2010

Aquifer Management Feasibility Study:

Utilizing Coal Creek within the Cedar Basin, Iron County, Utah

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BEYOND ENGINEERING

Contents

List of Figures v

List of Tables vii

EXECUTIVE SUMMARY 2

1 MOTIVATION FOR THE STUDY 4

1.1 How the Study Started 4

1.2 Purpose of Study 4

1.2.1 Water Usage 5

1.2.2 Enoch City Fissure 5

1.2.3 Wasted Water 7

1.2.4 Public Knowledge 7

2 DESCRIPTION OF THE GEOLOGY & HYDROLOGY 9

2.1 Cedar Valley - Geology 9

2.1.1 Stratigraphy 9

2.2 Cedar Valley - Hydrology 11

2.2.1 Geology – Water Quality 11

3 COAL CREEK 14

3.1 Coal Creek System 14

3.1.1 Diversions 14

3.2 Flow Data 15

3.3 Coal Creek Water Rights 15

3.3.1 Excess Flows Exceed Water Right Filings 16

4 AQUIFER MANAGEMENT 20

4.1 Surface Spreading 20

4.1.1 CICWCD Pilot 2005 20

4.1.2 Advantages of Surface Spreading 21

4.1.3 Disadvantages of Surface Spreading 24

4.2 Aquifer Storage and Recovery Wells (ASR) 24

4.2.1 Implementation 25

4.2.2 Advantages of ASR wells 25

4.2.3 Disadvantages of ASR wells 26

5 EXISTING PROGRAMS 28

5.1 National Ground Water Association Conference and Las Vegas, NV 28

5.1.1 Las Vegas Water District 28

5.1.2 Artificial Recharge Plan 28

5.1.3 Engineering of the Artificial Recharge Plan 29

5.2 Weber Basin Water Conservancy District, Weber, UT 29

5.3 Metropolitan Water District of Salt Lake and Sandy, Salt Lake City, UT 30

5.4 Brigham City, UT 30

5.5 Jordan Valley Water Conservancy District, Jordan, UT 30

6 SELECTION OF ALTERNATIVE 32

7 PROJECT DESCRIPTION 34

7.1 Project Objective 34

7.2 Evaluation of Water for Recharge 34

7.2.1 Water Quality 34

7.2.2 Potential Contaminants 34

7.2.3 Biological & Geochemical Clogging 35

7.2.4 Total-Suspended Solids 36
7.2.5 Baseline Data 36
7.3 Sediment –Water Conditions 36
7.4 Settling Methods 37
7.4.1 Settling Basin 37
7.4.2 Iowa Vanes 39
7.5 Evaluation of Soil Conditions for Recharge 40
7.5.1 Percolation Rate 40
7.5.2 Cedar City Test & Results 41
7.6 Evaluation of Site Conditions 44
7.6.1 Basin Fill 44
7.7 Evaluation of FAA Regulations 55
7.7.1 Requirements for Compliance 55
7.7.2 Separation criteria 55
7.7.3 Coordination Efforts with Local and Federal Agencies 56
7.7.4 Design Recommendation from Mr. Linnell 56
7.7.5 Steps for planning and approval 57
8 MONITORING WELLS 60
8.1 Microgravity Data Collection 60
8.2 Need for Monitoring Wells 60
8.3 Types of Monitoring Wells 61
8.3.1 Production Well Monitoring 61
8.3.2 Specific Application Monitoring 61
8.3.3 Vadose Zone Monitoring 61

8.4 Data to be collected from Monitoring Wells 62

9 PILOT PROGRAM 64

9.1 Expertise in Design 64

9.2 Improvement to Woodbury Diversion 64

9.3 Design of Facility 65

9.3.1 Design of Weir & Diversion 65

9.3.2 Design of Settling Basin 65

9.3.3 Design of Recharge Basin 65

9.3.4 Placement of Monitoring Wells 66

9.3.5 Permitting 66

References Cited 68

List of Figures

Figure 1 Demand vs. Supply 5
Figure 2 Formation of Fissures 6
Figure 3....................10
Figure 4....................10
Figure 5....................11
Figure 6 Coal Creek Water Rights 16
Figure 7 Monthly Coal Creek Flow 17
Figure 8 Drainage and Irrigation Facilities 18
Figure 9 Surface Spreading 20
Figure 10 Infiltration Sites....................22
Figure 11 2005 Pilot Site....................23
Figure 12 Las Vegas ASR Well....................25
Figure 13 Weber Basin Recharge Pit 29
Figure 14 Percolation Test Location 43
Figure 15 Well Site and Cross - Sections....................46
Figure 16 Cross Section A-A' 47
Figure 17 Cross Section B-B' 48
Figure 18 Cross Section C-C' 49
Figure 19 Cross Section D-D'....................50
Figure 20 Cross Section E-E'....................51
Figure 21 Cross Section F-F' 52
Figure 22 Cross Section G-G'....................53
Figure 23 Cross Section H-H'....................54

Figure 24 FAA Perimeter A & Approach Zones 58

List of Tables

Table 1 Water Contamination Sources....................35

Table 2 Stokes Law Assumptions....................38

Table 3 Infiltration Test Results....................41

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

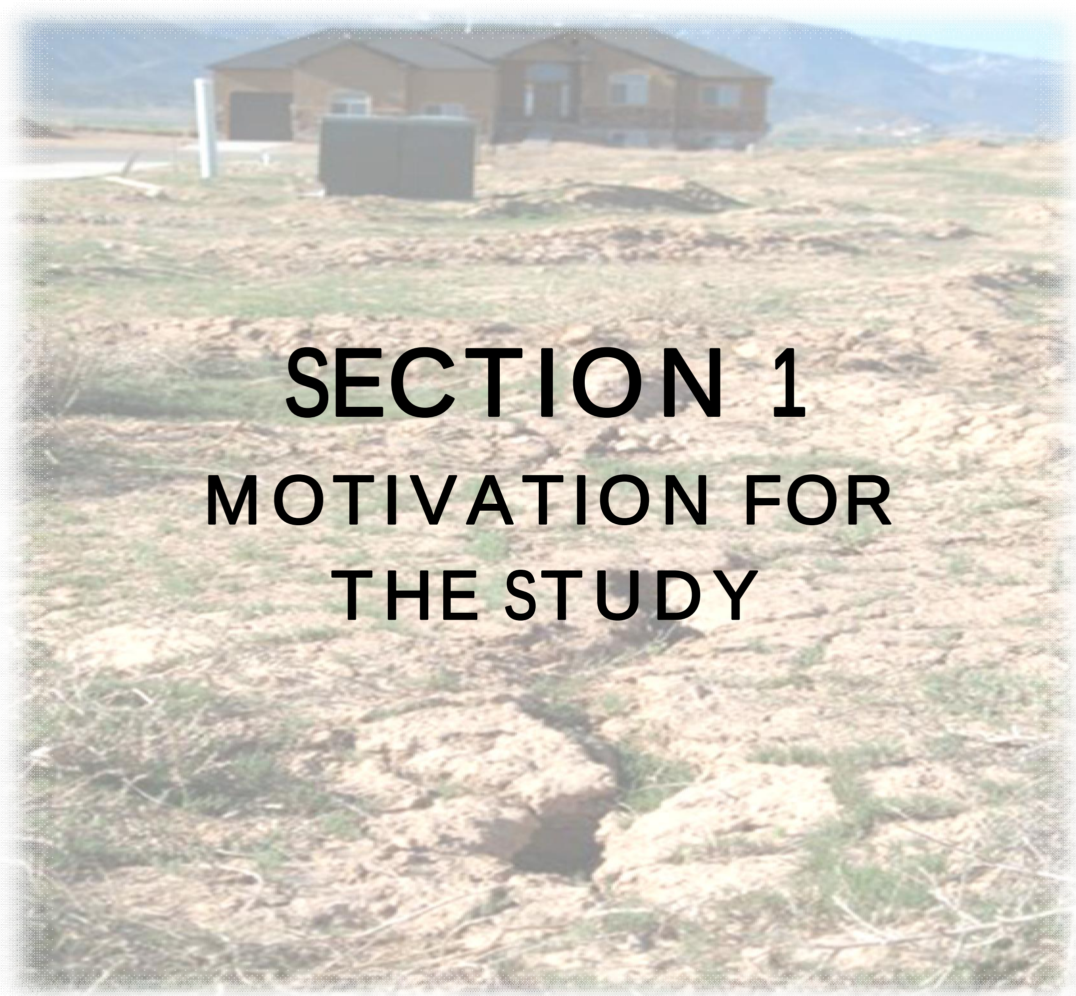
The Cedar Basin aquifer currently supplies water to Cedar City, Central Iron County Water Conservancy District, and Enoch City. Currently the aquifer is being over drawn an estimated 4,000 acre-feet a year, which is causing irreparable damage and decreasing the underground storage capacity. The over drawing is creating subsidence, namely fissures, that are direct lines to the aquifer and could cause potential contamination. As the water level drops, well casings and pumps will need to be modified to be able to access the deeper water. Both contamination and deeper wells will cause the cost of water to increase exponentially.

Coal Creek is the creek that supplies most of the surface water and natural recharge to the Cedar Basin. This water is used for irrigation, stock-watering, and non-consumptive uses. Through normal precipitation years, all of the water is used in Coal Creek, which overtime infiltrate to the aquifer. High precipitation years produce a lot of water that is unusable because of the high flows as well as the heavy sedimentation. This water is allowed to pass by the farms and reaches Quichapa Lake and Rush Lake to evaporate. This surplus water can be used, after cleaning, to recharge the aquifer.

Two methods were researched to determine the best process to recharge the aquifer using excess flows from Coal Creek. The first method is Aquifer Storage and Recover (ASR) Wells. ASR Wells are ground water wells that are capable of putting in and taking out water from the aquifer. This method is productive but expensive. Because the flow in Coal Creek is inconsistent, it would be difficult to operate the wells to be able to restore water to the aquifer. Also because they inject directly into the aquifer, a treatment facility would need to be constructed to be able to clean the water to state standards. The cost and sporadic flows made this method not feasible.

The second method researched is surface spreading. Surface spreading works by diverting water into a pit and letting it infiltrate through the ground, being cleaned naturally, until it achieves the aquifer. This method was deemed appropriate for Coal Creek because of the sporadic flows and limited funds available. Also, there are plenty of options for potential infiltration sites.

This study will provide the necessary information and recommendations for the Central Iron County Water Conservancy District to implement surface spreading for ground water infiltration. More coordination will be necessary with the state as well as other governing entities before implementing the recommended pilot program.



SECTION 1

MOTIVATION FOR THE STUDY

1 MOTIVATION FOR THE STUDY

1.1 How the Study Started

The Central Iron County Water Conservancy district was formed in 1997 and was given the charge to supply water to the residents that live within the Cedar Basin. Its mission statement states, "The Central Iron County Water Conservancy District. (CICWCD) was formed in 1997 to benefit the people and municipalities within the CICWCD boundaries. The District was organized under the Utah Water Conservancy District Act to achieve the following objectives:

- Conserve, develop and stabilize existing supplies of water for the beneficial uses of domestic, irrigation, power, manufacturing, aquatic life, wildlife, and stock watering for the direct benefit of the district residents.
- Develop additional supplies of water for use within both the municipalities and unincorporated areas of the CICWCD boundaries.
- Plan for, finance, design and construct reservoirs, pipelines, water distribution systems, wells, drainage improvements and other improvements necessary to utilize water supplies within the CICWCD boundaries.
- Benefit the municipalities within the CICWCD boundaries by providing adequate supplies of water for domestic, industrial and municipal use.
- Manage and stabilize the flow of water to directly benefit irrigated lands.[1]"

CICWCD expressed concern about their first objective: which is to "Conserve, develop, and stabilize existing supplies of water…" Through meetings with the executive director and the board members, an opportunity presented itself to help answer the question, "How can the public more effectively use the water in the Cedar Basin?"

1.2 Purpose of Study

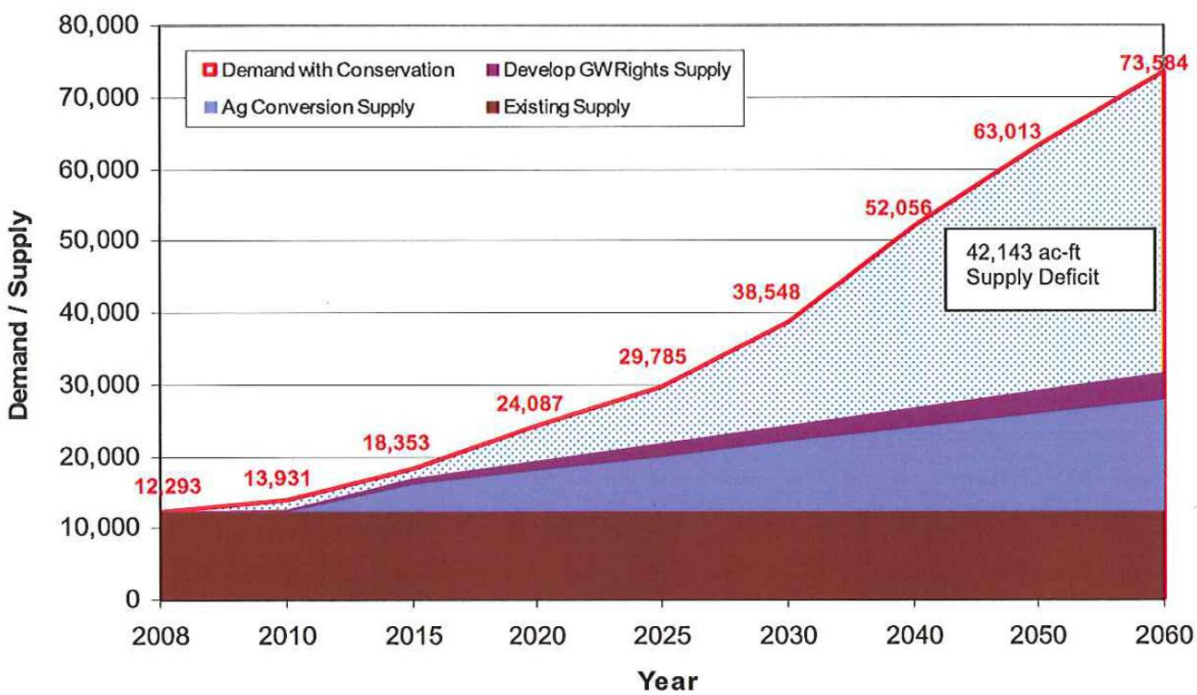
Currently the aquifer that supplies the Cedar Basin, including Cedar City, Central Iron County Water Conservancy District, and Enoch City, is being over drawn. Removing too much water from the aquifer will cause irreparable damage which will limit the storage capacity of the aquifer, cause land subsidence, and potentially contaminate the ground water.

[1] See CICWCD's website www.cicwcd.org

1.2.1 Water Usage

Public and private water companies and entities currently receive their water supply from the aquifer under the Cedar Basin. Based on reports published by the USGS, sustainable yield, or safe yield, of the aquifer is between 36,000-40,000 acre feet of water per year. Because of the extensive growth in the Basin and increased need of water, the aquifer is being over drafted by 4,000 acre feet each year and is continuing to increase. Figure 1 Demand vs. Supply shows that as the demand for water increases the supply does not specifically increase. Even through converting agricultural rights and developing any remaining ground water rights by 2060, the basin will still have a 42,143 acre foot of water deficit.

Figure 1 Demand vs. Supply



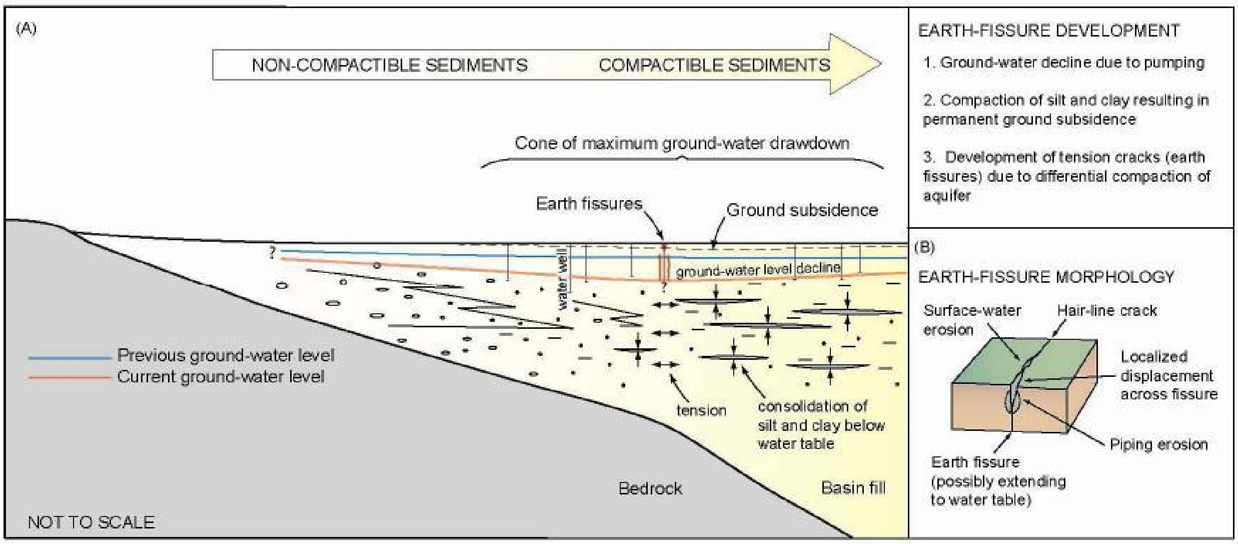
1.2.2 Enoch City Fissure

Currently the Cedar Valley Aquifer is being over drafted by nearly 4,000 acre-feet a year. It goes without consequence. In Enoch, east of Minersville Highway along 5600 North, there is a visible fissure. The fissure is the result of withdrawing too much water and causing the earth to separate and subside at different rates. A negative outcome of the fissure is that a new subdivision has been permanently damaged and resulted in the developer losing the property. Subsidence not only affects our drinking water, but also our standard of living, investments, and work.

1.2.2.1 How They Form

Fissures are similar to faults. The only major difference is that a fissure starts at the aquifer level and works its way to the surface, while a fault typically starts at the surface and works its way down. Fissures occur when the water table drops causing the "roof" of the storage area to cave in and subside (Figure 2 Formation of Fissures).

Figure 2 Formation of Fissures



1.2.2.2 UGS Study

The Central Iron County Water Conservancy District (CICWCD) has coordinated with the Utah Geological Survey (UGS) to perform a study on the fissure as well as other fissures within the Cedar Basin. The study performed will:

- Assess the nature and extend of existing land subsidence and earth fissures in the Enoch area (detailed mapping).
- Quantify changes in land surface elevation and define the extent and magnitude of subsidence in the Enoch area (surveying).
- Access the amount of ground-water level decrease in the Enoch area (water-level record review/new measurements).
- Define the nature and extend to potentially compressible sediments in the Enoch area (review well driller logs, make cross sections).

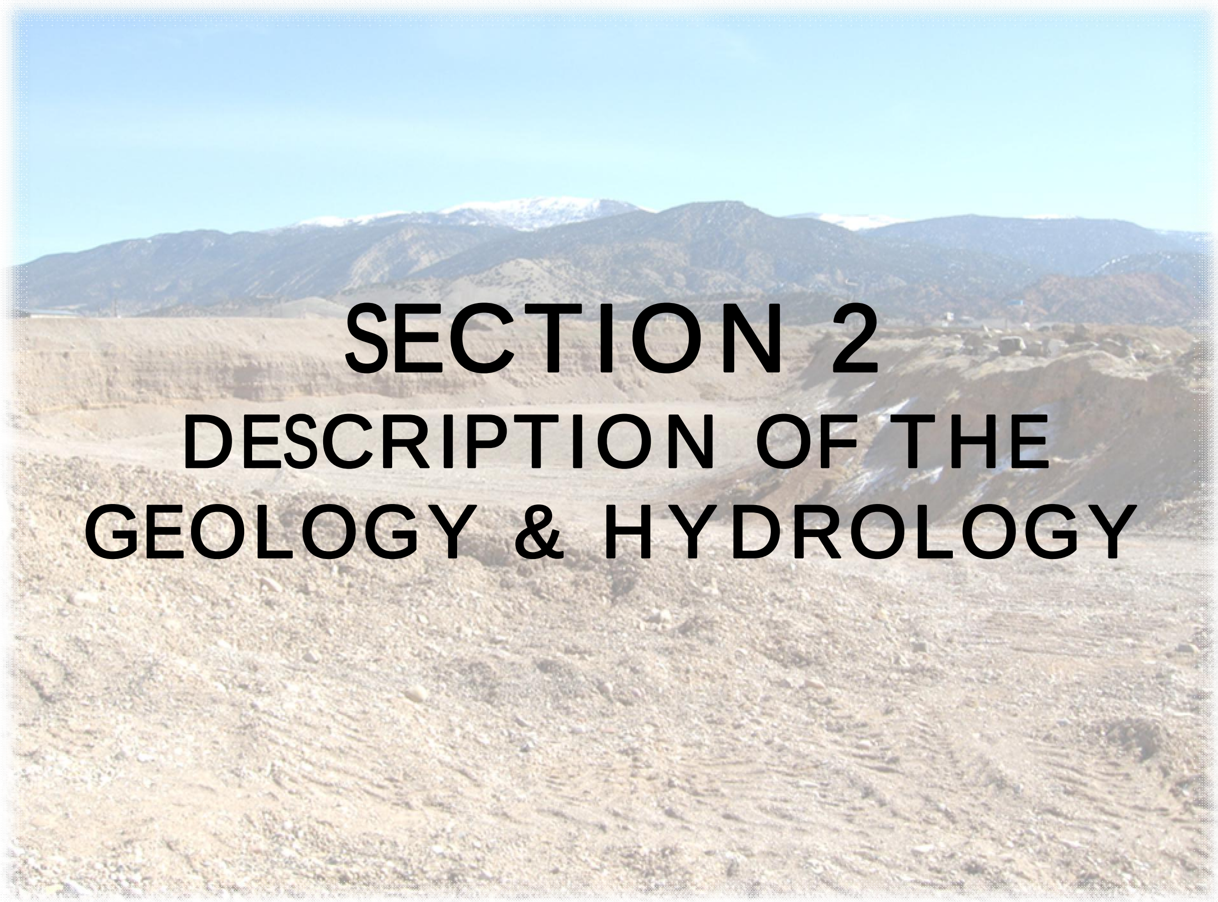
The completed information will give the CICWCD a greater understanding of the water problems within the Basin as well as help develop goals and a plan to conserve and protect our drinking water.

1.2.3 Wasted Water

Coal Creek flows are inconsistent and vary each year. When a high precipitation year occurs, water is wasted because it is so sediment loaded that the farmers cannot use it to irrigate and natural infiltration in the creek bed is halted because fine grained sediment creates a seasonal impermeable layer. This excess water is allowed to fill Quichapa and Rush Lakes and eventually evaporate. Depending on the year, the supply verses usage ratio could be increased on high precipitation years and even provide more storage for drought years.

1.2.4 Public Knowledge

This study will allow the public to gain knowledge and understanding of the Cedar Basin aquifer and the availability of water. Water conservation is a goal that CICWCD is promoting. If the aquifer continues to over drawn, water will become more expensive to purchase as well as limit the ability to withdraw water in the future.



SECTION 2

DESCRIPTION OF THE GEOLOGY & HYDROLOGY

2 DESCRIPTION OF THE GEOLOGY & HYDROLOGY

2.1 Cedar Valley - Geology

The principal aquifer in the Cedar Valley drainage basin consists of Tertiary sedimentary basin-fill deposits, chiefly interbedded sand, gravel, silt, and clay. Most recharge is derived from infiltration of Coal Creek into alluvial fan deposits near Cedar City. Coal Creek drains much of the Markagunt Plateau east of the Cedar Valley; this highland receives the majority of the precipitation that falls in the drainage basin. The drainage basin is closed to surface out flow except during extreme precipitation events, but some minor underflow of ground water has been documented in places along its north-western and southern margins. (Hurlow, 2002, p. 1).

2.1.1 Stratigraphy

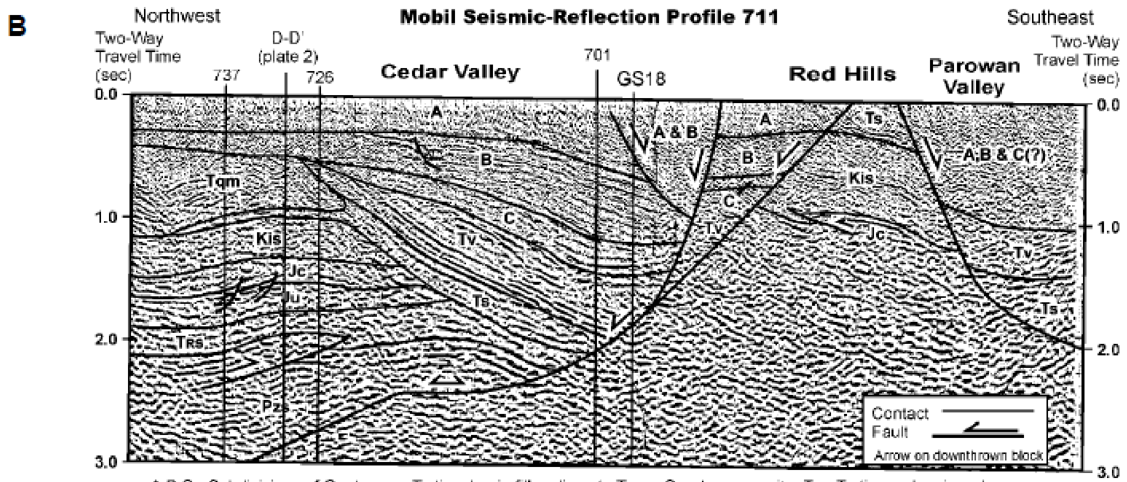
The basin fill contains two laterally persistent angular unconformities (Figure 3, Figure 4, and Figure 5), as interpreted from the seismic-reflection profiles. These two angular unconformities divide the basin fill into three informal units, in descending order A, B, and C. These units differ in reflectivity characteristics, geometry, and relations to the basin margins (Hurlow, 2002, p.13)

The following statements summarize interpreted timing relations between faulting and deposition of the basin-fill units.

1. Unit A overlies units B and C in all of the seismic-reflection profiles, and accumulated during displacement on the EBBFS (Eastern Basin-Boundary Fault System), continuing to present time.
2. Unit B accumulated entirely during displacement on the EBBFS, and unit C formed during the earliest stages of fault motion.
3. Units B and C exhibit depositional pinchout against the western subsurface basin margin, and are onlapped by unit A.

Interpretation of the seismic-reflection profiles suggests, therefore, that unit A corresponds to all of the exposed Quaternary basin-fill units in Cedar Valley and adjacent hills. Units B and C may correspond to older basin-fill units. These sediments are composed of weakly to well-consolidated, volcaniclastic sedimentary breccias, gravel, sand, and silt derived from the Harmony Mountains and the Pine Valley Mountains (Averitt, 1967: Anderson and Mehnert, 1979). Possible lithologic changes in these older basin-fill deposits toward the center of the Cedar Valley depositional basin include (1) increased thickens, (2) variation in clast composition to reflect bedrock in adjacent mountains, and (3) addition of inter bedded lacustrine deposits, as documented in other extensional basins in arid climates (Leeder and Gawthorpe, 1987) (Hurlow, 2002 p. 13).

Figure 3



A,B,C - Subdivisions of Quaternary-Tertiary basin-fill sediment; Tqm - Quartz monzonite; Tv - Tertiary volcanic rocks; Ts - Tertiary sedimentary rocks; Kis - Iron Springs Formation; Jc - Carmel Formation; Ju - Navajo Sandstone, Kayenta, and Moenave Formations, undifferentiated; T̄ks - Triassic sedimentary rocks; Pzs - Paleozoic sedimentary rocks.

Figure 4

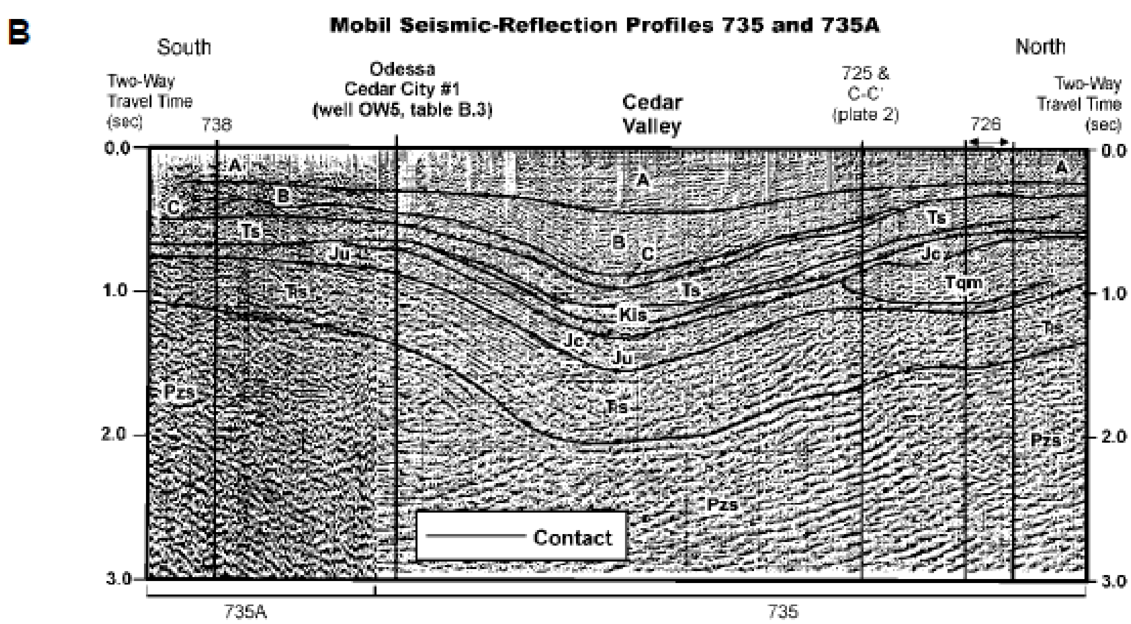


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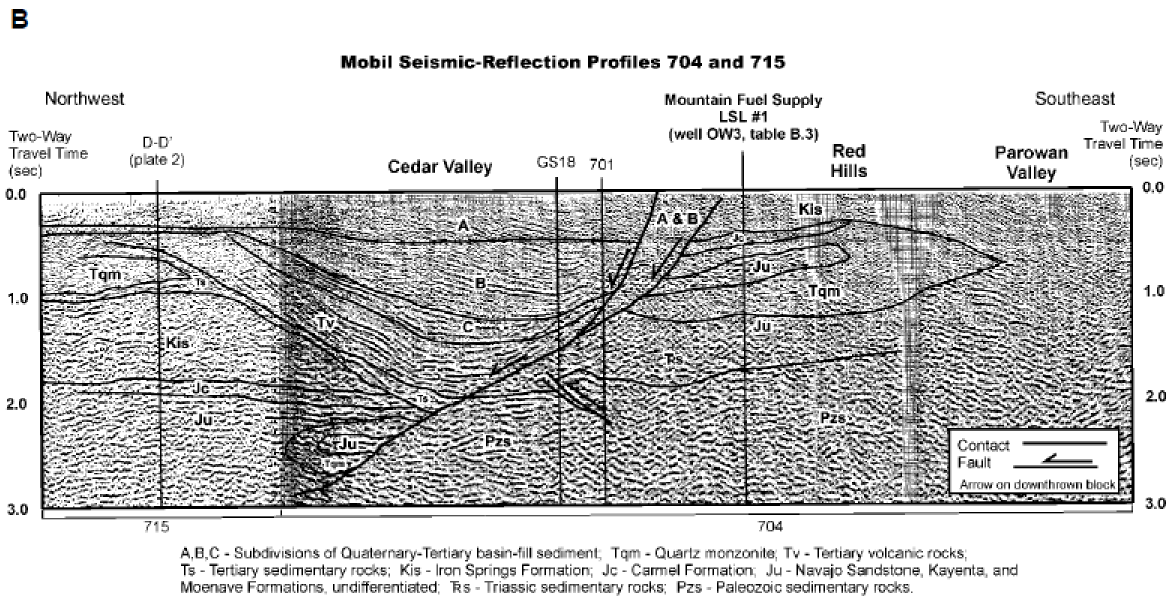
Figure 5



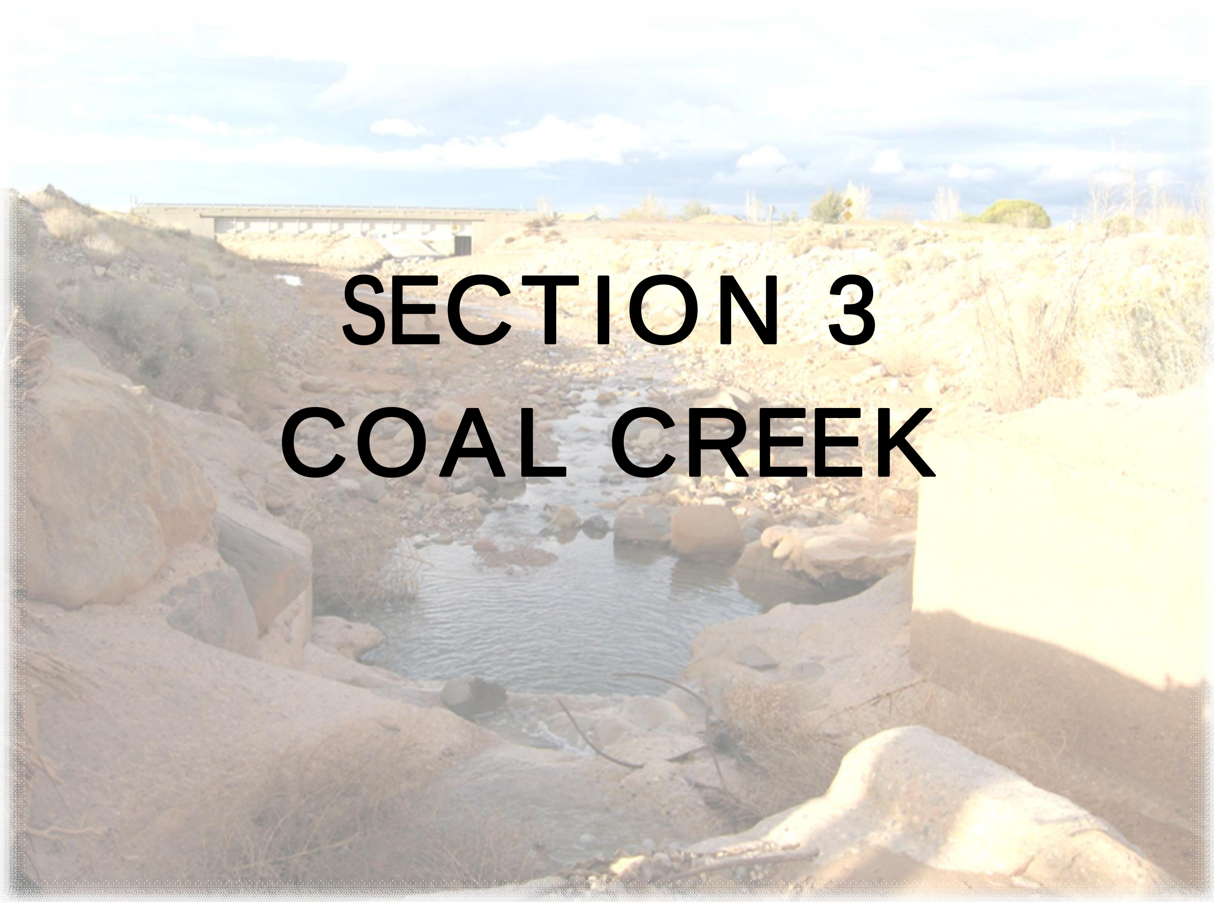
2.2 Cedar Valley - Hydrology

Cedar Valley, like most surface-drainage basins in the Basin and Range, is topographically closed and un-drained to partially drained with respect to surface water. The Cedar Valley drainage basin covers about 580 square miles including Cedar Valley, which ranges in elevation from about 5,300 to 5,900 feet, and adjacent hills and mountains. The hills bounding the western, northern and northeastern parts of the valley have relatively subdued relief. The precipitous Hurricane Cliffs form the southeastern boundary of the valley and the northwestern boundary of the Markagunt Plateau, locally over 10,000 feet in elevation. The Harmony Mountains, which bound the southwestern part of the valley, are locally over 8,000 feet in elevation. The drainage basin is open only at its south end, and at Iron Springs Gap and Mud Spring Canyon. Surface flow through these openings occurs only following extreme precipitation events (the most recent instance of surface outflow was about 50 years ago), and outflow of ground water is relatively minor (Hurlow, 2002 p. 8).

2.2.1 Geology – Water Quality

Ground water in Cedar Valley is primarily calcium of magnesium-sulfate type, and the concentration of total dissolved solids ranges from greater than 1,500 parts per million near the mouth of Coal Creek to less than 300 parts per million in the southwestern part of the valley. The high concentration of total dissolved solids in ground water at the mouth of Coal Creek is gypsiferous sedimentary rocks of the Triassic Moenkpi and Jurassic Carmel Formations, which crop out along the lower reaches of the creek and its tributary drainages. Nitrate concentrations in Cedar Valley ground water are generally low, except in a limited area southwest of Enoch (Hurlow, 2002 p. 8).

SECTION 3
COAL CREEK



3 COAL CREEK

Coal Creek, the largest perennial stream that flows into the Cedar Basin from the Markagunt Plateau east of Cedar City provides the largest percent of naturally occurring recharge. A few other small creeks, namely Shirts Creek and Fiddlers Creek, also contribute a small percentage of water annually to natural occurring recharge. Coal Creek has created a well formed alluvial fan spreading out from the mouth of Cedar Canyon on the east and sprawling to the west past the Cedar City Airport. Surface water, more especially Coal Creek, was considered for the purpose of recharge for this study. This study has taken into account winter flows, spring run-off, and summer "cloud burst" flows.

3.1 Coal Creek System

Research showed that Coal Creek's system is unique. The flow in the channel comes from mountains that are very "young", meaning they produce a lot of sediment from erosion. The water being diverted each of the irrigation companies can at times carry large amounts sediment such as gravel, sand, and bentonite clay making it difficult to irrigate and put to beneficial use. Another difference is the high volume flows in a short amount of time. 75% of the total flow occurs within a ninety day period. Both of these situations create circumstances that can produce a lot of wasted water. The irrigation companies use the water with reserve because of the consequences produced from the excess bentonite. Using too much water that is heavily loaded will eventually seal their fields and crop production will become obsolete. Also with the high flows, the irrigation companies aren't capable of handling and storing the large amount of water in a short amount of time. The excess water is allowed then to flow north and south to Rush Lake and Lake Quichapa to sit and evaporate because of the bentonite and other sediment. Figure 8 Drainage and Irrigation Facilities shows the location of all irrigation and drainage channels as well as splitting points.

3.1.1 Diversions

Along the Coal Creek Channel there are four major diversion sites. The first is the Southwest Fields Diversion which is located at the mouth of the canyon. This diversion site splits the water into the Southwest Field Irrigation Company's system. The next diversion is located at the intersection of Main Street and Coal Creek Road. This diversion site splits the water to the other three primary water companies and the Coal Creek Irrigation Company when the flow exceeds 90 cfs. Located at the intersection of 1045 North and Coal Creek Road is the Woodbury Split. This site divides the water to run north to Rush Lake or south to Quichapa Lake. Also at this site, 55% of the excess water is diverted north to Rush Lake. The fourth split is the Airport Split where water is diverted into Cedar City's maintenance yard and north to Rush Lake and smaller irrigation companies. Figure 8 Drainage and Irrigation Facilities shows the location of the diversion sites.

3.2 Flow Data

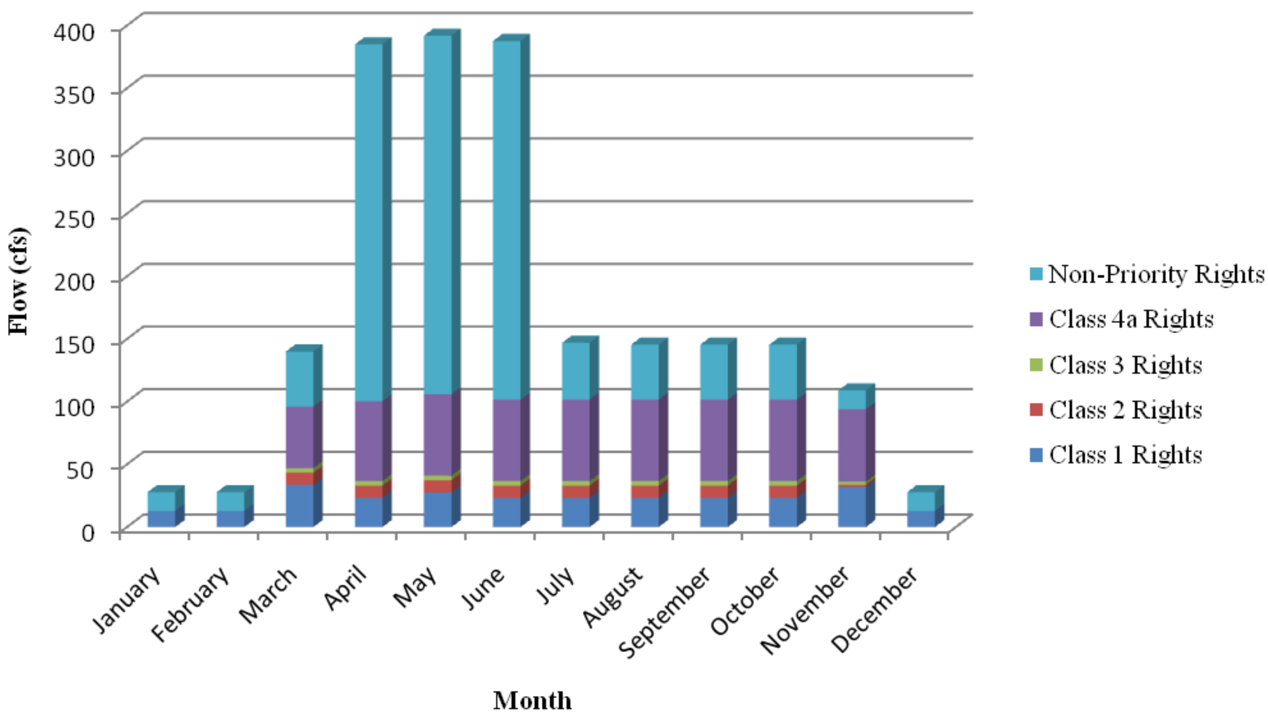
Each year 24,600 acre feet of water flow through Coal Creek, maximum flows are 2,000 cfs from winter snowmelt and 5,550 cfs from summer cloud bursts. Irrigation companies and farmers use this water for secondary water systems and agricultural purposes during the year. The challenge is that 75% of the flows occur between the month of April and June. Because of such high flows, the farmers and secondary systems take the water they can handle and allow the rest to pass. Once it passes it flows to the south to Quichapa Lake or north to Rush Lake and eventually evaporates.

There are five irrigation companies that have water rights for the water in Coal Creek and four of them have priority rights, Southwest Field Irrigation Company, Northwest Field Irrigation Company, Bulldog Irrigation Company, and East Extension Irrigation Company. The fifth is Coal Creek Irrigation Company and is allowed to draw water from Coal Creek when flows exceed 90 cfs.

3.3 Coal Creek Water Rights

Coal Creek water rights have been broken down into 4 classes based on priority day. Class 1 is filings prior to 1870, Class 2 range from 1870 to 1880, Class 3 range from 1880 to 1890, Class 4a range from 1890 to 1903, and any right that has been filed after 1903 is a low priority right. A list of approved water right numbers along with their priority date, period of use, and amount has been included in the Appendix. Reference Figure 6 Coal Creek Water Rights to see the breakdown or water rights class per month and year. According to the *Hydrology and Simulation of Ground Water-Flow in the Cedar Valley, Iron County, Utah* report produced by the United States Geological Survey, the annual discharge from 1939-200 is 24,200 acre-feet. From this flow, 25.19 cubic feet per second (cfs) are delivered to Class 1 rights. When the flow is between 25.19-35.63 cfs, Class 2 rights are permitted to withdraw. Amounts from 35.63-38.53 cfs flows are distributed to Class 3 rights, and Class 4a rights receive when the flow is 38.53-102.02 cfs. When flows exceed 102.02 cfs, the low priority rights are allowed to withdraw. Many of the non-priority rights are classified as non-consumptive use rights.

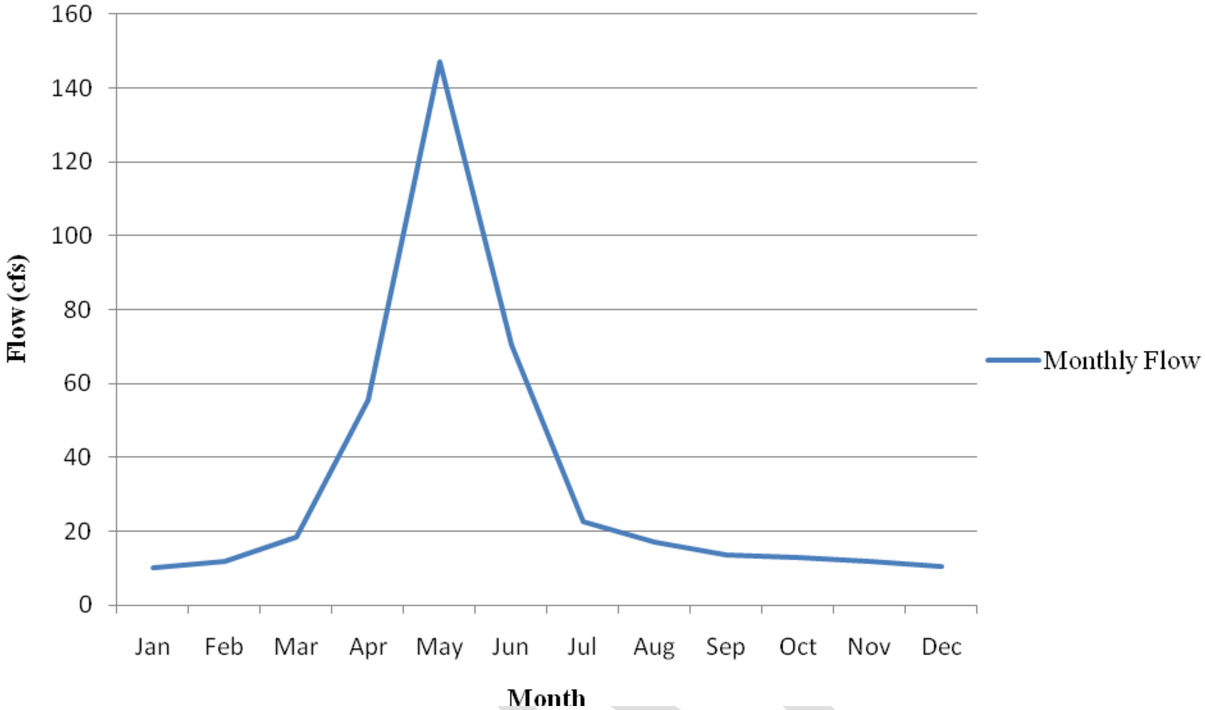
Figure 6 Coal Creek Water Rights



3.3.1 Excess Flows Exceed Water Right Filings

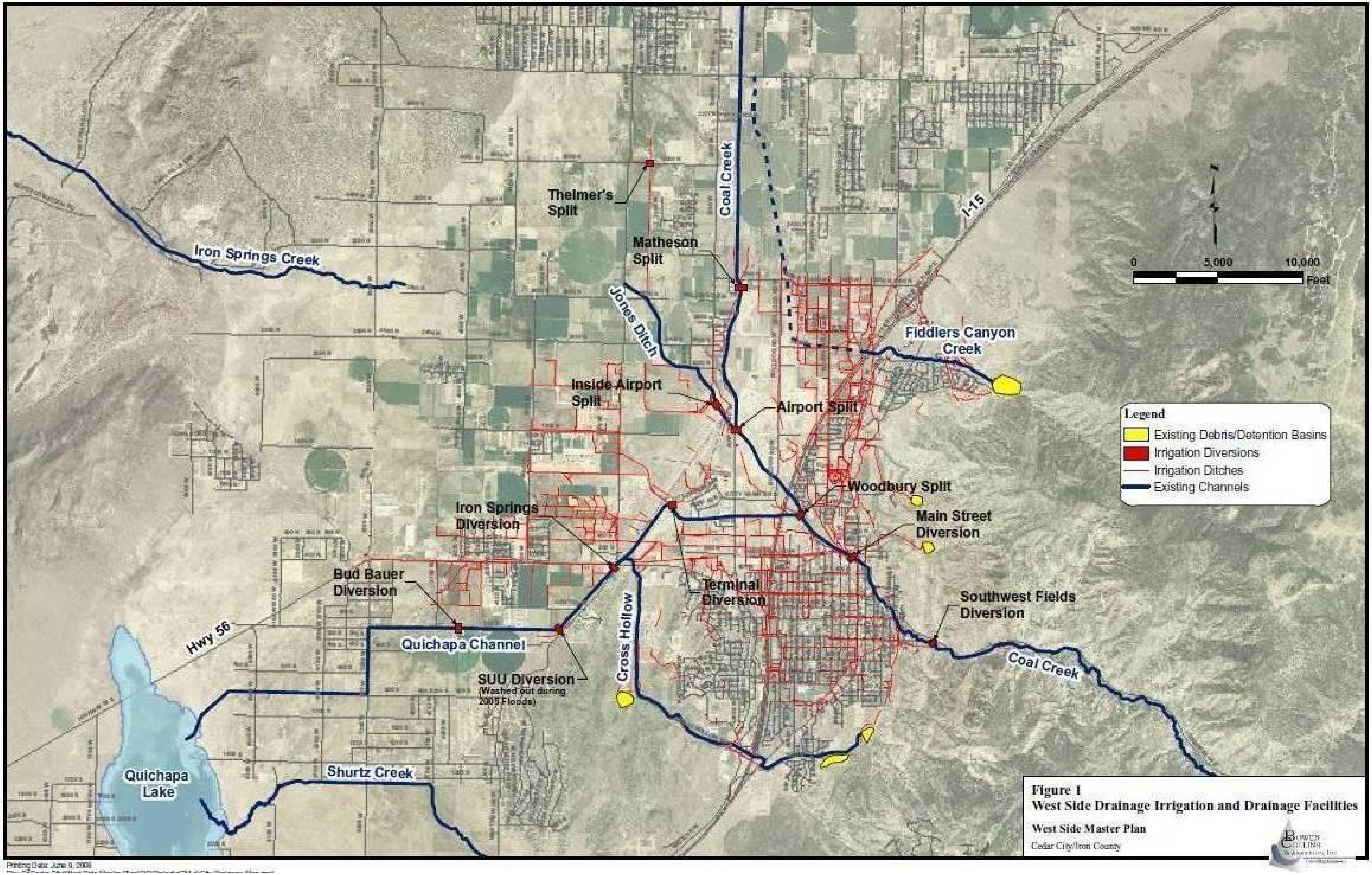
It is typical for surface water to have inconsistent flows for each time of year and also from year to year. Because some years the flow is greater than others, there is a lot of excess or unusable water (water that is loaded heavily with bentonite or other sediment). This excess water is allowed to continue past the fields and ultimately fill Quichapa Lake or Rush Lake where it is lost to evaporation. In 2006, CICWCD filed on the excess or unusable water for the purpose of artificial recharge. This filing has not been approved but upon approval, the water will be utilized for artificial recharge purposes. Figure 7 Monthly Coal Creek Flow shows that average monthly flow for Coal Creek averaged over 71 years. The bell curve of the figure is consistent with the flow during the spring run-off period.

Figure 7 Monthly Coal Creek Flow



Comparing Figure 6 Coal Creek Water Rights Figure 7 Monthly Coal Creek Flow shows that the curves for allotted water rights are similar. From past flow and usage data, there have been excess flow verses the allotted water rights that CICWCD will be able to utilize.

Figure 8 Drainage and Irrigation Facilities



SECTION 4

AQUIFER MANAGEMENT

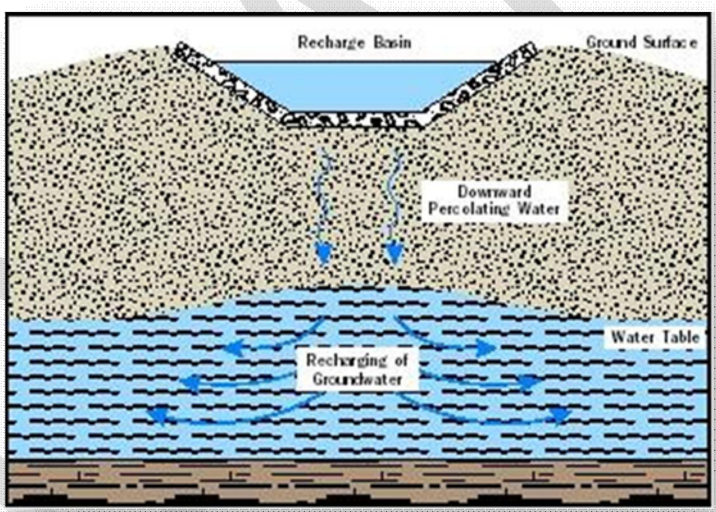
4 AQUIFER MANAGEMENT

To alleviate the excess over drafting of the aquifer, artificial recharge is a practice commonly used. Two methods that were studied and researched for the design were surface spreading and subsurface injection. Surface spreading can include a spreading basin/recharge pond, stream channel/bank infiltration, trench/infiltration gallery while subsurface injection includes vadose-zone wells, injection wells, aquifer storage/recovery wells (ASR). The research in this document compromises that of gravel pits and ASR wells.

4.1 Surface Spreading

Surface spreading entails utilizing excess water and disbursing it over large amounts of area allowing infiltration through the ground in the aquifer. Gravel pits are commonly used and are feasible for the Cedar Basin because of the gravel pits available along the channel and high on the alluvial fan. Figure 9 Surface Spreading shows the theory behind recharge basins.

Figure 9 Surface Spreading



4.1.1 CICWCD Pilot 2005

2005 was a flood year with excess flows. There was an estimated 350% snow pack in the mountains which prompted the idea of running a recharge pilot program. During the times of high flows, CICWCD diverted the excess water one-quarter mile from Coal Creek into an existing gravel pit. There the water settled and eventually percolated through the gravel bed into the aquifer. Because of the excessive amount of water, the total amount recharged is unknown.

The program was considered a success. Figure 11 2005 Pilot Site shows the diversion site and gravel pit used during the 2005 pilot.

4.1.2 Advantages of Surface Spreading

There are many advantages to using recharge pits or surface spreading. The capital cost of the pits is low compared to other alternatives. It does not require the water to be treated, because of the natural purification through the percolation of the water, no offsite or onsite treatment is necessary. It allows Mother Nature to do the work. There is minimal operation and maintenance costs. No electricity is required and there is not any service required for pumps or motors. Another important fact is the natural settling of solids that can take place in wide sections of the creek. Surface spreading has proven to work in the Cedar Basin through the 2005 pilot, performed by the CICWCD and also Iron County currently has a flood control pit used in the same manner Figure 10 Infiltration Sites shows possible locations that could be acquired for surface spreading. These areas are existing gravel pits or locations where possible surface spreading could be applied.

Figure 10 Infiltration Sites

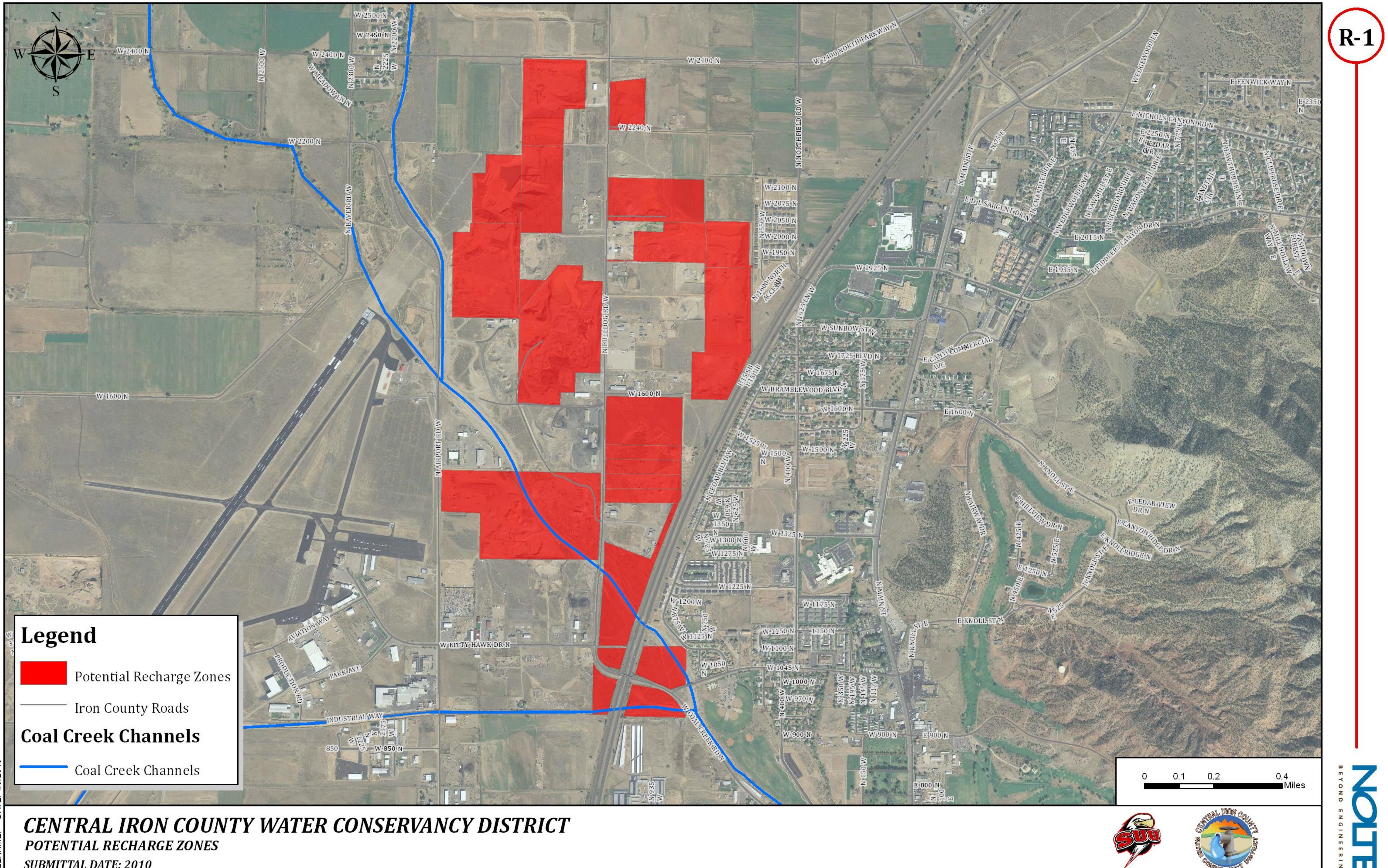
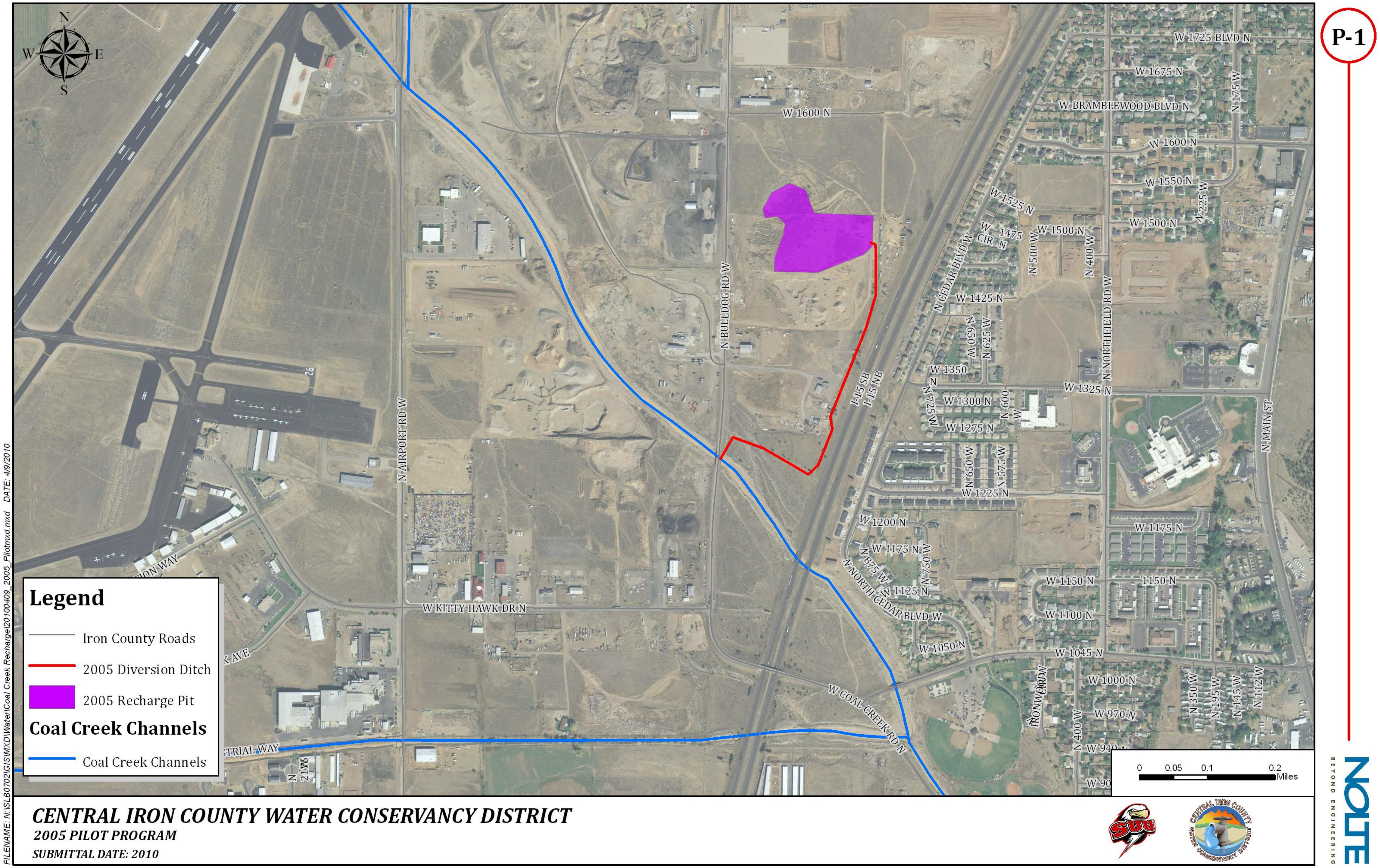


Figure 11 2005 Pilot Site



4.1.3 Disadvantages of Surface Spreading

A major disadvantage of surface spreading is the loss of water due to evaporation. Allowing large areas of water to sit in sun light will cause a loss of a significant amount of water. It is very difficult to target specific aquifer zones. There are two types of aquifers, confined and unconfined. Surface spreading would only allow the penetration of unconfined aquifers. Recharge may be impeded by clay layers. Though the water will be infiltrated into the ground, clay will cause the water to stop, perch, mound, or take an alternate route before reaching the aquifer.

The acquisition of land for the recharge pits could be very expensive. There are many locations of existing gravel pits within the basin but they are currently being mined for commercial purposes. These corporations would have to allow CICWCD to purchase or lease the area for a recharge site. The possibility of the pit becoming "plugged" by the bentonite or other clay material is a concern. If the pits are not appropriately maintained; the water will not infiltrate but evaporate like the water located at Lake Quichapa or Rush Lake. The pit utilized by Iron County has shown the impacts of the clay and bentonite as less and less water each year is infiltrated. Existing infrastructure is another disadvantage. Currently there are not any ditches or channels diverting water to the gravel pits. Also some work will need to be done to widen the existing channel for slowing purposes. By slowing the flow of the water it will allow the heavier sediment to settle. The disadvantages listed in this section are more fully considered in Section 7.

One of the greater disadvantages is the Federal Aviation Administration (FAA) regulations against standing water. The airport influence zone is described further in Section 7. The FAA regulations discourage placing standing water within these areas adjacent to the airport because of potential hazards from collisions between wildlife and aircraft. Contact has been made with representatives from the FAA and a summary of this contact is found in Section 7.

4.2 Aquifer Storage and Recovery Wells (ASR)

Injection wells are used to take surface water, treat it, and inject it directly into the aquifer. There are different classes and categories of injection wells. Research was done on the class and category pertaining to aquifer recharge and aquifer storage and recovery wells (ASR). Figure 12 Las Vegas ASR Well shows and ASR well that used by the Las Vegas Water District.

Figure 12 Las Vegas ASR Well

4.2.1 Implementation

ASR wells began to be used in 1968 and as of 2007 there are 80 operating ASR well fields in the United States. Currently there are three documented ASR wells in Utah. The operation of ASR wells has three phases. Phase one, they water is injected into the aquifer when excess runoff or supply is available. Two, potable water is stored in the aquifer. The storage is usually temporary, injected during the wet months and recovered during the dry months. Last is recovery. Recovered water is used for drinking water, irrigation, and other purposes.

4.2.2 Advantages of ASR wells

One advantage of an ASR well is the permanence. Because the well will be a structure in the ground, it won't have much possibility of having to be moved. Developments can be constructed around them with the proper protection. Another is that there is more capacity for storage. Water in recharge pits will eventually fill with sediment and need to be excavated. ASR wells will only inject treated water which will allow more capacity in the aquifer. Also because it is injected straight into the aquifer, there will not be any loss of water to evaporation. These wells will also prevent any threats to downstream contamination.

4.2.3 Disadvantages of ASR wells

The costs of an ASR wells are expensive. Because Utah requires the water injected to be a tertiary standard, all water will need to be treated. A treatment facility will be costly and the cost of maintaining the facility along with the wells will be expensive. The maintenance of the wells will also require a lot of time.

Injecting and recovering water from the aquifer causes problems with the pump as well as the fittings of the well head. The casing can become rusty and cause contamination to the aquifer and the pump will decay at a faster rate. Often it is recommended that the implementation of three or four ASR wells is sufficient to reduce the wear and tear.

Clogging is another disadvantage of ASR wells. There are many causes for clogging including physical clogging due to back flushing and when the surface water makes contact with the ground water, biological clogging due to bacterial growth, chemical clogging due to precipitates, gas bubbles and protective chemicals, and mechanical clogging due to air entrapment, fractured pipes, pump cavitations, and high velocities.

SECTION 5

EXISTING PROGRAMS

5 EXISTING PROGRAMS

5.1 National Ground Water Association Conference and Las Vegas, NV

In December of 2008, while attending the National Ground Water Association conference in Las Vegas, information was gathered relative to this report. Two days were spent meeting and discussing ground water issues with industry leaders in aquifer storage and recover, attending ground water modeling classes, and specialty group meetings relating to aquifer management. The information that was gathered at the conference has been taken into consideration and has been implemented into this report.

5.1.1 Las Vegas Water District

Today the Las Vegas valley gets the majority of its water from the Colorado River by means of Lake Mead. The water is pumped out of the lake, treated and piped in to serve the residents of Las Vegas. The rest of the water to meet the high demands comes from ground water located in the aquifer that runs under the whole valley. When Las Vegas was a new city and before water was ever pumped from Lake Mead it was pumped out of the aquifer and was easily available from artesian natural springs found throughout the valley. As the population increased in the beginning of the 20th century people began to over pump the aquifer. This over pumping led to land subsidence of up to 60’ in the middle of the valley. It was noted that from the years of 1960- 1988 the water table in some areas dropped down 100 – 150’.

5.1.2 Artificial Recharge Plan

During 1988 the Southern Nevada Water Authority in conjunction with the Las Vegas Water District formulated an Artificial Recharge Plan in order to stop the overdraft of the aquifer and at the same time eliminate land subsidence. The plan was laid out such that during the months of low use excess treated municipal water from Lake Mead would be injected back into the aquifer. This plan had been going now for 20 years and a total of 250,000 acre feet of water have been restored to the aquifer. This process has stopped subsidence across the whole valley. In the lower areas of the valley the water table has actually has recovered to levels noted before the large drop from 1960-1988. There are places also where the ground has been recorded as actually recovering from the subsidence and rising back up. The amount is very small (a few mm/month), but has been considered a success. On the peripheral of the valley the recovery effort has not been as positive. The water table levels have not continued to drop, but have maintained the same levels during the Artificial Recharge efforts.

5.1.3 Engineering of the Artificial Recharge Plan

All artificial recharge is carried out by the means of injection wells. There are currently many wells that are set up to accept recharge water. The majority of these wells are ASR wells. The operators stated that, for the most part, water can be pumped back into the wells as fast as it can be pumped out. A number of the wells are very large and have flow capacities of 3000 gpm or more. This allows for a large amount of water to be forced put back into the ground. The additional plumbing requires a bypass line with a radio controlled valve such that it can be turned on and off quickly based on other demands, a magnetic flow meter, an air vac valve and gate valves for isolation. The lack of complexity and ability to be used for dual purposes makes this type of recharge very cost effective if the excess water is available and contaminant free.

5.2 Weber Basin Water Conservancy District, Weber, UT

Weber Basin Water Conservancy District has run a four year pilot program at the mouth of Weber Canyon. Through the use of the Weber River and surface ponds they were able to recharge an unconfined aquifer. Initially they had the capacity to be able to flood 3.8 acres but have increased it to 7.5 acres (Figure 13 Weber Basin Recharge Pit). In fall of 2009 they are expanding to more existing pits in the area and eventually to the pits at the mouth of the canyon. By having the pits higher in the canyon, the possibility of hydropower generation will be included.

Figure 13 Weber Basin Recharge Pit

5.3 Metropolitan Water District of Salt Lake and Sandy, Salt Lake City, UT

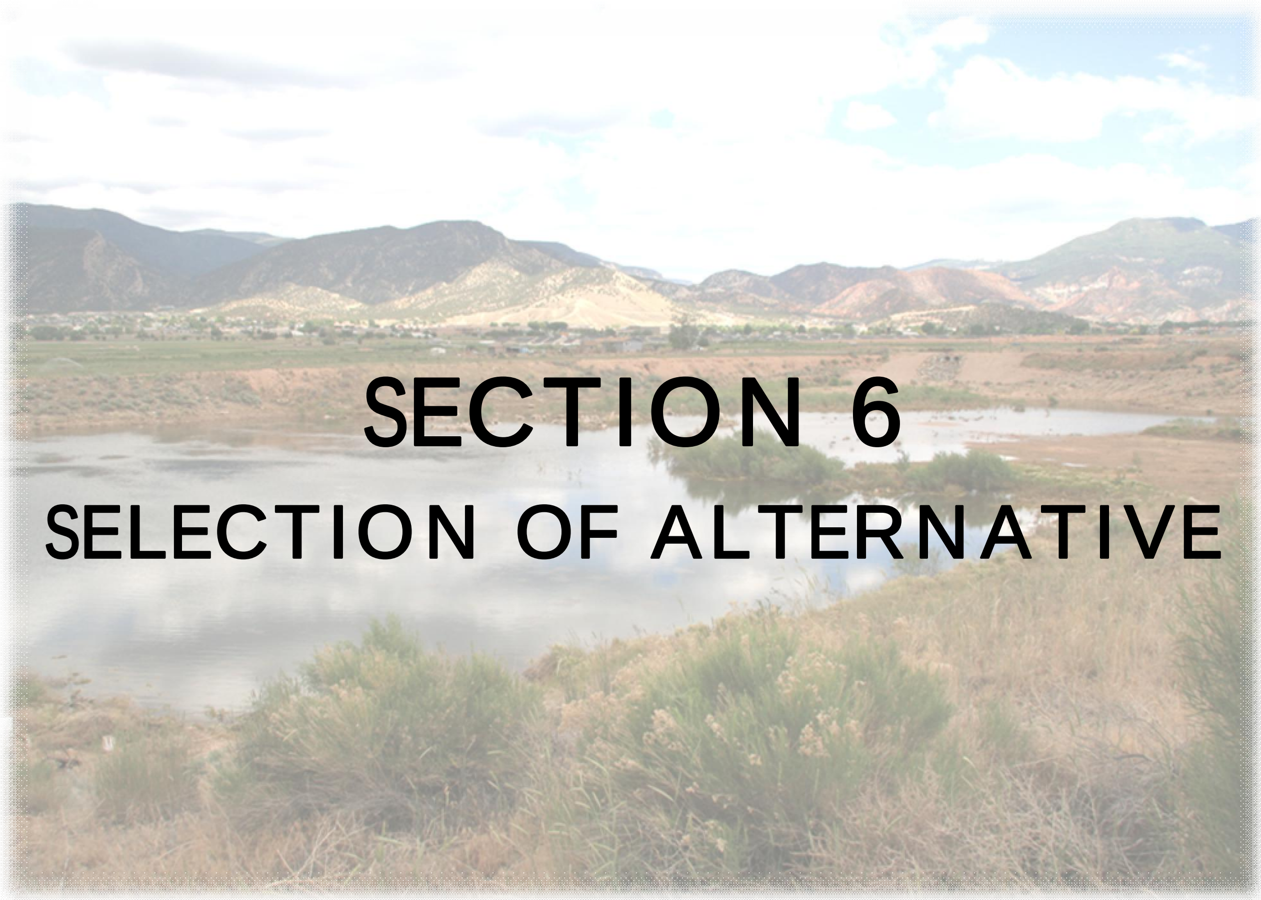
The Metropolitan Water District of Salt Lake and Sandy began its pilot program for aquifer recharge in 2006. The objective of the recharge was to store water seasonally and long term. The design was to use a one acre pond, forty foot deep and four foot diameter vadose well, and a three hundred foot long four inch perforated pipe. They have determined that all three methods were a success and have since started the recharge plan.

5.4 Brigham City, UT

Brigham City used ASR wells for their recharge plan. For their wells, they took three existing production wells and retrofitted them to become ASR wells. As their recharge source, they use a ground water spring that produces around 1,400 acre feet per year. Before they had iron and manganese problems and through injection they solved the problems and are currently at non detect levels. This is probably the most successful project in Utah. The ground water level has risen to the level it was five years prior to the project and took four years to complete with a cost of $180,000.

5.5 Jordan Valley Water Conservancy District, Jordan, UT

Their program was the first ASR project in Utah and became the leader in the aspect of the water supply industry. They retrofitted thirteen production wells to become ASR wells and added six new ASR wells. They also installed new thirty and twenty inch water lines, a bi-directional booster station, a treatment facility with the capacity of 10 Mgd-20Mgd. Several streams are their recharge source but because of drought conditions the benefits of the project are not fully realized. It took a total cost o $20,000,000 and nine years to complete.

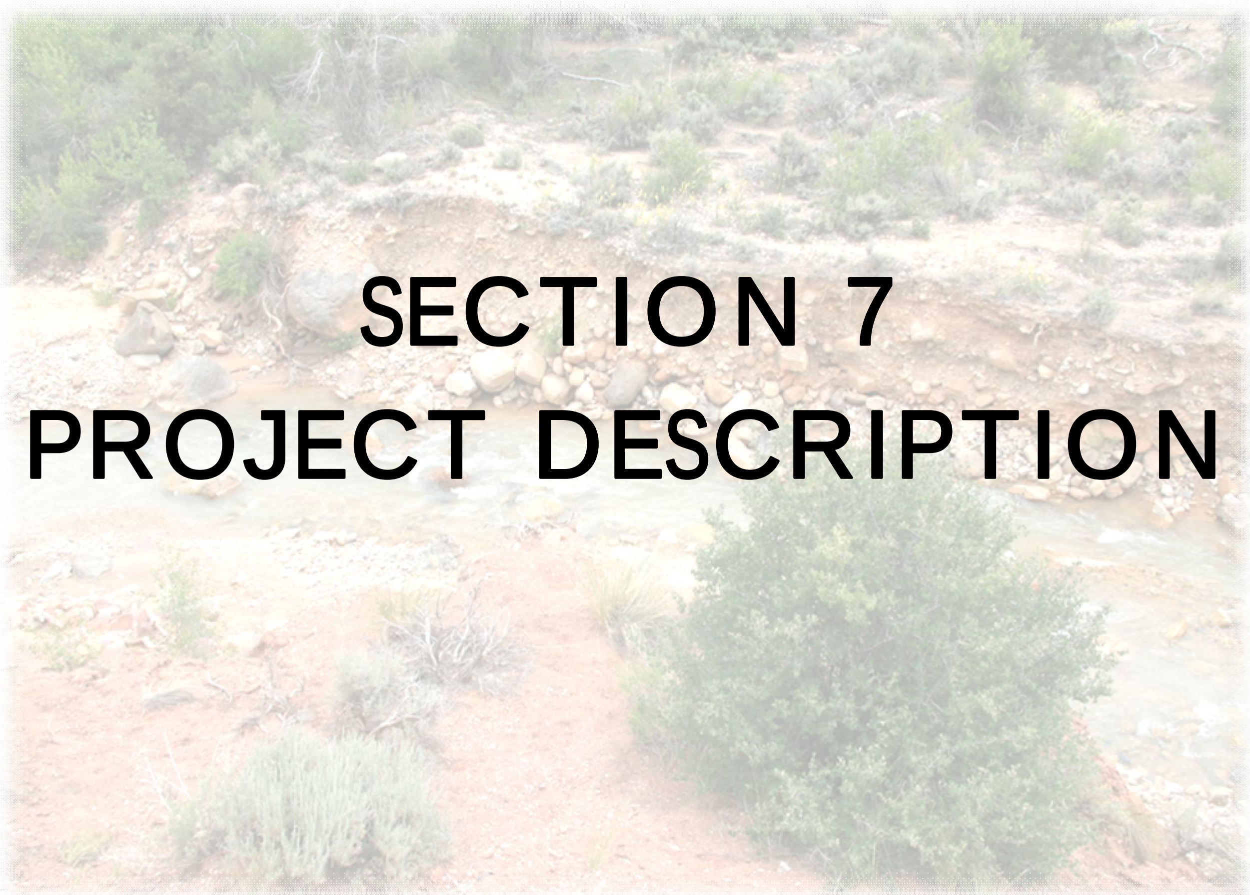


SECTION 6

SELECTION OF ALTERNATIVE

6 SELECTION OF ALTERNATIVE

Given the evaluations listed previously, it is in the best interest of CICWCD, Coal Creek water users and the Cedar Basin to create and initiate an aquifer recharge and management plan that will achieve its goals by means of surface spreading/infiltration. With surface spreading having been chosen as the best alternative an evaluation was done in relation to the actual soil and sediment conditions present in and around the Coal Creek drainage and within potential recharge sites. Descriptions of considerations for surface spreading specific to the Cedar Basin are listed below in Section 7.



SECTION 7
PROJECT DESCRIPTION

7 PROJECT DESCRIPTION

7.1 Project Objective

To evaluate the feasibility of artificial aquifer recharge and management by means of open pit infiltration, and more specifically the feasibility of implementing such a plan based on current soil, sediment conditions, and water quality conditions. High flows, being described as any flows above 200 cfs or water that has a large count of total suspended solids numbers to be of benefit for agriculture purposes, and excess winter flows will be utilized when available.

7.2 Evaluation of Water for Recharge

Actual water samples were taken from Coal Creek and by using known methods the water was analyzed based on the following criteria: size of suspended sediment under typical conditions for large flows in question, type of sediment present under typical conditions for large flows in question, and amount of sediment per cubic-foot of water. It is also important to note that this data was collected during the months of September – November when the flow is relatively low. With this low flow the amount and types of sediment present will be different. An attempt was made to mimic spring run-off conditions, but actual conditions may vary. Therefore, during the spring months, actual water samples have taken and analyzed based on the same criteria as the fall water.

7.2.1 Water Quality

Much of the information in this section (7.2.1 Water Quality) was taken from correspondence with Dr. Kim Weaver, Associate Professor of Chemistry at Southern Utah University. He is currently mentoring a group of students who are performing a very in-depth analysis of Coal Creek water quality. The scope of their study includes analyzing water out of Coal Creek according to the complete EPA list of contaminants and their MCLs under the Safe Drinking Water Act. Dr. Weaver was able to talk about this study, but the results have still not been published. This study along with coordination with Dr. Weaver will prove to be very successful in the water analysis for any future recharge experiments or pilot programs.

7.2.2 Potential Contaminants

When using pit infiltration the water quality does not need to meet drinking water standards. However, when considering the chemical characteristics of the recharge source care must be taken that the water shares similar characteristics with the water found in the aquifer. This becomes especially important in the cases where artificial recharge facilities are located a large distance from the historical natural recharge locations. For the basis of this report and for the consideration of recharge from Coal Creek it was assumed that the recharge water will not be transferred a large distance from the Coal Creek channel. However, analysis of the water source, water within the aquifer, along with the geological properties of the layers of materials that the water will be transferring through has been considered. One purpose of the water quality analysis is to ensure that the ground-water does not become contaminated by the recharge experiment, whether by poor quality water from the source to begin with, or by picking up pollutants or chemicals within the layers of material through which the water will travel on its way to the aquifer. If an existing gravel pit is chosen for the recharge experiment location then care should be taken to make sure that there haven't been any oil/gas/grease spills that could introduce pollution into the aquifer as the water passes through it. The potential contamination sources are shown in Table 1 Water Contamination Sources.

Table 1 Water Contamination Sources

Water Quality Contaminants	Potential Site Contaminants
Microorganisms	Oil, Gas, Grease from Industrial Operations
Disinfection Byproducts	Organic and Inorganic Chemicals
Disinfectants	
Inorganic Chemicals	
Organic Chemicals	
Radionuclides	

7.2.3 Biological & Geochemical Clogging

The water quality characteristics along with the geological characteristics of the recharge site must be considered and analyzed. If certain conditions are present clogging of the recharge site on surface and below surface is a possibility. Clogging on the surface can occur by biological growth. This typically occurs when water has time to settle and stay stagnant. However, Coal Creek water does not exhibit any characteristics necessary to support biological growth. A quick analysis of the Coal Creek channel reveals that there is very little if any biological growth within the channel. In Dr. Weaver's opinion there wouldn't be any possible clogging from biological growth on the surface. Clogging of the infiltration pit from geochemical reactions was taken into account. This can happen as chemicals in the water react with geological compositions below the recharge basin. These reactions can cause precipitates to form between the cobbles, rocks, and gravel and effectively halt or slow down recharge rates. Dr. Weaver also stated that there is low probability that there would be any clogging from geochemical reactions based on the water quality.

7.2.4 Total-Suspended Solids

The water quality parameter that offers the most constraint to the success of a recharge program is total-suspended solids (TSS). This is the amount of suspended material that is carried in the water. At times of higher velocity the stream has more energy and is able to carry a large amount of sediment along with the water. As the water begins to flatten out and spread out as it approaches the valley floor the velocity is significantly decreased. This decrease in velocity in conjunction decreases the total energy ability to carry material; therefore, the heavier sediments begin to drop out until only the lightest material is left suspended in the water.

The TSS for Coal Creek fluctuates throughout the year. During the spring and early summer months the amount of sediment (solids) in the stream are relatively high compared to the winter months when the stream volume and velocity are much lower. This high TSS number makes it difficult to use this water for recharge because there is higher probability that the sediment will settle out of the water in the recharge pit and will collect along the surface. Options for removal of this sediment will be considering in Section 7.

7.2.5 Baseline Data

Baseline water-level and chemical data should be collected monthly some time in advance of any recharge experiments and also after each experiment. Water-level data should be taken daily and chemical data should be taken weekly during any recharge experiments. Water should be tested from source (Coal Creek) and also at any adjacent monitoring wells that have been drilled or where use has been agreed upon. Ground-water levels can change in response to a variety of factors including: surrounding well pumping activity, local and regional precipitation, barometric pressure, irrigation and outdoor water use.

7.3 Sediment –Water Conditions

The sediment in the coal creek discharge is a large problem; if the water is not cleaned it will clog any infiltration pit in a short amount of time. There are many different types of sediment that come from the discharge of Coal Creek. They all come from different formations of rock and strata that is composed of clay and silt. This creates a problem as an attempt is made to try to indentify all the soil and clay types and their grain size present in the water. The creek is relatively young from a geological stand point and that means that it still has a lot of sediment that is washed downstream from higher elevations. The excess water that will be used to recharge the aquifer will vary in the amount of sediment that is suspended in the water. The large particles will settle out before the water reaches the settling pond. The particles that could potentially clog the infiltration will pit take much longer to settle out of the water. Any particle from 75 µm to 20 µm is classified as silt and will take hours to settle out; any particle that is under 20 μm is classified as clay and can take days to settle out. The actual calculations and equations for the settling time have been set forth in *Section 4.2.1 Stokes Law Evaluation.* The amount of sediment in the discharge water volume is very high during the spring run-off and in run-off from summer cloud burst type rain storms. The water that will be utilized is going to be discharge with high sediment amount ratios per volume of water. During winter flow there is approximately 0.3 pounds of silt/clay per cubic foot of water. The spring runoff will have a much higher percentage of silt/clay per cubic foot. The next step is to design a settling pond that will let the sediment fall out of the water as fast as possible with minimal time for evaporation.

7.4 Settling Methods

Two types of settling methods have been researched and considered for removing the bentonite sediment from the water. The first is utilizing settling basins and the second was Iowa Vanes.

7.4.1 Settling Basin

Settling basins are designed to be large retention ponds that will hold water that has been diverted from the main channel, be held at zero velocity for a period, and then return to the main channel for irrigation use as well as recharge using gates or a weir.

7.4.1.1 Stokes Law

In 1851, George Stokes derived an equation for the frictional force or drag force exerted on small spherical objects that have a very small Reynolds Number in a continuous fluid. The equation was originated by solving Stokes Flow Limit for the Reynolds Number of another equation, which is generally unsolvable, known as Navier-Stokes Equation.

$$F_d = 6\pi\mu RV \quad (1)$$

Where F_d=The Frictional Force (N); μ=The Dynamic Viscosity of the Fluid (kg/m*s); R=The Radius of the Spherical Object (m); and V=The Velocity of the Object (m/s).

7.4.1.2 Settling Velocity

If the spherical object is falling freely through a liquid due to its own weight and gravity, then the terminal or settling velocity is reached when the gravitational force and frictional force balance the buoyant force. The resulting velocity can be derived from the equation

$$v_g = \frac{gD^2(\rho_g - \rho_f)}{18\mu} \quad (2)$$

Where v_g=The Settling or Terminal Velocity of the Object (m/s); g=The Acceleration of Gravity (m/s^s); ρ_g=Density of the Particle (kg/m^3); ρ_f=Density of the Fluid (kg/m^3); and μ=The Dynamic Viscosity of the Fluid (kg/m*s).

7.4.1.3 Results

Assumptions were made to determine the settling velocity of the bentonite in the water. Because it would be difficult to measure the exact diameter of the grain size, it was assumed that the bentonite was quartz based clay. From the assumption, the diameter of the bentonite is 1/256 mm and the density is 2.8 g/cm^3. See Table 2 Stokes Law for assumptions and variable information.

Table 2 Stokes Law Assumptions

V_g	settling velocity						
D	grain Diameter	=	1/256	mm	=	3.91E-06	m
ρ_g	grain density	=	2.8	g/cm^3	=	2800	kg/m^3
ρ_f	fluid density	=	1	g/cm^3	=	1000	kg/m^3
μ	dynamic viscosity	=	0.1	g/(cm*s)	=	0.01	kg/(m*s)
g	acceleration of gravity	=	9.81	m/s^2	=	9.81	m/s^2

After applying all variables to the settling velocity equation;

$$v_g = \frac{g D^2 (\rho_g - \rho_f)}{18\mu} \quad (3)$$

The settling velocity determined for the bentonite was 0.42 feet per day, or 0.0175 feet per hour. This means that for every foot of water contained within the settling basin, it takes approximately 2 days for the clay to settle.

7.4.1.4 Field Testing

To determine if the assumptions were correct, field tests were done by capturing sediment loaded water in a bucket and timing how long it took the clay to settle. The results showed that it took 27 hours (1.125 days) for 0.5 feet of clay to settle. Comparing the test value of 0.0185 feet per hour to the calculated value of 0.0175 feet per hour shows a 5.5% difference. Therefore, the calculated result can be considered reliable.

7.4.1.5 Advantages of Settling Basins

An advantage of the settling basin is the cost. There is land accessible next to the main channel of Coal Creek. A lease may be obtained for the land owned by the Coal Creek Irrigation Company for a settling basin, or another area may be donated. Also, the settling basin can have a multi-purpose function. Because it will capture excess flow, the basin will be able to control flows and make them more accessible and useful to farmers. Another advantage is that settling basins have the ability to provide a nature park for the community.

7.4.1.6 Disadvantages of Settling Basins

There are a few disadvantages to utilizing settling basins for sediment removal. One is that, if an existing pit is not utilized then there would be an excavation cost. Many of the properties available are ten to fifteen feet higher than the flow line of the channel. To remove the necessary amount of dirt for the water to flow into the basin could be costly. Another disadvantage is the liability of the land owner as well as the Central Iron County Water Conservancy District for children to play around and possibly fall into the water. Also, the standing water may attract birds. Because all of the land areas are within the FAA Influence Zone, there are issues with migrating birds and the possibility of them disrupting airport traffic.

7.4.2 Iowa Vanes

Iowa vanes are designed to help protect stream banks from erosion, maintain flood-flow capacity of water, maintain navigation depth, and control sediment diversions. They are structures that are double curved and are useful for sediment control and management in rivers.

Iowa vanes were developed by Russian engineers in 1947 but have been modified and redesigned since. They work by creating a vane-generate secondary current which eliminates the centrifugal force within the secondary current. This creates a high velocity current outward and a low velocity current inward. Because of the difference of the velocity, the heavier material, namely the sediment, will draw toward the lower velocity current. By placing them on the edges of the channel, the velocity will slow down and allow the bentonite to eventually settle and the clean water to continue within the channel to be used for irrigation or recharge.

7.4.2.1 Advantages to Iowa Vanes

An advantage to utilizing Iowa Vanes is that the cost is minimal and could even be constructed using raw material. They also are easy to install and replace and have been proven efficient in several tests and areas. Last, they can be adjustable to determine how effective they change the velocity of the water to allow the water to settle.

7.4.2.2 Disadvantages to Iowa Vanes

One disadvantage to Iowa Vanes is that they are a newer technology. Though they have been tested and proven in other areas, there is some uncertainty that they will slow the velocity enough for the bentonite to settle. The settling experiment and calculations were all done assuming a zero velocity. When CICWCD begins the pilot program, it is recommended to further investigate Iowa Vanes.

7.5 Evaluation of Soil Conditions for Recharge

The soil is an important part in choosing a site for an infiltration pit. A few possible sites have been located that will work well. Soil is classified by *American Association of State Highway and Transportation Officials (AASHTO)* from the best A-1-a to the worst A-7. The soil classification for the site will have to be A-1-a to achieve the infiltration rate that is needed. Theses classifications rely on many different factors; the main classification that applies to this project is how many fine particles are composed in the soil. If it has too many fine particles in the soil it will clog easier and take longer for the water to infiltrate. The cutoff point to be classified as an A-1-a soil, it cannot have more than 15 % of all material smaller than 75 µm. The percentage is based on a dry weight. The pit needs to be able to let the water infiltrate quickly to minimize the amount lost to evaporation.

7.5.1 Percolation Rate

G.E.M. Engineering, a local geotechnical lab/engineering firm, has done percolation tests all over Southern Utah. They were willing to share some percolation data from an area that will be similar to the sites (gravel pits east of freeway and Coal Creek Irrigation Company property) in question for the infiltration pit. The data is measured in minutes per inch. The date taken by G.E.M. Engineering was 5 min/in. That means that over that area of the pit every 5 minutes an inch of water will be absorbed in to the ground. An example would be, if the infiltration pit was ½ an acre it would take 2 hours to absorb 1 acre foot or 43,550 ft^3 of water. This is an excellent rate and will allow for a small pit that will be able to recharge a large amount of water. Percolation rate is the velocity at which the soil will absorb the surface water. This measurement is critical information in designing a infiltration pit. If the ground has a slow percolation rate then the site will have to be large to be able to recharge an amount of water desired. If the percolation rate is fast then the infiltration pit can be much smaller and still allow the same amount of water to be recharged to the aquifer. The rate at which the water percolates in the alluvial fan will vary from site to site. G.E.M. Engineering provided some percolation data from a site in the alluvial fan. The results G.E.M. provided are 5 minutes per inch (mpi), this rate is based on a test method that was intended for the design of septic systems septic systems.

7.5.2 Cedar City Test & Results

From the to March 15, 2010, Cedar City diverted some excess water to some borrow pits so that a large scale test could be done (see Figure 14 Percolation Test Location). The method that was used as follows: A stake with measurements was placed in the center of the borrow pit and the drop in water level was recorded daily. The water that was placed in the borrow pits was not settled before it entered the test pit. The spring water run has about .1 % sediment load that was settled out in to the borrow pit. The borrow pit that was used as a test had also been used before to divert excess water. This may have affected the test because the pit may have been partially clogged from past sediment.

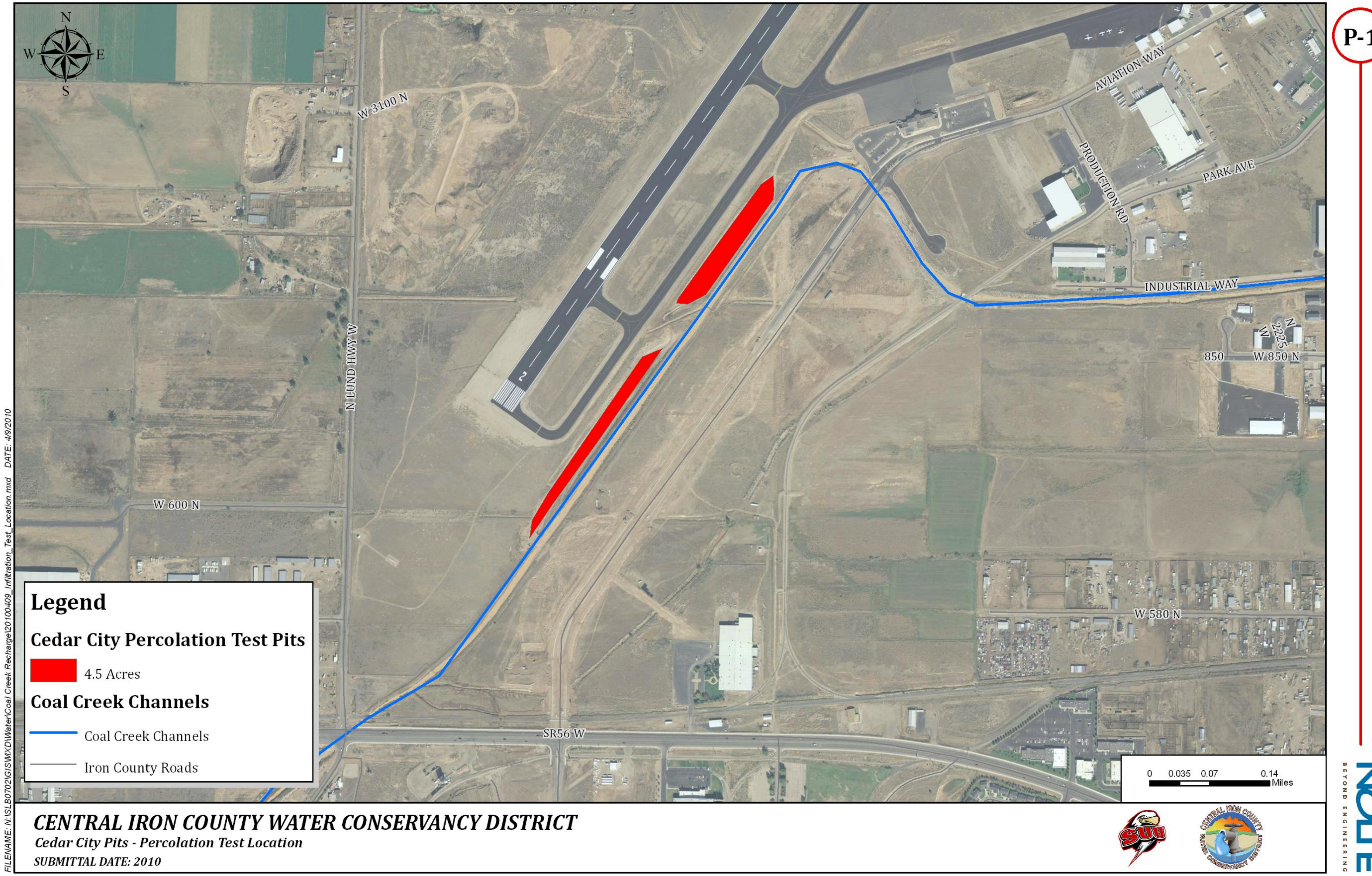
There are multiple variables that cause the percolation rate to change; some of them are water depth and barometric pressure. These variables were monitored daily. The water lost to evaporation was neglected in the results of this test. The reason that it was neglected was that it was relatively small amount of water and a short time period that the amount of water lost to evaporation would be minimal. The results of the test conducted are shown in Table 3 Infiltration Test Results.

Table 3 Infiltration Test Results

Dates (March 2010)	Time Period (hours)	Depth of Pond (feet)	Average Barometric Pressure (in Hg)	Precipitation (feet)	Measured Percolation Rate (feet)	Total Percolation (feet)
23rd - 24th	24	3.1	30.09	0	0.6	0.6
24th - 25th	24	2.5	30.01	0	0.4	0.4
25th - 27th	36	2.1	30.02	0.06	0.5	0.56
27th - 28th	26	1.54	30.28	0	0.2	0.2
28th - 29th	24	1.34	30.11	0	0.2	0.2
29th - 30th	25	1.14	29.76	0	0.2	0.2

The results show that the percolation rates decrease as the depth of the pond decreases, and it seems that the barometric pressure didn't vary enough to cause noticeable change in percolation rates. The ideal depth would be from three to six feet. There is a concern that if the depth is too deep the fluid pressure from the water would compact the soil on the bottom of the recharge pit and negatively affect the percolation rate.

Figure 14 Percolation Test Location



7.6 Evaluation of Site Conditions

A number of proposed sites have been evaluated based on their soil characteristics, proximity to Coal Creek, and overall availability for use. While carrying out this evaluation in the last couple of months it has been determined by the group that an exact site will not be chosen at this point in time. It will be necessary that the final site be found to be east of the Lund Highway and within a reasonable distance from the Coal Creek bed. A site at the intersection of Coal Creek Road and 1045 North is the most preferred site at this point in time. It is anticipated that this site could be used in conjunction with the Coal Creek Irrigation Company to achieve a multiuse project. This site and the availability will be considered further in the following months.

7.6.1 Basin Fill

The Cedar Valley depositional basin formed as a graben during Miocene to Quaternary time, due to displacement on normal faults along its eastern and western margins. Evidence presented below indicates that the eastern basin-bounding fault system referred to as (EBBFS), have greater displacement that the western faults, resulting in an asymmetric graben. Subsidence of the EBBFS hanging wall accommodated deposition and accumulation of basin-fill sediment, principally derived from the surrounding mountains in the footwall of the normal-fault system. The basin-fill deposits are chiefly alluvial and lacustrine sediments that thicken eastward toward the EBBFS. Fault displacement and sediment deposition occurred mainly during late Miocene through Pleistocene time (Anderson and Mehnert, 1979; Williams and Maldonado, 1995; Maldonado and others, 1997; Pearthree and others, 1998). Low sedimentation rates likely characterized the valley during Holocene time, except adjacent to active faults along the base of the Hurricane Cliffs and on both sides of the Red Mountains (Hurlow, 2002 p. 8).

The basin fill fans out from the sources of any stream that enters the Valley, in an alluvial fan. Alluvial fans form because, the stream losses energy as it enters the valley and to drops the heavy particles out, leaving a strata of course sand and gravel. The farther out in the valley the stream travels it changes the alluvial fan to much finer silt and clay. The primary source of aquifer recharge is in the alluvial fan because, its properties allow for fast percolation rates of the surface water. Well logs were used to create Schematic cross sections of basin fill deposits in the Cedar Valley. These cross sections were done across some ideal areas for potential recharge pits. Figure 15 Well Site and Cross - Sections detail the North-South and East-West cross sections. Figure 16 Cross Section A-A’, Figure 17 Cross Section B-B', Figure 18 Cross Section C-C', Figure 19 Cross Section D-D', Figure 20 Cross Section E-E', Figure 21 Cross Section F-F', Figure 22 Cross Section G-G', and Figure 23 Cross Section H-H' show the cross sections of the geology along those contours. The cross sections show positive results for a potential recharge pit near the gravel pits by the Cedar city airports. This data is from a preliminary draft of an assessment for artificial recharge potential in Cedar City, Iron County, Utah, prepared by the

Division of Water Resources (see Appendix for full report). The cross sections B-B' and H-H', show that there are some prime areas that would be perfect for a recharge pit. The well logs show that there will be a very little chance of hitting an impermeable clay layer that will stop the flow of water to the aquifer, and a direct line to the unconfined aquifer.

Figure 15 Well Site and Cross - Sections

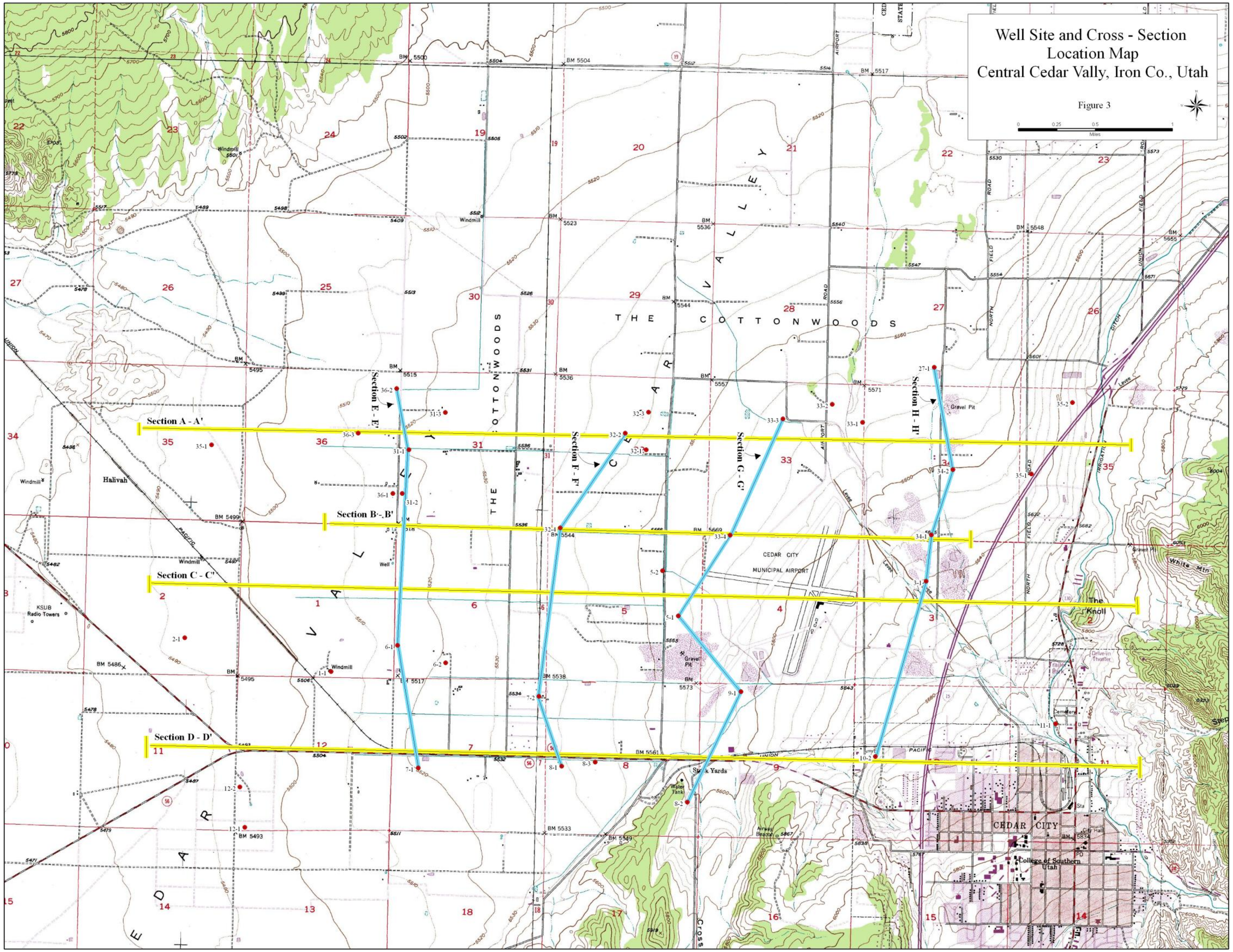
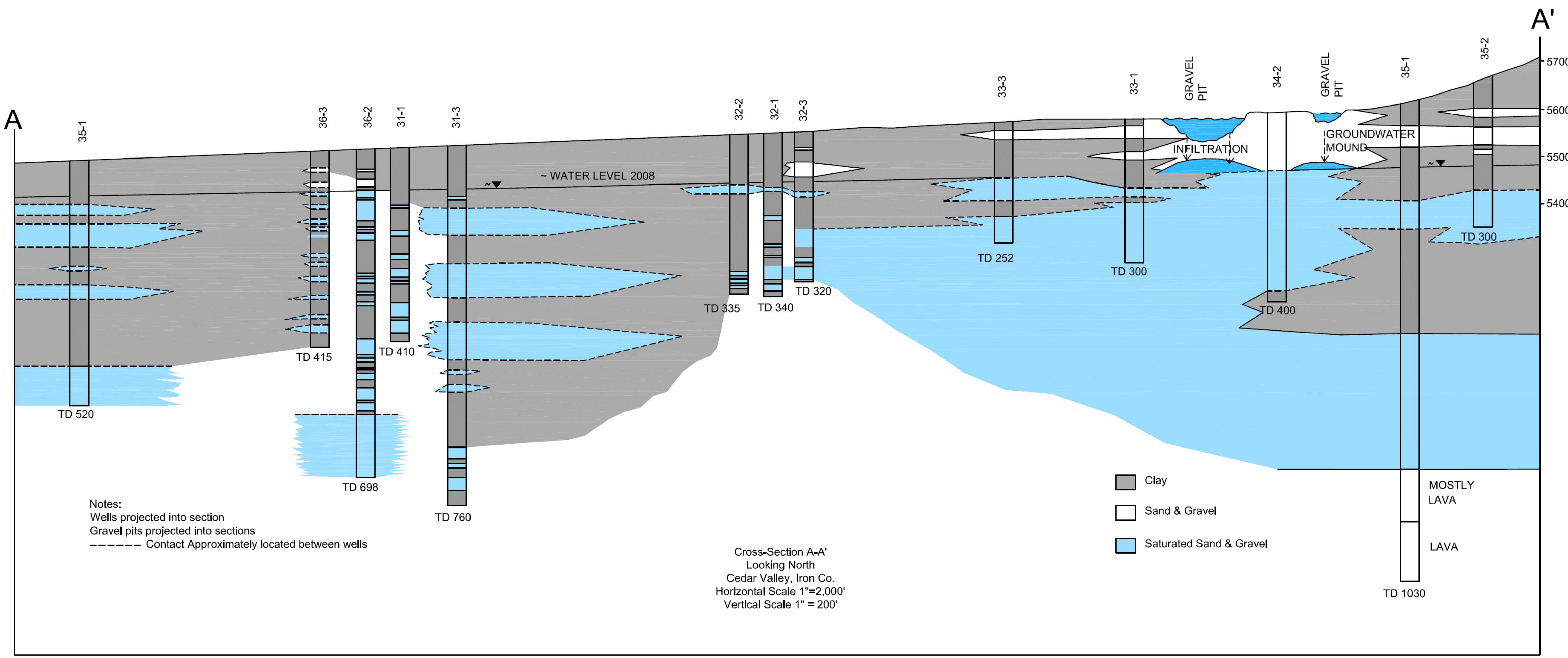


Figure 16 Cross Section A-A'



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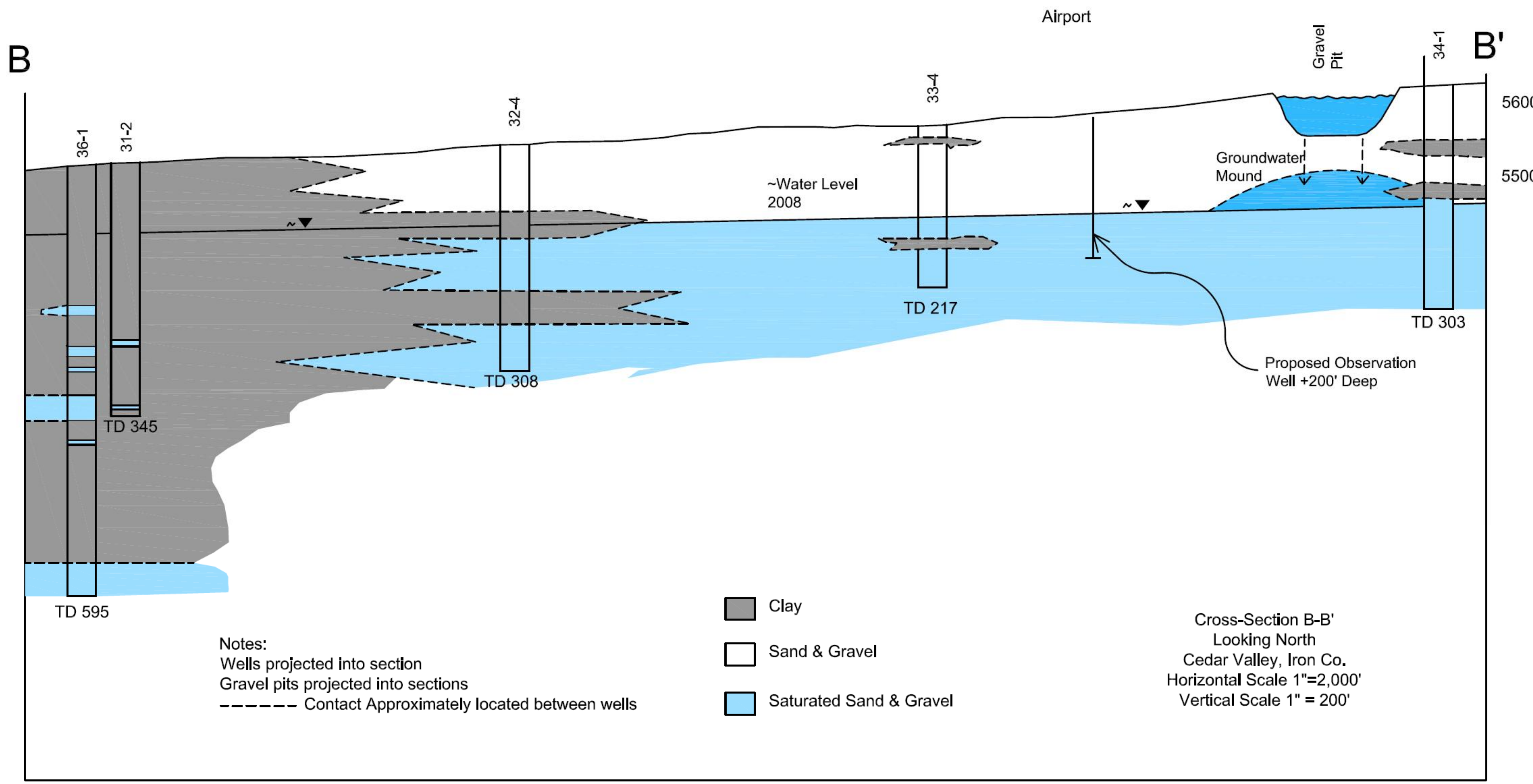
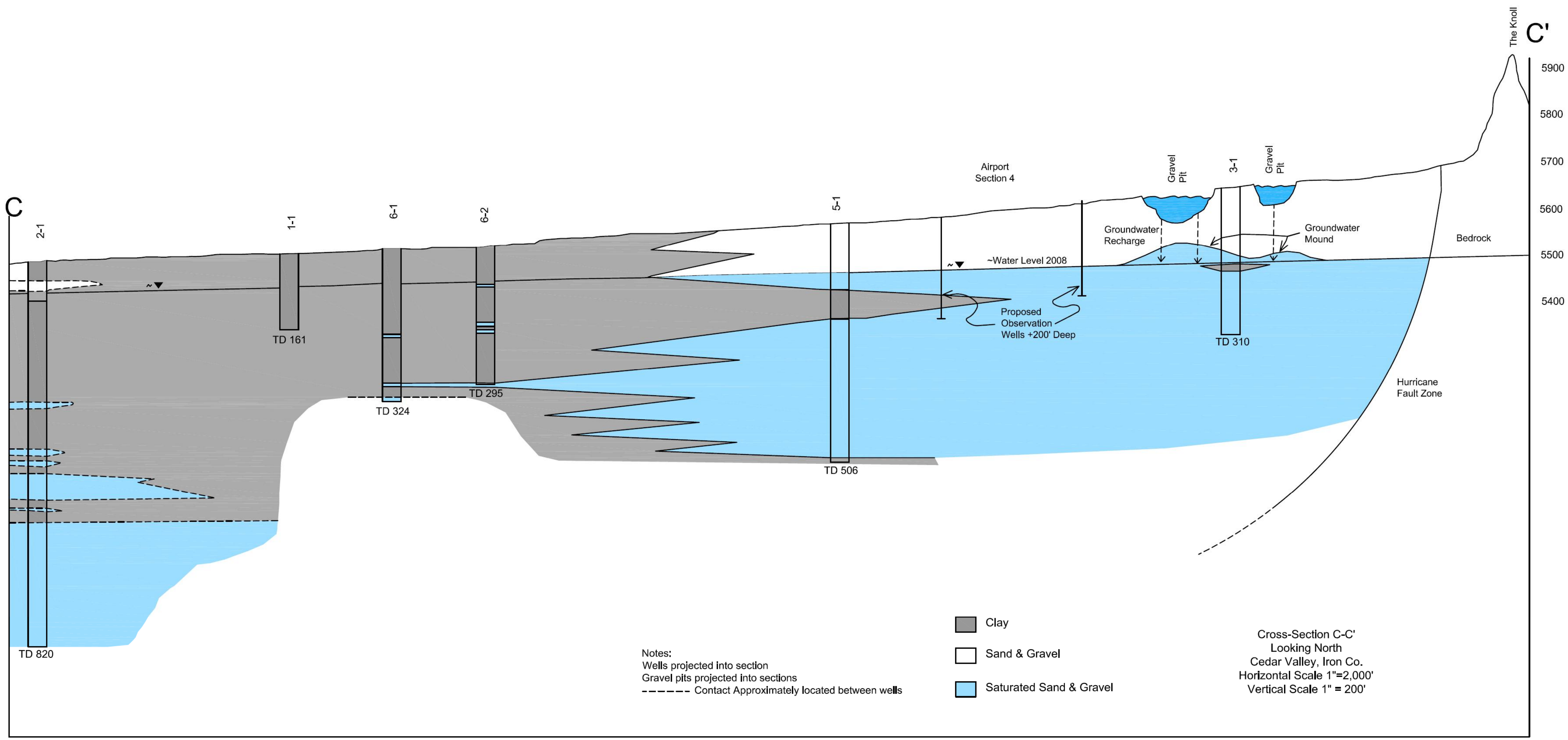


Figure 18 Cross Section C-C'



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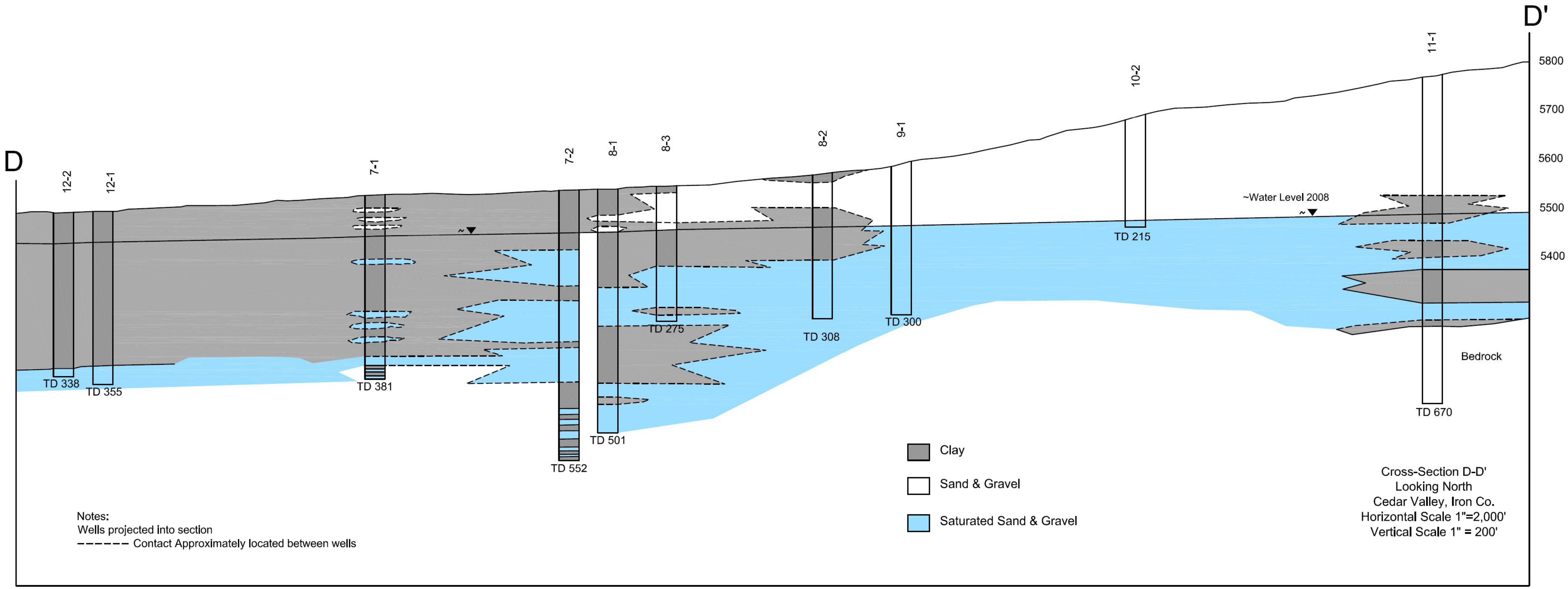

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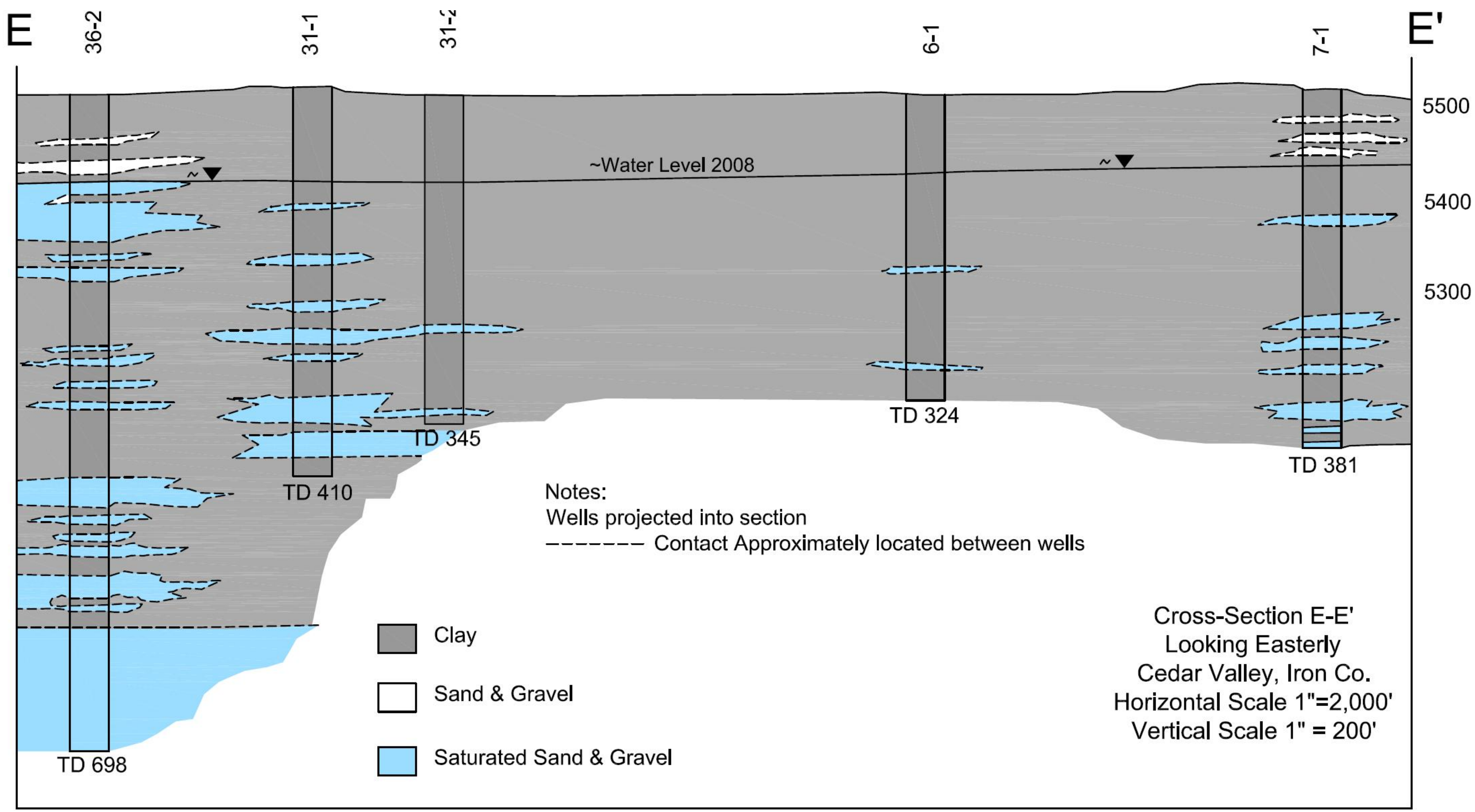


Figure 21 Cross Section F-F'

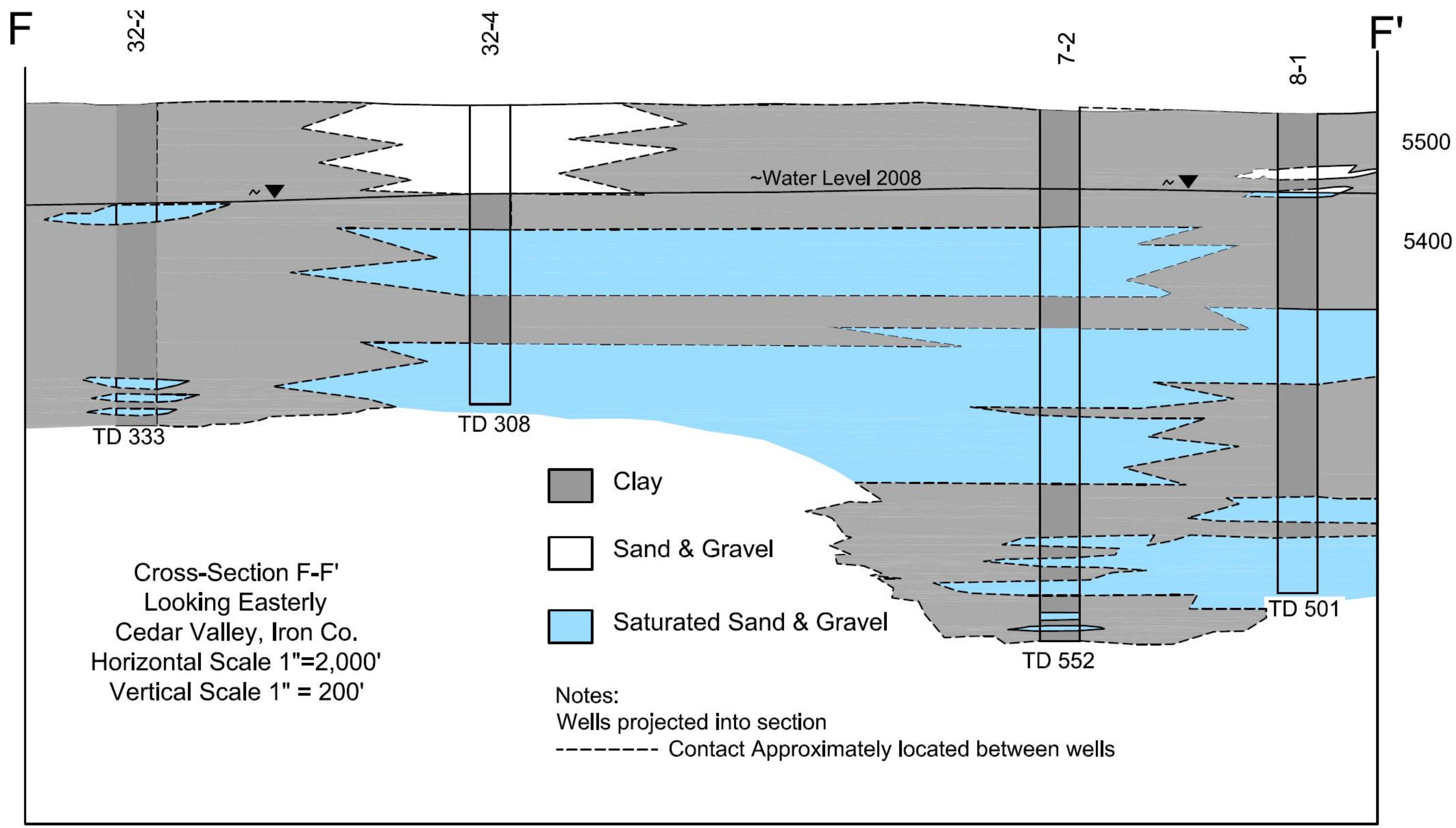


Figure 22 Cross Section G-G'

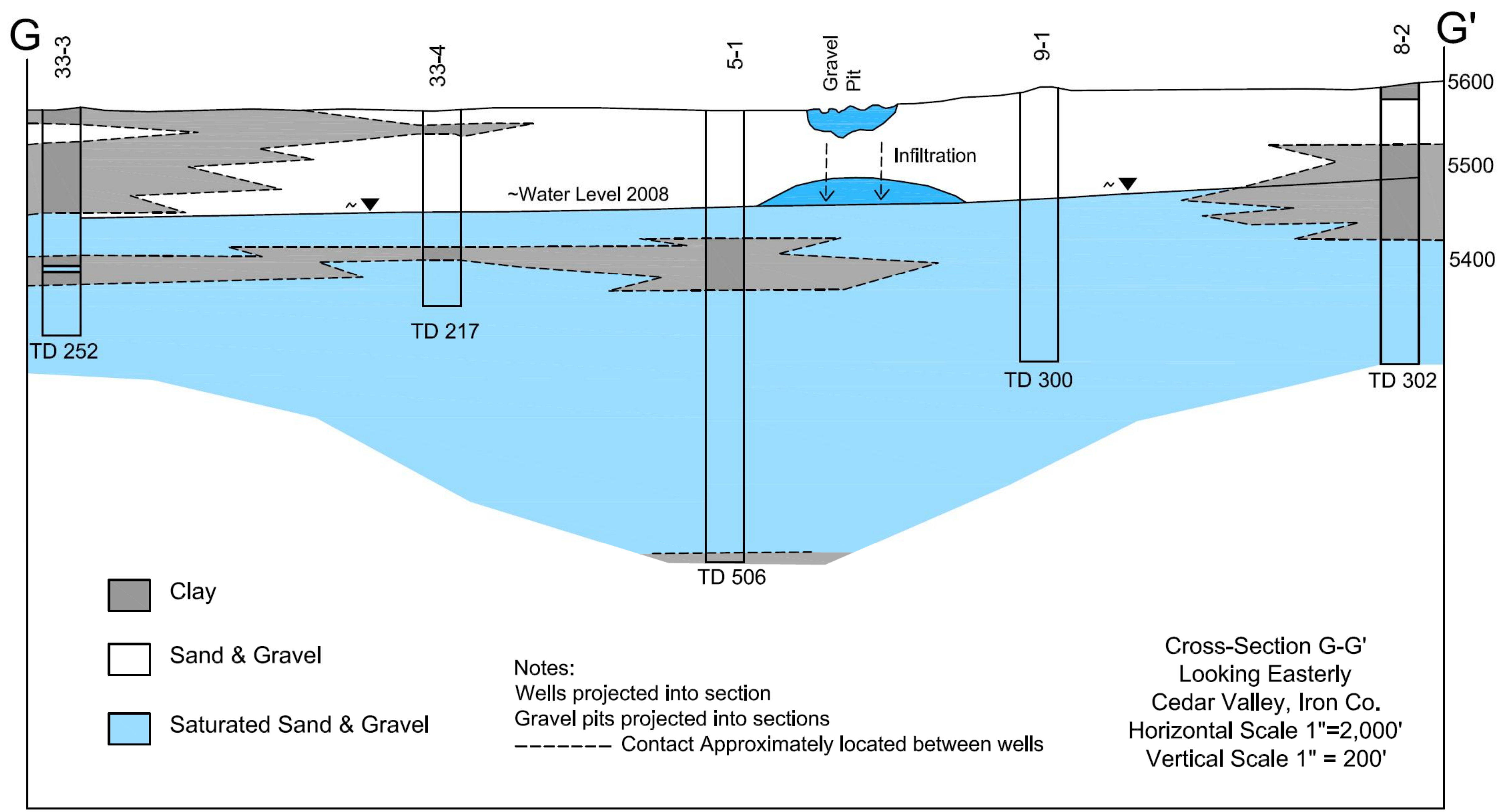
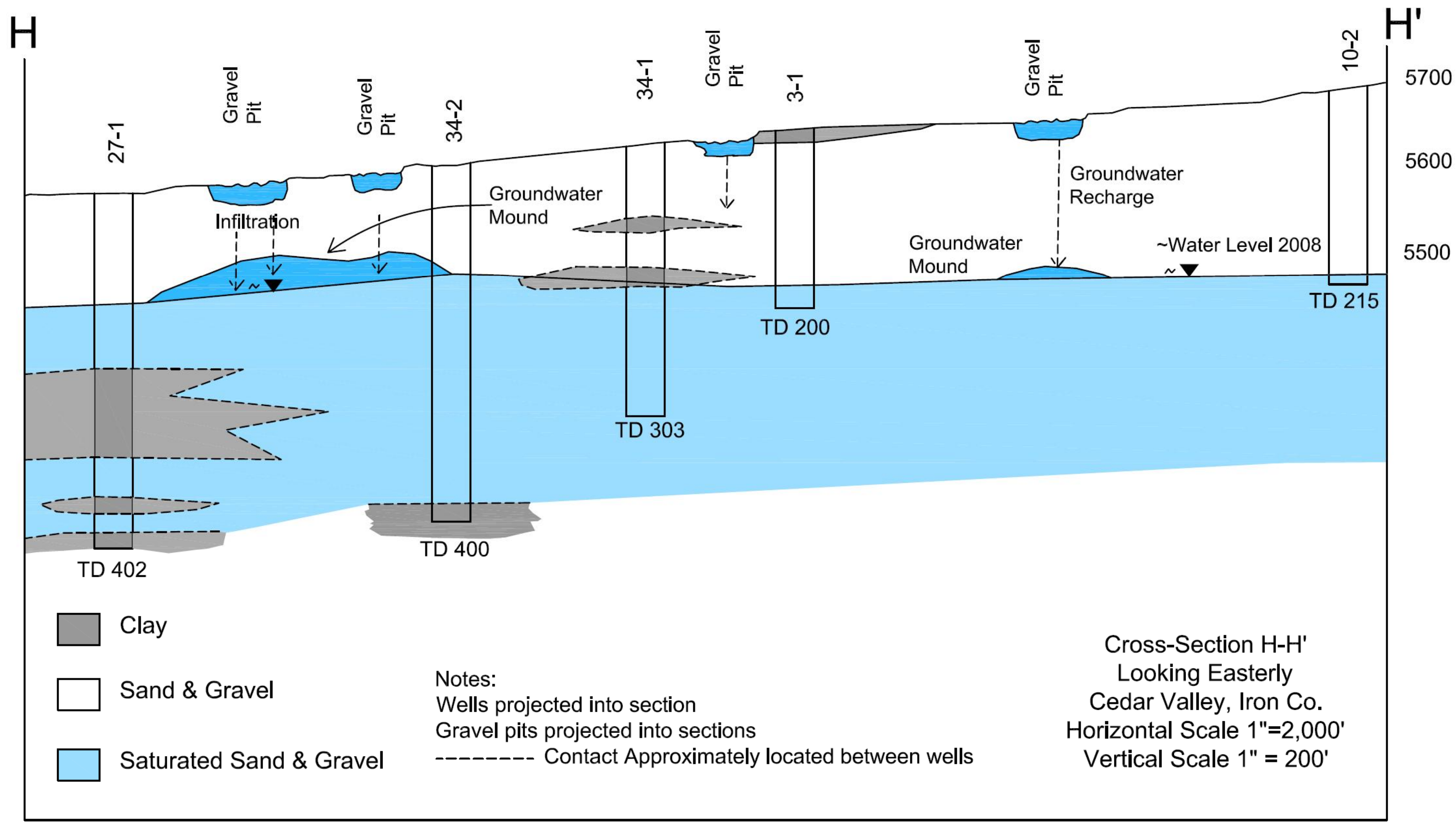


Figure 23 Cross Section H-H'



7.7 Evaluation of FAA Regulations

The Cedar City Airport is shown in Figure 24 FAA Perimeter A & Approach Zones. This figure also shows the ideal artificial recharge locations (existing gravel pits). This figure will be explained more in depth in the following paragraphs, it is sufficient to state that the proximity of the gravel pits to the airport required further investigation to determine the Federal Aviation Administration (FAA) regulations, planning steps, and feasibility of locating pit-infiltration type recharge pits within and around the existing gravel pits.

7.7.1 Requirements for Compliance

The Cedar City Municipal Airport has received Federal grant-in-aid assistance and therefore is required to meet certain standards. These standards cover a number of issues relating to airport operations, maintenance, and development procedures; for the purpose of this section the requirements pertaining to the management of hazardous wildlife attractants will be more fully considered.

Recent information and studies have shown that aircraft collisions with birds and other wildlife are a serious economic and public safety problem. In order to help airport officials mitigate potential collisions and the FAA has released *Advisory Circular 150/5200-33B* (AC). The purpose of this circular is to inform airport operators, local planners, and developers what they need to consider when making land planning decisions. They must take into account whether the proposed land uses will increase wildlife hazards. These hazards are increased as wildlife attractants are added to the areas on and around the airport. Potential wildlife attractants are listed as follows:

1. Waste disposal operations
2. Water management facilities
3. Wetlands
4. Dredge spoil containment areas
5. Agricultural activity
6. Golf courses

Each of the items listed above has been proven to attract larger than normal quantities of wildlife, especially waterfowl and other birds.

7.7.2 Separation criteria

The FAA recommends a minimum separation criteria outlined for land-use practices that attract hazardous wildlife, like those listed in the previous section. The following excerpt from the AC describes the separation criteria.

The basis for the separation criteria. . can be found in existing FAA regulations. The separation distances are based on (1) flight patterns of piston-powered aircraft and turbine-powered aircraft, (2) the altitude at which most strikes happen (78 percent occur under 1,000 feet and 90 percent occur under 3,000 feet above ground level), and (3) National Transportation Safety Board (NTSB) recommendations.

The Cedar City Municipal Airport currently serves piston-powered and turbine-powered aircraft. Notwithstanding more stringent requirements for land uses the FAA recommends a separation distance of 10,000 feet between the Cedar City Municipal Airport and any hazardous wildlife attractants. For all airports the FAA recommends a distance of 5 statute miles separation between the edge of the airport and any wildlife attractant that could cause wildlife migration across departure or approach airspace. A separation distance of 5,000 feet is shown in Figure 24 FAA Perimeter A & Approach Zones to show that all potential recharge sits are located within the 5,000 foot separation area and therefore within the 10,000 foot separation area.

7.7.3 Coordination Efforts with Local and Federal Agencies

In discussions with Steve Farmer, Cedar City Airport Manager, and Mike Linnell, State Director for the USDA-APHIS-WS, (Animal and Plant Health Inspection Service – Wildlife Services), a large amount of information was received pertaining to the possibility of locating recharge pits within the 5,000 foot separation area. Mr. Linnell works as a liaison between the FAA and local airports throughout the State of Utah in helping planning officials better understand the regulations and how to meet them. In regards to the Cedar City Airport, Mr. Linnell believed that with proper planning, strategic placement of recharge pits, implementation of possible wildlife repellants, and most importantly early agency integration a recharge program utilizing pit infiltration could receive approval from the USDA/FAA. Also, because of specific conditions present within the Cedar Valley pertaining to the potential hazardous wildlife threats from migratory and non-migratory birds; strict compliance to the 5,000 foot separation area may not be necessary.

7.7.4 Design Recommendation from Mr. Linnell

It was recommended from Mr. Linnell that any recharge pit or settling pond be as deep as possible and also that it be constrained to a small width. Along with these recommendations the sides of the pit or pond should be as steep as possible. Caution should be taken to design such that the pit or pond does not hold water for an extended period of time. Also, during operations care should be taken to mitigate and remove any aquatic vegetation that could provide habitat for waterfowl.

The following measures describe different methods currently being used to discourage waterfowl from collecting or utilizing a pond or marsh area (could be a settling basin or recharge pit).

1. The pond or structure could be covered with netting. The size and type of netting would be decided based on a survey of potential wildlife threats in the area.
2. Another method to discourage waterfowl from landing on or utilizing a pond is by running a number of thin steel cables in a net fashion. The intersecting layers being placed at different heights.
3. Moveable plastic coverings can be used that can be placed on the surface of the water and totally cover the water therefore effectively eliminated the attractant.

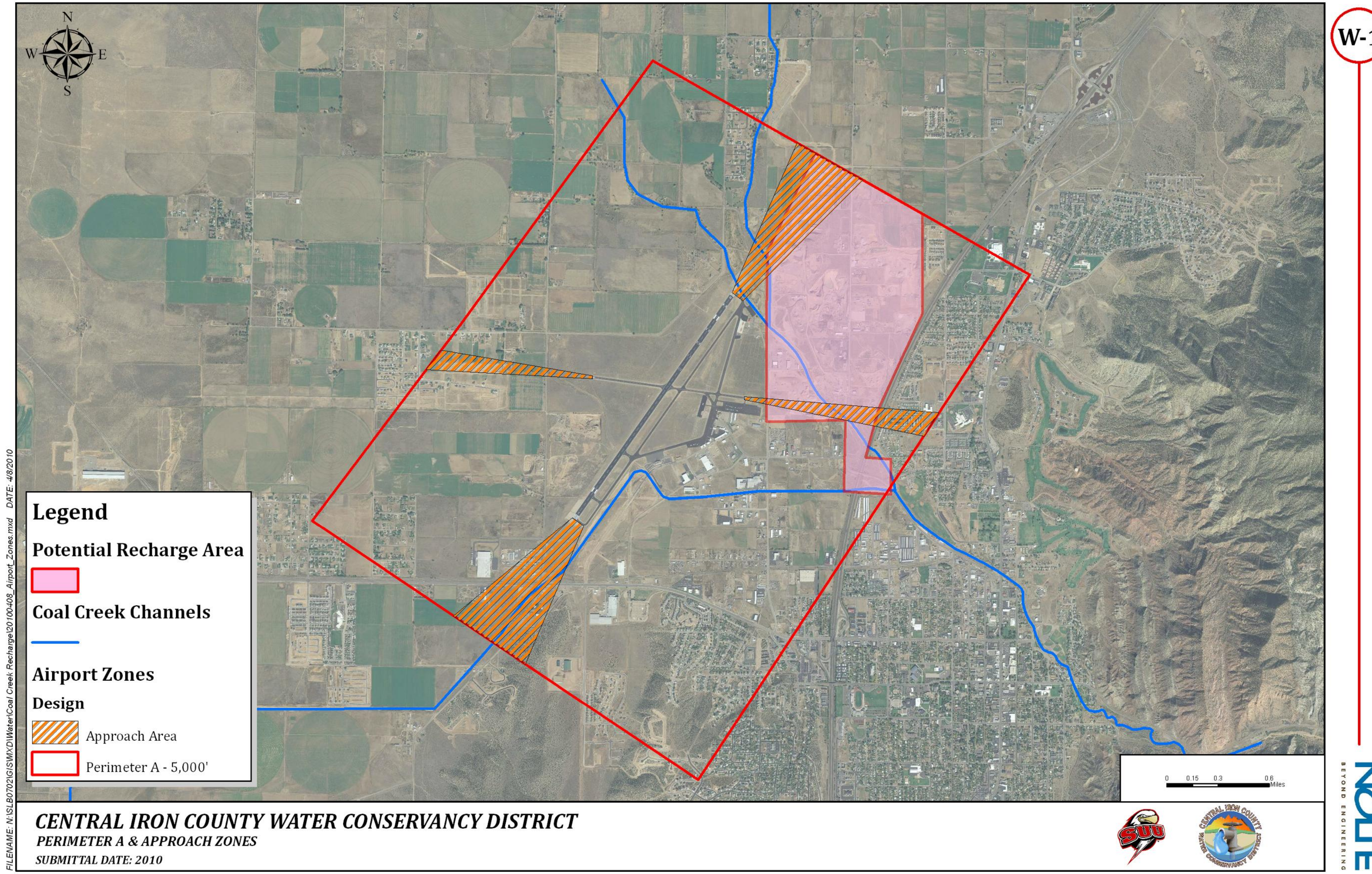
Figure 24 FAA Perimeter A & Approach Zones shows the 5,000 foot separation area, and also shows estimated approach and departure zones (labeled "Approach Zones" on the figure) for each runway. Placing recharge pits or allowing standing water should be avoided in these areas. Whereas, aircraft are at their lowest and most critical elevations within these zones, a collision with a wildlife hazard would be even more probable and dangerous.

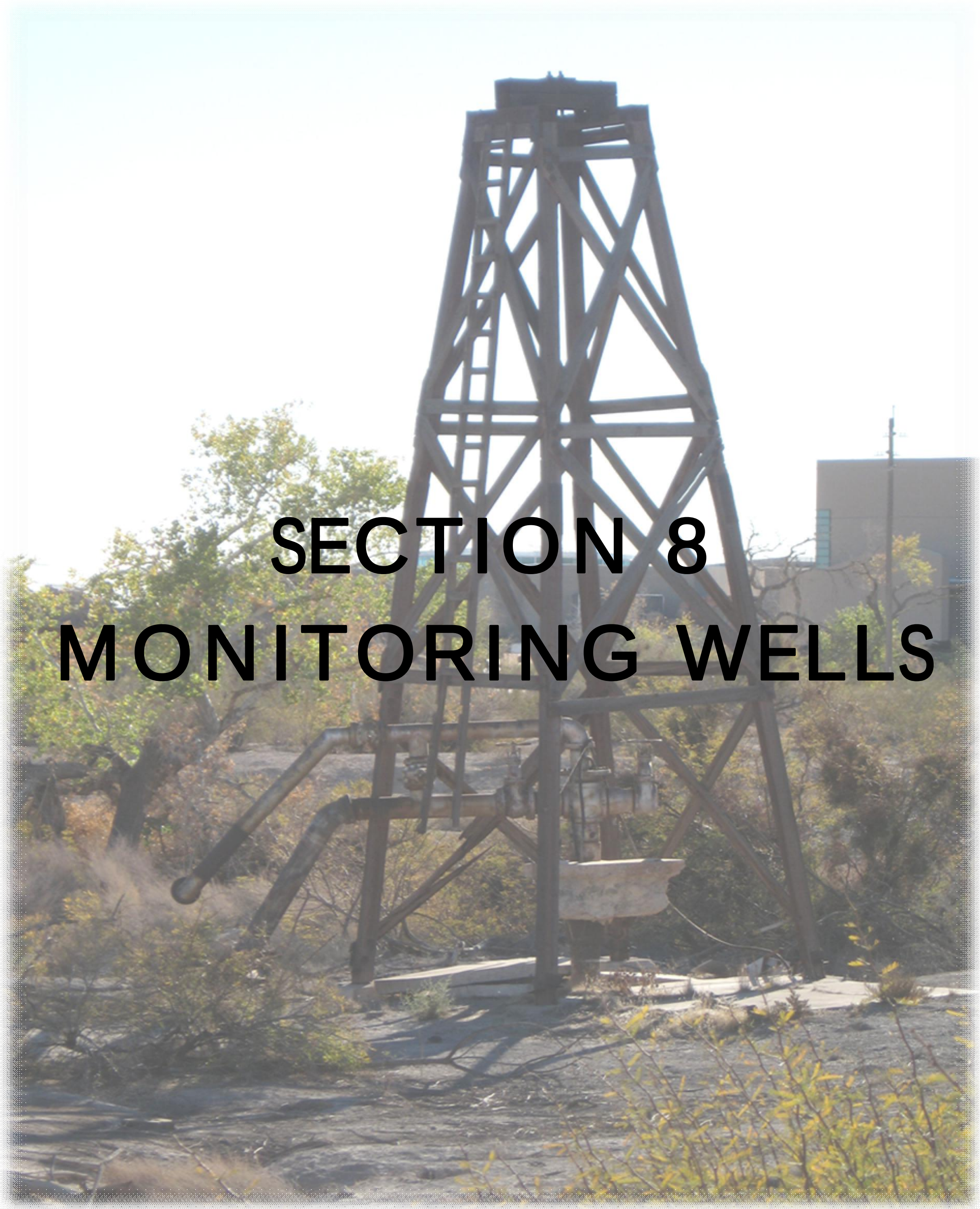
Infiltration pits and settling ponds will have greater probability of receiving approval from the FAA if they are placed closer to existing development; especially neighborhoods and I-15.

7.7.5 Steps for planning and approval

As each potential recharge site is located within the 10,000 feet of the airport it will be necessary to work closely with Mr. Linnell during preliminary project design. If integration with the Agency is included early on in the process, then a streamlining of project approvals will take place. Preliminary plan approval will be required by the Agency. Agency approval will be issued by a letter from the USDA, FAA or from both entities together. See Appendix for Mike Linnell's contact information.

Figure 24 FAA Perimeter A & Approach Zones





SECTION 8
MONITORING WELLS

8 MONITORING WELLS

As part of the underground monitoring of the recharge site it is important to understand what the existing water conditions are before any recharge efforts go forward. It is also necessary to understand how the water conditions change during and after any recharge.

8.1 Microgravity Data Collection

This type of initial data can be gathered through high-precision gravity surveys. This method utilizes ultra sensitive data reading equipment that is capable of measuring changes in gravity. Repeated measurements yield differences in gravity, which can be used to infer aquifer changes in properties and location. If the ground-water levels are closer to the ground surface then a higher gravity count is recorded on the equipment. This type of survey is typically called "microgravity" or "gravimetry". It is set up by created a grid of the site in question and then from each grid point data is collected and by doing so a dimensional model can be created of the water surface in relation to the ground surface. By utilizing this type of survey before any recharge efforts go forward it is possible to understand the ground-water characteristics. Microgravity surveys should continue throughout the pilot program to better understand the movement of the water.

It is recommended that a consultant firm be hired to complete and analyze this data. Another option would be to have one of the larger State Universities complete the survey. Weber State and the University of Utah have the necessary equipment and expertise to complete a microgravity survey. These surveys in conjunction with actual monitoring wells will give the operators the necessary safeguards to ensure that the recharge pilot program goes as planned.

8.2 Need for Monitoring Wells

As a pilot program moves forward it will be imperative that monitoring wells be found and that use be granted, or that these wells be designed, placed and drilled in strategic locations nearby the proposed recharge site. These wells will be used to collect water quality data before, during and after recharge. They will also be used to record water level fluctuations. It is important to understand how the water is moving in relation to the recharge site. Possible movement of water can be North, South, East, West, up or down. Based on the geological composition of the gravel pit areas in question it appears that the recharge water will move directly down into the aquifer and then move down gradient as it reaches the aquifer. For the most part monitoring wells should be placed down gradient from the recharge site to account for water as it moves in the direction of the monitoring well column, however in order to receive early warning of potential groundwater mounding, which happens when the recharge water comes in contact with a clay or other impermeable playa and begins to move laterally and upward creating a mound, wells should be placed in a perimeter around the recharge site.

8.3 Types of Monitoring Wells

There are a few types of monitoring wells that can be used depending on what type of information is needed. A discussion of the different types of monitoring wells is listed below.

8.3.1 Production Well Monitoring

An existing production well may be used as a monitoring well for monitor recharge levels, but is not ideal. This is because typically a production well in the Cedar Valley will be drilled to a depth far below the water table, depending on the designed flow production of the well. These production wells will then have a large percentage of the columns screened and/or perforated such that a large portion of the screen is submerged in the water. This allows for a large production volumes, but doesn't not work the best for a recharge monitoring well, because the water that will be pumped and tested for according to water quality indicators, may be water from far down in the aquifer and not necessarily that recharge water that is coming into the aquifer from the top. These types of production conversion monitoring wells are beneficial if they can be acquired, or access given for a small amount of money. They work well to see water level fluctuations.

8.3.2 Specific Application Monitoring

A monitoring well can also be designed specifically to monitor water levels and water quality. This type of well will be drilled to a depth of 20' below the seasonal low water table level. These types of wells are traditionally only 2" or 4" column diameter depending on what type of pump system or water reading equipment would need to be placed in the column. This means that that well will cost substantially less than a production well to drill. Wells of comparable design cost around $8,000 and $20,000 for drilling and set up. Weber Basin Water Conservancy District recently installed a 4" monitoring well to a depth of 230' with a 5 gpm pump for readings and full transducers and telemetry for around $40,000. So the cost can vary depending on what type of hardware is desired. It is recommended that during the pilot program a small number of inexpensive monitoring wells be drilled and if a more permanent site is found then a more sophisticated monitoring well could be installed.

8.3.3 Vadose Zone Monitoring

Another type of monitoring well that can be used for a specific purpose is a vadose zone monitoring well. These wells extend down into the vadose zone, but do not reach the water table, typically around 20' or so. They can be used to monitor mounding activity of the water in sensitive areas. For example, if the site that is chosen to put the recharge facility has residential homes, roadways, or commercial developments nearby then a vadose well or a few such wells could be placed between the recharge location and the locations of the homes etc. to monitor any lateral and upward movement of water that could potentially flood basements, undermine roadways or cause other such damage. These wells can also be used to monitor the water movement to ensure that flooding does not happen in active gravel pits nearby.

8.4 Data to be collected from Monitoring Wells

Data that needs to be collected each day during recharge is the following: monitoring well ID, date, time of day, temperature, barometric pressure, water depth, and water temperature. Water quality data should be analyzed weekly. The water quality and monitoring data will later be used in preparation of the pilot program research document that will be required to receive a recharge and recovery permit.

SECTION 9
PILOT PROGRAM

9 PILOT PROGRAM

It is recommended that the Central Iron County Water Conservancy District begin to move forward with the planning and implementation of an Artificial Recharge Pilot Program. This program should cover a large enough range of time that would allow the District to collect the necessary data to properly evaluate the project in order to file for a recharge and recovery permit through the Division of Water Quality. The different facets of a recharge program were considered throughout this report. A summary of material along with a few other recommendations are below in this section.

9.1 Expertise in Design

Based on the findings of this report it is recommended that a engineering consulting firm be hired that can move forward with an actual design of the settling basin, diversion structures, transmission lines/canals, and facilitate the permitting and data collection that will be crucial to the success and further implementation of a recharge program.

It is recommended that the relationship between CICWCD staff and the Southern Utah University engineering department continue to be strengthened. As part of a pilot program a large amount of data collection and documentation will be required. This will included taking water quality samples, reading monitoring well levels and reading flow quantities. These would be great tasks to coordinate with upper-level engineering students from SUU. They would be able to collect the data and prepare the necessary reports. Contact information for faculty and staff in the SUU engineering department are listed in the Appendix.

9.2 Improvement to Woodbury Diversion

It is assumed that any recharge efforts will be implemented downstream from the Woodbury Diversion. This diversion is found at the intersection of Coal Creek Road and 1045 North. Because of the increased wear on this diversion its water diversion accuracy is compromised. Any recharge program will require that accurate readings both upstream from the recharge pit, (Woodbury Diversion) and at the recharge pit itself. Diversion at the recharge pit will be described further in this section. It is recommended that assistance, both engineering and financial, be given to those responsible for the management of the Woodbury Diversion such that an improvement may be designed and constructed. This would help to improve relationships with those water managers and also create a more reliable method for taking water measurements.

9.3 Design of Facility

Based on the constraints listed in this report, the facility design should take place with the goals of data collection, low cost and actual feasibility.

9.3.1 Design of Weir & Diversion

A Diversion structure along with a weir or other volumetric measuring device must be designed. This diversion should be able to divert spring run-off, “cloud burst” storm run-off, and be placed low enough in the channel to be capable of diverting winter flows, if they become available. This does not need to be a costly design.

9.3.2 Design of Settling Basin

As described in previous sections, most of the water that has been considered for recharge has a large total suspended solids count. Times for settling and amount of material have also been described. It is recommended that the facility design include a settling basin sized according to sediment settling times and the anticipated quantity of water that will be recharged. This settling basin should allow the water to slow down and even come to a complete stop before exiting into the recharge pit. It is anticipated that within the settling basin, most of the larger and much of the finer sediments particles will be able to settle out of the recharge water. This pit could be cleaned each year to remove the deposited material. If the deposited material contains gravel it could be sold as such, but the finer grained material (clay) would need to be disposed of or a specific use could be found.

9.3.3 Design of Recharge Basin

The recharge basin should be located directly after the settling basin. The recharge basin could be located at any of the possible locations shown in Figure 10 Infiltration Sites. Care should be taken to avoid the areas of the overlapping “approach zones” shown in Figure 24 FAA Perimeter A & Approach Zones because this will make receiving approval from the FAA much more difficult.

9.3.3.1 Possible Partnership with Coal Creek Irrigation

A possibly beneficial partnership with the Coal Creek Irrigation Company should be implemented. This partnership would revolve around the land planning and use of a four parcels of land owned by the Coal Creek Irrigation Company around the Woodbury Diversion (intersection of Coal Creek Road and 1045 North). Coal Creek Irrigation Company has expressed an interest in utilizing a portion of this land for a small storage reservoir that would help to keep consistent flows downstream from the proposed storage reservoir. This storage reservoir could act as a settling basin and water could then be diverted off into a recharge basin. This type of joint-use program would require intensive coordination between Coal Creek Irrigation and the Water Conservancy District, but if implemented could prove to be a very successful model for other areas within the Cedar Basin and Utah.

9.3.4 Placement of Monitoring Wells

Monitoring wells should be placed in accordance with Section 8.

9.3.5 Permitting

The nature of the recharge project will dictate what type of permitting that will be required. Candace Cady from the Division of Water Quality handles all of the recharge and recovery permits. Email correspondence with her is listed in the Appendix.

APPENDIX

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