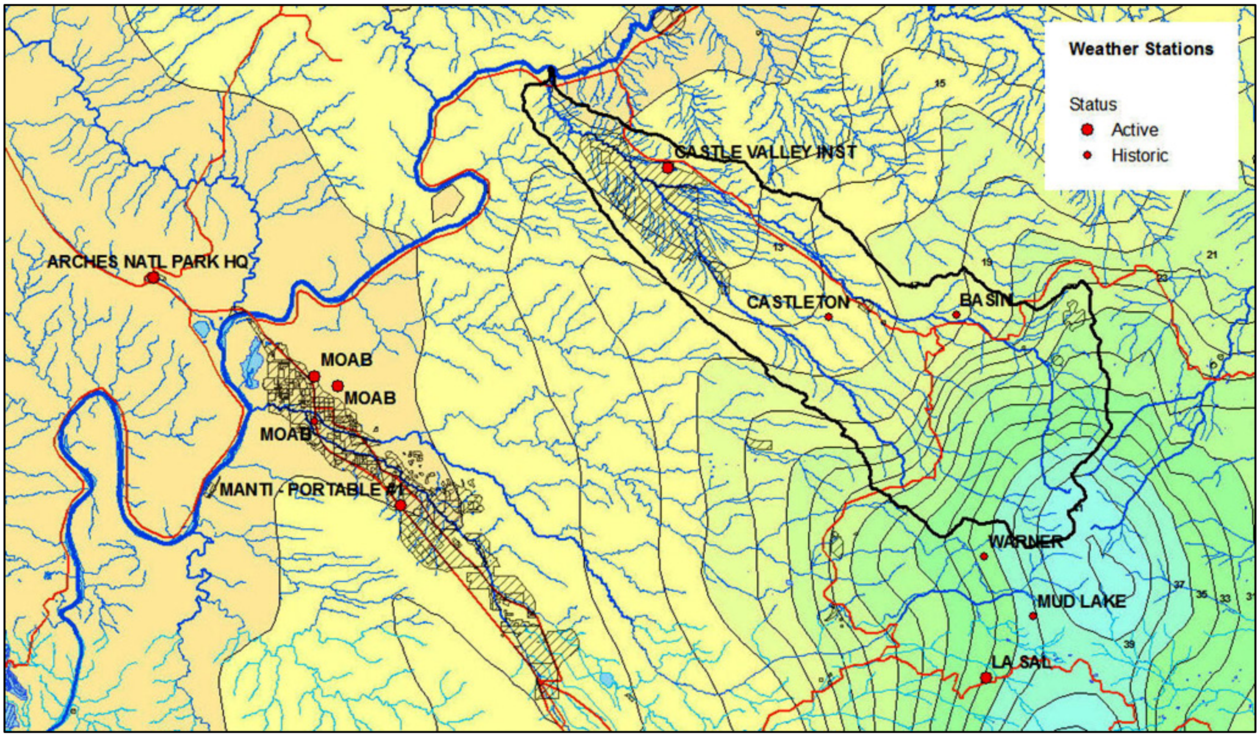

Figure 3. Location of NWS/COOP Weather Stations in and near the TCV Study Area (Utah GIS, 2013).

The NWS data were used to prepare a map of spatially distributed precipitation corrected for elevation (see Figure 4). As these data sources show, there is a gradual precipitation gradient in Castle Valley from about 10 inches annually at the far northwestern boundary of the TCV study area to about 14 inches near Castleton, UT, with a sharp increase in precipitation of about 17 inches on either the northeast and southwest rims of the study area, and up to greater than 40 inches at the higher elevations in the La Sal Mountains.

CASTLE VALLEY, UTAH (421241)

Period of Record Monthly Climate Summary

Period of Record : 08/01/1978 to 04/30/2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	40.0	47.9	58.2	67.4	77.3	88.7	94.9	91.6	82.6	69.4	52.9	41.0	67.7
Average Min. Temperature (F)	19.9	25.6	33.3	40.4	49.2	58.1	64.1	61.9	52.4	41.2	29.9	21.4	41.4
Average Total Precipitation (in.)	0.72	0.72	1.04	1.00	1.00	0.36	0.76	0.85	1.01	1.44	0.99	0.69	10.58
Average Total SnowFall (in.)	4.0	2.1	2.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	2.5	4.2	15.7
Average Snow Depth (in.)	1	1	0	0	0	0	0	0	0	0	0	0	0

Percent of possible observations for period of record.
Max. Temp.: 92.2% Min. Temp.: 92% Precipitation: 91.9% Snowfall: 90.6% Snow Depth: 86.5%
Check Station Metadata or Metadata graphics for more detail about data completeness.

Western Regional Climate Center, wrcc@dri.edu

Table 1a. Average Monthly and Annual Maximum and Minimum Temperature, Precipitation, Snow Fall and Snow Depth for Castle Valley Station (COOP421241 at 4730ft) for Period 08/01/1978 to 04/30/2009. (Source: Western Regional Climate Center (WRCC), Desert Research Institute, Reno, Nevada).

CASTLETON, UTAH (421230)

Period of Record Monthly Climate Summary

Period of Record : 11/01/1963 to 05/31/1978

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	35.4	42.7	51.4	60.7	72.7	82.8	89.5	87.2	77.8	63.1	49.4	38.2	62.6
Average Min. Temperature (F)	15.3	21.2	28.2	36.3	45.9	54.3	61.2	59.0	49.6	38.4	28.3	18.2	38.0
Average Total Precipitation (in.)	0.57	0.57	1.07	1.40	1.16	1.15	1.51	1.47	0.96	1.75	1.32	1.00	13.93
Average Total SnowFall (in.)	8.2	5.5	7.4	4.0	0.5	0.0	0.0	0.0	0.0	3.0	5.5	10.4	44.4
Average Snow Depth (in.)						No	Data						

Percent of possible observations for period of record.
Max. Temp.: 88.6% Min. Temp.: 88.4% Precipitation: 94.6% Snowfall: 94.9% Snow Depth: 89.7%
Check Station Metadata or Metadata graphics for more detail about data completeness.

Western Regional Climate Center, wrcc@dri.edu

Table 1b. Average Monthly and Annual Maximum and Minimum Temperature, Precipitation, Snow Fall and Snow Depth for Castleton Station (COOP421230 at 5950ft) for Period 11/31/1963 to 05/31/1978. (Source: Western Regional Climate Center (WRCC), Desert Research Institute, Reno, Nevada).

LA SAL, UTAH (424946)

Period of Record Monthly Climate Summary

Period of Record : 02/02/1901 to 03/31/1978

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	35.9	39.5	47.0	57.7	67.3	77.6	83.6	81.3	73.9	62.6	48.1	37.5	59.3
Average Min. Temperature (F)	12.7	16.8	23.0	31.0	39.1	47.8	54.6	53.4	44.6	33.8	23.6	14.8	32.9
Average Total Precipitation (in.)	0.85	0.83	0.79	1.00	0.89	0.76	1.43	1.53	1.20	1.57	0.90	1.05	12.80
Average Total SnowFall (in.)	8.1	8.6	6.0	3.2	0.9	0.0	0.0	0.0	0.1	1.6	5.4	10.5	44.4
Average Snow Depth (in.)	5	5	1	0	0	0	0	0	0	0	1	3	1

Percent of possible observations for period of record.
Max. Temp.: 78.2% Min. Temp.: 77.8% Precipitation: 79.6% Snowfall: 69% Snow Depth: 52.6%
Check Station Metadata or Metadata graphics for more detail about data completeness.

Western Regional Climate Center, wrcc@dri.edu

Table 1c. Average Monthly and Annual Maximum and Minimum Temperature, Precipitation, Snow Fall and Snow Depth for La Sal Mountain Station (COOP424946 at 6990ft) for Period 02/02/1901 to 03/31/1978. (Source: Western Regional Climate Center (WRCC), Desert Research Institute, Reno, Nevada).

Precipitation type (rainfall versus snowfall), amount, and temporal and spatial distribution are important for determining the amount of recharge that a groundwater system may receive, particularly when it consists of the thick unconsolidated materials or shallow, permeable bedrock under unconfined conditions. The distribution of average annual precipitation is an important indicator of the climate of a particular area, and in the case of the TCV study area, the climate ranges from semi-arid-to-arid in the valleys and rims, and subhumid to humid in the surrounding mountains. There is a small natural recharge potential, mostly from rain and some snow throughout the late fall, winter, and spring, in the valley floors and on the rims, and a moderate to large natural recharge potential from both rain and snow in the higher elevation areas of the La Sal Mountains. The summer months are characterized by high evaporation rates and are too desiccated for significant groundwater infiltration and recharge in the valley floors and rims, with the exception of some localized intense summer storms, especially on irrigated (high soil moisture content) lands and in the channels of the drainages. Thus, most of the natural groundwater recharge in the near-surface aquifers occurs during a short period of time in the late fall, winter and early spring (October to April) in the valley floors and rims. By comparison, the topographically higher terrains surrounding the TCV study area near the La Sal Mountains are humid-to-subhumid and cool and have excellent groundwater recharge potential, both from rainfall in the spring, summer, and autumn months, and from the melting of snowpack throughout the winter and early spring, especially where covered by gravels and slope deposits. It should be noted that the entire study area has groundwater recharge potential, with even the driest areas probably receiving approximately 1-2 inches of recharge annually. This is important when considering the ultimate groundwater system flow directions and areas of groundwater recharge, and for calculating water budgets.

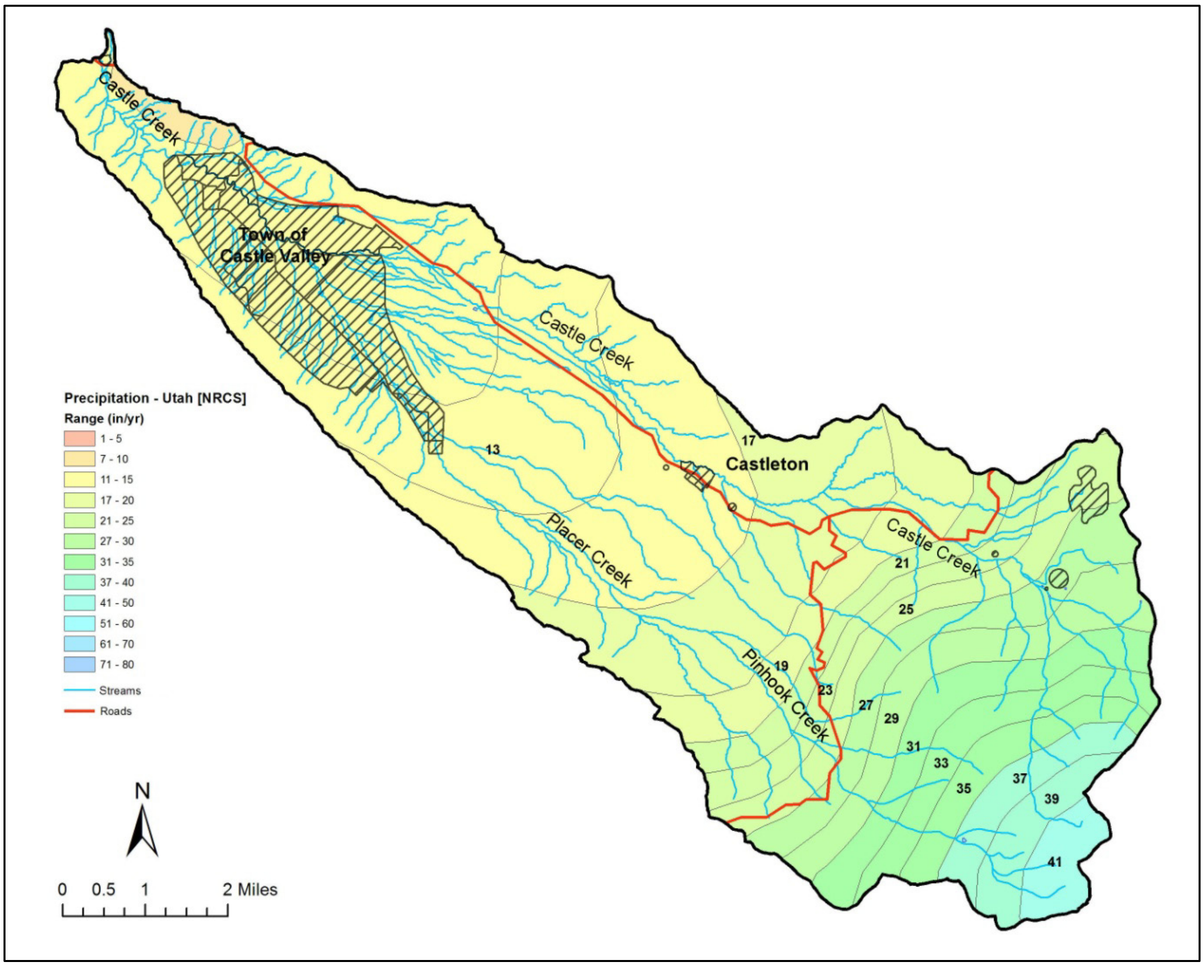

Figure 4. Spatial Distribution of the Average Annual Precipitation in the TCV Study Area (Source: Natural Resources Conservation Service, 2011).

2.2 Topography and Geomorphology

Castle Valley is located in the Colorado Plateau physiographic province, and geomorphically in the Paradox Basin subprovince (Thornbury, 1965). This subprovince is characterized topographically and geologically as a series of northwest trending salt anticlines with collapse features called grabens (to be discussed in subsequent chapters of the report) that result in landscapes that seem to be torn apart from the earth with gaping holes (valleys) and sharp serrated surrounding rimlands (Figures 1,2, and 5). This landscape is characterized as abrupt, angular, and discontinuous, and the result is for surface water and groundwater systems to be localized (non-regional). Castle Valley is a typical feature in this province.

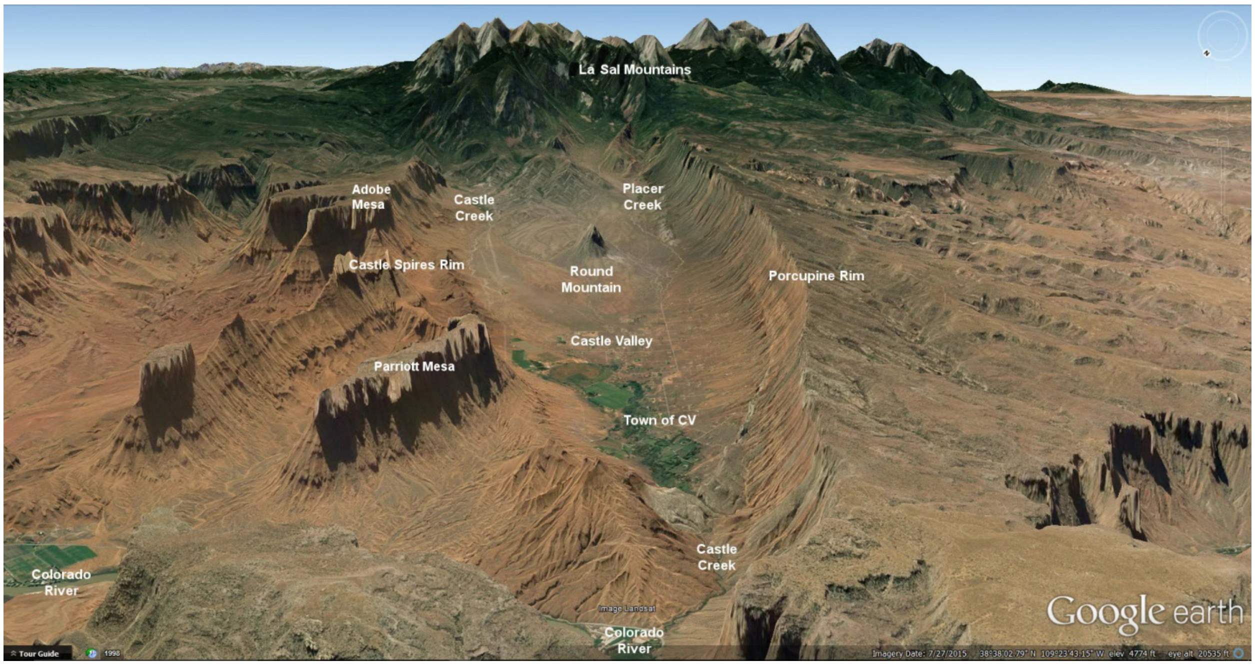

Figure 5. Topography in the TCV Study Area Looking Southeast. (Google Earth, Feb. 2016).

The surface elevation in the TCV study area ranges from about 1,300 m (≈4,000 ft) in the Colorado River Valley to about 3,500 m (≈12,100 ft) in the La Sal Mountains (Figure 1 and 6). The topography of the study area has three distinct terrains: 1) steeply sloping to gently rolling, dissected bedrock foothills and mountains of the La Sal Mountain region to the southeast of Castle Valley, and the dissected bedrock escarpments and plateaus along the northeastern and southwestern flanks of the surrounding rim lands; 2) poorly to moderately dissected, connected and disconnected, continuous and discontinuous hillslope fans and mass wasting features (particularly talus and debris flows along the rimlands), and older alluvial terraces and pediment features in the southeastern part of Castle Valley around Round Mountain; and 3) continuous alluvial valley bottoms associated with the two principal drainages of Castle Creek and Placer Creek (Figure 1, 5, and 6).

In the lower section of the TCV study area --including the Castle Creek and Placer Creek Alluvial Basin and the modern day talus, fans, and alluvial terraces-- are separated topographically from other watersheds regionally by the geologic structures and topography associated with the collapsed anticlines (Porcupine and Castle Spires Rims) and the La Sal Mountain Tertiary intrusives (Ti), and locally by inter-fluvial bedrock uplands associated with features such as Round Mountain (Ti) and the ridges associated with the La Sal Mountains. These bedrock features function as barriers to hydrologic connectivity, and therefore hydrologic systems in the valley are disconnected from adjacent hydrologic systems. The effects of the bedrock impediments and the stream and valley dissection on the groundwater systems will be discussed in the Groundwater System Conceptual Site Models sections.

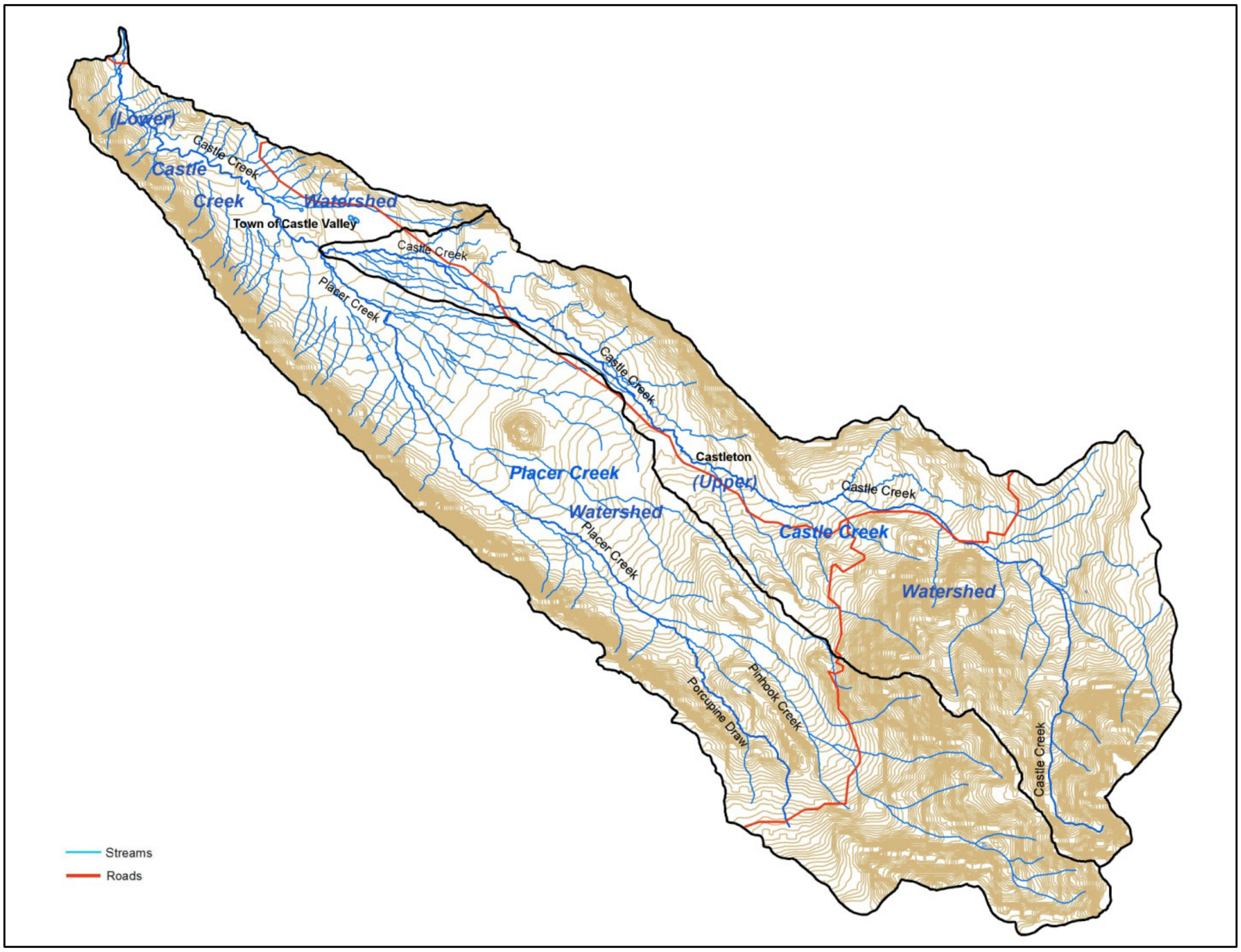

Figure 6. Topography (50ft Contours) and Surface Water (Streams and Watersheds) in the TCV Study Area. (Sources: Natural Resources Conservation Service, 2011; Grand County, 2011).

The deeper bedrock groundwater systems, if not topographically dissected by the surficial processes or affected by regional geologic structure and uplift activity, will be continuous and regional in nature. However, all of the deeper bedrock groundwater systems are affected by the regional geologic structure, and there is no continuity in the deeper bedrock systems across the region at this location (to be discussed in later sections of the report). Therefore, these deeper bedrock systems in the TCV area do not receive regional groundwater recharge and are recharged by, or are discharging into the local shallow groundwater systems depending on the geomorphic geometry. Most of the alluvial terraces, fans, and river bottoms in the study area are connected, but are isolated topographically from the rest of the region, which results in discrete and localized groundwater systems and can result in discrete and localized springs and connections to surface water systems. This is important in identifying various segments of the water budget.

The topographic gradients in the TCV area can be divided into three types: 1) steep gradient bedrock slopes (greater than 2% slope) mostly in the bedrock regions and flanks of the surrounding rimlands of the collapsed anticlines; 2) steep gradient unconsolidated materials slopes (greater than 2%) including the talus and alluvial fans forming beneath the rimlands of Castle Valley and along the exposed bedrock of the La Sal Mountains to the south east; and 3) low gradient (less than 2% slope) fan, terrace levels, and alluvial valley bottoms associated with Castle and Placer Creeks (Figures 5 and 6). The topographic gradient is useful in estimating the surface of the water table, for estimating the amounts of infiltration versus overland flow and interflow (rapid, shallow subsurface runoff), and for estimating residence times for subsurface water to be in contact with bedrock that may supply salt resulting in declining water quality.

2.3 Surface Water Characteristics and Springs

The TCV study area contains parts of local watersheds draining to the Colorado River via Castle Creek and Placer Creek (Figure 6). Streams can be gaining flow (from groundwater, rapid surface runoff, and interflow), or losing flow (to groundwater, diversions or evaporation through phreatophyte vegetation), dependent on local hydrology, hydrogeology, irrigation practices, and time of year. Both Castle Creek and Placer Creek are mostly dependent on groundwater interactions either as gaining or losing stream reaches.

Castle Creek originates from spring flow and groundwater discharge from the stream bed into the channel in Willow and Bachelor Basins in the La Sal Mountains, and, when not influenced by human diversions, remains perennial throughout its entire length (Ford, 2006). Seepage studies revealed that Castle Creek is a gaining stream from its headwaters to the Day Star Academy's (DSA) diversion (Ford, 2006) (Figure 7a). Castle Creek, from the DSA diversion to a point just downgradient of the Placer Creek/Castle Creek junction, is losing surface flow to groundwater (groundwater recharge from stream) (Figure 7b). Below the junction of Castle Creek and Placer Creek, Castle Creek becomes a gaining stream as evidenced by springs, increased surface water flow and phreatophytes along its channel, and remains a gaining stream as it leaves the Castle Valley to the northwest (Figure 7c).

Pinhook Creek, the main tributary to Placer Creek, originates from an abandoned mine and is a gaining stream in the La Sal Mountains until it emerges out of the glacial canyons and flows over thick glacial alluvial deposits. This stream recharges the alluvial aquifer and the creek bed goes dry during normal flow. Porcupine Draw, the other main tributary to Placer Creek, originates at Mason Spring and then flows over thick glacial alluvial deposits. This creek recharges the alluvial aquifer and the creek bed goes dry during normal flow. There are places that the bedrock is near the surface, due to faulting, and the alluvial deposits are thin forcing the groundwater to be near or at the surface, and in the case of Porcupine Ranch Spring, allowing the Porcupine Draw channel to briefly flow (Figure 7d). At that point, in the vicinity of Porcupine Ranch, the Placer Creek system has a diversion for irrigation and domestic use (Figure 7d). Below this spring, Placer Creek goes dry and the groundwater reemerges in Castle Creek below the junction (Figure 7c).

The gaining and losing dynamics of these streams are influenced by seasonal events, with bank full conditions occurring during the spring runoff and summer irrigation season, and low water conditions occurring during the rest of the year. In addition, some storm events of various durations and amounts can affect the yearly and seasonal flows. A graph illustrating these daily, seasonal, and annual events is shown in Figure 8.

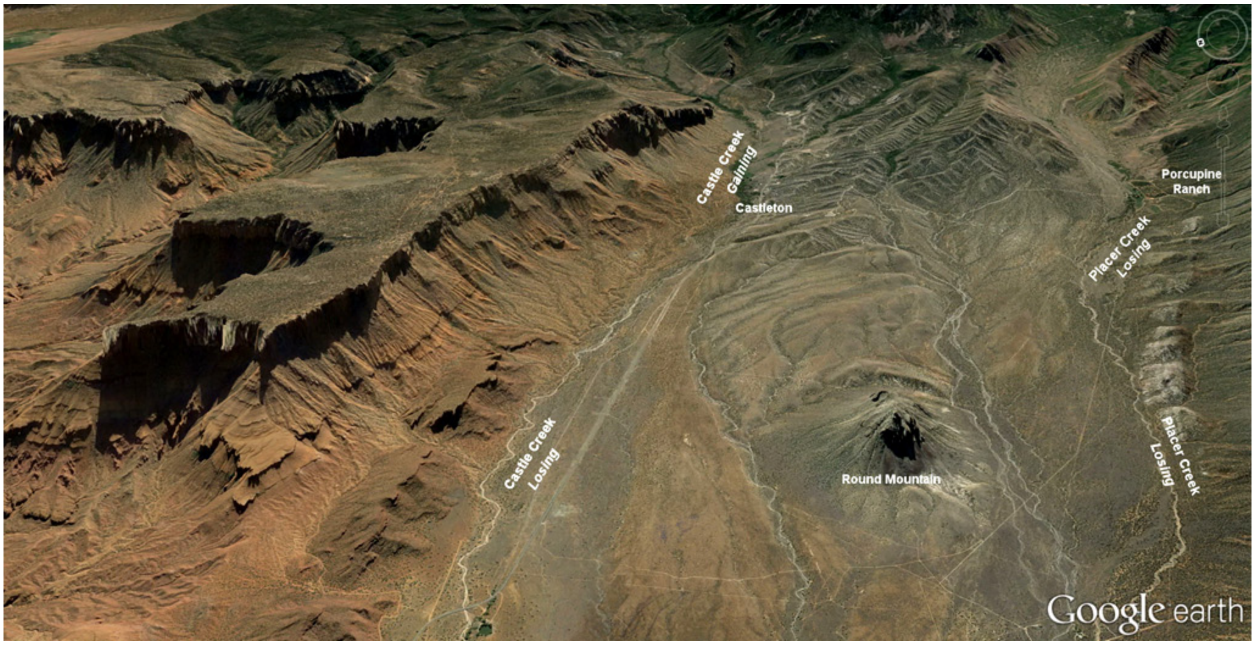

Figure 7a. Gaining and Losing Reaches of Castle Creek and Placer Creek in the Upper Part of the TCV Study Area.
(Source: Google Earth, Feb. 2016)

Figure 7b. Losing Reaches of Castle Creek and Placer Creek in the Middle Part of the TCV Study Area.
(Source: Google Earth, Feb. 2016)

Figure 7c. Gaining Reach of Castle Creek in the Lower Part of the TCV Study Area. (Source: Google Earth, Feb. 2016)

Figure 7d. Gaining and Losing Sections in the Upper Reaches of Placer Creek in the TCV Study Area, (Source: Google Earth, Feb. 2016)

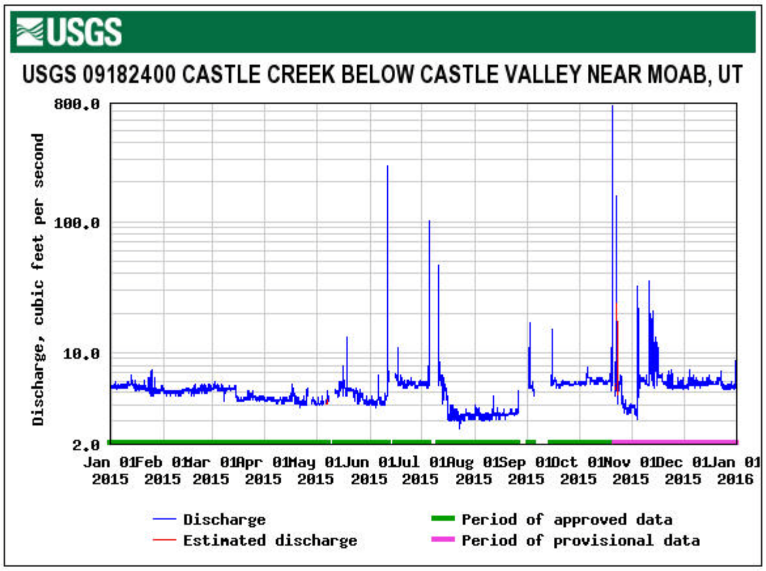

Figure 8a. Graph of Daily Discharge of Castle Creek at Gage 0918400, Grand County, Utah. for the Period January 2015-December 2015. (Source: USGS, http://nwis.waterdata.usgs.gov/nwis, March 2016)

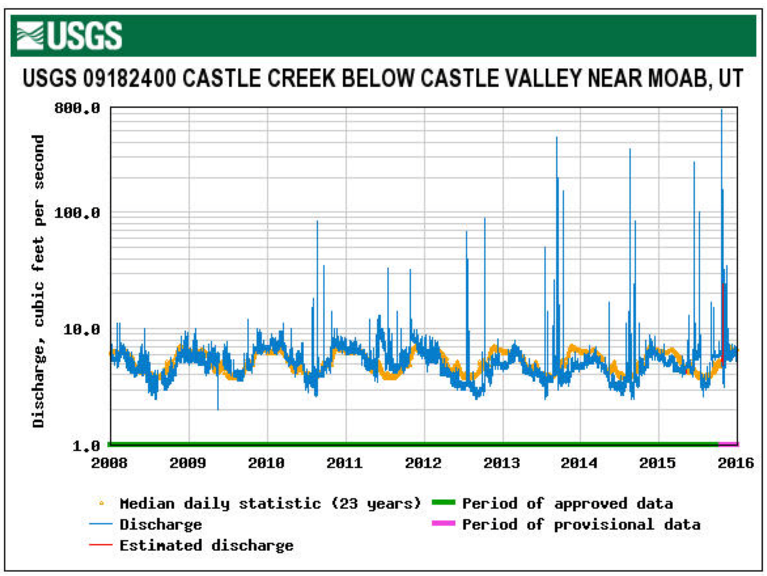

Figure 8b. Graph of Daily Discharge of Castle Creek at Gage 0918400, Grand County, Utah. for the Period 2008-2015. (Source: USGS, http://nwis.waterdata.usgs.gov/nwis, March 2016)

In the TCV study area, water is delivered from diversion points to the irrigated fields primarily by means of pipes. In the absence of (unlined) ditches, as often encountered in areas with a long history of agricultural development, water leaking from such ditches into the subsurface is not a major concern in the TCV study area and as such, does not have to be taken into account for the water balance of the groundwater system.

Where water is dispersed onto the crop field area, the excess water delivered to the soil drains down to the groundwater system and thus recharges the groundwater system. This water, called irrigation return flow, may have an altered water quality due to the agricultural chemicals used for the crops. Irrigation return flow is a source of groundwater recharge particularly on the lower part of the Castle Creek gravel and alluvial aquifer subsystem by Day Star Academy. Its significance for the water budget depends on the efficiencies of the agricultural practices applied.

According to the Utah state water right database, there are three areas with diversions in the TCV study area, two of which are affiliated with Castle Creek: 1) the diversions in the lower end of the valley near Day Star Academy and in the Town of Castle Valley (Figure 9a); and 2) diversions near the Castleton area east and southeast of Round Mountain (Figure 9b). The third diversion is located near the Porcupine Ranch in the Placer Creek watershed. The larger diversions are mostly piped and any leakage to the underlying aquifers would be minimal. However, they may a significant reducing effect on the flow in the streams.

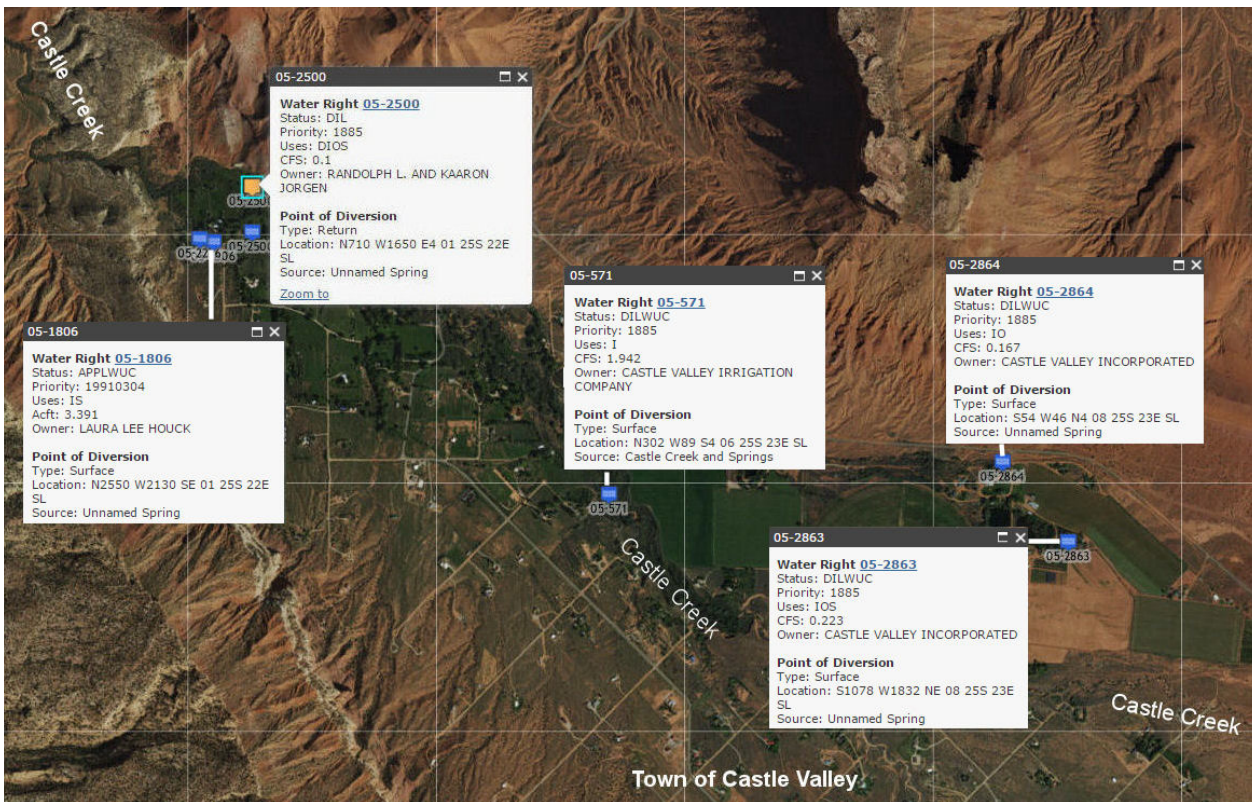

Figure 9a. Location of Selected Surface Water Diversions in the Lower Part of the TCV Study Area; Note the Return Flow Water Right in the Upper Left Corner, and Spring-related Diversions. (Source: Utah Division of Water Rights, February 2016)

As is indicated by wetlands, phreatophytes, and springs/seeps, some of these diversions and affiliated irrigation return flow move water into the groundwater systems of the Castle Creek gravels and alluvium (Qal). These groundwater systems may serve as aquifers used for irrigation and drinking water for landowners located topographically downgradient from the irrigated lands (see sections 2.5 and 2.6).

Springs and seeps indicate places where water flows naturally from a rock or the soil onto the land surface or into a body of surface water. They represent the contact between (saturated) groundwater and the land surface at that location. Springs usually emerge from a single point and result in a visible and measurable flow of water, or contribute measurably to the flow of a stream or the volume of a reservoir or pond. Seeps tend to be smaller than springs, with a more distributed character, and often no visible runoff, especially in this semiarid climate where, in many cases, the water emerging in seeps is lost to evapotranspiration. In semiarid climates such as in the TCV study area, springs and seeps may be identified by the presence of phreatophyte vegetation away from streams. Springs and seeps may be expressions of discharge of shallow groundwater from an unconfined aquifer, or of discharge from deeper aquifers at the contact between (more) permeable and (near) impermeable formations at or near the land surface, in fracture zones, or through karst conduits.

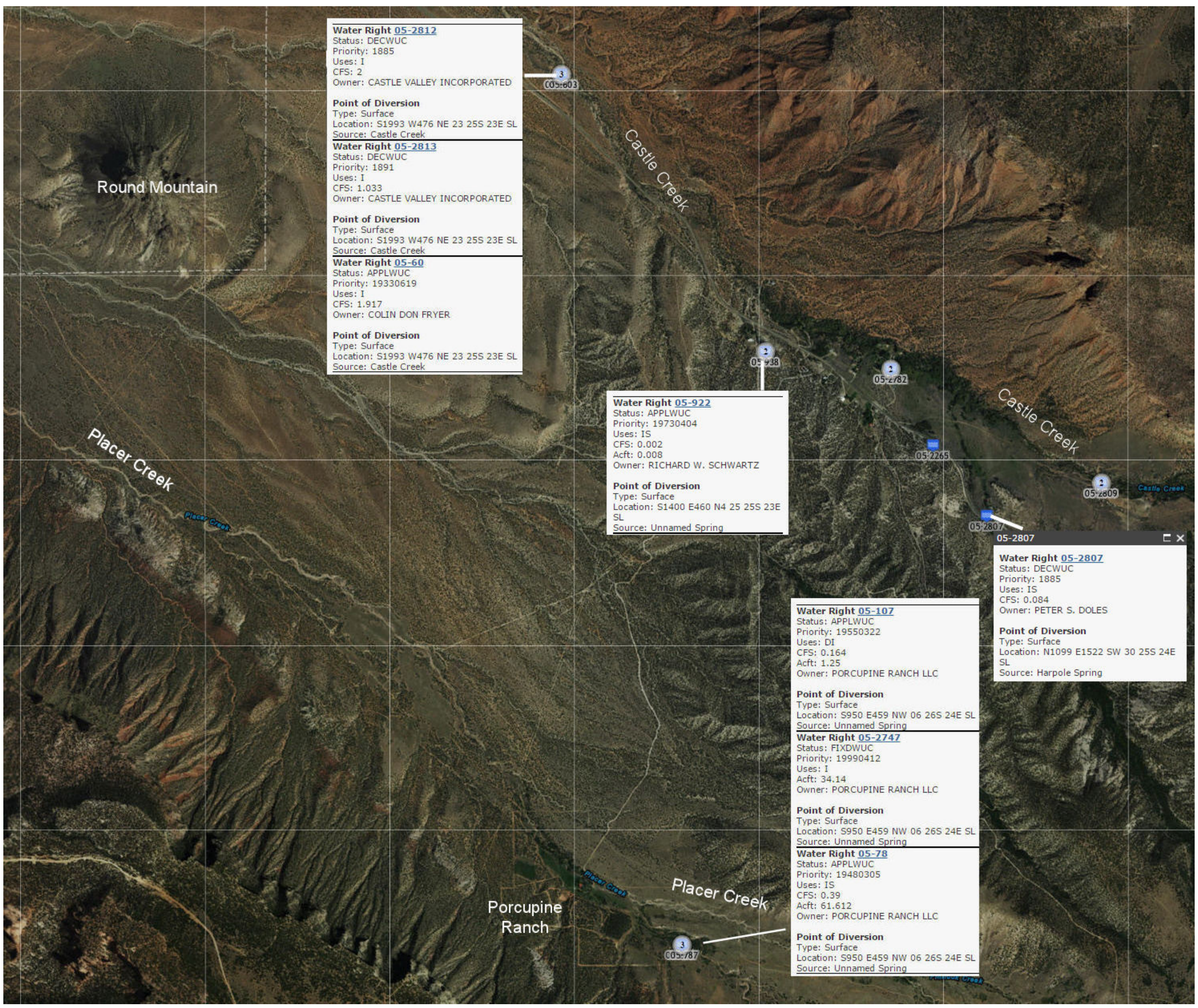

Figure 9b. Location of Surface Water Diversions in the Upper Part of the TCV Area, Grand County, Utah. (Source: Utah Division of Water Rights, February 2016)

The TCV study area contains a number of springs and seeps as identified from Google Earth analysis and field reconnaissance. Most of the springs are found in the upper reaches of Castle Creek and Placer Creek and their tributaries. Of particular interest are the spring/seep areas in the vicinity and upgradient from the Porcupine Ranch, along Castle Creek and its tributaries near Castleton, along Castle Creek northwest of Day Star Academy, and in the far northwest corner of the valley. Also of interest is the presence of seep type of discharges from irrigated parcels in the valley. A detailed discussion of springs and seeps in the TCV area and their relationship with the local groundwater systems is presented in section 2.5.

There are three spatial distributions of springs that are informative for the analysis of the surface water and groundwater systems in the TCV study area. The highest elevation springs in the TCV area are located in the La Sal Mountains: Willow Springs, Bachelor Basin Springs, Cold Spring, Mason Spring, and the springs located in the Miners Basin (Figure 10). These springs emanate from the Tertiary Bedrock systems in the La Sal Mountains, and represent the culmination of the groundwater flow in the Tertiary Intrusive rocks and associated glacial gravels and modern alluvium of the La Sal Mountain hydrologic subsystem. These springs are the beginning of the Castle Creek and Placer Creek surface water systems, which will affect the entire TCV hydrologic systems (Figure 10).

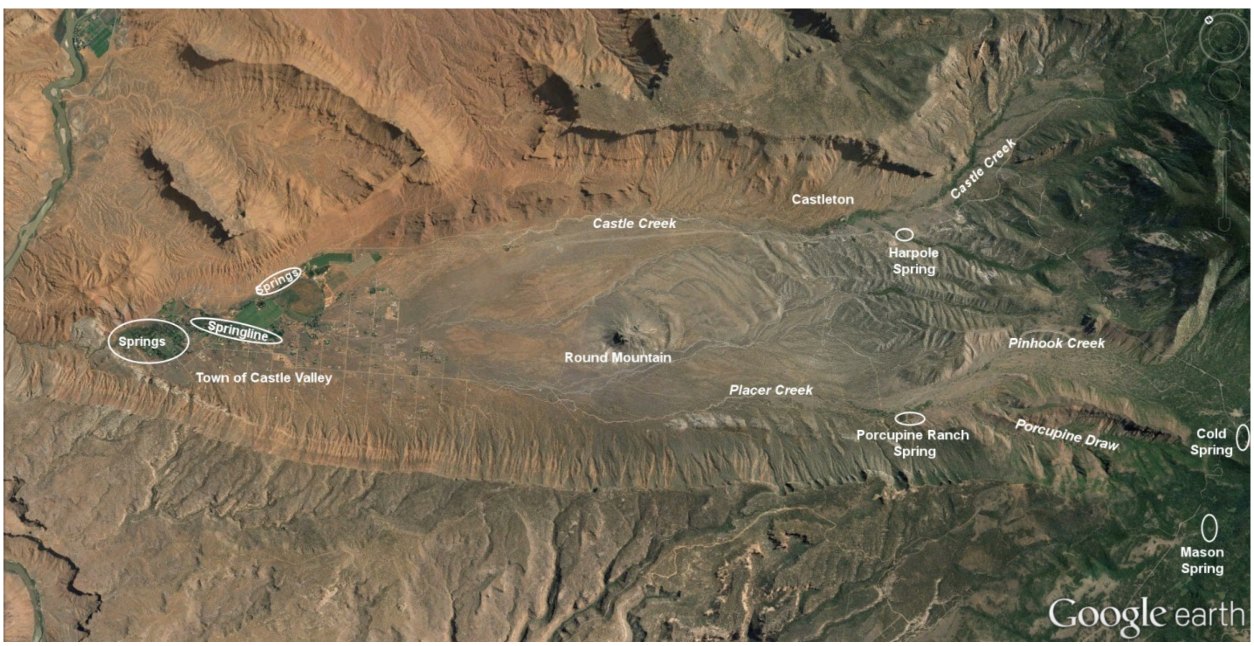

Fig 10. Location of Spring/Seep Areas in the TCV Study Area.
(Source: Google Earth, Feb. 2016)

The springs at Porcupine Ranch on Porcupine Draw and near Castleton represent a window into the middle parts of the Placer and Castle Creek hydrologic subsystems where bedrock faulting at depth has resulted in thinning the unconsolidated materials and therefore the thickness of the near surface aquifer, forcing groundwater to briefly daylight to the surface enhancing the surface water flow regimes. Downgradient of these features, the surface water eventually returns to the groundwater system as recharge or evaporates into the atmosphere. Finally, the springs located below Day Star Academy to the west and northwest, and below the confluence of Placer and Castle Creek, are the culmination of the Castle Creek and Placer Creek groundwater systems where the groundwater discharges into the surface water systems (Figure10). The rest of the Castle and Placer Creek groundwater systems discharge into Castle Creek along the main channel in the lower end of the Town, which manifests itself as a gaining stream.

2.4 Hydrogeologic Framework

Bedrock and unconsolidated materials have traditionally been classified as either aquifers or aquitards based upon being able to provide sufficient water for irrigation and industrial and municipal consumption, In this context, an *aquifer* is a permeable body of rock that is saturated with water and is capable of yielding economically significant quantities of water to wells (human and agricultural use) and springs (human and ecological use). A low-permeability formation overlying an aquifer is often called an *aquitard* or *confining unit*. As the terms “aquifer” and “aquitard” are rather ambiguous (*e.g., what are economically significant quantities?* or *how confining is a low-permeability unit with respect to the transport of contaminants?*), the use of these terms is replaced by that of the term *hydro-stratigraphic unit* or *hydrogeologic unit*, in combination with terms qualifying the permeability and/or saturation of the unit (*e.g.*, saturated, high-permeable hydrogeologic unit). A *hydrogeologic unit* is a geologic formation, part of a formation, or a group of formations with similar hydrologic characteristics (*e.g.*, similar permeability characteristics and storage capacity). It should be noted that hydrogeologic units may not equate to geological units such as *formations*, *formation members*, and *formation groups* due to the frequently encountered variability of the flow characteristics of such geologic units. The term *aquifer* in this report is used to indicate a significant source of water supply from hydrogeologic units, and may include the qualifier *potential* (*i.e.*, potential aquifer) when parameter uncertainty exists, especially with respect to average saturated thickness and water table fluctuations.

From a groundwater flow and water supply perspective, the most important property of rocks is the incorporated pore space and related permeability. The pore space, which defines the amount of water storage within a hydrogeologic unit, may be contemporaneous with the rock formation (primary or matrix porosity), or due to secondary geological processes, such as fracturing, faulting, chemical solution, and weathering (secondary porosity, fracture/karst porosity). The degree of connectivity and the size of the pore openings define the permeability of the rock, that is, the ease with which fluid can move through the rock. As with porosity, permeability may be primarily matrix based (matrix permeability), fracture and/or karst based (fracture/karst permeability), or may be a combination of both (*Davis and DeWiest, 1966*).

Unconsolidated sediments and clastic materials, as found in the TCV study area, and observed on the mass wasting colluvium and talus, pediment gravels and terraces, and alluvial floodplains in both the Castle Creek and Placer Creek drainages, are geologically very young and consist primarily of silts, sands, and gravels. They are generally very porous and permeable, but can be quite variable in their thickness, continuity, and hydraulic properties. For example, field observations revealed that the thickness of the unconsolidated sediments in the TCV study area ranges from less than 1 ft to greater than 300 ft. Estimates of hydraulic conductivity (K) of these unconsolidated materials range from 1 to 225 ft per day (*Lowe and other, 2004*). These hydrogeologic units most likely contain the greatest amount of groundwater.

Consolidated sedimentary rock and extrusive volcanic rock, by comparison, are often quite porous, but variable in permeability. Most fine-grained detrital rocks like shale, claystone, and siltstone may have relatively high matrix porosities, but very low permeabilities (*Davis and DeWiest, 1966*). These fine-grained bedrock hydrogeologic units are the dominant confining layers of sedimentary groundwater systems, with small hydraulic conductivity values typically less than 0.01 ft per day. Coarser-grained sedimentary rock, such as sandstone, and volcanic basalt, can pair relatively high matrix porosity with significant permeability, and may contain significant amounts of groundwater.

The hydraulic properties of sedimentary and extrusive igneous rock may be largely enhanced when fractures and faults are present (*Davis and DeWiest, 1966*). As a case in point, most of the sandstones and crystalline extrusive volcanic rocks in and near the TCV study area have enhanced permeability due to fracture and fault density and connectivity. Significant secondary porosity and permeability are developed through faulting, fracturing, and weathering of the sedimentary and extrusive igneous rock, especially in association with active faults, fracture zones, and near-surface stress-release.

2.4.1 Regional Hydrogeologic Units

From a regional geologic perspective, Castle Valley is part of the Paradox Subregion Section of the Colorado Plateau Physiographic Province, characterized structurally by northwest-southeast- trending salt anticlines (diapirs) with centrally collapsed areas or graben features due to salt dissolution by groundwater (Doelling and Ross, 1993; Blanchard, 1990) (Figures 11 and 12). Several Quaternary-aged faults related to this dissolution of salt and subsequent collapse structures have been mapped parallel to Porcupine Rim northwest of Round Mountain, and sinkholes along this fault indicate localized dissolution or piping (Mulvey, 1992). As a result, the near-surface sedimentary bedrock stratum ranges from younger rock to the northeast and southwest, to older rock in the core of the anticlines, and the stratum shows a regional dipping trend to the northeast, northwest, and southwest (see Figures 13 and 14). The youngest bedrock units in the TCV area are the Tertiary Geyser Creek Fanglomerate (Tg), and the Tertiary intrusive (granodiorite porphyry) units of the La Sal Mountains and Round Mountain (Ti). These units form mountains and foothills in the southeastern part of the study area, and the older sedimentary rocks form the topographic rimlands and valley bottoms of the main Castle Valley (Figures 13 and 14). It is in these sedimentary and volcanic units that regional and subregional groundwater flow systems are known to occur if the topographic, geomorphic, and geologic structure and continuity are favorable (*Freethey and Cordy, 1991; Geldon, 2003*).

Given the regional geology of the TCV area, the hydrogeologic framework, including hydrostructures, present in the Castle Valley Hydrologic System is very complex and is studied for the continuity and geometry of possible regional, subregional, and local hydrologic systems. Upon reviewing various groundwater reports for water budgets in the Mill Creek-Pack Creek drainages in Grand County (Sumsion, 1971); bedrock aquifer analysis in San Juan County

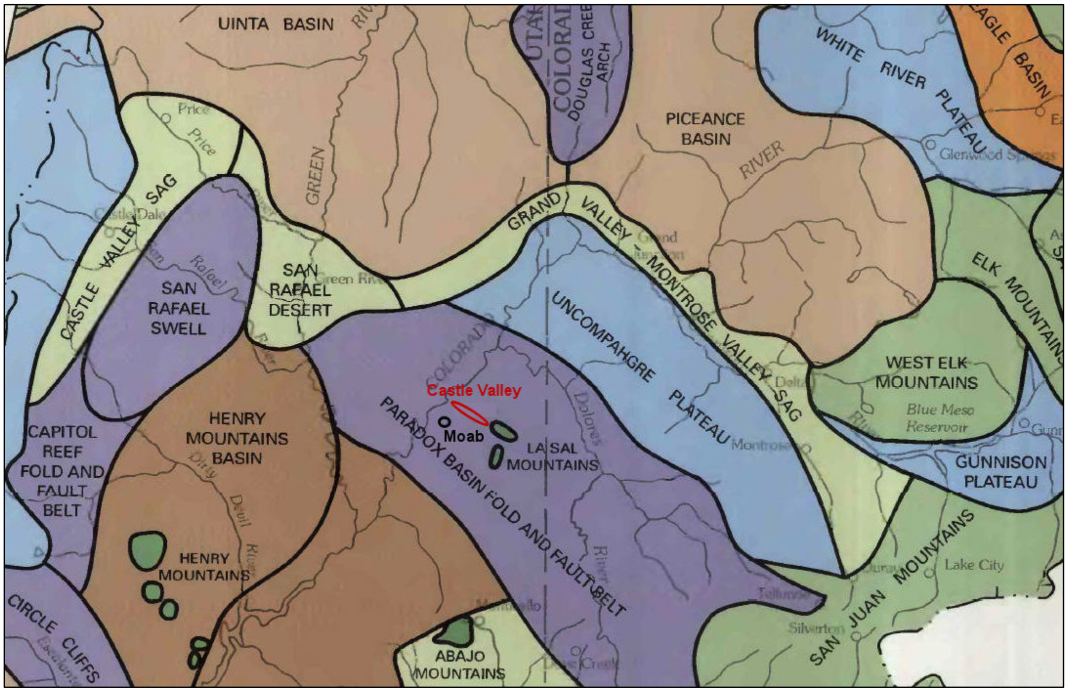

Figure 11. Regional Geographic Features in the Vicinity of the TCV Study Area (From Geldon, 2003).

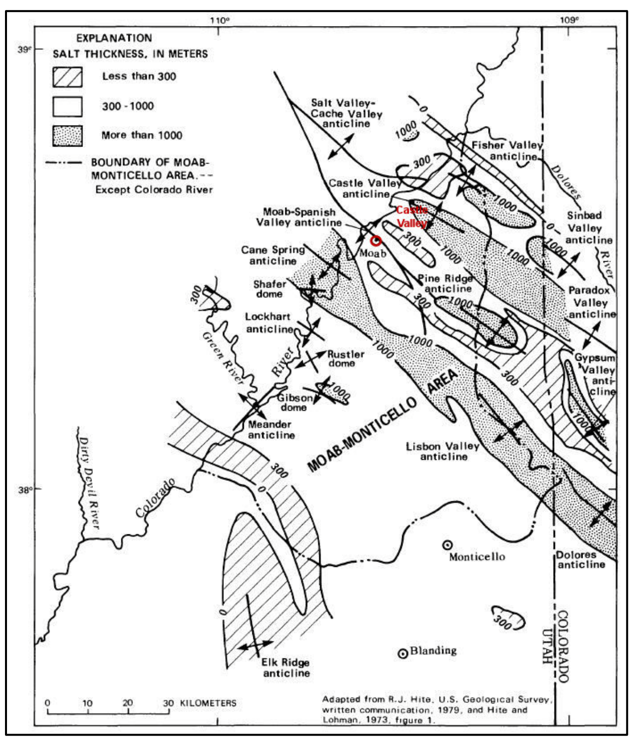

Figure 12. Generalized Salt Thickness and Major Structural Trends in the Vicinity of the TCV Area, Grand County, Utah (From Weir and Others, 1983).

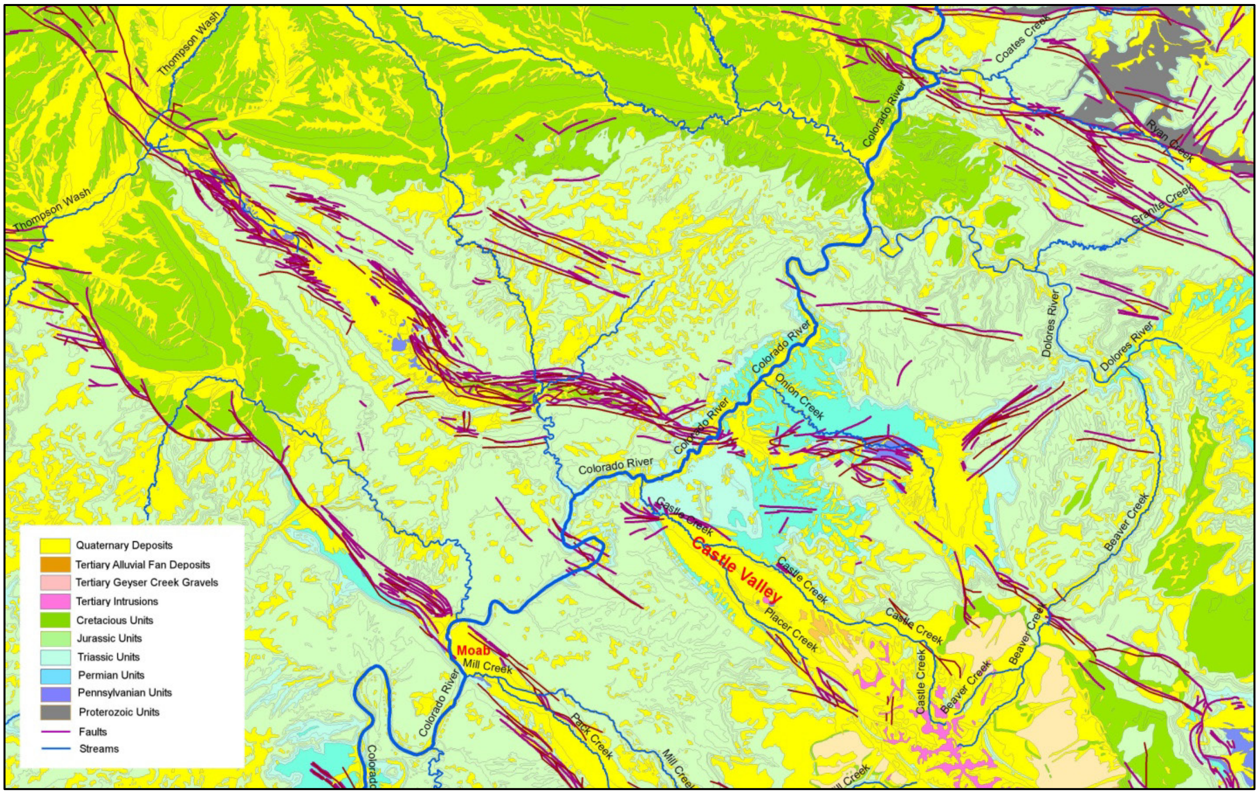

Figure 13. Generalized Map Showing Regional Geological Features in the Vicinity of the TCV area (Based on GIS Version of Utah Geological Survey Map 180 (Doelling, 2002); Utah, GIS 2015).

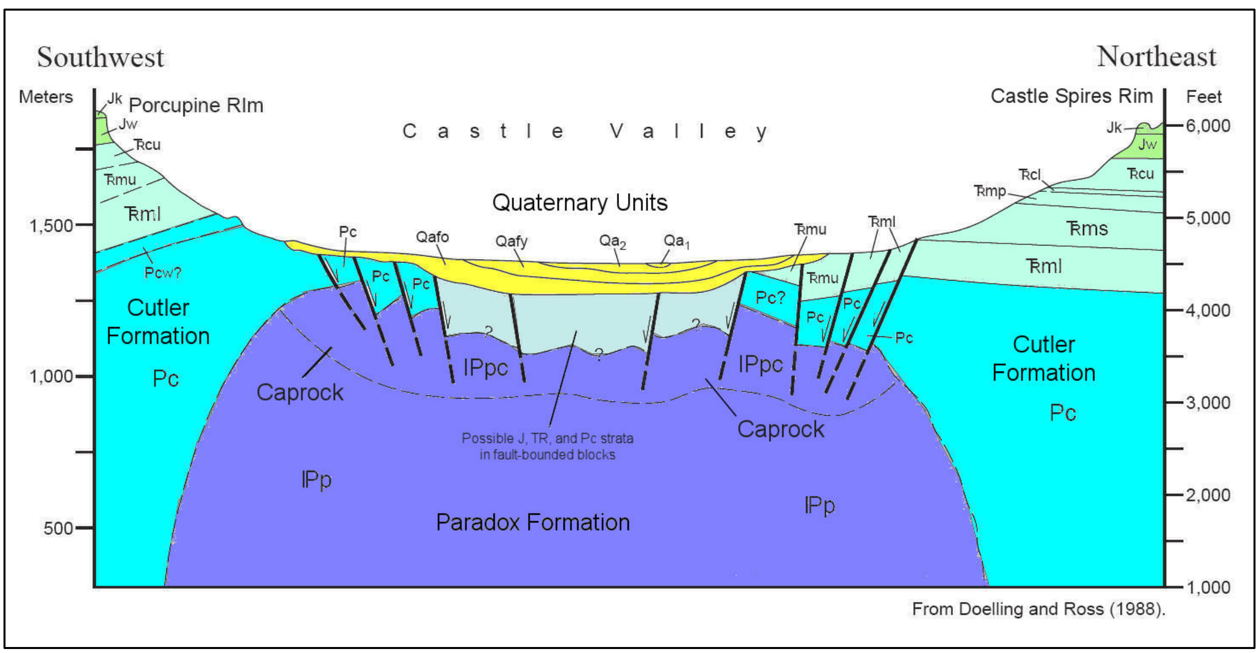

Figure 14. Generalized Northeast-Southwest Geological Cross Section Representative for Castle Valley. *(*Modified from Doelling and Ross, 1988*).*

(Avery, 1986); ground water conditions in Grand County (Blanchard, 1990; Esinger and Lowe, 1999); regional and subregional groundwater systems of the La Sal Mountains/Spanish Valley area (Geldon, 2003; Basye, 1994); recharge and water quality of the alluvial aquifer in Castle Valley (Snyder, 1996); and Castle Valley water studies and data (Ford and Grandy, 1997; Ford, 2006), the TCV study area hydrological systems consist of multiple distinct hydrogeologic and hydro-structural units, including unconsolidated units consisting of various Quaternary- and Tertiary-aged, highly permeable deposits and weathered bedrock deposits, and several water-bearing bedrock units and significant confining bedrock units, and fault and fracture zones of untested, but very high vertical and lateral transmissivity. The major hydrogeologic unconsolidated and bedrock units are presented in Figure 15 and described in Tables 2a and 2b; the thickness of the unconsolidated valley-fill aquifer and the location of paleo-paleo valleys are presented in figure 16; the major hydro-structural units are presented in Figure 17.

2.4.2 Hydrogeologic Units of the TCV Area

There are two significant groups of hydrogeologic units in the TCV study area: 1) Quaternary and Tertiary unconsolidated clastic materials (Figure 15, Tables 2a and 2b), which are predominantly Stream Alluvium (Qal), Alluvial Fan deposits (Qaf), Glacial Till (Qgt), Slumps and Slides (Qms), Talus and Colluvium (Qmt), Bouldery Colluvium (Qcb), and Older Alluvial Fan Deposits (QTaf), overlying 2) Tertiary, Mesozoic and Paleozoic bedrock units (Figure 15; Tables 2a and 2b), including the following potentially water-bearing units: Geyser Creek Fanglomerate (Tg); fractured Tertiary Intrusive Granodiorite (Ti); and the fractured White Rim and Arkosic members of the Cutler Formation (Pc). Tables 2a and 2b list the hydrologic characteristics of these units, and shows that most of these units have low matrix hydrologic conductivity and have springs with low yields less than 1 gal per minute. By comparison, the Triassic Chinle (Trc) and Moehkopi Formations (Trm), labeled as bedrock undivided on Figure 14, the unfractured Cutler Formation (Pc), and the Paradox Formation (IPpc and labeled "cap rock" on some figures) may act as thick, poorly transmissive confining layers *(Blanchard, 1990; Ford, 1997*).

From a water supply perspective, the unconsolidated clastic sediments, specifically when composed of larger size particles (>2.5 mm or 0.1 in) and observed to have sufficient saturated thickness and horizontal continuity, provide a significant and accessible water supply. The water supply function of bedrock units is largely dependent on rock type, large-scale structure and degree of fracturing, layer geometry and orientation, and the spatially variable hydrologic inputs and outputs, and may vary significantly dependent on location. The focus of this HESA was on both the shallow groundwater flow systems in the Quaternary and Tertiary unconsolidated clastic materials, which is the source of drinking and irrigation water for most households, the deeper bedrock units that have been tapped for water supplies in areas where the shallow unconsolidated aquifers cannot supply adequate quantities of water for the landowners or Town, and the relations of these hydrologic systems to the surface water systems of Castle and Placer Creeks. Additionally, water quality is also an issue that is addressed, both in discerning the nature of the shallow and deeper groundwater systems, the nature of the interactions between these two types of groundwater systems with Castle and Placer Creeks, and in the placement of future water wells for the Town water supply.

Geological Unit	Geological Subunit	Hydrogeological Unit	Hydro-geological Unit Symbol	Composition	Hydrogeological Characteristics	Permeability/Storativity	Depth to Water (small/ moderate/ large/ highly fluctuating)
Alluvium (Qa1, Qa2)		Stream Alluvium	Qal	Unconsolidated depostis of poorly to moderately sorted riverine silt, sand, and gravel; Qa1 located in active larger channels and floodplains; Qa2 deposits form first surface 6-40 ft. above the active channels. Thickness up to 25 ft.	Generally good local phreatic aquifer with matrix based permeability; limited variations in groundwater levels; often sustained by local and sub-regional discharge to adjacent stream or recharge directly from stream. Areas of alluvial fan deposits provide connectivity between adjacent aquifers but may not provide a sustainable source of water.	stream deposits have high matrix-permeability and high storativity; alluvial fan areas have moderate to high permeability and high storativity	small to highly fluctuating
Alluvial fan deposits (Qaf3, Qaf4, Qaf5, Qafy, Qafo)		Alluvial Fan Deposits	Qaf	Unconsolidated deposits of poorly sorted, muddy to sandy cobble gravel and boulders; Qaf3 and Qaf4 form dissected surfaces in Castle Valley; younger Qafy and older Qafo deposits form coalesced fans along margins of Castle Valley. Thickness up to 350 ft. as basin fill.	Potentially good, spatially continuous phreatic aquifer with high matrix based permeability; may be supported by underlying bedrock.	high matrix-permeability; high storativity	Moderate to large
Glacial till (Qgt)		Glacial Till	Qgt	Very poorly sorted, angular to sub-angular clasts of all sizes. Thickness up to 300 ft.	Potentially good local phreatic aquifer with variable matrix based permeability and high water table gradients.	high matrix-permeability; high storativity	Small on valley bottoms; moderate on ridges
Landslide deposits (Qms, Qmsy, Qmso)		Slumps and Slides	Qms	Large coherent blocks to fragmental masses of bedrock and surficial debris transported downslope by mass movement. Thicknesses vary.	Potentially good, highly localized phreatic aquifer with high matrix based permeability and high water table gradients.	high matrix-permeability; high storativity	highly fluctuating
Talus deposits and colluvium (Qmt)		Talus and Colluvium	Qmt	Angular rock-fall blocks, boulders, and small fragments deposited as veneers on slopes below ledges and cliffs; colluvium contains additional slopewash debris in a sandy to muddy matrix. Thickness 0-30 ft.	Potentially good, spatially continuous phreatic aquifer with high matrix based permeability; may be prone to significant (seasonal) water table fluctuations; tends to recharge bedrock systems.	high matrix-permeability; high storativity	highly fluctuating
Bouldery colluvium depposits (Qc, Qmb)		Bouldery Colluvium	Qcb	Qc deposits are poorly to moderately sorted, locally derived gravel, sand, and soil. Thickness 0-25 ft. Qmb rock-slope deposits are poorly sorted angular locally derived debris ranging from block to sand size. Variable thickness.	Having high matrix based permeability, presence of groundwater depends on location in topography and on landuse.	high matrix-permeability; high storativity	highly fluctuating
Older Alluvial fan deposits (QTaf)		Older Alluvial Fan Deposits	QTaf	Poorly sorted sands, silt, pebbles, cobbles, and boulders deposited at base of La Sal Mtns. Thickness is 200-300 ft.	Potentially good, spatially continuous phreatic aquifer with high matrix based permeability.	high matrix-permeability; high storativity	highly fluctuating

Table 2a. Correlation of Geological and Hydrogeologic Units in the TCV Study Area: Unconsolidated Sediments.

Geological Unit	*Geological Subunit*	*Hydrogeo-logical Unit*	*Hydro-geological Unit Symbol*	*Composition*	*Hydrogeological Characteristics*	*Permeability/ Storativity*	*Depth to Water* (small/ moderate/ large/ highly fluctuating)
La Sal Mtn. Intrusive Rocks (Th, Ttp, Tpt, Trp, Tn)		Tertiary Intrusions	Ti	Alkaline silicic rocks (Granodiorite and quartz monzonite) intruded at shallow depths as laccoliths, plugs, dikes, and sills. Thickness variable.	Fractured crystalline system with very low matrix permeability; not a (sub-)regionale aquifer; may produce locally water in fracture zones and support adjacent unconsolidated aquifers. These characteristics may extend into adjacent rocks,methamorphosed during the Tertiary intrusion.	mostly low permeability, localized zones with moderate fracture permeability; low storativity except in fracture zones with moderate storativity low storativity	moderate to large fluctuations on ridges and mountain tops; small fluctuations in valley bottoms
Geyser Creek Fanglomerate (Tg, Tgc)		Geyser Creek Fanglomerate	Tg	Yellow brown to light grey conglomerate, sandstone and siltstone derived from La Sal Mtns.; Poorly sorted and weakly cemented; thickness up to 1,000 ft., exposures less than 300 ft.	Overbank sandstones form a good aquifer system with moderate to good matrix and fracture based permeability; may be a locally good water producer; siltstones and shales are confining layers; outcrops are recharge areas for a regional flow.	layers with very low permeability and layers with moderate matrix and fracture permeability; low to moderate storativity	moderate to large fluctuations on ridges and hill tops; small fluctuations in valley bottoms
Triassic and younger rocks (undivided)	Dakota/Burro Canyon (Kdbc); Morrison (Jm)	Triassic and Younger Rocks (Undivided)	TRu and Younger	Interbedded silicious sandstones, siltstones, shales, and limestones of various thickness in the Castle Valley area.	Good regional bedrock aquifer system; sandstones and coals have both moderate matrix and fracture based permeability; may locally be a good water producer; shales are confining layers; outcrops are recharge areas for regional flow.	layers with very low permeability and layers with moderate matrix and fracture permeability; low to moderate storativity	moderate to large fluctuations on ridges and mountain tops; small fluctuations in valley bottoms
	Entrada (Je), Navajo (Jn), Kayenta (Jk)						
	Kayenta (Jk), Wingate (Jw)						
	Chinle Formation (TRc)						
	Moenkopi Fm (TRm)						
Permian Culter Formation (Pc, Pcw)	White Rim Sandstone Member (Pcw)	Cutler Formation	Pc	(Pcw) grey-white cross-bedded sandstone interbedded with minor siltstone and arkose; Thickness 0-250 ft.; (Pc) Red-brown to purple sandstone, conglomeratic sandstone, and conglomerate interbedded wih silty and sandy mudstone and shale; Thickness 0-6,235 ft.	Mostly aquitard with very low permeability serving as a confining layer for overlying or embedded aquifers; however, locally moderate aquifer conditions when highly faulted/ fractured. Pc High K Zones are observed in Castle Valley. Responsible for reduced water quality in Castle Valley wells.	very low permeability rock with some moderately permeable beds; low storativity. High permeability and storage in fault/fracture zones in Castle Valley.	highly fluctuating
	Arkosic Sandstone Member (Pc)						
Pennsylvanian Paradox Formation Caprock (IPpc)		Paradox Formation	IPpc	Cap rock consists of light-gray to yellow-gray gypsum, gypsiferous claystone, silty shale, fine-grained sandstone, and thin-beddede carbonates. Est. thickness up to 1,000 ft. Subsurface consists of interbedded coarsecrystalline halite and other salts, massive anhydrite, gray dolomite, gray to black shale, and gray siltstone; Est. thickness 300-9,5000 ft.	Mostly aquitard with very low permeability serving as a confining layer for overlying or embedded aquifers. Responsible for reduced water quality in Castle Valley when wells are placed nearthe Paradox Formation.	very low permeability rock ; low storativity.	n/a
		Older Bedrock (undivided)					

Table 2B. Correlation of Geological and Hydrogeologic Units in the TCV Study Area: Bedrock Unit.

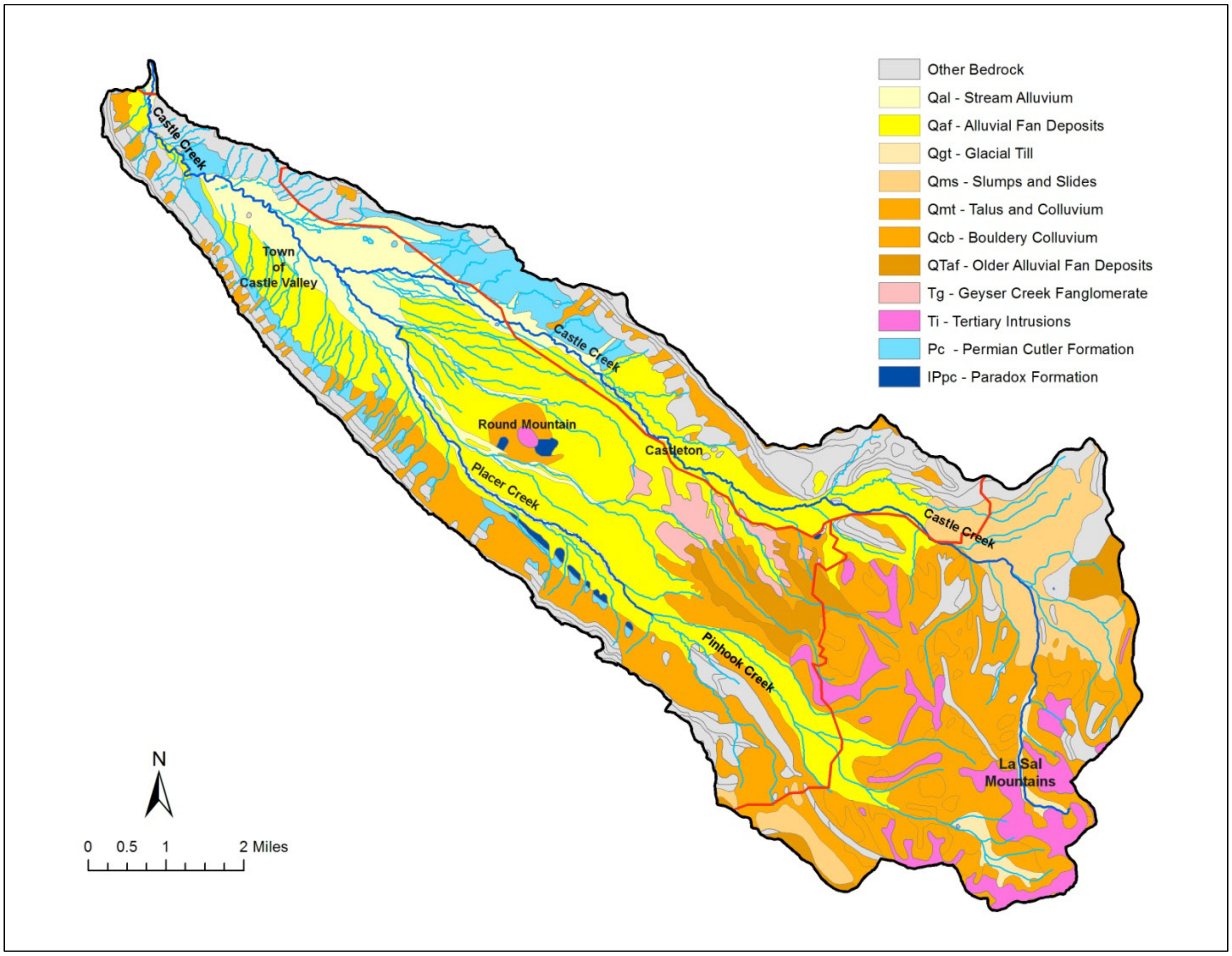

Figure 15. Map Showing the Main Hydrogeologic Units in the TCV Study Area.
(Based on GIS Version of Utah Geological Survey Map 180 (Doelling, 2002); Utah GIS, 2015).

The Quaternary unconsolidated clastic units (Qal, Qaf, Qgt, Qms, Qmt, Qcb, and QTaf in Table 2a and Figure 15) are locally heterogeneous, with predominantly a mix of coarser materials in the older alluvial deposits, and a mixture of coarser and finer materials in the younger deposits. These deposits, which are moderately to highly permeable, are recharged by infiltration from precipitation that is non-uniformly distributed due to the slope steepness, slope aspect, and to position in the landscape; by the incidental leaky irrigation ditch and irrigation return flow; and by flow in ephemeral stream channels and losing streams in perennial reaches where favorable. The unconsolidated units are variably to fully saturated, based on spatial location and seasonal precipitation events. There is lateral and vertical groundwater flow connection between the unconsolidated materials and the underlying bedrock formations that is critical for understanding the hydrologic systems and water quality of Castle Valley.

The thickness of subsurface distribution of these unconsolidated sediments may be estimated based upon the isopach maps produced in earlier studies (Lowe and others, 2004). The thicknesses range from less than 25 ft in the southeastern part of Castle Creek above Castleton and the southeastern part of Placer Creek above Porcupine Ranch, to greater than 300 ft in the northern part of Castle Valley near Day Star Academy (Figure 16). The greatest thickness of the unconsolidated material is in the collapsed part of Castle Valley northwest of Round Mountain where average thicknesses ranging between 100 – 200 ft. are common (Figure 16).

The subsurface distribution of thickness is indicative of the structural collapse and faulting with subsequent erosion and filling of fault zones with gravels. A linear paleovalley and subsequent groundwater conduit is observed along the northeastern margin of the valley fill beneath the modern day Castle Creek from Castleton extending to near Parriott Mesa (Figures 16). The second linear paleovalley and subsequent groundwater conduit is observed along the southwestern margin of the valley fill beneath the modern day Placer Creek above the Porcupine Ranch extending to beneath the Town of Castle Valley town hall to the northwest (Figure 16). These groundwater conduits approximately overly the bedrock conduits to be discussed in subsequent sections of this report.

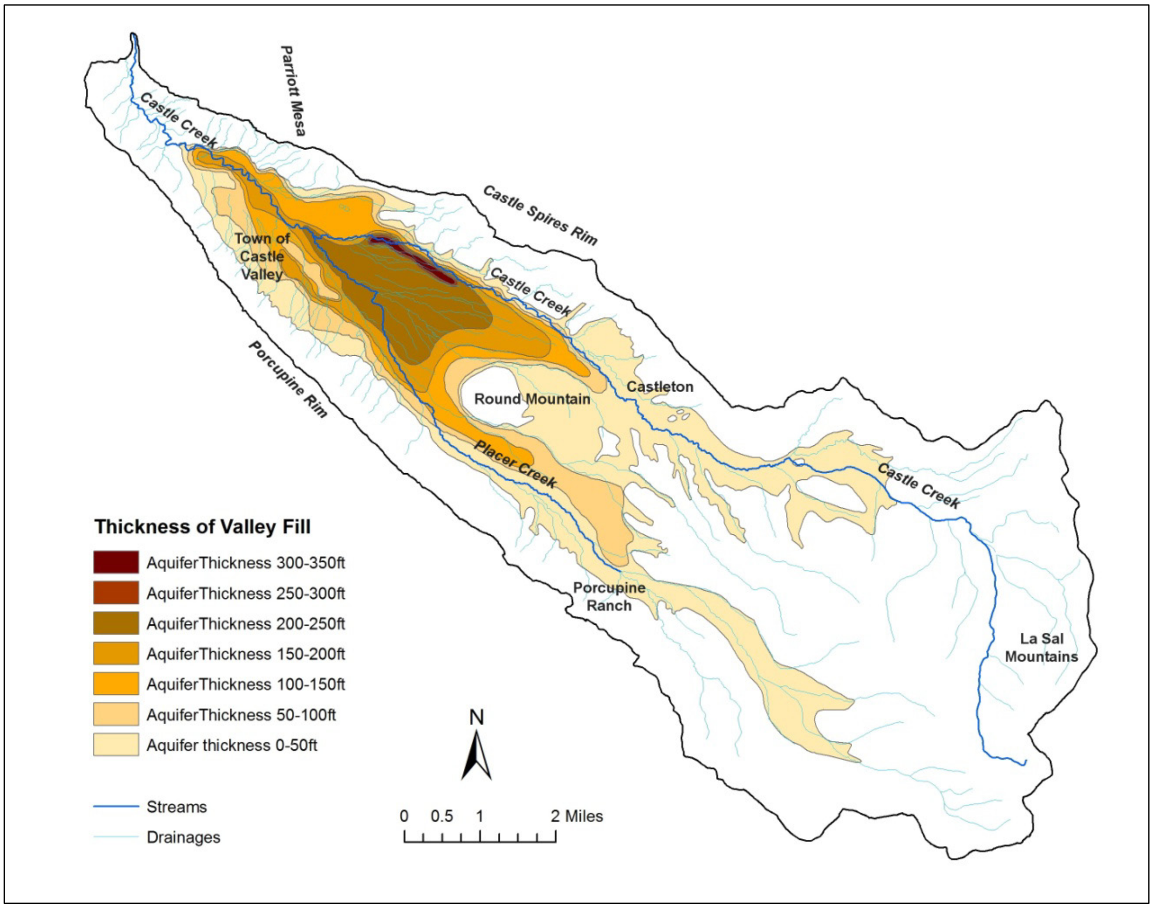

Figure 16. Isopach Map Showing Thickness of Valley Fill Deposits of TCV Study Area. The Valley Fill deposits are the Shallow Unconsolidated Hydrogeologic Units in the TCV Study Area (after Lowe and Others, 2004).

2.4.3 Hydro-structural Units of the TCV Area

Geologic faults and fracture zones, sometimes expressed at the surface as lineaments or linear drainage segments, may influence the hydrogeology and hydrologic systems of Castle Valley, including Castle and Placer Creek (Figure 17). These hydrostructures underlie the drainages in the bedrock systems (White Rim and Arkosic Members of the Cutler Formation (Pc) and Tertiary Intrusive Granodiorite (Ti), primarily) and are most likely associated with preferential groundwater flow along fault and fracture zones that are observed or hypothesized to transmit groundwater either vertically or laterally along the fault or fracture planes or zones.

These structures may serve as distinct hydrogeologic units, may enhance the permeability of sections of bedrock hydrogeologic units, may connect multiple hydrogeologic units together, or may restrict the thickness and flow of overlying unconsolidated deposits resulting in springs and groundwater discharge areas. These hydrostructures, if “open”, may also result in connectivity between deeper groundwater systems and the streams, which may be a concern if future water well drilling occurs. Each fault and fracture zone should be evaluated for the following characteristics: 1) fault and fracture plane geometry, including the vertical or horizontal nature of the fault/fracture plane and the relations of rock types and geometry on both sides of the structure; and 2) the transmissive nature of the fault/fracture plane or fault/fracture zone, including the nature of fault gouge, if any (clay, gravel) and tectonic setting of fault/fracture plane or zone (extension or compression). The fault/fracture plane geometry is important to evaluate if groundwater can move horizontally across the zone from one transmissive unit to another, or whether the groundwater is forced to move vertically upward to the surface, in many cases, or downward into a different hydrogeologic unit, or laterally parallel to the fault and fracture zone like a geotechnical French drain. The tectonic setting helps determine whether the fault/fracture plane is “open”—able to easily move water (extension), or “closed”—not able to easily move water (compression).

Hydrostructures, which are defined by folds, faults and fracture zones, control the location of Castle Valley, the location of the Castle Creek, Placer Creek, and major tributaries, the location of drainages that are part of the Porcupine and Castle Spires Rims, and the locations of streams draining the La Sal Mountains. These hydrostructures can exist sub-regionally and regionally if structural and topographic continuity exist (Figures 13, 14, and 17). The main subregional fold and fault structure is the Castle Valley Salt Anticline with corresponding graben/collapse structure (Figures 13, 14, and 17). The bounding faults of the collapse, located on the northeast and southwest sides of Castle Valley, dip almost vertically and strike from the southeast to the northwest (Figures 14 and 17). These two fault zones, which are in the White Rim and Arkosic Members of the Cutler Formation are subregional hydrogeologic conduits (high hydraulic conductivity zones or High “K” zones). These conduits are continuous from the southeastern part to the northwestern part of Castle valley and have high hydraulic conductivity and high yields of groundwater with high TDS water quality (Figure 18). These hydrostructural units pinch out at either end of the valley and with depth keeping the groundwater system subregional and discontinuous beyond the Castle Valley topographic feature. These hydrostructural units also block lateral flow perpendicular to the fault zone. Therefore, no deep regional ground water is laterally entering or exiting Castle Valley from the northeast or the southwest. The termination of these hydrostructural units to the southeast and northwest also blocks lateral flow, so no deep groundwater is laterally entering or exiting Castle Valley from the southeast or the northwest. It is hydrologically important that the entire valley is underlain by a deep “flat lying” caprock of the Paradox Formation, which is a confining unit that, when interacting with groundwater, produces poor water quality due to dissolution of the salt bedrock. Effectively, these hydrogeologic/hydrostructural units ensure that the Castle Valley Bedrock groundwater flow system is entirely contained within the valley, and that the water quality derived from these units is not necessarily favorable (high TDS) (Figures 14, 17 and 18).

The Castle Valley Anticline/Graben also results in the younger bedrock hydrogeologic units being observed on the Porcupine and Castle Spires Rims, in some locations, and dipping away to the northeast, northwest, and southwest (Figures 14 and17). This results in local and subregional groundwater and surface water systems that flow away from the Castle Valley

Rimlands into the La Sal Mountain/Spanish Valley Systems, into the Onion Creek or Professor Creek Systems, or towards the Colorado River (Figures 14 and 17).

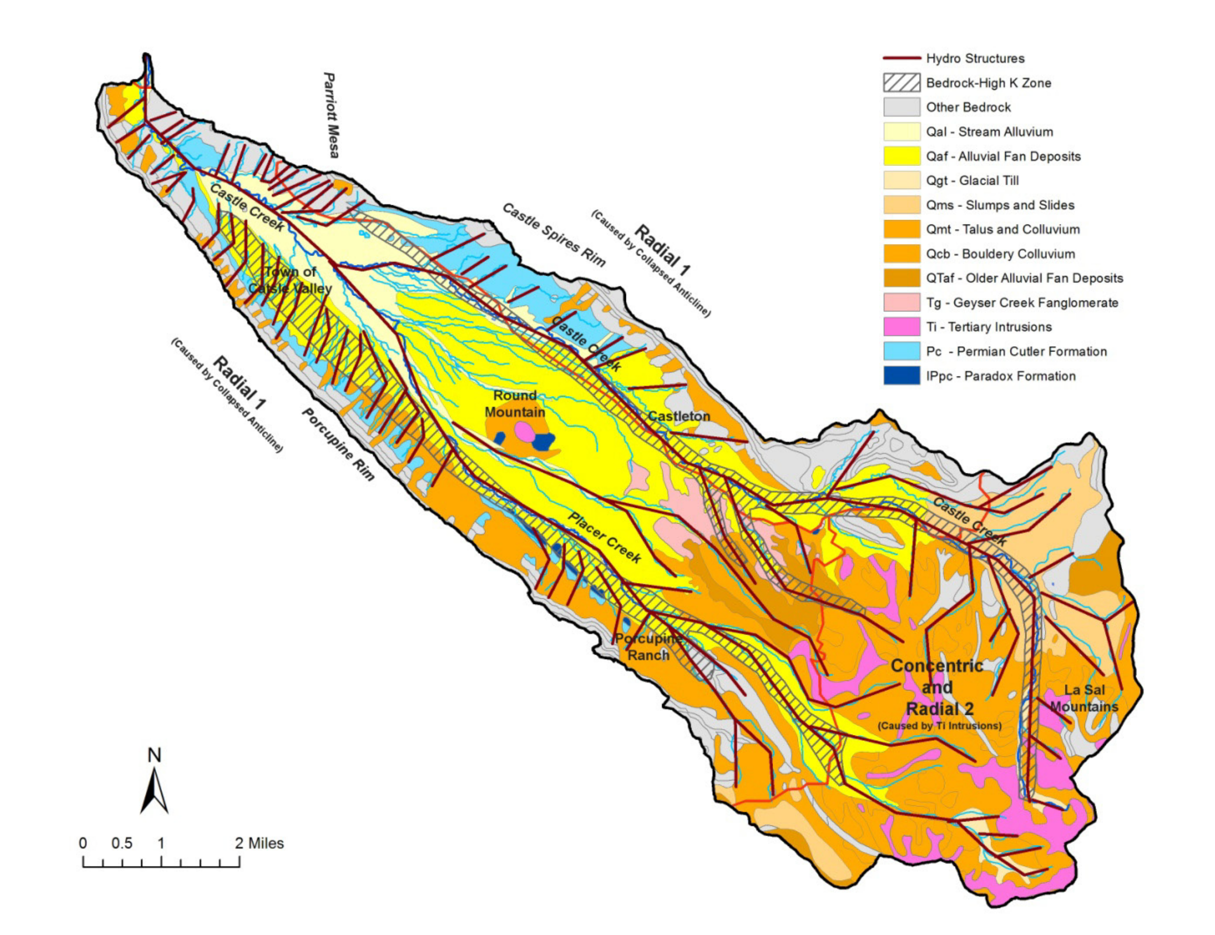

Figure 17. Map Showing Major Hydro-structures (Faults and Fracture Zones) in the TCV Study Area.

The fault and fracture zones have influenced the location of the main surface water drainages in the TCV study area by providing zones of weakness whereby the streams have downcut into or through the unconsolidated deposits into the underlying Cutler Arkosic and White Rim Members bedrock, the Paradox bedrock, and the Granodiorite Porphery (Figures 16 and 17). As a result, the TCV study area is dissected into two distinct surface hydrologic subsystems of varying connectivity: Castle Creek and Placer Creek, both of which are separated in the southeastern part of the Valley by Round Mountain and the La Sal Mountain ridges, and become connected in the northwestern part of Castle Valley near the confluence of the drainages (Figures 16 and 17).

Local hydrostructure fracture/fault groups occur in the TCV area: 1) the northeast-southwest trending faults and fractures that are radial to the main Castle Valley Anticline; 2) the northwest-southeast trending faults and fractures that are parallel to the main Castle Valley Anticline collapse structures; and 3) radial and concentric fractures associated with the Tertiary Intrusive (Ti) rocks (Figure 17).

The northwest-southeast trending drainages mirror the underlying faults and fracture zones that include the collapse structures located on the northeast and southwest sides of Castle

Valley, and the underlying faults and fracture zones that are parallel to these bounding structures (Figure 17). These structures are open, and function as groundwater conduits in bedrock, and paleo-valley groundwater conduits in unconsolidated materials (Figure 16).

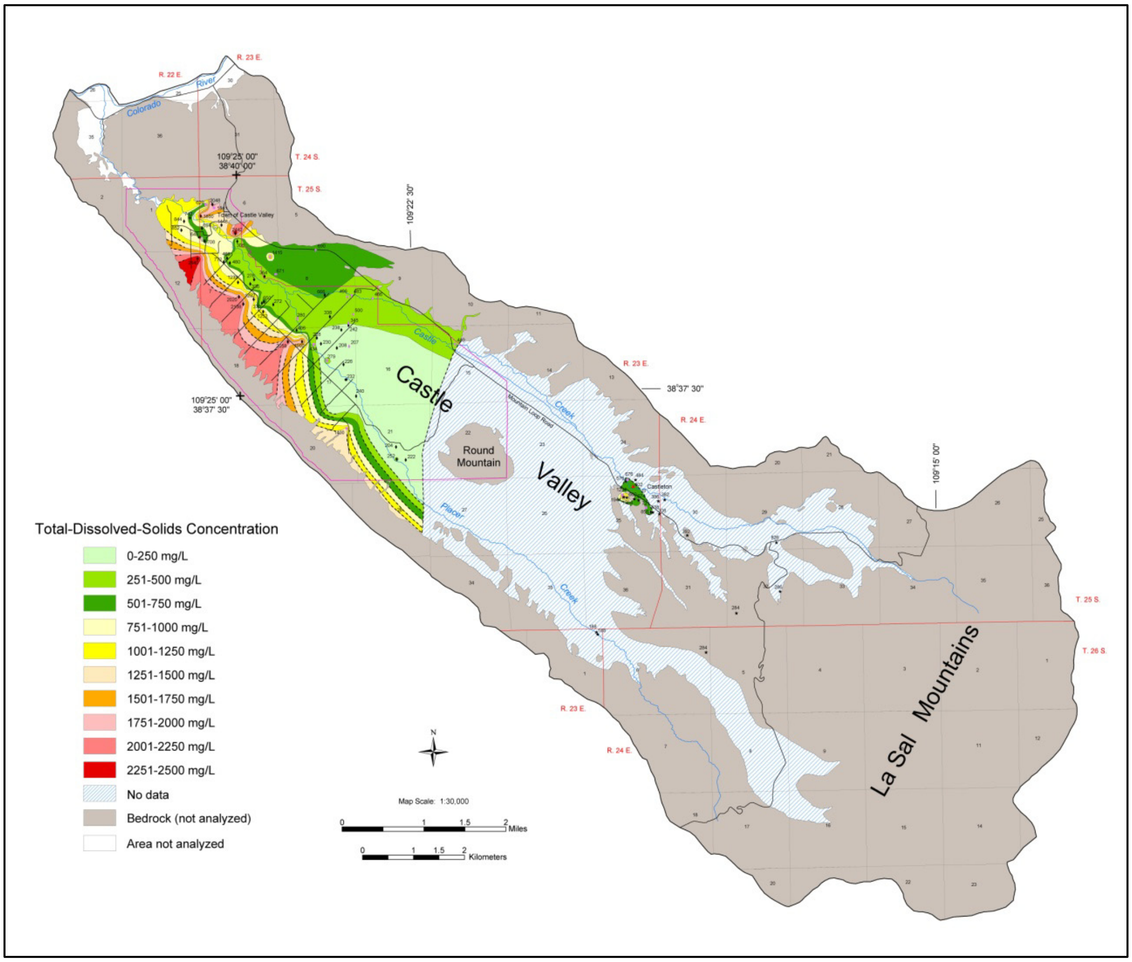

Figure 18. Total Dissolved Solids (TDS) of the Castle Valley Groundwater System (From Lowe and Others, 2004)

The northeast-southwest trending drainages/fracture zones (Radial 1 in Figure 17) control most of the steep drainages on the flanks of the Castle Valley rimlands. These drainages are mostly ephemeral, and have the main hydrologic functions of delivering surface water down into the valley floor for groundwater recharge or surface water flooding and sediment transport into Placer and Castle Creeks and associated tributaries (Figure 17).

The radial and concentric fracture pattern surrounding the La Sal Mountain intrusions (Ti) (Radial 2 in Figure 17) control the surface water drainages, and are open, therefore, supporting “French-drain” bedrock groundwater systems in the Tertiary intrusive (Ti) bedrock, and focusing groundwater towards drainages in the Tertiary Geyser Creek fanglomerate (Tg) locally. Examples of this are the minor drainages around Round Mountain, and the drainages in the southeastern part of the study area including the northern flanks of the La Sal Mountain systems where Placer Creek and Castle Creek originate (Figure 17). In the Tertiary intrusive rocks (Ti), groundwater moves laterally down valley and vertically downward along these radial fault and fracture zone planes, and may move vertically up along the fault and fractures plane near the lower reaches of the various drainages as evidenced by gaining reaches in streams, increased groundwater head with depth in local wells, and by the springs that are the origin of Castle and Placer Creeks. The concentric fracture zones, which function as “French drains”, control the locations and origins of upper Castle Creek and Pinhook Creek (Figure 17).

2.5 Groundwater Flow Systems

Groundwater flow is the movement of water from the earth’s surface into the subsurface (groundwater infiltration and recharge), through the subsurface materials (groundwater flow and storage), and from the subsurface back to the Earth’s surface (groundwater discharge), expressed in terms of flow directions, patterns and velocities. The driving force for groundwater flow is a difference in piezometric “head” or groundwater levels, as expressed, for example, by the slope of the water table. The general Conceptual Site Model (CSM) of the groundwater flow system consists of 1) water inputs (recharge); 2) storage in and movement through subsurface hydrogeologic units (groundwater flow); and 3) water outputs (discharge). The general Conceptual Site Model (CSM) is helpful to determine the water balance of the groundwater flow system, which is the quantitative balance of the water inputs with the water outputs discussed in later sections of the report. Natural recharge is based on climate and soils resulting in infiltration of precipitation and snowmelt. Groundwater interaction with streams, vegetation (evapotranspiration), and human activity (irrigation, urbanization, wells and individual sewage disposal systems, reservoirs and ponds, oil and gas activity, mining, dewatering) will affect groundwater movement to varying degrees. The CSM also incorporates topography (steepness, slope aspect, degree of landscape dissection), geomorphology, and soil and rock properties. Because of the time-space variance of these inputs and outputs, a groundwater system often shows significant variations in water levels, water storage, flow velocities, and flow patterns. Some of the variations are seasonal; others may be related to multi-year periods of above-average or below-average precipitation. This results in variations in the availability of water from these hydrogeologic units.

Based on the HESA approach (*Kolm and others, 1996*), and previously collected supporting data, the regional, sub-regional, and local scale groundwater flow systems are delineated. The broad hydrologic system inputs include infiltration of precipitation as rain and snowmelt; areas of losing perennial and ephemeral streams (for example, reaches of the Castle Creek and Placer Creek above the Town of Castle Valley, reaches of ephemeral streams on the sides of Porcupine and Castle Spires Rims); infiltration and runoff from water bodies (cattle and house ponds), upland irrigation areas (leaking ditches, irrigation return flow, lawn watering), and inter-aquifer transfer of groundwater between unconsolidated materials and bedrock systems (horizontally and/or vertically). The general hydrologic flow subsystems, including the Mountain, Mesa Top, Hillslope, and Valley Bottom subsystems, consist of the hydrologic processes of surface runoff (channel and/or overland flow) and rapid near-surface runoff (interflow or shallow through-flow); saturated groundwater flow in parts of the bedrock units, landslides, terraces, and valley bottoms; and discharge to springs and seeps, graining streams, by plants as evapotranspiration, and by pumping wells. In general, shallow groundwater flow in these systems is with topography away from the mountain and ridge tops, along the axis of the mesa tops, and/or towards the valley bottoms, perpendicular to the major streams. Where permeable bedrock units underlie the mountains, mesa tops, hill slopes, and valley bottoms, recharge by groundwater moving from unconsolidated hydrogeologic units into the bedrock hydrogeologic units may force the groundwater into a more regional or subregional pattern determined by geological structure, independent from local topography and hydrography.

However, the TCV groundwater subsystems are a complex mix of bedrock aquifers, and predominantly shallow Hillslope and Valley Bottom aquifer systems underlain by either bedrock aquifers, or more confining hydrogeologic units, such as the Pennsylvanian Paradox Formation and the undivided lower Triassic rocks. Locally and sub-regionally, various hydrostructures may influence interconnectivities of the shallow units with deeper bedrock systems, but in general, there are no regional systems due to a lack of hydrogeologic, structural, and geomorphologic (including topographic) connectivity.

The La Sal Mountain Subsystem, located in the southeastern part of the study area, is a complex mix of bedrock (Tertiary Igneous Intrusive rocks or Ti and Tertiary Geyser Creek Fanglomerate or Tg) and unconsolidated deposits (Bouldery Colluvium, Talus and Colluvium, Glacial Till, Alluvial Fan deposits, and Stream Alluvium) which form a robust groundwater system that is directly connected to the surface water systems forming the headwaters of Castle and Placer Creeks (Figures 19 and 20). The top of this subsystem is directly hydraulically connected to Mesa Top subsystems not located in the TCV study area, and to the Castle Creek and Placer Creek Valley Bottom Subsystems in the TCV study area (Figures 19 and 20).

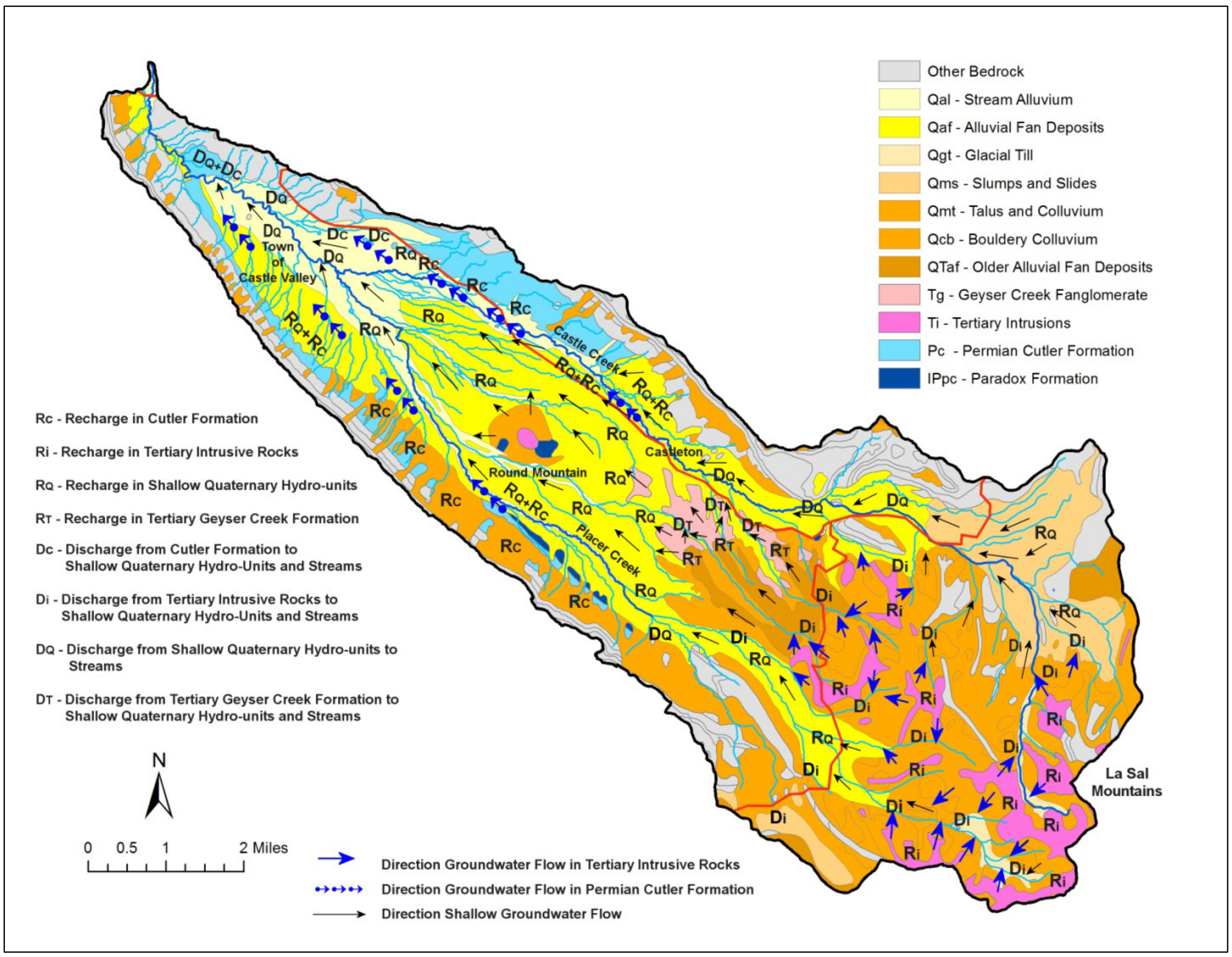

Figure 19. Plan View of the Conceptual Site Model of the Hillslope and Valley Bottom Shallow Aquifer Subsystems, and the Bedrock Subsystems with Recharge and Discharge Zones and Groundwater Flow Direction.

The Porcupine Rim/Sand Flats Mesa Top Subsystem, located to the west of the Porcupine Rim of Castle Valley, has a unique, sometimes complex groundwater story. Under natural conditions, this subsystem has hydrologic system inputs and outputs similar to the Mountain, Hillslope and Valley Bottom subsystems of Castle Valley. However, the natural topography and geologic setting has blocked this subsystem from attaching to the Castle Valley subsystems, and the groundwater and surface water is part of the La Sal Mountains/Spanish Valley hydrologic system.

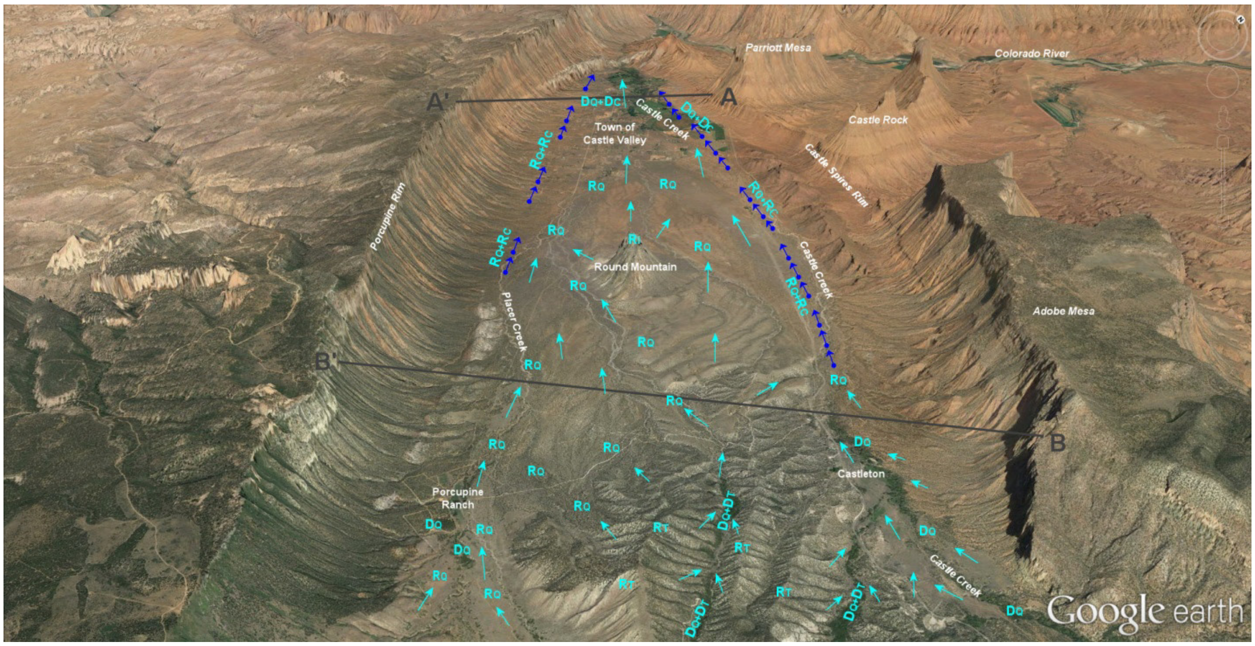

Figure 20. Google Earth View of the Conceptual Site Model of the Hillslope and Valley Bottom Shallow Aquifer Subsystems, and the Bedrock Subsystems with Recharge and Discharge Zones and Groundwater Flow Direction (see Figure 19 for explanation).

The Porcupine Rim and Castle Spires Rim Hillslope Subsystems, located in the steep terrain surrounding the Castle Valley area, are attached/linked to the Valley Bottom subsystems. These Hillslope subsystems have hydrologic system inputs and outputs, similar to the Valley Bottom subsystems. However, natural influences have created unique hydrogeologic units (Quaternary debris flows and fans, talus, weathered bedrock) that frequently attach these subsystems hydrologically to adjacent Valley Bottom subsystems, and there is minor bedrock support for significant groundwater contribution.

The Castle Creek and Placer Creek Subsystems, where stream-aquifer-wetland interactions occur, are areas of both groundwater recharge and discharge, and groundwater flow can have a rather diffuse character and often flows towards or aligns more or less with the streams and rivers. These subsystems depend primarily on interactions with their main tributaries and associated alluvial groundwater systems such as Castle Creek and Placer Creek; discharge from the Porcupine Rim and Castle Spires Rim subsystems; discharge from the bedrock subsystems such as the Geyser Creek fanglomerates, the fractured arkoses and White Rim sandstones of the Cutler Formation, and the Tertiary intrusive rocks of the La Sal Mountains foothills; and the management of subsurface return flow from irrigation lands. The wetlands associated with the local hydrogeologic conditions in the Castle Creek and Placer Creek drainages, and in the adjoining tributaries, are a mix of slope-type and riverine-type classifications given the groundwater support of various irrigation schemes, unconsolidated hydrogeologic unit groundwater systems, bedrock hydrogeologic unit groundwater systems, and hydrostructures.

As springs are discharge points of groundwater flow systems, their presence in the TCV study area provide clues about these groundwater flow systems, including the role of the hydrogeological units, hydrostructures, and the effects of natural and anthropogenic recharge on flow and water quality. To identify the location and discharge rates of springs and seeps in the TCV area the State water rights database was searched in Jan 2016 (*UDWR 2016*).

There are three general categories of springs, based on spring location with respect to hydrogeologic location, that are identified on topographic maps, field excursions, and in the State water rights records (Figure 10): 1) Unconsolidated Unit/Faulted Shallow Bedrock springs; 2) Unconsolidated Unit springs controlled by topography, geomorphology, and upward gradient groundwater flow; and 3) bedrock associated springs. The Unconsolidated Unit/Faulted Shallow Bedrock (Qal/Pc) springs are located at areas where the deeper bedrock aquifers are faulted and pinched out, and the groundwater is forced to the surface as surface water, such as the springs located north and west of the Day Star Academy, or where a cross-valley fault system or resistant bedrock unit has caused the shallow unconsolidated units to thin resulting in groundwater being forced to the surface, such as the springs above the Porcupine Ranch Spring in upper Placer Creek (Figure 10). The unconsolidated unit (Qal, Qaf) springs, which indicate discharge of local or subregional groundwater to Castle Creek are located above the hamlet of Castleton on tributaries of Castle Creek in the Tertiary Geyser Creek Fanglomerates (Tg), and below the confluence of Castle and Placer Creeks in the Town of Castle Valley (Figure 10). The bedrock-controlled springs are located mostly in the La Sal Mountain foothills in the southeastern part of the watershed, and the discharge of groundwater is from the Tertiary intrusive granodiorite (Ti) through the Quaternary hydrogeologic units (Qgt, Qcb, and QTaf) to the streams where Castle Creek and Placer Creek tributaries originate (Figure 10).

2.6 Groundwater System Conceptual Site Models by Subsystem

Based on the presence and orientation of various hydrogeologic and hydro-structural units, hydrography and topography, two categories of CSMs will be discussed in the TCV study area:

1. La Sal Mountain Subsystem, which include the Tertiary Intrusive Granodiorite and Tertiary Geyser Creek Fanglomerate bedrock hydrogeologic units and associated high K zone hydrostructures; and
2. Castle Creek and Placer Creek Hillslope and Valley Bottom Shallow Aquifer Subsystems, which include the Castle Spires Rim and Porcupine Rim Subsystems, and the fractured arkose and White Rim members of the Permian Cutler formation bedrock hydrogeologic unit and the associated high K zone hydrostructures.

The La Sal Mountain Subsystem will be discussed first since it is located at the highest topographic level, and is the headwaters of the overall Castle Valley surface and groundwater hydrologic system (Figures 19 and 20). In addition, a discussion of the interface between the three subsystems will be presented. The conceptual models are discussed in forthcoming sections and illustrated by cross-sectional and plan view figures. The locations of representative cross-sections are shown in Figure 21. Note that all of the subsystems have some interconnectedness with the surrounding subsystems, whether by subsurface groundwater flow, or by tributary stream flow (Figures 19).

2.6.1 La Sal Mountain Subsystem

As stated in Section 2.4.2, there are two significant hydrogeologic groups in the La Sal Mountain Subsystems:

1. Quaternary and Tertiary unconsolidated clastic materials (Figures 15, and 16; Table 2a), which are predominantly Alluvial Fan deposits (Qaf), Glacial Till (Qgt), Slumps and Slides (Qms), Talus and Colluvium (Qmt), Bouldery Colluvium (Qcb), and Older Alluvial Fan Deposits (QTaf); overlying
2. Tertiary bedrock units (Figures 14, and 15; Table 2b), including the following potentially water-bearing units: Tertiary Geyser Creek Fanglomerate (Tg) and Tertiary Intrusive Granodiorite (Ti).

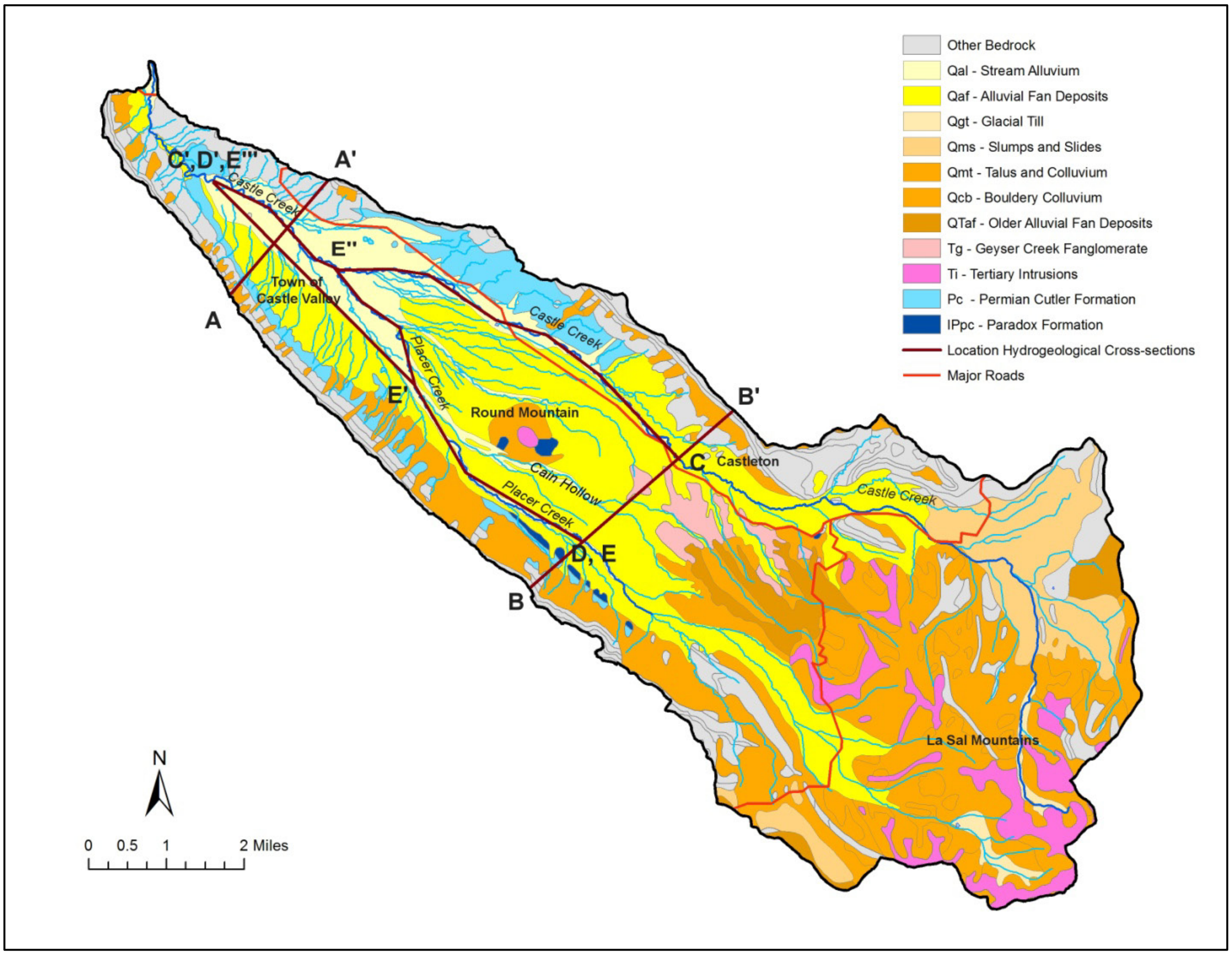

Figure 21. Map Showing the Locations of the Cross-sections Representative for the Conceptual Site Models in the TCV Study Area on Top of the Hydrogeologic Units.

In addition, there are two types of geological structures of significance to the hydrogeology in the La Sal Mountain Aquifer Subsystems:

1. Northwest-southeast trending fault/fracture zone hydrostructures (southeastern extent of the high K zones extending to the northwest part of Castle Valley) that are observed on both the northeastern and southwestern sides of Castle Valley dipping vertically (Figures 14, 17, 19, and 22); and

2. Radial and concentric fault/fracture zone hydrostructures that are observed radiating out from and surrounding the Tertiary intrusions and dissecting the Tertiary Geyser Creek unit (Figures 14, and 19).

The shallow Quaternary and Tertiary unconsolidated materials in the La Sal Mountain Subsystem are ubiquitous, and include alluvial, glacial-alluvial, glacial, mass wasting, and paleo-alluvial (terrace) deposits mostly derived from the Tertiary Intrusive rocks (Figures 15, and 16; and Table 2a). These highly-permeable deposits are locally heterogeneous, with a mix of coarser and finer materials in all of the deposits. These deposits are underlain by a paleo-topographic surface carved out by paleo mass wasting and fluvial systems that originally deposited the Tertiary Geyser Creek unit. The glacial, fluvial, and mass wasting processes continued to eventually deposit the Quaternary unconsolidated materials that are the shallow aquifers in continuity with the Castle Creek and Placer Creek subsystems (Figure 19). It should be noted that the paleo-alluvial and modern alluvial systems followed structural fault zone controlled valleys and account for increased aquifer thicknesses in these valleys (Figure 17, 22, and 23).

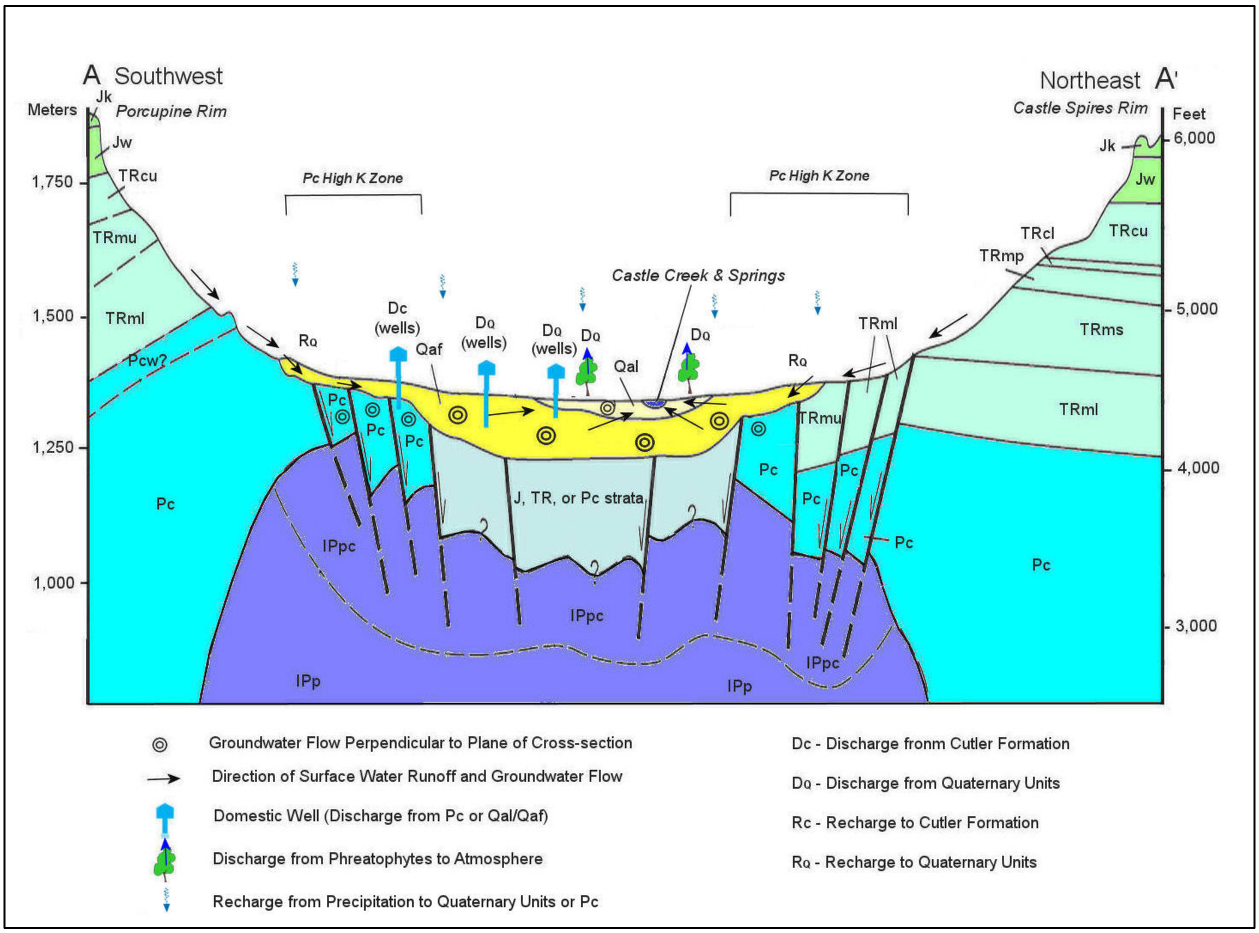

Figure 22. Schematic Northeast-Southwest Cross-sectional View of the Conceptual Site Models of the Hillslope and Valley Bottom Shallow Aquifer Subsystems in the Vicinity of the Town of Castle Valley (A-A' in Figure 21).

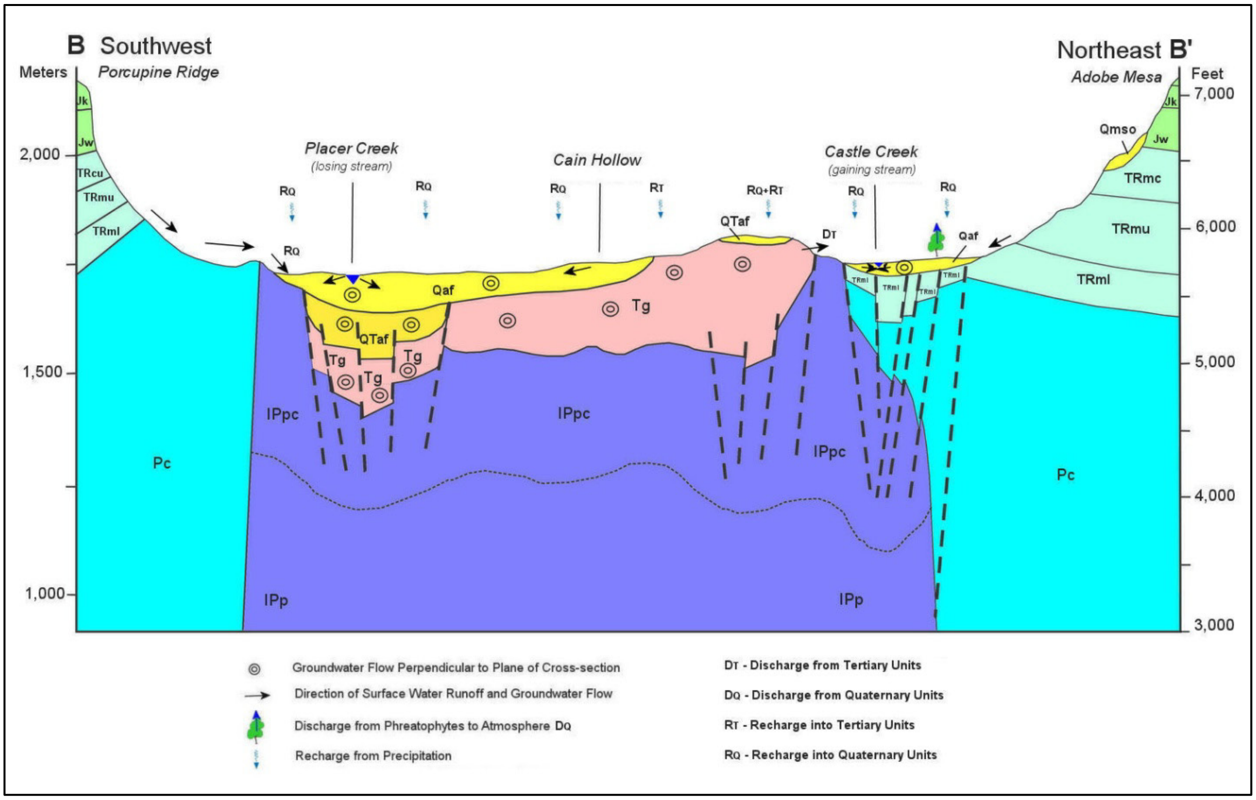

Figure 23. Schematic Northeast-Southwest Cross-sectional View of the Conceptual Site Models of the Hillslope and Valley Bottom Shallow Aquifer Subsystems Southeast of Round Mountain (B-B' in Figure 21).

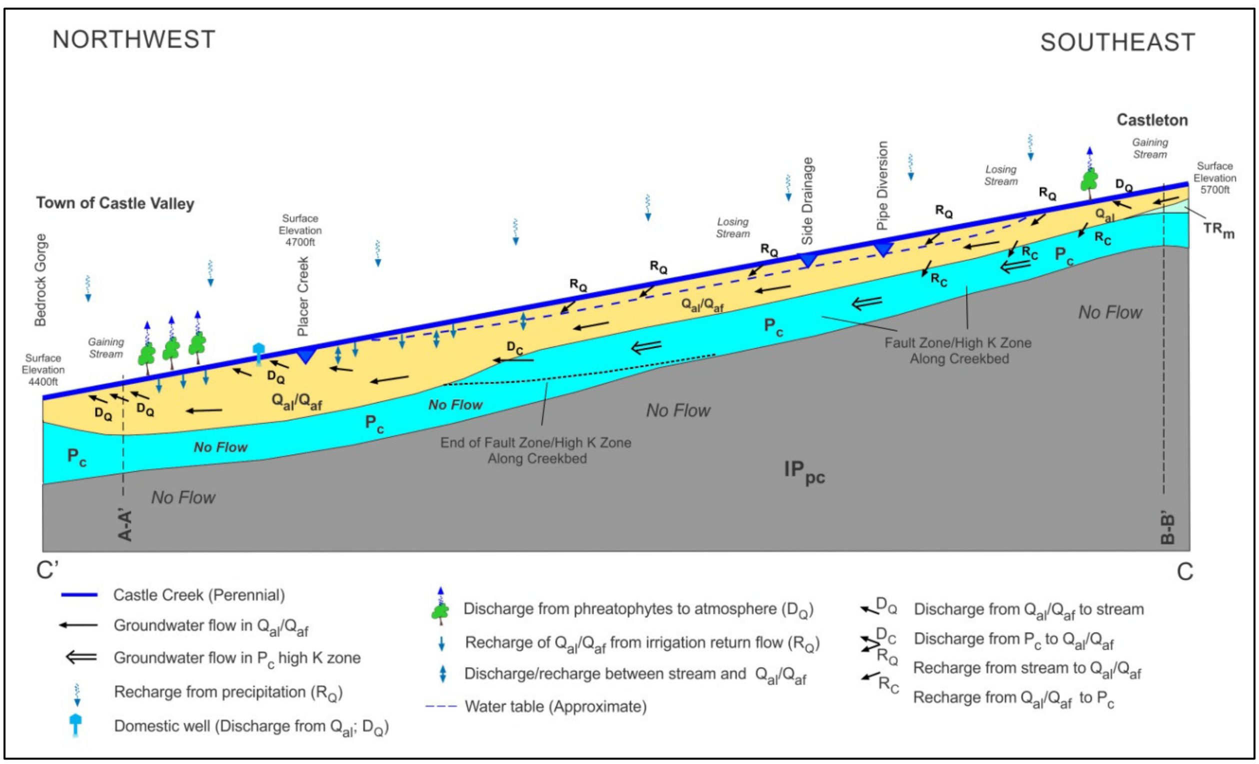

Figure 24. Schematic Northwest-Southeast Cross-sectional View of the Conceptual Site Models of the Hillslope and Valley Bottom Shallow Aquifer Subsystems along the Northeast Side of Castle Valley (C-C' in Figure 21).

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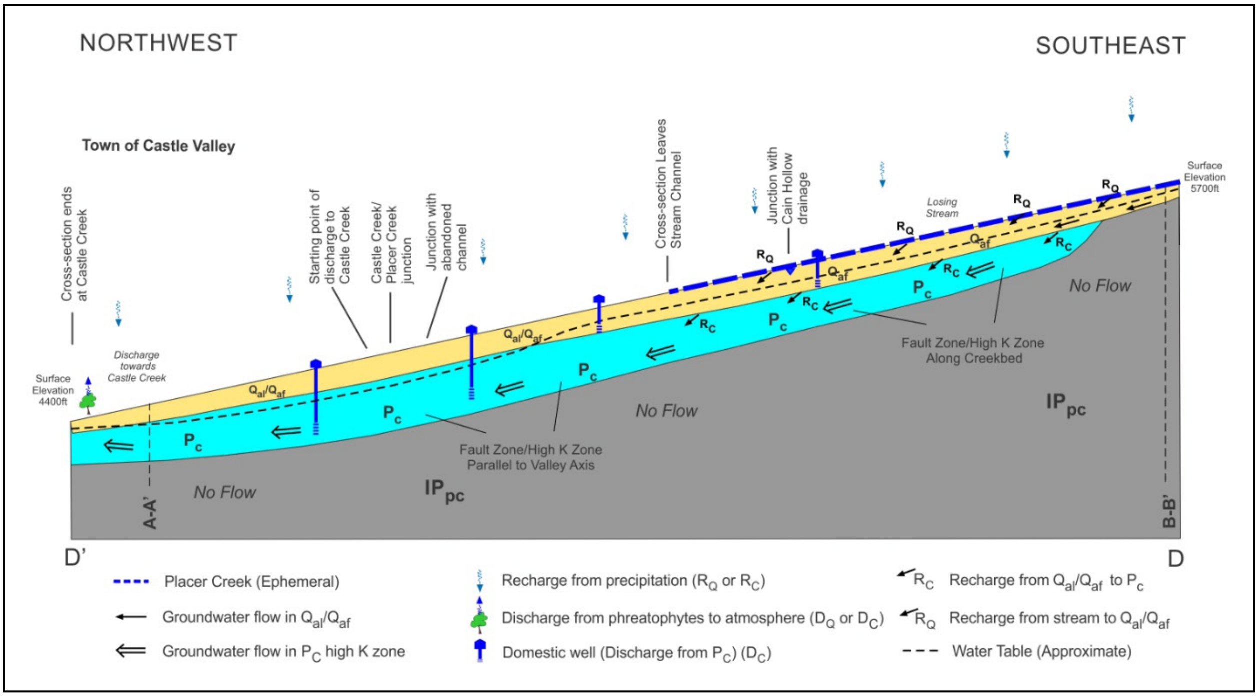

Figure 25. Schematic Northwest-Southeast Cross-sectional View of the Conceptual Site Models of the Hillslope and Valley Bottom Shallow Aquifer Subsystems along the Southwest Side of Castle Valley (D-D’ in Figure 21).

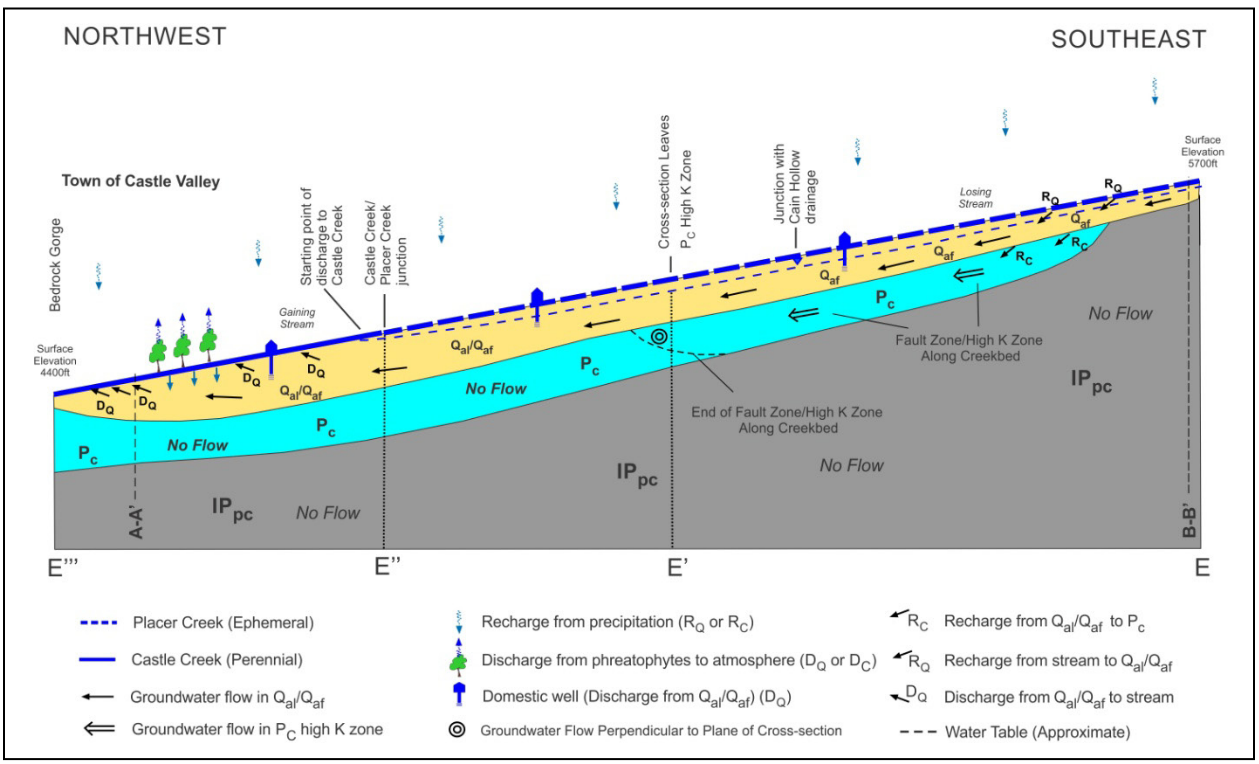

Figure 26. Schematic Northwest-Southeast Cross-sectional View of the Conceptual Site Models of the Hillslope and Valley Bottom Shallow Aquifer Subsystems along the Placer Creek and Lower Castle Creek Drainages (E-E''' in Figure 21).

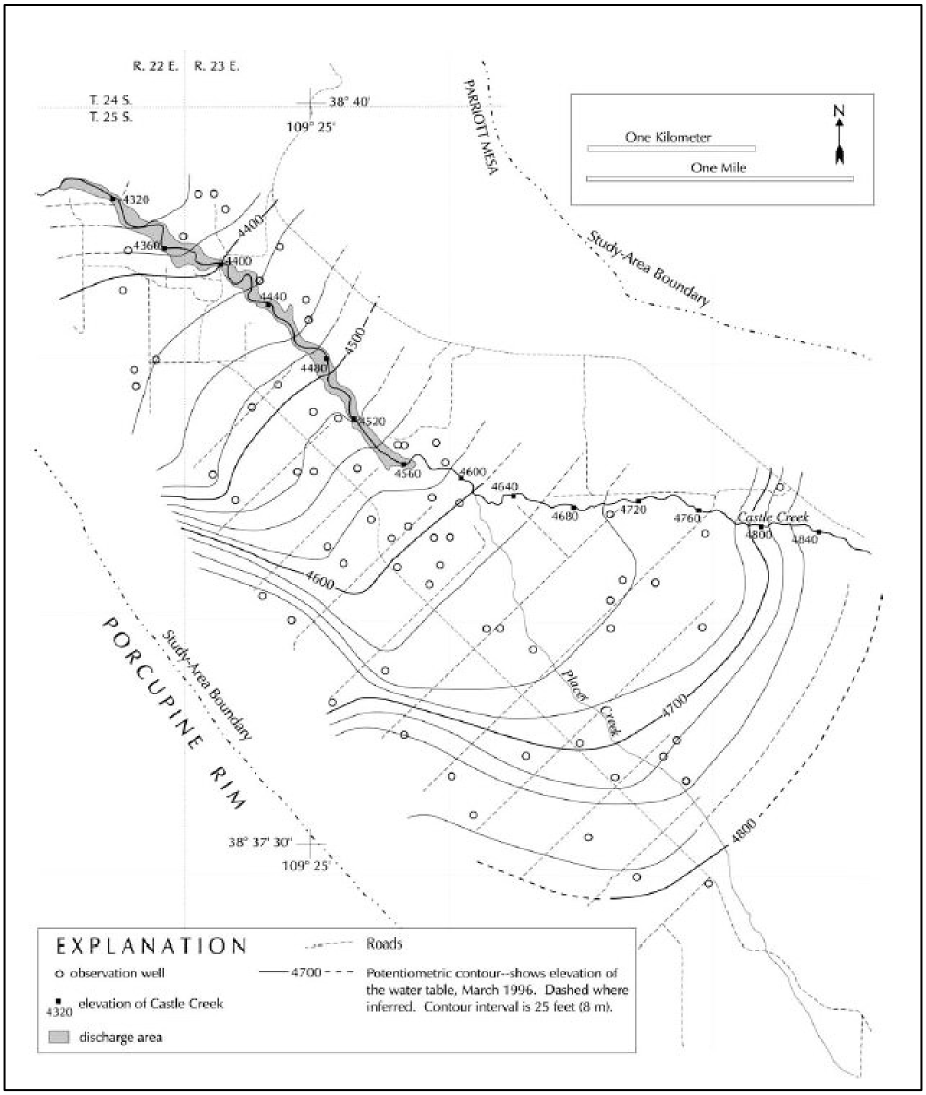

Figure 27. Potentiometric Surface of the Castle Valley Unconfined Aquifer (from Snyder, 1996).

The general aspects of groundwater flow in the Quaternary unconsolidated materials have been discussed in Section 2.5. Specifically, the shallow groundwater in the La Sal Mountain Subsystem is dominated by the Quaternary alluvium (Qal); Quaternary Alluvial Fan Deposits (Qaf), Glacial Till (Qgt); Slumps and Slides (Qms); Talus and Colluvium (Qmt); Bouldery Colluvium (Qcb); and Older alluvial Fan deposits (QTaf), which receive natural recharge (R_Q) by infiltration of precipitation (snow and rain); input from hillside (slope) deposits located upgradient from a given location; and input from the two bedrock aquifers: the Geyser Creek Fanglomerate (Tg), and the Tertiary Intrusive units (Figures 19, 20, 22, 23, 24, 25, and 26).

Groundwater flow in the La Sal Mountains unconsolidated materials is with topography from hilltop and ridgetop down the hillslope to the valley bottom, and then parallel with the valley bottom steams (Figure 19). Groundwater in the valley bottom stream unit moves in the same direction as the stream with various stream reaches being gaining (D_Q) or losing (R_Q) depending on subsurface topography, saturated thickness of the alluvium, or the seasonal variations caused by snowpack runoff or storm events (Figure 19). These streams and tributaries are the headwaters of Castle Creek and Placer Creek, and most reaches are gaining from the alluvial and bedrock aquifers (Figure 19). There is also groundwater discharge (D_Q) from the alluvium locally by groundwater wells and by phreatophytes.

The shallow groundwater in the La Sal Mountain Subsystem is sustained by and connected directly to the underlying bedrock groundwater systems: the Tertiary Intrusive hydrogeologic unit (Ti), and the Tertiary Geyser Creek Fanglomerate hydrogeologic unit (Tg) (Figure 19). The connection of these two units is further enhanced by the radial and concentric faults/fracture zones where preferential (high K zones) groundwater flow occurs in the bedrock (Figures 17 and 19).

Groundwater recharge (R_I) occurs on the mountain tops and ridges where the Tertiary Intrusive units are frequently exposed (Figure 19). Groundwater then flows downgradient with topography along the radial faults and fractures to the radial and concentric valley bottoms, also preferred high K fault and fracture zones that serve as groundwater "French drains", where the groundwater discharges (D_I) into the unconsolidated materials and streams (gaining streams) (Figure 19). These valley bottoms, with combined bedrock and unconsolidated deposits, have increased groundwater flow and storage, and connectivity between the two hydrologic systems (Figure 19). Given the granodiorite composition of bedrock, the natural water quality is good except where mining activity has been undertaken.

Groundwater recharge (R_I) also occurs on the hills and ridges where the Tertiary Geyser Creek Fanglomerate units are exposed (Figure 19). Groundwater then flows downgradient with topography to the northwest-southeastern linear valley bottoms, also preferred northwest-southeast trending high K fault and fracture zones that serve as groundwater "French drains", where the groundwater discharges (D_I) into the unconsolidated materials and streams (gaining streams) (Figure 19). These valley bottoms, with combined bedrock and unconsolidated deposits, have increased groundwater flow and storage, and connectivity between the two hydrologic systems (Figure 19). Given the fanglomerate composition of bedrock, the natural water quality is good unless nearby human activity (cattle grazing) has locally had an effect.

2.6.2 Hillslope and Valley Bottom Shallow Aquifer Subsystems

As stated in Section 2.4.2, there are two significant hydrogeologic groups in the Hillslope and Valley Bottom Shallow Aquifer Subsystems, which include the Castle Creek Subsystem, and the Placer Creek Subsystem:

1. Quaternary unconsolidated clastic materials (Figures 15, and 16; Table 2a), which are predominantly Stream Alluvium (Qal), Alluvial Fan deposits (Qaf), Slumps and Slides (Qms), and Talus and Colluvium (Qmt); overlying
2. Tertiary and Paleozoic bedrock units (Figures 14, and 15; Table 2b), including the following potentially water-bearing units: Tertiary Intrusive Granodiorite (Ti) (Round Mountain); and the White Rim and Arkosic members of the Cutler Formation (Pc).

In addition, there are two types of geological structures of significance to the hydrogeology in the Hillslope and Valley Bottom Shallow Aquifer Subsystems:

1. Northeast-southwest trending fault/fracture zone hydrostructures (Figure 17); and
2. Northwest-southeast trending faults, and fault/fracture zone hydrostructures (bedrock high K units) that are observed on both the northeastern and southwestern sides of Castle Valley dipping vertically (Figures 14, 17, 22, and 23).

The shallow Quaternary unconsolidated materials in these two subsystems are ubiquitous, and include alluvial, mass wasting, and paleo-alluvial terrace and fan deposits (Figures 15, 16; and Table 2a). These highly-permeable deposits are locally heterogeneous, with a mix of coarser and finer materials in all of the deposits. These deposits are underlain by a paleo-topographic surface carved out by paleo mass wasting and fluvial systems that eventually deposited the Quaternary unconsolidated materials that are the aquifers being evaluated. It is noted that the paleo-alluvial and modern alluvial systems followed structural fault zone controlled valleys and account for increased aquifer thicknesses in these paleo-valleys (Figure 16). The general aspects of groundwater flow in the Quaternary unconsolidated materials have been discussed in Section 2.5. Specifically, the shallow groundwater in the Castle Creek subsystem is dominated by the Quaternary alluvium (Qal) and Quaternary alluvial fan deposits (Qaf), which receive natural recharge (R_Q) by infiltration of precipitation (snow and rain; losing streams; input from hillside (slope) deposits (Qms and Qmt) derived from the mass wasting gravels and northeast-southwest trending fracture-controlled ephemeral stream channels and deposits (Qms and Qmt); and additional recharge from return flow from irrigation locally (Figures 19, 20, 22, 23, and 24). Water leaking from the irrigated areas enters into the (connected) gravels underneath and flows downgradient towards the discharge zones (D_Q) (gaining streams, springs and seeps, and wetlands) (Figures 19, 20, 22, 23, and 24).

Groundwater flow in the Castle Creek alluvium moves in the same direction as the stream with various stream reaches being gaining (D_Q) or losing (R_Q) depending on subsurface topography, bedrock hydrogeology, hydrostructures, and saturated thickness of the alluvium, or the seasonal variations caused by snowpack runoff or storm events (Figures 19, 20, 22, 23, and 24). There is also groundwater discharge from the alluvium (D_Q) locally by groundwater wells and by phreatophytes.

The shallow groundwater in the Castle Creek alluvial subsystem would normally have little connection to the local bedrock or the regional groundwater systems, given the very low permeability Pennsylvanian Paradox Formation (IPpc), unfractured Permian Cutler Formation (Pc), and other unfractured younger bedrock (Figures 22 and 23). However, underlying the northeastern side of Castle Valley is the northwestern-southeastern trending Castle Creek fault/fracture zone that formed with the collapse of the Castle Valley salt anticline (Figure 18). This area of hydrostructures is an open vertical and horizontal conduit (High K zone), where the faulted and fractured Permian Cutler (Pc) bedrock combines with the alluvium (Qal) to form a French Drain affect resulting in increased groundwater flow and storage, and connectivity between the two hydrologic systems (Figures 22, 23, and 24).

The fractured and faulted Permian Cutler bedrock aquifer is variably to fully saturated based on location and proximity to recharge area. In the Castle Creek Subsystem, groundwater recharge (R_C) by losing stream reaches and infiltration of precipitation is possible only by connection to the Castle Creek fault and fracture zone, and by the northeast-southwest fault and fractures that control drainages below the Castle Spires Rim (Figures 19 and 20). The subregional groundwater flow direction is from southeast to northwest parallel to the Castle Valley salt anticline collapse structures and Castle Creek (Figures 22, 23, and 24). This High K Zone flow system ends at the northwest end of Castle Valley, and the groundwater moves vertically upward into the Qal and ultimately into springs as discharge (D_C) and into Castle Creek (D_C) (Figures 19, 22, 23, and 24). This results in decreased water quality either naturally (Permian Cutler hydrogeologic unit water has higher TDS) or due to human activities, such as agriculture or human waste disposal activities (Figure 18). A Google Earth view of the Hillslope and Valley Bottom subsystem in the Castle Creek drainage is shown in Figure 20.

The second Hillslope and Valley Bottom Subsystem in the TCV study area is the shallow groundwater in the Placer Creek Subsystem. This subsystem is dominated by the Quaternary alluvium (Qal) and Quaternary alluvial fan deposits (Qaf), which receive natural recharge (R_Q) by infiltration of precipitation (snow and rain; losing ephemeral streams from the southeast (Cain Hollow and Placer Creek, for example); input from hillside (slope) deposits (Qms and Qmt) derived from the mass wasting gravels and northeast-southwest trending fracture-controlled ephemeral stream channels and deposits (Qms and Qmt); and additional recharge from leaky irrigation ditches originating from the Porcupine Ranch Spring area, and return flow from irrigation locally (R_Q) (Figures 19, 20, 22, 23, 25 and 26). Water leaking from the unlined ditches and irrigated areas enter into the (connected) gravels underneath and flows downgradient into the main Placer Creek groundwater flow system (Figures 19, 20, 22, 23, 25, and 26).

Groundwater flow in the Placer Creek alluvium moves in the same direction as the stream with most of the stream reaches being losing (R_Q) when surface water flow occurs due to the seasonal variations caused by snowpack runoff or storm events (Figures 19, 20, 22, 23, 25, and 26). There is also groundwater discharge (D_Q) from the alluvium locally by groundwater wells and by phreatophytes.

The shallow groundwater in the Placer Creek alluvial subsystem would normally have little connection to the local bedrock or the regional groundwater systems, given the very low permeability Pennsylvanian Paradox Formation (IPpc), unfractured Permian Cutler Formation (Pc), and other unfractured younger bedrock (Figures 22 and 23). However, underlying the southwestern side of Castle Valley is the northwestern-southeastern trending Placer Creek fault/fracture zone that formed with the collapse of the Castle Valley salt anticline (Figure 17). This area of hydrostructures is an open vertical and horizontal conduit (High K zone), where the faulted and fractured Permian Cutler (Pc) bedrock combines with the alluvium (Qal) and Alluvial Fan Deposits (Qaf) to form a French Drain affect resulting in increased groundwater flow and storage, and connectivity between the two hydrologic systems (Figure 22, 23, 25,and 26).

The fractured and faulted Permian Cutler bedrock aquifer is variably to fully saturated based on location and proximity to recharge area. In the Placer Creek Subsystem, groundwater recharge (R_C) by losing stream reaches and infiltration of precipitation is possible only by connection to the Placer Creek fault and fracture zone, and by the northeast-southwest fault and fractures that control drainages below the Porcupine Rim (Figure 17). The subregional groundwater flow direction is from southeast to northwest parallel to the Castle Valley salt anticline collapse structures and Placer Creek (Figures 19, 20, 25, and 26). This High K Zone flow system ends at the northwest end of Castle Valley, and the groundwater moves vertically upward into the Qal and ultimately into springs as discharge (D_C) and into Castle Creek (D_C) (Figures 19, 20, 24, 25, and 26). This results in decreased water quality either naturally (Permian Cutler hydrogeologic unit water has higher TDS) or due to human activities, such as agriculture or human waste disposal activities (Figure 18). A Google Earth view of the Hillslope and Valley Bottom subsystem in the Castle Creek drainage is shown in Figure 20.

A potentiometric surface map of northwestern Castle Valley showing discharge area and water table elevations is presented in Snyder (1996) (Figure 27). This potentiometric surface map, a more simplified representation of the northwestern end of the Combined Castle Creek and Placer Creek subsystems presented in this Section, shows that the groundwater flow in the Valley is generally from southeast-to-northwest and has a somewhat uniform gradient throughout, but a flatter gradient where the unconsolidated sediments thicken (Figure 27). Given the conceptual model that is presented in this section and throughout the report, Figure 27 does not show the presence of the two Permian Cutler (Pc) high K bedrock zones on the northeastern and southwestern sides of the Valley that connect with the groundwater system in the unconsolidated units. Figure 27 also does not show the very pronounced connections of Castle Creek with the groundwater system (losing in the up valley reaches, gaining in the down valley reaches indicated by springs), the groundwater discharge represented by springs along the northwestern margin of the Valley, and the effects of irrigation on the water table or the potentiometric surface. Figure 27 does indicate that regional groundwater flows into the system on the western side of the Valley, whereas the conceptual model presented in this Section indicates that the western side of the system has a no flow boundary, and that no regional groundwater system connects to the Castle Valley.

2.7 Anthropogenic Influences

Human activity in the TCV study area has affected both the surface and subsurface parts of the hydrologic systems. Past land use and human activity was mostly associated with cattle grazing, irrigation, and small reservoir construction and operation, or subdivision of lands for domestic use. These activities have been accompanied by removal or selective reduction of native vegetation, introduction of irrigation and high-ET (evapotranspiration) crops or vegetation associated with homes, construction of (often leaking) irrigation ditches (now mostly piped), and the drilling of primarily domestic wells. This activity has resulted in localized changes of groundwater water levels and flow directions that are affected due to changes of recharge (return flow from primarily irrigation and, to a lesser extent, leaky irrigation ditches); and to changes in discharge (new domestic wells, reduction of groundwater flow due to reduction of surface water flow that has been diverted in local, shallow aquifers of the Quaternary materials in the alluvium (Qal) of the Castle Creek and Placer Creek Subsystems. In addition, this activity may result in increased mobility of various salts in the groundwater and surface water systems, particularly in the Castle Creek watershed below Castleton, and the Placer Creek groundwater system in and around the fractured High K Zone in the Permian Cutler hydrogeologic unit in the northwestern part of Castle Valley.

Current land use and human activity changes are mostly associated with minor subdivision of natural or agricultural lands, such as the expansion of the Town of Castle Valley in the northwestern part of Castle Valley, and the potential changes of land use at Day Star Academy. These changes result in changes to surface water throughflow/interflow, overland flow, and channel flow, as well as changes in groundwater recharge, flow directions, and discharge. Water quality changes may result as well.

2.7.1 Effects of Land Use Changes on Groundwater Systems

The main irrigation activities in Castle valley take place upgradient of the bottomlands (Qal) on the alluvial fans (Qaf) of the Hillslope and Valley Bottom Subsystems, while most grazing activities are scattered about the Hillslope and Valley Bottom Subsystems. Agricultural production of animal feed is supported by surface water irrigation, often delivered through pipes or a center pivot conveyance system (Figure 28). The main irrigation method in use is flood irrigation, which tends to provide more water to the fields than can be consumed by vegetation. Excess water from irrigation results in infiltration to the water table and recharge of the groundwater system at the location of these fields (*i.e.*, R_Q, irrigation return flow), or direct runoff of surface water to Castle Creek (Figure 28). At this time, Castle Valley is not experiencing a major shift from agricultural to nonagricultural land use, and the return flow from irrigation and subsequent groundwater recharge is stable. However, changes in groundwater quality due to fertilization practices of home owners and ranches with irrigation should be monitored.

The TCV study area consists primarily of the combined Hillslope and Valley Bottom Castle Creek and Placer Creek Subsystems, limiting the irrigated areas to the lower (Qal: alluvium and Qaf: alluvial fans) portions of the subsystems (Figures 28). Here, there are some unlined irrigation ditches and canals that are excavated primarily in unconsolidated Quaternary (Qal) deposits (Figure 28). When carrying water, the ditches may leak into the underlying and surrounding unconsolidated materials as evidenced by the phreatophytes (such as Cottonwoods) often found alongside. The water leaking from the ditches may be used by vegetation and discharged as evapotranspiration, or may recharge the underlying groundwater system, forming a local groundwater mound. As most of the groundwater systems in the study area are local in nature, ditch and canal leakage may contribute significantly to the local water balance, increase the water table elevation, and influence groundwater flow patterns.

Figure 28. Anthropogenic Influences: Irrigated Parcels in TCV Study Area.

As discussed previously, irrigation return flow can be a significant recharge element in the local groundwater balance, and in the surface water balance within the lower part of the Castle Creek watershed. Taking irrigated fields out of production and re-allocating pipe-conveyed water reduces recharge of groundwater resulting in lowered water tables, reduced groundwater discharges to nearby wetlands and streams, and decreased water supplies.

Water wells are found throughout the TCV study area, primarily in the unconsolidated Quaternary deposits (Qal) at valley bottoms and in the High K Zone of the Permian Cutler (Pc) Hydrogeologic Unit (Figure 29). Most of these wells serve domestic water supply or irrigation needs, and the effect on the groundwater system locally may be significant. However, if additional water is needed by urban or agricultural development, or water is displaced by urban and recreational activities, for example, the compound effect on the groundwater system could be more significant in the future, resulting in a possible lowering of the water table, changes in flow direction, decreasing discharge to streams or increasing stream loss to groundwater, draining of wetlands, or even depletion of local aquifers. It should be noted that areas with higher density of wells, such as the Town of Castle Valley, the community of Castleton, and the area west of Round Mountain, also have a higher density of septic tanks.

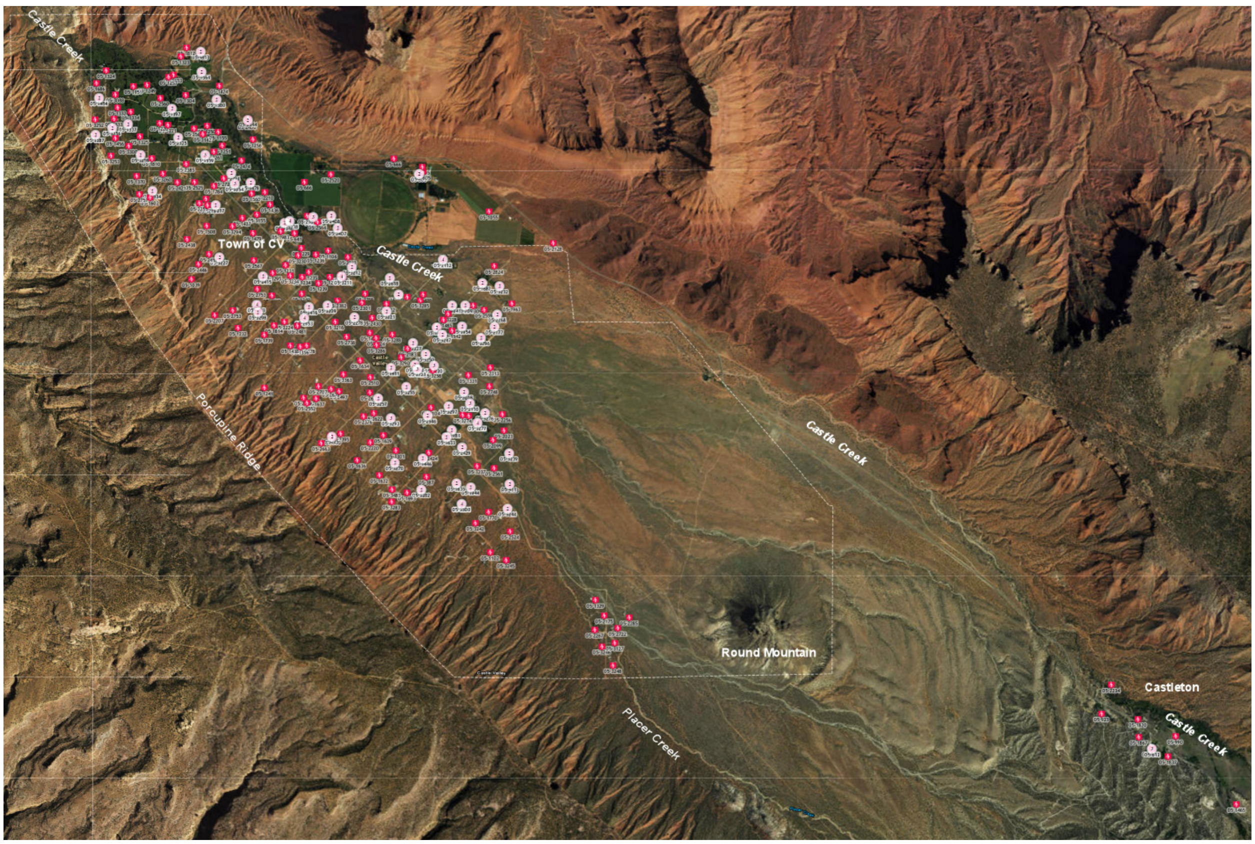

Figure 29. Anthropogenic Influences: Constructed Wells in the TCV Study Area. (From Utah Division of Water Right Data Base with Filter Setting: Perfected, Underground, Water Right, All Uses; Accessed March 2016).

2.7.2 Potential Effects of Groundwater Use on Water Quality

The HESA evaluation of the TCV hydrologic systems can also be used for assessing the vulnerability of groundwater and surface water to contaminants in both the natural and anthropogenic environment. Regionally, salt concentrations (Total Dissolved Solids or TDS) are known to frequently exceed drinking water and ecosystem standards, whether naturally or human-induced. Salts are very soluble and mobile in surface and groundwater environments, and tend to concentrate in surface water environments in arid and semi-arid climates. The Permian

Cutler Group (Pc) and Pennsylvanian Paradox Formation (IPpc) hydrogeologic units, usually considered groundwater flow system confining layers, are the main source in Castle Valley for naturally occurring salt in a chemically soluble form. The faulted and fractured Cutler Group (Pc), referred to as two High K Zones located under Castle Creek and Placer Creek (Figures 17, 19, and 20), allow large quantities of groundwater to flow through these conduits where large quantities of soluble salt are incorporated into the groundwater flow system. These salts are then transported in the groundwater and/or surface water to exposure sites such as wells, lakes, and surface water bodies like Castle Creek where they may be measured in quantities unacceptable by drinking water and/or ecosystem regulatory standards. Many spatial (3-dimensional) and temporal (past, present, and future time frames) factors affect how the salt is being mobilized and transported including: 1) Salt source location with respect to hydrogeologic framework, specifically the hydrogeology of unweathered and weathered Cutler and Paradox Formation bedrock and the hydro-geomorphology of overlying unconsolidated Quaternary deposits, such as landslides, glacial and alluvial gravels, soils and weathering profiles; 2) Groundwater flow pathways including exposure sites such as groundwater discharge zones to the surface water systems; and 3) Past, present, and future hydrologic "stresses" to the system, for example irrigation of weathered Cutler or Paradox Formation bedrock, and irrigation on geomorphologic deposits on weathered Cutler and Paradox Formation bedrock.

2.7.2.1 Hillslope Subsystems Water Quality

The hydrogeology of the Porcupine Rim and Castle Spires Rim Hillslope Subsystems, as previously described in Section 2.6, is primarily Quaternary and Tertiary unconsolidated clastic materials, which are predominantly Stream Alluvium (Qal), Alluvial Fan deposits (Qaf), Glacial Till (Qgt), Slumps and Slides (Qms), Talus and Colluvium (Qmt), Bouldery Colluvium (Qcb), and Older Alluvial Fan Deposits (QTaf); overlying Tertiary and Paleozoic bedrock units, including the following potentially water-bearing units: the Tertiary Geyser Creek Fanglomerate (Tg); Tertiary Intrusive Granodiorite (Ti); and the White Rim and Arkosic members of the Cutler Formation (Pc), and the following confining hydrogeologic units: Paradox Formation (IPpc), unfractured Permian Cutler (Pc), and undivided bedrock (mostly Triassic) units. A small weathered zone exists as the interface between the Quaternary unconsolidated hydrogeologic units and the Bedrock hydrogeologic units. The hydrologic system of these steep Hillslope Subsystems, as previously described in Section 2.6, is that surface water in fracture-controlled channels, and overland and interflow from precipitation rapidly runs off the steep hillslopes until flowing across or through the Quaternary and/or Tertiary unconsolidated hydrogeologic units, where the water quickly disappears into the aquifer as groundwater recharge (R_Q and R_C, Figure 18). In the process of channeled surface water, or overland and interflow, soluble salts in the bedrock are incorporated into the surface and near surface water to be transported into the unconsolidated deposits aquifers. The fringes of these aquifers would have higher TDS than the central parts of these aquifers in the main valley (Figure 18).

The natural pollutants that are most likely occurring include salts (carbonates and sulfates), and the most likely source of these pollutants is the weathered zone of the older bedrock upgradient. It is hypothesized that the natural system has been flushing salt through this system since the erosion of the landscape commences resulting in the deposition of the Quaternary and Tertiary unconsolidated material in the various drainages and Castle Valley.

The anthropogenic pollutant sources to these subsystems are from the homes that are located on the unconsolidated materials and would include mostly fertilizers for grass (urban) or crops, or rural septic tank waste. Most of these are organics and nutrients, and would need to be monitored accordingly.

2.7.2.2 Valley Bottom Subsystems Water Quality

The hydrogeology of the two Valley Bottom Subsystems, as previously described in Section 2.6, is primarily Quaternary and Tertiary unconsolidated clastic materials, which are predominantly Stream Alluvium (Qal), Alluvial Fan deposits (Qaf), Glacial Till (Qgt), Slumps and Slides (Qms), Talus and Colluvium (Qmt), Bouldery Colluvium (Qcb), and Older Alluvial Fan Deposits (QTaf); overlying Tertiary and Paleozoic bedrock units, including the following potentially water-bearing units: Geyser Creek Fanglomerate (Tg); Tertiary Intrusive Granodiorite (Ti); and the White Rim and Arkosic members of the Cutler Formation (Pc), and predominantly the following confining hydrogeologic unit: Paradox Formation (IPpc). A major rubbly weathered zone called the “cap rock” exists as the interface between the Quaternary and Tertiary unconsolidated units, and the Bedrock hydrogeologic units. A weathered zone most likely exists as the interface between the two groups of hydrogeologic units. The hydrologic system of the two Valley Bottom Subsystems is described previously in Section 2.6.

The natural pollutants that are most likely occurring includes salts (high TDS), and the most likely source of these pollutants is the weathered zone at the interface between the two main hydrogeologic bedrock units: The Permian Cutler Formation (Pc) and the Pennsylvanian Paradox Formation Cap Rock (IPpc) and the Quaternary and Tertiary unconsolidated materials. It is hypothesized that the natural system has been flushing salts through this system since the deposition of first the Tertiary Gravels, then the Quaternary glacial, mass wasting, and alluvial gravels (Qal). Given the large water quantities being circulated, and long period of time of flushing, it is unlikely that large amounts of salts are being leached and transported directly from the bottom of these subsystems. However, it is hypothesized that a substantial amount of these natural pollutants enters the wells of Placer Creek and the Castle Creek Subsystems through the High K Zones of the fractured Permian Cutler Units (Pc) groundwater systems to eventually daylight into the Castle Creek surface water system (See Figure 18).

The anthropogenic pollutant sources to these Valley Bottom subsystems are mostly fertilizers for grass (urban) or crops, industrial pollutants (local garages, for example), or rural septic tank waste. Most of these are organics and nutrients, and would need to be monitored accordingly.

3 PRELIMINARY WATER BALANCE

The components of the Castle Valley (TCV) area hydrologic system have been determined and the surface water and groundwater flow systems analyzed, using the HESA approach, and discussed in Section 2. Three Subsystems have been identified and characterized: the La Sal Mountain Subsystem; Castle Creek Hillslope and Valley Bottom Subsystem; and the Placer Creek Hillslope and Valley Bottom Subsystem (Section 2.6 and Figure 18). Each of these hydrologic systems have been analyzed for their surface water dynamics (stream input or stream flux in, stream flow through the given area, stream output or stream flux out) and measurements of stream dynamics (discharge and velocity over time) have been collected at various stations (Section 2.3). In addition, precipitation measurements have been collected at various locations as input into the watershed (Section 2.1). Likewise, each of the Subsystems has been analyzed for groundwater systems (Section 2.4-2.6), and the groundwater input or recharge areas, groundwater flow system, and groundwater output or discharge areas been determined (Section 2.6). Well measurements have been collected at well locations to quantify groundwater output, and spring measurements, which are also groundwater output, have been collected *(Ford, 2006)*. In addition, groundwater level data have been collected at wells, which enable the determination of groundwater flow direction and amount of water storage and well yield at a given point in the groundwater system, and calculations of groundwater flux and storage over time can be done *(Snyder, 1996)*.

In order to further understand how the hydrologic systems in the TCV area work, and to determine quantitatively if the hydrologic system is properly analyzed, a water balance can be calculated for a given part of, or the entirety of the TCV study area. The hydrologic system water balance, or water budget, is the quantitative listing of the surface water and groundwater inputs and outputs, and changes in internal storage over a particular period of time. In its most simple form, the period of time is chosen such that the internal storage is so small that it does not have to be taken into account. Considering climatic variability, often a multi-year period with averaged inputs and outputs is selected to determine the water budget for a particular hydrologic system. Without a storage term, the water budget inputs should be equal to or "balance" the water budget outputs. The selection of the time period for which to calculate the water budget depends, among others, on the nature of the climatic variability, and the availability of climatic and hydrologic records. Frequently this is done for a one- or multi-year period to capture a full cycle of seasons, or multi-year trends. For shorter periods of time, such as the growing season, water budget calculations may involve estimating the release from or addition to internal storage. This change in storage could be seasonal changes in measured water tables, or changes in reservoir water levels.

The first step in determining an accurate water balance for the Castle Valley hydrologic system is to determine the correct Hydrologic System Conceptual Model using HESA. With HESA individual components of the hydrologic system are analyzed, followed by evaluating the aggregate of components and their interactions, to locate and quantify relevant hydrologic subsystems. The results of the HESA for the TCV study area are given in Section 2. Step 2 in determining the water balance is setting up a logic diagram based on the conceptual models to show all the significant hydrologic units and processes, including the external hydrologic system inputs, outputs, and internal storage areas, and internal exchanges. Step 3 is to subset the overall conceptual model area to a manageable area where quantification of the hydrologic system will be most practical and accurate given the available data and the landscape terrain measurability (estimates of inputs and outputs where engineering data is not available or not practical/cost-effective at this time).

3.1 Water Balance Logic Diagram

The generalized hydrologic system components and processes diagram for the study area (TCV), based on the HESA-derived conceptual models, shows all the significant hydrologic and hydrogeologic units or storage components (boxes), and the hydrologic exchange processes or fluxes (arrows) (Figure 30). The main hydrologic units are: atmosphere; unsaturated zone (between ground surface and water table), shallow groundwater zone (saturated valley-fill unconsolidated sediments); and deep groundwater zone (bedrock hydrogeologic units and hydrostructures). Figure 30 also shows the process-type interactions between these hydrologic units as present in the TCV study area. Not included are the processes internal to the hydrologic units, such as atmospheric flow, stream flow, and groundwater flow. These processes can be quantified as fluxes or flow rates such as precipitation rates (in/hr, in/yr), groundwater recharge

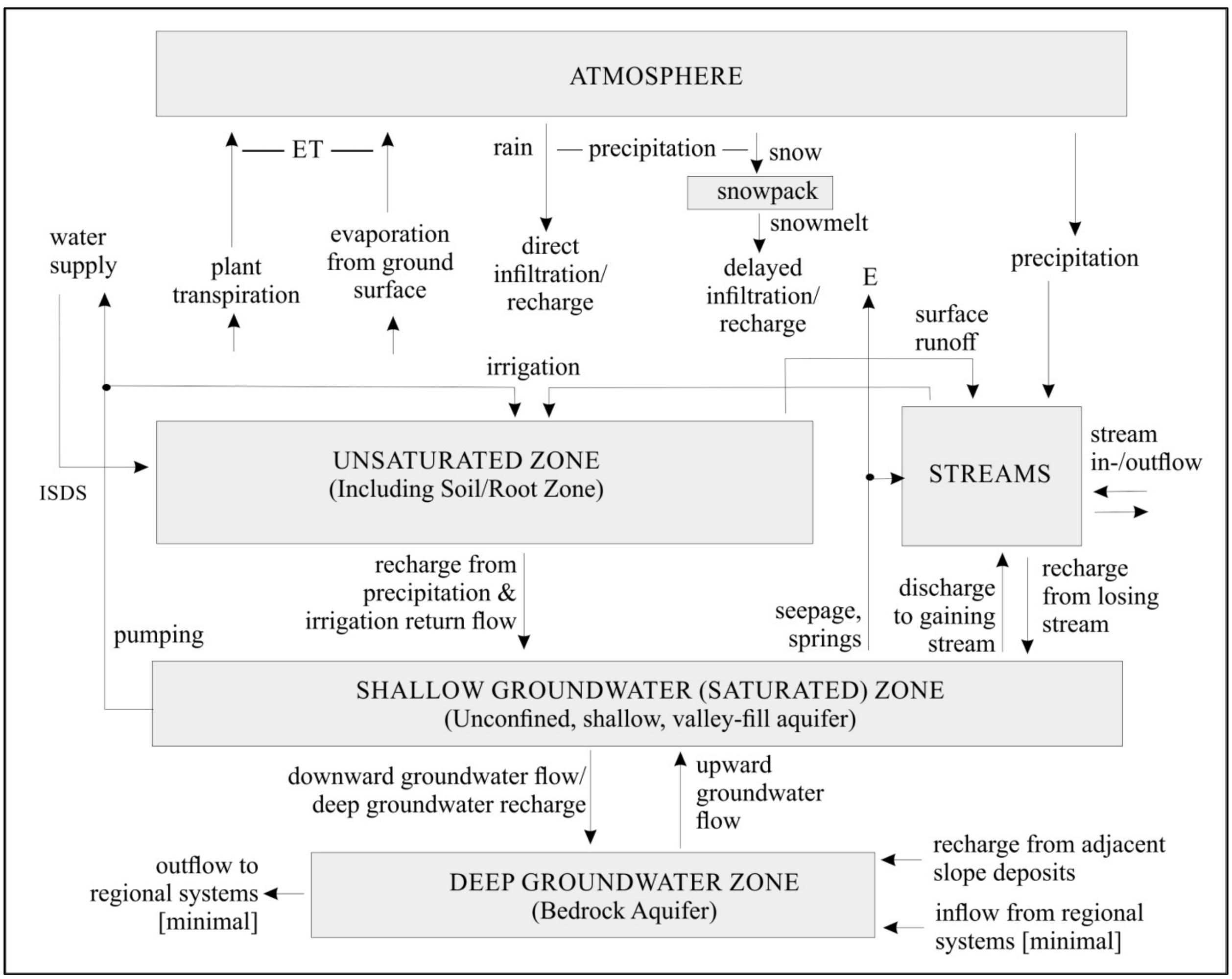

Figure 30. Generalized Hydrologic System Components and Processes.

(in/yr), spring discharge (gpm), groundwater discharge to/recharge from streams (ft^3/d/ft'), and well discharge (gpm). It should be noted that many of the processes are difficult to measure or estimate and introduce significant uncertainty in water budget calculations when used.

Often, to get a better understanding of the water budget components and reduce uncertainty, the complex set of hydrologic units and processes shown in Figure 30 is replaced a subset of units and processes by a single inflow/outflow flux. For example, a water budget may focus on surface water and its interaction with the atmosphere. In that case, the subsurface units and processes, depicted in Figure 30 as the unsaturated zone, the shallow groundwater (saturated zone), and deep groundwater zone (bedrock) and related processes, would be represented by a single gain or loss flux. In the same fashion, a focus on the groundwater system may replace the atmosphere, streams, and unsaturated zone by inputs and outputs only, and any change in storage would be limited the shallow and deep aquifers.

The Conceptual Site Models resulting from the HESA of the TCV study area, together with the location of the Castle Creek stream flow gages, provided guidance on how to simplify the complex hydrologic system components and process illustrated in Figure 30 to develop a preliminary water budget for Castle Valley.

3.2 Preliminary Water Balance for the TCV Project Area

A preliminary water balance (PWB) for the (TCV) project area has been calculated based upon the information previously collected and analyzed by Ford (2006), and the HESA-based conceptual model determined as part of this study. The area in Castle Valley of the water balance is determined in part based upon the locations of two USGS stream gages on Castle Creek, the location of most anthropogenic activities (domestic and agricultural), and the natural boundaries of the TCV hydrologic systems (lower Castle Creek and Placer Creek Hillslope and Valley Bottom Subsystems which merge in the northwestern part of Castle Valley under the Town of Castle Valley) (Figure 31). The water balance area is from Cross-section B-B' in the southeastern part of Castle Valley, to the Castle Creek exit in the northwestern part of Castle Valley, and extends to the Porcupine Rim to the southwest and to the Castle Spires Rim to the northeast (Figure 31).

The inputs of the PWB are: Castle Creek surface water at Castleton, UT; Castle Creek Subsystem groundwater flux flowing in the unconsolidated hydrogeologic units (Qaf) from the southeast; Placer Creek subsystem groundwater flux flowing in the unconsolidated hydrogeologic units (Qaf) and Tertiary Geyser Creek hydrogeologic unit (Tg); and recharge by infiltration of precipitation (rain and snow) across the entire Castle Valley area. The outputs of the PWB are: Castle Creek at the northwestern end of Castle Valley; Evapotranspiration by native Phreatophytes (Cottonwoods and Willows); and Consumptive Use by irrigation and domestic wells. Figure 32 shows a diagrammatic representation of the water budget components. It should be noted that the groundwater inflow components "irrigation return flow" and "septic tank leach field infiltration" shown in Figure 32 are considered small enough not to be taken into consideration for the PWB; all terms on the left side except "stream flow" are considered consumptive use.

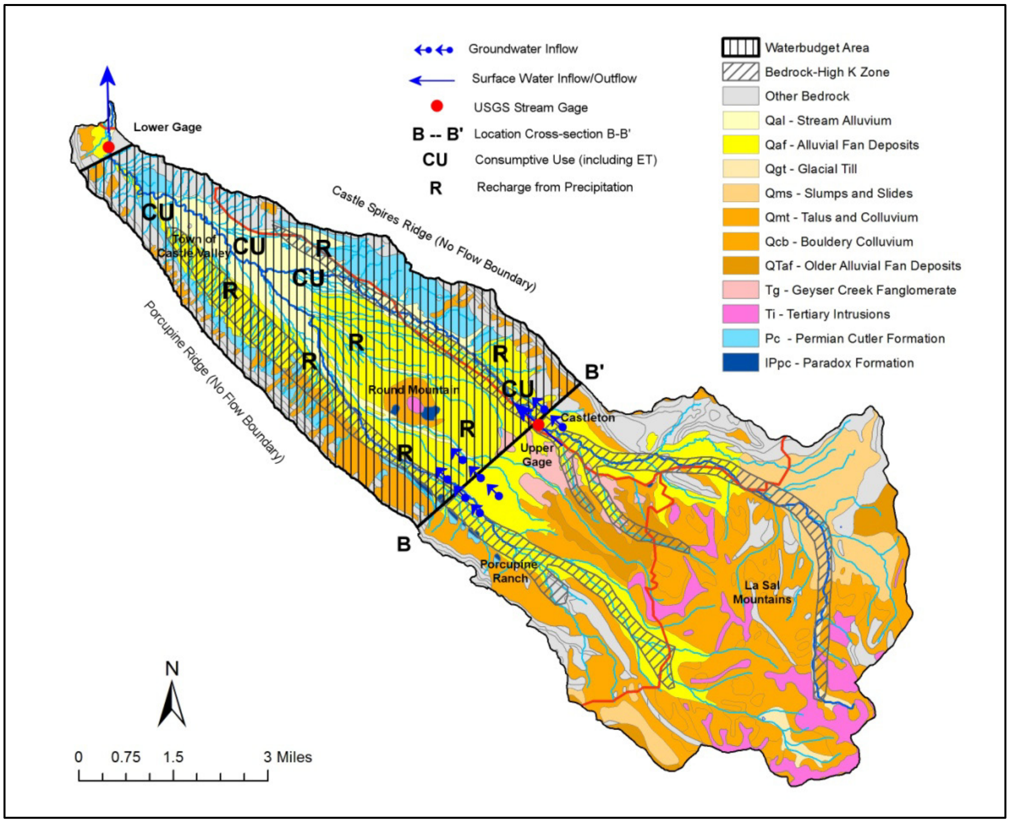

Figure 31. Map Showing the Location of Preliminary Water Balance (PWB) Area with Inputs and Outputs. Based on the Conceptual Site Models in the TCV Area and locations of Stream Gages.

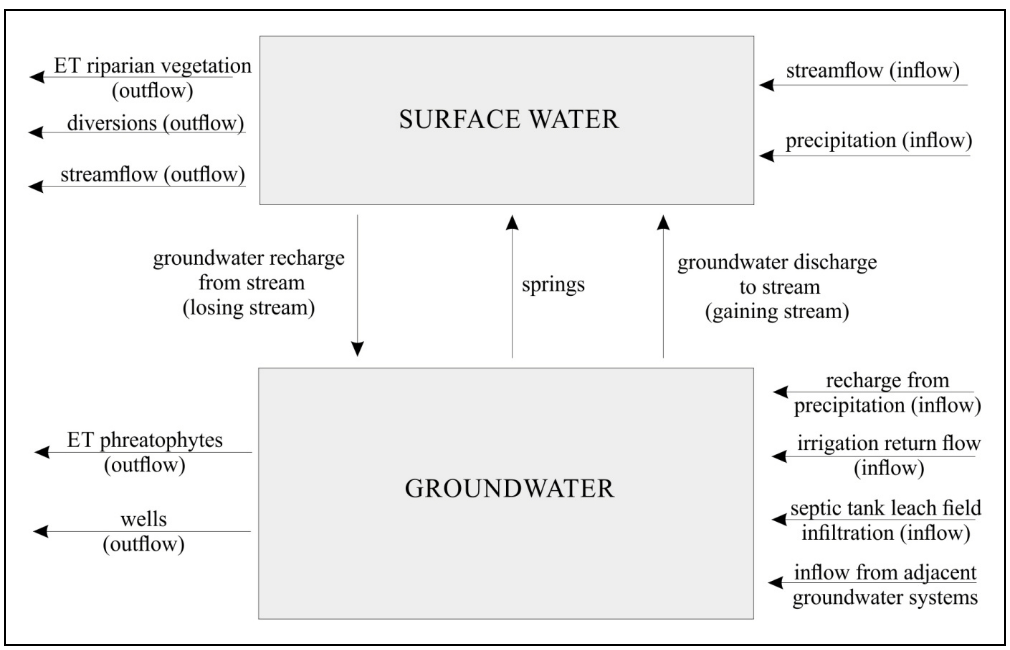

Fig 32. Inflows and Outflows of the Simplified Water Balance Calculation for the TCV Study Area.

A starting point for determining the PWB is the report by Ford (2006) which includes a section on the water budget for the valley. Ford (2006) specifically addresses stream flows and quantification of consumptive use, including domestic (wells) and irrigation (stream diversions) water use, and water loss through riparian vegetation (evapotranspiration – ET). For stream inflow and outflow Ford (2006) uses USGS Station 09182200 below Castleton (upper gage; inflow) and USGS Station 09182400 between Red Cliffs Ranch and the Colorado River (lower gage; outflow). The stage and discharge records for Station 09182200 cover the period 1992 - 2001, and the records for Station 09182400 cover the period 1992-present. For calculation of a multi-year average for both stations, Ford (2006) selected the period 1992-1998, resulting in an average discharge at Station 09182200 of 3.48 cfs or 2,521 ac-ft/yr, and at Station 09182400 of 7.00 cfs or 5,071 ac-ft/yr. Ford (2006) reported a total consumptive use in the valley (irrigated crops, ET from riparian vegetation, and domestic wells) of 1,748 ac-ft/yr. Balancing these inflows (2,521 ac-ft/yr) and outflows (6,819 ac-ft/yr) indicates that 4,298 ac-ft/yr enters the valley as groundwater and effective precipitation (primarily groundwater recharge).

To further analyze the groundwater inflow and groundwater recharge components, several PWB scenarios were calculated for the in Figure 31 shown water budget area, varying the saturated thickness and water table levels of the Placer Creek and Castle Creek groundwater boundary conditions. In addition, groundwater recharge due to infiltration of precipitation was varied. The PWB used calculations by Ford (2006) for consumptive use, and the data for Castle Creek surface water in, and Castle Creek surface water out.

The basis for the calculation of groundwater recharge due to infiltration of precipitation (rain and snow), and infiltration along ephemeral stream channels during flooding events was generalized as to spatial location, and spatially distributed across the entire 16,000 acres of the Qal/Qaf surface area between B-B' in the southeast and the valley exit of Castle Creek in the northwest. Three calculations were completed: Recharge of 1.4 in/yr (roughly 10% of precipitation, a common estimate in groundwater modeling for these environments) or a total of 1,867 ac-ft/yr; 2.0 in/yr or a total of 2,667 ace-ft/yr; and 3.0 in/yr or a total of 4,000ac-ft/yr. This would leave the remaining groundwater input as flux across the cross-sectional area of B-B' as: 2,368 ac-ft/yr; 1,568 ac-ft/yr; and 235 ac-ft/yr, respectively. Given these calculations, the range of recharge rates of 1-2 in/yr is most likely and commonly observed in other areas of similar climates and hydrogeologic materials.

The basis for the calculation of groundwater flux across the southeast part of the PWB area (B-B' in Figure 31) is Darcy's Law:

$$Q = KIA;$$

where Q is discharge per unit time; K is hydraulic conductivity of the Hydrogeologic Unit; I is dH/dL or hydraulic gradient (change in head H over a distance L); and A is cross-sectional area. Q will be the groundwater input/inflow into the water budget that is derived from the La Sal Mountain subsystem (Section 2.6.1). K is determined by aquifer tests, which reveal a range of values from approximately 1 – 10 ft/day (*Lowe and others, 2004*). Hydraulic gradient was determined using the potentiometric surface map of Snyder (1996) to be 0.0322 (Figure 27).

The cross-sectional area used to calculate flux was estimated from cross-section B –B' (modified from *Lowe and others, 2004*), and primarily focused on the Qal/Qaf hydrogeologic unit (Figure 33). The cross-sectional area of the Placer Creek subsystem was the sum of the total cross-sectional area (total depth times surface length of two distinct areas) minus the shallow unsaturated cross-sectional area (top 100 ft times surface length based on depth to water table) . The well logs (available from the Utah Division of Water Rights web site) show that the water table at cross-section B-B' is approximately 100 ft below the land surface. The Placer Creek Qal/Qaf saturated cross-sectional area was calculated to be 1,399,617 sq.ft.

The cross-sectional area of the Castle Creek subsystem was the sum of the total cross-sectional area (total depth times surface length of one distinct area) minus the shallow unsaturated cross-sectional area (top 20 ft times surface length based on depth to water table) . Well logs in this area show that the water table is approximately 20 ft below the land surface. The Castle Creek Qal/Qaf saturated cross-sectional area was calculated to be 475,200 sq.ft.

Several PWB scenarios were calculated, first varying the K values between 1 and 10 ft per day; then varying the cross-sectional area values by 10%. The closest fit was using K values between 5 and 7 ft/day, which fit the aquifer test data closely, and cross-sectional areas about 10% less that estimated yielding 2,276 – 2,833 ac-ft/yr which centered on the 2,431 ac-ft/yr needed to balance the recharge value 1.4 in/yr (1,867 ac-ft/yr) across the project acreage. The Preliminary Water Budget results summarized: Surface water in (2,521 ac-ft/yr) + Recharge in (1,867 ac-ft/yr) + Groundwater in (2,431 ac-ft/yr) = Surface water out (5,071 ac-ft/yr) + Consumptive use out (1,748 ac-ft/yr) = Total Water Budget (6,819 ac-ft/yr).

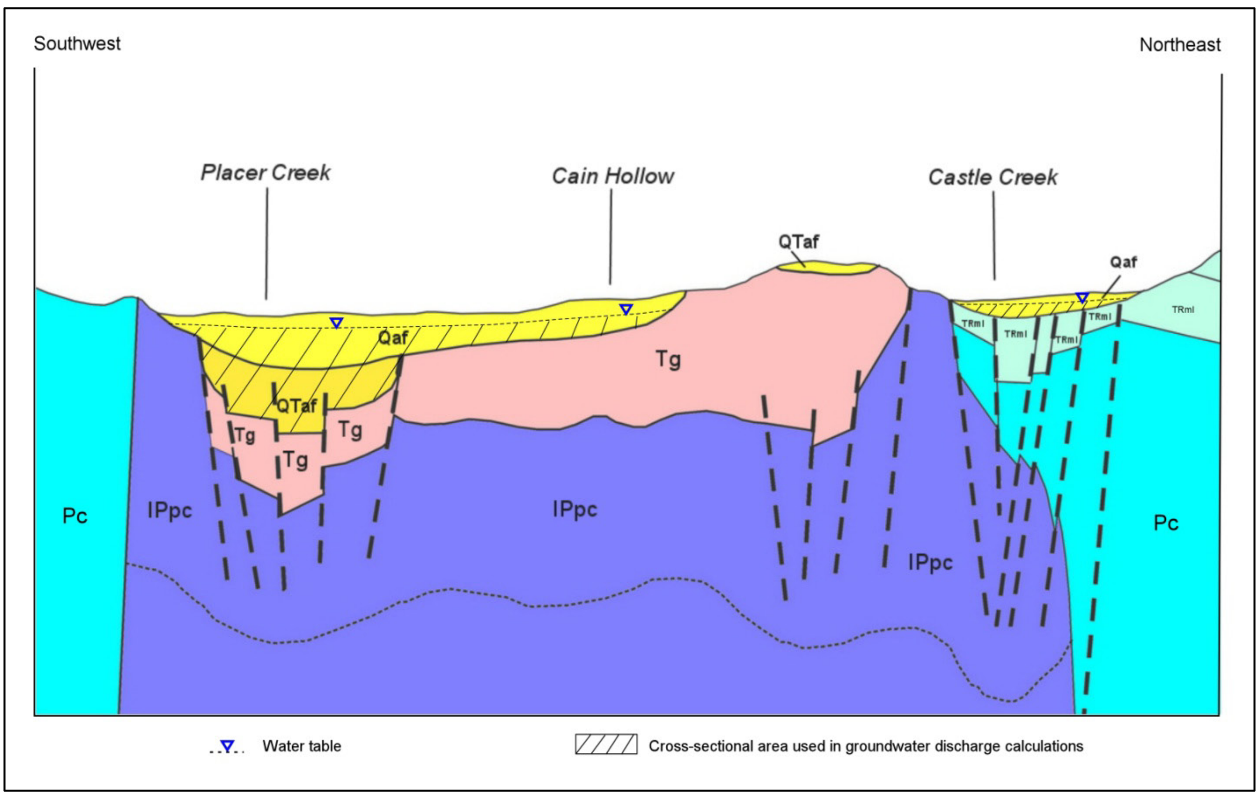

Figure 33. Detail of Cross–section B-B' Showing the Location of the Cross-sectional Southern Boundary Areas Used for Calculation of the Groundwater Inflow Component of the Preliminary Water Balance (PWB).

There are many uncertainties in these preliminary calculations, so further analysis is planned and needed. The primary significance of the PWB is that there is a significant amount of groundwater contributed to the Castle Creek and Placer Creek subsystems from the La Sal

Mountain subsystem, or in percentages of input into the Castle Valley system: surface water (Castle Creek) counts for 37%; local recharge from precipitation or ephemeral channel loss counts for 27%; and groundwater counts for 36%. This means that the La Sal Mountain subsystem contributes 72% of the total inflow in the PWB area.

The reduction of water contributions originating from the La Sal Mountain subsystem in amounts and timing of precipitation (rain and snowfall) and snowmelt resulting from climate change may have a significant impact on streamflows, groundwater recharge and subsurface inflow into the valley. In addition, water diversion projects to other watersheds, especially up-valley, will result in decreased surface water flows and groundwater recharge from losing streams. Impacts on the valley's water budget may also result from deforestation due to lumbering or fire (increased surface runoff and stream flows); increased forestation (increased ET; decrease of runoff and stream flows); and mining (increased or decreased stream flows and groundwater fluxes). Land use conversions/changes resulting in more or less consumptive uses need to be evaluated regarding the surface water output to Castle Creek at the northwest end of Castle Valley. Increased consumptive use would result from increased urbanization (more wells, non-native vegetation), or increased irrigation.

4 SUMMARY AND CONCLUSIONS

Under an agreement with Town of Castle Valley, Utah, Hydrologic Systems Analysis LLC (HSA) of Golden, Colorado, in conjunction with Heath Hydrology, Inc. (HHI) of Boulder, Colorado, was tasked: 1) to perform a Hydrologic and Environmental System Analysis (HESA) of the surface water and groundwater resources of the valleys and uplands of the Castle Creek Watershed and Castle Valley Groundwater Basin in the vicinity of the Town of Castle Valley in Grand County, Utah**;** 2) develop hydrological, hydrogeological and other data bases necessary for constructing a water budget for the Valley; and based on the HESA results and GIS databases developed: 3) develop an as-accurate-as-possible water budget for the Valley in support of watershed management issues including water supply and allocation, water quality and protection, and watershed protection; and 4) determine the siting and protecting of a municipal well and a shallow well(s) near the Castle Valley Ditch Co. diversion to augment surface flows in Castle Creek and irrigation ditches. Each of these tasks constitutes a phase of the project. This report contains the results of phase 1, Hydrologic and Environmental System Analysis (HESA) and includes a preliminary water budget analysis.

The HESA showed that there are two significant groups of hydrogeologic units in the TCV study area: 1) Quaternary and Tertiary unconsolidated clastic materials, overlying 2) Tertiary, Mesozoic and Paleozoic bedrock units. Potentially water-bearing units include: 1) unconsolidated clastic materials; 2) weakly-cemented Tertiary Geyser Creek Fanglomerate: 3) faulted and fractured Tertiary Intrusive Granodiorite; and 4) White Rim and Arkosic Members of the Cutler Formation. The significant non-water bearing units or confining units, which may be a source of salts in the groundwater system and wells, are: 1) Triassic Chinle and Moenkopi Formations; 2) unfractured Permian Cutler Formation; and 3) Permian Paradox Formation including Caprock.

The Quaternary unconsolidated clastic units are locally heterogeneous, with predominantly coarser materials in the older alluvial deposits, and a mixture of coarser and finer materials in the younger deposits. These deposits, which are moderately to highly permeable, are recharged by infiltration from precipitation that is non-uniformly distributed due to the slope steepness, slope aspect, and to position in the landscape, by the incidental leaky irrigation ditch and irrigation return flow, and by flow in ephemeral stream channels and losing reaches in perennial streams where favorable. The unconsolidated units are variably to fully saturated, based on spatial location and seasonal precipitation events. There is lateral and vertical groundwater flow connection between the unconsolidated materials and the underlying bedrock formations that is critical for understanding the hydrologic systems and water quality of Castle Valley.

The thicknesses and subsurface distribution of these unconsolidated sediments range from less than 25 ft in the southeastern part of Castle Creek above Castleton and the southeastern part of Placer Creek above Porcupine Springs ranch to greater than 300 ft in the northern part of Castle Valley near Day Star Academy. The greatest thickness of the unconsolidated material is in the collapsed part of Castle Valley northwest of Round Mountain where average thicknesses ranging from 100 to 200 ft are common. The subsurface distribution of thickness is indicative of the structural collapse and faulting with subsequent erosion and filling of fault zones with gravels. Linear paleo-valleys and subsequent groundwater conduits are observed along: 1) the northeastern margin of the valley fill beneath the modern day Castle Creek from Castleton extending to Day Star Academy; and 2) the southwestern margin of the valley fill beneath the modern day Placer Creek from above the Porcupine Springs Ranch extending to beneath the Town of Castle Valley town hall to the northwest.

Geologic faults and fracture zones, sometimes expressed at the surface as lineaments or linear drainage segments, may influence the hydrogeology and hydrologic systems of Castle Valley, including the location of Castle Creek and Placer Creek. These hydrostructures underlie the drainages in the three bedrock hydrogeologic systems, and are most likely associated with preferential highly transmissive groundwater flow along fault and fracture zones that are observed or hypothesized to transmit groundwater either vertically or laterally along the fault or fracture planes or zones.

The main subregional fold and fault structure is the Castle Valley Salt Anticline with corresponding graben/collapse structure. The bounding faults of the collapse, located on the northeast and southwest sides of Castle Valley, dip almost vertically and strike from the southeast to the northwest. These two fault zones, when located in the White Rim and Arkosic Members of the Cutler Formation, are subregional hydrogeologic conduits or high hydraulic conductivity zones or High “K” zones. These conduits are continuous from the southeastern part to the northwestern part of Castle Valley and have high yields of groundwater with elevated TDS water quality. These hydrostructural units pinch out at either end of the valley and with depth, keeping the groundwater system local and discontinuous beyond the Castle Valley topographic feature. These hydrostructural units also block lateral flow perpendicular to the fault zone. Therefore, no deep regional groundwater is laterally entering or exiting Castle Valley from the northeast or the southwest. The termination of these hydrostructural units to the southeast and northwest also blocks lateral flow, so no deep groundwater is laterally entering or exiting Castle Valley from the southeast or the northwest. The entire valley is underlain by a deep “flat lying” caprock of the Paradox Formation, which is a confining unit that, when interacting with groundwater, produces poor water quality due to dissolution of the salt bedrock. Effectively, these hydrogeologic/hydrostructural units insure that the Castle Valley Bedrock groundwater flow system is entirely contained within the valley.

The Castle Valley Anticline/Graben also caused the younger bedrock hydrogeologic units being observed on the Porcupine and Castle Spires Rims, to dip away to the northeast, northwest, and southwest. This results in local and subregional groundwater and surface water systems that flow away from the Castle Valley rimlands into the La Sal Mountain/Spanish Valley systems, the Onion Creek/Professor Creek systems, or towards the Colorado River. The fault and fracture zones have influenced the location of the main surface water drainages in the TCV study area by providing zones of weakness whereby the streams have downcut into or through the unconsolidated deposits into the underlying bedrock. As a result, the TCV study area is dissected into two distinct surface water and groundwater hydrologic subsystems of varying connectivity: 1) Castle Creek; and 2) Placer Creek. Both subsystems are separated in the southeastern part of the Valley by a third subsystem, the La Sal Mountain subsystem, and become connected in the northwestern part of Castle Valley near the confluence of the two drainages.

In addition to the bounding faults of the Castle Valley Anticline/Graben, three groups of local hydrostructures occur in the TCV area: 1) the northeast-southwest trending faults and fractures that are radial to the main Castle Valley Anticline; 2) the northwest-southeast trending faults and fractures that are parallel to the main Castle Valley Anticline collapse structures; and 3) radial and concentric fractures associated with the Tertiary Intrusive rocks. The northwest-southeast trending drainages mirror the underlying faults and fracture zones that include the collapse structures located on the northeast and southwest sides of Castle Valley, and the underlying faults and fracture zones that are parallel to these bounding structures. These structures are open, and function as groundwater conduits in bedrock, and paleo-valley groundwater conduits in unconsolidated materials. By comparison, the northeast-southwest trending drainages/fracture zones control most of the steep drainages on the flanks of the Castle Valley rimlands. These drainages are mostly ephemeral, and their main hydrologic function is delivering surface water down into the valley floor drainages.

The radial and concentric fracture pattern surrounding the La Sal Mountain intrusions control the surface water drainages, and are open, therefore, supporting “French-drain” bedrock groundwater systems in the Tertiary Intrusive bedrock, and focusing groundwater towards drainages in the Tertiary Geyser Creek fanglomerate locally. This includes the minor drainages around Round Mountain, and the drainages in the southeastern part of the study area including the northern flanks of the La Sal Mountain systems where Placer Creek and Castle Creek originate. In the Tertiary intrusive rocks, groundwater moves laterally down valley and vertically downward along these radial fault and fracture zone planes, and may move vertically up along the fault and fractures plane near the lower reaches of the various drainages as evidenced by gaining reaches in streams, and by the springs that are the origin of Castle Creek and Placer Creek tributaries.

Based on the HESA approach, and on the presence and orientation of various hydrogeologic and hydro-structural units, hydrography and topography, two types of Conceptual Site Models (CSMs) are delineated in the TCV study area: 1) La Sal Mountain Subsystem; and 2) Castle Creek and Placer Creek Hillslope and Valley Bottom Shallow Aquifer Subsystems. The La Sal Mountain Subsystem, which includes the Tertiary Intrusive Granodiorite and Tertiary Geyser Creek Fanglomerate bedrock hydrogeologic units and is located in the southeastern part of the study area, is a complex mix of bedrock and unconsolidated deposits, which form a robust groundwater system that is directly connected to the surface water systems forming the headwaters of Castle and Placer Creeks. The top of this subsystem is directly hydraulically connected to Mesa Top subsystems not located in the TCV study area, and the bottom of this subsystem is directly hydraulically connected to the Castle Creek and Placer Creek Hillslope and Valley Bottom Subsystems in the TCV study area. In addition to the hydrogeological units, there are two types of geological structures of significance to the hydrogeology in the La Sal Mountain Subsystem: 1) Northwest-southeast trending fault/fracture zone hydrostructures (southeastern extent of the high K zones of Castle Valley) dipping vertically; and 2) Radial and concentric fault/fracture zone hydrostructures that are observed radiating out from and surrounding the Tertiary intrusions and dissecting the Tertiary Geyser Creek unit.

The shallow groundwater in the La Sal Mountain Subsystem is dominated by the Quaternary deposits, which receive natural recharge by infiltration of precipitation (snow and rain); input from hillside (slope) deposits located upgradient from a given location; and input from the two bedrock aquifers: 1) the Geyser Creek Fanglomerate, and the Tertiary Intrusive units. Groundwater flow in the La Sal Mountains unconsolidated materials is with topography from hilltop and ridgetop down the hillslope to the valley bottom, and then parallel with the valley bottom stream. Groundwater in the valley bottom stream units moves in the same direction as the stream with various stream reaches being gaining or losing depending on subsurface topography, saturated thickness of the alluvium, or the seasonal variations caused by snowpack runoff or storm events. These streams are the headwaters of Castle Creek and Placer Creek tributaries, and most reaches are gaining from the alluvial and bedrock aquifers. There is also groundwater discharge from the alluvium locally by groundwater wells and by phreatophytes. Given the granodiorite composition of bedrock, the natural water quality is good except where mining activity has been undertaken. Groundwater recharge also occurs on the hills and ridges where the Tertiary Geyser Creek Fanglomerate units are exposed. Groundwater then flows downgradient with topography towards the Castle Creek and Placer Creek Hillslope and Valley Bottom Subsystems.

The two dominant hydrogeologic features of the Castle Creek and Placer Creek Hillslope and Valley Bottom Subsystems are the highly-permeable unconsolidated hydro-units in the center of the valley, and the northwest-southeast trending high K hydrostructures that are observed on both the northeastern and southwestern sides of Castle Valley. The Castle and Placer Creek Subsystems receive natural recharge by infiltration of precipitation (snow and rain); losing perennial streams; input from hillside (slope) deposits and fracture-controlled ephemeral stream channels and deposits. Additional recharge occurs locally from irrigation practices and septic sewer system infiltration. Discharge from the groundwater system occurs downgradient towards gaining streams, springs, seeps, wetlands, phreatophytes, and by wells.

Groundwater flow in the Castle Creek alluvium moves in the same direction as the stream with various stream reaches being gaining or losing depending on subsurface topography, bedrock hydrogeology, hydrostructures, and saturated thickness of the alluvium, or the seasonal variations caused by snowpack runoff or storm events. Groundwater flow in the Placer Creek alluvium also moves in the same direction as the stream, but with most of the stream reaches being losing when surface water flow occurs. There is also groundwater discharge from the alluvium locally by groundwater wells and by phreatophytes in both subsystems.

Underlying both the northeastern and the southwestern sides of Castle Valley are northwestern-southeastern hydrostructures that act as open vertical and horizontal conduits (high K zones). At the northeastern side the faulted and fractured Permian Cutler bedrock combines with the alluvium to form a French Drain effect resulting in increased groundwater flow parallel to the fault and fracture zone, storage, and connectivity between the two hydrologic systems. At the southeastern side the faulted and fractured Permian Cutler bedrock combines with both the alluvium and the alluvial fans to form the same type of French Drain effect as on the Castle Creek side. The fractured and faulted Permian Cutler bedrock aquifers are variably to fully saturated, based on location and proximity to recharge area. In the Castle Creek Subsystem, groundwater recharge by losing stream reaches and infiltration of precipitation is possible only by connection to the Castle Creek fault and fracture zone, and by the northeast-southwest fault and fractures that control drainages below the Castle Spires Rim. In the Placer Creek Subsystem, groundwater recharge is by losing stream reaches when flowing, and infiltration of precipitation is possible only by connection to the Placer Creek fault and fracture zone, and by the northeast-southwest fault and fractures that control drainages below the Porcupine Rim. In both systems groundwater flow direction is from southeast to northwest parallel to the Castle Valley salt anticline collapse structures and Placer Creek. These high K zone flow systems end at the northwest end of Castle Valley, where the groundwater moves vertically upward into the alluvium and ultimately discharges into springs and seeps and into Castle Creek, or is transpired by phreatophytes.

The HESA evaluation of the TCV hydrologic systems was used for assessing the vulnerability of groundwater and surface water to contaminants in both the natural and anthropogenic environment. The Permian Cutler Group and Pennsylvanian Paradox Formation hydrogeologic units are the main source in Castle Valley for naturally occurring salt in a chemically soluble form. The faulted and fractured Cutler Group, referred to as the high K zones located under Castle Creek and Placer Creek, allow large quantities of groundwater to flow through these conduits where large quantities of soluble salt are incorporated into the groundwater flow system. These salts are then transported in the groundwater and/or surface water to exposure sites such as wells, ponds, and surface water bodies like Castle Creek.

The hydrologic system of the steep Porcupine Rim and Castle Spires Rim Hillslope Subsystems is surface water in fracture-controlled channels, and overland and interflow from precipitation that rapidly runs off the steep hillslopes until flowing across or through the Quaternary and/or Tertiary unconsolidated hydrogeologic units, where the water quickly disappears into the aquifer as groundwater recharge. In the process of channeled surface water, or overland and interflow, soluble salts in the bedrock are incorporated into the surface water and near surface water to be transported into the unconsolidated deposits aquifers. The fringes of these aquifers would have higher TDS than the central parts of these aquifers in the main valley. The natural pollutants that are most likely occurring include salts (carbonates and sulfates), and the most likely source of these pollutants is the weathered zone of the older bedrock upgradient. The anthropogenic pollutant sources to the Hillslope and Valley Bottom subsystems are mostly fertilizers for grass (urban) or crops, industrial pollutants (local garages, for example), or rural septic tank waste. Most of these are organics and nutrients, and would need to be monitored accordingly.

A preliminary water balance (PWB) for the (TCV) project area has been calculated based upon the calculations previously published by various authors and the HESA-based conceptual model determined as part of this study. The area in Castle Valley of the water balance is determined in part based upon the locations of two stream gages on Castle Creek, the location of most anthropogenic activities (domestic and agricultural), and the natural boundaries of the TCV hydrologic systems, specifically the lower Castle Creek and Placer Creek Hillslope and Valley Bottom Subsystems that merge in the northwestern part of Castle Valley. The water balance area is from a cross-sectional boundary in the southeastern part of Castle Valley linking Castleton to the Porcupine Ranch, to the Castle Creek exit in the northwestern part of Castle Valley, and extends to the Porcupine Rim to the southwest and to the Castle Spires Rim to the northeast. The inputs of the PWB are: Castle Creek surface water at Castleton, UT; Castle Creek Subsystem groundwater flux flowing in the unconsolidated hydrogeologic units from the southeast; Placer Creek subsystem groundwater flux flowing in the unconsolidated hydrogeologic units and Tertiary Geyser Creek hydrogeologic unit; and recharge by infiltration of precipitation (rain and snow) across the entire Castle Valley area. The outputs of the PWB are: Castle Creek at the northwestern end of Castle Valley; Evapotranspiration by native Phreatophytes (Cottonwoods and Willows); and Consumptive Use by irrigation and domestic wells.

Balancing the published inflows (2,521 ac-ft/yr) and outflows (6,819 ac-ft/yr) indicates that 4,298 ac-ft/yr enters the valley as groundwater and effective precipitation (primarily groundwater recharge). A first approximation of the recharge from precipitation in the water balance area using 1.4 in/yr (roughly 10% of precipitation, a common estimate in groundwater modeling for these environments) over 16,000 acres of surface area results in a total of 1,867 ac-ft/yr. This would leave the remaining groundwater input at 2,432 ac-ft/yr. Calculation of groundwater flux across the southeast part of the water balance area using Darcy's Law yields 2,276 to 2,833 ac-ft/yr, which centered on the 2,431 ac-ft/yr. The Preliminary Water Budget results summarized: Surface water in (2,521 ac-ft/yr) + Recharge in (1,867 ac-ft/yr) + Groundwater in (2,431 ac-ft/yr) = Surface water out (5,071 ac-ft/yr) + Consumptive use out (1,748 ac-ft/yr) = Total Water Budget (6,819 ac-ft/yr).

The reduction of water contributions originating from the La Sal Mountain subsystem in amounts and timing of precipitation (rain and snowfall) and snowmelt resulting from climate change may have a significant impact on streamflows, groundwater recharge and subsurface inflow into the valley. In addition, water diversion projects to other watersheds, especially up-valley, will result in decreased surface water flows and groundwater recharge from losing streams. Impacts on the valley's water budget may also result from deforestation due to lumbering or fire (increased surface runoff and stream flows); increased forestation (increased ET; decrease of runoff and stream flows); and mining (increased or decreased stream flows and groundwater fluxes). Land use conversions/changes resulting in more or less consumptive uses need to be evaluated regarding the surface water output to Castle Creek at the northwest end of Castle Valley. Increased consumptive use would result from increased urbanization (more wells, non-native vegetation), or increased irrigation.

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Appendix WC-6

HYDROLOGIC ASSESSMENT OF THE SURFACE WATER AND GROUNDWATER RESOURCES OF CASTLE VALLEY, UTAH: PART 2: HESA-BASED SITING OF CULINERY WELL FOR TOWN OF CASTLE VALLEY

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Prepared For:
Town of Castle Valley, Utah

December 2016

Front Page: Town of Castle Valley, Utah (November 2013)

Table of Contents

List of Figures

1 INTRODUCTION

Under an agreement with Town of Castle Valley, Utah, Hydrologic Systems Analysis LLC (HSA) of Golden, Colorado, in conjunction with Heath Hydrology, Inc. (HHI) of Boulder, Colorado, was tasked: 1) to perform a Hydrologic and Environmental System Analysis (HESA) of the surface water and groundwater resources of the valleys and uplands of the Castle Creek Watershed in the vicinity of the Town of Castle Valley in Grand County, Utah**;** 2) to collect climate, hydrological, and other data necessary for constructing a water budget for the lower section of the Valley in the vicinity of the Town of Castle Valley, and to develop such water budget; and 3) to determine the siting of a town well for culinary water supply and fire protection application. The first two tasks were reported in: The report "*Hydrologic Assessment of the Surface Water and Groundwater Resources of Castle Valley, Utah: Part 1: Hydrologic and Environmental System Analysis (HESA) and Preliminary Water Budget*" prepared by Dr. Kenneth E. Kolm, Hydrologic Systems Analysis, LLC., Golden, Colorado and Paul K.M. van der Heijde, Heath Hydrology, Inc., Boulder, Colorado for The Town of Castle Valley, Utah (March 2016). The current report presents the HESA/GIS - based siting considerations for a new Town of Castle Valley well.

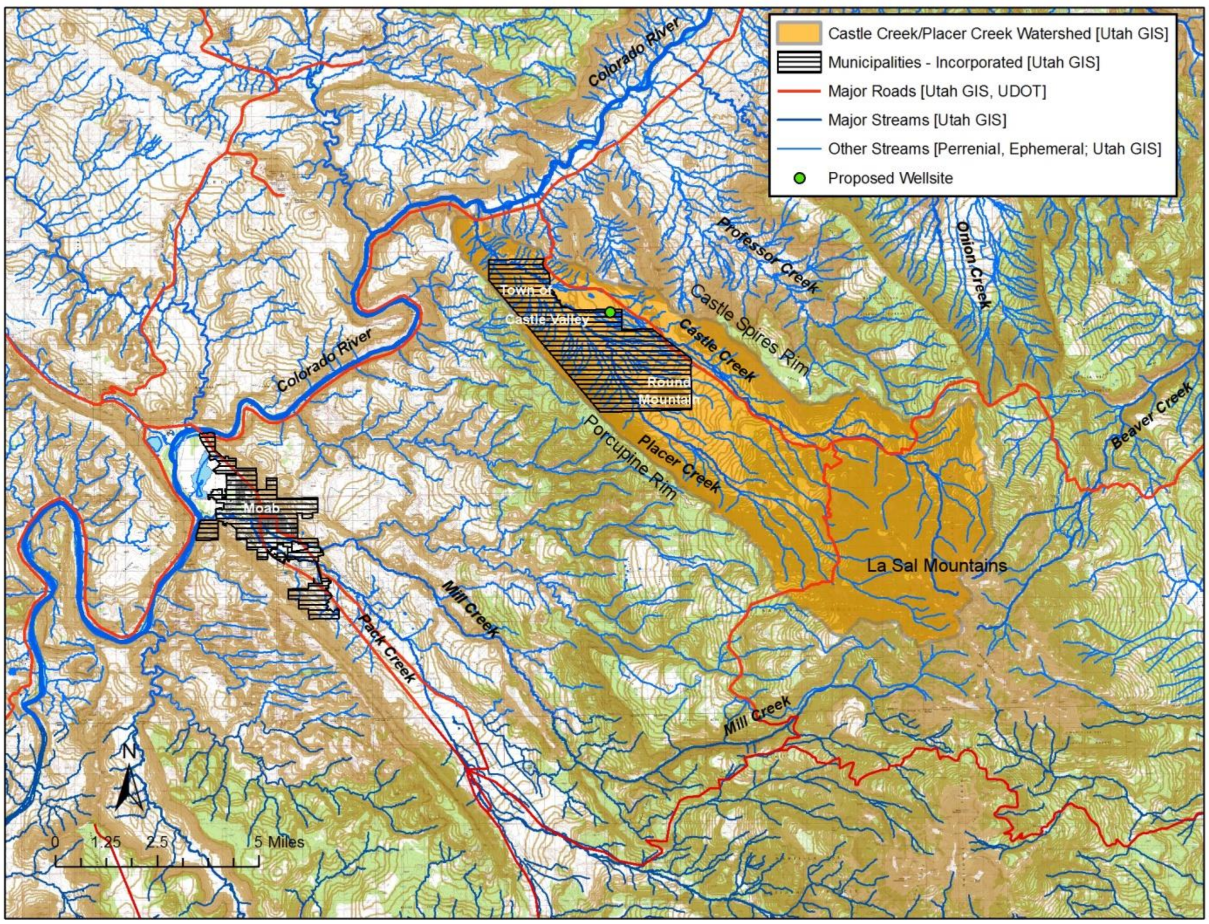

Figure 1. Topographic Map Showing the Locations of the Town of Castle Valley, the Castle Creek/Placer Creek Watershed, and the Proposed Well in a Regional Setting (Utah GIS, 2016).

Castle Valley is located between the La Sal Mountains to the south, the Colorado River to the north, the Porcupine Rim to the west, and the Castle Spires Rim to the east (Figure 1). The HESA performed under Task 1 distinguishes between 3 hydrologic entities: 1) the entire Castle Creek watershed (including Placer Creek drainage); 2) the lower Castle Valley hydrologic system (northwest of roughly a line from the Castleton area to the Porcupine Ranch); and 3) the Castle Valley Groundwater Basin (Quaternary and Tertiary sand and gravels, and underlying fractured bedrock). The lower Castle Valley hydrologic system is the setting for the preliminary water budget discussed in Kolm and van der Heijde (2016).

The siting of a Town well in the lower Castle Valley is based on the nature and extent of the major hydrogeological systems present; the surface water hydrology of the area; water resources-related land use considerations such as nearby irrigation, landfill disposal, septic tank locations, and domestic water wells; access during construction and (occasional) water utilization; and proximity to the Town jurisdictional areas and fire station. According to Town staff, the proposed well will provide backup water supply and additional fire protection use, and will not be part of a piped municipal water supply distribution system. The preferential site identified by Town staff is located at approximately 109°23'23.552"W and 38°38'37.515"N in the eastern part of parcel 090000367, located on the northeast side of the platted area just north of Castle Creek, within the incorporated area of the Valley (Figures 2 and 3). The study included a site visit together with Town staff.

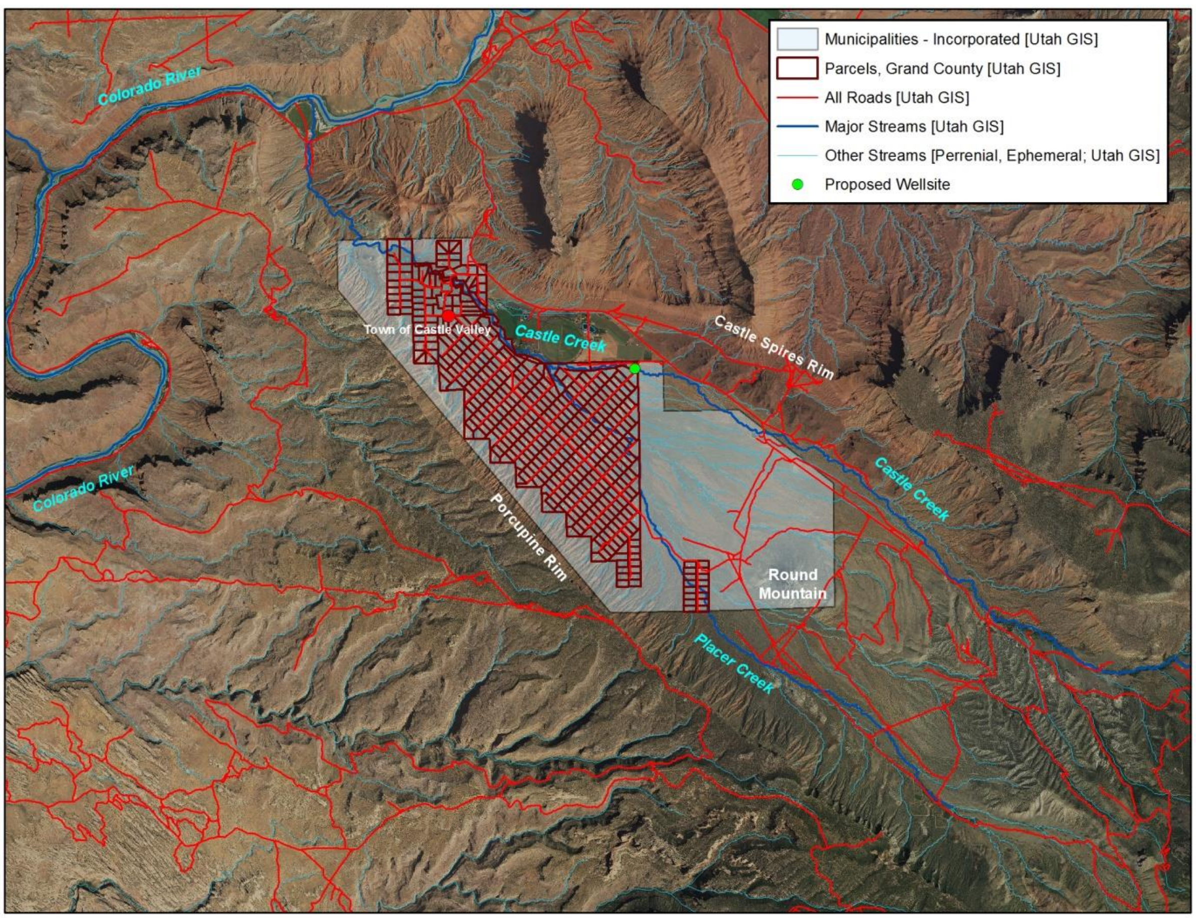

Figure 2. Ortho Image Showing the Locations of the Incorporated Area of the Town of Castle Valley, Parcels, and the Proposed Well (Utah GIS, 2016).

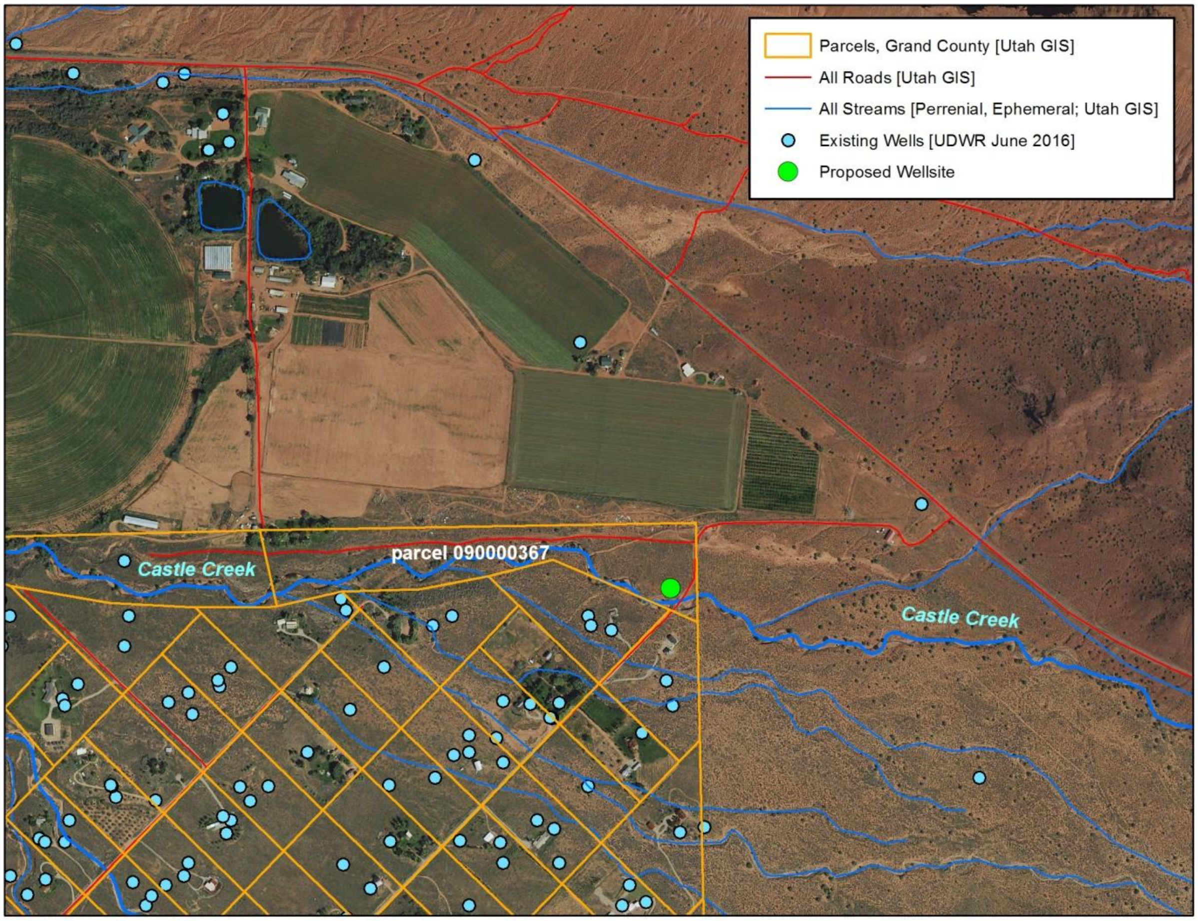

Figure 3. Ortho Image Showing the Locations of Parcels and the Proposed Well (Utah GIS, 2016).

2 HYDROLOGIC AND HYDROGEOLOGIC CONSIDERATIONS REGARDING LOCATION OF CASTLE VALLEY CULINARY WELL SITE

The proposed well site is located in the Castle Creek watershed, and is part of the lower Castle Valley Groundwater Basin composed of Quaternary and Tertiary sand and gravels, and underlying fractured bedrock (Figure 4). The site is located in the Stream Alluvium (Qal) hydrogeologic unit, possible underlain by other Quaternary unconsolidated sand and gravel units. The estimated thickness of the unconsolidated deposits at the well site is 300-350 ft (Figure 5). Neighboring well depths show a depth to water table of about 100 ft, therefore, the potential saturated thickness at the well site is approximately 200 – 250 ft.

The proposed well site is located on the edge of the Permian Cutler Bedrock High K Zone hydrostructure (Figure 4), which may increase its saturated thickness and yield, but may also decrease the water quality. Otherwise, the impermeable bedrock under the well site location is Permian Cutler Formation (Kolm and van der Heijde, 2016).

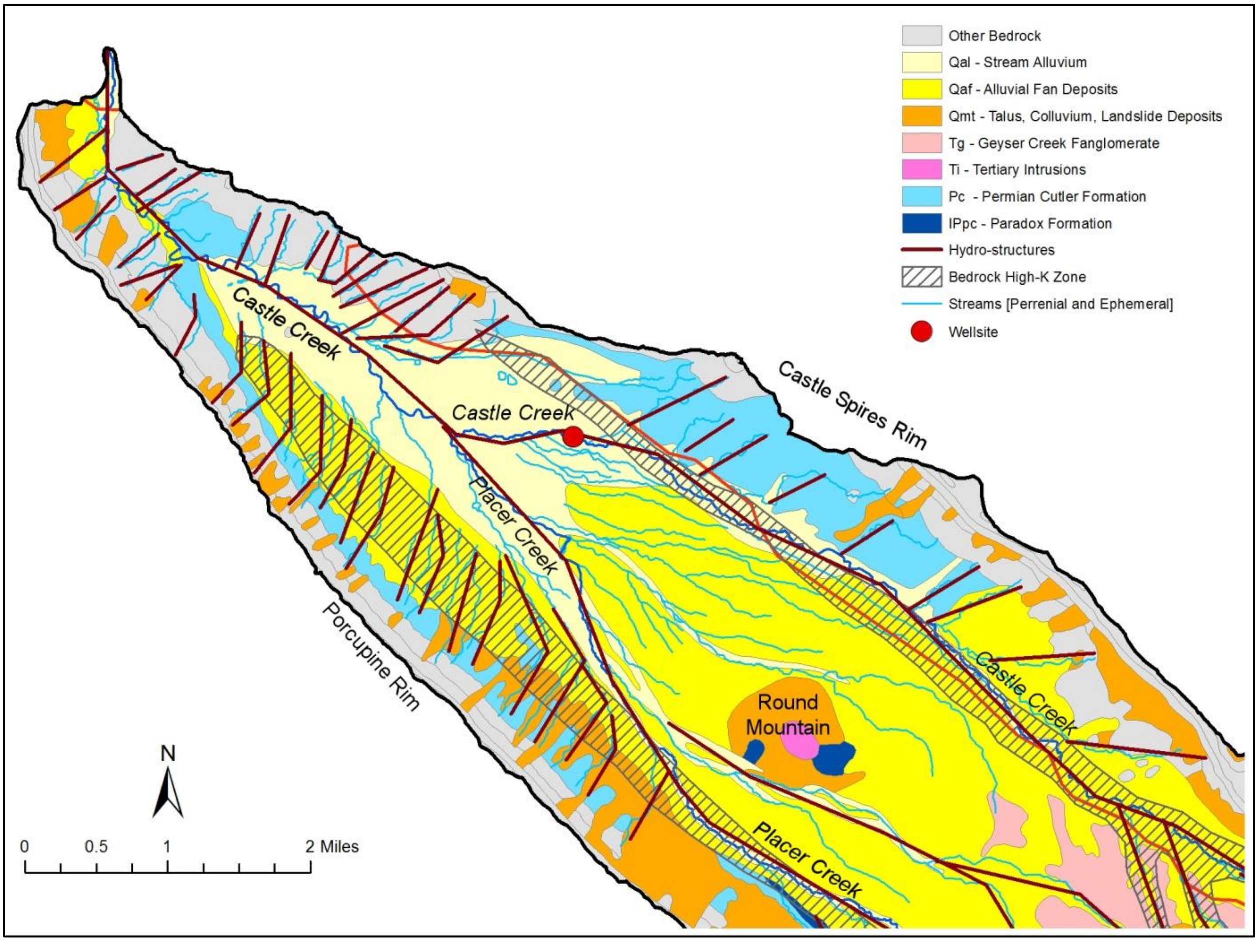

Figure 4. Map Showing Major Hydro-units and Hydro-structures (Faults and Fracture Zones) in the Lower Castle Valley Area (Detail; from Kolm and van der Heijde, 2016).

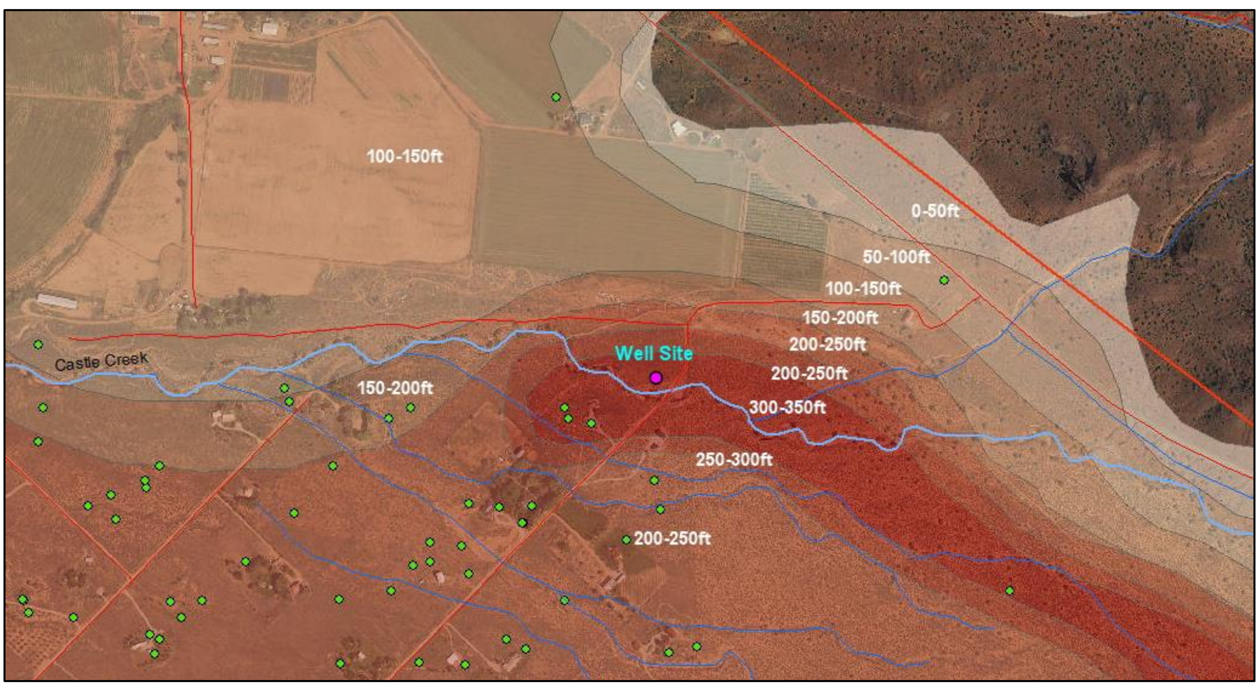

Figure 5. Map Showing the Location of the Proposed Well Site and Shallow Aquifer Thicknesses (After Kolm and van der Heijde, 2016).

According to Kolm and van der Heijde (2016), the proposed well location is in the Castle Creek Subsystem in the middle of the flow system where Castle Creek is a losing stream, and recharge (Rc) to the Quaternary gravels is occurring (Figures 6). Castle Creek in this area is 80-100ft above the water table and pumping at of a well at the proposed site location should not affect the stream (Castle Creek) since the stream and the groundwater systems are not connected.

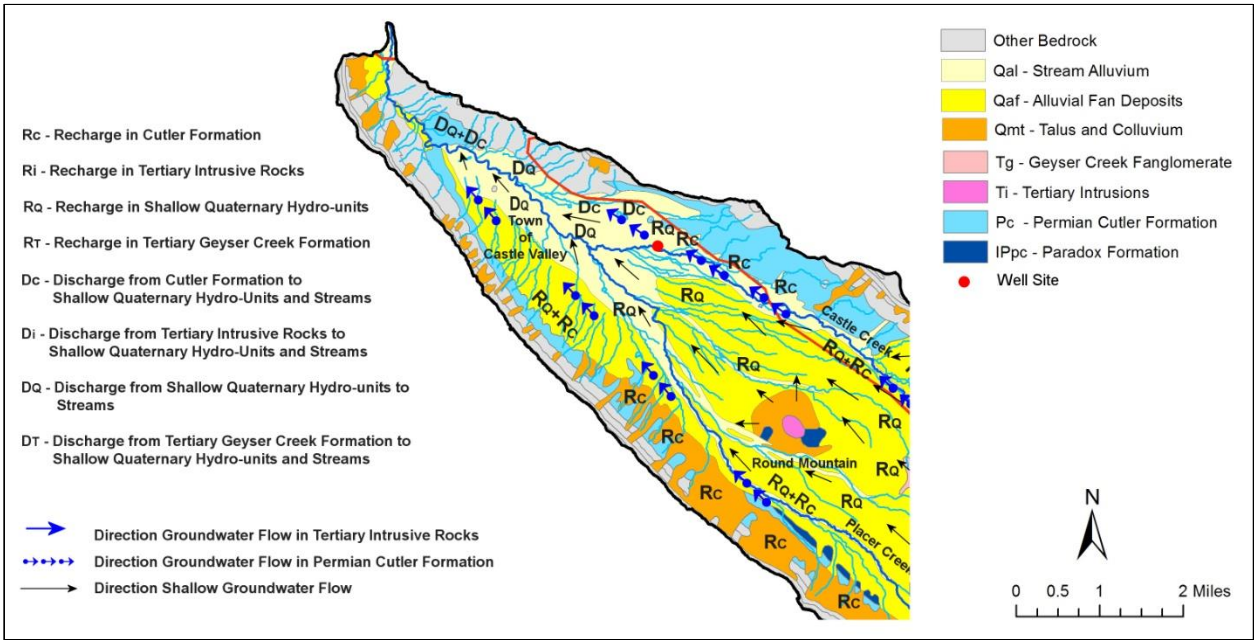

Figure 6. Recharge and Discharge Zones and Groundwater Flow Direction in Shallow Unconsolidated and Deep Bedrock Aquifers (Detail from Kolm and van der Heijde, 2016).

3 OTHER CONSIDERATIONS REGARDING LOCATION OF CASTLE VALLEY CULINARY WELL SITE

The water quality data indicate that regardless of the hydrogeologic framework configuration, good water quality of low TDS (251-500 mg/l) to slightly higher TDS (501-750 mg/l) water is expected in the vicinity of the proposed well site (Lowe and Others, 2004) (Figure 7). The proposed well site is located up gradient approximately 425 ft and 540 ft from the nearest well and septic sites, 115 ft from Castle Creek, which is a losing stream at this location, and over 375 ft from the nearest trash disposal site and irrigated lands, none of which are upgradient of the proposed well (Figure 8).

The proposed well is intended for domestic culinary supply and fire protection. The Town does not anticipate to operate the well as part of a conventional municipal distribution system, but to deliver water in 1,000 gallon loads once an hour (a rate that will hardly if ever actually occur) on an occasional basis. This means that the Town wants to be able to pump 50-100 gallons per minute for 10-20 minutes once every hour during the day from the proposed well. If the Town wants to be able to fill fire trucks quickly, then perhaps more pumping capacity may be needed, but it would only be used once in a great while. The Town does not anticipate to get into any arrangements where it is pumping from this well to supplement Castle Creek or enhance the green belt.

So, the worst case scenario is: 2,000 gal/hr for 24 hrs = 48,000 gal/day. If this pumping rate would be sustained for an entire year, it results in a consumptive use of 53.767 acre-ft/yr, which is far below the 2400 acre-ft/yr of groundwater coming into the Valley according to Kolm and van der Heijde (2016).

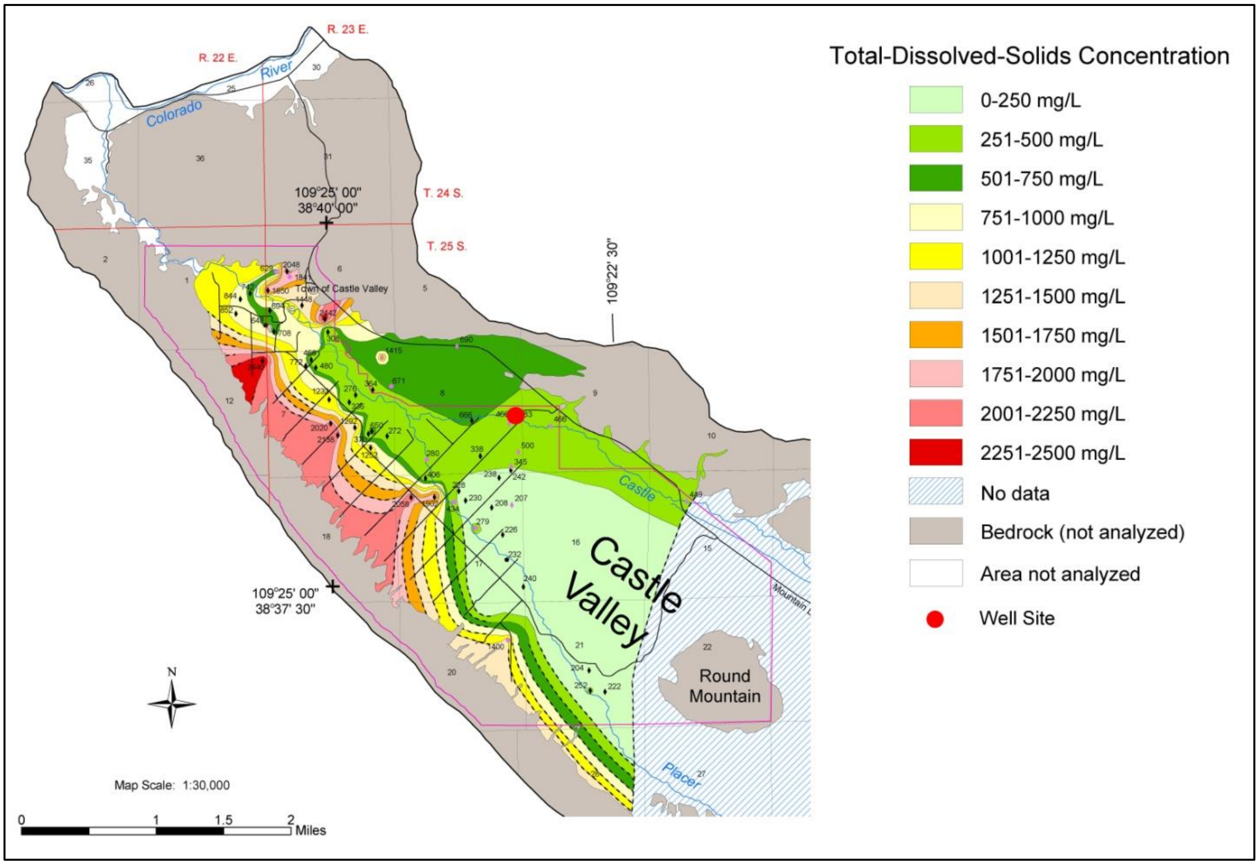

Figure 7. Total Dissolved Solids (TDS) of the Castle Valley Groundwater System (From Lowe and Others, 2004)

The next phase is for the Town of Castle Valley to complete a well design and aquifer test to determine the precise effects and yields of the new Town well at the recommended site location.

Figure 8. Map Showing the Location of the Town of Castle Valley Culinary Well Site Based on the HESA-Derived Castle Creek Subsystem and Preliminary Water Balances in the TCV Area.

4 SUMMARY AND CONCLUSIONS

Under an agreement with Town of Castle Valley, Utah, Hydrologic Systems Analysis LLC (HSA) of Golden, Colorado, in conjunction with Heath Hydrology, Inc. (HHI) of Boulder, Colorado, was tasked to perform a Hydrologic and Environmental System Analysis (HESA) of the surface water and groundwater resources of the valleys and uplands of the Castle Creek Watershed**;** 2) to collect climate, hydrological, and other data necessary for constructing a water budget for the lower section of the Valley in the vicinity of the Town of Castle Valley, and to develop such water budget; and 3) to determine the siting of a town well for culinary water supply and fire protection application. The first two tasks were reported in: The report "*Hydrologic Assessment of the Surface Water and Groundwater Resources of Castle Valley, Utah: Part 1: Hydrologic and Environmental System Analysis (HESA) and Preliminary Water Budget*" prepared by Dr. Kenneth E. Kolm, Hydrologic Systems Analysis, LLC., Golden, Colorado and Paul K.M. van der Heijde, Heath Hydrology, Inc., Boulder, Colorado for The Town of Castle Valley, Utah (March 2016). The current report presents the HESA/GIS - based siting considerations for a new Town of Castle Valley well.

Summary of the Town of Castle Valley municipal well site characteristics, based on the HESA-derived information (Kolm and van der Heijde, 2016) is as follows: 1) The well is located in the Stream Alluvium (Qal) hydrogeologic unit with a potential thickness of 300-350 ft. Neighboring well depths show a depth to water table of about 100 ft, therefore, the potential saturated thickness at the well site is approximately 200 – 250 ft; 2) The well site is located on the edge of the Permian Cutler Bedrock High K Zone hydrostructure, which may increase its saturated thickness and yield, but may also decrease the water quality. The impermeable bedrock under the well site locations is Permian Cutler Formation; 3) The water quality data indicate that regardless of the hydrogeologic framework configuration, good water quality of low TDS (251-500 mg/l) to slightly higher TDS (501-750 mg/l) water is expected; 4) The well site is in the Castle Creek Subsystem in the middle of the flow system where Castle Creek is a losing stream, and recharge to the Quaternary gravels is occurring. The pumping of the well at the site location should not affect the stream (Castle Creek) since the stream and the groundwater systems are not connected at this location; and 5) Human affects should be minimal since most of the neighboring well activity, irrigation, septic systems, and trash disposal are located downgradient from the proposed well site. The anticipated maximum well use is about 54 acre-ft/yr, well below the more than 2,400 acre-ft/yr of groundwater flowing into the Valley. The next phase is for the Town of Castle Valley to complete a well design and aquifer test to determine the precise effects and yields of the new Town well at the recommended site location.

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HYDROLOGIC ASSESSMENT OF THE SURFACE WATER AND GROUNDWATER RESOURCES OF CASTLE VALLEY, UTAH: PART 2: HYDROLOGIC AND ENVIRONMENTAL SYSTEM ANALYSIS (HESA) – BASED AQUIFER STORAGE

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Table of Contents

List of Tables

List of Figures

EXECUTIVE SUMMARY

This report presents the findings of Phase 2 of a 2-phase project focused on improving the understanding of the hydrogeological setting of the water supply sources for the Town of Castle Valley, Utah, the quantification of the water resources available to the Town, and updating the Town Water Balance with respect to new spring and stream flow data. In Phase 1, a Hydrologic and Environmental System Analysis (HESA) of the Castle Creek and Placer Creek watersheds was performed to identify the hydrological systems of specific importance to the sustainability of the Castle Valley springs and wells as water supply for the Town and Valley. It was concluded that the Valley's water supply was mainly dependent on the hydrologic system formed by the Castle Creek and Placer Creek Watershed and the Hillslope and Valley Bottom Shallow Aquifers and supporting hydrostructure aquifers on the Valley sides. This Valley hydrologic system was chosen for determining a water budget in Phase 1, and was chosen in Phase 2 of the project as the setting for the quantification of the water storage available to the Town and Valley.

Based on the HESA performed in Phase 1 of this study (Kolm and van der Heijde, 2016a), there are three areas (i.e., storage zones) important for groundwater storage calculations: 1) the Valley Fill Aquifer; 2) the Castle Creek Fracture Zone; and 3) the Placer Creek Fracture Zone. The Valley Fill Aquifer is mostly under unconfined or water table conditions and is characterized by specific yield estimates for unconsolidated sand and gravel deposits in the range 10 – 30%. Due to the extent and depth of these unconsolidated sediments, the Valley Fill Aquifer will be most important for estimating total groundwater storage and dynamic groundwater storage in the Castle Valley.

The Permian Cutler bedrock that underlies the rest of the Castle Valley predominantly has no significant flow or storage capabilities. However, the Castle Creek and the Placer Creek Fracture Zones are high K zones, and provide fracture storage up to 300 feet below the surface with an average effective depth of 200 – 230 feet (well log based) and a specific yield (Sy) range of 20% – 40% at the surface diminishing to close to 0% at 300 ft, amounting to an average Sy of about 20% taken over an average 150 ft of saturated thickness.

Each hydrogeologic zone had an estimated volume (GIS area multiplied by a representative average depth), and the storage zone volume was multiplied by the storage zone Sy to yield a hydrogeologic zone water content value. Only part of this total water storage is considered variable or recoverable storage; accessing additional storage is unsustainable and considered groundwater mining. A first approximation for variable storage used in this Phase 2 report is 10% of total water content. The calculations show that the total average water volume of the Valley Fill Aquifer is in the range of 42,160-126,490 ac-ft while the average variable or "dynamic" storage ranges between 4,220-ac-ft, and 12,650 ac-ft. The average water volume for the two fracture zones together is estimated at 112,800 acre-ft with a variable or dynamic storage of 11,280 ac-ft. Average ground water content for the entire TCV hydrologic system is estimated between 154,960 ac-ft and 293,290 ac-ft with a variable water storage between 15,500 and 23,930 ac-ft.

It should be cautioned that groundwater storage or the presence of an underground water reservoir is primarily a measure of how robust and sustainable the TCV hydrologic system is under the current climatic and human use conditions. If the reservoir is significantly reduced by aquifer development, the hydraulics of the system will be affected initially by stream flows (riparian habitat both aquatic and vegetation), and by a rapid reduction of spring flows and well yields. In addition, the effects of reduced stream flows in Castle Creek and Placer Creek through diversion or climate change will rapidly affect the recharge and storage functions of the storage zones forming the Castle Creek groundwater system, which are critical to Castle Valley Springs, and the Town of Castle Valley Wells.

1 INTRODUCTION

This report presents the findings of Phase 2 of a 2-phase project focused on improving the understanding of the hydrogeological setting of the water supply sources for the Town of Castle Valley, Utah, and the quantification of the water resources available to the Town. In Phase 1, a Hydrologic and Environmental System Analysis (HESA) of the Castle Creek and Placer Creek watersheds was performed to identify the hydrological systems of specific importance to the sustainability of the Castle Valley springs and wells as water supply for the Town and Valley. It was concluded that the Valley's water supply was mainly dependent on the hydrologic system formed by the Castle Creek and Placer Creek Watershed and the hillslope and valley bottom unconfined aquifers and supporting bedrock hydrostructures on the Valley sides. This Valley hydrologic system was subsequently chosen for determining a water budget in Phase 1, and in Phase 2 of the project as the setting for the quantification of the water storage available to the Town and Valley. The results of the Phase 1 study are documented in Kolm and van der Heijde (2016a and 2016b). A supplementary report contained a discussion regarding siting, sustainability and protection of the planned Town culinary well (Kolm and van der Heijde 2016c). A review by the Utah State Engineers office (2017) produced comments and questions regarding the bedrock hydrogeologic parts of the system, and regarding some of the calculations of the preliminary water budget. A memoranda was written in response to these questions (Kolm and van der Heijde, 2017). It has been requested by the Town that a project extension be implemented to refine/update the water budget and resource quantification with a specific focus on the ground water hydrologic system, including the calculation of groundwater storage in the shallow aquifers of Castle Valley. As no new data or other information relevant for updating the water budget has become available, this phase 2 report focuses on groundwater storage evaluation.

The study area is located between the La Sal Mountains to the south, the Colorado River to the north, the Porcupine Rim to the west, and the Castle Spires Rim and Adobe Mesa to the east (Figure 1). The delineation of the study area is based on the nature and extent of the major hydrogeological systems present, the surface hydrology of the area, and water resources related land use considerations. The area covers the Castle Creek and Placer Creek watersheds. The study distinguishes between 3 hydrologic entities: 1) the entire Castle Creek Watershed (including Placer Creek drainage); 2) the lower Castle Valley hydrologic system (northwest of roughly a line from the Castleton area to the Porcupine Ranch); and 3) the Castle Valley Groundwater Basin (quaternary and tertiary sand and gravels, and underlying fractured bedrock). The lower Castle Valley hydrologic system was the setting for the water budget developed in Phase 1 of this study (Kolm and van der Heijde, 2016a).

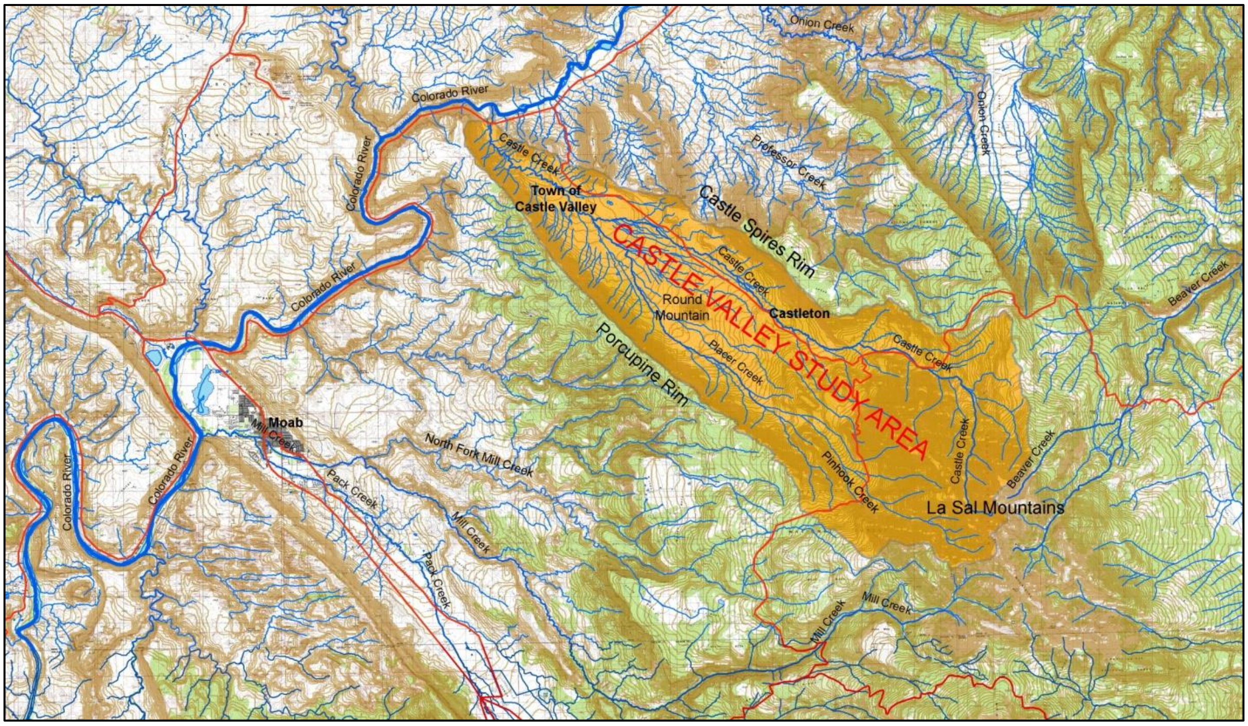

Figure 1. Topographic Map Showing the Location of the Castle Valley Study Area, Grand County, Utah. (Utah GIS, 2015).

2. HYDROLOGIC SYSTEMS OF THE CASTLE VALLEY (TCV) STUDY AREA

Based on field surveys and a preliminary HESA (Hydrologic and Environmental System Analysis), two hydrologic subsystems were identified within the Castle Valley (TCV) study area in Phase 1 of this project (Kolm and van der Heijde, 2016): 1) La Sal Mountain subsystem; and 2) Castle Creek and Placer Creek hillslope and valley bottom unconsolidated aquifer subsystem. The La Sal Mountain subsystem, located in the southeastern part of the Castle Valley study area, is a complex mix of bedrock and unconsolidated deposits, which form a robust groundwater system that is directly connected to the surface water systems forming the headwaters of Castle and Placer Creeks. The bottom of this subsystem is directly hydraulically connected to the Castle Creek and Placer Creek hillslope and valley bottom aquifer subsystem, which includes the Castle Spires Rim and Porcupine Rim, and the fractured arkose and White Rim members of the Permian Cutler formation bedrock hydrogeologic unit and the associated high-K hydrostructures. This subsystem is the focal point of the groundwater storage analysis presented in later sections of this report.

There are two significant groups of hydrogeologic units in the TCV study area (Figure 2): 1) Quaternary and Tertiary unconsolidated clastic materials, overlying 2) Tertiary, Mesozoic and Paleozoic bedrock units. Group 1 consists predominantly od water-bearing Stream Alluvium (Qal), Alluvial Fan deposits (Qaf), Glacial Till (Qgt), Slumps and Slides (Qms), Talus and Colluvium (Qmt), Bouldery Colluvium (Qcb), and Older Alluvial Fan Deposits (QTaf); group 2 includes the following potentially water-bearing units: Geyser Creek Fanglomerate (Tg); fractured Tertiary Intrusive Granodiorite (Ti); and the fractured White Rim and Arkosic members of the Cutler Formation (Pc). Most of these bedrock units have low matrix hydrologic conductivity and have springs with low yields (less than 1 gal per minute) (Figure 15, Tables 2a and 2b in Kolm and van der Heijde, 2016a). By comparison, the Triassic Chinle (Trc) and Moehkopi Formations (Trm), labeled as bedrock undivided on Figure 14 in Kolm and van der Heijde (2016a), the unfractured Cutler Formation (Pc), and the Paradox Formation (IPpc and labeled “cap rock” on some figures) may act as thick, poorly transmissive confining layers (Blanchard, 1990; Ford, 1997).

The thickness of subsurface distribution of these unconsolidated sediments are estimated based upon the isopach maps produced in earlier studies (Lowe and others, 2004). The thicknesses range from less than 25 ft in the southeastern part of Castle Creek above Castleton and the southeastern part of Placer Creek above Porcupine Ranch, to greater than 300 ft in the northern part of Castle Valley near Day Star Academy. The greatest thickness of the unconsolidated material is in the collapsed part of Castle Valley northwest of Round Mountain where average thicknesses ranging between 100 – 200 ft. are common (Figure 3).

The subsurface distribution of thickness is indicative of the structural collapse and faulting with subsequent erosion and filling of fault zones with gravels. A linear paleovalley and subsequent groundwater conduit is observed along the northeastern margin of the valley fill beneath the modern day Castle Creek from Castleton extending to near Parriott Mesa (Figure 3, 4 and 5). The second linear paleovalley and subsequent groundwater conduit is observed along the southwestern margin of the valley fill beneath the modern day Placer Creek above the Porcupine Ranch extending to beneath the Town of Castle Valley town hall to the northwest (Figure 3, 4 and 5). These groundwater conduits approximately overly the bedrock conduits to be discussed in subsequent sections of this report.

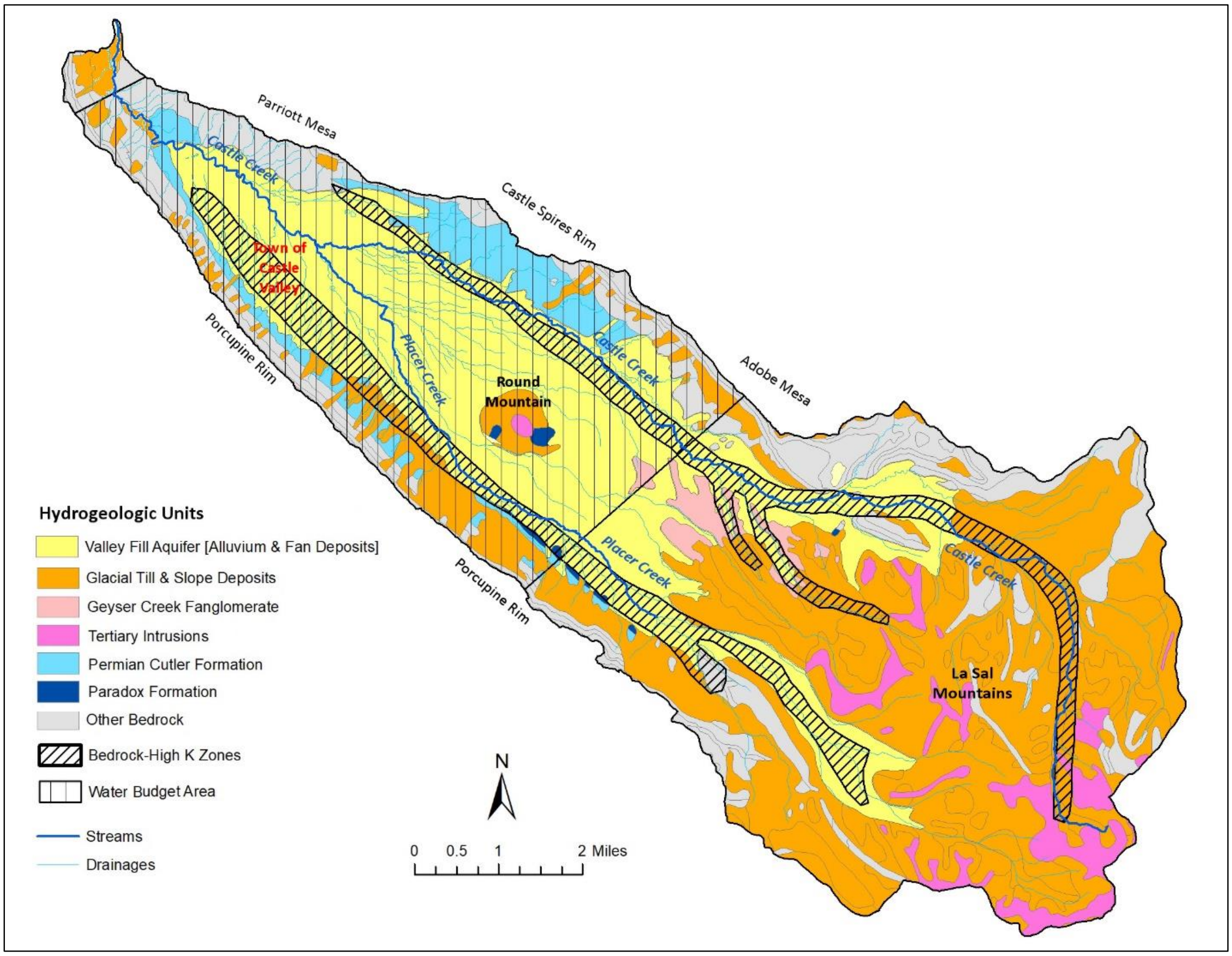

Figure 2. Map Showing Hydrogeological Systems of TCV Study Area, Including the Bedrock-High K Zones, and the Preliminary Water Budget Area of Phase I of This Project (after Kolm and van der Heijde, 2016a).

Hydrostructures, which are defined by folds, faults and fracture zones, control the location of Castle Valley, the location of the Castle Creek, Placer Creek, and major tributaries, the location of drainages that are part of the Porcupine and Castle Spires Rims, and the locations of streams draining the La Sal Mountains. The main fold and fault structure is the Castle Valley Salt Anticline with corresponding graben/collapse structure. The bounding faults of the collapse, located on the northeast and southwest sides of Castle Valley, dip almost vertically and strike from the southeast to the northwest. These two fault zones, which are in the White Rim and Arkosic Members of the Cutler Formation are major hydrogeologic conduits (high hydraulic conductivity zones or High "K" zones) (Figures 2 and 3). These conduits are continuous from the southeastern part to the northwestern part of Castle Valley and have high yields of groundwater with high TDS water quality (Figure 18 in Kolm and van der Heijde, 2016a). These hydrostructural units pinch out at either end of the valley and with depth keeping the groundwater system local and discontinuous beyond the Castle Valley topographic feature as outlined in Figure 1. These hydrostructural units also block lateral flow perpendicular to the fault zone. Therefore, no deep regional ground water is laterally entering or exiting Castle Valley from the northeast or the southwest. The termination of these hydrostructural units to the southeast and northwest also blocks lateral flow, so no deep groundwater is laterally entering or exiting Castle Valley from the southeast or the northwest. It is hydrologically important that the entire valley is underlain by a deep "flat lying" caprock of the Paradox Formation. Effectively, these hydrogeologic/hydrostructural units ensure that the Castle Valley Bedrock groundwater flow system is entirely contained within the valley.

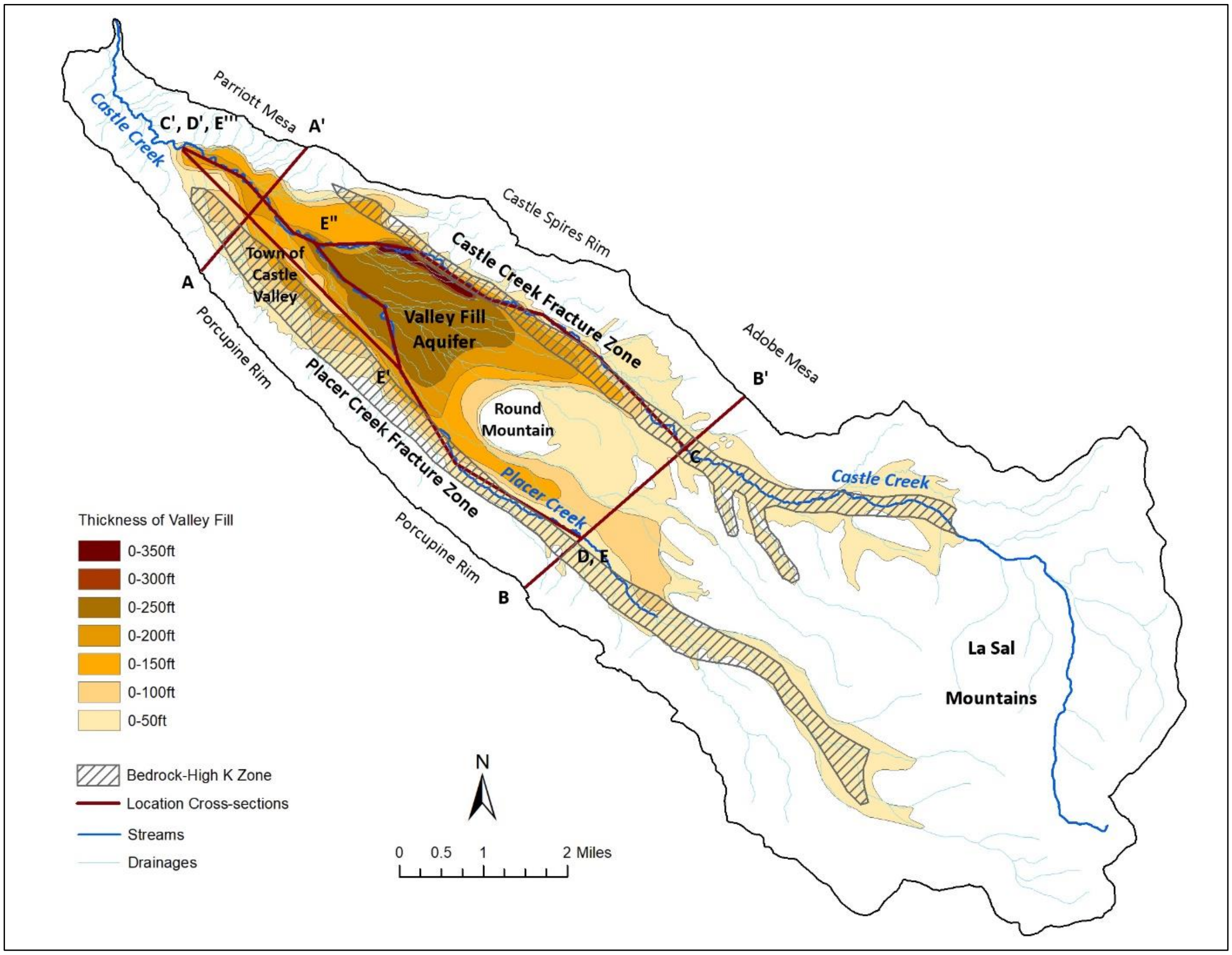

Figure 3. Map Showing Valley Fill Thickness, Three Major Hydro Storage Zones and Location of Cross-sections in the TCV Study Area (After Kolm and van der Heijde, 2016a).

The fault and fracture zones have influenced the location of the main surface water drainages in the TCV study area by providing zones of weakness whereby the streams have downcut into or through the unconsolidated deposits into the underlying Cutler Arkosic and White Rim Members bedrock, the Paradox bedrock, and the Granodiorite Porphery. As a result, the TCV study area is dissected into two distinct surface hydrologic subsystems of varying connectivity: Castle Creek and Placer Creek, both of which are separated in the southeastern part of the Valley by Round Mountain and the La Sal Mountain ridges, and become connected in the northwestern part of Castle Valley near the confluence of the drainages. The northwest-southeast trending drainages mirror the underlying faults and fracture zones that include the collapse structures located on the northeast and southwest sides of Castle Valley, and the underlying faults and fracture zones that are parallel to these bounding structures (Figure 3, 4 and 5). These structures are open, and function as groundwater conduits in bedrock, and paleo-valley groundwater conduits in unconsolidated materials. These hydrostructures also contain storage for groundwater discussed in later chapters of this report.

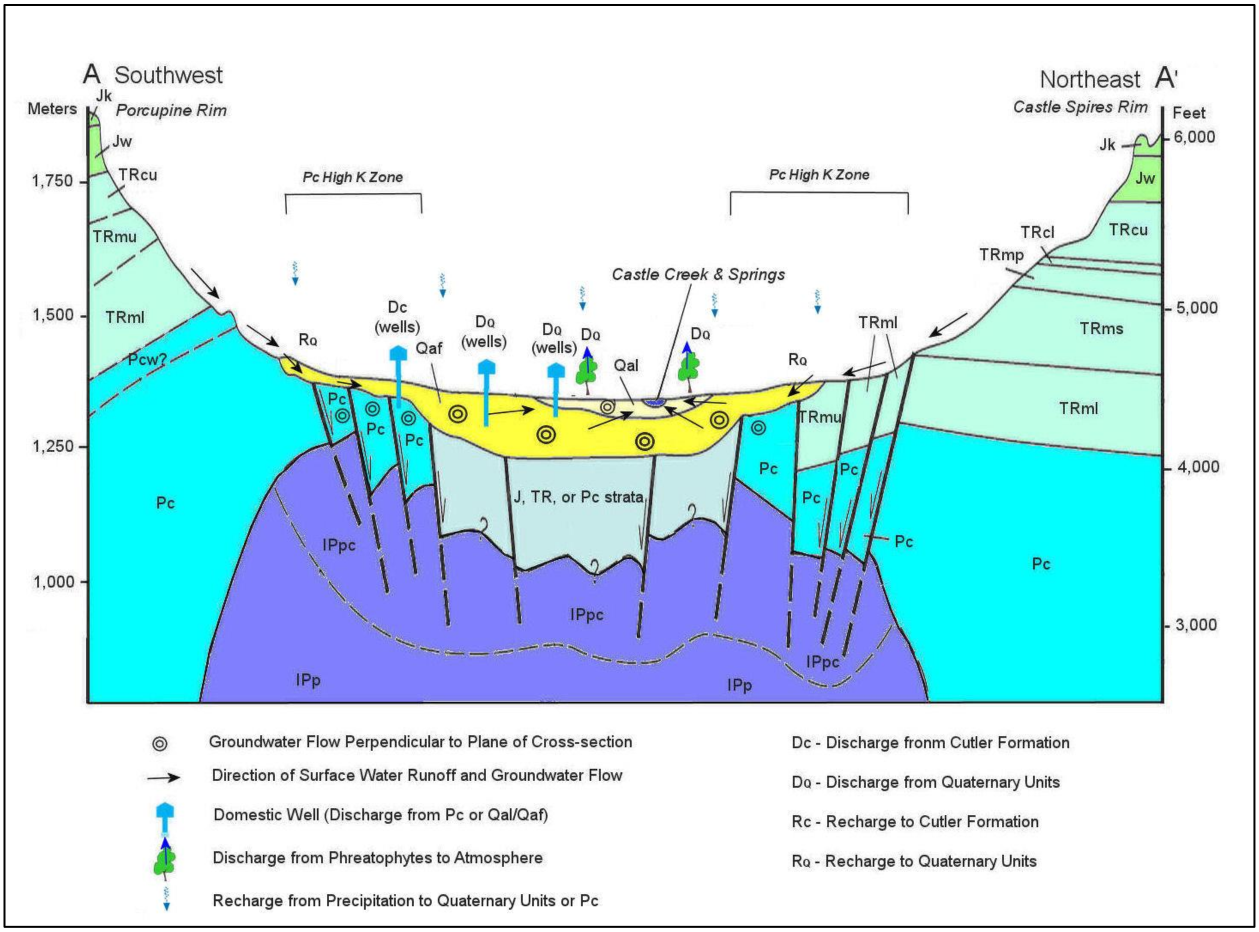

Figure 4. Schematic Northeast-Southwest Cross-sectional View of the Conceptual Site Models of the Hillslope and Valley Bottom Shallow Aquifer Subsystems in the Vicinity of the Town of Castle Valley (A-A' in Figure 3) (from Kolm and van der Heijde, 2016a).

Kolm and van der Heijde (2016a) delineated the regional, sub-regional, and local scale hydrologic systems and identified the presence of Mountain, Mesa Top, Hillslope, and Valley Bottom subsystems in the Castle Valley study area. In general, shallow groundwater flow in these systems is with topography away from the mountain and ridge tops, along the axis of the mesa tops, and/or towards the valley bottoms, perpendicular to the major streams. Where permeable bedrock units underlie the mountains, mesa tops, hill slopes, and valley bottoms, recharge by groundwater moving from unconsolidated hydrogeologic units into the bedrock hydrogeologic units may occur.

The Castle Creek and Placer Creek subsystems are the focus of this report. Groundwater flow in these subsystems can have a rather diffuse character and often flows towards or aligns more or less with the streams and rivers. These groundwater flow systems depend primarily on local recharge from precipitation; interactions with the main streams; discharge from Porcupine and Castle Spires Rim, and Adobe Mesa; discharge from the bedrock subsystems such as the Geyser Creek fanglomerates, the fractured arkoses and White Rim sandstones of the Cutler Formation, and the Tertiary intrusive rocks of the La Sal Mountains foothills; and the management of subsurface return flow from irrigation lands (Kolm and van der Heijde, 2016a). The wetlands associated with the local hydrogeologic conditions in the Castle Creek and Placer Creek drainages, and in the adjoining tributaries, are in general indicative of a near-surface groundwater level, an important element in determining aquifer water content and dynamic storage . They are often found near stretches of perennial creek flows, and near springs.

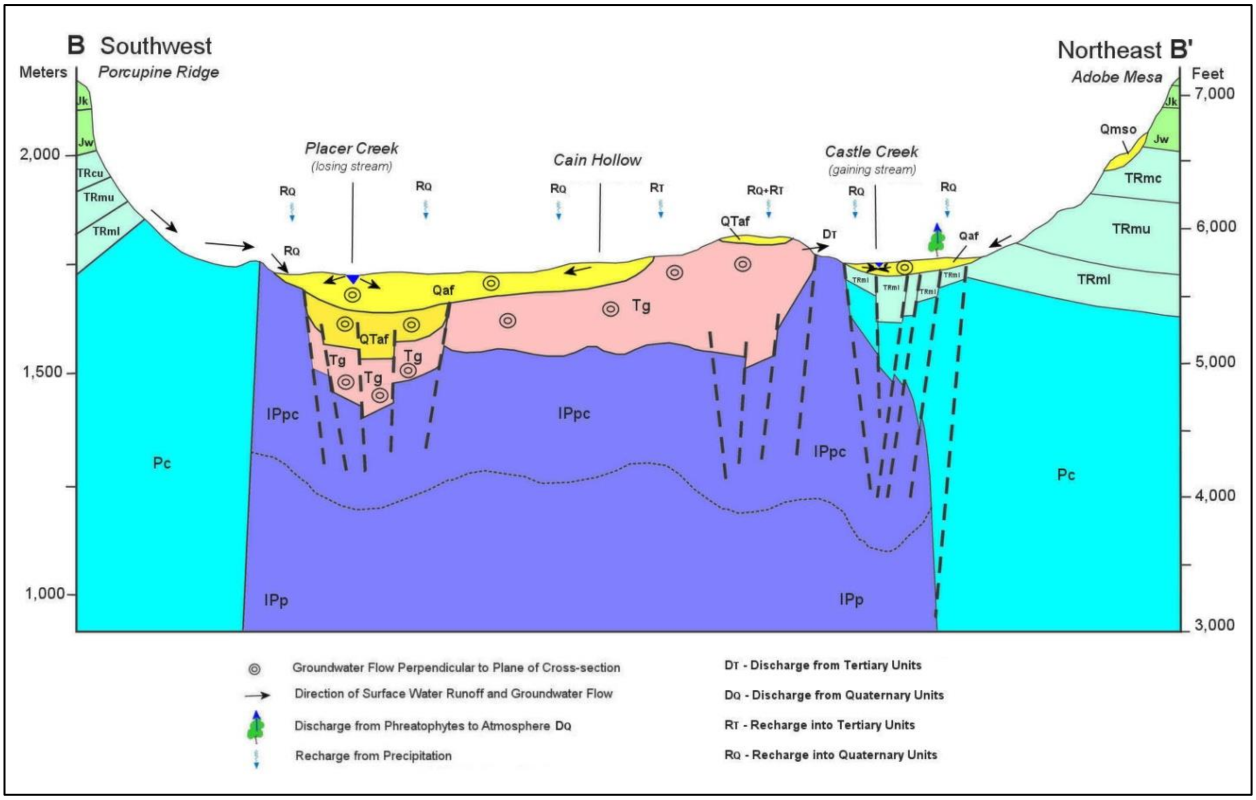

Figure 5. Schematic Northeast-Southwest Cross-sectional View of the Conceptual Site Models of the Hillslope and Valley Bottom Shallow Aquifer Subsystems Southeast of Round Mountain (B-B' in Figure 3) (from Kolm and van der Heijde, 2016a).

As springs are discharge points of groundwater flow systems, their presence in the TCV study area provide clues about these groundwater flow systems, including the role of the hydrogeological units, hydrostructures, and the effects of natural and anthropogenic recharge on flow and water quality. Kolm and van der Heijde (2016a) identified three general categories of springs: 1) unconsolidated unit/faulted shallow bedrock springs; 2) unconsolidated unit springs controlled by topography, geomorphology, and upward gradient groundwater flow; and 3) bedrock associated springs. As with wetlands, they are indicative of a near-surface groundwater level.

3. PRELIMINARY GROUNDWATER STORAGE CALCULATIONS FOR THE CASTLE VALLEY (TCV) STUDY AREA

3.1Groundwater Storage Definitions

Groundwater is potentially stored in the pore spaces between the sand grains of unconsolidated hydrogeologic units, in the pore spaces of the sedimentary bedrock, or in hydro-structures including fractures, fracture zones, bedding planes, faults, or fault zones. Groundwater that is stored in the pore spaces is considered matrix water and may be in considerable amounts in unconsolidated materials (such as the Castle Valley stream alluvium and alluvial fans) or may be in very small amounts in well consolidated bedrock (such as *******). Groundwater that is stored in the hydro-structures may be in very small amounts in microfractures or may be in considerable amounts in large scale fracture and faults zones (such as the Castle Creek and Placer Creek fracture zones, Figure 3). Most of the unconsolidated materials that form the colluvium or slope deposits in the Castle Valley area are unsaturated and the amount of groundwater storage is small. By comparison, the unconsolidated stream alluvium (Qal) and alluvial fan deposits (Qaf) are partially saturated, and the storage is significant as indicated by the extensive phreatophyte vegetation that is observed in area with shallow groundwater.

There are multiple descriptors of storage in aquifers. Storativity or the storage coefficient is the volume of water released from storage per unit decline in hydraulic head in the aquifer, per unit area of the aquifer. Storativity is a dimensionless quantity, and ranges between 0 and the effective porosity of the aquifer, or the percentage of open space in a unit of rock from which water can be drained under gravity. For a confined aquifer or aquitard, storage is described by specific storage, i.e., the volume of water released from one unit volume of the aquifer under one unit decline in head. Specific storage is related to both the compressibility of the aquifer and the compressibility of the water itself. Volumetric specific storage (or volume specific storage) is the volume of water that an aquifer releases from storage, per volume of aquifer, per unit decline in hydraulic head (Freeze and Cherry, 1979).

In hydrogeology, volumetric specific storage is much more commonly encountered than mass specific storage. Consequently, the term specific storage generally refers to volumetric specific storage. The compressibility terms relate a given change in stress to a change in volume. Specific yield, also known as the drainable porosity, is a ratio, less than or equal to the effective porosity, indicating the volumetric fraction of the bulk aquifer volume that a given aquifer will yield when all the water is allowed to drain out of it under the forces of gravity. Specific yield is primarily used for unconfined aquifers since the elastic storage component is relatively small and usually has an insignificant contribution. Specific yield can be close to effective porosity, but there are several subtle things which make this value more complicated than it seems. Some water always remains in the formation, even after drainage; it clings to the grains of sand and clay in the formation. Also, the value of specific yield may not be fully realized for a very long time, due to complications caused by unsaturated flow.

When groundwater levels in an aquifer go up or down, water goes into or comes out of storage. Typically water is stored in an aquifer during recharge events from direct precipitation on the land surface of the aquifer, or from infiltration from streams during high surface runoff events such as spring snowmelt. Water comes out of storage when discharge to streams and consumptive use by vegetation outpaces recharge. Water also comes out of storage by domestic, agricultural or municipal withdrawal of groundwater. A dynamic equilibrium exists when periods of storage loss are compensated by periods of storage gain. However, when long-term groundwater discharge exceeds long-term recharge, the dynamic equilibrium is replaced by groundwater mining. To evaluate storage conditions in a hydrologic system, a multi-year (e.g., wet vs. dry years) approach may be required. A first estimate for dynamic storage in regional or subregional aquifers like the Valley Fill Aquifer in the TCV area is taken at about 10% of total water volume in the aquifer. Note that variations in groundwater levels variations (or water table in an unconfined aquifer) are relative small in discharge areas near springs and streams, but may be significant at some distance from the discharge areas.

3.2 Approach and Calculation of Groundwater Storage for the TCV System

Based on the HESA performed in Phase 1 of this study (Kolm and van der Heijde, 2016a), there are three areas (i.e., storage zones) important for groundwater storage calculations: 1) the Valley Fill Aquifer; 2) the Castle Creek Fracture Zone; and 3) the Placer Creek Fracture Zone (Figure 3). The Valley Fill Aquifer is mostly under unconfined or water table conditions and is characterized by specific yield estimates for unconsolidated sand and gravel deposits in the range 10 – 30%. Towards the southeast of the Valley Fill Aquifer and near the valley rims, the thickness of the valley fill diminishes while the elevation increases, resulting in mostly unsaturated, or seasonally saturated conditions. Due to the extent and depth of these unconsolidated sediments, the Valley Fill Aquifer will be most important for estimating total groundwater storage and dynamic groundwater storage in the Castle Valley (Figures 2 and 3; Table 1).

Although the Castle Valley unconsolidated fill has thicknesses up to 300+ feet measured from ground surface (Figure 3), saturated thickness may be significantly less, especially in areas where the water table is well below ground surface (up to 90ft in the center of the area between Castle and Pack Creek when comparing the potentiometric map published by Snyder (1996) with surface elevations from USGS Digital Elevation Maps, and from well records). A first approximation would assume that as an average number the first 40-60 feet thickness of total valley fill is unsaturated and does not contribute to the volume of groundwater in the aquifer. This means that the total valley fill volume needs to be reduced accordingly to obtain the average total volume of groundwater in this aquifer (i.e., the average total groundwater storage) when multiplied by specific yield Sy, making the first 50 feet of valley fill in Figure 3 mostly unsaturated. Note that part of this unsaturated zone functions as additional storage capacity in the aquifers “dynamic storage” calculations. The specific yield (Sy) for this unit is in the range of 10%-30%. Low total water content was estimated using low Sy percentages as a minimum, and high total water content was estimated using the high Sy percentages as a maximum (Table 1).

The Permian Cutler bedrock that underlies the rest of the Castle Valley predominantly has no significant flow, and has insignificant storage capabilities. The fracture flow rate is undetermined but is estimated to be 10-20 ft/day. Therefore, fracture flow will dominate travel times in the fractured Permian Cutler aquifer and the well-connected fractures in these zones will be most important for estimating groundwater storage. As the fractured Permian Cutler groundwater systems in storage zones 2 and 3 are mostly unconfined (water table conditions), its storage capability is characterized by specific yield estimates. While estimates for the matrix specific yield estimates generally are less than 1.0%; estimates for the specific yield in fracture-dominated zones are in the 20 – 40% range (Table 2). Therefore, fracture dominated areas will be most important for estimating groundwater storage in these zones.

In addition to being high-K (permeability) zones for groundwater flow, the Castle Creek and the Placer Creek Fracture Zones also provide fracture storage up to 300 feet below the surface with an average effective depth of 200 – 230 feet (well log based) and a specific yield (Sy) range of 20% – 40% at the surface diminishing to close to 0% at 300 ft, amounting to an average Sy of about 20% taken over an average 150 ft of saturated thickness (Table 2).

Each hydrogeologic zone had an estimated volume (GIS area multiplied by a representative average depth), and the storage zone volume was multiplied by the storage zone Sy to yield a hydrogeologic zone water content value (Tables 1 and 2). Only part of this total water storage is considered variable or recoverable storage; accessing additional storage is unsustainable and considered groundwater mining. A first approximation for variable storage (used in this Phase 2 report) is 10% of total water content (Tables 1 and 2).

The Geyser Creek Fanglomerate (Tg) is in direct contact with the Valley Fill Aquifer south east of Round Mountain. However, this bedrock hydrogeologic unit is considered poorly fractured with low matrix permeability and storage. In addition, this unit probably disappears (thins) very quickly under the south end of the valley aquifer as it is a fan delta deposit defining the paleo shoreline of its time. Therefore, the Geyser Creek Fanglomerate (Tg) is not considered an important volume of groundwater storage.

The calculations show that the total average water volume of the Valley Fill Aquifer is in the range of 42,160-126,490 ac-ft while the average variable or "dynamic" storage ranges between 4,220-ac-ft, and 12,650 ac-ft (Table 1). The average water volume for the two fracture zones together is estimated at 112,800 acre-ft with a variable or dynamic storage of 11,280 ac-ft (Table 2). Average ground water content for the entire TCV hydrologic system is estimated between 154,960 ac-ft and 293,290 ac-ft with a variable water storage between 15,500 and 23,930 ac-ft (Tables 1 and 2).

It should be cautioned that groundwater storage or the presence of an underground water reservoir is primarily a measure of how robust and sustainable the TCV hydrologic system is under the current climatic and human use conditions. If the reservoir is significantly reduced by aquifer development, the hydraulics of the system will be affected initially by stream flows (riparian habitat both aquatic and vegetation), and by a rapid reduction of spring flows and well yields. In addition, the effects of reduced stream flows in Castle Creek and Placer Creek through diversion or climate change will rapidly affect the recharge and storage functions of the storage zones forming the Castle Creek groundwater system, which are critical to Castle Valley Springs, and the Town of Castle Valley Wells.

3.3 Storage and the TCV Hydrologic System: Discussion of Uncertainty

There are many uncertainties in these preliminary calculations, so further analysis is needed, benefitting from more rigorous and continuous data collection. The primary significance of the storage calculations is that there is a significant amount of groundwater stored in the TCV hydrologic system, both in the unconsolidated deposits of storage zone 1 and in the open fractures of the fractured bedrock units of zone 2 and 3. The storage in zone 1 is of greatest importance to the to the Town of Castle Valley as the main source of water supply for the town.

The largest uncertainties in the storage calculations is the delineation of each hydrogeologic zone area (volume), the attribution of specific yield to each hydrogeologic zone, and the location of the average water table.

Depth	Area at top [acres]	Area bottom [acres]	Average net area [acres]	Volume [acre.ft]	Average total saturated storage volume [acre.ft] (Sy=0.1–0.3)	Average dynamic storage [acre.ft] (10% of total)
0-350ft	65	0	½*65= 32.5	32.5*350=11,375	≈ 1,135- 3, 405	
0-300ft	100	65	½*35= 17.5	17.5*300=5,250	≈ 525 - 1,575	
0-250ft	1350	100	½*1250= 625	625*250=125,000	≈ 12,500 - 37,500	
0-200ft	2335	1350	½*985= 492.5	492.5*200=98,500	≈ 9,850 - 29,550	
0-150ft	3655	2335	½*1330= 665	665*150=99,750	≈ 9,975 – 29,925	
0-100ft	5300	3655	½*1635= 817.5	817.5*100=81,750	≈ 8,175 – 24,525	
0-50ft	11270	5300	½*5970= 2985	2985*50=149,250	0 (unsaturated)	0 (unsaturated)
Total	--	--	--	570,875	≈ 42,160-126,490	≈ 4,220-12,650

Table 1. Total open pore space in valley fill deposits in Castle Valley hydrologic system [note that water table is below ground surface and actual groundwater volume is less than volume of valley fill]

Name of High-K zone	Area [acres]	Average effective depth [ft]	Total volume [acre.ft]	Average total storage [acre.ft] (Sy=0.2)	Average usable storage [acre.ft] (10% of total)
1. Castle Creek NE CV Fracture Zone.	1485	150	222,750	44,550	4,455
2. Placer Creek SW CV Fracture Zone.	2275	150	341,250	68,250	6,825
Total	3760	--	564,000	112,800	11,280

Table 2. Total open pore space in High-K zones in Castle Valley hydrologic system.

4 SUMMARY AND CONCLUSIONS

This report presents the findings of Phase 2 of a 2-phase project focused on improving the understanding of the hydrogeological setting of the water supply sources for the Town of Castle Valley, Utah, the quantification of the water resources available to the Town, and updating the Town Water Balance with respect to new spring and stream flow data. In Phase 1, a Hydrologic and Environmental System Analysis (HESA) of the Castle Creek and Placer Creek watersheds was performed to identify the hydrological systems of specific importance to the sustainability of the Castle Valley springs and wells as water supply for the Town and Valley. It was concluded that the Valley's water supply was mainly dependent on the hydrologic system formed by the Castle Creek and Placer Creek Watershed and the Hillslope and Valley Bottom Shallow Aquifers and supporting hydrostructure aquifers on the Valley sides. This Valley hydrologic system was chosen for determining a water budget in Phase 1, and was chosen in Phase 2 of the project as the setting for the quantification of the water storage available to the Town and Valley.

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5. REFERENCES

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LOCAL MITIGATION PLAN REVIEW TOOL

The *Local Mitigation Plan Review Tool* demonstrates how the Local Mitigation Plan meets the regulation in 44 CFR §201.6 and offers States and FEMA Mitigation Planners an opportunity to provide feedback to the community.

- The Regulation Checklist provides a summary of FEMA's evaluation of whether the Plan has addressed all requirements.
- The Plan Assessment identifies the plan's strengths as well as documents areas for future improvement.
- The Multi-jurisdiction Summary Sheet is an optional worksheet that can be used to document how each jurisdiction met the requirements of the each Element of the Plan (Planning Process; Hazard Identification and Risk Assessment; Mitigation Strategy; Plan Review, Evaluation, and Implementation; and Plan Adoption).

The FEMA Mitigation Planner must reference this *Local Mitigation Plan Review Guide* when completing the *Local Mitigation Plan Review Tool*.

Jurisdiction: Town of Castle Valley, Utah	**Title of Plan:** Hazard Mitigation Plan 2020	**Date of Plan:** **7.15.2020**
Local Point of Contact: **Jocelyn Buck**	**Address:** HC 64 Box 2705 Castle Valley, Utah 84532	
Title: **Town Clerk**		
Agency: **Town of Castle Valley**		
Phone Number: 435-259-9828	**E-Mail:** townclerk@castlevalleyutah.com	

State Reviewer:	**Title:**	**Date:**

FEMA Reviewer:	**Title:**	**Date:**
Date Received in FEMA Region VIII		
Plan Not Approved		
Plan Approvable Pending Adoption		
Plan Approved		

Multi-jurisdictional form not applicable

SECTION 1:
REGULATION CHECKLIST

1. REGULATION CHECKLIST **Regulation** (44 CFR 201.6 Local Mitigation Plans)	Location in Plan (section and/or page number)	Met	Not Met
ELEMENT A. PLANNING PROCESS			
A1. Does the Plan document the planning process, including how it was prepared and who was involved in the process for each jurisdiction? (Requirement §201.6(c)(1))	Original Plan Pg. 6 2020 Updated Plan pg. 9		
A2. Does the Plan document an opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, agencies that have the authority to regulate development as well as other interests to be involved in the planning process? (Requirement §201.6(b)(2))	Pg. 9		
A3. Does the Plan document how the public was involved in the planning process during the drafting stage? (Requirement §201.6(b)(1))	Pg. 9		
A4. Does the Plan describe the review and incorporation of existing plans, studies, reports, and technical information? (Requirement §201.6(b)(3))	Throughout Plan studies are cited for Hazards – see Appendices		
A5. Is there discussion of how the community(ies) will continue public participation in the plan maintenance process? (Requirement §201.6(c)(4)(iii))	Pg. 8 and Pg. 59		
A6. Is there a description of the method and schedule for keeping the plan current (monitoring, evaluating and updating the mitigation plan within a 5-year cycle)? (Requirement §201.6(c)(4)(i))	Pg. 59		
ELEMENT A: REQUIRED REVISIONS			
ELEMENT B. HAZARD IDENTIFICATION AND RISK ASSESSMENT			
B1. Does the Plan include a description of the type, location, and extent of all natural hazards that can affect each jurisdiction(s)? (Requirement §201.6(c)(2)(i))	Hazards Pg. 12-54		
B2. Does the Plan include information on previous occurrences of hazard events and on the probability of future hazard events for each jurisdiction? (Requirement §201.6(c)(2)(i))	Hazards Pg. 12-54		
B3. Is there a description of each identified hazard's impact on the community as well as an overall summary of the community's vulnerability for each jurisdiction? (Requirement §201.6(c)(2)(ii))	Profile Pg. 3-4 Hazards Pg. 12-54		
B4. Does the Plan address NFIP insured structures within the jurisdiction that have been repetitively damaged by floods? (Requirement §201.6(c)(2)(ii))	N/A		

1. REGULATION CHECKLIST **Regulation** (44 CFR 201.6 Local Mitigation Plans)	Location in Plan (section and/or page number)	Met	Not Met
ELEMENT B: REQUIRED REVISIONS			
ELEMENT C. MITIGATION STRATEGY			
C1. Does the plan document each jurisdiction's existing authorities, policies, programs and resources and its ability to expand on and improve these existing policies and programs? (Requirement §201.6(c)(3))	Resources Pg. 10-11		
C2. Does the Plan address each jurisdiction's participation in the NFIP and continued compliance with NFIP requirements, as appropriate? (Requirement §201.6(c)(3)(ii))	N/A		
C3. Does the Plan include goals to reduce/avoid long-term vulnerabilities to the identified hazards? (Requirement §201.6(c)(3)(i))	Strategies pg.12-54 Goals pg. 55-58		
C4. Does the Plan identify and analyze a comprehensive range of specific mitigation actions and projects for each jurisdiction being considered to reduce the effects of hazards, with emphasis on new and existing buildings and infrastructure? (Requirement §201.6(c)(3)(ii))	Strategies pg.12-54 Goals pg. 55-58		
C5. Does the Plan contain an action plan that describes how the actions identified will be prioritized (including cost benefit review), implemented, and administered by each jurisdiction? (Requirement §201.6(c)(3)(iv)); (Requirement §201.6(c)(3)(iii))	Goals pg. 55-58		
C6. Does the Plan describe a process by which local governments will integrate the requirements of the mitigation plan into other planning mechanisms, such as comprehensive or capital improvement plans, when appropriate? (Requirement §201.6(c)(4)(ii))	Strategies pg.12-54 Goals pg. 55-58		
ELEMENT C: REQUIRED REVISIONS			
ELEMENT D. PLAN REVIEW, EVALUATION, AND IMPLEMENTATION (applicable to plan updates only)			
D1. Was the plan revised to reflect changes in development? (Requirement §201.6(d)(3))	Yes, hazards and mitigation strategies were reviewed		
D2. Was the plan revised to reflect progress in local mitigation efforts? (Requirement §201.6(d)(3))	Yes		
D3. Was the plan revised to reflect changes in priorities? (Requirement §201.6(d)(3))	Yes		
ELEMENT D: REQUIRED REVISIONS			
ELEMENT E. PLAN ADOPTION			

1. REGULATION CHECKLIST **Regulation** (44 CFR 201.6 Local Mitigation Plans)	Location in Plan (section and/or page number)	Met	Not Met
E1. Does the Plan include documentation that the plan has been formally adopted by the governing body of the jurisdiction requesting approval? (Requirement §201.6(c)(5))	Resolution 2020-8 Passed 7.15.2020		
E2. For multi-jurisdictional plans, has each jurisdiction requesting approval of the plan documented formal plan adoption? (Requirement §201.6(c)(5))	N/A		
ELEMENT E: REQUIRED REVISIONS			
ELEMENT F. ADDITIONAL STATE REQUIREMENTS (OPTIONAL FOR STATE REVIEWERS ONLY; NOT TO BE COMPLETED BY FEMA)			
F1.	N/A		
F2.			
ELEMENT F: REQUIRED REVISIONS			

SECTION 2:
PLAN ASSESSMENT

A. Plan Strengths and Opportunities for Improvement

This section provides a discussion of the strengths of the plan document and identifies areas where these could be improved beyond minimum requirements.

Element A: Planning Process

Element B: Hazard Identification and Risk Assessment

Element C: Mitigation Strategy

Element D: Plan Review, Evaluation, and Implementation (Plan Updates Only)

B. Resources for Implementing Your Approved Plan

TOWN OF CASTLE VALLEY, UTAH

RESOLUTION 2020-8

A RESOLUTION ADOPTING THE 2020 CASTLE VALLEY, UTAH HAZARD MITIGATION PLAN

WHEREAS the Town of Castle Valley recognizes the threat that natural hazards pose to people and property within Castle Valley; and

WHEREAS the Castle Valley has prepared a multi-hazard mitigation plan, hereby known as 'The 2020 Castle Valley, Utah Hazard Mitigation Plan' in accordance with the Disaster Mitigation Act of 2000; and

WHEREAS 'The 2020 Castle Valley, Utah Hazard Mitigation Plan' identifies and updates mitigation goals and actions to reduce or eliminate long term risk to people and property in Castle Valley from the impacts of future hazards and disasters; and

WHEREAS adoption by the Town of Castle Valley demonstrates their commitment to the hazard mitigation and achieving the goals outlined in 'The 2020 Castle Valley, Utah Hazard Mitigation Plan'.

WHEREAS the Town Council of the Town of Castle Valley believes it is in the best interest of the Castle Valley to adopt 'The 2020 Castle Valley, Utah Hazard Mitigation Plan.'

NOW THEREFORE, BE IT RESOLVED BY THE TOWN COUNCIL OF THE TOWN OF CASTLE VALLEY, UTAH, THAT:

<u>Section 1.</u> That the Town of Castle Valley hereby adopts the 'The 2020 Castle Valley, Utah Hazard Mitigation Plan'.

<u>Section 2.</u> That the Town of Castle Valley will submit this Adoption Resolution to the Federal Emergency Management Agency to enable the plan's final approval.

Passed, Adopted, and Approved by the Town Council of The Town of Castle Valley in open session on the 15 day of July, 2020 by the following vote:

Those voting AYE: Mayor Duncan, Council Members: Gibson, Hill, Holland and O'Brien

Those voting NAY: None

Absent: None

APPROVED:	**ATTESTED:**
Jazmine Duncan	Jocelyn Buck
______________________________	______________________________
Jazmine Duncan, Mayor	**Jocelyn Buck, Town Clerk**